— Master thesis —

FROUKJE OTTEMA

BETWEEN LAND & SEA

Building with nature to sustain, secure and live on a sustainable Schouwen-Duiveland.

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Between Land & Sea

Froukje Ottema

Metropolitan Ecologies of Places Series

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PROLOGUE

PARADIGM SHIFT

WORKING WITH NATURE INSTEAD OF AGAINST IT

The southwest delta has brought unprecedented prosperity. This is the result of the natural advantages of a delta: fertile soils, transport connections between sea and the hinterland and sufficient water. Besides the financial-economical value of the delta, it is also rich in natural capital. The value of natural capital is overlooked most of the time, but it's directly and indirectly contributing to human-well-being. (Vlieger, 2017)

Deltas all over the world are facing an extraordinary range of problems, the further we move into the twenty century the clearer it becomes. The pressure of climate change, rising sea levels, growing demands on limited freshwater supplies and increasing extreme weather are exposing the limitations of the make-ability of the world. (Meyer, 2014)

It will also require a different mindset: if we want to stay living in our beautiful landscapes, we need to work for it. And preferably do so together with nature, instead of against the grain of nature. This is not necessarily something new, as the inhabiting of land in the delta was never an easy job. All who lived here had to deal with water one way or another. Centuries of engineering made this land as it is today. But what people tend to forget is that not only men made this land liveable. The 'dance between sea and rivers' created the base of the land. In this process of land formation, water is the element that gives the power to this process. It has the power to take, but also to give. Sediment travels the rivers and sea, to settle where both meets, in the delta. But this natural process is pushed more and more out of the landscape. Step by step the delta has been made 'hard' and engineered. And the water is often pushed away to the borders of the water catchment areas. This way of dealing with the land makes us vulnerable for climate change: it gives little room for fluctuations and the landscape doesn't have room to adapt to changes. You could say, we locked ourselves in.

There is a need to find a middle ground, a sweet spot where there is a balance between the natural process and the liveability of the landscape. Where the people are part of the delta and therefore can jointly flourish.

To make the delta more climate adaptive, the natural layer must be leading.

MOTIVATION

When I was 3 years old, we moved to the island of Schouwen-Duiveland. The former windmill that was built in 1724 in Brouwershaven became my new home. I've had a wonderful childhood. The landscape was full of adventures as we could play outside all day long.

Due to all the storms I have been in, I learned to understand the power of nature. When the wind is in your face and you're standing in the vast landscape of water and land it makes you feel fragile, humble and it makes your own problems become small in comparison. At the same time, I learned the power of working with nature. For instance, when I was sailing with my father and little brother on the North Sea, it was wild. Up to 6 meter high waves were pushing us forward, the wind in our sails gave us power in the water to steer. As we worked with natural forces and didn't fight it but found our place, 'riding this storm', we made it home. What came to me is, that if you give space and acceptance to the forces of nature, there is a sweet spot where you can make use of these extreme forces.

So, as I grew up on the island of Schouwen-Duiveland, I have always had this respect and understanding for natural forces and what you can do with it.

When I came to the university and learned about the impacts of climate change, I was always drawn to the upcoming issue of sea level rise. I know what water can do, and how vulnerable we are. You could say, we tamed the sea, resisted it, set it to our hand, pushed it back in a box just big enough to control.

But in the future, due to climate change, this box won't be big enough. So, we need to start thinking on how we can deal with the system we created, while at the same time cope with the required additional space resilience of the system requests. How can we live more in balance with water? How can we keep living on in the delta while giving space to nature?

My motivation for writing this thesis is a result of the pressure our near future gives us and the need to do things differently this time. I want to explore if there is a way where the delta becomes more open and dynamic, and therefore more adaptive, while we will still be able to stay living, working, and recreating in it.

(Storm on North Sea, n.d.)

(Rijkswaterstaat, n.d)

Figure 1: Author + (Euratlas-Nüssli, 2023)

CONTEXT

The Netherlands is to a large extent a Delta: almost 2/3 of the country can be considered part of the North-western European delta. Two major rivers find their way to the sea in this delta. The IJssel-Vecht and the Rhine/Meuse. The IJssel-Vecht delta is located in northern part of the Netherlands and enters the IJsselmeer, the largest, sweet water reserve of the country, in the northern part of the province Overijssel. The Meuse and Rhine meet the sea in the south-west of the Netherlands. This so-called Southwest delta is the biggest and the economical largest of the two. This thesis will focus on this Meuse-Rhine delta also known as the Southwestern delta.

The delta is traditionally a dynamic landscape where the land is subjected to tides, wind, and currents. In the last centuries however, man has dominated more and more, taken over control and in-habituated this landscape, which made the delta less dynamic and adaptive over the years. This could also happen as technological prosperity made us less dependent from spatial restrictions of soil and water. The dynamic landscape is mechanically controlled with dikes, dams, sluices, and pumps. These highlights of water engineering make the Netherlands considered a pioneer in water management and flood protection.

The control over the delta happened gradually overtime. Bit by bit the foreshore areas were claimed. Dikes were built around so the land wouldn't flood with every high tide anymore. But the consequences of this is that the sedimentation of the land stops as well. The tides brought sand and clay on the land and therefore the land was higher than the sea level. In figure 1 the transformation of the delta through the years is shown. The reclaimed land has a fertile soil due to sediment from the rivers and is therefore ideal for agriculture.

The delta is always ravaged by floods, time over time a big storm would hit the coast and the dikes would breach. In figure 2 a time line is shown. But the Dutch would always fight back and reclaim the land again. The last major flood was in 1953, 1836 people lost their lives. 160.000 square meters of land was submerged. 50.000 animals of the live stocks drowned. There was 1,5 – 2,0 billion guilders economic damage. Half of the 1100 km of dike were damaged and 30.000 houses and farms. The tragedy of this flood is that the storm surge commission had warned for the conditions of the dikes but priority laid with the post-World War II reconstruction. (Steenhuis, 2016)

After the flood the delta commission was installed. This public authority had as goal to ensure the water safety of the delta with as secondary goal combating salinization. To ensure the safety, the delta commission had two options; to strengthen all the primary dikes or to shorten the coastline. By shortening the coastline less dikes had to be strengthened. The Netherlands faced a historical choice, shortening was chosen. Only the Western Scheldt and the Nieuwe Waterweg would stay open. But social perceptions changed and in the eighties, ecological importance gained momentum. Serious environmental scandals and political acclaim in the form of the Club of Rome triggered a change of mind of the general public. After resistance and protest a compromise had been reached, the Eastern Scheldt dam would be built semi open. On the completion of the Eastern Scheldt barrier the former queen of the Netherlands, Beatrix spoke the famous words, the flood barrier is closed, the Delta works are completed, Zeeland is safe.

But now due to climate change and rising sea levels there is a new challenge for the Delta. The delta works were supposed to keep people safe forever and therefore it is hard for people to imagine danger from the sea again. (Steenhuis, 2016)

Seth Godin says in the pre face of the book 'De Klimaat Almanak': 'Over the past hundred years, we have extracted almost free energy from the ground in the form of cheap fuel. We have used this to build the world around us. We have created amazing things, but also wasted a lot, polluted and made a mess of it.'

On the 12th of December 2014 the Paris agreement was presented in Paris. 195 countries signed the agreement. The average global temperature rise should remain well below two degrees, with a target of 1,5 degrees. (NEA Nederlandse Emissieautoriteit, n.d.) But now, 9 years after the Paris agreement, the feasibility to keep to the agreement is shaky. If the current climate policies continue, the world will have warmed up with 2,8 degrees before the end of the century. (Hoekstra, 2022) That is 1,3 degrees more than the target of 1,5 degrees. This doesn't sound as much but for the climate it is. With a extra 0,5 degrees of warming, there is an additional 10 million persons that are at risk from sea level rise. (Godin et al., 2022) So the urgency to prepare for a significant climate change is more than ever.

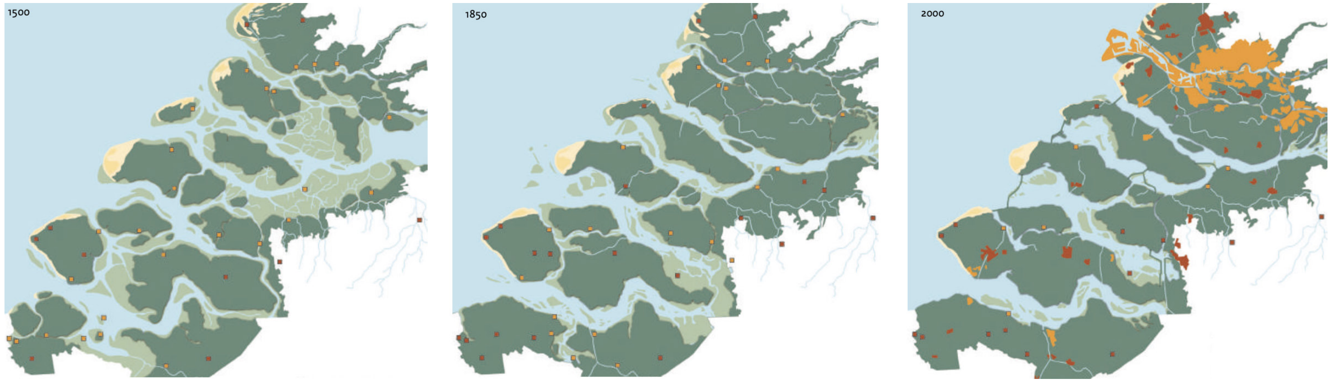


Figure 2: (Kernteam Rijk-regio Gebiedsagenda Zuidwestelijke Delta 2050, 2020)


Figure 3: (Watersnoodramp, 1953)

GRADUATION FRAMEWORK

PROBLEM ANALYSIS

The Southwest Delta is under increasing stress of climate change. The sea is rising faster than originally assumed in the delta program. This increased sea level rise is, among other, linked to recent insights that the ice caps of Antarctica become unstable and possible will break off sooner and melt faster. (Haasnoot, L. Bouwer, et al., 2018) This makes the challenges in the delta even more urgent. Besides climate change, the delta also needs to deal with the challenges of agricultural intensification, urbanisation pressure and recreation pressure.
The delta faces multiple complex challenges, for water and spatial development. These complex challenges are divided into 6 challenges.

1. Sea level rise
2. Wetter soils and larger fluctuations
3. Salinization of the water system
4. Higher frequency of high temperatures and droughts
5. Zandhonger
6. Biodiversity loss

Sea level rise
If the sea level rises the current flood barriers become under pressure, higher sea levels will lead to more frequently closing the open barriers and eventually the flood barriers are not sufficient anymore.
The Eastern Scheldt barrier, considered one of the most prestigious delta works will be insufficient with a sea level rise of more than 50 cm. A sea level rise of 50 cm can already be happing with accelerated sea level rise due to unstable ice plates around 2050. See figure 4. That is in 27 years. By sealing gaps between the sliders and sills the lifetime could be extended with 25 years.
The frequency of closing the Eastern Scheldt barrier influences the water system behind it. The building of the barrier has impact on the ecology and safety of the Eastern Scheldt because of the phenomenon that is called zandhonger Increased frequency of closing the dam increases this process further. (Schengenga et al.) The phenomenon of zandhonger is further explained in the paragraph zandhonger.
The Haringvliet barrier will need changes around 2025, however, afterwards, the expectation is that it can be functional until approximately 2075. (Schengenga et al.)
Suppletion of sand along the coast of the southwest delta makes sure the dunes and coastline are protected for sea level rise. The amount of suppletion will grow significantly. Nowadays 12 million cubic meters each year of sand is supplied over the coastline of the Netherlands to balance out the erosion. The amount of extra sand that is needed is linked to the speed of sea level rise. For example, with a sea level rise of 10 mm/year, 40 million cubic meters of sand is needed to maintain the coastline, so three till four times the amount of today. With an accelerated sea level rise, in 2100 this amount can grow to the extreme amount of 240 million cubic meters a year. The amount of sand present in the Dutch North Sea is enough to maintain the coastline. Three factors to influence availability and usability of the sand are: the quality, the land/sea use of other functions (like wind parks) and the wining depth of the sand. (Haasnoot, Bouwer, et al., 2018)

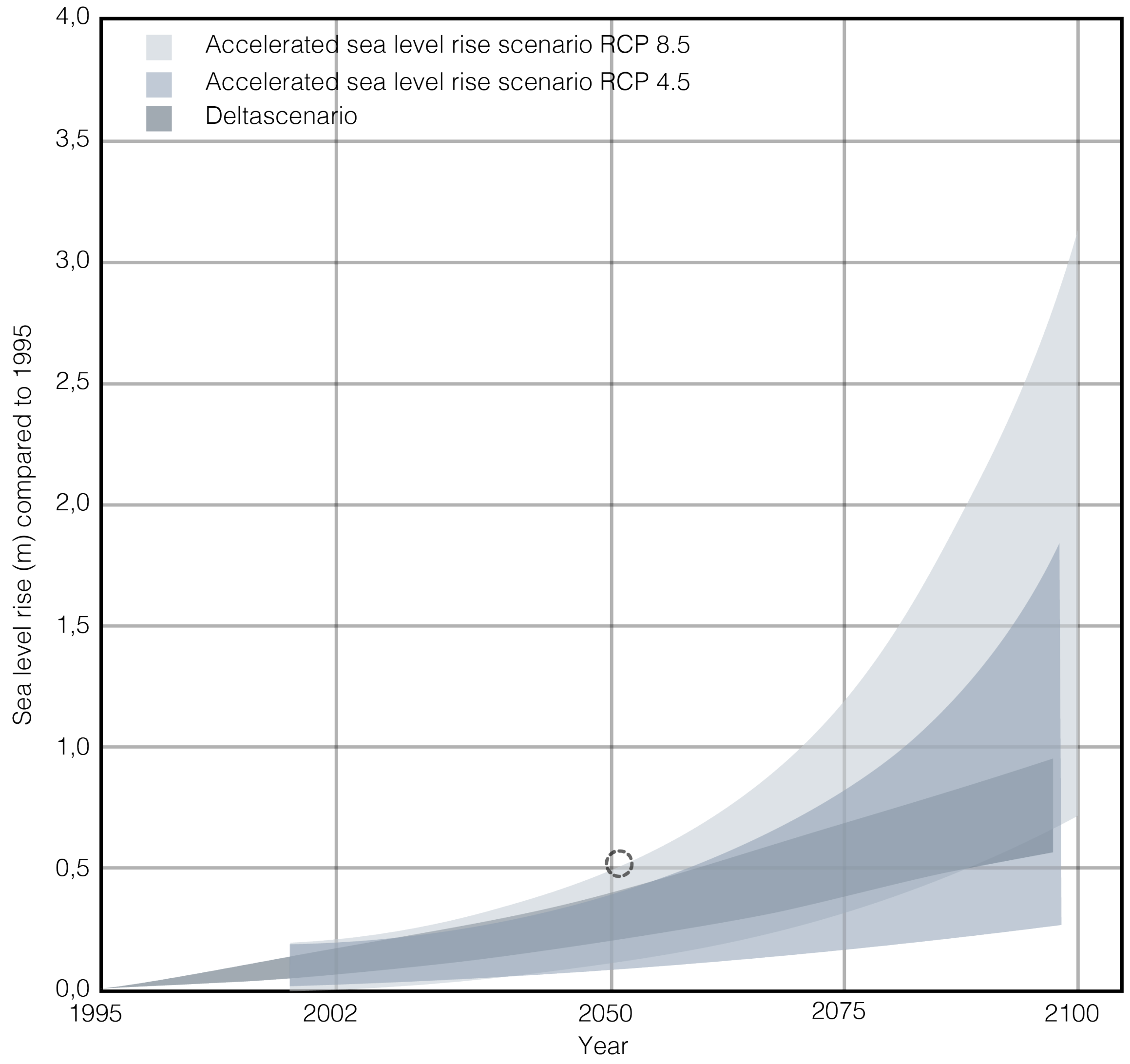


Figure 4: author + (Haasnoot, 2018)

Figure 5: Water logging after long periods of rain on agricultural land on Schouwen-Duiveland, author

Wetter soils and larger fluctuations

Another consequence of climate change is that there will be more extreme rainfall. These extreme events will lead more frequently to water logging as the water storage capacity of the ground isn't high enough. Agriculture will probably more often deal with drowned harvests, while heavy equipment can't be used as much on the lands.

Furthermore, the sea level rise will put pressure on the drainage capacity. When the sea rises the ratio between the water in the polders and the level of sea becomes higher. The same happens for the closed off water basins. Like the Grevelingenmeer, Veerse meer and Volkerak Zoommeer. If the distance rises, the pump capacity needs to rise as well. And where nowadays there is a free flow of water, pumps need to be installed. (Schengenga et al.)

Salinization of the water system

Salinization of the groundwater nowadays already is an existing problem, but will be increasing in the future. The islands of the southwest Delta are depending on the freshwater lenses of rainwater. In wet periods the water lenses are filled up with rainwater in dry periods the lenses become thinner due to evaporation. Due to this greater evaporation overspill, the need for freshwater storage increases in the future, but the possibilities for this are limited in the Southwest delta. Salt seepage will have consequences in the southwest delta. Only a small percentage of extra salt seepage can already have a impact on the availably of freshwater (Schengenga et al.).

The Haringvliet was a saline environment before The Delta Works, but has become a fresh water based environment for agricultural purposes. In 2008 is has been decided that the Haringvliet barrier needs to be opened, because of the negative consequences on the ecosystem behind it. This has lead to a more salt Haringvliet. The agriculture on Goeree Overvlakkee, St. Philipsland, Tholen, Voorne-Putten, Hoekse Waard, West-Brabant and Zuid-Beverland use the fresh water of the Haringvliet and Volkerak-Zoommeer. The salinity levels at the freshwater inlet points are now fixed, but when the Haringvliet becomes saltier this source of freshwater is no longer possible (Schengenga et al.).

Higher frequency of high temperatures and of droughts

Higher temperatures not only have impact on the sea level but they also affect on a regional scale. The most important consequences when it becomes warmer are: a greater chance on lower water levels in rivers, longer periods of drought and increased evaporation rates.

Like explained before most of the islands in the southwest delta are dependent on their rainwater lenses. Nowadays the arability of groundwater is sufficient but in the future the ground water is becoming scarcer. Due to the longer periods of drought, agricultural land needs to be sprinkled more to prevent damage to the crops (Schengenga et al., 2009). Sprinkling with brackish water causes less damage then shortage of water. Widely cultivated arable crops are less sensitive for brackish water then is usually assumed (Stuyt et al., 2006). When the sprinkling with surface water lowers the water levels under the defined summer levels, sprinkling can be forbidden. This ban ensures that irreversible damage is limited (Scheldestromen, 2022).

Fresh water basins are vulnerable to blue-green algae growth. The blue-green algae, which actually are bacteria, flourish in nutrient-rich waters with temperatures between 20-30 degrees. When the bottom of the blue-green algae decomposes, toxins can be released. The toxins in the water makes the water unable as freshwater source (Krimpenerwaard, n.d.).

Zandhonger

The intertidal areas of salt marshes, mud flats and banks are subject to sea level rise. If the sea rises faster than the intertidal areas can grow, they will submerge. The Eastern Scheldt nowadays already has problems with it's intertidal areas because of human intervention like the delta works, widening of shipping routes and reclamation of the land. The system is out of balance. The erosion of intertidal areas is greater than sedimentation. The phenomenon is called zandhonger

The construction of the Eastern Scheldt barrier led to less water flows in and out of the Eastern Scheldt. The tidal channels that are present in the Eastern Scheldt are too wide for the lesser amount of water that is now passing. This results in a slower water flow than before. This slower water flow has not enough power to move sand from the channels on the intertidal areas. But during storms the sand from intertidal areas is washed off and enters the gullies. So, only the deconstructive forces work and the constructive ones don't.

Around 160 million cubic meters sand erodes each year where only 1 million cubic meters of sand is sedimented by the North Sea. This leads to the loss of 43 hectares of intertidal areas each year. To restore the balance 400 till 600 million cubic meters of sand is needed. This amount of sand is infeasibly and prohibitively expensive to bring in.

The intertidal areas are important of the ecological value of the eastern Scheldt and also have a protecting function. The sand bodies work as a wave breaker and therefore the dikes must deal with less force. The consequence of zandhonger is that the dikes need to be reinforced earlier than expected. As a result of sea level rise, the decline of the tidal areas will accelerate.

Figure 6: Satellite image of salt marsh in the Eastern Scheldt near St. Annaland author + (pdok, 2022)

Biodiversity loss

Besides climate change, general consent is that there's also a biodiversity crisis. In the long run, biodiversity is even more important than the climate, as it will disrupt ecosystems and affect all life on earth, and consequently, more importantly (our) food production. There is a need to adapt, to enable living in a changed climate. The biodiversity is highly determinant for our adaptation ability. But the political and social attention is bigger for climate change then for biodiversity loss (Schengenga et al., 2022).

Most of pristine nature has been lost in the Netherlands, as in Europe and globally also a significant decline has taken place. Land use and fragmentation caused a reduction in population size of native species. The loss of area and quality of original nature is in the Netherlands bigger than for Europe and the world. The MSA (relative Mean Species Abundance of originally occurring species) for the Netherlands is 15%. An MSA of 100% would mean a situation with no human intervening. In 2010 the MSA was estimated globally on 70% and for Europe less then 50% remains. The relatively low percentage of the Netherlands is the combined result of the quality of the remaining natural areas and the historical loss of natural areas. In addition, the agricultural intensification and urbanization ensured the decline of the quality of nature in rural areas. By comparison, around 1900 over 40% remained (CBS et al., 2016). in open connection (except the Western Scheldt)

Besides the global importance of biodiversity, the Southwest delta also carries a European and global responsibility for ecological connections. The delta has an important role to connect especially aquatic European ecosystems. (For migratory birds and fish even globally) The transition between land, sea and river is internationally of great importance. The southwest delta is, in terms of habitat, rich in this macro gradients (salt/fresh, land/water, wet/dry). Especially the high dynamic estuarian habitats and the wide wet coastal zones are of great importance, just as the ecological connection between them.

But these habitats are still declining. In total, more than half of the marine species and habitats with a protective status are in unfavourable statues. The estuarian habitats and mudflats even belong to the habitats with the least favourable status of preservation. Before The Delta Works were built, the Southwest delta had five sea inlets (Nieuwe Waterweg, the Haringvliet, the Grevelingen, the Eastern Scheldt and the Western Scheldt). The inlets were characterized by: the tidal dynamics, the gradual transition between sweet and salt and the open connections between the inlets. (Except for the Western Scheldt) The Delta Works compartmentalized these inlets and turned much of these waters into a series of (semi-) enclosed fresh, brackish and salt-water lakes (except the Eastern Scheldt). Due to the compartmentalization the tidal dynamic and the sediment transport have disappeared or been greatly reduced (Kuiper et al., 2013). 33% of the intertidal area has disappeared and the amount of salt marches has declined significantly from 1725 acres to 625 acres (Stuyt et al., 2006).

In the Southwest delta thousands of acres of eelgrass disappeared, destroying practically an entire community. The compartmentalization has led to unsustainable ecosystems with ecological problems. Besides the very limited possibilities for mitigation fish, there are problems in the Volkerak-Zoommeer with blue green algae, the habitats of sandbanks, mudflats and salt marshes are disappearing and the Grevelingen has problems with oxygen shortage in the deeper part (Kuiper et al., 2013). The pressure on nature is expected to increase further the coming decades, due to population growth. The expected growth of the level of prosperity will lead to an increasing pressure on nature from energy, food and urbanization. Also the way we produce food, the intensive agriculture what results in degradation of soils, agricultural toxin use, eutrophication, nitrogen deposits and land subsidence contribute to the increasing pressure on nature (Schengenga et al., 2022).

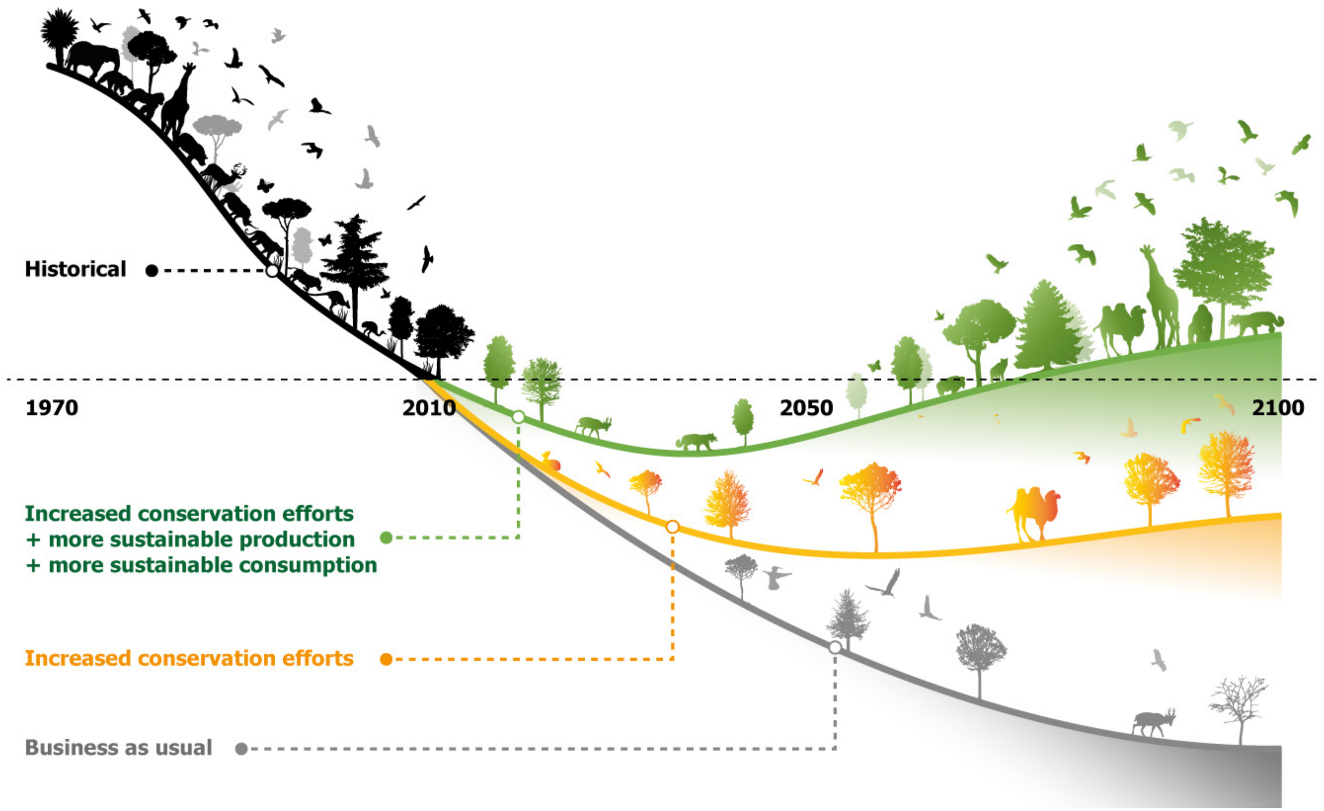


Figure 7: Bending the curve (WUR, 2020)

Figure 8: Overview of the 'inlaag' of the Eastern Scheldt near Moriaanshoofd, Author

Green-Blue networks

The challenges explained in the previous paragraph are all connected to the green-blue infrastructure in the landscape. Green-blue infrastructures are all natural or (semi-natural) landscape elements that form or could form a blue-green network. Green landscape elements are for example, hedges, tree lines, ecological parks, woodlands and natural grasslands. Blue landscape elements are connected to water, like pools, ditches, wadis and channels. (Green4gray, n.d.)

Blue green network planning focuses on using the natural systems when making structural plans. While protecting the ecological and hydrological values. Blue-green networks can facilitate resilient solutions to address climate change and at the same time improve the quality of life. (Mayri et al., 2017) It is also an efficient way to provide habitats for flora and fauna. (European Commission, n.d.)Loss of habitat is directly connected to loss of biodiversity (Jackson et al., 2013) Figure 9 shows the problem field and the correlating connection between the challenges.

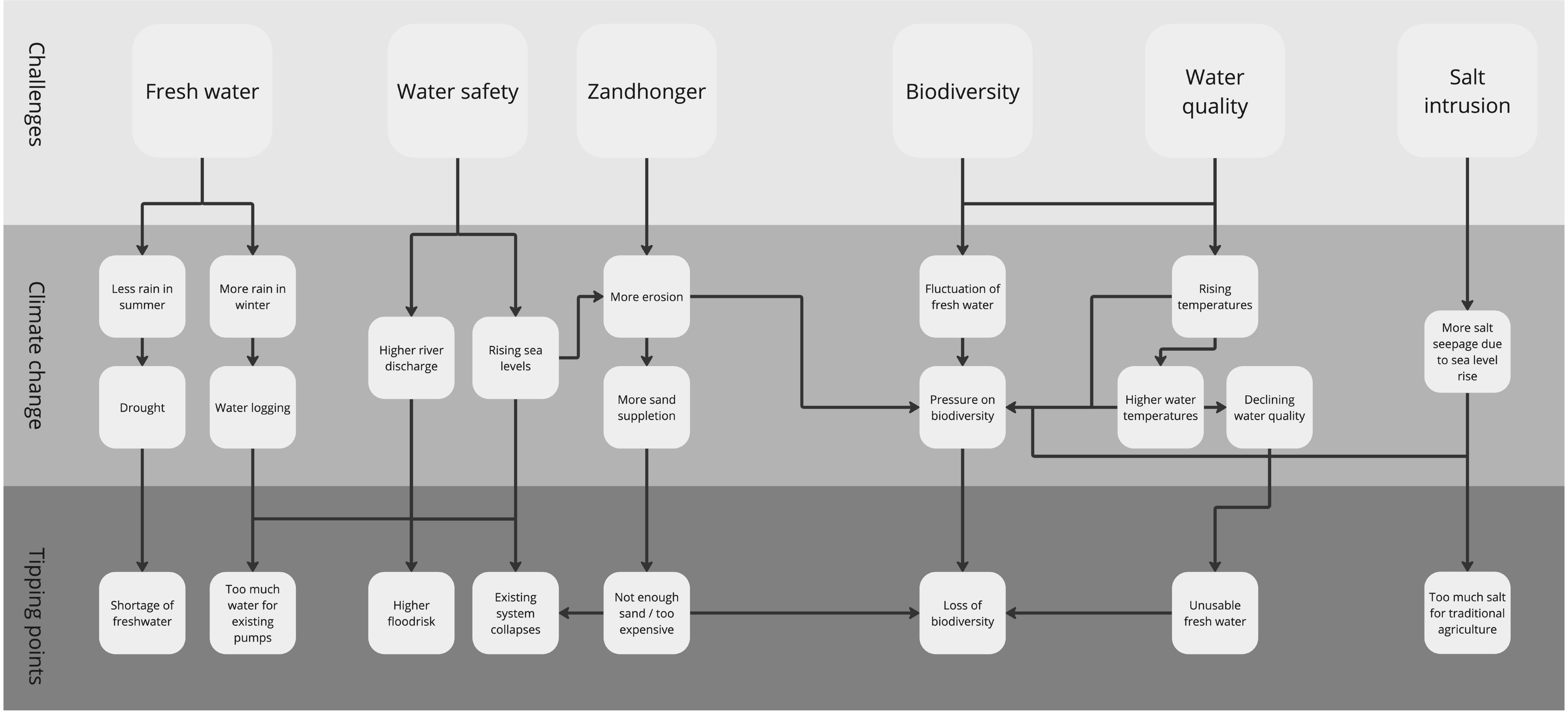


Figure 9: Problem field scheme, author

PROBLEM CONTEXT

The problem analysis led to the problem context listed here below. The problem context is divided in to four categories, Environment, Agriculture, Water safety and Synergies

Environment
1. Poor **water quality** in the Volkerak-Zoommeer due to long-term inputs of nutrient-rich river and agricultural water and insufficient refreshment or flow.
2. Hardly any possibilities for **fish migration** through the delta to the Rhine-Meuse river system.
3. **Nutrient deficiency** in the Eastern Scheldt due to the excess production of shellfish and compartmentalization of the delta which cut of the river flow through the Eastern Scheldt.
4. **Oxygen deficiency** in the stagnant lakes due to the compartmentalization of the delta which has led to less dynamics.
5. Increase **erosion of intertidal areas** due to the delta works and sea level rise.
6. **Decreasing intertidal areas** due to change in the morphological system and in the Western Scheldt due to the **intensive dredging** and deposit policies which led to steeping of the seabed.
7. The lack of **natural dynamics** has led in the Biesbosch to siltation of the creeks because not enough silt being drained to the North Sea.
8. **Increase pressure on nature** due to intensive agriculture and population growth
9. **Sea level rise** will push salt-water further upstream which will have consequences for the **freshwater inlet points**

Agriculture
10. **Availability of the freshwater** supply will be under pressure due to **dryer summers**.
11. Increase **water logging** due to more **extreme rainfall**
12. More **salt seepage** due to **sea level rise**.
13. **Sprinkling** with freshwater is limited.

Water safety
14. **Higher sea levels** and possibly more frequent **extreme river discharges** leads to more pressure on safely discharging of river water.
15. **Sea level rise** will shorten the lifespan of the **delta works**

Synergies
16. **Salt-water intrusion** affects freshwater supply for **agricultural land** while the **nature** needs more tidal- and salt dynamics.
17. The growing **housing demand** puts extra pressure on the current land use, while there is already a need for more **nature** and preservation of **agricultural land.**
18. There is a growing demand of **nature** for **recreational** purpose, but this can have negative effects on the **restoration of nature.**

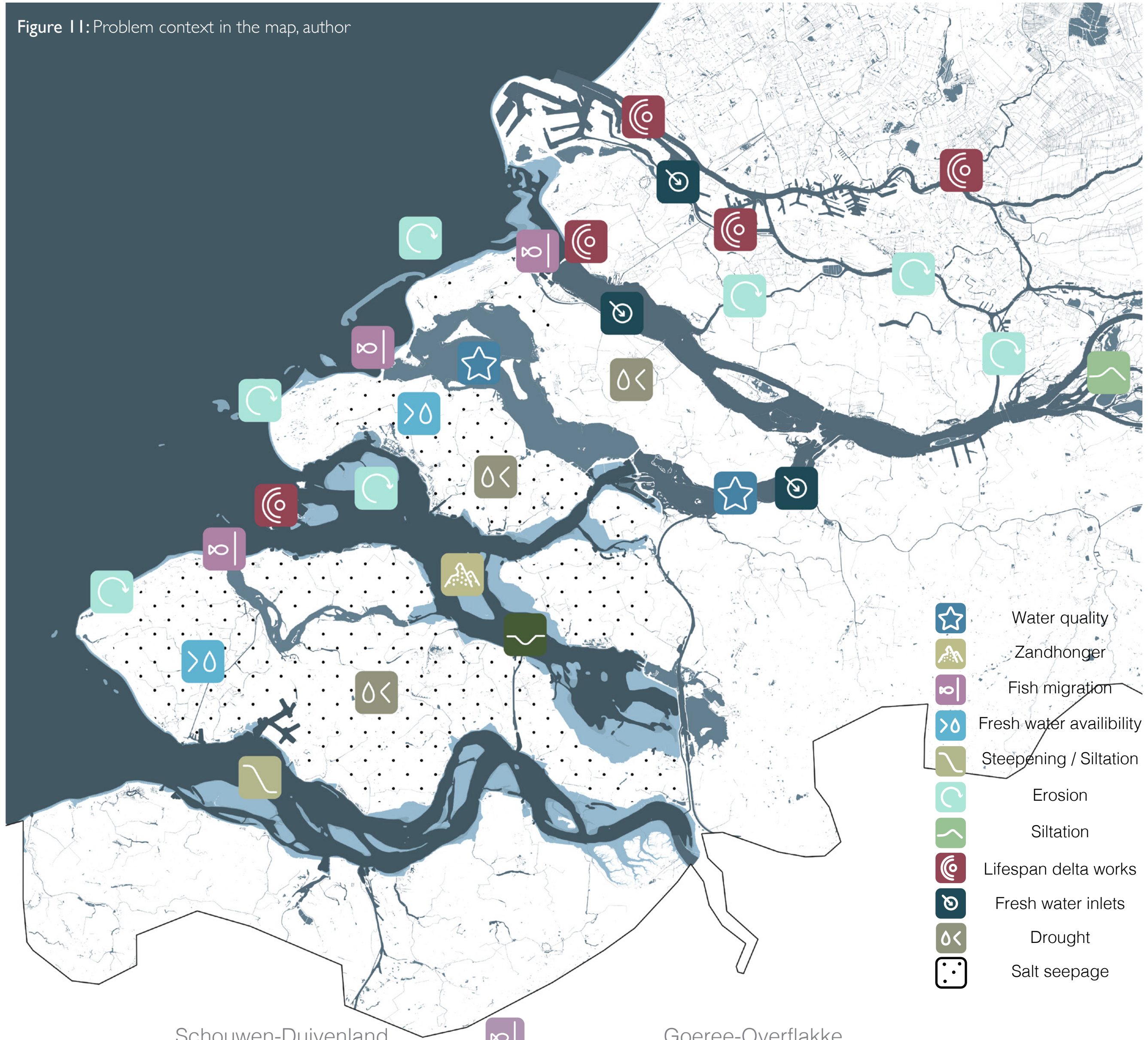


Figure 11: Problem context in the map, author

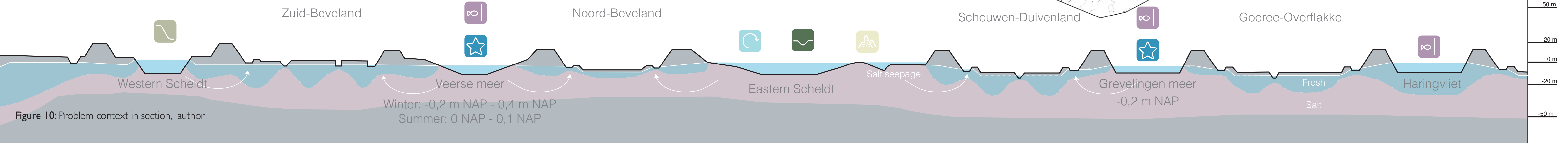


Figure 10: Problem context in section, author

PROBLEM STATEMENT

The Southwest delta is facing environmental and agricultural challenges now and in the future. The question arises whether these challenges should be addressed in a defensive, offensive or BAU (business as usual) way, and whether the concept of a (semi-) open delta would be possible and helpful. By understanding what a (semi-) open delta implies for Schouwen-Duiveland and in particular for the agricultural landscape, the ecology and their carrying green-blue network, the environmental and agricultural challenges can be addressed. While implying a (semi-) open delta the water safety of the society should at all times be guaranteed.
A spatial framework can help to understand the spatial implications of solutions to the multiple challenges and guide the green-blue network and existing living qualities, while adding new qualities.

RESEARCH QUESTIONS

What would the return to a (semi-) open delta mean for the green blue network of Schouwen-Duiveland, and what spatial framework and guiding design principles would be necessary to sustain and upgrade both green blue networks and liveability, now and in the future?

Sub questions

What is a (semi-) open delta approach?
How can a (semi-) open delta solve existing and future challenges?

What are the existing qualities and threats of the green-blue network and the liveability on Schouwen-Duiveland?
How can these qualities be sustained and/or upgraded when returning to a (semi-) open delta?

How can the green blue structures of Schouwen-Duiveland be improved when returning to a (semi-) open delta?
What are the spatial implications when Schouwen-Duiveland is situated in a (semi-) open delta?

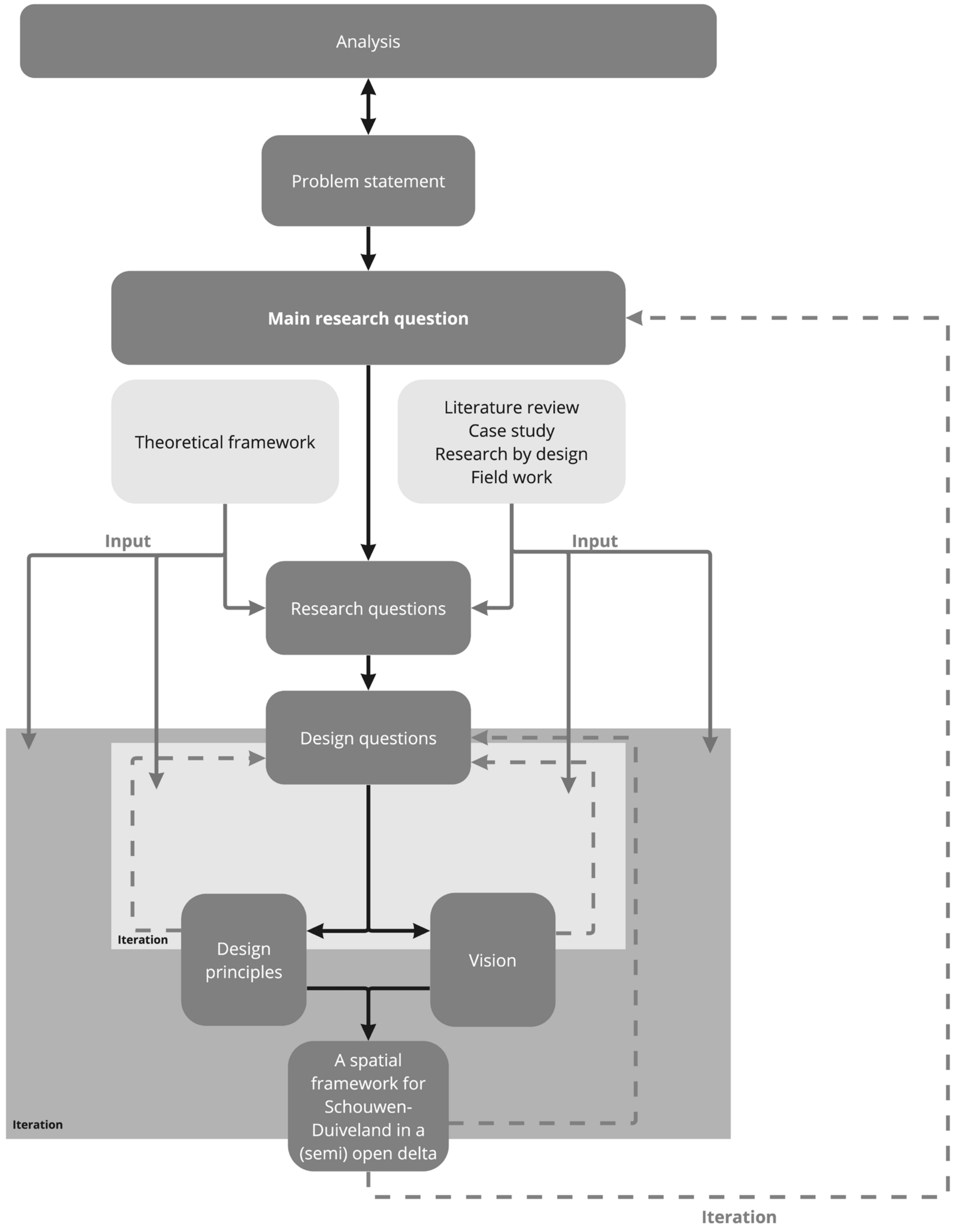


Figure 12: Flow chart of the method, author

METHOD

The method of writing this thesis is explained in the flowchart in figure 12 and can be divided in 3 stages. First the exploration stage, secondly the research stage and thirdly the design stage. In the exploration stage the context is analysed, and the main problems are stated. The problem statement leads to a main research question.
In the second stage the more theoretical research is going to be done. The main research questions has led to seven sub questions. The input for answering these questions are a theoretical framework, literature review, case study, field work and research by design. There are three research questions that are more theoretical orientated and four that are more design orientated. In the flowchart these two categories are called the research questions and the design questions. The research questions give input for the design questions.
In the third stage the design questions are going to be answered. The design questions will lead to design principles and a vision. The design questions aren't going to be answered in one go but have multiple iteration loops. In the flow chart these iterations are visualized with the dotted lines. The vision and the design principles are input for the spatial framework. This spatial framework also has multiple iteration loops. Finally in the last iteration round I will test if this spatial framework gives an answer to the main research question.

AIM OF STUDY

This thesis is focusing on the Southwest delta in the Netherlands. At this scale it largely focuses on the water system and the effect climate changes has on this system, as well as how the Southwest delta as a system can become more biodiverse and adaptive.
Within this larger context, the thesis will zoom in on the most northern island of Zeeland, Schouwen-Duiveland. At this scale the aim is to look for potential solutions to adapt to climate change while at the same time supporting biodiversity and ecology in particular. But also, the combination with human settlements and activities, so humankind is part of the ecosystem instead of consumer; to work with nature instead of against it.
Overall, this thesis investigates and designs on how to live safely in the delta while promoting the ecological value of the estuarian. Therefore this thesis combines design/planning and environmental/technology and ecology orientated focus and development strategies.

