WATERLAND

water-based decarbonization

Colophon

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Abstract

Excessive carbon emission has led to global warming, resulting in climate change. Due to this, the natural carbon and water cycles are disbalanced leading to extreme (water-related) events, such as flooding, periods of drought and diminished water quality. The degradation of ecosystems and threat to human survival are direct consequences of this process.

There is an urgency to act in the upcoming seven years to remain below the 1,5 degree global temperature rise. Aside from reducing CO2 emissions in long-term processes, carbon capturing is crucial to achieve short-term ambitions. Therefore, this study investigates the implementation of (nature-based) carbon sinks strategies, using water(bodies) as a tool, in North-West Europe.

This report fills the gap of knowledge on how to implement water-based decarbonization through spatial interventions in North-West Europe.

Firstly, the technical aspects of water-based decarbonization are studied by reviewing existing literature, providing the required spatial conditions for the implementation of water-related carbon sinks. The historical and current conditions in North-West Europe are mapped and analysed. Comparing these results, an evidence-based selection of feasible intervention areas are determined.

Our analysis shows that the EuroDelta is the strategic location for the spatial vision for North-West Europe. There is a need for a paradigm shift to restore the self-sustaining system of the Delta, demanding Nature Based Solutions. Wetland restoration is the most efficient, low cost approach of climate change mitigation as the free, well-functioning services of these carbon sinks naturally make way for long-term restoration of the natural balance and societal well-being. They should be restored in original historical sites and the Dutch Delta is suitable. Therefore bottom-up approaches are required in global visions as wetlands restoration is context-specific.

We conclude that de Krimpenerwaard polder and the Port of Rotterdam are effective, feasible, and inclusive solutions to tackle both climate change and societal challenges while providing long-term water-resilience and livability through all scales. Agricultural sectors will shift to sustainable farming and (port-)industries are held accountable for their emission. A limitation is the disregard on the emission of methane which in further research should be taken into account.

Keywords: climate change mitigation, wetland, blue carbon ecosystem, carbon uptake, EuroDelta

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01 Introduction

Introduction

Worldwide, wetlands are destroyed at a rapid pace mainly due to human activities by constructed high-impact interventions such as infrastructure, shoreline enforcement and housing (Fennessy & Lei, 2018). By this, we have created a man-constructed world, trying to control nature. However, nature has reached its limits and is turning its back towards us. They belong to the most threatened ecosystems of the world (Tweede Kans Om Wetlands Te Beschermen, 2023). Therefore, World Wetlands Day was introduced on February 4th 2012, as it marks the date of the Ramsar Convention signed in Iran (1971) of international cooperation to conserve and restore wetlands by contributing to sustainable development worldwide (uwaterloo, 2016).

Climate change caused by rising atmospheric CO2 concentrations leads to more frequent occurrences of weather extremes. Often this appears in water-related weather events, such as long periods of droughts, rising sea levels and pressure on river peak discharges. As a result, water availability and quality are threatened. Globally this is expressed in different trends, but the dominant trend in North-West Europe is increase in peak discharges and floodings due to increased winter precipitation (Blöschl et al., 2019).

However, during summer long periods of drought occur, whereby large parts of Europe encounter subsidence (Ministerie van Infrastructuur en Waterstaat, 2021). As the soil dries out, peat comes into contact with oxygen, resulting in large amounts of CO2 being released and further soil subsidence.

In addition, subsiding soil makes it difficult to cope with the threat of flooding due to rising sea levels. As a result, more money for protection against flooding is crucial (Ministerie van Infrastructuur en Waterstaat, 2021). Sinking soil is a result of the large-scale water management in our Delta. The Dutch landscape, which shapes the EuroDelta, is designed to drain excess water efficiently to reclaim land for housing development and agricultural activities (Hudson, Kenworthy, & Best, 2021). This has affected the natural hydrological cycle.

Due to this human interaction humankind tries to outsmart the natural balance, but now it is our task to restore the health of our planet. Therefore water-resilient Nature Based Solutions are essential to reach this aim. Even though ''... mitigation options are available across every major water-related sector, they remain largely unrecognized'' (UN Water, 2020, p. 3).

To counteract the consequences of climate change, the atmospheric CO2 concentrations will have to decrease significantly. On the one hand, this must be done by reducing the amount of CO2 that is emitted by transition to renewable energy. On the other hand, efforts will have to be made to increase natural absorption of CO2, by restoring oceanic waters, coastal and inland sinks. This report focuses on this second transition, which is necessary in addition to and parallel to the energy transition in order to prevent further temperature rise.

"35% of the world's wetlands have disappeared in the last 50 years" (worldwetlandsday, n.d.).

Problem Statement

Since the industrial revolution, excessive global atmospheric carbon concentrations (from here: ACC) have increased by 50% as human activities continuously demand large-scale burning of fossil fuels for industrial processes, traffic, energy production, and building material markets (Staff, 2021). In 2021 carbon emission levels have reached globally 37.124 MtCO2, which is almost 4 times the amount in 1960 of 9.388 MtCO2 (CO2 Emissions | Global Carbon Atlas, n.d.). This rapid incline of ACC is illustrated in figure 1. Additionally, agricultural activities also contribute as a source of CO2 emissions, as lowering groundwater required for farming emits CO2 from dry soil (FAO, 2020) (Koushki, Warren, & Krzmarzick, 2022).

Increased ACC reinforces the greenhouse effect, resulting in a rise in the average global temperature. This disbalance of the carbon cycle affects the climate globally and has among other consequences an impact on the hydrological cycle (UN Water, 2020). Extreme weather events occur, which threaten society with flood risks from both the sea level rising and the increased pressure of river discharge due to heavy rainfall and melting ice caps in arctic climates and in moderate altitudes.

Contradictory, long periods of drought take place, pressuring water accessibility with health risks for the (living) environment. Thawing permafrost releases millions of years of captured carbon into the atmosphere as arctic temperatures rise twice as fast as the average global temperature rise. Causing it to be a silent and widely unknown ticking timebomb to humanity as it is an irreversible process (Staff, 2021b).

The global temperature rise also affects the capacity of blue carbon uptake as carbon naturally dissolves into oceans and wet land. Due to the absorption of climate heat water acidification deteriorates water quality with a decline in the capacity of carbon uptake and loss of ecosystems as consequences (United Nations, n.d.).

Thus, climate change causes hydrological changes and affects the availability, quality, and quantity of water (UN Water, 2020). There is a great urgency to act in the upcoming seven years to keep the global temperature rise below 1,5 C and minimize its environmental impact (Staff, 2022) (figure 1). This requires a global response, rapid societal transformations, and sustainable development (IPCC, 2022)(CO2 Emissions | Global Carbon Atlas, n.d.).

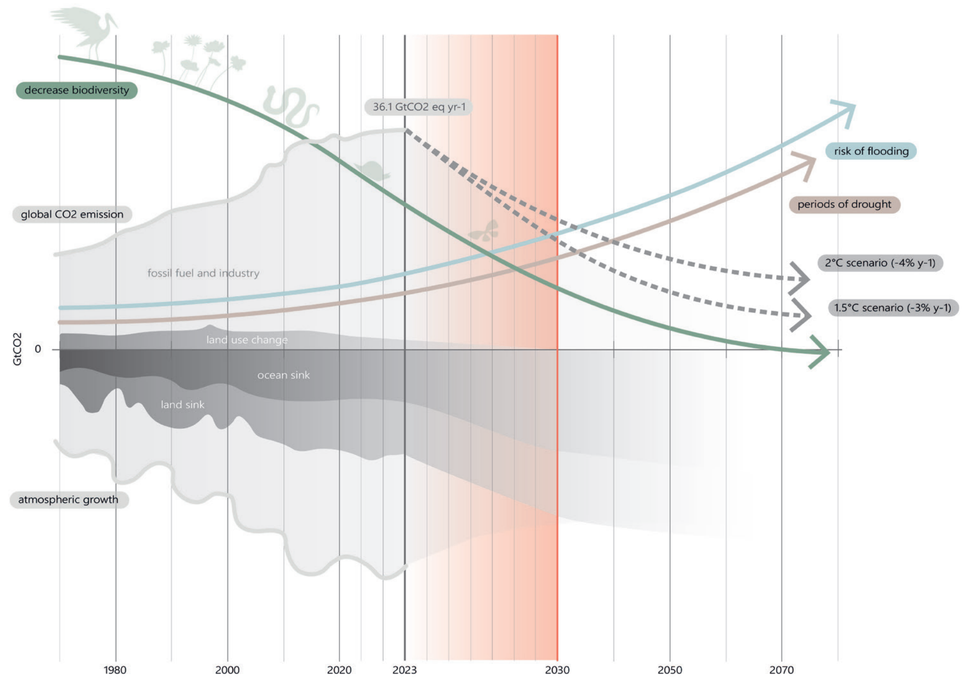


Figure 1: Carbon emission/uptake and related climate effects (adapted from Nature Reviews Earth & Environment, 2022)

Context

As the frame of this research concerns North-West Europe, the mapping of the problem statement in this area has presented the precise context of our vision and strategy implementation. The most vulnerable area regarding carbon emissions and flood risks, is the EuroDelta, as illustrated on the problem statement map (figure 2). Therefore the focus of this research will be on this area.

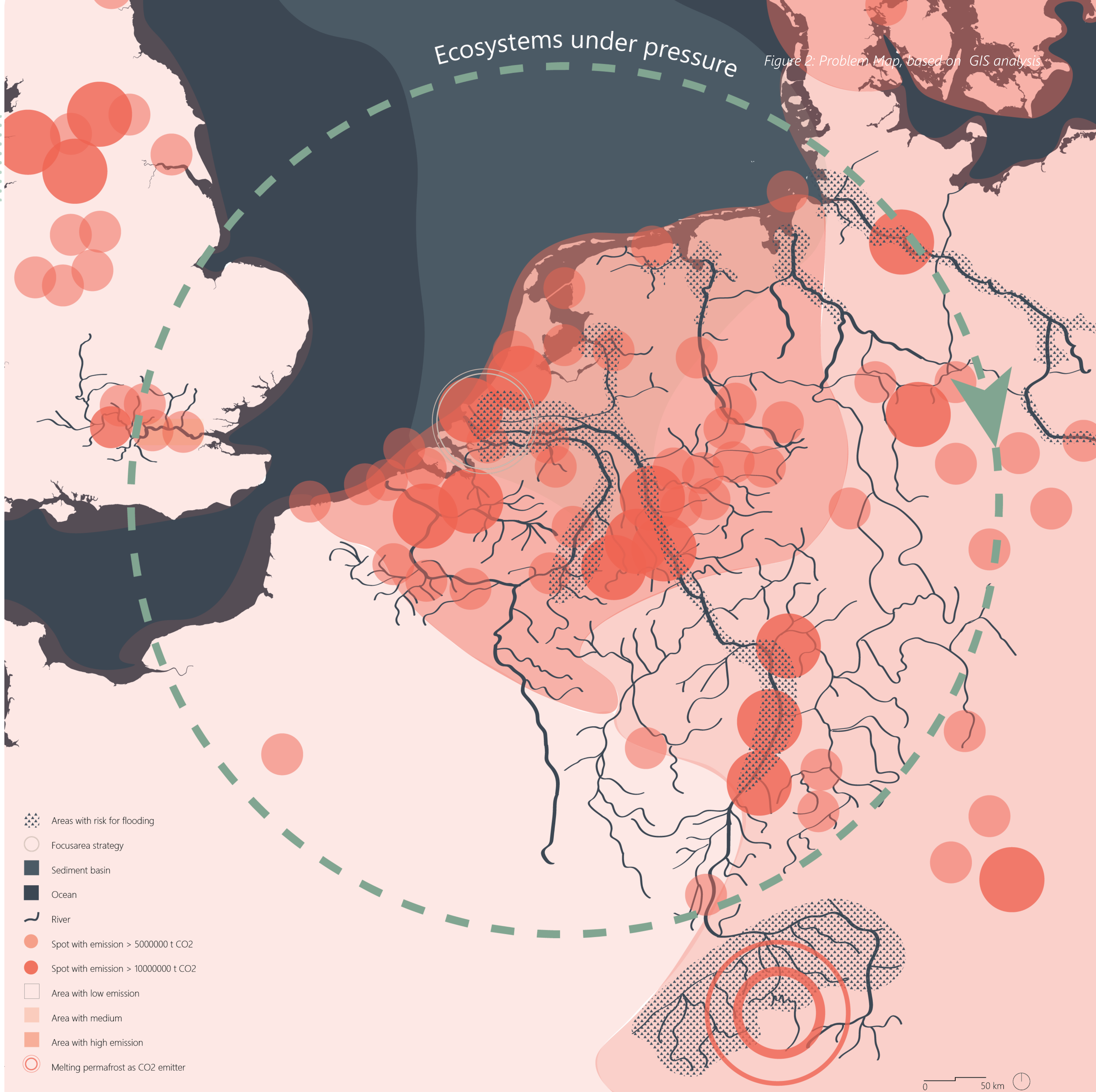


Figure 2: Problem Map, based on GIS analysis

Spatial Claims

North-West Europe is a densely populated area, as you can see in the appendix (p.99). There are multiple societal and environmental challenges, requiring space, shown in figure 3. It is important to define these spatial claims in order to answer them with this strategy.

Firstly the flood risk in Europe is increasing, on multiple levels. The sea level is rising, peak discharge of rivers is higher during winter and weather extremes, such as heavy precipitation, can cause flooding. This requires protection measures, so excess water can be retained, stored and eventually drained. These protection measures can be nature-based. ''Working with nature and enhancing crucial ecosystem services is at the centre of nature-based solutions to climate change adaptation and disaster risk reduction. Such solutions reduce social and environmental vulnerabilities and can bring multiple co-benefits such as mitigating climate change, improving human health and well-being, and providing jobs and business opportunities'' (European Environmental Agency, 2021, p. 11).

Secondly the availability of fresh water is threatened, the demand is increasing, due to a growth of population and more periods of drought. Therefore it is important to create more waterbuffers and purify wastewater to reuse (Rijksinstituut voor Volksgezondheid en Milieu, 2023).

Biodiversity also claims space, because restoration of ecosystems is needed to stop the current decline of species. Restoring forest, soils and wetlands will also achieve climate change mitigation. The European Union has set biodiversity targets such as 30% of land should be protected and planting 3 billion trees by 2030 (European commission, 2020).

Conventional agriculture has negative effects on the climate and biodiversity. On the other hand this form of agriculture is threatened by water shortages and the quality of agricultural land decreases as a result of salinization. Therefore a sustainable transition to a wetter form of agriculture is needed. To sustain long term productivity of the soil, thus food security for future generations, this transition should be prioritised. The use of fertilizers and pesticides should be reduced, resulting in lower yields per hectare, but more focused on land management with associated alternative revenue models (De Pous & OneWorld, 2020). So, more productive space is required to produce the same amount of food to provide for all citizens of North-West Europe or a shift in our eating habits (Bremmer, 2022).
The World Health Organization (2012) recommends 9 square meters recreational green space per inhabitant. For Europe this means approximately 1,8 billion square metres of green space.

With an increasing population, there is a massive housing shortage. The total housing need in North-West European countries is 1.354.100 per year. So this already urbanised area has to build even more homes (calculation based on Housing Europe, 2021).

Heritage is a spatial claim which does not need additional room, but existing room for heritage should be preserved. ''Cultural heritage can be defined as the legacy of physical artefacts (cultural property) and intangible attributes of a group or society inherited from the past'' (Central European University, n.d., The Concept and History of Cultural Heritage). Heritage is attached to values and identities of communities and societies and should be maintained now for the benefit of future generations (Central European University, n.d., The Concept and History of Cultural Heritage).

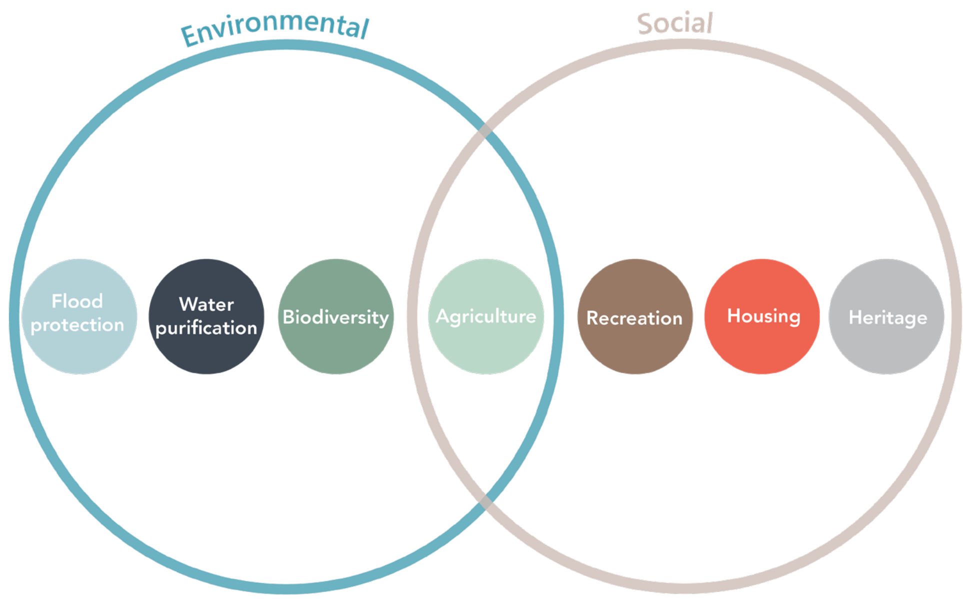


Figure 3: Spatial claims in North West Europe

Spatial Justice

Available land is limited, as stated in the previous chapter, but it is crucial to create a spatial strategy that answers these claims. In spatial planning, sustainability and social justice go hand in hand and should be prioritised, as sustainability concerns environmental, economic, and social layers. The definition of social sustainability describes justice in the sense that meeting the needs of society now, does not compromise needs of future generations (Rocco et al, 2021).

Spatial justice can be divided into procedural and distributive justice. Procedural justice is about participation of all stakeholders during the planning process, all voices should be heard in decision-making (Rocco et al, 2021). Distributive justice is about equal distribution of burdens and benefits of human activity. This means that public goods, services and environmental quality are accessible for all, across the city (Rocco et al, 2021).

While designing the spatial strategy it is important to ask the question: 'Are benefits and burdens of implementing sustainable transitions shared fairly across areas and communities?' Just projects should implement multifunctionality to provide several benefits for the society (Danenberga, 2021).

Concluding, the defined spatial claims should be combined, to provide solutions to societal and environmental challenges. Therefore it is of great importance to perform in-depth stakeholder analysis for an inclusive design of all involved perspectives.

Just projects should implement multifunctionality to provide several benefits for the society (Danenberga, 2021).

Goals

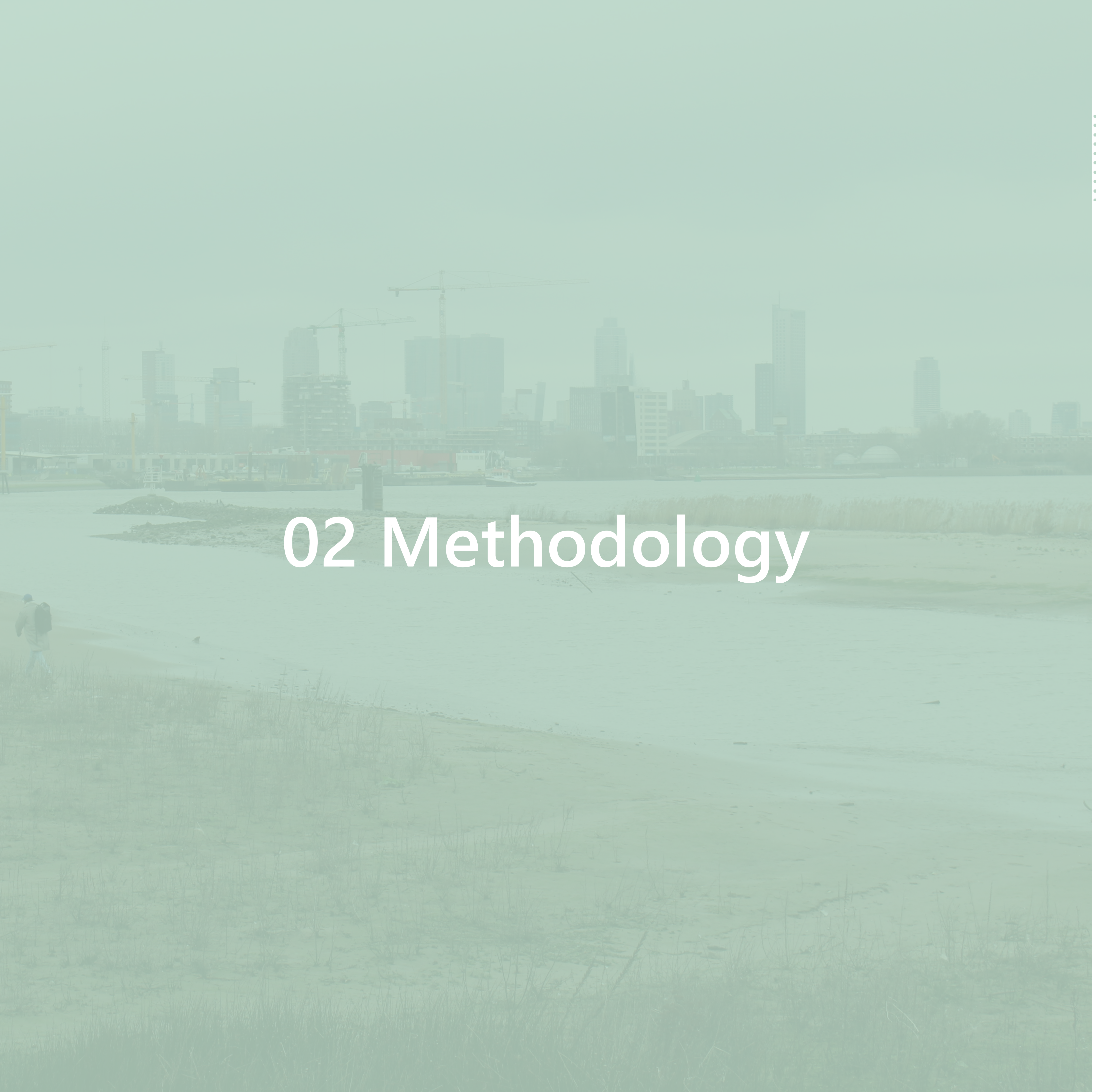
The main goal of this research is to contribute to the mitigation of climate change by providing resilience against water-related threats through the implementation of water-based decarbonization. Multiple societal and environmental spatial claims in North-West Europe will be addressed to provide spatial justice for current and future society.
This goal to implement water-based decarbonization should be combined with the goal for each spatial claim, these are stated in the right column.

Flood protection	• Reduce flood risk through nature-based solutions.
Water purification	• Drinking water supply is sufficient now and in the future.
Biodiversity	• Protect and restore ecosystems, with native flora and fauna.
Agriculture	• Develop sustainable agriculture in cooperation with local farmers.
Recreation	• All inhabitants of North-West Europe have access to recreational areas.
Housing	• Develop water resilient housing to reduce to housing shortage.
Heritage	• Preservation and restoration of heritage, focusing on the genius loci.

Political Frameworks

There are several political frameworks, on different scales, that can be aligned with the goals defined in the previous paragraph. Firstly, on a global scale, the Paris agreement (2015) targets to limit the temperature rise by 2°C compared with pre-industrial levels. Therefore balance between emission and capture is needed. On a European scale the Green Deal (2020) aims to have zero net emissions of greenhouse gases by 2050, while leaving no person or place behind.
On a national scale the current Dutch government has stated in the coalition agreement to make soil and water leading in spatial planning (Ministerie van Infrastructuur en Waterstaat, 2022).
Lastly our goals can be aligned with ten of the Sustainable Development Goals of the United Nations (2015).

2 ZERO HUNGER	• Improving food security
3 GOOD HEALTH AND WELL-BEING	• Higher environmental quality • Improving physical and mental health through improvement accessibility nature
6 CLEAN WATER AND SANITATION	• Water resilience • Supports healthy soil conditions
8 DECENT WORK AND ECONOMIC GROWTH	• Creating more jobs related to sustainable production means • Creating new economic revenue models
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	• Innovating to a more nature based drinkwater treatment system • Innovating desalination techniques and corrosion-resistant pipes • Innovating and developing salty agriculture
11 SUSTAINABLE CITIES AND COMMUNITIES	• Improve access to nature • Shift to more sustainable wastewater treatment • Shift to renewable energy sources • Strengthen efforts to protect and safeguard the world's cultural and natural heritage
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	• Reuse of waste materials for eco-friendly river banks • Shift in diet
13 CLIMATE ACTION	• Restoring natural balance ecological cycles • Promoting carbon sequestration • Improving flood resilience • Improving climate change awareness
14 LIFE BELOW WATER	• Creating aquaculture to support land-based agriculture • Restoring and improving marine biodiversity
15 LIFE ON LAND	• Supporting engagement through providing new alternatives



02 Methodology

Research Question

Following from the problem statement, a solution to minimize climate change and provide resilience against the water- and carbon-related risks is needed. ''Adaptation and mitigation are complementary strategies for managing and reducing the risks of climate change'' (UN Water, 2020, p.3). Adaptation provides solutions to moderate harm due to climate change. Mitigation presents interventions to reduce sources or enhance sinks of greenhouse gases (UN Water, 2020). To tackle climate change the focus should be on mitigation. Although we acknowledge the importance of diminishing global emissions, carbon sequestration is crucial to mitigate the effect of existing (and future) ACC in the atmosphere (Foster, 2022).

As stated before, there is an interrelation between the carbon and water cycle. ''While mitigation options are available across every major water-related sector, they remain largely unrecognized'' (UN Water, 2020, p. 3). Thus, as most research focuses on diminishing global CO2 emissions, this project aims to fill the scientific gap. The importance of the role of water in relation to carbon uptake as a mitigation strategy against climate change will be the inception. As human activities are the fundamental cause of the disruption of nature's balance, nature-based solutions provide opportunities to restore ecosystems and safeguard human health and safety, using the natural qualities of water for carbon sequestration (IUCN, n.d.).

The research question that will be answered is 'How to integrate water-based decarbonization (technologies) in spatial strategies for a sustainable NW-EU?' The last part (chapter 5) of this research will focus on implementation of these strategies in South-Holland.

How to integrate water-based decarbonization (technologies) in spatial strategies for a sustainable NW-EU?

Theoretical Framework

To understand the imbalance of the carbon and water cycle due to global warming which causes climate change, the theoretical framework will briefly elaborate on the functioning of the cycles, which will serve as the base of this understanding of this water-based decarbonization project (figure 4).

Carbon Cycle
Carbon is a vital element for all living organisms. It is a key component of the atmosphere as it regulates earth's temperature. Carbon can form into carbon dioxide (CO2) and methane (CH4). For this research, we focus on CO2.

Carbon can be absorbed by water bodies, such as the ocean (largest carbon reservoir) and permafrost. Oceanic waters partly dissolve CO2 and create carbonic acid, while marine plants sequestrate carbon. Also permafrost captures carbon, twice as much as what the atmosphere contains. The frozen state of permafrost does not allow plants to decompose, thus never releasing carbon.
On the terrestrial biosphere CO2 can be absorbed by vegetation for photosynthesis. They depend on this process as they grow from this. But also animals and humans release CO2 through breathing processes, animals eat plants that store CO2, and release it into the atmosphere and soil during secretion. Soil absorbs this secretion and decomposed plants.
And lastly, the earth's interior contains carbon as these piled-up deposits transform under large pressure into cole rocks and limestone (What is the Carbon Cycle?, n.d.).

Hydrological cycle
Water evaporates from the ocean and condensates into clouds. Wind blows these clouds across land where it precipitates on lower/higher longitudes by rainfall and in upper longitudes by snowfall. Water will be partly absorbed by vegetation and surface runoff will transfer water through streams and rivers where in the end it discharges into the ocean. During this process, water also infiltrates into ground, where underground discharge flows into the ocean. It is a process of storage and flow.

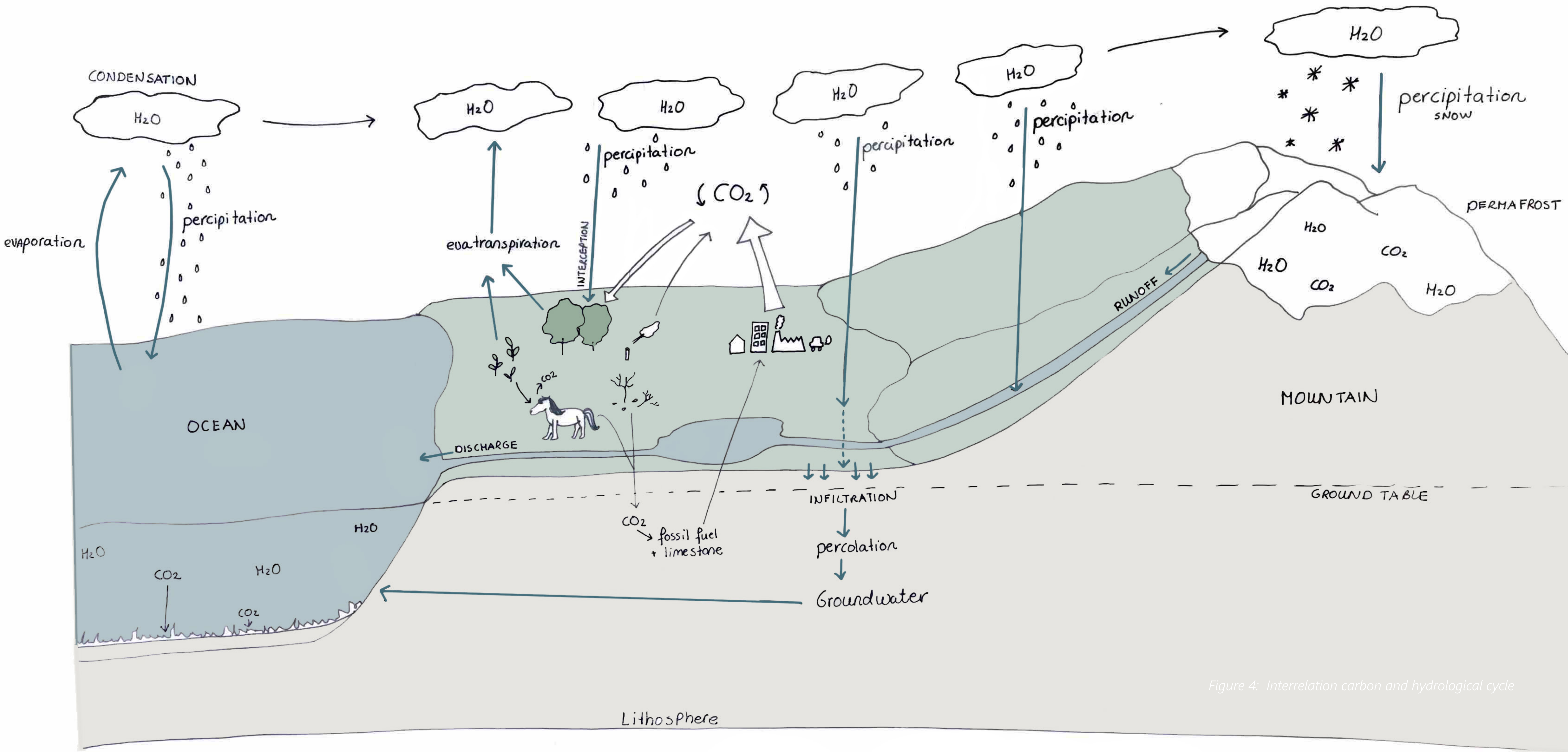


Figure 4: Interrelation carbon and hydrological cycle

Conceptual Framework

The conceptual framework provides an abstract overview of the fundamental structure of the study and helps in this way to define and understand the complexity of this study.

The foundation is the interrelation of the carbon and water cycle, as their disbalance caused by climate change can be tackled by using this connection. Sustainable land-use, circularity and nature-based solutions are the pillars of this water-based decarbonization strategy. This tackles both mitigation and adaptation of climate change, and restores the balance in and between the two circles.
The third dimension in this research is social justice. This means answering to multiple spatial claims through the strategy, with a fair distribution of benefits and burdens. This strategy will be looked at through the geographical lens of the Eurodelta.

Conceptual Framework

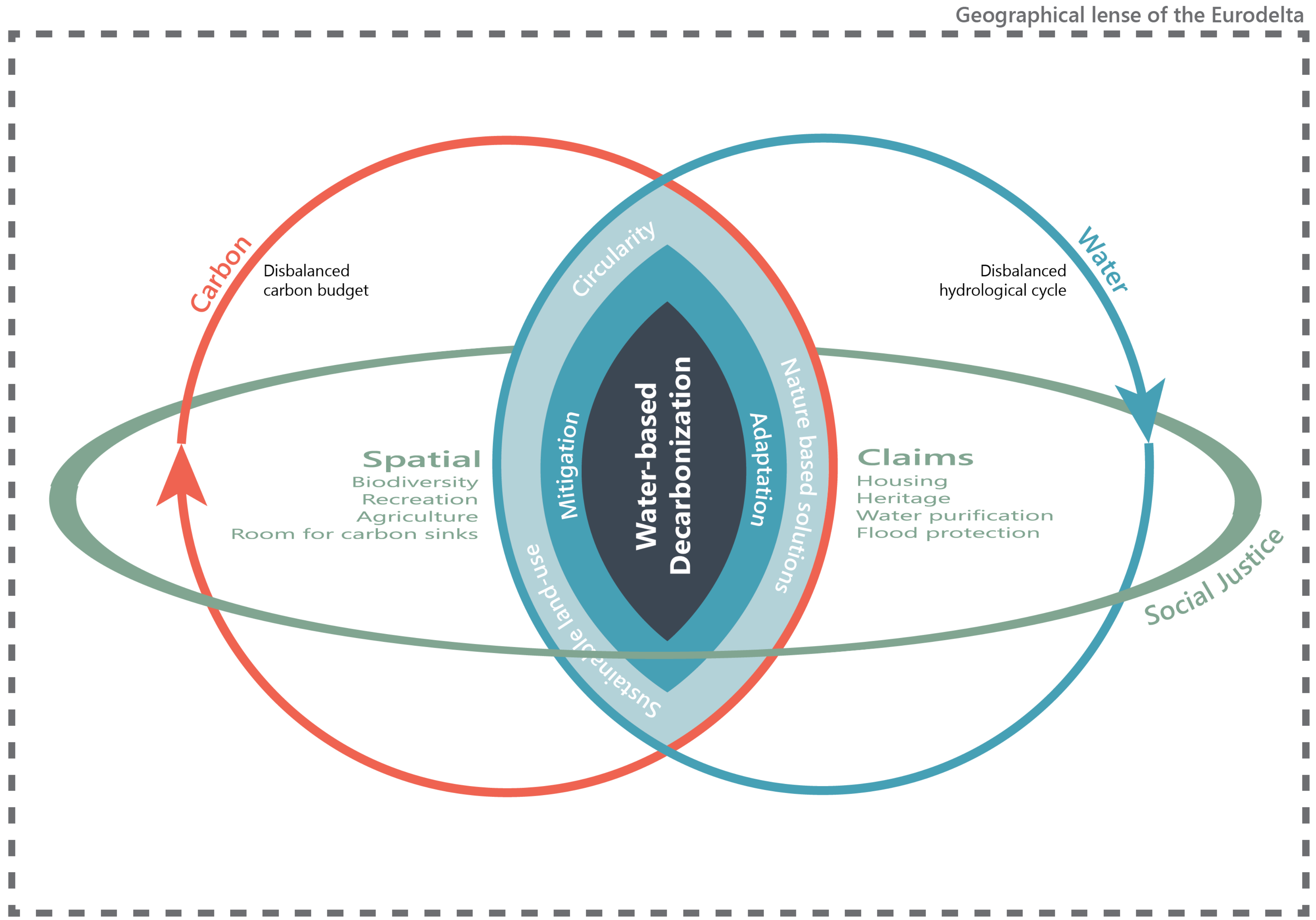


Figure 5: Conceptual framework

Method

The research question is answered through literature research, historical analysis, GIS analysis, policy analysis, and design exploration. This is a mix of quantitative and qualitative approaches.

These methods have been used to produce an evidence-based strategy. Based on literature research, the interrelation between carbon and water has been investigated (see theoretical framework). Subsequently, historical analysis was used to investigate landscape history, with natural and man-made changes which has been resulting in a reduction of wet land. This has been done because the needed solution requires a change of this system, but the cultural value of the landscape must be taken into account. Based on literature research, the conditions and factors that influence the probability of success for ocean and wetland restoration and creation have been investigated. Based on this knowledge, the high potential areas for wetland restoration or creation have been mapped out. The data used in GIS is partly obtained by TU Delft and supplemented with data from open data sources. To prevent outdated data, this project made use of the latest available GEO data.

Based on comparison with other sources, we tested the validity of the literature sources. Through GIS it was possible to analyse geographical information in an accurate manner. Overlapping these maps made it possible to classify different areas in NW Europe with different potentials to be successful for recovery or creation of ocean or land sink. This was based on related conditions.These conditions concern river flood risk, type of soil, soil water capacity, type of sediment and location of ecological areas.The variables used for the zoom in interventions are: type of land use, and specific type of agriculture, landowners, water table height and ground level height.The variables used work well to do an initial exploration and determine where options are more likely to work better. Nevertheless, it is advisable to consult a water expert for advice on exact determination.

