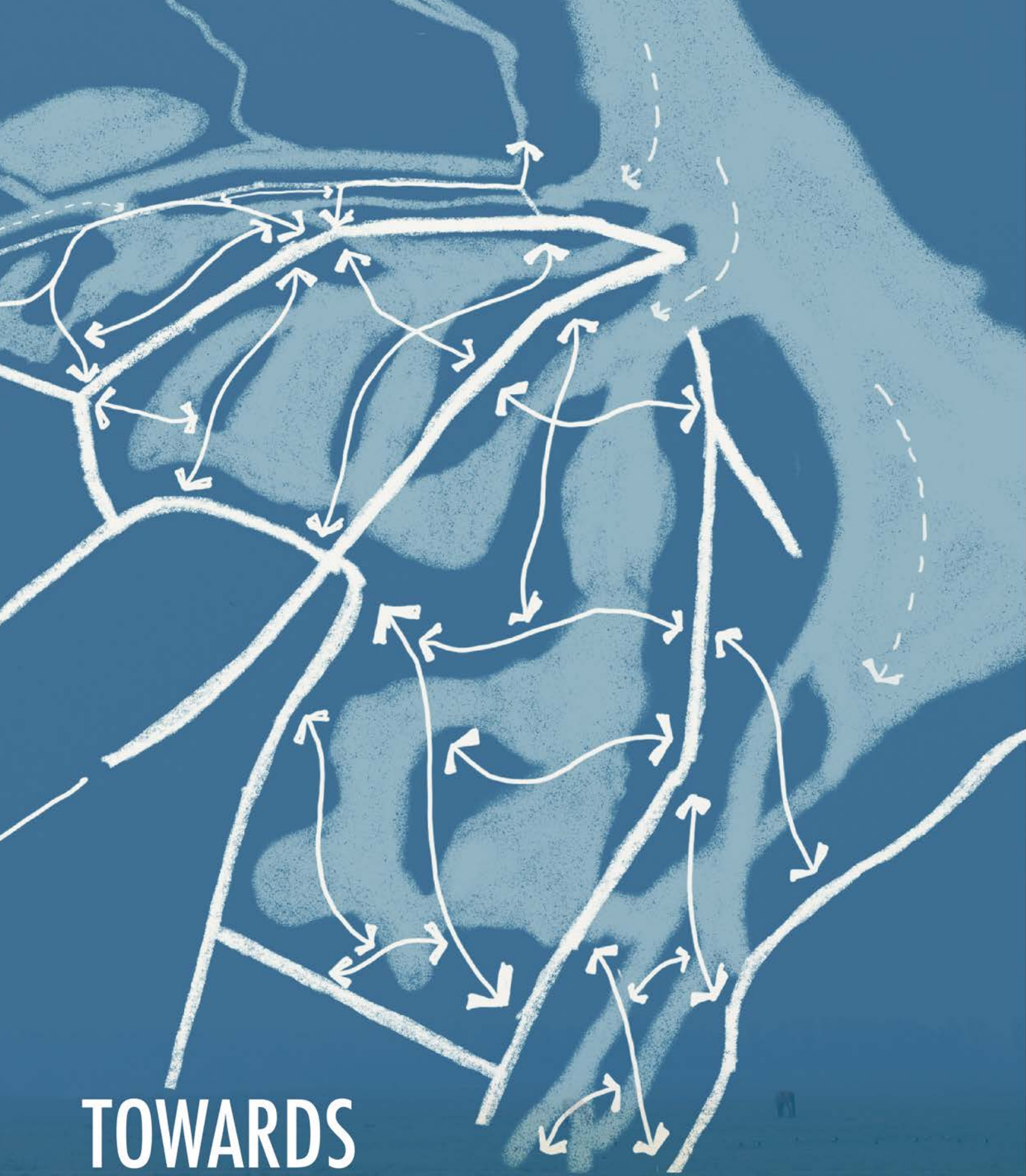


TOWARDS RESILIENT DELTA

Designing integration of natural dynamics of Dutch river delta landscape as water safety and climate adaptation measures within the urbanised delta city of Dordrecht

by Timothy Radhitya Djagiri

June 2018
MSc Landscape Architecture Thesis

TU Delft

Towards Resilient Delta

Designing integration of natural dynamics of Dutch river delta landscape as water safety and climate adaptation measures within the urbanised delta city of Dordrecht

MSc Landscape Architecture
Flowscapes graduation studio

TU Delft Faculty of Architecture and the Built Environment
Department of Urbanism - Chair of Landscape Architecture

By

Timothy Radhitya Djagiri
4586700
t.r.djagiri@outlook.com

Mentored by
ir. Denise Piccinini
dr. Fransje Hooimeijer

Delegate of the Board of Examiner
ir. Alexander de Ridder

29 June 2018

Acknowledgements

My sincere gratitude to people who helped me through the process of this thesis. I could have never done this without you.

To my mentors; Denise Piccinini, for your support, care, and attention to details, and for our debates on issues and concepts which motivated me to always ask questions and further explore realms of possibilities to go forward. To Fransje Hooimeijer, for our conscise yet inspiring discussions that keeps my head ticking with new (and bold) ideas.

To academic staff of the Chair of Landscape Archtecture of TU Delft, for your teachings, perspective, and expertise, as well as our 1-on-1 discussions which gives me valuable understanding and ways to go further.

To Ellen Kelder, Rik Heinen, and Berry Gersonius from Living Lab Dordrecht for your knowledge and support during early stages of my thesis as I get to know more (and eventually fall in love) with Dordrecht.

To my parents for your support from far and for always believing in every decision I make and every dreams I have. Although we are far away, your words and wisdom always engraved in me during my most difficult times.

To my partner, Monica, for your love and cheerful laugh from a distance. Although you are 5 hours ahead, you have always been my greatest cheerleader. Thank you for your patience during stressful times that I have.

To my sister, as we both are fighting on for our degrees abroad and I could never get the time difference between here and OZ, we always support each other in our most difficult times.

To friends and families both here in the Netherlands and at home, for always making dark days brigther.

Summary

A landscape architecture graduation research-by-design project which looks into the urbanised river delta of the Netherlands facing the problematique of collision course of urbanisation process, water safety, and climate adaptation. This thesis seeks to design adaptive green and blue network for the city of Dordrecht in order to increase the city's resiliency towards climate change and to challenge the monofunctional and non-adaptive measures of water safety in Dutch river delta landscape as well as evoking new landscape qualities in the urban fabric of Dordrecht. This design project challenges the idea of building with nature and nature based solutions to seek balance between urban and nature through the design of a new landscape composition which presents the new perspective of living on the river and with the river.

Dordrecht represents the ongoing relationship of man and nature as a palimpsest of past processes and exchanges between the two. Here, the amalgamation of urbanisation and natural processes results in spatial separation of what is inside and outside the embanked landscape. Water safety infrastructure separates the two processes. To understand the landscape, lenses of landscape as palimpsest and landscape as process is used as main point of view of the research. Looking into practices of climate adaptation measures and case studies as well as landscape structures of the site, design framework is produced as the cornerstone of the design outcome.

The design solution seeks a balance of re-connecting the river dynamics of the rivers through the city of Dordrecht, which not only re-establish the river as part of the city, but also to develop new ecological values. The concept of "living with the river" guides the urban processes on the newly established riverscape, and provides open-endedness of the landscape with the dynamic of the river continuously shaping and reshaping the landscape overtime. This landscape redefines not only the urban processes, but the economic value, ecology and water safety as part of the adaptive system.

CONTENTS

FASCINATION

In a cold and dark night, Hans Brinker walks home along the dikes that protect his city from the high water outside. Suddenly he sees water dripping down the dike from a hole that is no bigger than a size of an index finger. Realising about the danger of a small breach on the dike to his whole city, he puts his finger to block the dike, and the water stops dripping.

"Ha, ha!" he says to himself. "The water can't come down now.
The town shall not be drowned while I am here to keep the flood back."

He endures through the cold night until the villagers come and help him in the morning.

Fig. 1
Statue of Hans Brinker in Madurodam.
Source: www.waterstof-ezine.nl

This is a story of resilience and vulnerability. Resilience in terms of quick and intuitive action of young Hans Brinker to act against the danger that loomed his village. On the other hand, vulnerability in regards to the dependency on hard infrastructures that when it fails, new measures are needed as mitigating measures. These two opposing perspectives are my starting point of this research.

Hearing about the technological marvel of the Netherlands in regards to water management from a distance filled me with fascination and curiosity. Being more than half of the country under the sea level I couldn't help but thinking that there must be something special that the Dutch has done to be able to not only survive, but become a prosperous nation today. I have grown more and more curious and interested in the aspect of water in from landscape architecture point of view during my studies.

Looking back into a couple of years ago whilst I was looking into which place to continue with my master study, the Netherlands immediately became my first choice due its reputation in water management. My introduction to the country has exceeded my expectations and learning about these flood defence and water management structures over the course of my study makes me realise about their necessity, complexity and potential. Standing next to a sea dike in the north of the Netherlands for the first time, pondering amongst the vast polder landscape with the northerly wind on my face, and witnessing the sheer scale of a storm surge barrier among others are an experience of wonder and bewilderment that I will never forget. These structures, among others, captivates me to explore the relationship between man and water, and therefore, between man and nature.

I found myself reflecting on this fascination prior to choosing my graduation thesis topic. Upon experiencing, learning and analysing these structures for the past year, the magnificent sea dikes become walls to keep the natural dynamics out of the much more regulated landscape, the immense openness of polder landscapes become mono functional and inaccessible emptiness, and engineering marvels of colossal storm surge barriers, dams, and pumps become aliens in complex and dynamic natural landscapes. I was questioning the ability of landscape architecture to transform the paradigm of these infrastructures. How can landscape architecture provides ways of challenging the separation of natural dynamics outside the dikes and urbanisation inside the dikes? How can concept of water safety be questioned to open up new possibilities?


Leeuwarden
Groningen
Ems
Dollard
Assen
Lake
IJsselmeer
Overijsselse
Vecht
Lake Markermeer
Lelystad
Zwolle
Noordzeekanaal
Haarlem
Amsterdam
Amsterdam-
Rijnkanaal
Den Haag
Utrecht
IJssel
Nieuwe Waterweg
Rotterdam
Neder-Rijn
Arnhem
Haringvliet
Lek
Waal
Rhine
Merwede
Maas
Grevelingen
Bergsche Maas
Oosterschelde
Middelburg
Den Bosch
Westerschelde
Scheldt
Roer
Meuse
Maastricht

I. INTRODUCTION

"Drown or Be Dutch"

The Netherlands is distinguished around the globe through its engineering capabilities to 'work' the water to ensure the longevity of the country. With almost 60% of the country is under the mean sea level, the country has taken measures to separate, drain, and reclaim land from water or simply protect and prevent it from drowning. Therefore comes the saying; "Drown or be Dutch". These measures have created different landscape characteristics in the Netherlands. In this research, the focus will be on the low lying Dutch river delta landscape. This landscape is the frontline of relationship between anthropogenic processes and the forces of nature. It is also the relics of past success and failures.

Fig. 2 (previous page left)
Map of the Netherlands and its rivers.
Source: Rijkswaterstaat, 2011.

Fig. 3 (previous page right)
Map of dikes of the Netherlands. Due to the low lying condition of the country, dikes are essential infrastructure to protect the country from water. Here, it is clear how the dikes structure the familiar shape of the Netherlands.
Source: LOLA Landscape Architects, 2014.

The lowlands of the Dutch river delta have been protected to minimise the influence of the tidal forces of the North Sea as well as the dynamics of great rivers Rhine, Meuse, and Scheldt. These lowlands have provided fertile lands for agriculture, and strategic access for water transport and trade to the European region for centuries. These qualities create dual images of the delta. On one hand, quiet, open and endless polder landscape with dikes stretching on the horizon protecting the agricultural land from water. On the other hand, busy industrial harbour and urban landscapes that frame vast open body of water with traffics of boats and ships going in both directions. In between these two images, ecologically rich natural lowland landscapes are protected to become a place of refuge for both nature and culture. These images and landscape characteristics are influenced by centuries of anthropogenic manipulation of water and the dynamics of the delta.

Due to the low lying topography, and the forces of nature, different measures to keep the water out, and make the land productive and habitable have been taken. This knowledge of flood defence and water management has become one of the Dutch strongest commodity and has been exported to corners of the world that deal with similar problem. It stretches from a simple mound structure to create a slightly higher household living spaces safe from fluctuating tidal water level to the construction of the 4 km giant sluices of Eastern Scheldt storm surge barriers which one of 13 ambitious projects of the Delta Works. Therefore, these measures directly shape the present day Netherlands framing the ongoing and overlaping relationship between man and water.

Towards new paradigm

Until the past few decades, the measures to separate the land from water are mostly by constructing utilitarian infrastructures that are strictly functional and work against the forces of nature. This approach is criticised and argued that the capacity of such utilitarian infrastructure does not able adapt to the uncertainty of climate change as well as losing the value of nature. Completed in 1986, the Eastern Scheldt barrier started a paradigm shift by not completely closing off the tidal influence of the North Sea from the inland rivers, therefore ecosystems that depend on this fluctuating tidal influence are still allowed to flourish. This did not happen without a fight, a number of protests and campaigns for a more 'environmental' approach gained momentum in the 1970s as the report Club of Rome was published. Since then, the approach shifted from 'working against' to 'working with' the dynamics of landscape. This is supported by more attention put towards climate change in the Dutch water safety policies since the river flood & high water of 1993 & 1995. Notably the Room for the River project as high water mitigation measures in rural areas of Dutch great rivers, which was completed in 2015, is an example of the new approach.

Growing urbanisation process in the Dutch river delta landscape inevitably asks for integration of these water safety measures with the neighbouring landscapes. Structures such as dikes, dams, canals, and ditches are in collision course with the processes of urbanisation and increasing conflict of spatial interests in the urban fabric. In this research, the 'old' and 'new' approaches are criticised. Both approaches can be argued to be effectively protect low-lying areas from water and able to adapt to contemporary issue of climate change to a certain degree.

The old tradition of reclaiming land can be seen in most part of the country. One of the recent examples of this tradition is the construction of the Maasvlakte 2 which is a large scale land reclamation on the west of the Nieuwe Waterweg for a new port landscape on the deeper waters of river mouth. This project sacrifices the natural ecosystem of the coast which changes the transport of nutrients, sludge, and fish in the Dutch coast in favour of the economic benefit of the seaward port landscape (De Vlieger, 2017, p. 80).

An example of a more contemporary approach of working with nature is the depoldering of the Noordward polders which is a part of the Room for the River. The project is aimed to transform the agricultural polders into nature reserve area by breaking the embankment and recreating meandering geometry of the water body inside the polder area. Both these approaches tend to stay away from integrating with the urban fabric and implemented on the rural areas. Therefore, the future of urbanised delta will depend on new opportunities development which addresses the complexity interweaving flood defence, urban development, environmental issues, and economy (Meyer, Nijhuis, & Broesi, 2014, p. 45).

Paradigm shift in south western delta & the river landscape

1953 1958 1970 1986 1993 1995 2008 2018

North sea flood

1,836 people died
20,000 farmlands flooded
47,000 buildings damaged
100,000 people evacuated

Delta Comitee established (1953)

Ijssel barrier started construction (1954)

Delta Works initiated (1958)

Hollandse Ijsselkering (1958)

Club of Rome report (1972)

Resistance to damming the Eastern Scheldt grew (1970)

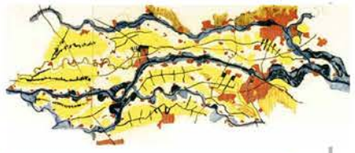
Eastern Scheldt decided to be closable barrier (1976)

Volkerak dam (1970)

Haringvliet dam (1971)

Brouwers dam (1972)

Plan Stork (1986)



Eastern Scheldt barrier (1986)

River high water

200,000 people evacuated
170 km2 floodplain inundated (1993)
Total damage 100 mil. EURO in 1993 & 400 mil. EURO in 1995 with the cost of evacuation.

Natuurbeleidsplan (1990)

Duursche waarden (1989)

Blauwekamer Grebbeberg (1992)

Room for the River as policy(1996)

Natura 2000 (1998)

Maeslantkering (1997)

Room for the River underway (2006)

Delta Committee II (2008)

Annual Delta Programme (2010)

34 projects along river floodplains (2006 - 2016)

Depoldering Noordwaard (2015)

Room for the Waal (2016)

Large scale enclosure of the delta from sea

Dams and barriers were constructed as part of the delta plan to separate the sea arms of the south western delta from the North Sea with only connection in the Nieuwe Waterweg. Thus reduce the dynamics of the delta.

Environmental movement

Due to the missing dynamic forces of the sea, the ecology degraded and the Club of Rome report gave the environmental movement momemntum in the 1970s.

Plan Stork won land-use planning competition for the river landscapes which seeks to restore the ecology along the floodplains as a service for agriculture and urban landscapes.

Climate adaptation & nature restoration

Floods of 1993 & 1995 brought the realisation and the urgency of climate change and persuaded the adaptivity towards climate change to be included in water safety policies & planning.

Future adaptive delta

Room for the River projects are aimed to restore the capacity of the floodplain to contain water and to re-establish the natural dynamics of the flood plains. These projects address the adaptive capacity towards uncertain change on the river landscape.

Fig.4.
Timeline of the paradigm shift on the Dutch river delta

Dutch river delta as area in focus

The Netherlands is located in the lower reaches of the Rhine, Meuse, and Scheldt rivers. These rivers join the North Sea through the south western part of the country which shape the unique landscapes of the Dutch south western delta. The landscape naturally experienced frequent flooding which made the landscape very dynamic through the processes of sedimentation and erosion. In the middle ages, 9th century onwards, the landscape started to be systematically reclaimed and inhabited. This process of land reclamation has been limited the dynamic ability of the delta landscape to adapt to the changing circumstances. In the delta, land reclamation is mainly done in the fertile floodplains and peat bogs for agriculture. New land reclamation can be done outside the dike once the land has been naturally accreted. Therefore the spatial structure is characterised by large number of polders with remnant of old dikes visible on the landscape either dysfunctional or function as second dike if the primary one is breached (Meyer, 2017, p. 29). This anthropogenic process has brought flourishing economic activities which in turn promote urban developments in the reclaimed landscapes. Before, urban developments were only feasible on top of natural river levees or dwelling mounds due to the uncertainty of possible flooding. These urban developments are close to and with connection to water, either mandmade canals or natural channel, as means of transport and trade. The city of Rotterdam and Dordrecht are examples of historic urban developments around natural waterways.

Diking the landscapes of the delta reduces the dynamic ecological qualities of the landscape with different biotopes suffer and degrade due to loss of sedimentation, shift in water flows, and lower water qualities. This process overtime defines the boundaries of the river landscapes, limiting the rivers from naturally shifting their courses to accommodate changes in water flow. Most notable ecological change occured after the construction of the Delta Works which was initiated as a response to the devastating 1953 flood in the south western delta. Delta Works practically separates the south western delta and the North Sea, reducing the influence of the sea significantly. The delta becomes basins. This largely affects the ecosystems that depend on the exchange between the sea and the rivers. Notably, among others, lost of various brackish water ecosystems in Zeeland, and highly reduced tidal influence of the Biesbosch national park which is still the largest freshwater tidal wetland park in Europe.

To mitigate contemporary problems and challenges both inside and outside the dikes, new adaptive ways of management in the delta have been researched, designed, and start to be implemented. Most prominent is the founding of Delta Programme which is a national programme involving goverment bodies and civilian stakeholders in formulating strategies with the focus of water safety and fresh water in the delta.

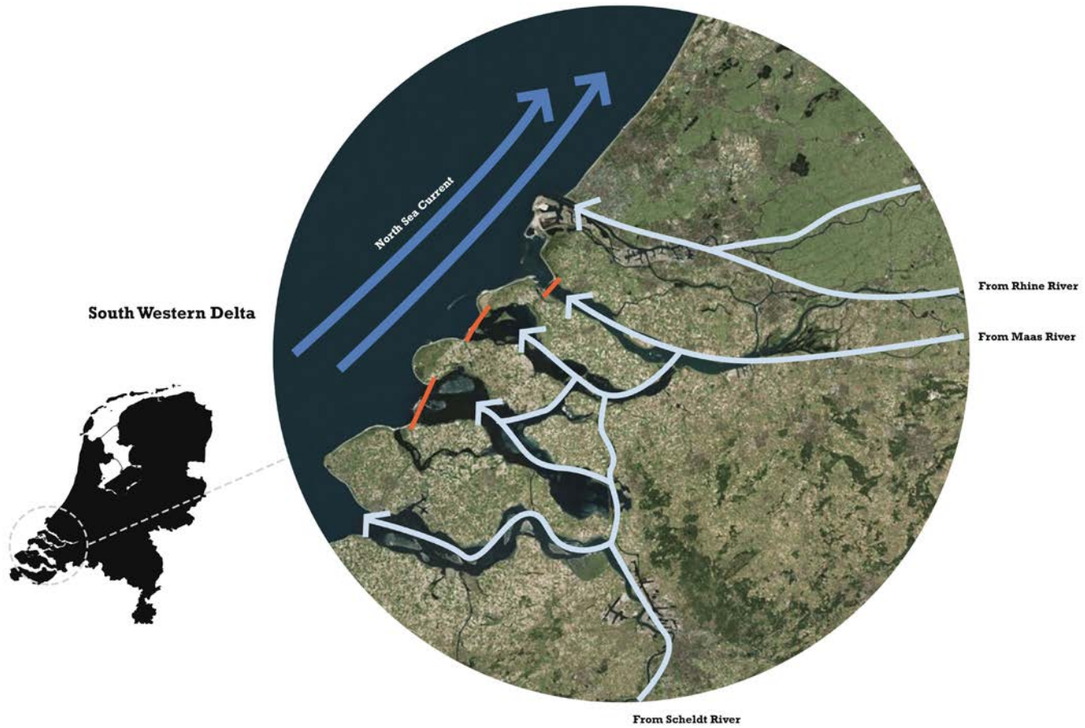


Fig.5
The Rhine, Meuse, and Scheldt delta which shapes the south western part of the Netherlands. Closure of the Delta Works are marked in red line

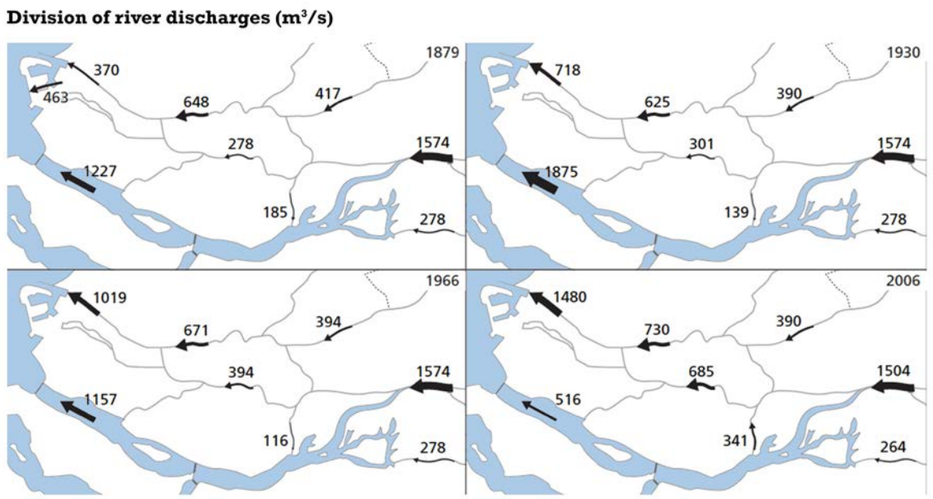


Fig.6
River flow of the Rhine and Meuse delta with significant changes before and after the Delta Works in late 1960s.
Source: Huismans & Hoitink, 2017

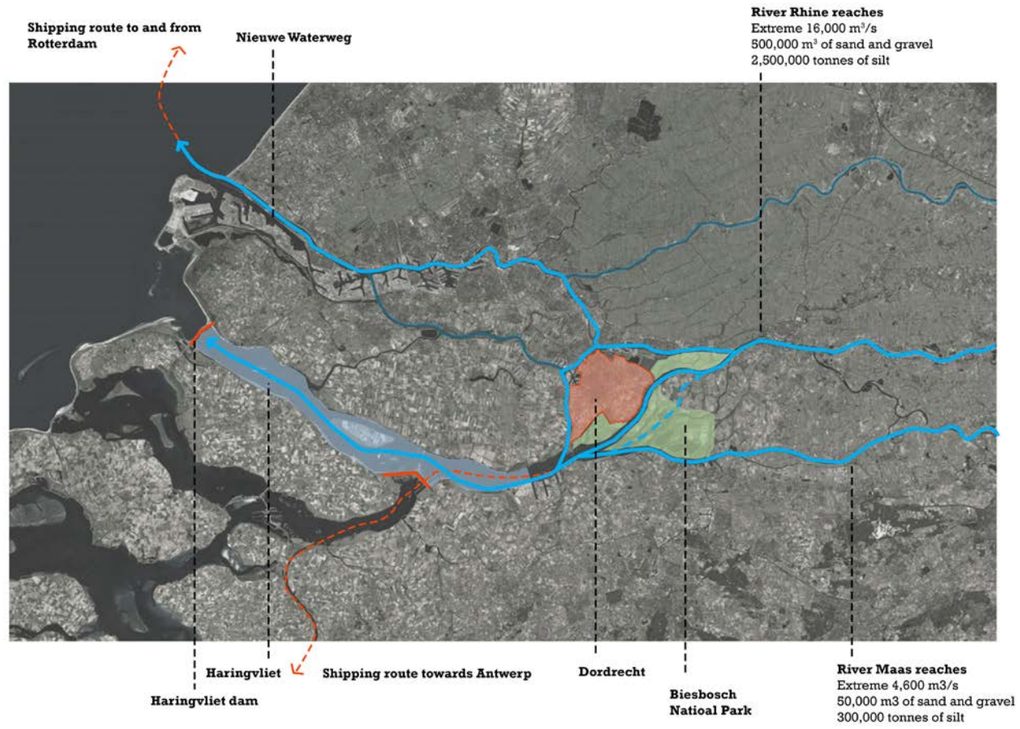
Dordrecht as case study

This research will look into the landscape of the Dutch river delta, in particular an urbanised meeting point of river basin of Rhine and Meuse in the Island of Dordrecht. The landscape is a collection of embanked urban and agricultural areas that are protected against the dynamics of the river. Outside the dike protection, industrial ports and nature reserve areas with high ecological value of the Biesbosch National Park, and the Dordtse Biesbosch are present. The development of the city is focused on the historic city centre on the north west of the island on the intersection of Oude Maas, Noord, and Beneden Merwede rivers which is busiest shipping junction in Europe.

The landscape itself is the artefacts of the larger polder body of South Holland's Grote Waard and remnants of centuries of battle between nature and culture. St. Elizabeth Flood in 1421 created the river channels and landscapes that surrounds modern day Dordrecht. Getting further inside the island, branching from the historic city centre, are housing suburbs that were built on top of previously agricultural polder landscape. Currently agricultural areas dominated the south east side of the island, alongside fresh water tidal nature areas of Dordtse Biesbosch. Over the dike on the south east is the late 19th century manmade channel Nieuwe Merwede and beyond it, the Biesbosch national park. After the St. Elizabeth flood, the remaining is the historic city centre, and south east of it is open and dynamic fresh water tidal zone that slowly accreted overtime. The people of Dordrecht, overtime, reclaim this accretion with embankments for agricultural purposes. From the 17th century til early 20th century, this process of land reclamation took place which shape today's island of Dordrecht. Due to subsidence, the land within the embankments are lower than the river water outside.

Here the practical urgency of flood defence measures and water management strategy has been paramount and has been demonstrated throughout history. However, the site is also an example of separation of spaces and functions between conflicting elements of urban landscape, cultural landscape, and natural landscape. The lack of coherence between these landscapes are not limited in terms of programming, but also in terms of visual and physical connectivity, spatial coherence, and interrelation between landscape elements. The growing process of urbanisation and its spatial interests are conflicting with the effort of making the landscape of the river delta more resilient which takes the urban fabric out of the flood defence landscapes and these measures are applied limited to the rural areas.

The focus of this research is on the entire Island of Dordrecht itself and looks through its history and its urban and landscape processes that shape the landscape structures and qualities of the island.



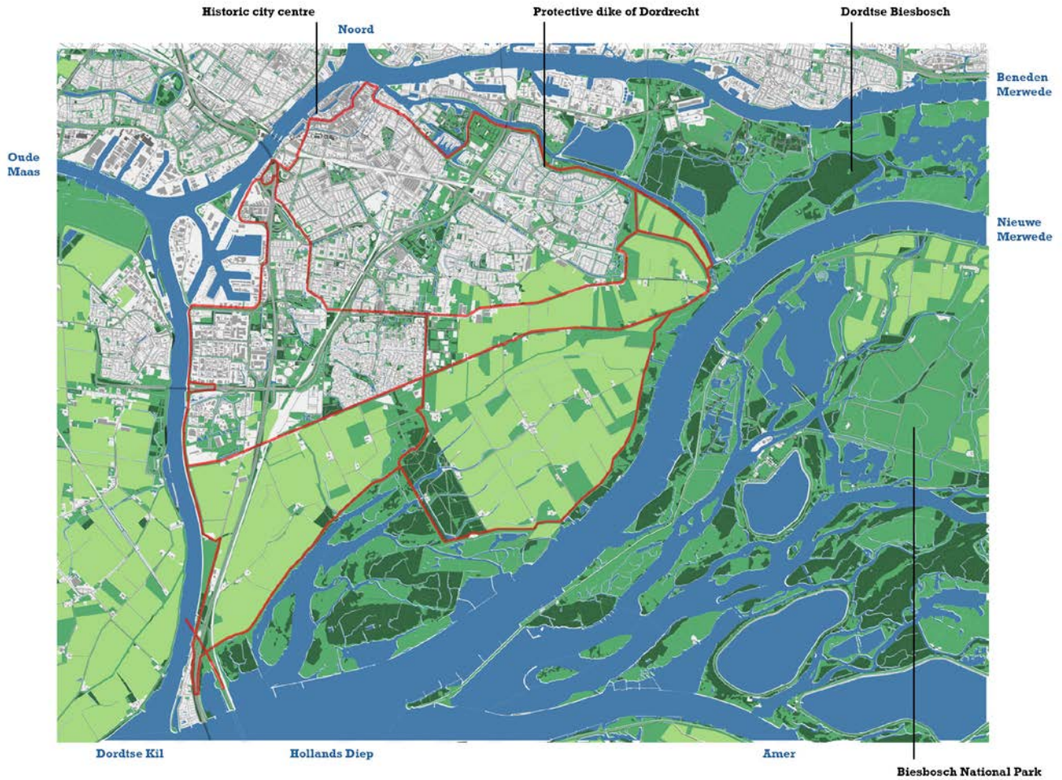


Fig. 7.
The Dutch river delta with the dynamics with the flowing characteristics of the two major rivers that feed the landscape.

Fig. 8.
Map of Dordrecht and its surroundings rivers and landscapes. Protective dike of the city is marked with red line.

Fig. . 9
Urban riverfront of Dordrecht with apartments facing the river Beneden Merwede. Source: Author's photograph

Fig.11
Urban waterways as part of the historic city centre. Used to be used as trasportation. Source: Author's photograph

Fig. 10.
Harbour in the historic city centre facing the leaning tower of the old church. Source: Author's photograph

Fig.12
One of the quays on the historic city centre as the 'back-yard' of old historic houses. Source: Author's photograph

Fig.13
Cycling along an old dike with housing on the sides. Source: Author's photograph

Fig.14
Residential townhouses along the Zuidendijk with different levels as the dike is no longer part of the outer dike. Source: Author's photograph

Fig. 15
Striking height difference of protective dike and residential areas around it. Source: Author's photograph

Fig.16
Housing neighbourhood built around artificial waterbody in Amstelwijk. Source: Author's photograph

Fig. 17
Cycling along the agricultural polder with the outer dike on the right. Source: Author's photograph

Fig. 18
Preserved creek as main waterline of the Nieuwe Biesbosch polder. Source: Author's photograph

Fig. 19
Nieuwe Biesbosch polder. Source: Author's photograph

Fig. 20
Ditch of a polder on the southern tip of the outer ring dike. Source: Author's photograph

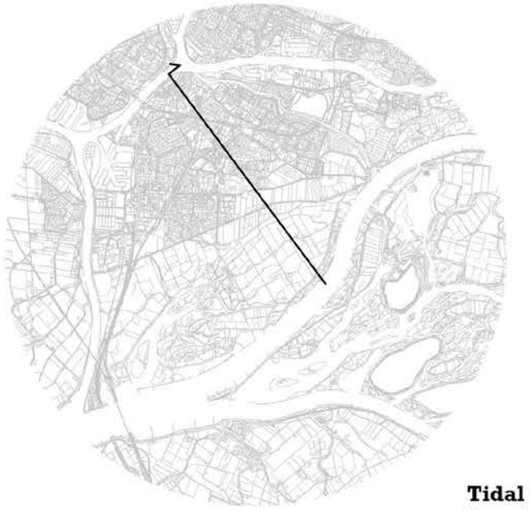
Fig. 21
Walking along the Wantijdijk. Source: Author's photograph

Fig. 22
Alluvial forest outside of the outer dike in the Sliedrechtse biesbosch. Source: Author's photograph

Fig. 23
Frozen creek of Sliedrechtse biesbosch separating grassland and willow forest. Source: Author's photograph

Fig. 24
Natural creek cuts through the nature park of Sliedrechtse Biesbosch with sluice gate at the background. Source: Author's photograph

Fig. 25
Cross-sectional division of Dordrecht from west to east which transform from urban riverfront into polder cities and into polder landscapes. From dense to sparse within the outer embankment of the city. Source: Author's photograph



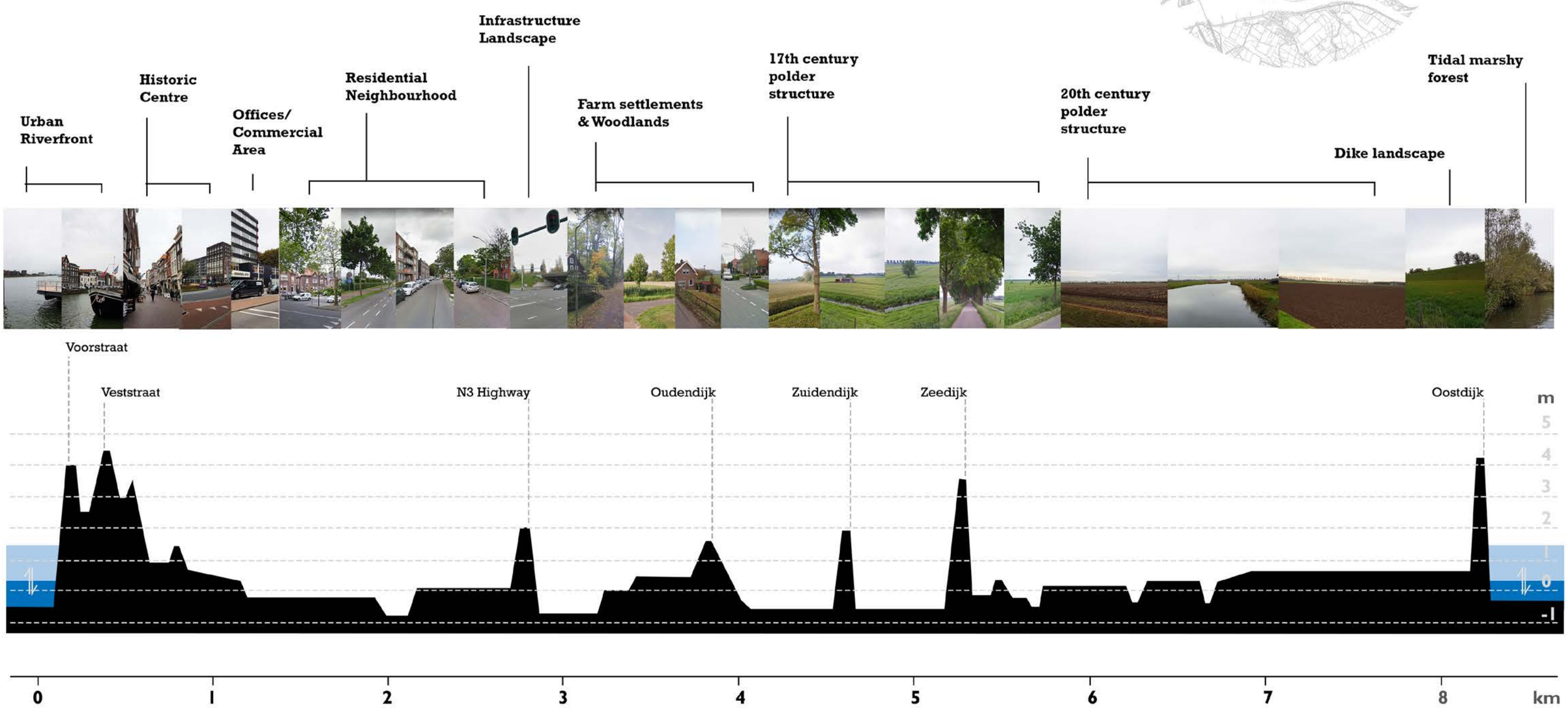


Fig. 26
Hard and soft edges between land and water inside and outside protective embankments of Dordrecht. This demonstrates the inflexibility and rigidity of regulated water bodies and lines in urbanised delta city in comparison to the natural gradients of the river landscape. *Source: Author's photograph*

Problem statement

On the landscape of urbanised delta, existing water safety measures, such as dikes, dams, and waterways, are monofunctional infrastrustures which are inflexible and inadaptive to uncertain change, and does not evoke the qualities of the natural landscapes. A contrast of qualities, both spatial and ecological, and the capacity to adapt to uncertain change between these measures in an urbanised landscape and the natural systems are 'black and white'. In Dordrecht, the natural river dynamics stop at the outer dike of as primary boundary, leaving the water system inside as a completely regulated system separated from these natural dynamics.

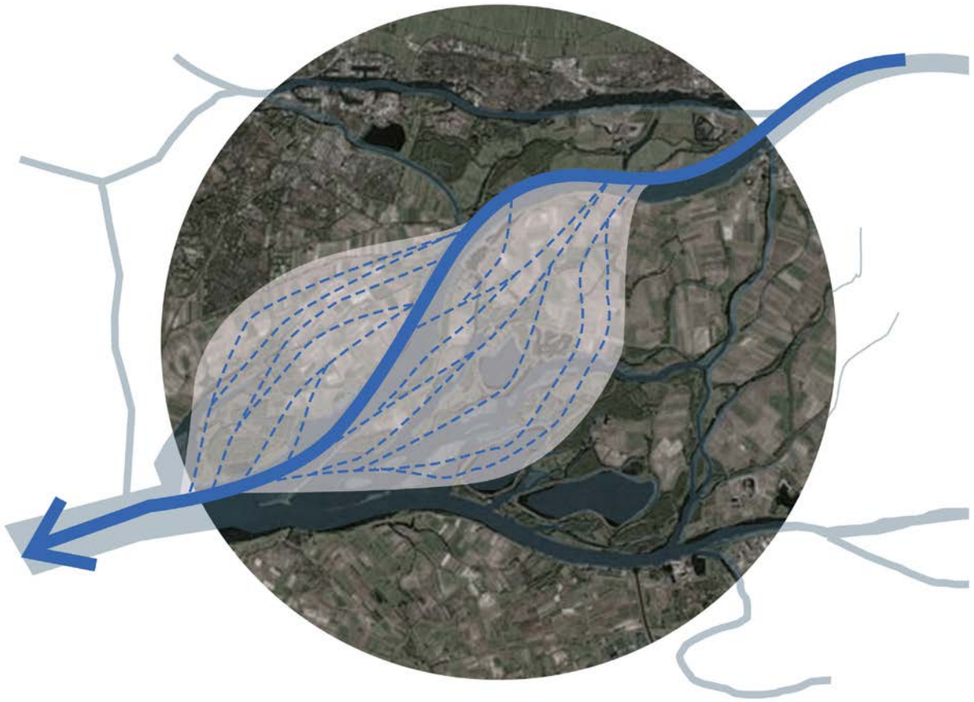
This results in the incapability of the inside system to cope with sudden changes in water level, not only due to the river water, but also due to cloudburst flooding. In an extreme case of dike failure, the urban and agricultural landscapes inside the protection of these dikes will not be able to 'absorb' these natural forces. Furthermore, as the landscape is increasingly urbanised with new housing suburbs are planned along the pheriphery, without a visionary new water safety measure, it will increase the risk of flooding and unable to adapt to the changing climate.

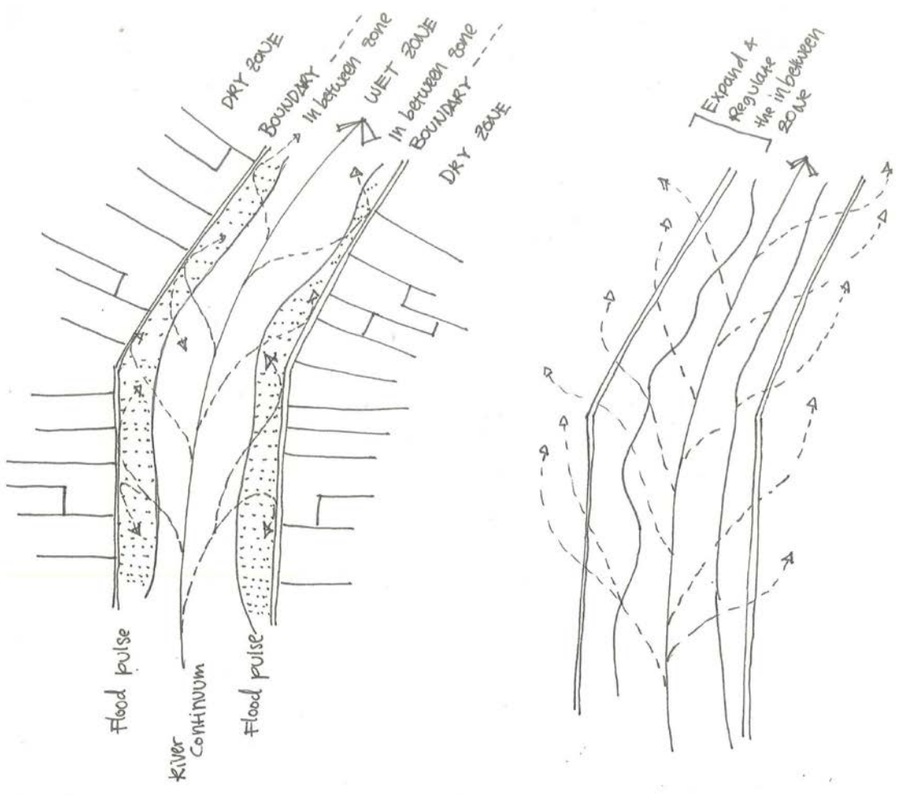
Spatially, these rich landscape qualities of the natural river landscape is missing in the urban landscape as the water canals and channels are regulated with strict edges and limited dynamics. Therefore the 'river' characteristic of this river delta city itself is non existent in the majority of the landscape.

