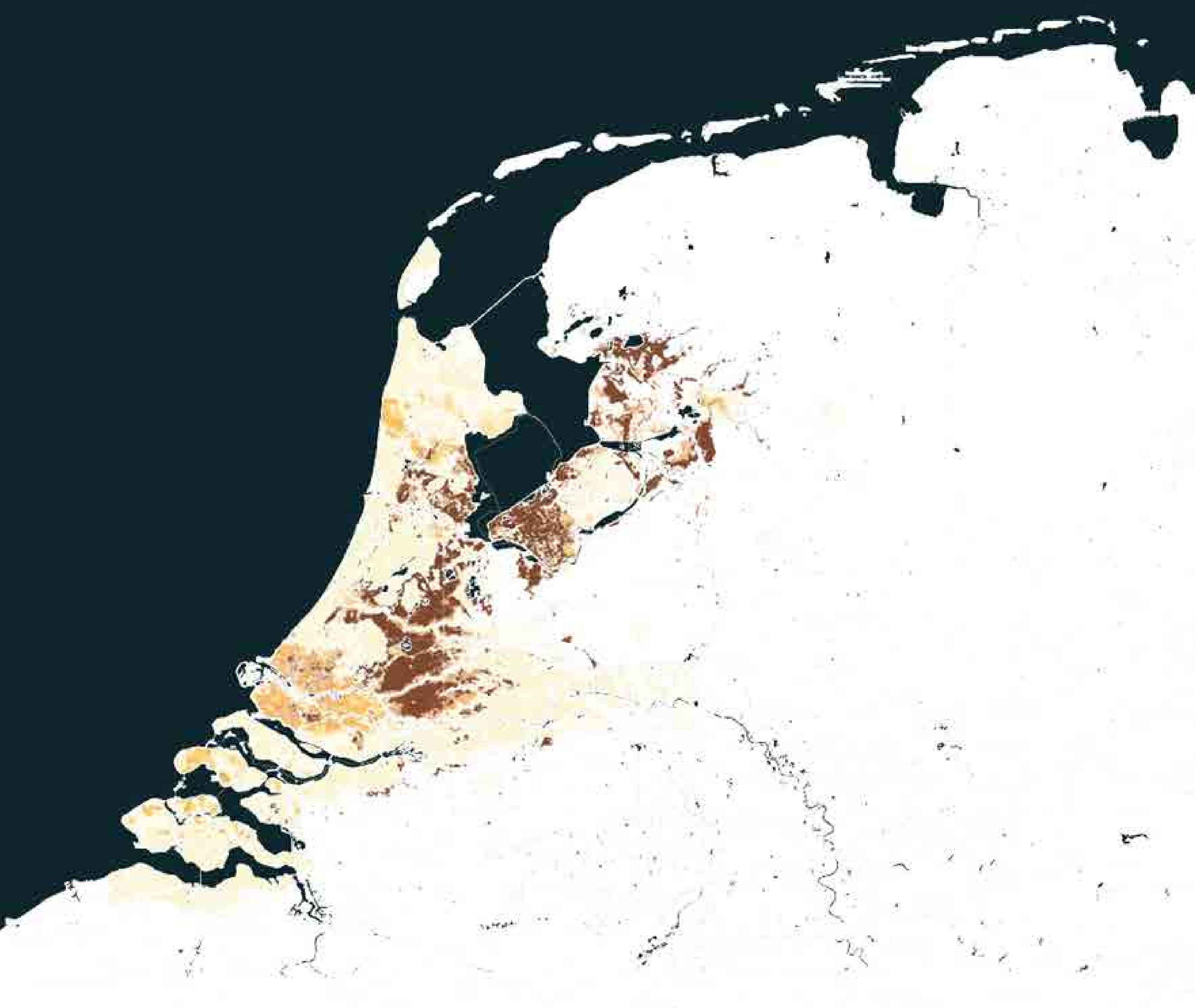
DROWNING DELTAS

A STRATEGICAL SPATIAL APPROACH TO SOIL SUBSIDENCE IN DELTA REGIONS



COLOPHON

Drowning Deltas:
A strategical spatial approach to the effects of soil subsidence in delta regions

Graduation project
P5 Report

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KEYWORDS

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ABSTRACT

Delta cities all around the world are under pressure from different forms of climate change effects. Soil subsidence as a result of peat oxidation, and anthropogenic loading of the soil. The soil in many of the heavily urbanised deltas around the world is subsiding faster than the see level is rising as a result of climate change. Few people are however aware of the problems that soil subsidence can cause and the threat that it poses for the cities and their hinterlands, in Delta regions. Soil subsidence has been going on for such a long time that few people seem to realise that it can pose a threat in the nearby future. Delfland is a part of the Dutch delta that has been polderized and it has been subsiding ever since these polders where created.