03 Analysis

Using Feedback Loops

As stated in the problem statement, the carbon cycle is imbalanced due to excessive CO2 emissions, which causes global warming and changes the water cycle as a result. The theoretical framework has explained the balanced carbon and water cycle, however, a brief elaboration on the human induced imbalance of the cycles will be explained.

Because the cycles are imbalanced, climate changes. Climate change amplifies itself by positive feedback loops. For example, due to temperature rising, more water evaporates from the ocean, which acts as greenhouse gas and therefore causes the temperature to rise more. Another example is that due to heightened global temperature, permafrost is melting, which releases its stored carbon and also increases the greenhouse effect.

Contrary, negative feedback loops can diminish climate change. This could be relevant information for our research to discover if these feedback loops can contribute to the strategy. One important negative feedback loop is that due to increased temperature, plant growth will increase. More plants take up more carbon from the atmosphere, resulting in a diminished greenhouse effect. Unfortunately, due to the previously mentioned heightened evaporation of water, there will be less rain globally, which puts a limit on additional plant growth. So the advantage of this negative feedback loop will not be that useful as less water will be available due to climate change as well. However, it is an opportunity to enhance water resilience, as during periods of drought plants will still be able to grow and capture carbon (NASA Earth Observatory, 2010).

THE DUTCH WATERLANDSCAPE

Hendrik Marsman, 1936

Denkend aan Holland
zie ik breede rivieren
traag door oneindig
laagland gaan,
rijen ondenkbaar
ijle populieren
als hooge pluimen
aan den einder staan;
en in de geweldige
ruimte verzonken
de boerderijen
verspreid door het land,
boomgroepen, dorpen,
geknotte torens,
kerken en olmen
in een grootsch verband.
de lucht hangt er laag
en de zon wordt er langzaam
in grijze veelkleurige
dampen gesmoord,
en in alle gewesten
wordt de stem van het water
met zijn eeuwige rampen
gevreesd en gehoord.

Thinking about Holland,
*I see **wide rivers***
flowing slowly
*through **infinite lowland.***

And in all provinces
the voice of the water
*with its **everlasting disasters***
*is **feared** and heard.*

Figure 6: Poem 'Memories of Holland' (Marsman, 1941)

Historical Approach

Historical Approach

As is stated in the problem statement, the disbalance in the carbon cycle due to human activities also causes drastic changes in the water cycle. Water is becoming a threat as it pressures societies livability and safety by the effects of sea level rising and increasing stress on river (peak) discharges. Or better phrased, water is becoming a bigger threat.

Delta's are low-lying areas and provide homes to 500 million people in the world, of which 45 million inhabit the EuroDelta (Metrex, 2023). The high threat of water in the EuroDelta stresses the vulnerability of these territories. Consequences of flooding in delta regions are devastating as high-density (metropolitan) populations will be affected and soil subsidence due to human control will increase sinking of the delta landscape (IADC Dredging, 2022). Especially the Netherlands, the common Delta of the three rivers, will suffer from the threat of the water (Meyer, 2016). However, the Netherlands has a rich history of dealing with the threat of water. So how did they cope with this?

The Netherlands is a waterlandscape. That the Dutch had to deal with water is not only symbolized in the polderlandscape, but also emphasized in many paintings and poems. Hendrik Marsman clearly explains this relation with the waterlandscape in his poem 'Memories of Holland' (1941). He talks about the wide rivers of Holland that flow through the infinite lowlands, but how the voice of the water with its everlasting disaster is feared (figure 6).

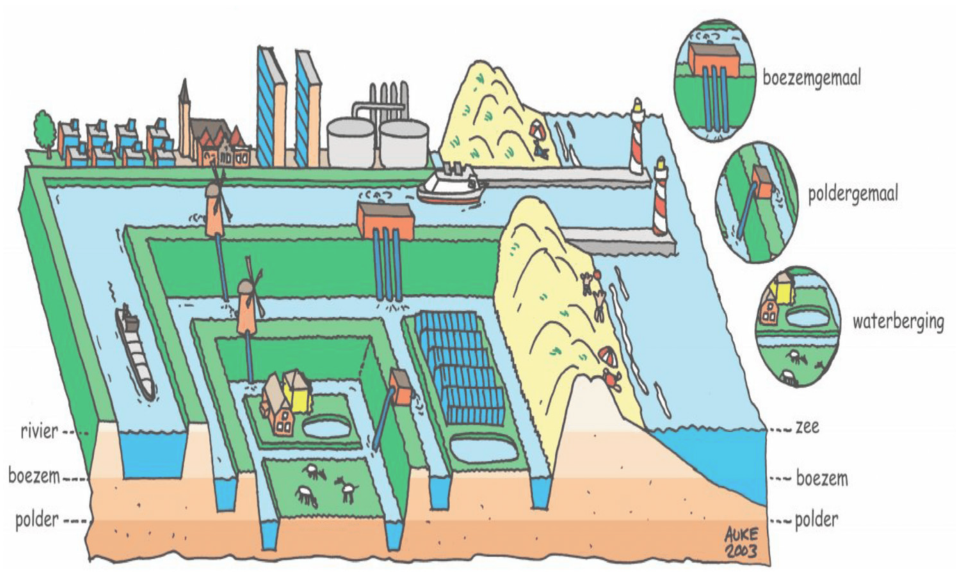


Figure 7: Polder-boezem system (Delft.com, n.d. -b)

As a result, de Dutch began to fight the threat and control the water by creating a large-scale polder system (uwaterloo, 2016). Andries Vierlingh advised to create a soft approach of controlled flooding during the sixteenth century, by regulating floodings through dikes and polders (Van Alphen, 2020). In a nutshell, polders are low-lying areas that exist by the fact that pumping stations pump water from ditches to boezems, and from boezems to large canals that transfer water into the North Sea (figure 7)(Delft.com, n.d.-b). In this way, polder areas do not flood through draining mechanisms and can facilitate other functions such as agricultural activities and housing. But due to these human interventions, soil subsidence occurs and Netherlands' instability increases. As at the same time sea level rises rapidly and pressure on river discharge increases, this growing gap between these two trends (figure 8) enlarges this threat of water.

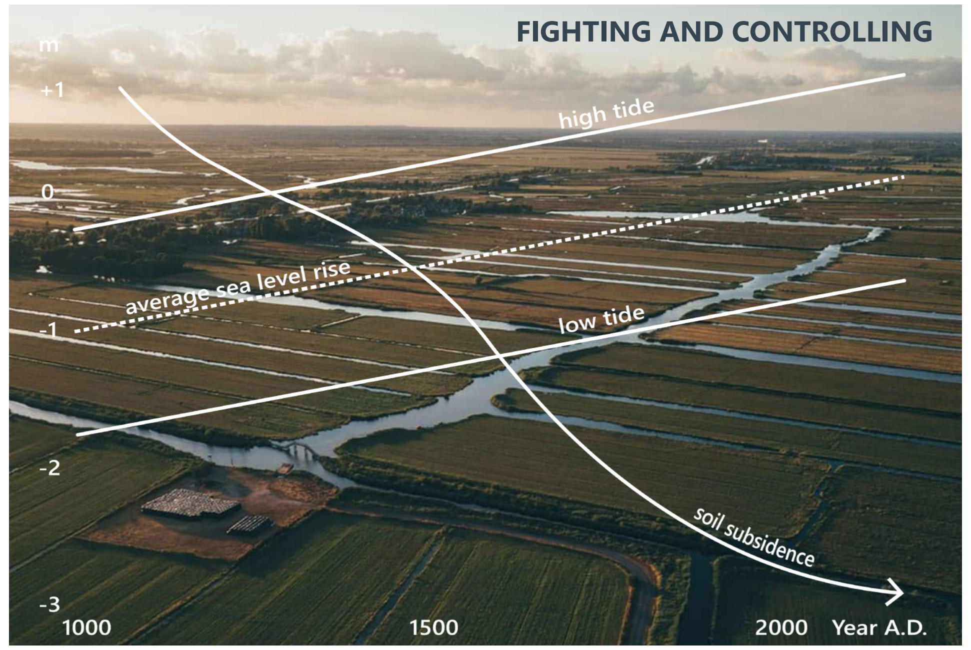


Figure 8: Soil subsidence and sealevel rise (adapted from World Wetlands Day, 2016)

relation of the Dutch with controlling the water. Nevertheless, before the poldering the inhabitants of the Delta region lived with water. To understand this, a brief view back in history will explain the dynamics of the real Delta waterlandscape and the transformation to the contemporary Delta (polder) landscape.

In prehistoric times around 10.000 years ago the Netherlands and Great Britain were connected through an ancient land bridge Doggerland (figure 9). This area existed of a rich, fertile landscape occupied by meadows, marshlands, swamps and wooded areas (National Geographic - Education, n.d.) and hunter-gatherers that inhabited these lands moved and adapted to its dynamics (Rijksmuseum van Oudheden, n.d.). But at the end of the Last Ice Age, 8000 years ago, climate change raised sea levels up 35 meters in two millennia (Freund, 2020). . But Doggerland teaches us again that we are just a small element in a large, complex dynamic system that we cannot control.

After rising sea levels slowed down, Modern Humans lived for centuries in the dynamic North-West European Delta landscape that formed the first outlines of the Netherlands as the common Delta of three major rivers as we know it nowadays (Freund, 2020)(uwaterloo, 2016). Thus, they already live in wetlands for 2000 years.

Figure 9: Doggerland (National Geographic - Education, n.d.)

Historical Approach

From 3850 B.C. the Dutch Delta landscape stopped shrinking as natural sedimentation created an equilibrium between sea level rising and land growth. Due to rising groundwater levels water drainage got resistance and far reaching peatland dominated the western half of the Netherlands (figure X) (Atlasleefomgeving, 2021). As a result, 2000 years ago the Netherlands consisted of mainly fertile wetlands (figure 10) (uwaterloo, 2016).
Although the Dutch lived with the water and adapted to it, water has always been a large threat. Up until Roman times wetlands existed, but they introduced poldering by cultivating peat and building dikes and dams (Ministerie van Onderwijs, Cultuur en Wetenschap, 2020). From then, human activities changed the Delta waterlandscape completely: they disrupted nature's balance and destroyed the self-sustaining mechanism (uwaterloo, 2016). Dr. Jos Verhoeven, an wetland ecologist, quotes in the uwaterloo public lecture in commemoration of the Ramsar Agreement (2016) "the Dutch are actually famous for destroying wetlands" as 97% of the countries wetlands has been teared down (Warner et al., 2018).

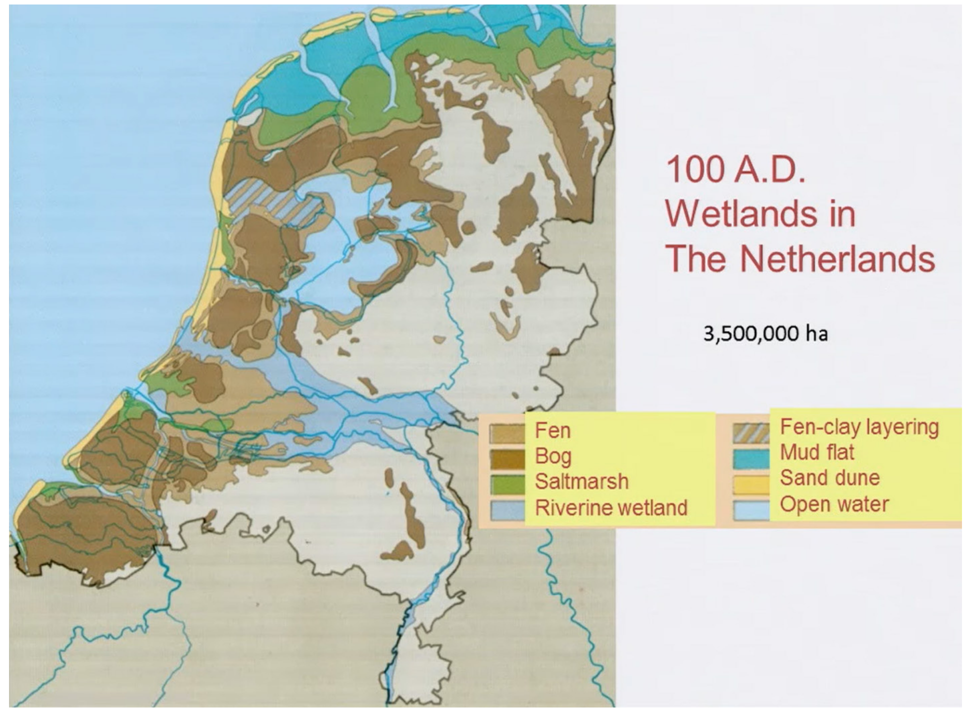


Figure 10: Fertile wetlands in the Netherlands (uwaterloo, 2016)

Carbon sink: wetlands

The North-West European Delta, formed by the Netherlands, consisted before human interventions of wild wetlands for which inhabitants adapted to the Delta dynamics. Figure 10 shows the different types of wetlands that dominated the Dutch landscape. It is important to understand what types of wetland exist, their characteristics, and required conditions to be able to select suitable areas for successful implementation of wetlands.

Types of wetlands
Generally wetlands are defined as borders of areas where water submerges land seasonally or permanently, vegetation has adjusted to the saturated conditions and occurs in all different climates and longitudes. They are separated into two overarching categories: coastal or tidal wetlands in estuaries where salt water meets fresh water, and inland or non-tidal wetlands around rivers, lakes and ponds, low areas where groundwater submerges the ground level. Different types of coastal wetlands are coral reefs, seagrasses, saltmarshes, and mangrove forests (swamps). Inland wetland types are marshes, swamps, bogs, and fens (US EPA, 2023).

Firstly **coastal wetlands**
Coastal wetlands are also known as 'blue carbon' ecosystems, they cover little surface on earth and are threatened by urbanization. When these ecosystems are converted, the carbon in their biomass is emitted back into the atmosphere (Hoegh-Guldberg et al., 2019). There are several types of coastal wetlands.

That coral reefs are categorized as wetlands, if they occur in shallow waters, is an uncommon fact. They mainly occur in warm waters in tropical climates, but also inhabit the deep cold arctic waters (Coral Reefs | WWT, ,n.d.). In the context of this research, coral reef wetlands do not play a part in the wetland ecosystem of North-West European coastal ecosystems and therefore will not be elaborated on.

Seagrasses are also wetland habitats. They occur as underwater grasslands in coastal waters and consist of the nickname 'prairies of the sea'. Exposure to sunlight is crucial for photosynthesis processes for seagrasses to be able to grow in shallow waters at a maximum of 4 meters. There are 50 different species, but two types occur around the North Sea: dwarf eelgrass Zostera noltii and eelgrass Zostera marina (Dolch et al, 2017).

Tidal marshes belong to this category as they appear in sheltered coastline areas and estuaries and are dependent on the oceanic tides (National Ocean Service, 2023). They can be fed by sweet, brackish or salt water sources and are part of an interconnected coastal system (Hudson, Kenworthy, & Best, 2021). Mudflats are sandbanks that accumulate by silt and mud deposits provided by tidal conditions. They transform into tidal marshes as sediment is captured in the intertidal zone twice a day, creating peat as a result (U.S. National Park Service, n.d.). This pioneer zone transforms into the lower/intertidal zone and gradually expands into upper/high marshes (US EPA, 2023). Tidal-marshes have unique flora and fauna that differ in the lower and high zones. The different vegetation zones are mainly covered by different types of grasses, herbs, and low shrubs (Wadden Sea Quality Status Report, (Ecomare, 2019). In the low zone salicorne and cordgrass grows, transitioning in sea meadow grass, and into the high zone, thrift, red fescue, and sea couch (Esselink, van Duin, Bunje, Cremer, Folmer, Frikke, Glahn, de Groot, Hecker, Hellwig, Jensen, Körber, Petersen, & Stock, 2017).

Mangroves are clusters of shrubs and trees in coastal areas and have the nickname 'walking trees'. Coral reefs depend on mangroves as they purify the water from toxic particles (Ocean S., 2018). In-depth information will not be introduced as they only occur in tropical climates, which is out of the scope of this research.

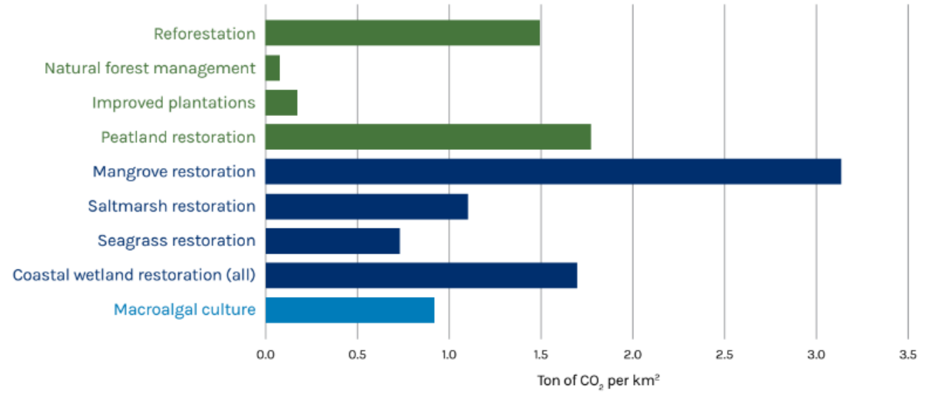


Figure 11: Carbon storage in natural ecosystems (Hoegh-Guldberg et al., 2019).

Carbon sink: wetlands

Then the **inland wetlands**
Non-tidal marshes appear in shallow waters and are mainly fed by the fresh water sources rain, snow or groundwater (Non-Tidal Wetlands | DNREC, n.d.). Mainly during winters these areas are flooded, but are generally continuously saturated. They are treeless and herbaceous vegetation varies from wetland wildflowers, cattails, reeds to bulbushes (US EPA, 2023). Wet meadows are similar to non-tidal marshes, but are naturally longer drained from water (Non-Tidal Wetlands (U.S. National Park Service), 2016).

Swamps are similar to marshes, but vegetated with trees. They are fully saturated or flooded with water and occur in different climates worldwide. Water saturated adapted vegetation inhabits these wetlands and grows beneath the dominating trees up until four meters deep (EPA: Wetlands - Swamps, n.d.).

Peatlands can be divided into bogs and fens. Bogs are acidic (pH 3-3.5) and fens have a high pH (6-9). Bogs are fed by rainfall and therefore low in nutrients. They are dominated by peat mosses and dewars shrubs (uwaterloo, 2016). Fens are fed rainfall, groundwater and surface water, relatively high in nutrients and thus species-rich. Fen peatlands accelerate and expand into bog sponge landscapes that float on the water underneath (Wisconsin Wetlands Association, 2016).

Conditions for wetland restoration and creation
As stated wetlands depend completely on the hydrological cycle (both natural and regulated by man) of the surrounding water catchment area. Suitable conditions are substrates that are saturated and or covered by shallow water temporarily or permanently. Soil types that match this kind of conditions are peat and clay. These types have a high water retention capacity.
Creating suitable conditions for wetland can be done by raising the water table, allowing water to flow back into the area, deregulation of rivers, closure of drainage systems or
by active pumping of water to wetlands and returning mineral quarries to wetlands (Macreadie et al., 2021).

Services
The most crucial service of wetlands is the capacity of carbon uptake with long-term storage and they are the most effective carbon sink on this planet.

Peatlands, mangroves, intertidal marshes, and seagrasses are most efficient (Blue Carbon, n.d.). Coastal wetlands absorb carbon 35 times faster than rainforests and "store more CO_2 than all forests combined" (Robinson, Blue Carbon, n.d.). And inland wetlands sequestrate ten times more carbon than coastal wetlands, especially regarding peatlands (figure 11) (Carbon Sequestration in Wetlands | MN Board of Water, Soil Resources, n.d.). And this is crucial information, as half of the global wetland area is peatlands thus here lay opportunities (Anisha et al, 2020).

Wetlands provide one of earth's most crucial ecosystems. As water flows downstream in wetlands and the water system is interconnected, problems downstream are related to problems upstream. This all comes together in the watershed, an area where all surface waters end up in a common waterbody. But water is managed differently in each elevated part of the watershed, upper, middle and low, and crucial to each functioning (Wisconsin Wetlands Association, 2016).
Inland wetlands upstream are fed by rainwater and snowfall and slow down water with their sponge-like mechanisms and provide the opportunity for water to infiltrate into the ground, preventing erosion and flood peaks in the lower-lying areas. They provide clean drinkwater sources as they naturally purify water by trapping sediments and pollutants (Wisconsin Wetlands Association, 2016). Even though these are small areas, they have large-scale impacts.
Middle areas of the watershed are mainly formed by riverine wetlands that are called floodplains, which give room for the river. Again this decreases erosion and flood peaks.
The water in lower areas gets in contact with the common waterbody, the ocean or a lake. The coastal wetlands are guardians of the coast as they act as a stormbreak barrier, reducing wave energy and preventing shoreline erosion, and protecting the land from oceanic waters (Fennessy & Lei, 2018). They clean water as sediments with pollutants get trapped into the (roots of) the vegetation. Hereby, healthy water habitats occur, increasing biodiversity and providing habitats for (rare) wildlife that depend on these wetlands. The well-being of the (local) society increases as opportunities for recreation and economic and cultural benefits arise (Fennessy & Lei, 2018).
All these services are summarized in Figure 12.

Carbon sink: wetlands

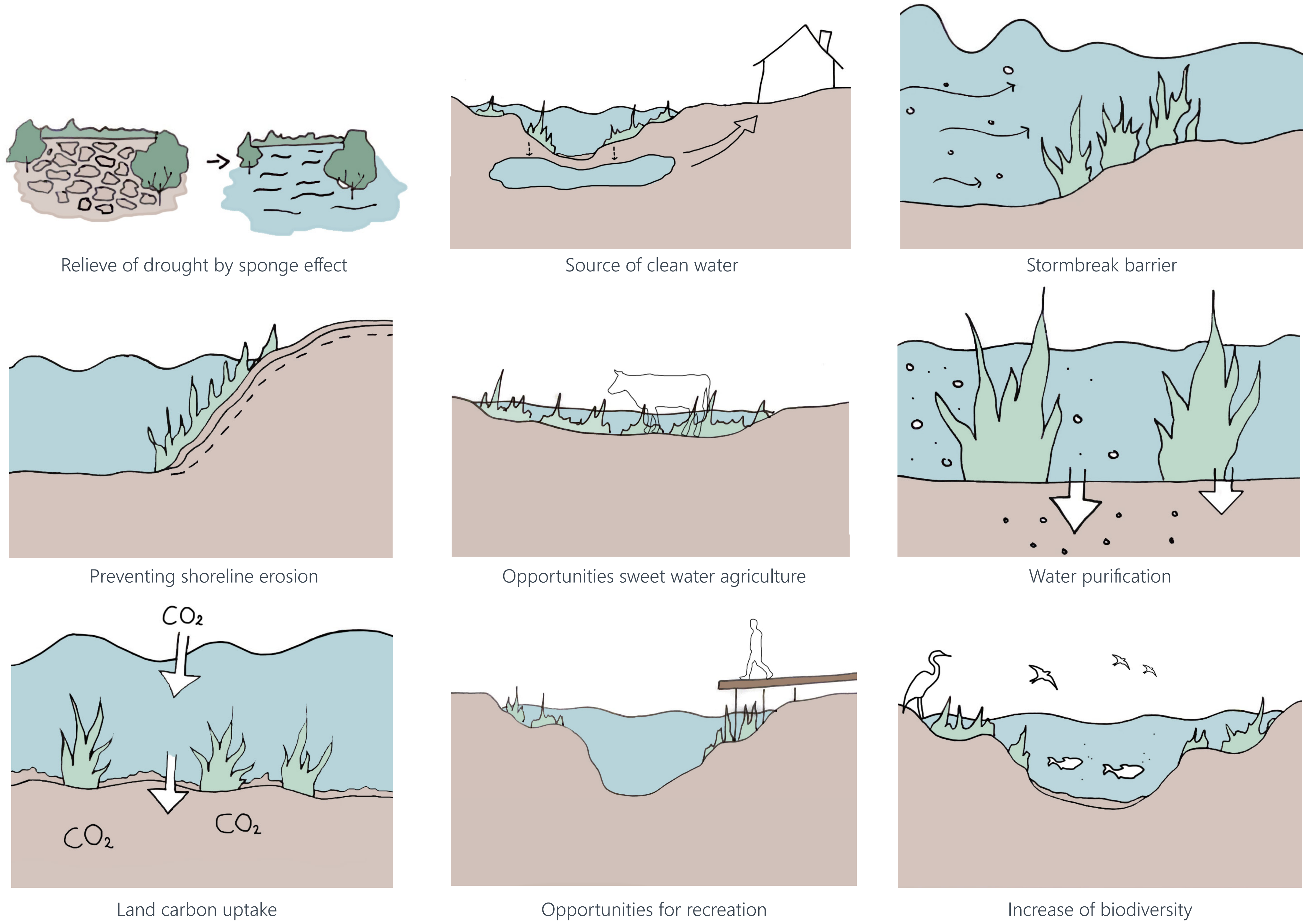


Figure 12: Services of wetlands

Carbon sink: wetlands

Urgency of wetlands restoration

Understanding these complex processes of the watershed system is crucial for restoration of wetlands, which play a great role in this mechanism. There is a great urgency to restore wetlands as most losses were induced by human activities which causes the imbalance of carbon and water cycle (see introduction). Wetland restoration is the most efficient, low cost approach of climate change mitigation as the free, well-functioning services of these carbon sinks naturally make way for restoring the natural balance and societal well-being (Fennessy & Lei, 2018).

Figure 13: current Dutch wetland area (CBS, 2009)

Carbon sink: ocean

Natural storage

The ocean is a massive natural carbon sink, it is estimated that the ocean contains 50 times more CO2 than the atmosphere. This carbon uptake can be divided into 2 processes, a biological and physical pump (Ocean & Climate Platform, 2020).

Firstly, plankton takes up CO2 through photosynthesis. This carbon is, via the food web, taken to the seabed when organisms die and sink. The carbon can be stored for long periods of time. Plankton is responsible for 10% of the carbon storage of the ocean (Ocean & Climate Platform, 2020). The other 90% is dissolving CO2 in cold waters. In polar regions CO2 can easily dissolve because of the low temperature. The natural ocean circulation takes this dissolved CO2 to the deepsea (Ocean & Climate Platform, 2020). These processes are shown in figure X.

The ocean as a natural carbon sink is at risk by increasing levels of CO2 in the atmosphere. The water is getting warmer, and acidification takes place. This affects the physical and biological pump, resulting in less possibilities for the ocean to capture carbon. This will enhance the greenhouse effect, emphasising the need to act now (Hoegh-Guldberg et al., 2019).

As explained in the previous paragraph, coastal ecosystems are important in carbon sequestration as well. Besides mitigation-potential, adaptation to climate change is enhanced as well by coastal ecosystems since vegetated habitats protect the shoreline. Lastly, these ecosystems provide habitat for a wide range of species, reinforcing biodiversity (Hoegh-Guldberg et al., 2019).

Man-made mitigation

Apart from the natural storage of carbon, the ocean also provides opportunities for man-made carbon storage. (Hoegh-Guldberg et al., 2019). Since the ocean has such a major role in the global ecosystem, it is important to carefully research first and preserve marine ecosystems. (Ocean & Climate Platform, 2020).

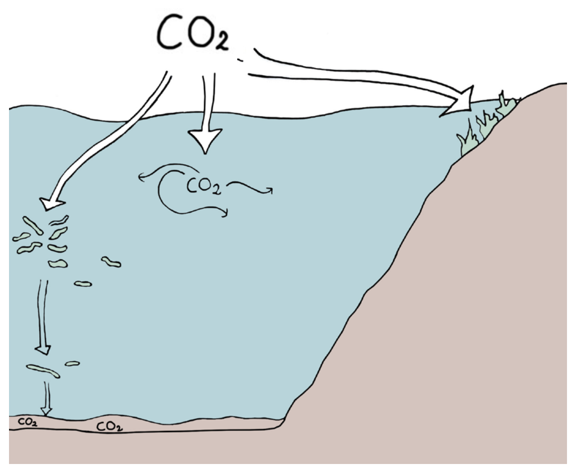
There are 3 types of climate change mitigation interventions to implement in the ocean.

The first intervention is to preserve, restore and expand the coastal ecosystems. As is explained in the previous paragraph, blue carbon ecosystems have high potential for mitigation. Therefore, protection and conservation of existing coastal ecosystems is crucial to stop further emissions due to land-use change. Degraded blue carbon ecosystems will revive their ability to sequester and store carbon. Therefore, rehabilitating the soil and associated organisms is needed (Hoegh-Guldberg et al., 2019). Recognition of the value of these coastal ecosystems for mitigation, biodiversity, and flood protection is needed. The preservation and restoration of blue carbon ecosystems should be included in climate policies and linked with achieving the UN Sustainable Development Goals. Carbon trading credits can be implemented to finance the restoration of these ecosystems (Hoegh-Guldberg et al., 2019).

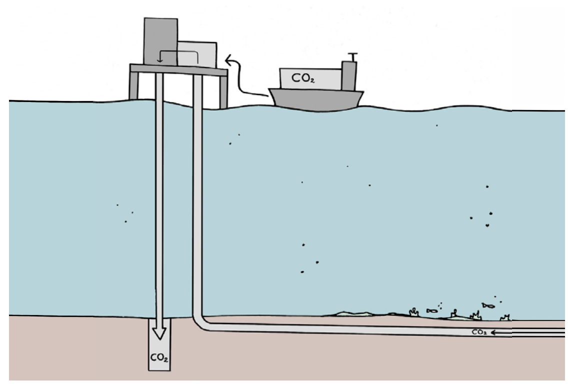
Secondly it is important to focus on enlarging the production of seaweed. Because seaweed farming captures carbon, while producing food, feed, fuel, and materials. This can replace land-based options and might replace products with a higher carbon footprint. Seaweed as animal feed might reduce methane emission as well. Expanding seaweed production provides jobs (innovation and harvesting), contributes to global food security targets, and stimulates local economies (Hoegh-Guldberg et al., 2019). Existing projects, such as North-Sea Farmers, are innovating and can expand in the future. The North-Sea Farmers try to contribute to the sustainable development goals, such as zero hunger and economic growth (North Sea Farmers, n.d.).

Carbon sink: ocean

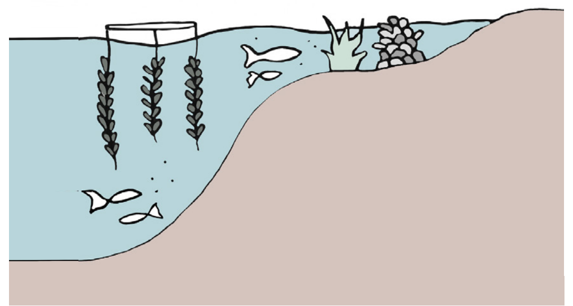
Lastly it is possible to inject carbon into the seabed. This requires carbon to be captured, concentrated, compressed and transported to the injection platform. This process, called Carbon Capture and Storage (CCS), is quite costly. It is estimated that the potential for seabed storage of carbon is 2,5 percent of CO2 emissions globally. It is relatively safe for marine ecosystems, especially compared to other options of carbon seabed storage. For example storage on the seafloor or carbon injected into the deep sea are proposed, which has higher risk for ocean acidification and damaging marine ecosystems (Hoegh-Guldberg et al., 2019). There are already two projects under development that connect emitting industries in the harbour of Rotterdam to empty gas bubbles in the North Sea: Porthosco and Aramis. Porthos is planning to store 2,5 Mt CO2 per year, with 37 Mton CO2 in total. These projects can be used as examples to maybe expand CCS in the North Sea in the future (Porthos, 2022).
Services of the ocean are summarized in Figure 14.



Ocean carbon uptake



Carbon injection into seabed



Opportunities salt water agriculture

Figure 14: Services of the ocean

Conclusion

To conclude, the main findings based on previous conducted analysis will be presented.

Firstly, negative feedback loops can be used for the design of the vision, as enhancing water resilience will result in more plant growth, increasing biodiversity and carbon capturing.

In the past, delta inhabitants lived with the water dynamics, but due to the polder system, the European Delta has become vulnerable. Therefore there is a need for a shift in paradigm to restore its self-sustaining system. Coastal wetlands naturally provide water-resilience against rising sea levels and inland wetlands against peak river discharges. Wetlands naturally absorb large amounts of carbon and store them for long-term. Peatlands are especially effective. It is crucial to restore wetlands in original historical sites, the Dutch Delta is suitable for wetlands restoration. And therefore bottom-up approaches are needed in global visions as wetlands restoration is context-related.

Besides, there is an urgency to restore wetlands due to global losses caused by human activities and thus, there is a need for Nature Based Solutions to benefit from these naturally given services.
Wetland restoration is the most efficient, low cost approach of climate change mitigation as the free, well-functioning services of these carbon sinks naturally make way for restoring the natural balance and societal well-being.

The ocean has a big impact on the global ecosystem, but is threatened by climate change. Therefore its vulnerability should be protected and to be able to use its naturally provided services to capture carbon.

04 Vision

With all the research and knowledge gained from the theoretical research and analysis, concluded in the previous chapter, the vision map is presented. First the planning principles will be defined as a foundation for the vision and secondly the multifunctionality of these principles will be elaborated on. Lastly, the vision will be introduced.

Planning Principles

In chapter 1 goals are defined, based on both the spatial claims in North-West Europe and water-based decarbonization. To achieve these goals planning principles are defined, using theoretical research. Herein services provided by the ocean and wetlands were described which could contribute to answering the spatial claims.
All these principles are visualized in figure 15.

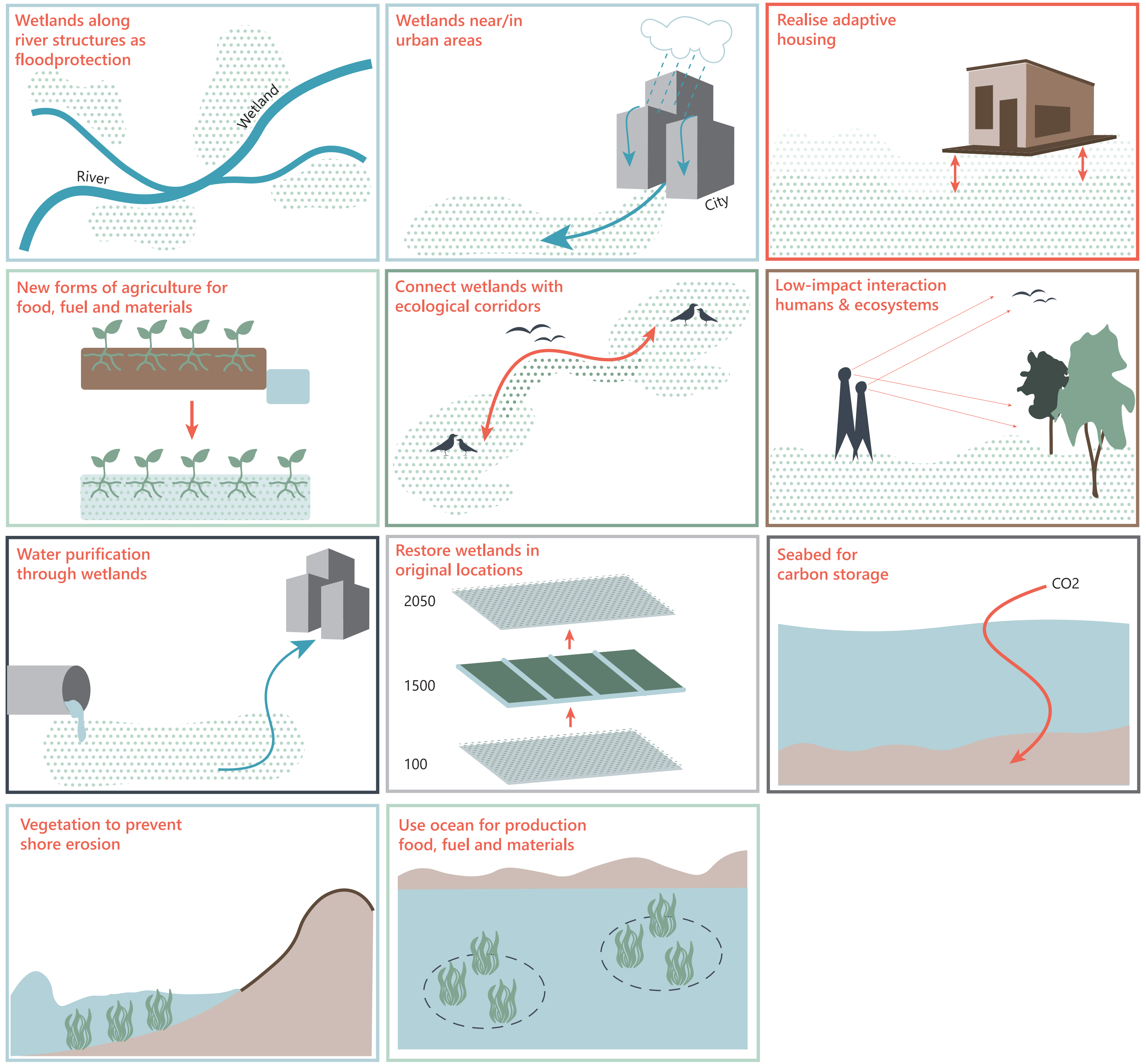


Figure 15: Planning principles for vision

Multifunctionality

Some of the design principles can be combined, to create spatial justice through multifunctionality (Danenberga, 2021). This can for example result in a wetland with low-impact recreation, where flora and fauna is enriched, along a river to provide water protection, figure 16.

Figure 16: recreation, flood protection and biodiversity wetland collage (adapted from Clemente Rodriguez, 2023)

Multifunctionality

Another multifunctional wetland produces food, with some water-resilient houses, while wastewater is purified, figure 17.