Fig. 27
Preliminary concepttual diagram of inviting the river to 'flow through' the embanked landscapes of Dordrecht.

Hypothesis

The forces and dynamics of nature, that for centuries has been kept outside, the dikes can be 'invited' inside in order to generate unique landscape qualities of the delta, and make the urbanised landscapes more resilient and adaptable to uncertain change, not solely dependent on the integrity of dike structures. By inviting the dynamic of the river landscape inside the embankments of Dordrecht, new measures of urban developments can be designed alongside the natural dynamics. This challenges the concept of 'building with nature' in regards to water safety which until now is limited to the rural landscapes of the river. Inviting the flow of the river to 'flow through' instead of 'flow around' can be explored as a way to intertwine the the two dynamics. In the end, a balance of both urban and nature can be achieved by interweaving one another, without sacrificing one or the other.





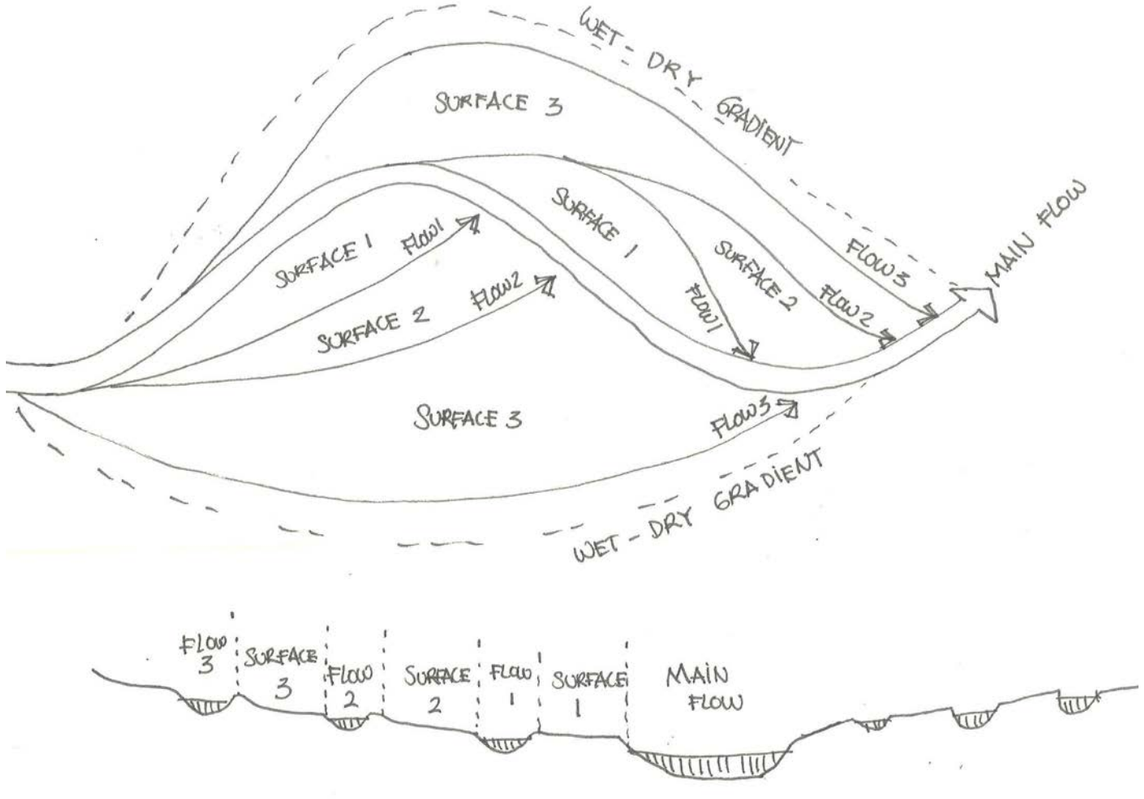


Fig. 28
Preliminary concepttual diagram (continued) of different gradients of flows and the surfaces that created by the different flow conditions.

Research objective

This research is aimed to address the conflict between process of urbanisation and measures towards flood defence and climate adaptation landscapes by developing new green and blue network for Dordrecht. This new network is designed to adapt the dynamics of the river delta into an urbanised landscape without compromising its safety whilst making the urbanised landscape as part of climate adaptation measures. Understanding the river delta landscape as accumulation of layers of human intervention in time as well as ongoing battle against the climate, the design seek to respect, reveal, and incorporate relics of the past and present as unique landscape characteristics and to create enabling and guiding conditions for uncertain future. The objective of this research is also to introduce new landscape structures and typology to the existing landscape of Dordrecht through different design interventions and management plans which takes into accoung both urban and ecological perspectives and processes.

Main research question

How can the dynamics of river delta landscape be integrated to the urban landscape of Dordrecht as measure of water safety, to increase climate resiliency and generate unique landscape qualities in the urbanised delta city?

Sub-questions

How has the ongoing relationship of man and nature shaped the urbanised river delta landscape?

How to utilise landscape characteristics of Dordrecht as guiding elements for future resilient green and blue network?

What design principles can be extracted from precedence of contemporary flood defence measures?

How can the current practice of flood defence and climate adaptation be challenged further and be implemented to create robust and multifunctional flood resilient landscape that is not only limited to the rural landscape?

How can the landscape architectonic design principle developed in this research become a framework of robust and adaptive design in urbanised river delta landscape?

Fig. 29
Farm house on top of a new mound as part of depoldering Noordwaard project. 3 different water level can be seen in this picture; polder level, intermediate level, and tidal river level. This project creates room for water fluctuation whilst restoring the ecological qualities of the landscape.

Scope & relevance

This research contributes to the discourse of landscape architecture and climate adaptation especially in the urban landscapes. The attitude towards water and landscape processes are challenged and explored to address climate resiliency in an urbanised delta city. In this context, the process of urbanisation is on a collision course with the existing hydraulic engineering structures in the urban fabric and necessary future measures toward the changing climate. This research is aimed to provide new possibilities of climate resiliency in urban fabric through incorporating natural landscape processes in urban areas and urban developments. Furthermore, this research is hoped to be able to promote future discussions of climate resiliency in an urban fabric and to encourage further refining and adapting of the resulting design principles.

The scope of this research focuses on the urbanised delta city of Dordrecht. This research starts with multi-scalar temporal and spatial analysis to understand the existing landscapes through different scales. Design principles that are the results of research by design process address the whole city scale of Dordrecht. The principles are tested on site specific areas as case study to generate possible landscape qualities and implications.

This research, furthermnore, seeks to show the otherside of the coin of 'building with nature' as water safety measures in the low-lying delta landscape which has gained momentum in over the past 3 decades in terms of policy, research, and implementation. Until now the practice is limited to the rural landscape with the focus of nature restoration and mostly limited to enhancing ecological qualities. This research looks closer into the possibilities of interweaving this concept into the processes of the urban landscape. Therefore, the research-by-design project is will try to show the spatial qualities and new landscape structures that emerge of such exploration which adds to the current research of 'building with nature' itself by adding the element of 'living' with these restored ecologies.

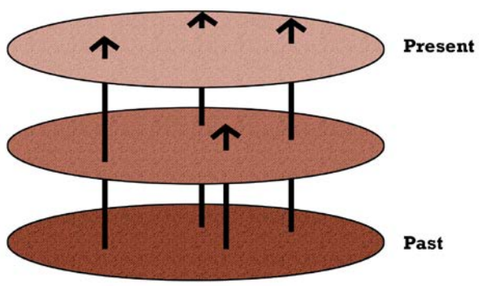
Thesis structure

Following this introduction, this research starts with presenting theoretical framework as entry points of the research in chapter 2. The theoretical framework focuses on 3 statements regarding to the Dutch river delta and the implications that they have to the methodology of this research. In chapter 3, elaboration of understanding the site is presented which consists of site analysis through the perspectives developed in the theoretical framework. Following this elaboration, reference case studies are presented in chapter 4 and its importance to developing design experiments on the site. In chapter 5, the results from design experiments are explored further and implemented on site specific conditions to generate final design principles of this research. Finally, the overall result of this research will be evaluated and reflected against the research objective, research framework, and the discourse of landscape architecture and climate adaptation.

Landscape as Palimpsest

Dutch river delta landscape as palimpsest of ongoing relationship between man and nature.

Landscape biography

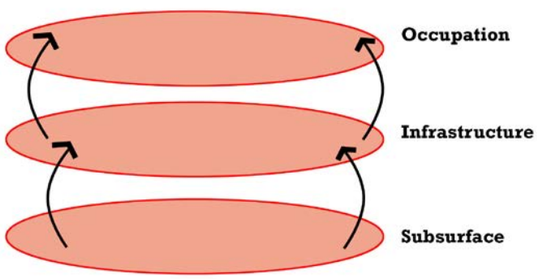


Roymans, et al. (2009), Kolen & Renes (2015)

Landscape as Process

Dutch river delta landscape as amalgamation of urbanisation and natural processes.

Layers of landscape processes



Hoog, Sijmons & Verschuuren (1998), Meyer & Nijhuis (2016)

II. THEORETICAL FRAMEWORK

1. Dutch river delta landscape as palimpsest of ongoing relationship between man and nature

Historian JB Jackson (1984) characterised landscape as "where we speed up or retard or divert the cosmic programme and impose our own" (p. 157). Jackson argued that the contemporary landscape is "always artificial, always synthetic, always subject to sudden or unpredictable change" (p. 156). The river delta landscape suits this definition. Over the course of the centuries the landscape has changed based on the processes of urbanisation which flourishes on trade and agriculture alongside, or sometimes against the processes of nature. Today, the landscape is a product of ongoing accumulation of technical measures that transforms the natural landscape to be productive and liveable (Bobbink & Nijhuis, 2010, p. 46). Overtime, these measures are reordered, evaluated, enhanced, and/or replaced which significantly alter the natural landscape structure. The relics of past measures of flood defence, water management, and climate adaptation are either idyllically preserved, in a form of decay, or eroded by the process of urbanisation. Whereas the currently functioning infrastructures are carefully maintained and evaluated. These structures are inevitably gradually incorporated into the growing urban fabric and natural restoration which presents a conflict between future flood risk management and its spatial impact (Van Veelen et al., 2015, p. 277).

Landscape biography

Recognising the delta landscape as accumulation of hydrological measures and societal development through time requires critical overview and understanding of the different layers of processes that shape the landscape. On one hand, the landscape is a product to the instability of terrestrial morphology, such as land subsidence, sedimentation and erosion, and on the other hand it is an ongoing process of remodelling space due to human activities (Corboz, 1983, p. 16). Along the same line, Marwyn Samuels (1979) refer the idea of human intervention as authored landscape on which different individuals or cultures have important roles in shaping of landscapes and our understanding of landscapes. Tim Ingold (2000) further emphasises on the necessity of understanding landscape as not 'land'

this case the first layer of dynamics is the surface and subsurface layers where the changes are slow, repetitive, and almost imperceptible. The second layer is the infrastructural networks that support long term social, economic, and cultural history. The third layer is land use where the changes are directly influenced by short-term social development and political decisions (Meyer & Nijhuis, 2016, p. 295). From these three layers, similarities and dissimilarities can be analysed and spatial organisation based on different structuring elements and dynamics can be explored.

Landscape architecture and dynamic processes

Landscape is not static and the concept of beauty in landscape architecture has been shifted away from creating a finished landscape that is frozen in time. In landscape architecture we alter the programmes of nature and impose our own rules (Jackson, 1984, p. 156). In other words, landscape is where manmade and natural systems influence each other to create spatially and temporally open system (Prominski, 2005, p. 27). Therefore, the beauty of landscape is not a highly maintained and nurtured landscape, but a dynamic and open-ended process.

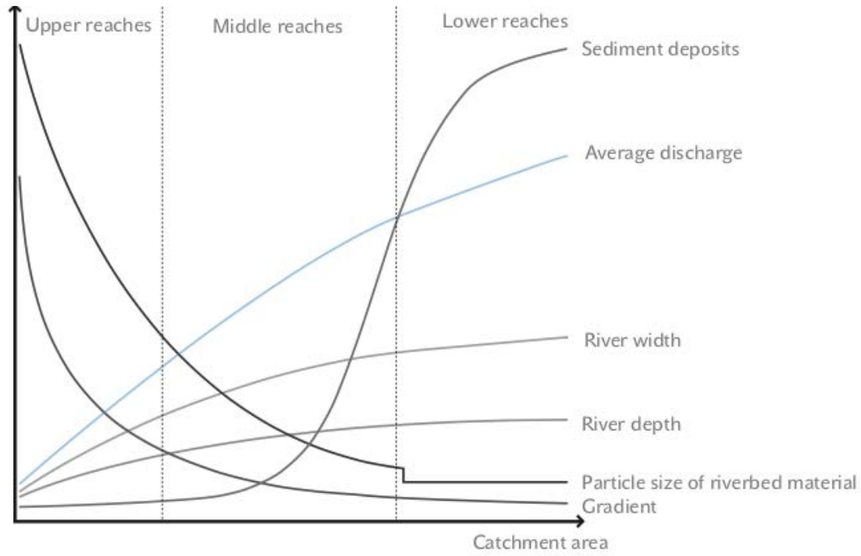
Designing with the dynamic forces of the natural landscape requires temporal and spatial understanding of the processes themselves. How do these forces shape the landscape? What are the driving forces of these processes? How can we intervene and implement our systems to achieve a certain design goal? In a river landscape, the water courses shape and reshape the landscape that they flow through. Historical overview of a riverine ecosystem shows this process of change. Influence of human interventions, in this case; in the Dutch river delta, has been against the natural processes and only shifted over the last three decades. This shift has demonstrated the trend towards "working with nature" instead of against it.

To explore the possibility of process-oriented design, the Dutch river delta is an excellent case study. 'Process oriented design means thinking and planning in terms of options, follow-up measures, and responses to spontaneous developments…they are shaped by a multiplicity of cultural and natural processes: settlement growth, transport access, the changing seasons, vegetation growth, geological processes and climate change.' (Prominski et al., 2012, p. 16). This method of design addresses uncertainty and the relationships between systems which is suitable for constantly changing landscapes.

Dynamics of river landscape

Naturally river systems are in dynamic equilibrium (Das, et al, 2014, p. 7). This means that the river system, if alterred by natural conditions, will always find and readjust itself, through process of sedimentation and erosion, in regards to profile, dimension, and pattern to reach its former balance (Couture, 2008). Determined by topography, in the upper reaches, the river cuts through the landscape creating steep river banks with high kinetic energy whilst transporting the material downstream (see fig…). As the river goes downstream, it starts to cut sideways or laterally which increases the river width. In the lower reaches, the river's energy focuses on the laterall movement to create meandering rivers as it gets closer to the sea. Impeding force from the sea further influence this diversion of main river channel in lower areas which creates unique delta landscapes. The natural process of sedimentation and erosion shifts the river continously, changing its channel and leaving marks within the landscape. Martin Prominski, et al (2012) describe the river dynamic processes as spatiotemporal expression on the landscape, as it form the landscape from interplay between topography, geology, climate, and energy of the current. More specifically, they classify these formative processes under two kinds of dynamics; (i) temporary flow fluctuations, and (ii)morphodynamic processes.

Fig. 30
Different river types on upper, middle and lower reaches. As the river goes downstream, sedimentation, river width and river depth increases while particle size of the sediments and gradient steepness decreases.



i. Temporary flow fluctuations

This dynamic represent cyclical change in water level which floods and dries the floodplains. Changing in annual climate conditions influence this process as well as the conditions and local climate of the flood plains. The result is variety in river discharge which creates fluctuations both vertically and laterally (see fig. 32). Vertical water level change directly related to the discharge of the catchment area which can overflow laterally from the bank carrying energy and sediments to its floodplains. High and low water levels affects the ecosystem of the floodplains as well as anthropogenic programming and interventions in different point of the river course.

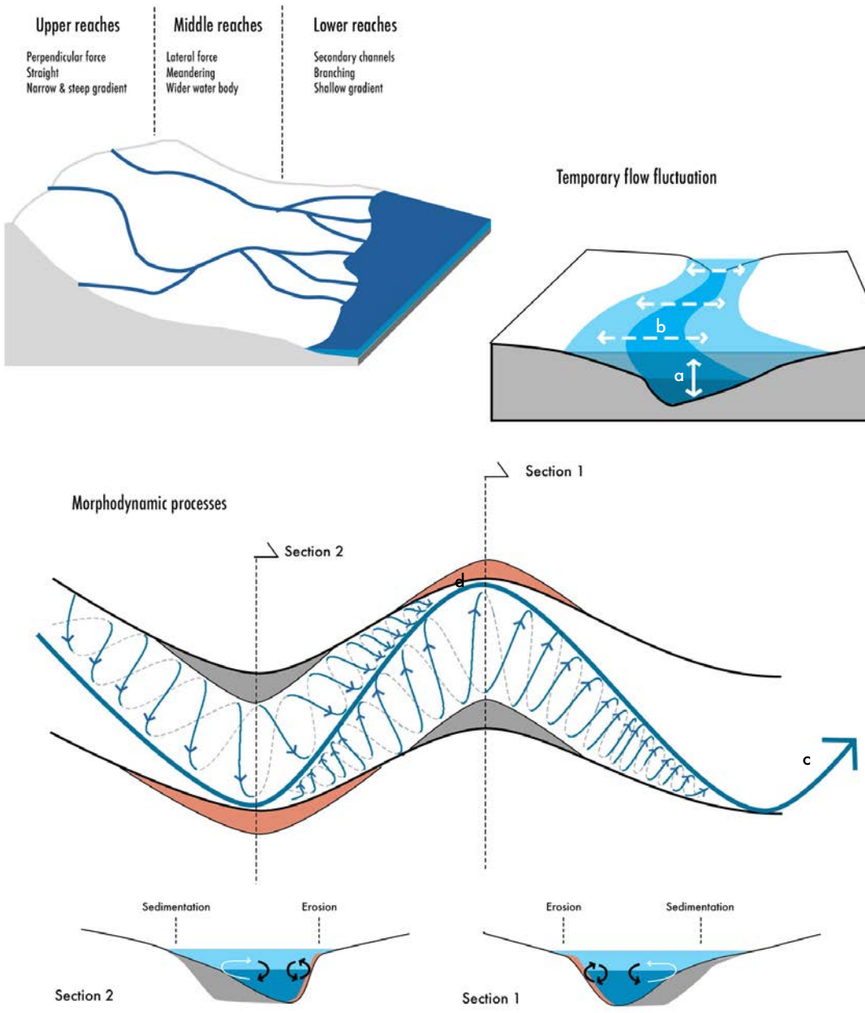


Fig. 31 (opposite top - left)
River schematic morphology as the river flows downstream, the shift in forces change the shape of the river and the landscapes around it.

Fig. 32 (opposite top - right)
Temporary flow fluctuation of a riverbed with vertical (a) and lateral (b) water changes.

Fig. 33 (opposite below)
Primary (c) and secondary (d) currents of a river.

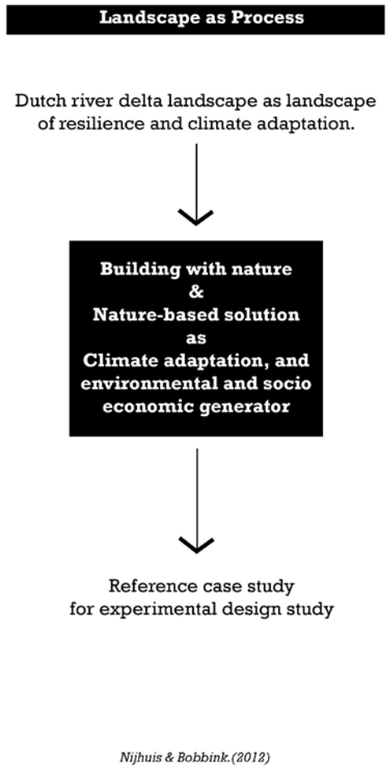
ii. Morphodynamic processes

As was elaborated, the river shapes the landscape and leaves "fingerprints" on the landscape overtime. This morphodynamic process represents the processes of sedimentation and erosion. The river flows downstream through a main channel and processes of sedimentation and erosion can happen within this channel and slowly transforming it overtime. In general, a river channel has primary and secondary currents (see fig.33). Primary current flows and carries water downstream, and secondary current rotates around the primary current which slows down when it reach the riverbed due to friction and accelerates when it reach the primary channel due to its force. In a river bend, this secondary current is stronger on the outer bank and weaker on the inner due to the different distances between primary current and the river bed. Shift in river course can happen due to accummulation of these processes where the outer banks are "eaten away" and sedimentation occurs at the inner bank due to slower and weaker, current allowing particles time to settle. A new channel can be formed branching from erosion of the main channel until part of the old channel is abandoned completely, leaving rich sediments of river clay and sand.

Anthropogenic interventions & river dynamics

Intervening within the stretch of a river course disturbs the equilibrium of river dynamics and accelerate the rate of bank erosion (Das et al, 2014, p.8). Most prominently in the Dutch river delta is the embankments that reclaim land from water. This embankments do create productive land for agriculture and safer land for living, however, socio-environmental problems arise such as soil subsidence and increased risk of high economic value areas behind the embankments overtime (Warner et al, 2018).

Further changes in the river landscape can also be expected from climate change. Extreme storms and more intense rainfall directly lead to changes in river discharge which challenge the current dike conditions and our way of creating intervention within the river landscapes (Hulscher, 2017, p. 54). This research seeks new relationship of anthropogenic activities and the nature of river dynamics over the next chapters.



Nijhuis & Bobbink.(2012)

3. Dutch river delta landscape as landscape of resilience and climate adaptation

In the face of changing climate, past measures of highly engineered flood defence are seen as no longer appropriate and their flexibility against future. A paradigm-shift towards working with nature that has developed over the last 30 years in the Netherlands creates a new challenge of developing and adopting an approach that works with nature in an interdisciplinary way (Stive & Vrijling, 2008, p. 41). In regards to the Dutch river delta, as a starting point, water must be allowed to have more space before the water takes it for itself which requires combination of technical solutions and spatial design (Peters & Hendricks, 2008, p. 91). Working with the dynamic of the delta, and inclusion of environmental processes in flood defence measures have been promoted and demonstrated as ecosystem based flood management (Van Staveren, 2017, p. 18). Therefore, the approaches to flood defence in order to create resilient landscapes keep evolving towards ecological design and different measures require interdisciplinary approaches. Regarding to infrastructure, spatial design, and ecological landscape, landscape architecture has the ability to play an integrative role between different disciplines (Stokman, 2013, p. 288).

This more ecological approach to flood defence allows resilience to future changes as well as coping with unpredictable future events compared to the conventional infrastructure. Resilience can be described as the ability of systems to absorb changes of state and still persist, however, a system can be very resilient and greatly fluctuate (Holling, 1973, p. 17). Here, the objective is not to achieve stability or equilibrium, as the dynamics of culture and nature are highly complex, but the ability of a system to be stretched to accommodate changes and endures. Consequently, as a soft system, ecology has robustness that derive from its capacity to handle and process movement, difference, and change (Corner, 2003). Not only as added value to infrastructure, understanding he maintenance of the resilience of the natural systems becomes key part of flood defence strategy as a response to climate change (Meyer, 2017).

Building with Nature & Nature Based Solutions

In the Netherlands, the approach to infrastructural elements transformed from not paying much attention to the environmental impact; building instead of nature, to minimising environmental impact; building in nature, to opportunities to develop new nature; building with nature (Ecoshape). This concept has been successfully applied in different conditions and landscapes as measure of climate adaptation. Building with nature analyses the underlying ecology and natural systems of the landscape and use it as operative forces for landscape interventions and development to generate causally constructive measures between urban and nature.

Kelly Shanon (2013) argues that working/ building with nature results in a 'soft engineering' approach that guided by new interplays of landscape, infrastructure, and urbanisation (p. 165). This concept develops along the same lines of nature based solutions concept which promotes the maintenance, enhancement, and restoration of ecosystems as systemic approaches to address multiple problems urban landscapes (Kabisch et al., 2016). Furthermore, building with nature and nature based solutions takes into account the accommodating ecosystem services that can be generated to benefit both human and the natural ecosystems themselves.

The Economics of Ecosystems & Biodiversity (TEEB) studies describe the different categories of ecosystem services such as provisioning material and energy, regulating flows and climate, providing habitat and biodiversity, and cultural services such as recreation, tourism, and spiritual connection (www.teebweb.org). These services can be used to measure the functionality and benefits of the concept of building with nature to the both societal and natural processes. Building with nature concept can be managed through understanding the system (natural and societal systems), identifying alternatives that use and/or provide ecosystem services, evaluating these alternatives in order to come into design solution (Ecoshape, n.d.). In practice of urban landscapes, this concept has been demonstrated in several project such as the Plan Tij in Dordrecht as combination of restoration of riparian gradient and housing developments, and the Waterdunen in coast of Breskens, Zeeland as combination of natural restoration, enhancing socio-economic, and generating unique landscape qualities. These reference case studies are analysed in this research as means of understanding and generating design principles to be explored further. This approach results in experimental design study to generate knowledge and understanding by studying the effects of actively and systematically varying design solutions in a specific context (Nijhuis & Bobbink, 2012, p. 248). In this research this experimentation is done on the city scale of Dordrecht and influences the further design study which looks into smaller scale and site specific landscape interventions.

Climate adaptation in Dutch river delta

Unexpected peak Rhine river discharge in 1993 and in 1995 brought the realisation of the vulnerability of dike as the primary water safety infrastructure in the river landscape. Although no dikes were broken, 200,000 people were evacuated. These near-flood events brought the new sense urgency in finding new way of water safety and climate adaptation plan for the riverine landscapes while looking into the importance of nature restoration and flood protection as equal (Warner et al, 2018 p.5). This called into action the Rhine Action Plan on Floods and policy guidelines called "Room for the River". 30 interventions were funded to re-introduce the natural dynamics of the river on the previously highly regulated landscapes. The programme was initated in 2006 and finished in 2015.

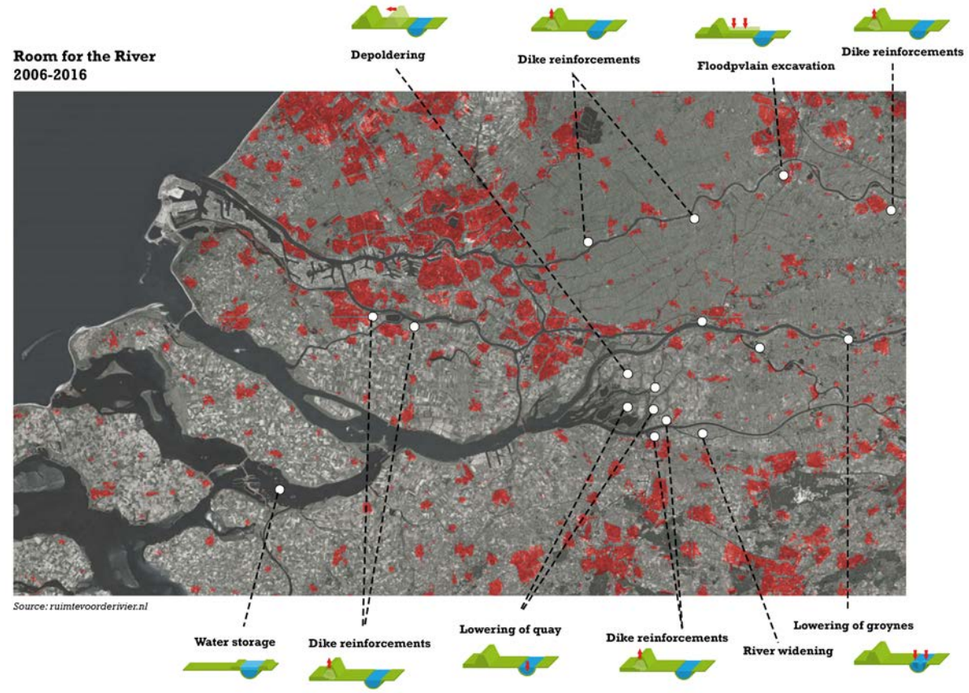
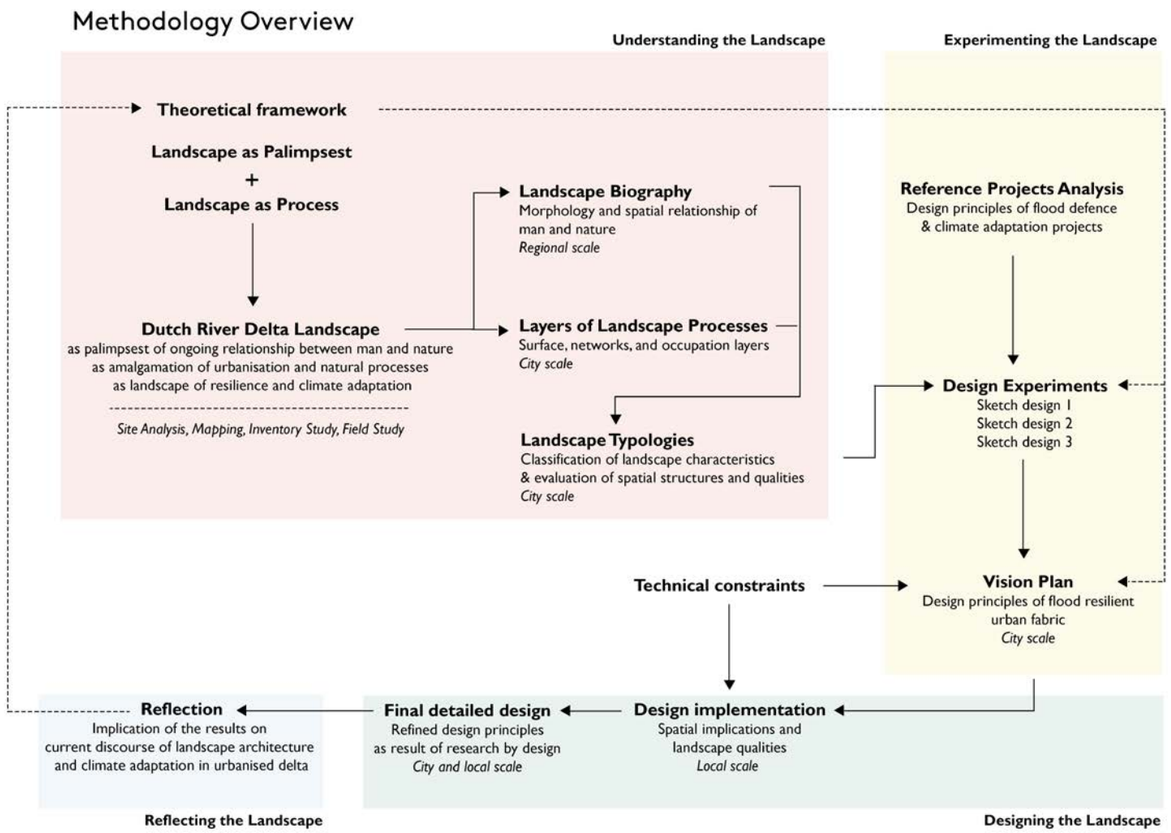


Fig. 34
Measures of climate adaptation from Room for the River programme on the rural landscape of the Netherlands.

The policy plan was based on the Stork Plan which was an award winning plan of ecologically connected systems of the river landscapes almost a decade prior to the near-flood events. Stork Plan which symbolised the effort to bring the population of rare black stork back into the river landscapes of the Netherlands contains framework of land use planning in the rural river landscapes with designated areas for nature restoration as well as agriculture. The Room for the River programme is aimed to adapt the river landscapes towards uncertainty of high river discharge of 18,000 m3/s on the river Rhine as realistic target whilst historically the highest Rhine river discharge recorded in the Netherlands is 12,600 m3/s. Different measures of adaptation (see fig…) has been implemented to provide more room for water flow and natural dynamics with measures such as de-poldering, most notably in the Noordwards polders, and lowering of quays and floodplain excavation, with notable project in the river Waal close to Nijmegen as well as creating the possibility of controlled flooding during high water situation, notably in the agricultural polders of Vessen and Wapenveld.

The programme demonstrates that management of water safety in the river landscape is not only through hard and mono-fucntional structures, but a systematic nature restoration and rehabilitation of embanked landscapes towards the natural dynamics. This further signify the ongoing process of paradigm shift in the Netherlands.



RESEARCH BY DESIGN METHODOLOGY

The 3 statements presented becomes the entry point of exploration and framework of this research. Theories are elaborated in order to develop ways of understanding the landscape, methods of design exploration, and application of design principles. The methodology of this research starts with research design of Understanding the landscape which continues to research-by-design process of Experimenting the landscape, Designing the landscape, and Reflecting the landscape.

1. Understanding the landscape

- Dutch river delta landscape is analysed in a temporal scale which focus on the development of human intervention over the natural landscape and the natural dynamics that shapes the morphology of the site over time. (Regional scale)
- Processes within the landscape are analysed through dissecting the landscape into 3 layers; surface layer (long-term processes, >100 years), network layer (medium to long term processes 50-100 years), occupation/ land use layers (short term processes 10-50 years). (City scale)
- Landscape characteristics are explored and classified into landscape typologies. Measurable parameters are developed based on spatial implications of landscape processes and history to evaluate these typologies. (City scale)

2. Experimenting the landscape

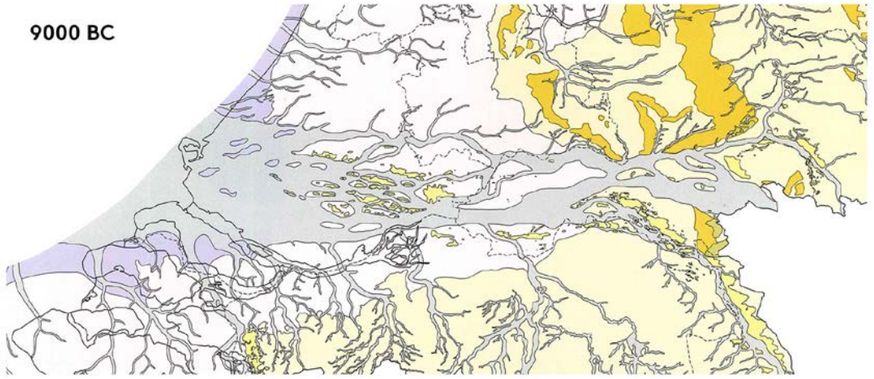
- Reference flood defence and climate adaptation measures are analysed and evaluated in a similar manner and parameters with the landscape typologies presented before.
- Design principles based on these references are related to the existing landscape typologies and are tested on suitable/ accommodating typologies in a city scale.
- A number of design experimentations are made and overall plan for the city of Dordrecht which based on reference case studies and theoretical approaches elaborated. (City scale)

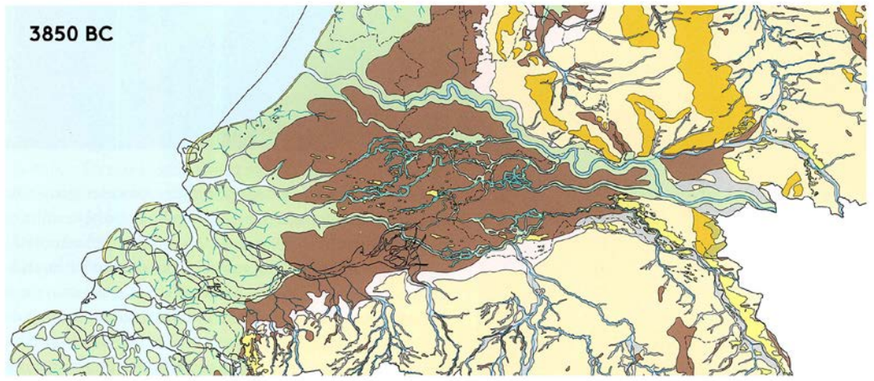
3. Designing the landscape

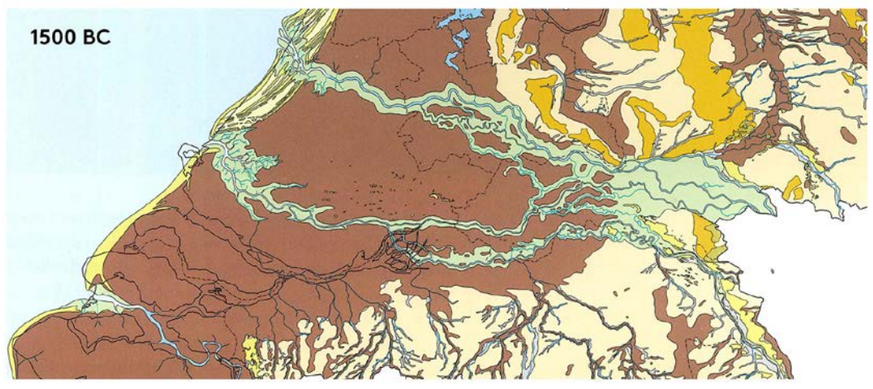
- The overall plan is developed further a set of design principles will be made. (City scale)
- These sets of principles are implemented and evaluated on a number of local scale sites to reveal the spatial implications and landscape qualities that they generate. (Local scale)
- One site is chosen where further detailed design will be explored and formulated. (Local scale)

4. Reflecting the landscape

- The result of this research-by-design is reflected upon the main objective and current discourse of landscape architecture and climate change.
- Points for future discussion and recommendations are formulated as new framework which can influence future research around the topic.







Map source: Vos, Peter, 2011, Atlas van Nederland in het Holoceen.

III. UNDERSTANDING THE LANDSCAPE

1. Geological transformation from the Holocene to the Anthropocene

Layers of Pleistocene sand (<9000BC)

The southwestern delta is located in a valley position which does not change since the end of the last ice age. It was located between higher Pleistocene sand covers and was characterised by freely and meandering rivers (Nienhuis, 2008, p. 539). In 9000 BC, today's North Sea was mostly dry and the sea was futher north and pleistocene rivers flowed through this valley. The landscape of the south western delta was already a sediment transport route and exporting sand as sediment through its meandering rivers.

Rising sea levels (9000-3850BC)

In the begining of the Holocene, the sea level rose significantly as the ice from previous ice age started to melt. Due to its valley position and the rising sea levels, the landscape became sedimentation area from upstream which resulted in layers of alternating clay, silt, and sand. As the coastline was developing under the North sea dynamics, peat layer started to develop behind this coastline. The landscape was characterised by dense swampy forest. Since 6300BC, hunters and fishermen built their camps in this delta landscape. At this time, the Rhine and Meuse estuary were separate with the mouth of river Rhine was in the north of Leiden and the mouth of Meuse was in Rotterdam.

Accummulation of peat (3850-1500BC)

The coasline continued to develop as the sea level rise slowed down. Sand dunes therefore were developed along the coastline which increase the amount of peat layer cover the landscape of the delta. In the year 2000 BC, the peat landscape reached its maximum volume and peat bogs, fens and swamps were developed (Huismans & Hoitink, 2017, p. 4). Due to deforestation in upstream of the river in the Iron Age (2500 BC onwards), flooding events brought double amount of

silt and clay which deposit layers of clay on top of the peat layers. Due to the defined coastline, the rivers of Rhine and Meuse were forced to readjust their paths which caused groudnwaterlevel to rise. This rise in ground water created wet and swampy landscapes with little or poor drainage which allowed organic materials to accumulate and peat layers grew rapidly.

Avulsion and meandering estuary (1500BC-100)

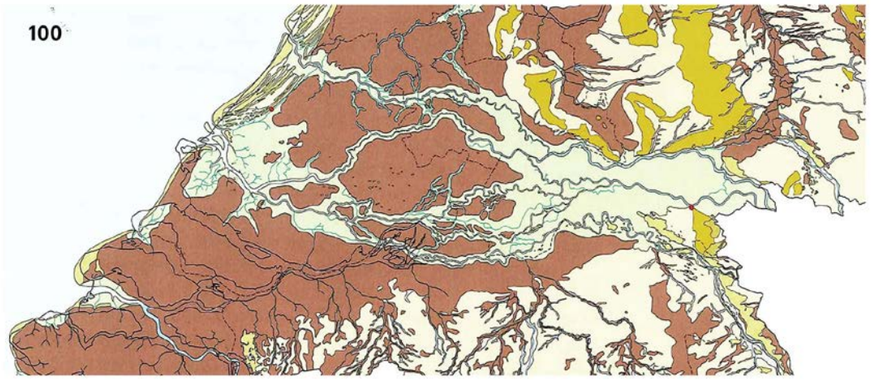
During this period, flooding of the delta landscape became more and more frequent which in turn resulted in river avulsions through the peat landscape. Avulsion was also supported by the influence of the sea and high discharge water from upstream which encouraged the rivers to hurdle and forcefully change its courses to accommodate the forces. In this period, the peat bog landscape started to be systematically cultivated. Excavations show the oldest manmade dikes dated 100-200BC with manmade levees and culverts. This period also marks the Roman occupation (from 15 BC) which started to implement manmade waterworks on top of the natural waterways with canals and dams.

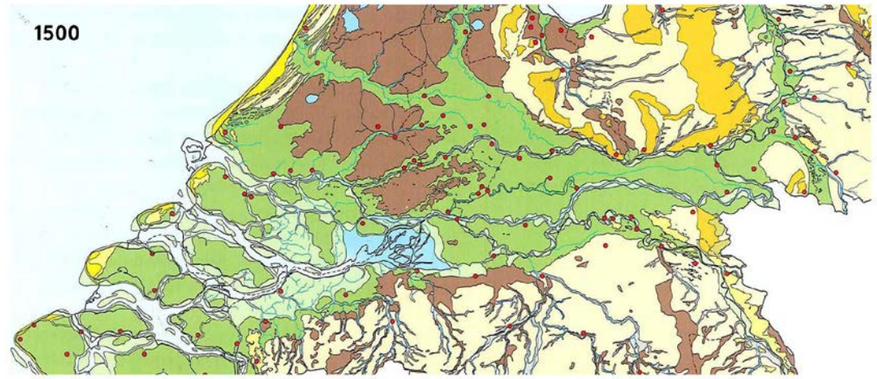
Human settlements and agriculture (100-1500)

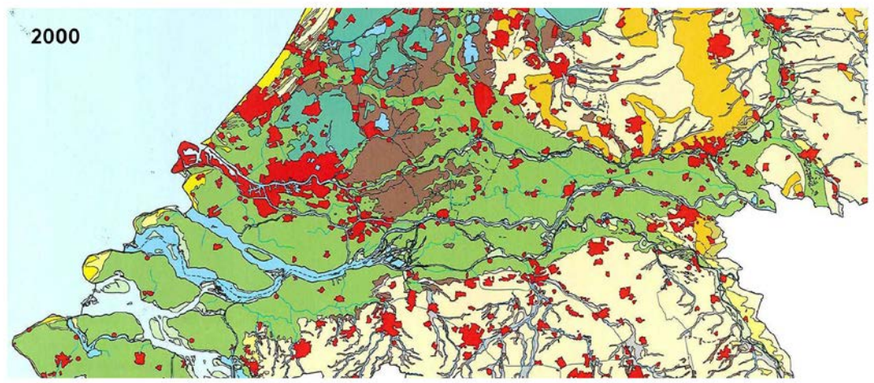
Sea level rise were accelerated in this period which makes most of the delta inhabitable. Farmers built dwelling mounds on the floodplains to adapt to the changing water levels. From 9th century onwards, people of the delta realised that the marshy peat landscape can be simply drained by digging ditches towards lower points of the landscape (Meyer, 2017, p. 21). Human influence on the landscape of the delta increased in this period with large scale reclamation of the floodplains and marshy peat landscapes to be cultivated. In some areas, peat layers were mined for fuel and salt extraction, as well as to be building material for dikes. This diminished the peat layer and caused the landscape to start to subside and more vulnerable to flooding.