Figure 13: Overview map of the waterways and bodies of the Netherlands, author + (pdok, 2022b)

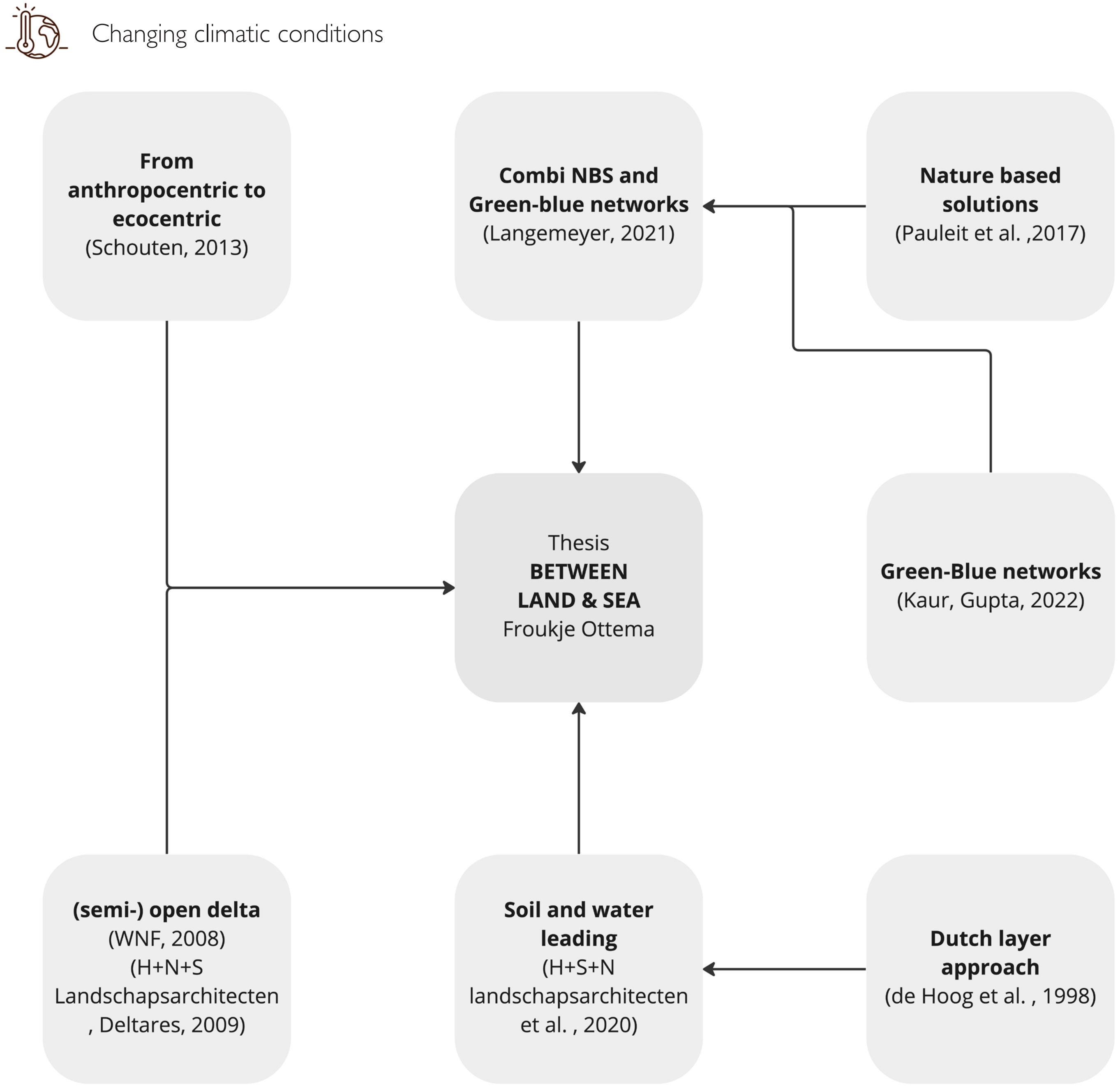


Figure 14: Scheme of the theoretical framework, author

THEORETICAL FRAMEWORK

From anthropocentric to ecocentric

In the current debate about climate change and how to move on to a more sustainable future we focus most on the instrumental elements like: innovation, finance, policy. But besides this there is also a need for a mental change. To move on to a more sustainable world we also need to change our attitude towards the natural world.

This attitude towards nature has its origin in classical Greek and Roman thought. Humans are seen as the supreme creatures on earth and the ability to reason distinguish humankind form all other creatures. In this world view nature is there to directly or indirectly serve humans. (Schouten, 2013) But this is changing. Two-thirds of the Dutch see them self as part of nature and feel the responsibility to good care of nature. This is a combination of being a steward and participant. But our attitude is different in private situations than at work. There is a gap between feeling and acting. We feel like our personal actions will do little on the global scale. But if we see our self as part of this world and connected with a complexity of relations with this world. Then that means that we have impact on our surroundings. (Schouten, 2013)

Layer approach – soil and water leading

The classic Dutch layer approach distinguishes three layers: the layer of the substratum, the layer of the networks and the layer of the occupation pattern. (Hoog, 1998) The layers where equivalent to one another and the system was in balance. But due to economical and technological prosperity the layers are unequally distributed, and the substratum level is no longer leading. Centuries ago, soil and water were clear restrictions for the use of land, but the technological development made the layers of network and occupation leading. But this way of dealing with the world is not sustainable and leads to vulnerabilities due to climate change. When building a sustainable future, the substratum layer must be leading again. The conditions of soil and water must be a dominant starting point when determining where we should develop. (H+N+S landschaparchitecten, 2009)

Green-blue networks with nature-based solutions

As previously described in the chapter context green-blue infrastructures are all natural or (semi-natural) landscape elements that form or could form a green-blue network. (https://green4grey.be/en/green-blue-infrastructure/what) Green-blue networks can exist in different scales, form urban level to the regional level and uses the natural system while protecting the ecological and hydrological values.

Nature based solutions are according to the IUCN (2016, p2.) : 'Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.' Nature based solutions have a wide range of fields form small rooftop design till forest protection. But these solutions have in common their multi functionality, they add mass to the natural capital, they preserve and contribute to a resilient landscape. Nature based solutions are seen as a top down concept but also action orientated and are likely to be more developed and implicated in the future (Pauleit, 2017)

Johannes Langemeyer and Francesc Baró say in their paper: 'Nature-based solutions as nodes of green-blue infrastructure networks: A cross-scale, co-creation approach' that the integration of nature based as nodes in green-blue networks are a way forward for urban and landscape planning. The integration strengthen cross-scale interventions and narrows the chance of small-single scale nature based solutions. (Langemeyer, 2021)

(Semi-) open delta

When looking at the water safety for the south-west delta in the long-term, two fundamental directions are possible.:

- A closed system, where the coastline is one super barrier
- A (semi-) open system, where the rivers are in direct open connection with the sea

The first strategy is a further development of the current water safety strategy. In the Haringvliet and in the long term perhaps also in the Western Scheldt, barriers need to be placed. Depending on the sea level rise, sluices or pumps must be installed to let river water in the sea. A consequence of a closed system is that there needs to be enough water storage capacity to ensure the water safety when there is a high river discharge in combination with high water levels on sea.

In the second strategy the Haringvliet discharges the main amount of river water. A consequence of this is that the (lower) river area is influenced by the sea. The dikes along the rivers and the Haringvliet should be dimensioned for long-duration high water levels and high tidal range. This strategy is a fundamental change of mindset in comparison to the mindset at the time of building the delta works. In figure 15, the integrated plan map of a future image, created for the report Toekomstbeeld Zuidwestelijke Delta 2050, is shown. (H+N+S landschaparchitecten et al., 2009)

This thesis further investigates what the implications of the second strategy, a (semi-) open system, are for the island of Schouwen-Duiveland.

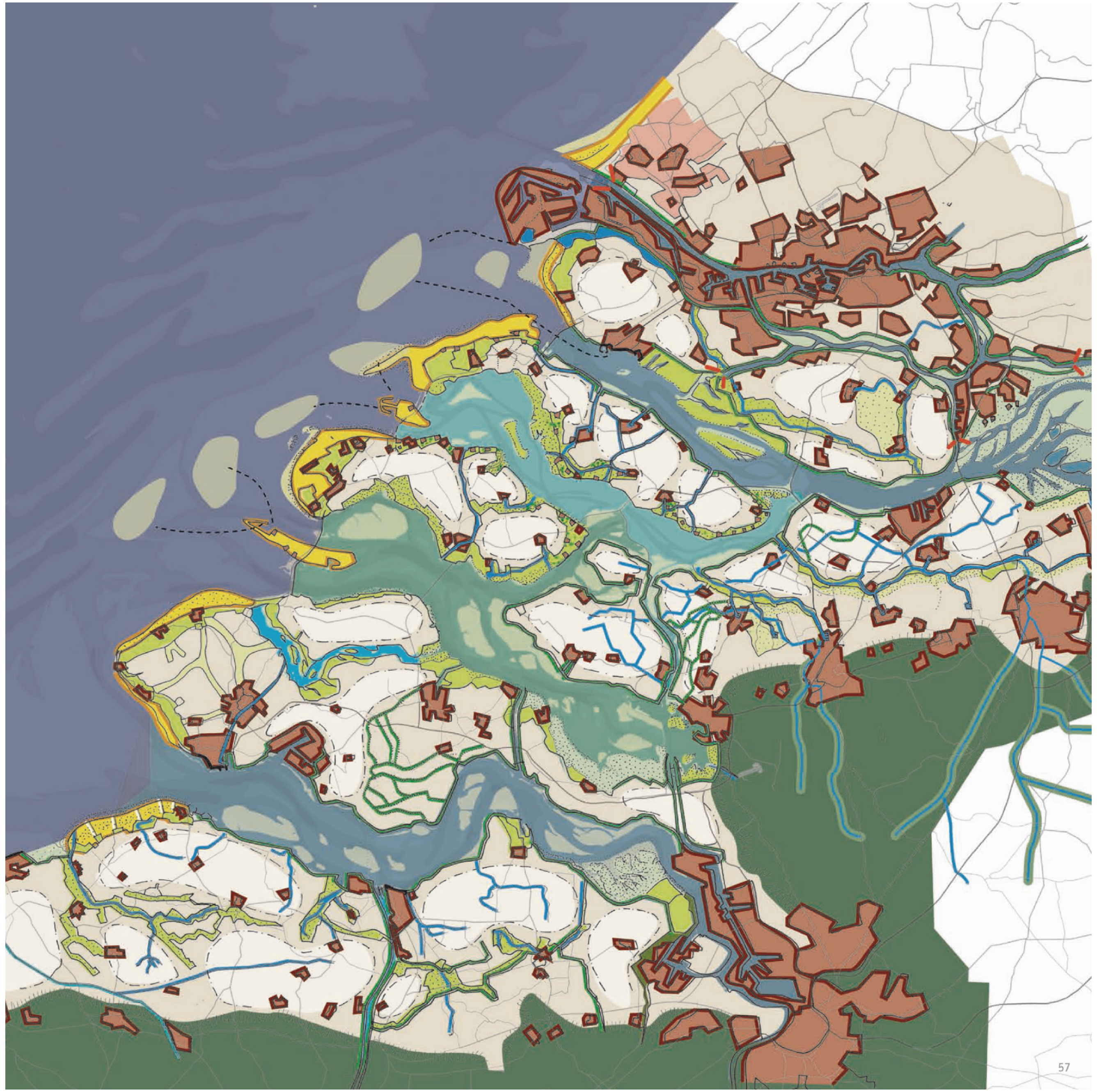


Figure 15: Plan map of future image (H+N+S landschaparchitecten et al., 2009)

SOCIETAL RELEVANCE

The societal relevance of this thesis can be divided into four components. First the scale of Schouwen-Duiveland, secondly the Southwest delta, thirdly the Netherlands and at last the world. For the society on the island of Schouwen-Duiveland this thesis is directly relevant because the design principles, vision and spatial framework are created for the island. Although this thesis isn't made to give one right answer for the future, it provides a different view on how future generations could live on the island.
The island is part of the larger water system of the southwest delta and therefore this thesis is relevant for the entire southwest delta as well. The Dutch are seen as pioneers in water management,. To keep this position, pioneering is what we must keep doing. The thesis proposes a new way of interacting with the water. This new way of thinking can be used on a regional scale and can create new opportunities for the Southwest delta.
This thesis is relevant for the Netherlands because the spatial framework looks for answers on how future generations could keep living in the delta while responding to climate change and sea-level rise. Land is sacred in the Netherlands so it is important for the whole country that land we have isn't lost in the future.
The design principles are not location specific and could be transferred to different locations, where it could help solve the same challenges. The transferability makes that this thesis is also helpful for other locations in the world.

SCIENTIFIC RELEVANCE

Deltas are with their fertile soils, their rich biodiversity and geographical characteristics a hotspot for both agriculture, industry, trade and related population growth. 500 million people live in deltas and coastal urban regions. And this number is expected to be doubled in 2050 (Musmanni, 2022). Climate change will be experienced through weather extremes, and in particular through (overexposure/ lack of) water, and therefore deltas are especially vulnerable to the effects. Although the climate adaptation of deltas is just starting (Musmanni, 2022). Patrick Verkooijen, CEO of the Global Center on Adaptation (GCA) says "In the race to adapt to climate change, deltas currently stand at the starting line. A lot of work must be undertaken to address adaptation in deltas, and we must begin by understanding just how valuable these environments are as biodiversity hotspots and engines of economic growth, and just how gravely threatened they are by climate risks," (Musmanni, 2022).

Deltas need an interdisciplinary approach for climate adaptation due to their complexity and the multiple factors active in and depending on the delta. Therefore, this thesis aims to combine landscape architecture, urbanism and environmental design. The focus of this thesis will be on the island of Schouwen-Duiveland. This area hasn't been in much attention in design research and the design principles that will arise from this can be used on different locations.

ETHICAL CONSIDERATION

The Dutch have adapted the land for personal interest, development and safer living for centuries. Where in the beginning nature, water and people lived hand in hand, industrialization expanded possibilities for exploitation. Technological prosperity resulted in lower dependency of soil and water for spatial developments and different land uses. However, is this way of dealing with the land and natural forces sustainable on the long haul, and is this to be considered ethical just? If we look at the construction of the delta works and the consequential changes of natural habitats of animal species and the consequences of biodiversity loss it entails, we may argue the ethical justification.
This thesis therefore also explores how we can live in an ethically more sound, biophilic relation between nature and human culture in the South-western delta, Schouwen-Duiveland in particular, where ecosystems are no longer a subordinate of humans but humans are participators in the ecosystem.

GRADUATION PLANNING

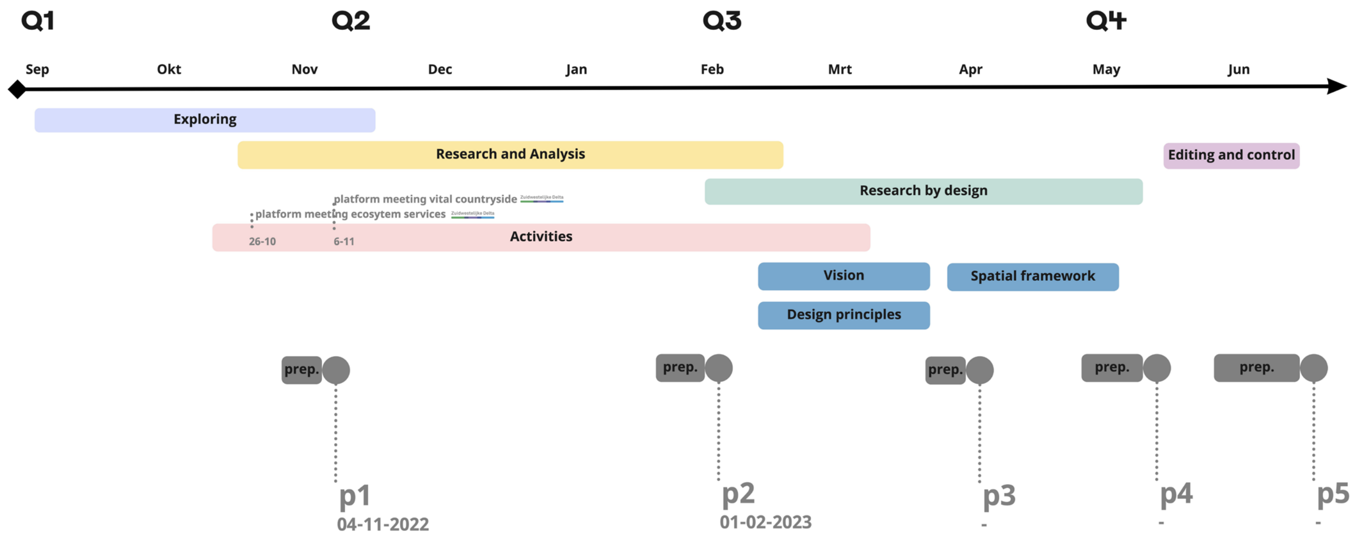
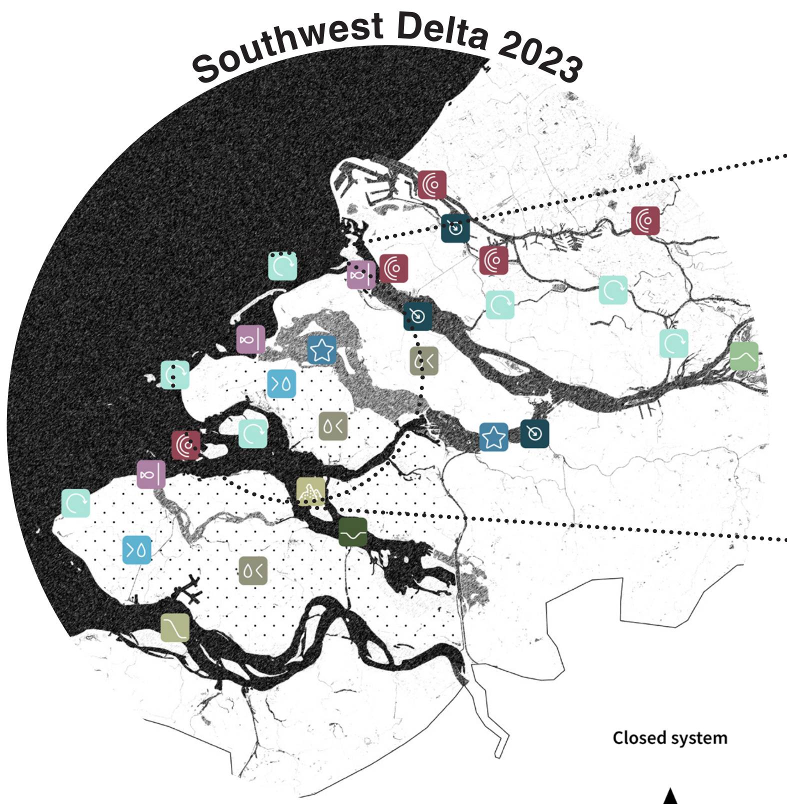


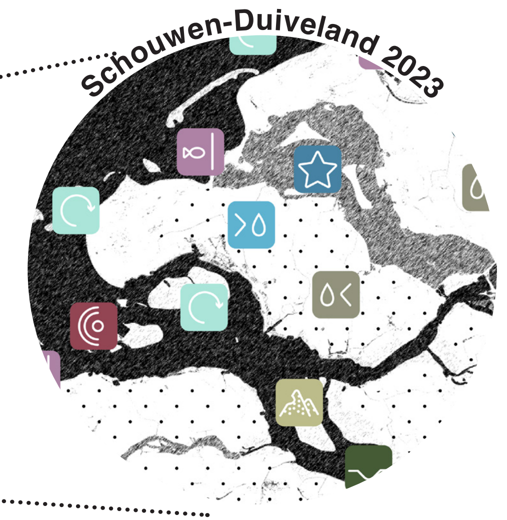
Figure 16: Graduation planning, author

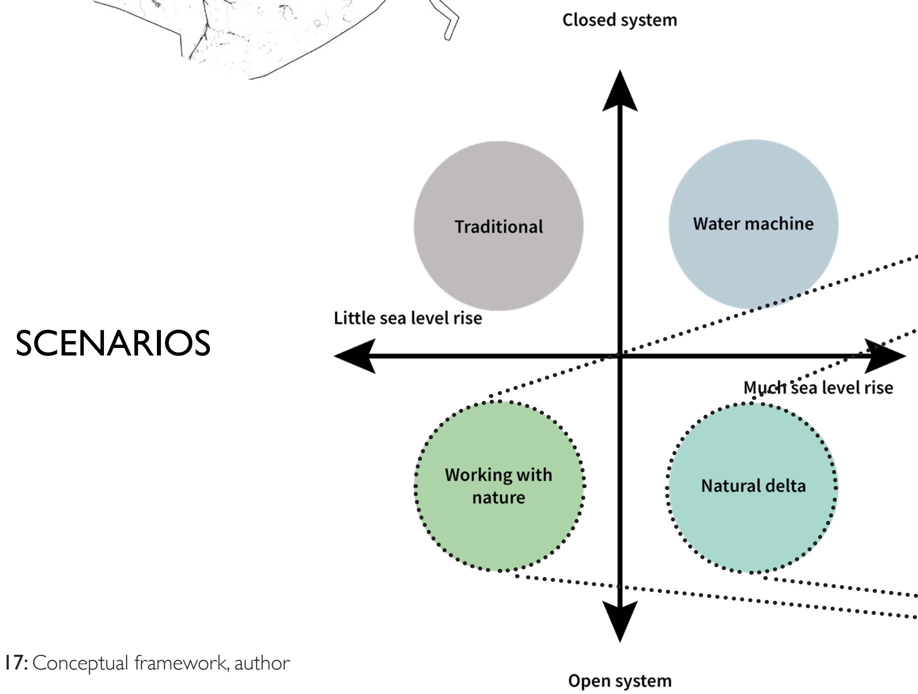
CONCEPTUAL FRAMEWORK

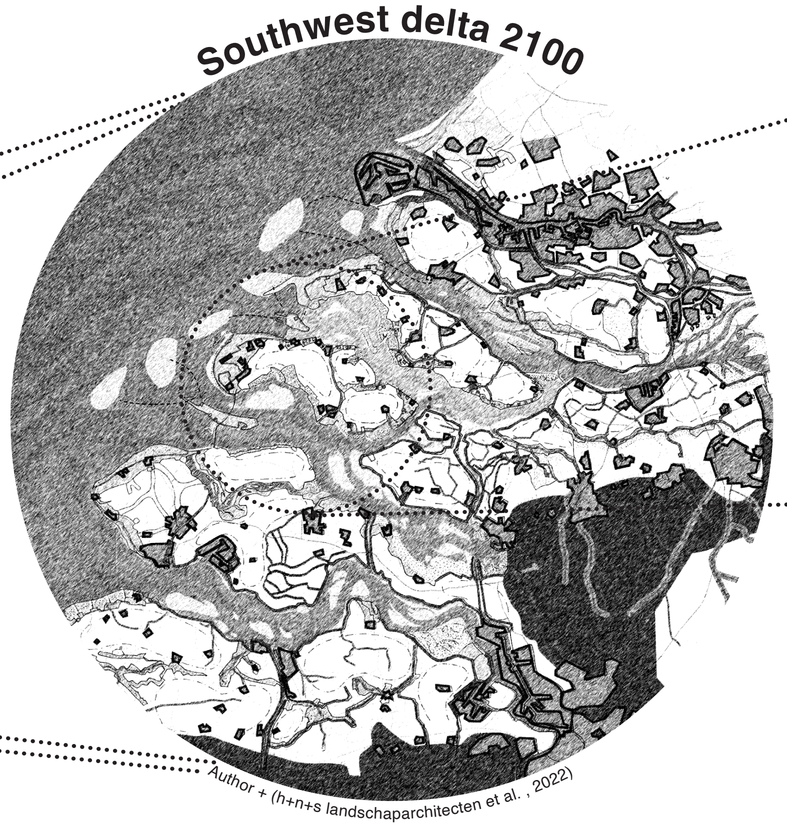
The conceptual framework, illustrated here in figure 17, shows the different steps of this master thesis. The Southwest delta is dealing with multiple challenges and climate change will intensify these challenges. The uncertainty of climate change makes it helpful to work with different scenarios. The variables for the scenarios used in this thesis are on the x-axis the amount of sea level rise. The variables on the y-x is the fundamental direction of a open system or a closed system. This gives the following 4 scenarios: Traditional, Water machine, Working with nature and Natural delta.

This thesis is looking at the scenario of the natural delta and will zoom in to the island of Schouwen-Duiveland. On the scale of the island the implications of this scenario will be further researched.









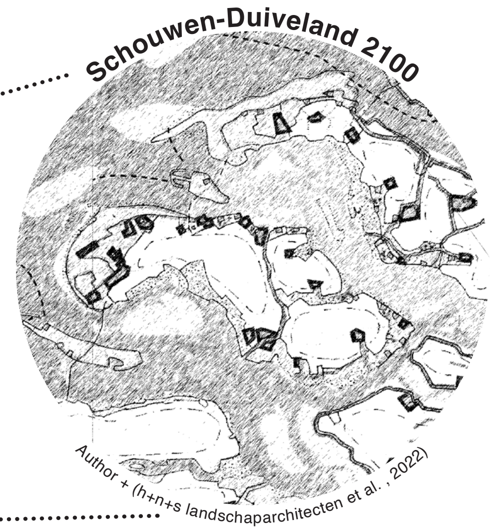


Figure 17: Conceptual framework, author

RESEARCH

Figure 18: Base map Southwestern delta, author + (Geofabrik, 2022e) (pdok, 2022c) (Geofabrik, 2022b) (pdok, 2022b) (Geofabrik, 2022d) (Geofabrik, 2022h)

SOUTHWESTERN DELTA

To understand the context of this thesis, multiple maps and diagrams are made. In this chapter these are shown and explained. The chapter starts with the bigger scale of the whole Southwestern delta and zooms in on the island of Schouwen-Duiveland.
The Southwestern delta is shown in figure 18. The Southwestern delta is the area that is formed by the delta waters, the islands and the Southwestern coast of the Netherlands. The delta includes 3 provinces, Zeeland, the islands of Zuid-Holland including Rotterdam and its harbour and the western part of North Brabant. It then stretches into the Dutch neighbouring country, Belgium. With the harbour of Antwerp at the end.
The urbanisation of the delta is shaped like a horseshoe around the islands. Starting in Rotterdam and ending in Antwerp. The islands lay in the centre and have more a countryside perception.

Legend | Base map

- Agricultural land
- Forest
- Grassland
- Dunes
- Buildings
- Mudflat
- Mudflat late
- Salt water with no tides
- Salt water with tides

WATER SYSTEM

The water system of the Southwestern delta is quite complex and therefore the system of rivers, water bodies and estuaries are simplified into a diagram. This diagram is shown in figure 19. Overtime the system is changed. After the flood of 1953 with the reaction of delta works, major shifts happened in the water system. The top image shows the system in 1965 and the bottom image shows the current system. The installation of dams, storm surges and weirs made the delta safer, easier to control and better to use for shipping. The civil interventions also ensured the accessibility of freshwater for agriculture. There is much gained but also things are lost, like the dynamics, the brackish environments and the open connections between the waters. (Haas et al., 2001)

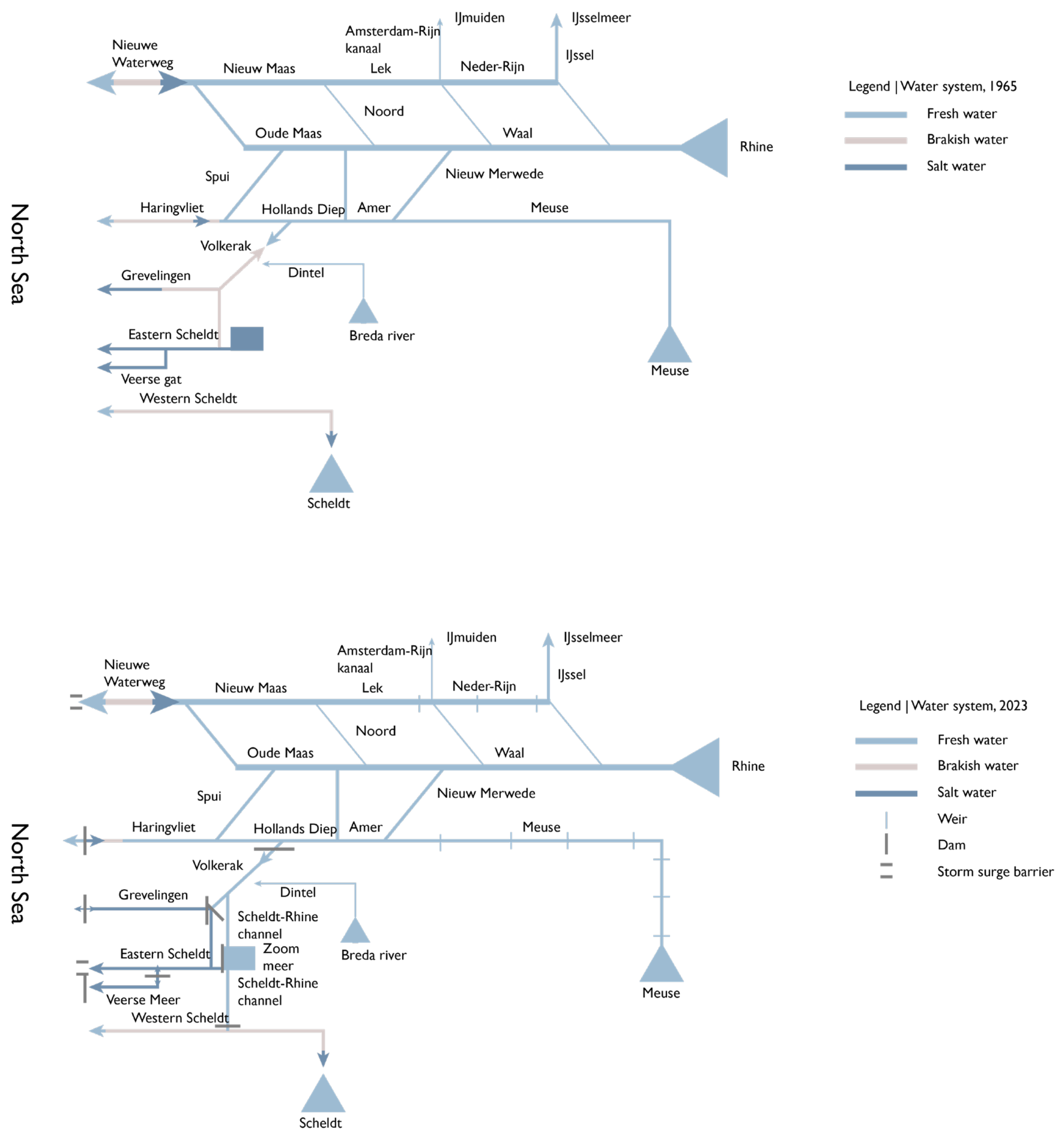


Figure 19: Water system, 1965 en 2023, author + (Haas et al., 2001)

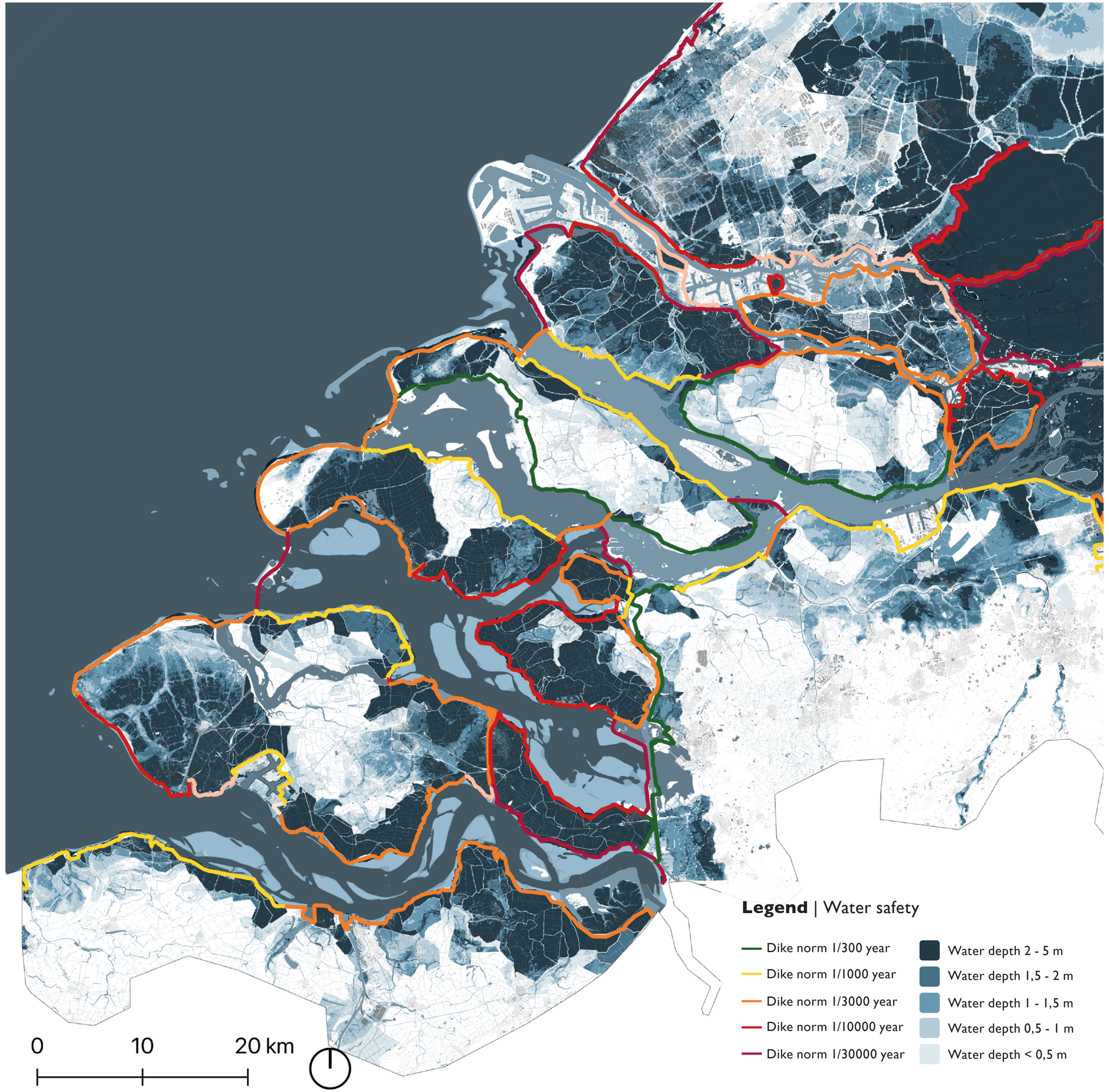


Figure 20: Water safety and dike norms, Southwest delta, author + (pdok, 2022c) (Geofabrik, 2022f) (Klimaateffectatlas et al., 2021) (Esri NL StoryMaps et al., 2014)

WATER SAFETY

The water safety of the delta is ensured with dikes, dams and storm surges. Each water barrier has a norm of exceedance probability. In figure 20 these norms are shown for each element. The higher the norm, the better it can resist a storm. The number is the probability of failure. So a dike norm of 1/3000 years means that it can breach in a storm that can happen once in the 3000 years. The blue colours illustrated the water depth in case of flood, how darker the colour how deeper the water.

DEMOGRAPHY AND SPATIAL PLANNING

The infrastructural connections between the islands in the delta and the major cities is greatly improved after the construction of the delta works. The islands are no longer isolated communities like they were in the fifties. In the sixties there were concerns that the Randstad (the megalopolis Stretching from Utrecht in the east, Amsterdam in the north, and the Hague and Rotterdam in the south) would be overcrowded. This made that the policies were focusing on spreading the population throughout the Netherlands. But the expected population growth after the war was not achieved. The islands in the delta remained sparsely populated and are in sharp contrast with the densely populated clusters of cities surrounding them. The cities, the Hague, Rotterdam, Dordrecht, Breda, Antwerp, Ghent and Bruges form a horseshoe around the open central area of the delta. The highway and railway from Breda to Vlissingen stimulated the development of regional cities along it, like Middelburg, Goes and Bergen op Zoom. (Vlieger, 2017) In figure 21 the major roads, railway and buildings are shown.

Legend | Infrastructure and built environment

- Built environment
- Primary roads
- Secondary roads
- Tertiary roads
- Railway
- Mudflat
- Mudflat late
- Salt water with no tides
- Salt water with tides

Figure 21: Infrastructure and built environment, Southwestern delta, author + (Geofabrik, 2022e) (pdok, 2022c) (Geofabrik, 2022g) (geofabrik, 2022c) (Geofabrik, 2022h) (Geofabrik, 2022d) (Geofabrik, 2022f) (Geofabrik, 2022a)

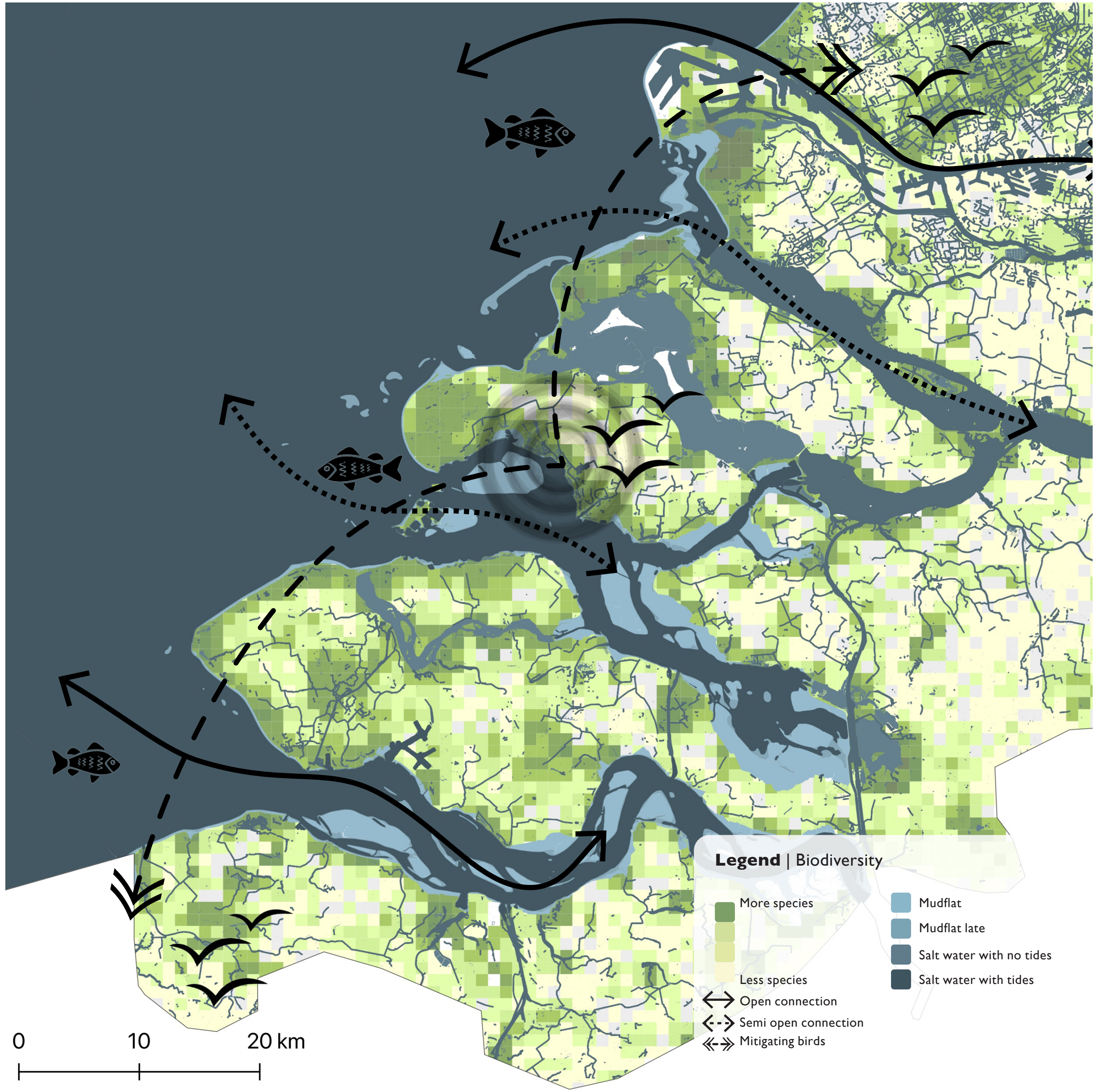


Figure 22: Species diversity from species from the red list, author + (pdok, 2022c) (Nationale Databank Flora en Fauna, 2017) (WNF et al., 2008)

BIODIVERSITY

In figure 22 the biodiversity of the land in the Southwest delta is illustrated. The darker green the colour, the more species are present. As can be seen in the figure, the biodiversity is the highest on the edges of the land. Where the biodiversity increases more in the centres of the islands. This is where the land use is mainly agricultural.

The South west delta is the most important resting spot for many migrating birds. They stop to gather strength for their long journeys between their wintering and breeding sites. Besides the importance of the delta for migrating birds, it is also the gateway for migrating fish up and down stream. Because of the presence of gradients and the supply nutrient-rich river water, The Southwest Delta has the potential to grow in to one of the richest nature areas of Europe. (WNF et al., 2008)

SOIL TYPES

The island has multiple soil types. The middle part of the island holds the most clay. The new polders on the East side have more of a sandy loam soil type. Sandy loam is also clay but there is sand mixed in. (Trikt, n.d.) The West side has a sand soil. This is directly to link with the big dunes on the head of the island. In figure 23 is the location of each soil type is drawn.

Figure 23: Soil types Southwestern delta, author, (pdok, 2022c) (dataportaal.zeeland, 2020) (Geofabrik, 2022f)

Figure 24: Basemap Schouwen-Duiveland, author + (pdok, 2022c) (pdok, 2022b) (Geofabrik, 2022f)

SCHOUWEN-DUIVELAND

The next set of analysis maps will zoom in to the island of Schouwen-Duiveland. Schouwen-Duiveland is the most northern island of Zeeland and has a surface of 488,21 km², and has 34.148 inhabitants. (allecijfers.nl, 2023) The island is surrounded by 3 waters. The Grevelingenmeer on the north, the Eastern Scheldt on the south and East side and the North sea on the West side. Schouwen-Duiveland is connected with the other islands by 2 dams (Brouwersdam, Grevelingendam), 1 storm surge barrier (Eastern Scheldt barrier) and a bridge (Zeelandbrug). Most of the island lays below sea level, except for the most west point of the island. There is the dune area (kop van Schouwen) with a highest point of 42 meters above sea level (Schouwen-Duiveland, n.d.) The island is drawn in figure 24.