The purpose of this thesis is to research what the spatial and strategical requirements are, to make it possible for Delfland to deal with soil subsidence, and its effects within the region. There is however no certainty about the future impact of soil subsidence or the which actions are required to counter soil subsidence and its effects. The dynamic adaptive policy pathways (DAPP) method is used to deal with this uncertainty. This method has been developed to be able to plan for an unknown future. This is done though the development of dynamic pathways that function as a plan that can change, depending on future developments. This makes it possible to deal with uncertainty within the soil subsidence problem field, as well as, external uncertainties. For example uncertainties from climate change, economical changes, or political changes.

The strategical impact, of dealing with soil subsidence and its effects through the use of DAPP, is reviewed by taking a closer look at how decisions are made within the DAPP method, and how these same decisions could be made on a regional scale for all of Delfland. This requires knowledge of the possible stakeholders and their role and influence within Delfland and in relation to soil subsidence and its effects.
The spatial impact, of dealing with soil subsidence and its effects through the use of DAPP, is reviewed by taking a closer look at the pathways that could be chosen when using the DAPP method. Spatial reflections of different pathways, on the Delfland region, offer an insight in the possible spatial outcomes of different pathways and the actions that are taken within these pathways.

PREFACE

This report is the embodiment of a graduation thesis for the master track of urbanism at the faculty of architecture and the built environment at the TU Delft. This research is done within the urban metabolism research studio. Marjolein Pijpers-van Esch is one of the mentors within this gradation studio, and therefore the first mentor that is supervising the research. This is done together with Arie Romein from the Chair of Spatial planning and strategy.

this project aims to create an insight in the spatial impact of dealing with soil subsidence and its effects and the decision-making requirements that come with it. This is research by using parts of the DAPP method to be able to take uncertainty concerning the soil subsidence problem field into account. The design part consist of a projections of different possible pathway choices on Delfland, to see the different spatial impacts that pathways choices can have on the whole of Delfland, as well as, the a more local scale. The theory paper that is part a mandatory part of the research can be found in the addendum of this report.

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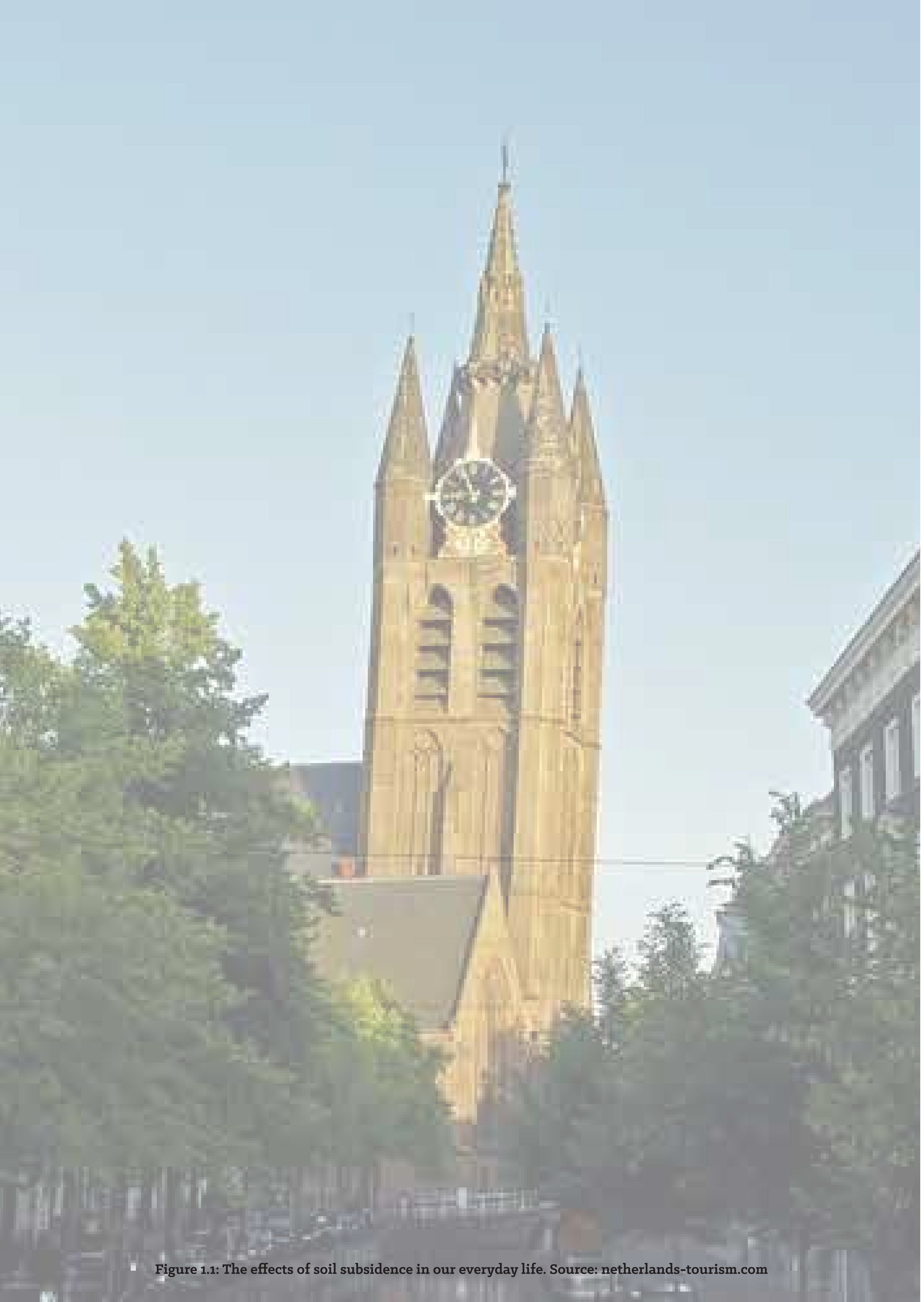