Modification and technological advancements (1500-2000)

It was technically viable in this period to further drain the subsiding landscapes and peat lakes with help of windmills. This result in higher risk of flooding and land subsidence which encouraged alteration of natural river flows through canals and manmade. In 19th and 20th century, the power of steam engine allowed upscalling of land reclamation for agriculture. During this period the natural river landscape has been highly regulated, and delta cities started to develop and grow due to the flourishing economy.







2. Human intervention, social development, & relationship between land & water

n-1100

The natural landscape of the riverine system was characterised by open meadows and marshes with wide levees. Naturally formed river levees flanked the rivers whilst framed large peat landscapes. Distinction from lower reaches and the upper reaches is the influence of the tide from the North Sea with marine sediments dominated the lower reaches and going further east was perimarine area with influence of the tide but without marine sediments (de Wit, 2009, p. 21). The composition of the landscape was coarse sediments, mostly sand, close to the rivers, deposited silt and clay sediments further inland, before reaching then high peat marshes and peat bogs.

During this period, people started to drain the peat landscape for agriculture. However, mostly settlements were on the higher sandy levees to avoid high water conditions. Simple ditches were created to drain water from the peat landscape into the natural river. As the peat oxidises, farmers moved further inland towards higher peat marshes to be drained. Here, the drainage was still mostly by gravity.

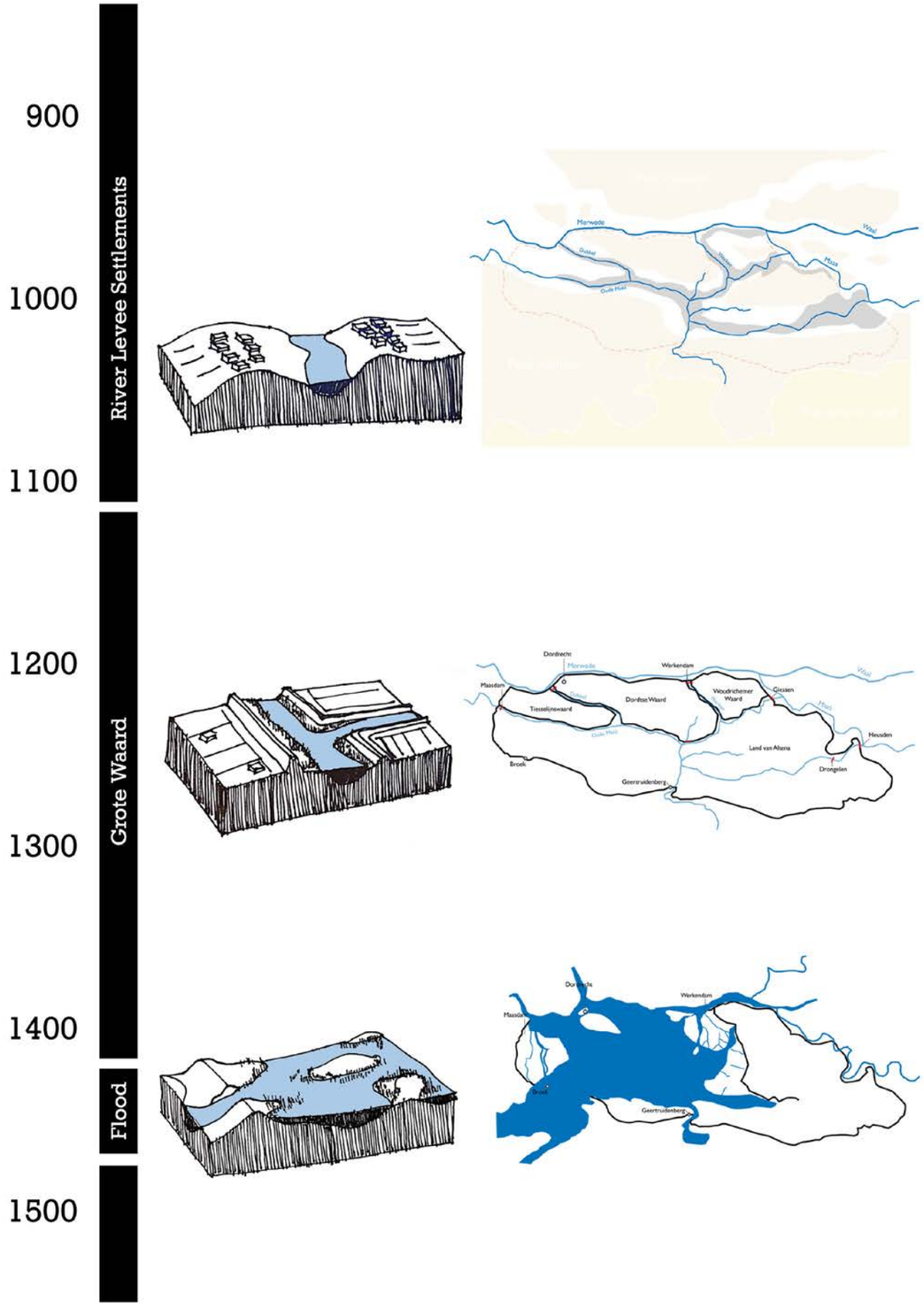
1100-1400

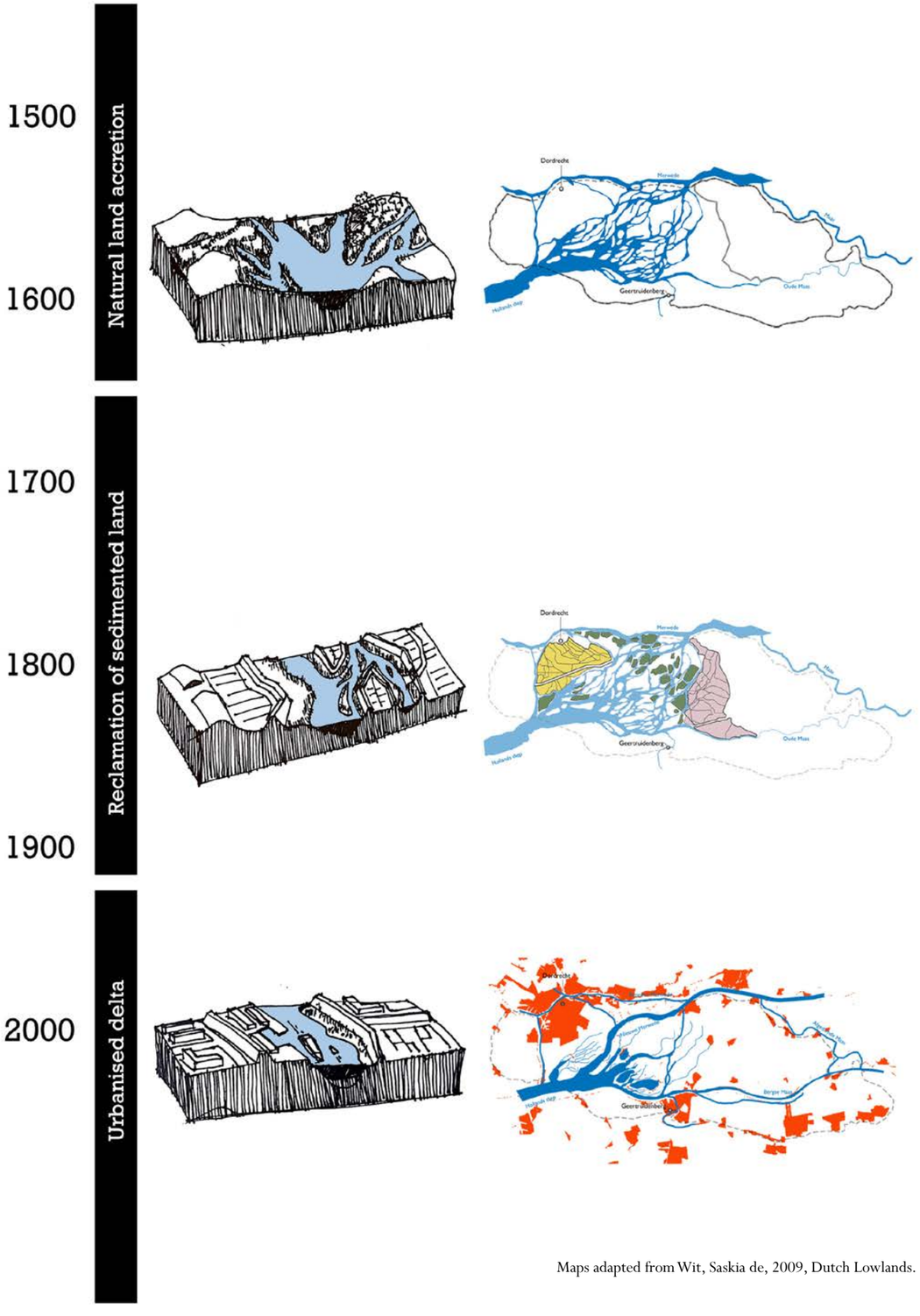
This period marked systematic land reclamation due to the low condition of drained peat landscape. Farmer had to start building dikes to ensure the safety of the farmlands. Dordrecht was founded in the beginning of 12th century by Count Dirk VII of Holland and immediately became an important trading town where ships that passed through have to pay tolls in the city.

Construction of Dubbeldam and Maasdam on the river Dubbel and Oude Maas respectively made it possible to coherently dike the polder landscape which later became the Grote Waard. Due to this process of embankments, the siginificance of Dordrecht increased as passing ships had to go Merwede and port of Dordrecht to reach the hinterland. Here, coherent diking and damming of rivers were made possible due to the formulation of the first waterboards which consisted of polder representatives and appointee of the Count of Holland. The waterboard was responsible for the maintenance of dikes, and for the control of sluices and dams.

1400-1450

In 1421, severe northwesterly storm ravaged the deteriorating dikes of the Grote Waard. Incosistency of the waterboard, political unrest, peat cutting, salt extraction, and subsiding land affected the integrity of the dikes its management. Since the end of 14th century, dike breaches became more and more frequent until the St. Elizabeth flood created massive breaches in at 3 locations and river





Maps adapted from Wit, Saskia de, 2009, Dutch Lowlands.

water flooded the subsiding polder landscape behind the dikes. Therefore, most of the Grote Waard polder became open water or an inland sea. This water body was mostly on the western area and the the east, polders of Land van Altena, remained due to surviving dikes. Here, the city of Dordrecht survived due to its location on higher natural levee. After the flood, and another dike breaches in 1424, the flooded polder became a dynamic fresh water tidal zone due to the high expense of repairing and restoring destroyed dikes.

1450-1650

Due to the dynamic natural processes of the flooded landscape, land accretion started to take place due to the dynamic of the tides and water flow. The inland sea itself became a ground for salmon fishing while mudflats started to grow overtime while the water was low. Reeds and rushes started to grow naturally on the sandbanks of these mudflats increasing its capability to trap sedimentation. These wetland rushes and reeds were harvested to be weaved into seats, mats, or baskets.

The landscape remained dynamic for the next centuries and reclamation of land accretion did not start until the begining of 17th century.

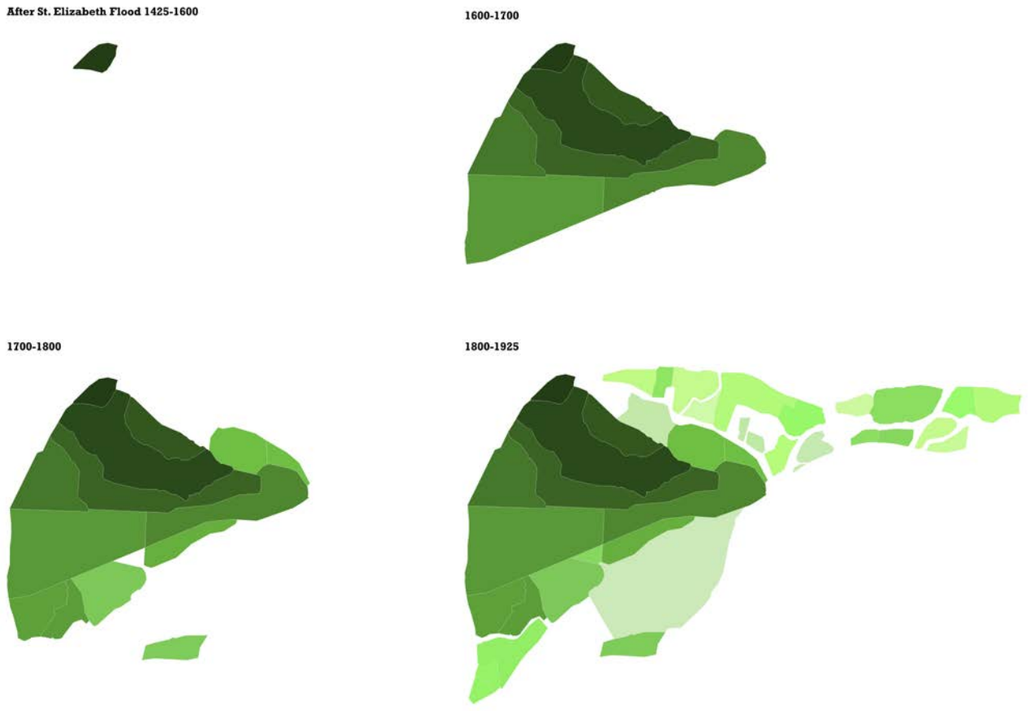
1650-1900

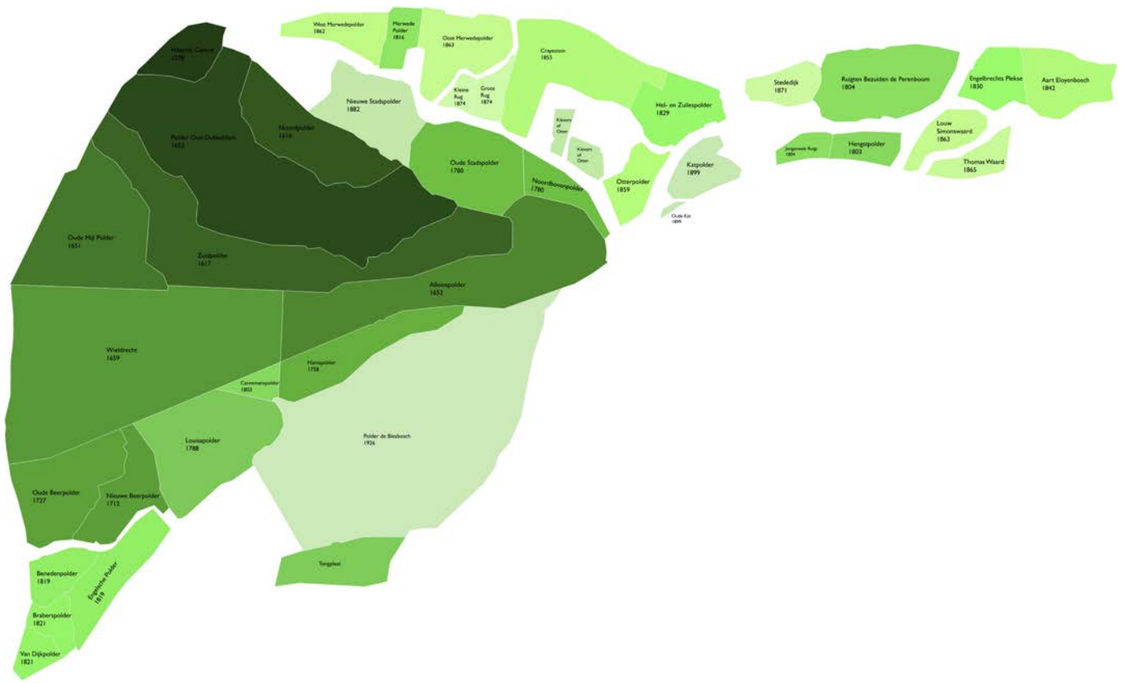
For the most part of the 17th-19th centuries, land accretion was graudally reclaimed to be agricultural polders. The parcelation of this polders are irregular due to the decision to follow the pattern of natural accretion. Most notably are the 3 distinct polder landscapes (see fig...), accretion polders (yellow) on the west which forms modern day Dordrecht, holms polders (green) in the middle which are individual polders built around naturall sandy ridges, and lastly mudflat polders (purple) on the east which are characterised by larger parcelations and more rational. Outside the dikes, willow farming flourished due to its high demand and accommodating natural conditions.

1900-Today

Urbanisation of the landscape started following the industrial revolution where upscaling of polder agriculture pactices were possible and the rivers became important trading routes. Polder landscapes started to be developed into urban extensions and smaller villages started to grow. Manmade river channel, the Nieuwe Merwede was constructed to make the dynamic biesbosch landscape more navigable.

Construction of Haringvliet dam in 1970 reduces the tidal influence of the river landscape from previously 2m tidal difference into 70cm difference. This affects the landscape greatly with diminishing willow farming in the intertidal zones and more land reclamation due to the lower river water.





3. Polder reclamation pattern

After the St. Elizabeth Flood in 1421, the landscape east of the surviving historic city centre became sedimentation zone. Due to changing tidal exposure and the peel shape of the city, this sedimentation landscape started to develop sandy banks and mudflats which were frequently flooded. Here the processes of sedimentation and erosion played a major role in defining the shapes and boundaries of the landscape. In the beginning of 17th century the accretion of sedimented mudflats on the south eastern border of the historic city centre which consist of river clay and silt was high enough that it could be diked. Therefore, polder Oud-Dubbeldam was reclaimed in 1603, and followed by Noord and Zuid polder in 1616 and 1617 respectively. Over the next centuries, more and more of the accreted land were diked. Meandering river creeks used to flow through the accretion were mostly used as main water channel of the polder landscape. The wantij river separates the main part of Dordrecht to its northern counterpart. As it was diked from inside out one by one (from the historic city centre outwards), the spatial structure of the polders is irregular which followed the natural sedimentation rate and pattern of the fresh water tidal landscape. This made rational parcelation inside the dike ring difficult. Structure of these polders are large parcels with few farms and farmhouses, encircled by high dikes on the horizon. The drainage of the polders used to be through gravity towards the rivers during low tide, however, due to land subsidence the landscape now sits below the normal tidal regime of the rivers, therfore, discharge pumps are necesary.

Urban development pattern

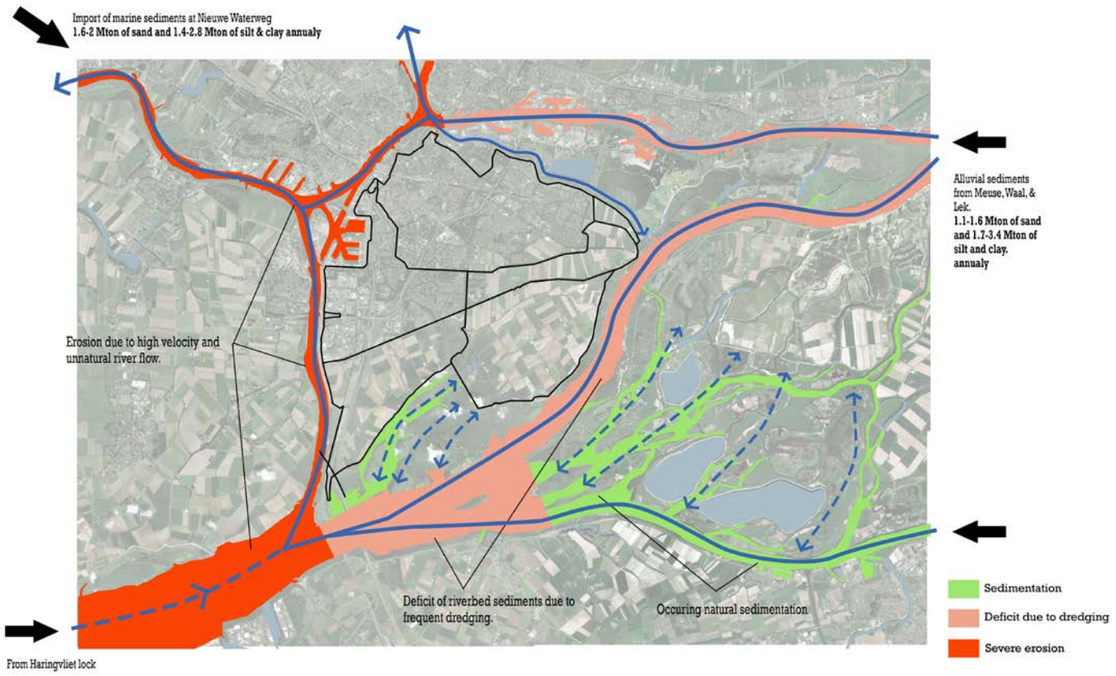
As the urbanisation grew, more land was needed for development. Polder landscapes adjacent to the historic city centre were the first ones to be transformed into new urban neighbourhoods. The urban developments rolled out like a carpet autonomously following the parcelation and pattern of the preceding polder landscapes (de Wit, 2009, p. 44). Main transport infrastructure lines were constructed crossing the polder parcelations on a right angle to the east-west oriented polder landscapes. The parcelations of old polder landscape is still visible in the urban fabric of Dordrecht today where one has to go over an old dike to get to another neighbourhood. Therefore, these old polder boundaries separates one urban development to another.

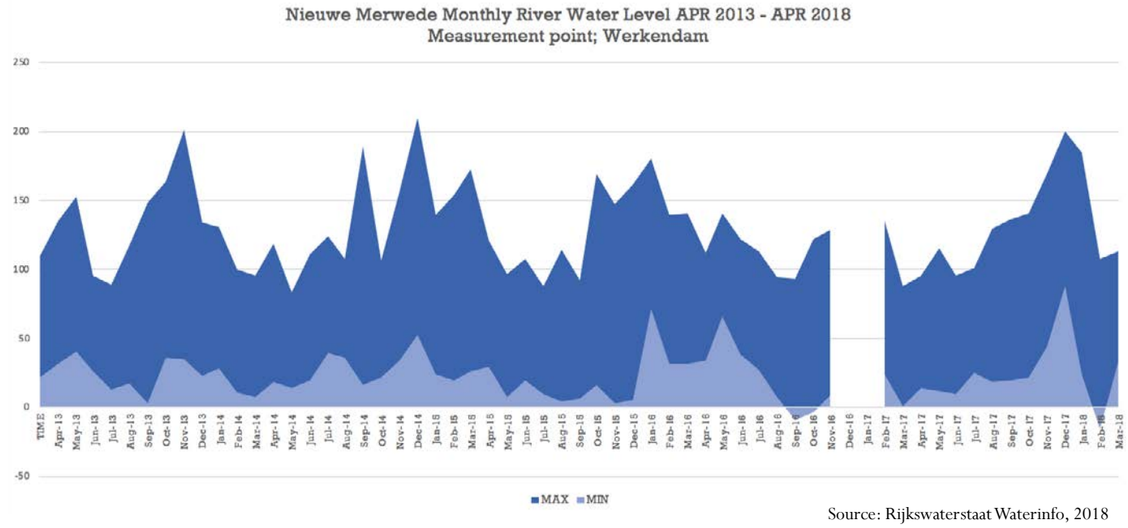
4. River dynamics of Dordrecht

Flowscapes

Due to the closure of Haringvliet dam, the river discharge through the island of Dordrecht shifted from prevously from the north east to the south west into the north west through the Rotterdam and Nieuwe Waterweg. The river discharge from Oude Maas and Nieuwe Merwede naturally flows into the Hollands Diep and the Haringvliet basin before flowing North through the Dordtse Kil due to the waterlevel difference between Hollands Diep and the Nieuwe Waterweg.

This change in water flow, therefore, causes shift in natural sedimentation and erosion of the river landscape. Due to the high velocity of water flow through the Dordtse Kil, the riverbed is experiencing high rate of erosion and deficit in sedimentation which cause regular strengthening of the riverbed. Sedimentation occurs on the the Nieuwe Merwede and the Beneden Merwede and it frequently dredged to maintain requirements for passage of cargoships which results in net balance of sedimentation. Natural sedimentation, however, is happens along the river Oude Maas and Amer, as well as the tidal landscapes of Biesbosch. Alluvial sediments that pass through the riverscapes of Dordrecht reach up to 1.6 Mton of sand and 3.4 Mton of silt and clay. This sediments mostly silt up in the Haringvliet basin and how much of the sediments transport in each distributaries are not yet known due to lack of research and measuring points.





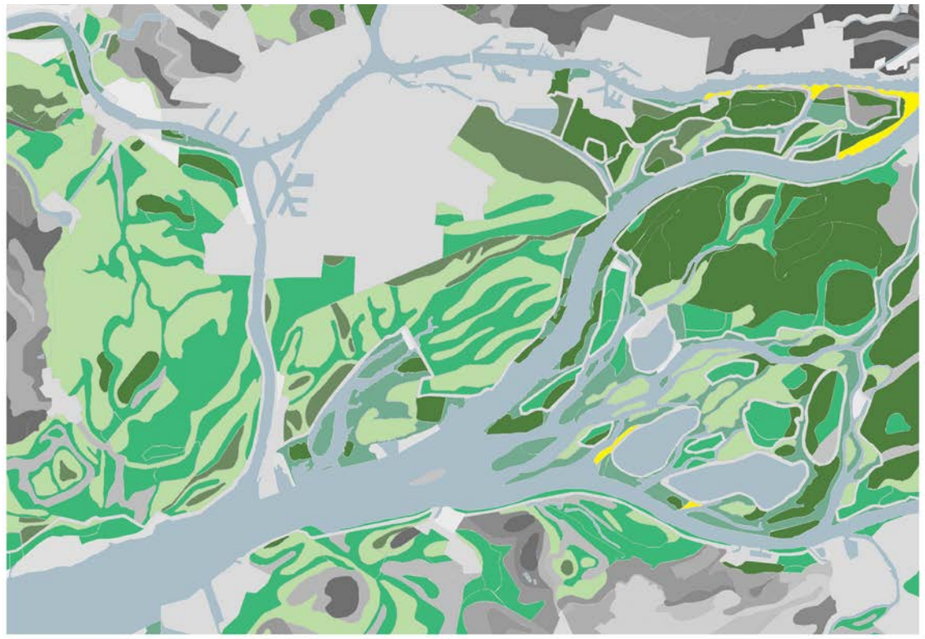
Source: Rijkswaterstaat Waterinfo, 2018

River water level

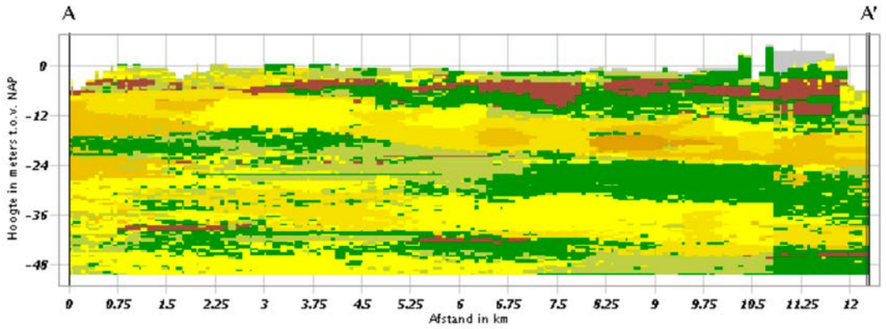
As was mentioned before in this research, the tidal influence since 1970 has dropped from 2m into 50-70cm daily due to the Haringvliet dam. In this research, the river water level of the Nieuwe Merwede is used as reference. Here, the low tide is valued as below 50cm above NAP and mostly during August. High tide level can reach up to 200cm above NAP during winter months of November and December.

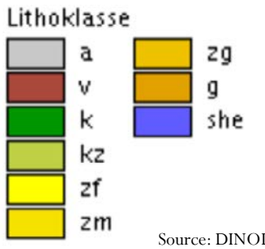
Daily tidal movement causes the water to to fluctuate in this area by 50-70cm. In a normal condition the water level can reach its peak twice a day, once in the morning and once at night. As was mention earlier in this thesis the river water level used to have 2m tidal difference prior to the closing of the Haringvliet sea arm which removes the influence of the sea to the river. This resulted in diminished ecologies that depend on such water fluctuations.

A research done by Deltares (2010), focused in the Wantij river, made a prediction based on the WB21 average climate scenario that the extreme water level around Dordrecht of 1/2000 years return period of +3,01m NAP water level will increase in frequency into 1/500 years in 2050 and 1/100 years in 2100 (p. 13). This prediction will be used as reference of high water condition in this research.



Verticale Doorsnede GeoTOP v1.3





Source: DINOLoket, 2018

5. Analysis of landscape layers of Dordrecht

Composition of the subsurface

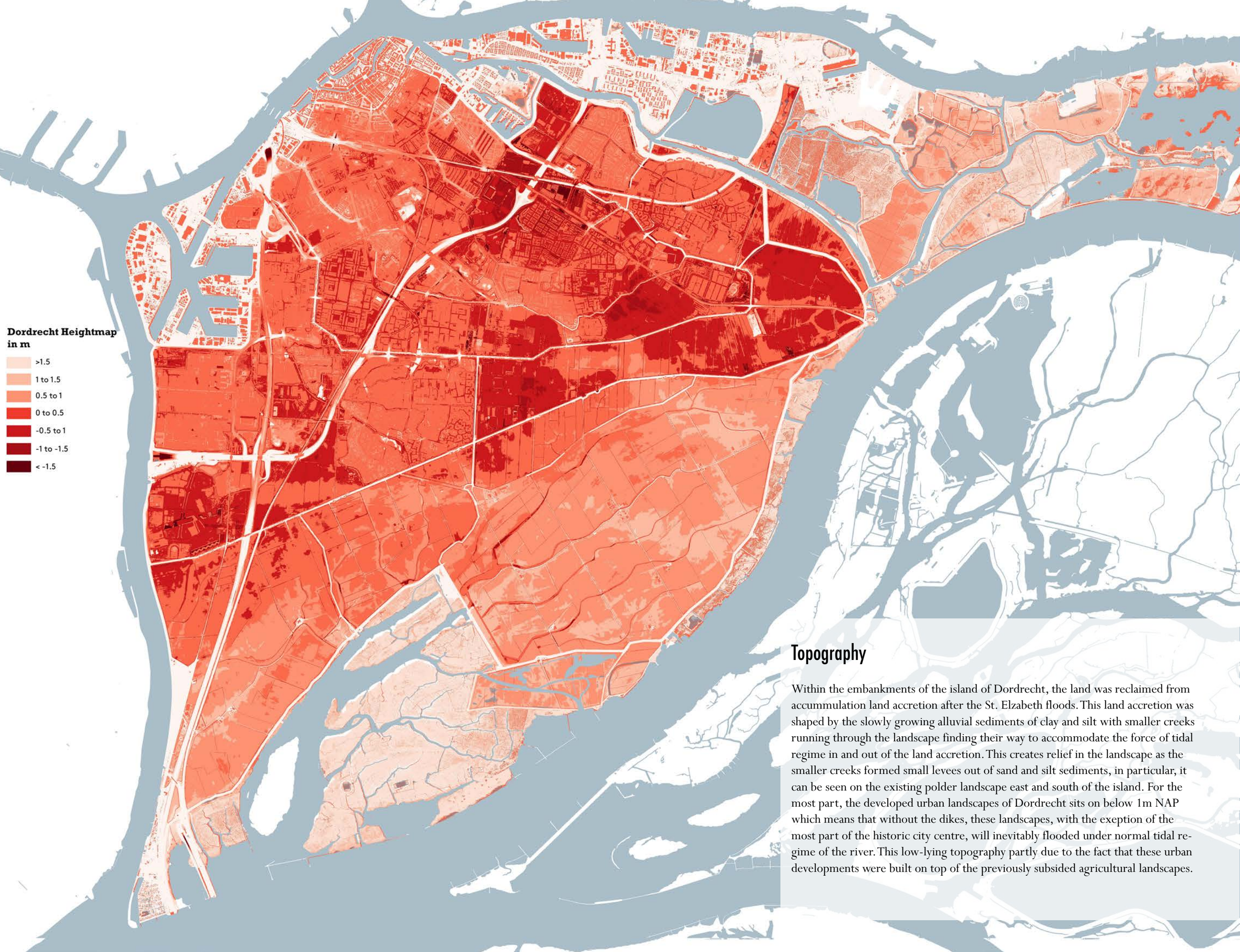
As a remnant of the Grote Waard, Dordrecht sits on the edge of flooded polder landscapes. Leaving the flooded land to the powers of nature for centuries before being reclaimed for cultivation, makes the composition of the soil in this location dominated by river sediments. River sediments settled during slow water flow creating mudflats which were naturally vegetated and grew overtime. This river sediments are fertile therefore were diked, drained, and turned into agricultural polders.

Old creeks that ran through the land accretion still can be seen on the map as it leaves silt material of heavy sabulous clay and leaving light clay layer on its flood plains. The pattern of the soil layer also shows the south western direction of the water flow in the delta.

Underground layers

If we look at cross sectional view of the subsurface composition, mixture sand and clay composes the subsurface as far down as 50 metres below ground. This is influence by the fact that the landscape has always been a sedimentation route and river basin. Below 20 metres underground were sediments from the Pleistocene, and a distinct layer of sand fills between 15-20m undersground due to sedimentation carried by melting ice through Rhine during the beginning of the Holocene. Above this layer is thick layer of clay and fine sand which was deposited here during he Holocene. As the coastline that we know now is formed, peat layer started to develop due to the rising ground water level as the river's journey to the sea becomes closer and due to poor drainage of then new swampy landscapes. Above this layer, from 7,5 metres to the ground level, are the river sediments after the flood of 1421 which underlying today's river landscape of the area.

The water level inside the embankments of Dordrecht is relatively close to the ground. On the polder landscapes of the eastern and southern part of the embankments, the water level is ranging from 0,6 - 0, 8 metres below ground level. On the urban extensions that took over old polder areas in the middle of the Dodrecht, the water level is ranging from 0, 8 - 1 metres below ground. The water level of the historic city centre and the harbour areas on the north east is under 2 metres deep due to its higher location on a natural levees.

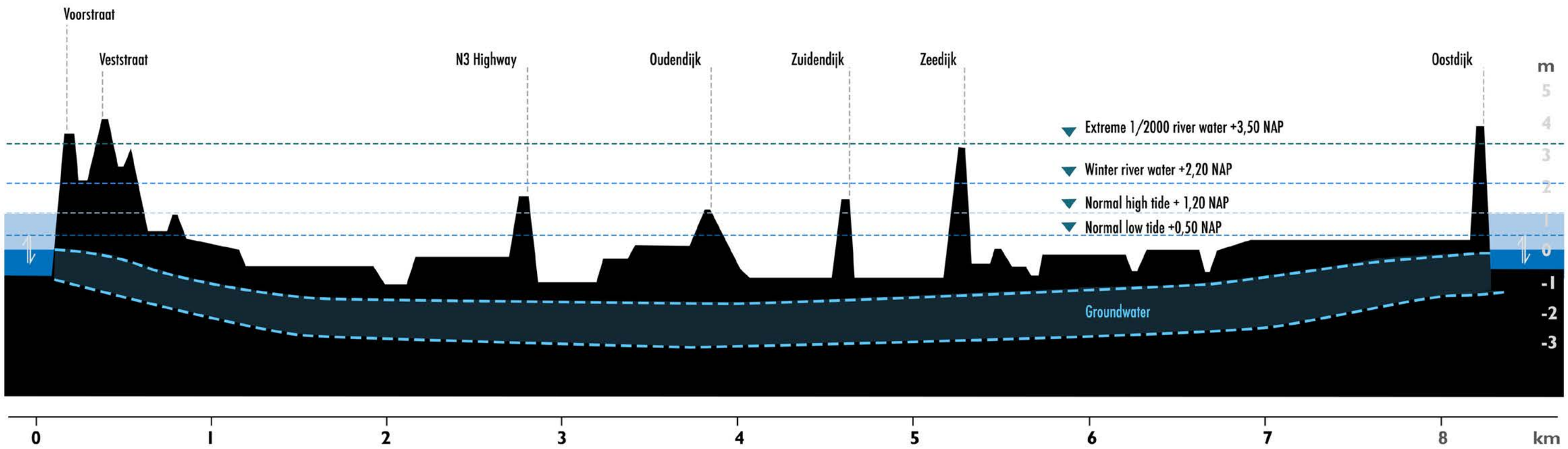


Topography

Within the embankments of the island of Dordrecht, the land was reclaimed from accummulation land accretion after the St. Elzabeth floods. This land accretion was shaped by the slowly growing alluvial sediments of clay and silt with smaller creeks running through the landscape finding their way to accommodate the force of tidal regime in and out of the land accretion. This creates relief in the landscape as the smaller creeks formed small levees out of sand and silt sediments, in particular, it can be seen on the existing polder landscape east and south of the island. For the most part, the developed urban landscapes of Dordrecht sits on below 1m NAP which means that without the dikes, these landscapes, with the exeption of the most part of the historic city centre, will inevitably flooded under normal tidal regime of the river. This low-lying topography partly due to the fact that these urban developments were built on top of the previously subsided agricultural landscapes.

The remnants of 17th century agricultural polders running east-west and recreation landscapes running north-south of the island sits below 0 NAP as compared to the southern polders which was diked two centuries after. This fact makes the older polders harder to maintain and slowly being transformed into urban and commercial landscapes. Older dikes are present on the landscape as massive relief within the topography and is utilised as access roads. Furthermore, infrastructural lines were also built on higher embankments crossing through the landscapes. As was mentioned in the previous sections, these infrastructures of dikes, roads, and railways create compartments and contain the developments within the existing space that it provided. The urban expansion of Dordrecht has been following this pattern.

In general, cross sectional view of the landscape within the dikes shows a bowl shaped landscape with the middle of the island as the lowest areas. Lower areas are framed by access infrastructures and older dikes. The topography of the historic city centre and the landscapes outside the dikes are significantly higher than the polder landscapes.

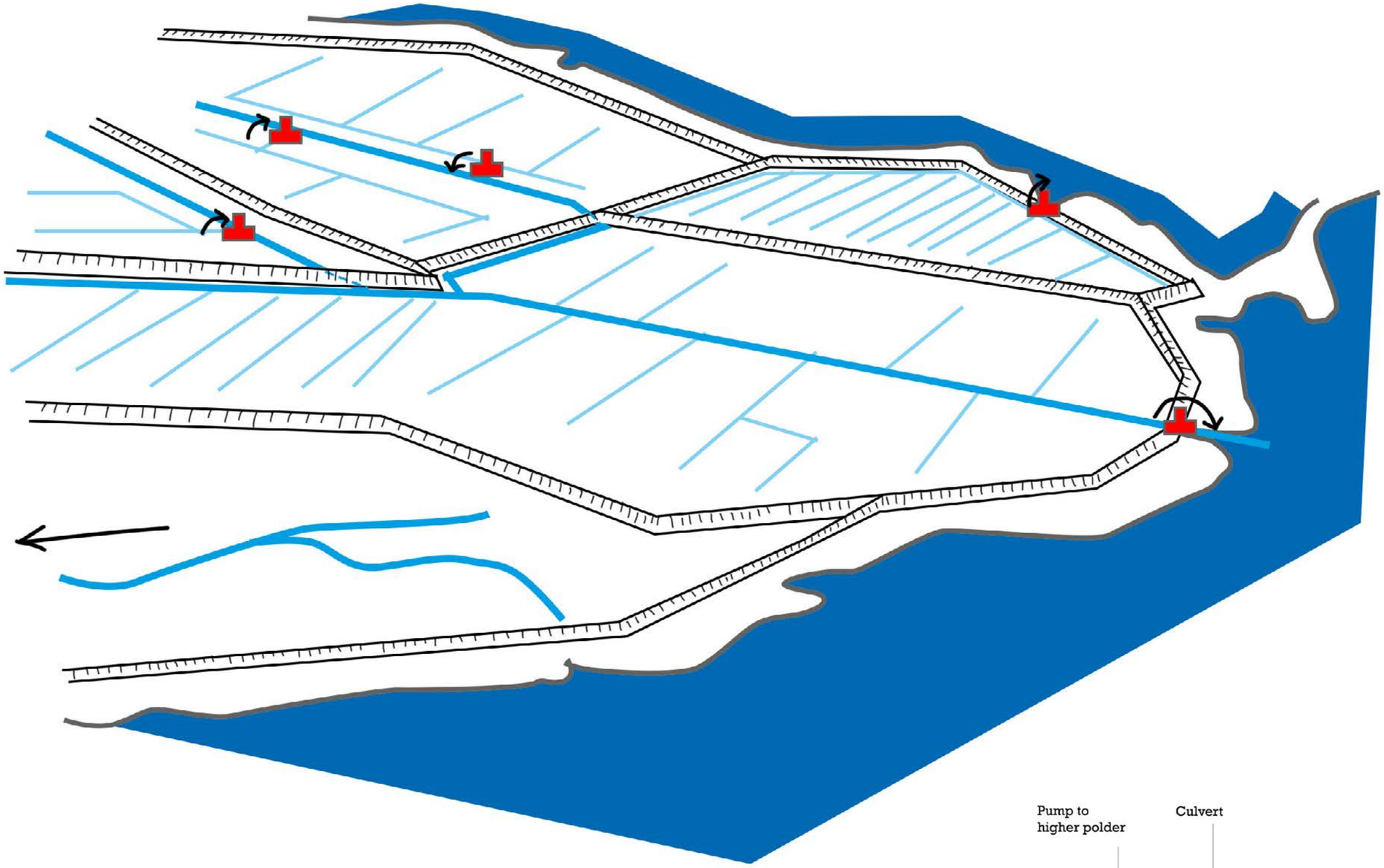


Main waterline
Branching waterline
Pump
Inlet/outlet

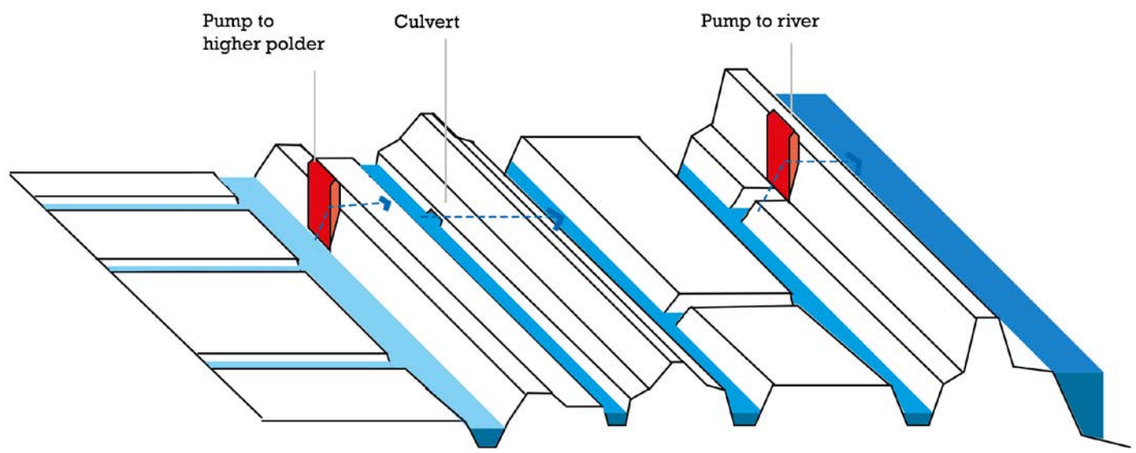
Water System

The water system of Dordrecht is managed by the Hollandse Delta water board with smaller systems managed by different private individuals and organisations such as the municipality themselves. The municipality provides the agenda of the green and blue networks of the water system with cooperation with the water board as well as the Rijkswaterstaat, a national body for water management. Cooperation with the Rijkswaterstaat is requiered in projects and policies of landscapes outside the dikes, therefore the rivers and unembanked areas. The water system of the polder landscapes are mainly managed privately by the farmers and owners of the polders.

