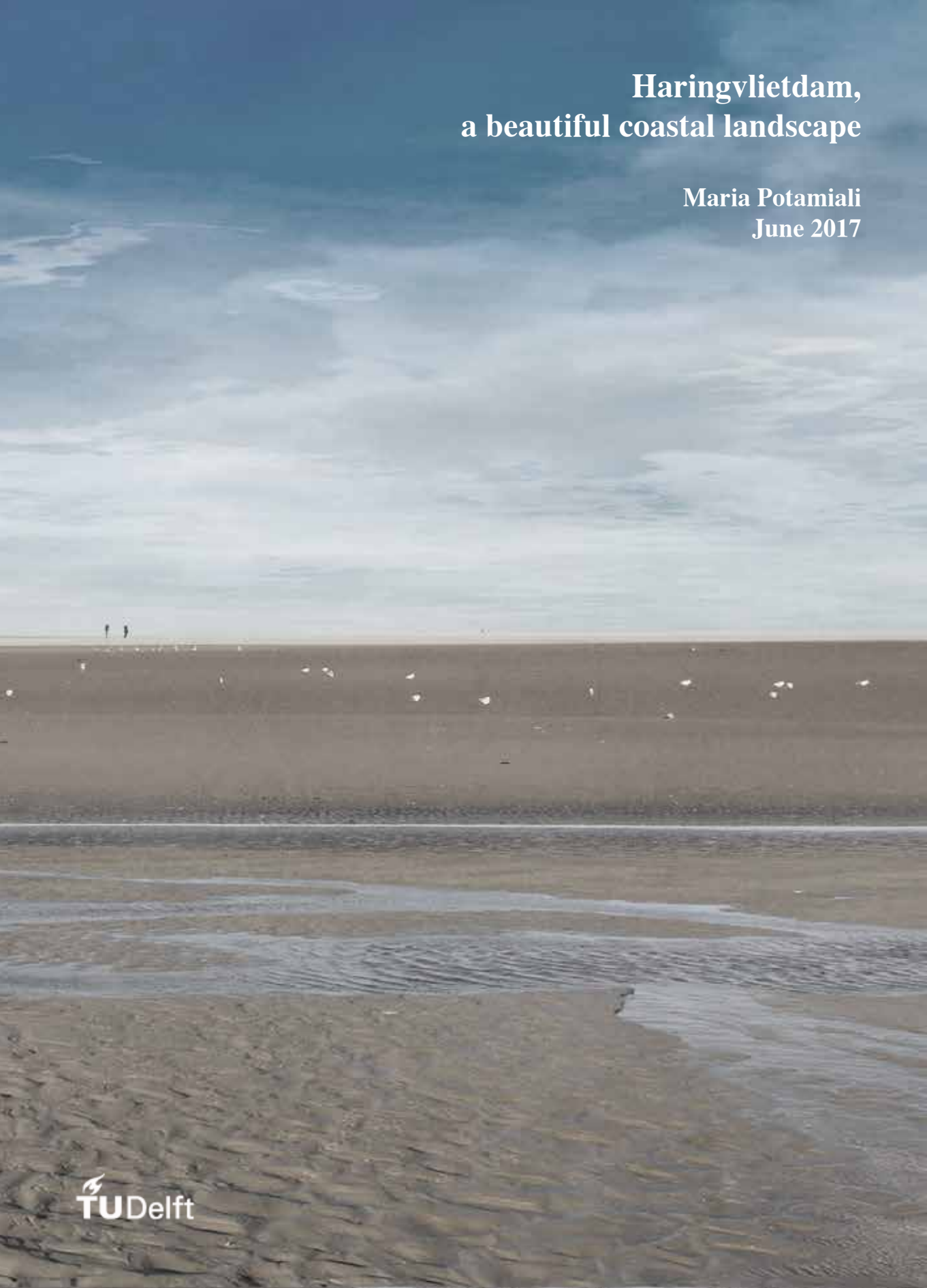


Haringvlietdam, a beautiful coastal landscape

Maria Potamiali
June 2017



Master Thesis:
Haringvlietdam, a beautiful coastal landscape
Maria Potamiali
June 2017

Graduation studio: Flowscapes
Landscape Architecture
The faculty of Architecture
TU Delft

This thesis has been produced with the
guidance of the mentors:

First mentor: Inge Bobbink,
TU Delft - Faculty of Architecture
Department of Urbanism
Chair of Landscape Architecture

Second mentor: Susanne Komossa,
TU Delft - Faculty of Architecture
Department of Architecture
Chair of Architectural Composition - Public
Building





Acknowledgements

This Thesis is the result of my Master Graduation project in Landscape Architecture in the Architecture Faculty of Delft University of Technology. In this short note, I would like to express my gratitude to all those who gave me strength to complete this project.

First of all, I would like to thank my parents who gave me the opportunity to do this master and have been always supporting me during my studies. My sincere gratitude to my tutors, Inge Bobbink and Susanne Komossa for all the valuable lessons that have been teaching me while working on my thesis. Thanks to Inge, for teaching me how a project can be developed with logical and critical arguments, but also with creativity and imagination as well. Thanks to Susanne, for pushing me in taking clear decisions in my design and incorporating my architecture skills in the project. During this last academic year both of my mentors have believed in me and always pushing me to show my strong skills and to improve my week points, and for this I am truly grateful.

I would also like to thank all the Landscape students that helped me during this project, hearing me out and offering valuable advies and new ideas. Thanks to my friends Eleni and Egli who have been supporting me from the first day of my master and offering happy moments during my studies. Last but not least, i would like to thank my boyfriend Andreas who has been there for me every step of the way and giving my strength every day with his support.

Contents

1. Framework

2. Design by Research

1.1 Fascination	10	2.1 Fast and slow dynamics	30
1.2 Introduction	12	2.2 Abiotic processes	34
1.3 Coastal defence	14	2.3 Biotic processes	38
1.4 Problem Statement	20	2.4 Interrelations	40
1.5 Research Question	22	2.5 Design principles	44
1.6 Relevance	24	2.6 Implementation of Principles	50
1.7 Methodology	26		

3. Research by design

3.1 Design Concept	54
3.2 Island - Dam Relation	56
3.3 Offering new perspectives	62
3.4 Monitoring	64
3.5 Islands Development	66
3.6 Dam	74
3.7 Perceiving the change	84

4. Epilogue

4.1 Reflection	90
4.2 Bibliography	95

1. Framework

1.1 Fascination	10
1.2 Introduction	12
1.3 Coastal defence	14
1.4 Problem Statement	20
1.5 Research Question	22
1.6 Relevance	24
1.7 Methodology	26



1.1 Fascination

The story of the Barnafoss Waterfall is fascinating as it is showing that every landscape combines natural and cultural processes. Natural processes have the power to develop different kinds of landscapes through the years but also to destroy them if we consider natural disasters. However, since every landscape is highly related and affected by human actions, cultural forces have also a huge influence upon the landscape.

In the case of the waterfall, the landscape is hunted until nowadays by the curse of a mother who lost her children. This teaches us that cultural processes affect the landscape even if they are not visible on it. A curse had the power to control in a way the human actions in the area and moreover had the power to influence the landscape.

On the other hand, the Netherlands, has always been threatened by the natural processes and more precisely by the water. For this reason it has a long history of defence against these natural threats which had influenced and transformed a unique landscape.

It could be suggested that the landscapes that represent best the combination of dynamic natural processes and cultural and economic developments are the urbanized delta landscapes. If we focus on the Southwest Delta, this landscape is hunted by major flooding disasters that happened and caused many people's lives. But due to the Delta works, the area was highly developed economically.

This graduation project was selected because I was fascinated in working in regions that combine natural and cultural processes.

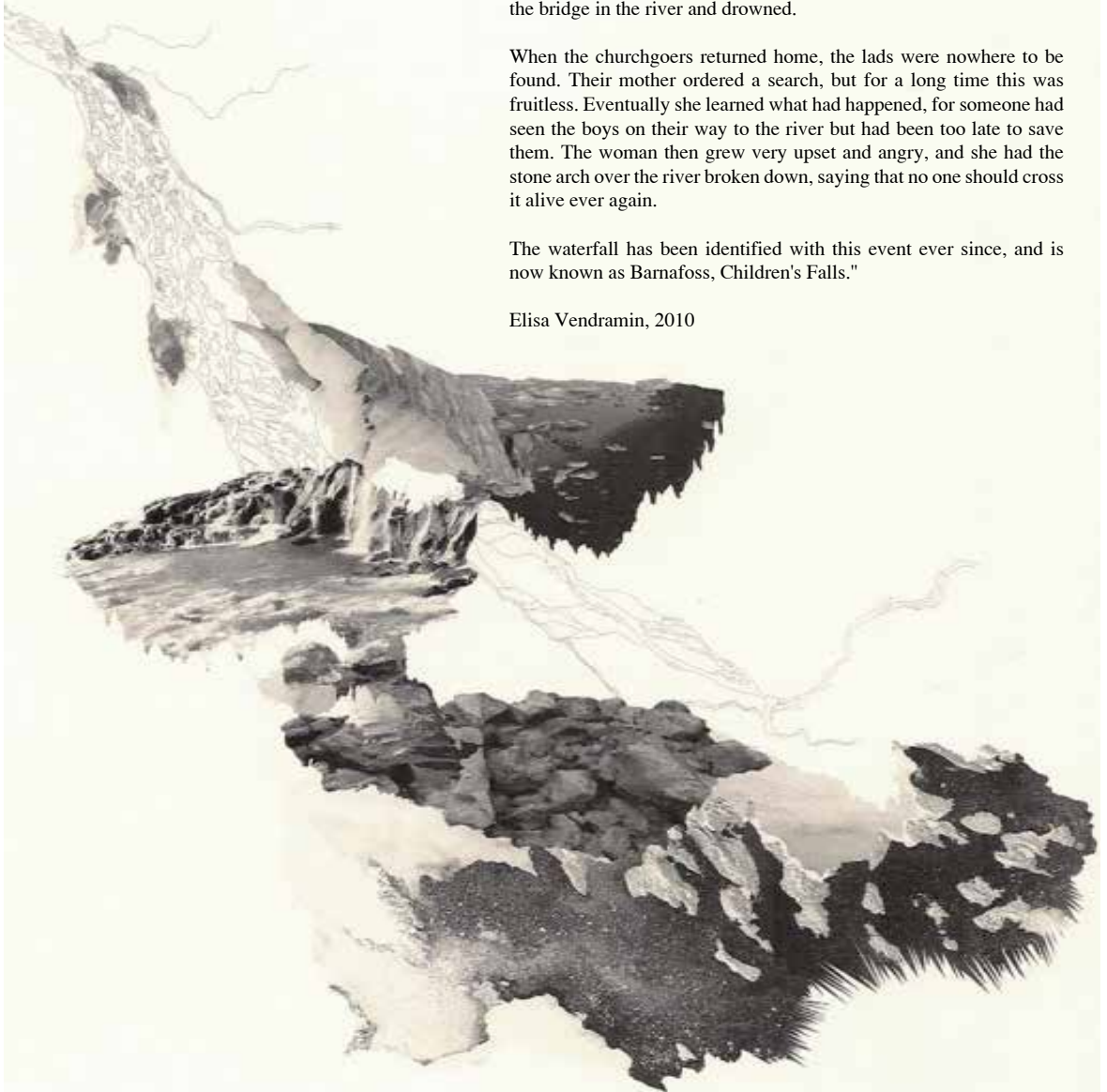
"Once upon a time a wealthy woman lived at Hraunsas, and she had two young sons. One day she went with the entire household to church at Gilsbakki, north of the river, but both boys stayed behind. She told her sons to stay at home and not to stray from the house while she was away. But when everybody had gone, the boys grew bored and eventually decide to go after the others to church.

They walked down to the Hvita River and soon reached the stone arch. The arch is said to have been rather narrow, with a long drop down to the river and the waterfall beneath. The boys were frightened and held hands to cross the river. Things went well until they reached the stone arch and looked down into the maelstrom below. They grew so dizzy looking down into the eddies that they fell from the bridge in the river and drowned.

When the churchgoers returned home, the lads were nowhere to be found. Their mother ordered a search, but for a long time this was fruitless. Eventually she learned what had happened, for someone had seen the boys on their way to the river but had been too late to save them. The woman then grew very upset and angry, and she had the stone arch over the river broken down, saying that no one should cross it alive ever again.

The waterfall has been identified with this event ever since, and is now known as Barnafoss, Children's Falls."

Elisa Vendramin, 2010



1.2 Introduction

Netherlands is significantly linked with water, which is part of its culture for centuries. Until now Dutch have a long history of dealing with water, creating the polder system, inventing new water infrastructures, dealing with river floods and sea storms but have managed to keep people safe. This long and deep knowledge could be described as part of the Dutch culture. The Dutch water management has been spread out to other countries that learned and applied some of the techniques and infrastructures.

However, nowadays there is a new perspective in dealing with water internationally. In which instead of working against the water confronting it as an enemy, we could work with it. This is also something that is being examined and tested from the Dutch which have been always trying to evolve their knowledge and develop new approaches. Already polders are flooded, rivers are widened with more space to flood, dams are partially opened and dikes are combined with recreational uses.

With the climate change, there is now need for reconsidering the existing water system in a way that could be adaptive with the sea level rise and be able to handle heavier rain fall and sea storms. The coastal landscape provide multiple opportunities for new adaptive defence, but also alternative energy production for self-sufficient regions, aqua agriculture, tourism and recreation.

This graduation project which is described in this booklet deals with a new perspective of coastal defence on the Southwest delta of Netherlands, by using natural forces in combination with existing civil engineer works to transform the coastal landscape in such way that the biodiversity is increased and people can benefit and be part of the development.



1.3 Coastal Defence

The protection of coastal landscapes from flooding disasters is traditionally approached by engineering perspective. This approach has often resulted in negative impacts on local ecology and ecosystems (Borsje, 2010). As well as massive mono-functional infrastructures that act only as intermediate space without culture and program value.

One example of this kind of coastal defence approach occurred in the Southwest delta region in Netherlands. Originally the delta was formed by the combination of river sediment transportation and strong tidal movements and sea currents. These processes led to the formation of a delta with a sand barrier coastline of beaches and dunes. This natural system changed dramatically in the second half of the nineteenth century due to some previous major flooding disasters. For this reason, the Delta works were needed in order to protect the people and the land. During the Delta works a lot of water infrastructures were built in the area as technical solutions, such as the Haringvlietdam. The Delta Works brought safety and made the area more accessible. Agriculture in particular benefited from the generous supply of fresh water in the area. The damming of the estuaries resulted in a serious decay of the ecosystems. Many species of fish, shellfish, birds and plants disappeared (Meyer, 2014).

The environmental decay of the delta became an issue of public and political concern and at present, the repair of the estuarine nature in the whole delta is a central matter of attention (Meyer, 2014).

Taking this in to account, it could be indicated that there is a strong need to incorporate landscape architecture and ecological services in coastal protection. Two main reasons for this incorporation could be introduced. First, there is a strong need for innovative, sustainable and cost-effective coastal protection solutions that deal with threats related to climate change. Second, there is need for measures that minimize anthropogenic impacts of coastal protection structures on ecosystems and that might perhaps even offer possibilities to enhance ecosystem functioning (Borsje, 2010).