Figure 1.1: The effects of soil subsidence in our everyday life. Source: netherlands-tourism.com

1. Living in a sinking city

Introduction

The Dutch have built polders in the Netherlands to keep their lands from flooding and to be able to control the water level within the different parts of the country and prevent the Dutch delta from flooding. The techniques to develop the polders have been spread and applied all around the world, and polders and similar system can, therefore, be found all around the globe. There is, however, a downside to the creation of polders and the regulation of the groundwater level within those polders. This downside is the subsidence of the soil within those polders as the result of peat oxidation. The peatlands in the polders are pumped dry, which allows peat, that was previously covered by water, to react with oxygen in the air. The reaction with oxygen results in the transformation of solid organic materials into methane and carbon dioxide gas. The soil will lose a big part of its mass, which results in shrinkage of the soil. This shrinkage is called soil subsidence. This soil subsidence problem can be experienced in our everyday live, especially in a city like Delft that is built on soil that is slowly but continuously subsiding. This can be seen when walking through the city centre, some of the old houses have structural damages because of the changes in the soil. A good example of soil subsidence can be found in the city centre of Delft. The old church in the centre of the city that is built on a very weak soil. The mass of the church and the subsidence in the soil have caused the church to hang forward over the canal in front of it. Very few people are, however, aware of this problem, even though, the soils in the Netherlands have been subsiding faster than that the sea-level is rising because of climate change. Yet people are much more aware of the threat that the sea-level rise poses. This, lack of awareness for soil subsidence, is also one of the reasons that soil subsidence has not been getting enough attention when it comes to preparing our cities for the effects that soil subsidence can have. That is why this thesis is focused on researching and reviewing the impact that soil subsidence could have on a region like the Delfland. What are the effects on a large region like this? How could a region cope with the effects? And what role can the different stakeholders play? All of these questions will be reviewed within this Thesis.

2. The Threat Of Subsidence To Cities And Their Hinterlands

Problem field

Large delta cities all around the world are built on a soil that has slowly but continuously been subsiding over time. The subsidence in these larger delta regions is caused by different factors, such as the weight of the city, the soil conditions, the lowering of the groundwater table to benefit agriculture, and climate change effects. The soil subsidence results in water stress, structural damages, pollution and changes to the local environment and ecology (Willemse, 2017).

This chapter will give a better understanding of soil subsidence in these delta regions. This is done by first taking a look at what soil subsidence is, and what causes it. The second paragraph will describe the impact of soil subsidence. This is done by looking at the impact of soil subsidence on its surroundings as well as the reciprocal relation that soil subsidence has with some of its causes and effects. The reason for choosing Delfland as a research location is defined in the third paragraph. The chapter will conclude with a problem statement that gives a short overview the problems that play central role within this research.

2.1 The Causes Of Soil Subsidence

Subsidence is defined by the National Research Council (1991) as: "the sudden sinking or gradual downward settling of the ground's surface with little or no horizontal motion". This means that whether or not something is subsidence, is not defined by the pace or rate of the subsidence. Subsidence could therefore occur in many different forms and intensities. It can be caused by natural causes as well as by human interventions (National Research Council, 1991). The largest natural causes for soil subsidence are: tectonic movement and sediment compaction. Subsidence caused by human interventions come in different forms and intensities. Extraction of oil, coal, gas, salt and groundwater can lead to subsidence in the deeper soil layers. This form of subsidence can for example be found Groningen in the north of the Netherlands where gas is extracted from deep in the underground.

The subsidence in the Delta regions around the globe are for the largest part caused interventions in the top soil layers. Figure 2.1 shows the areas all around the globe that are threatened by subsidence at this moment or in the future. The subsidence in these delta regions is for the largest part the result of shrinkage of organic materials in the top soil layers. This research will focus in this form of subsidence, since it is a problem in all the large delta cities around the globe (Figure 2.1). Most of these cities are growing fast and they will continue to do so over the next decades. This means that, this form of, subsidence in these areas could have huge effects on human life all over the world. (Meyer & Nijhuis, 2013). The shrinkage is caused by anthropogenic loading, or by extraction from these organic soils. Anthropogenic loading is the result of heavy urbanisation on top of the weaker soils, which adds a lot of extra weight and, thus, pressure on to the soil. Water is extracted from the soil to benefit construction or agriculture, but also as a result of long periods of drought that are caused by climate change. The weaker soils in the delta regions are for a large part made up out of clay and peat.