Series of ditches connects the urbanised polders and the agricultural polders with a line of boezem channel, a water canal with higher water level than the polder, before being discharged to the rivers. Due to the city's island landscape, the drainage of the entire water system can be from several direction outwards towards the rivers that frame the landscape. This makes the polder compartments not necessarily have to be connected between each other in order to drain. Although, thsi system provides shorter ways to drain the water out of the compartments, it also provides lack of connection from different parts of the island through water.



Series of ditches connects the urbanised polders and the agricultural polders with a line of boezem channel, a water canal with higher water level than the polder, before being discharged to the rivers. Due to the city's island landscape, the drainage of the entire water system can be from several direction outwards towards the rivers that frame the landscape. This makes the polder compartments not necessarily have to be connected between each other in order to drain. Although, thsi system provides shorter ways to drain the water out of the compartments, it also provides lack of connection from different parts of the island through water.



Water Compartments
Water level (in m)

0 to -0.2
-0.4 to -0.2
-0.6 to -0.4
-0.8 to -0.6
-1.0 to -0.8
-1.2 to -1.0
-1.4 to -1.2
-1.6 to -1.4
-1.8 to -1.6
-2.0 to -1.8

Polder compartments

The different water compartments are the remnant of the older polder comparments. Due to the fact that the polders were reclaimed gradually and it followed the organic shape of land accretion, new water system was established on the newly reclaimed land within the embankments. This system is still visible today, although the ongoing urban developments has made changes within the system and created new compartments.

Due to the low lying topography and desired water levels, pumping between compartments is necessary to properly drain the landscapes. This demonstrates the non-adaptive nature of the established water system and due to the fact of minimum water storage and water basins within the embankments, it is necessary to propose a new or adjusted system which can adapt to not only extreme river water discharges, but also the problems within the systems it self such as land subsidence and cloud burst flooding. Initiatives to respond to these problems has been focused more by the municipality together with the residents especially with the effort to utilise green and blue networks of the previously natural creeks to accommodate more water, as well as to establish the landscape as new landscape values within the urban fabric. This has been a slow process, however, due to, among other things, the availability of funding.

Infrastructure

Dordrecht is framed by the regional access infrastructures of highways and railroads. Theses infrastructures were built running through the polder landscape connecting the north west-south direction which connects the city of Rotterdam to Breda, and the west to north direction which connects the 's Gravendeel and another harbour city of Papendrecht. With most of the regional infrastructure occupying the western and norhtern part of the island, the urbanisation process therefore is focused on these areas leaving the most parts of the west and south as open rural landscapes. The main access within this rural landscape is concentrated on the east-west direction following the structure of the dikes with smaller roads on the level of the polders going north-south providing access within the compartments.

Building footprints

Polders

Parks/ green spaces

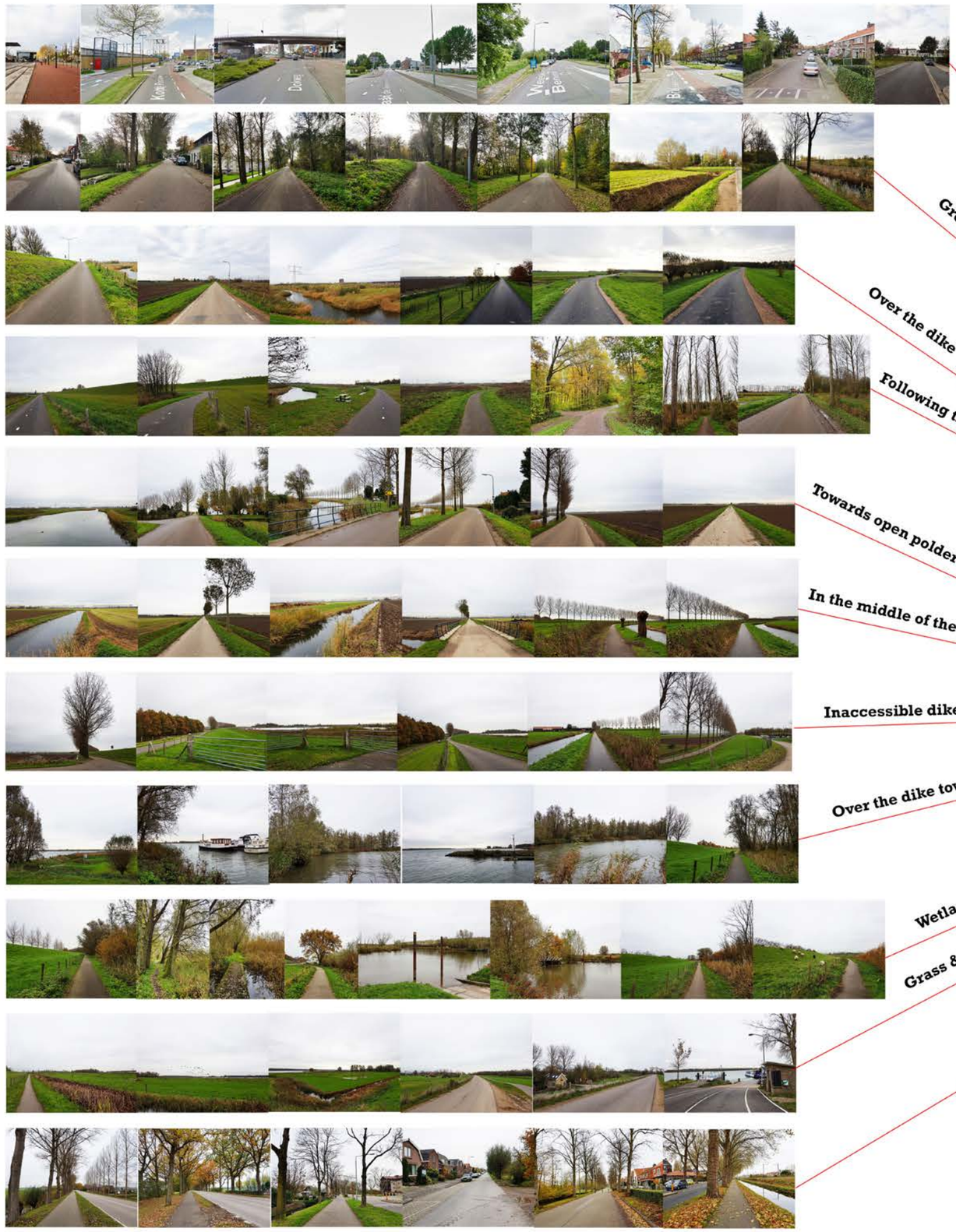
Access

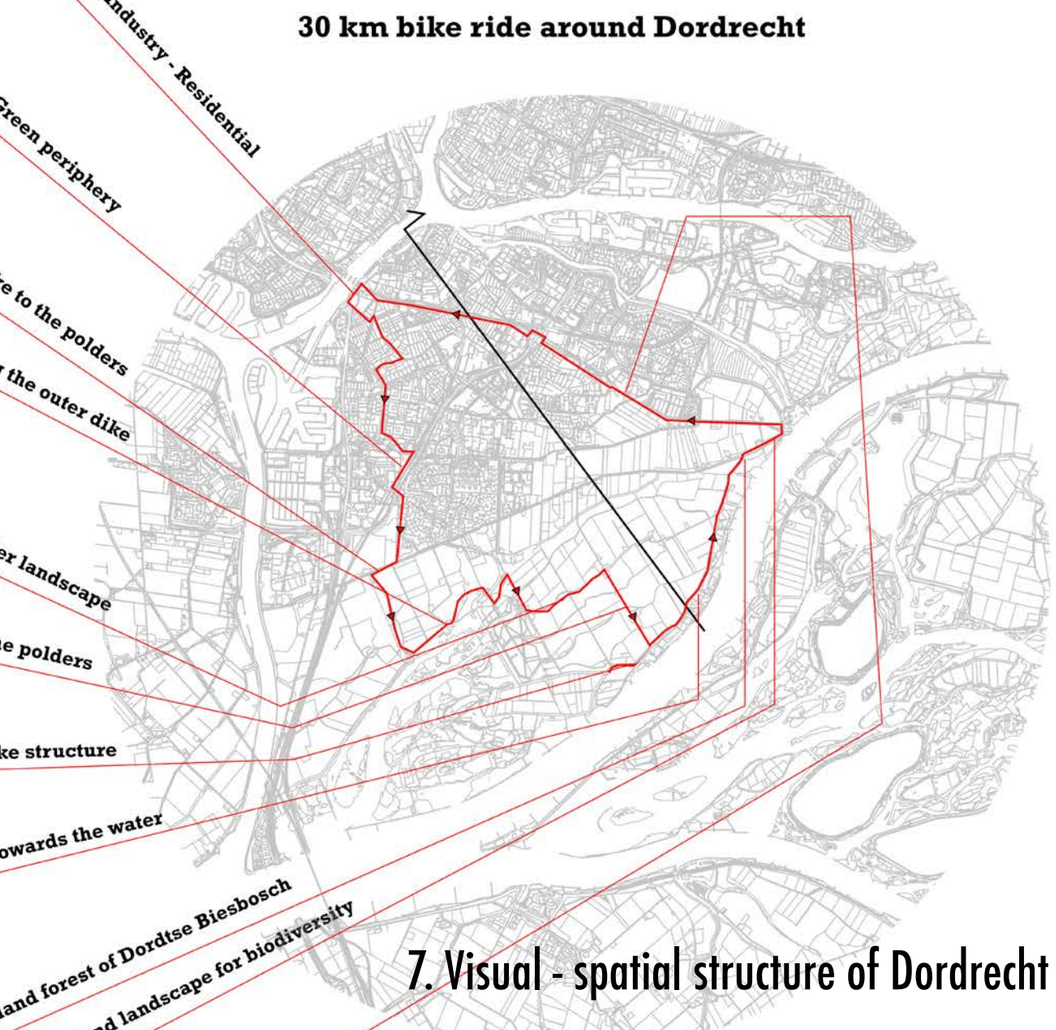
Occupation

The programme layer of the island of Dordrecht is a mixture of urbanisation and agriculture with commercial and industrial landscapes occupies the harbour landscapes outside of the embankments. The urbanisation process expanded from the historic city centre on the north west of the embankments on the intersection of rivers Noord, Beneden Merwede, and the Dordtse Kil. Due to its location on the cross roads of shipping routes between North Sea, Rotterdam and the hinterland of western Europe, the higher landscapes outside the dikes are utilised as habours and industries with maximum access towards the water. Only in late 20th century that the landscape outside the embankments are started to be utilised as residential. Within the embankments, the urban expansion has been urbanising the polder landscapes branching outwards from the historic city centre with the first expansion towards Dubbeldam. The landscapes of the east and south are occupied by agricultural activities with urban parks and sportfields occupy left over spaces in between. Outside the embankments, to the north and south is the fresh water tidal landscape of Dordtse Biesbosch with the 21st century polder Nieuwe Biesbosch separates the two parts. The landscape of the Dordtse Biesbosch is the landscape of nature restoration and conservation which started in late 20th century.

6. Dikes and canals

Within the outer embankments, the waterlines are regulated within a controlled system. Here, the waterlines are used primarily as drainage and spatially disconnected with the surrounding landscapes. Water transport are not possibile within the system as the systems are separated within the compartments. To move between one compartment to the other is not possible as they are mostly connected by pumps and divers. It is possible, however, outside of the dike on the rivers and creeks with harbours located throughout the outside of the dikes, as well as on the historic city centre. Therefore this character of a water city is missing in Dordrecht and the waterlines themselves are not being utilised as amenity, and purely functional. More importantly the natural characteristics of the river landscape is missing.

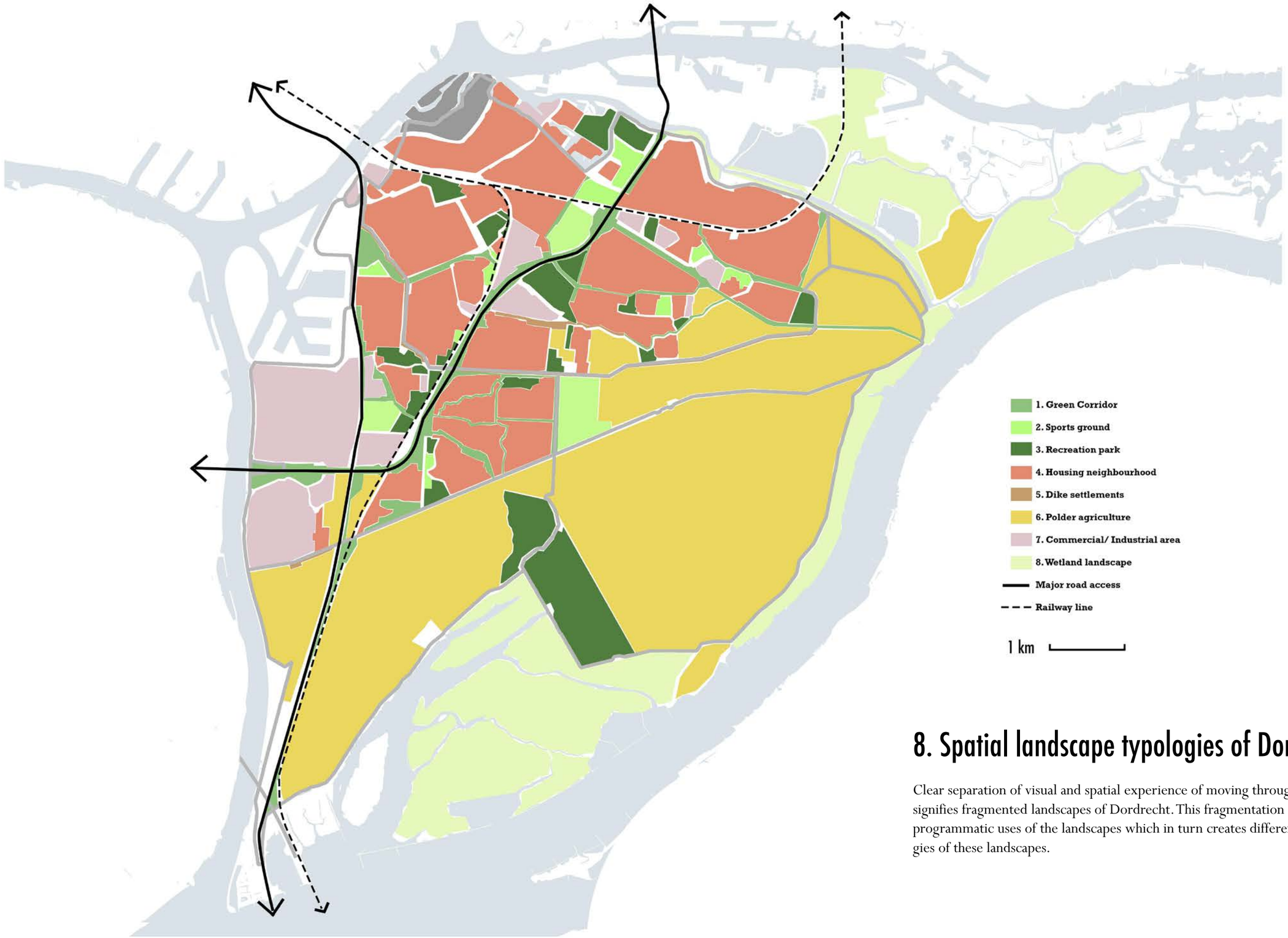




30 km bike ride around Dordrecht

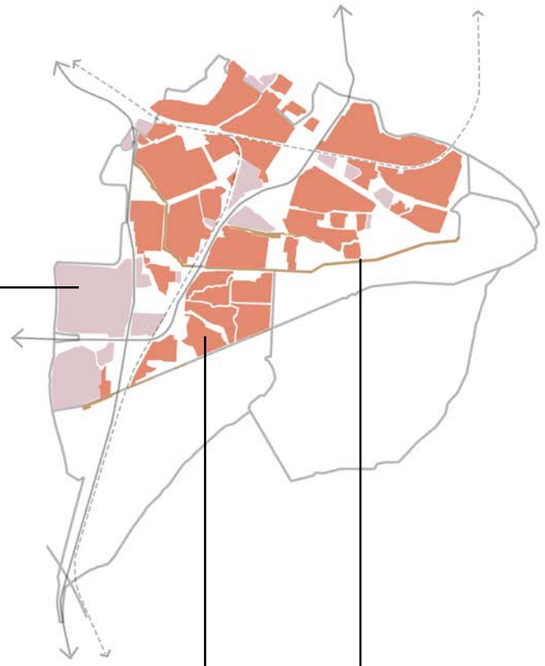
7. Visual - spatial structure of Dordrecht

Moving through the landscapes of Dordrecht by bike, unfolds the clear thresholds that separates different landscapes within the city. These thresholds can be in a form of green urban periphery, dikes, and infrastructural lines such as highways and 4 lane roads. Visual experience is vary as one moves from the city centre, through the suburbs, towards the open polders, over the dike towards the river, and back. Each landscape seem to have their own characters as the connections between landscapes are missing. The view towards the horizon is always limited due to the structures of the dikes that enclosed the landscape. Very clear visual and spatial threshold is the Zuidendijk as one move from the suburbs towards the open polders by climbing the dike, a clear separation of urban and rural by a single infrastructure. This demonstrates how, on different locations, dikes define clear threshold, a spatial and visual barrier, of one side and the other.

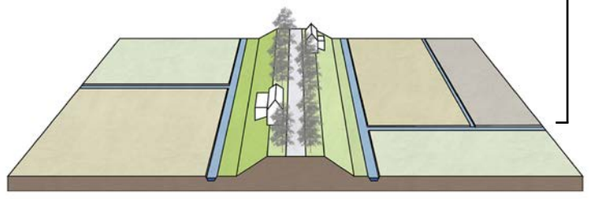


8. Spatial landscape typologies of Dordrecht

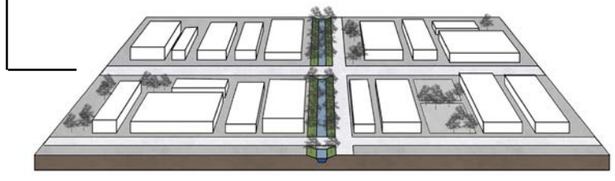
Clear separation of visual and spatial experience of moving through the landscape signifies fragmented landscapes of Dordrecht. This fragmentation is related to the programmatic uses of the landscapes which in turn creates different spatial typologies of these landscapes.



Housing neighbourhood



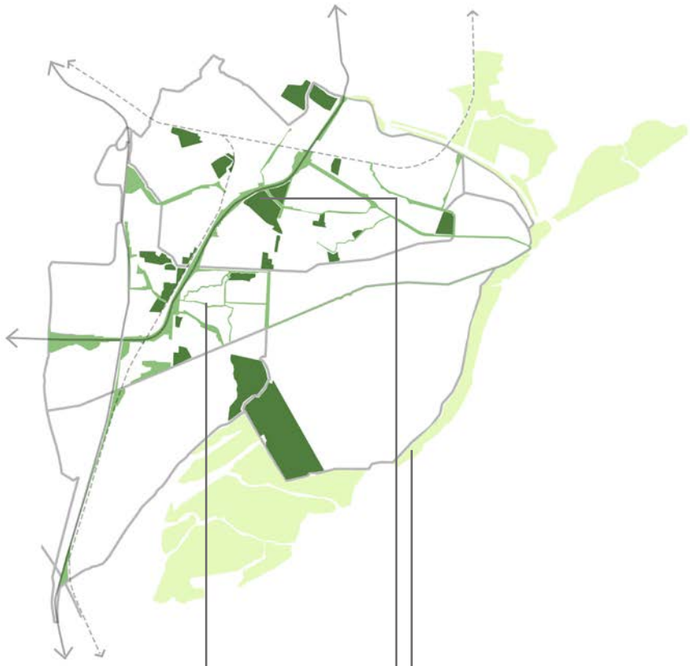
Dike housing



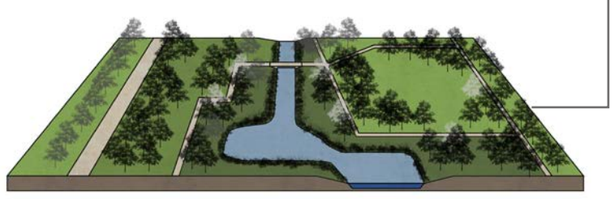
Commercial/ business parks

Urban landscapes

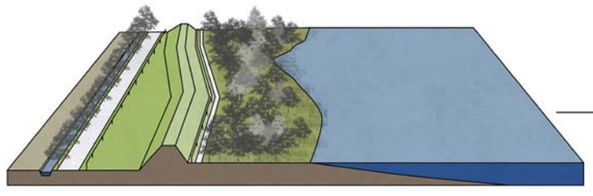
The urban landscapes takes the most part of the west and north side of Dordrecht. Commercial and business parks takes place close to the river with close proximity to the harbour area as well as the highway. Here, the element of water takes form of a rigid line and the amount of green is limited compared to the built up impermeable surfaces. The dike housing typology takes places on the remnant of the old dike landscapes with direct acccess tot the polders. Spatially, the landscape is narrow and the row of housing follows the form of the dike. with housing adjacent directly with the road access on top. Housing neighbourhood typology differs for each neighbourhood with their own regulated water levels and the spatio-visual qualities are also differ from one another. However qualities of the natural landscape is missing in this typology with the water is mostly used as utility rather than amenity.



Urban green corridor



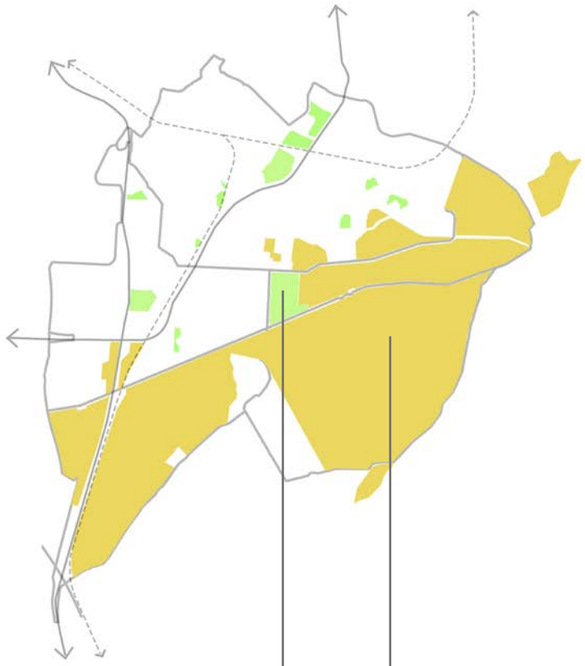
Public parks

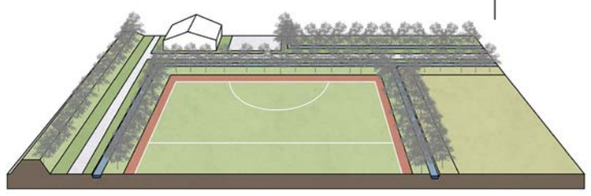


Riverside nature

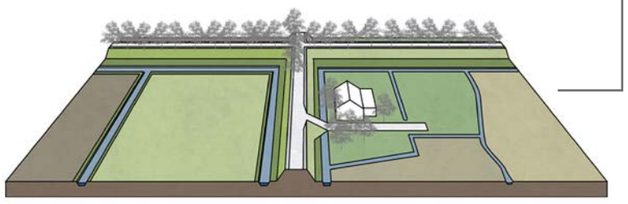
Green-blue landscapes

Parks and narrow green corridors are spread in the inside of the outer embankments. The green corridors follows infrastructural lines in some cases and through the urban landscape on the the other. This green corridor typology is a network together with the main waterlines which stretches on a narrow width through the island compartments. Park typology takes place in between as a threshold separating one landscape to the other. It takes place on low parts of the landscape and have water as their main element due to the seepage and high ground water condition. Outside of the dike, alluvial forest of willow and ash dominates the space inbetween water and the outer embankments. It is exposed to the fluctuating water and has limited access.





Sports ground landscape



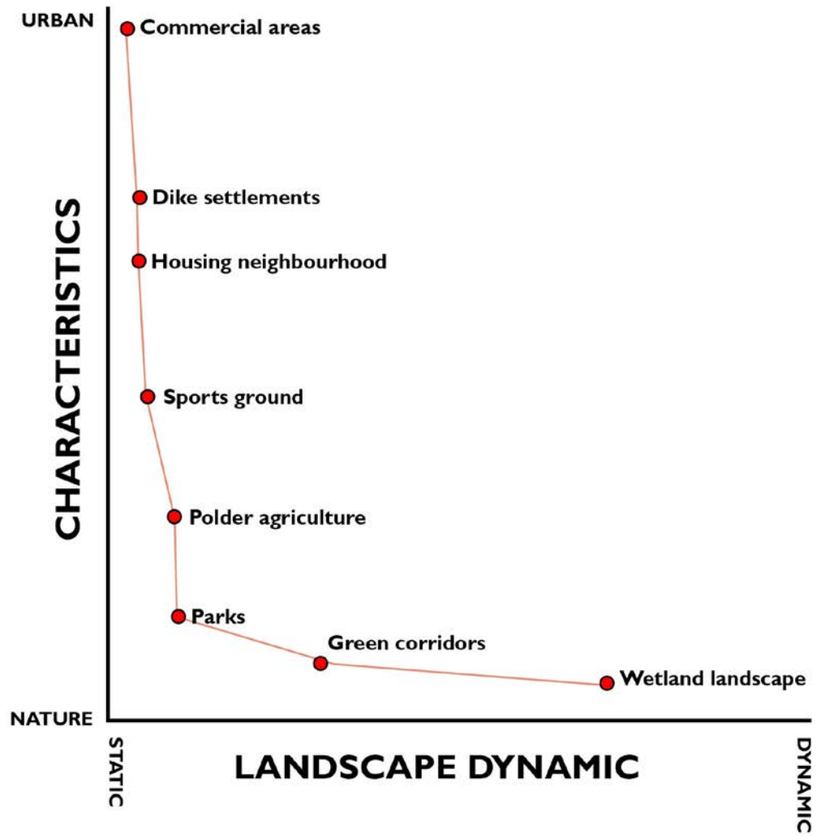
Polder landscape

Private green landscapes

The east and south side of the islad is dominated by agricultural polder which sits on the private categories of open green structure. Here the forms and shapes are very rigid with regulated water levels. Main access are on a higher dike line with smaller access downwards. The sports field and the agricultural polder have similar spatial qualities due to the sports grounds are established on top of the previously agricultural polders. Here both of the landscape typologies have limited access for public with the sports ground visually screened by trees and the polder landscape is open with the dike as the element in the horizon.

Conclusion: Framing the typologies

Framing these typologies into comparable chart as below gives an insight on the qualities of the existing landscape and adds clarity to the problematique that needs to be addressed in this project. Comparing each of the typologies on the chart of urban vs nature and static vs dynamic reveals not only the qualities of each landscapes but also the framework of where the new resilient landscape should take place. Most of the typologies sit on the static side, whether it has nature or urban qualities. The middle ground is therefore missing and most of the typologies cannot cope with uncertain change with this static quality. In the following chapter, different precedents will be analysed and plotted on the same chart to reveal the ideal condition sought in this research-by-design.



IV. EXPERIMENTING THE LANDSCAPE

1. Precedent analysis of resilient landscapes

Case study 1: Waterdunen

Location: Breskens, Zeeland
Year: 2013 - ongoing
Client: Province of Zeeland, Gemeente Sluis, Scheldestromen Waterboard, Molecaten, Stichting Het Zeeuwse Landschap
Scale/ Area: 350 ha

The landscape of Waterdunen project invited the dynamics of the North Sea through a controlled gate/barrier which is openned during favourable condition of low tide and closed during extreme conditions. Therefore, it provides new qualities that generate new ecological structures of the previously polder landscape. Dug out creeks provide the land necessary for filling elsewhere on the landscape and gradients between land and water is established.

Key elements:

- With the concept of envoking the identity of Zeeland.
- Excavated polder structure following natural tcreek form.
- Tidal culvert built through the dike to let the tidal water in and out.
- New urban development and holiday houses on natural areas.
- Promoting tidal ecology and aquaculture due to tidal dynamic.
- Excavated soil is used to heightened the sea dike.
- New dune landscape is created along the sea dike.
- Road access and foothpath through the landscape.

Drivers:

- Aging population and declining economy.
- Required strengthening of sea dike along Breskens.
- Declining employment in agriculture.

Impact:

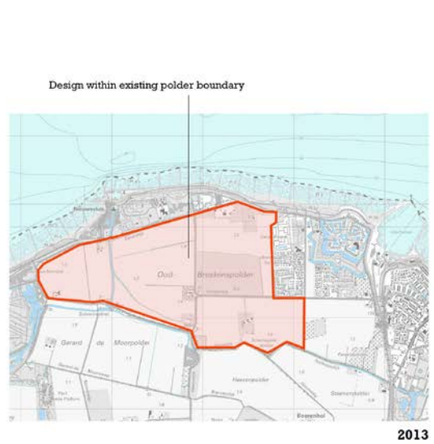
- Unique new landscape qualities inside the protection of the dike.
- Working with tidal dynamics for dynamic visual and spatial qualities.
- Allowing low maintenance recreational landscape due to natural processes.

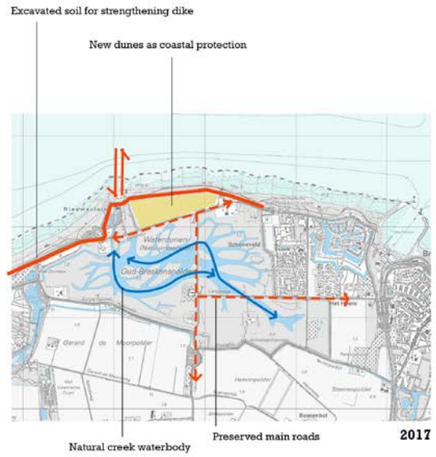
Bird-eye view impression of Waterdunen

Living on the natural dune ecosystem

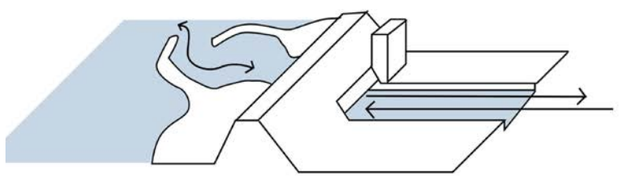
Dike and tidal culvert as social space

Images source: Waterdunen.com, 2018

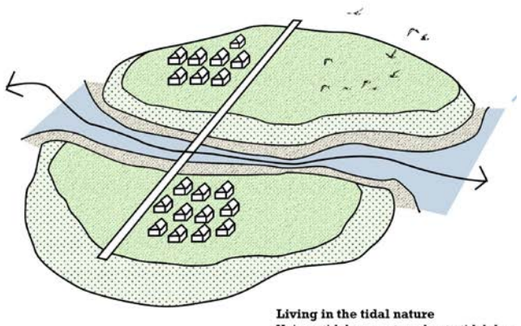




Key design principles:



Tidal culvert inlet - closed during high water
Allowing the dynamics of seatide to penetrate inside the dike
Energy generator from tidal forces



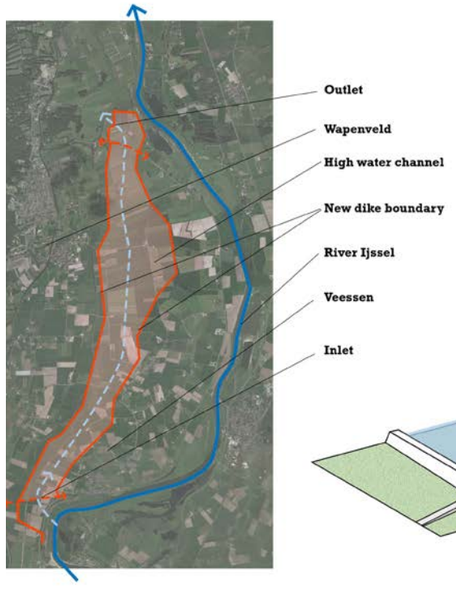
Living in the tidal nature
Unique tidal ecosystem due to tidal dyna
Generating natural ecology alongside u

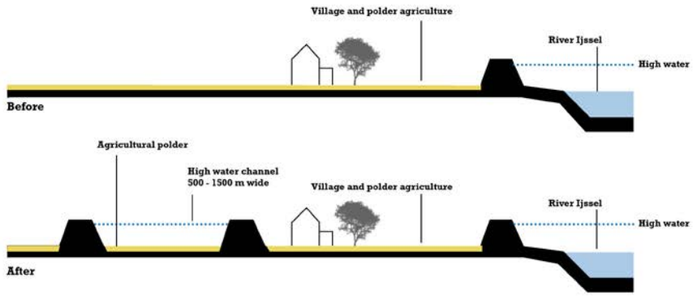
Bird-eye view impression of the high water bypass channel and new dike boundary. Polder landscape is preserved.

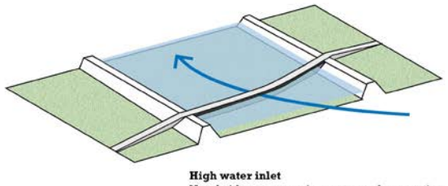
New birdge as accessway when the bypass is used.

Beneath the bridge is the inlet that can be manually operated to allow flood water to come in.

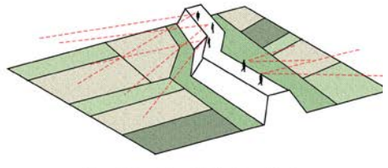
Images source: Lodewijk Baljon & Dennis Guzo, 2018







High water inlet
New bridge structure is constructed connecting the two dikes which functions as sluices to allow high water in. In normal condition, agricultural polder is functional



New Dike as Visual Orienting object
As boundary of high water channel, new lines of dikes are built with orientation to maximise visual experience of the polder landscape.

Case study 2:
Veessen-Wapenveld High Water Channel

Location: Veessen & Wapenveld, Gelderland
Year: 2013 - 2017
Client: Vallei en Veluwe Waterschap, Rijkswaterstaat, Gemeente Heerde

Veessen-Wapenveld channel is a part of the room for the river programme and it was amongst the latest project that was finished. The concept is pretty straight forward, to allow the agricultural landscape to stay functional as is and can be used as 'bypass' channel during extreme conditions. New dike is constructed as a boundary of this channel and it is designed to be the main recreational access which provides attractive visual sequence of the surrounding landscape. Two new bridges perpendicular to the channel is constructed as main evacuation route as well as the entry point of the extreme river water. This project is unique compared to other room for the river project which transforms existing agricultural land into nature restoration area.

Key elements:

- High water channel as part of Room for the River programme.
- Preserving agricultural function of the land.
- The channel is able to bypass the river Ijssel during high water condition.
- 500-1500 wide bypass channel is able to reduce the river Ijssel by 71 cm.
- Recreational cycling and footpath to experience the area.
- 2 new dikes of 8km long are constructed as boundary of the bypass channel.
- A bridge as water inlet is constructed and can manually operated during high water.
- Series of natural restoration areas are constructed along the new dikes.

Drivers:

- Climate change and increasing volume of river discharge.
- Agricultural preservation as part of climate adaptation.

Impact:

- New way to experience the polder landscape and natural restoration.
- Introducing new way of climate adaptation without sacrificing the agricultural land.
- By pass channel for one in a lifetime flooding event.

Case study 3:
Plan Tij

Location: Dordrecht, South Holland
Year: 2003 - 2004
Client: VolkerWessels
Scale/ Area: 11 ha, 96 households

Plan Tij is located on the outside of the outer dike of Dordrecht and directly connected to the Wantij river. Previously it was a polder landscape adjacent to the outer dike. Opening up to the river creates the possibility of having large amount of water close to the houses and allows each house to have access towards the water. The houses are built on top of the extreme water conditions with gentle slope towards the water as their backyard outside the house. Fluctuating river water level develops riparian ecology on the gradients which increase not only the ecological qualities of the development, but also the real estate value of the site.

Key elements:

- Housing area is outside the dike-protected area.
- The dynamics of the river tidal currents are allowed to come close to the houses.
- Previously a polder area, soil improvements were done to promote natural restoration.
- House are elevated on piles to accommodate high water situation.
- Reeds, woodlands, and marshy forests are naturally generated as unique landscape qualities.
- Soft edges between land and water varies between gradients of shores.
- The waterways were designed as natural meandering creek from where water is circulated.

Drivers:

- To create unique real estate
- Transformation of agricultural polder
- High and unpredictable water condition of outside dike
- To increase bio diversity and water recreation close to the residential areas

Impact:

- Promoting new real estate value through living in the dynamic delta.
- Demonstrate the possibility of integration between natural restoration and residential development.
- Generating unique river delta landscape qualities within the living environment.

Bird -eye view impression of Plan Tij

Natural creek from for water flow

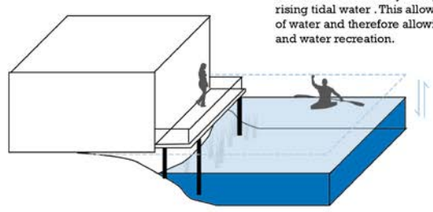
Houses are elevated to accommodate high water

Gradients of riparian ecology is developed in the edges between land and water.

Images source: urbangreenbluegrids.com, 2018

Key design principles:

Gradients of Riparian Vegetation
Due to the tidal condition, different natural ecologies are developing and promoting biodiversity on the soft edge between land and water.



Stilt Housing & Water Recreation
Houses are built safely on top of stilts that can accommodate rising tidal water . This allows houses to be built on the edge of water and therefore allowing unique living experiences and water recreation.

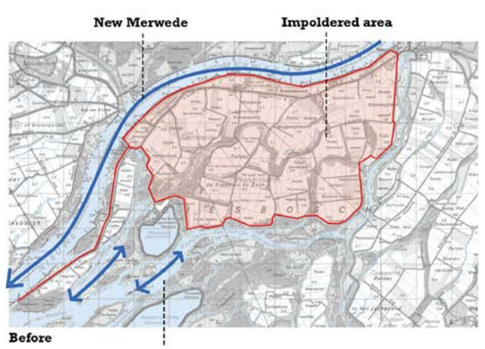
Bird-eye view of depoldered Noordwaard looking towards the south

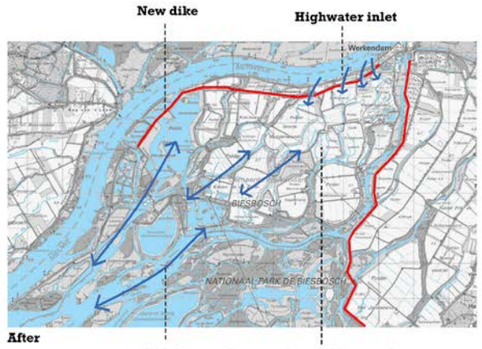
Bridges are constructed to join the separated polders

Agricultural polder are still present and becomes part of more space for high water.

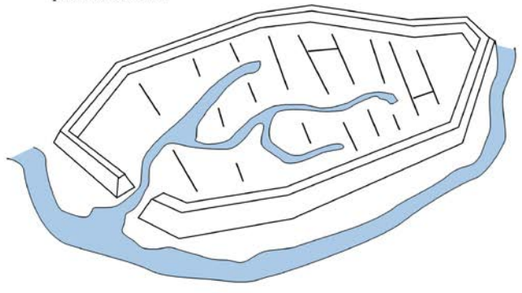
Depoldered area generates new riparian biodiversity due to influence of river dynamics.

Images source: Rijkswaterstaat & West8, 2018

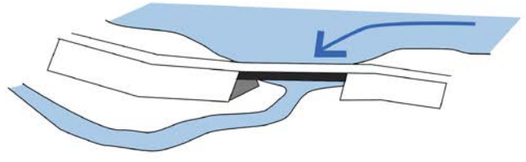




Dug creek channels
Depoldered area has different stages of overflow capacity. The creeks are flooded daily, when water becomes higher, the polders are flooded



High water inlet
Dikes has opening to allow excess water to flow inside the depoldered area. New bridges are constructed as part of the dike opening as access roads.



Case study 4:
Depoldering Noordwaard

Location: Werkendam, Nieuwe Merwede
Year: 2012 - 2015
Client: Rijkswaterstaat, Projectbureau Ontpoldering Noordwaard
Scale/ Area: 4.450 ha

This project is one of the largest room for the river project and uses the idea of controlled flooding in the previously agricultural polders. The landscape itself is a series of different smaller polders with their own dike rings. A new connection with the tidal dynamics of the Biesbosch transforms these polders into nature reserve area. On a normal condition, water flows through smaller creeks on the landscape and will flood surrounding polders during high water condition. New accessways is established throughout the previously private and disconnected polders with meandering pathways that goes up and down the landscape. Combination of fluctuating waterlevel and different measurements towards these changes create the possibility of establishing different landscape structures in combination with appropriate landscape management of the area.