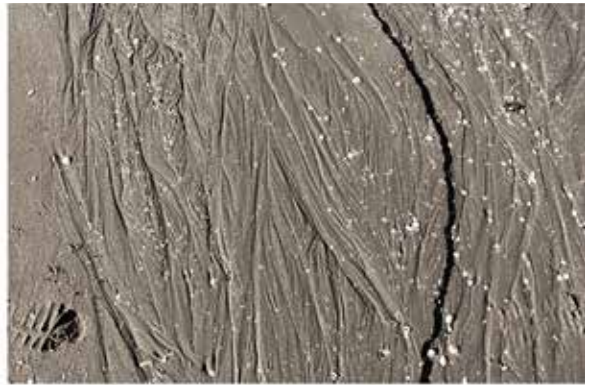


source: <http://www.tktpro.nl/projecten/engineering-brandcompartimenten-haringvliet-sluizencomplex/4>

This different mindset has inspired a different design philosophy known as "Building with Nature" that utilizes the forces of nature to strengthen nature, economy and society. Building with Nature not only implies that ecosystems should suffer as little as possible from flood protection measures, but also that natural processes should be incorporated to strengthen the coast (Brand, 2014). These objectives are reflected in two approaches by which landscape architecture can integrate natural processes into coastal protection systems: a) creating conditions for natural processes to modify the environment to enhance safety on coastal protection and b) adapting classical coastal constructions like dams and dikes to enhance local biodiversity and ecosystem functioning (Borsje, 2010).

Having said that, the main question is how can natural processes create conditions for adaptive coastal defense?







Ouddorp

1.4 Problem Statement

As was already mentioned, due to the major flooding disasters particularly in the Southwest region, the Delta works were needed in order to protect the people and the land. During the Delta works a lot of water infrastructures were built in the area as technical solutions, such as the Haringvlietdam. The Delta Works brought safety and made the area more accessible. Agriculture in particular benefited from the generous supply of fresh water in the area. However, nowadays we realized some negative effects as well, since ecosystems were damaged and lost.

Moreover, Haringvlietdam can be considered as a linear technical structure which has a single purpose and act as intermediate space that people pass through.

Finally, urbanized areas in delta environments are becoming increasingly vulnerable. The ongoing climate change aggravates this vulnerability since the sea level is rising and due to storms and heavy rainfall rivers discharge are increasing. These effects place delta regions under enhancing stress and could have considerable consequences for the Southwest Region. Therefore, innovative long term solutions need to be designed so that the area stays protected.





1.5 Research questions

Main Question:

How can the Haringvlietdam be slowly transformed to an operative landscape infrastructure in the context of Haringvliet area?

Sub questions:

- a. How was Haringvliet area developed through time after the construction of the dam, with a focus on the natural processes involved in the development?
- b. Which design principles for coastal transformation could be concluded from the research of biotic and abiotic processes?
- c. How can we use these principles in order to transform the dam and create a barrier island?
- d. Could this strategy end up with an adaptive framework that could be used as precedents in other Deltas?



1.6 Relevance

Related to the problems of the Southwest Delta region lots of plans, scenarios, visions and designs had been made. The majority proposes the opening of the sluices of Haringvlietdam so that the two water bodies of sea and river could connect. However, all the designs considered the existing dam as something that cannot be changed or transformed. In my project I focus not only in the opening but mainly in the slow transformation of the dam along with the creation of a barrier island for protection.

Together the dam and the island create a network which can solve problems related to climate change, contribute to the ecology, the economic development and create a unique experience for resident and visitors. It is important that the coastal transformation focus on finding the balance between these factors and not focus in one of them. That way, the design will be sustainable and adaptive for future conditions.

The relevance of this plan focuses in offering a new view in relation to the problems of the region and showing a strategy that could be done in other delta areas as well.

As was already mentioned the coastal protection is often being approached only by an engineering perspective. However, the new inspired mind set of building with nature is showing new original ways to deal with coastal defence.

In my opinion, both civil engineer and building with nature are necessary and the challenge is to find a way to incorporate landscape architecture and ecological services in coastal protection. In the specific project, a balance between human interventions and nature is emphasized in every scale. Therefore, hopefully, the project is showing new insights and contributes in the subject of adaptive coastal defence.

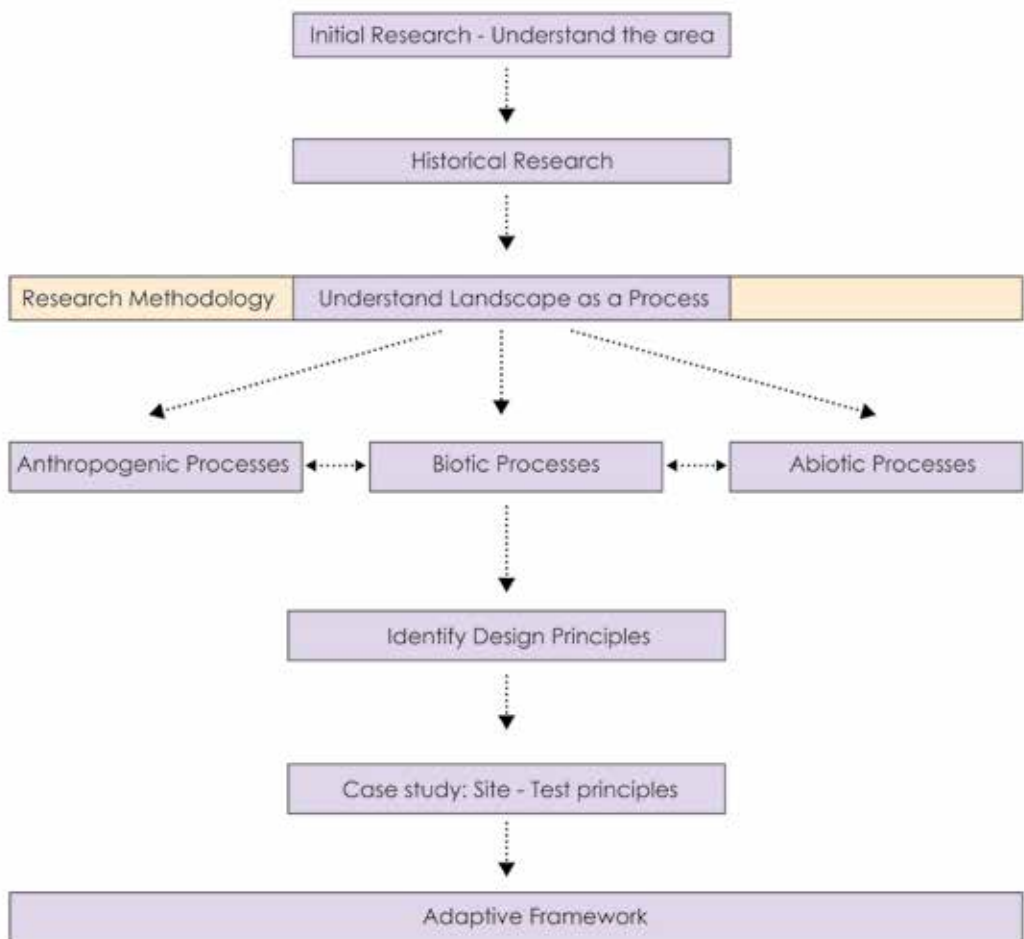


1.7 Methodology

In order to answer the questions that were said, it is important to frame our context in which we will investigate this. It could be indicated that the thinking of Landscape as a process is adopted in the specific research, since landscape is regarded as a system in which different processes and subsystems influence each other and have different dynamics of change (Meyer, 2016).

Landscape architecture as a discipline, can be characterized by the interplay of four principles of study and practice, understanding the landscape as (I) three-dimensional construction, (II) history, (III) scale-continuum and (IV) process (Nijhuis, 2013). The thinking of Landscape as a process is adopted in the specific research, since landscape is regarded as a holistic and dynamic system of systems. In that respect landscape is an expression of the dynamic interaction between ecological, social and economic processes. "The landscape is considered as a process rather than as a result. Natural and social processes constantly change the landscape, making the dynamics of the transformation a key issue in research and design. The design is considered to be an open strategy, aimed at guiding developments, no blueprint design. Projects play a role as an open-ended strategy, as in staging or setting up future conditions" (Nijhuis, 2013).

Since the landscape is considered as a process, the research is focused on understanding the different dynamics (fast and slow) and processes (anthropogenic, biotic, and abiotic) in the area. Studying this processes can give us clues, design tools and principles that could be used in the design. These principles should be then tested in our case study in order to develop at the end an adaptive framework. Such a framework could be used as a basis for future developments and designs in other Deltas.



2. Design by Research

2.1 Fast and slow dynamics	30
2.2 Abiotic processes	34
2.3 Biotic processes	38
2.4 Interrelations	40
2.5 Design principles	44
2.6 Implementation of Principles	50



2.1 Fast and slow dynamics

In order to deal with both continuity and change, Braudel divided time into three different scales, the long-term (*longue duree*), the medium and the short term. The long-term scale deals with slow processes such as the natural environment. The medium term, is focusing on conjunctures (cycles) of for instance a social, economic, ideological or demographic nature, they form social, economic and cultural history. The small time scale refers to events and concerns actions of individuals or groups (Amkreutz, 2013). It is exactly, the dialectical relationship between the different scales that provides insight into the dynamics of change, stasis and transformation. Since all scales influence each other, it is articulation of the different scales with respect to each other which is important. Short-term events may therefore form the fabric of long-term developments, but should themselves also be understood from this context (Amkreutz, 2013).

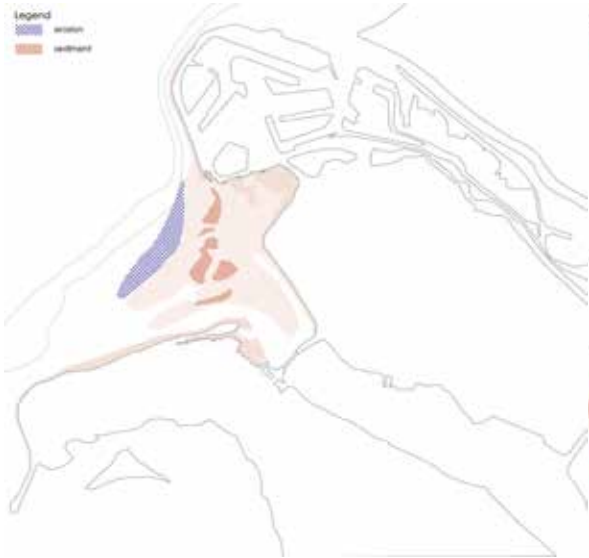
To better understand these dynamics part of the research concentrated on how the area developed through time after the construction of the dam, with a focus on the natural processes involved in the development.

As can be seen clearly from the drawings, the area in 1950 was characterized by a long tidal basin, deep channels of 80m deep and sedimentation depositions in the mouth of the estuary but also close to the islands. In 1960, the dam started to be constructed and the area started to be changed. In the next decade, it's obvious that these tidal flats were reclaimed since the ongoing silting up processes created new dry land outside the dikes. These areas became part of the island by the creation of new dikes. In 1980, the dam was already constructed and the tidal basin became considerably short with the tidal activity decreasing by 70%. It is obvious that in 1990 the tides instead of going in the river followed the coast. This change in the direction of the tides along with the wave energy led to the formation of new tidal flats in front of the mouth. As can be seen in the next drawings these tidal flats were pushed by the waves towards the coast and along with the creation of Maasvlakte 2, the area today became dramatically shallow.

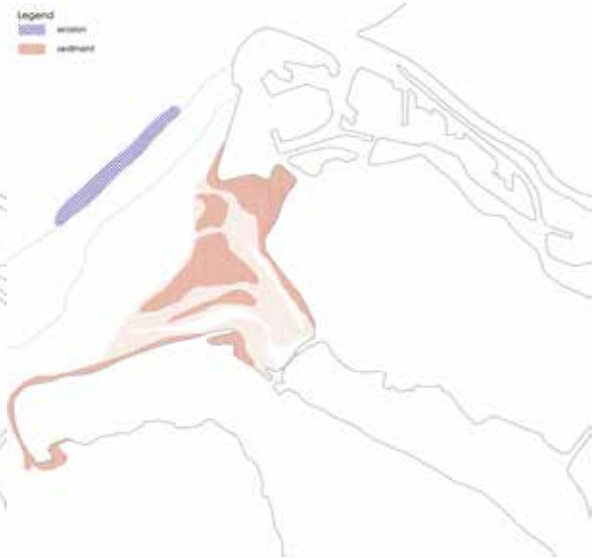


fast and slow processes form 1950 - 2016

In conclusion, the historical research showed that from a tide dominated area in 1950, the area became wave dominated, since the tidal activity decreased but the wave energy stayed the same. Additionally, it can be suggested that for the changes in the area both fast and slow dynamics were involved. This could be seen with the comparison of the slow natural processes that were involved in the development, with the really fast development of the towns in the area.



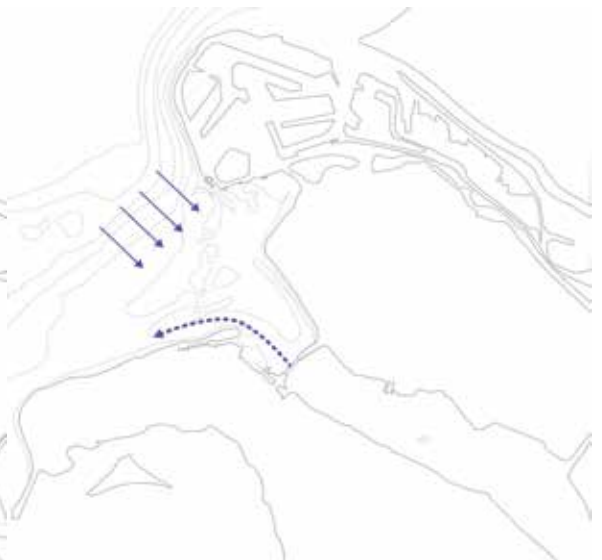
1960 erosion- sediment diagram



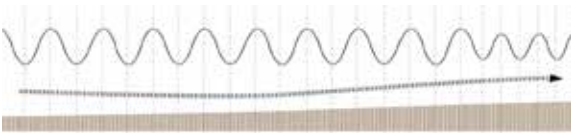
2016 erosion-sediment diagram



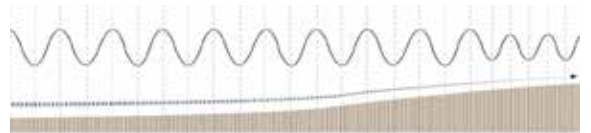
1960 tidal dominated



2016 wave dominated



waves and tidal activity 1960



waves force stayed the same and tidal activity decreased 2016



sections show how the bathymetry of the area changed

2.2 Abiotic Processes

Zonneveld (1979) used the following terms to describe the landscape: ecotope, land facet, land system, main landscape. Zonneveld described ecotope as the basic unit of landscape. An ecotope is defined as a physically limited ecological unit, whose composition and development are determined by abiotic, biotic and anthropogenic aspects together. More precisely, anthropogenic processes are related to human interventions, biotic refer to flora and fauna and abiotic to water, soil and geology.