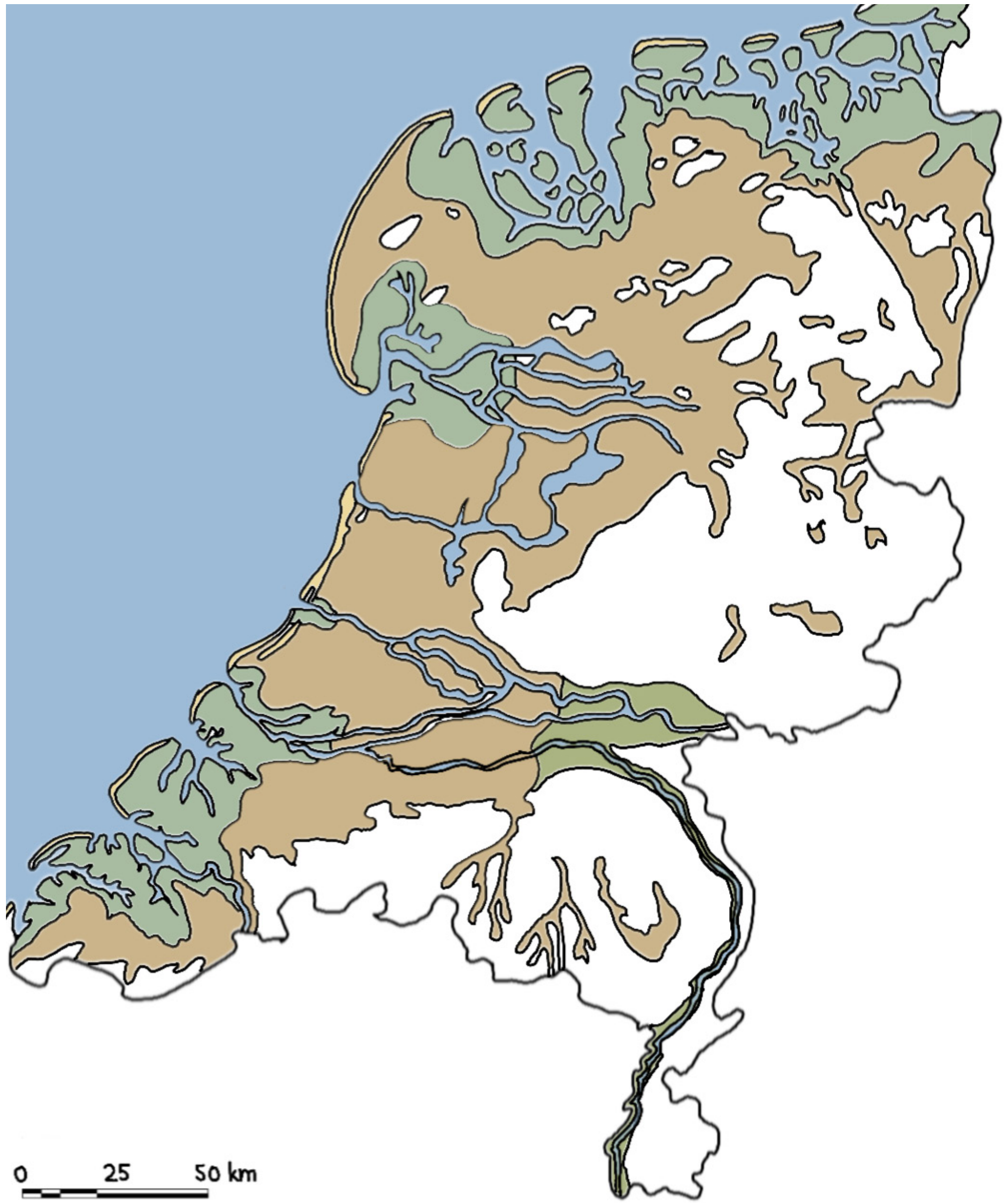


Figure 25: The Netherlands in 2750 BC, author + (Vos et al., 2006)

HISTORY

Due to the shifting of the old dunes new dunes are formed on the west side of the island Schouwen-Duiveland. More people start living on the higher parts of the island (Brons partners landschaparchitecten bv, 2011)
The first permanent residents of the island settled here in the New Stone Age (approximately 4300 to 2000 BC). These first settlements were all situated in the dunes around Haamstede. In the late Iron Age almost all habitation has disappeared. Around 50 BC the Roman Empire conquered the land till the Rijn and Zeeland become part of the Roman Empire. The romans described Zeeland as a practically uninhabitable wilderness. The romans inhabited the higher part of Zeeland between 75 and 270 AC, they de-watered and excavated the peat. But due to this excavation and major floods, the area become inhabited again around 270 AC. In a period of 300 years a lot of clay was deposited in the delta. Around 7th century the flooding activities declined, the landscape can be compared with the current Wadden region in the North side of the Netherlands (Haartsen, 2009)

Figure 26: Section of The Netherlands in Roman times (Kroese et al., 2003)

The island of Schouwen-Duiveland has been formed out of four islands, Schouwen, Duiveland, Dreischor en Bommenede. See figure 28. Overtime these four islands fused together into one.
In the 9th century a ring wall burg is made in the dunes on the island of Schouwen at Burgh. This ring wall protected the islanders from invasions of the Vikings and from floods. In the 10th century Zierikzee is founded. Zierikzee was situated along a creek that discharged in de Gouwe. See the map of 1200 - 1600. The island Dreischor was used for sheep. (Brons partners landschaparchitecten bv, 2011)
In the period between 1200 and 1500 a lot is changing in the area. On the edges of the islands dikes were made so the land would be less affected by the sea. In the 13th century Brouwershaven comes to development. The water between Schouwen en Dreischor (de Gouwe) is dammed in 1374 with two dams because it had become unnavigable. The polder that was created is called the Noordgouwe polder. Small villages are formed on Bommenede, Dreischor and Duiveland. These villages were arranged in a ring with the church in the middle with another ring of buildings around. (Brons partners landschaparchitecten bv, 2011)
After the 13th century dikes were not only made to keep the sea out but also to create more land. See the map of 1500. The peat on the islands is useful for salt and as fuel. The peat can be extracted by first removing the layer of clay. After excavation of the peat the clay is put back. This creates an irregular ground level (Brons + partners landschapsarchitecten bv, 2011).
In the 17th century Brouwershaven and Zierikzee have are prosperous period. On the higher sand soils of Schuddebeurs country estates are established. De Gouwe dam and Schouwen and Duiveland are connected. The dam in the Gouwe silted up the creek. See map 1750 The new polders of Schouwen-Duiveland have a more rational parcelization in comparison to the old polders. The new polders have a higher ground level than the old ones (Brons partners landschaparchitecten bv, 2011)
After the flood of 1953 the delta works were created. These dams had to make sure floods like the one in 1953 would not happen anymore. On the south side of the islands large areas of land were taken back by the sea. In this side of the island plan Tureluur was created to compensate for the adverse impact of the Delta Works. Still clearly visible is the large-scale land consolidation that took place after the flood of 1953. See figure 27. (Brons partners landschaparchitecten bv, 2011)

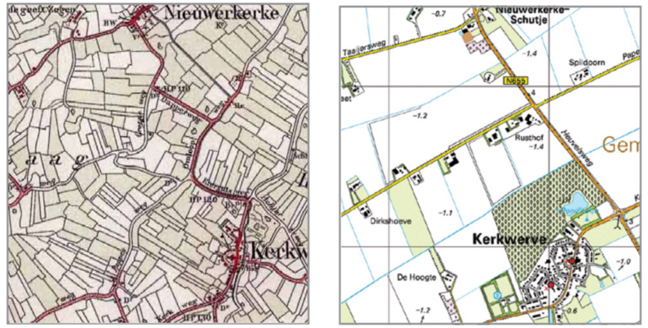


Figure 27: Parcellation 1910 vs 2011, (Brons partners landschaparchitecten bv, 2011

Figure 28: Development of the island of Schouwen-Duiveland, author + (Brons partners landschaparchitecten bv, 2011)

Figure 29: Watersytem of Schouwen-Duiveland, author + (pdok, 2022c) (Geofabrik, 2022f) (Waterschap Scheldestromen, n.d.-b) (Waterschap scheldestromen, 2021a) (Waterschap scheldestromen, 2021b) (Verzandvoort, 2013)

WATER SYSTEM

The water system on the island consists of two main parts, related to the former Schouwen and Duive land. Inside these two areas smaller drainage areas exist. To start with the polder of Schouwen: Schouwen can be seen as one unified drainage system. The water that needs to be pumped out of this area concerns mostly rainwater and seepage. There is no option to pump fresh water from the outside in this internal water system. The two main pumps are pumping station 'Prommelsuis', which pumps the water in the Eastern Scheldt and pumping station 'Den Osse', which pumps the water in the Grevelingen. The waterway system of main canals with smaller veins lets the water flow to the two pumping stations. The locally lower inner dike areas are pumped dry through the stated outlet pumps. Prunje is the biggest polder that is pumped dry with these outlet pumps. Finally, there is one area east of Brouwershaven and the inner city of Zierikzee that uses these pumps (Waterschap Scheldestromen, 2021b).

The second polder of Duiveland is divided into 5 drainage areas, viz. : t' Sas, Dreischor, Duiveland-Ouwerkerk, Duiveland-Oosterland and Zuidhoek. Most of the water flows to one of the 4 pumping stations where it is pumped into the Grevelingen or Eastern Scheldt. The Eastern Scheldt is subject to tide, and this is especially notable inside the polder at times of extreme high tide. Important to know is that the pumping stations for the drainage areas t' Sas and Zuidhoek can't pump during high tides, as the lock will then be closed (Waterschap Scheldestromen, 2021a). In figure 29 the water system is shown

WATER SAFETY

The island of Schouwen-Duiveland is protected from sea by dikes on the north, east and south side and on the west by dunes. The flood probability of the dikes and dunes are defined by the dike norm. The dike along the Grevelingenmeer has the highest flood probability, this is because of the Brouwersdam, which closes off the lake from the sea. The Brouwersdam is part of the Delta works. Like the Eastern Scheldt barrier on the south side of the island. The eastern Scheldt barrier is not a solid dam like the Brouwersdam but has slides that go down in the case of a storm. Because of the fail probability of the slides, the dikes on the South side of the island are stronger dimensioned.

The blue colour inside drawn inside the island is the water depth in case of a flood. How darker the color how deeper the water. Figure 31 shows the dikes and water depth in case of flooding. Figure 30 shows the dike around the island. The entire dike ring has a fail probability of breaking by a storm that can apear once in 4000 years. (Kwadijk, 2007)

Dike ring 26: 1:4000 years

Figure 30: Axo of Schouwen-Duiveland

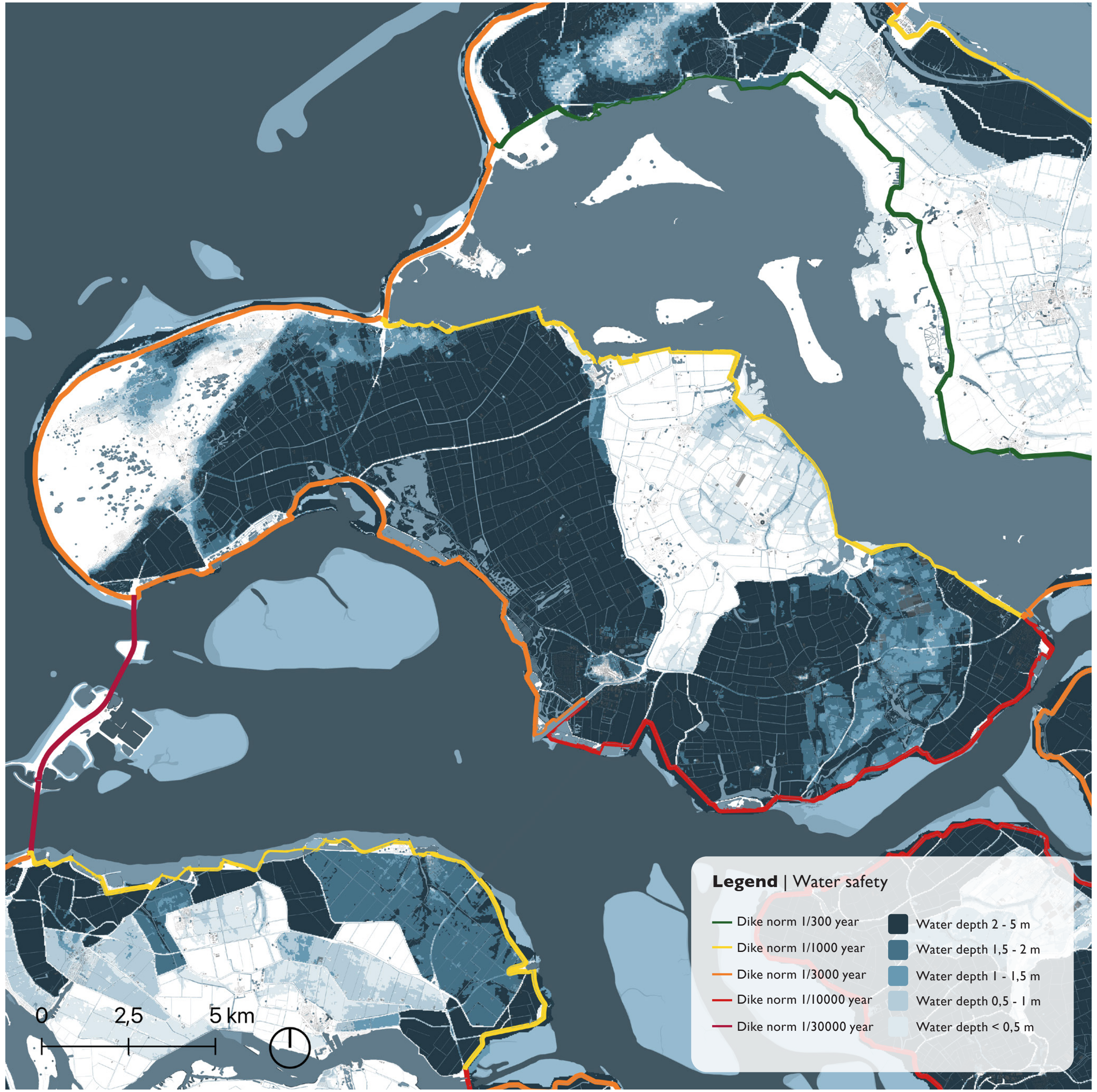


Figure 31: Water safety and dike norms Schouwen-Duiveland, author (pdok, 2022c) (Geofabrik, 2022f) (Klimaateffectatlas et al., 2021) (Esri NL StoryMaps et al., 2014)

Figure 32: Salt intrusion on Schouwen-Duiveland, author + (pdok, 2022c) (Geofabrik, 2022f) (pdok, 2022b) (Klimaateffectatlas et al., 2016)

SALT INTRUSION

The island of Schouwen-Duiveland is surrounded by saltwater. The dikes and dunes separated the salt form the fresh water inside the island. But the dikes are not completely waterproof. Saltwater can enter the freshwater system pushing through the underground. When freshwater is affected by saltwater we call it salt intrusion. In figure 30 the salt intrusion is illustrated. The salt intrusion is the highest on the deeper surface levels and more towards the edges of the island.

FRESH WATER

Freshwater on the island is limited. Freshwater can only be found in the soil in the dune area on the west side of the island and on the bit higher and sandy soil of the old creek ridge. Before drinking water can be extracted from the dunes on the west side, the water needs to be drained from the Haringvliet and pumped into the dunes. The dunes filter the water. (DNWG, n.d)
Figure 31 shows the different components of the freshwater system on the island.

Figure 33: Ground water management, author + (pdok, 2022c) (Geofabrik, 2022f) (pdok, 2022b) (Waterschap scheldestromen, n.d.-a)

Figure 34: Growing and shrinking settlements on Schouwen-Duiveland, author + (pdok, 2022c) (Geofabrik, 2022f) (Geofabrik, 2022h) (Verzandvoort et al., 2013)

DEMOGRAPHIC

Between 2020 - 2030 the municipality of Schouwen-Duiveland expects a population growth of 405 households. This growth will be mostly elderly people above 65 years, this because of the strong aging of population on the island. Younger people are moving away towards the bigger cities to study and find eventual jobs there. Between 2030 and 2040 a decrease of 390 households is to be expected.
The municipality is focusing the expansion plans on senior dwellings and apartments. So elderly people can move to smaller houses and therefore their bigger houses will be released for younger people (Stec groep, 2019)
The island has 17 settlements. These are shown in the image below. They are divided in to three classes; transition cores, balance cores and growth cores. Expansion will mostly happen inside these cores. The structural vision of the municipality says that there is housing need of 1.615 dwellings, where 235 are part of the transition program (Stec groep et al., 2022)

SOIL TYPES

The island has multiple soil types. The middle part of the island holds the most clay. The new polders on the East side have more of a sandy loam soil type. Sandy loam is also clay but there is sand mixed in. (Trikt, n.d.) The East side has a sand soil this is directly to link with the big dunes on the head of the island. In figure 35 is the location of each soil type is drawn.

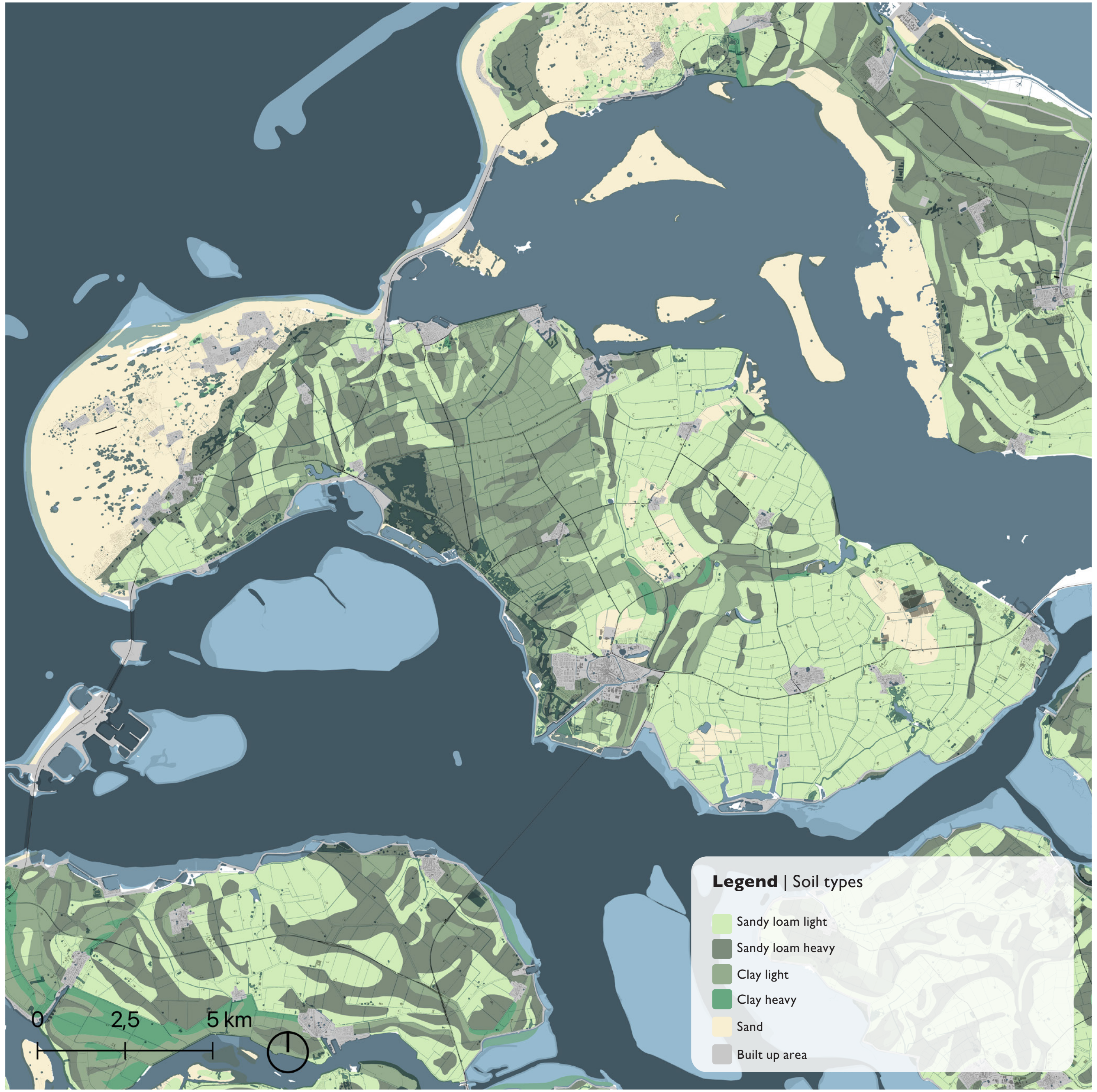


Figure 35: Soil types Schouwen-Duiveland, author + (pdok, 2022c) (dataportaal.zeeland, 2020) (Geofabrik, 2022f)

DELTA SCENARIOS

DELTA SCENARIOS

When looking into the longterm strategies of the water safety of the Netherlands, two fundamental scenarios are possible.

- A closed system, where the coastline is one super barrier
- A (semi-) open system, where the rivers are in direct open connection with the sea

These two strategies are drawn in figure 36 and 37. In the long run, with a sea level rise of over 3 meters only the (semi) open system is sustainable. This thesis is looking in to the consequences and opportunities of this (semi) open system.

This chapter explores the multiple strategies of the primary water defense lines. Four options are created, a closed delta, an open Eastern Scheldt, a semi open delta and a open delta. These different strategies are assessed on the impact on, the environment, agriculture, living and water safety. The different strategies are drawn on the plan map of H+N+S landschaparachitecten shown in figure 38.

Sub-questions to be answered in the chapter:
What is a (semi) open delta approach?
How can a (semi) open delta approach solve existing and future challenges?

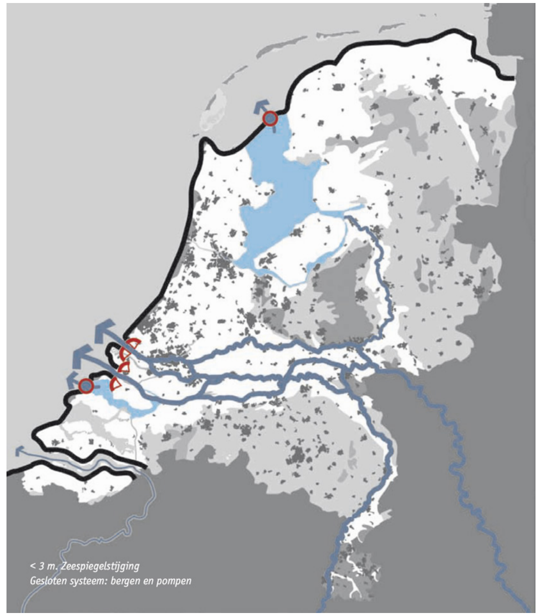


Figure 36: Plan map of future image (H+N+S landschaparchitecten et al., 2009)

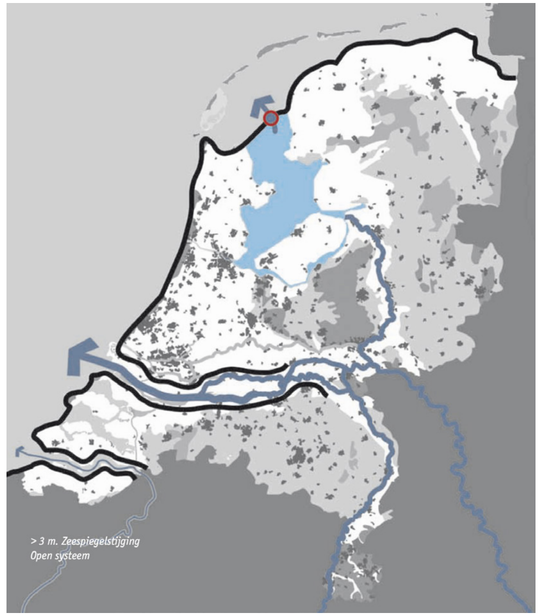


Figure 37: Plan map of future image (H+N+S landschaparchitecten et al., 2009)

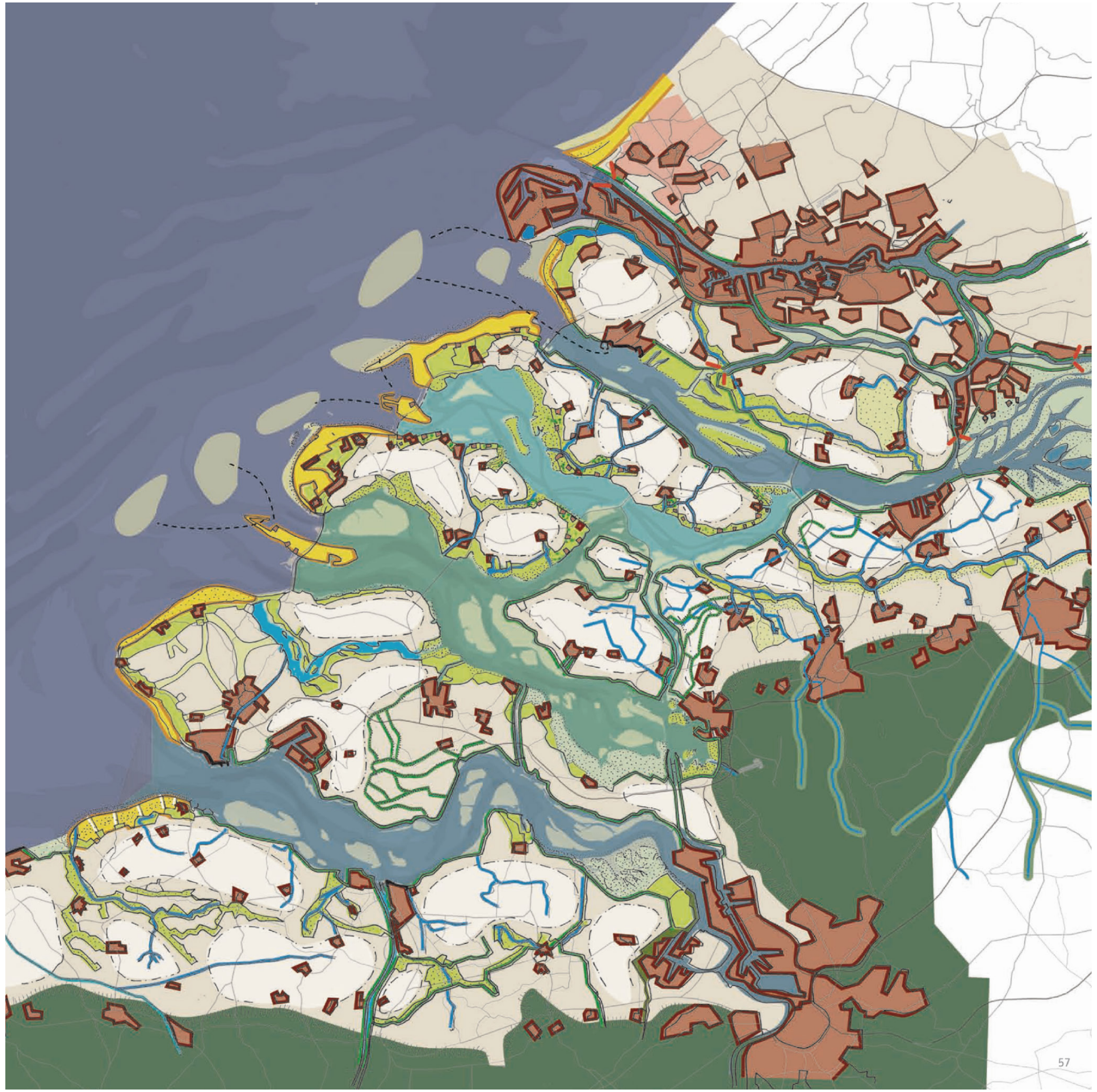


Figure 38: Plan map of future image (H+N+S landschaparchitecten et al., 2009)

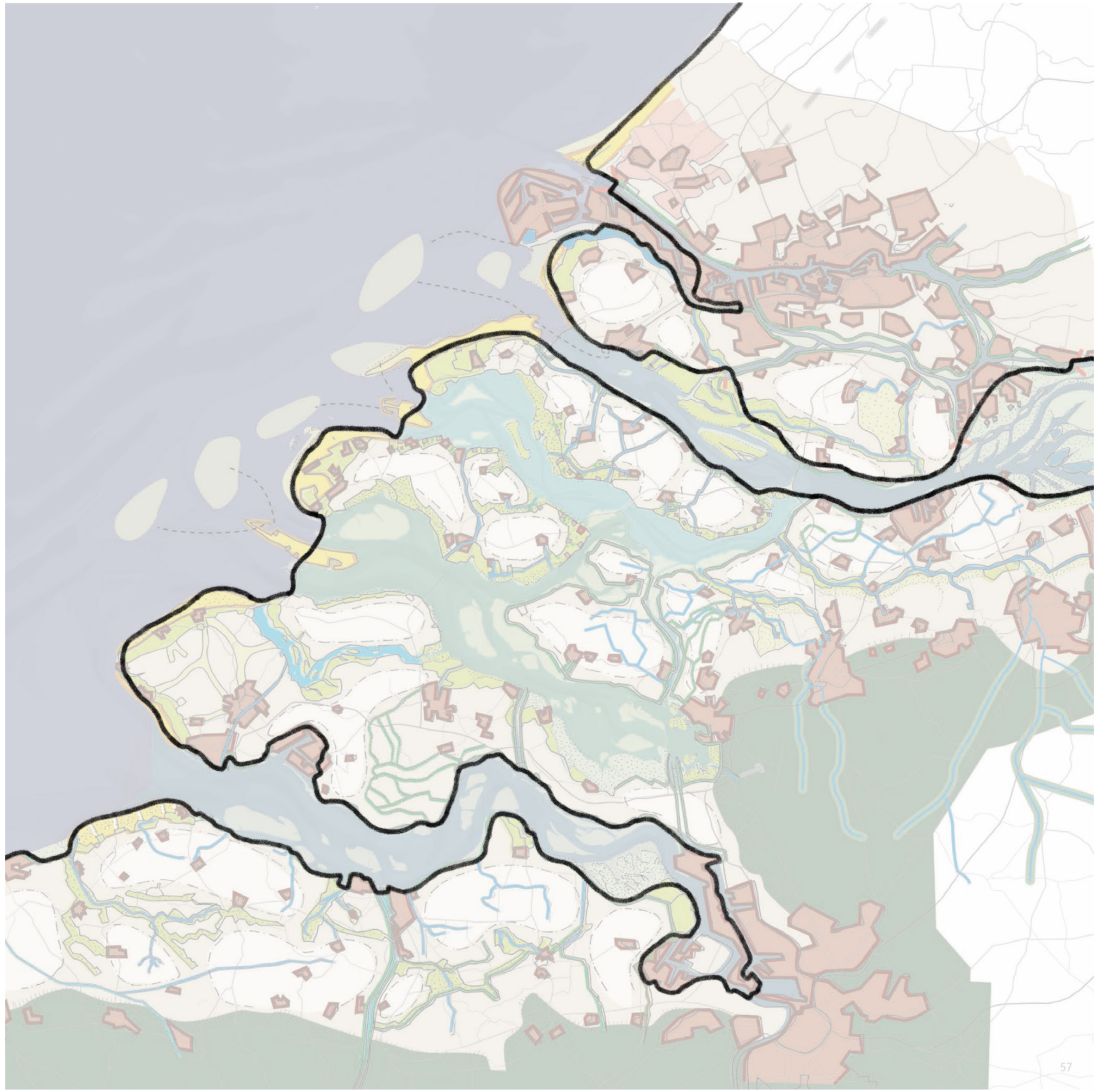


Figure 39: Plan map of future image, author + (H+N+S landschaparchitecten et al., 2009)

CLOSED DELTA

This strategy is a direct copy of the one drawn by H+N+S landscape architects, shown in figure 39. In the report of H+N+S landscape architects, this is called an open system, because the river is in open connection with the sea. But this strategies isn't open delta. The sea arms, the Grevelingenmeer, Eastern Scheldt and Volkerark are closed off by a dam and the river water only flows into the sea through the Haringvliet.

Environment

In this strategy only the Haringvliet will be on open connection with the sea, which means that only this sea arm can be considered as a delta, and for the rest of the sea arms the natural dynamics aren't reintroduced. This has bad consequences for the environment of these water bodies.

Agriculture

When the water bodies inside the primary barrier aren't following the sea level rise and kept at the water level they have now, this strategy can help prevent that the salt seepage on the delta islands will increase. The strategy doesn't solve the problems with water logging, droughts, and the limited freshwater supplies. Overall this strategy scores average for the agricultural problems

Living

The livability of the delta islands also does not score good, because of the direct relation with the environment. The unique ecosystem of the delta is lost and this is vital for the livelihood of the local community. The economy of the islands is strongly water connected and a healthy environment and diverse landscape are essential for the thriving economical actives on the islands.

Water management

This strategy scores good for the water management part. Good opportunities arise for water storages in the closed off basins, while the delta works keep their functions.

OPEN EASTERN SCHELDT

In this strategy the Eastern Scheldt is kept as an open sea arm and will be influenced by the sea. In this strategy the river water will also only flow out through the Haringvliet. The Eastern Scheldt isn't part of the estuary, because the river and sea arm are not directly connected.

Environment
This strategy already has a more positive effect on the environment, because when the Western Scheldt is kept open, the natural dynamics of the sea are let in. For the rest of the water basins the environmental problems aren't solved, and that is why this strategy still scores bad on environmental issues.

Agriculture
Opening the Eastern Scheldt means that the water levels in the sea arm will rise at the same speed as the sea. This means that the land located along water will have more salt seepage. This has consequences for the traditional fresh water agriculture. This strategy also doesn't solve the problems with drought, water logging or the freshwater supply and there for scores bad for agricultural functions.

Living
A open Eastern Scheldt has a positive effect on the livability of the delta islands, because the vital connection with the water along the Eastern Scheldt is preserved, and the landscape keeps its diversity.

Water management
The water management of river water discharge isn't influenced by a open Eastern Scheldt, because the river water is entering the sea only through the Haringvliet. The eastern Scheldt barrier is no longer in use in this strategy, while the other delta works keep their position. Generally this strategy scores neutral on water management.

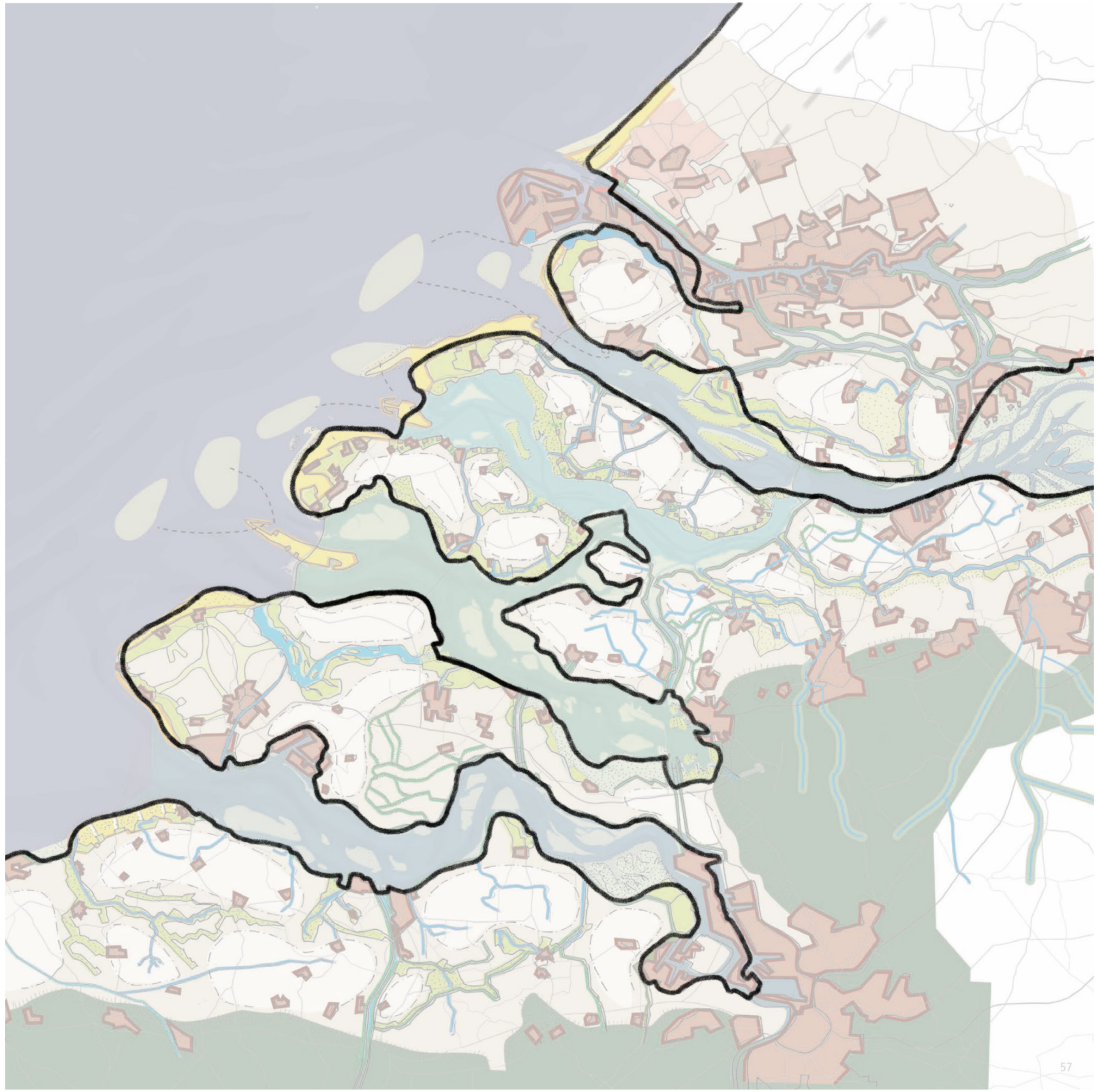


Figure 40: Plan map of future image, author + (H+N+S landschaparchitecten et al., 2009)

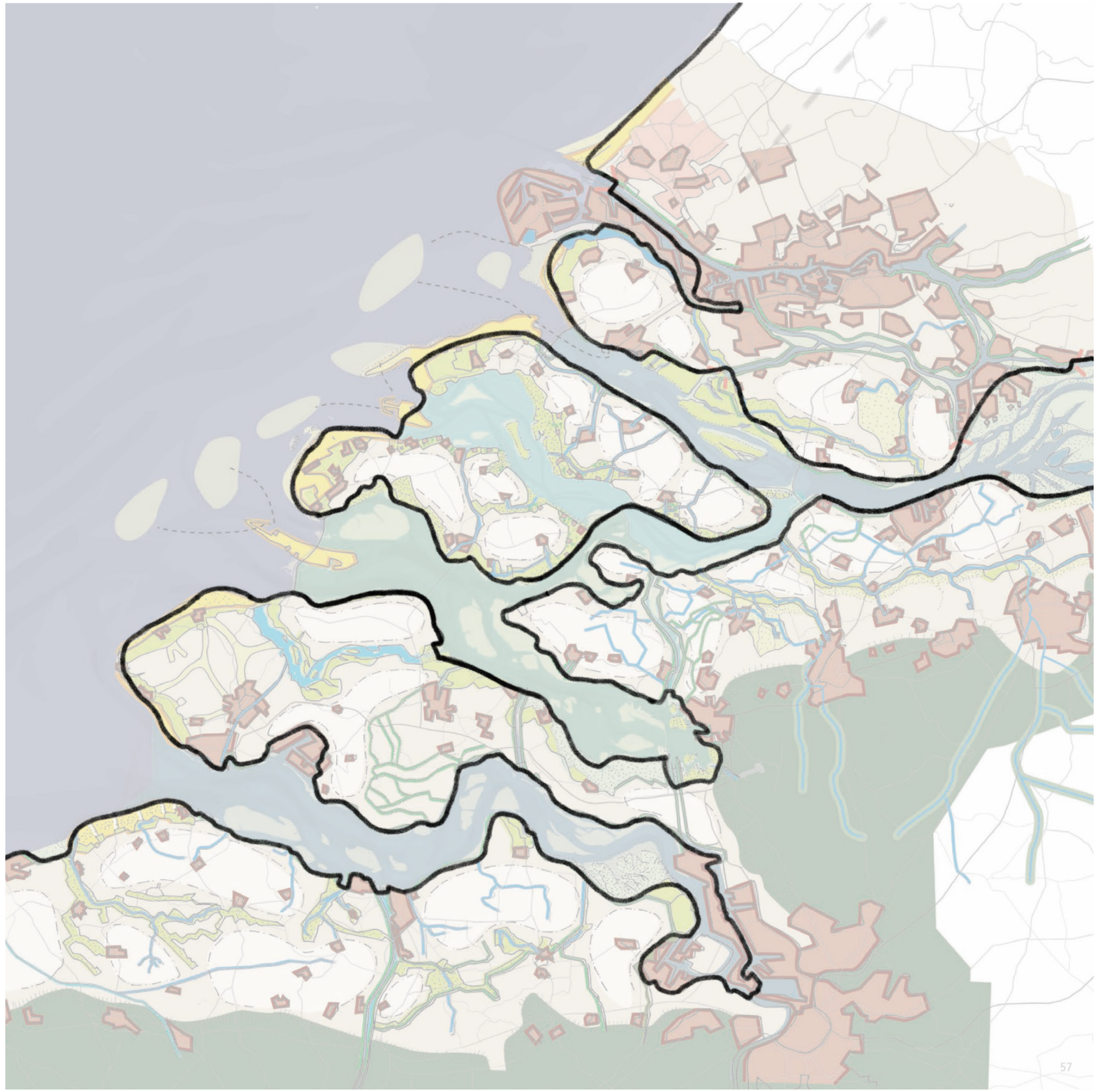


Figure 41: Plan map of future image, author + (H+N+S landschaparchitecten et al., 2009)

SEMI OPEN DELTA

This strategy differs from the open Eastern Scheldt one in the action of opening the Volkerak-zoommeer. This opening will have consequences for the river water flow. Instead of discharging the river only through the Haringvliet, the river water will also be entering the sea through the Eastern Scheldt. The island of Schouwen-Duiveland and Goeree-Overflakkee with the Grevelingenmeer in the middle will function as one ring dike, as well as Zuid-Beveland and Noord-Beveland with the Versemeer in the middle.

Environment

Letting the river water discharge through the Haring vliet and the Eastern Scheldt will have a positive effect on the environmental conditions. There are now more possibilities for fish migration, the water quality of the Volkerak-Zoommeer will improve and the nutrient deficiency in the Eastern Scheldt will improve. The oxygen deficiency in the Grevelingenmeer isn't solved by this strategy. But overall this strategy scores good for the environment.

Agriculture

In this strategy more salt seepage will occur due to the influence of the sea has on the Eastern Scheldt and Volkerak-Zoom meer. Like all other strategy this one does not solve the problems of drought, water logging and the limited water supplies.

Living

In this strategy the livability of the delta islands scores good, just like in the open Eastern Scheldt strategy, because of the good environmental conditions this strategy provides. A point of attention for this strategy is that the connections that are made with the major cities are sustained, so this island won't become isolated.

Water management

The water management part of the strategy scores good as well, because of the extended options for river discharging and the option to use the Grevelingenmeer as water storage. The delta works can be partly reused and need to partly to change.

OPEN DELTA

In the strategy of the completely open delta, all the former water basins are opened up again. River water can discharge through all the sea arms. All the delta islands have their own ring dike around them.

Environment

This strategy has the best outcomes for the environmental conditions. The natural dynamics of all waterbassins is restored and nature can act freely. Where in the semi open delta strategy the Grevelingmeer and Versemeer were still compartmentalized, they now are in open connection with the sea and river water. This will have a positive effect on the water quality of these waters. The possibilities of fish migration will increase because of the increased openings. The fresh salt gradient is restored to the natural conditions which as well has great impact on the qualities of the ecosystem.

Agriculture

For the agriculture this strategy is the most challenging because all of the islands need to deal with more salt seepage. Like in all the other strategies the other problems the agriculture sector is facing aren't solved in this strategy.

Living

For the livability of the islands this strategy scores good as well but a consequence of opening all waterbassins can be that the diverse landscape, which makes the islands attractive for a diverse group, will be lost. Also attention needs to be kept to the accessibility of the island and the connection to the major cities.

Water management

For the water management this strategy is the hardest due to the multiple dike rings and the loss of the delta works. Also the water storage options are lost. But in this strategy the river water can discharge through multiple openings which gives room for extreme river discharges.