- water storage
- capture carbon
- agriculture
- water purification
- housing

Figure 17: agriculture, housing and purification wetland collage

Multifunctionality

In the ocean a seaweed farm is created, near the horizon you can see the carbon injection platform while vegetation along the shore protects and provides habitat for birds and fish, figure 18.
Economic sustainability includes not only multifunctionality, but also local economic prosperity. The proposed design interventions should provide sustainable alternatives for involved stakeholders with new revenue models that contribute to the local economies.

- capture carbon
- flood resilience
- biodiversity
- CCS
- aquaculture

Figure 18: Multifunctional ocean sink collage

Vision Map

The vision map for our project Waterland: water-based decarbonization is presented in figure 19.

The backbone of the vision is the water structure of the EuroDelta. Along the main river structure, flood plains and eco-friendly riverbanks will relieve pressure from peak river discharges. To connect these structures, inland wetlands will be restored. The high-density hatch areas illustrate the areas with highest suitability and probability of success, based on soil conditions.
Coastal wetlands will be restored along the shoreline to connect the ocean with land. This structure will function as a stormbreak barrier to provide water-resilience against rising sea levels, while also absorbing carbon. Seaweed production will be implemented further into the sea. Carbon will also be injected into the seabed in the ocean, in empty gas holes to prolong this carbon uptake structure.
Lastly, through these elements, ecological corridors will arise and strengthen the water-based decarbonization system in the EuroDelta through all scales. The bird icons emphasize existing natural areas in which biodiversity will certainly increase.

The vision illustrates the shift in paradigm in which society lives in balance with the water dynamics of the Delta, capturing carbon to mitigate climate change and sustain livability for all in the real EuroDelta landscape.

Figure 19: vision map, based on GIS analysis

Vision Statement

In the sustainable EuroDelta, the natural river structure is the backbone of our water-based decarbonization strategy, connecting land and ocean. The implementation of this spatial strategy mitigates climate change by restoring the balance in the carbon and water cycle. Providing water-resilience against flood risks and absorbing and storing carbon will ensure this. The conditions of the various landscapes in the EuroDelta provide opportunities to create and restore wet land that serve as a carbon sink and provide resilience against water-related threats, while fostering sustainable land-use.
sustainable agri

As there are multiple spatial claims coming from society the water bodies should provide economic and social sustainability, by multifunctionality uses and revenue models. Water-based decarbonization has potential for sustainable agriculture, increasing biodiversity, flood protection, housing, recreation, water purification, and restoration of the Delta identity. Combining these functions with water bodies stimulates (local) economic prosperity.
Delta regions have always faced challenges when it comes to living with water. In ancient times, local inhabitants lived in balance with the water dynamic, but to maintain this balance the urge arose to control and fight the threat of water. This high governing scale control is unable to adapt to the changing hydrological systems on a local level. And so, society will remain at high risk of water-related disasters. By choosing local implementation of nature-based solutions from a water-based carbonisation strategy, life with water could improve, which is where the priority lies.

Another way to enhance the livability and safety of the people is by integrating ecological corridors. Adding these in both urban and non-urban areas will intertwined the different living environments
To conclude this, the approach of a global vision with local interventions will lead us to a environmentally, socially, and economically just sustainable future, using the watershed to connect through different scales. Large scale systems are the foundation for local strategies that will make use of the given conditions for sustainable land-use, while answering to their spatial claims for just transitions.

An atmospheric impression of this vision is shown in figure 20.

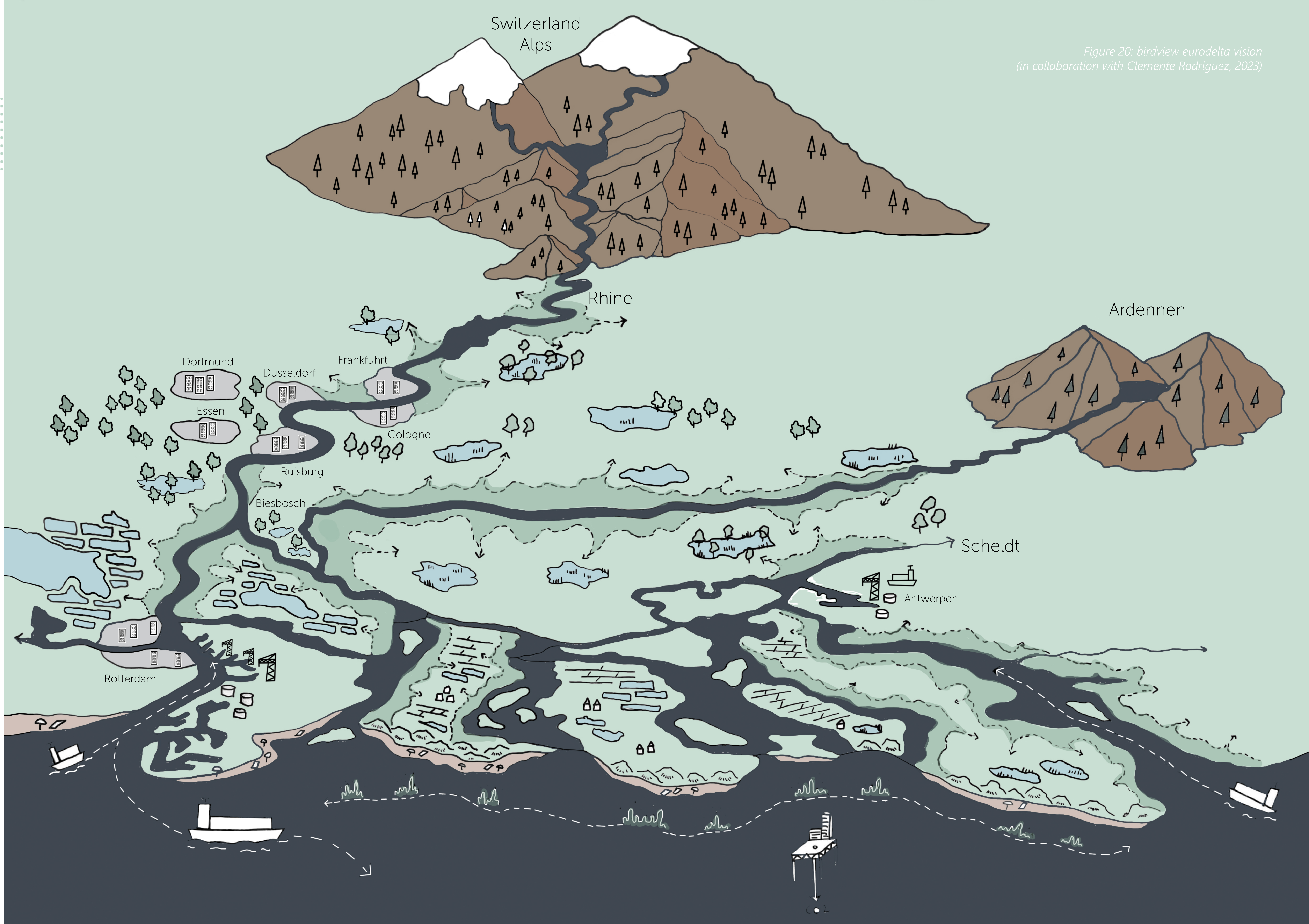


Figure 20: birdview eurodelta vision
(in collaboration with Clemente Rodriguez, 2023)

05 Strategy

As this research is visualized by a global vision, there is a need for local strategies. The scope of this research is the EuroDelta in North-West Europe, as in the problem statement the scope is defined by the highest risk area: the Netherlands. After zooming in on two specific areas and the total strategy of South Holland, principles will be provided that can be implemented on the European and even global scale.

South-Holland

For the strategy, the zoom-ins will be focussing on the estuary in the watershed of the Delta, the province of South Holland, as a strategic point. In map 21 the current situation of South-Holland is shown. This area is a strategic point, for several reasons.

Firstly, this estuary of the Eurodelta is the main connection between land and ocean, which our design principles are focusing on.
Secondly, this province houses the biggest harbour of Europe. This harbour has a massive industrial sector. As shown in the problem statement, this area is high in CO_2 emission.
Thirdly, this is a highly urbanised area (shown in appendix), with a lot of inhabitants, resulting in high pressure on land.
Lastly, the agricultural sector in this province also claims a lot of space, (shown in appendix). As stated in the paragraph spatial claims in chapter 1, there is high urgency for conventional agriculture to shift towards sustainable agriculture.

These characteristics result in the selection of the two zoom-ins: the Krimpenerwaard polder and the harbour of Rotterdam, wherefore a more in-depth strategy has been designed and proposed. The structural elements, as shown in map 21, waterbodies, roads, dikes and nature areas, form the base of the strategy.

Figure 21: Existing situation South-Holland based on GIS data

Stakeholder analysis

The stakeholders in South-Holland can be divided into four categories, across different scales (figure 22). Firstly the public sector, with governmental institutions, such as the municipalities or executing institutions as Rijkswaterstaat. The environmental sector does not have a 'real' voice, since these are animals, the planet and future generations, these are represented by environmental non-governmental organisations.They belong to civil society, just like inhabitants.
Lastly the private sector contains the industrial and agricultural companies, but also the building sector. Some of these parties are in conflict with each other, shown by the red lines in figure 23. This is mainly the industrial and agricultural companies with the government and environmental NGO's, which in this case are the voice of the (future of the) environment.

When looking at conflicting stakeholders, it is good to know the power and interest of all parties in our vision. Figure 24 shows the stakeholders in a power/interest matrix, where 6 clusters can be defined. Firstly the public sector forms a cluster with high interest, but the degree of power is diverse. Secondly civil society has medium power and medium interest. The environmental sector has high interest but no power. Lastly there are 3 clusters of the private sector. The investors and project developers have high power, as they will make the vision happen by respectively money and actions. But they do not have interest in the goals themselves. The sewage, transport and industrial companies are low in interest and power. The fishing industry, the greenport-network and urban planners do have interest in the vision, but lack power.

The farmers are separate, since they have high power as landowners and interest in the vision, although probably not being supportive. For the strategy it is important to get the industrial and agricultural sector to engage.

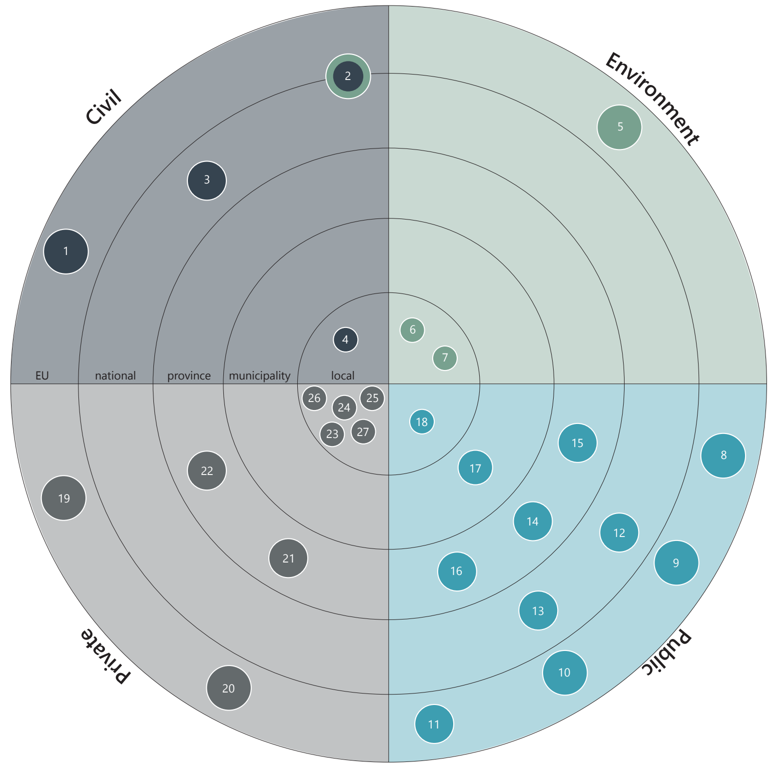


Figure 22: Stakeholders and their scale of operation

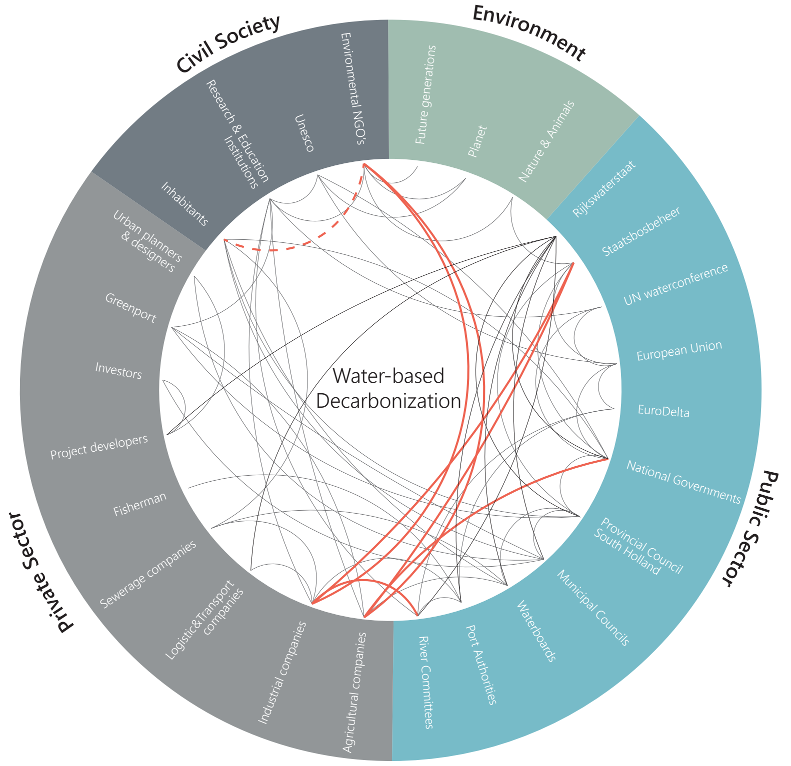


Figure 23: Stakeholders and their interrelation

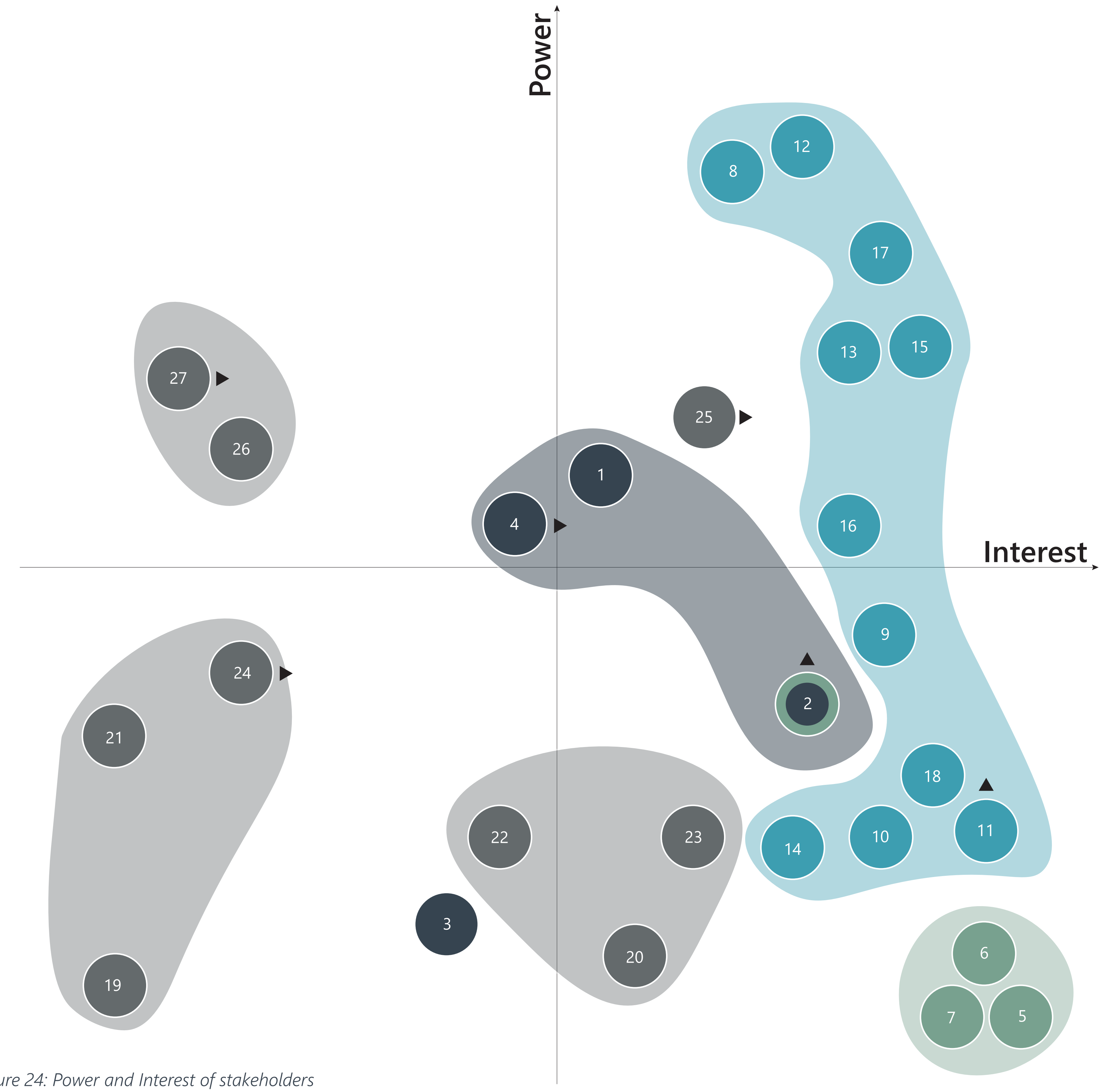


Figure 24: Power and Interest of stakeholders

Stakeholders

In this area the main stakeholders are cattle-farmers and villagers. In figure 25 the relations between all relevant stakeholders are shown. The red relations are conflicting stakeholders. You can see the disagreement between the agricultural sector and the environmental NGO's, who are supported by public institutions.
Farmers want lower groundwater levels, while nature conservationists want a higher groundwater level. For the strategy, we want alternatives softening the border between nature and agriculture and the interests of both stakeholders are heard. This alternative form of agriculture is therefore a link between the interests of nature conservationists and those of farmers.

To get farmers to cooperate in this project, effort is needed, the conflicts should be overcome. Current form of agriculture becomes less profitable because of reduced EU subsidies and increased restrictions, as well as increasing costs caused by climate change. It's important to provide an alternative future for farmers (Goosen & Vellinga, 2004). The green relationships should grow to accomplish this project.
Inhabitants want to keep living in their homes, without losing quality in their living environment.

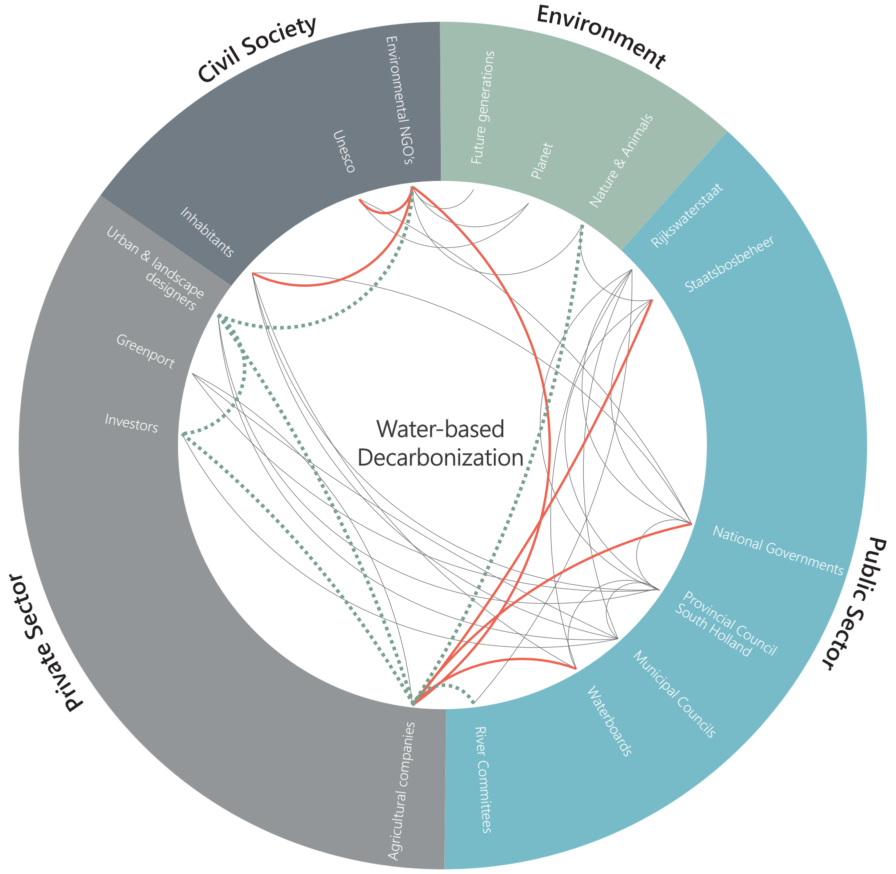


Figure 25: Stakeholders and their interrelation in the Krimpenerwaard

Krimpenerwaard Polder

SWOT

The strengths and weaknesses of this area are shown in table 26, together with external opportunities and weaknesses. This non-urban area has some great strengths in terms of agriculture and heritage, in addition to the great community feeling. Climate change is the biggest threat, but housing-shortage is a problem as well. The Dutch are aware of floodrisk, but the urgency in terms of climate change and biodiversity loss is less known (Goosen & Vellinga, 2004). Farmers see great ecological value in their land as well as the aesthetic value of openness. This makes it harder to get them to cooperate in nature development (Goosen & Vellinga, 2004).

Strengths	Opportunities
Good livestock industry Openness of landscape Strong feeling of community - among farmers - among villagers Soil has a high water capacity Dutch awareness of floodrisk	Innovation & Technology for farming Climate protests raise awarenesst Recreational activities Wetlands as sustainable alternative to polderscape Grazers have potential to inhabit wetlands and be farmed
Weaknesses	**Threats**
Heritage cultural landscape (Kinderdijk & Groene hart) Farmers feel blamed by government, resulting in lack of trust The urgency of climate change & loss of biodiversity is not clear among inhabitants Subsiding land, beneath sea-level Lack of connection between urban and non-urban (nature & spatial quality)	Climate change due to emissions: • River flooding • Drought • Water quality Other spatial claims, as Housing shortage

Figure 26: SWOT-matrix

The SWOT can be used to come up with strategies, maximizing potential of strengths and opportunities, while minimizing the weaknesses and threats. Table 27, shows possible strategies for this agricultural polder.

To overcome the conflict between farmers and the government, focus should be on communication and participation. This helps to (re)build trust and stimulates cooperative actions between the two parties (Goosen & Vellinga, 2004). Awareness about climate change among all inhabitants in the area is important for engagement.

SO	ST
Innovation for sustainable Livestock industry Engage inhabitants with awareness of climate change and focus on community Keep the open landscape as quality to stimulate recreation Create wetlands (based on soil capacity) where grazers can be farmed	Soil gives characteristics to create wetlands: to provide water-resilience and mitigate against climate change by capturing carbon Raising awareness of the value of openness in landscape, so other spatial claims wont consume it Wetlands can answer to other spatial claims, for example water purification or housing on water
WO	**WT**
Conservation of heritage-areas for tourism & recreation Cooperation between farmers & government is needed, to innovate agriculture and provide a desirable future Implement wetlands to stop subsidence Create transitional green/blue corridors to soften the edges between urban & non-urban	Enhance cultural heritage by looking at historical ways to live with water, in terms of housing and agriculture Give solutions to climate change threats by bringing back the ancient landscape structure Raise awareness about how climate change affects the way of (a) living. Cooperation among stakeholders to provide social justice

Figure 27: SWOT-TOWS strategies

This zoom-in shows a polder with subsiding land, which emits CO2 and is threatened by water. This area will be transformed into a wetland which captures carbon, provides water resilience, while housing sustainable agriculture. The strategies suggested in this part are based on the SWOT-analysis, and previous experiences from depoldering-projects. Strategies that proved to be effective in the transformation of the polderscape to a wet-landscape are adapted to this area.

Agriculture (sweet)
Currently most farmers in this area have cattle on pasture land, for milk and meat production. To stop CO2 emission from the pastureland, and prevent more subsidence, and avoid crop damage due to freshwater scarcity, the land should be rewetted by heightening the water table (Tanneberger et al, 2021). This means a transition to sustainable agriculture; this will provide an alternative future for farmers. This heightening of the water table will be done in three phases, this makes the transition less rigorous.

The first phase will raise the groundwater level to approximately 10 centimeters below the surface. Current pastureland shifts to herb-rich grassland. This will reduce CO2 emission, while biodiversity increases, birds and insects can benefit from the diverse vegetation. Cattle-farming is still possible, but in a more nature-inclusive manner (Altenburg & Wymenga ecologisch onderzoek et al, 2022). Farmers are likely to engage in this transition to sustainable cattle-farming as it is close to what they are doing now.
There should be less livestock per area and maybe the type of cow must change, with more wetland-sufficient characteristics. It is important that cows are monitored, so cows will not get stuck when the water is too high. To ensure safety, some physical crossings could be implemented (Bourne et al, 2017). To realize this, landowners should get compensation for delivering ecosystem services, as an additional source of income (Altenburg & Wymenga ecologisch onderzoek et al, 2022). Because of a trend in reduced dairy and meat consumption, cattle-farming will become less necessary & profitable.

Resulting in the second phase, being wet cultivation. This means that the water-table will be raised 10 to 40 cm above current ground level. This will stop emission of CO2 and soil subsidence, biodiversity increases because the wetland provides habitat for other flora and fauna (Altenburg & Wymenga ecologisch onderzoek et al, 2022).

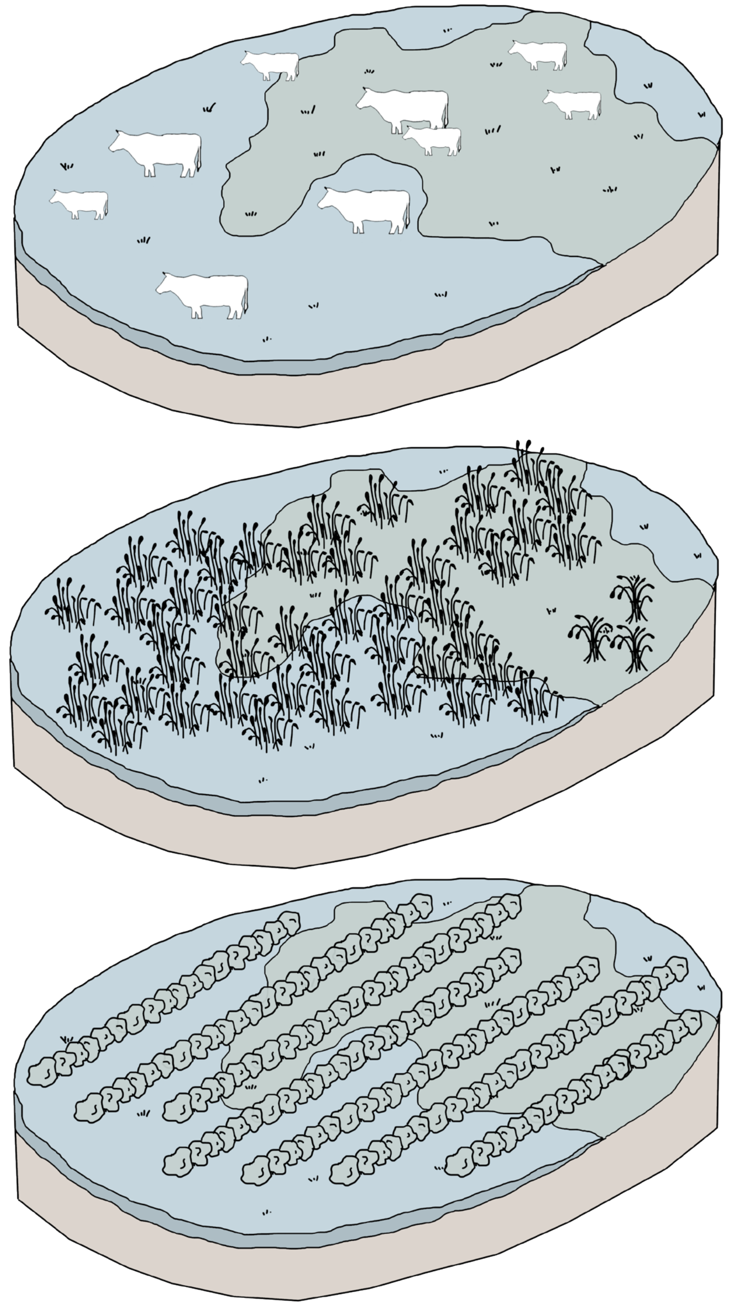


Figure 28: 3 design principles of wetland agriculture

Wet cultivation, also known as paludiculture, has the potential to produce biobased (fibrous) material. This can be used as biofuel, feed or in the construction industry, as insulation boards (Tanneberger et al, 2021). This will provide a source of income for current farmers (Altenburg & Wymenga ecologisch onderzoek et al, 2022). Producing biobased building materials is useful in building sustainable housing, reacting to the current housing shortage. Biofuel will be useful in the coming years, shifting away from fossil fuels, but will become less necessary when only renewable energy is implemented.

Lastly the peat bogs will be restored, to capture CO2 and again increase biodiversity. The groundwater level will stay around 10 till 40 cm above current groundlevel. But interventions should be done with the soil and vegetation, this requires thorough preliminary research on each location.
There are options for food production on peatland, for the climate of North-West Europe these are under development (Tanneberger et al, 2021). Thus, we will start in 2030 with two pilot-projects for innovative wet food-crops with local farmers. In 2060 these innovative crops will be widely implemented.

The physical transition is shown as a detail-section, where you can see the rising of groundwater levels, while vegetation changes (figure 29).

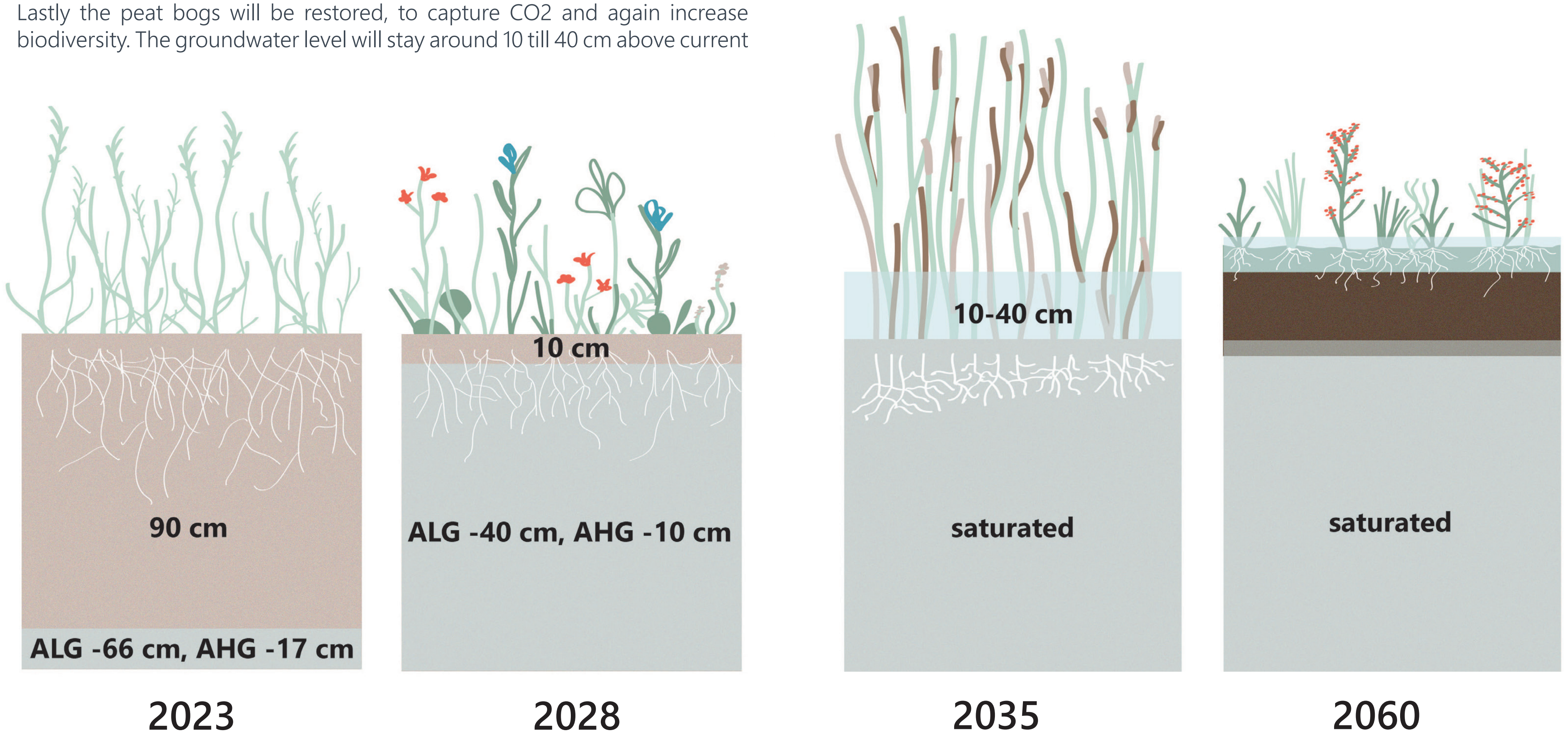


Figure 29: detail-section of transition agriculture by raising groundwater level

Krimpenerwaard Polder

The transition will be done gradually, spatially the phases can exist simultaneously. The main form of agriculture will shift over the years. Right now (2023) around 90% of this area is pastureland and 10% is covered by crops. In 2026, 80% will be 'new pasture' with the heightened water-table. The current cropland also raises the water-table and therefore shifts towards semi-wet crops. 10% of this polder will produce biobased materials as this is a deeper area and therefore will easily acquire the 10 to 40 cm water above soil. In 2060 around 50% of this area will be food producing peat bogs, 30% will stay wet cultivation and 20% will stay cattle farming.

In the figure (30) you can see an atmospheric impression of this transition.

Figure 30: impression of agricultural transition

Krimpenerwaard Polder

The Common Agricultural Policy of the EU gives subsidies to farmers. This policy will inform the European Green Deal, the new regulations provide opportunities for sustainable agriculture on rewetted peatland. This existing policy framework could be helpful to stimulate farmers in the transition. Farmers are provided an alternative future, without compromising on their income (Tanneberger et al, 2021).

The transition to agriculture in time is shown in figure 31.

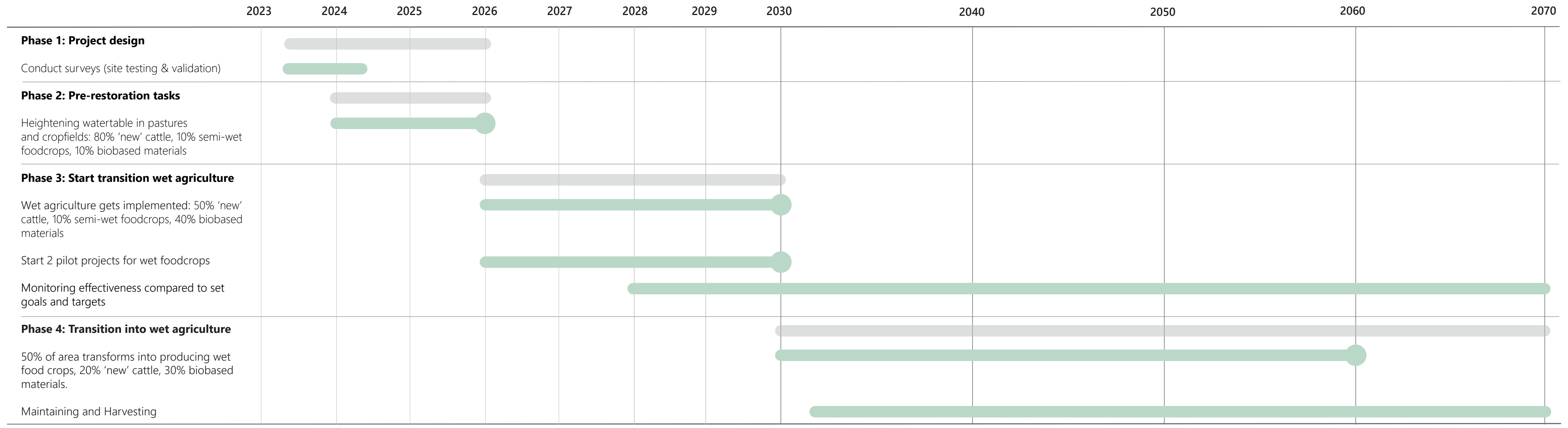


Figure 31: timeline agriculture strategy

Krimpenerwaard Polder

Flood protection
Flood protection is important, the threat of water is increasing, as stated in the problem statement. Therefore, preliminary research should be done by hydrological experts of Rijkswaterstaat. Based on that research location and design of the protection measures can be decided.

The heightening of the water table will result in 10 till 40 cm water above the current groundlevel. This does not need massive protection measures, but infrastructure should remain safe & reliable. Existing roads and dikes will be strengthened where necessary. This strengthening of infrastructure is also needed to provide evacuation routes in the future, this will be explained later (Van Alphen, 2020).