Abiotic processes of Wind, Wave, Tide and Sediment:

Processes that work in coastal waters include winds, waves, tides and currents, which together provide the energy that shapes and modifies a coastline by eroding, transporting and depositing sediment (Bird, 2008). Although this processes interact with each other, it is convenient to first discuss them separately.

A. Tides

Tides are movements of the oceans set up by the gravitational effects of the moon and the sun in relation to the earth (Bird, 2008). Tidal volume velocity depends on the depth and so the tidal volume is bigger where the bed level is deeper.

B. Wind

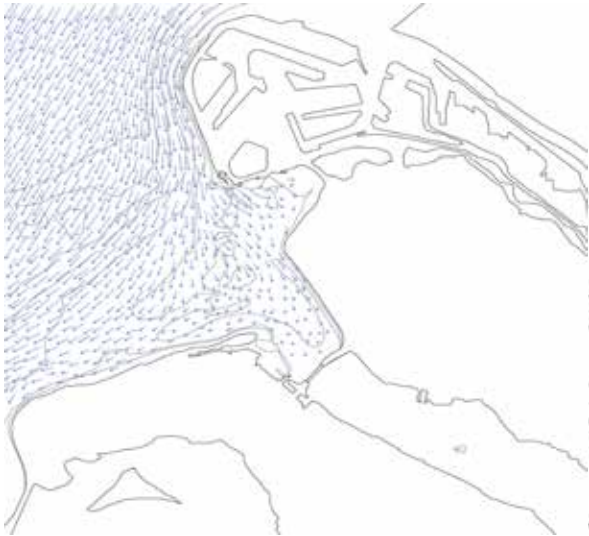
Coastal landforms may be shaped or modified by the wind. Strong winds deflate fine grained sediment (sand, silt and clay) from beaches and tidal flats (Bird, 2008). An aspect that is related to wind force is water level set-up. If wind stresses are directed in a certain direction for a longer period, the generated stress cause water level set-up (Winter, 2008). The longer length over which the wind stress occur, the larger water level set-up ($\text{Distance} = \text{Velocity} \times \text{Time}$).



phase 1: high tide



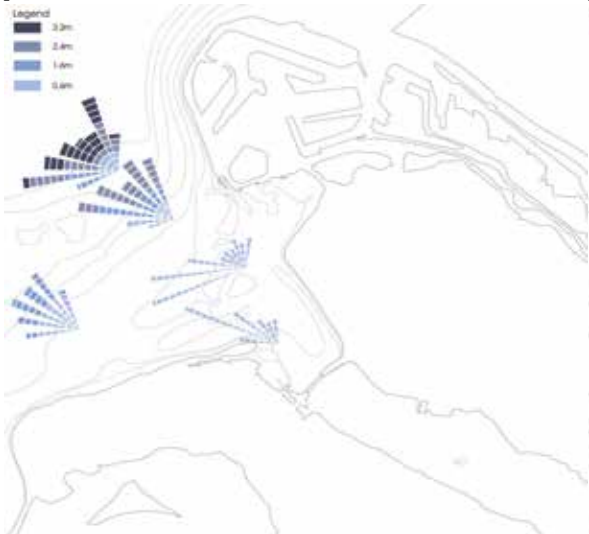
phase 2: inside current 3 hours after the high tide



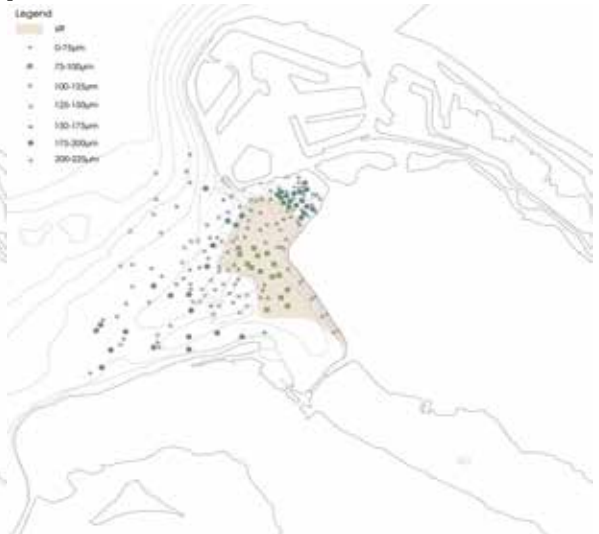
phase 3: low tide



phase 4: inside current 3 hours after the low tide



wave height



grain size

C. Waves

Waves are undulations on a water surface produced by wind action and they are generated offshore (Winter, 2008). When a wave reaches a height of equal to three quarters of the water depth the wave will break. During calm weather, large waves typically reach breaking depths far from the shoreline. During storm conditions, the elevated water level generated by storm surge allow waves to penetrate much closer to the shoreline (Bird, 2008). Moreover, due to the circular orbit process, waves carry sedimentation. Depending on the fast or slow energy, waves can be destructive or constructive.

D. Erosion and Sedimentation

Wind, waves and tides could create the loss or transportation of sediments. There is always a balance in the sedimentation process, which means that sediment is redistributed from one area to another.

Understand and work with natural processes

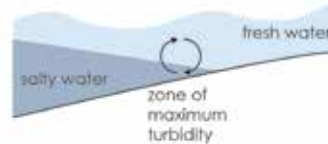
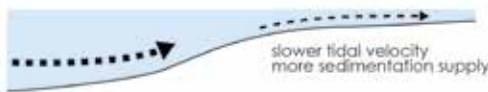
In order to understand and work with these natural processes, a variety of methods such as mapping, modelling and computer simulations, exists in relation to each discipline. Mathematical modelling is used by engineers as a basis for computer simulations of coastal processes. With this method engineers can study the effects of integrated processes systems and the way in which these processes will respond on the introduction of breakwater structures (Bird, 2008). Moreover, laboratory simulations are used by the creation of scale models that could generate wave, tides and currents in water tanks. The aim of this technique is to test a hypothesis concerning the ways in which these processes will cause erosion, move sediment or promote deposition. However, this method have limitations and is not always accurate due to the difficulty of scaling down the materials and the processes without modifying their physical properties (Bird, 2008). In addition, mapping this processes is a common method in order to understand them. Especially by landscape architects which work with the general understanding of these processes and do not involve mathematical calculations in their designs.

Tides:

Tides are movements of the oceans set up by the gravitational effects of the moon and the sun in relation to the earth. Tidal currents transport sedimentation.

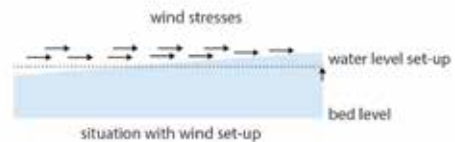
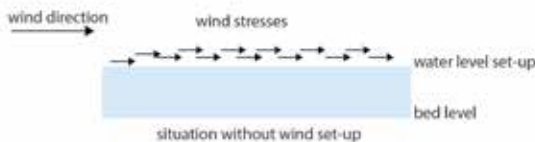


Tidal volume velocity depends on the depth and so the tidal volume is bigger where the bed level is deeper. If the water velocity becomes smaller then accretion of sediment will occur. When saltwater interacts with freshwater, there is maximum turbidity and more sedimentation occurs in the area.



Wind:

If wind stresses are directed in a certain direction for a longer period, the generated stress cause water level set-up. The longer length over which the wind stress occur, the larger water level set-up ($\text{Distance} = \text{Velocity} \times \text{Time}$). Haringvliet wind direction is from North West, this direction has a large fetch and the water level set-up can be up to 1.5m

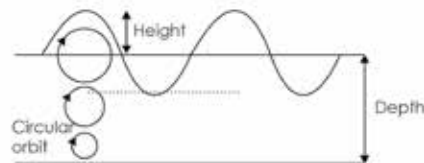


Storm surges:

Storm surges occur when strong onshore winds build up coastal water to an exceptionally high level for a few hours or days, and are most pronounced when they coincide with high spring tides.

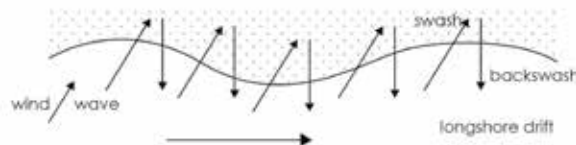
Waves:

Waves are generated offshore. When a wave reaches a height of equal to three quarters of the water depth the wave will break. During calm weather, large waves typically reach breaking depths far from the shoreline. During storm conditions, the elevated water level generated by storm surge allow waves to penetrate much closer to the shoreline. Moreover, due to the circular orbit process, waves carry sedimentation. Depending on the fast or slow energy, waves can be destructive or constructive.



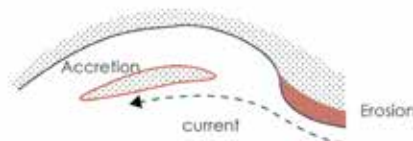
Longshore Drift:

Waves approach the beach at an angle similar to the wind. With the swash and backwash, the material is transported along the beach in zigzag movement.



Sedimentation and Erosion:

There is a balance in the sedimentation process, which means that sediment is redistributed from one area to another. Wind, waves and tides could create the loss or transportation of sediments.

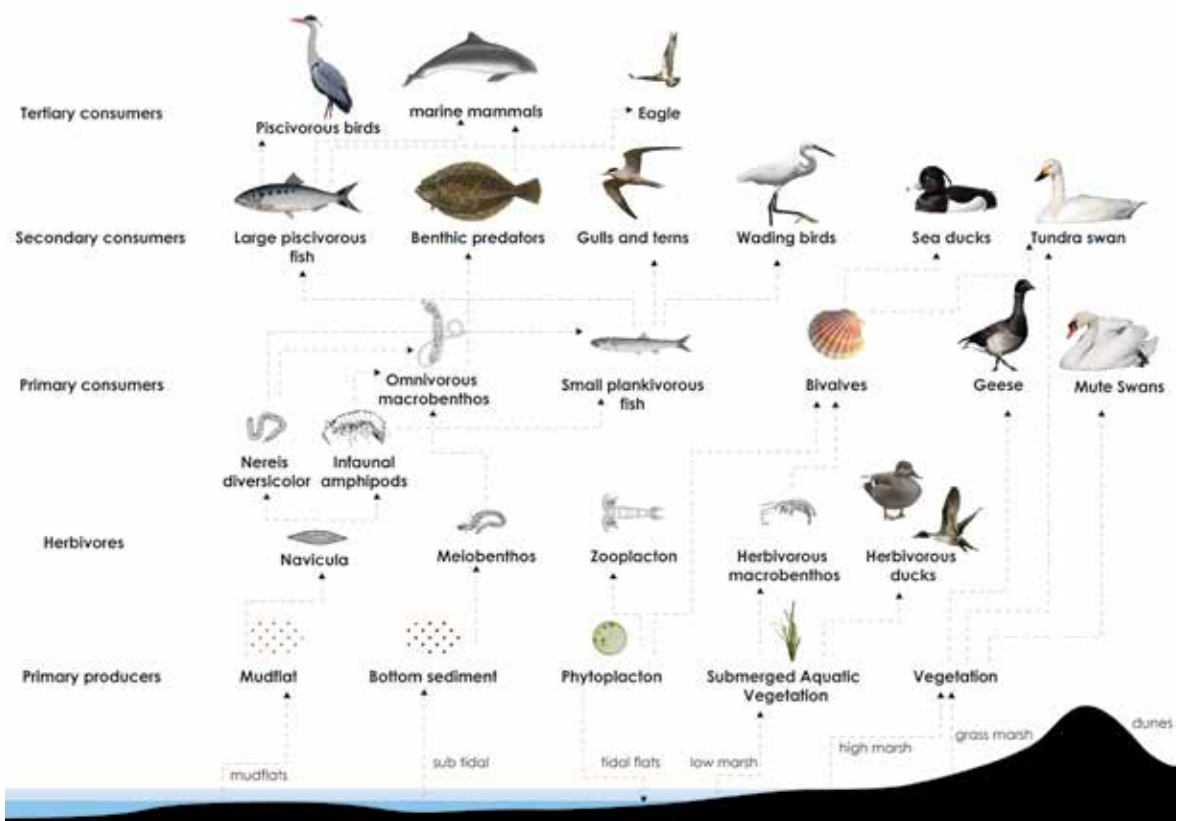
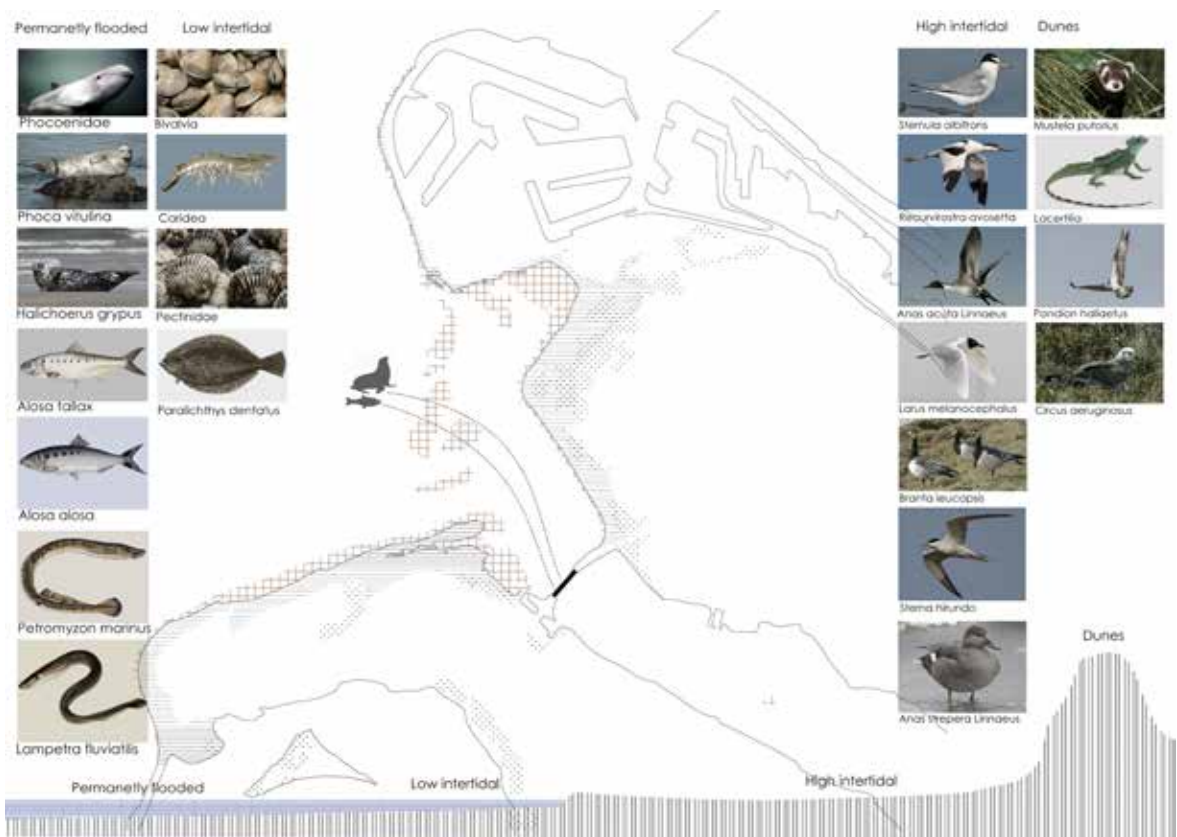