The peatlands consist of organic materials that where stored in the peat during the Atlantic period, 9000 to 5000 years ago (Berendsen, 2004). These peatlands where originally found below the surface- or groundwater. The water prevented the peat from reacting with the oxygen in the air. The creation of polders has changed is situation. Much of the water is pumped out of the polders, which causes peat to dry out and react with the oxygen in the air. This causes oxidation, which, releases carbon dioxide and methane from the organic materials that where stored in the ground. Solid organic material are released from the soil in a gas form, which results in a loss of mass and therefore subsidence (Figure 2.2).

This process is very slow and was therefore not seen as a problem when it stated occurring after the first polders where constructed (van den Born et al., 2016).

The process of subsidence has been going on for a very long time with an ever increasing pace. The construction of larger buildings and cities has only further increased the pressure on the peat soils. This causes the, soft, peat to be pushed together even faster and the weight of the cities is therefore only enhancing the pace of soil subsidence. The fact that pumping out water causes a lot of subsidence might seem like easily reversible or at least stoppable process, this is, however, not the case. The polders that are pumped now filled with large cities and nature reservations. Keeping the polders from flooding has, therefore, become vital for the people and the ecology in the delta regions below sea level all around the globe. But there is another reason the continue pumping out the water, even in areas where only very few people live. This is often done for the benefit of agriculture. Many crops require a lower groundwater table to be able to grow efficiently. This clearly shows the conflict of interest when it comes to preventing soil subsidence and its consequences (Willemse, 2017).

Soil subsidence and peat oxidation are not only caused by interventions in or on the weak soils. Climate change plays a role within the subsidence problem as well. The changing climate on earth results in higher temperatures, heavier rainfall and longer periods of drought. The summers will become hotter and drier, and will therefore cause the evaporation of water in the top soil. This will further dry out the organic soils and cause oxidation. Stopping human interventions in and on top of weaker soils is impossible, but it would also not be enough to stop soil subsidence. climate change will continue to cause soil subsidence, unless climate change and its effects are dealt with(Freeman et al., 2002).

All these different causes together make soil subsidence a difficult to tackle issue that many cities are already facing, or they will be facing it in the future. Looking at just the causes of soil subsidence might therefore not be enough to be able to deal with it. That is why the next paragraph will take a closer look at the effects of soil subsidence and its reciprocal relation with its causes and effects.

2.2 The Effects Of Soil Subsidence

Soil subsidence causes problems all over urbanized deltas. The effects are, however, not only noticeable in the cities, that are built on these subsiding soils, but also in the landscapes surrounding these cities. The problems that soil subsidence causes for cities, agricultural areas and nature reserves can be very different and related to soil subsidence in different ways.

The type of subsidence of peatlands, on which this projects focusses, is caused by the oxidation of peat lands. The oxidation occurs when the groundwater level is lowered, to al level below the peat soils. Oxidation has a direct effect on th2e climate change, since a lot of carbon dioxide and methane gasses, that where stored in these peatlands, are released in to the air as a result. Soil subsidence is the source for: 5% of the world wide carbon dioxide production and 20% of the word wide methane productions (Girkin et al., 2018)

Another problem that soil subsidence causes is the shrinkage of the water buffer zone in the soil. The top layers of the soil are slowly but steadily subsiding. This means that the top of the soil is moving closer to the height of the groundwater table. This results in a lower water retention capacity for the soil, since the soil can only absorb water in the dry parts of the soil, that can be found above the groundwater table. A reduction of the water retention capacity results in more water nuisance, such as floodings, since water is no longer absorbed in to the soil.

This does not only cause problems during heavy rain showers, but also during periods of drought. Low retention capacity and low absorbance of water means that there is less water to evaporate during periods of drought. This causes the environment to dry out and it lowers the cooling capacity (Willemse, 2017). Drought has become a huge problem in the Netherlands over the last years, the negative effects as a result of drought during 2018's dry summer are still noticeable today.

Drought and floodings will cause problems wherever they occur, but the impact is especially big within the built environment. The buildings and pavement within the built environment cover a large part of the soil. It is more difficult, or sometimes even impossible, for the soil to absorb water when it is covered by buildings or pavement. The lack of green elements in the built environment reduce the water retention capacity even further, since plants and trees could absorb a lot of water as well. The urban environment is therefore more prone to floodings and drought. These floods result in flooded buildings, public spaces, infrastructure and tunnels but they could also result in the growth of mildew in houses or other buildings. This is could in the end pose a threat to the public health (van den Born et al., 2016). Drought within urban environments poses a risk to the public health as well, since the temperature in the cities will rise when there is less water to be vaporized. This results makes it difficult for people to cool down during longer periods of drought (Hoeven & Wandl, 2015). The evaporation of groundwater during long periods of drought will cause the groundwater table within the city to fluctuate. This fluctuation in the groundwater table poses a threat to wooden foundation poles, since these poles could start to decay when they get wet and dry out again.