As Room for the River is the main strategy for flood protection, this will be a base for protection interventions. This means working with natural dynamics and using its benefits, such as sedimentation. Instead of heightening dikes, living with floods will be the strategy, rebalancing nature and society (Warner et al, 2018).For the relatively short-term this may result in dike replacement inland.

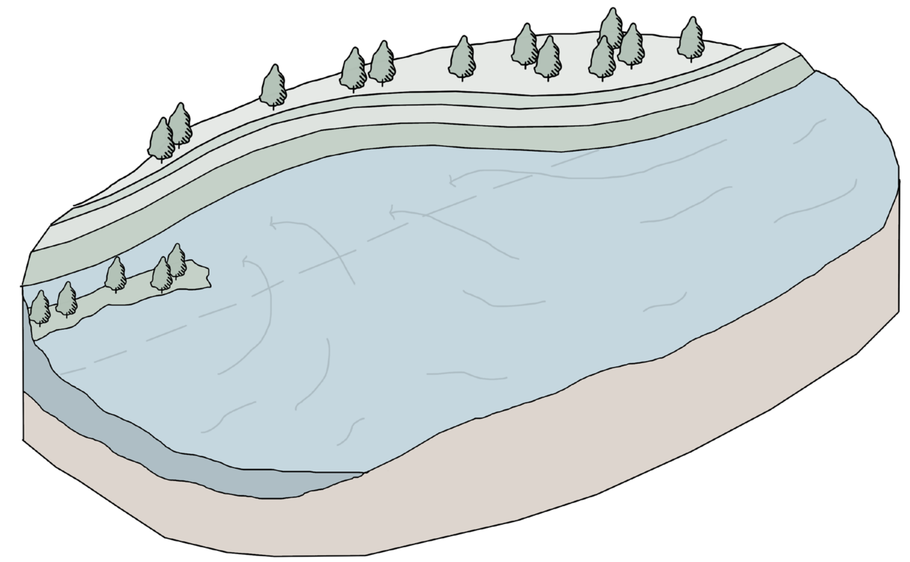


Figure 32: design principle dike replacement inland

Krimpenerwaard Polder

This will result in wetlands along the river, also known as uiterwaarden. During peak discharge these areas will be taken up by the waterflow (figure 32). This could be a new economic revenue model for landowners in the future.

The construction of the eco-friendly river banks made from natural materials allow for improvement of flood protection and creates a new habit for flora and fauna by using structural elements as dead wood along the banks. This results in an increase in population and diversity of plant and fish species. These banks do not interrupt the contact with the surrounding areas both hydrologically and ecologically (´Eco-berms` Replace Concrete to Boost Riverbank Biodiversity Near German Hydropower Stations, 2021).

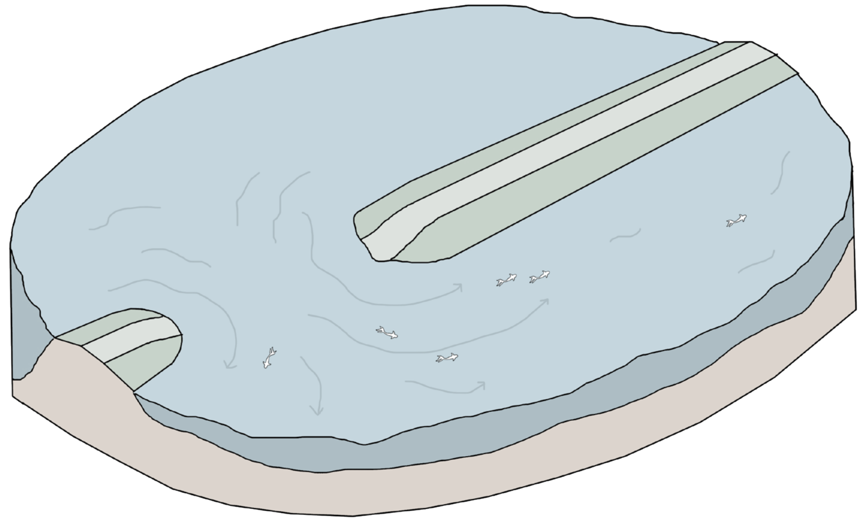


Figure 33: design principle lowering dike

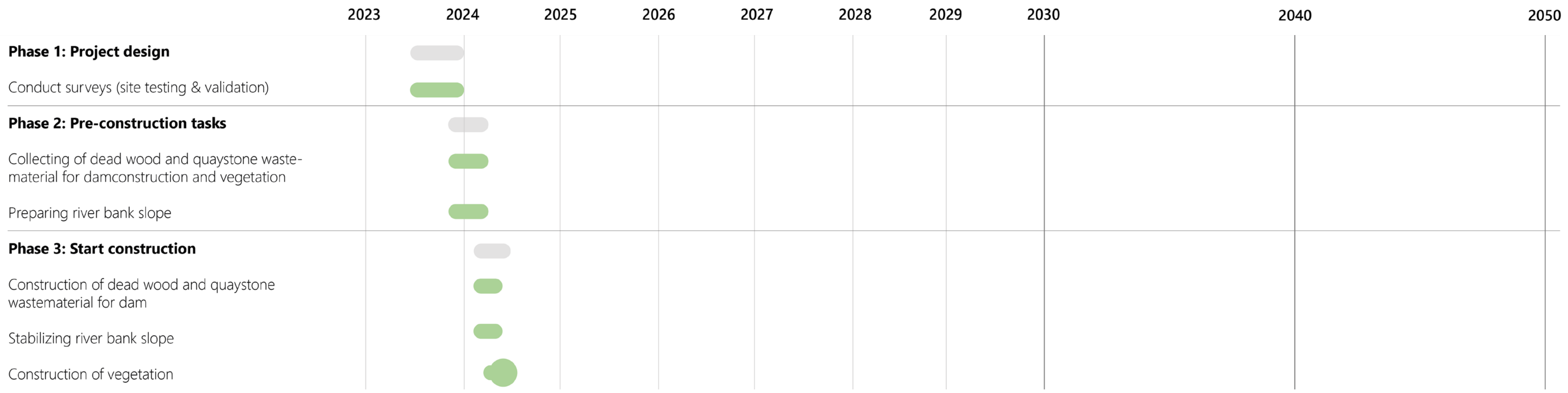


Figure 34: timeline ecological river bank strategy

Krimpenerwaard Polder

In the long term, more of the current polder should be able to flood during peak discharge, mostly in winter. Paludiculture and peatbogs provide good opportunity for water storage (Altenburg & Wymenga ecologisch onderzoek et al, 2022). Bringing in the river water results in the need for dike rings around villages and probably some farms and houses should be replaced on mounds. This will enhance local livelihoods, quality of landscape and perceived safety (Warner et al, 2018). At some places the river dike should be lowered to let the water in (Van Staveren et al, 2014) (figure 33).
For this flooding scenario the previously mentioned evacuation routes are necessary.
To prevent villages being surrounded by a high dike that blocks the view, there is another possibility. Namely, creating a (willow) forest on a gentle slope is a possibility to make dike re-enforcement less necessary (Van Staveren et al, 2014).
The use of land to store water and thus guarantee water safety and availability can be a new economic revenue in the future.

The flood protection interventions are shown in a timeline in figure 36.

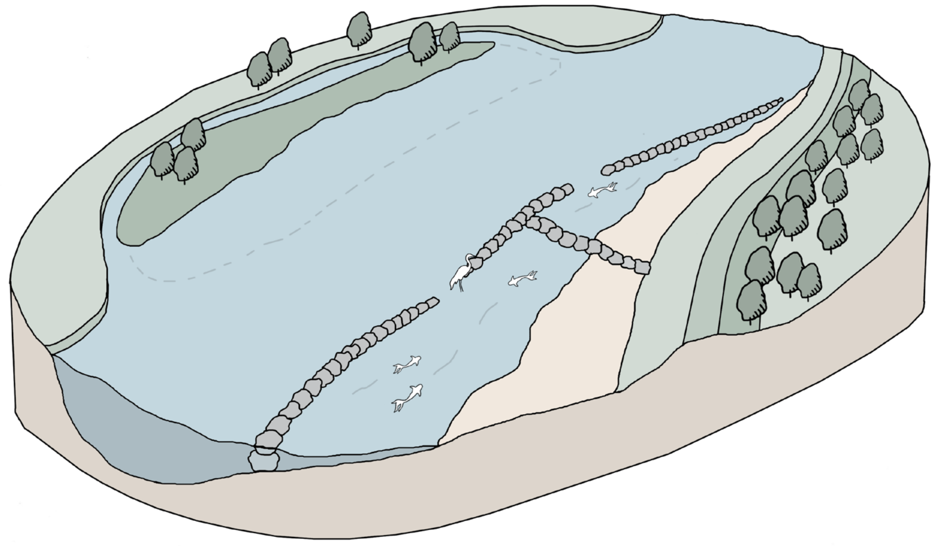


Figure 35: design principle river flood plain

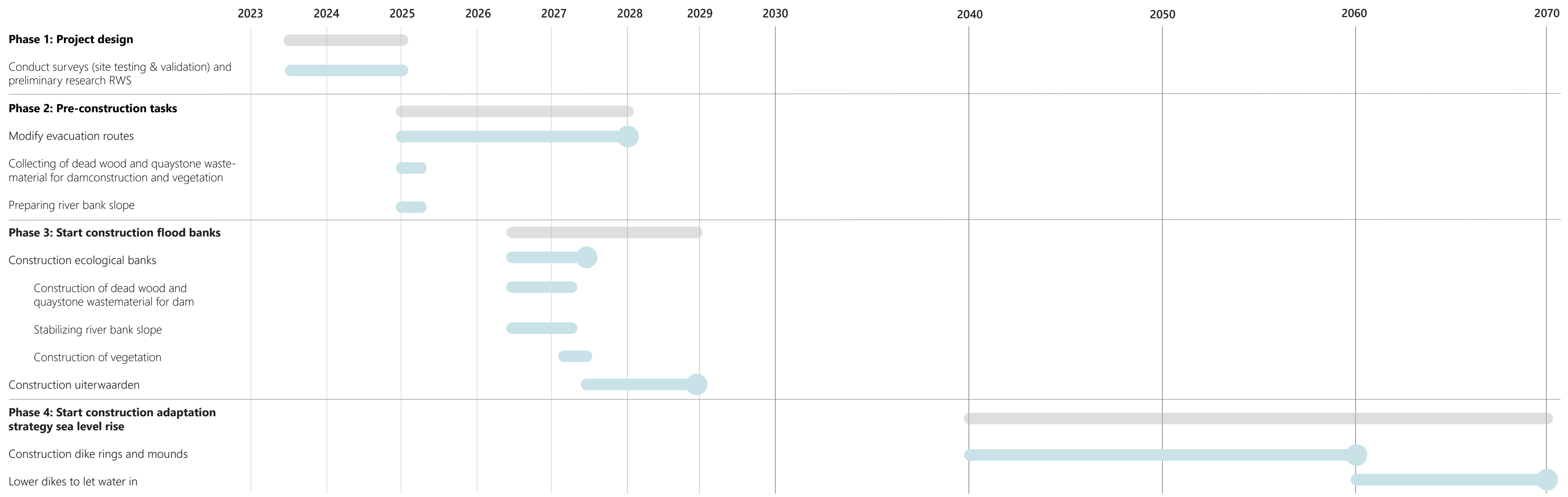


Figure 36: timeline flood protection strategy

Housing

To answer the housing shortage, possibilities for additional housing in this area have been researched. New housing should be future-proof, in the sense that it is resilient to water extremes. A preliminary research should point out which housing possibilities there are and in what quantity they should be built on which locations.
There are several flooding-resilient options to implement.
Existing villages have to grow, without putting too much pressure on land. This has the potential to soften the borders between the urban and non-urban too.
For example, floating housing can be developed, as an innovative solution in a wetland.
Elevated housing also has great potential, because this is a historical solution. In Marken, a former island in the Zuiderzee, there are still some houses on wooden poles, this gave room to fluctuating water levels.
These design options are shown in figure 37.

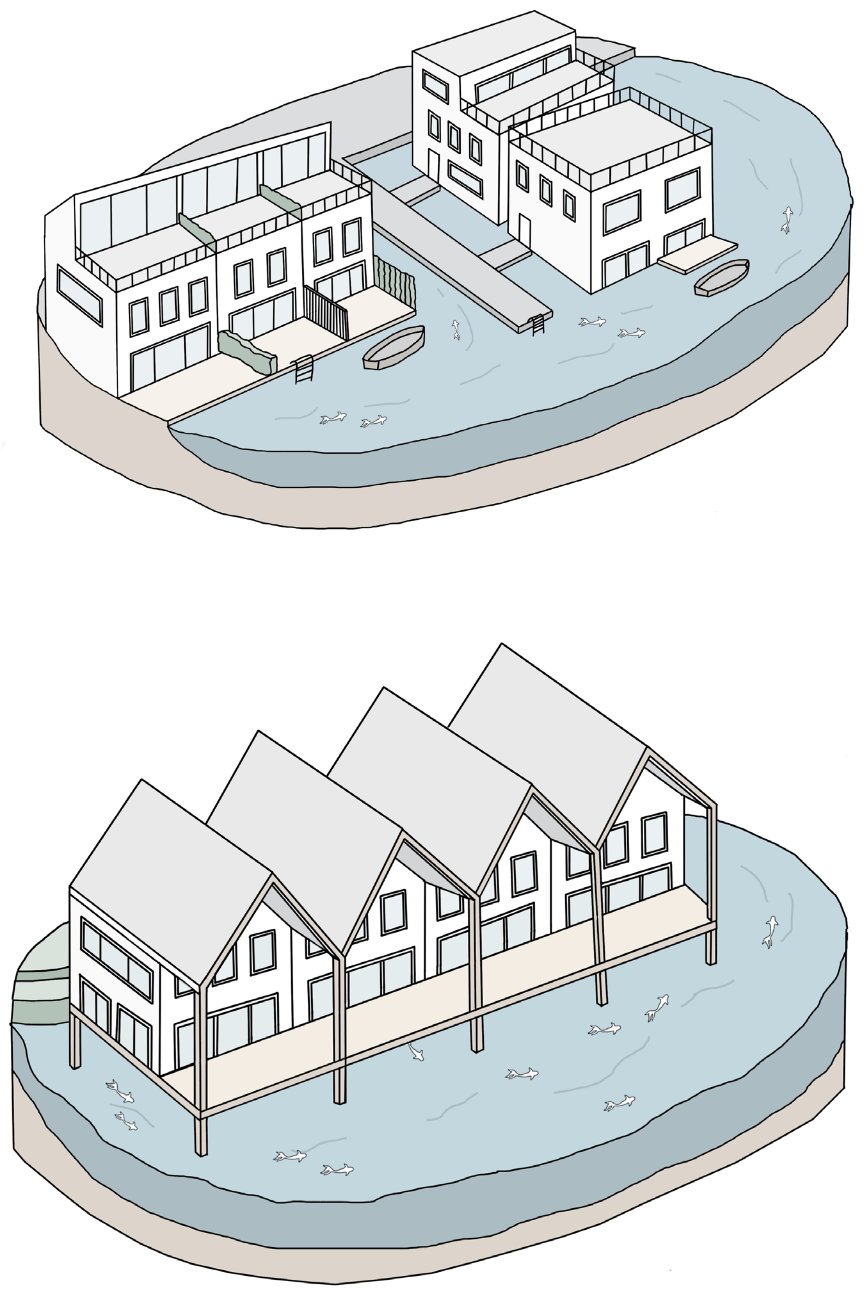


Figure 37: 2 design principles water resilient housing

Krimpenerwaard Polder

As stated before, in the future villages will be surrounded by dikerings and some farms and houses will be relocated on mounds. Living on mounds is cultural heritage, as this strategy was implemented long before in flood-prone areas (Van Alphen, 2020) (figure 38).
Although relocating farmers and inhabitants within the area probably will be possible, probably not all locals can or want to stay. This results in financial compensation being the only possibility (Goosen & Vellinga, 2004).

The development of housing in the coming decades is shown in figure 39.

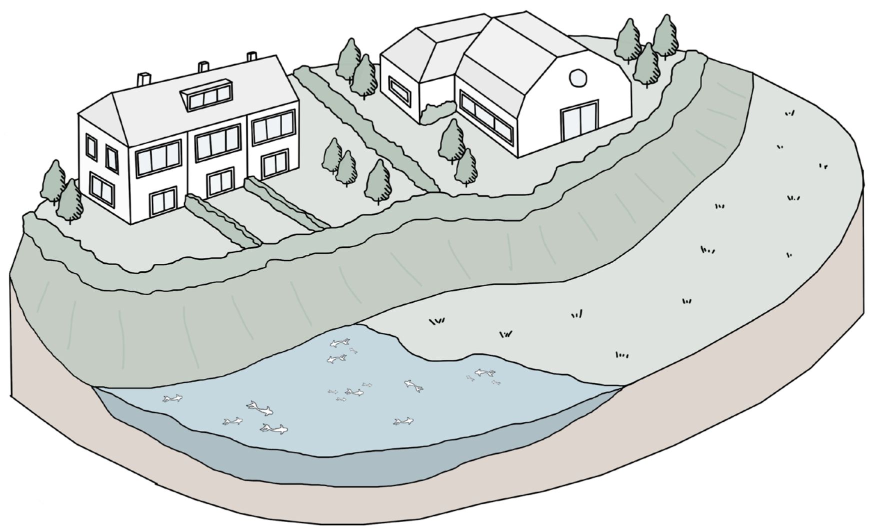


Figure 38: design principle living on mounds

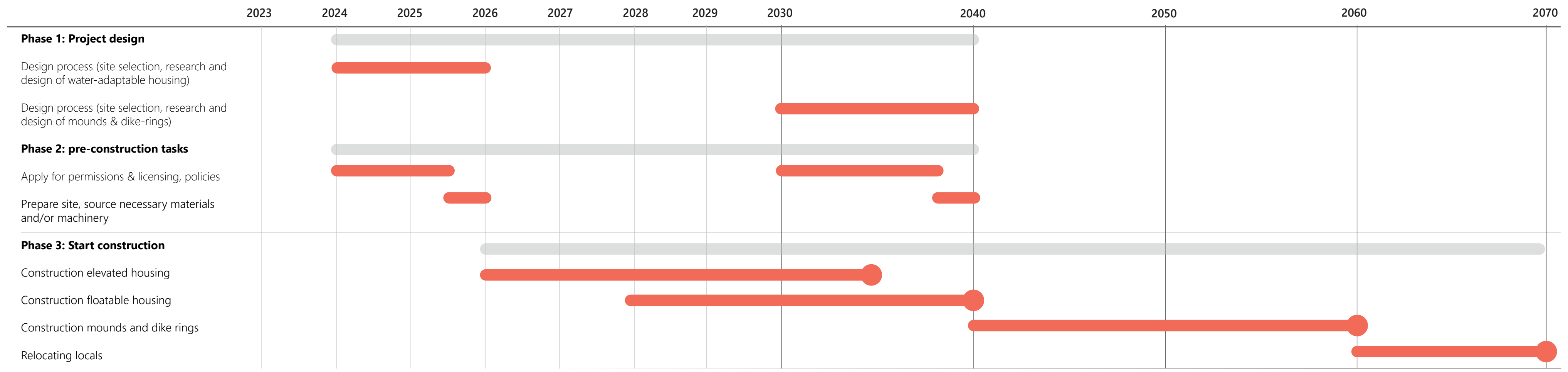


Figure 39: timeline housing strategy

Krimpenerwaard Polder

Water purification
Due to climate change, longer periods of drought occur which threatens the water availability for society. As wetlands have the capacity to absorb and store water, this could be a strategy to prevent periods of drought as wetlands function just like sponges. They absorb water and release flows of water as surrounding soil gets less saturated. At the same time, as explained in the services of wetlands, wetlands naturally purify water.
Wetlands filter toxic particles and pollutants by trapping sediment in (the roots of) vegetation, by which water will be cleaned.

Furtermore, wetland can be used for simple and effective wastewater treatment of domestic, agriculture and industrial. The construction costs of these so-called constructed wetlands, operating costs and energy costs are much lower than conventional treatment systems. Besides that they look pleasant in an open landscape, provide a new flora and fauna and educational opportunities (National Small Flows Clearinghouse, n.d.).
Wastewater first flows through a pretreatment filter for separate gross solids and plastics. Then the water flows through a septic (primary) tank where suspended solids are settled by gravity. After that the wetland removes the remaining pollution and the water is collected by drainage pipes, the effluent is suitable for water reuse or discharge into the environment. The process does not generate waste and it is very adaptable to the rural landscape with peat bogs (Altenburg & Wymenga ecologisch onderzoek et al, 2022). The phases of the development of this water purification strategy is illustrated in figure 40. Most importantly it shows that the realisation has two steps, firstly the level of purification can not be used for drinkwater, but by 2060 this will be the case. This can be a new economic revenue for landowners.

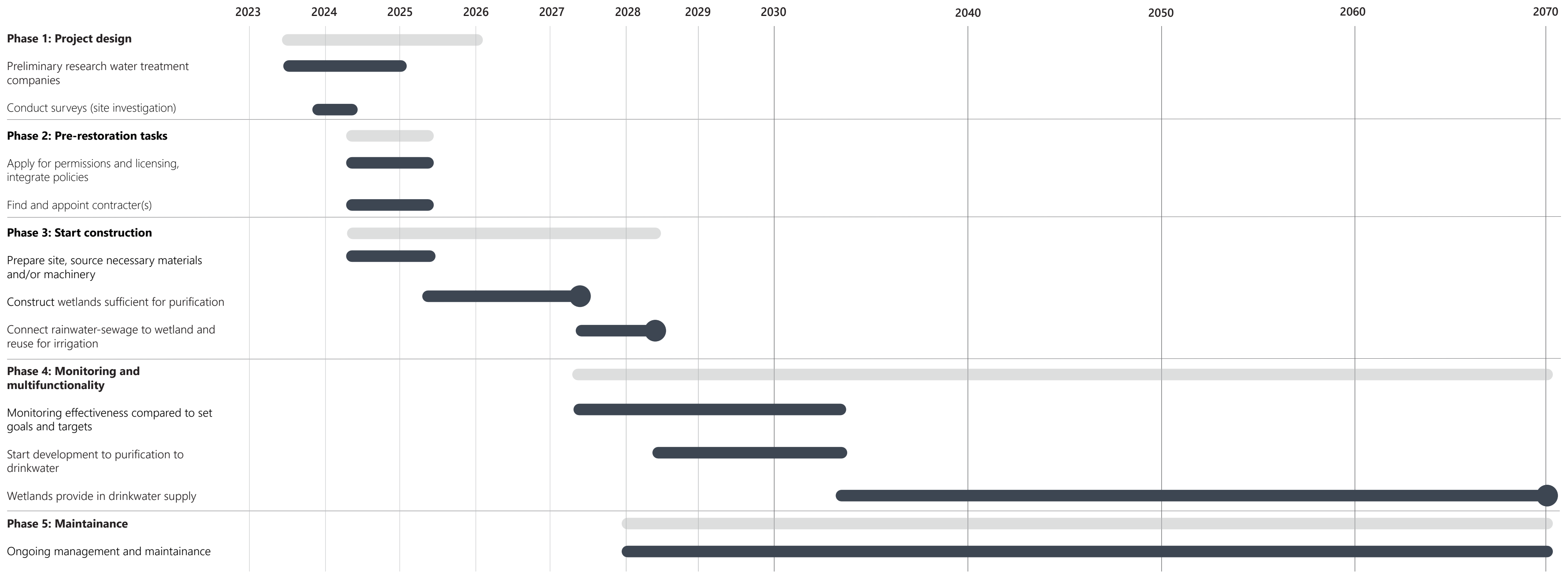


Figure 40: timeline water purification strategy

Krimpenerwaard Polder

Heritage
The Krimpenerwaard contains the cultural heritage of Kinderdijk. This polder with windmills is Unesco World heritage, hence conservation being important. Although this strategy will be slightly de-poldered by heightening the water table, that does not necessarily mean the whole area will flood. The windmills will keep working, but may pump less water out. The still existing cattle-farming in 2060 will be located around Kinderdijk, preserving the 'Dutch polder heritage'. Existing tourism in Kinderdijk can expand in this area, as the wetlands provide opportunities for tourists.

But this strategy answers heritage in the sense that living with the water is reintroduced, based on history. Long ago this area was a peat bog as well and that genius loci will be restored. The quality of openness of landscape will be maintained. Therefore, a 'new' public good will be created for society, as they can identify with this cultural heritage.

Krimpenerwaard Polder

Economic Sustainability
This whole strategy will provide benefits for the planet in terms of climate change mitigation, adaptation and biodiversity. It will provide benefits for the people in terms of basic needs such as water, housing, safety, right to nature and a future. Lastly, it will create jobs, enhance and help to scale up emerging markets and create new economic revenues for landowners with a lot of land, like farmers, that are more sustainable for the long-term than the existing form. For example the biobased material market will grow, but also the water-sport industry can enlarge. The benefits for people, planet and profit are shown in figure 41.

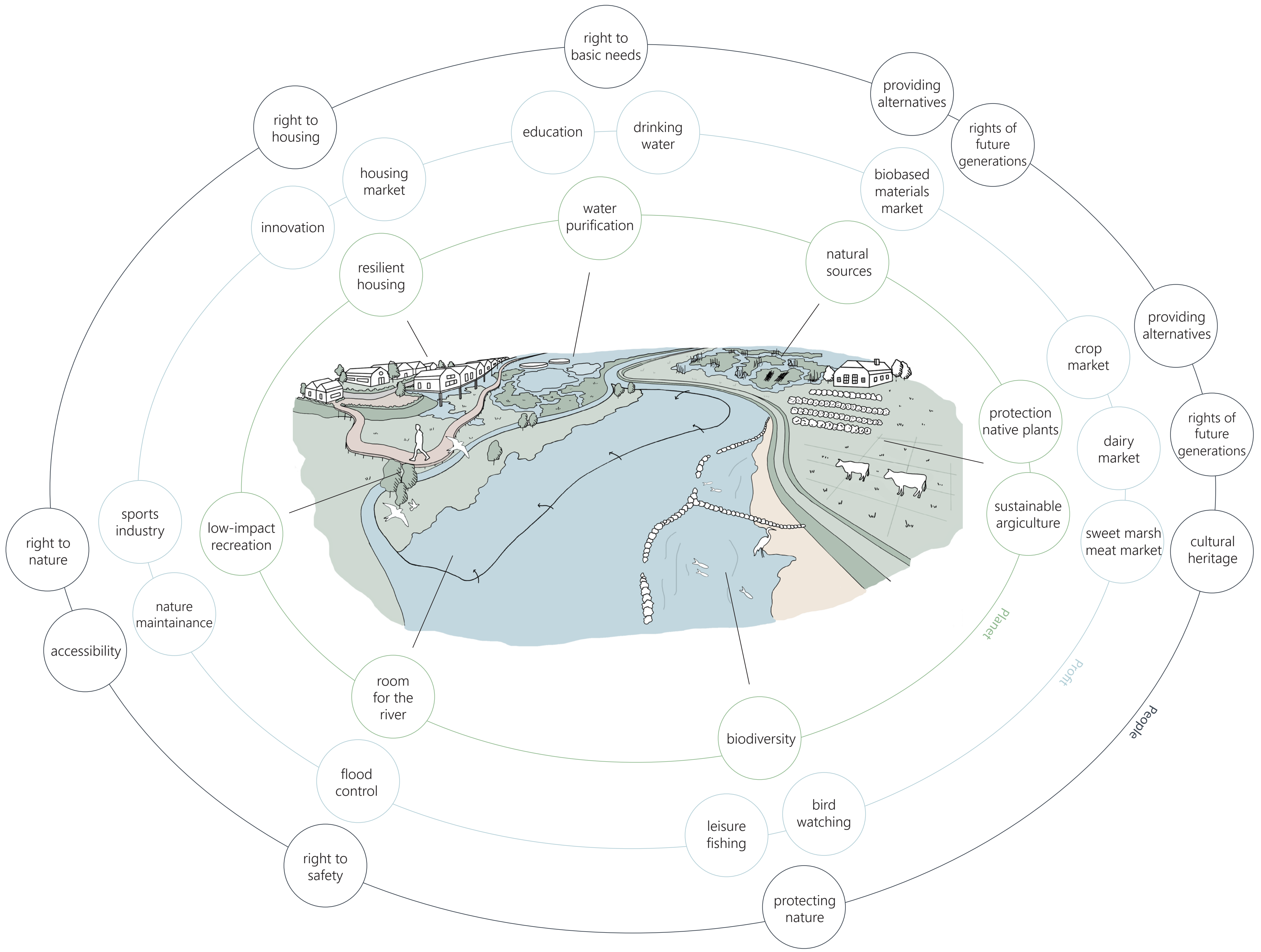


Figure 41: Economic sustainability in the Krimpenerwaard Polder

Krimpenerwaard Polder

Krimpenerwaard Polder

Conclusion
In figure 42 you can see the different aspects of this strategy evolving spatially over time.
The goal of this whole polder is mainly the transition into wetland with sustainable agriculture that captures carbon. Meanwhile the spatial claims housing, water purification and flood protection are answered as well.

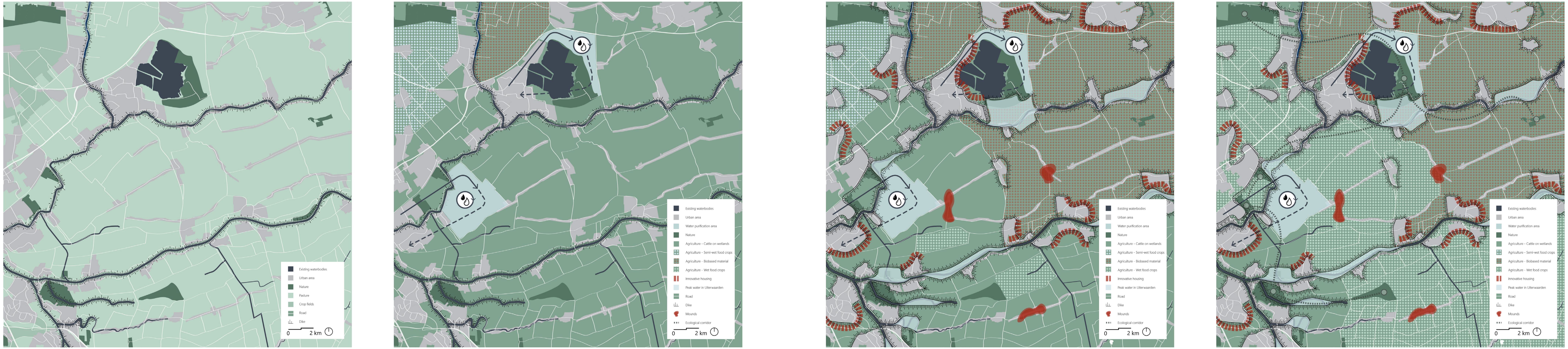


Figure 42: Spatial map of the transition in the Krimpenerwaard Polder

Harbour of Rotterdam

Our second zoom-in for this strategy is the Harbor of Rotterdam and its surrounding areas. The focus lays upon the non-urban areas in relation to the Harbor, while urban areas will be taken slightly into account.
The Harbor of Rotterdam is the top CO2 polluter of European Ports (Rotterdam Tops Ranking of Port Carbon Polluters - Transport & Environment, 2022) with a total of 22,4 MtCO2, caused by coal power stations (3,4 MtCO2), natural gas plants (3,8 MtCO2), chemical and other industries (6,1 MtCO2), and oil refineries (9,1 MtCO2) (CO2-uitstoot Haven Rotterdam Daalt Sneller Dan Landelijk Gemiddelde, n.d).

With the energy transition to clean energy and a carbon-neutral 2050 in the near future, the aim of this strategy is to contribute to the carbon uptake of this mass polluting area to clean the air of this already emitted CO2. During this process, stakeholder participation and engagement is of great importance, as this polluting area has a great impact on the well-being of one of the most densified living environments of the Randstad. Also, great economic flows and industries have positioned themselves in the harbour of Rotterdam, whereby impacts of the interventions will also have far-reaching impacts on these economic systems.

Just as the previous strategy, this chapter will be summarizing the main stakeholders regarding this area, approaching each intervention through overarching spatial claims that needs to be answered in the Province of South Holland.

Stakeholders
In this area the main stakeholders are industrial companies, the Port of Rotterdam Authority, agricultural companies, NGO's and inhabitants. Diagram X shows which stakeholders should be empowered or stimulated. Most importantly, NGO's should be empowered as their voices often do not get a lot of power. Additionally, polluting industries should be held accountable for their emissions. Agricultural companies will be influenced by interventions in this area, as they own most land. Therefore, just transitions should be implemented by providing sustainable alternatives, as they are in high need of new, sustainable ways to be able to continue their activities. The municipality of Rotterdam should be integrated in the process to cooperate in engagement processes and provide fundings/subsidies, which are crucial to the success rate of this project.

Harbour of Rotterdam

Flood protection
The essence of the water-based decarbonization strategy is to mitigate climate change by carbon uptake and provide water-resilience against flood risks caused by the changes of the hydrological cycle due to global warming.

As figure 21 shows, the harbour of Rotterdam is located in the estuary of the EuroDelta where the expanded part of the Rhine river mixes with the North Sea. Therefore the main emphasis lies upon flood protection from rising sea levels. In chapter 2 figure 10 illustrates how salt marshes, bogs and fens dominated the landscape of this area. Currently a large part of this area has been transformed into reclaimed land, destroying its natural water-resilient protection. Before the land reclamation, a fourth of the Netherlands was occupied by salt marshes (Ecomare, 2019).
A few steps can be taken to restore this historical wetland site, namely restoring coastal stormbreak barriers such as seagrasses and oyster reefs, saltmarshes, and fens and bogs under the overarching concept 'living & resilient shoreline'. This will rehabilitate the ancient delta landscape as it is of great importance to restore wetlands in historical original sites to succeed. In a coastal wetland ecosystem the different types of wetlands that inhabit the area depend on one another.

Firstly, the construction and restoration of seagrasses and oyster reefs in shallow shoreline waters. Besides that seagrasses absorb one of the greatest amounts of carbon, as introduced in the paragraph about wetlands, they function as stormbreak barriers. Together with oyster reefs, which transform in a short time frame into vast, concrete-like structures, they reduce wave energy and protect inland areas against storm events. Therefore, it is of great importance that this resilient shoreline structure is constructed before the endphase of the second step, saltmarsh restoration (figures 44-46).

This stormbreak barrier structure protects the saltmarshes (and inland) against shore erosion and prevents complete inundation of sea water, which will eliminate the saltmarsh. The salt marshes will be restored in original sites and will naturally grow with sea level rising. Transported sediments will be captured in the roots of the vegetation and accelerate, creating a carbon substrating organic soil, peat. This interdependent coastal structure therefore provides water-resilience against the increasing threat of the rising sea level. After 2 to 5 years, it probably will have a plant diversity greater than or equal to that of similar natural wetlands (Fretwell, J. D., et al, 1995).