2.3 Biotic Processes

Biotic processes of vegetation and ecosystems

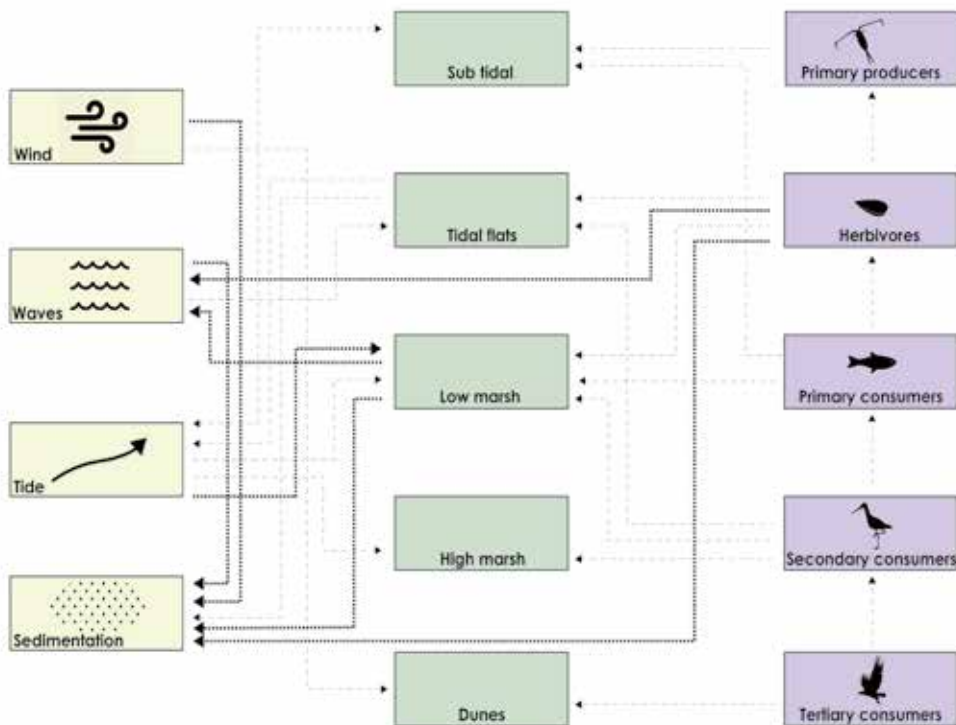
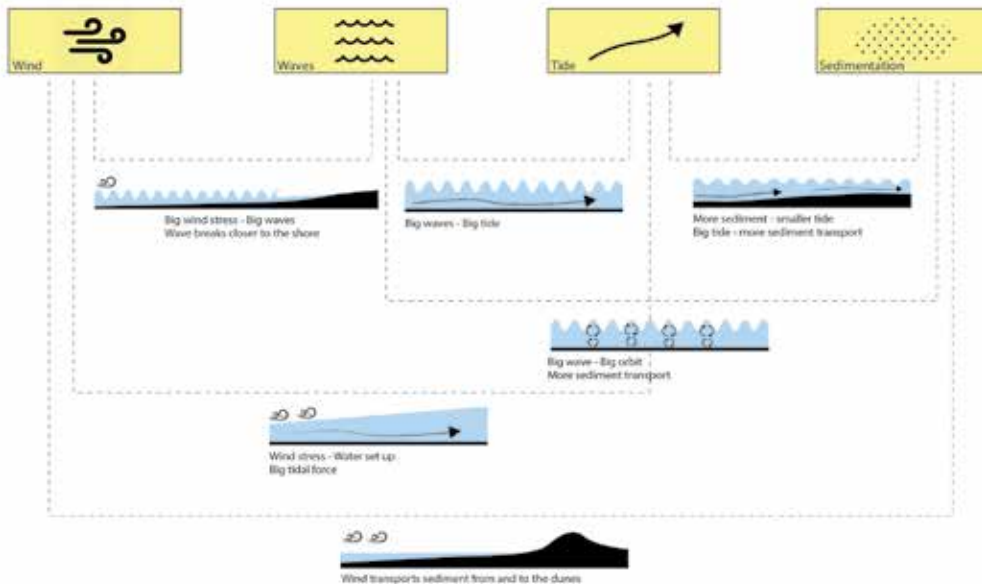
The concept of ecosystems recognizes that all life is interconnected and interdependent. In other words, there is an organization among plants and animals in response to their physical environment that promotes the optimal efficiency in transferring the energy essential for life and growth within the group of organisms living in a given area (Carlozzi, 1975).

It can be indicated that the coastal ecosystems of sand flats, low marshes, high marshes and dunes are highly related and support the whole food chain of species with coastal habitat. This can be seen clearly in the diagram, which explains how these ecosystems are associated with the primary producers, herbivores, primary consumers, secondary consumers and tertiary consumers.



2.4 Interrelations

After the general understanding of these processes, it is necessary to find the interrelations between the processes of Wind, Waves, Tides and Sediment with the vegetation and the ecosystems. As can be shown in the diagram, too many relations could be concluded between these processes. In order to find ecosystems in an area, specific vegetation is needed to be developed so that the ecosystems could find food and survive. In addition, the specific vegetation is highly dependent on the natural forces since these forces could provide conditions for the vegetation to grow or to disappear. Finding this kind of interrelations provide useful information in order to conclude design principles.



2. Design by research

Precedents study

water management

program

ecology



Sand motor



Oyster dam
Oosterschelde



Robust Adaptive
Framework-Haringvliet



west 8 - Blue dunes



Posad
Ijmeer Markermeer



Sea bed landscaping



Maasvlakte 2



Garza and Thomas
de-Damming the Dutch
Delta



CAU + ZUS + URBANISTEN
New Meadowlands



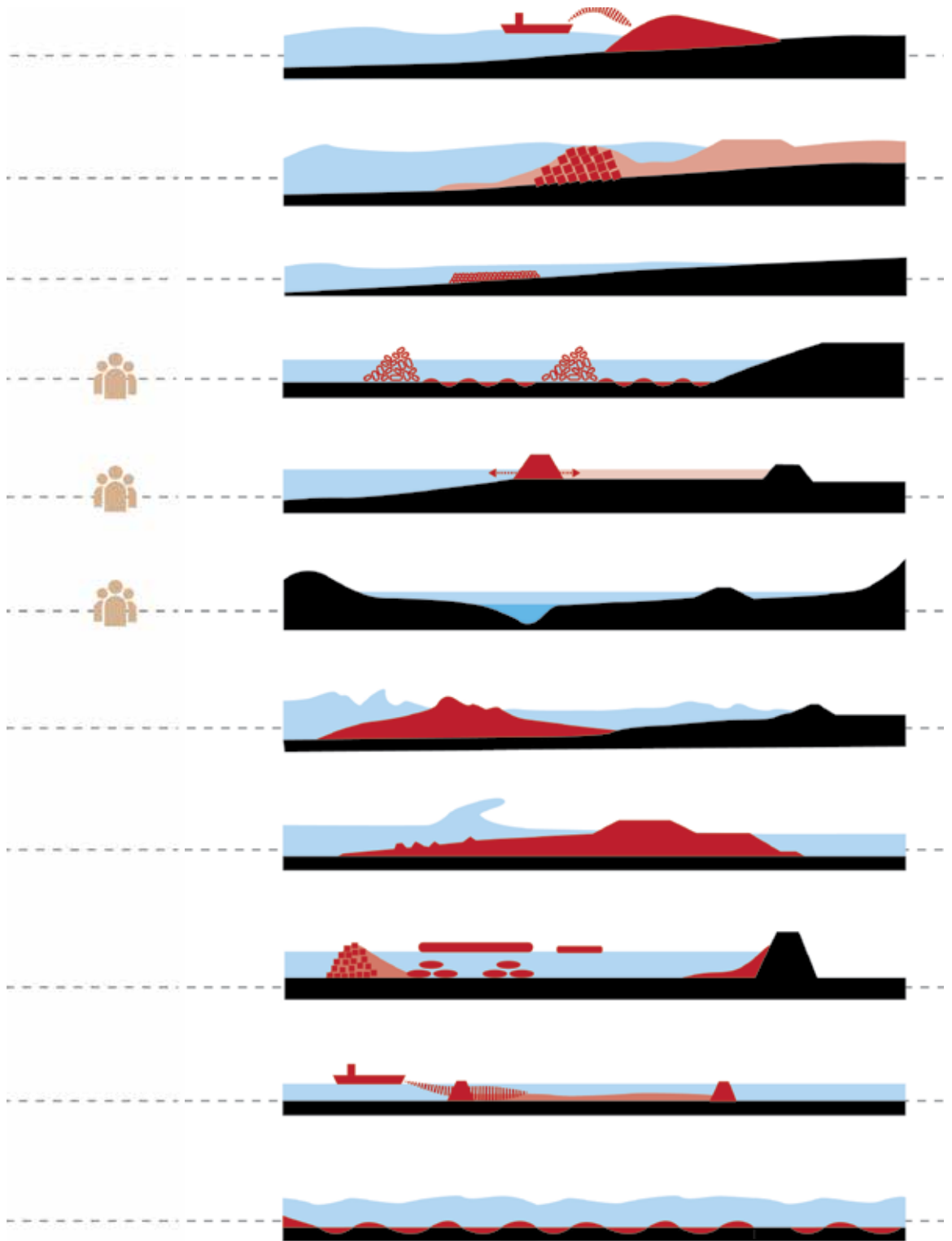
Scape - Living breakwaters



Vista - Marker Wadden



culture



2.5 Design Principles

The reason for studying in depth these natural processes is to be able to conclude design principles that could be used for coastal defense. This kind of principles are described in this chapter.

a. Use the forces of wind, waves and tides

By using the forces of tides and waves, erosion or deposition of sediments can be promoted. This can be used to redistribute the sediment or to form soft foreshores and new intertidal areas. In addition, waves and wind could be used to produce energy.

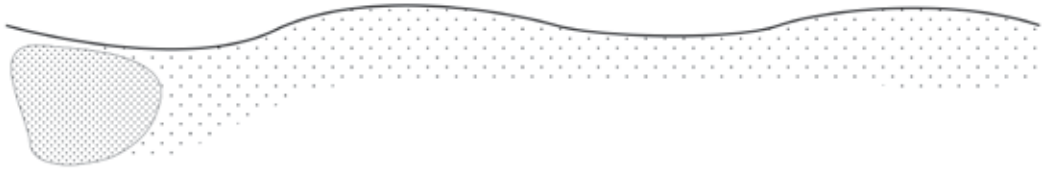
Different landscape types could be developed by using these natural forces, such as tidal flats, saltmarshes, wetlands or dunes. However, each of these landscapes need different conditions in order to be developed. For example, tidal flats could be created easily by placing a wooden barrier that will trap sediment that is transported with the tides. In contrast, in order to create saltmarshes, the soil has to be silted up in order to be more stable and above the water level. Then saltmarsh vegetation can grow and the area would be occasionally flooded.

b. Use coastal vegetation

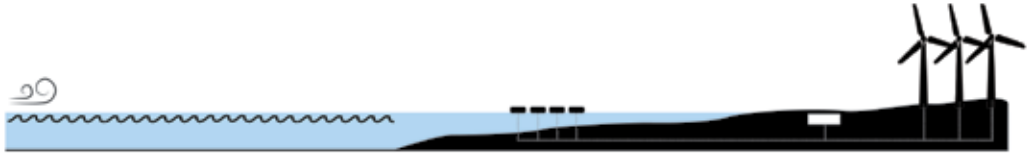
Coastal vegetation could be used in order to prevent erosion or to reduce wave energy. Natural stabilizers like salt marshes are known to increase soil elevation that can significantly decrease wave impact on hinterlands. More precisely, salt marshes are developed using sedimentation fields, in which groins create conditions of low hydrodynamic energy level that embrace the precipitation of sediment. A second coastal vegetation that could be used is eelgrass that is able to also trap sediment, reduce current velocities and clarify water. Moreover, by increasing soil elevation, vegetation processes have the ability to keep up with sea level rise, implying that they might offer sustainable and cost-effective coastal protection solutions (Borsje, 2010). It is worth mentioning, that the restoration or creation of these coastal landscapes is significant for many species. Productivity and biodiversity are enhanced and also the whole food chain can benefit from it.

Principles:

A. Use the forces of tides and waves



Use the forces of tides and waves to redistribute sediment



Use wave and wind to produce energy



Use wave and wind to create soft foreshores or to new intertidal areas

Principles:

B. Use coastal vegetation as a coastal defence



Use nature stabilizers like salt marshes to prevent erosion



Use nature stabilizers like salt marshes to reduce wave energy

C. Use ecosystem engineer



Use oyster reefs for soil formation or enlarging intertidal areas



Use oyster reefs for maintaining intertidal areas (reduce wave energy)

c. Use ecosystem engineering

Ecosystem engineering could be used for soil formation and to enlarge or maintain intertidal areas. Ecosystem engineering species have the ability to modify the local physical environment by their structures or activities, like mussel and oyster beds. Also, these various species are capable to reduce current velocities, trap and stabilize sediment, so that soil elevation increases and subsequently attenuate waves, make them suitable to execute functions similar to dams (Borsje, 2010). Moreover, these ecosystems can influence water quality by filtering the water and provide a habitat for a large biodiversity community (Borsje, 2010).

d. Dike realignment

Coastal landscapes always had an open ended relation between land and water. From this relation a lot of coastal areas were developed due to land reclamation by building more and more new dikes towards the water. The dike realignment could be done by opening the new dike in such areas (areas between new and old dikes) and letting the natural processes inside. It is considered a cost-effective and sustainable response to loss of biodiversity and sea level rise. The goal is to create the right circumstances for succession of tidal flat and saltmarsh vegetation. Once saltmarshes develop the vegetation will enhance sedimentation and the area will become higher and will be able to grow with sea level rise. As was mentioned earlier, saltmarshes can reduce wave energy and improve the stability of the dike.

e. Creation of barrier island

These natural processes that were mentioned could be used to create a barrier island that will protect the inland from storms and waves and will have the ability to grow with sea level rise. This could be done with soft or hard solutions or with a combination of them. For example, by placing a barrier in a specific spot, the waves and the tides will redistribute the sediment and as time passes the sediment will be trapped in the area.