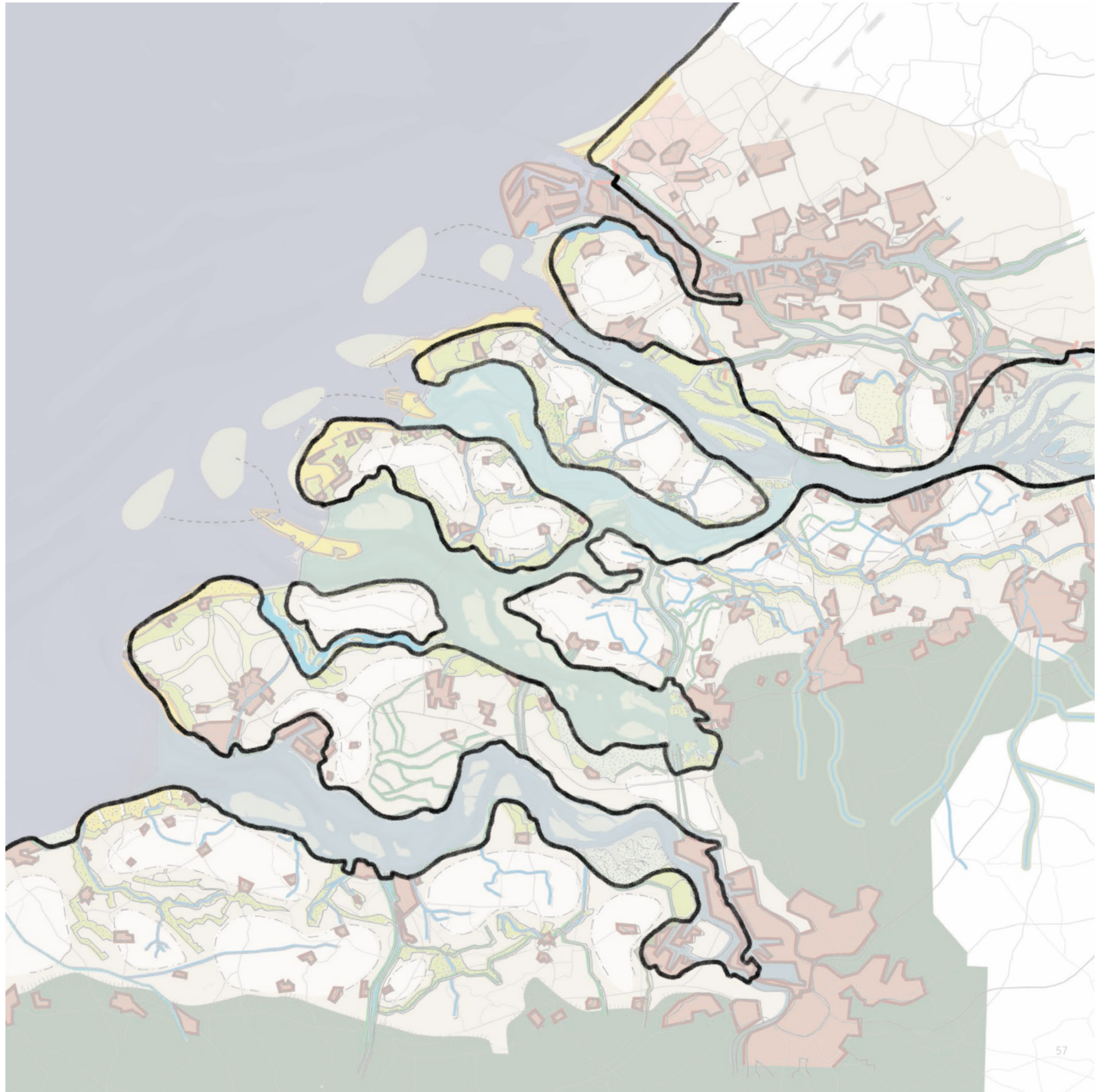


Figure 42: Plan map of future image author + (H+N+S landschaparchitecten et al., 2009)

SWOT ANALYSIS

SWOT ANALYSIS

This chapter focuses on exploring the qualities and threats of the green-blue structure and livability of the island of Schouwen-Duiveland. This is done by a SWOT analysis. A SWOT stands for Strength, Weaknesses, Opportunities and Threats. In figure 43 the table of the SWOT analysis is shown.
Beside identifying the Strength, Weaknesses, Opportunities and Threats of the island of Schouwen -Duivenland, the analysis also shows which strategies emerge when combining the elements. For example, the opportunity of stimulating sedimentation for biodiversity can minimize the weakness of the water safety of the island.

Next sub-chapters will zoom in to each SWOT element.

Sub-questions to be answered in the chapter:
What are the existing qualities and threats of the green-blue network and the livability on Schouwen-Duiveland?

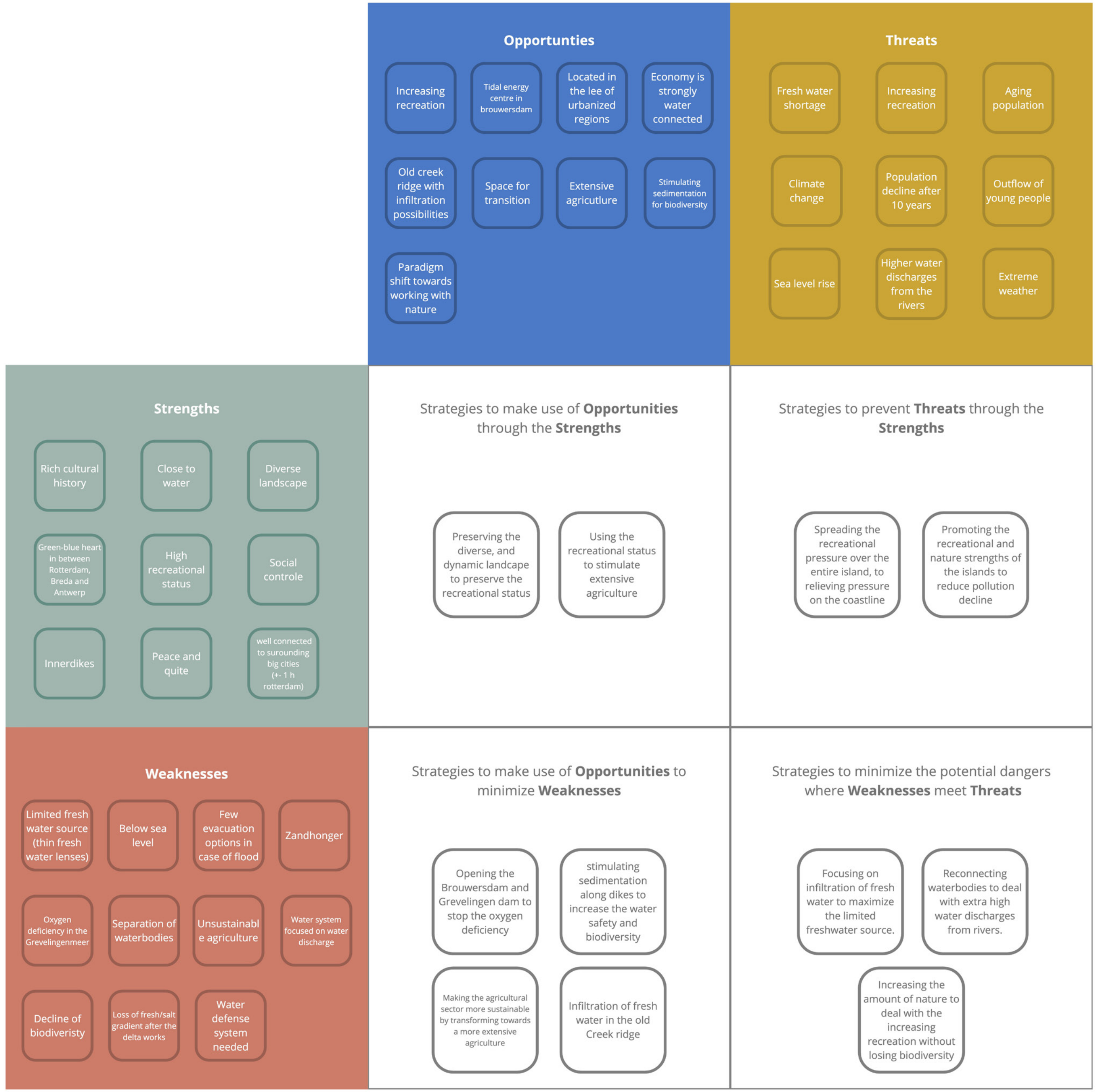


Figure 43: SWOT analysis, author

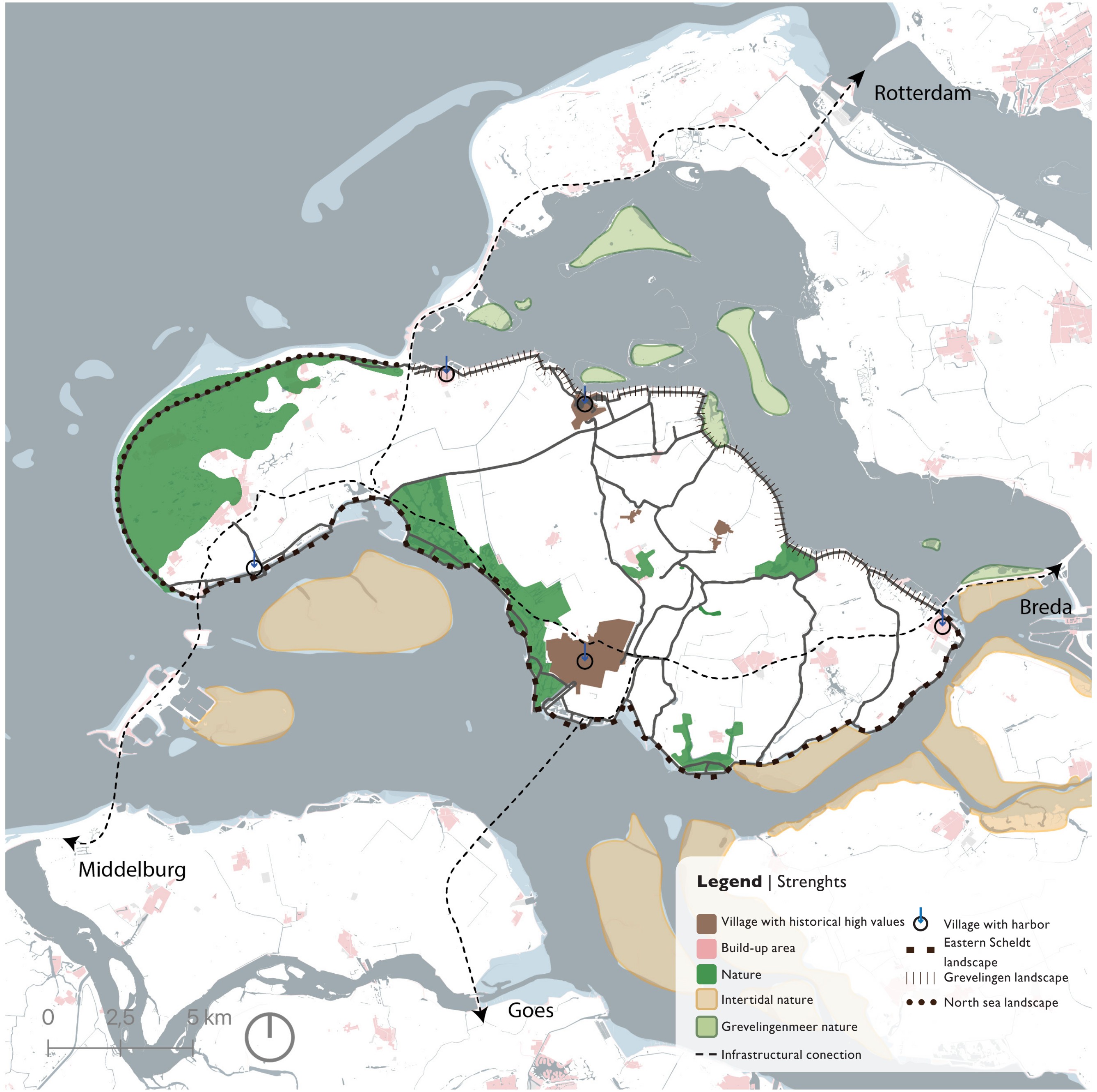


Figure 44: Strengths Schouwen-Duiveland, author + (pdok, 2022c)

STRENGHTS

Green-blue heart
Schouwen-Duiveland is located in the Green-Blue lee in between Rotterdam, Breda, and Antwerp. (Zeeuwse kustgemeenten et al., 2017) The island is characterized by green spaces and water bodies, with smaller cities and towns situated in this landscape. This provides a natural environment that attracts people who enjoy outdoor activities.

Rich cultural history
Schouwen-Duiveland has a rich cultural history that is seen in it's architecture, old village centers and other historical sites. This strength creates a sense of identity and community pride in the region. (Gemeente Schouwen-Duiveland, 2011) It also attracts tourists who want to explore the history of the area, thus contributing to the region's economic growth.

Close to the water
Being close to the water is a significant strength of Schouwen-Duiveland. The region is surrounded by the North Sea, the Eastern Scheldt and the Grevelingenmeer providing opportunities for water sports, fishing, and other water-based activities.
Therefore, the economy is also closely tied to water. (Gemeente Schouwen-Duiveland, 2011)

Good social control
Schouwen-Duiveland has strong social control, which is a strength that contributes to safety, security and wellbeing of the community. (Gemeente Schouwen-Duiveland, 2011) The community members look out for each other and there is always a helping hand close by.

Peace and quiet
The peace and quiet of Schouwen-Duiveland is a strength that is attractive to people who prefer a serene environment. It creates an ideal setting for people to relax and recharge, away from the hustle and bustle of city life. This strength also attracts retirees who want to spend their golden years in a peaceful and quiet environment. (Gemeente Schouwen-Duiveland, 2011)

High recreational value
Schouwen-Duiveland has a high recreational value, which is a significant strength. (Gemeente Schouwen-Duiveland, 2011) The region has several nature reserves, parks, and other outdoor recreational activities, making it attractive to tourists and residents alike.

Diverse landscapes
The region has diverse landscapes, ranging from sandy beaches to dunes, forests, and wetlands. This strength attracts people who enjoy outdoor activities, as they can choose from a range of environments to suit their preferences. (Gemeente Schouwen-Duiveland, 2011)

Well connected to surrounding big cities
Schouwen-Duiveland is well connected to surrounding big cities such as Rotterdam, Breda, and Antwerp, which are located within an hour's drive. This strength provides access to the labour market of these cities. (Zeeuwse kustgemeenten et al., 2017)

Highly engaged society
Schouwen-Duiveland has a highly engaged society, which is a strength that contributes to the region's social cohesion. (Gemeente Schouwen-Duiveland, 2011)

Inner dikes
Schouwen-Duiveland has several inner dikes. These dikes can work as ecological connections between the different habitats. They strengthen the habitats. (Brons partners landschaparchitecten bv, 2011)

WEAKNESSES

Decline of biodiversity

Schouwen-Duiveland is experiencing a decline in biodiversity (van der Zee, et al., 2019) due to habitat loss and fragmentation, among others, caused by human activities such as agriculture, urbanization, and infrastructural development. This has a negative impact on the ecosystem and it's inhabitants, including endangered species. (Nieuws Europees Parlement, 2021)

Zandhonger

Zandhonger, which translates to "sand hunger," is a phenomenon caused by the human modification of the coastal landscape, including the construction of dikes and dams. This has led to a decrease in the amount of sand that is transported from the sea to the sand plates resulting in the loss of intertidal area. (Delta expertise, n.d.)

Below sea level

Schouwen-Duiveland lies below sea level, which makes it vulnerable to flooding in case of a breach in the dikes and rise in sea level due to climate change will increase the flooding probability. This can have disastrous consequences for the population, economy, and environment of the island.

Few evacuation options in case of flood

The limited number of evacuation options in case of a flood can make it difficult to ensure the safety of the population in the event of an emergency. This highlights the need for effective disaster management and evacuation planning. (Hillen et al., 2011)

Freshwater lens

Schouwen-Duiveland's limited freshwater resources are dependent on the freshwater lens, a layer of fresh water that floats on top of the salt water in the underground aquifers. This makes the area vulnerable to salt seepage and over-extraction, which can have serious consequences for the local habitats and agriculture. (de Louw, 2015)

Loss of fresh salt gradient after the Delta Works

The construction of the Delta Works has resulted in the loss of the fresh salt gradient in the water bodies of Schouwen-Duiveland, which has led to a decrease in biodiversity and naturalness of the delta. (Tangelder et al., 2020)

Oxygen deficiency in the Grevelingenmeer

The Grevelingenmeer is experiencing oxygen deficiency, which is caused by the limited exchange of water between the lake and the North Sea. This has a negative consequences for the aquatic ecosystem . (Nolte, 2011)

Unsustainable agriculture

The agricultural practices are often unsustainable, relying heavily on chemical fertilizers and pesticides, which can negatively impact the soil quality, water quality, and biodiversity. Only 4% of the agricultural practice in the Netherlands is biological. (WUR, 2022)

The intensification of agriculture has come at a cost. Dutch agriculture has exerted substantial pressure on the environment and animal welfare due to its intensive practices. (CBS, 2022)

Water system

The water system on Schouwen-Duiveland is primarily focused on water discharge, which can lead to drought and loss of water resources. (Waterschap Scheldestromen, 2021a&b)

Fragmentation of the water bodies

The separation of the water bodies around Schouwen-Duiveland has lead to a loss of biodiversity and the formation of stagnant water bodies that are prone to contamination. (Nolte, 2011)

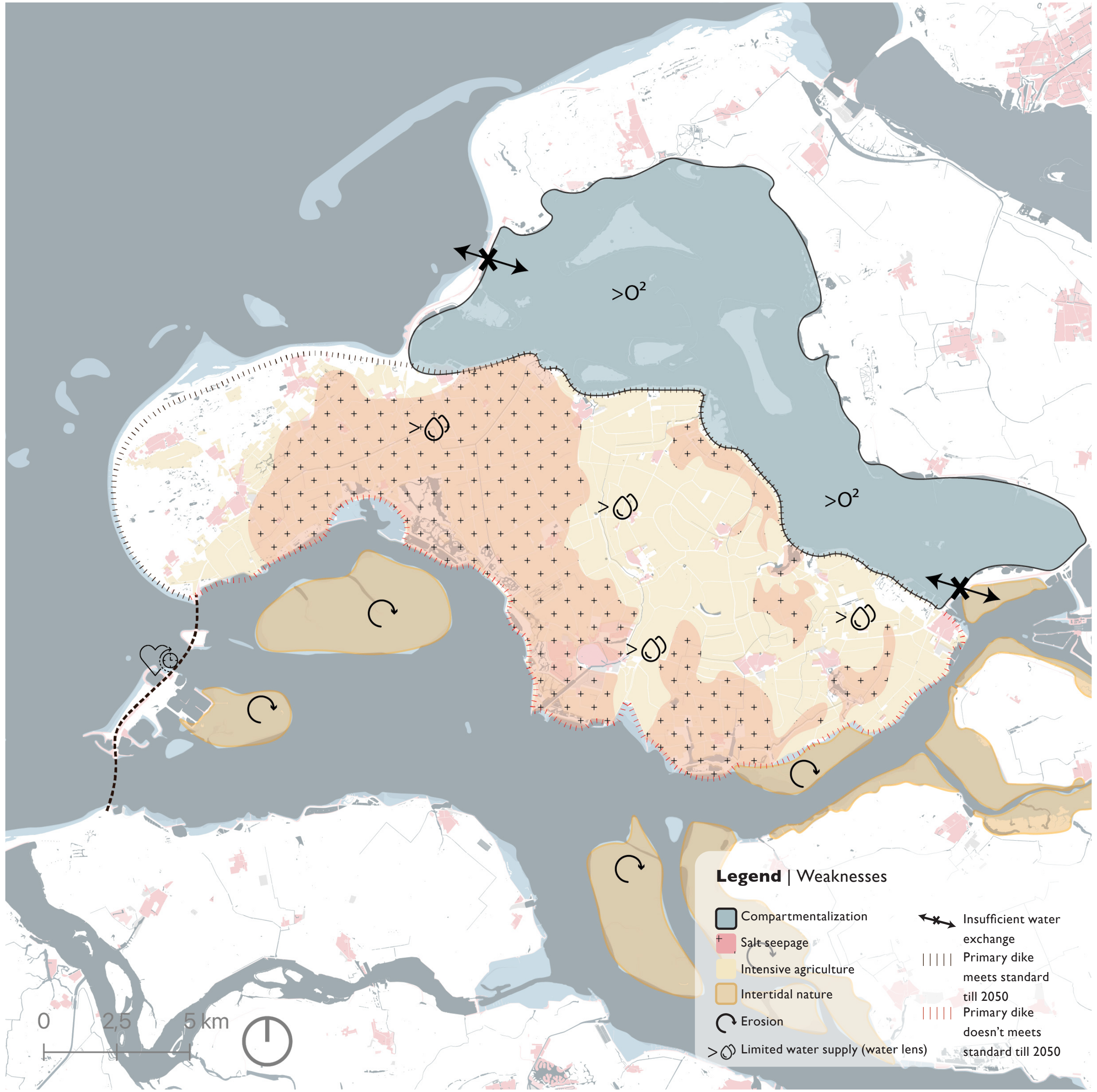


Figure 45: Weaknesses Schouwen-Duiveland, author + (pdok, 2022c)

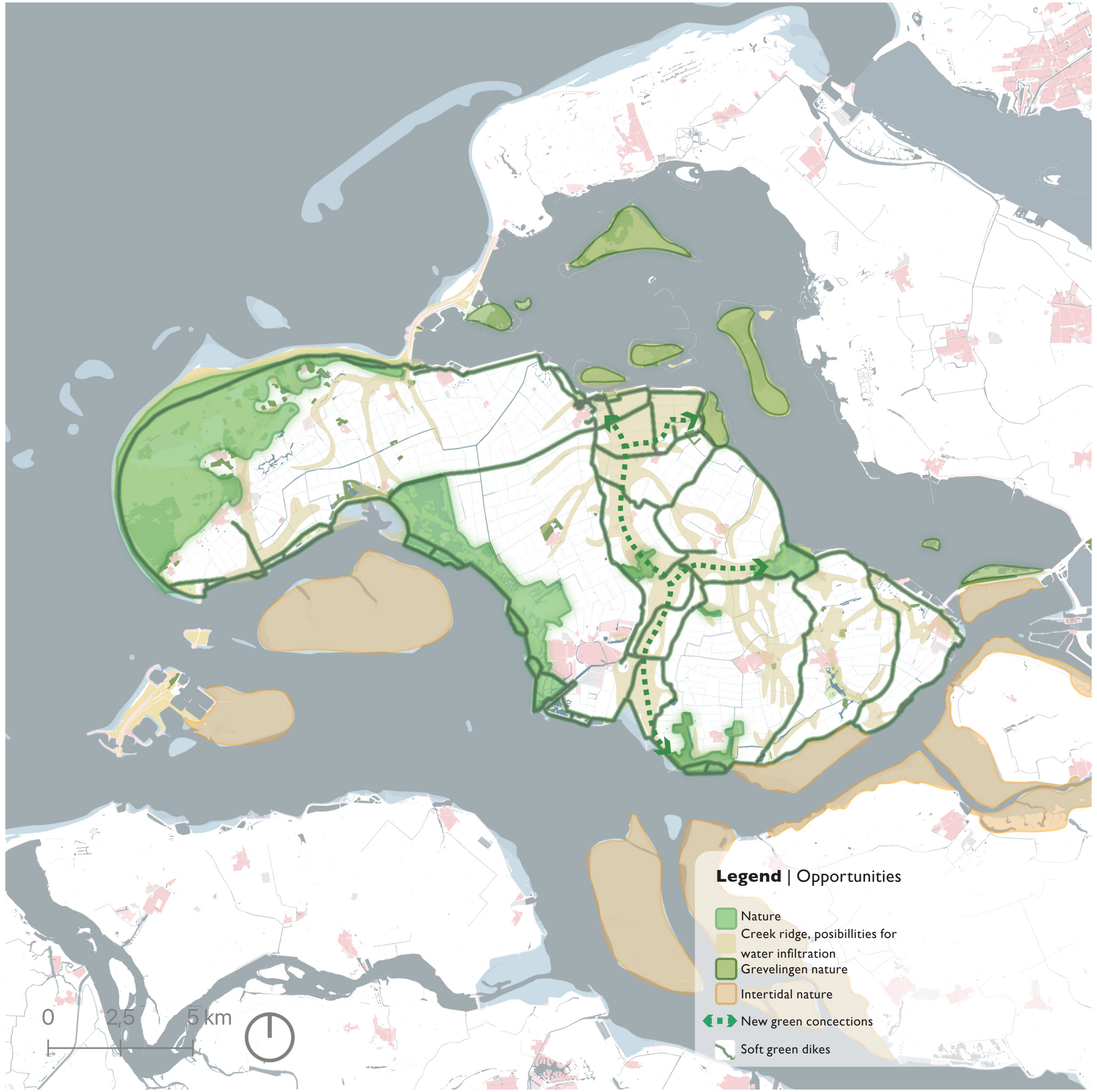


Figure 46: Opportunities Schouwen-Duiveland, author + (pdok, 2022c)

OPPORTUNITIES

Old creek ridge
This feature provides an opportunity for Schouwen-Duiveland to improve its water management by utilizing this natural feature for water infiltration. This could lead to a more sustainable and efficient use of water resources. (Baaren, n.d.)

Stimulating sedimentation for biodiversity
Creating conditions that promote sedimentation can increase the amount of intertidal areas around Schouwen-Duiveland, this could enhance biodiversity in its aquatic ecosystems. (Haterd et al., 2010) This would not only support the conservation of these ecosystems but also provide opportunities for eco-tourism.

Increasing recreation
The natural environment of Schouwen-Duiveland provides opportunities for various recreational activities such as hiking, cycling, bird watching, and water sports. The municipality could capitalize on this by investing in tourism infrastructure and promoting Schouwen-Duiveland as a destination for nature-based tourism. (Gemeente Schouwen-Duiveland, 2011)

Tidal energy centre in the Brouwersdam
Schouwen-Duiveland could become a leader in renewable energy by promoting the development of a tidal energy centre in the Brouwersdam. This would not only reduce the municipality's dependence on fossil fuels but also create new economic opportunities. (Zuidwestelijke Delta, n.d.)

Located in the lee of urbanized regions
Schouwen-Duiveland's location in the lee of urbanized regions provides an opportunity for the municipality to position itself as a green oasis. This could attract people looking for a peaceful and natural environment to live, work, or visit. (Zeeuwse kustgemeenten et al., 2017)

Space for transition
Schouwen-Duiveland has a relatively low population density, which provides an opportunity to experiment with innovative solutions to social, economic, and environmental challenges.(Gemeente Schouwen-Duiveland, 2011) The island could become a testing ground for sustainable and inclusive development.

Nature reservation as income for farmers
Schouwen-Duiveland's natural environment provides opportunities for farmers to diversify their income by engaging in eco-friendly agriculture and nature conservation. This could create new economic opportunities and support the sustainability of the agricultural sector. (Elliott et al., 2022)

Paradigm shift towards working with nature
Schouwen-Duiveland has the opportunity to adopt a new paradigm that emphasizes working with nature instead of against it. By embracing this approach, the municipality could promote sustainable development that is in harmony with the natural environment.

Extensive agriculture
Schouwen-Duiveland could promote extensive agriculture. This provides opportunities for the development of sustainable farming practices such as organic farming, salt farming, and agro-forestry. This could support the sustainability of the agricultural sector and promote biodiversity conservation.

THREATS

Increasing recreation
The island is popular with tourists and recreational visitors, and this has put pressure on the environment and the local infrastructure. As visitor numbers increase, there is a risk of overuse and degradation of natural resources and habitats. This could undermine the island's attractiveness as a destination for tourism and recreation. (Gemeente Schouwen-Duiveland, 2011)

Freshwater shortage
Schouwen-Duiveland has limited freshwater resources, and this is becoming a growing concern due to climate change, sea-level rise, and population growth. As the demand for water increases, there is a risk of shortages, which could impact agriculture, industry and local communities. (de Louw, 2015)

Sea level rise
Schouwen-Duiveland is located below sea level, and rising sea levels pose a significant threat to the island's future. As the sea level rises, the risk of flooding, salt seepage and erosion increases, which could lead to loss of property, infrastructure, and natural habitats. (KNMI, 2021)

Aging population
The island's population is aging, and this could have implications for the local economy and social fabric. As the population ages, there may be a decline in the workforce, reduced demand for goods and services, and a shift in the balance of social and political power. (Gemeente Schouwen-Duiveland, 2011)

Climate change
Climate change is a global threat that could impact Schouwen-Duiveland in several ways, including more extreme weather events, sea-level rise, and changes in the natural environment. These impacts could have far-reaching consequences for the local economy, environment, and society. (KNMI, 2021)

Extreme weather
Schouwen-Duiveland is vulnerable to extreme weather events, such as storms, floods, and heatwaves. (KNMI, 2021) These events can cause damage to property, agriculture yield, infrastructure, and natural habitats, and can disrupt local communities.

Population decline after 10 year
Schouwen-Duiveland faces the challenge of population decline, especially among young people. This trend could have implications for the local economy, social fabric, and cultural identity (Gemeente Schouwen-Duiveland, 2011)

Outflow of young people
The island has a high outflow of young people, who leave to pursue education and career opportunities elsewhere. This trend could contribute to population decline, and also result in a brain drain, as the island loses its most talented and innovative individuals. (Gemeente Schouwen-Duiveland, 2011)

Higher water discharge from the rivers
Climate change is leading to more frequent and intense rainfall events, which are causing higher water discharge from the rivers. The delta needs to be prepared to deal with more river water. In case of storm on sea, when the outlet to sea is limited, problems can occur. This could lead to flooding and erosion, which could impact infrastructure, agriculture, and natural habitats. (KNMI, 2021)

Figure 47: Threats Schouwen-Duiveland, author + (pdok, 2022c)

VISION

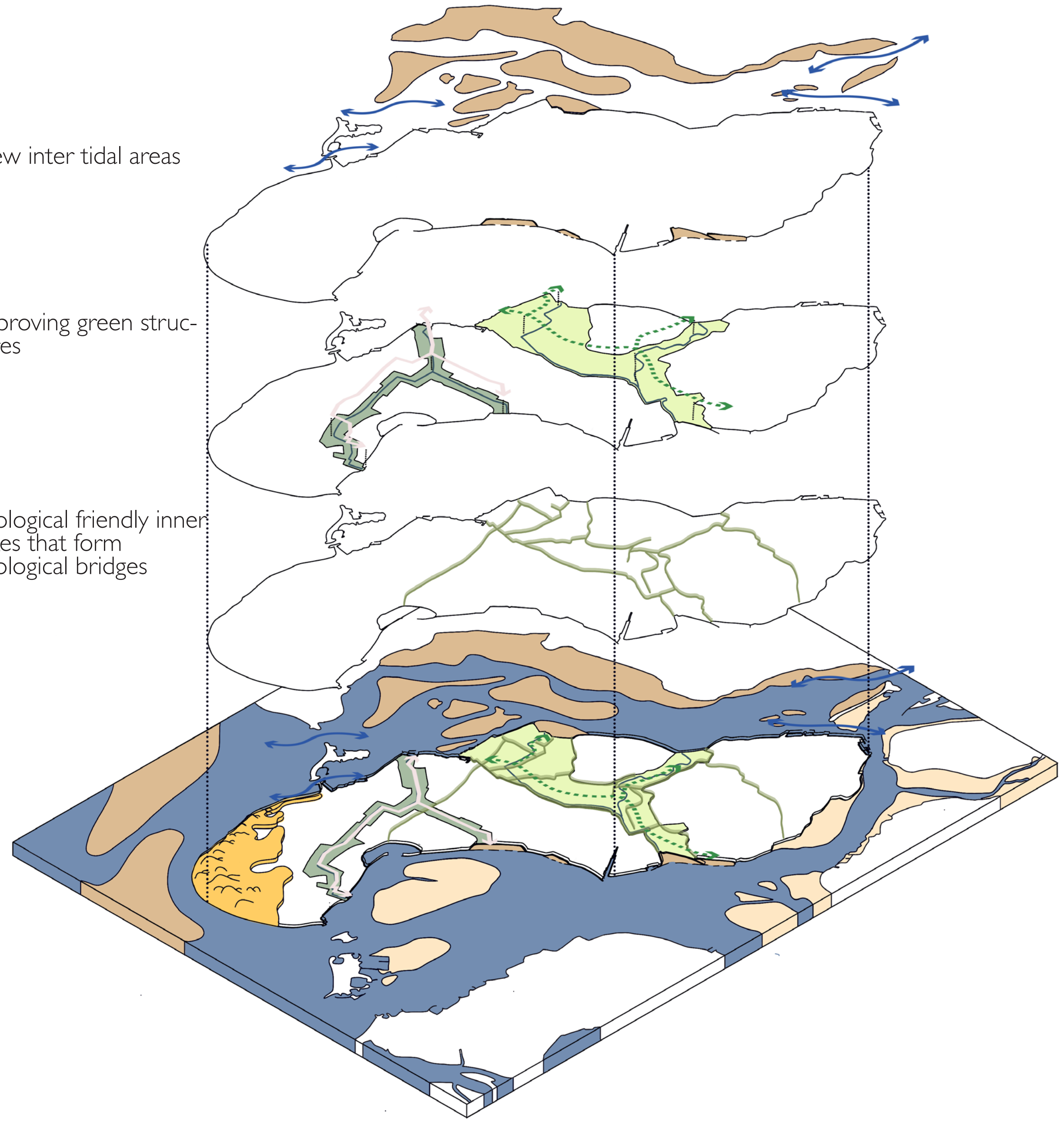


Figure 48: Axo, stacking vision, author

VISION

I envision a future for Schouwen-Duiveland that embraces its unique geological formation and leverages its potential to become a sustainable and nature-inclusive island.

The island's geological formation naturally divides it into four distinct areas: the Duiveland polders, the Dreishor polder, the former creek area known as the Gouwe, and the Schouwen polder. The inner dikes within these areas hold immense potential for connecting the various nature areas, functioning as an interlocking unit that enhances the robustness of the ecosystems. By utilizing these dikes to create cohesive corridors, we can facilitate the movement of flora and fauna, allowing for the preservation and expansion of biodiversity.

The former creek area, the Gouwe, holds particular promise as a valuable water infiltration zone. To ensure the availability of fresh water, this area should focus on optimizing its capacity for water infiltration, replenishing the underlying water lens. By prioritizing water infiltration, we can maintain a healthy balance and mitigate the effects of salt water intrusion, ultimately preserving the island's freshwater resources.

In the Schouwen polder, where salt intrusion is already occurring and will only increase in the future, we need to adapt a strategic approach to coexist with the salt water environment. Given that the main watercourse in this area has a brackish to salt composition, we can seize opportunities to engage in salt agriculture on the surrounding agricultural land. By cultivating crops that are salt tolerant or accepting salt, we can adapt to the changing conditions and secure agricultural productivity while improving the ecosystem. This innovative approach will not only enable us to thrive in a salt water environment but also contribute to the sustainable development of Schouwen-Duiveland.

To create a sustainable and thriving ecosystem on Schouwen-Duiveland, we need to address the impacts of the Delta works and restore what has been lost. This means reconnecting the waters, revitalizing brackish environments, and promoting the natural dynamics of the delta. By breaking down barriers and fostering greater interconnectivity, we can ensure a resilient and thriving ecosystem for the island and the surrounding waters.

By implementing these nature-inclusive approaches to water management and land use, we can transform Schouwen-Duiveland into a model of sustainable development.
Through utilising the islands unique features and environmental conditions we can ensure a prosperous and thriving future for Schouwen-Duiveland, where humans and nature coexist harmoniously, benefiting both present and future generations.

PROGRAM OF DEMANDS

This chapter outlines the program of demands for Schouwen-Duiveland, which is divided into five topics: Environment, Water safety, Agriculture, Living, and Recreation.

Environment

Immediate action is necessary to address the environmental challenges facing the island. The quality of water in the Grevelingenmeer, a critical ecosystem, can be improved by reintroducing tidal dynamics. The nutrient deficiency in the Eastern Scheldt caused by shellfish overproduction and compartmentalization of the delta must also be tackled. Agriculture must minimize its impact on the environment, while inter tidal areas must be increased. In case of drought, fresh water should have priority for nature.

All surface water quality must meet European legal norms by 2027 with maximum nitrates of 50 mg/l and active pesticide substances limited to 0.5 ug/l (European Union, 2006)

As part of the EU biodiversity strategy, 30% of land use must be protected for nature. (Ongerepte-natuur, 2023)

The rural area, excluding ecological main structure and built-up areas, should have 10% green-blue landscape lining, including 5% woody elements such as hedges and wooded banks, 2.5% natural embankments, pools, and reed beds, and 2.5% herbal and flowery edges along fields and meadows, partly on flood defenses. (Samen voor biodiversiteit, 2022)

Agriculture

Agriculture is a significant source of pressure on the island's environment, and reducing its environmental footprint is essential. Sustainable agricultural practices, such as strip cultivation, reduced use of pesticides and fertilizers, saline agriculture, and organic farming, must be promoted. Agriculture should reduce or stop the use of chemical pesticides. Any pesticides used must not produce emissions or residues on agricultural products and eutrophication to groundwater.
Nitrogen deposition in Natura 2000 areas should be reduced below critical levels.

The agricultural sector must prepare for less freshwater availability, more water logging due to extreme rainfall, and more salt seepage due to sea level rise and begin transitioning towards these new environmental conditions.

Water safety

Water safety for villages must be a priority. When improving flood barriers and dikes, an integral approach must be taken to ensure that they serve not only water safety but also biodiversity and recreation.

Living

On the island 1,119 new dwellings need to be constructed to meet the regional housing challenge while maintaining or improving the quality of life on the island. The construction of new dwellings must not increase water logging or seepage and should be flood-resilient.

Recreation

Recreation is an important economic driver for the island, and it is therefore essential for the community. Maintaining a balance is crucial, with free access to nature for recreational purposes while limiting access to maintain a healthy ecosystem. To keep the island attractive to a diverse group, the variety in landscapes must be maintained.

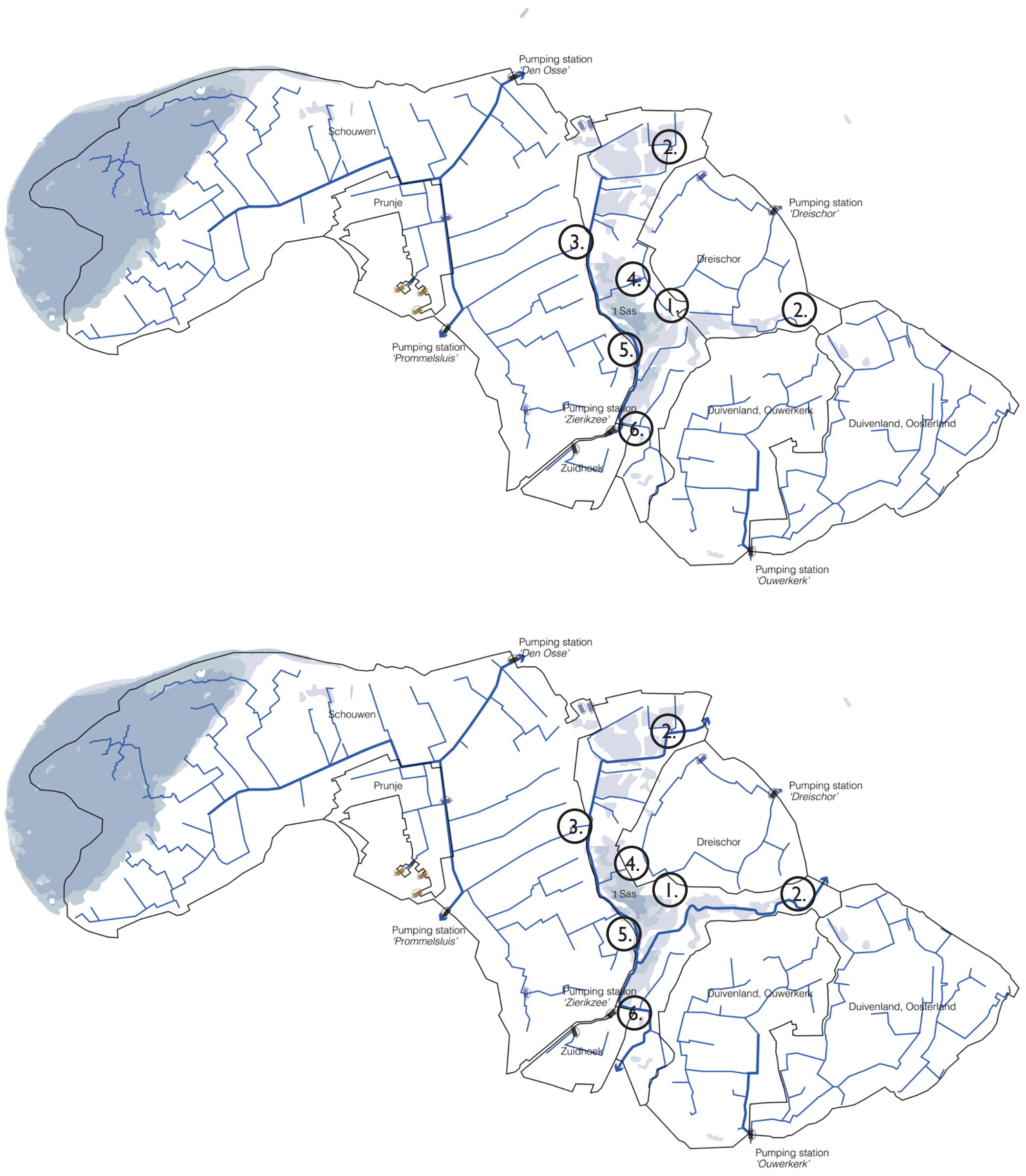


Figure 49: Changes in the water system of Schouwen-Duiveland, author + (Waterschap scheldestromen, 2021a) (Waterschap Scheldestromen, 2021b)

WATER SYSTEM

This chapter outlines a desired water system and its potential changes over time, with a focus on the water system surrounding the former creek in T'sas. This particular area is critical for increasing the freshwater supply. The following steps are proposed:

1. Enlarge the catchment area called t'Sas, using the former creek bed as the base.

2. Extend the main watercourse in t'Sas towards Dijkwater and Bommende.

3. Connect the main watercourse of t'Sas to the catchment area of Schouwen, allowing for division of water in events of extreme rainfall.

4. Cut off the ditch north of Schuddebeurs and reroute it towards the Dreischor catchment area. This watercourse contains salty/brackish water and should be kept separate from the freshwater creek system.

5. Widen the main watercourse in t'Sas to increase water storage capacity.

6. Redirect the main watercourse of t'Sas near Zierikzee, so that excess water can be pumped directly into the Eastern Scheldt instead of the harbor channel. This avoids the need to switch off the pump when the harbor channel is closed, which can cause water logging issues.

7. Raise the water level of t'Sas to increase water infiltration into the creek system.

The catchment area of t'Sas will function as an infiltration zone, with its borders based on the underlying former creek system. The former creek system brought in sand into the subsoil, allowing for water infiltration and increasing the availability of freshwater.

STAKEHOLDERS

The transformation of the delta and Schouwen-Duiveland involves a diverse range of stakeholders, each playing a unique role in the planning, implementation, and success of the project. These stakeholders can be categorized into influencer's, key figures, spectators, and interested parties. The stakeholders are organized in a diagram illustrated in figure 50 on the next page.

Influencer's such as the European Union, the central government, and funding organizations play a significant role in shaping policies and providing financial support. Key figures like government ministries, provincial bodies, and water management organizations contribute expertise and coordination. Spectators include implementers, industries, residents, and water treatment companies who observe and participate in the project. Interested parties like hospitality businesses, planners, neighboring municipalities, and flora and fauna conservationists have specific interests related to the project.

Collaboration among these stakeholders is essential for achieving the project's goals of creating a resilient and nature-inclusive delta landscape that balances economic, environmental, and social considerations. Effective engagement, dialogue, and cooperation among the stakeholders are necessary to ensure the success of the delta and long-term sustainability.