Another negative effect of soil subsidence that can be found within the built environment is the settling of the soil. The sand soil below streets and other public spaces is settling as a result of soil subsidence in the weaker soils below the sand soils. This results in a height difference between buildings, that are built on foundation poles, and the streets. This requires streets to be raised and renewed every few years, to make sure that the difference in height, between buildings and streets, does not become a nuisance. The sand that is used to raise the streets and publics spaces will only further increase the weight that is put on top of the weak soils and thus will it only further enhance the subsidence in those areas. The settling of the soil will also result in damages to buildings and infrastructure that are founded on those soils, as can be seen in figure 2.3. The settling of the ground will also result in damages to underground infrastructures such as sewage pipes. This could result in filthy odours within the city or even in pollution of the soil and water (Willemse, 2017).

Subsidence would normally not occur in a natural landscape, because of the natural balance that is maintained by nature. The lowering of the groundwater table to counter soil subsidence does, however, not only effect the agricultural lands, but the nearby natural landscapes as well. The groundwater form these natural areas flows underground towards the areas where the ground water is lowered. The lowering of the groundwater table in agricultural lands does therefore not only lower the water table in these lands, but in the natural areas surrounding it as well. The natural peat areas will therefore dry out, which causes them to oxidise and subside. This means that the natural balance is disturbed and the plants and animals, that live in these natural areas, will have a smaller water buffer during the summer and they will experience more floods during rain showers. The oxidation does not only cause the soil to subside, it also releases organic material from the peat. These organic materials interconnect with, and release, heavy materials in the ground. These heavy materials will, as a result, contaminate the soil, groundwater and surface water all throughout these natural landscapes. Another cause of soil and water pollution is the salinization of the soil. This is also caused by the lowering of the groundwater table. Groundwater flows, like surface water, towards the lowest point. Lowering the groundwater table, does therefore result in water flowing from the surrounding lands towards the polders with the low groundwater table. Seawater could seep groundwater and flow towards the lower lands, which would then turn the fresh water groundwater in to salt water. This process has salinization of the groundwater, surface water and soil as a result. (Freeman et al., 2002).

Oxidation is not the only reason for water contamination in the natural landscapes. Contamination is also caused by the input of water from outside the water system. The water from outside the water systems is often required to counter soil subsidence and the drought that comes with it. The mineral ratios in the water from outside the system

Figure 2.1: Subsiding cities all around the globe. Image: by Author. Source: Deltares 2013