Design Principles: Creation of new intertidal zones



Existing Situation



Dike realignment



- + marsh vegetation
- + sedimentation
- + buffer
- + oyster - mussel production

Reefs creation parrarel to river banks



- + marsh vegetation
- + sedimentation
- + ecology
- + recreation

Reefs creation vertical to river banks



- + marsh vegetation
- + sedimentation
- + ecology

Design Principles: Barrier Island



Existing Situation with tidal flats



Soft solutions



- + ecology
- + use natural processes
- takes time

Sand nourishment



- + less time
- + use the sand from draining the channels
- ecology

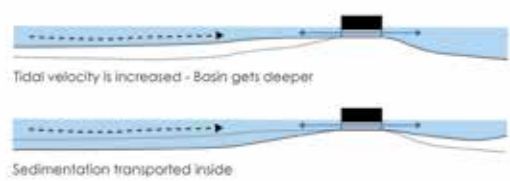
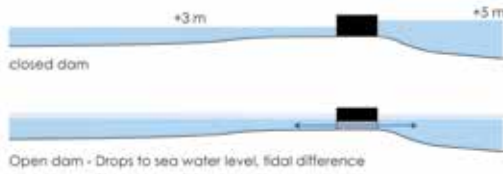
Combination of Soft and Hard solutions



- + less time
- expensive

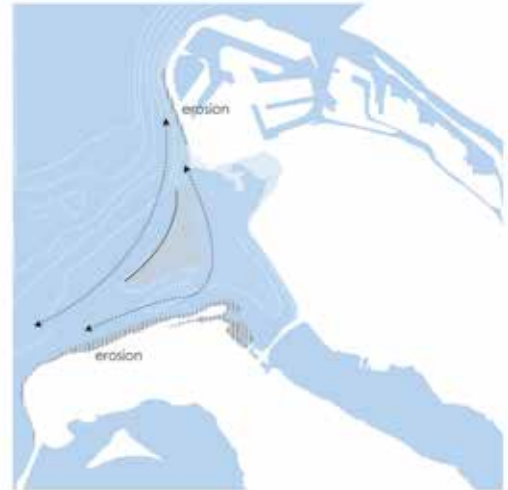
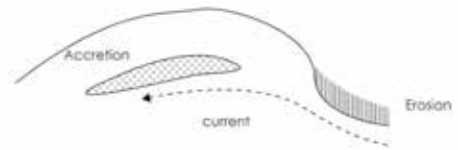
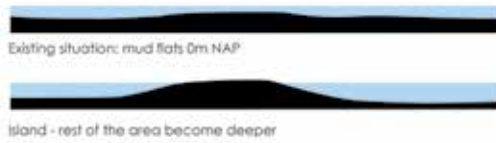
2. Design by research

What would happen if we open the dam?

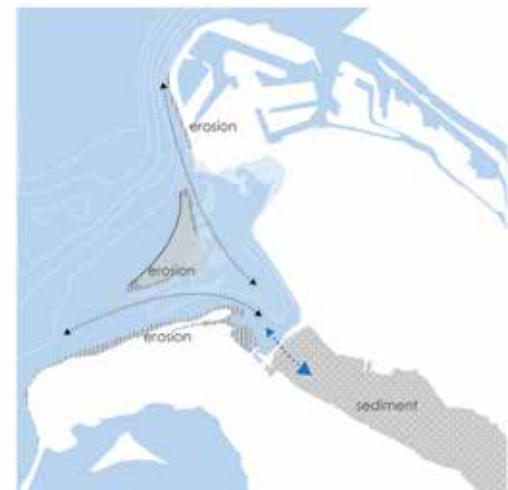
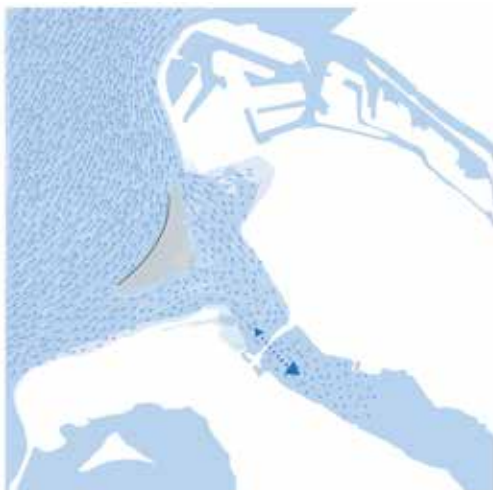


Two important questions had to be answered in order to understand what would change in the natural system if we intervene. The first intervention is the opening of the dam, which will result significant differences in the system, since the tidal activity will increase because the basin will become bigger. It is also important to keep in mind that since the force of the tide is bigger when it is going inside than when it is going out, more sedimentation will be transported inside and some existing areas might erode.

What would happen if we create an island?



What would happen if we create an island and open the dam?



The second intervention is the creation of the barrier island. From the research, it was clear that if a water barrier is constructed in the existing system then the tide will transport sediment and a barrier island would be developed. However, if both interventions, the barrier island and the opening of the dam happen at the same time, probably the sedimentation instead of being transported to the barrier island would be transported inside the river. Taking this into account, it is obvious that the creation of the barrier island must precede the partial opening of the dam.

2.6 Implementation of Principles

The design principles that were concluded in the research could be implemented in the specific site. These principles could lead to specific design opportunities and decisions and the first general guidelines that were concluded until now in the research will be presented. The areas of interventions were decided in relation to the historical research of the area which was briefly described above.

Firstly, the forces of wind, waves and tides could be used for the creation of the barrier island. This could be achieved by placing a barrier and waiting the natural process to redistribute the sediment in the area.

Moreover, in the river area, the intermediate areas between the new and old dike could be transformed in new intertidal areas by dike realignment. The tidal activity will create the right conditions for saltmarsh vegetation to develop. Once saltmarsh vegetation grows, the sedimentation will be enhanced and the area will become higher and will be able to grow with sea level rise. As already mentioned, saltmarsh vegetation can reduce wave energy and improve the stability of the dike.

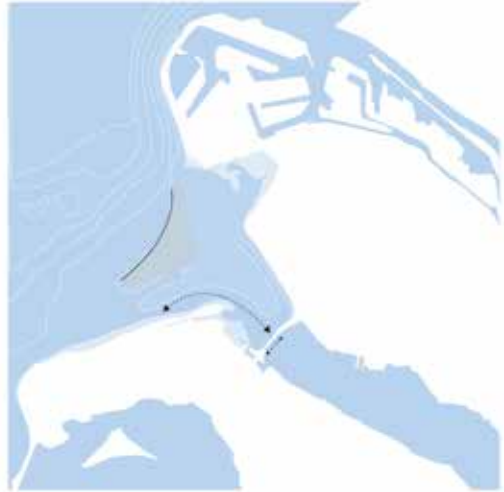
Concerning the ecosystem engineering, this could be used both in the barrier island and the dam. Providing conditions for these ecosystems to develop in these areas will have as a result an increased elevation, attenuated waves and enhanced biodiversity.

Principles

1. Creating the island before opening the dam
Areas endangered from erosion should be protected



2. Opening of the dam as a process
Dam should open slowly in order to understand the effects on the rest of the system.

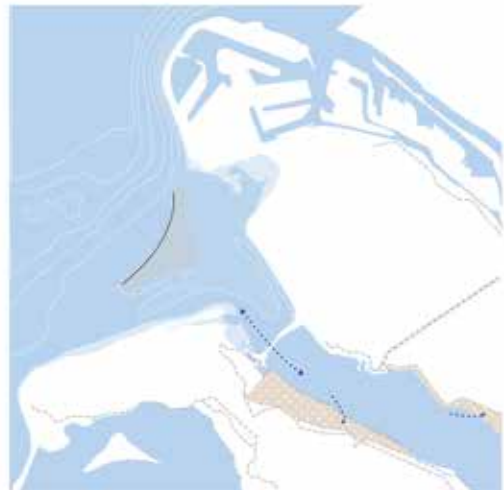


Principles

3. Control the water flow
By a deep channel or a dam



4. Creating new tidal areas by dike realignment
Use the zones between new and old dike as intermediate area. Once saltmarshes develop the vegetation will enhance sedimentation and the area will become higher. This will be able to grow with sea level rise.



3. Research by design

3.1 Design Concept	54
3.2 Island - Dam Relation	56
3.3 Offering new perspectives	62
3.4 Monitoring	64
3.5 Islands Development	66
3.6 Dam	74
3.7 Perceiving the change	84



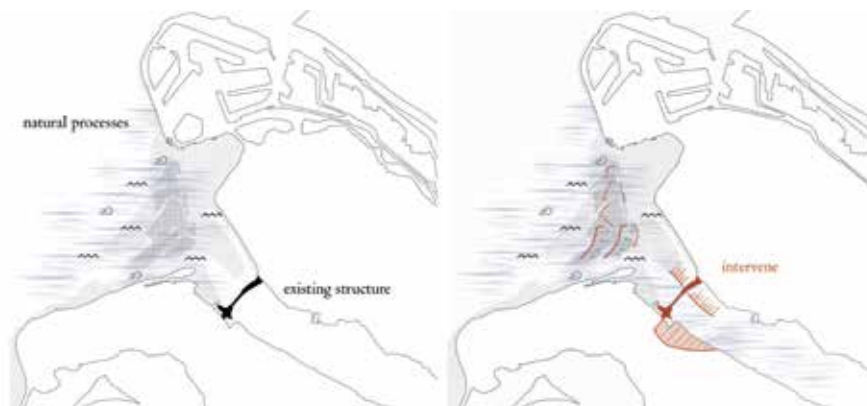
3.1 Design concept

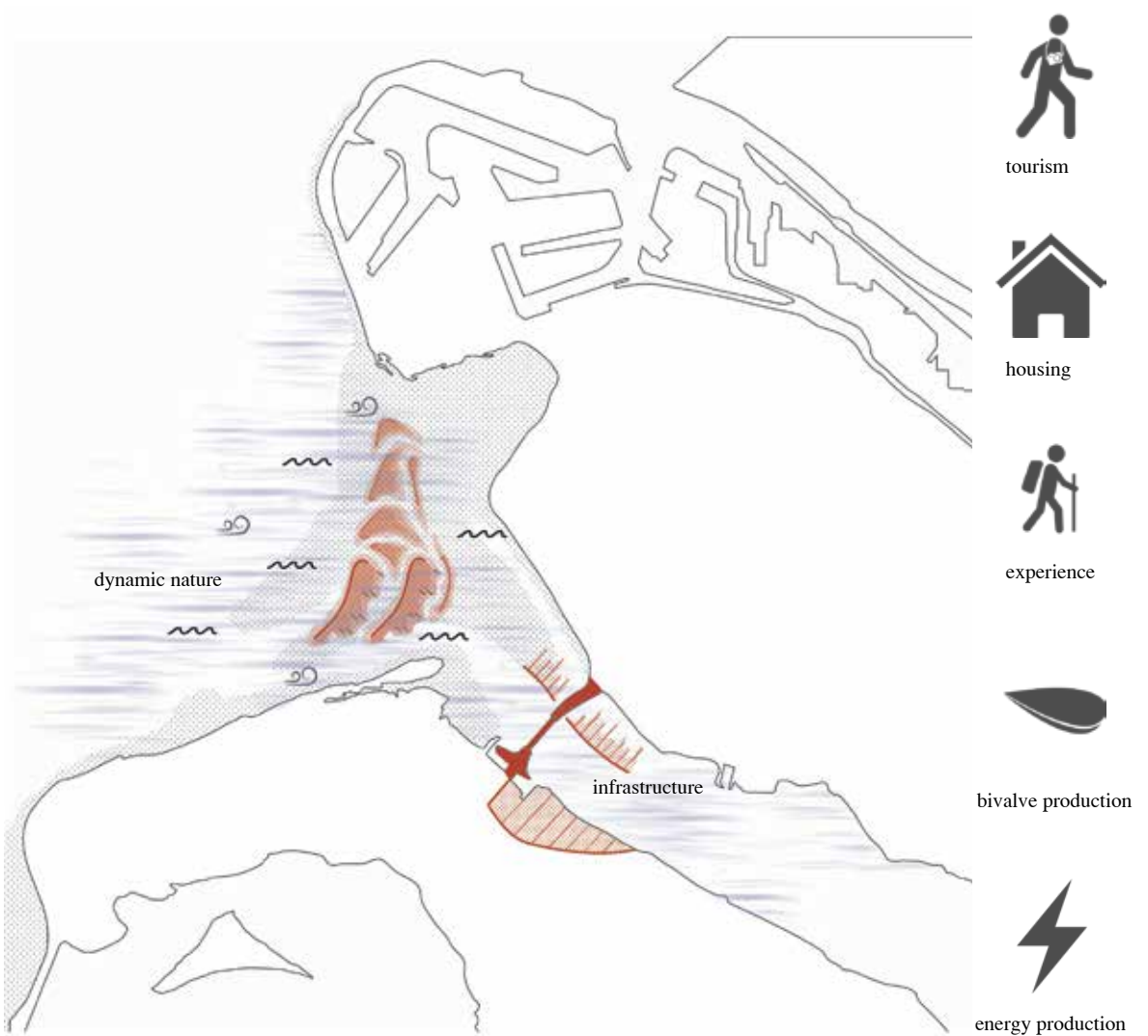
dynamic Vs infrastructure

The design concept is based on two different existing conditions in the area. From the one hand the existing coastal landscape with the natural processes and dynamics and on the other hand the existing structure of Haringvlietdam. Taking into account the existing conditions, the design is based on intervening to develop the barrier islands and to let the natural processes inside.

The proposed design aims to connect this dynamic nature and this infrastructure. The two of them have a contrasting character but together create a network that combines tourism, housing, experience, bivalve production and energy production.

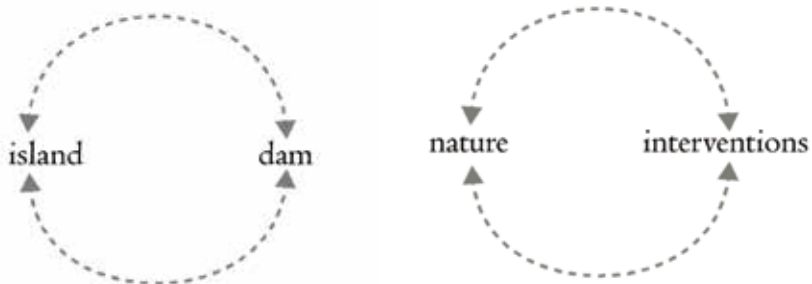
The concept is based in two relations. The first is the dialogue between nature and interventions, since in every scale there is a dialogue between the interventions and nature. For instance, to create the islands a barrier would be needed at first, which would be the intervention, and then nature will take over and build the sedimentation with the processes of tidal activity, waves and wind. In a zoom scale, building units would be stabilized in specific positions in order to help the development of the islands. Again an intervention would take place and then nature can do the rest. On the other hand, the dam would be transformed and will be partially opened and then due to the reconnection of salty and fresh water, the brackish water will allow the bivalve ecosystems to grow.