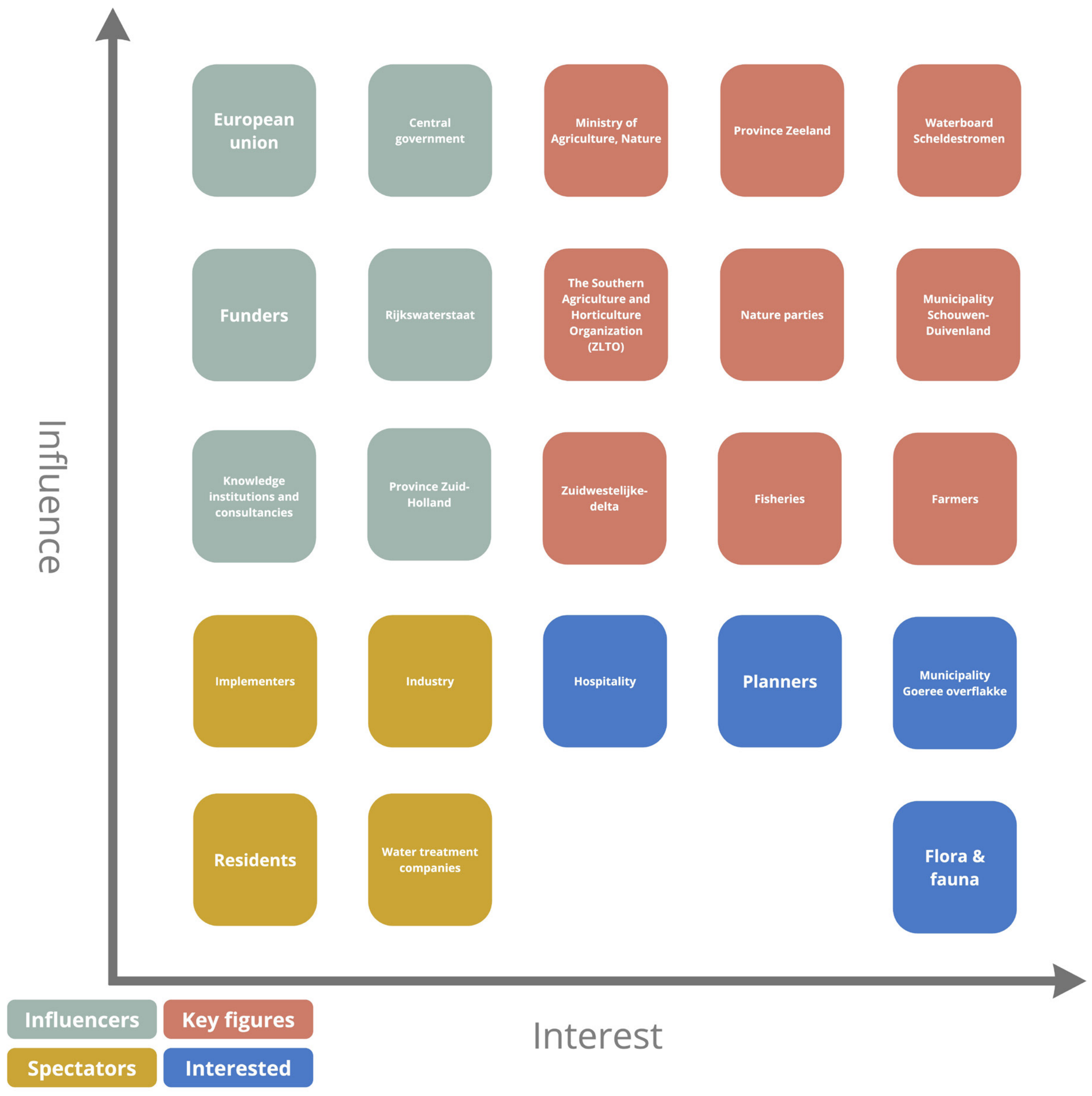


Figure 50: Stakeholder diagram

SYSTEMIC SECTION

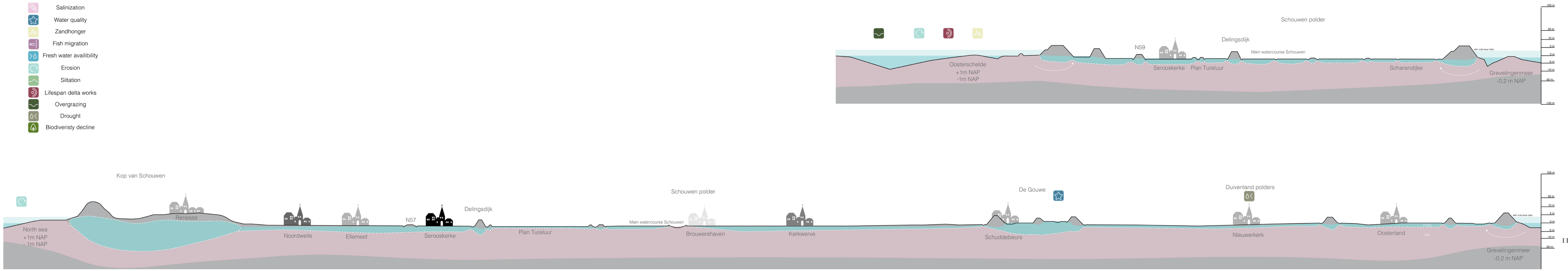


Figure 51: Systemic section Schouwen-Duiveland, future

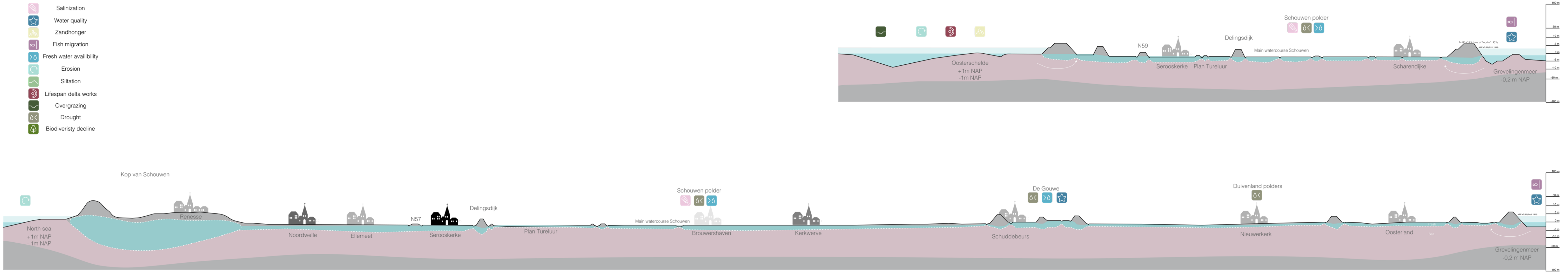


Figure 52: Systemic section Schouwen-Duiveland, current situation

DESIGN PRINCIPLES

To provide a solid foundation for the design approach, a series of design principles has been developed. Figure 53 illustrates an example of one of these cards, each of which features a small explanatory drawing, a memorable title, a sub-title, a brief explanation, and the underlying theory. While these cards are designed specifically for the island of Schouwen-Duiveland, they can be applied to other locations with similar contexts.

In the focus areas, these cards are used to demonstrate the various actions that can be taken to steer Schouwen-Duiveland towards a more sustainable and nature-inclusive future. All of the cards are included in the appendix and are also available as a separate card deck.

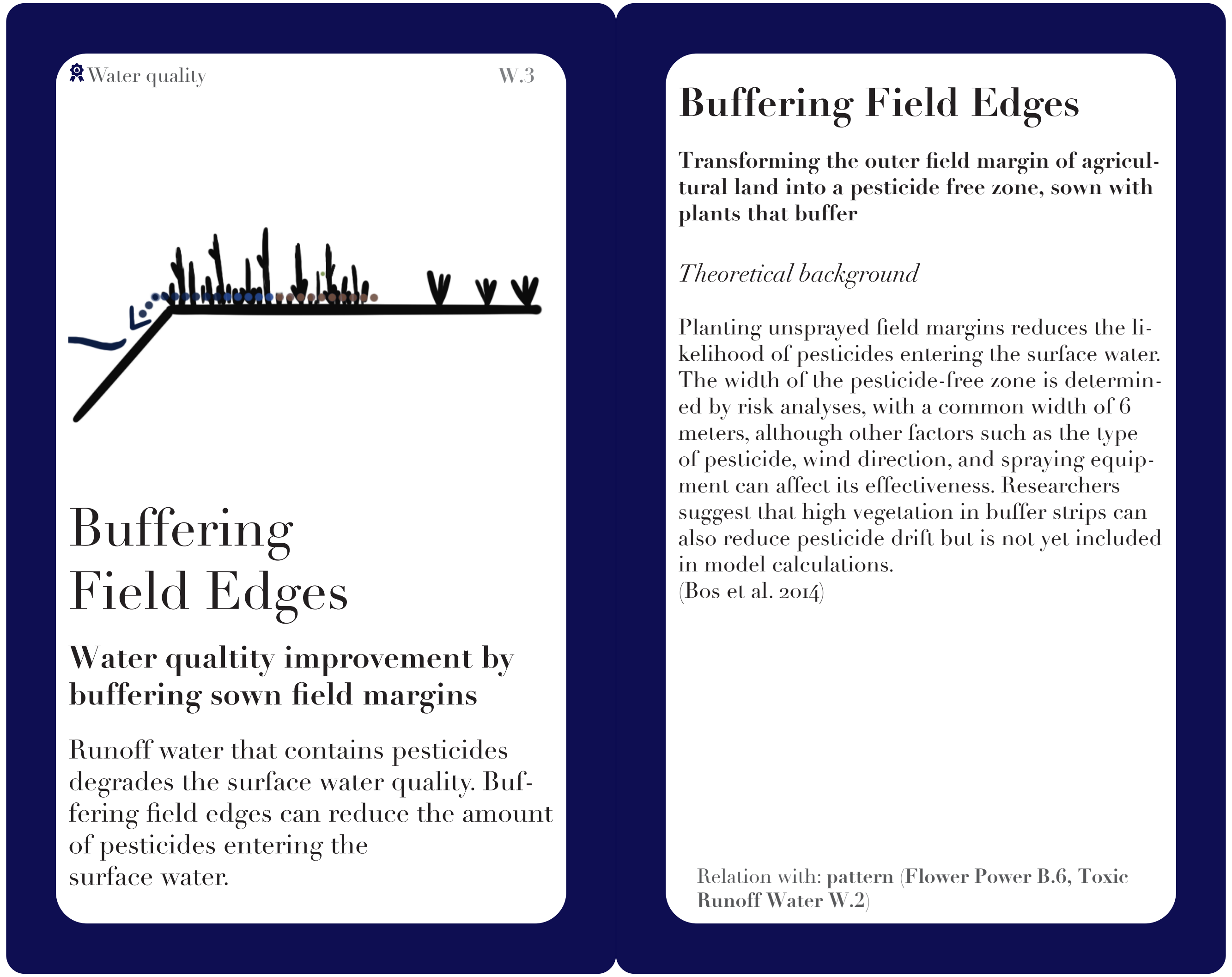


Figure 53: Example pattern cards

GREEN-BLUE STRATEGIES

Figure 54: Opportunities Schouwen-Duiveland, author + (CBS, 2010)

SCHOUWEN-DUIVELAND

In this chapter the different steps to transform the island of Schouwen-Duiveland towards a sustainable and nature inclusive island are explained.
This is done in multiple steps. On the next page, the different actions that are needed are drawn and explained. The drawing in figure 54 is the result of the land use after these actions are taken.

To see the spatial implications of this transformed island, I will zoom in towards 4 different focus areas.

Sub-questions to be answered in the chapter:
How can the green blue structures of Schouwen-Duiveland be improved when returning to a (semi) open delta?

What are the spatial implications when Schouwen-Duiveland is situated in a (semi-) open delta?

I Enlarging the Voordelta

2. Strengthening inner dikes, as ecological structure

3. Transforming the water system in the catchment area t'Sas towards the infiltration area de Gouwe.

4 Constructing dams along the Eastern Scheldt coast to stimulate sedimentation and create new intertidal areas.

5 Transforming the agriculture along the main watercourse on Schouwen towards saline agriculture

6. Opening the Brouwersdam and Grevelingen dam to stimulate sedimentation, in the Grevelingen

7. Formation of new intertidal areas in the Grevelingen.

THE FOUR FOCUS AREAS

This sub-chapter will focus on four different focus areas on Schouwen-Duiveland, which have been designated for improvements to their green-blue structures. The areas are Grevelingen, De Gouwe, Salt Agriculture, and Eastern Scheldt. Through a zoomed-in approach, I will explore the spatial implications of these improvements, the challenges faced in implementing these changes, and the benefits that these changes will bring to the island.

Each focus area has its unique set of challenges and opportunities, making the implementation of green-blue infrastructure different in each location. By examining these four focus areas, I hope to provide insight in how green-blue infrastructure can be tailored to meet the specific needs of an area. Ultimately, the goal is to demonstrate how the implementation of green-blue infrastructure can lead to a more sustainable and resilient water management system in the Netherlands.

The areas are :
1. Grevelingen
2. De Gouwe
3. Salt agriculture
4. Eastern Scheldt

Figure 55: The four focus areas, author + (CBS, 2010)

Figure 56: Focus area (semi) open Grevelingen, author + (CBS, 2010)

(SEMI) OPEN GREVELINGEN

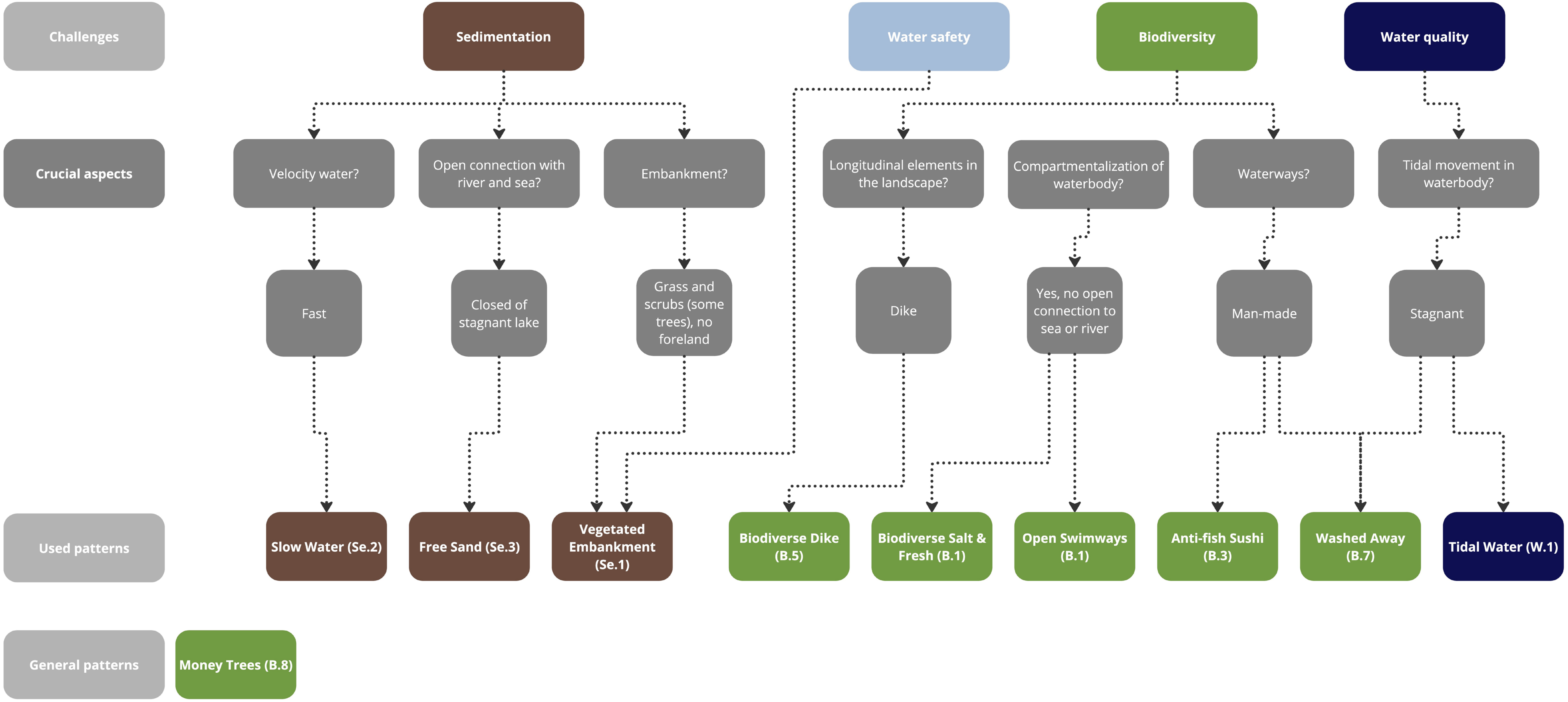
The first area I'm focusing on is the Grevelingenmeer. The Grevelingen is suffering from the consequences of the delta works. The construction of the dams compartmentalized the former sea arm into a stagnant salt water lake. To restore the ecosystem and make the lake sustainable for future, the natural dynamics should return. By closing the sea arm the lake is trapped in time and the natural sedimentation of the islands and coast can't occur. With rising sea levels it is of great importance to enhance the sedimentation so inter tidal areas won't be lost and drown. This chapter shows how the Grevelingenmeer can transform into a (semi) open water body where the sedimentation is strengthened and the tide is returned.

This green-blue strategy only fits the delta strategies that allow river and sea water to influence the Grevelingenmeer, because to transform the Grevelingenmeer towards a (semi) open inter tidal area it needs the tide from the sea and the sediment from the river.

Possible delta scenarios:
+/- Semi open delta
+ Open delta

On the next page a decision tree is shown. Here you can see which challenges there are and what crucial aspects are to be analyzed to choose a fitting design principle.

DECISION TREE



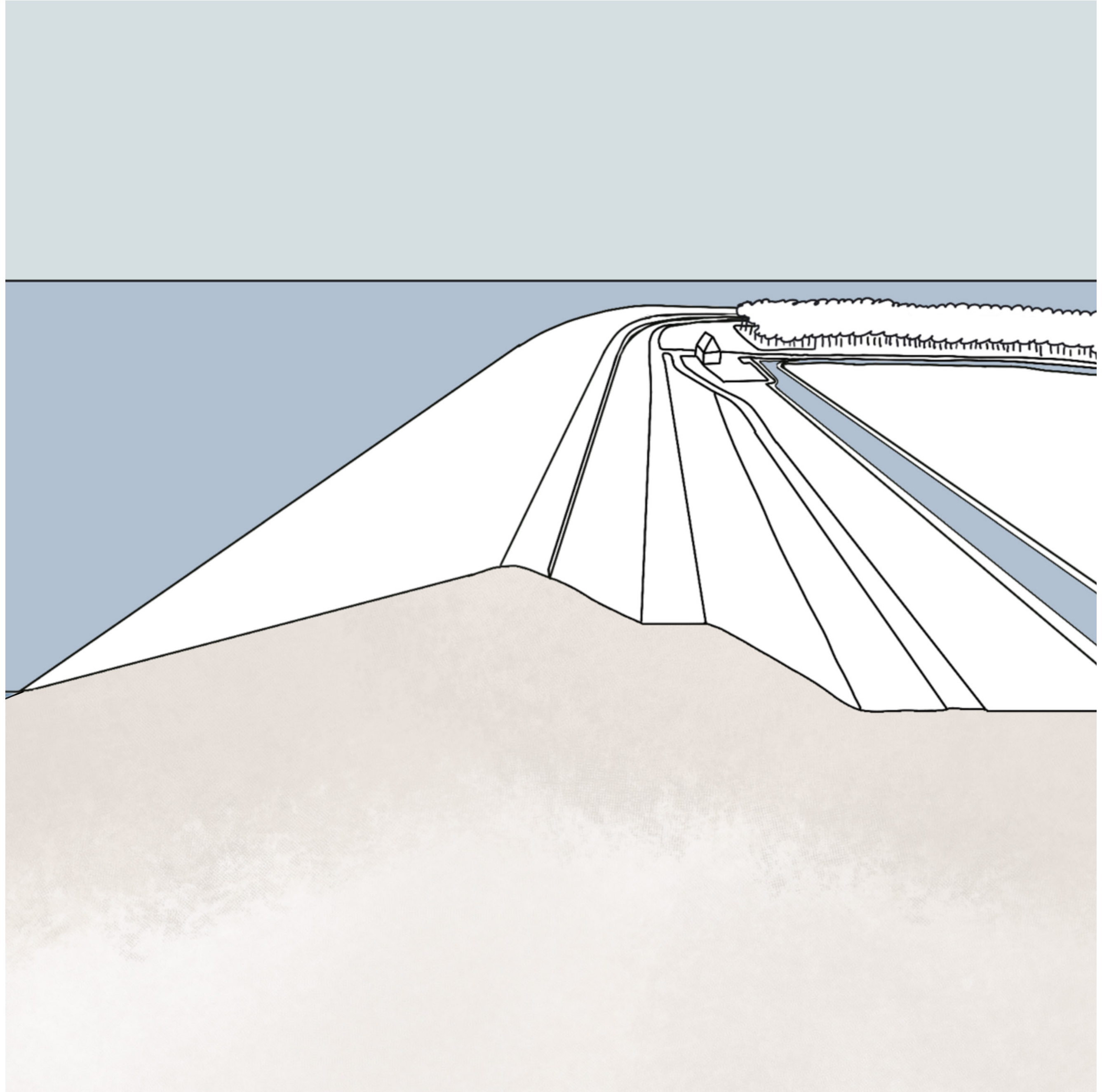
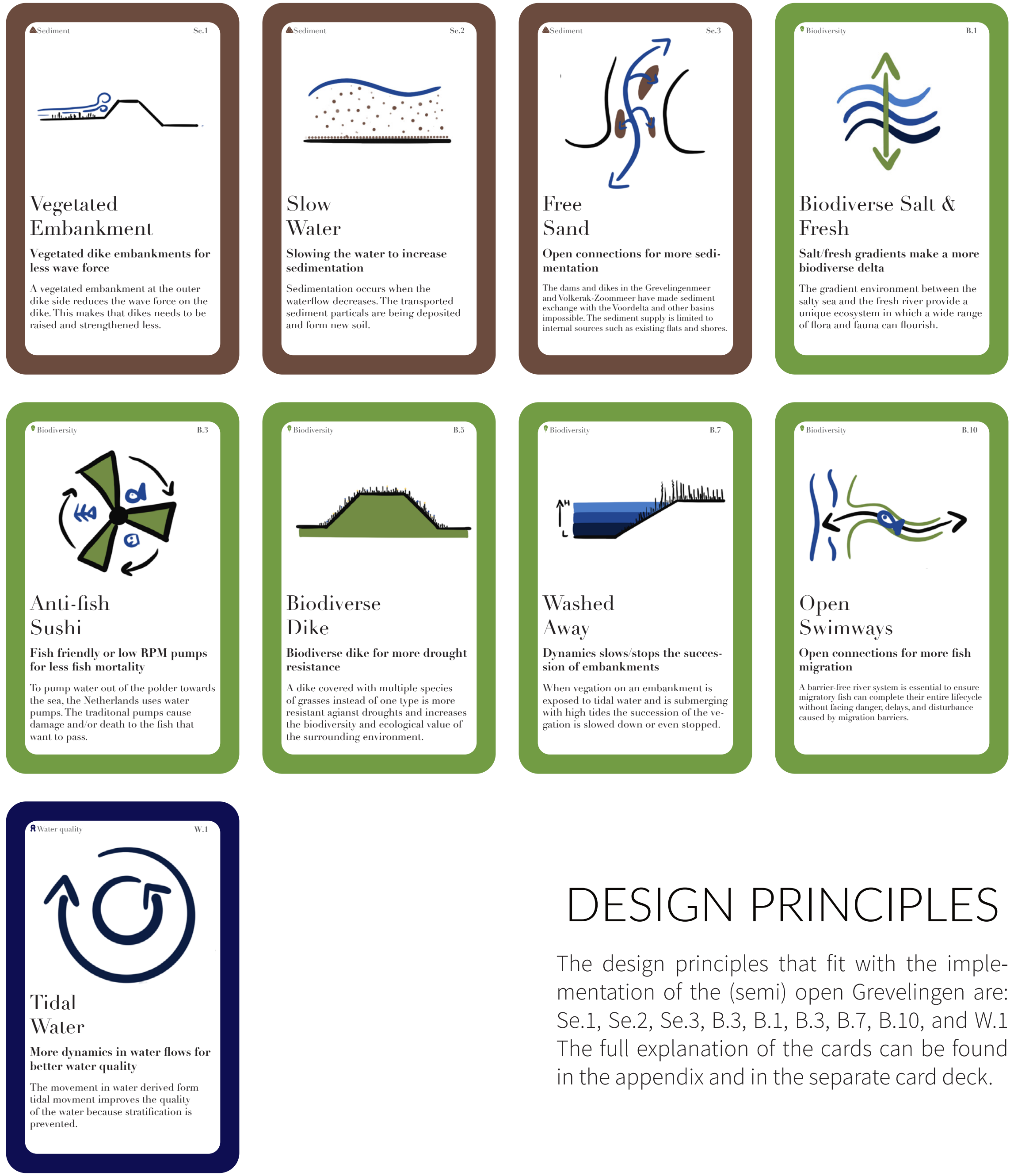


Figure 57: Section / birds eye view lange dijk, author



DESIGN PRINCIPLES

The design principles that fit with the implementation of the (semi) open Grevelingen are: Se.1, Se.2, Se.3, B.3, B.1, B.3, B.7, B.10, and W.1 The full explanation of the cards can be found in the appendix and in the separate card deck.

PLAN VIEW

The drawing on the right show where inter tidal areas will occur when the full tide is returned to the Grevelingenmeer. In figure 58 the current state of the Grevelingenmeer is shown. There are very deep gully's as well as shallow oyster riffs and plates. If we want to transform the Grevelingenmeer to a (semi) open delta we need to let the tidal dynamics back into the lake. This means that the lake will have the same tidal movement as the sea. In figure 59 is the Grevelingenmeer at high tide. As you can see only the highest parts of the island are above the water level. If more sedimentation occurs, more parts of the island will get higher. In figure 60 the Grevelingenmeer is shown at low tide .Here you can see the inter tidal area occurring. These areas are constricted along the island as well as the dikes. To prevent erosion constructions or vegetation is needed to slow the water down.
On page 140 and 141 the sections of figures 58, 59 and 60 are shown.

Legend | Grevelingen

- Scrubs / Trees
- Grass land
- Agriculture land
- Sand

- Deep water
- Shallow water
- Low tide
  - \- 1,00 m NAP
  - \- 0,70 m NAP
  - 0,00 m NAP
- High tide
  - \- 1,00 m NAP
  - \- 0,70 m NAP
  - 0,00 m NAP

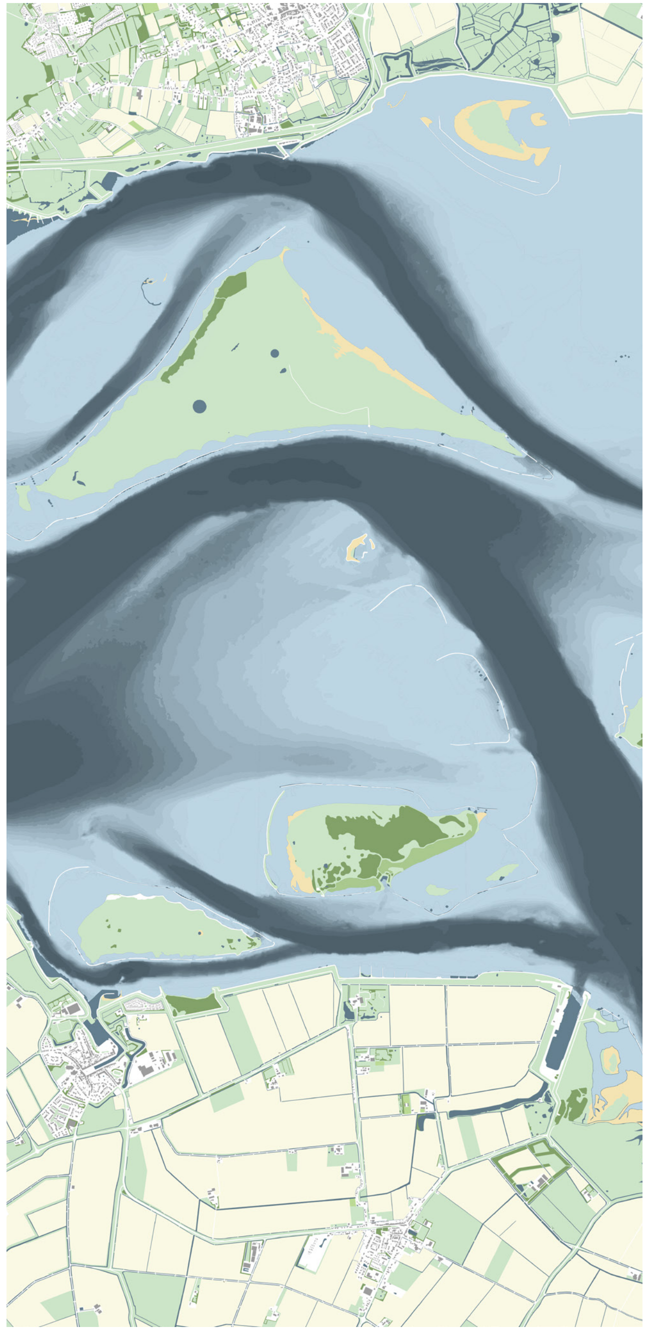


Figure 58: Cut out of the Grevelingenmeer in the current state.

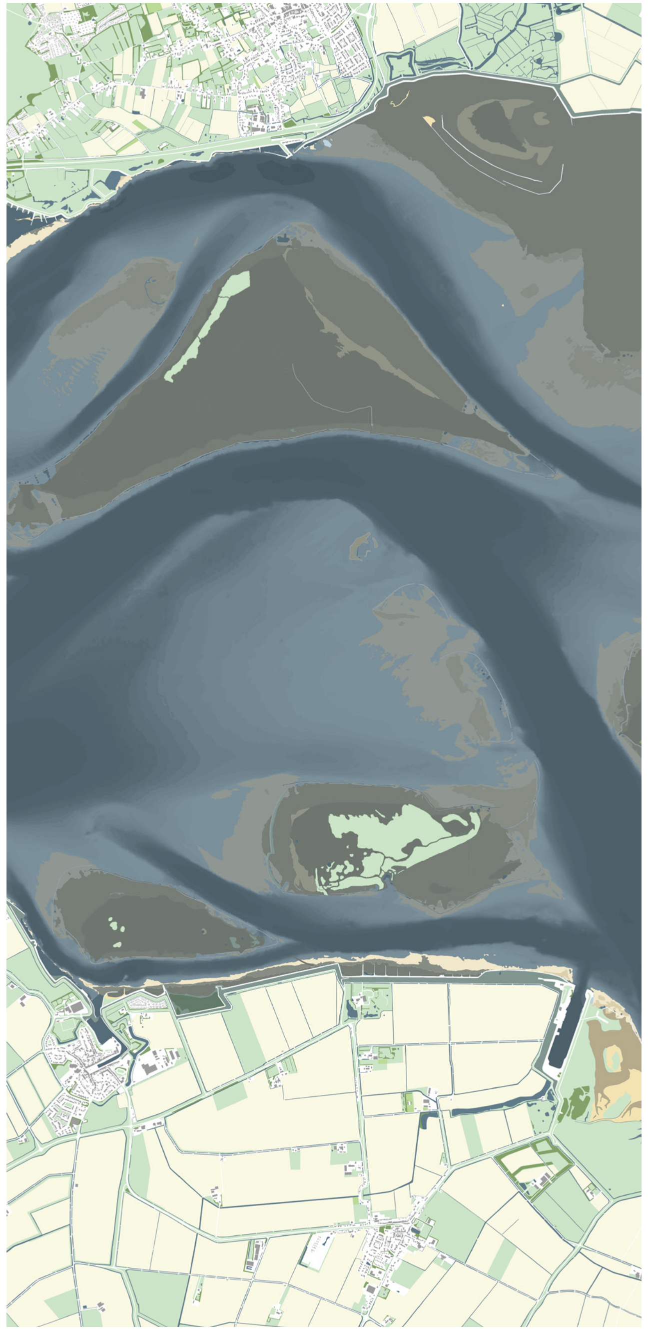


Figure 59: Cut out of the Grevelingenmeer with a high tide of +1.00m NAP

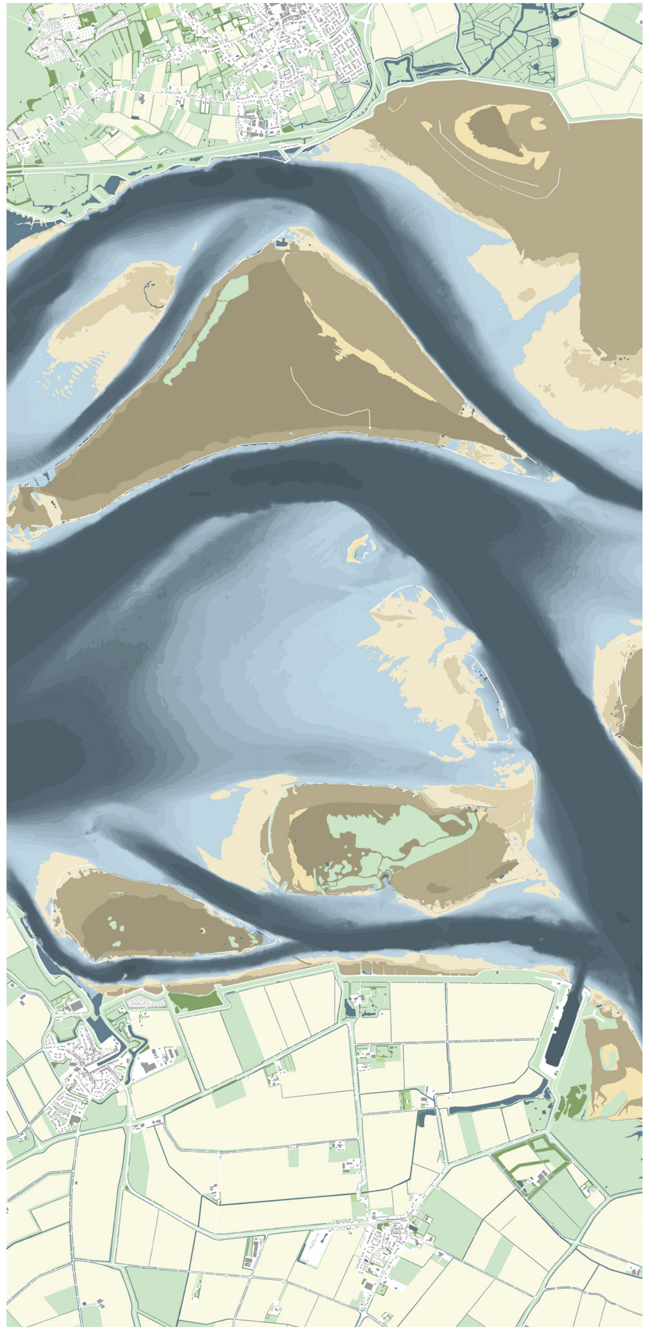


Figure 60: Cut out of the Grevelingenmeer with a low tide of -1.00m NAP

PHASING

This chapter explains the phased approach to opening the Grevelingen.

Phase I involves enlarging the Voordelta, strengthening dikes, using floating docks, and removing vegetation under +1 m NAP to prepare for increased water flow.

Phase 2 focuses on opening a controlled section of the Brouwersdam to restore tidal exchange between the Grevelingen and the North Sea, reintroducing natural processes and promoting tidal movement, increasing oxygen levels and sediment exchange.

Phase 3 entails opening the Grevelingen Dam to restore the salt-fresh gradient, promoting sedimentation with artificial reefs, oyster beds, vegetation and other structures and promote nature restoration.

The 3 different phases are illustrated on the left. Each phase is accompanied by an overview of the challenges that need to be addressed, the key stakeholders involved, and the pattern cards that can be utilized to guide the process.

PHASE 1

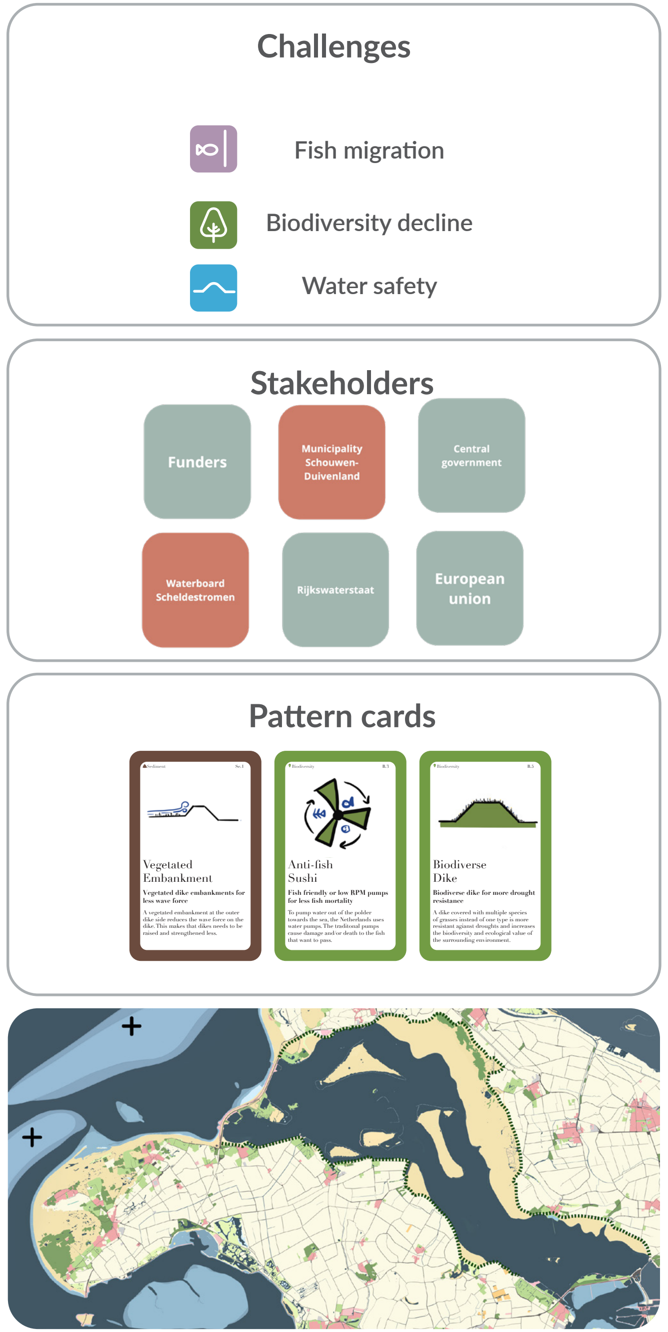


Figure 58: Grevelingenmeer, T=1

PHASE 2

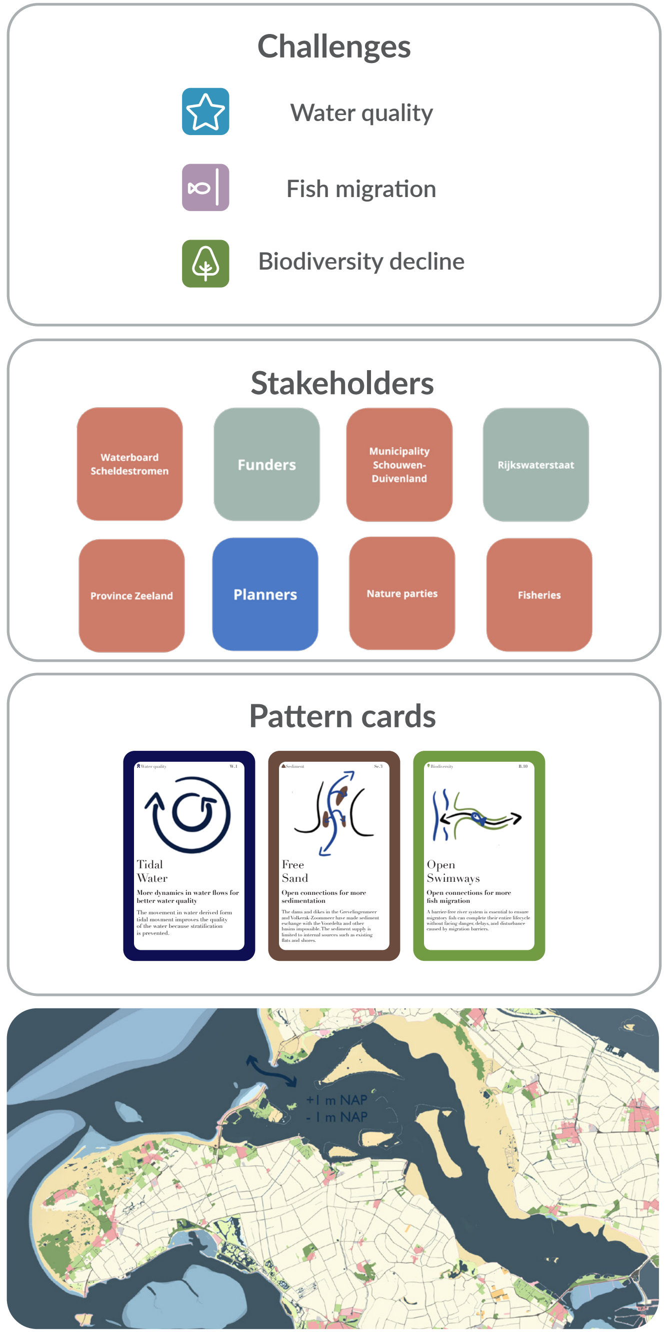


Figure 58: Grevelingenmeer, T=2

PHASE 3

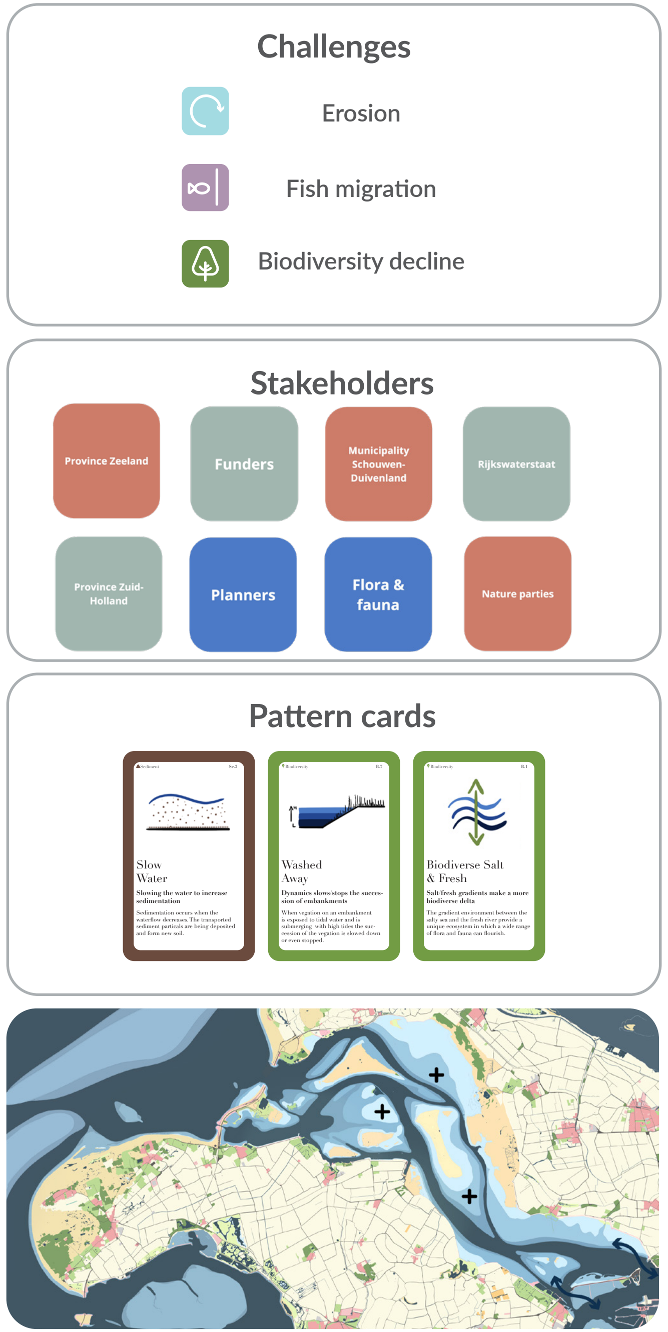


Figure 58: Grevelingenmeer, T=N

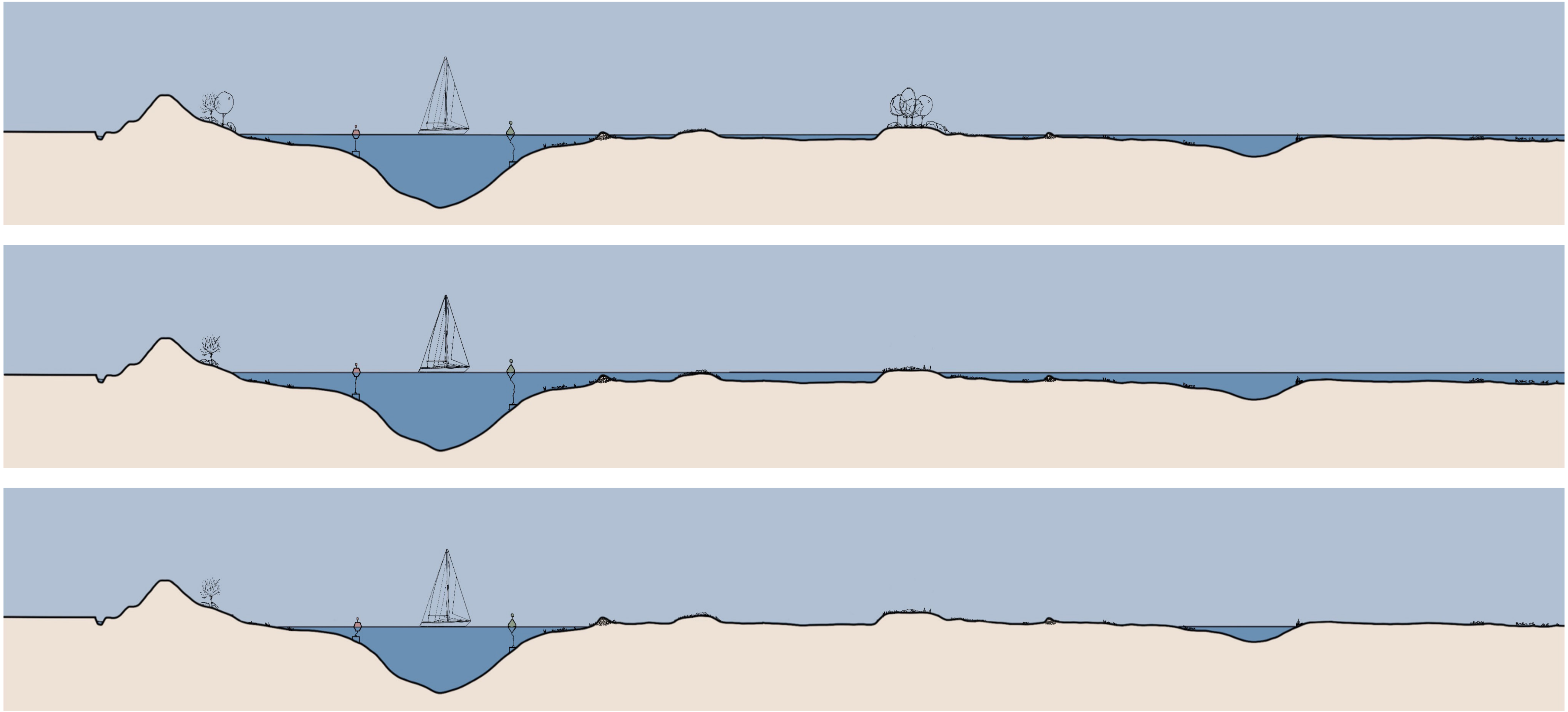


Figure 61 Sections Grevelingenmeer, current and open situation high tide and open situation low tide author

SALT MARSH VEGETATION

The return of the tidal movement in the Grevelingenmeer will have an impact on the already existing unique environments that are present on the islands. The tide will remove these habitats, but new unique habitats will also be created. Examples of these new vegetations and where they can occur are shown here on the right.