Key elements

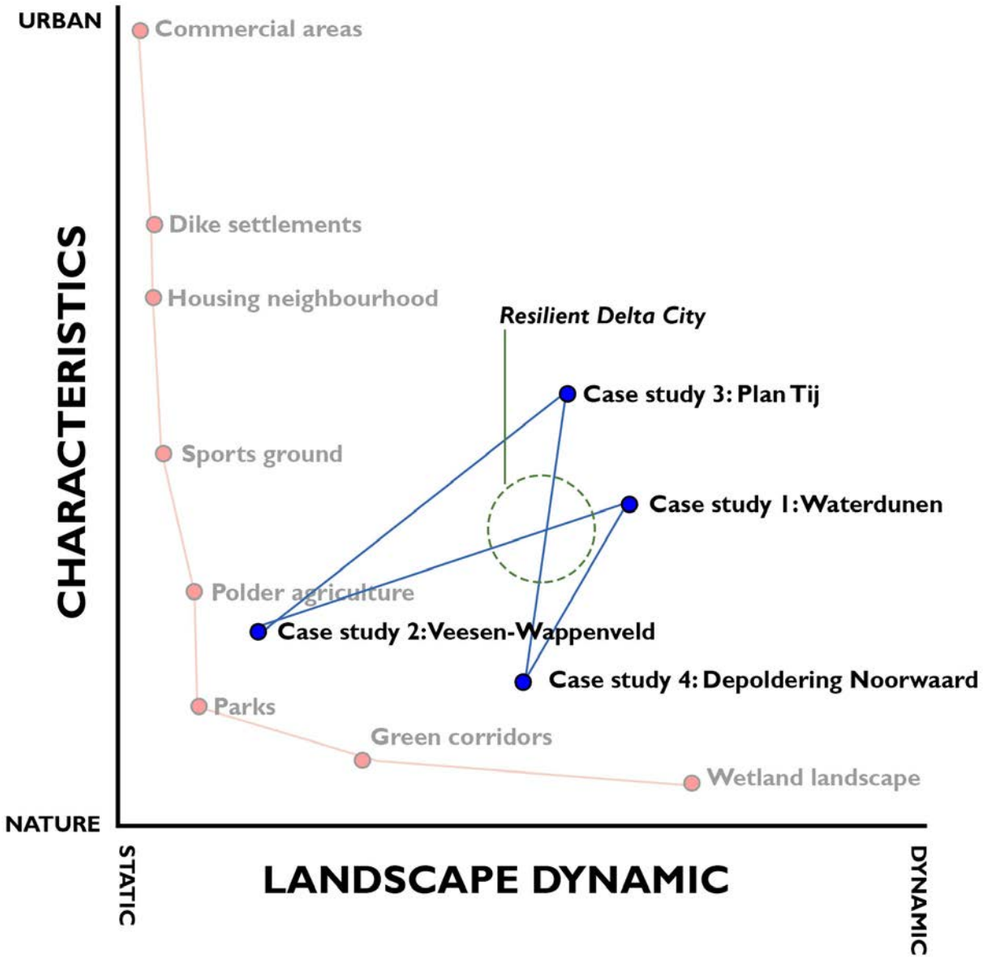
- Depoldered landscapes as part of water safety against extreme conditions
- Bringing the polders back into riverine ecologies
- Creeks as main water channels in between polders
- Inundation of remaining polders in different water conditions
- New roads and access through the depoldered landscapes
- Meandering accessways to create visual sequences
- In normal condition, water mainly comes in and out of the Biesbosch
- During high water condition, inlet from Nieuwe Merwede allows water to flood the depoldered landscape.
- Some old polders are totally opened for the river and others can be seasonally flooded.
- Creek channels inside the polders are dug as overflow channel on on the old polders.
- Existing farm houses are elevated on dwelling mounds.

Drivers

- To be adaptive to climate change.
- To provide more space for water during extreme conditions.
- To develop new nature recreation areas together with Biesbosch National Park.

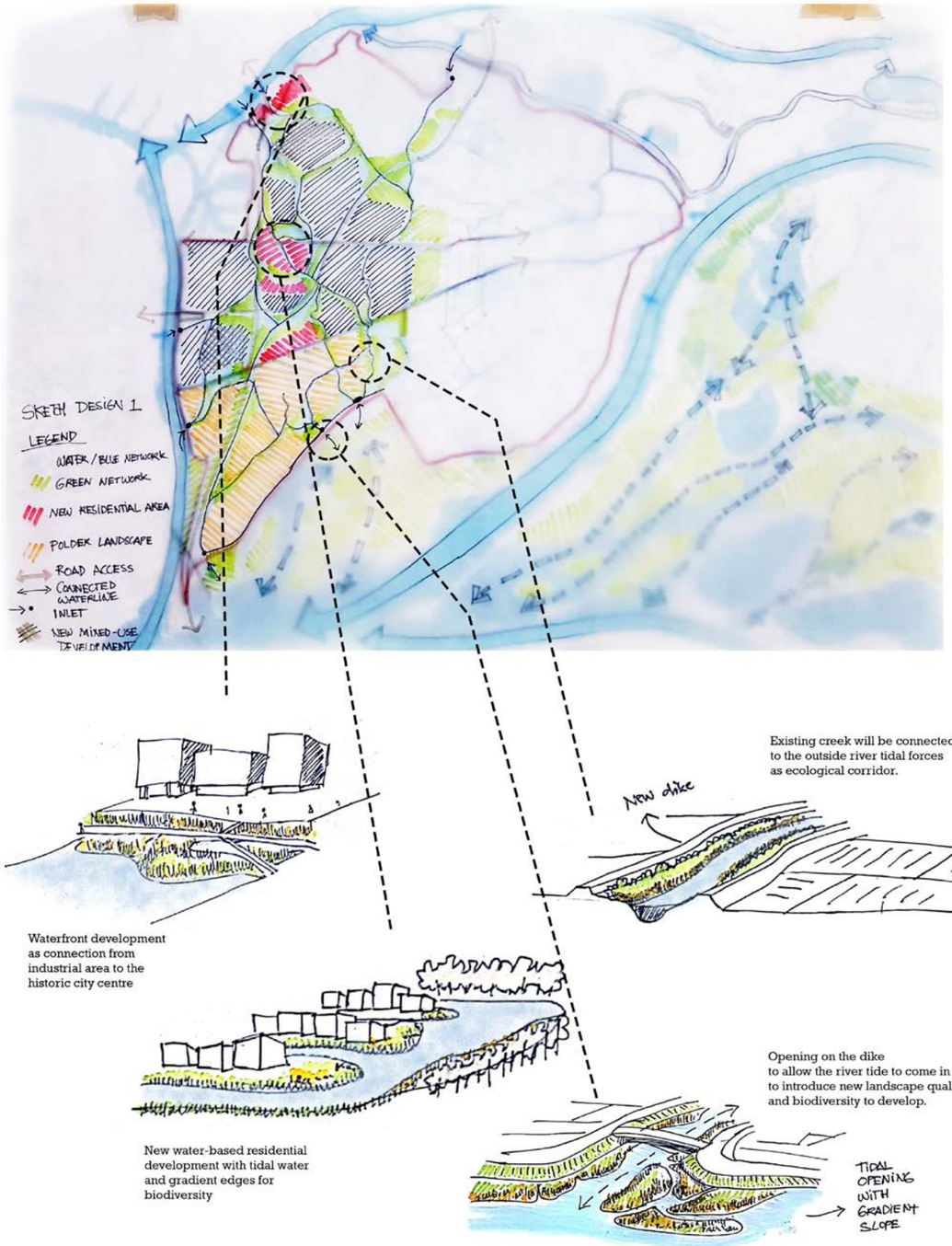
Impact

- Successful implementation of large scale depoldering after 10 years of negotiation with stakeholders and planning.
- Show the possibility of increasing biodiversity and integrate the polder landscape with the dynamics of the rivers while maintaining the productivity of some of the polders.
- Creating different scenarios of water levels as part of resiliency against uncertain future climate changes.



Conclusion: The existing vs the ideal

Comparing these precedents with the existing landscape typologies of Dordrecht will develop a chart as below. In this thesis the new design will sit in the marked circle which stands on the middle ground with back and forth relationship between urban and nature, and the static and dynamic. This finding frames the research and the desired design outcome. Looking towards new resilient delta, is looking towards enabling relationship between man made intervention which allow the natural dynamics to develop, as guiding structures not barriers. Without losing the necessity of water safety, the design should therefore have a certain framework as the main formal agent that satisfy the necessary water safety and adaptive measures.



2. Design experiment on scale of Dordrecht

Sketch Design 1:

Implementation of tidal inlet & establishing water-based residential neighbourhood.

Key elements

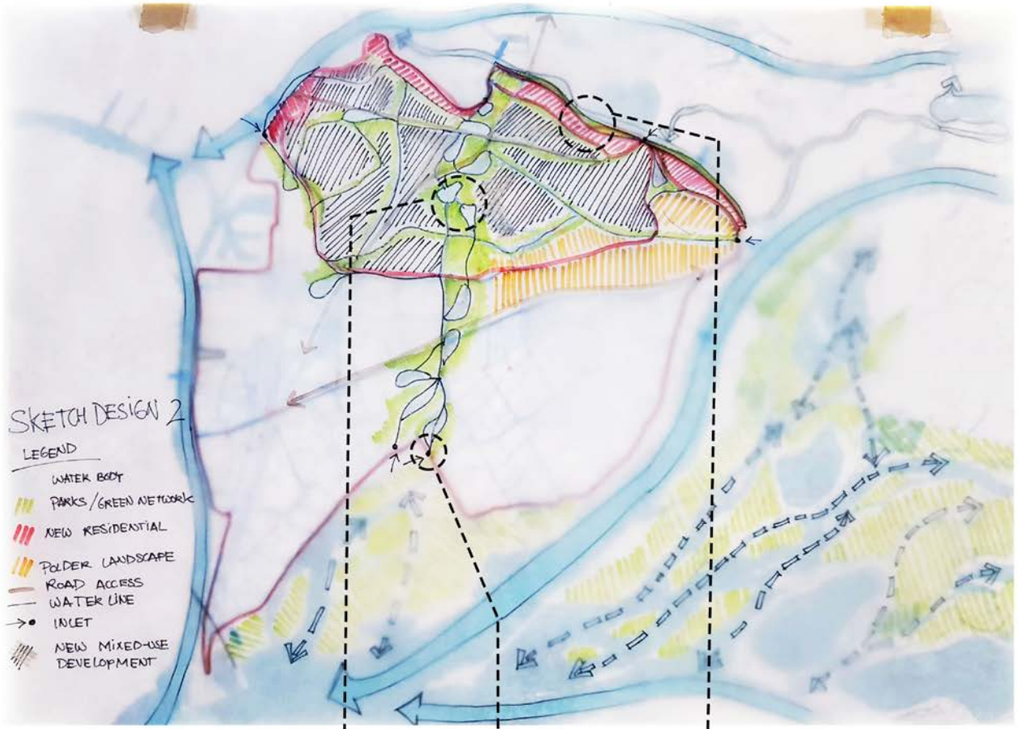
- Opening the embankments to expose to the tidal regime of the river landscape
- Channeling this tidal exposure through new dikes to protect low-lying polders
- New waterline as ecological corridors and connective landscapes.
- Developing gradients between land and water.
- Water based-residential developments connected to the new waterlines.
- Strategic flooding of extisting polder level with river water as new ecology.
- Establishing river flow through the embanked island.
- Emergent ecologies with new urban developments.
- Development of waterfront landscapes, outside the dikes.
- Extend outer dike protection with gradient slope towards the water.

Drivers

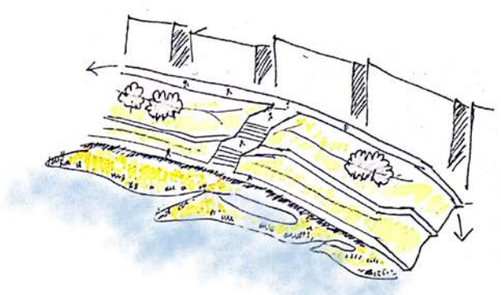
- To establish new ecological structures
- To establish gradients between land and water as measure of biodiversity and safety
- To establish new mixture of urban and natural landscapes in the island.
- To bring the landscape qualities of the river landscape through the currently embanked landscape.

Impacts

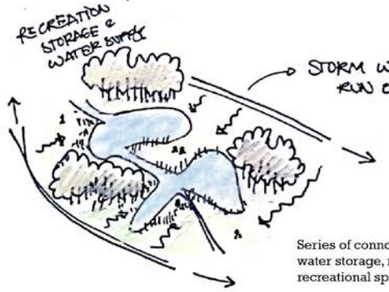
- Preservation of agricultural polders and polder urban landscapes while bringing new river water level through the island.
- Creating more room for water within the embankment and closer in case of necessary drainage of surrounding landscapes.
- New north-south connection through new ecological corridor.



The waterlines promotes connection with outside ecology through opening on dikes



Riverfront development integrated with upgrading dike protection while developing gradient for riparian ecology.



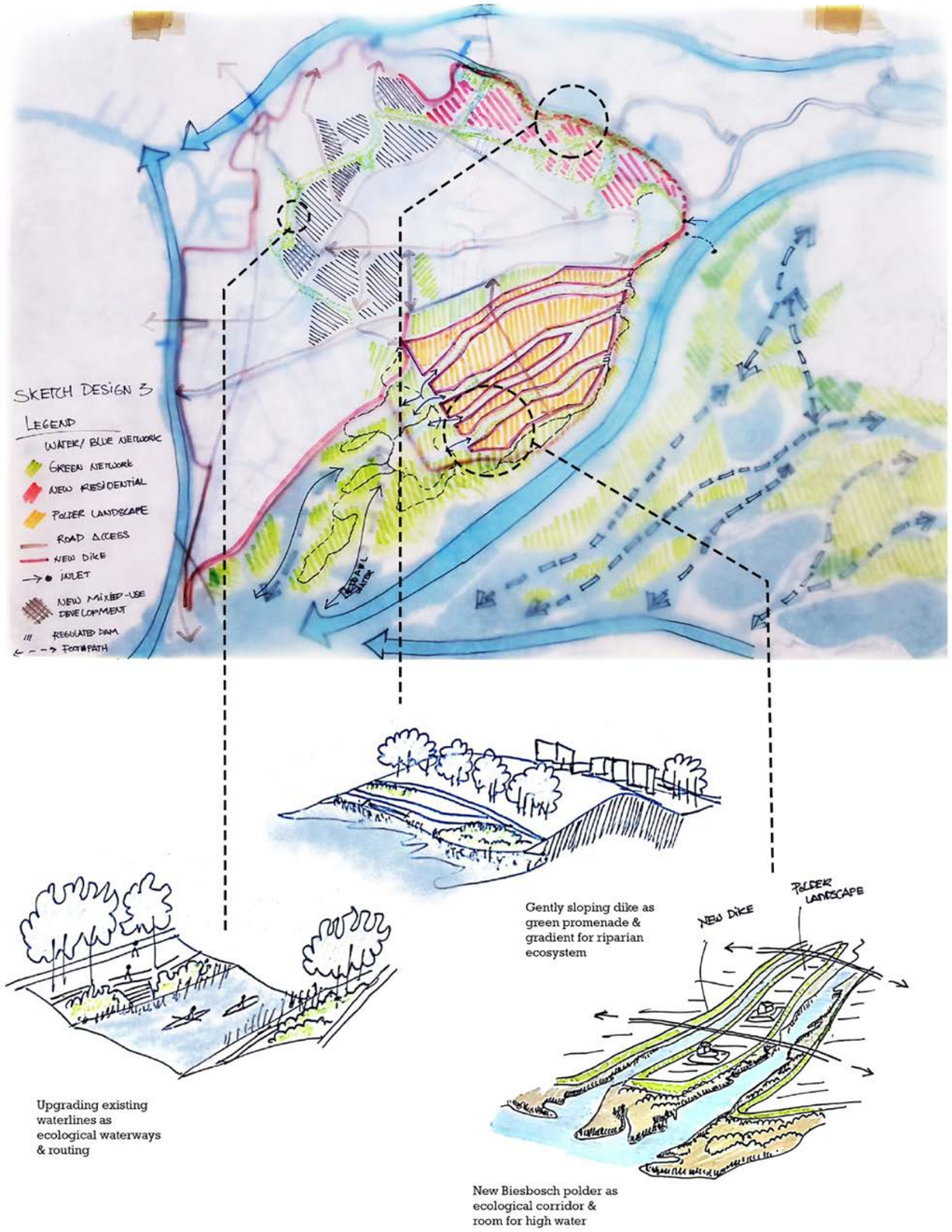
Series of conncted lakes for water storage, runoff, and treatment as well as recreational spaces in urban landscape.

Sketch Design 2:
Developing riverfront & creating water treatment landscapes.

Key elements
- Reserving lowest points of the landscape for water basins.
- Water basins as storage water during dry periods and space for excess water.
- Adaptive landscape againsts cloudburst flooding within the embankments.
- Water basins as recreation parks and interconnected green spaces.
- New green-blue corridor connecting lowest points of the landscapes.
- Open up to the river level with regulated flow.
- Water from the basins can be pumped out to the rivers if necessary.
- New recreation parks close to the urban neighbourhood.
- Developing riverfronts as busy and high density developments on the Wantij.
- Access to and from water on the new riverfront
- Accessible dikes as recreation promenade.

Drivers
- To develop riverfront landscape as east-west connections.
- To establish north south connection through new recreation parks.
- To create spaces for urban water runoffs and seepage.
- To promote new landscape structure within the embankments.
- To promote riverfront spaces as new development.

Impacts
- Resilient urban structures with new discharge spaces of excess water.
- New source of water during dry periods for both urban and agriculture.
- New spaces for nature and recreation.
- Possibility of riverside community.



Sketch Design 3:

Strengthening ecological and recreational connections & focusing on flood defence against high water.

Key elements

- Reconnecting old creeks with the river as new waterline.
- Space for water flow through reconnected waterlines.
- Separate the Nieuwe Biesbosch polder as ecological corridor reconnecting north and south Dordtse biesbosch landscape.
- New embankments flanking the creeks to protect the polders.
- Creating access on the landscapes outside the dikes with new waterline as new connective landscape.
- Flooding Nieuwe Biesbosch polder during extreme conditions with necessary access for evacuation.
- Upgrading the existing waterlines throughout the embankments as ecologically rich corridors.
- Developing accessibility of the ring dike as new recreation corridors.
- Expanding existing ring dike with gradients to increase the safety of the dikes.
- Connecting waterlines as water recreation corridor around the island.
- Promoting riparian ecosystem on the boundary of land and water.

Drivers

- To develop adaptive measures towards extreme water conditions.
- To establish connection around the island through new green and blur network.
- To promote riparian ecosystem to develop on gradients.
- To create gentle dikes which reduce visual impact.

Impacts

- Available space for high water conditions.
- Reconnected dordtse biesbosch landscapes.
- Bring the qualities of flowing creeks back to the landscape.
- Landscape connections for east-west and north-south.
- Accessible dikes and riverside spaces

Key Design Principles

From the reference study analyses and the design experiments, these design principles can be used as entry points for further design process;

- Creating Water Basins

In low and vulnerable areas, water basins can be created to capture excess water and runoffs, as well as for water storage and recreation. The dug soil can be used to raise the surrounding land to be safe from flooding (creating mounds) while being close to the water body.

- Preserving Agricultural Polders

Construction of new embankments to protect agricultural area can be done to allow creeks and waterlines to become tidal ecological wetland area which act as biodiversity corridor and water supply.

- Strategic Tidal Exposure

Inlets of river water and river tidal forces can be done on the existing embankments to no longer isolate the urban fabric from the outside landscape dynamics. The inlet can be regulated to maintain the waterlevel required inside the embankments while allowing the river dynamics to penetrate through the dikes.

- Water-based Community

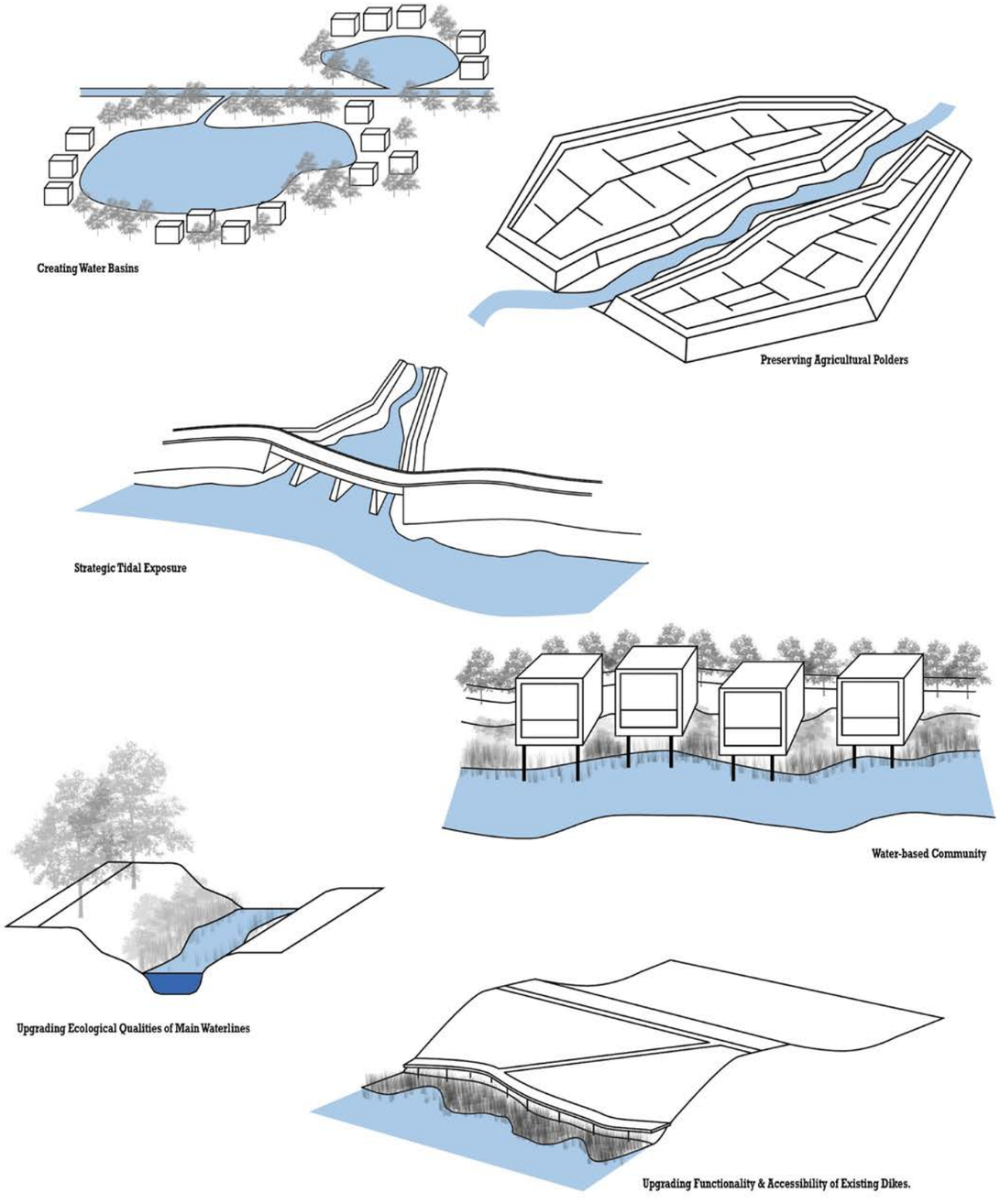
Urban climate resiliency can be combined with investment in housing by creating water-based communities with high biodiversity. Waterbodies and waterlines can be as water storage and the main attraction & recreation of the new housing areas which is connected to the newly established connection with outside tidal dynamics.

- Upgrading Ecological Qualities of Main Waterlines

Waterlines can become corridors that connects different neighbourhoods and different landscapes with gradients of riparian landscape ecologies which perform as both ecological and recreational corridors. Exposing the site's characteristics of running creeks.

- Upgrading Functionality & Accessibility of Existing Dikes

The dikes can be upgraded as part of connecting the urban fabric with the river, whether providing more access, viewing points or as part of riverfront developments with mixed use buildings. Promenades can be constructed on existing dikes to allow closer access to the water from the otherside of the dike.



V. DESIGNING THE LANDSCAPE

1. Implementation of design

The design principles gathered from the design experiment excercise is used as starting points to find suitable areas to be implemented. Opportunities and restraints are explored further by looking at the scale of the city to develop the design framework for the intervention. The design evolves from the idea of three main components; implementing building with nature and nature based solutions in designing with the river. necessity of looking into the spatio temporal processes urban and nature which require slow transformation of the existing landscapes, and finally a climate change scenario in order to implement the adaptivity of the deisgn.

Living with the river

The cornerstone of the design solution is the exposure and reconnection of the river landscapes in the embanked landscape. This will involve strategic depoldering in order to implement strategic "re-colonisation" of the reclaimed landscape by the dynamics of river landscape. The intervention will alter the water system as it will implement new level of water in Dordrecht, that is, the river water level. In order to do so, the possibilities of opening sections of the dikes are explored with different consequences to the landscapes. Following this re-establishment of the river water flow, new landscape qualities are evoked as new ecologies takes over the previously regulated polders as well creating new landscape values unique to the landscape as the river delta, not only as part of the water system, as basins and as main discharge destinations, but also as part of new economy that is working with the dynamics of the rivers. Here the possibilities of new type of housing developments, and preservation and creation of new type of agriculture are explored. The new river flow will bring the water resources closer to the city to accommodate both in summer and winter time.

Infrastructures will become structuring elements and accessways which has little influence on the newly reintroduced dynamics. Other designed interventions that affect the morphodynamic processes is done strategically on suitable locations as means of directing, divert, or enhance the landscape processes. New way of urban developments will be built as a response to the processes of the river and designed in such a way that whilst being safe to live on the river, also live with the river as the processes of the landscape will be allowed to continue shaping and reshaping the landscape.

Slow transformation

The design solution in thie research-by-design process is based on the landscape's slow transformation both naturally and anthropogenically. Naturally, to incorporate the river's natural morphodynamic processes, that is the process of sedimentation and erosion requires a bigger timeframe to take shape. Interventions such as new roads and new dikes that are necesssary to allow the new river landscape will be built in the beginning of the intervention, in other words, it is to prepare the landscape for the eventual de-poldering stage. After being exposed to the river, morphodynamic process will be allowed to take place as the landscape become new landscape structure within the city as valuable fresh water tidal landscape.

Anthropologically, such radical intervention which goes against the long tradition of water safety in an embanked urbanised landscape will provoke protests from stakeholders, in particular, the land owners. By developing a design framework for the intervention, and slowly implementing it within a large timeframe, will provide room for communication and conversations between stakeholders. The design framework ensures that the bigger goal will remain the same even if changes are made on the smaller scale.

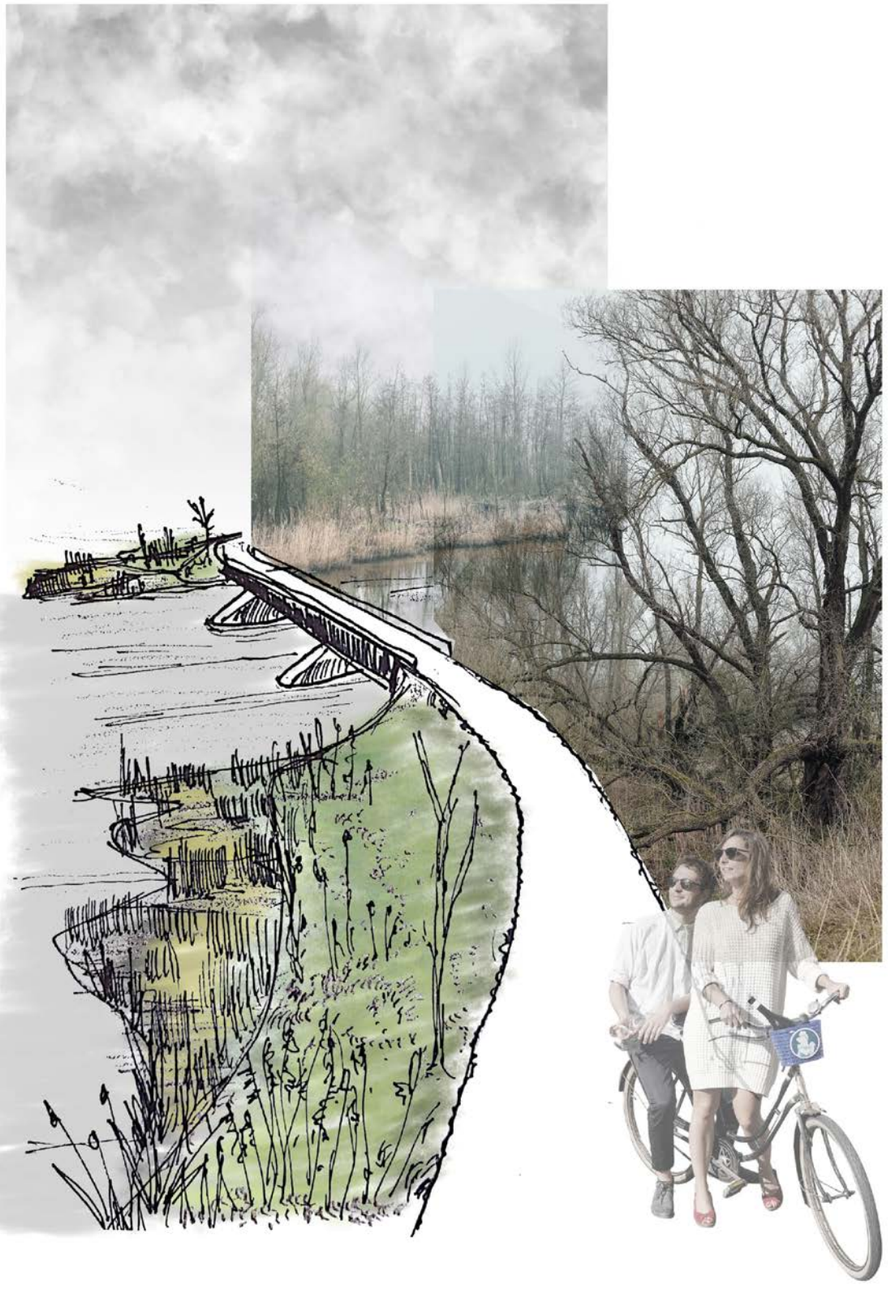
Climate change scenario

The design will attempt to create a new landscape structure that is open-ended, adaptive to future changes whilst on the bigger scale operate to increase the climate resiliency of the urbanised delta landsape. Here, the design is aimed to be able to accommodate different water conditions from normal tidal regime to extreme flooding conditions. Through controlled flooding, more frequent high discharge water can be accommodated and "welcomed" as part of the invited nature processes. Whilst allowing the processes of sedimentation and erosion to take place, the landscape will be formed by local alluvial sediments which deposited naturally creating new ecologies that are adapt to both normal and extreme water discharge and the protective dikes and infrastructures can be strengthened by this extra layer of sediments.

In this design, as the climate change accelerates, it is assumed that more and more anomalies in river discharge will occur, thus, challenging the integrity of the exisitng dikes. The polder landscapes will subside further and overtime, it is assumed that the farmers will deemed the lower parts of the Island of Dordrecht as unprofitable and will choose to relocate. In this scenario, the effort to implement the design decisions as part of creating adaptive landscapes will be supported by both the government and the residents through constant communicaiton and discussions as the necessity of such intervention increases to maintain the longevity of the urbanised river delta landscapes. New urban development is aimed to demonstrate the high value of being resilient towards climate change whilst allowing the natural dynamics to take place in its vicinity.

2. Visions

A connection with the river landscape outside of the dike to let the river dynamics take over the polder landscape. Processes of sedimentation and erosion as well as fluctuating river water will transform the polder landscape overtime.



A living experience on emerging marshy riverine landscapes where people can live close to the biologically diverse new gradients inbetween land and water. The new landscape will therefore becomes everybody's backyard all the way towards the horizon.

An accessible dynamic landscapes where people can move through to visually and spatially experience the emerging ecologies. Close to the ground, on the gradient, on top of dikes, and viewpoints allows different way to experience the landscape and always changing with the water level.

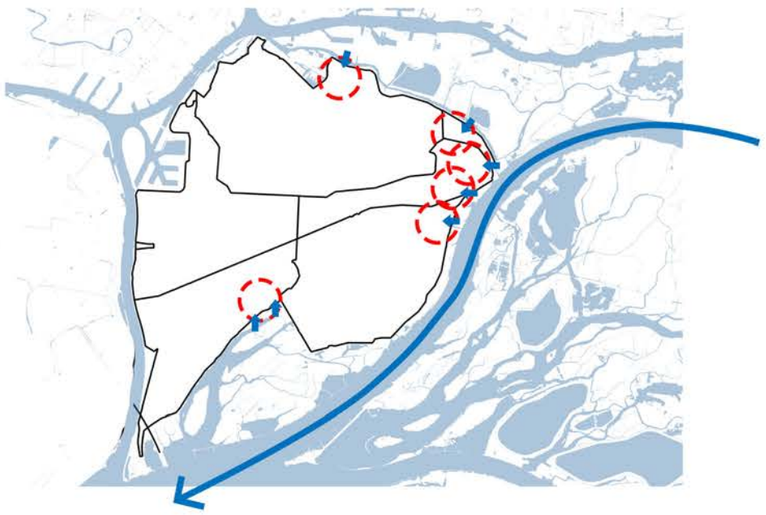
A restoration of the landscape structure and dynamics of marshy landscapes, mudflats, and land accretion which is directly influenced by the rivers and evoke the cultural history of living on the river and with the river.

3. Design for new green-blue network

The intervention will start on the larger scale of Dordrecht. Here the intervention will take place on the lower agricultural polders of middle, east and south of Dordrecht. Here, other than availability of spaces, issues such as high groundwater level, subsiding land, and seepage condition are taken into considerations. Strategic opening of dikes will allow river water to come inside the embankments and transform the polders into dynamic zones. Here, the dynamic of the rivers will shape the landscape overtime and will develop new and emergent ecologies. It will eventually become ecological corridor which connect the separated north and south part of Dordtse Biesbosch. This new dynamic zones will be integrated with developments of dynamic agriculture, resilient housing neighbourhoods as well as recreation landscapes. Overtime this new landscape will generate adaptive landscapes to contain forces of extreme river discharge as well as basins to drain the urbanised polders during cloud burst events. Moreover, this landscape will become source of clean water for the the city and agriculture which incorporate emergent riverine ecologies as natural water filtration system.

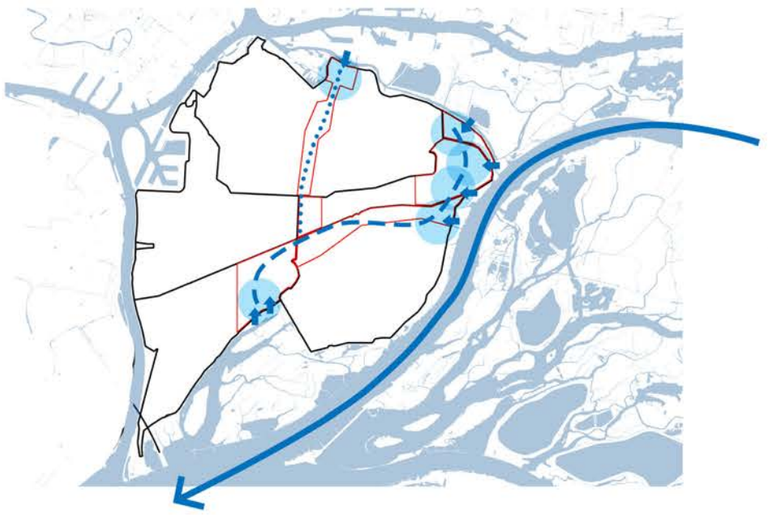
Invite the river

Creating inlet by breaking up the dikes on several points to allow the dynamic of the river to come inside the embankments. Through small interventions, this river dynamic will slowly shape the new landscape.



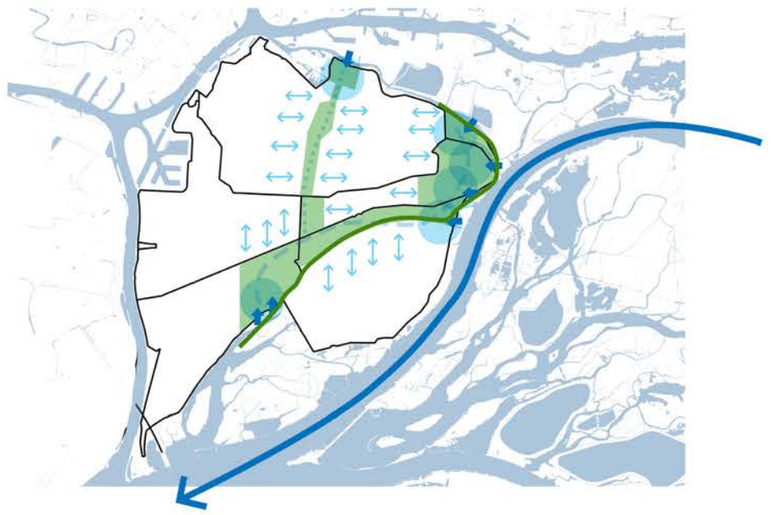
Establish new green and blue network

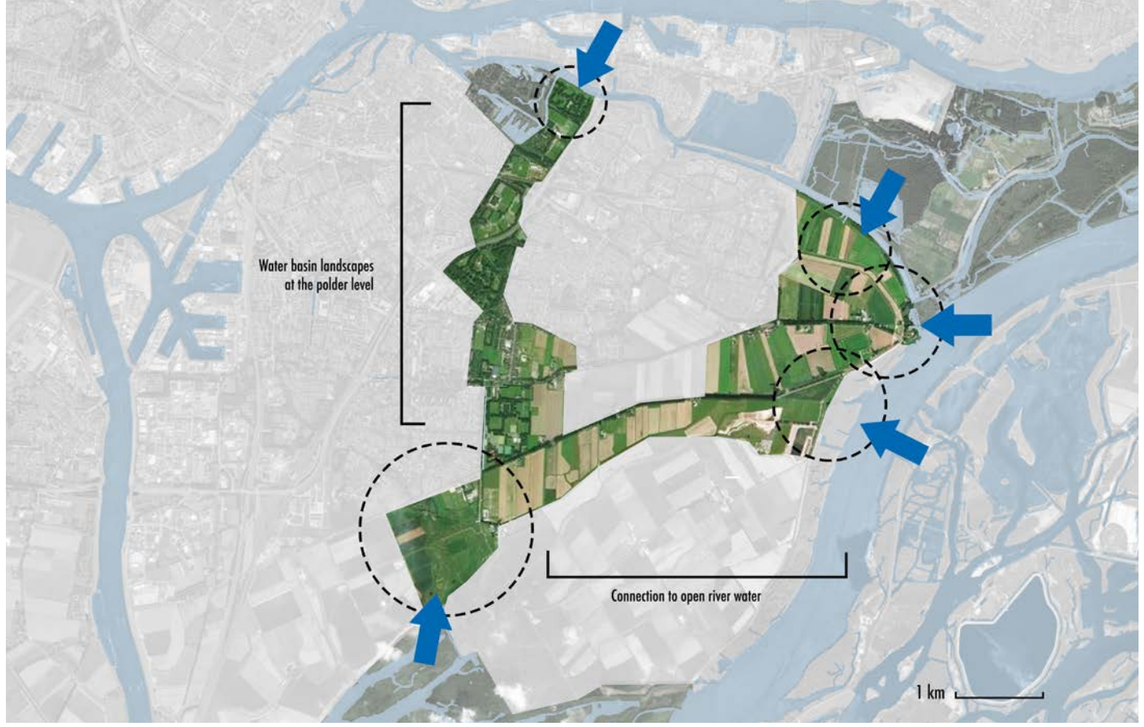
These new landscapes are connected as part of the new level of green and blue network of the island of Dordrecht, that is, the dynamic network. Necessary new embankments will be constructed to frame the new landscape, access through, and most importantly, protect the lower areas.



Develop dynamic zones

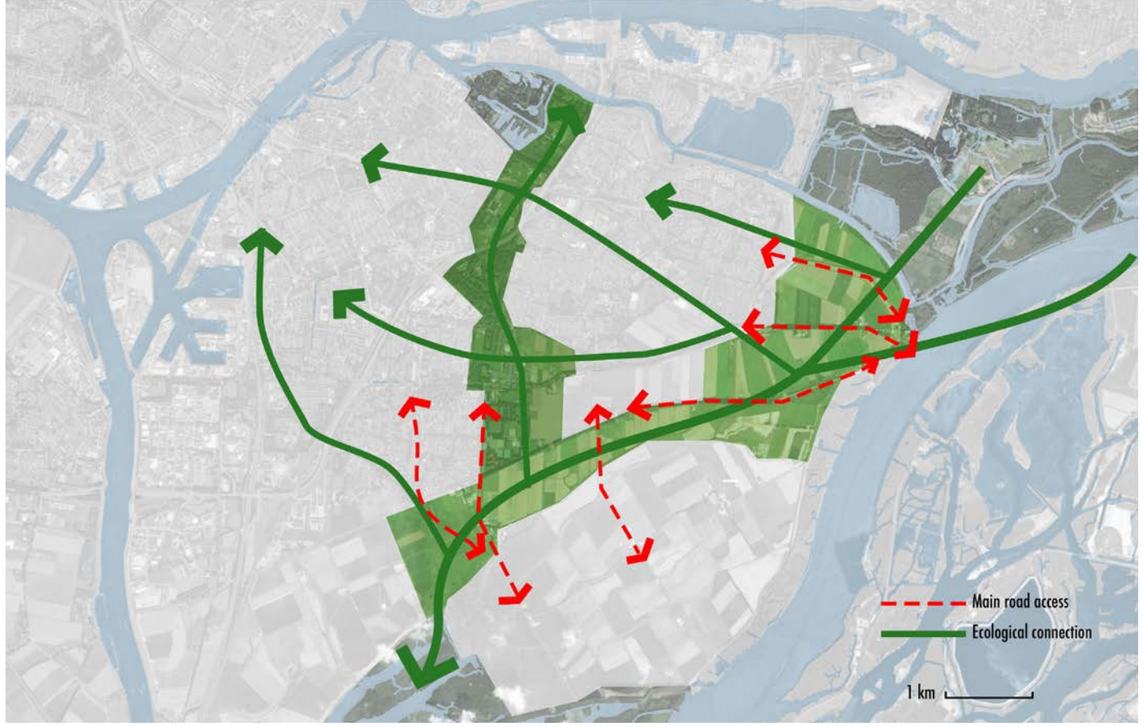
Natural forces and water has the major influence in “colonising” the lowland polders. The process of urbanisation will be integrated with the development of the new landscapes. Overtime these dynamic zones will become gradients that adapt the city of Dordrecht to the uncertainty of the changing climate.