3.2 Islands - Dam Relation

The second important relation is the one of the dam and the barrier island. The two of them work one for each other and create a unique network. Firstly, the dam is transformed and the barriers are constructed in order to develop the islands. When the islands start to grow, a landmark is placed on the first island. This attract a lot of people to the dam in order to see from far the islands. Since people start to visit the dam, people also start to experience it and to discover that there are a lot of things to do in the area. In this point building units are placed to the islands to speed up the development and the dam is partially opened. After one year people can visit the island by a boat from the marina of the dam. Two years later, people can finally go to the island to stay with their assembled vacation houses that are in pieces. People have electricity because the dam is producing energy from wind and tidal turbines. A boat connection is also created with Rotterdam since a lot of people are traveling for summer vacations.





existing situation



2017: intervene (water barriers - dam)



2020: put landmark on island, attract people on dam



2021: people can visit the island, open dam

3. Research by design



2022: put units



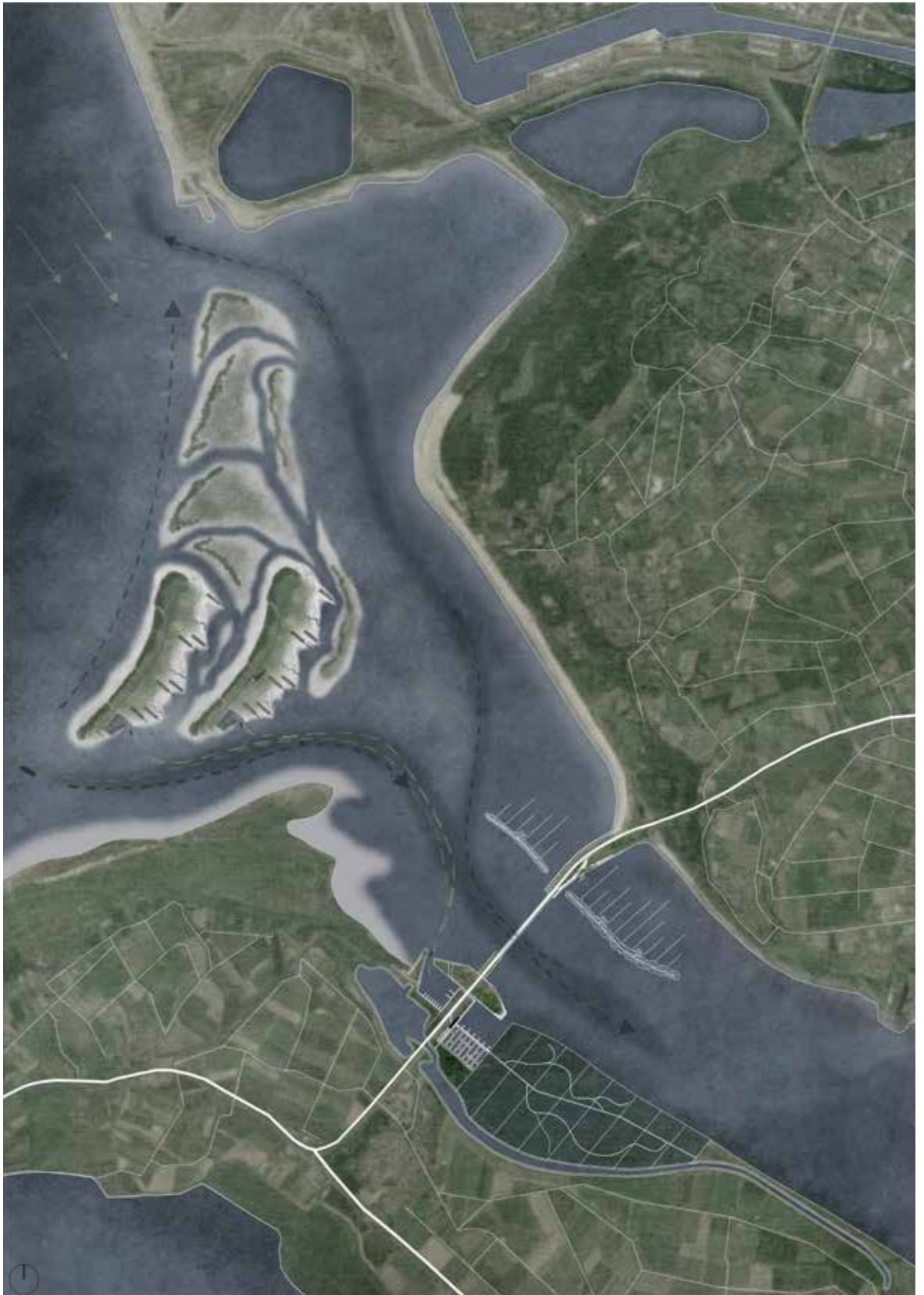
2023: people can stay on the islands



2025: intertidal areas are developed, recreation use



2050: the islands become one



masterplan

3. Research by design



birds eye view showing how the are will be transformed



3.3 Offering new perspectives

a slow transition to a self-sufficient region

As was mentioned earlier it is important to slowly transform this area in such a way that people will be part of the development and can profit from it. The design should be considered as an open ended slow process towards an adaptive coastal self-sufficient region.

This slow process, would give people the time to realize what would change and understand the future possibilities of this area. As this area was affected by the huge flooding of 1953, it is understandable why people could be scared and unwilling for a change. However, this slow transition would provide them with new insights of the necessity of this plan and their own benefits from it, for instance the energy production, the bivalve production, the recreation and the vacation houses. All these aspects could develop a self-sufficient region which is producing energy from alternative resources (water, wind, sun), producing aqua agriculture that is consumed domestically or is exported to other countries, attracting tourism to the extended coastline (islands) and providing a unique experience both for the residence of the region and for the visitors.

Additionally, this slow process give opportunities for the initial plan to change in relation to what is happening in the region. This could be concern issues related to safety, the unpredicted natural system, the cultural landscape or the economy of the region. For example, the oyster production could be developed firstly in a small area and then be extended if is profitable enough.



start of the oyster production



oyster production is expanding



existing situation



2017: intervene (water barriers - dam)



2020: put landmark on island, attract people on dam



2021: people can visit the island, open dam



2022: put units



2023: people can stay on the islands



2025: intertidal areas are developed



2025: recreation use

3.4 Monitoring

observing and working with nature

A significant aspect of this graduation project is the proposed monitoring in relation to what happens to the natural system after the intervention. More precisely, it is clear that in order to realize this ambitious plan, research and calculations from experts of coastal engineering would be needed in order to understand every aspect of these coastal complicated system. However, since nature is unpredictable, even with all these calculations, there is no guarantee that everything will go as planned. For this reason, a continuous observation of the natural system will be needed in order to understand what was the effect of every intervention in this natural system. Following this kind of procedure the initial design could be changed, to adapt to new situations. As a result, future problems that may occur could be addressed immediately.

A couple of examples of this unpredictable situations is shown in these diagrams. If erosion is observed in one of the islands, that would mean that the intervention was extended too far and an island would be lost since it will slowly erode. Additionally, concerning the issue of safety of the people that will spend time on the island for vacation, if it is observed that there is not enough protection from the tide (when the tide comes out), then another island could be developed.



a. if erosion is observed.....one island is lost

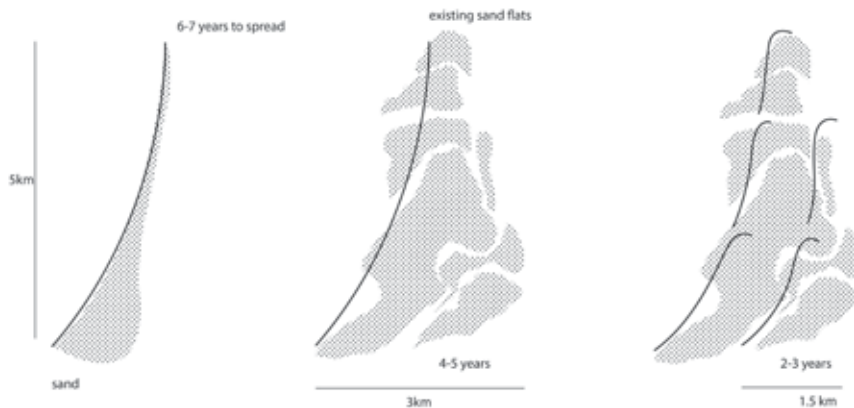


b. if protection from tide is not enough.....another island is needed

3.5 Islands Development

The barrier island was decided to be created as a group of islands that in the future might become one, instead of one island from the beginning. This decision was based due to time, since smaller islands would be developed much faster. There are two types of islands, artificial islands where people will have their vacation houses and more dynamic islands for ecosystems which people cannot visit. The first type of island will be developed by constructing a wall with concrete blocks. Then the natural processes of waves, tides and wind will bring sediment. When sedimentation will take place, we can plant seeds in order to create dunes and speed up the process of the development. By planting vegetation, the sediment will be stable and more sediment can be transported there by wind. Moreover, to speed up the development of the island concrete building units will be fixed. This units will contribute in the growth of the island since they can catch sediment and in the experience of people who will stay, since each unit will provide a shelter from the wind, a common place for communication, a storage for the vacation houses in the winter and the distribution of water and energy to the summer houses.

The second type of island will be only for ecosystems and will not be accessible by people. The island will be developed by placing wooden sticks and letting the natural processes of tide and sediment to do the rest. This process will take immensely more time than the artificial islands.

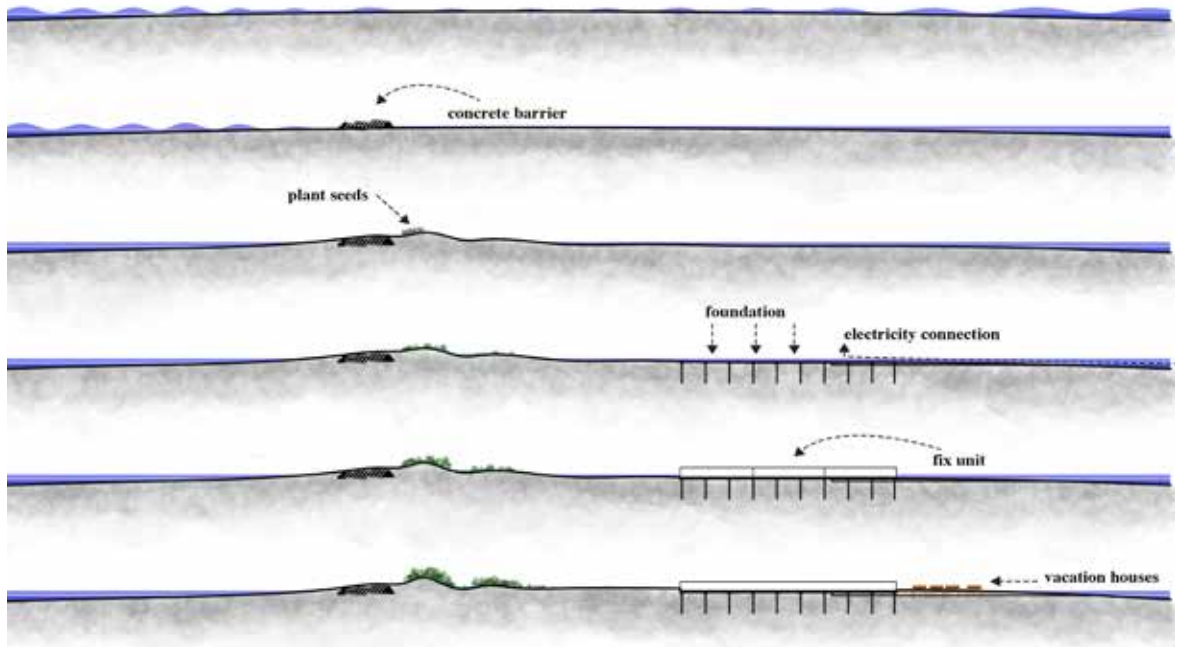




island for ecosystems



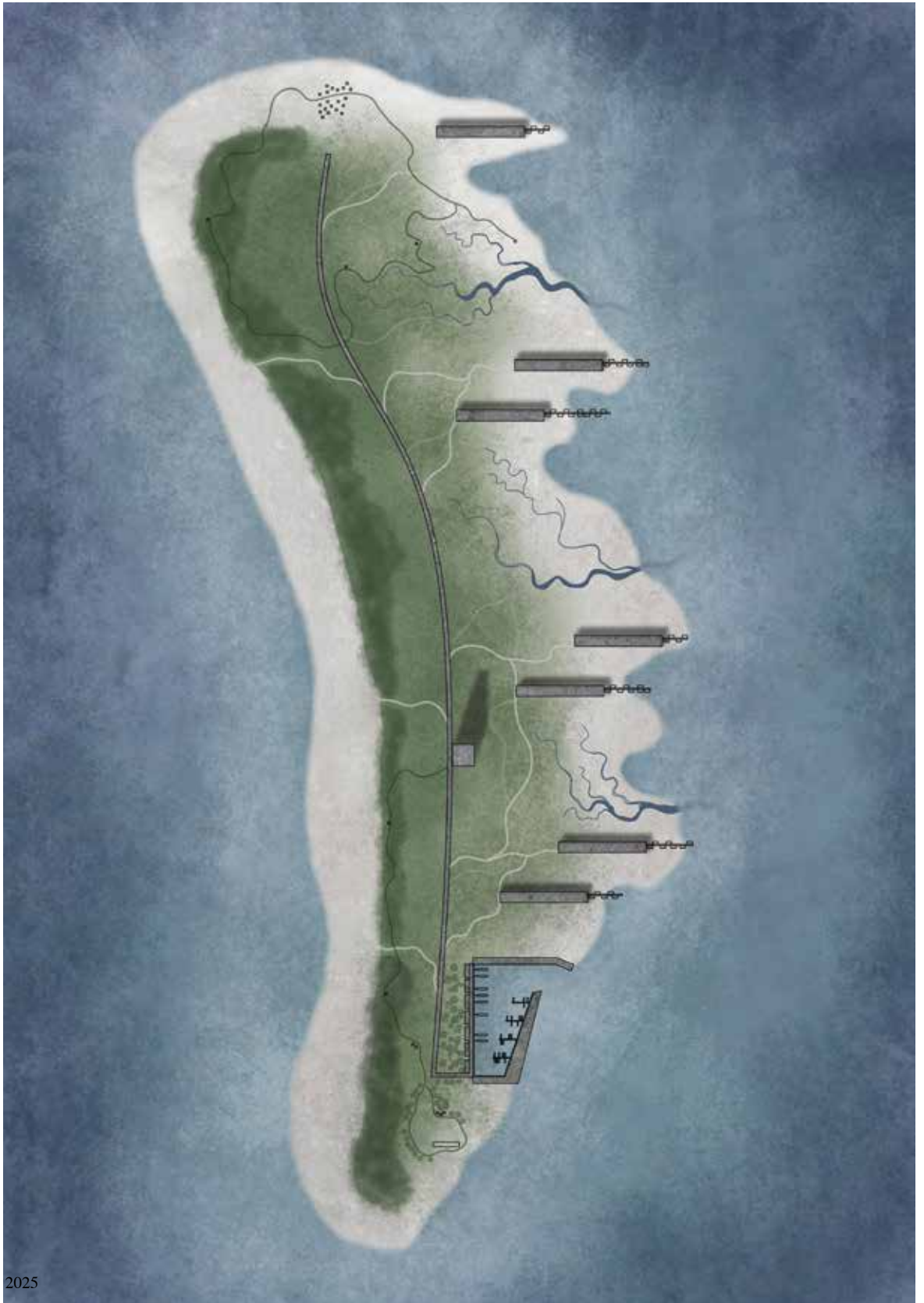
artificial island for people



artificial island development

3. Research by design





building units

The building units will be transported in pieces by boat to the islands and will be fixed. They will contribute to the faster development of the artificial islands. However, these building units will not be placed only for the catchment of the sedimentation, but will be the distribution points of electricity and water to the vacation housing. More importantly, these units will provide the common space in which the people will spend time, communicate and share their vacations.