Avocet in the mud (np Eastern Scheldt, n.d.


Eelgrass (Govers, 2021)


Red fescue (Dijksen, n.d.)


Zeerus (de Jong, 2010)


Common marsh grass (Schelde-schorren, n.d.


Sea purslane, (Roek 2020)


Samphire (Ophen, 2019)


Cord grass (Itkor, n.d.)

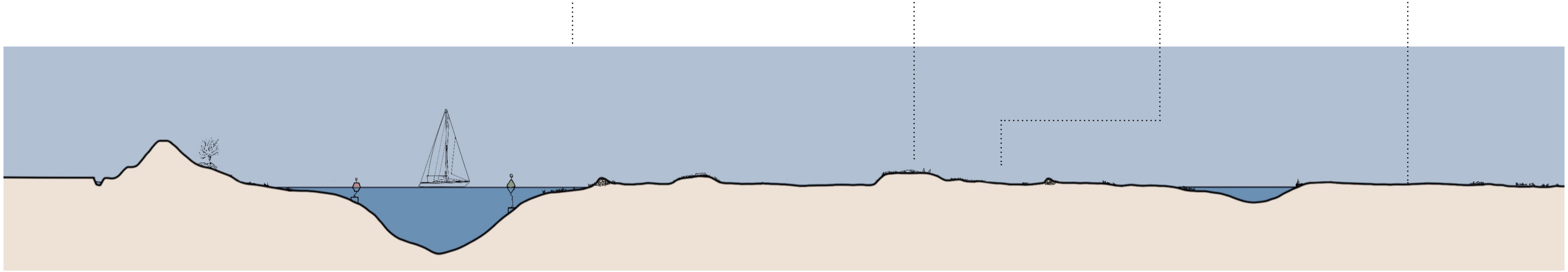


Figure 62: Section Grevelingenmeer, open situation low tide

DESIGN PRINCIPLES IN CONTEXT

The map of figure 63 shows the possible locations where the design principle can be implemented. In the table the design principles are organized by priority / order.

Priority / Order (+ to -)

Pattern	Code	How
Tidal Water	W.1	Reintroducing the tidal movement by opening the Brouwersdam
Washed Away	B.7	Letting tidal dynamics back into the stagnant lakes
Anti-fish Sushi	B.3	Installing new pumps or slowing down the rotation per minute
Slow Water	Se.2	Construction of oyster dams, breakwater or other elements that slow the current
Vegetated Enbankment	Se.1	Creating a marshland on the seaside of the dike
Biodiverse Dike	B.5	Sowing the dike with a biodiverse seed mix
Open Swimways	B.1	Connecting waterbodies by open connections and/or installing fish ladders
Free Sand	Se.3	Removing dams or making bigger passages
Biodiverse Salt & Fresh	B.1	Breaking the compartmentalization by opening dams

Figure 63: Design principles in context, author + (pdok, 2022b), (pdok, 2022c),

TARGET SPECIES
Kentish Plover

The Kentish Plover is experiencing a rapid decline in Western Europe, largely due to the loss and disturbance of its breeding grounds. These include primary dunes, beach plains, permanently exposed sandbanks, shell beaches, as well as man-made islands, slopes of sea dikes, and similar environments. Vegetation succession is causing breeding sites to disappear, and the reduction of natural coastal dynamics is a major factor, leading to existing breeding areas becoming overgrown too quickly and too few new breeding areas emerging. Recreational activities also disturb the breeding habitat. As a result, the Kentish Plover has experienced a significant decline, with only approximately 150 breeding pairs remaining in the Netherlands.

The Kentish Plover in Zeeland relies heavily on the Grevelingenmeer and the Western Scheldt as its primary habitats. In the Grevelingen, the number of breeding pairs has decreased significantly from approximately 300 prior to 1992 to approximately 50 in the last decade. A similar drastic decline is evident in the Western Scheldt, with the number of breeding pairs dropping from around 120 before 1992 to around or below 20 in the last 10 years.
Measures to protect the Kentish Plover can center on restoring natural coastal dynamics and promoting the development of islands in saline areas. In these areas, recreational activities that cause disturbance must be prevented. Alternatively, other countries have successfully implemented a different approach, where the beach is shared with the Kentish Plover through partnerships between professional organizations and volunteers who actively safeguard breeding areas. Volunteers mark nesting sites and install signs to educate beach visitors. (Zee et al., 2019)

Diet: Mollusks, insects, and crustaceans which can be fished out of the mud with short jabs of the beak. (vogelvisie, n.d.)
Breeding season: May (vogelvisie, n.d.)
Habitat: Large-scale dune or salt marsh landscape, beaches and embryonic dunes. (Zee et al., 2019)

Figure 64: Kentish Plover (staatbosbeheer, 2023)

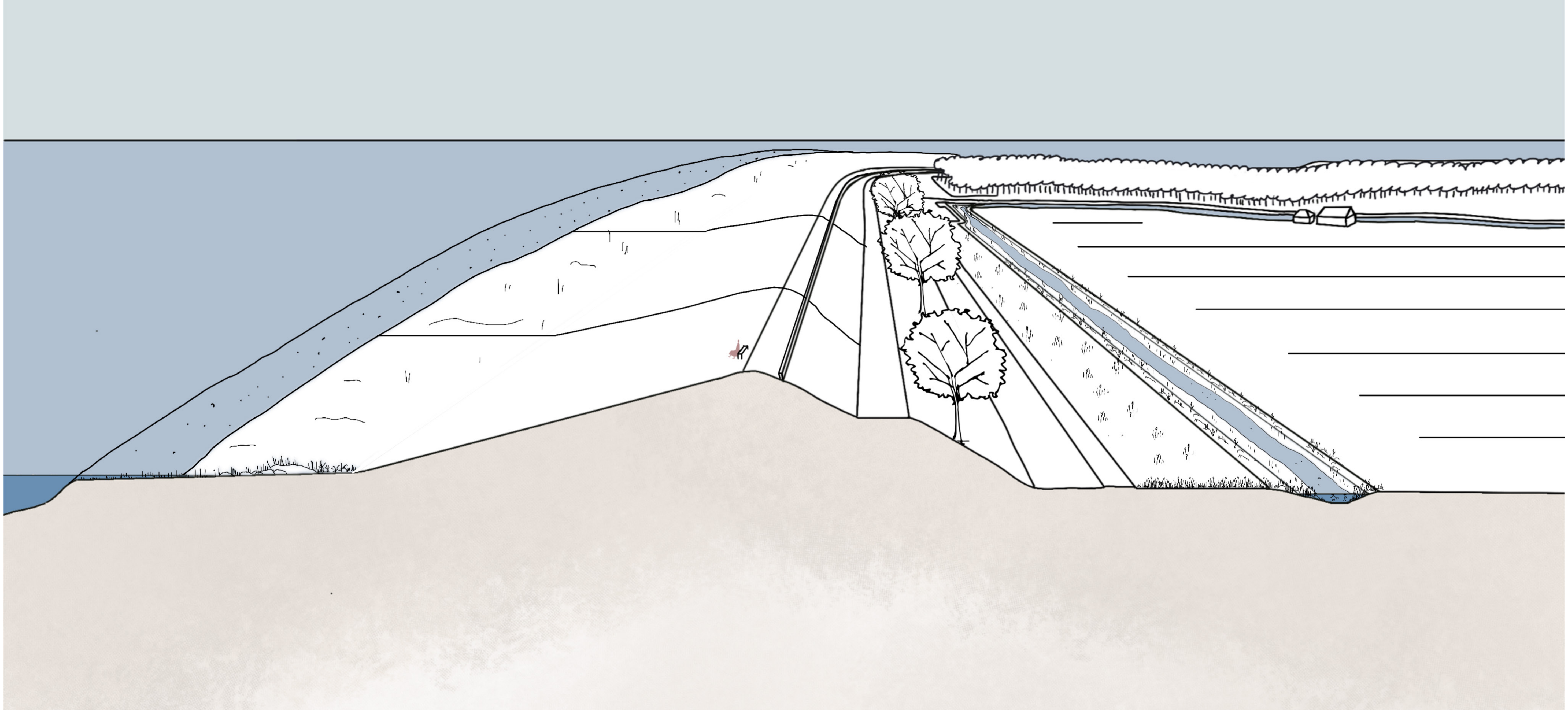


Figure 65: Section / birds eye view lange dijk implementation of design principles

Figure 66: Focus area de Gouwe, author + (CBS, 2010)

DE GOUWE

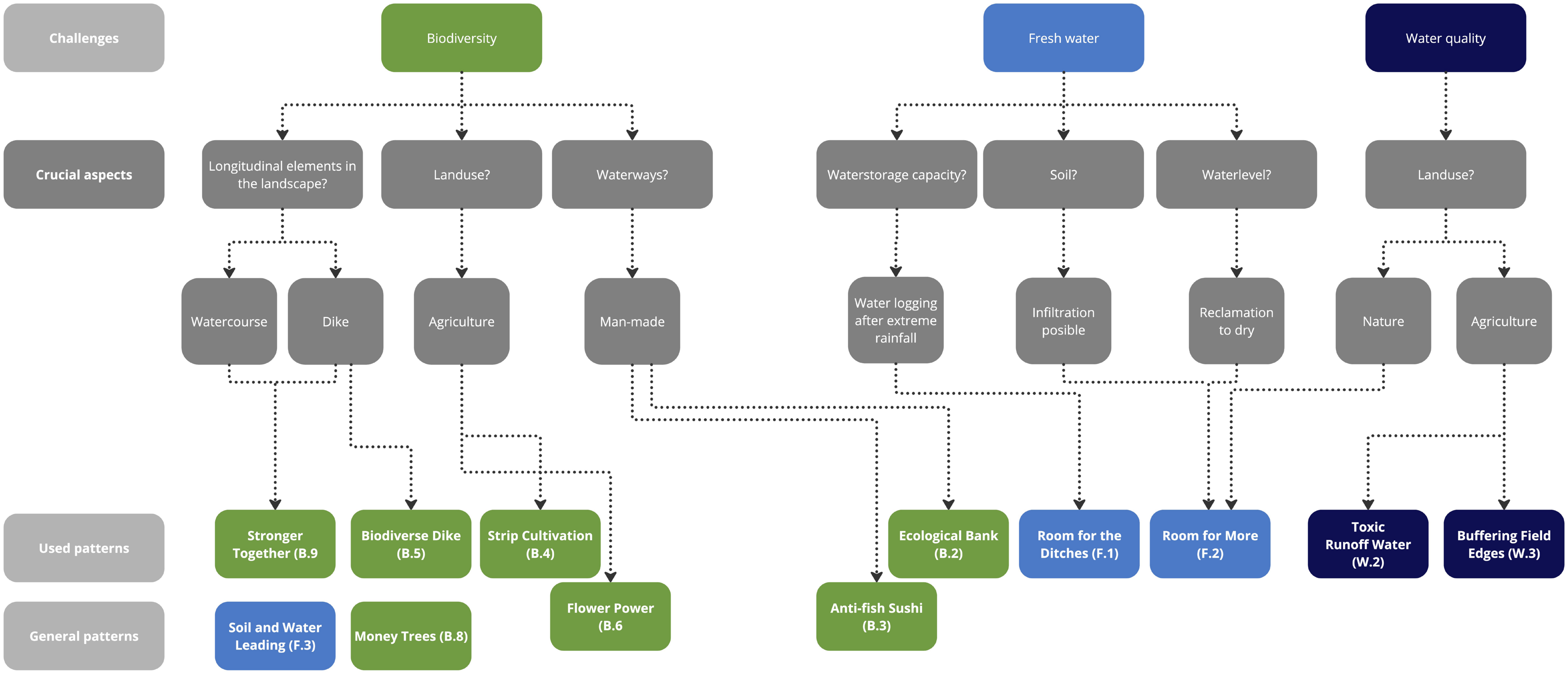
The second habitat that I focused is de Gouwe. This area is to be transformed to a infiltration area where the water system is changed and the water level needs to rise. This habitat focuses on increasing the freshwater availability.

This green-blue strategy fits all delta strategies and could be executed in any strategy. This is because no matter what strategy is chosen, in the future the droughts will only occur more while nowadays the islands is already dealing with a shortage of freshwater.

Possible delta scenarios:
+ Closed delta
+ Open Eastern Scheldt
+ Semi open delta
+ Open delta

On the next page a decision tree is shown. Here you can see which challenges there are and what crucial aspects are to be analyzed to choose a fitting design principle.

DECISION TREE



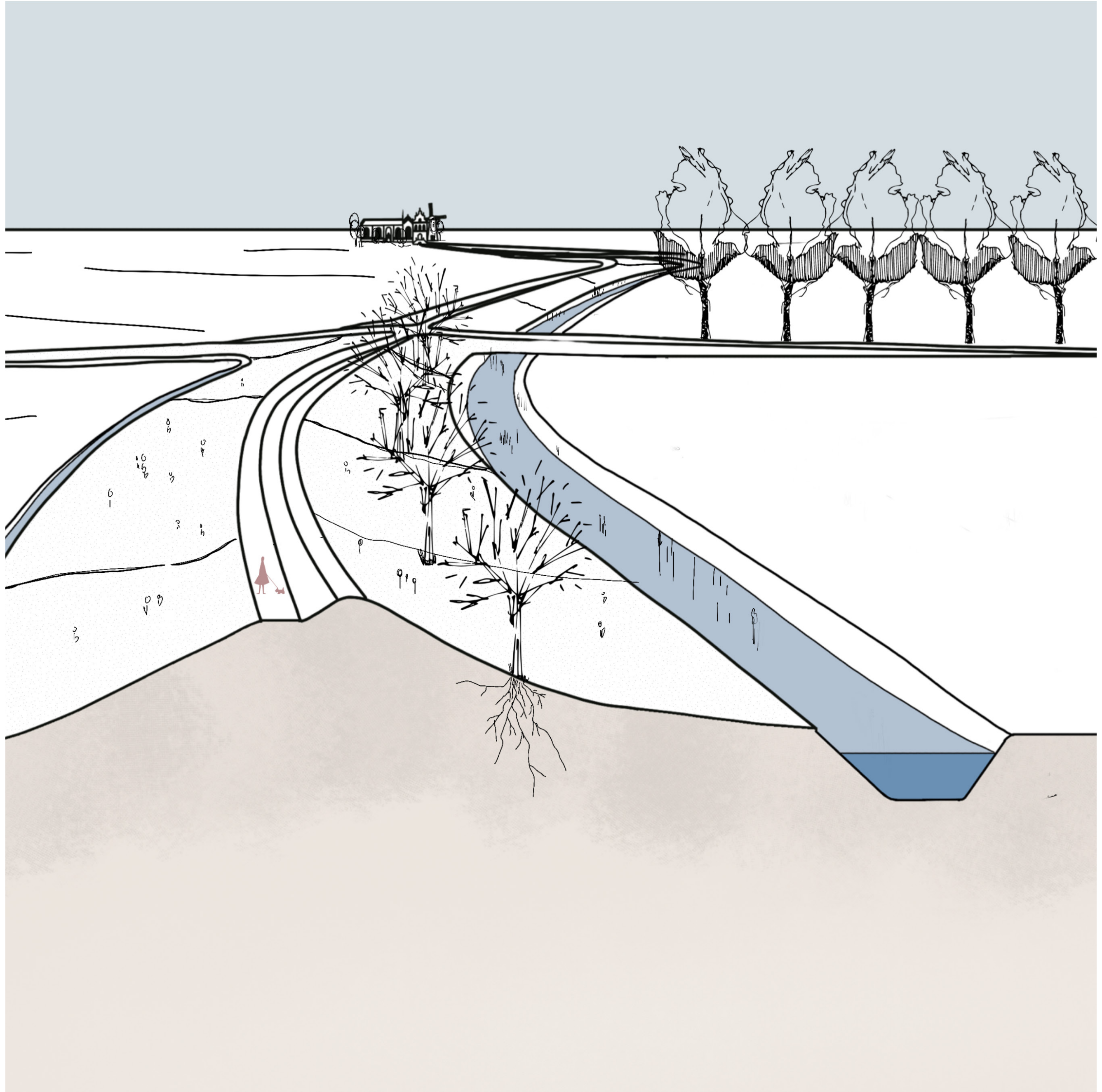
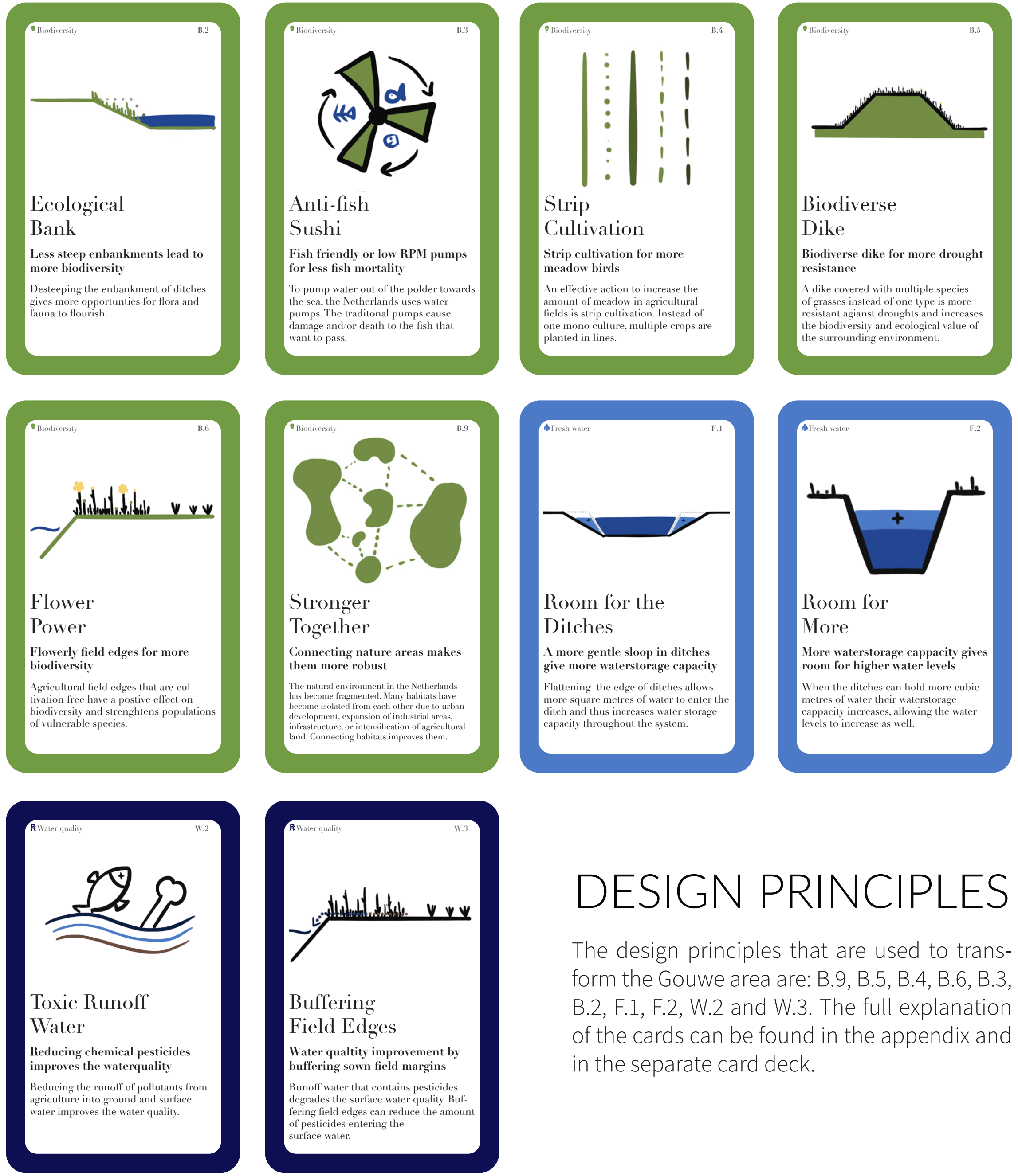


Figure 67: Section / birds eye view, Schouwse Djik, current situation



DESIGN PRINCIPLES

The design principles that are used to transform the Gouwe area are: B.9, B.5, B.4, B.6, B.3, B.2, F.1, F.2, W.2 and W.3. The full explanation of the cards can be found in the appendix and in the separate card deck.

PLAN VIEW

The plan view drawings on the right page show the transformation of the Gouwe area. In figure 69 is the current Gouwe area drawn. In figure 70 the possible future is drawn. The main watercourse is extended with a watercourse going to the Dijkwater area. Instead of one outlet in Zierkzee, the catchment area has now 3 outlets, Dijkwater, Bommenede and Zierikzee. In figure 68 is the section of the Gouwe area is drawn with the occurring soil types and the water levels. The water levels are already too low and the area is suffering from drought. The agriculture land along the main water course needs to change towards cultivations that are more resilient against wet feet. The main watercourse should be widened and the water level should be raised. This improves the infiltration to the water lens and increase the fresh water availability.

Legend | de Gouwe

- Clay
- Sand
- Sandy loam (mix of sand and clay)
- Silty sandy loam
- Optimum water level (waterschap)
- Actual water level
- Set summer level
- Set winter level

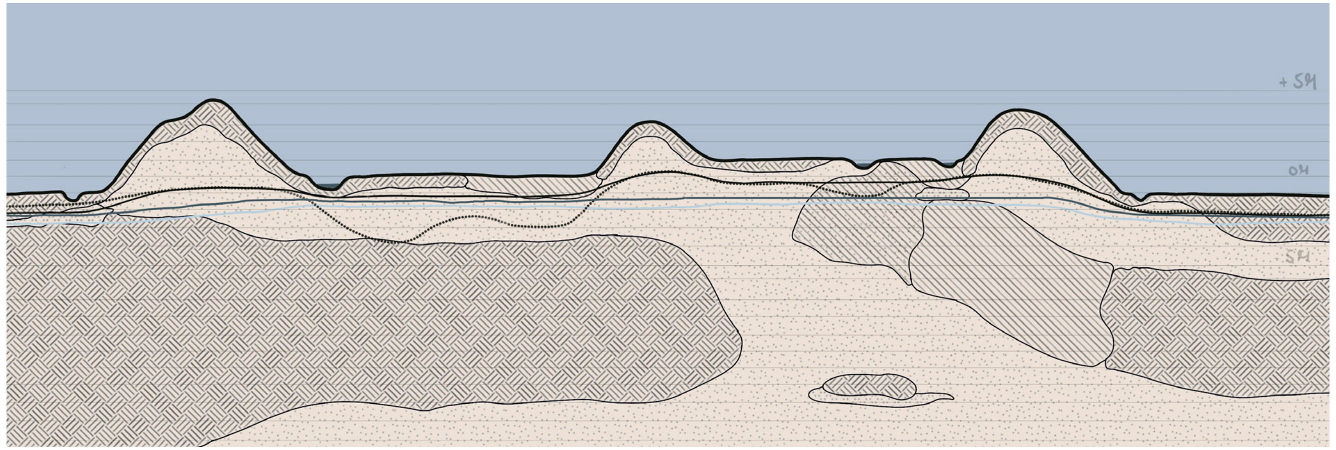


Figure 68: Section de Gouwe, sub soil and water levels

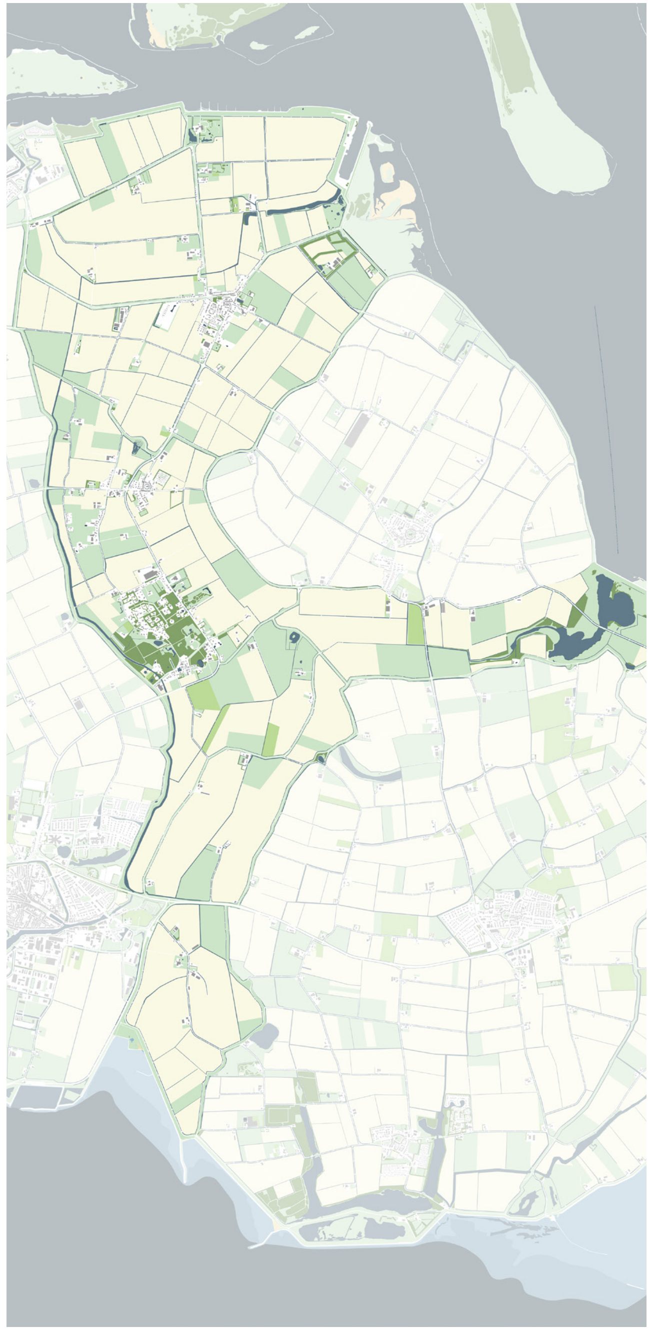


Figure 69: Plan view de Gouwe current situation author + (pdok, 2022b), (pdok, 2022c),

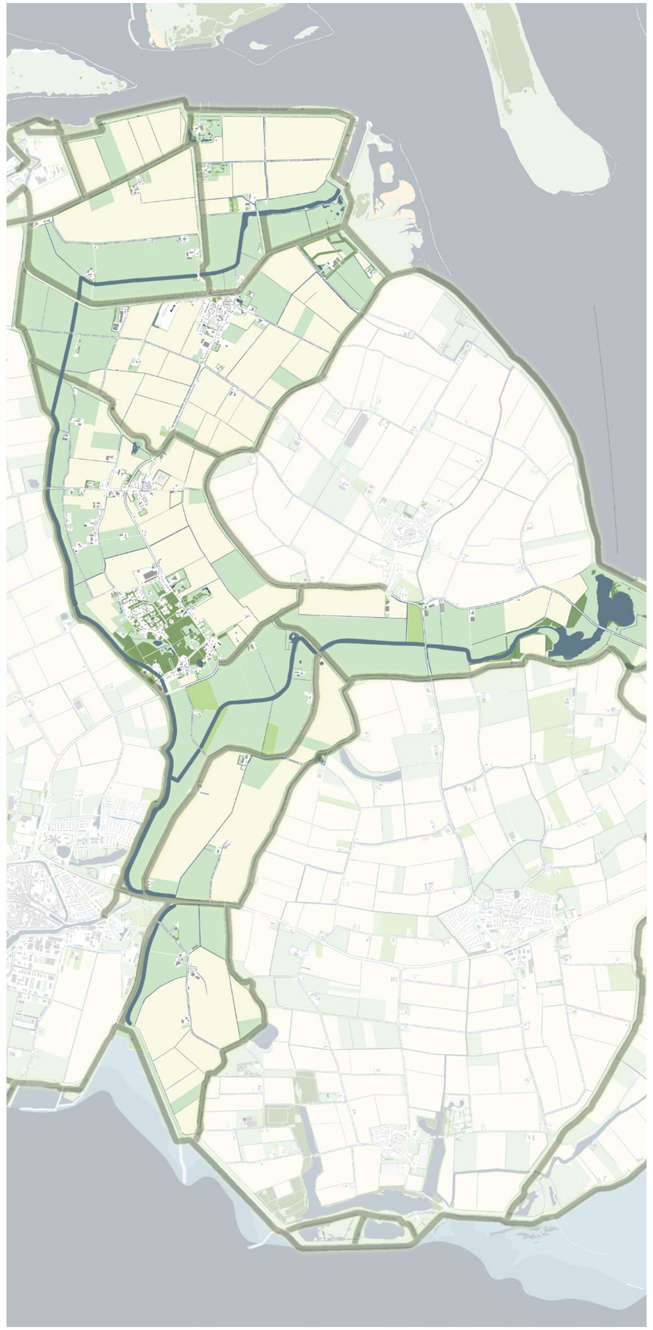


Figure 70: Plan view de Gouwe after implementation of design principles author + (pdok, 2022b), (pdok, 2022c),

PHASING

The chapter outlines the phasing for the transformation of the Gouwe area.

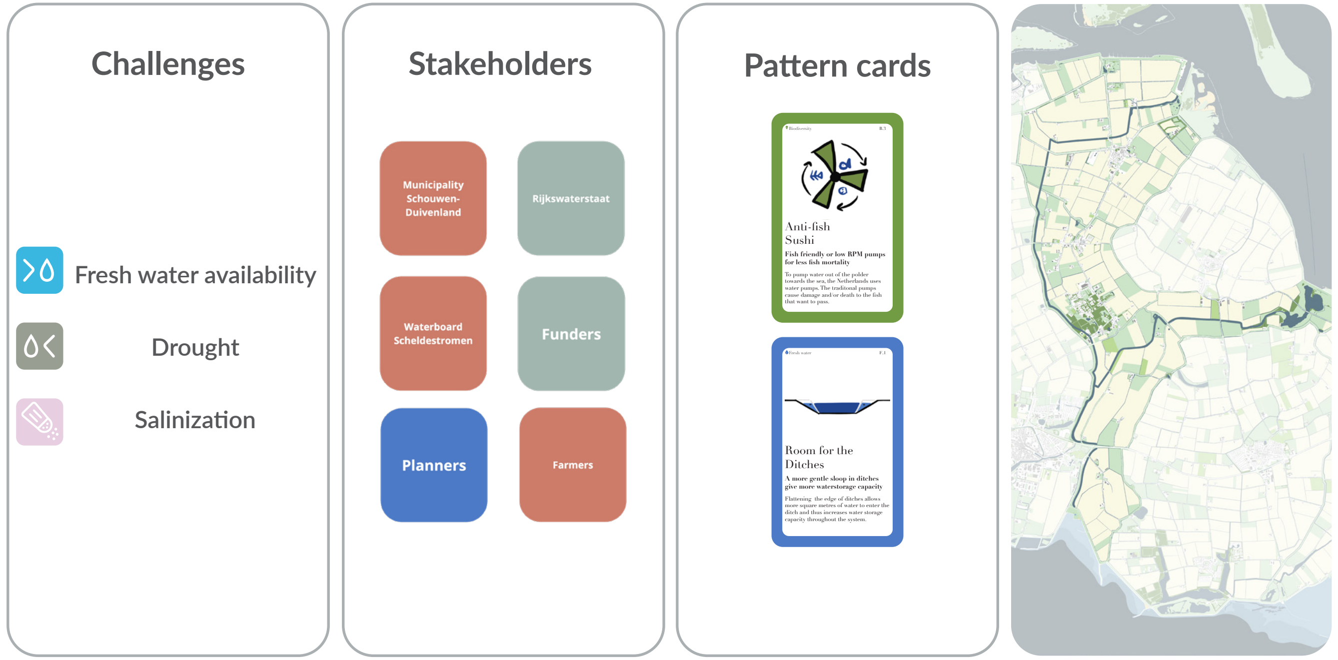
Step 1 involves changing the water system by widening the main watercourse, redirecting waterways, and changing catchment areas. The new water system can be found on page 114. Other actions are increasing the angle of the banks, installing fish-friendly pumps, and simplifying fish migration routes.

Step 2 focuses on increasing water levels, transforming inner dikes into ecological routes, and making embankments ecological friendly to promote biodiveristy.

Step 3 emphasizes sustainable agricultural practices, such as changing crop choices to adapt to wetter conditions, promoting buffering and biodiverse field edges, reducing pesticide use.

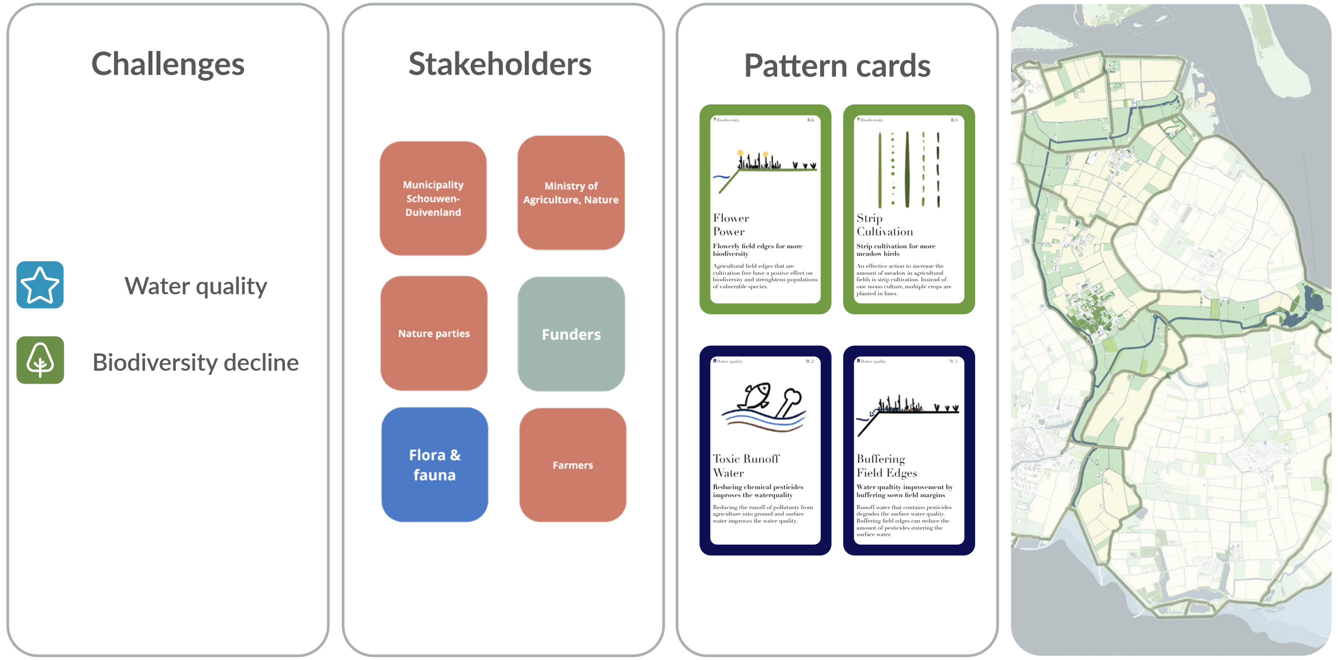
The 3 phases are illustrated down here and on the right. Each phase is accompanied by an overview of the challenges that need to be addressed, the key stakeholders involved, and the pattern cards that can be utilized to guide the process.

PHASE 1



PHASE 2

PHASE 3



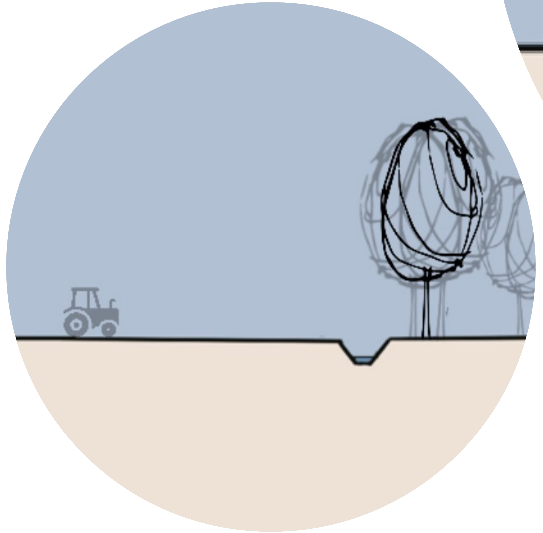
DESIGN PRINCIPLES IN CONTEXT

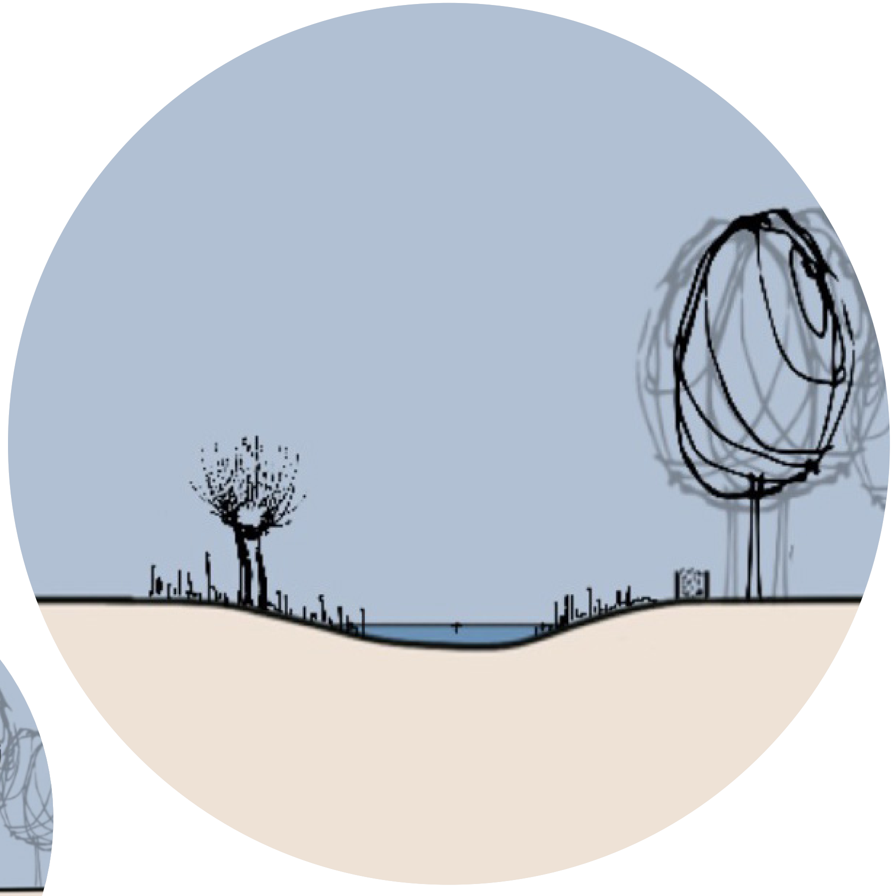
The map in figure 71 shows the possible locations where the design principle can be implemented. In the table the design principles are organized by priority / order.

+ Priority / Order -

Pattern	Code	How
Room for the Ditches	F.1	Ground can be excavated and used to heighten other places on the island
Room for More	F.2	Changing 'het Peilbesluit'
Ecological Bank	B.2	Changing the slope and adding planting
Biodiverse Dike	B.5	Sowing the dike with a biodiverse seed mix
Stronger Together	B.9	Connecting the different habitats with ecological routes
Flower Power	B.6	Sowing the field edge with a biodiverse seed mix
Buffering Field Edge	W.3	Sowing the field edge with a buffering seed mix
Strip Cultivation	B.4	Instead of one mono cultivation, cultivating in strips
Anti-fish Sushi	B.3	Installing new pomps or slowing down the rotation per minute
Toxic Runoff Water	W.2	Banning chemical pesticides

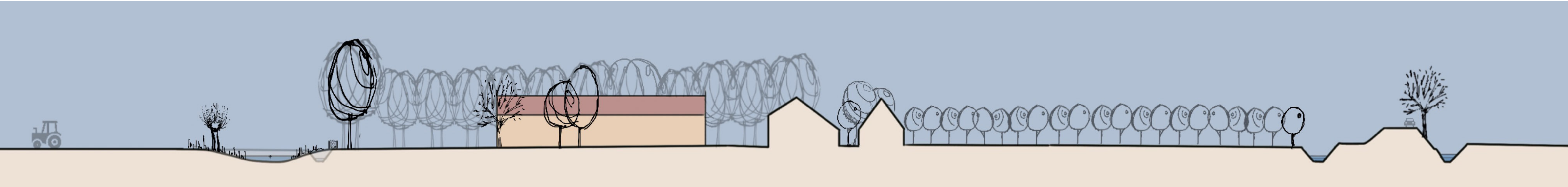
Figure 71: Design principles in context





GREEN-BLUE VEINING

The sections show the spatial qualities the new green-blue structure can have. The now small and steep ditch is transformed into a wide gently sloped watercourse. This eco-friendly embankment opens the possibility for multiple flora and fauna to settle. The embankment can be enriched with wooded elements and pollard willows. The renewed watercourse can function as a green-blue vein that connects different habitats and strengthens the biodiversity of the area.



TARGET SPECIES

The little owl

The little owl is a burrowing bird that typically nests in trees, buildings, or nesting boxes in small-scale agricultural landscapes. It requires nearby hunting grounds with open terrain, low vegetation, and perches to hunt from, as well as shelter for its young. The surrounding landscape should feature wooded banks, hedges, meadows, and pollard trees. The population of little owls in Zeeland has sharply declined from around 2,200 breeding pairs in 1940 to around 400 pairs today due to land consolidation, modernization of agriculture, acts of war (inundation), and flood disasters.
Zeeuws-Vlaanderen is a stronghold for the little owl, but its population has gradually declined from 419 to fewer than 300 territories since 2007. Today, only a few pairs of little owls remain on the other islands of Zeeland besides the populations in Zeeuws-Vlaanderen and Zuid-Beveland.
Causes of the decline in Zeeland may be the demolition of old sheds, cutting down pollard trees, intensive agricultural grassland management, large-scale greenhouses and the development of the port areas. However, the population in Zuid-Beveland has more than doubled in recent years due to planting standard fruit trees, maintaining pollard willows, hanging nesting boxes, and improved management. (Zee et al., 2019)

De Gouwe area can be a good habitat for the little owl when transformed. De-intensifying the agricultural land and providing shelter (wooded banks, hedges) and lookout points like pollard trees or posts.

Diet: Birds, small mammals, insects, earthworms and amphibians. (Stone, n.d.)
Breeding season: April till June (vogelbescherming, n.d.)
Habitat: Agricultural landscape

Figure 72: The little owl (Marle, n.d.)