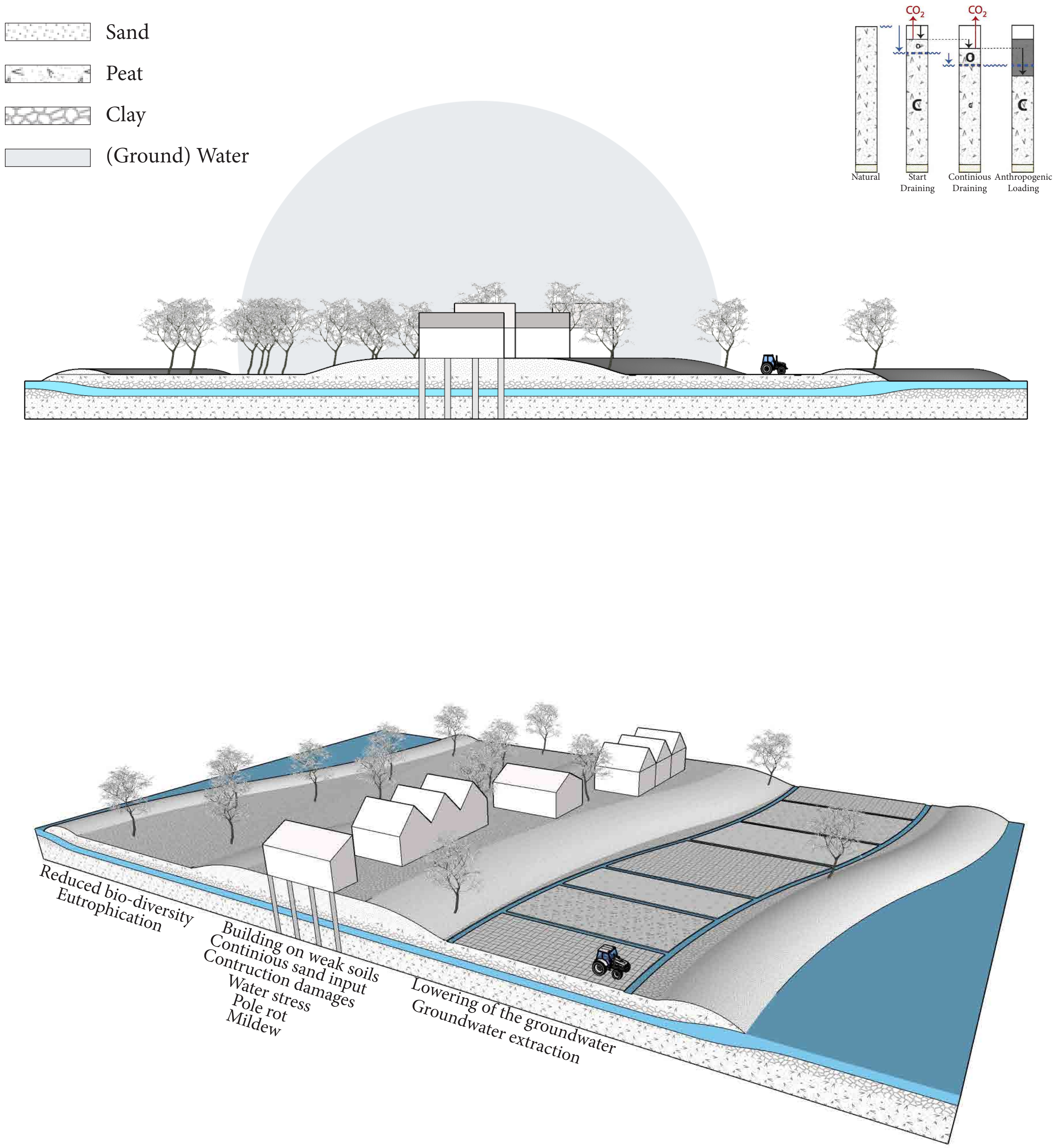


Figure 2.2: Subsidence over time. Source: by Author

are often different from the mineral ratios of the water within the system. This difference can cause disruptions, such as, eutrophication within local ecology. The bio diversity could therefore be reduced when a lot of water from outside the water system is introduced within the system (van den Born et al., 2016).

Soil subsidence is not a problem on its own. It has several causes and effects, that have been described in the previous paragraphs. Many of the causes for soil subsidence are for a part caused by soil subsidence itself. This is shown in figures 2.4 and 2.5. These figures show the different effects and causes of soil subsidence and the reciprocal relations between the different causes and effects. There are five groups of causes and effects that can be identified within this scheme that will be used throughout this research to categorize the different effects, causes and possible counter actions of soil subsidence.

The reciprocal relations within the problem scheme are highlighted in figure 2.7. Climate change is a good example one of the causes for soil subsidence that is also partly caused by soil subsidence. Ground water extraction is another example of such a downwards spiral that keeps itself in place while only enlarging the soil subsidence problems and the drought problems within an area.