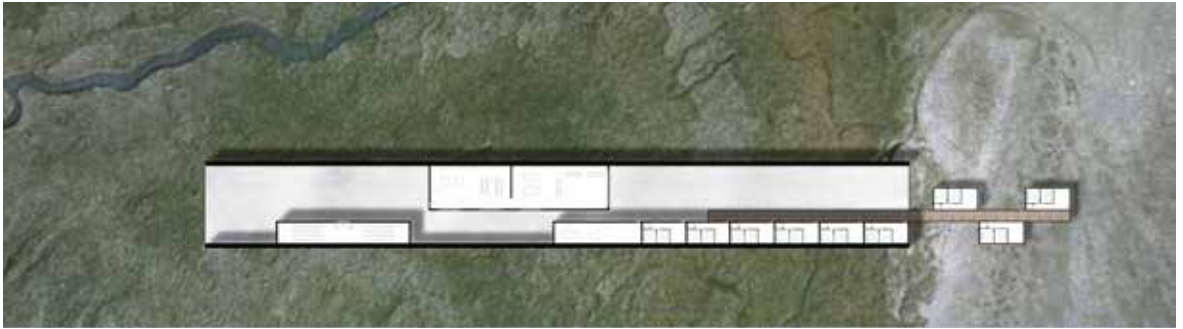
The basic unit would have some vacation houses, some common areas of kitchen and living room and a storage room in which the wooden houses would be stored during winter. A clear axis is open through the unit, from nature to nature and people can have a framed view towards the dam.

Every unit could be transformed differently by the people who will spend their vacations there, so different possible units are showed. They could place wooden pergolas, tents and wooden houses inside or outside the unit.

As can be seen from the drawings nature could infiltrate inside and since the micro climate would be different from the surrounding landscape (providing shelter from wind), different type of vegetation might grow.



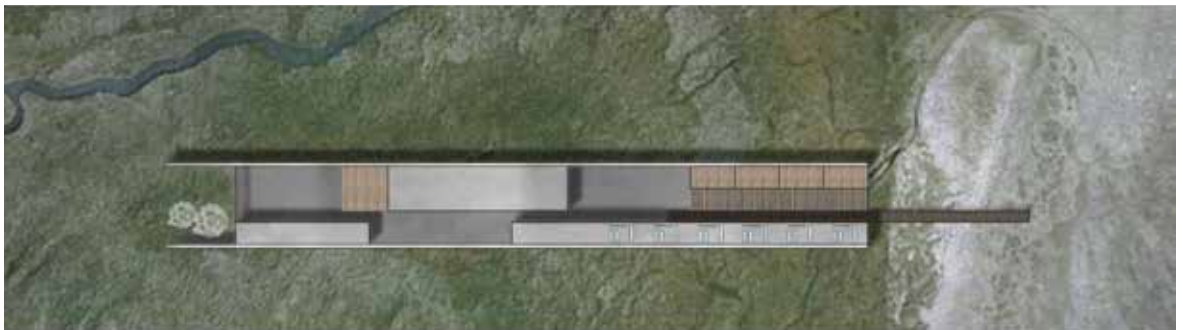
section



basic unit



possibility 1



possibility 2



possibility 2

3. Research by design





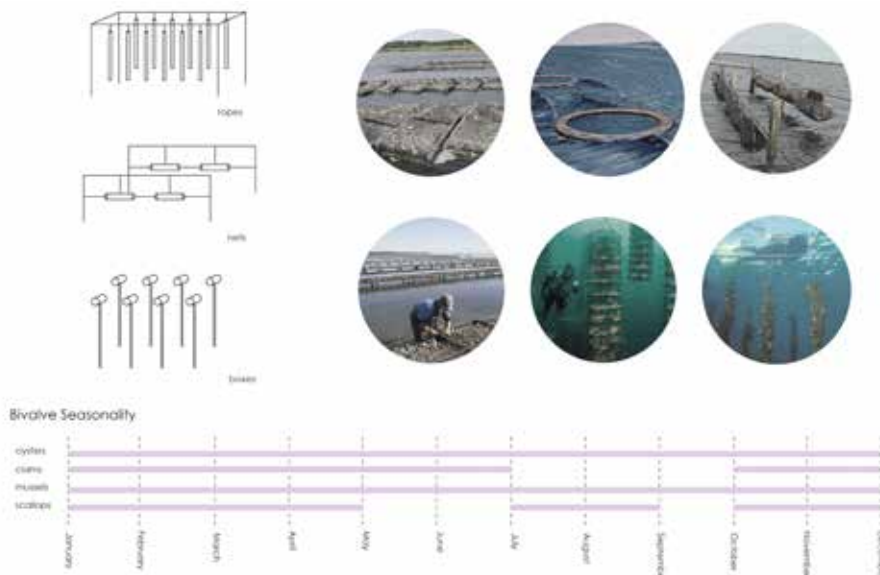
3.6 Dam

bivalve production

In order to include the production of oysters and mussels in the design a research on this kind of cultures was needed. The research have showed that bivalve habitats support over three hundred species of commercial value and there are various methods and armatures used to establish bivalve habitat. Also, after a visit to the village of Yerseke, we were able to experience and understand deeper the procedure that is needed for mussels and oysters production.

In conclusion, in the specific design, rope agriculture would be developed for the production of mussels. The mussel's seeds could be taken from the Wadden Sea and brought to the area to grow. In relation to the oysters, the seeds would be taken from plots of the government in the Oosterschelde and brought to the area to grow and then placed in the pools to be purified.

It is worth mentioning, that people will have the opportunity to understand the procedure that is needed for this aqua-agriculture in a show room that is designed to make them more familiar with mussels and oysters.



Oysters reproduce in the summer months.

The larvae go to the bottom and search for something to attach themselves to. Ships have to spread empty mussel shells.

Ships do small circles to spread them evenly to the plot, to create a bed of mussel shells. A lot of oysters will attach themselves to the mussel shells.

One year later all the mussel shells with tiny oysters are brought out of the water and redistributed in a different plot. By doing that, mussel shells break apart, creating more room for oysters to grow.

After 3 years, the oysters are big enough for consumption.

Oysters are brought in Yerseke. They are full of sand. They put the oysters in oyster wells where the oysters perch themselves in a week.

Once they have been purified, they are removed from the pools and cleaned on at a time. After they are sorted by weight and return to the pools to recuperate.

The oyster wells are cleaned daily with the help of tidal cycles. When the tide goes out the sluice gates are open. In that way the sand that has been removed from the oysters get out. When the tide comes back, the oyster wells are full back again with water.



European flat oyster



Pacific oyster



Mussels produce eggs in the spring

In the water look for something to attach themselves to.

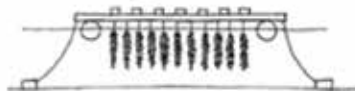
Grow to 2-3 cm. The ropes are pulled out of the water.

Seed is removed and planted to grow into market size.

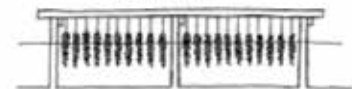
Plant mussels on plots that they can grow further.



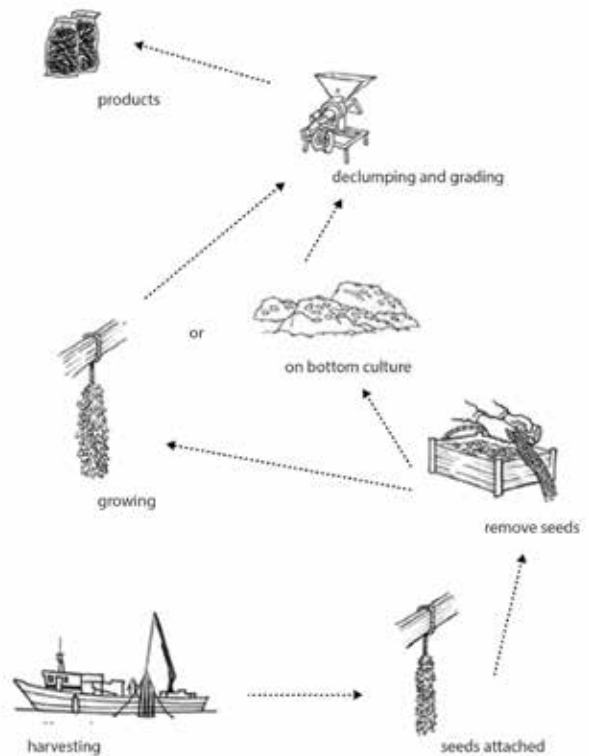
Longline culture



Raft culture



Rack culture



design concept

In this graduation project the partial opening of the dam is proposed. The opening of the dam should be considered as a really slow process which would be monitored in relation to how the natural system is changing because of this intervention. Also, the dam is transformed to operate and contribute in the whole region. However, since the Haringvlietdam as the constructed dam of 1970 is a national monument, the transformation does not include the building structure but the surrounding area which will be transformed to facilitate energy production from wind and tide and also mussel and oyster production. For this reason a line of mussel production is designed vertical to the dam and an oyster production unit is placed on the left side of the dam. On the river side, some buildings are integrated in the dam and placed inside. The buildings will include a show room where people can see and understand how mussels and oysters are produced, an underwater space that people could see the mussel ropes, a restaurant and an underground tunnel that leads to the other side of the dam where people have a view of the islands. The experience of the dam is designed with walk paths and a bike path from the one side of the dam to the other, while finding some interventions during the routes. For example on the centre of the dam, a viewpoint is designed, that frame the view towards the islands and the landmark tower.

In the proposed design, the character of the dam is staying the same while trying to emphasize it. The side towards the river is more green and natural and every intervention is integrated in the surroundings. The side towards the sea has a more tough view since protection is needed in that side. This characteristic is emphasized with some elements.