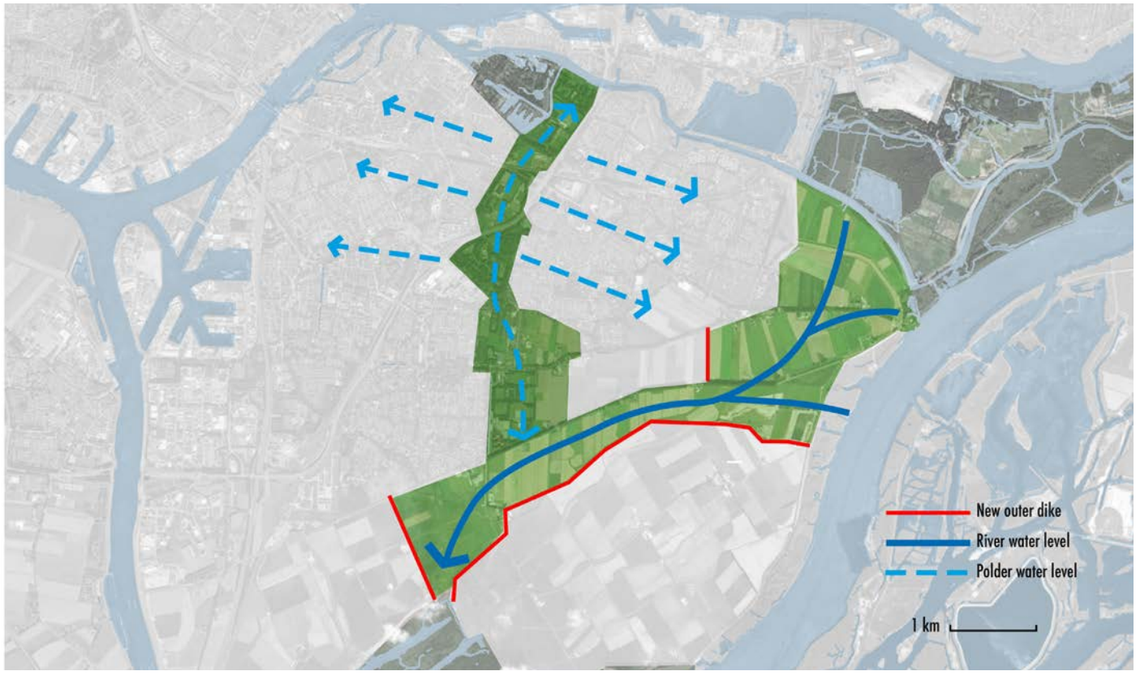
Establishing two new levels of water system

Two systems of green-blue network is created through connecting one to the open river water with new river ecological qualities from east to west, through opening up different points of the dikes and the other is on the polder level which is supplied from the former system and acts as a new water basin for the polder level.



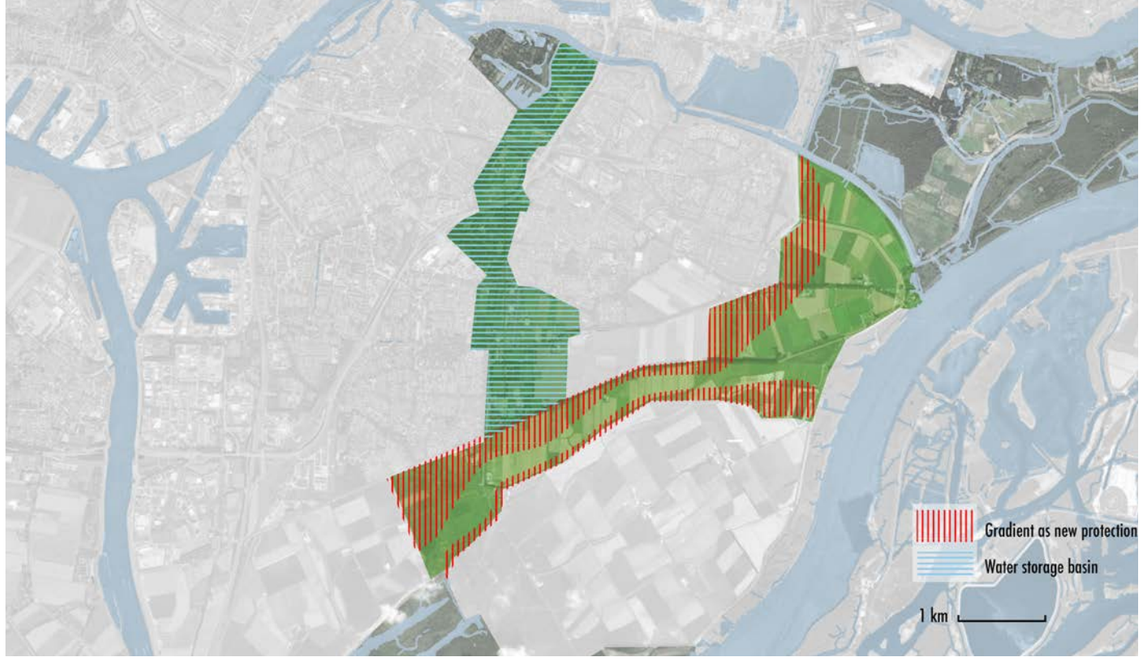
Ecological connections and accessways

The new landscape will generate new ecological network that connects the urban landscape of Dordrecht directly to the nature areas surrounding it namely the direct connection from the Sliedrchtse Biesbosch towards the Brabantse Biesbosch.



Allowing the river to flow through instead of around

Upon completion, the new green-blue network will allow the flow of the river toward south west from the Nieuwe Merwede. The river water nourishes the newly developed gradient and therefore promoting new ecologies along its way. It will be connected through sluice gate and pumping stations to the new water basin landscape inside the embankment as water suplly.



New water safety measure

The landscape will in the end become new water safety measure of Dordrecht through ustilising the natural dynamics and gradients as protection from the river forces as well as the water basins on the polder level as new water storage facility which allows drainage from surrrounding polder cities.

A vision masterplan for Dordrecht

The intervention on the Dordrecht scale will re-introduce river flow from north east towards the Hollands Diep on the south-west. The landscape will accommodate normal tidal regime through the excavated main flow channel and the the flow of the water will change as the regime changes.

The depoldered landscapes are mainly agricultural polders with new dikes as its boundary to with the preserved polders. The preserved polder landscape of Nieuwe Biesbosch will become polder island with necessary access towards the city.

Through the middle of Dordrecht, water basin landscapes will be created on polder levels on the existing low-lying parklands. This landscape will add new recreation value closer to the city with direct connection towards the depoldered landscapes.

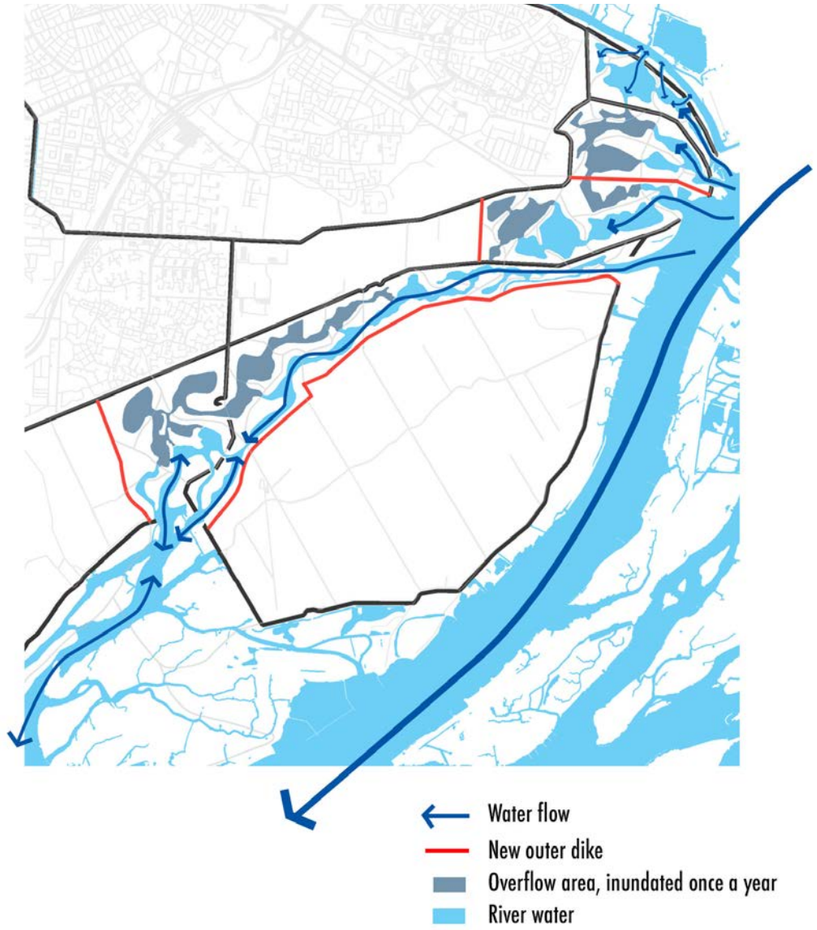
1 km

Landscape transformation

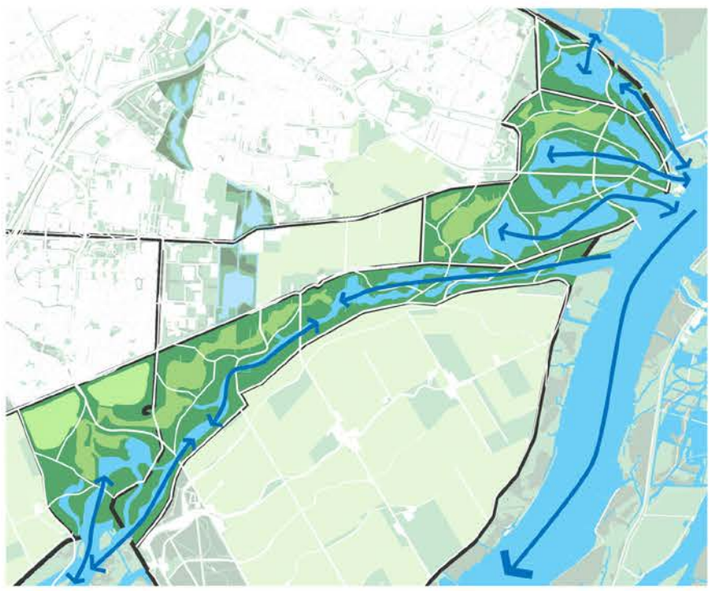
The design transforms the existing polder landscape into a dynamic zone by preparing the necessary groundworks to expose the low-lying landscape into the river dynamics. Here, the river is allowed to flow through the landscape and thus exposing it to the temporary fluctuation of the river water and the morphodynamics processes of the river. New gradients are developed naturally which can generate new riparian ecologies. Existing dikes is utilised as main access roads supported by new road access/dikes through the dynamic zone by emphasizing natural relief currently present on the landscape.

‘Let it flow’

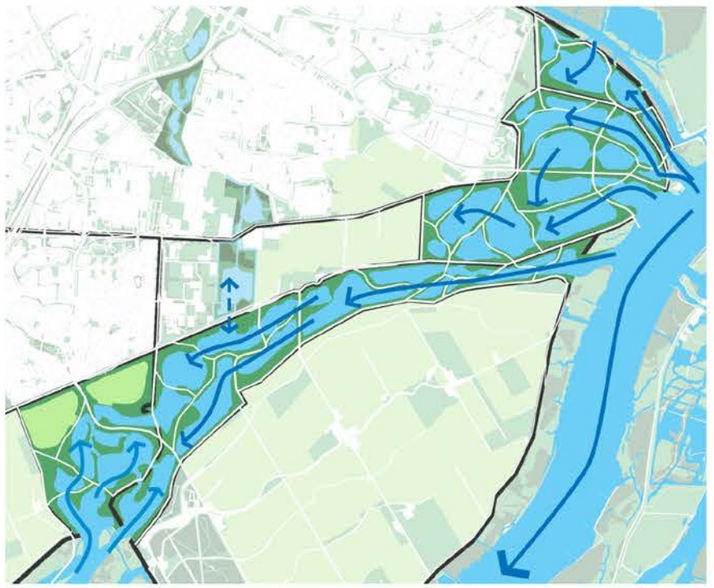
Connected to the river, the landscape allows the river water to flow through from north east to the south west. Here the landscape is designed to be able to adapt to uncertain changes in the future in regards to the sheer force of the river discharge as well as the fluctuating water level. During normal tidal regime, the river Nieuwe Merwede supplies the north east section of the landscape whereas the south east section is influenced by tidal water from the Brabantse Biesbosch. Once a year, the water flows from Nieuwe Merwede flows throught the whole landscape towards the south west and most of the gradients are exposed to water and grassland flooded. During extreme conditions of water reaching above 3m NAP, most of the the landscape can be flooded and evacuation routes are safe above water for necessary evacuation. The continous supply of river water will generate sedimentation and erosion process in the new landscape, silting up new lands and developing new ecologies that depend on the moving fluctuating river water.



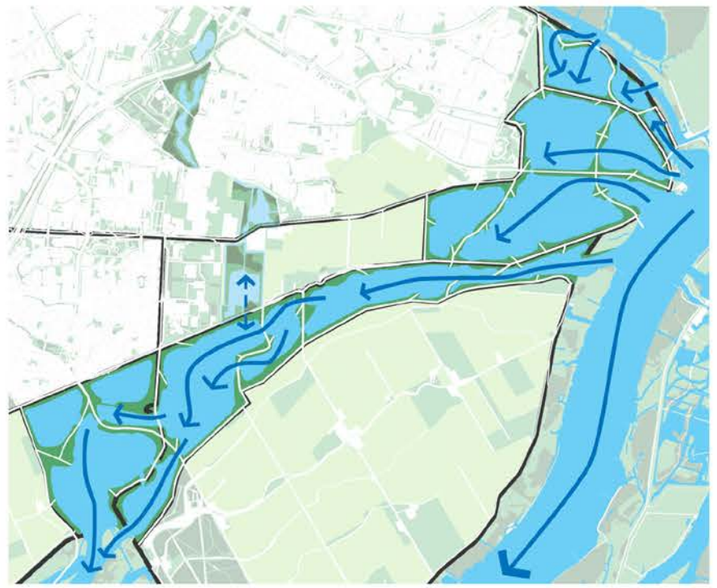
Normal tidal regime <120cm above NAP
Water flows in and out of the site, flooding lowest areas of the landscape



Annual high water flow 200cm above NAP (30 days a year)
Water flows towards south west, flooding landscapes with low embankments



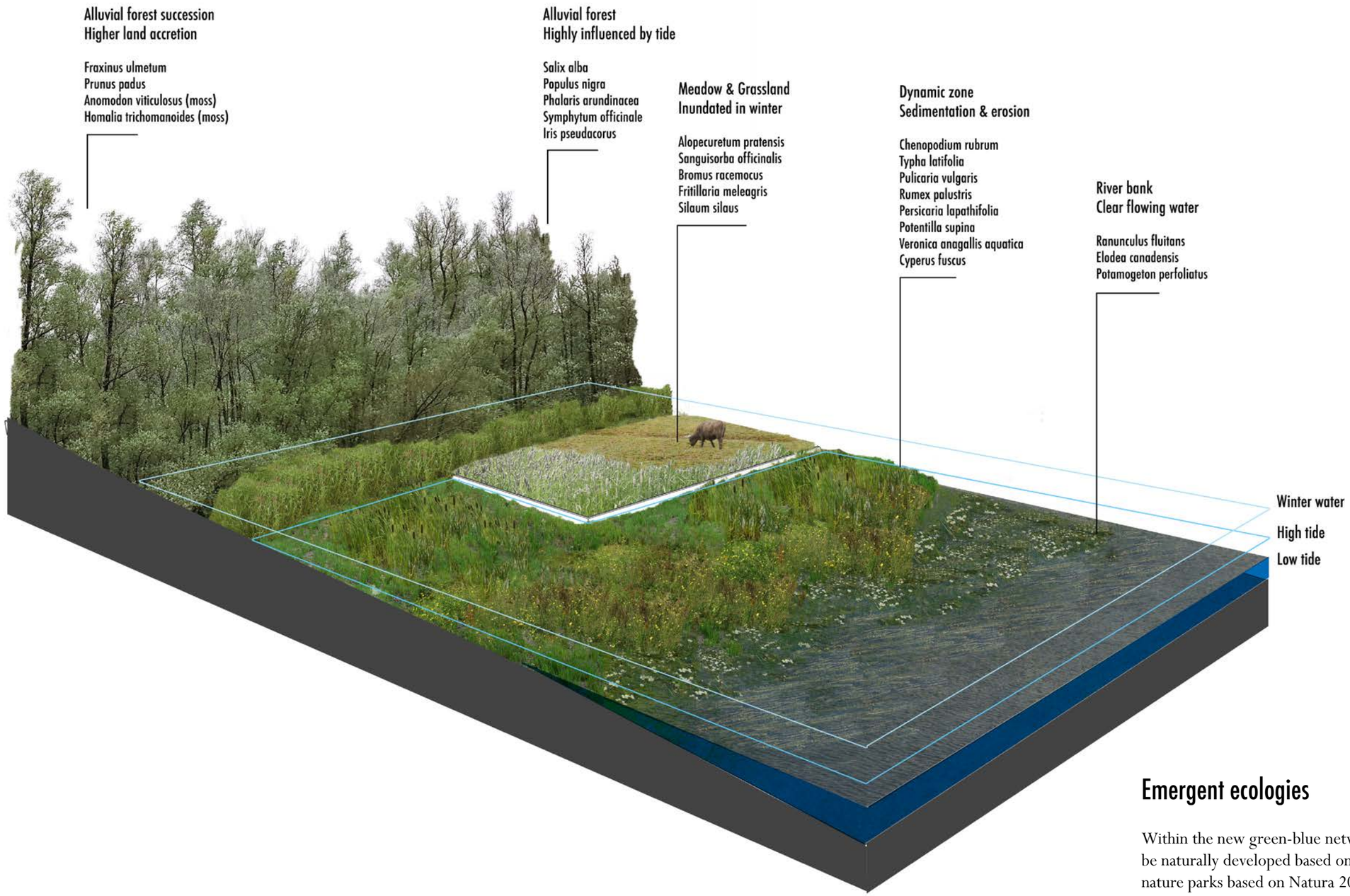
Extreme water condition 300cm above NAP
Landscape flooded, lower access roads are flooded leaving vital evacuation access



Grassland/ Agriculture
Marshland
Alluvial woodland/ forest

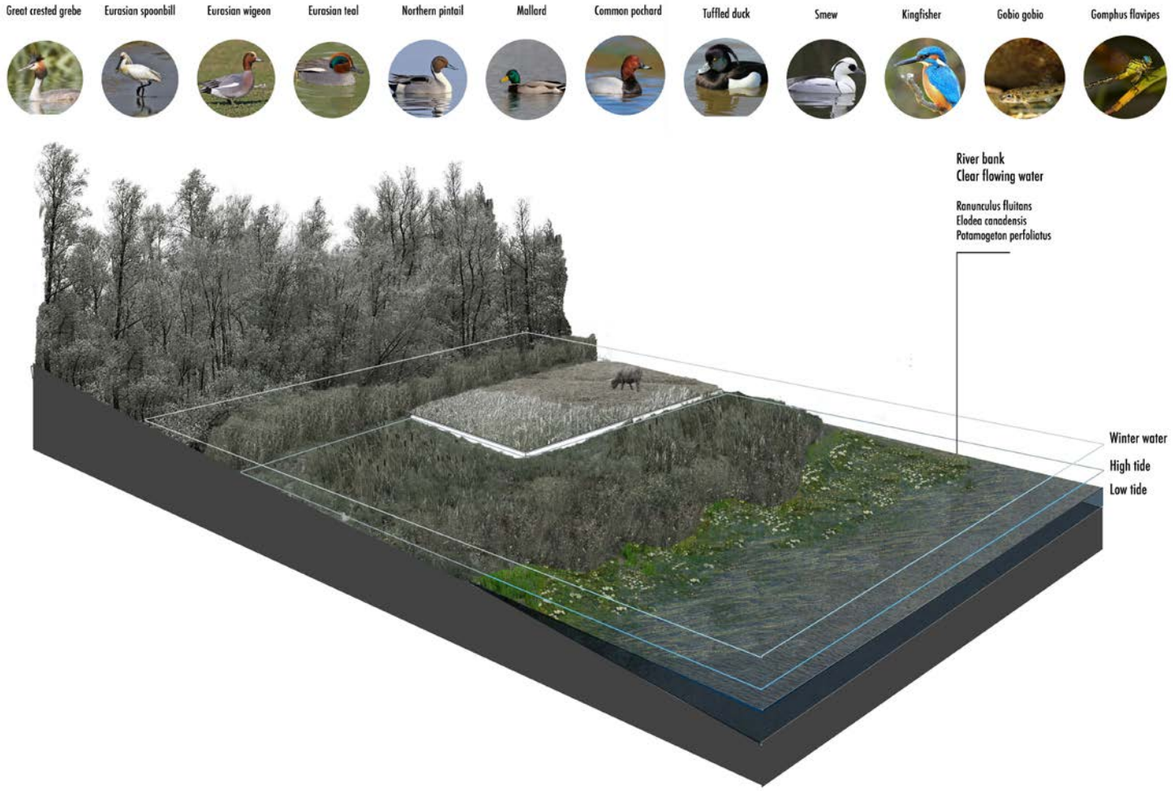
‘Let it grow’

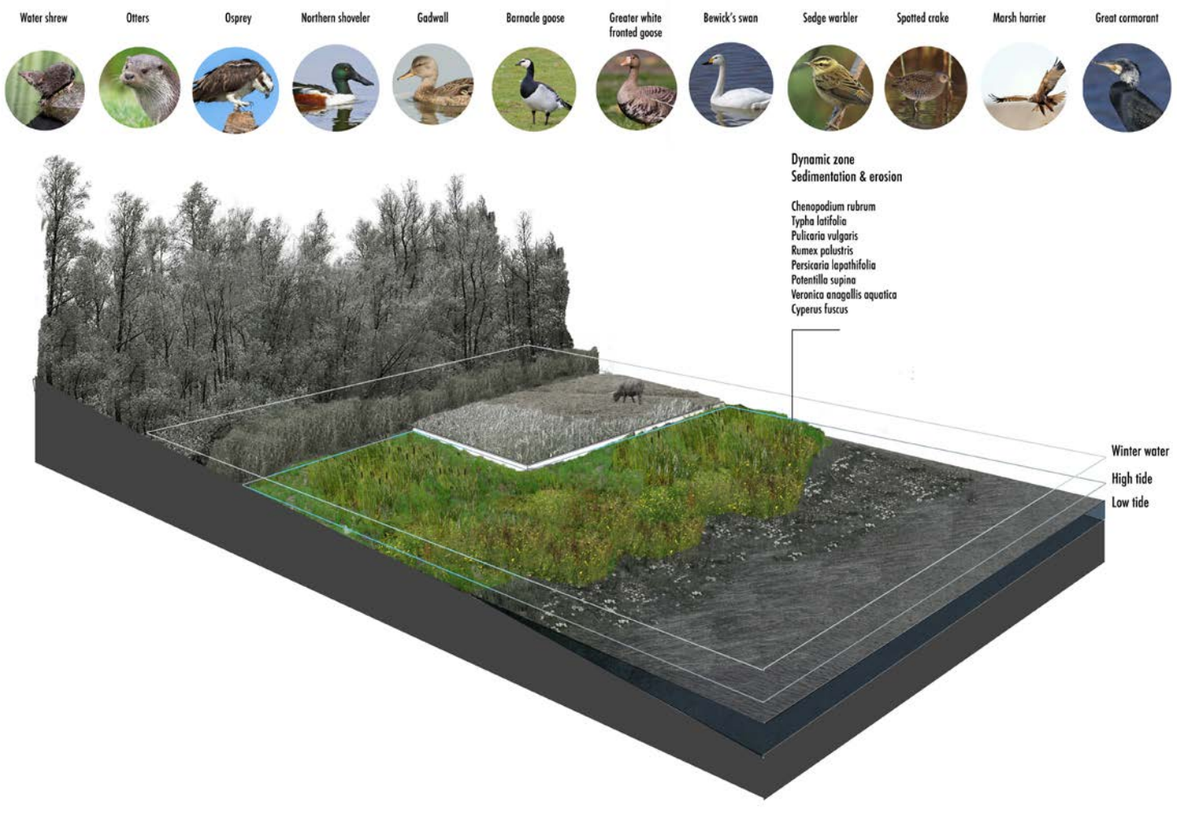
The dynamic zone will develop new ecologies on the landscape with dependence on the gradients and the treatments/management strategies. These dynamic zones will be divided through different programming and therefore, different structures adn ecologies will be generated. Landscape management such as grazing, water level control, and leaving out to nature strategies will be elaborated later on and encourage different landscape structures. Marshland will develop on the gradient of land accretion with frequent exposure to river water. Succession and further land accretion will allow these marshland to transform into alluvial woodlands overtime with wet loving trees such as willow and ash can grow both planted and naturally. Overflow areas can be used as grassland for cattle or agriculture with fertile alluvial sedimentation that takes place on top of the existing soil.

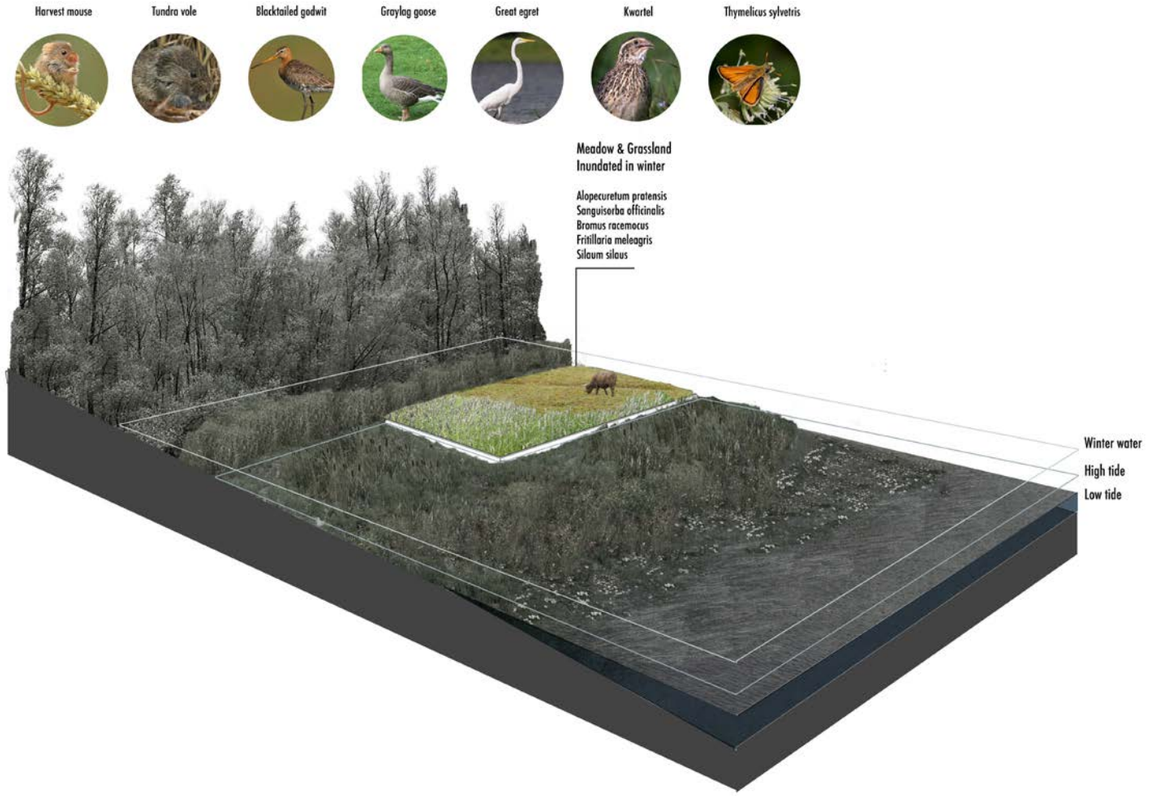


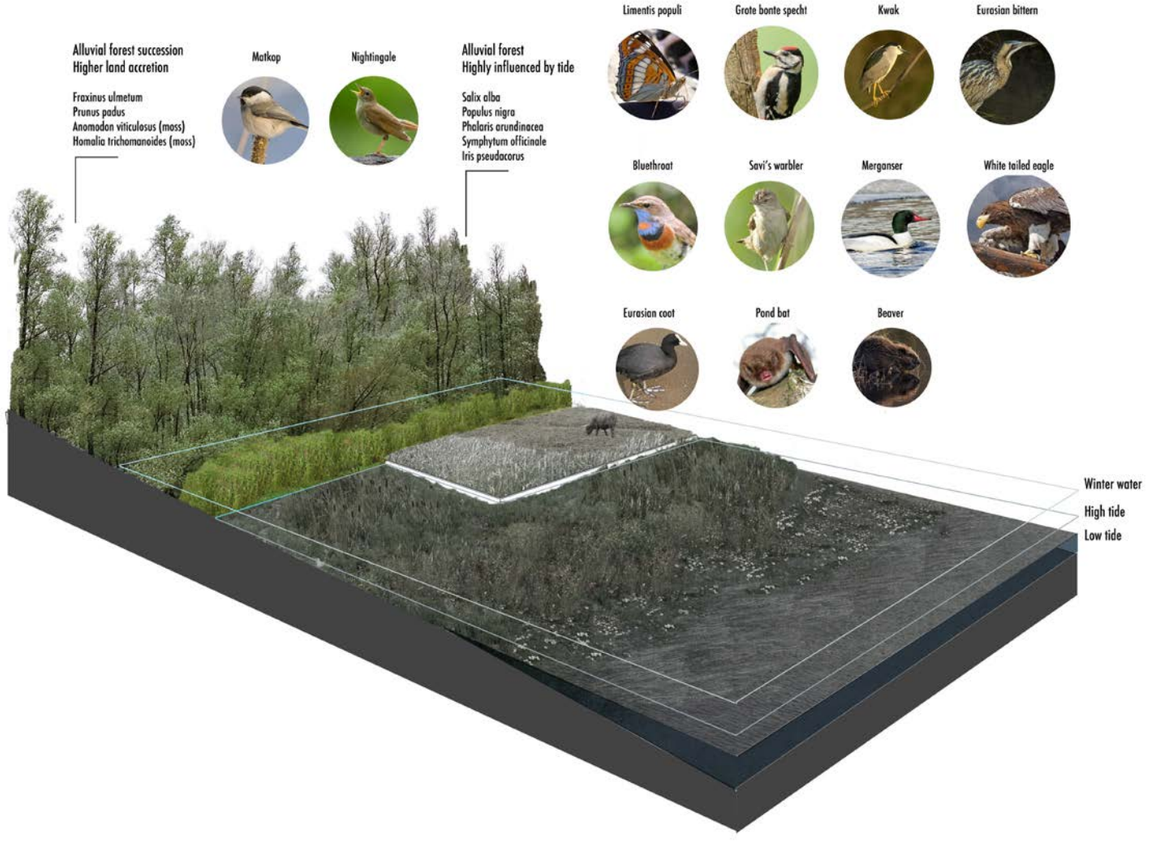
Emergent ecologies

Within the new green-blue network, 4 different new ecologies can be predicted to be naturally developed based on the similar conditions on the existing neighbouring nature parks based on Natura 2000 classifications. At the edge of water body, submerged plants will grow on the shallow water. Moving further inland and slightly higher gradient will develop riparian marshes that dominated by reeds and perennials will grow and can tolerate daily inundation from the river. Meadow and grassland grows on the sedimentation with low embankments in combination with grazing. As the gradient goes higher, the alluvial woodlands with willows will develop and inundated annually. Overtime succeed into mature alluvial forests with ash and variety moss species.


Great crested grebe
Eurasian spoonbill
Eurasian wigeon
Eurasian teal
Northern pintail
Mallard
Common pochard
Tuffled duck
Smew
Kingfisher
Gobio gobio
Gomphus flavipes
River bank
Clear flowing water
Ranunculus fluitans
Elodea canadensis
Potamogeton perfoliatus
Winter water
High tide
Low tide


Water shrew
Otters
Osprey
Northern shoveler
Gadwall
Barnacle goose
Greater white fronted goose
Bewick's swan
Sedge warbler
Spotted crake
Marsh harrier
Great cormorant
Dynamic zone
Sedimentation & erosion
Chenopodium rubrum
Typha latifolia
Pulicaria vulgaris
Rumex palustris
Persicaria lapathifolia
Potentilla supina
Veronica anagallis aquatica
Cyperus fuscus
Winter water
High tide
Low tide

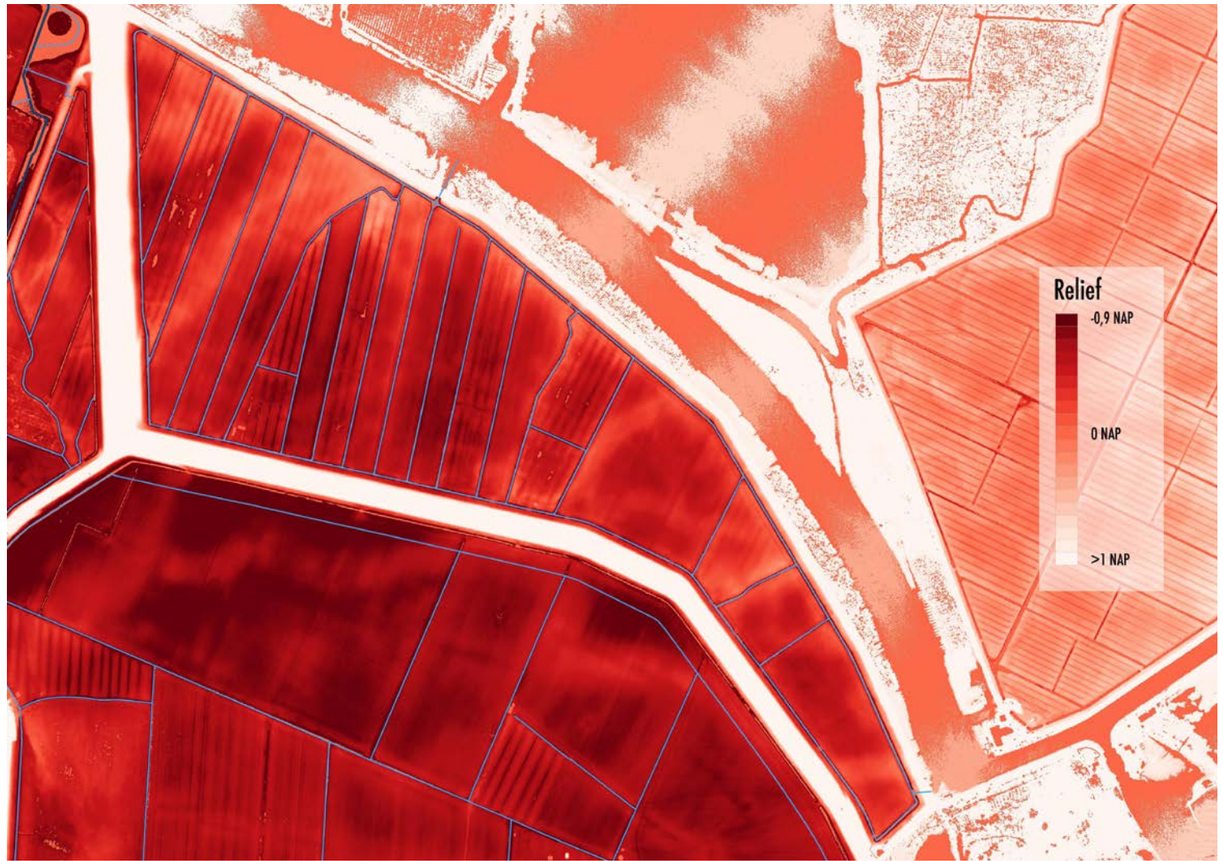

Harvest mouse
Tundra vole
Blacktailed godwit
Graylag goose
Great egret
Kwartel
Thymelicus sylvetris
Meadow & Grassland
Inundated in winter
Alopecuretum pratensis
Sanguiserba officinalis
Bromus racemocus
Fritillaria meleagris
Silaum silaus
Winter water
High tide
Low tide

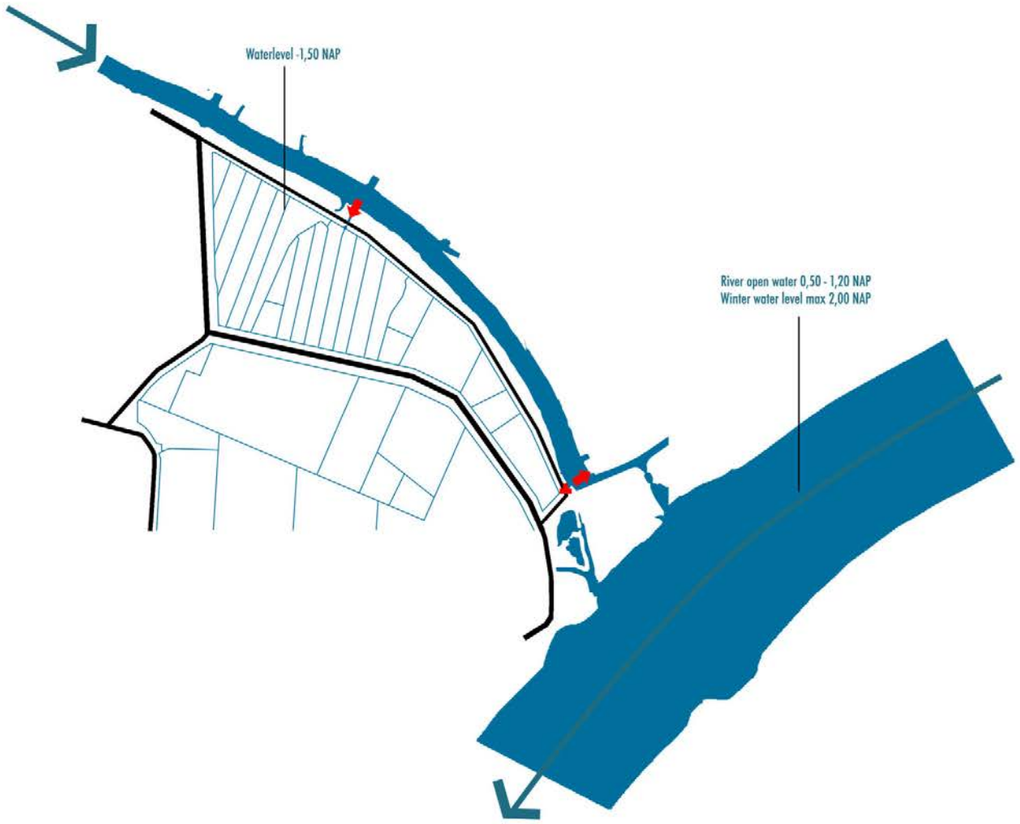

Limentis populi
Grote bonte specht
Kwak
Eurasian bittern
Alluvial forest succession
Higher land accretion
Fraxinus ulmetum
Prunus padus
Anomodon viticulosus (moss)
Homalia trichomanoides (moss)
Matkop
Nightingale
Alluvial forest
Highly influenced by tide
Salix alba
Populus nigra
Phalaris arundinacea
Symphytum officinale
Iris pseudacorus
Bluethroat
Savi's warbler
Merganser
White tailed eagle
Eurasian coot
Pond bat
Beaver
Winter water
High tide
Low tide

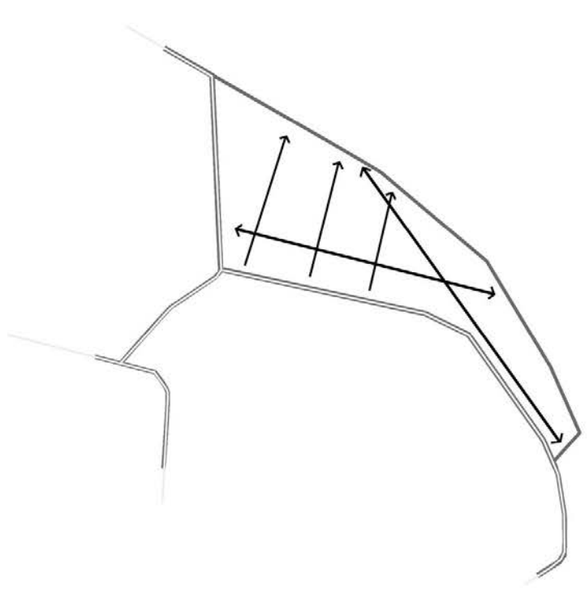
Site in focus: Noordboven Polder

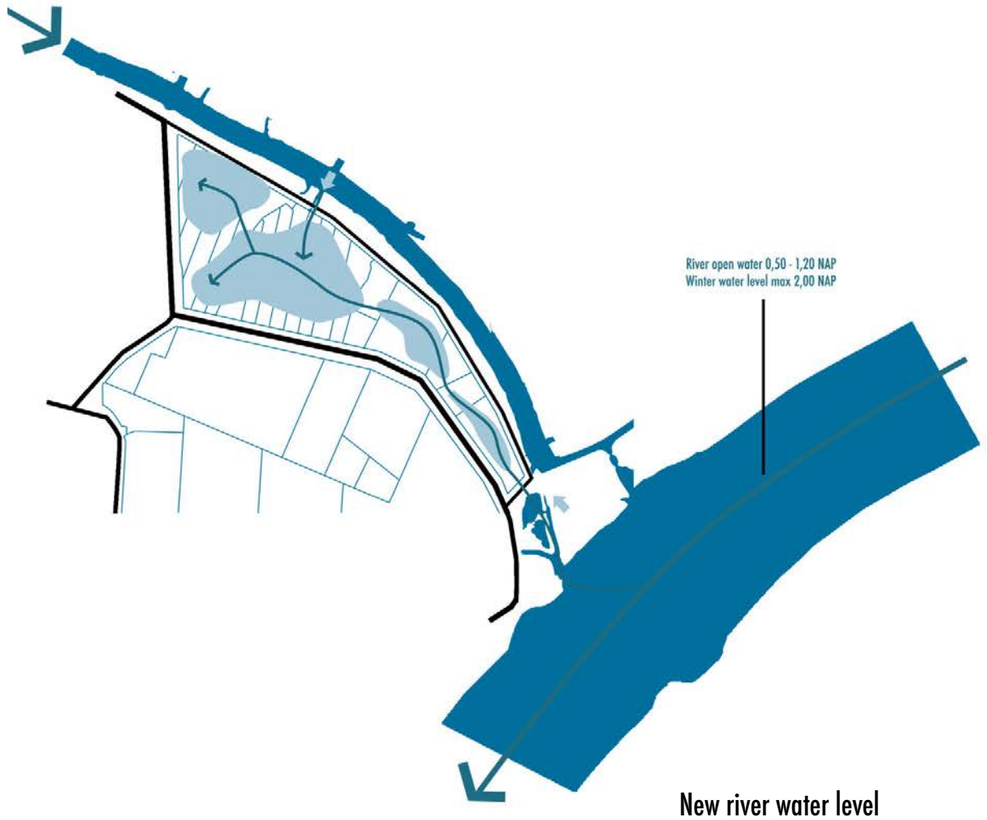
The Noordboven polder is located on the north eastern tip of the outer dike of Dordrecht and a part of the agriculture polders of the eastern site of Dordrecht. The site borders with the Wantij river on the north, Stadspolder residential neighbourhood on the west, Zeedijk on the south and Nieuwe Merwede river on the east. It is currently is used as both agricultural polder and grasslands for sheeps to graze. The Zeedijk on the southern border is part of the protective dike ring of Dordrecht, which makes the site is technically outside the ring dike. Separating the Wantij river and the agricultural polder is a 2,5m high dike which can be overtopped during extreme conditions.