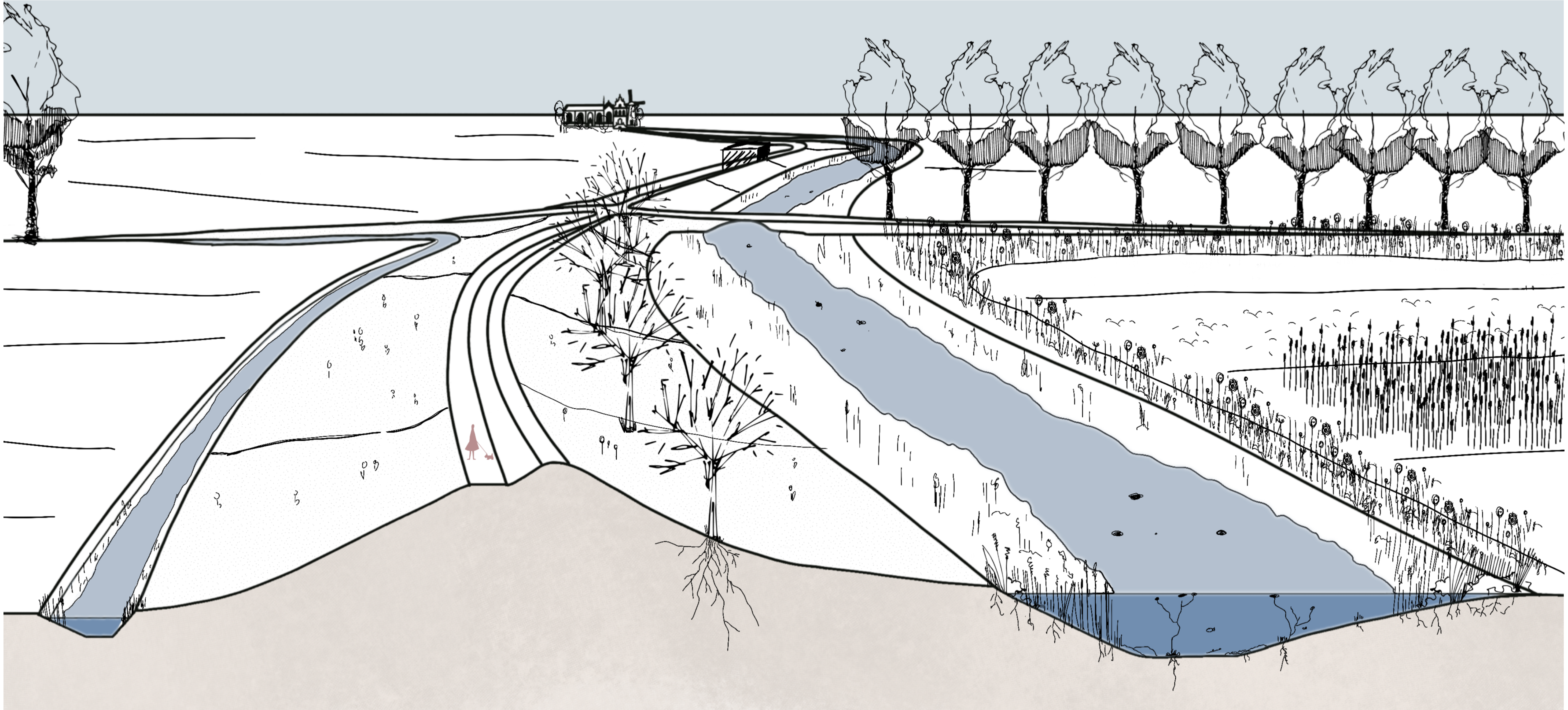


Figure 73: section / birds eye view, after implementation of design principles

Figure 74 : Focus area, salt agriculture author + (CBS, 2010)

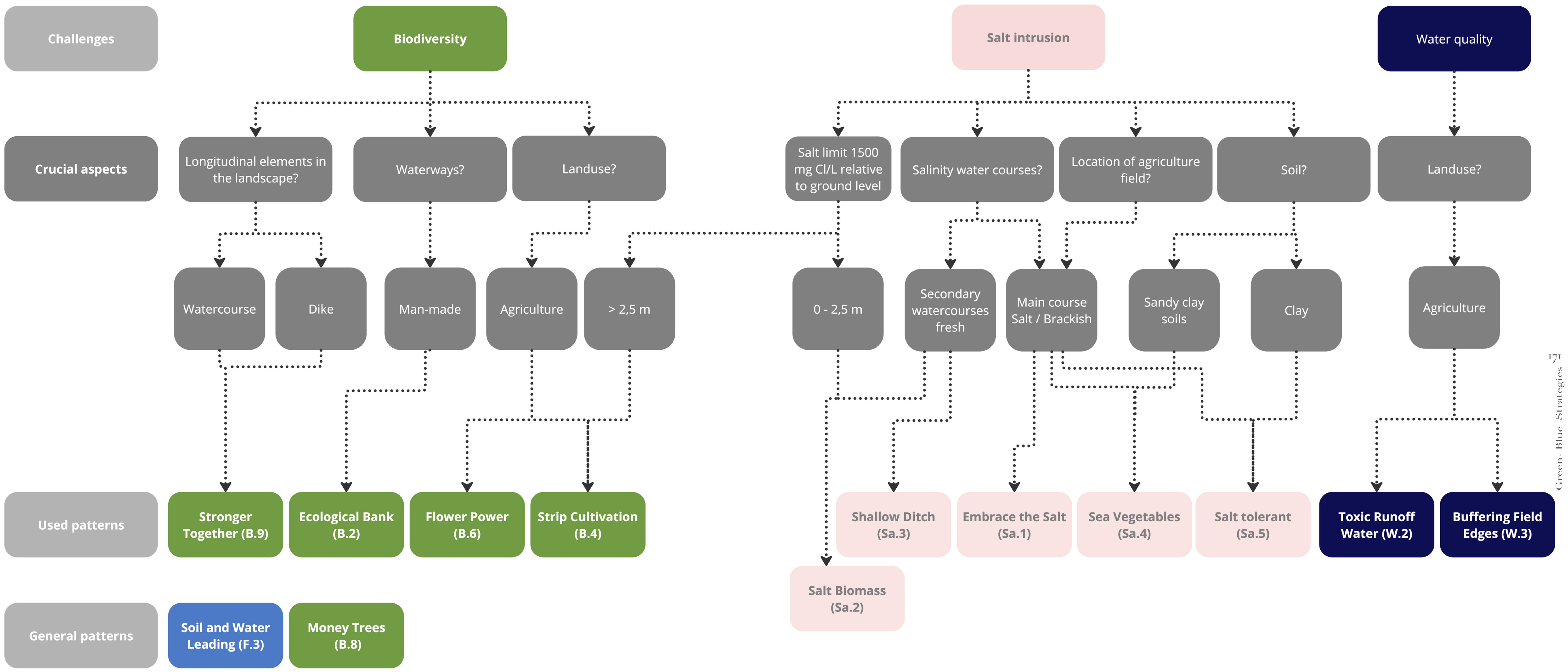
SALT AGRICULTURE

The third area I'm zooming into is the salt agriculture area in the Schouwen polder. This area is suffering from salt seepage, and due to climate change this problem will only grow bigger in the future. That is why I have chosen that instead of fighting the salt in this area, we should learn to deal with it and use it as advantage.
Therefore this area is focusing on to possibilities of salt agriculture.
In every delta strategy the salt seepage remains a problem and therefore this strategy should be executed in any possible delta strategy.

Possible delta scenarios:
+ Open Eastern Scheldt
+ Semi open delta
+ Open delta

On the next page a decision tree is shown. Here you can see which challenges there are and what crucial aspects are to be analyzed to choose a fitting design principles.

DECISION TREE



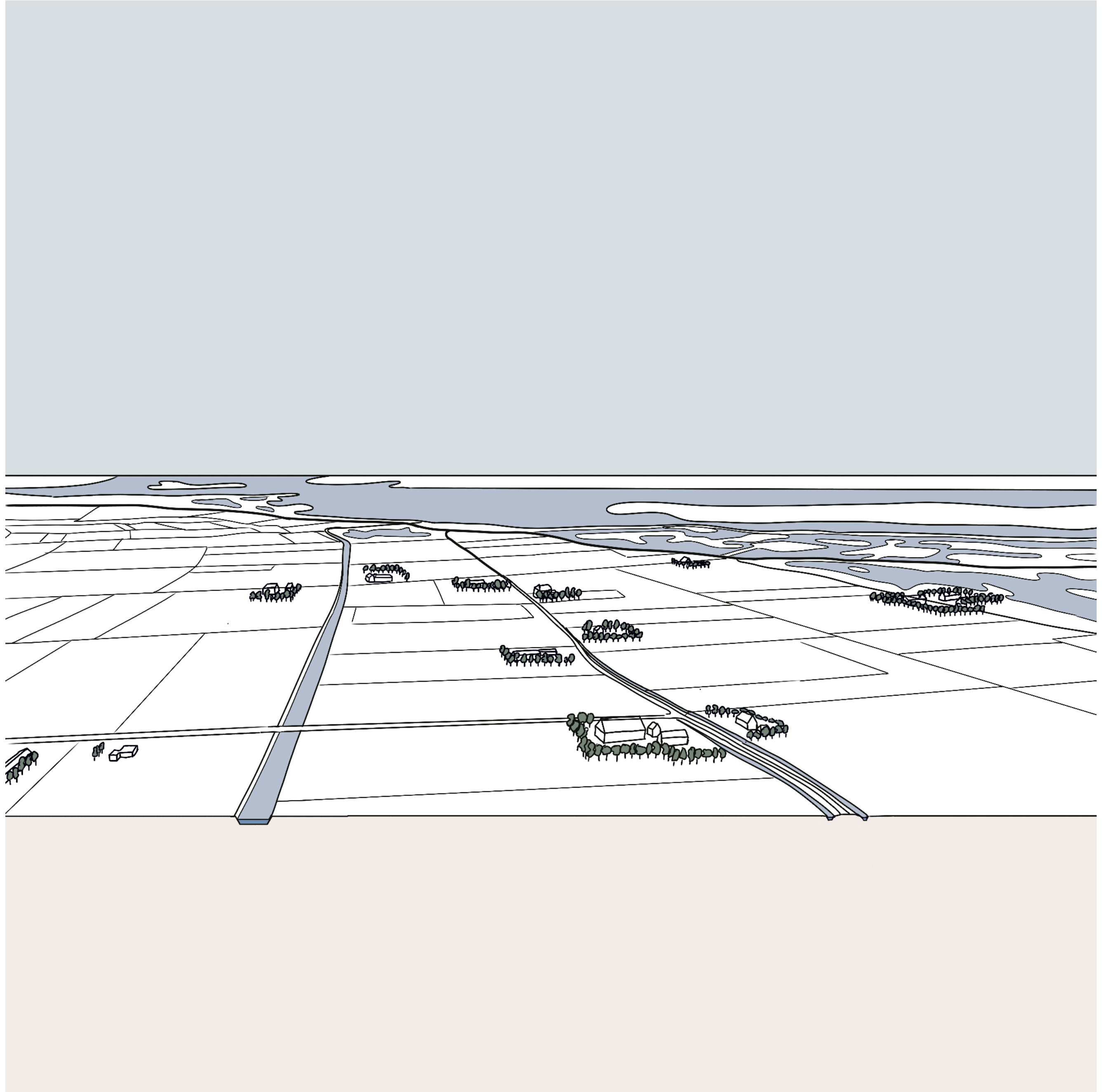
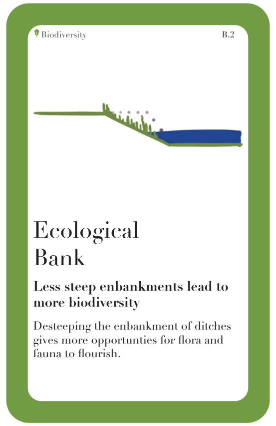
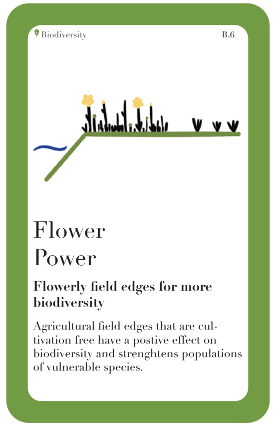
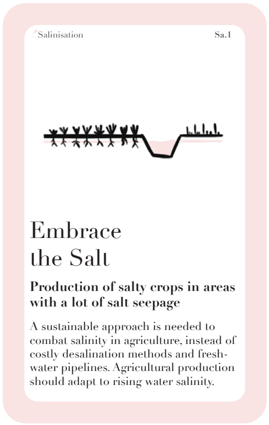
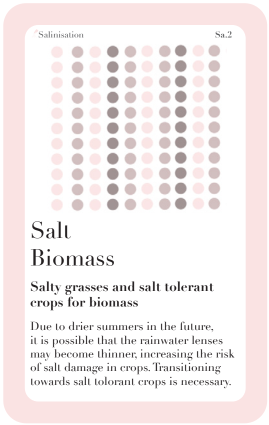


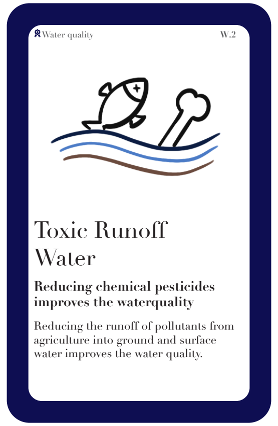
Figure 75: Section / birds eye view, current situation

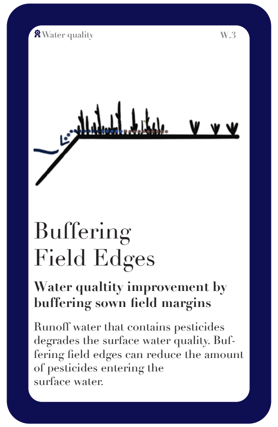












DESIGN PRINCIPLES

The design principles that are used to transform the Schouwen polder are: B.2, B.4, B.6, B.9, Se.1, Se.2, Se.3, W.2, W.3. The full explanation of the cards can be found in the appendix and in the separate card deck.

PLAN VIEW

On the right page the plan views of the salt agriculture area are drawn. Figure 76 shows the existing situation. The agricultural land is traditional and most fields are mono culture and intensive agricultural practices. In figure 77 a possible change in agricultural use is shown. Along the main watercourse which consists out of salt/brackish water, new forms of salt agriculture can occur. The crop choices in the Schouwen polder should follow from the soil type of the agriculture field and the amount if salinization. On sandy clay soil sea vegetables can be cultivated. The watercourse can be used to flood the salt needing vegetables like glasswort. Glasswort needs to be inundated with salt water at least once a week and maximum once a day. (Grondmij b.v., 2010) On the more clayish soil salt tolerant species like celery can be produced. The agricultural fields that aren't connected to the main watercourse canned be inuadated directly with salt/brakish water from the main watercours but they have still a lot of salt water in the ground. These agricultural fielsd that can be used to cultivate salt biomass. This biomass can be used to produce bio fuels.

Legend | Salt agriculture

- Scrubs / Trees
- Grassland
- Agriculture land
- Dunes
- Main salt/ brackish watercourse
- Salt vegetables fields that needs inundation (sandy clay soil)
- Regular agriculture (less salt seepage fields)
- Salt tolerant fields (with clay soil)
- Salt biomass

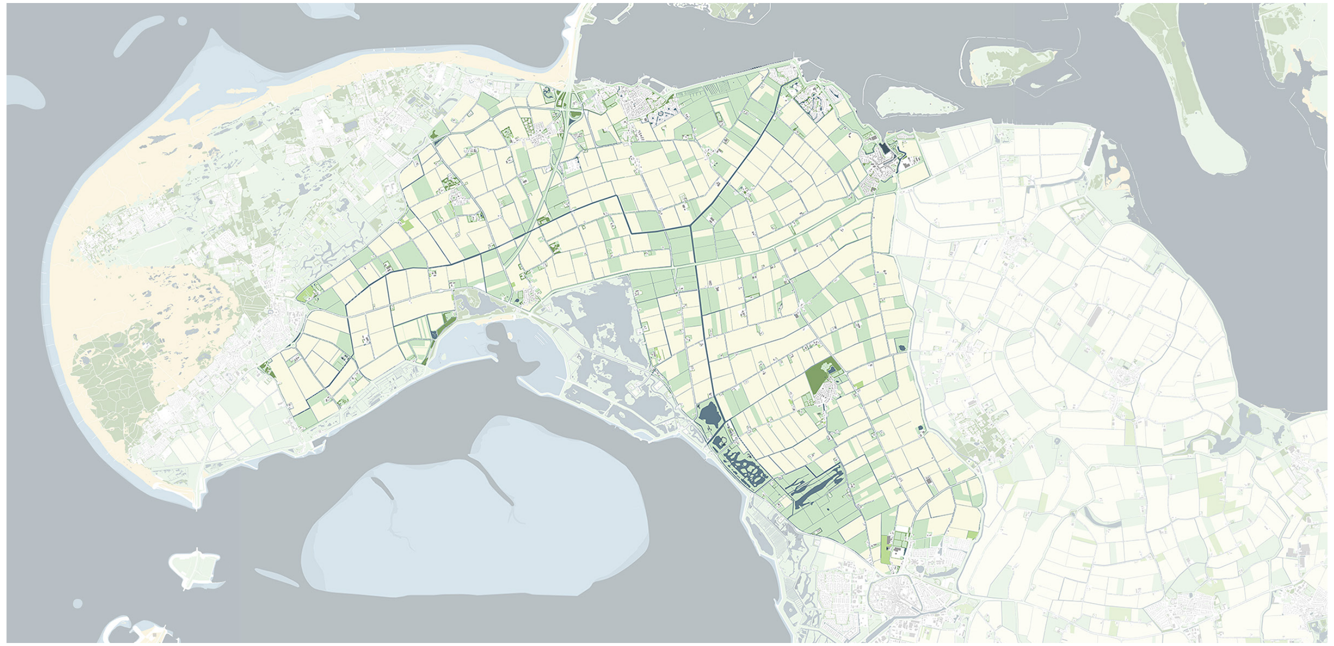


Figure 76: Plan view Salt agriculture, current situation author + (pdok, 2022b), (pdok, 2022c),

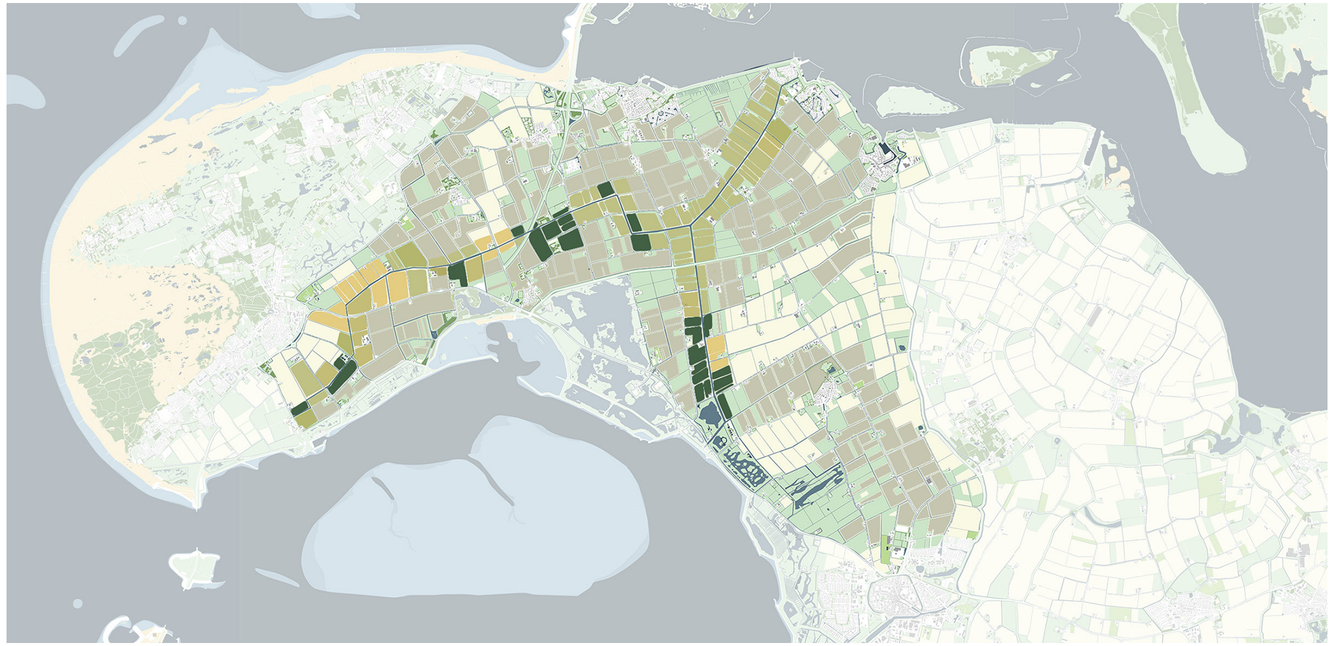


Figure 77: Plan view Salt agriculture after implementation of design principles author + (pdok, 2022b), (pdok, 2022c),

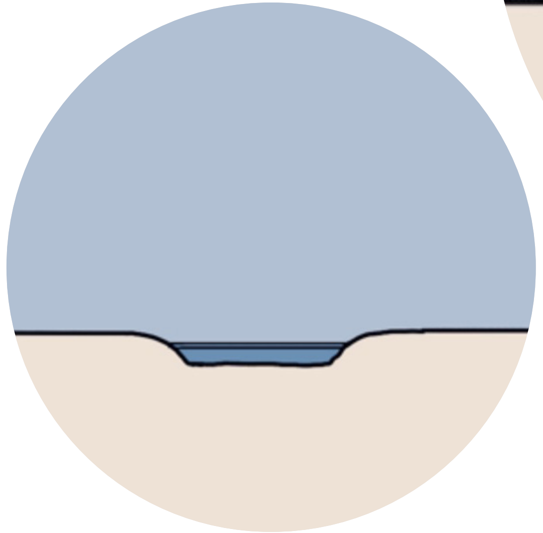
DESIGN PRINCPLES IN CONTEXT

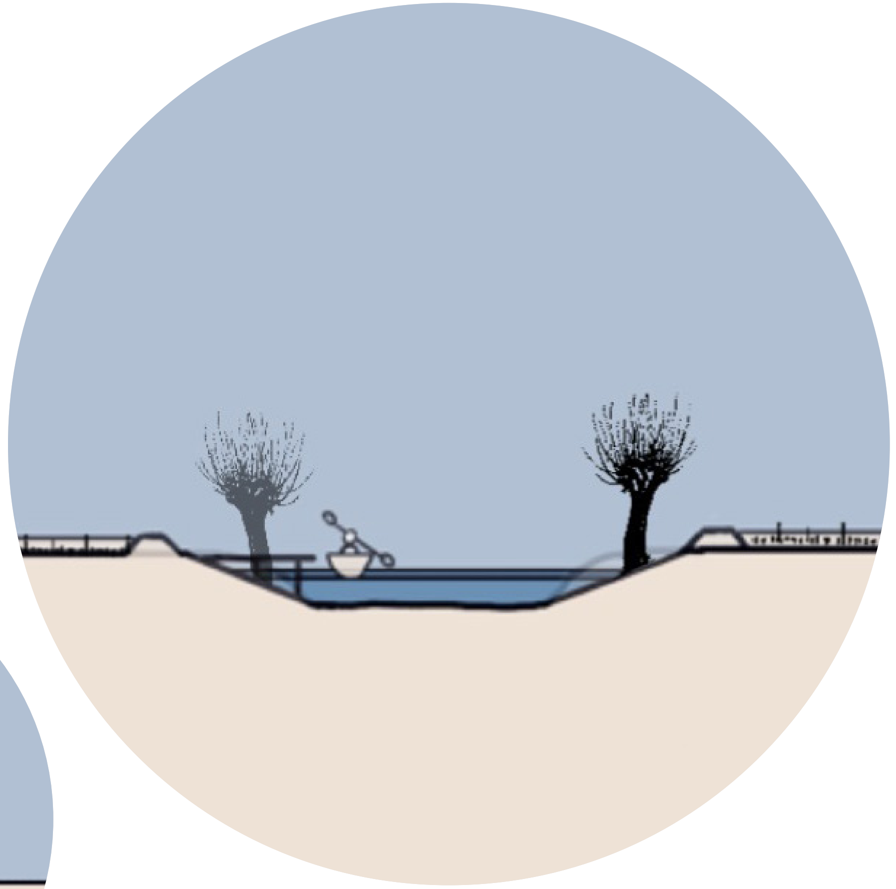
The map in figure 78 shows the possible locations where the design principles can be implemented. In the table the design principles are organized by priority / order.

Priority / Order (+ to -)

Pattern	Code	How
Water and Soil Leading	F.3	Cultivation choices on the basis of the main soil type of the field
Embrace the Salt	Sa.2	Changing the crops towards a more salt tolerant species or salt needing crop
Ecological Bank	B.2	Changing the slope and adding planting
Strip Cultivation	B.4	Instead of one mono cultivation, cultivating in strips
Salt Biomass	Sa.2	Sowing the dike with a biodiverse seed mix
Buffering Field Edge	W.3	Sowing the field edge with a buffering seed mix
Flower Dower	B.6	Sowing the field edge with a biodiverse seed mix
Shallow Ditches	Sa.3	Excavating the slopes to make the ditches less steep and using the soil to make the ditch less deep
Toxic Runoff Water	W.2	Banning chemical pesticides

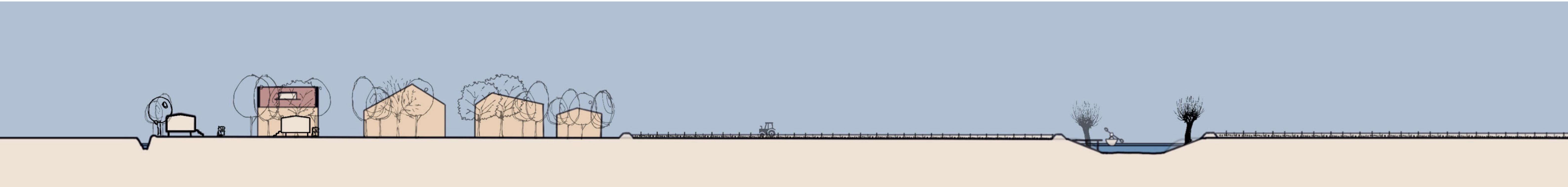
Figure 78: Design principles in context





GREEN - BLUE VEINING

The sections show the spatial qualities the new green-blue structure can have. The main watercourse can be transformed into a much more attractive en biodiverse waterway. The embankment can be made less steep and the removed soil can be used for the fields that needs to be inundated with saltwater. The created gentle slope will have a positive effect on the biodiversity and experiential value of the watercourse. In a recreation hotspot, like camping sites, jetties can be build so the water can be used for multiple activities like canoeing. The watercourse can be used to experience the salt agriculture landscape and contributes to the economic prosperity of the region.



TARGET SPECIES
Dutch tundra vole

The Dutch tundra vole (Microtus oeconomus subsp. arenicola) , is a species of high priority that is experiencing a significant decline throughout the country . In the Netherlands, this subspecies is exclusive to the region. The species is present in both the Natura 2000 areas and outside of them in Zeeland. The Eastern Scheldt and Kop van Schouwen Natura 2000 areas have been specifically designated for this species.

The preferred habitat of the Dutch tundra vole includes tall vegetation with an abundance of grass or herbs, such as reed beds, swamps, moist dune valleys, brackish marshes, and saline grasslands. The species thrives in areas with fluctuating water levels, and it is easily out competed by more common species like the field mouse or common vole in that thrive in drier habitats. The construction of the Delta Works has led to the gradual displacement of the Dutch tundra vole by these species, resulting in a decline in their population on the Zeeland islands.

The decline of the Northern Red-backed Vole in Zeeland is attributed to various factors, including fragmentation, competition, loss of suitable habitat, and climate change. Physical barriers like roads and steep waterways have led to a decrease in populations and spatial isolation. The remaining habitats have also declined in quality, with stabilizing water levels and competition from other vole species being key factors. In protected areas, managers face a dilemma between the management of the Dutch tundra vole and coastal breeding birds, as actions that benefit one can negatively impact the other. Additionally, climate change has led to drought and decreased rainfall, presenting long-term challenges for the species.

The salt agriculture area can function as new habitat for the Dutch tundra vole, the habitat is suitable because of the possibilities of changing water levels and the transformation of the agricultural land towards more saline sustainable agriculture (Zee et al., 2019)

Diet: green parts of reeds, rushes, sedges and other plants, as well as roots, seeds and bark.
Breeding season: April till October (Natura2000, 2008)
Habitat: Reed beds, marsh and wet dune valleys but also brackish marsh and saline grasslands, they benefit from varying water levels. (Zee, 2019)

Figure 79: Dutch tundra vole (NDFF Verspreidingsatlas Zoogdieren, n.d)

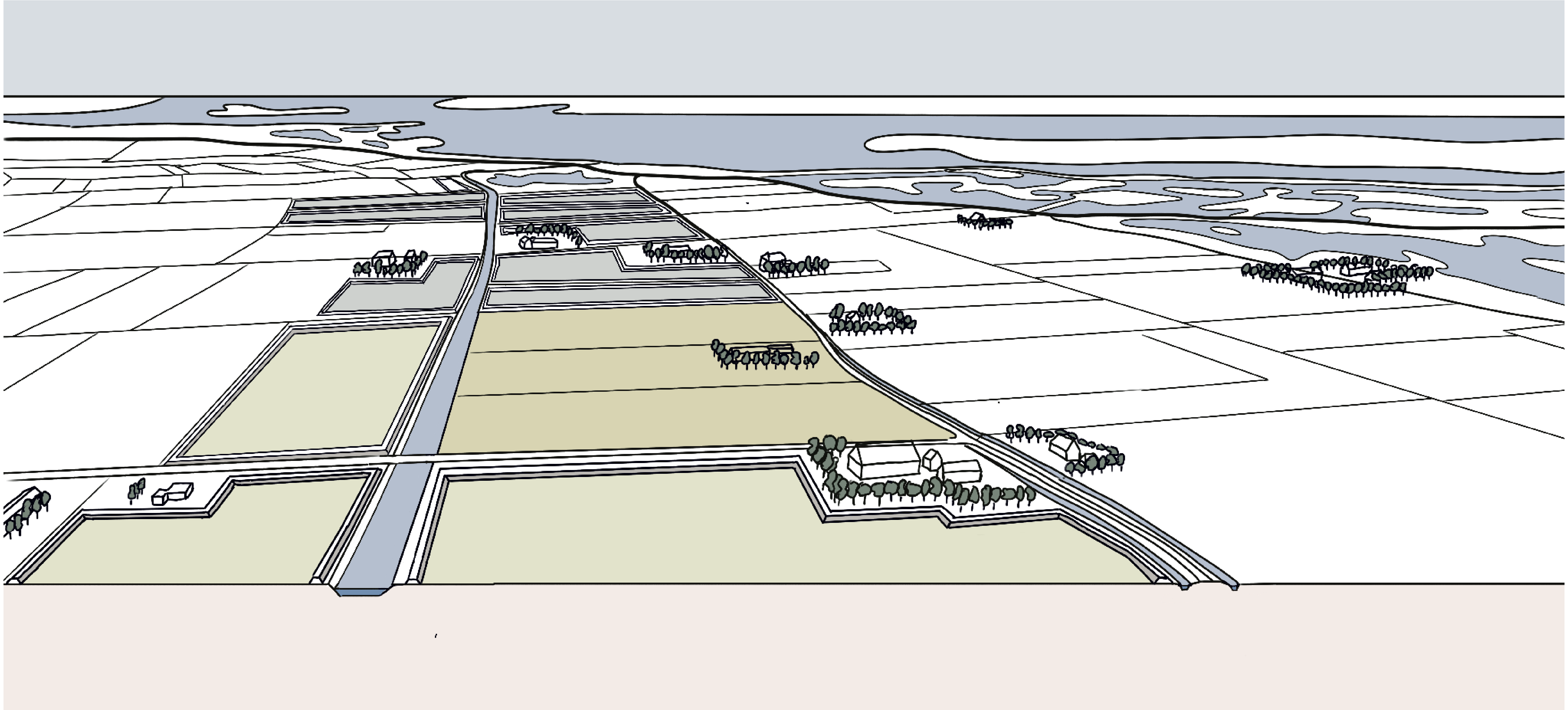


Figure 80: Section / birds eye view after implementation of the design principles

Figure 81: Focus area, Eastern Scheldt, author + ()

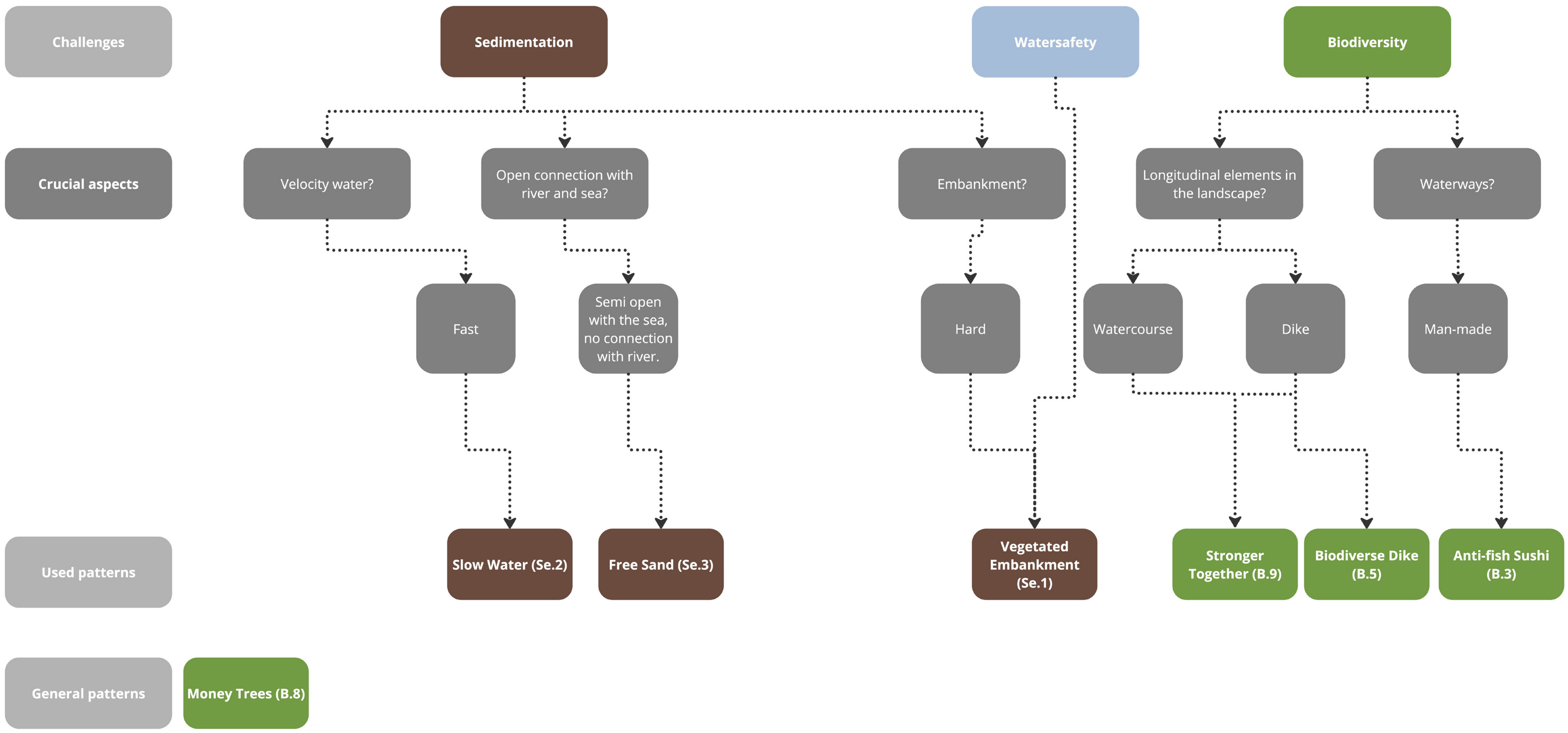
EASTERN SCHELDT

The last area I'm looking into is the Eastern Scheldt coastline. The Eastern Scheldt is suffering from loss of inter tidal areas due to the phenomena called 'Zandhonger'. This green-blue strategy is focusing on strengthening the dikes by creating new salt marshes on the outer side of the dikes. These salt marshes decrease the wave force on the dikes which improves the water safety of the island. Besides this, the newly created salt marshes also contribute to the arsenal of inter tidal areas. Inter tidal areas are of great importance for the functioning of the ecosystem of the delta.
This green-blue strategy can only be implemented with an open Eastern Scheldt, because the salt marshes need tidal movement and sediment from the sea.

Possible delta scenarios
+ Open Eastern Scheldt
+ Semi open delta
+ Open delta

On the next page the decision tree is shown. Here you can see which challenges there are and what crucial aspects are to be analyzed to choose the fitting design principles.

DECISION TREE



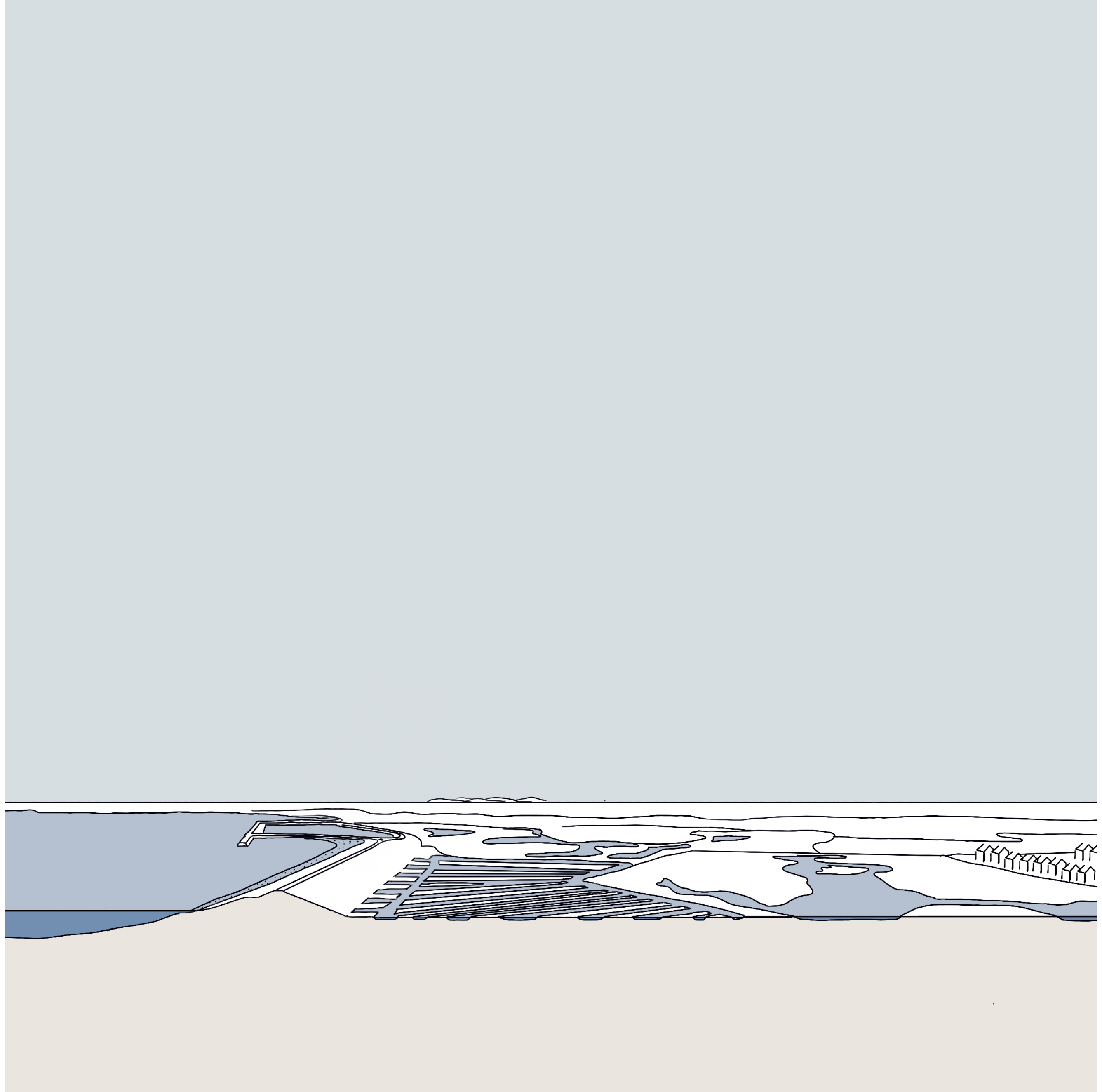
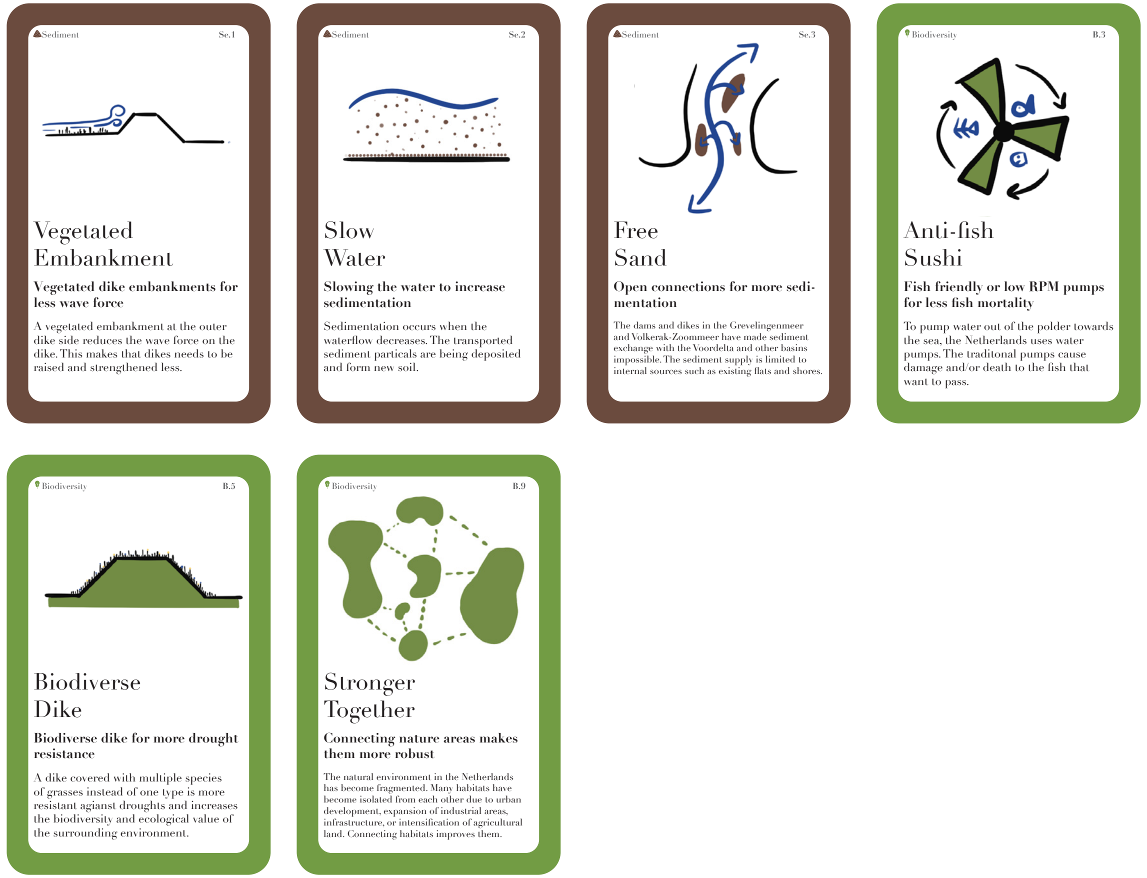


Figure 82: Section / birds eye view Eastern Schedt dike, current situation



DESIGN PRINCIPLES

The design principles that are used to transform the Eastern Scheldt are: Se.1, Se.2, Se.3, B.3, B.5 andB.9. The full explanation of the cards can be found in the appendix and in the separate card deck.

PLAN VIEW

The right page shows the plan view of the newly created salt marshes. In figure 83 the current situation is drawn. The gullies along the coastline are very steep, so construction is needed to slow the water along the dike and enhance the sedimentation. In figure 84 the new salt marshes are drawn. The white thin lines on the sea side of the salt marshes are dams. These dams create a calm bay where the sediment can sink to the seafloor. On the next page the section of one of these salt marshes is shown.