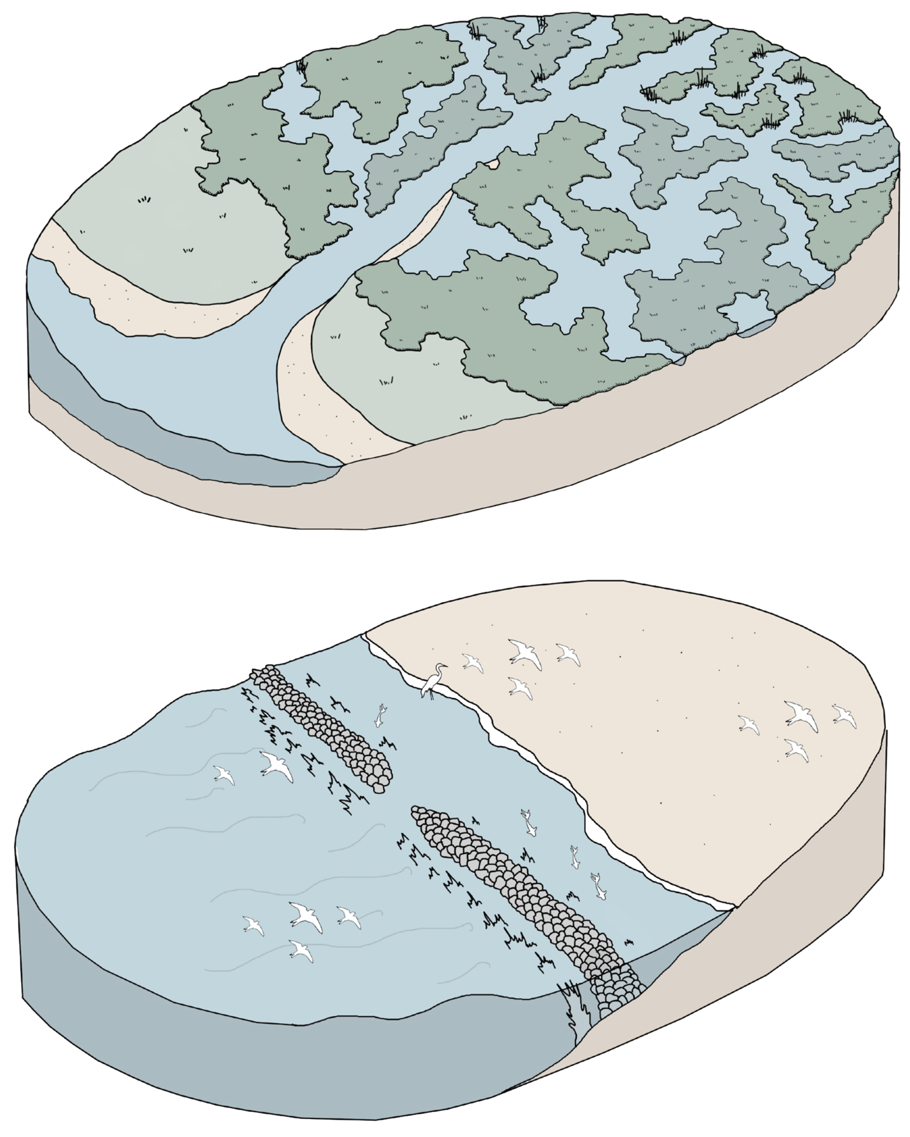


Figure 43: 2 design principles for coastal flood protection

Harbour of Rotterdam

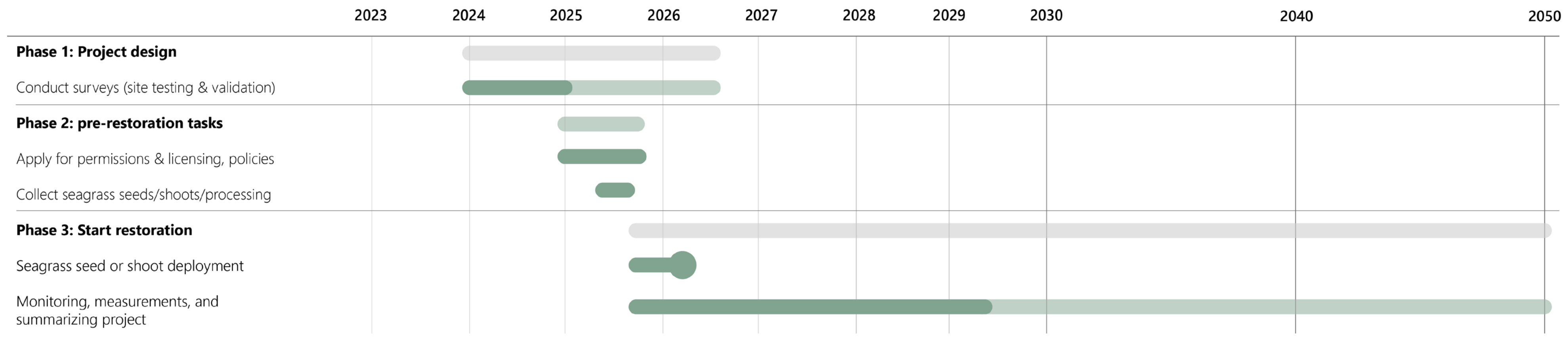


Figure 44: timeline seagrass strategy

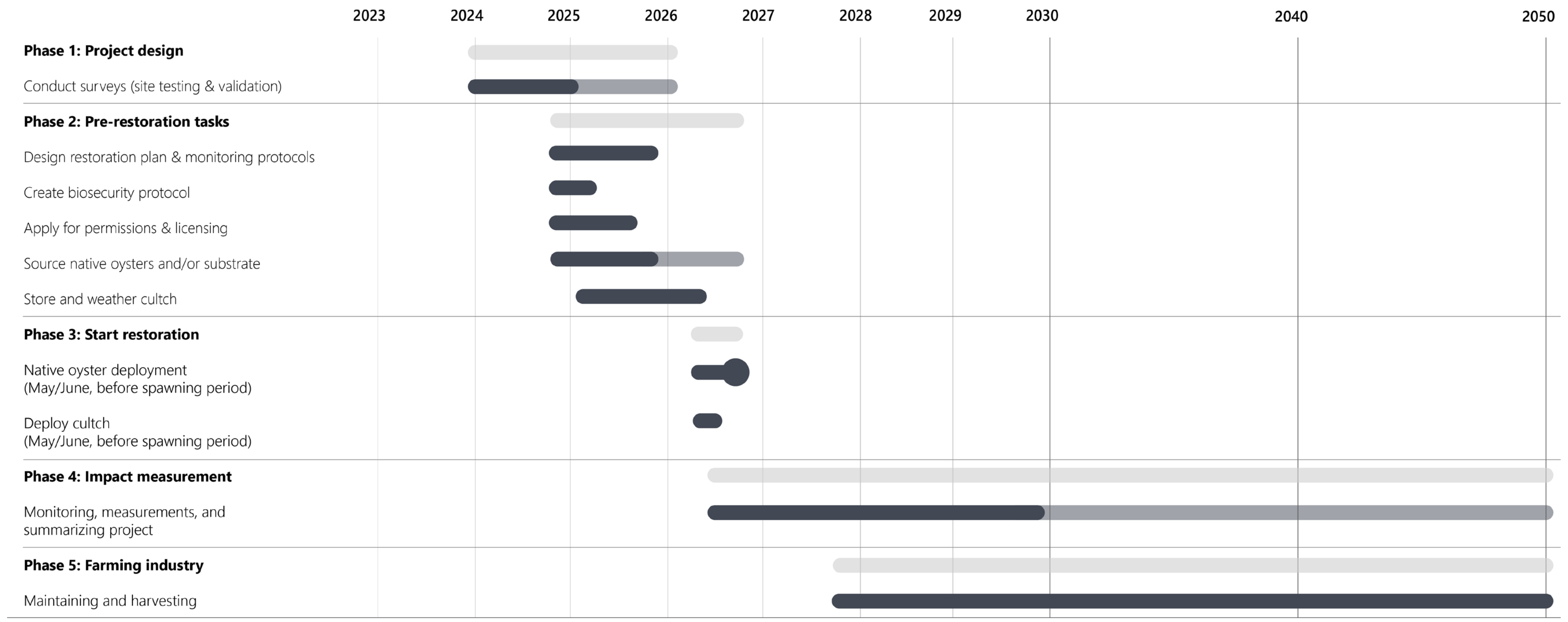


Figure 45: timeline oysterbank strategy

Harbour of Rotterdam

Also, just as the Krimpenerwaard zoom-in, groundwater will be heightened to saturate the soil. Therefore automatically peatlands (fens and through time bogs) will be created, connected to the salt marshes, and create a natural system of water absorption and release. This will slow down water runoff and provide protection against erosion and peak floods from inland. Because this area also is related to the river landscape of the Delta, eco-friendly riverbanks and floodplains will be implemented to create soft borders and provide room for river peak discharges (see zoom-in Krimpenerwaard).

Salinization

As currently the border of sweet and salty water is quite hard and most inland water is fresh, salinization of the water in this area will happen. During high water at sea, the salty sea water penetrates further and further into the Rijnmond via the Nieuwe Waterweg. In addition, the rising sea level causes salt to raise brackish groundwater (Adviesgroep Borm & Huijgens, Integrated Water Management, n.d.). This phenomenon is called salinization and mainly occurs in coastal areas such as the port of Rotterdam.

To combat salinization, the Haringvliet was separated from the North Sea in 1970 by the Haringvliet locks. The locks formed a barrier and made the Haringvliet water sweeter again and the tides stopped. As a result, the brackish ecosystem has been almost completely lost and the population of fish species in these degraded waters has declined sharply.
Since 2018, Rijkswaterstaat has opened the Haringvliet locks ajar at high tide so that fish can pass through. Restoring fresh-salt transitions has a positive effect on fish migration and restoration of delta nature from the past, but also has an effect on uses dependent on the freshwater supply, such as drinking water companies, drinking water companies, and industry (Kierharingvliet. nl, n.d.).

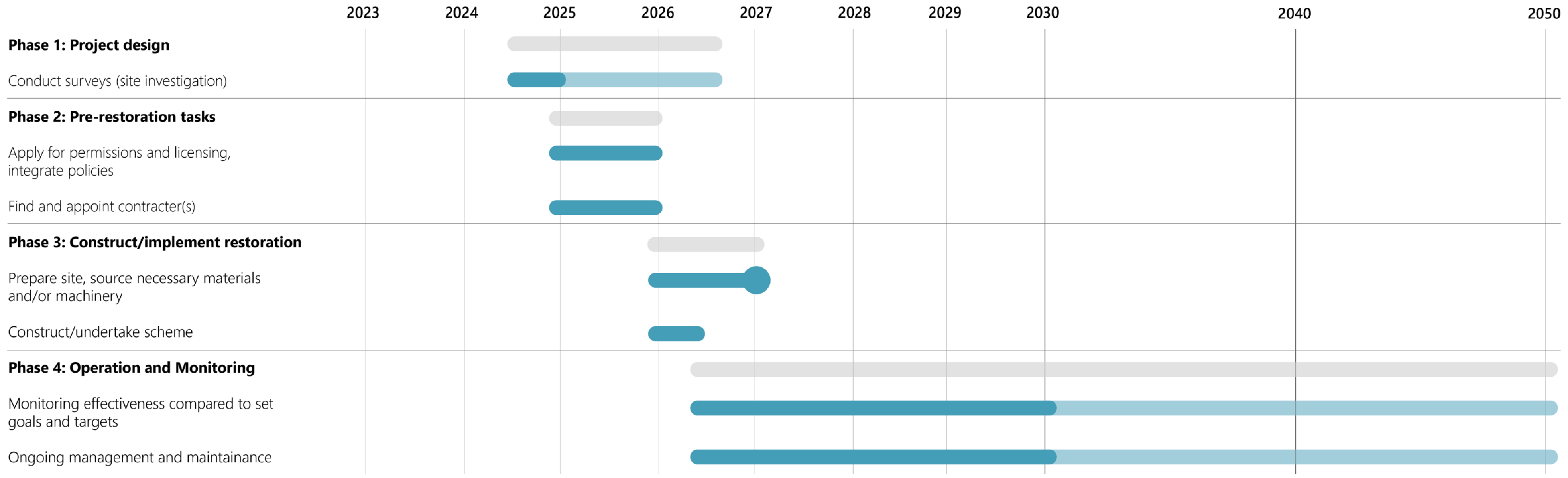


Figure 46: timeline salt marsh restoration strategy

Production of drinking water
As a result of the gap decision, drinkwater producer Evidens has moved the intake point for bringing in freshwater inland. This makes the drinking water system robust and future-proof. However, by opening the lock ajar more often and longer, the salt water boundary will move further inland. When replacing the treatment plant, which happens every 30-40 years, it is therefore wise to take into account moving the intake point during the regular replacement. In addition, the drinking water company is innovating desalination techniques and corrosion-resistant pipes. In this way, drinking water in the province is not endangered (Jorritsma, 2022). According to Timmer, drinkwater producer, this will not lead to noticeable price increases for consumers in the future.

Agriculture (salt)
As currently large parts of the non-urban areas surrounding the harbour are occupied by reclaimed land for sweetwater-based agricultural activities, the salinization of these areas will require transformation into salty, wet agriculture.

The shortage of fresh water and the threat of salinization are problematic for farmers. To freshen up polder ditches, 40% of the river water is used to flush the ditches (Adviesgroep Borm & Huijgens, Integrated Water Management, n.d.). With the likelihood of more frequent periods of drought, the extensive use of freshwater by the agricultural sector is unsustainable.
In addition, the salinisation areas in the Netherlands correspond to the areas where freshwater is scarce. Combating salinization costs too much freshwater, which is not available in times of drought. When freshwater is scarce, the drinking water supply is given priority over other water users such as agriculture (Jorritsma, 2022). This offers an opportunity to move along and to focus on the development of saline agriculture, making crop damage due to salinization of freshwater shortages a thing of the past. Moreover, with this alternative, food can continue to be grown with less water, on otherwise unusable agricultural land (Nieuwe Oogst, 2021).

Research by Wageningen University (n.d.) shows that potatoes, carrots, red onions, beets and white cabbage can grow on saline farmland. This form of agriculture not only makes it possible to grow food on depreciated agricultural land and thus forms a new revenue model. The knowledge about

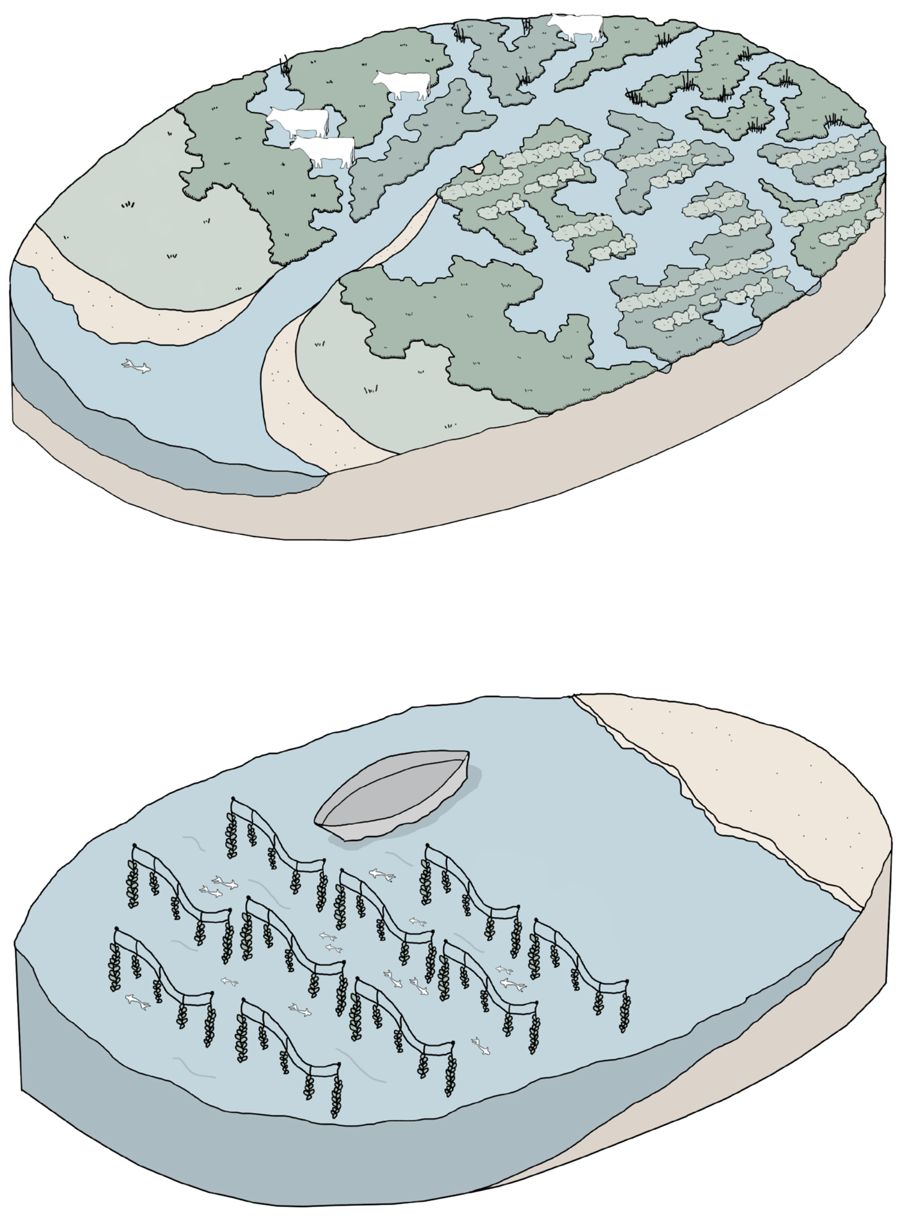


Figure 47: 2 design principles for saltwater agriculture

saline agriculture is very valuable and needed on a global scale, especially in delta areas. About 25 percent of irrigated agricultural land worldwide currently suffers from salinization. This is increasing daily by about 2,000 hectares. Training farmers for saline agricultural cultivation is therefore a second revenue model (Nieuwe Oogst, 2021).

Thus, our intervention will use the new salty conditions to provide a sustainable future for the wet agriculture in the estuary of the Delta to provide long-term economic revenue for the agricultural landowners of this area.

To provide alternatives for the agricultural landowners for a just transition, seaweed production is introduced. Several companies in the Netherlands are already active in seaweed cultivation, but it is still happening on a small scale. Nevertheless, there is an opportunity to scale up seaweed production considerably because the European demand for seaweed is growing. There is particularly great potential for combining seaweed with offshore wind farms in the North Sea, according to research commissioned by sector organization North Sea Farmers (Van Der Molen, 2021) Therefore this market is feasible and will bring economic revenue.

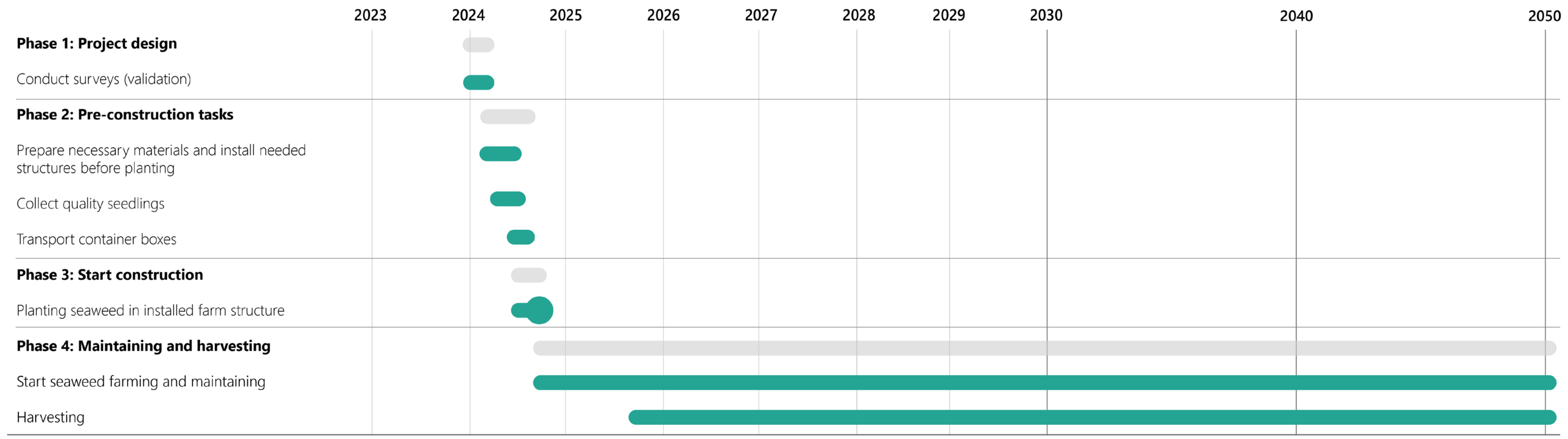


Figure 48: timeline seaweed farming strategy

Harbour of Rotterdam

Industry and CCS
As stated in the introduction of this chapter, the harbour of Rotterdam is a great polluter. Therefore in our strategy it will be of great importance that these polluting industries will be held accountable for their actions. This will be done through the policies that will contribute to carbon storage, naturally or by human interventions.


Figure 49: Industries are held accountable for their emission - collage

Industry and CCS

Firstly we implement the CCS (Carbon Capture and Storage) interventions of Porthos and Aramis. 14% of the total Dutch emission proceed from the harbour of Rotterdam (CO2 Reduction Through Storage Under the North Sea - Porthos, 2022). Therefore, the Port of Rotterdam Authority, Gasunie and EBN implemented a CCS project where CO2 captured from polluting industries are transported through pipeline-infrastructure underground into the North Sea, where they will be injected into empty gas hole fields. Aramis is an addition to this project, searching for other possible areas in the North Sea to continue this process.

On the other hand we are creating wetlands along the Harbor of Rotterdam to naturally capture carbon, as this is more effective when wetlands are located near emitting sources (Luo, Wang, Ma, Wu, Zheng & Xie, 2022).

The policy regarding spatial justice will be based on the accountability of the polluting industries, namely 'Polluting industries which can easily capture or reuse CO2, have to plug into the CCS-infrastructure. For instance, horticulture can plug into this system so the carbon which is emitted by the industry can be reused there. Polluting industries where this will be more difficult, have to contribute to restoring wetlands and pay for this process.' They in turn can use wetland water to cool down machineries and discharge wastewater which wetlands will naturally purify.

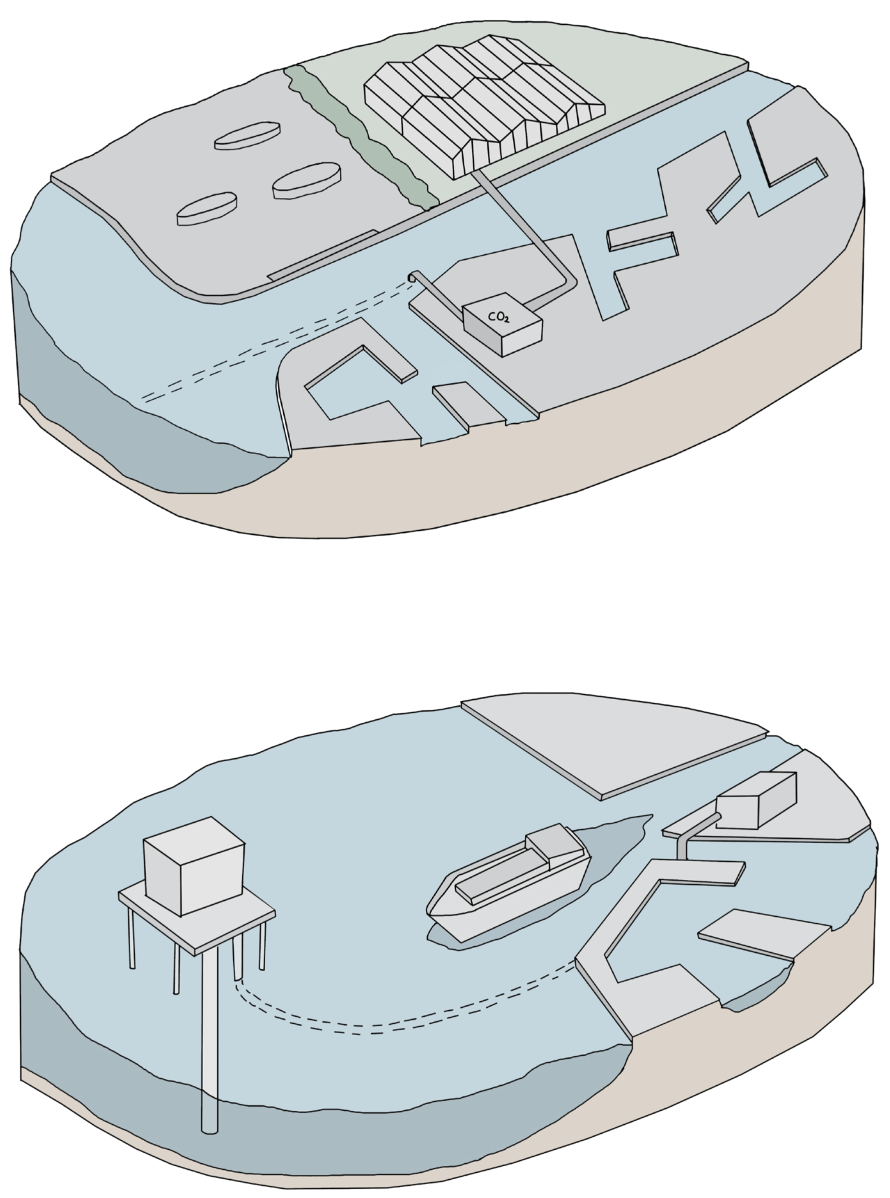


Figure 50: 2 design principles connecting emitting industries to respectively horticulture and injection platforms at sea.

Harbour of Rotterdam

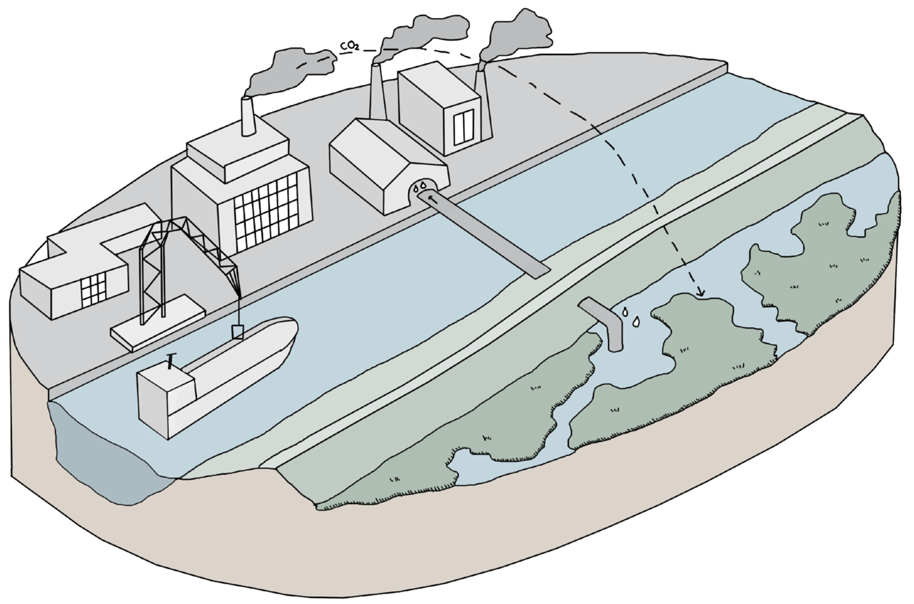


Figure 51: design principle connecting industry with purifying wetland

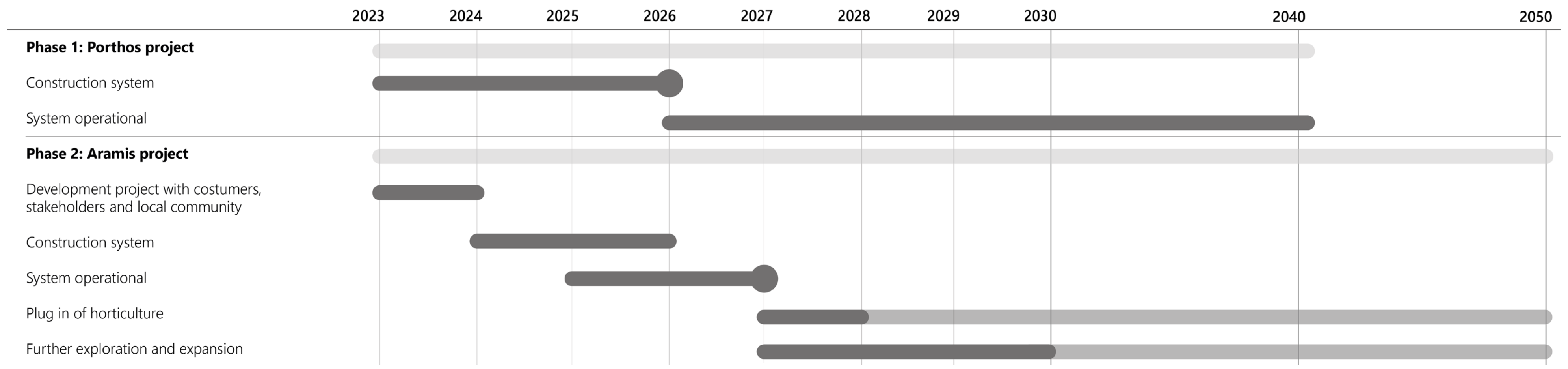


Figure 52: timeline CCS strategy

Harbour of Rotterdam

Housing
As the energy transition continues and hydrogen will be introduced, large parts of the port area will be available for new uses. Therefore our strategy builds further on this trend and will move the remaining industry to the outer part of the harbour. The impact of the industry therefore will be less on the urbanized areas, such as Rozenburg which is an Island in industrial land, and new accessible land will be used for (water-adaptable) housing development to contribute to the housing crisis (shown in Krimpenerwaard), and realisation of a bio-hub for bio-materials production.

Biodiversity
All of these interventions will increase biodiversity as nature will be restored, new ecological corridors will arise and also connect urban areas with non-urban areas. Wetlands are nursery grounds for migrating birds and fishes and protect shelter, whereby they will attract wildlife. Wetland wildflowers and vegetation will blossom and bring back rare species. The restored hydrological system will provide healthy environments not only for animals, but also for society. In this area, a natural protected area will be implemented in the center area to provide citizens the right to nature.

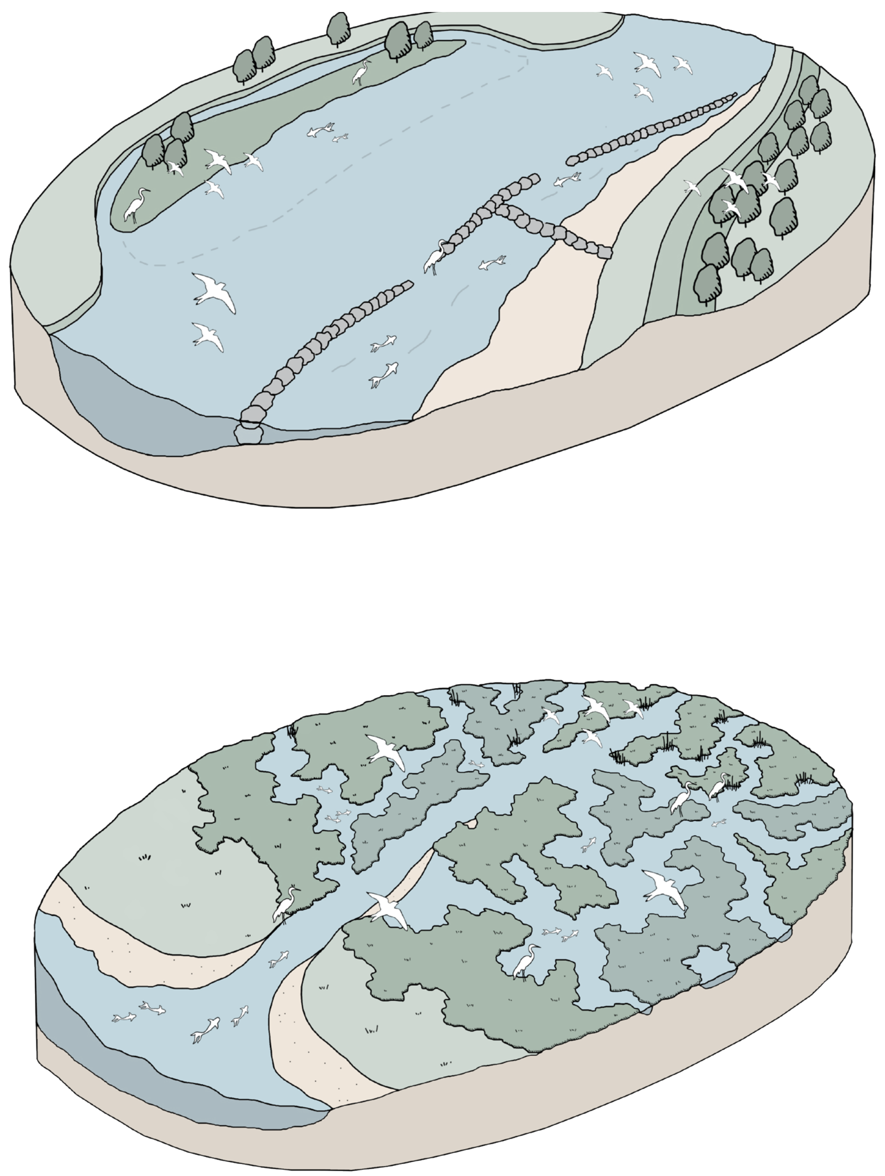


Figure 53: 2 design principles increasing biodiversity

Economic Sustainability
As this area is located in a highly densified space, many spatial claims need to be answered to prevent pressure on societies' well-being. Therefore wetlands will be multifunctional and will provide opportunities for different sectors and stakeholders. Wetlands provide these opportunities naturally whereby implementation-costs will be relatively low.

Firstly, the restoration of fresh-salt transitions has a positive effect on fish migration and restoration of delta nature from the past, but leads to salinization. Instead of combating salinization, sustainable robust alternatives for agriculture are proposed. Aside from the salt wet agriculture in the areas of heightened groundwater levels, seaweed production, oyster reefs, bio-based materials production, and salt basins open up doors for new markets. Restoring wetlands also stimulates local fisheries as fish will migrate to these areas again.

At the same time, natural wetland areas will be protected as high human interaction will negatively impact their effectiveness (Dolch, et al., 2017). Therefore the policy 'restored wetland areas will be added to the Ramsar sites of protected wetland areas and it is not allowed to transform this land into other uses.'

However, to provide society with the right to nature, low-impact recreation will be realised. Hereby also opportunities for tourism arise, as the various, wild landscape with its flora and fauna will attract tourists. Again, this will provide new economic revenue for the area as it also can stimulate art markets for artists and souvenirs for the tourism-industry.

Lastly, some wetland areas will be functioning as 'test areas' to support educational and innovative purposes such as research and application of solar panels on top of wetland surfaces.