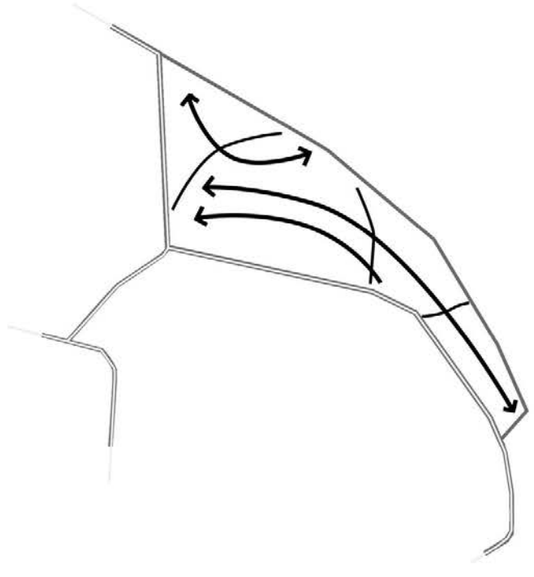
The municipality of Dordrecht together with the Rijkswaterstaat has been planning to transform the site into a tidal park which makes this site suitable as research-by-design site for this project. The water system on the site is independent compartment with inlet and pump to move the water in and out from the Wantij river.









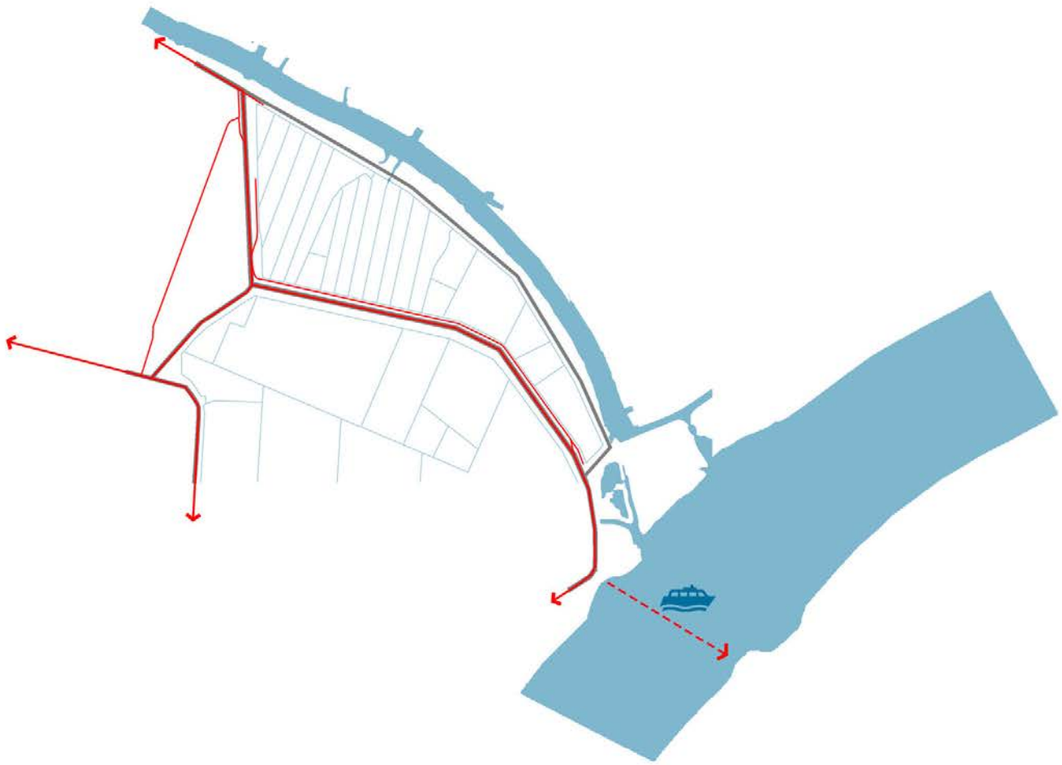


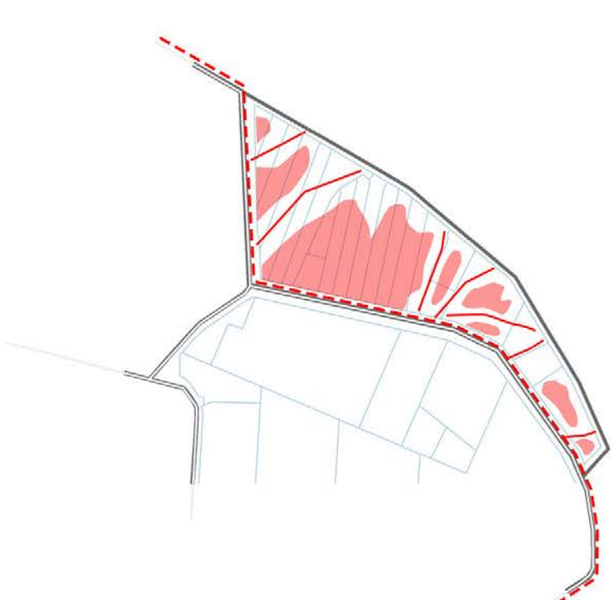
New river water level

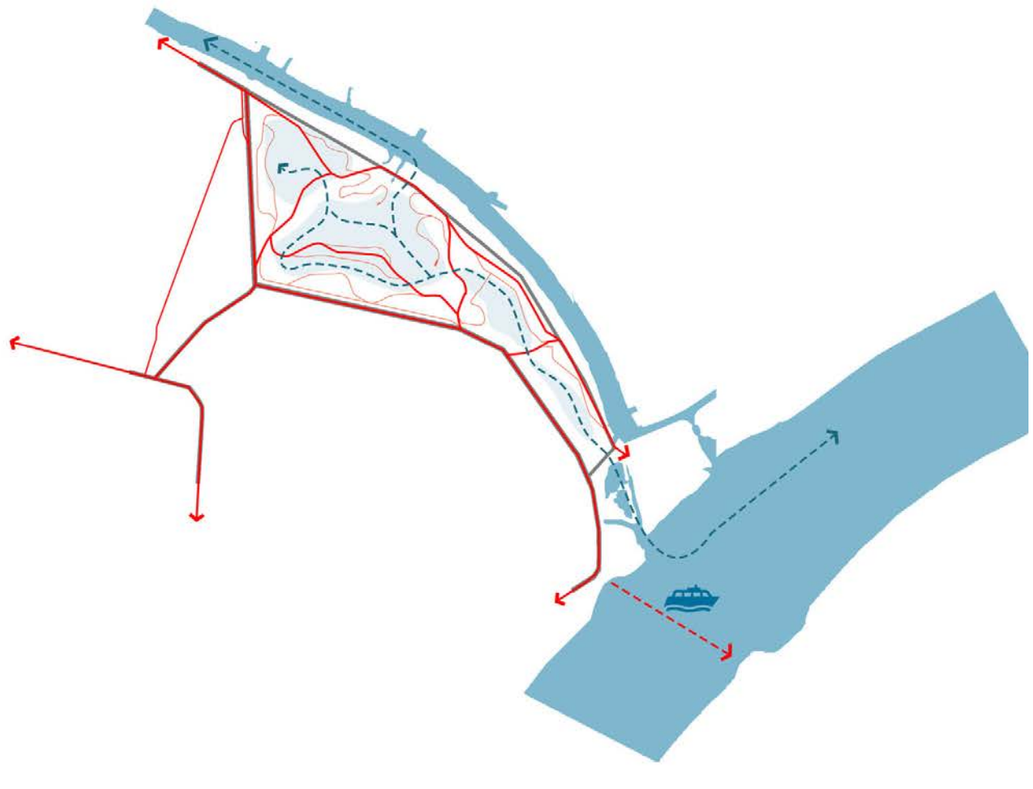
Two inlets exposing the polder landscape into both Wantij & Nieuwe Merwede river. This transforms the rigid water river into flowing water body as the main element. The flow feeds the landscape and exposing it into the natural dynamics of the river. The water level is therefore raised into the fluctuating river tidal water.

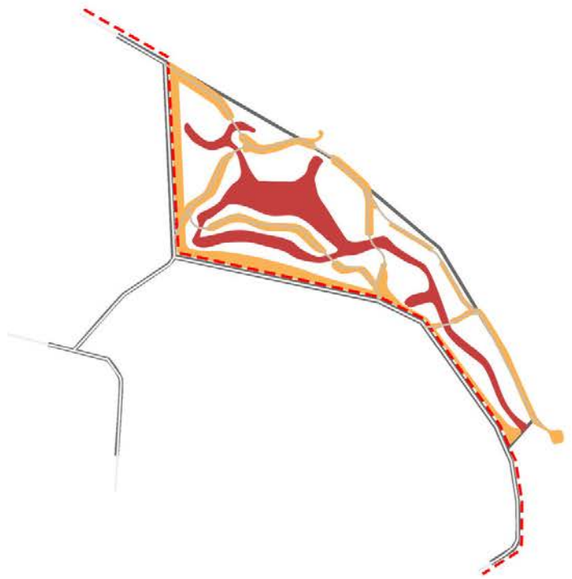
Transformation of spatial structure

The existing spatial structure and visual orientation is following the rigid structures of the dikes and ditches. New spatial structure follows the new flow of water and relief in the landscape transforming the spatial structure in a more dynamic and organic.







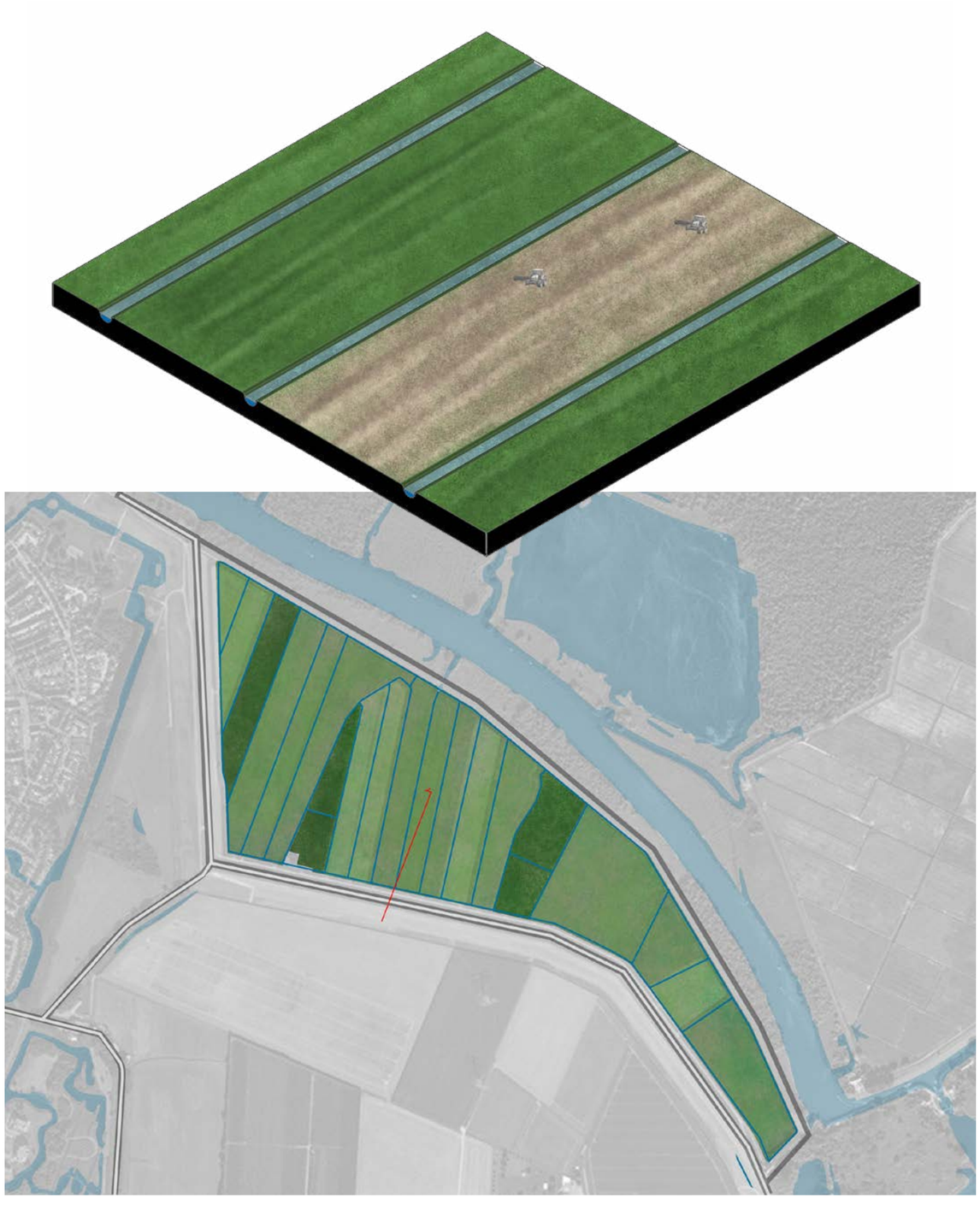


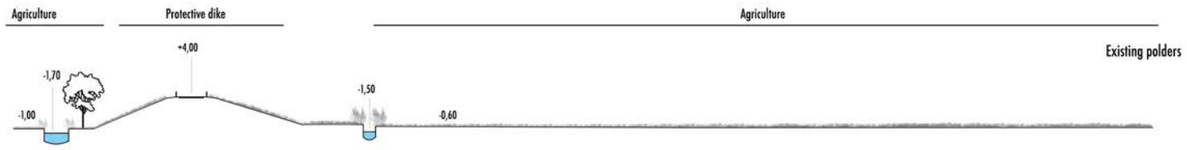
Accessibility

The existing polder is inaccessible and the accessway are limited to the existing dikes. New accessways are created crossing the existing landscape through new accessway based on the relief of the landscape. The new water network will also be connected to the river with water transport and recreation.

Excavate and fill

In order to create access, relief of the landscape is emphasized with raising the ground level as the main accessway through the landscape. The soil required is cut from the lower parts of the polder which will become new water channel. The new access will frame different part of the landscape which allows different rate of nature morphodynamic and landscape management and intervention to take place.





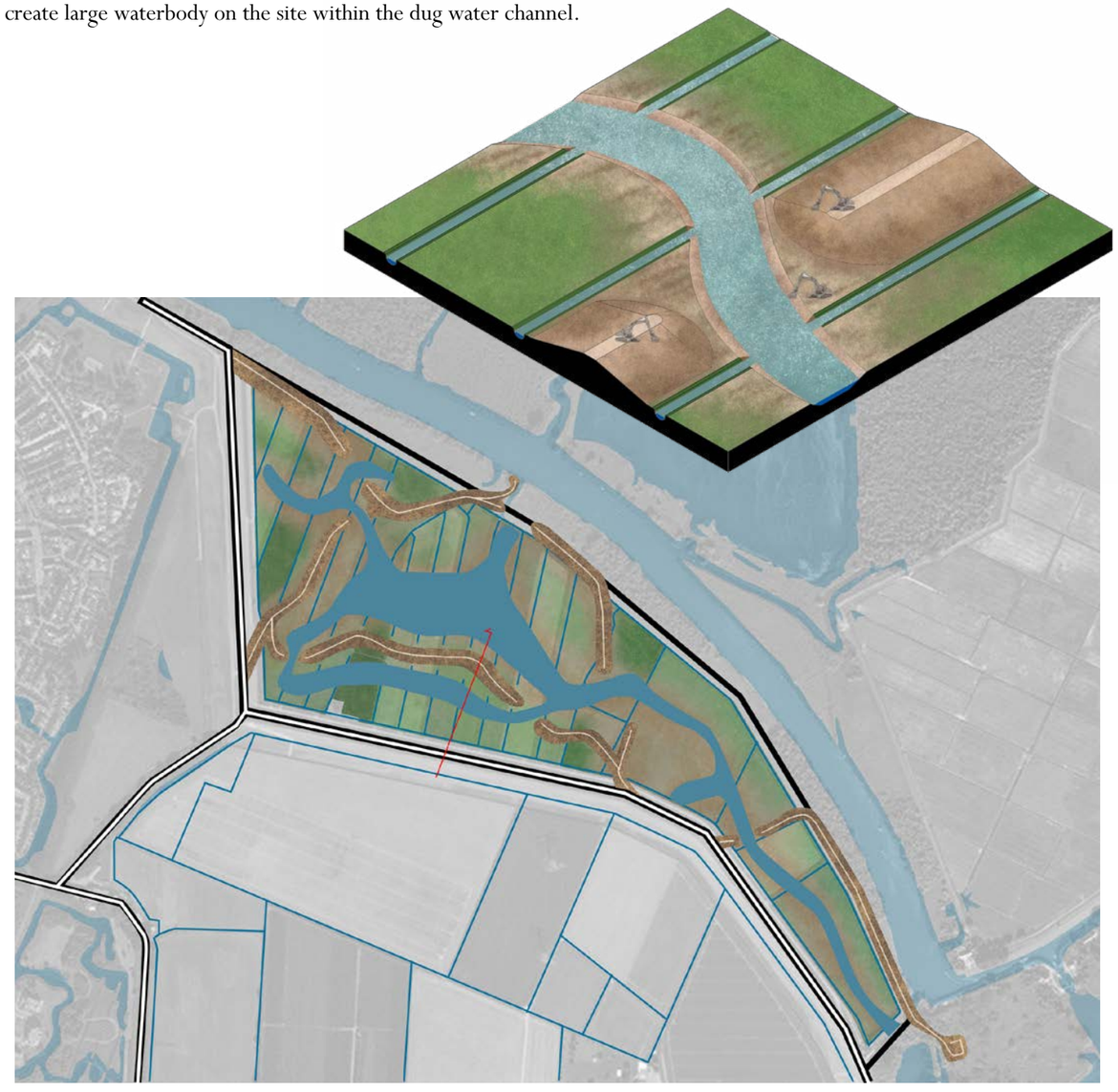
Phase 0: Today

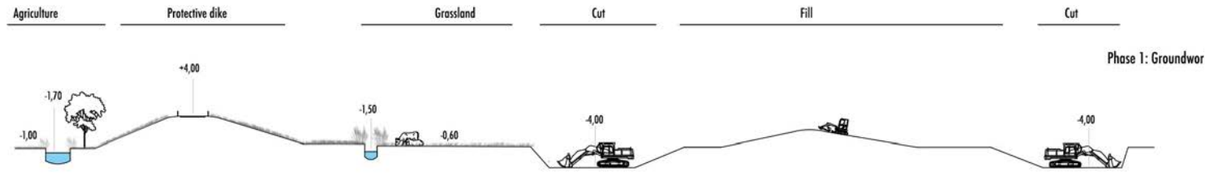
Recognising that the development will be a slow process, not only from the perspective of the ecology, but from the perspective of anthropology, the design will be presented in different stages. In the existing agricultural polder, the intervention will start with negotiation of land ownership between stakeholders. Due to the scale of the intervention, it would require the necessary acquiring of land to start the groundworks.

The existing polder lies below the river water level outside of the dike with straight ditches to regulate the water. The water level is regulated at -1.50m NAP compared to the water level of the river outside which under normal tidal regime is between 0.50 to 1.50m NAP.

Phase 1: Groundworks 2020-2022

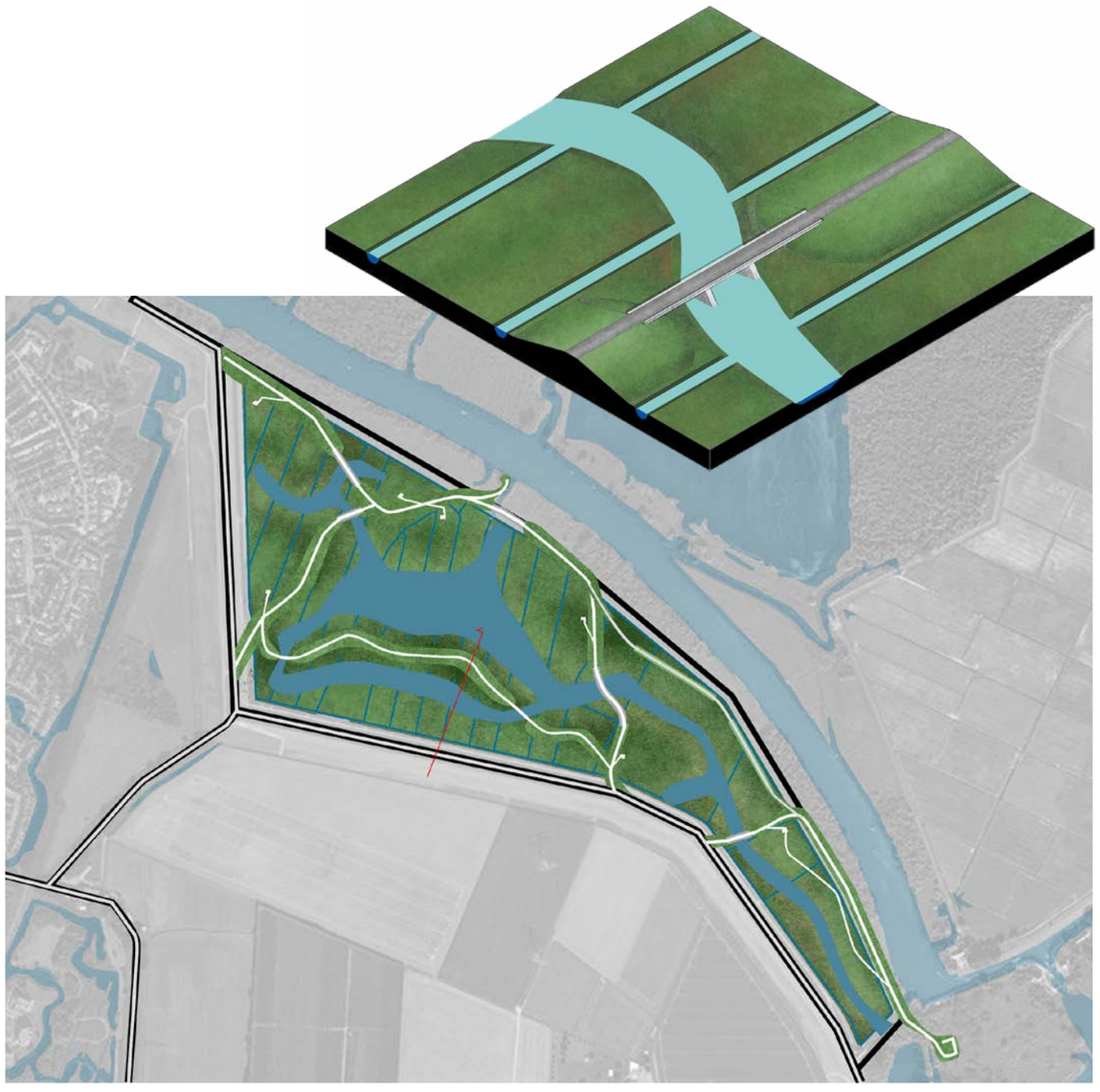
The first step of the development of the green-blue network will be preparing the groundworks for the new infrastructural lines and water channel. The cut and fill process will be from the same site and therefore, digging the water channel will provide land for filling the new dike/roads. The digging for water channel will be on the lower parts of the site and the filling will emphasize the reliefs on the landscape. The digging will therefore reveal the ground water and create large waterbody on the site within the dug water channel.

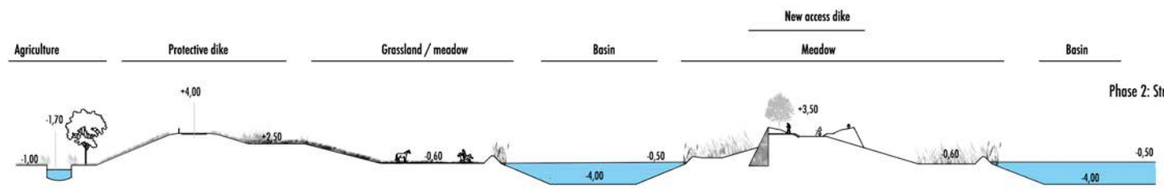




Phase 2: Infrastructure 2022-2025

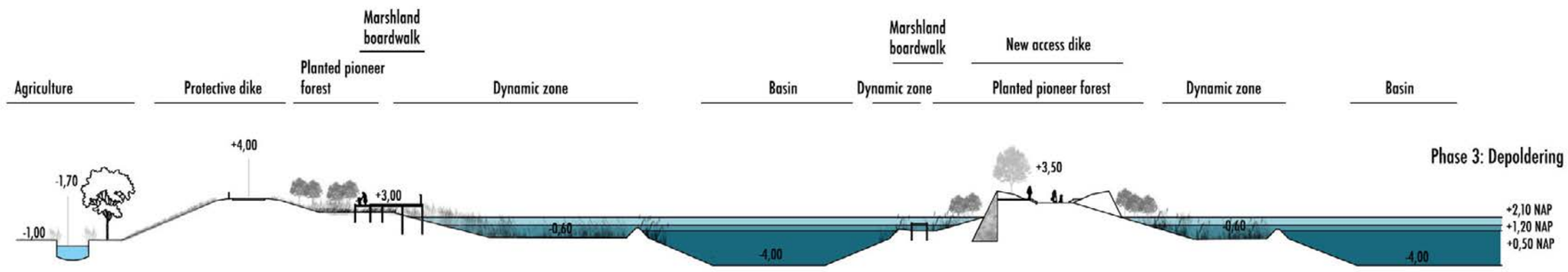
Bridges and road access is constructed as the final part of the land preparation before depoldering. This will create the infrastructures that act as the formal and guiding agent of the natural river dynamics. The water level will also be increased and the agriculture during this time will be limited to grassland for cattle grazing. Here people can visit the site and move through the designated pathways, however, use for public will be limited to the accessways.





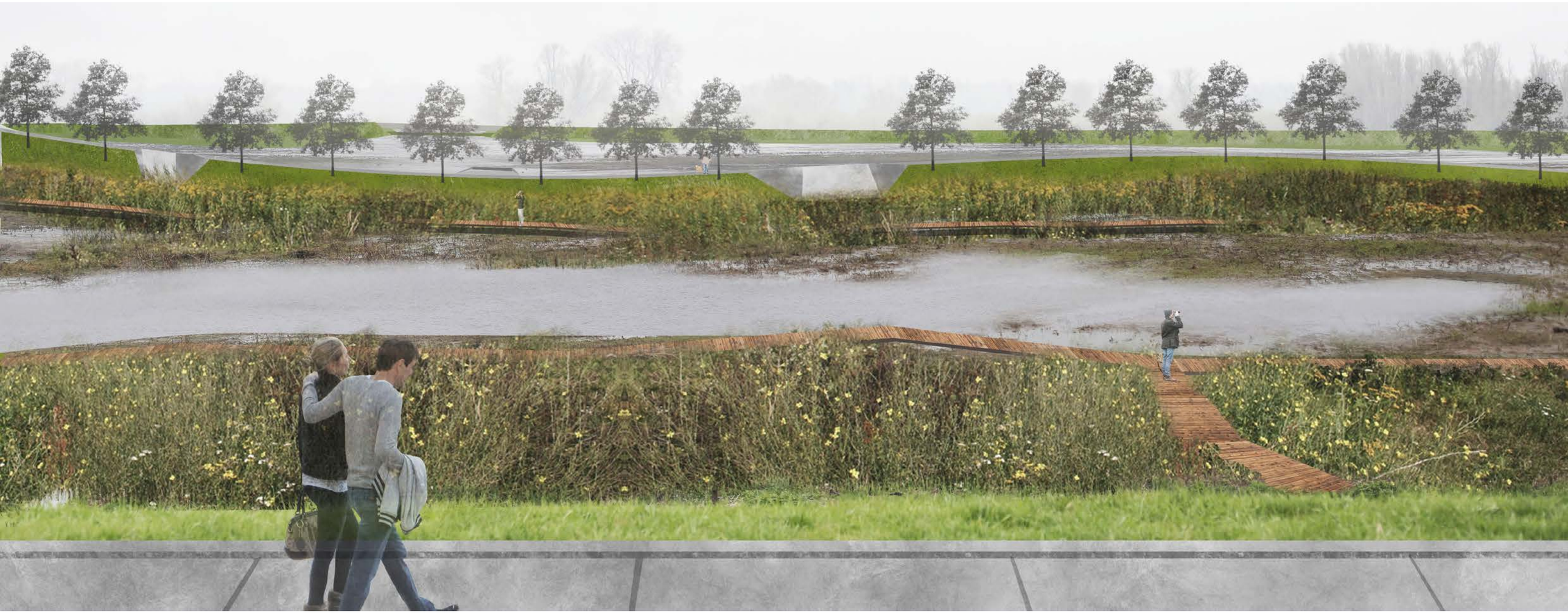
Perspective view from the Zeedijk looking north. Groundwork process is underway and most of the polders are used as grassland for grazing.

New infrastructure provides access for people to access through the previously polder landscape on a higher ground. Excavated site becomes waterbody with limited movement and new ecologies start to emerge on the side of the water.

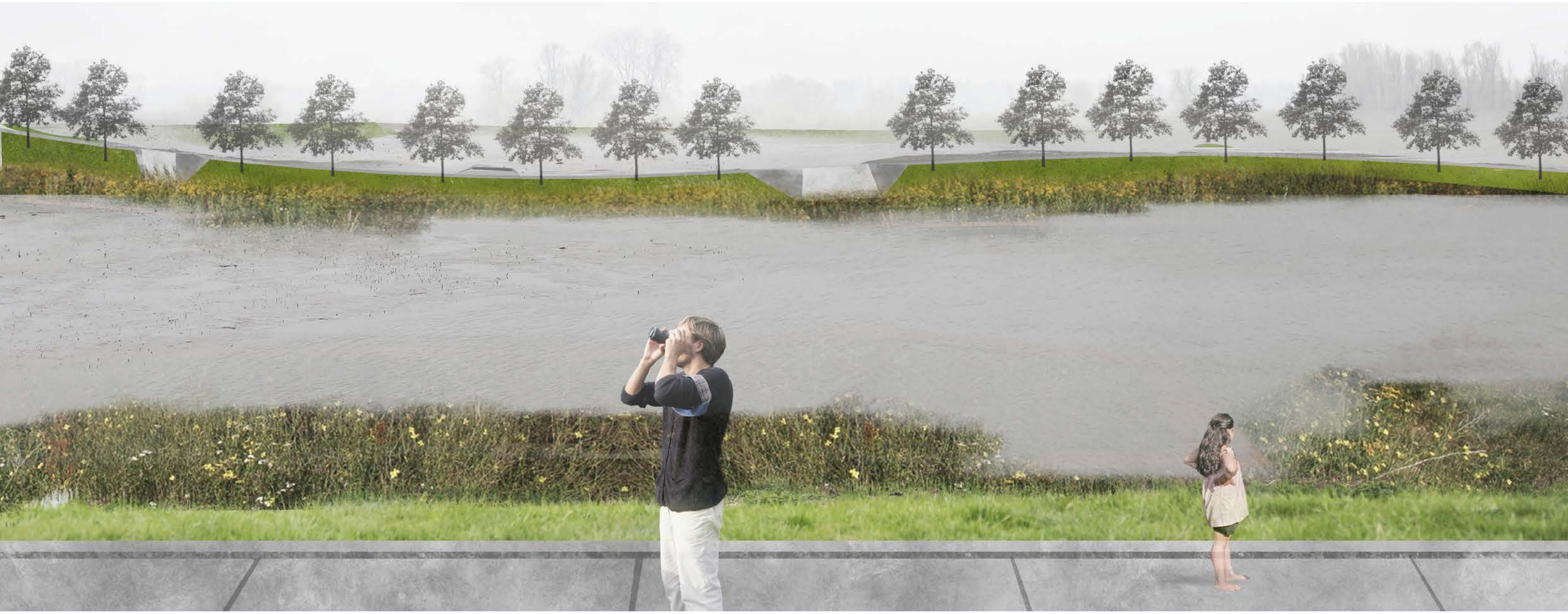


Phase 3: Depoldering & Accretion 2025-2030

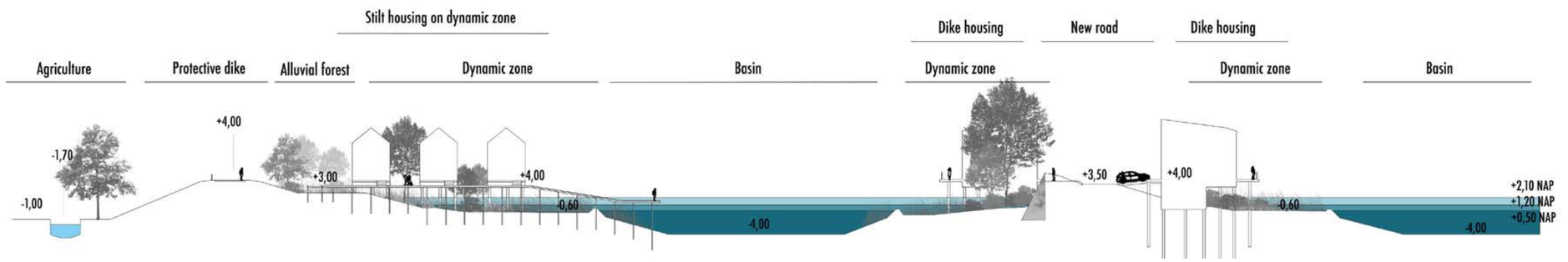
With the infrastructure constructed to 'guide' the natural processes, dikes are openned on two location and raised the water level by 1m. Due to the laid out small embankments on the landscape, sedimentation and morphodynamic processes are encouraged to take place on designated spaces. Here, these spaces will have different sedimentation processes and landscape structure that is generated is based on the interventions on each sedimentation zones. Gradients and between land and water is silting up and over time the river 'transforms' the lowlying polder landscape into natural riparian state with emerging riparian ecologies. In this stage nature recreations such as walking, cycling, birdwatching, and water recreation such as canoeing and fishing can take place in the landscape.



With the depoldering, the water level has increased and marsh ecology start to develop on the gradients due to the changing natural dynamics. These emerging ecologies take part in the sedimentation processes to build up higher gradient over time.

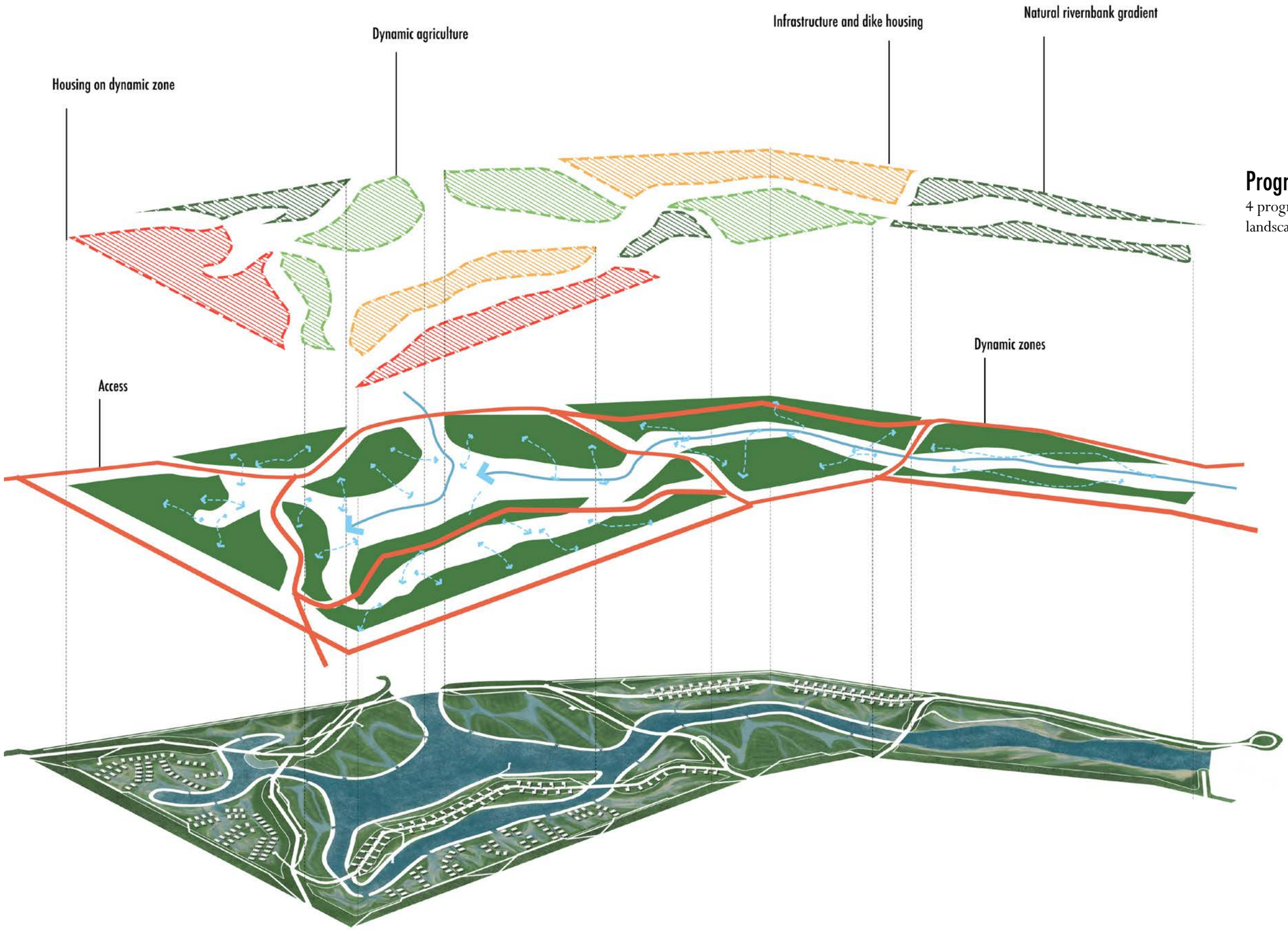


With the connection to the river, the landscape accommodates water fluctuation. The main access are above the extreme water level for evacuation. This changes in water level transforms the spatial qualities of the landscape continously.



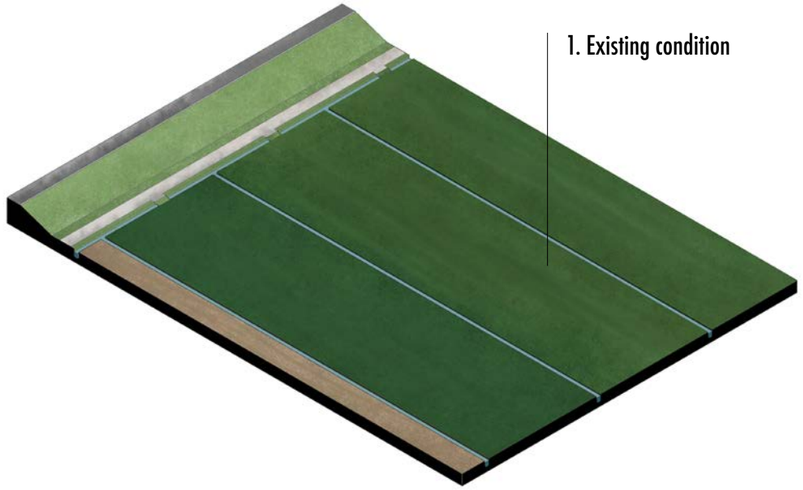
Phase n: Occupation 2030-n

The result of the river's natural morphodynamics with the support of manmade interventions and infrastructure creates new amenity & qualities for occupation/ programming. Here, on the dynamic new landscape, 4 different programmes can be planned with their own unique landscape structures. These landscape structure is a result of different method of management and interventions. Overall, the design gives new insight on how the layers of nature, infrastructure, and programming can be intertwined and support one another to create a resilient and dynamic landscape.

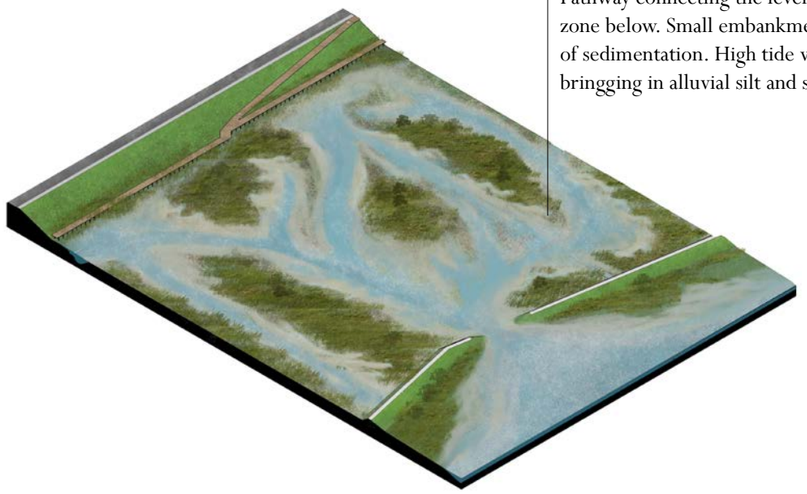


Programmes and landscape structure

4 programmes that are introduced to the site defines the landscape structure and management of the site.