Figure 2.3: Damages because of subsidence. Source: http://www.slappebodem.nl/

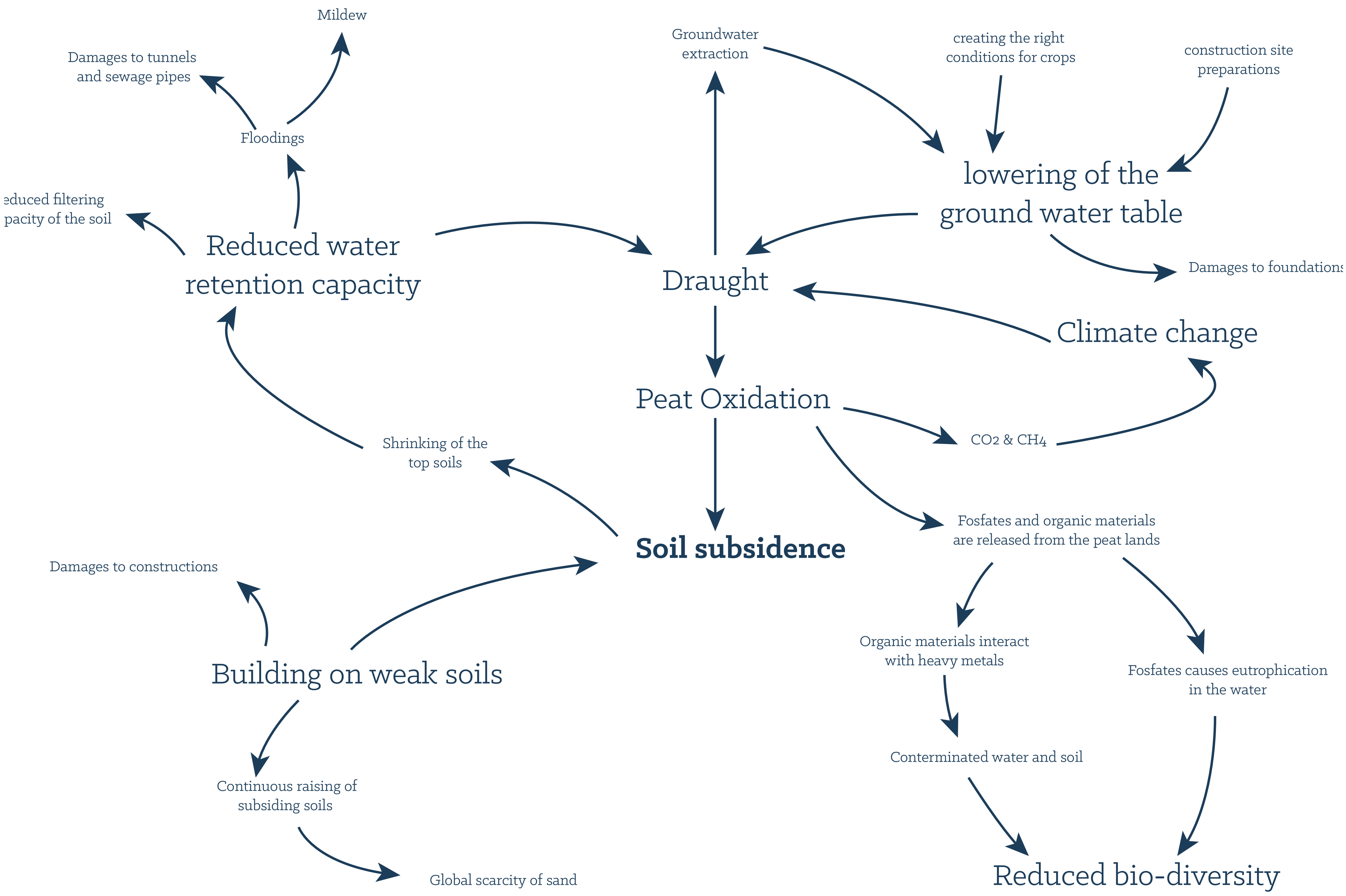


Figure 2.4 Problem framework. Source: by Author

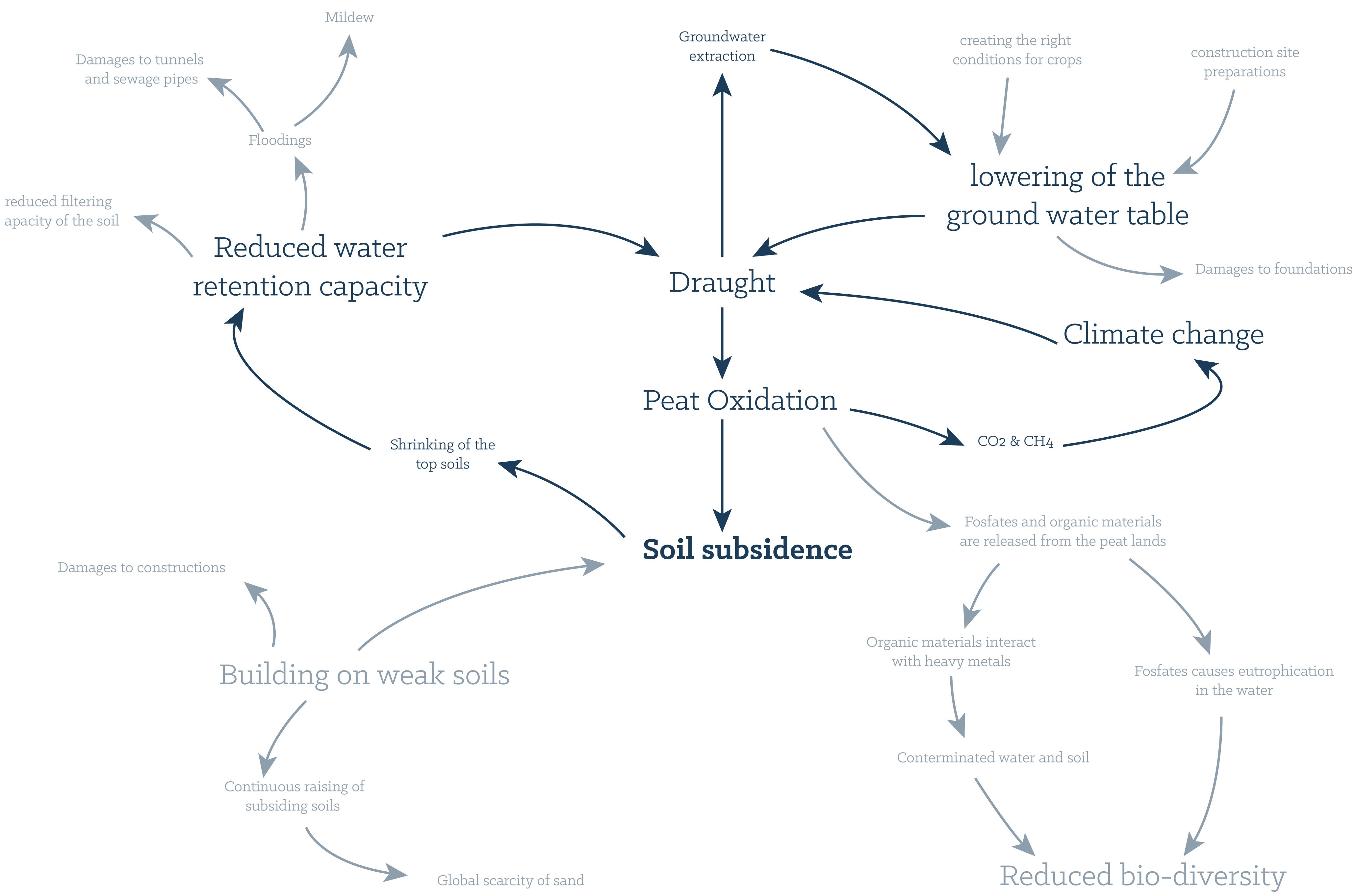


Figure 2.5 Problem framework reciproal relations Source: by Author

2.3 The Delfland location

The subsidence in the rest of the Netherlands is caused by peat oxidation and anthropogenic in urban areas and peat oxidation in the top soil layers. These types of subsidence are found in the Dutch delta that spreads over almost the whole country. Figure 2.8 shows the parts of the Netherlands that are currently subsiding, as a result of subsidence in the top soil layers.

The Dutch government has started the Delta program to find the problem areas where these problems occur now and in the future. This program tries to determine what measure should be taken to keep the Netherlands climate proof and safe from the water when it comes to spatial planning. The Delta program 2018 (Ministerie van Infrastructuur en Milieu, & Ministerie van Economische Zaken, 2018) states that the relation between the water system and measure and soil subsidence still doesn't get enough attention in many of the projects and interventions. A future goal that is described within the Delta program is however, to tackle these soil subsidence and related issues within cities and their hinterlands. This make the Dutch delta an interesting location to review within this research. The goal and willingness to deal with soil subsidence is there, but it is still unknown how this will be done and what the impact will be. This research will focus on Delfland, which is part of the Dutch delta. Delfland is chosen as a research location for multiple reasons.

The first reason to focus on Delfland are the soil conditions in Delfland. The Delfland region has a variety of soil types but the most common soils are: calcareous soils, dry sand soils, clay and peatlands. The dune lands in the west of Delfland are mostly made up out of dry sand and calcareous soil. The rest of the Delfland landscape is made up out of sand sediments from old creeks and clay and peat lands. The old sand sediments or "kreekruggen" are easily recognizable within the landscape, because they are the only parts of the landscape that have not subsided. These "kreekruggen" where once the lowest point in the landscape, since they are old creek beds filled with sand. This sand has not subsided over the years, while the rest of the landscape has. This subsidence has been so extreme that the "Kreekruggen" are now the highest places within the landscape (Figure 2.7).