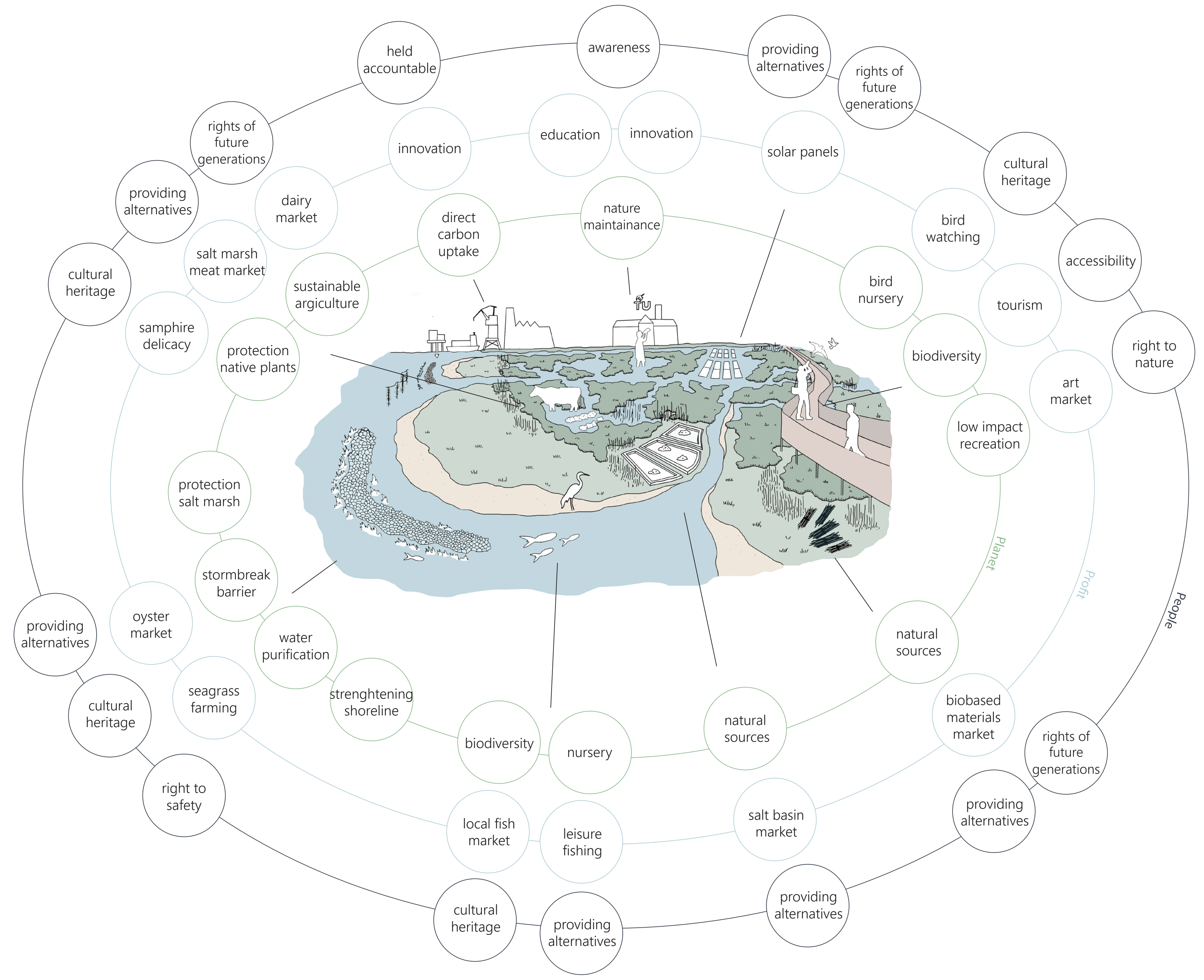


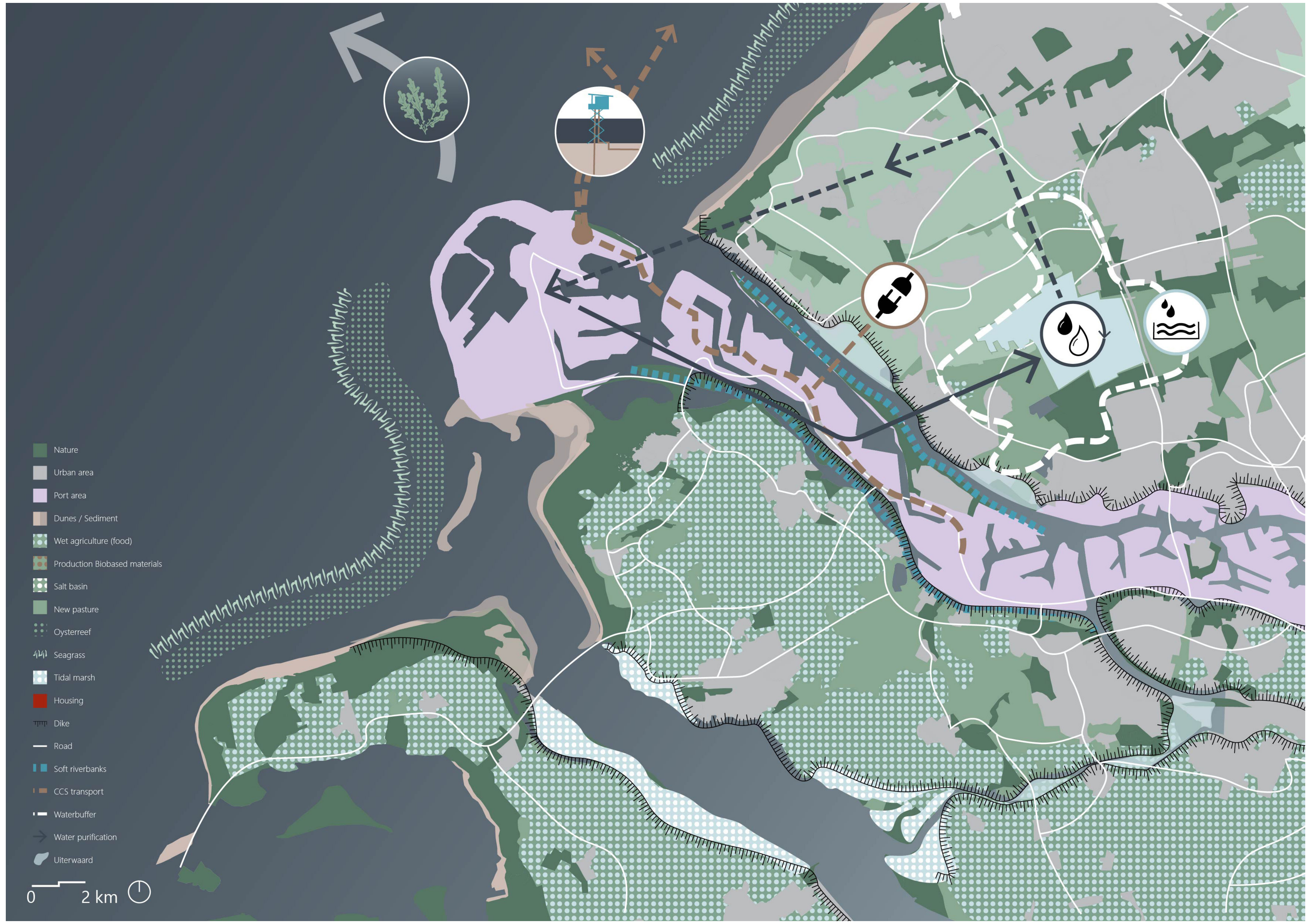
Figure 54: economic sustainability around the harbour of Rotterdam

Harbour of Rotterdam

2023


Nature
Urban area
Port area
Dunes / Sediment
Wet agriculture (food)
Production Biobased materials
Salt basin
New pasture
Oysterreef
Seagrass
Tidal marsh
Housing
Dike
Road
Soft riverbanks
CCS transport
Waterbuffer
Water purification
Uiterwaard
0
2 km

2026


Nature
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Wet agriculture (food)
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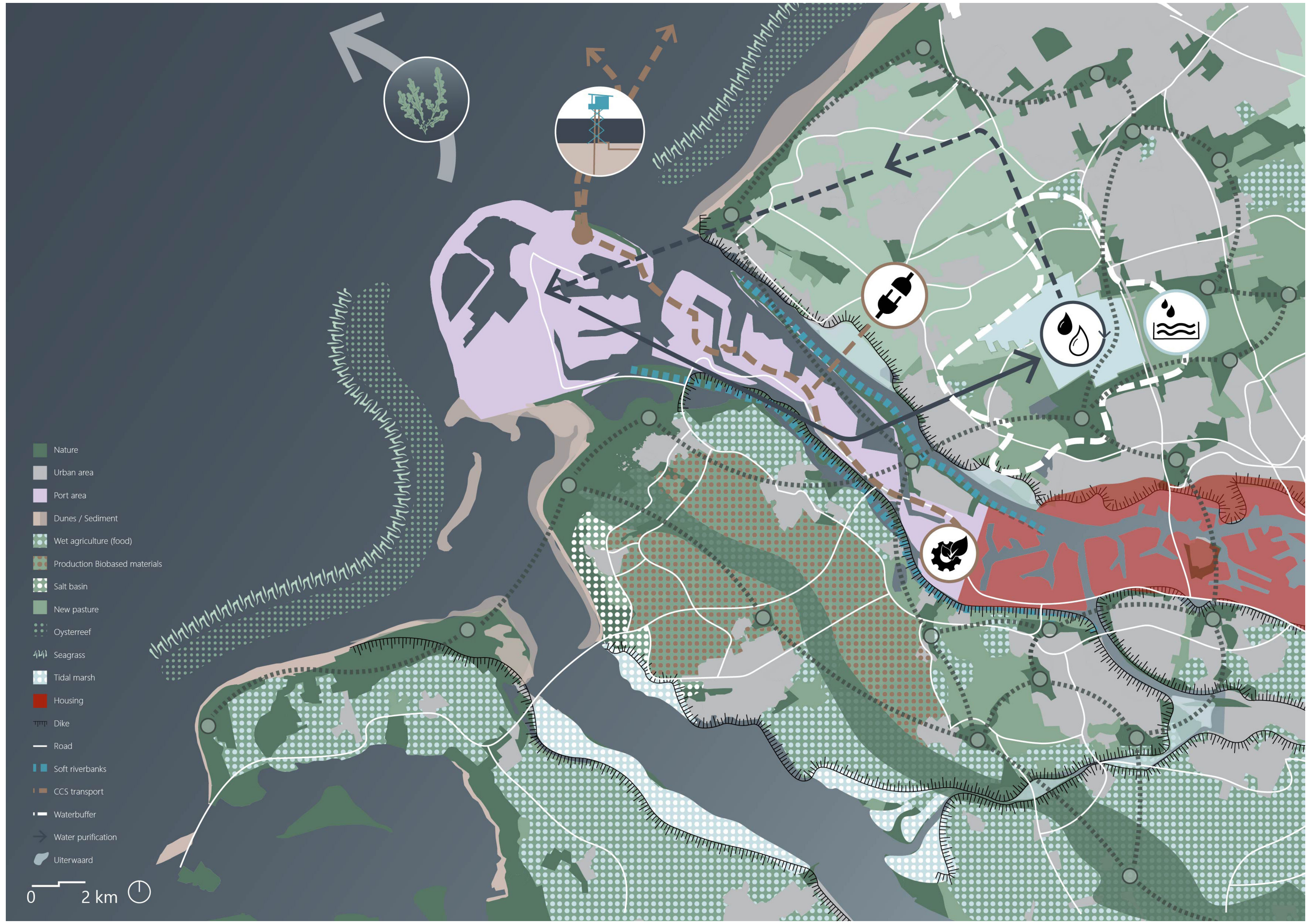
New pasture
Oysterreef
Seagrass
Tidal marsh
Housing
Dike
Road
Soft riverbanks
CCS transport
Waterbuffer
Water purification
Uiterwaard
0
2 km

2027

Harbour of Rotterdam



2040

Stakeholder Engagement

Stakeholder engagement
Stakeholder engagement is crucial to the success rate of the implementation of interventions. Therefore, investment in this process should not be limited.

It starts in phase 0: raising awareness and scope of engagement (figure 55). The first community events should be organised, to raise awareness. Often society does not want to cooperate as the urgency of the problem is not recognized due to lack of knowledge. This should be provided for them in accessible and attractive ways. For example, local community events, festivals, food events, etc. During this engagement process, a comprehensive feasibility study should be simultaneously constructed as for most interventions conditions of sites and their historical background are crucial for implementation.

After these first moments of introduction and site research, the first spatial models should be presented to spatially convince stakeholders of the feasibility of the project. Then, goals should be defined to create understanding of what the end result should be. It is of great importance to emphasise here on the engagement, to reassure that the voices of all stakeholders will be implemented in the design. Also, the first volunteers should be selected on which in the following step, skill development through training should be organized, to provide knowledge and skills they do not consist of.

It is of great importance that all stakeholders should create a common network and connect with other related networks. This is an efficient way to share and gain knowledge, and keep spreading awareness on different scales to stimulate cooperation. This could be through festivals, merchandise sales, art works, and especially media. It is important that one spokesperson should be selected to answer interviews. Also making a reliable celebrity the face of this project will provide benefits.

At the end of this first stakeholder phase, even though this process should continue along the complete process, conclusions can be formulated on the first fundings and cooperation network to formulate the reach of the project and what is feasible.

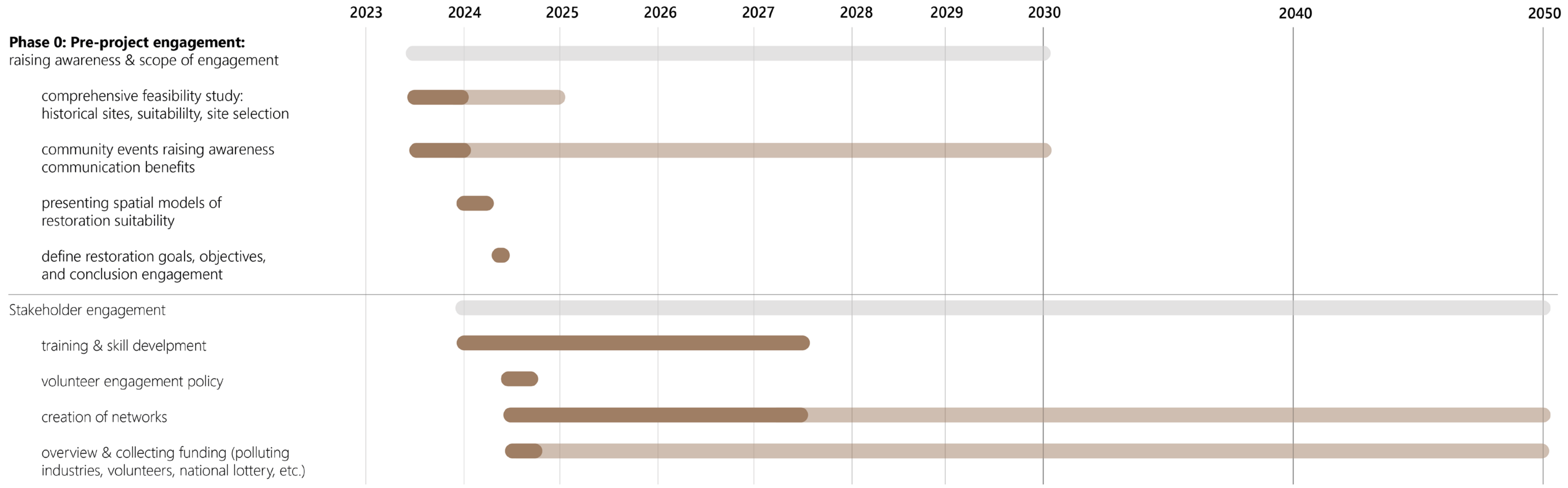


Figure 55: timeline engagement & participation strategy

Participation

Participation
Focus on participation is important during the whole strategy. We will start with getting to know the attitude of stakeholders, by surveys or open conversations. This can result in some ground rules for participation to follow during the planning process. A ground rule could be that stakeholders get clarity about their future within 2 years and have the opportunity to stay or get good compensation (Edelenbos et al, 2013). Afterwards spatial models of the transition will be presented, to establish the goals for this area.
During the whole project open participation will be stimulated by process managers (or other coordinators). This can be done by conversations in a casual atmosphere between different stakeholders, such as Rijkswaterstaat with inhabitants. This will result in less conflict, although consensus might still be a struggle (Van Alphen, 2020; Goosen & Vellinga, 2004). In the planning process the interests of all local stakeholders should be considered (Warner et al, 2018). When an intervention is decided upon, this will be communicated timely to all relevant actors. Lastly the different institutional levels should communicate and cooperate closely to get the project to work (Goosen & Vellinga, 2004).

Figure 56: impression engagement through art and kitchen-table participation

Policies

The overarching policy for these strategies is the cruciality of stakeholder processes and how they should be prioritized to provide just transitions. This is described in previous paragraphs.

Spatial Claim	Intervention	Policy	Goal	Funding/Financing
Biodiversity	Connect natural (and non-urban) areas through ecological corridors.	-	Increasing land and marine biodiversity. Strengthening the large-scale green structure of the EuroDelta through local interventions.	-
	Realisation of natural green center in the large-scale natural structure of the Province of South Holland.			
	Construction of soft and eco-friendly river banks.			
	Living shoreline: increase of biodiversity through wetland construction.			
Heritage	Conservation and protection of historically lost and existing heritage.	Restored wetland areas will be added to the Ramsar sites and Natura2000 of protected wetland areas for which it is not allowed to transform these lands into other uses.	Creating a 'new' public good for society.	-
Carbon sequestration	CCS	Polluting industries which can easily capture CO2, have to plug into the CCS-infrastructure. Polluting industries where this will be more difficult, have to contribute to restoring wetlands and pay for this process.	Carbon uptake by using emitting industries. Accountability for emitting industries.	As polluting industries should pay for their negative impacts on the environment, financing of CCS-infrastructure and wetland restoration is mandatory.
	Plug-in horticulture	Emitted carbon from horticultural agriculture will be captured and plugged into the CCS infrastructure.		
Recreation	Low impact recreational areas.	Protecting nature and its ecosystems regulations are defined to not allow visitors or passers-by to overpass each natural area.	Creating and enhancing ecological corridors to improve access to nature for all inhabitants, with mimized impacts on the natural structure. Contributing to providing at least 9 m2 of nature to all inhabitants.	As the government has the responsibility to provide nature for its citizens, collective taxes through society need to be collected to support the financing.

Spatial Claim	Intervention	Policy	Goal	Funding/Financing
Agriculture	Heighten the water table up to 40 cm.	Farmers will be provided with additional income proportionately with their carbon emission reduction.	Reducing carbon in the atmosphere and providing water resilience.	Financement of these interventions will be partly ensured by polluting industrial companies (spatial claim 'CCS'). Fundings can be applied by the Sustainable Water Fund - FDW. To stimulate swift to higher groundwater tables, the first pioneers (acting in the first 2 years of project introduction) will be awarded for their willingness. Rewards will be depending on the impact of carbon uptake: - If the transition into wet agriculture will decrease carbon emissions and the agricultural activity will stay the same, rewards will be from the lowest category. - If the transition captures carbon and agricultural activities transform completely, rewards will be from the highest category. After this period, a small compensation can be applied for for transitioning to wet agriculture, however, main financing will be dependent on the agricultural companies. The stakeholder engagement process will provide the first fundings, investments, and financial support from phase 0 (National Postcode Lottery, private, NGO's, etc.)
	Introducing agricultural alternatives.	Equally to 'heighten the water table up to 40 cm'.	Conventional agriculture has negative effects on the climate and biodiversity. threatened by water shortages and the quality of agricultural land decreases as a result of salinization. Wet agriculture land management with associated alternative revenue models	Financement of these interventions will be partly ensured by polluting industrial companies (spatial claim 'CCS'). Great part of oyster reefs will be financed by Rijkswaterstaat, waterboards, municipalities and provinces to ensure shore protection. After this period, a small compensation can be applied for transitioning to salty wet agriculture and seaweed production, however, main financing will be dependent on the agricultural companies. The stakeholder engagement process will provide the first fundings, investments, and financial support from phase 0 (National Postcode Lottery, private, NGO's, etc.)
Water purification	Shift to natural purification of domestic, agricultural and industrial wastewater for reuse purposes.	Combine replacement of the treatment system, which occurs every 30-40 years, with relocating the intake point more inland to ensure drink water availability. Provide testing grounds for educational institutions for innovation of water purification by wetland for drinkwater purposes.	Provide clean water, disburden overloaded water purification system and reduce energy use and costs And provide a new flora and fauna and educational opportunities	Drinking water companies are responsible for financing the expansion of infrastructure to provide for clean drinking water. Government stimulates innovation through educational institutions by providing subsidies for testing grounds. As drinking water companies will benefit from these innovations, small contributions will be mandatory.
Flood Protection	Construction of floodplains and water buffers	Rijkswaterstaat, water boards, municipalities and the province of South Holland need to implement these water-resilient interventions into the regional measures of the National Waterplan 2022-2027 and provide these water protections for all inhabitants.	Improve water resilience in the upper and middle part of the EuroDelta watershed.	As this is the responsibility of Rijkswaterstaat, waterboards, municipalities and provinces the financing depends on these parties.
	Resilient shoreline: create stormbreak barriers and water buffers	Equally to 'construction of floodplains and water buffers'. In addition, they should be added to the management of the coastline areas 'Hollandse Kust' and 'Deltakust' (Ministerie van Infrastructuur en Waterstaat, 2023).	Improve water resilience in the lower part of the EuroDelta watershed.	Equally to 'construction of floodplains and water buffers'.
Housing	Realising water-adaptable housing in agricultural lands and newly available industrial land.	Housing development will be implemented in non-urban areas around existing villages as a border while functioning as a buffer zone for these areas.	Realising future-proof, flexible housing to the possibility of extreme scenarios occurrence.	Subsidies will be available for innovation to research large-scale appliance of water-adaptable housing.

Timeline

To summarize the interventions of the strategy in the zoom in the figure on the right shows an overview of the main phasing of both zoom ins. See for detailed total version the appendix.

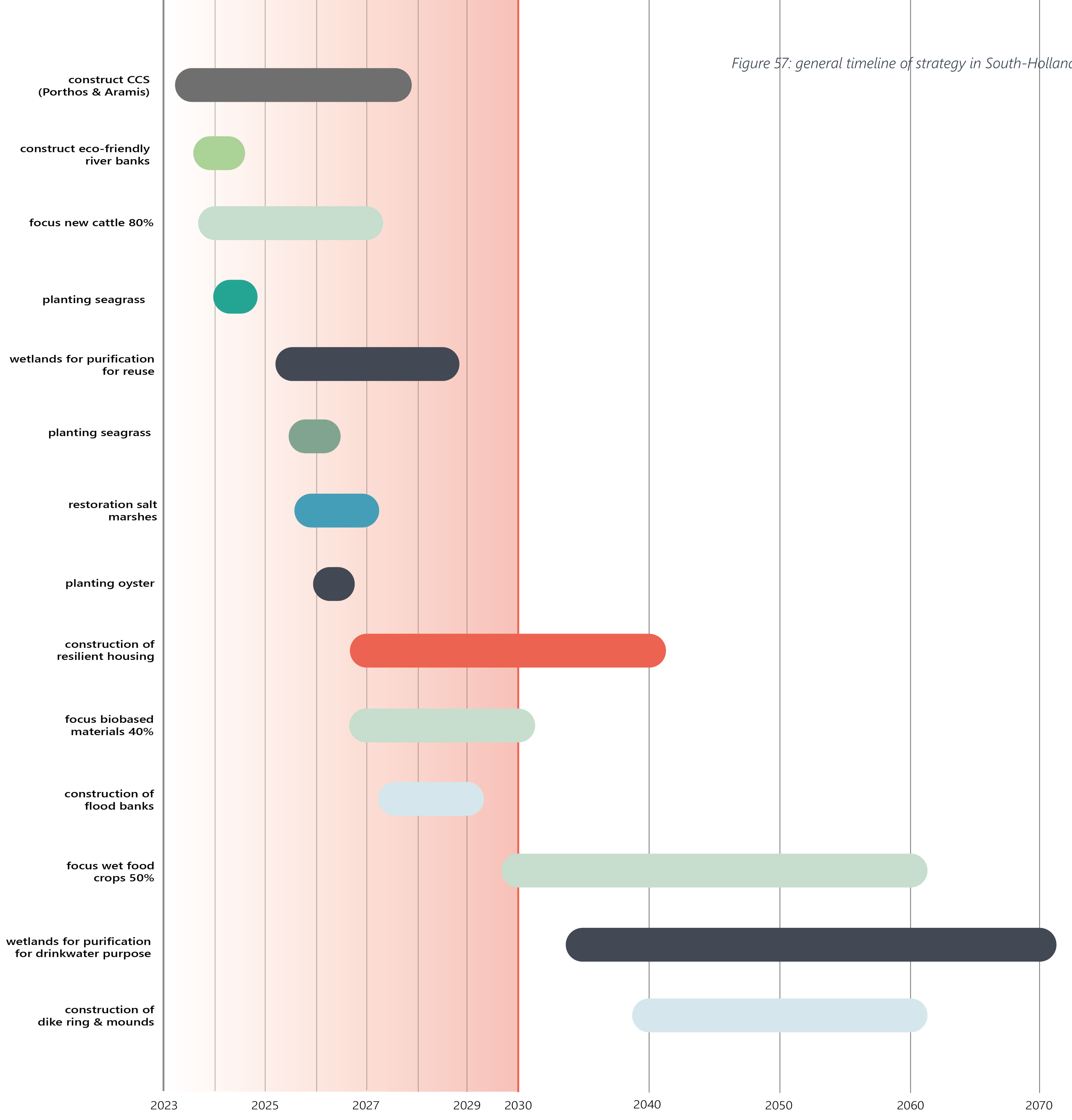


Figure 57: general timeline of strategy in South-Holland

Strategy Map

To summarize the previous zoom-ins on the provincial scale, the integration of all interventions will strengthen, restore and construct large-scale structures.

Firstly, the interventions which provide water-resilience against both flood risks from sea level rising and pressure on peak river discharges restores the Delta water system by the implementation of the living & resilient shoreline, room for the river, soft river banks and inland water buffers. At the same time, they contribute to the uptake of carbon.

Secondly, wetland creation and heightening of the groundwater table strengthen ecological corridors as biodiversity will increase, connecting non-urban and urban areas on different scales.

Lastly, new economic revenues and societal benefits will arise from these interventions, increasing social well-being and sustaining long-term opportunities for new rising markets.

Figure 58: strategy Map South-Holland

Conclusion

This whole strategy will change existing flows in this area on different levels, as shown in figure 59.

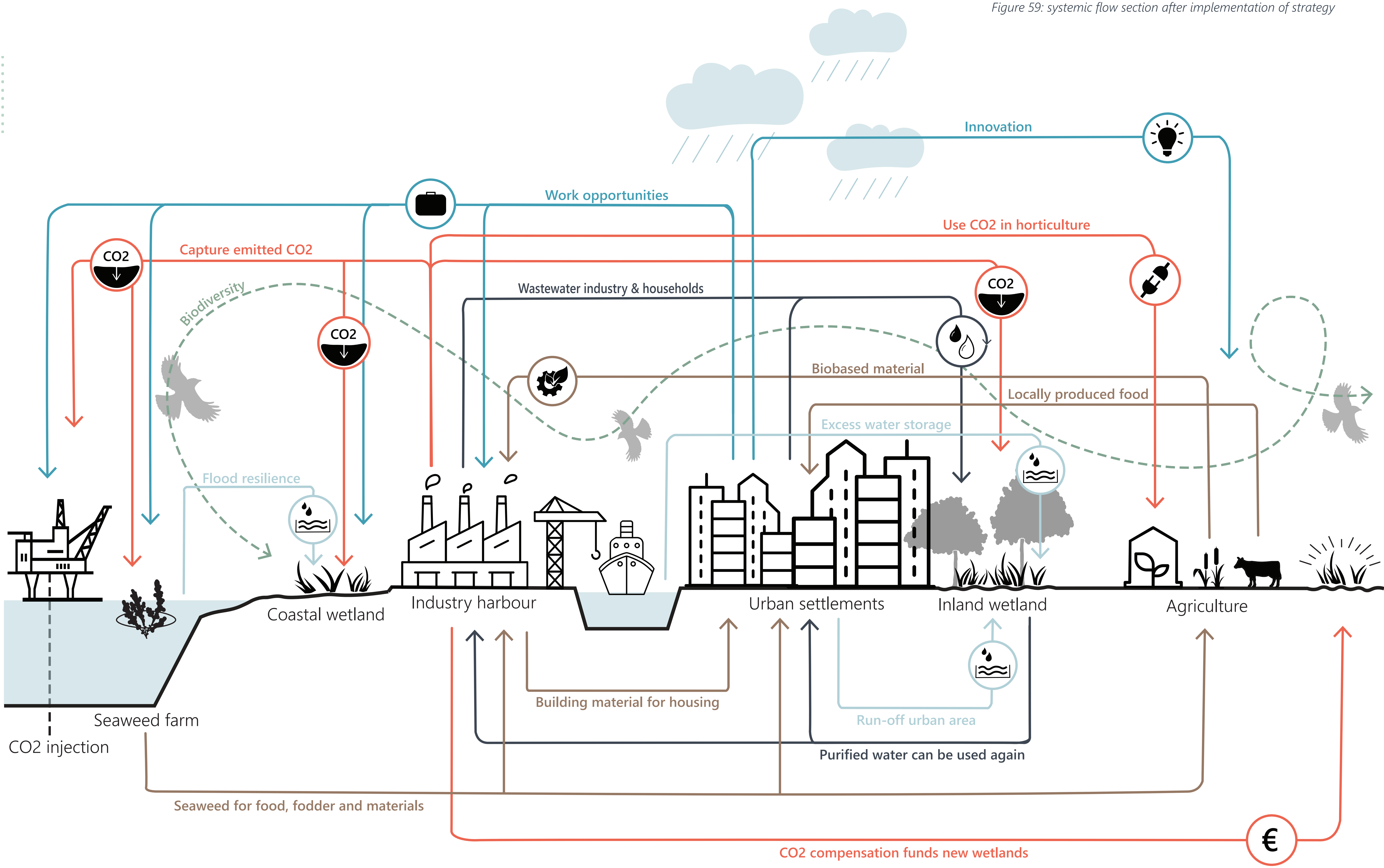
Firstly the flow of CO_2 from industry to the atmosphere will be minimalized. Wetlands will capture carbon naturally. Compressed CO_2 will be transported and injected into the seabed or used in horticulture. This creation of wetlands will be paid for by emitting industries.

Secondly water circularity will increase in two ways. Wastewater of industries and households will be transported to wetlands for natural purification, so it can be reused again. And excess water, from river, ocean or city run-off can be stored at the wetlands.

Thirdly the production of materials will increase in South-Holland, by farming fibrous materials on land and ocean. At the bio-hub in the harbour this will be processed into building materials, thereby helping to solve the housing shortage.

Lastly, the economic sector will get a boost, new jobs arise and innovation in the agricultural sector is desired.

Figure 59: systemic flow section after implementation of strategy



06 Conclusion

Conclusion

The research question was 'How to integrate water-based decarbonization (technologies) in spatial strategies for a sustainable NW-EU?'.

The foundation in the spatial strategies are natural water bodies that capture carbon. These are oceanic waters, coastal wetlands, and inland wetlands. Besides storing carbon, thus mitigating climate change, the wetlands provide water resilience against extreme weather events caused by climate change.

The ocean and wetlands can answer other spatial claims, such as agriculture, recreation and housing. Oceans can also accommodate man-made carbon sequestration technologies as CCS. The safety and liveability of the Eurodelta is enforced by the wetlands, additionally inhabitants can benefit from new job-opportunities. All in all the strategy provides social, environmental and economical sustainability for the Eurodelta.

The planning tools, as shown in figure X, were designed for South Holland. However, they can be implemented along the Eurodelta. But the tools should be adapted to local conditions, as they are context-specific. Therefore, in-depth site surveys and research should be executed for each specific location.

The essence of this vision and strategy is a shift in paradigm, from fighting against water to living with water. This will provide safety and sustains livability for all EuroDelta inhabitants.

Discussion

During our research, inclusion of the impacts of methane emissions is disregarded, as this is out of our scope. However, it is crucial to understand the influences of methane emissions before wetlands restoration as this is also a greenhouse gas.

For further exploration of water-based decarbonization in spatial strategies, stakeholder research should be prioritized at the start of the project. This can contribute to policy making and therefore to the feasibility of the strategy implementation.

To provide a more realistics strategy proposal, local experts of different disciplines should be consulted. Especially when the toolbox is implemented in other contexts, knowledge of local conditions is essential as this research is formulated by evidence-based proposals with lack of conversed context-specific knowledge of experts.

Relevance
The urgency to minimize climate change is high, direct action is needed before 2030, as stated in the Paris Agreement (2015). With this strategy alone this goal is not feasible, as this strategy attempts to maximize mitigation. However, it is crucial to combine this project with the energy transition to have a significant impact on minimizing global warming.

This research focuses on the role of water in mitigation strategies, as this is a largely unrecognized approach. The conclusion of this research emphasizes the need for a shift in paradigm to live with water and to smartly use its naturally provided services. Water-based decarbonization offers opportunities to increase social and economic sustainability, therefore this design also provides societal relevance.

Lastly, this project supports and contributes to the sustainable development goals of the United Nations (2015), stated in chapter 1.

07 Appendix

Reflection

Individual reflection Tim van Oorspronk
For the individual reflection, I will elaborate on the role of a vision in the planning and design proposal of this project and how it has influenced our development strategy.

Our vision has served as the base for our development strategy. It provided a strong foundation to understand the scale and complexity of this project more easily. The purpose of a vision is to provide a narrative through visualizations that imagine a desirable future.
A vision should be persuasive and encourage the engagement of actors that is required to achieve this desirable future and therefore should be simplified to make it comprehensible for non-experts. For that, it is preferable to keep the level of abstraction higher and not hold on to boundaries to provide flexibility, but at the same time provide concrete objectives to clarify the aim of the research that can be measured afterward. This will increase the feasibility of the project.
In our vision, we have formulated the following abstract planning and design principles. Inland water resilience should be provided by relieving pressure from river discharge through flood plains and water buffers. At the edge of the ocean, water resilience is mainly provided by coastal wetlands that function as storm break barriers.
We use the watershed of the EuroDelta as a backbone to connect our story. It brought to light the great potential of which the EuroDelta consists. Especially regarding the watershed, a natural element that in itself connects different contexts. Therefore it is important to explain these potentials from the watershed to the stakeholders. For example, the watershed provides a natural structure on which ecological corridors can arise and provide benefits for society and the environment. The natural water system of the watershed formulates the main structure of the watershed and therefore efficiently can connect inland wetlands, coastal wetlands, and oceanic waters in one mechanism. The restoration of wetlands along this structure is crucial for its effectiveness, as wetlands depend on one other.

But how does this influence the development strategy? In the vision, areas are classified based on coarse conditions suitable for wetland restoration and/or creation. The vision presents the overarching conditions that will connect all the interventions through the EuroDelta in one system. But as each area has other coarse conditions site surveys, and location-specific research are crucial for the implementation of our spatial interventions.
Local conditions such as the water capacity of the soil, groundwater level, and type of landowner, can provide an overarching framework for planning interventions on its own. The strategy serves as an argument that can be used to achieve broad objectives which benefit society, the economy, and the environment.
In our strategy, these local conditions have resulted in for example the planning interventions: flood plains, heightening of groundwater table, and salt marsh restoration. And all these interventions are guided by the provided principles from the vision.

To summarize it all, the implementation of our vision is at a certain level abstract enough to provide flexibility and understanding but also very precisely provides a designed framework that depends strongly on local conditions. However, a common factor through all scales is required for new economic revenues to engage landowners because they have to participate to realize the vision.

Individual reflection Kim Schneider
For the individual reflection I will reflect on the role of a vision in the planning and design proposal of this project and how it has influenced the development strategy.

The frame of this research is North-West Europe. This mega scale concerns different contexts with different conditions, norms and values, governmental policies, and communities. To bring the complexity of over-border planning and design together, a vision can be very helpful to prevent overwhelming. It provides a large-scale interrelated 'red line' that clarifies its complexity through planning and design principles, to which interventions should contribute and reflect on. It provides a purpose with a system that overlooks borders and connects them.

As climate change mitigation is the main objective of this research, a global approach is crucial to supply an integral design as each country should cooperate to succeed in tackling this global threat. However, a statement that proves its importance in all my design processes, is 'designing through scales'. As context differs, also in different dimensions: societal, economic and environmental, context-specific interventions should be designed to support these dimensions and include all perspectives, on all scales. This provides an understanding that otherwise would be overlooked.

During this research, zoom-ins were designed to conduct in-depth research and determine the feasibility and suitability of a project in the area of the Krimpenerwaard polder and the Port of Rotterdam. It proved that even on this scale, context differs greatly. The interventions of wetland restoration require original historical sites and suitable soils to have a high-success rate. But the conditions of the wetlands in these two zoom-ins varied: brackish in the Port area and sweet in the polder. Therefore the transition into new types of agriculture was implemented differently.

But simultaneously, smaller-scale strategies provide planning principles for the overarching vision. As a vision in the first instance can be quite abstract, strategies can provide more exact planning principles that can be implemented along the whole mega-scale. In this project, the vision provided large scale systems such as the ecological corridors, the wetland restoration areas that connect the water system of the EuroDelta and water-resilient structures, but interventions such as eco-friendly river banks, the living & resilient shoreline, and new sustainable agriculture provided concrete implementation. In this way, a clear understanding of each different scale and dimension is supported.

However, it is not as easy as said as other factors will also influence this process. These large-scale planning and design proposals are often designed by big teams in which all perspectives are represented. Ofcourse designing through scales will be a helpful tool to combine all these perspectives, which is why stakeholders engagement processes should be highly prioritized. But it will always be a tough task to find consensus which all parties agree to.

Individual reflection Margot Kruizinga
I will reflect on the relationship between research and design in the project WATERLAND: water-based decarbonization.

We started off with water and carbon as subjects for this project and it was quite challenging to connect these two at first notice. Therefore, we researched the interrelation between the hydrological and carbon cycle and quickly found the current imbalance in both cycles. The industrial and agricultural sector connect to these cycles. They are currently disbalancing the carbon cycle by emission, but are threatened by diminished water availability. Spatially these sectors are linked with the rivers of the Eurodelta, connecting land with ocean, with flood-related threats.

So first literature research was done to define the problem, secondly solutions were explored to tackle both problems at once by water-based decarbonization. This resulted in several nature-based solutions, but the required spatial conditions had to be investigated. These conditions create boundaries for the design and show the potential for implementation of the vision in the Eurodelta. By mapping soil conditions, water threats and land use, the vision is linked to realistic locations. All in all, this vision is supported by scientific evidence, with a combination of literature and data.

For the strategy the scope was narrowed, to explore strategic interventions in detail. In the zoomins the previously mentioned sectors were investigated and by literature the possibilities to minimise their impact were explored. The agricultural sector needs a shift to sustainable land-use to feed current and future generations. The industrial sector should be held accountable for their emissions, by paying for the CO2-capturing interventions.
The additional social and economic benefits for society of the multifunctional interventions support the realisability of the strategy. The research generated the framework for the design of the strategy.

The functionality of the interventions is quite extensively researched and therefore the design of the strategy is evidence-based. However, a more elaborate stakeholder research, for example with interviews, would have enhanced policy making. This would have provided more spatial justice in WATERLAND. In the scope of this project, there was little time to explore this in-depth. The methodology course awakened my interest in this spatial justice and I hope to develop my knowledge about this subject in the future.