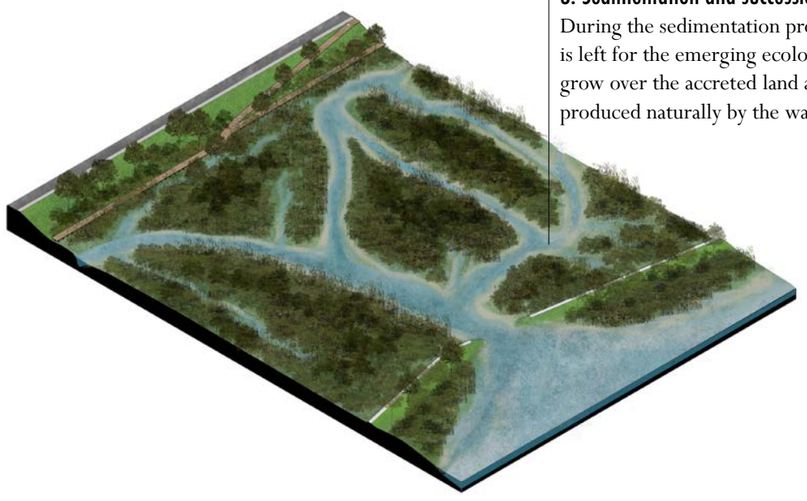


1. Existing condition



2. Depoldering

Pathway connecting the level of the dike into the dynamic zone below. Small embankments capture the processes of sedimentation. High tide will overtop this small dikes, bringging in alluvial silt and sand to be deposited.



3. Sedimentation and succession

During the sedimentation process, the landscape is left for the emerging ecology to naturally take grow over the accreted land and smaller creeks are produced naturally by the water flow.

Housing on the dynamic zones

The dynamic zones that develop on after the depoldering phase will develop new land based on sedimentation. New emergent ecologies will be kept on its natural state and succession 'colonising' the new landcape. As the landscape is silting up overtime, access can be created from the existing dike through wooden pathways to move through the marshes.

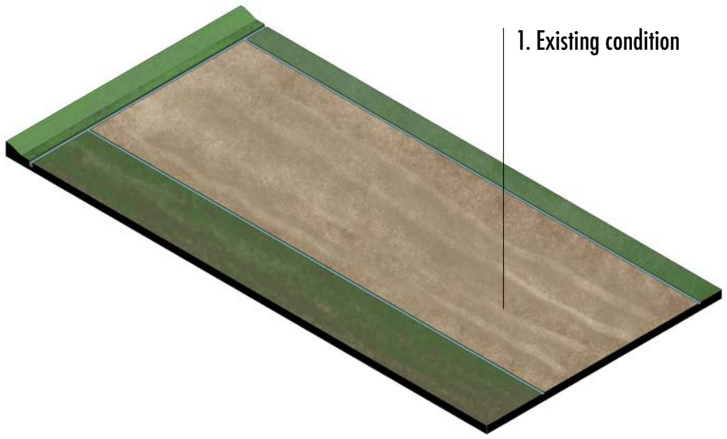
Overtime, housing can be introduced on these dynamic zones to provide living experience on the natural river dynamic landscape. As the houses sits on top of the high water level on stilts to allow the natural dynamics to continously shaping the landscape below it. Living with river dynamics adds new housing typology of the netherlands with combination of urban and nature.

4. Stilt housing

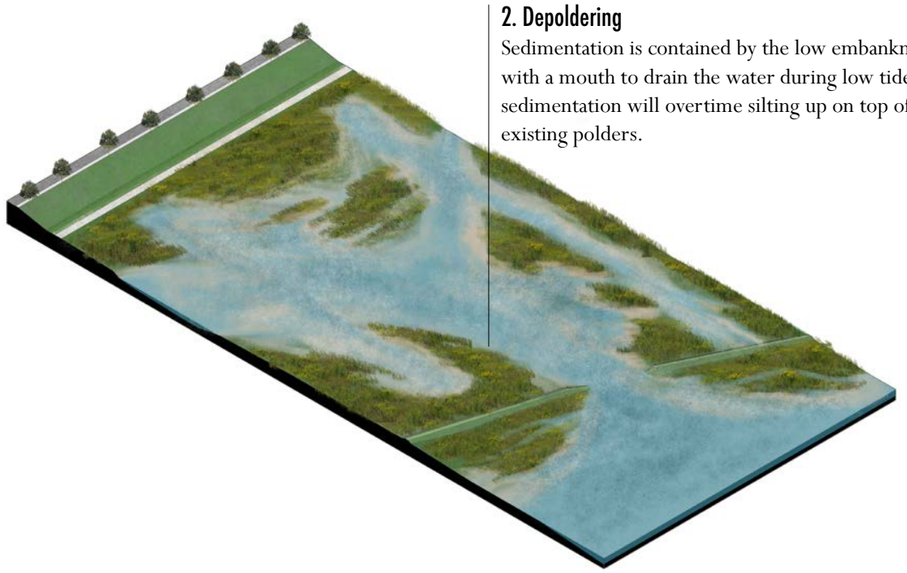
Built on top of the tidal fluctuation and above extreme water conditions, the houses are built with floor level on +4,00 m NAP on stilts with small foor area. View from the houses are open towards the dynamic landscape outside. Tidal difference shifts the landscape views continously and the dynamic zone itself becomes the resident's public space.

During low tide, the emerging marshland can be explored on foot or on water. The river water is flowing in and out of the sedimentation containment zone through its mouth.

During high tide, the dynamic zone is flooded with river water over the embankments. Houses are built on stilts high above the high waterline. This changing scene creates dynamic landscape experience on the overall landscape.

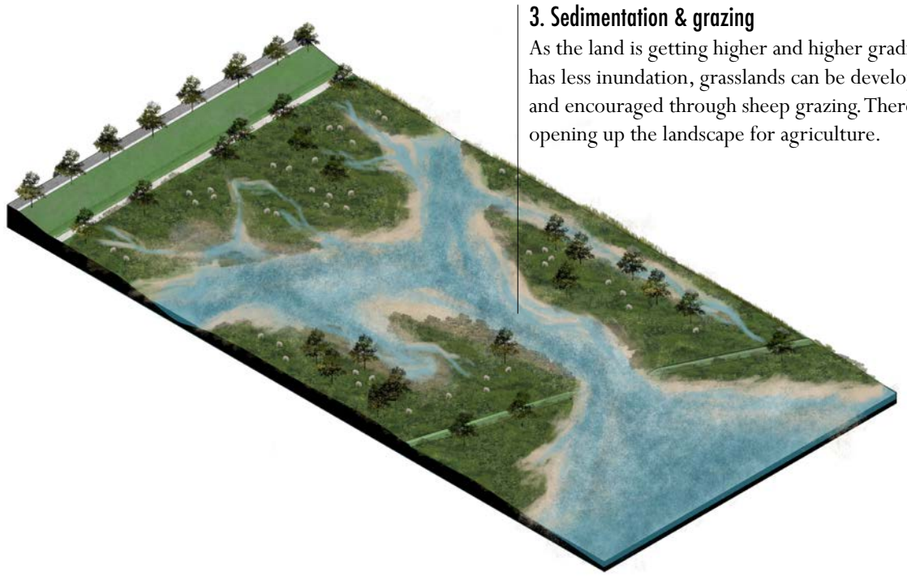


1. Existing condition



2. Depoldering

Sedimentation is contained by the low embankments with a mouth to drain the water during low tide. The sedimentation will overtime silting up on top of the existing polders.



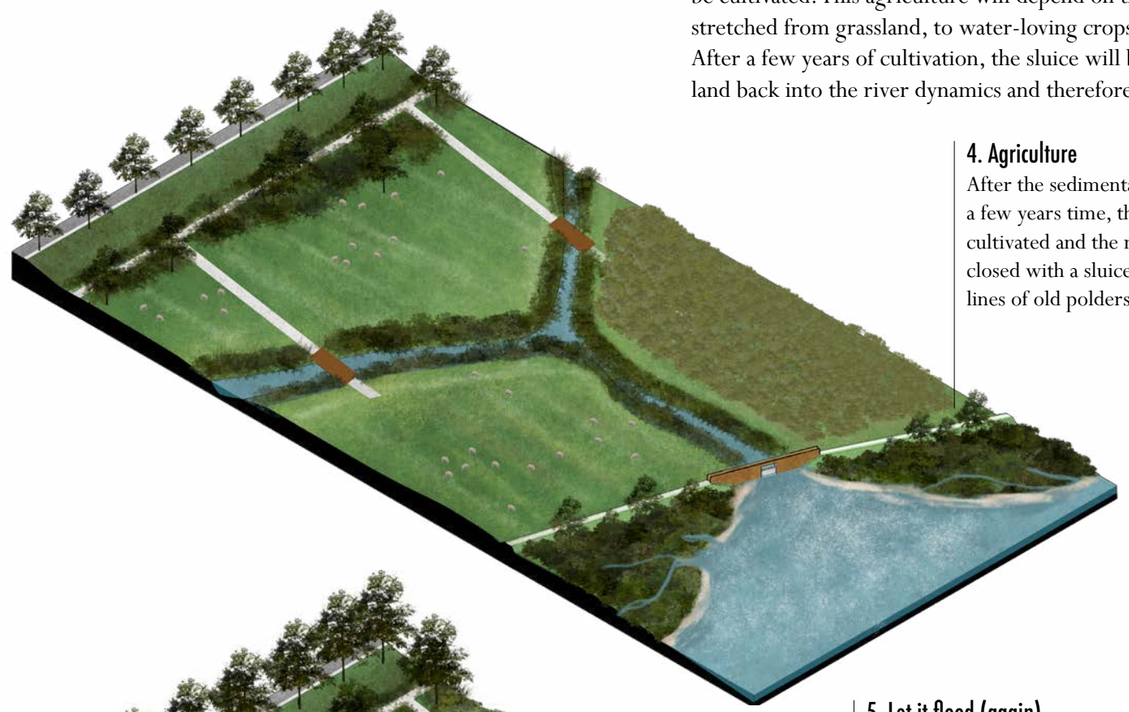
3. Sedimentation & grazing

As the land is getting higher and higher gradient has less inundation, grasslands can be developed and encouraged through sheep grazing. Therefore opening up the landscape for agriculture.

Dynamic agriculture

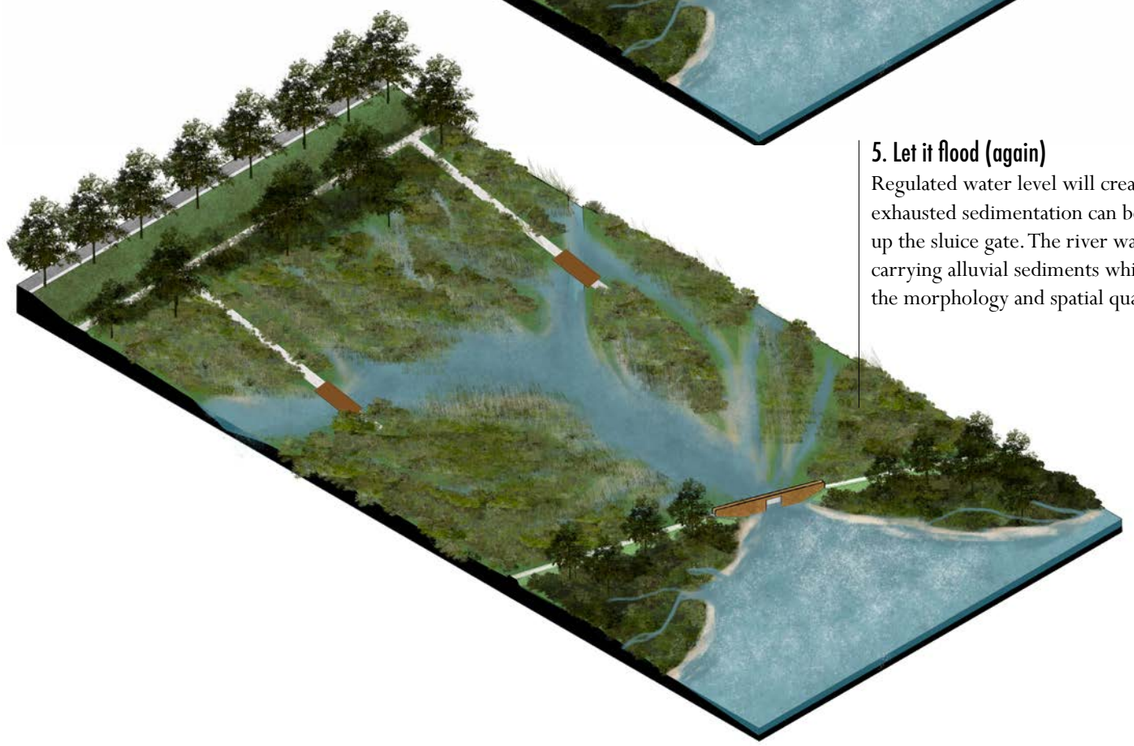
New way of agriculture can be introduced that works together with the natural dynamics overtime. Here, small embankments will be created as barrier for sedimentation process which in turn will generate land accrettion behind it. This embankment will have an opening and overtime this opeining is closed with a sluice that will allow the water inside to be regulated.

This process will 'refresh' the soil, adding new alluvial sediments on top of the existing soil. It brings new qualities to the agriculture and new fertile soil to be cultivated. This agriculture will depend on the new condition which can be stretched from grassland, to water-loving crops, and to normal arable land. After a few years of cultivation, the sluice will be opened again to expose the land back into the river dynamics and therefore, starts the whole process again.



4. Agriculture

After the sedimentation process deemed enough over a few years time, the fertile sedimented land can be cultivated and the mouth of the embakments can be closed with a sluice. This process transforms the rigid lines of old polders into a natural creek quality.



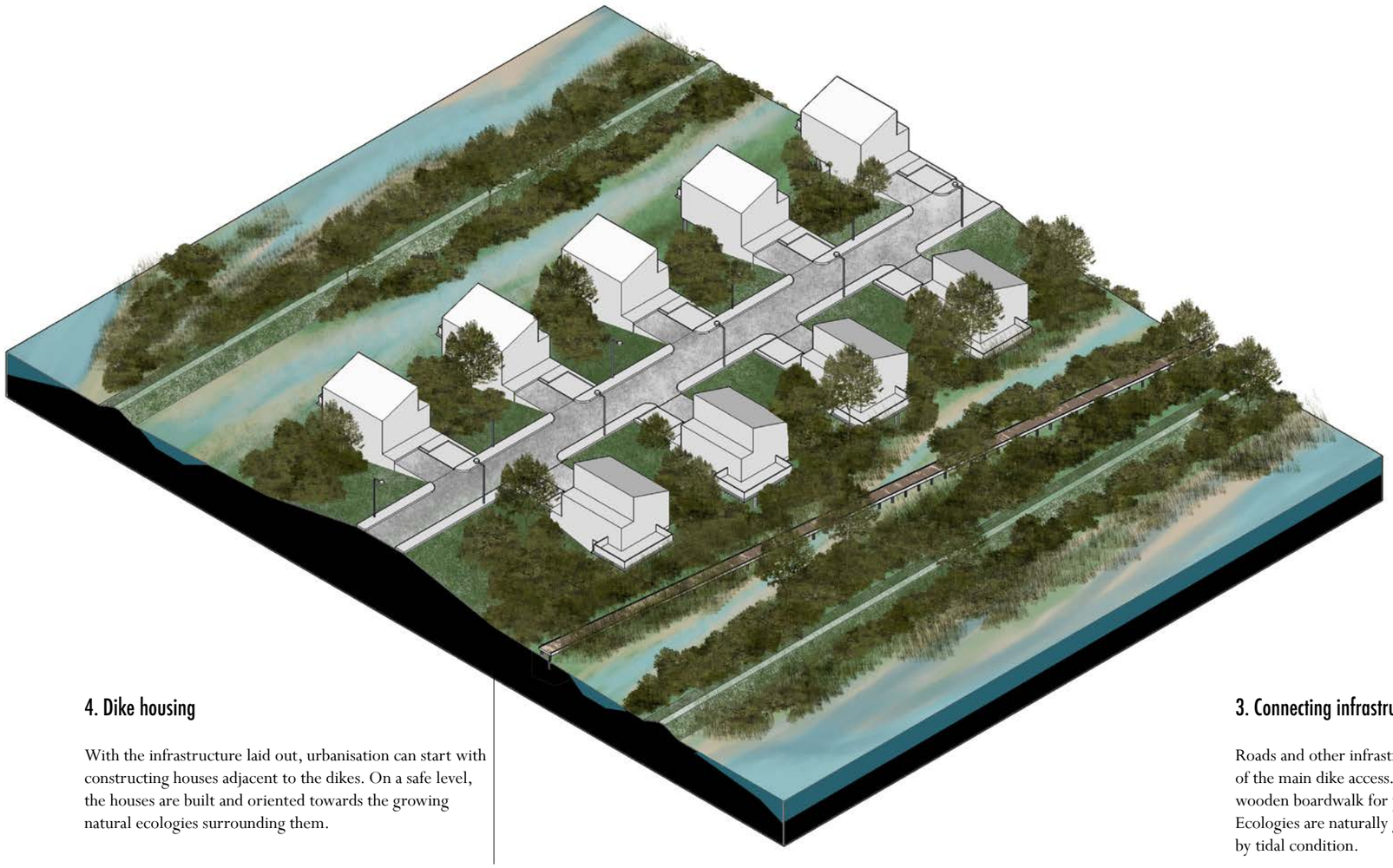
5. Let it flood (again)

Regulated water level will create subsidence and the exhausted sedimentation can be renewed by opening up the sluice gate. The river water flows in once more carrying alluvial sediments which later on transforms the morphology and spatial qualities of the landscape.

Infrastructure and dike housing

New dikes are created emphasizing the relief in the topography through cut and fill process that takes place on the site. From the polder level, a dike infrastructure above the flooding line is constucted and smaller embankments adjacent to it are contructed as sediment containment. Here, the main access through the site is established on the top of the new dike with necessary infrastructure such as power, pipping, etc.

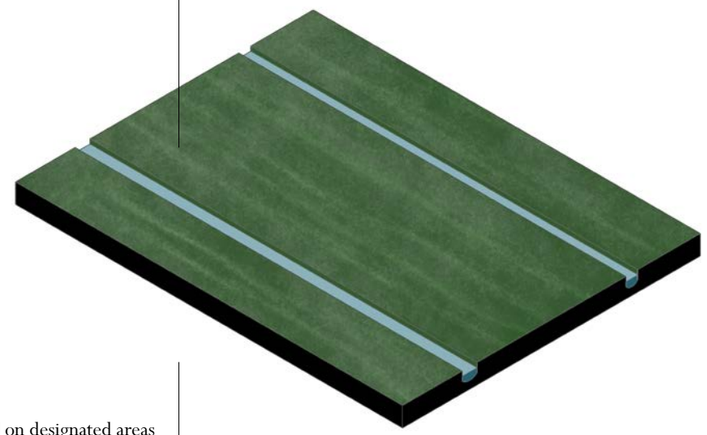
The dike housing can be constructed as soon as the dike is created. Therefore this housing typology can be implemented earlier in the project due to the safe condition on the dike. This typology is inspired by the dike housing in the netherlands with the qualities of safe living from the water, as well as, oriented towards the landscape beyond, in this case, towards the dynamic zones.



4. Dike housing

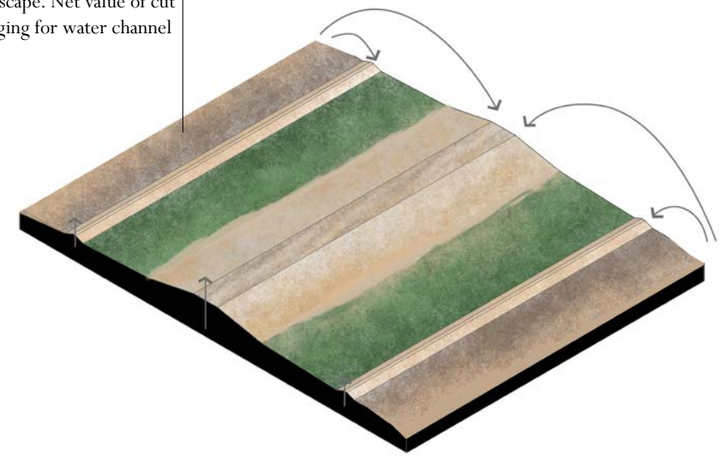
With the infrastructure laid out, urbanisation can start with constructing houses adjacent to the dikes. On a safe level, the houses are built and oriented towards the growing natural ecologies surrounding them.

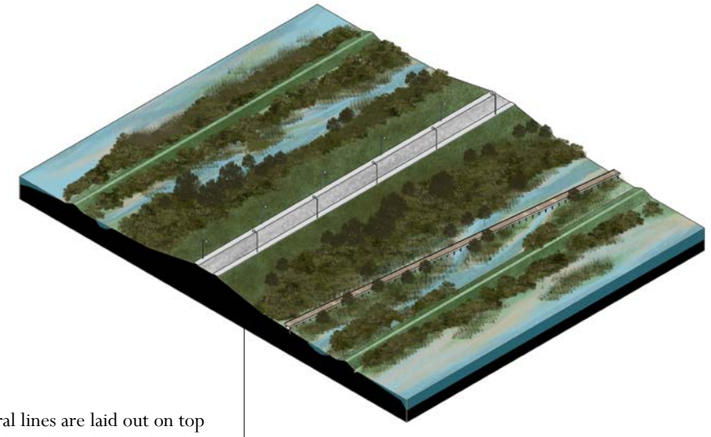
1. Existing condition



2. Raising the dikes

In the starting phases, dikes are raised on designated areas taking over the low-lying polder landscape. Net value of cut and fill will be tried to achieve as digging for water channel is used for the dike construction.



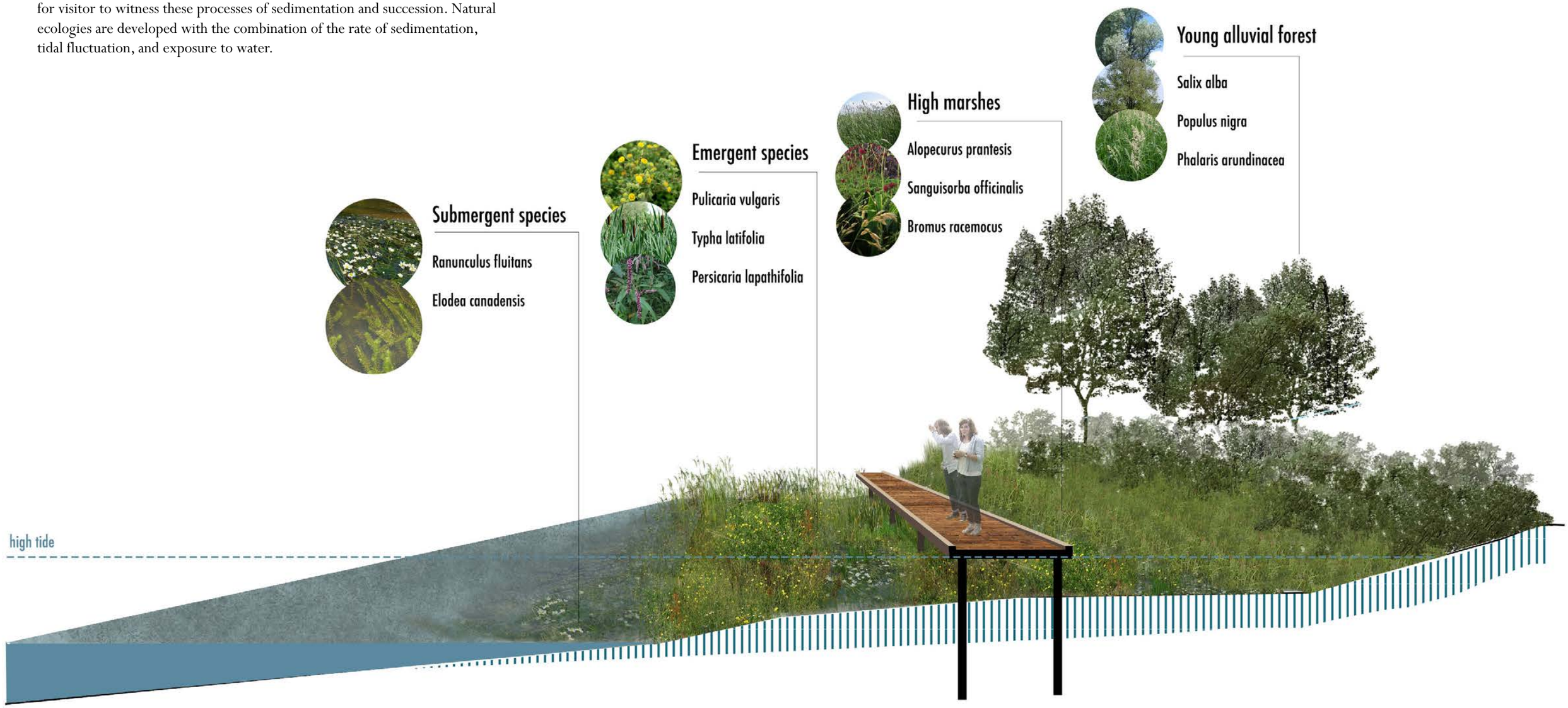


3. Connecting infrastructure

Roads and other infrastructural lines are laid out on top of the main dike access. Branching from this level is the wooden boardwalk for people to access the dynamic zone. Ecologies are naturally generated on the gradient influences by tidal condition.

Natural riverbank gradients

On parts of the landscape, it is alocated to allow the natural morphodynamic to develop a gradient and to generate new ecologies. Here, the intervention is minimum and natural processes takes over to create natural gradient on the previously low-lying polder. A wooden boardwalk will be constructed as access for visitor to witness these processes of sedimentation and succession. Natural ecologies are developed with the combination of the rate of sedimentation, tidal fluctuation, and exposure to water.



Conslusion: Infrastructure as structuring agent

Relief within the landscapes will direct the shape of new access roads. This relief is remnant of the old natural levee structure on the side of creeks that were flowing through the land accretion zone prior to being reclaimed and diked for cultivation. These levees were the "safe" zones where people can walk on top of the accumulating sediments and mudflats. This will once again become the main access-ways through emphasizing the relief with constructing roads that are safe from extreme water conditions.

This new access will become the "backbone" of the new landscape which not only direct the flow of the river's morphodynamic processes, but also the future urban developments and anthropogenic programming of the landscape. A few infrastructure lines will be higher than the other as evacuation roads during extreme water conditions.

Inviting the rivers inside the embankments would mean flooding the low-lying embanked landscapes even under normal tidal regime. Due to the existing polder compartments, the depoldering process can be done in strategic locations of the polders which minimises the necessary land transformation.

The depoldered landscape and the new accessways will frame different parts of the depolderred areas with different treatments can be done within the zones. These zones will therefore continue to develop into different emerging ecologies as well as landscape structures. Within these zones, various activities such as grazing on summer polders, reeds farming, willow farming, as well as nature restoration for different native animals such as otters can take place. This therefore will be decided on the smaller scale of the interventions. The designated summer polders will provide more space for high water conditions and being inundated less frequently, therefore different programmes can be applied within it.

Overtime, this principle can be applied on the other parts of Dordrecht starting from the polders adjacent to the rivers and all the way to connect one side to the other. Therefore, this new landscape will become a buffer, a dynamic water safety feature which combines both urban and nature as supportive system. Room for the river, and room to live with the river.

VI. REFLECTING ON THE LANDSCAPE

The graduation studio "Flowscapes" and graduation project

The landscape architecture graduation studio Flowscapes focuses on research by design approach on the discourse of landscape as "carrier" of flows where flows of materials, energy, resources, and other components are accommodated, diverted, or enhanced through landscape architecture. The theme of "landscape as infrastructure" and "infrastructure as landscape" is discussed more specifcally and is used as starting points for students to find his/her own interest in exploring particular issues. The self-defined graduation project looks through 4 possible lenses of landscape architecture; landscape as process, landscape as palimpsest, landscape as spatial-visual structure, and/or landscape as scale-continuum.

In this graduation project, I started my research-by-design process from the problematique of the non-adaptive water safety infrastructures in the Netherlands. What are seem to be technological marvel, man over nature, can no longer sustain the changing climate and uncertainty of the future. The awareness of this problematique evolves from my previous studies and more importantly from being and learning about such objects in my first year in the Netherlands. I spent most of my first months of the research to learn the logic and the system of Dutch water safety, in particular in the river delta, which in turn changed into never ending discoveries of new knowledge for the most part of the year.

As was mentioned, the project is self-defined and with help of my mentors, I can slowly piece together and shape my project throughout the year. Starting from own fascination is good to really explore our own take on issues, however, a well defined sub-studios within the graduation studio which grouping together students with similar interests can help in the early stages of the projects. Discussions, critiques, and feedbacks from conversation with my mentors has helped me susbtantially in the research-by-design process, to expand or narrow my focus and my approach. Furthermore, interest from the municipality of Dordrecht has brought me valuable insights on the matter at a hand.

The theme "landscape as infrastructure" in this research-by-design evolves into the exploration of re-connecting the natural dynamics within the embanked landscapes of Dordrecht and seeing the possibilities of spatial integration of urban and natural processes. The "new landscape" will, therefore, becomes "soft" water safety infrastructure to adapt the city to uncertain change.

Graduation project and developed methodology

In this graduation project, the chosen methodology is expanded based on the "Design-related research in landscape architecture" by TU Delft's Steffen Nijhuis and Inge Bobbink. The methodology presented in the paper focused on the combination of design research (analytical precedent study) and research-by-design (design experiments and design outcome). However, in order to get into the design research process, it is necessary to shape and formulate research framework which in the case of this research is started with expanding three statements in relation to the Dutch river delta, and research of the logic and structures of underlying layers of history and processes.

Therefore, in this research, exploration of the problematique gives way to three starting statements which later shape and frame the necessary research to understand the landscape before starting the experimentation. In addition to desk studies, excursions to the site and discussions with urban planners, policy makers and hydrology engineer from the municipality of Dordrecht adds more insights and values to the research process. The advantage of this addition of prior research is to understand the possibilities and limitations as well as strength and weaknesses of the landscape. However, due to the complexity of the site as research subject, the issue is time available and expertise. Therefore, a few assumptions and logical decisions and considerations are taken.

The experimentation process starts with analysing precedent case studies in terms of its key design elements, drivers, and impacts to spatially and systematically. Later, the outcome of this case study analysis provides inspires design decisions on quick sketch designs. Key design principles based on these sketch designs starts the exploration design outcome. This method complements the preceding research and understanding of the landscape which influence later stages of design. While looking for possibilities of application of these principles, design framework is developed for the bigger scale of intervention. The design decisions are mostly based on the logic river morphodynamics, where its capability of sedimentation and erosion, and carrying ability of valuable ecology are used as the main driver and structuring element within the intervention to create adaptive new landscapes. In this later stages, the design and the research are intertwined in a back and forth "conversation" within the process which is an interesting part to be in.

In terms of collecting data, thanks to the open data from various organisations, such as the municipality of Dordrecht, Rijkswaterstaat, Hollandse Delta waterboard, DINOloket, as well as research repository access of TU Delft library, necessary information are available and accessible. The municiplity of Dordrecht, especially through the Dordrecht Living Lab, more necessary information can be requested and obtained. The most challenging part is to process this expanse of information and narrow down to the ones valuable and necessary in the design process.

Graduation project and the societal context

The lowland landscape of the Netherlands is defined by its necessity of water safety with most of the country sits below sea level. In the past, these measures of water safety implements static control of landscape systems and processes. Measures were built at the expense of nature and ecology to maximise the anthropogenic utilisation of the landscape. In the case of the the Dutch river delta, the landscape has been diked, reclaimed, and regulated in order to cultivate the peat and alluvial sediment landscapes over the most part of the millenia, with systematic reclamation and poldering started as early as 800 AD. In turn, these measures limits the dynamic qualities of the river landscape and losing the "room" for the river to "hurdle" as it flows towards the sea.

Today, as the processes of urbanisation grow in the economically valuable delta landscapes, the measures of water safety can no longer be separated. Adding to this, is the accelerated rate of climate change which ask for a new developments which combine measures of flood defence & water safety, urban development, and address both environmental and economic issues. This has been an issue that the people and the municipality of Dordrecht is addressing as they organised collaborations, research labs, and workshops which I am priviledged to be involved. In particular, the loss of the "feeling" of being a river city with lack of spatial connections and orientations towards the river further inland as the landscapes are highly structured and rationalised. Issues of climate adaptation towards extreme river water conditions as well as cloudburst flooding shape the agenda of the green and blue planning of the municipality.

Paradigm change of building with nature and nature based solutions over the past four decades, notably with the Room for the River projects, has brought different perspectives towards a more balanced developments which seek balance of anthropogenic programming and the natural processes. However, the issue remains clear that these measures are limited to applied into the rural landscape and integrated into agriculture. This research-by-design project builds up on and expands these new paradigm with exploring the balance of creating adaptive, resilient, and open-ended landscapes with the principles of urban processes.

The design outcome of this project "invites" the dynamics of the river inside the embankments or Dordrecht as new green and blue network which brings fort the landscape qualities of the river landscapes closer to the urban structures of the city as well as increase the city's adaptivity towards extreme conditions. It will become new destination for recreation and conservation as it establishes creeks, marshes, and woodlands that connects the existing fresh water tidal landscapes of the Dordtse Biesbosch. By allowing the natural dynamics to have room and to slowly shape the landscape, the design is open-ended and highly resilient towards the uncertain changes with respect to new way of "living on the river."

Ethical issues and dilemmas

Whilst expanding from the paramount necessity of integration of water safety, climate adaptation, and urban delta developments today, the design soultion in this research-by-design project provides radical solutions for new and adaptive landscapes. It seeks large scale intervention and space availability. Here, the solution is to transform the existing low-lying polders to be de-poldered and exposed to the open water of the river landscape. Therefore, in the design solution it is decided to sacrifice agricultural polders in favour of safety and ecology.

From a landscape point of view, the this is justifiable through re-structuring and depoldering subsiding landscapes with high risk of flooding, high ground water condition, and high seepage condition which needs high maintenance and regulation to keep it productive. The landscape is vulnerable to extreme conditions as well as the growing urbanisation from the suburbs nearby. This approach asks for farmers and owners of the agricultural polders to move their businesses and income elsewhere which will bring the moral and ethical dilemma of implementing the new design. Similar issue has been experienced in the neighbouring de-poldering project of the Noordward polders which needed 10 years of negotiations, and a number of protests.

In this research-by-design, however, the intervention will come in different phases over the course of a century. During this 100-year implementation period, it is assumed with a scenario that the climate adaptation agenda has become high national importance due to the accelerated rate of climate change. Increase in sea level, and discharge of the rivers, as well as increasing high costs to maintain subsiding polders, farmers would cooperate to "give up" their land for the continuity and resiliency of the city of Dordrecht overall. The landscape will then shift the economic value of the previously agricultural landscape into real estate, recreation, nature conservation, and wetland and summer polder agriculture.

Overall, the new proposed design will ask for a shift in priority agenda within the embanked urbanised river delta towards higher safety against climate change and open-endedness. Although it will be a slow transformation as was mentioned and suggesting a more top-down approach due to its necessary scale, in order to solve the moral dilemma of such intervention, this design will require on-going communication between stakeholders. To make people aware of the project and the long-term benefit of it would be an important aspect in successfully implementing such approach. Design in this scale requires an open-ended design framework and principles so that the outcome will achieve the original design goals whilst details of the implementation and structures can be altered overtime. Therefore, it is worth to promote a dicussion in regards to new adaptive landscape, indeed needs adaptive attitude of the people as well.

REFERENCES

Bobbink, Inge & Steffen Nijhuis. (2010). The Making of Dutch Delta Landscapes. In Han Meyer, Inge Bobbink & Steffen Nijhuis (Eds). Delta Urbanism the Netherlands (pp. 45-63). Chicago: American Planning Association

Corboz, Andre. (1983). The Land as Palimpsest. In Diogenes No. 121; 12-34

Corner, James. (2003). Landscape Urbanism. In Mostavafi, Mohsen (Ed.), Landscape Urbanism; A manual for machinic landscape. Princeton: Architectural Press

Couture, S. (2008). River Dynamics and Erosion, Presented to Great Bay Siltation Commission, December 1, 2008. Conference paper. Online version

Das, Tuhin K., Sushil K. Haldar, Ivy Das Gupta and Sayanti Sen. (2014). River Bank Erosion Induced Human Displacement and Its Consequences. Living Reviews. Landscape Research 8,3.

De Hoog, M., D. Sijmons,& S. Verschuuren. (1998). Laagland. HMD (Het MetropolitaneDebat)

Deltares (2010). Flood risk in unembanked area. KNMI

De Vlieger, Bianca. (2017). The New Delta. Heijnignen: Japsam Books

Holling, C.S. (1973). Resilience and Stability of Ecological Systems. In Annual Review of Ecology and Systematics. vol. 4, pp. 1-23.

Huismans, Y & Hoitink A. J. F. (2017). Towards Control over Rhine-Meuse Delta Channel Network: Historical overview and contemporary research needs. Research paper submitted to Advances in Water Resources

Hulscher, Suzanne. (2017). Multifunctional Flood Defenses: Dealing with future change and uncertainty. In Kothuis, Baukje & Kok, Matthijs (Eds.). Integral Design of Multifuntional Flood Defences. Delft: Delft University Publishers

Ingold, Tim. (2000). The Perception of the Environment. New York: Routledge

Jackson, J.B. (1984). Discovering the Vernacular Landscape. New Haven: Yale University Press

Kabisch, N. et al. (2016). Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action. Ecology and Society 21(2):39

Kolen, Jan & Johannes Renes. (2015). Landscape Biographies: Key Issues. In Rita Hermans, J. Renes, & Jan Kolen (Eds.). Landscape Biographies (pp. 21-47). Amsterdam: Amsterdam University Press

Meyer, Han, Steffen Nijhuis & Robert Broesi. (2014). Rhine-Meuse-Scheldt Delta. In Han Meyer, & Steffen Nijhuis (Eds.). Urbanized Deltas in Transition (pp. 41-50). Almere: AD Mercurius

Meyer, Han & Steffen Nijhuis. (2016). Designing for Different Dynamics: The Search for New Practice of Planning and Design in the Dutch Delta. In J. Portugali and E. Stolk (eds.), Complexity, Cognition, Urban Planning and Design (pp. 290-312). Springer

Meyer, Han (2017). The State of the Delta. Nijmegen: Van Tilt

McHarg, Ian (1998). Open Space from Natural Processes. In Forster O. Ndubisi, (2014). The Ecological and Planning Reader (pp. 181-190). Washington DC: Island Press

Nassauer, Joan Iverson. (2013). Landscape as Method and Medium for the Ecological Design of Cities. In S.T.A. Picket, , M.L. Cadenasso, Brian McGrath (Eds.). Resilience in Ecology and Urban Design (79-98). Dordrecht: Springer

Nienhuis, Piet H. (2008). Environmental History of the Rhine-Meuse Delta. Springer

Nijhuis, Steffen & Inge Bobbink. (2012). Design-related Research in Landscape architecture. In Design Research, vol. 10 no. 4, pp. 239-257

Nijhuis, Steffen & Michiel Pouderoijen. (2014). Mapping Urbanized Delta. In Han Meyer, & Steffen Nijhuis (Eds.). Urbanized Deltas in Transition (pp. 11-22). Almere: AD Mercurius

Peters, Renske & Michelle J.A. Hendriks. (2008). Water and Space in the Netherland. In IFLA 2008. Transforming with Water (pp. 88-95). Wageningen: Blauwdruk

Prominski, Martin. (2005). Designing Landscape as Evolutionary Systems. In The Design Journal 8 (3). 25-34

Prominski, Martin. (2012). River. Space. Design: Planning Strategies, Methods, and Projects for Urban Rivers. Birkhäuser

Roymans. N, F. Gerritsen, C. van der Heijden, K. Bosma, & J. Kolen. (2009). Landscape Biography as Research Strategy: The Case of South Netherlands Project. In Landscape Reseach 34(3): 337-359

Samuels, Marwyn. (1979). The Biography of Landscape: Cause and Culpability. In D.W. Meinig (Ed.) The Interpretation of Ordinary Landscapes: Geographical Essays (pp. 51-88). Oxford: Oxford University Press

Shannon, Kelly (2013). Eco-engineering for Water: From Soft to Hard and Back. In S.T.A. Picket, , M.L. Cadenasso, Brian McGrath (Eds.). Resilience in Ecology and Urban Design (163-182). Dordrecht: Springer

Stokman, Antje. (2008). Water Purification Landscapes. In IFLA 2008. Transforming with Water (pp. 51-61). Wageningen: Blauwdruk

Stokman, Antje (2013). On Designing Infrastructure Systems as Landscape. In Christophe Girot, Anette Freytag, Albert Kirchengast, Dunja Richter (Eds.). Topology (pp. 285-311).

Stive, Marcel & Han Vrijling (2008). Draining, Dredging, Reclaiming. In Han Meyer, Inge Bobbink & Steffen Nijhuis (Eds). Delta Urbanism the Netherlands (pp. 21-41). Chicago: American Planning Association

Van Staveren, Martijn F. (2017). Bringing in the Floods (Doctoral dissertation).

Van Veelen, Peter, Mark Voorendt, Chris van der Zwet. (2015). Design Challenges of Multifunctional Flood Defences. In Steffen Nijhuis, Daniel Jauslin, & Frank van der Hoeven (Eds). Flowscapes: Designing Infrastructure as Landscape (275-291). Delft: TU Delft

Warner, Jeroen F., Martijn F. van Staveren, Jan van Tatenhove. (2018). Cutting dikes, cutting ties? Reintroducing flood dynamics in coastal polders in Bangladesh and the Netherlands. Online journal. Retrieved from https://doi.org/10.1016/j.ijdrr.2018.03.020

Wit, Saskia de. (2009). Dutch Lowlands. Amsterdam: SUN Architecture.

TOWARDS RESILIENT DELTA

As the landscape of the south western river delta in the Netherlands is increasingly urbanised, the processes of urbanisation and the dynamics of nature can no longer go in their separate ways. Measures for water safety, that over the course of recent history has been diverting, regulating, and controlling natural dynamics away from the urban landscapes, need to be re-imagined to cope with the uncertainty of both natural and urban processes, as well as spatially integrated in a new resilient urbanised delta.

The fundamental question is thereofore how can the two dynamics intertwined as one? How can the natural dynamics be integrated to the urban landscapes as measures of water safety and climate resiliency and generate unique landscape qualities in the urbanised delta city?

This research-by-design in this thesis recognises the landscape as both palimpsest and process. It seeks understanding of past processes and the landscape's ability to accommodate future processes and uncertainties. Using the city of Dordrecht as case study, a design for a new green and blue network with the concept of 'living with the river'which invites the natural river dynamics to be once again be a formal component of the city. The river is therefore continously shaping and reshaping the landscape developing new ecological values and resiliency of the city.