underwater space



underground tunnel

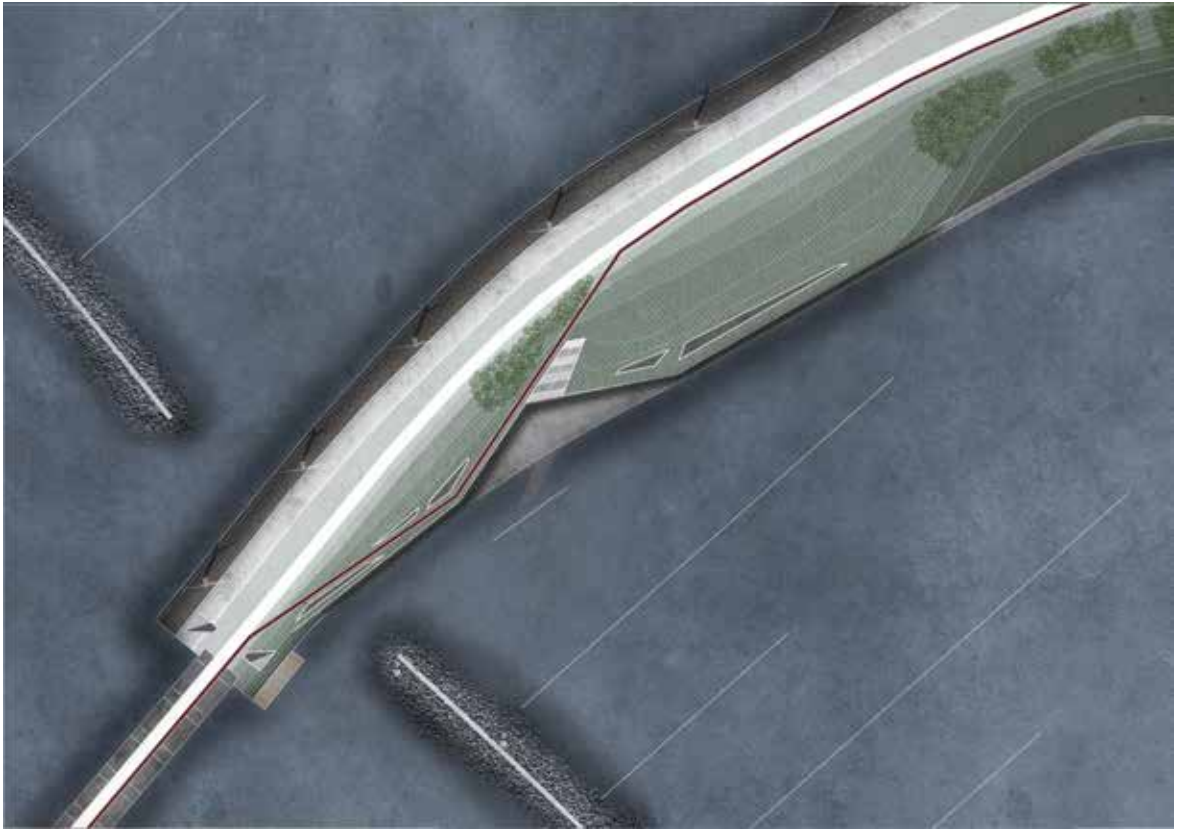


main viewpoint on dam

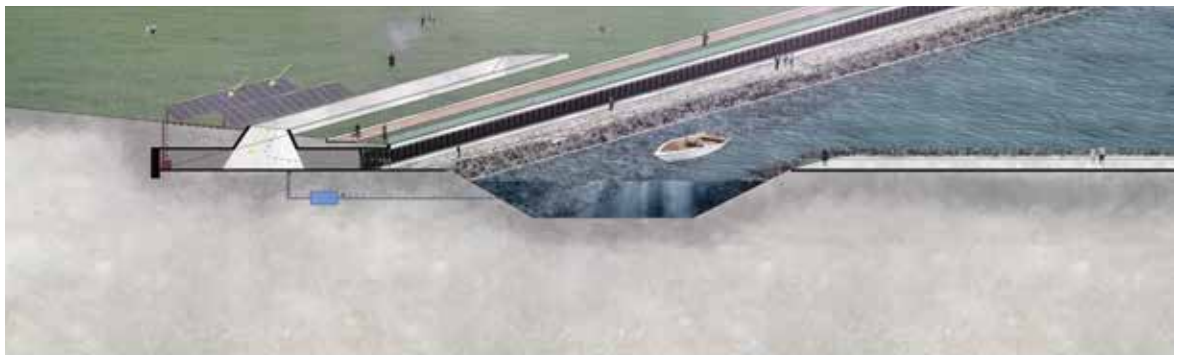


building integrated in the dam

3. Research by design

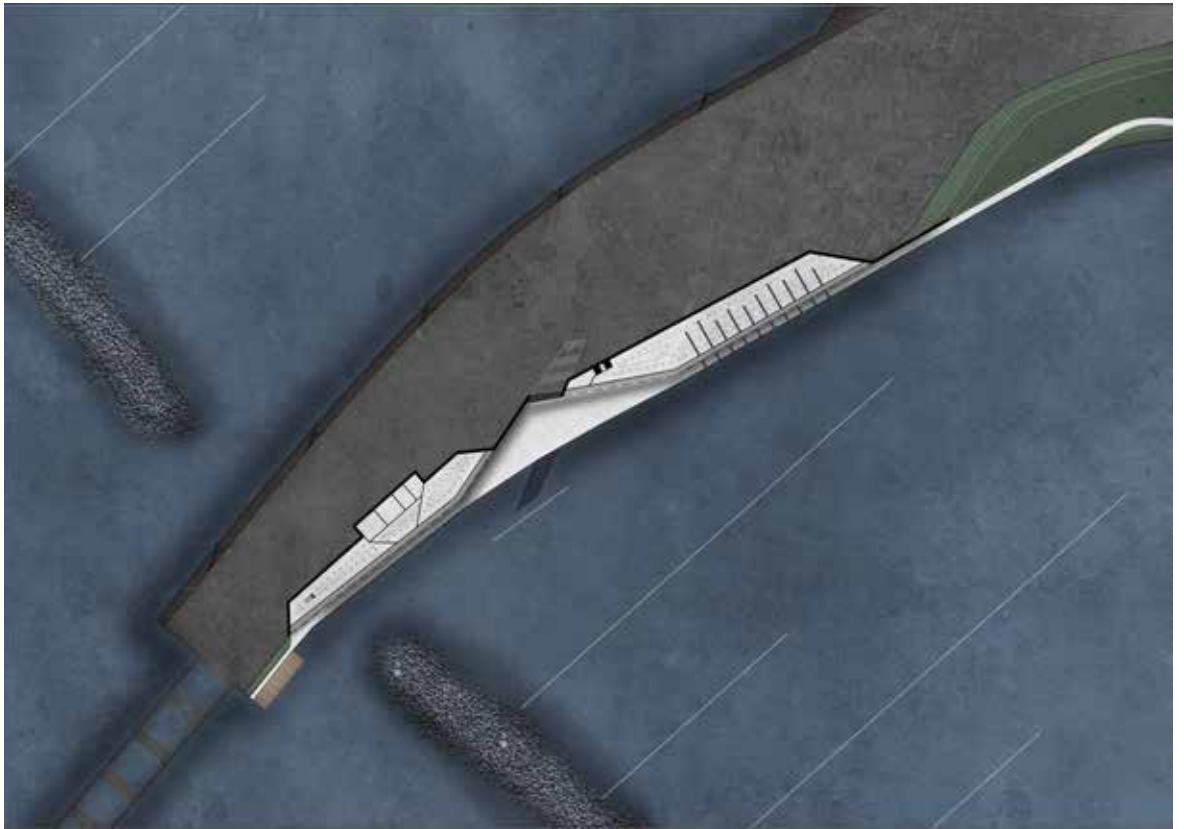


zoom in : dam



Section of building :

Self-sufficient building using solar panels for energy, skylights for natural light and fresh air and water filters. Since is placed underground, the building has stable temperature.



plan of integrated buildings



view of the dam - looking from inside the river

materialization

As was mentioned before, some buildings were integrated inside the dam. For these buildings a catalogue of possible materials that could be used is created. Concrete, gravel, rocks and bricks are some of the materials that could be used for the construction of the building in a combination. Moreover, the concept about the materialization of these buildings is to use things that can be found in the area to enhance the character of the building and have a stronger connection with the surrounding landscape. Some things that could be used are sea weed, mussel's shells, vegetation and sand. For example, mussel's shells or sand could be placed in concrete or other cast material and give a unique texture inside the buildings. Also, sea weed or other type of vegetation could be placed on the mould so that the texture of this vegetation appear on the cast material.

From the catalogue some materials were picked and are showed in the perspectives of the buildings as possible materialization of the buildings. Of course the catalogue offers multiple other possibilities.





Bricks, stones, gravel and concrete could be used for the construction of the buildings.



wooden planks

However, other type of things could be also used in combination with cast materials to create more interesting textures that are highly related with the specific area.



sea weed



sand



mussels shells



other type of vegetation that could be found in the area

3. Research by design





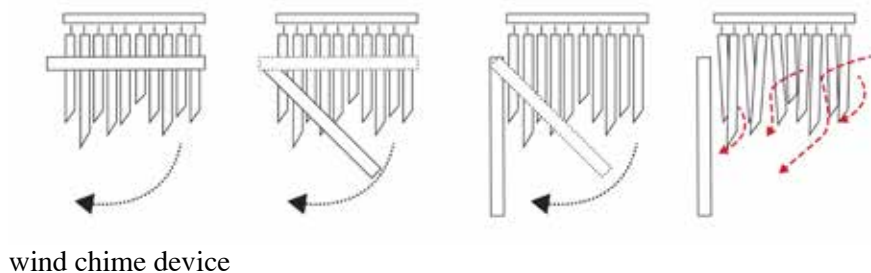
3.7 Perceiving the change

opening of the gates

Since the slow transformation is the key of this graduation project and part of this transformation is the opening of the gates of Haringvlietdam, it is significant that people are aware of the opening of the gates. More precisely, people should be able to understand how many gates are open at any time, day or night, while passing with their car, bike or by foot. From the perspective of a driver, this would be done by the interruption of the radio signal of the car every time the car passes from an open gate. From the perspective of the bike user and the pedestrians, sound will be used. More precisely, when a gate is open, a wind chime will be released, and due to the wind, sound will be produced.

Moreover, during night, lighting will be used to indicate which gates are open and in which direction the tide is going at the moment. So pedestrians, bike users and drivers can understand if the tide is going inside or out in that particular time.

In conclusion, in the project an effort is being made for people to be part of the transformation of the area and to be aware of the natural processes involved in the transition.









4. Epilogue

4.1 Reflection 90

4.2 Bibliography 95



4.1 Reflection

*relationship between the theme of the graduation
studio and graduation project*

The graduation studio of landscape architecture has established the concept of Flowscapes. "Flowscapes explores infrastructure as a type of landscape and landscape as a type of infrastructure. The hybridisation of the two concepts seeks to redefine infrastructure beyond its strictly utilitarian definition, while allowing spatial design to gain operative force in territorial transformation processes" (Nijhuis, 2015). As it is suggested, "when conceiving landscape as infrastructure, landscape is treated as an operative field that defines and sustains the urban development and ecological and economic processes are employed as formative design tools". On the other hand, "considering infrastructure as landscape, the infrastructure is treated as an interdisciplinary landscape design brief with emphasis on the scapes" (Nijhuis and Jauslin, 2015).

In this specific graduation project this concept of Flowscapes is adopted since an infrastructure (dam) is considered a landscape and landscape (islands) is considered as infrastructure. The dam and the islands are transformed in operative landscape infrastructures that include spatial, ecological, technical and social perspectives. This operative field is based on using the natural processes on the one hand, and on the other using spatial and architectonic interventions. In other words, the project presents a slow territorial transformation process for the whole region but at the same time a design with emphasis on the space and the experience. The network that is created is related to ecology, safety, climate change, tourism, housing and energy production.

*relationship between the project and the wider
social context*

In the past, the protection of coastal landscapes from flooding disasters was approached only by engineering perspective with not significant concern for the consequences on ecology. Infrastructures were build whereby the environment has been denied its natural dynamism and resulted controlled and static systems.

In Netherlands, the creation of such infrastructures transformed the Southwest Delta to an industrialized, wealthy and integrated part of the nation, with intensive agriculture which benefited significantly from the fresh water basin. However, the damming of the estuaries had dramatic impacts on ecosystems which became an issue of public and political concern. Along with the repair of the estuaries as a matter of attention, a new philosophy was introduced, called 'Building with nature', which proposes to compensate for lost nature by creating new nature. The new inspired mind set of building with nature is showing new original ways to deal with coastal defence using the natural processes and dynamics. In the project, the civil engineering structure of Haringvlietdam, is considered important for the safety of the Southwest Delta. It is transformed in an operative landscape infrastructure with spatial quality, functions and bivalve and energy production. In this way, it will be visited and appreciated from the people not only as a national monument that already is but also as an important part of the landscape that contributes constantly to their safety, economy and society. Additionally, the islands are designed with the principles of building with nature, in which people intervene and create the general conditions and let nature do the rest.

In my opinion, both civil engineer and building with nature are necessary and the challenge is to find a way to incorporate landscape architecture and ecological services in coastal protection. In the specific project, a balance solution towards coastal defence is emphasized using these two different approaches, showing new insights and contributes in the subject of adaptive coastal defence.

method, possible application and ethical dilemmas

It could be argued that the chosen methodology could be considered to have strong and weak sides. The research on understanding the different dynamics (fast and slow) and processes (anthropogenic, biotic and abiotic) in the area, provided design tools and principles for the design. In this respect, the research and the design were highly interrelated and the design was based on evidence and logical arguments that were concluded from the research. Taking this into account, the chosen methodology provided the necessary supplies to be able to link the research and the design. However, while working with these dynamics and processes difficulties occurred, especially due to the relation of this field to coastal engineering. For this reason some meeting with Civil engineers and coastal engineers were necessary, since the literature study was not enough to grasp all the aspects of the coastal complicated system. Moreover, the data collection related to natural processes of erosion, sedimentation and the tidal velocity was hard to find, especially data about the existing situation of 2016. However, this problem was also solved through the meeting with Civil engineers which were doing research on the specific area.

The graduation project shows an ambitious design of the slow transformation of the Haringvlietdam along with the creation of barrier islands for protection. This intervention could be consider as a huge change in a very complicated system. Every intervention changes the natural system which tends to find an equilibrium and adapt to the new situation. The application of this project in practice is considered feasible after a discussion with a civil engineer (with specialization to coastal engineering). However, it is important to mention that this kind of huge interventions would have a really high cost. Of course, a further and deep study must be done by experts which will calculate all the parameters in order to make the application possible. Moreover, the most significant aspect of this graduation project is the proposed monitoring in relation to what happens to the natural system after the intervention.

With a major percentage of the world's population centres in vulnerable delta areas, the field of coastal defence is a very important subject that has to phase extraordinary challenges. Especially, with the effects of climate change and sea level rise. This give us the opportunity to generalize the results of this

graduation project since this discussion can give clues about the academic research related to this topic but also the spatial design of delta areas in the future.

It could be suggested, that the specific graduation project defined a spatial framework in which a robust and adaptive system was developed with regard to flood defence, climate change, as well as environmental qualities, tourism, economic development and energy production. Due to this, it could work as precedents in other delta landscapes with similar conditions. Additionally, around the world numerous civil engineer structures, dams, dikes and infrastructures exists which could be considered as mono-functional technical solutions. The project showed that landscape could be considered as infrastructures and infrastructures as landscapes. More precisely, the infrastructure (Haringvlietdam) was understood as part of the landscape which was designed and transformed in order to serve on the region with bivalve production, energy production, spatial quality and a unique experience. Concerning the design of the islands, the approach of building with nature could offer a new way of creating new landscapes while using the natural processes of tide, waves, wind and sedimentation.

Ethical issues and dilemmas

A significant moral issue was involved in the research from the beginning of the graduation project concerning the opening of the dam. Taking a decision about whether the dam could be opened or not is a subject of public discussion and debate.

This issue includes many aspects, firstly the safety of people living in the area, the farmers and their need of fresh water for their agriculture, the constantly decreasing water quality of the river basin and the loss of a significant percentage of ecosystems due to the disconnection of salty and fresh water. In order to solve this moral issue creativity is necessary and the ability to think original ways of dealing with such complex subjects. For instance, the slow

transformation of the area will allow both the people and the natural system to adapt to the changes. Also, monitoring the transformation in a way that after each intervention, a study in the natural system will determine whether the project should continue as was initially designed or changes must be made due to the complexity and unpredictability of the natural system.

The specific issue could be seen from different viewpoints. Ecologists could argue that repairing the estuarine nature in the whole delta is a central matter of attention, as was already mentioned by World Wildlife Fund. In contrast, engineers have always as priority the safety of people instead of the ecosystems. Moreover, concerning the farmers and the agriculture, the opening of the dam will mean a big change to the production. In my opinion, this is a multifaceted issue in which every viewpoint has right arguments. But such issues could not be solved using one specific perspective but using multidisciplinary criteria and actors.

For this reason, in my project both safety and ecological systems are important. The opening of the dam should be considered a slow process that would be monitored in relation to the consequences on the natural system. In this way, the opening of the dam will initially start with a really small opening, and as the time passes the experts would be able to understand if and when the opening will become a bit bigger. Obviously, at any time the system is not safe for the people staying at the area, the dam will be able to close again. Finally, this kind of solutions could not only contribute to a balance and adaptive system that people and ecosystems are both considered important, but also to a one to one laboratory to conduct scientific research about natural processes, sea conditions, bathymetry, wave and current measurements and ecology.

4.2 Bibliography

- Borsje B., Wesenbeeck B., Dekker F., Paalvast P., Bouma T., Katwijk M. , Vries M. (2010) Ecological Engineering. How ecological engineering can serve in coastal protection. Volume 37, Issue 2, p. 113 122 Elsevier
- Brand N., Kersten I., Remon P., Warmerdam M. (2014) Research by Design on the Dutch Coastline: Bridging Flood Control and Spatial Quality, Built Environment, Volume 40, Number 2, Spring 2014, pp. 265-280 Alexandrine Press
- Amkreutz Luc W.S.W. (2013) Persistent Traditions: A long-term perspective on communities in the process of Neolithisation in the Lower Rhine Area (5500-2500 cal BC), Sidestone Press: Leiden p. 272
- Meyer, H. and Nijhuis S. (2016) Designing for Different Dynamics: The Search for a New Practice of Planning and Design in the Dutch Delta
- H.S. Sharma and P.R. Binda (2007) Modeling In Resource Management And Environment Through Geomatics Concept Publishing Company
- Meyer H., Bregt A., Dammers E., Edelenbo J. (2015) New perspectives on urbanizing deltas: a complex adaptive systems approach to planning and design, MUST Publishers.
- Meyer, H. and Nijhuis S. (2014) Urbanized deltas in transition, Jap Sam Books
- Meyer H., Bobbink I. and Nijhuis S. (2010) Delta Urbanism. The Netherlands, American Planning Association: USA
- Nijhuis S. (2013) Principles of Landscape Architecture , in: E. Farini and S. Nijhuis (eds.) Flowscapes. Exploring landscape infrastructures. Universidad Francisco De Vitoria: Madrid

- Nijhuis S. and Jauslin D. (2015) Urban landscape infrastructures. Designing operative landscape structures for the built environment. Research In Urbanism Series
- Nijhuis S., Jauslin D. and Van Der Hoven F. (2015) Flowscapes: Designing infrastructure as landscape. Research In Urbanism Series, Vol.3
- Vried H. and Koningsveld M. (2010) Building with nature, Ecoshape: Netherlands
- Bird E. C. F. (2008) Coastal geomorphology : an introduction, Second edition, John Wiley & Sons: Englands
- Winter R. (2008) Exploratory Research into the Maintenance of the Slijkgat: An Analysis of the morphology of the Haringvliet, Deltares: Netherlands
- Carlozzi C., King K. and Newbold W. F. (1975) Ecosystems and resources of the Massachusetts coast Massachusetts Coastal Zone Management: Boston
- Zonneveld, I.S. (1979) Land Evaluation and Land(scape) Science. ITC Textbook VII.4 (2nd ed.), ITC Enschede