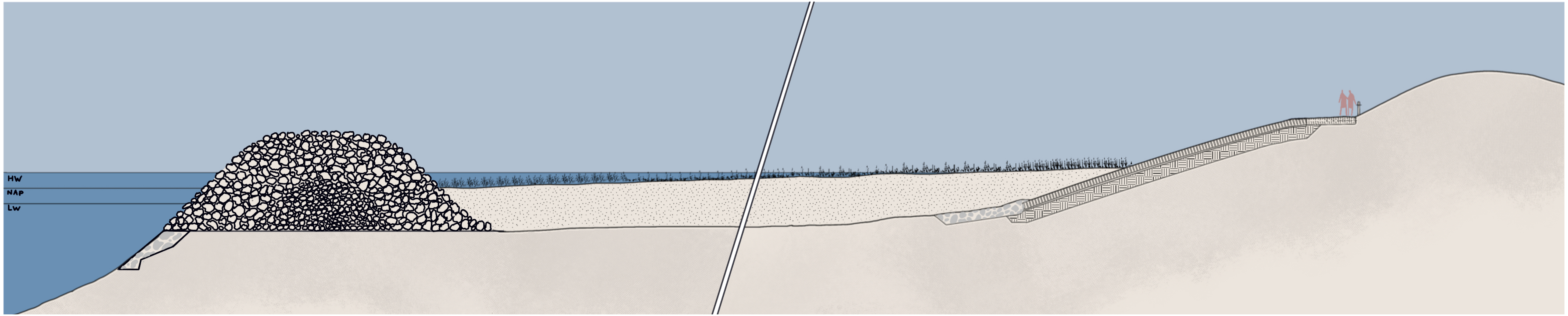
Legend | Eastern Scheldt

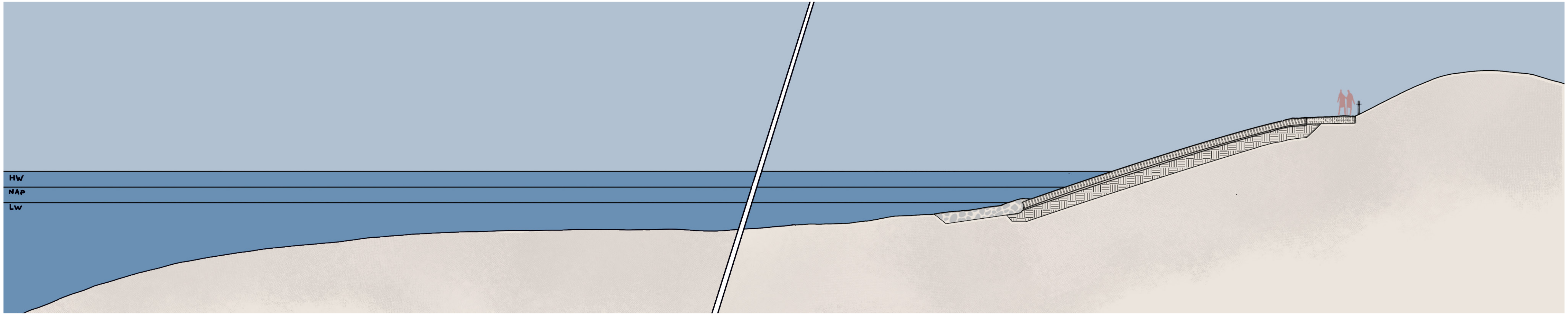
- Scrubs / Trees
- Grassland
- Agriculture land
- Deep water
- Shallow water

Figure 83: Plan view Eastern Scheldt, current situation, author + (pdok, 2022b), (pdok, 2022c),

Figure 84: Plan view Eastern Scheldt, new inter tidal area, author + (pdok, 2022b), (pdok, 2022c),

WETLAND DIKE





DESIGN PRINCIPLES IN CONTEXT

The map of figure 85 shows the possible locations where the design principle can be implemented. In the table the design principles are organized by priority / order.

Priority / Order (+ to -)

Pattern	Code	How
Biodiverse Dike	B.5	sowing the dike with a biodiverse seed mix
Slow Water	S.2	Construction of oyster dams, breakwater or other elements that slow the current
Vegetated Enbankment	S.1	Creating a marshland on the seaside of the dike
Anti-fish Sushi	B.3	Installing new pumps or slowing down the rotation per minute
Money Trees	B.8	Investing in projects that increase the biodiversity

Figure 85: Design principles in context

TARGET SPECIES
White-tailed Eagle

The White-tailed Eagle population in the Netherlands has been steadily increasing since the first breeding pair settled in the Oostvaardersplassen in 2006. (Rijn & Dekker, 2017)

To thrive, White-tailed Eagles require suitable nesting trees that are large and sturdy, in peaceful locations close to wetlands teeming with fish and waterbirds. They prefer floodplains with marshy forests, deciduous forests near large lakes, and deltas with islands. During winter, they inhabit the same areas and also extend their range to encompass large peat lands, moors, and extensive fields.

The diet of the eagles consists mostly waterbirds and fish. They catch fish just below the water surface, without plunging like Ospreys. The waterbirds they prey on are ducks, coots, and young geese, mammals like hares are consumed less frequently. In winter, when there is ice, they feed on carrion. Despite appearing slow and sluggish, they can be fast and nimble when hunting, able to strike flying ducks and snatch fish from other birds. They also feed on fish scraps. (vogelbescherming, n.d. b.)

Breeding success has been slowly increasing
The survival rates and main risk factors are unclear, but poisoning and collisions with man-made objects are known risks. The population is expanding to new breeding areas in the Netherlands, and if breeding success remains high, it may serve as a source for neighboring populations. (Rijn & Dekker, 2017)

The Eastern Scheldt coastline has the potential the be a good habitat for the white-tailed Eagle due to the abundance of food and the large open and quite landscape.

Diet: waterbirds, fish, small mammals and carrion (vogelbescherming, n.d. b.)
Breeding season: January till May (vogelbescherming, n.d. b.)
Habitat: wetlands

Figure 86: White-tailed Eagle (Rijn & Dekker, 2017)

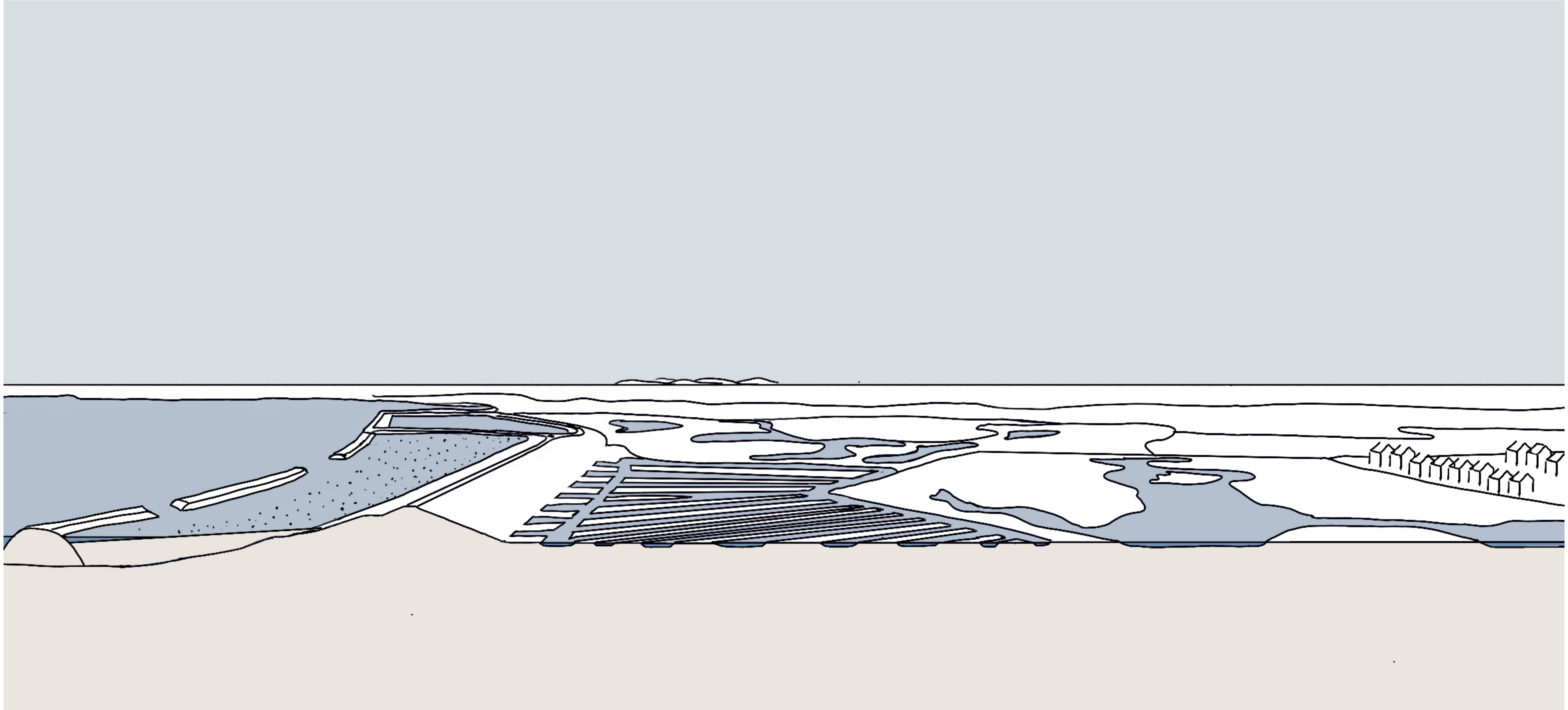


Figure 87: Section / birds eye view Eastern Schedt dike after implementation of the design principles

CONCLUSION AND REFLECTION

CONCLUSION

This master thesis has explored the research question of what the return to a (semi-) open delta would mean for the green-blue network of Schouwen-Duiveland, and what spatial framework and guiding design principles would be necessary to sustain and upgrade both the green-blue networks and liveability, now and in the future.

Through an analysis of the bigger scale of the delta this research has identified key challenges related to fresh water, zandhonger, water safety, biodiversity, water quality, and salt intrusion.
Through a more focused analysis on the island scale, research was done on how these challenges can be tackled and a set of design principles was established. The design principles form the foundation of this master thesis.

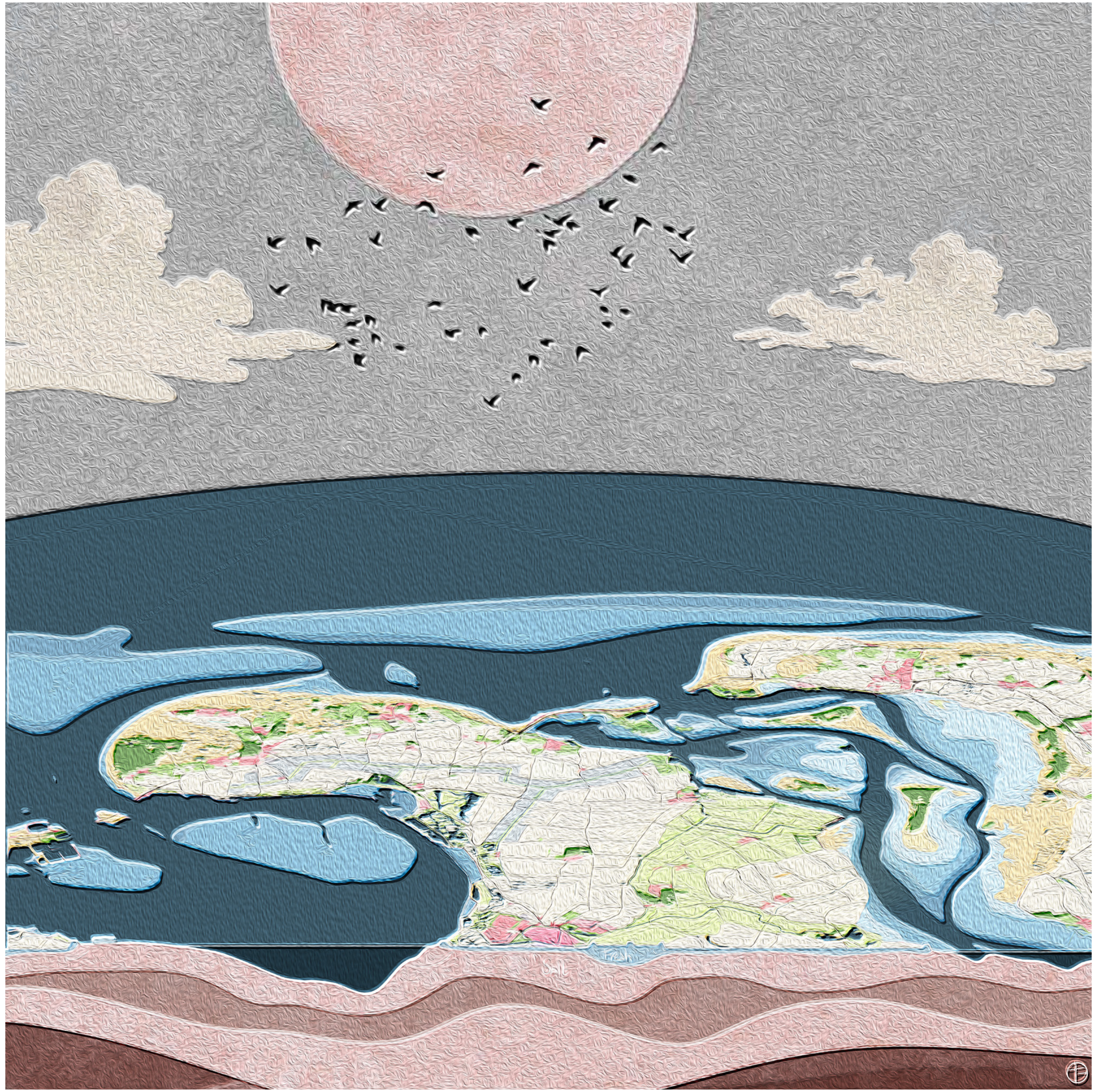
The proposed design principles aim to protect and conserve the natural environment of Schouwen-Duiveland while also considering the needs and well-being of its residents. By embracing these principles, the island's future can be shaped towards a more sustainable and nature-inclusive state.

The design principles have been created with a vision centred around nature-based solutions, where soil and water are key elements. These principles aim to protect and conserve the natural environment while also considering the needs of the island's residents. To ensure the applicability of these design principles in different locations, they have been transformed and explained through pattern cards.

The pattern cards address the ecological challenges posed by agriculture, urbanization, and climate change. The findings of this research provide a spatial framework and guiding design principles that can effectively sustain and upgrade both the green-blue network and liveability of the island, ensuring its long-term resilience and well-being.

In order to ensure the appropriate implementation of pattern cards, a thorough understanding and analysis of the location must be conducted on three distinct levels: the subsoil level, the network level, and the occupation level. Each level provides valuable insights and considerations for designing and implementing a design principle.
To move to a more sustainable future the subsoil level must be leading.

In conclusion, this master thesis has provided valuable insights into the potential benefits and spatial implications of returning to a (semi-) open delta in Schouwen-Duiveland. The research highlights the importance of integrating green-blue infrastructure, ecological considerations, and liveability aspects to create a resilient and thriving environment for both nature and people.



REFLECTION

This reflection provides an insight into the emotions and lessons I have experienced throughout the process of creating this master thesis.

I began with a broad focus on the delta system, analyzing the challenges it faces and how climate change influences them. I already knew the delta was going through tough times, but gaining a deeper understanding of the complex context and impact of climate change made me realize the urgency of these issues even more. It became very clear that we need to confront these challenges not tomorrow, but today.

Studying the effects of climate change and rising sea levels made me anxious about our future. The political debate and the current setting we live in often leaves me feeling powerless and angry. The growing polarization in society can make it disheartening, as it seems that no matter how intensely and precisely I research, there are always people who refuse to listen or believe. In a world where distinguishing between facts and fiction is increasingly difficult, finding my position becomes a struggle.

At times during the process of this master thesis, these feelings made it challenging to continue. It felt like I was putting all my energy and effort in a world that doesn't want to change, and that my individual impact would be insignificant. However, as my mother always reminds me, every voice counts. And we can't give up. Developing this master thesis and expressing my thoughts is my way of moving towards a brighter future, where gradual changes in mindset can bring about fundamental transformations.

There were moments when frustration arose because I wanted to do more and delve deeper. If I were to redo this master thesis again, I would narrow down the number of challenges I researched and focus on a specific area. Although I appreciated the wide scope initially, which allowed for an integrated approach, I would have liked to develop a more specific and detailed design. Nevertheless, I also valued the conceptual thinking and the range of solutions I was able to explore now.

The pattern cards played a significant role in organizing the arguments and solutions that were swirling in my mind. I found them helpful, and I intend to continue expanding the card deck by adding new ones.

Overall, this process of completing my master thesis has given me a clear understanding of the kind of designer and researcher I aspire to be. It is less about the specific projects I wish to undertake and more about what kind mindset and principles as an urbanist, landscape architect, and human being I value.

APPENDIX

ASSESSMENT CLOSED DELTA

Problem context	Very bad	Bad	Neither good or bad	Good	Very good
Environment					
1. Poor water quality in the Volkerak-Zoommeer due to long-term inputs of nutrient-rich river, agricultural water and insufficient refreshment or flow.					
2. Hardly any possibilities for fish migration through the delta to the Rhine-Meuse river system.		Only through haringvliet			
3. Nutrient deficiency in the Eastern Scheldt due to the excess production of shellfish and compartmentalization of the delta which cut of the river flow through the Eastern Scheldt.					
4.Oxygen deficiency in the stagnant lakes due to the compartmentalization of the delta.					
5. Increase in erosion of intertidal areas due to the delta works and sea level rise.					
6. Decreasing intertidal areas due to change in the morphological system and in the Western Scheldt due to the intensive dredging and deposit policies which led to steeping of the seabed.					
7. The lack of natural dynamics has led to siltation of the creeks in the Biesbosch because not enough silt is being drained to the North Sea.					
8. Increase pressure on nature due to intensive agriculture and population growth.					
9. Sea level rise will push saltwater further up- stream which will have consequences for the fresh- water inlet points.					
Agriculture					
10. Availability of the freshwater supply will be under pressure due to dryer summers.					
11. Increase water logging due to more extreme rainfall.					
12. More salt seepage due to sea level rise.					
13. Sprinkling with freshwater is limited.					
Living					
14. Well connected with the major cities.					
15. Strong water connected economy and recreation sector.					
16. Diverse landscape.					
Watermanagement					
17. Water safety.					
18. River discharge.					
19. Water storage.					
20. Reuse of delta works.					

ASSESSMENT OPEN EASTERN SCHELDT

Problem context	very bad	bad	neither good or bad	good	very good
Environment					
1. Poor water quality in the Volkerak-Zoommeer due to long-term inputs of nutrient-rich river, agricultural water and insufficient refreshment or flow.					
2. Hardly any possibilities for fish migration through the delta to the Rhine-Meuse river system.					
3. Nutrient deficiency in the Eastern Scheldt due to the excess production of shellfish and compartmentalization of the delta which cut of the river flow through the Eastern Scheldt.					
4.Oxygen deficiency in the stagnant lakes due to the compartmentalization of the delta.					
5. Increase in erosion of intertidal areas due to the delta works and sea level rise.					
6. Decreasing intertidal areas due to change in the morphological system and in the Western Scheldt due to the intensive dredging and deposit policies which led to steeping of the seabed.					
7. The lack of natural dynamics has led to siltation of the creeks in the Biesbosch because not enough silt is being drained to the North Sea.					
8. Increase pressure on nature due to intensive agriculture and population growth.					
9. Sea level rise will push saltwater further up- stream which will have consequences for the fresh- water inlet points.					
Agriculture					
10. Availability of the freshwater supply will be under pressure due to dryer summers.					
11. Increase water logging due to more extreme rainfall.					
12. More salt seepage due to sea level rise.					
13. Sprinkling with freshwater is limited.					
Living					
14. Well connected with the major cities.					
15. Strong water connected economy and recreation sector.					
16. Diverse landscape.					
Watermanagement					
17. Water safety.					
18. River discharge.					
19. Water storage.					
20. Reuse of delta works.					

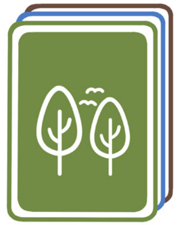
ASSESSMENT SEMI OPEN DELTA

Problem context	Very bad	Bad	Neither good or bad	Good	Very good
Environment				■	
1. Poor water quality in the Volkerak-Zoommeer due to long-term inputs of nutrient-rich river, agricultural water and insufficient refreshment or flow.					■
2. Hardly any possibilities for fish migration through the delta to the Rhine-Meuse river system.				■	
3. Nutrient deficiency in the Eastern Scheldt due to the excess production of shellfish and compartmentalization of the delta which cut of the river flow through the Eastern Scheldt.					■
4.Oxygen deficiency in the stagnant lakes due to the compartmentalization of the delta.	■			■	
5. Increase in erosion of intertidal areas due to the delta works and sea level rise.					
6. Decreasing intertidal areas due to change in the morphological system and in the Western Scheldt due to the intensive dredging and deposit policies which led to steeping of the seabed.			■		
7. The lack of natural dynamics has led to siltation of the creeks in the Biesbosch because not enough silt is being drained to the North Sea.					■
8. Increase pressure on nature due to intensive agriculture and population growth.			■		
9. Sea level rise will push saltwater further up- stream which will have consequences for the fresh- water inlet points.	■				
Agriculture			■		
10. Availability of the freshwater supply will be under pressure due to dryer summers.			■		
11. Increase water logging due to more extreme rainfall.			■		
12. More salt seepage due to sea level rise.		■			
13. Sprinkling with freshwater is limited.			■		
Living				■	
14. Well connected with the major cities.		■			
15. Strong water connected economy and recreation sector.				■	
16. Diverse landscape.					■
Watermanagement				■	
17. Water safety.			■		
18. River discharge.		■		■	
19. Water storage.					■
20. Reuse of delta works.		■			

ASSESSMENT OPEN DELTA

Problem context	Very bad	Bad	Neither good or bad	Good	Very good
Environment					■
1. Poor water quality in the Volkerak-Zoommeer due to long-term inputs of nutrient-rich river, agricultural water and insufficient refreshment or flow.					■
2. Hardly any possibilities for fish migration through the delta to the Rhine-Meuse river system.					■
3. Nutrient deficiency in the Eastern Scheldt due to the excess production of shellfish and compartmentalization of the delta which cut of the river flow through the Eastern Scheldt.					■
4.Oxygen deficiency in the stagnant lakes due to the compartmentalization of the delta.					■
5. Increase in erosion of intertidal areas due to the delta works and sea level rise.					■
6. Decreasing intertidal areas due to change in the morphological system and in the Western Scheldt due to the intensive dredging and deposit policies which led to steeping of the seabed.			■		
7. The lack of natural dynamics has led to siltation of the creeks in the Biesbosch because not enough silt is being drained to the North Sea.					■
8. Increase pressure on nature due to intensive agriculture and population growth.			■		
9. Sea level rise will push saltwater further up- stream which will have consequences for the fresh- water inlet points.	■				
Agriculture			■		
10. Availability of the freshwater supply will be under pressure due to dryer summers.			■		
11. Increase water logging due to more extreme rainfall.			■		
12. More salt seepage due to sea level rise.		■			
13. Sprinkling with freshwater is limited.			■		
Living			■		
14. Well connected with the major cities.	■		■		
15. Strong water connected economy and recreation sector.				■	
16. Diverse landscape.				■	
Watermanagement				■	
17. Water safety.			■		
18. River discharge.					■
19. Water storage.			■		
20. Reuse of delta works.	■				

Category



Pattern Cards

Design principles for the master thesis *Between Land & Sea*

These design principles explain the concepts used in the designs made in the master thesis. Allthough they are made for Schouwen-Duiveland they are also applicable to different locations.

Pattern Cards

The icons and the colours indicate the category of the pattern cards, the code is card specific.

Biodiversity	B.1 up to B.10
Fresh water	F.1 up to F.3
Salinisation	Sa.1 up to Sa.3
Water quality	W.1 up to W.3
Sedimentation	Se.1 up to Se.3

Relation with: **pattern** (**name, code**)

Biodiversity B.1

Biodiverse Salt & Fresh

Salt/fresh gradients make a more biodiverse delta

The gradient environment between the salty sea and the fresh river provide a unique ecosystem in which a wide range of flora and fauna can flourish.

Biodiverse Salt & Fresh

In the Southwest delta the natural salt/fresh gradients should be restored

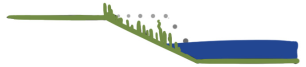
Theoretical background

Salt/fresh gradients are of ecological significance because of the high gradient variation but also because they are the physical connection between sea and river. This physical connection makes sedimentation processes and migrating species possible. The ecological importance can be divided in 4 aspects:
- Habitat and species diversity
- Food for the food web
- Maternity and nursery function
- Migration corridor (swim way)

(Tangler, Winter, Nolte, & Ysebaert, 2020)

Relation with: **pattern** (**Free Sand Se.3, Open Swimway B.10**)

Biodiversity B.2



Ecological Bank

Less steep enbankments lead to more biodiversity

Desteeping the enbankment of ditches gives more opportunities for flora and fauna to flourish.

Ecological Bank

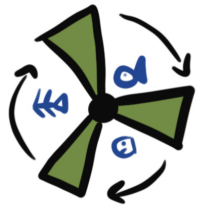
A natural friendly embankment slope can vary between 1:2 till 1:20. But if there is enough space the slope can be even more gentle

Theoretical background

Most of the time the slopes of ditches are very steep for optimal land use. But this steepness is bad for the biodiversity. a flatter slope will provide more types of fauna.
(Sollie et al., 2011)

Relation with: **pattern** (**Room for the Ditches F.1**)

Biodiversity B.3



Anti-fish Sushi

Fish friendly or low RPM pumps for less fish mortality

To pump water out of the polder towards the sea, the Netherlands uses water pumps. The traditonal pumps cause damage and/or death to the fish that want to pass.

Anti-fish Sushi

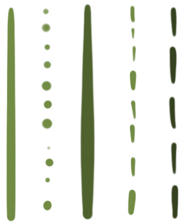
Fish friendly pumps can be installed instead of the traditonal pump to decrease the amount of dead fish that pass

Theoretical background

Pumping water from hinterland drainage systems into a river or sea has impact on fish health. All pump types cause injuries to fish, leading to mortality, with immediate mortality and injury intensity increasing with higher revolutions per minute (RPM). The 'fish-friendly' Pentair pump and the low RPM Köster pump were found to be the most fish-friendly. The study recommends running pumps on low RPM as often as possible to reduce potential damage to fish, especially after long periods of stagnation.
(Bierschenk et al,, 2018)

Relation with: **pattern** (**Open Swimways B.10**)

Biodiversity B.4



Strip Cultivation

Strip cultivation for more meadow birds

An effective action to increase the amount of meadow in agricultural fields is strip cultivation. Instead of one mono culture, multiple crops are planted in lines.

Strip Cultivation

In the test area of 200 ha on Schouwen-Duiveland, the amount of skylarks breeding increased from zero to ten in five years

Theoretical background

The Burgh-Westlandpolder area in Burgh-Sluis has seen an increase in skylarks due to effective measures that include strip cropping, where multiple crops are grown in strips next to each other. The method of stripcutlivation including customized management for meadow birds has an additional cost of €150/ha compared to monoculture plots. However, on the most agriculturally efficient plot it only costs €22/ha. These plots used long strips as well as the headfields. Meadow bird numbers increased in the demonstration area but remained low in the reference area. The numbers of yellow wagtail, meadow pipit, lapwing, oystercatcher and skylark increased by a factor of 4 on average in strip cultivation fields.
(Zee et al., 2019)

Relation with: **pattern** (**Toxic Run-off Water W.2**)

Biodiversity B.5

Biodiverse Dike

Biodiverse dike for more drought resistance

A dike covered with multiple species of grasses instead of one type is more resistant agianst droughts and increases the biodiversity and ecological value of the surrounding environment.

Biodiverse Dike

Dikes can be sown with a variety of species to make them more drought resistant and biodiverse

Theoretical background

Research has demonstrated the resilience of a biodiverse cover against the erosive impact of floods. The variety above ground is mirrored in a diverse and deeply rooted system that holds the soil layers together, providing an excellent initial layer of protection both above and below ground. Furthermore, a species-rich cover can aid in restoring biodiversity by providing habitats for unique plant and insect species. Additionally as dikes meander through the Dutch landscape, they can form a bridge between different ecosystems.

Finally, their flowery nature improves the living environment and generates support from local residents for dike reinforcement.
(Kroon & Rooijen, 2023)

Relation with: **pattern** (**Stronger Together B.9**)

Biodiversity B.6

Flower Power

Flowerly field edges for more biodiversity

Agricultural field edges that are cultivation free have a postive effect on biodiversity and strenghtens populations of vulnerable species.

Flower Power

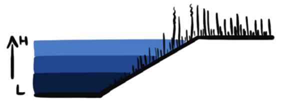
A research by Noordijk et al. (2011) examined flower-rich seeded faunaborders in Zeeland for 11 years, revealing rapid overgrowth but only a minor decline in plant species richness

Theoretical background

The establishment of sown field margins for crop protection and pollination has a positive effect on biodiversity, including stimulating natural enemies of agricultural pests. Pesticide-free buffer strips can double the number of plant species, insects, and insect groups, as well as increase the diversity of vegetation in field margins. However, the positive effect depends on the adjacent crop on the agricultural land. Studies have shown that sown field margins can have a positive effect on food availability and chick survival of farmland birds, with the effect on actual population size proven only for the Grey Partridge. Therefore, field edges established for natural pest suppression can also have a positive effect on insect-eating farmland birds.
(Bos et al. 2014)

Relation with: **pattern** (**Buffering Field Edge W.3**)

Biodiversity B.7



Washed Away

Dynamics slows/stops the succession of embankments

When vegation on an embankment is exposed to tidal water and is submerging with high tides the succession of the vegation is slowed down or even stopped.

Washed Away

Reintroducing tidal movement in the Grevelingenmeer will lead to less succession on the enbankments of the islands and dikes

Theoretical background

Dynamic environments such as dunes and river areas are characterized by pioneer situations and formations of dynamic gradients between old and young vegetation, driven by wind and water. Such dynamics are essential for maintaining and developing the required variety in a landscape that offers appropriate habitats for animal species. In contrast, rigidity hampers development and is detrimental to fauna. (natuurkennis, n.d.)

Relation with: **pattern** (**Tidal Water W.1**)

Biodiversity B.8

Money Trees

Increasing biodiversity is economically rewarding

The conservation of biological diversity is essential for several ecosystem services, including agriculture, forestry, fisheries, hydrological cycles, and climate regulation. Biodiversity is also critical for food production, medicinal plants, and pharmaceuticals.

Money Trees

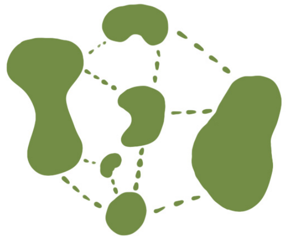
Restoring biodiversity isn't only a cost it is rewarding in the long run

Theoretical background

The benefits of biodiversity, including economic and environmental benefits, are estimated to be substantial, with services in the United States contributing $319 billion per year and estimated benefits for the world being $2928 billion per year. Other studies estimate global economic benefits to be $33,000 billion per year. Diverse species provide essential services, such as organic waste disposal, soil formation, biological nitrogen fixation, crop and livestock genetics, biological control of pests, plant pollination, and the development of drugs and medicines. These services are crucial for the sustainability of the environment and human society.
(Cliff et al., 1997)

Relation with: **pattern** (**all of biodiversity category B.1 up to B.10**)

Biodiversity B.9



Stronger Together

Connecting nature areas makes them more robust

The natural environment in the Netherlands has become fragmented. Many habitats have become isolated from each other due to urban development, expansion of industrial areas, infrastructure, or intensification of agricultural land. Connecting habitats improves them.

Stronger Together

The Dutch nature policy aims to reduce fragmentation through a cohesive nature network, the Ecological Main Structure (EHS)

Theoretical background

The three goals of making robust connections are: (1) preserving biodiversity at a national level by linking small habitats to create sustainable nature networks, (2) preserving biodiversity at a regional level by facilitating access to new habitats, and (3) preserving biodiversity during unforeseen events, such as disease outbreaks, harsh winters, or climate change, by creating alternative habitats. These goals are cumulative, with measures taken for the second goal contributing to the first and those for the third goal contributing to both previous goals. Robust connections increase the resilience of the nature network, improving its chances of survival.
(van der Grift & Bouwma, 2013)

Relation with: **pattern** (**Biodiverse Dike B.5**)

Biodiversity B.10

Open Swimways

Open connections for more fish migration

A barrier-free river system is essential to ensure migratory fish can complete their entire lifecycle without facing danger, delays, and disturbance caused by migration barriers.

Open Swimways

Removing dams, permeate dam, installing fishladders and fish friendly pomps

Theoretical background

While a barrier-free river system suffices for most species, various salmonids, eels, and lampreys require free migration out into estuaries and oceans to complete their entire lifecycle. The construction of barrages, weirs, dams, and sluices are the primary factors affecting natural in-stream flow. These barriers are built for several reasons, such as water conservation during dry periods, navigation, hydropower, irrigation, water supply, or flood protection. In the Netherlands, where a significant portion of land is below sea level, thousands of pumping stations and sluices are required to maintain engineered river channels and safeguard the area from flooding. Fish migration capacity around the world is threatened by hundreds of thousands of barriers of various kinds.
(Brink et al., 2018)

Relation with: **pattern** (**Free Sand Se.3, Biodiverse Salt Fresh B.1, Anti-fish Sushi B.3**)

Fresh water F.1

Room for the Ditches

A more gentle sloop in ditches give more waterstorage capacity

Flattening the edge of ditches allows more square meters of water to enter the ditch and thus increases water storage capacity throughout the system.

Room for the Ditches

Transforming traditional enbankments towards more sustainable flatter enbankments

Theoretical background

The water storage capacity in the waterways increases slightly with the construction of sustainable riverbanks. This makes it possible to capture more water during periods of heavy rainfall. (Zuiderzeeland, n.d.)

With a higher water storage capicity in the watersystem the waterlevels can be raised towards the more desirable levels. Nowadays the waterlevels in some areas are kept deliberately low to provide sufficient water storage during periods or extreme rainfall.
(Scheldestromen, 2021)

Relation with: **pattern** (**Ecological Bank B.2**)

Fresh water F.2

Room for More

More waterstorage cappacity gives room for higher water levels

When the ditches can hold more cubic meters of water their waterstorage cappacity increases, allowing the water levels to increase as well.

Room for More

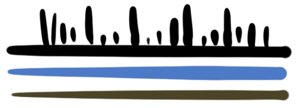
The catchment area t'Sas on Schouwen-Duiveland is kept deliberately low although a higher water level would be desired to reduce drought and increase infiltration

Theoretical background

With a higher water storage capicity in the watersystem the waterlevels can be raised towards the more desirable levels. Nowadays the waterlevels in some areas are kept deliberately low to provide sufficient water storage during periods or extreme rainfall.
(Scheldestromen, 2021)

Relation with: **pattern** (**Room for the Ditches F.1**)

Fresh water F.3



Soil and Water Leading

Leading soil and water conditions leads to a productive landscape

Soil and water conditions should be leading for the land use and crop cultivation choices.

Soil and Water Leading

In 2022 the Dutch government decided that water and soil must be guiding when making spatial decisions. (Harbers & Heijnen, 2022)

Theoretical background

The classic layer approach in spatial planning, which includes the occupation layer, network layer, and subsoil, is no longer balanced, with the occupation and network layers dominating and making the subsoil subordinate. This approach is unsustainable and vulnerable to climate change, particularly sea-level rise and flooding. Instead, a new approach should be adopted, starting with soil and water as the guiding principle and prioritizing high and dry areas for living and working.
(H+N+S Landschapsarchitecten et al., 2022)

Relation with: **pattern** (**Embrace the Salt Sa.1, Salt Biomass Sa.2**)

Sediment Se.1

Vegetated Embankment

Vegetated dike embankments for less wave force

A vegetated embankment at the outer dike side reduces the wave force on the dike. This makes that dikes needs to be raised and strengthened less.

Vegetated Embankment

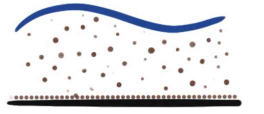
At the Houtribdijk in the Netherlands between Lelystad and Enkhuizen a new sandy enbankment will be created to strengthen the dike

Theoretical background

A vegetated embankment of aproximately 300 meters can reduce the wave force on the dikes in a storm with 50%. In events of heavy storms the higher located foreland will especially help to reduce the wave force on the dike.
The roots of the vegation on the embankment ensure the stability of the soil, which helps to prevent erosion.
(Vuik et al., 2019)

Relation with: **pattern** (**Slow Water S.2**)

Sediment Se.2



Slow Water

Slowing the water to increase sedimentation

Sedimentation occurs when the waterflow decreases. The transported sediment particals are being deposited and form new soil.

Slow Water

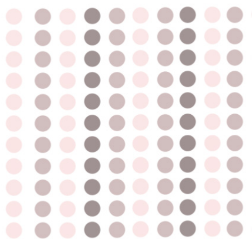
Multiple solutions are possible, like reef constructions and suplementation. The theory is to reduce flow velocity so that sedimentation exan occur

Theoretical background

Materials carried by a river settles down when the speed of the river slows down, causing sedimentation. The largest and heaviest particles settle first, and the smallest continue downstream. As the river nears the sea, the speed slows down, leading to the settling of finer particles. Clay particles sink to the bottom in calm water.
(Netten, n.d.)

Relation with: **pattern** (**Vegated Embankment S.1**)

Salinisation Sa.2



Salt Biomass

Salty grasses and salt tolerant crops for biomass

Due to drier summers in the future, it is possible that the rainwater lenses may become thinner, increasing the risk of salt damage in crops. Transitioning towards salt tolorant crops is necessary.

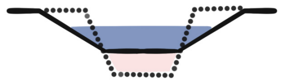
Salt Biomass

Large scale cultivation with salt tolerant and salty grasses can be harvest to produce biomass

Saline crops can be approached through two methods: large-scale cultivation and small-scale cultivation. The large-scale cultivation can lead to the production of bio-energy through biomass, using existing crops that have shown salt tolerance, such as barley, spelt, or beets, or introducing new crops such as sea arrowgrass or salt marsh grass. In the saline environment, we encounter numerous transitions from wet to dry, fresh to salt, and production environment to landscape and nature development. By utilizing the bulk biomass produced, various fermentation and digestion techniques can provide a significant contribution to the production of biofuels, along with other forms of land use.
(Grondmij , 2010)

Relation with: **pattern** (**Embrace the Salt Sa.1**)

Salinisation Sa.3



Shallow Ditch

Less deep ditches for less salt seepage

Because ditches are deeper parts in the land the salt water is drawn towards the ditches. This resluts in salt/brakish water in the ditch.

Shallow Ditch

Making the ditches wider and less deep

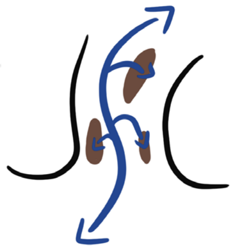
Theoretical background

The low water level of the ditches results in highly elevated seepage flows, which lead to the presence of solely salty seepage water beneath the ditch bed, without any admixture of rainfall.
(Louw, 2015)

Allthough no scientific sourse is found for this, ordinary reasoning explains small shallower ditches will be less salty than larger deeper ones, because the bigger deeper ones are closer to the a salt water layer.

Relation with: **pattern** (**Ecological Embankment B.2**)

Sediment Se.3



Free Sand

Open connections for more sedimentation

The dams and dikes in the Grevelingenmeer and Volkerak-Zoommeer have made sediment exchange with the Voordelta and other basins impossible. The sediment supply is limited to internal sources such as existing flats and shores.

Free Sand

Reintroducing tidal movement, removing dams, enlarging openings in dams

Theoretical background

The sediment balance of the Voordelta has been significantly affected by the construction of closure dams. These dams have greatly reduced the external sediment supply, making sediment exchange with neighboring water bodies impossible. The strong tidal currents that once filled and emptied the basins have also diminished, leading to a reduction in the total tidal energy of the region. In addition, the rising sea level leads to a increase in sediment demand resulting in internal redistribution of sediment. Local erosion occurs where wave energy is dominant, while sedimentation takes place in other areas. All these factors have led to a shift in the sediment balance of the Voordelta, with the closure dams playing a significant role.
(Mulder et al., 2012)

Relation with: **pattern** (**Open Swimways B.10, Tidal Water W.1**)

Salinisation Sa.1

Embrace the Salt

Production of salty crops in areas with a lot of salt seepage

A sustainable approach is needed to combat salinity in agriculture, instead of costly desalination methods and freshwater pipelines. Agricultural production should adapt to rising water salinity.

Embrace the Salt

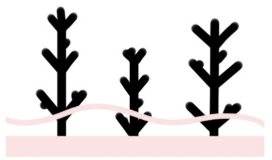
Salt tollerant crops (barley, spelt, or beets, celery green asparagus), salty vegatables (glasswort, sea lavender, sea kale)

Theoretical background

Aquaculture has experienced substantial growth and has gained importance for the Netherlands in recent decades. At the same time, the challenges of globalization and climate change are putting pressure on traditional agri-production companies.
The use of saline sources for cultivating salt-tolerant crops leads to the neutralization of the saline source, which in turn makes more freshwater available for other users, creating a win-win situation.
(akker, 2014)

Relation with: **pattern** (**Soil and Water Leading F.3**)

Salinisation Sa.4



Sea Vegetables

Production of saline plants in areas with saline coditiontions

The production of saline plants can help with the pressing challenges posed by rising sea levels and the increasing salinization of coastal agricultural land.

Sea Vegatable

A distinction can be made between saline vegetables (saline plants) and normal agricultural crops that can also produce well in saline conditions (salt-tolerant plants) see card Sa.5

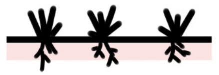
Theoretical background

Species	Suitable soil type	Degree of salt water
Glassworth	Wet, nutrient-rich, saline, brackish or sometimes fresh soil	Occasional to regular inundation. Sprouting in fresh to brackish water
Lamb's lettuce	Wet, nutrient-rich, saline, brackish or sometimes fresh soil. Sandy cover has an advantage over clay soil	Occasional flooding with salt water
Sea kale	Nutritious, brackish, moist soil with high humus content	Occasional flooding with salt water

(Grondmij B.V., 2010)

Relation with: **pattern** (**Embrace the Salt Sa.1**) & (**Salt Tolerant Sa.5**)

Salinisation Sa.5



Salt Tolerant

Agricultural crops that can also produce well in saline conditions

Cultivating salt-tolerant crops can provide a valuable solution to address the urgent challenges presented by rising sea levels and the growing salinization of coastal agricultural land.

Salt Tolerant

By cultivating crops that are naturally more resistant to salt, we can optimize food production and mitigate the negative impacts of salinity on traditional agriculture

Theoretical background

Species	Suitable soil type	Degree of salt water
Celery	Clay, loam and loamy clay, moist to often wet, nutrient-rich, slightly saline to brackish soil	Tolerates salty conditions well
Asparagus	Dry, nutrient-poor to moderately nutrient-rich, more or less calcareous, humus-rich soil	Tolerates salty conditions well
Beetroot	Sand/clay, moist, nutrient-rich soil	Tolerates salty conditions
Spelt	Poor sandy (clay) soil	Tolerates salty conditions

(Grondmij B.V., 2010)

Relation with: **pattern** (**Embrace the Salt Sa.1**) & (**Sea Vegetable Sa.4**)

Water quality W.1

Tidal Water

More dynamics in water flows for better water quality

The movement in water derived form tidal movment improves the quality of the water because stratification is prevented.

Tidal Water

The Grevelingenmeer is facing stratification due to its stagnation. Reintroducing tidal movements improves the waterquality

Theoretical background

The ecological state of the Grevelingenmeer is declining, with regular occurrences of oxygen-free or oxygen-poor conditions in the water column being identified as one of the causes. As a measure to improve the water quality and consequently the ecological state, the reintroduction of tidal flow is being considered.
Research done by deltares shows a tidal movement of 40 cm is sufficient to largely avoid oxygen-deficient conditions. A bigger tidal movement leads to limited improvement.
(Nolte & Spiteri, 2011)
However, the bigger the tidal amplitude the more intertidal habitats.
(Tangelder et al., 2019)

Relation with: **pattern (Washed Away B.7, Free Sand Se.3)**

Water quality W.2

Toxic Runoff Water

Reducing chemical pesticides improves the waterquality

Reducing the runoff of pollutants from agriculture into ground and surface water improves the water quality.

Toxic Runoff Water

Reduce or stop the use of chemical pesticides and use sustainable alternatives

Theoretical background

The contamination of surface water from diffuse sources involves many substances, including those from agriculture, road traffic, shipping, industry, and households. However, in the Netherlands, agricultural sources are the most prominent. The high levels of nitrogen and phosphorus (especially in the form of nitrate and phosphate) as well as pesticides, biocides, and animal medicines in surface water mainly result from groundwater leaching and agricultural field runoff. (te Brinke et al., n.d.)

Relation with: **pattern (Buffering Field Edges, W.3)**

Water quality W.3

Buffering Field Edges

Water qualtity improvement by buffering sown field margins

Runoff water that contains pesticides degrades the surface water quality. Buffering field edges can reduce the amount of pesticides entering the surface water.

Buffering Field Edges

Transforming the outer field margin of agricultural land into a pesticide free zone, sown with plants that buffer

Theoretical background

Planting unsprayed field margins reduces the likelihood of pesticides entering the surface water. The width of the pesticide-free zone is determined by risk analyses, with a common width of 6 meters, although other factors such as the type of pesticide, wind direction, and spraying equipment can affect its effectiveness. Researchers suggest that high vegetation in buffer strips can also reduce pesticide drift but is not yet included in model calculations.
(Bos et al. 2014)

Relation with: **pattern (Flower Power B.6, Toxic Runoff Water W.2)**

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