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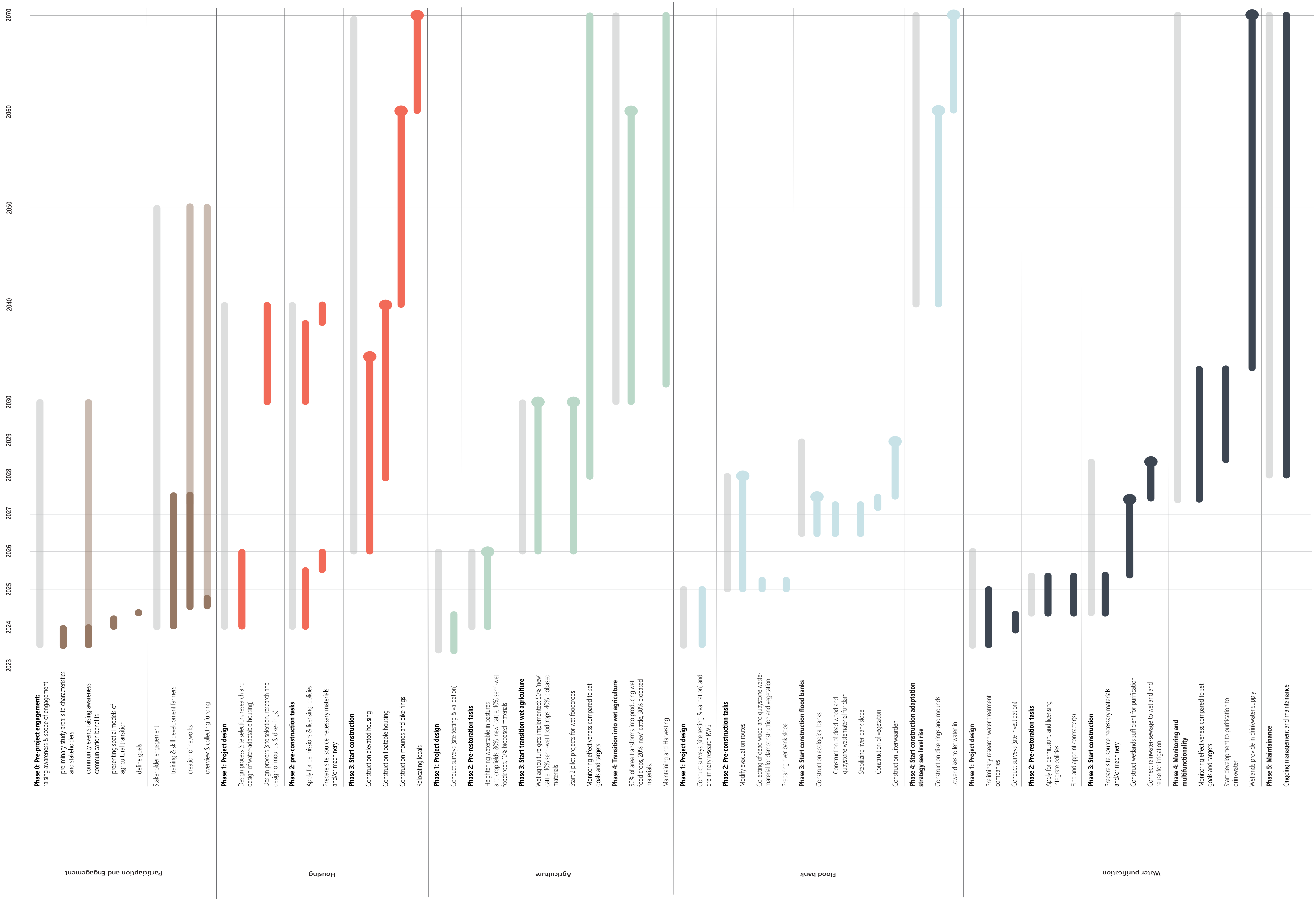
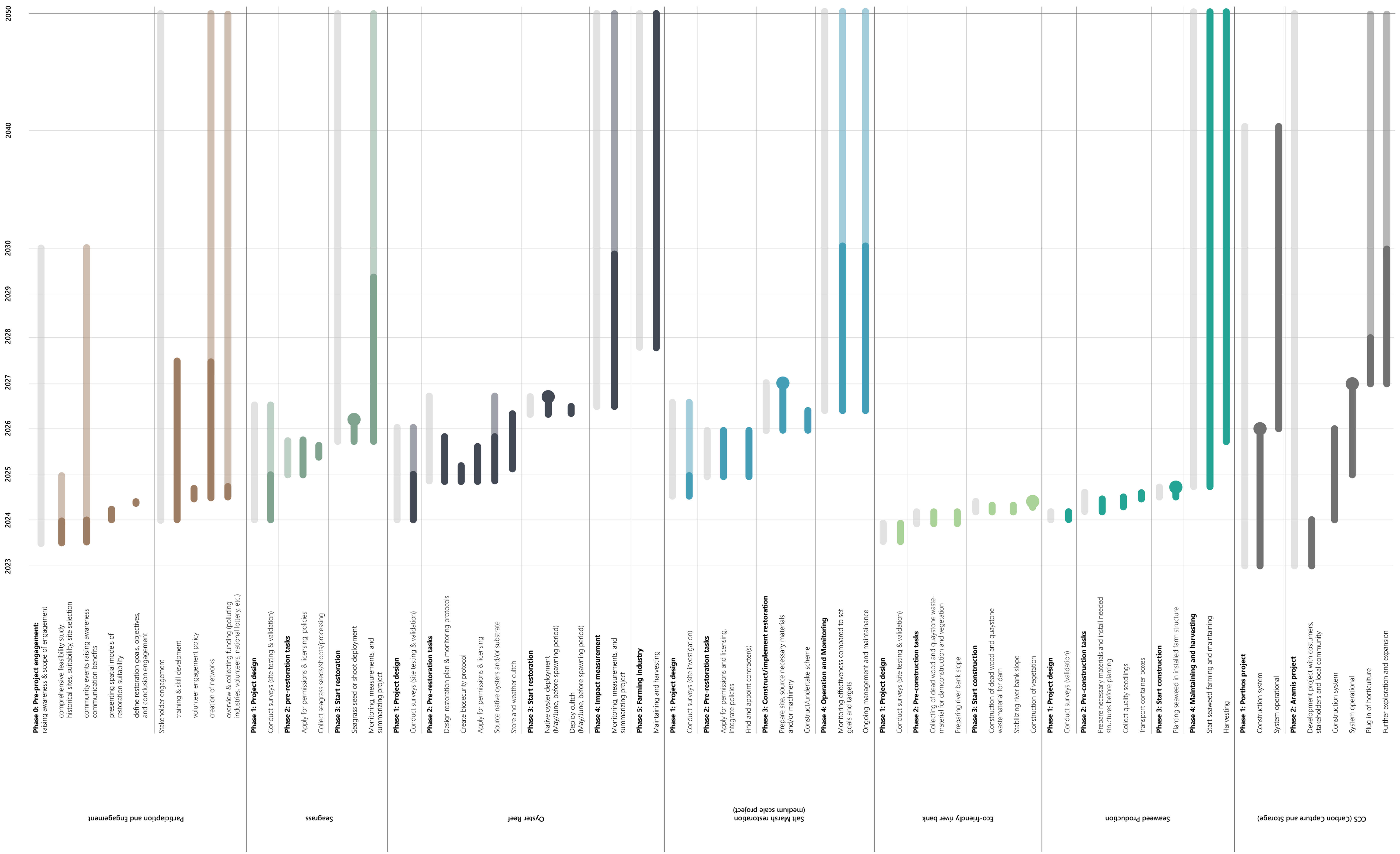
Timeline



2070
2060
2050
2040
2030
2029
2028
2027
2026
2025
2024
2023
Phase 0: Pre-project engagement: raising awareness & scope of engagement
preliminary study area: site characteristics and stakeholders
community events raising awareness communication benefits
presenting spatial models of agricultural transition
define goals
Stakeholder engagement
training & skill development farmers
creation of networks
overview & collecting funding
Participation and Engagement
Phase 1: Project design
Design process (site selection, research and design of water-adaptable housing)
Design process (site selection, research and design of mounds & dike-rings)
Phase 2: pre-construction tasks
Apply for permissions & licensing, policies
Prepare site, source necessary materials and/or machinery
Phase 3: Start construction
Construction elevated housing
Construction floatable housing
Construction mounds and dike rings
Relocating locals
Housing
Phase 1: Project design
Conduct surveys (site testing & validation)
Phase 2: Pre-restoration tasks
Heightening watertable in pastures and cropfields: 80% 'new' cattle, 10% semi-wet foodcrops, 10% biobased materials
Phase 3: Start transition wet agriculture
Wet agriculture gets implemented: 50% 'new' cattle, 10% semi-wet foodcrops, 40% biobased materials
Start 2 pilot projects for wet foodcrops
Monitoring effectiveness compared to set goals and targets
Phase 4: Transition into wet agriculture
50% of area transforms into producing wet food crops, 20% 'new' cattle, 30% biobased materials.
Maintaining and Harvesting
Agriculture
Phase 1: Project design
Conduct surveys (site testing & validation) and preliminary research RWS
Phase 2: Pre-construction tasks
Modify evacuation routes
Collecting of dead wood and quaystone waste-material for damconstruction and vegetation
Preparing river bank slope
Phase 3: Start construction flood banks
Construction ecological banks
Construction of dead wood and quaystone wastematerial for dam
Stabilizing river bank slope
Construction of vegetation
Construction uiterwaarden
Phase 4: Start construction adaptation strategy sea level rise
Construction dike rings and mounds
Lower dikes to let water in
Flood bank
Phase 1: Project design
Preliminary research water treatment companies
Conduct surveys (site investigation)
Phase 2: Pre-restoration tasks
Apply for permissions and licensing, integrate policies
Find and appoint contracter(s)
Phase 3: Start construction
Prepare site, source necessary materials and/or machinery
Construct wetlands sufficient for purification
Connect rainwater-sewage to wetland and reuse for irrigation
Phase 4: Monitoring and multifunctionality
Monitoring effectiveness compared to set goals and targets
Start development to purification to drinkwater
Wetlands provide in drinkwater supply
Phase 5: Maintainance
Ongoing management and maintainance
Water purification

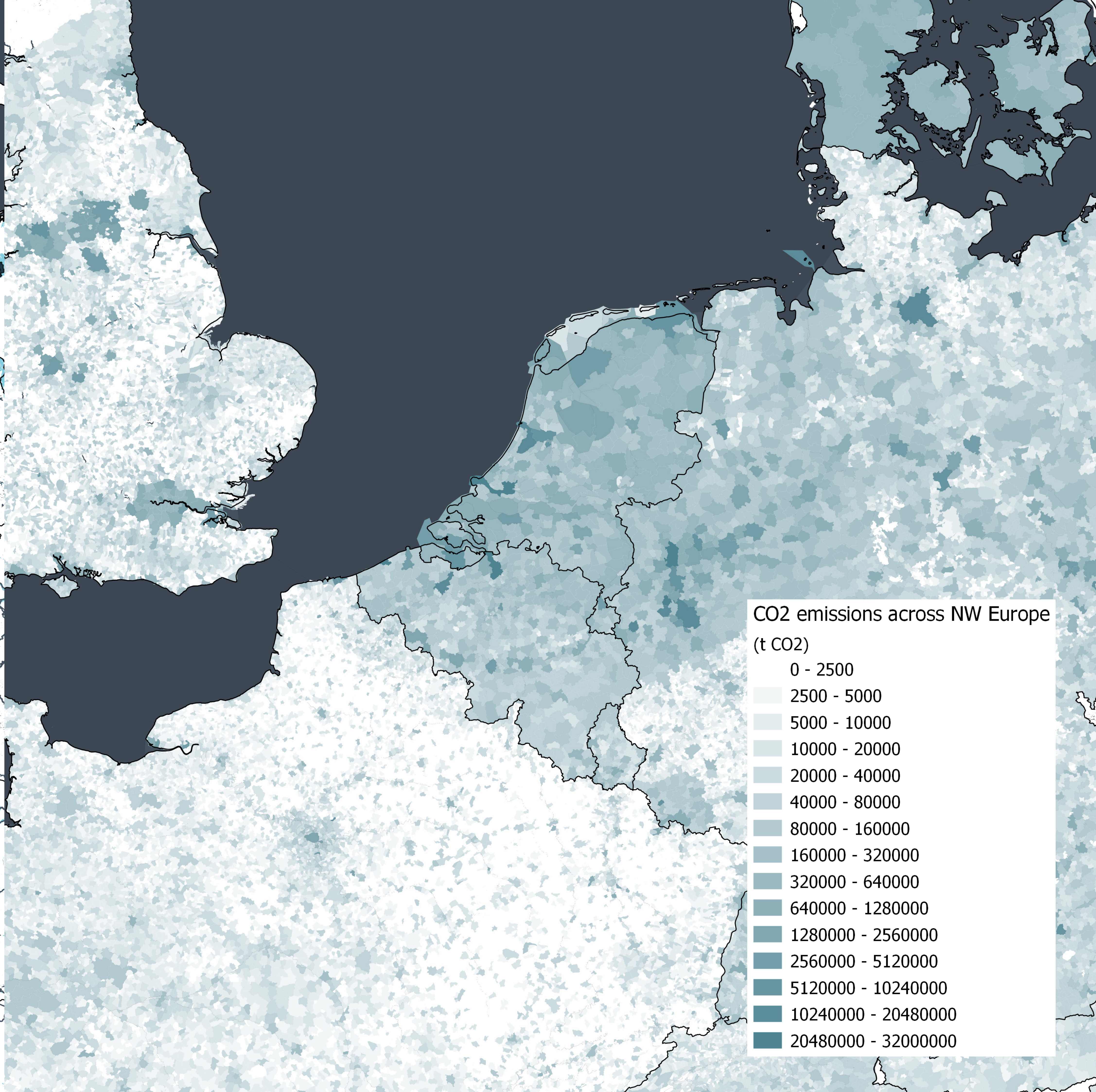
Timeline

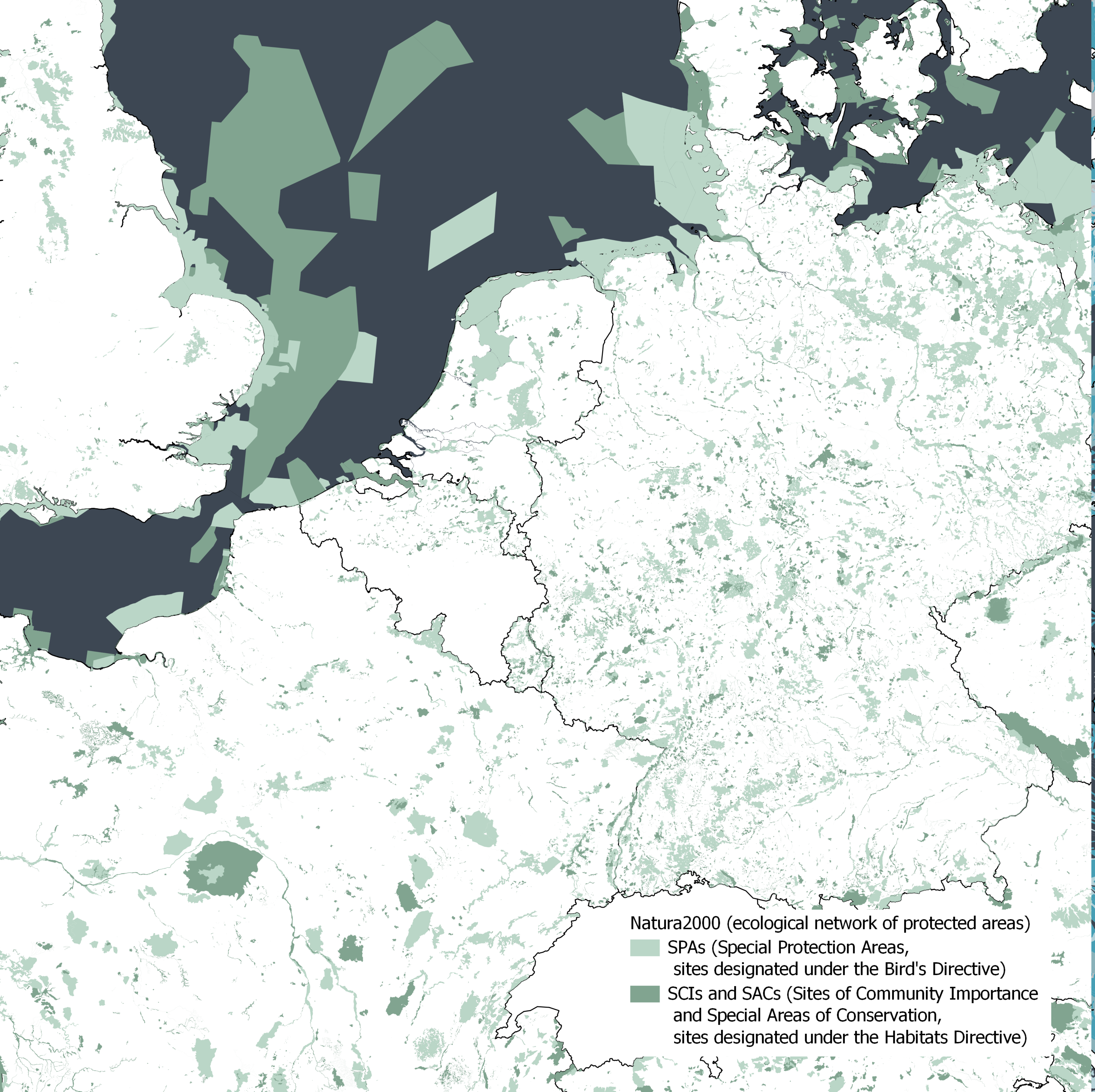

2050
2040
2030
2029
2028
2027
2026
2025
2024
2023
Phase 0: Pre-project engagement: raising awareness & scope of engagement
comprehensive feasibility study: historical sites, suitability, site selection
community events raising awareness communication benefits
presenting spatial models of restoration suitability
define restoration goals, objectives, and conclusion engagement
Stakeholder engagement
training & skill development
volunteer engagement policy
creation of networks
overview & collecting funding (polluting industries, volunteers, national lottery, etc.)
Participation and Engagement
Phase 1: Project design
Conduct surveys (site testing & validation)
Phase 2: pre-restoration tasks
Apply for permissions & licensing, policies
Collect seagrass seeds/shoots/processing
Phase 3: Start restoration
Seagrass seed or shoot deployment
Monitoring, measurements, and summarizing project
Seagrass
Phase 1: Project design
Conduct surveys (site testing & validation)
Phase 2: Pre-restoration tasks
Design restoration plan & monitoring protocols
Create biosecurity protocol
Apply for permissions & licensing
Source native oysters and/or substrate
Store and weather cultch
Phase 3: Start restoration
Native oyster deployment (May/June, before spawning period)
Deploy cultch (May/June, before spawning period)
Phase 4: Impact measurement
Monitoring, measurements, and summarizing project
Phase 5: Farming industry
Maintaining and harvesting
Oyster Reef
Phase 1: Project design
Conduct surveys (site investigation)
Phase 2: Pre-restoration tasks
Apply for permissions and licensing, integrate policies
Find and appoint contracter(s)
Phase 3: Construct/implement restoration
Prepare site; source necessary materials and/or machinery
Construct/undertake scheme
Phase 4: Operation and Monitoring
Monitoring effectiveness compared to set goals and targets
Ongoing management and maintainance
Salt Marsh restoration (medium scale project)
Phase 1: Project design
Conduct surveys (site testing & validation)
Phase 2: Pre-construction tasks
Collecting of dead wood and quaystone waste-material for damconstruction and vegetation
Preparing river bank slope
Phase 3: Start construction
Construction of dead wood and quaystone wastematerial for dam
Stabilizing river bank slope
Construction of vegetation
Eco-friendly river bank
Phase 1: Project design
Conduct surveys (validation)
Phase 2: Pre-construction tasks
Prepare necessary materials and install needed structures before planting
Collect quality seedlings
Transport container boxes
Phase 3: Start construction
Planting seaweed in installed farm structure
Phase 4: Maintaining and harvesting
Start seaweed farming and maintaining
Harvesting
Seaweed Production
Phase 1: Porthos project
Construction system
System operational
Phase 2: Aramis project
Development project with costumers, stakeholders and local community
Construction system
System operational
Plug in of horticulture
Further exploration and expansion
CCS (Carbon Capture and Storage)

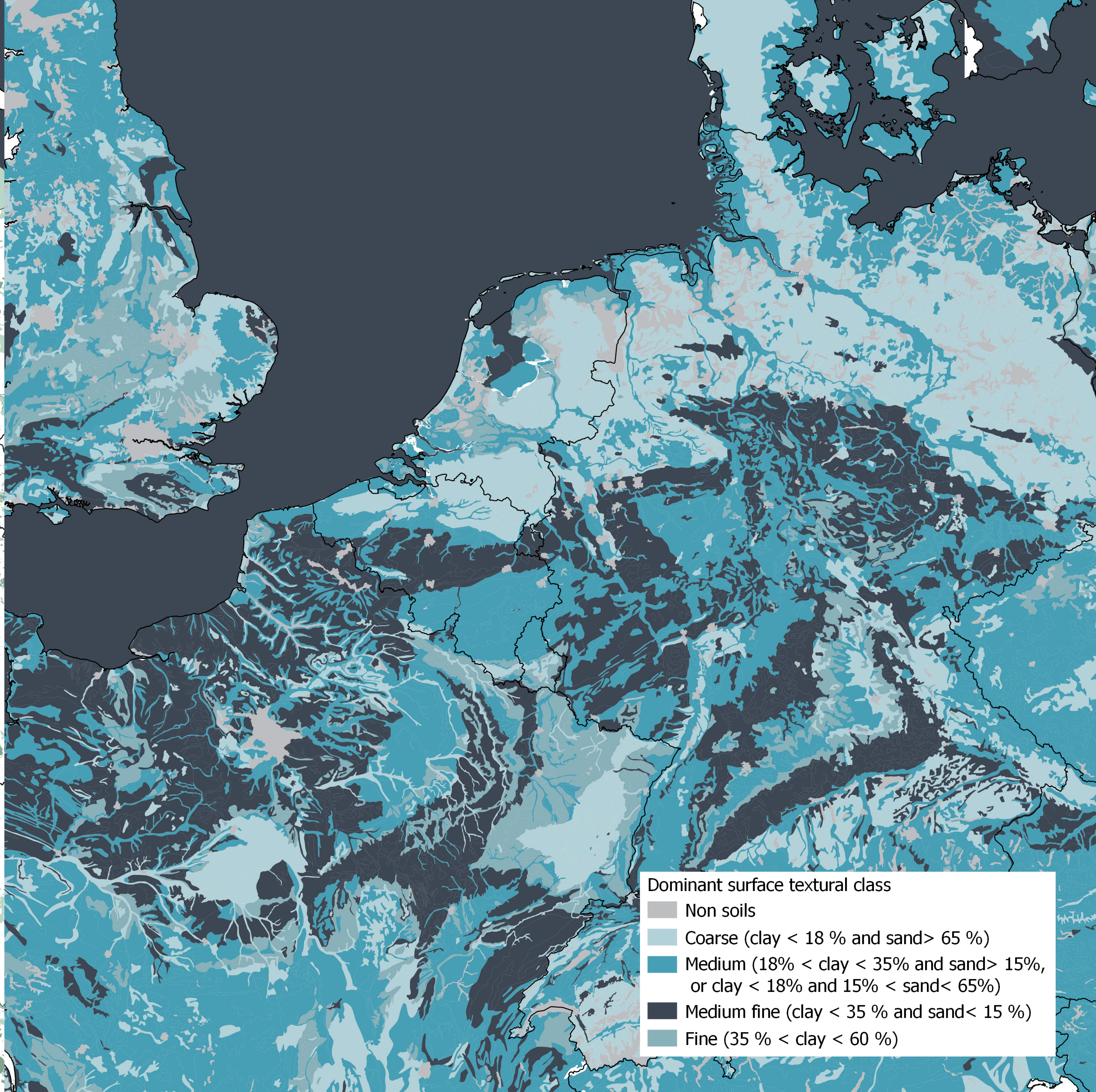
Maps

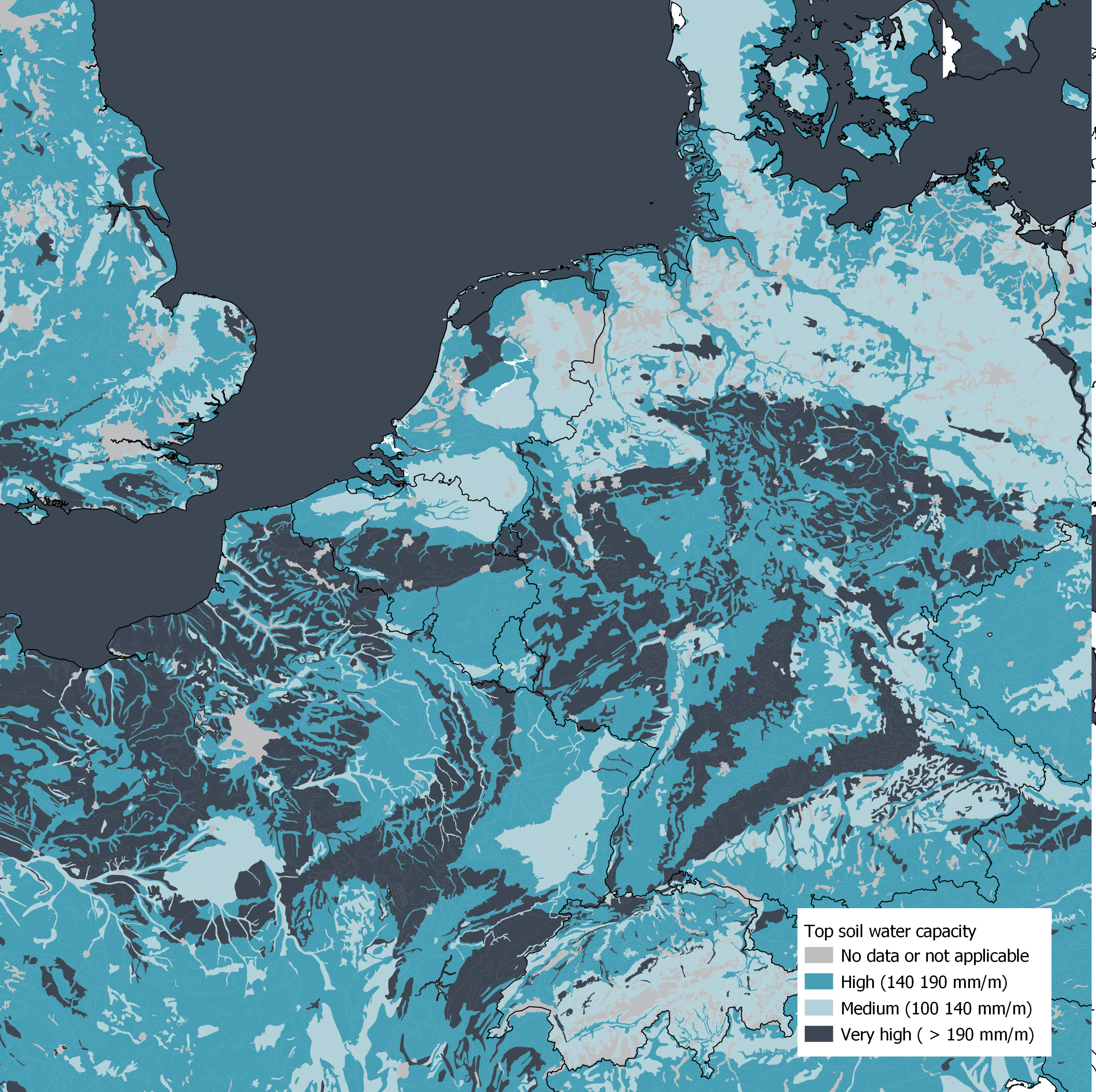
Following pages contain the maps that were used for the vision of North-West Europe, the strategy for South-Holland and the Zoom-ins on the harbour of Rotterdam and the Krimpenerwaard Polder.


River Flood Risk
River Flood Risk Area (occurrence of once every 100 years)

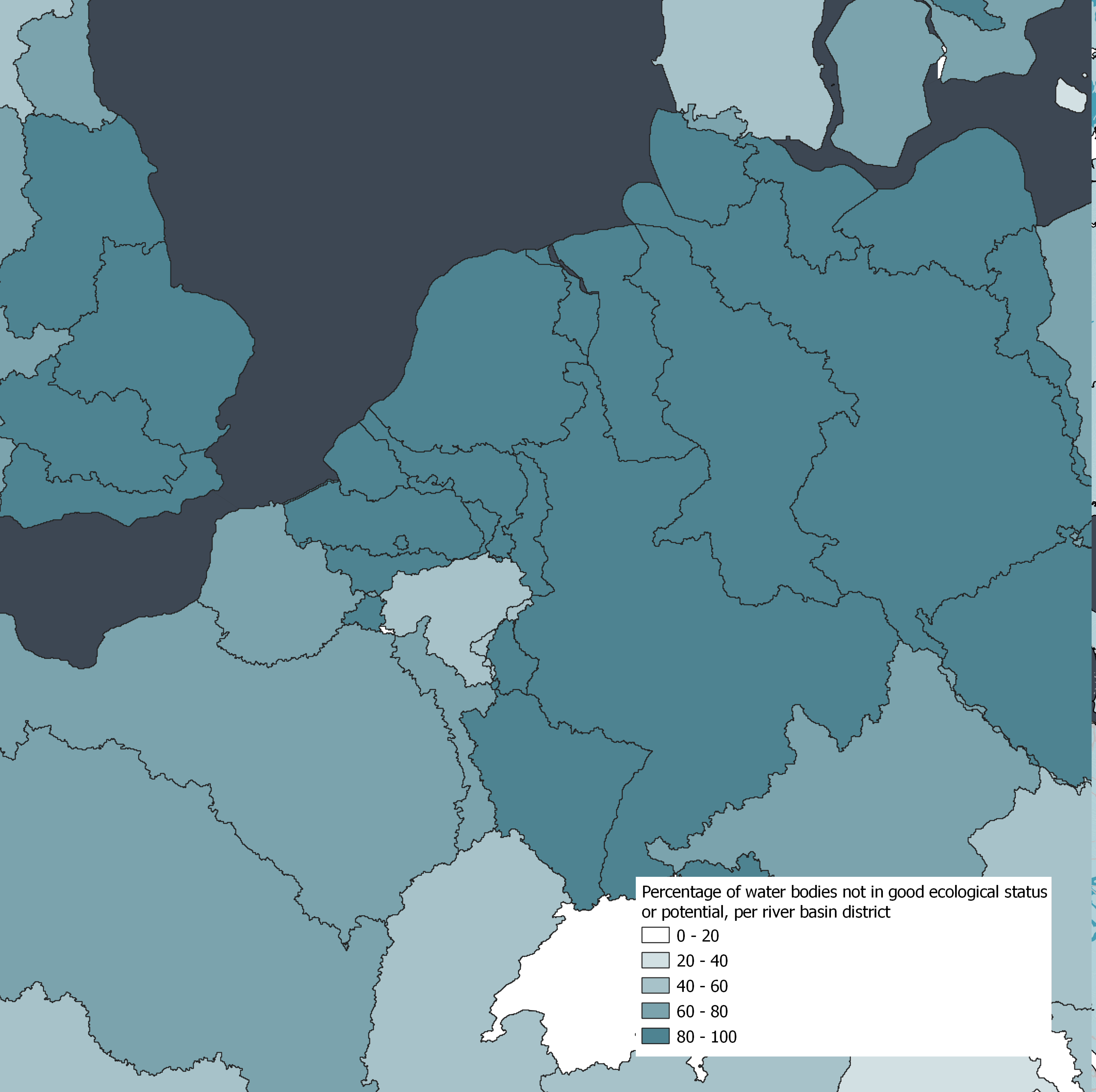

CO2 emissions across NW Europe
(t CO2)
0 - 2500
2500 - 5000
5000 - 10000
10000 - 20000
20000 - 40000
40000 - 80000
80000 - 160000
160000 - 320000
320000 - 640000
640000 - 1280000
1280000 - 2560000
2560000 - 5120000
5120000 - 10240000
10240000 - 20480000
20480000 - 32000000


Natura2000 (ecological network of protected areas)
SPAs (Special Protection Areas, sites designated under the Bird's Directive)
SCIs and SACs (Sites of Community Importance and Special Areas of Conservation, sites designated under the Habitats Directive)

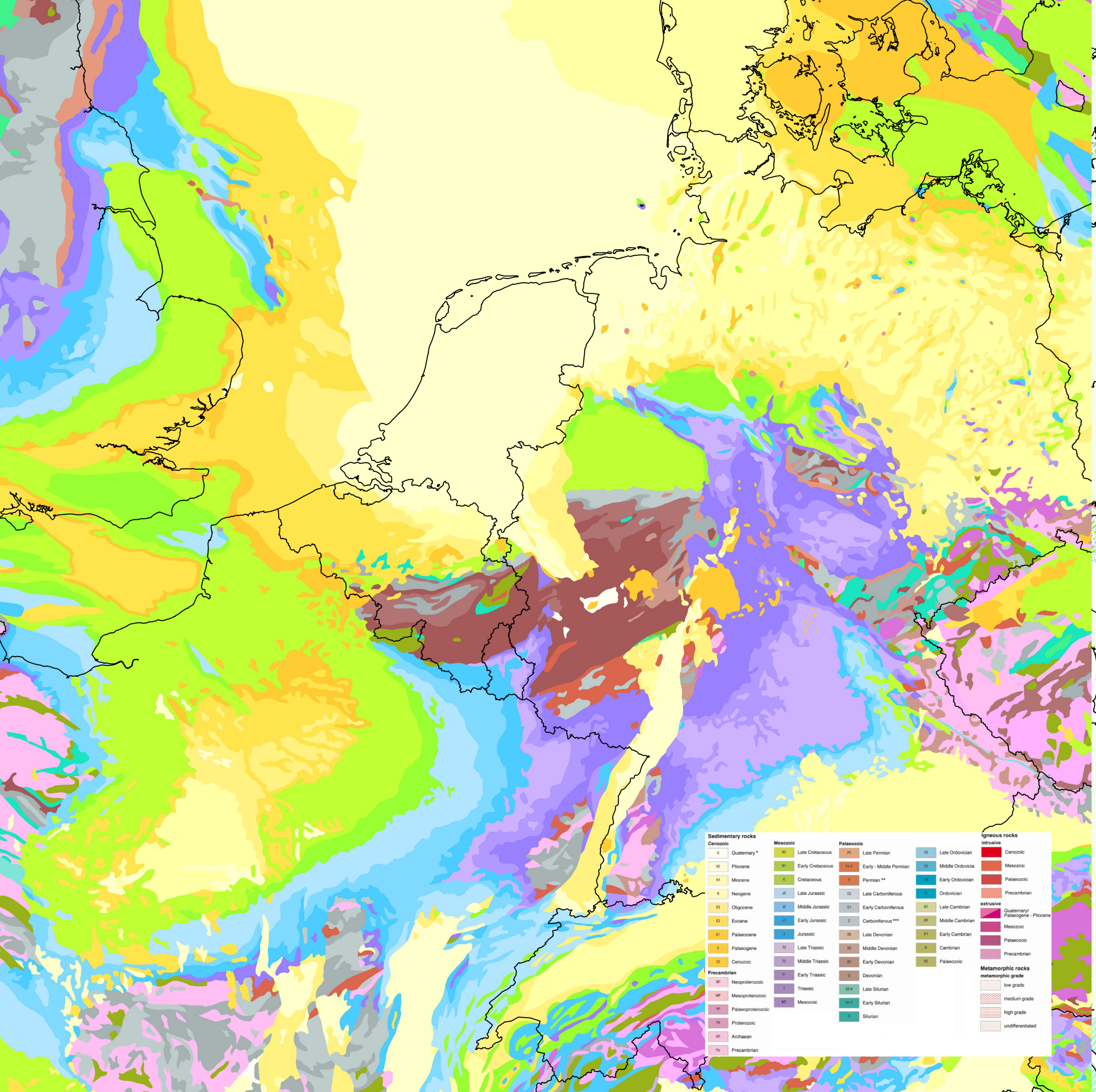
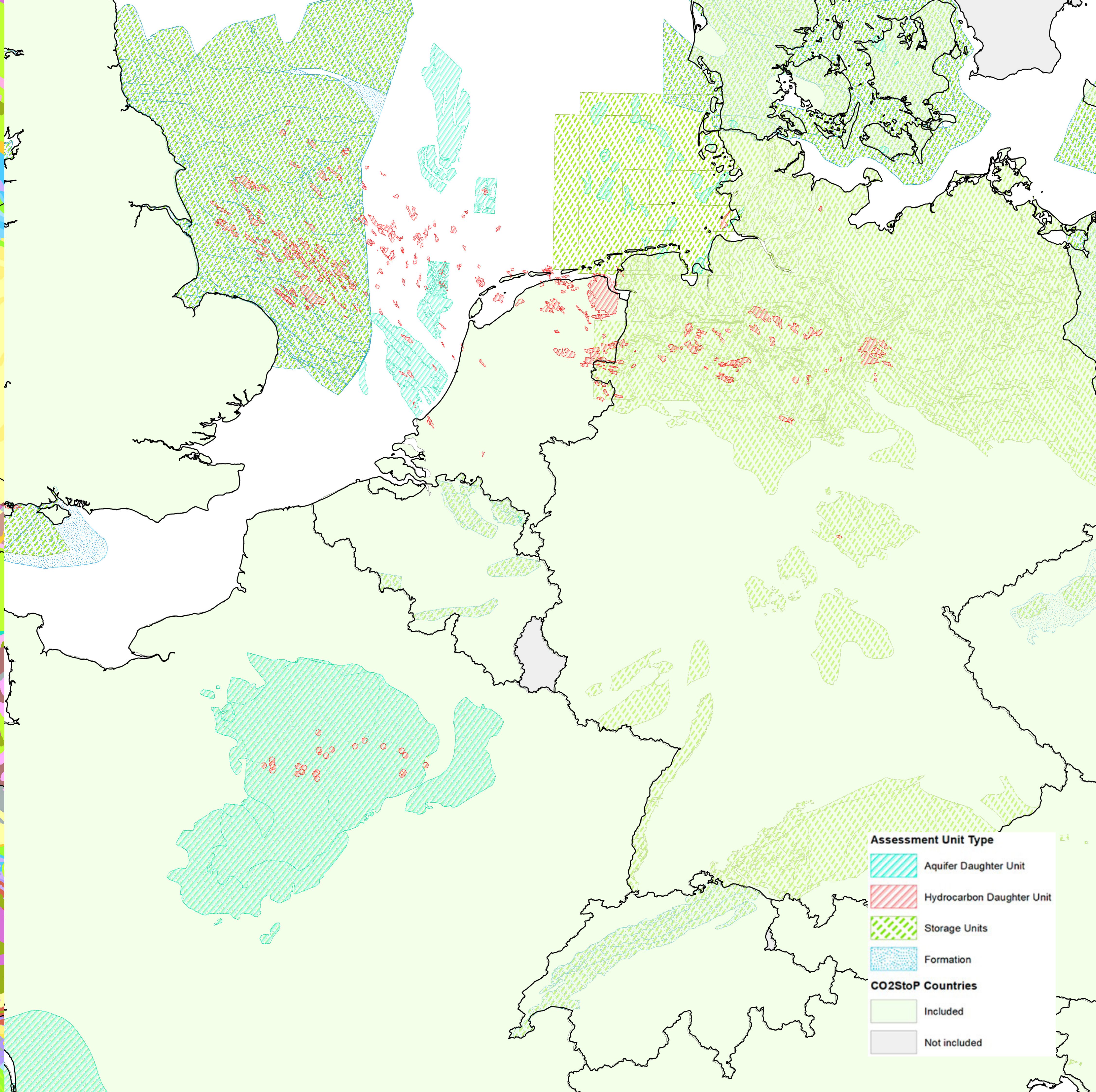

Dominant surface textural class
Non soils
Coarse (clay < 18 % and sand> 65 %)
Medium (18% < clay < 35% and sand> 15%, or clay < 18% and 15% < sand< 65%)
Medium fine (clay < 35 % and sand< 15 %)
Fine (35 % < clay < 60 %)

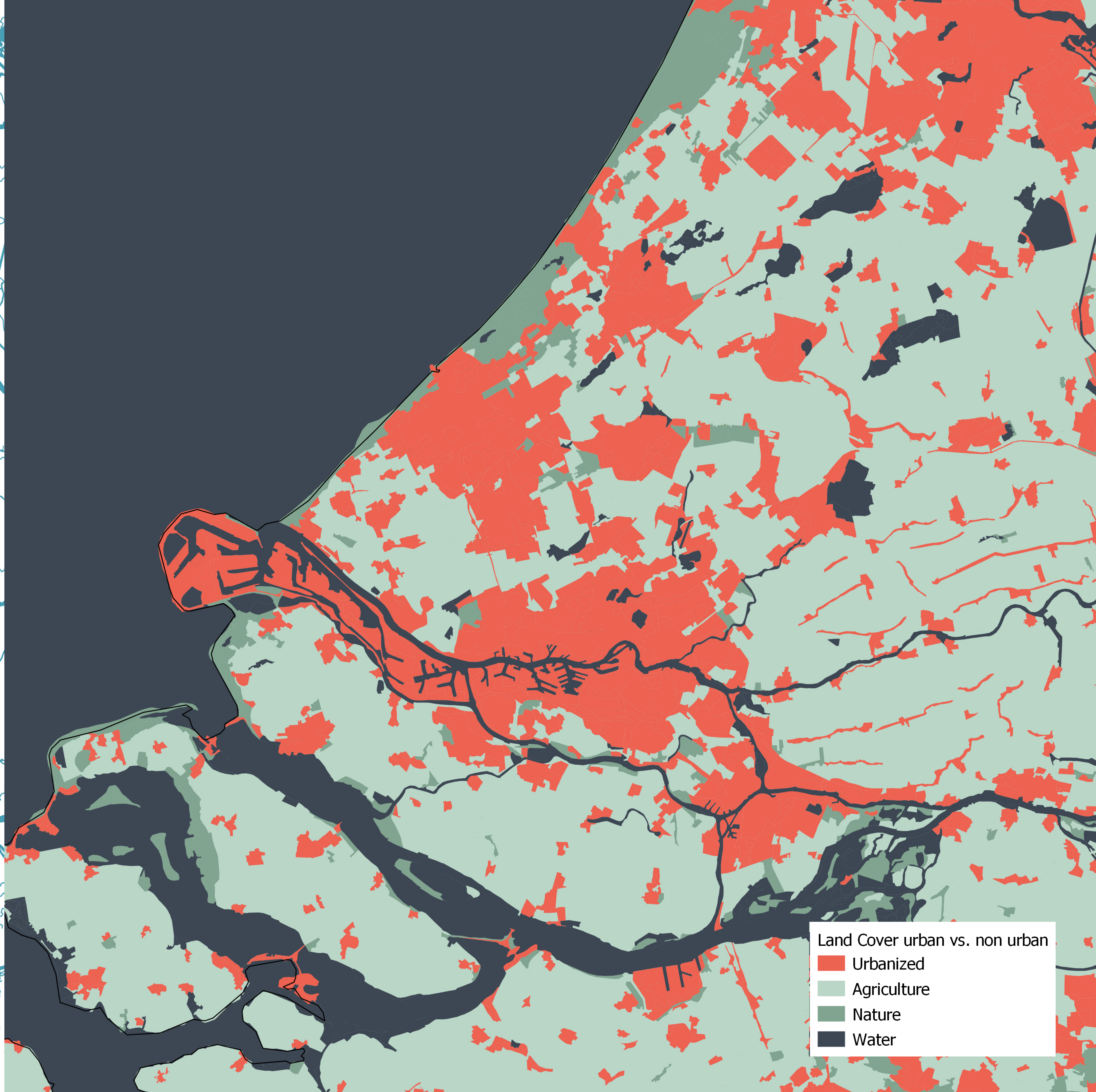

Top soil water capacity
No data or not applicable
High (140 190 mm/m)
Medium (100 140 mm/m)
Very high (> 190 mm/m)

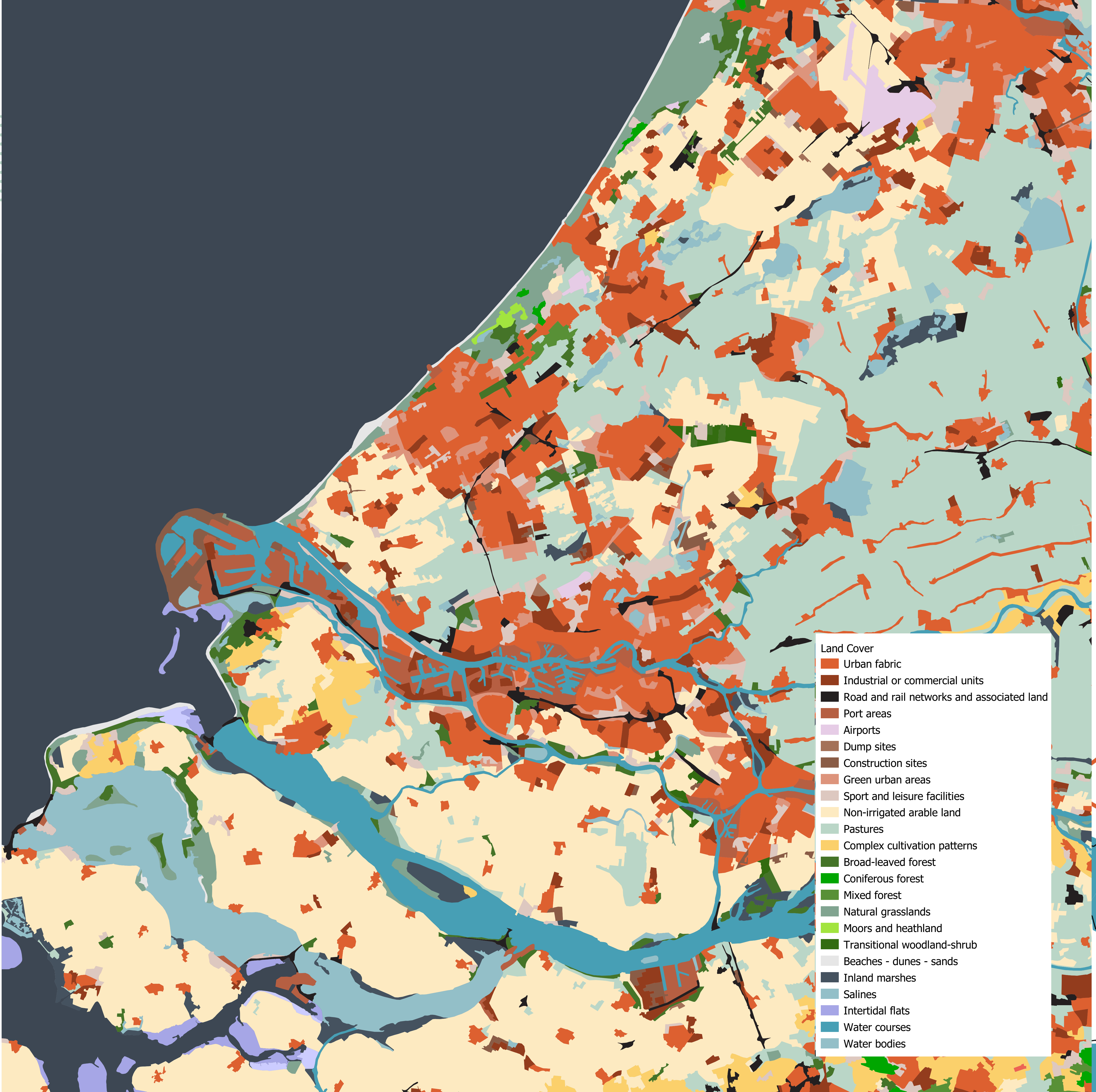

Existing wetlands
Wetlands


Percentage of water bodies not in good ecological status or potential, per river basin district
0 - 20
20 - 40
40 - 60
60 - 80
80 - 100

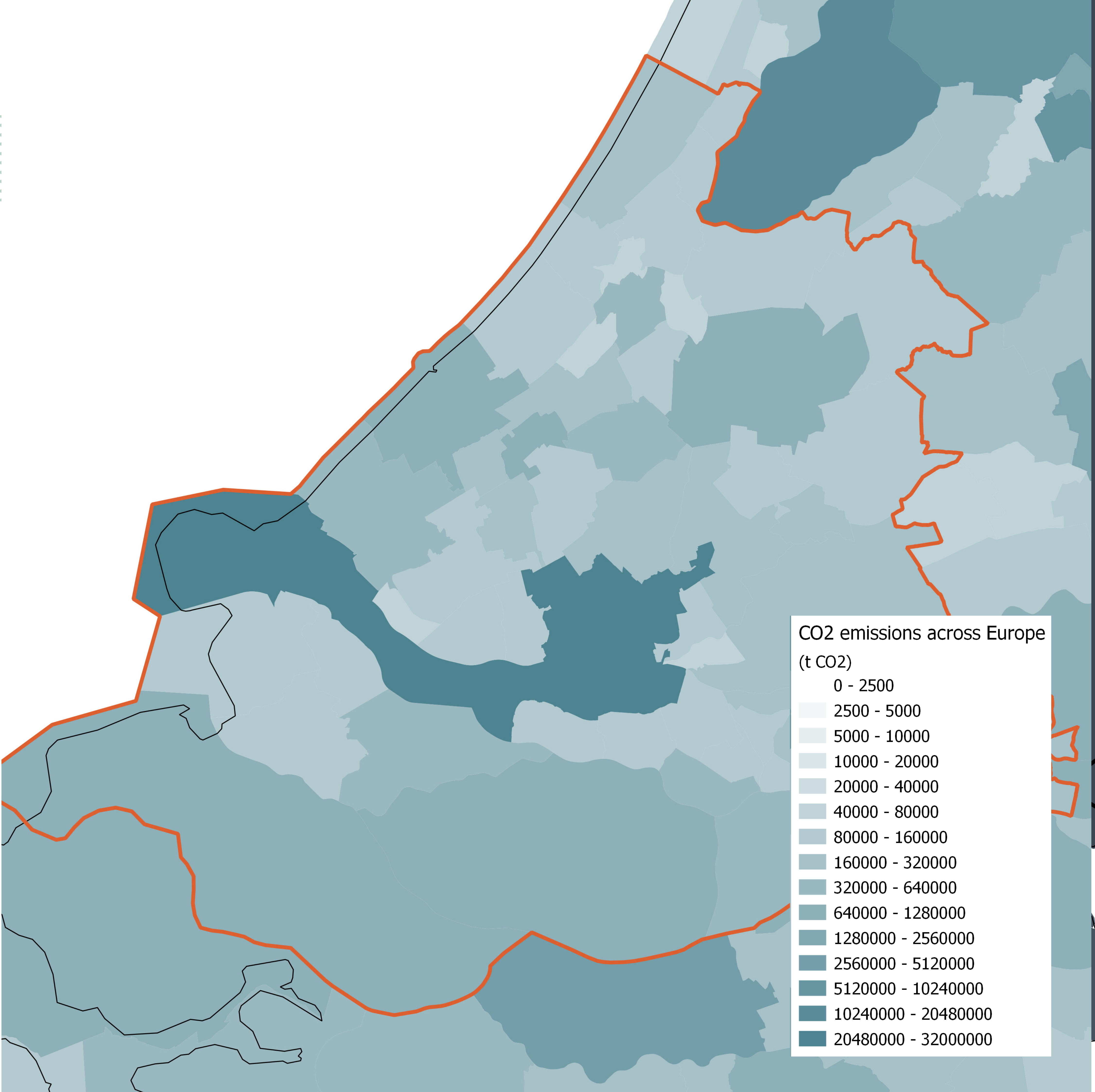

Heights in Landscape
No information
Lowlands & intermediate
Uplands & mountains

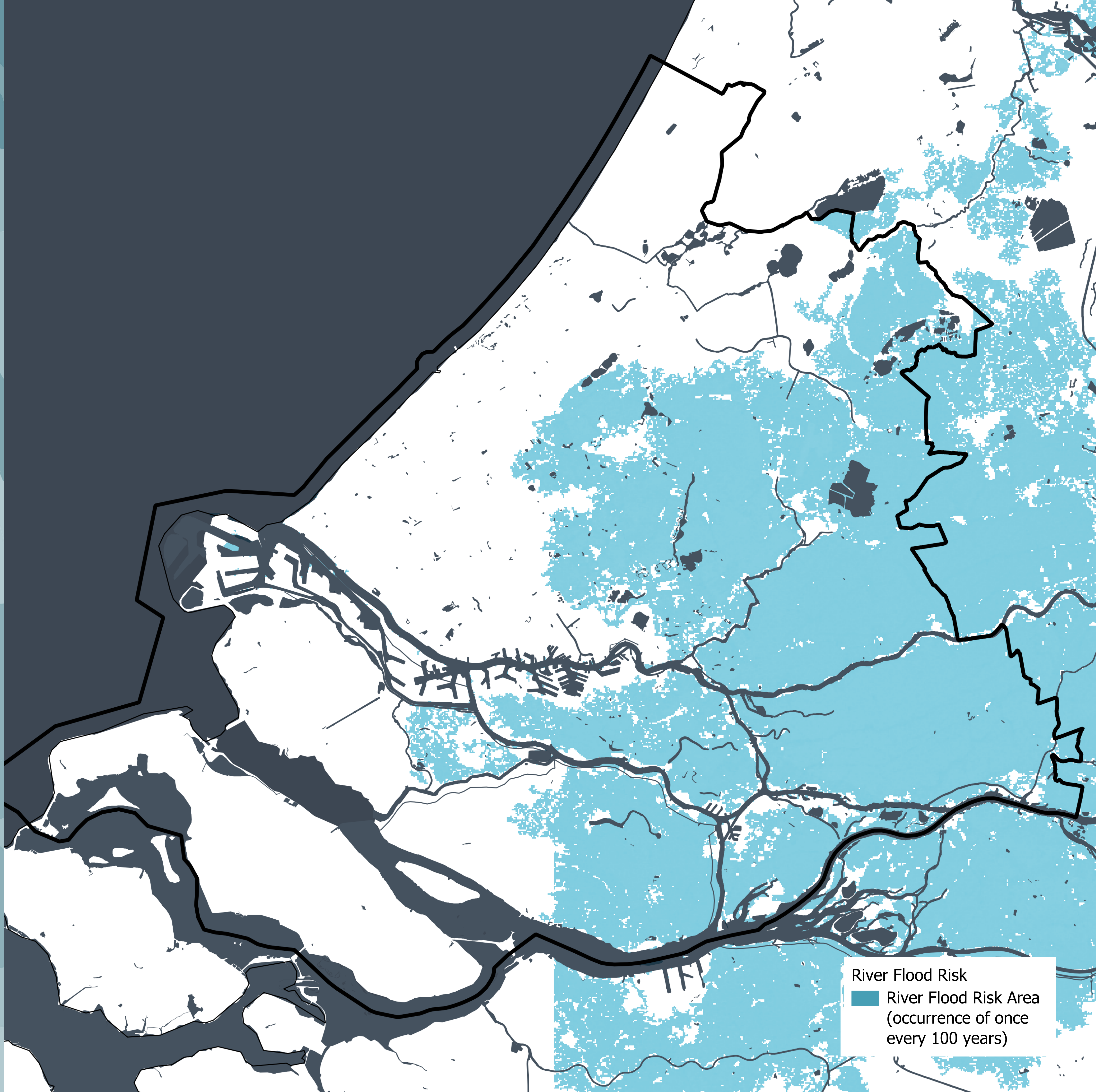

Sedimentary rocks
Cenozoic
Q Quaternary *
N2 Pliocene
N1 Miocene
N Neogene
E3 Oligocene
E2 Eocene
E1 Palaeocene
E Palaeogene
CZ Cenozoic
Precambrian
NP Neoproterozoic
MP Mesoproterozoic
PP Palaeoproterozoic
PR Proterozoic
AR Archaean
Precambrian
Mesozoic
K2 Late Cretaceous
K1 Early Cretaceous
K Cretaceous
J3 Late Jurassic
J2 Middle Jurassic
J1 Early Jurassic
J Jurassic
T3 Late Triassic
T2 Middle Triassic
T1 Early Triassic
T Triassic
MZ Mesozoic
Palaeozoic
P3 Late Permian
P1-2 Early - Middle Permian
P Permian **
C2 Late Carboniferous
C1 Early Carboniferous
C Carboniferous ***
D3 Late Devonian
D2 Middle Devonian
D1 Early Devonian
D Devonian
S3-4 Late Silurian
S1-2 Early Silurian
S Silurian
O3 Late Ordovician
O2 Middle Ordovicia
O1 Early Ordovician
O Ordovician
Late Cambrian
Middle Cambrian
Early Cambrian
Cambrian
PZ Palaeozoic
Igneous rocks
intrusive
Cenozoic
Mesozoic
Palaeozoic
Precambrian
extrusive
Quaternary/ Palaeogene - Pliocene
Mesozoic
Palaeozoic
Precambrian
Metamorphic rocks
metamorphic grade
low grade
medium grade
high grade
undifferentiated

Assessment Unit Type
Aquifer Daughter Unit
Hydrocarbon Daughter Unit
Storage Units
Formation
CO2StoP Countries
Included
Not included


Land Cover urban vs. non urban
Urbanized
Agriculture
Nature
Water


Land Cover
Urban fabric
Industrial or commercial units
Road and rail networks and associated land
Port areas
Airports
Dump sites
Construction sites
Green urban areas
Sport and leisure facilities
Non-irrigated arable land
Pastures
Complex cultivation patterns
Broad-leaved forest
Coniferous forest
Mixed forest
Natural grasslands
Moors and heathland
Transitional woodland-shrub
Beaches - dunes - sands
Inland marshes
Salines
Intertidal flats
Water courses
Water bodies


Top soil water capacity
No data or not applicable
High (140 190 mm/m)
Medium (100 140 mm/m)
Very high (> 190 mm/m)


CO2 emissions across Europe
(t CO2)
0 - 2500
2500 - 5000
5000 - 10000
10000 - 20000
20000 - 40000
40000 - 80000
80000 - 160000
160000 - 320000
320000 - 640000
640000 - 1280000
1280000 - 2560000
2560000 - 5120000
5120000 - 10240000
10240000 - 20480000
20480000 - 32000000


River Flood Risk
River Flood Risk Area
(occurrence of once
every 100 years)


Land Cover detailled CLC2018
Urban fabric
Industrial or commercial uni
Road and rail networks and associated land
Port areas
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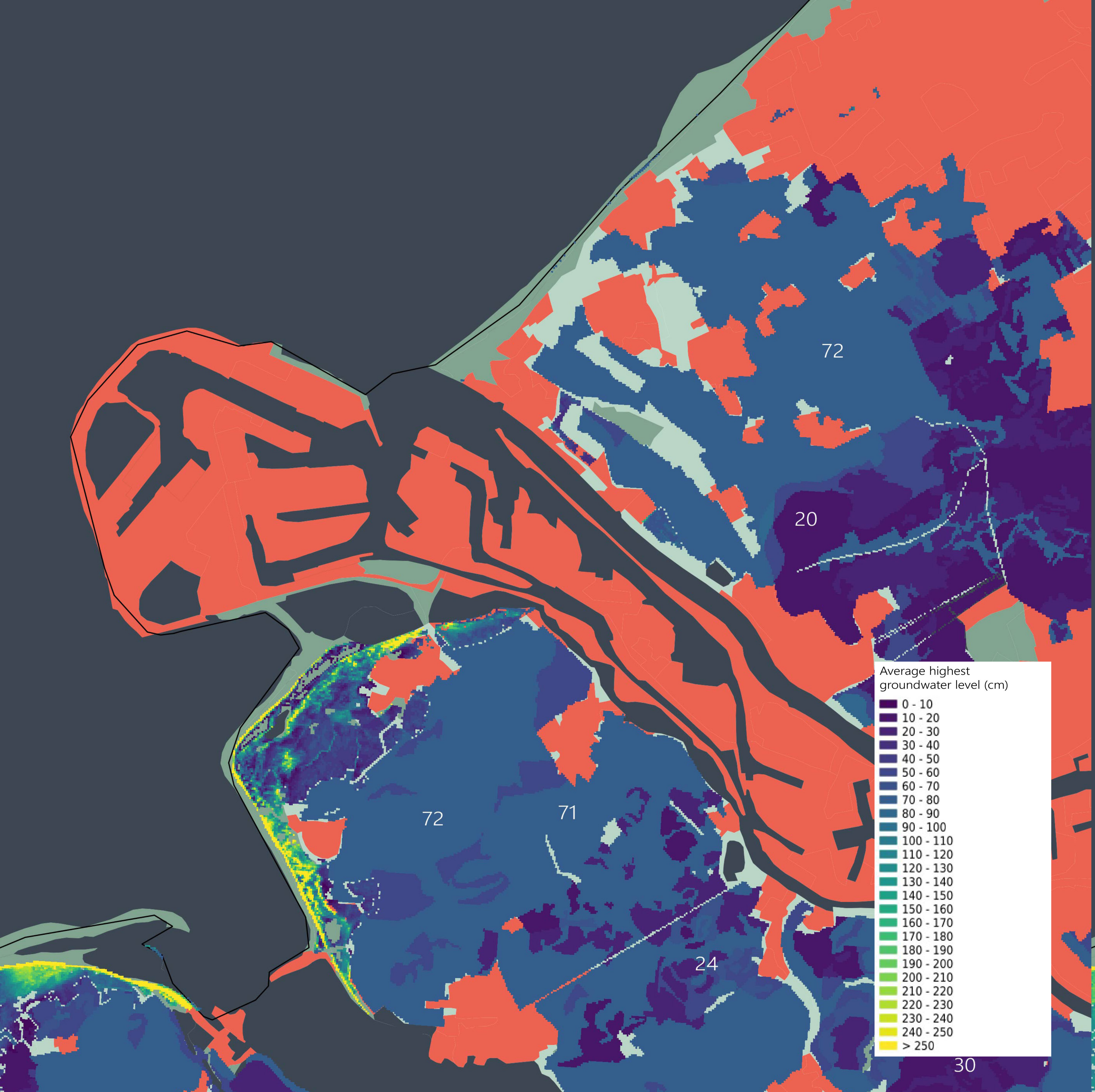
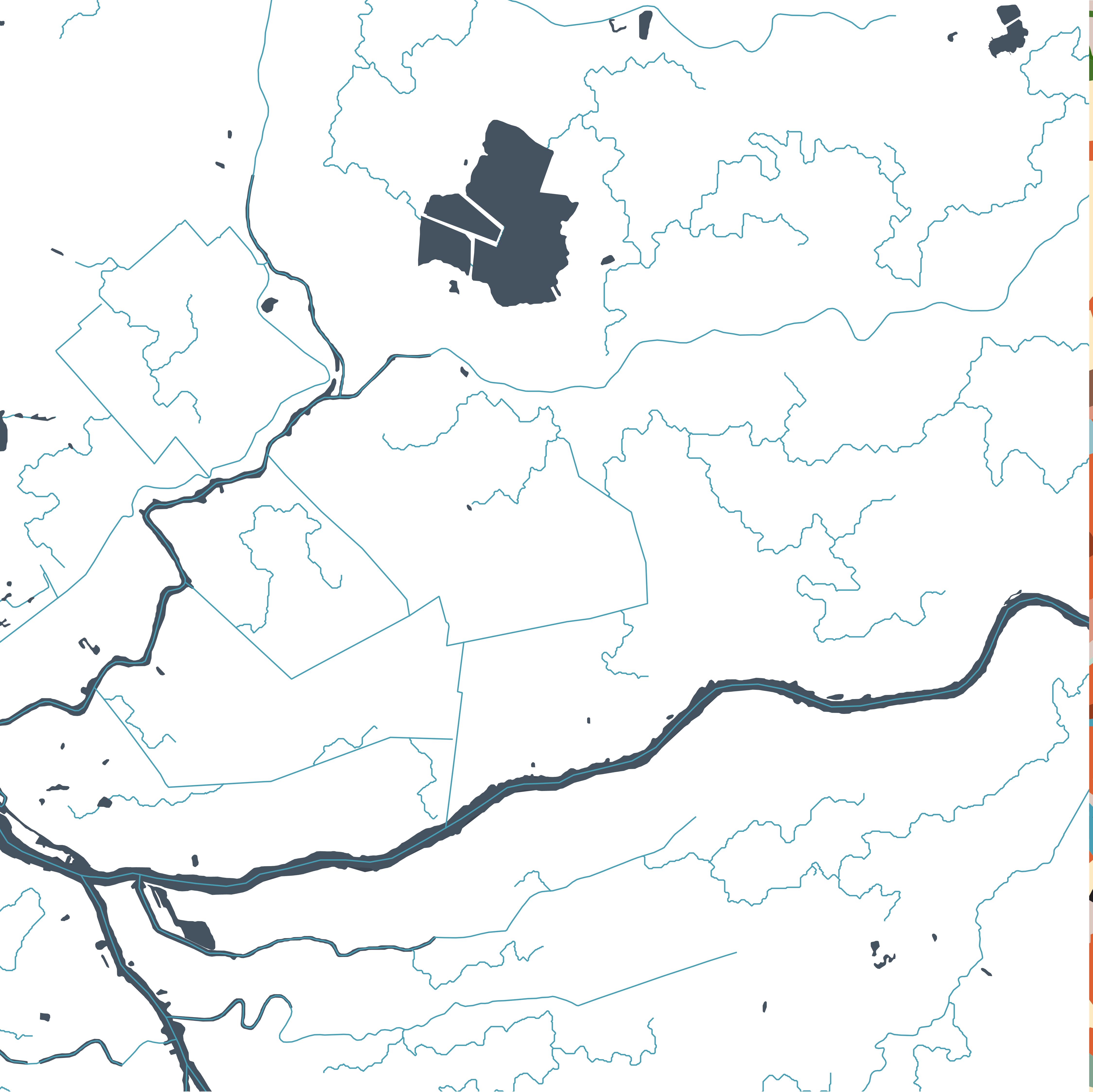
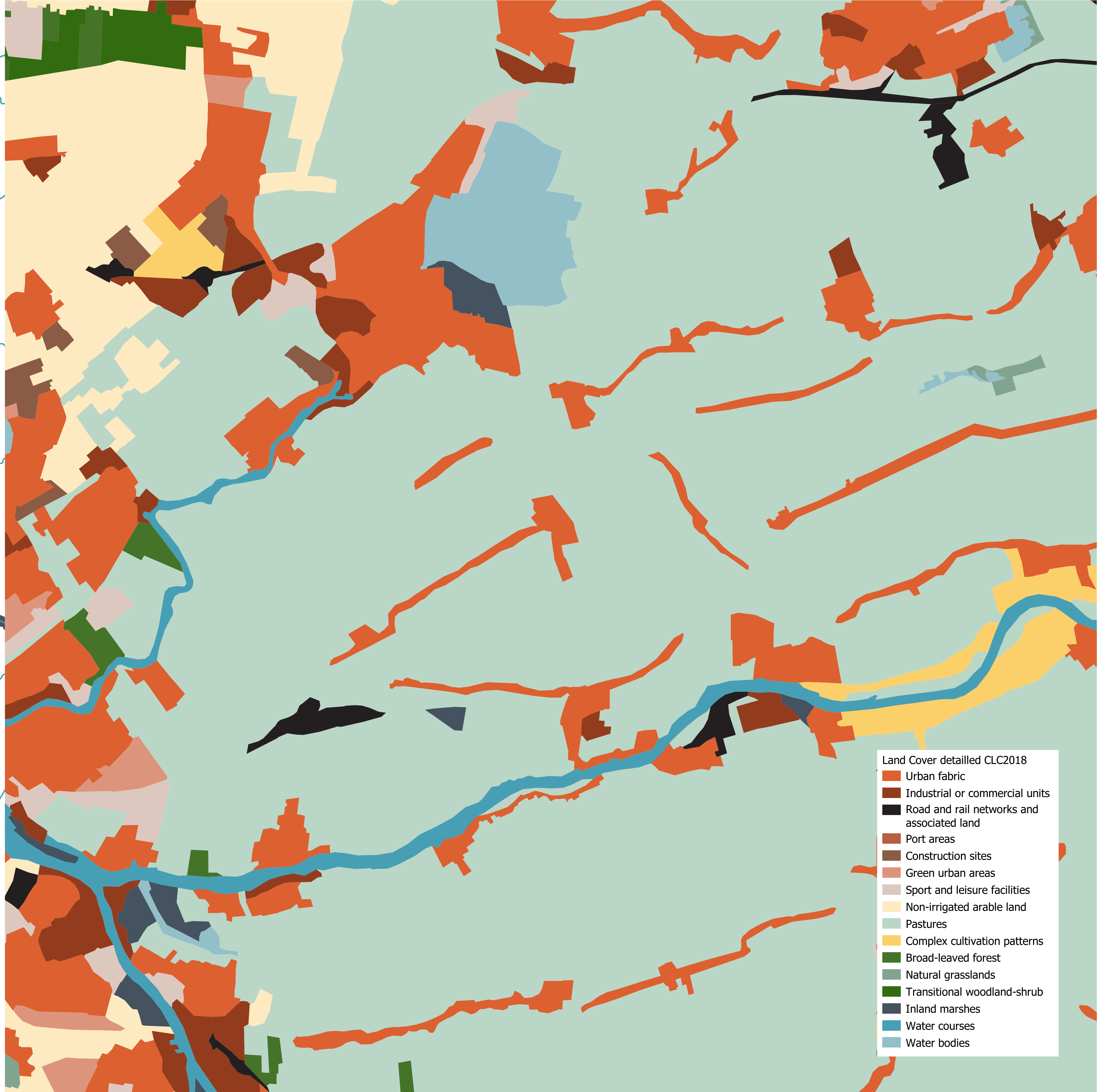


72
20
72
71
24
30
Average highest groundwater level (cm)
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
200 - 210
210 - 220
220 - 230
230 - 240
240 - 250
> 250

120
123
120
146
116
81
Average lowest groundwater level (cm)
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
200 - 210
210 - 220
220 - 230
230 - 240
240 - 250
> 250

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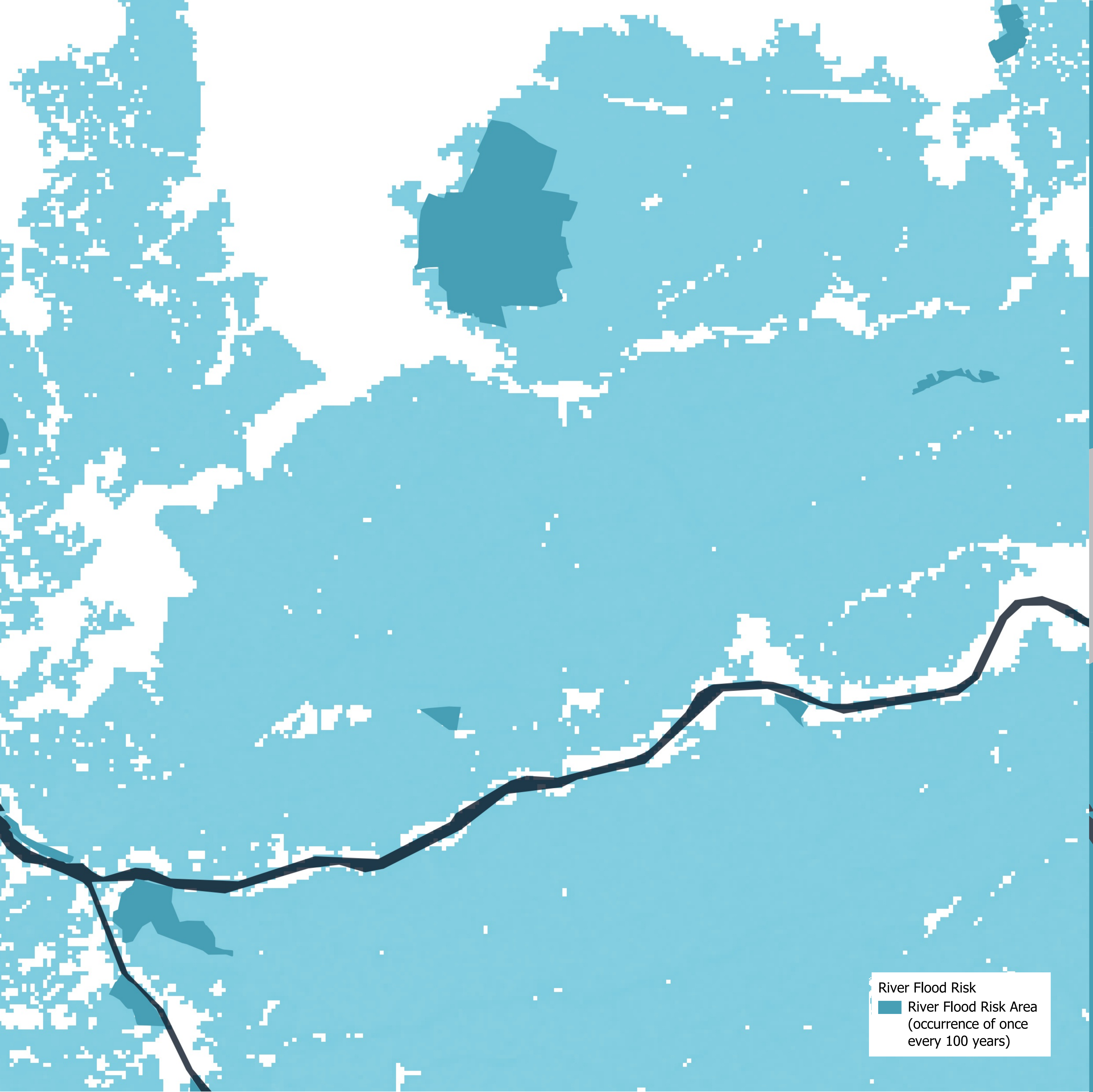
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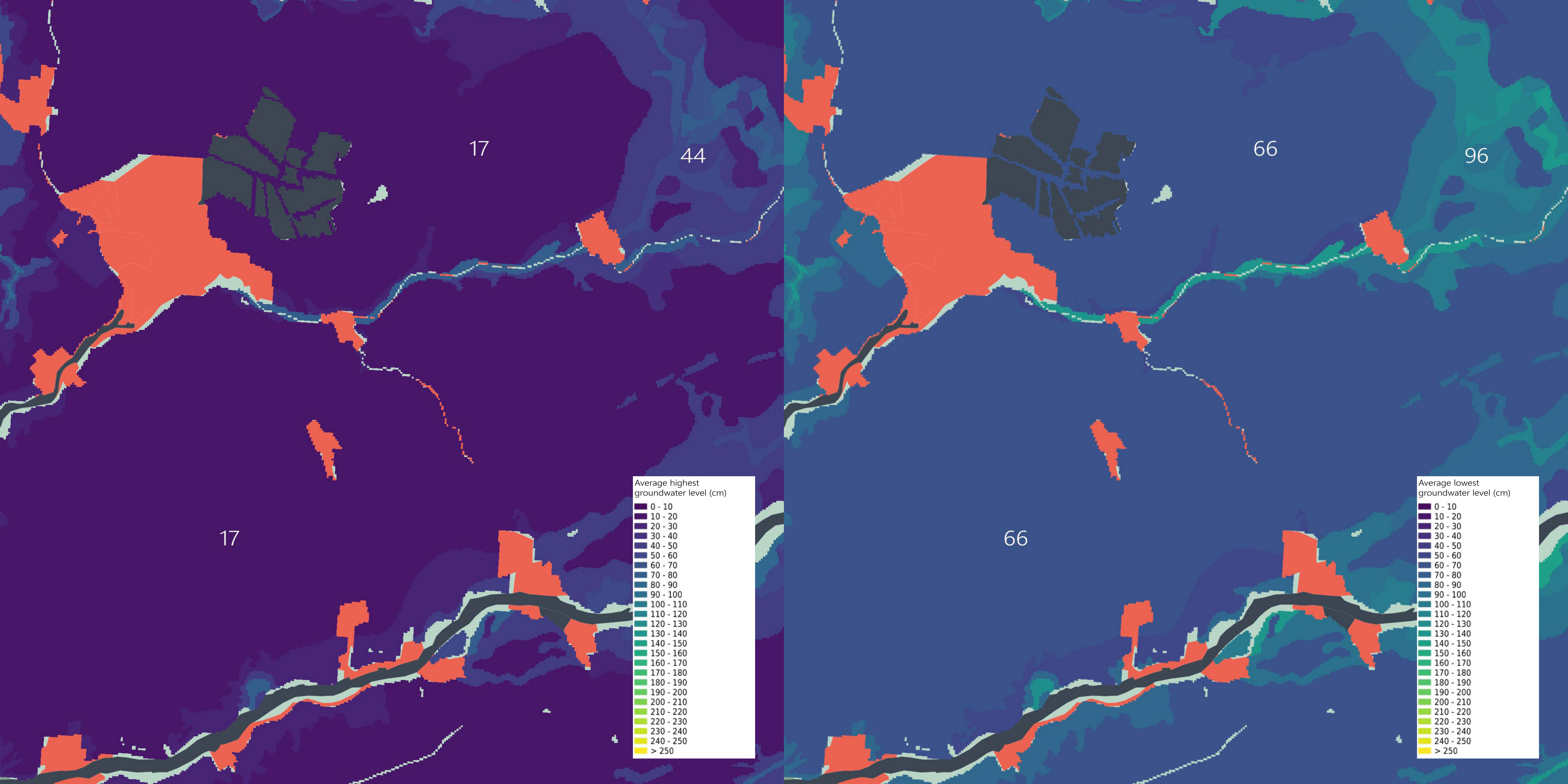
17
44
17
Average highest groundwater level (cm)
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
200 - 210
210 - 220
220 - 230
230 - 240
240 - 250
> 250
66
96
66
Average lowest groundwater level (cm)
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
200 - 210
210 - 220
220 - 230
230 - 240
240 - 250
> 250