Another reason for choosing Delfland is the variety of landscapes that can be found in the region. This makes it possible to research the impact and counter actions of soil subsidence within multiple environments. Delfland consists of dense urbanized areas, large areas with greenhouses, ecological vital areas for plants and birds, and agricultural lands. All of these landscapes can be found close to the coast which could play a role when it comes to salinization of the soil.

Subsidence of the peatlands could therefore have a disastrous outcome for ecology in the Delfland region (Freeman et al., 2002). The water board of Delfland is currently looking in to possible measurements against soil subsidence and its negative influence on the environment. A possible solution could be groundwater extraction from deeper grounds, but it remains to be seen whether or not this is a viable solution (van Ek, 2007).

The many different landscapes have different stakeholders that could be effected by soil subsidence or that action to counter subsidence and its effects. The Delfland location would therefore also help to review the impact and involvement of different stakeholder when dealing with soil subsidence. The Delta program 2018 has already revealed that the government is an important stakeholder when it comes to tackling soil subsidence and its effects, but there are many other stakeholders on the scale of Delfland as well. The largest stakeholders within this region are the municipalities, the water board, and the province of south Holland. But other parties have a role to play when it comes to countering soil subsidence as well. Inhabitants of the cities and villages within Delfland want to make sure that their houses will not be damaged, while farmers will try to create the best possible environment to grow their crops. Nature preservation organisations will have to be involved as well, since there is already very little room left for nature in the Delfland. These organisations will try to make sure that they can protect the little bits of nature that are left within Delfland as good as possible.

All of this together makes Delfland an interesting research location when it comes to soil subsidence. Delfland is Representable for soil subsidence in delta regions in general, as well as the Dutch delta region, because of its typical peat soil, different urban landscapes, the combination of open peat landscapes and dense urban areas, no plans regarding subsidence have been made and the many different types of stakeholders that will have to come together when dealing with soil subsidence and its effects.

Figure 2.7: Kreekruggen in Delfland. Source: https://www.middendelflandvereniging.nl/

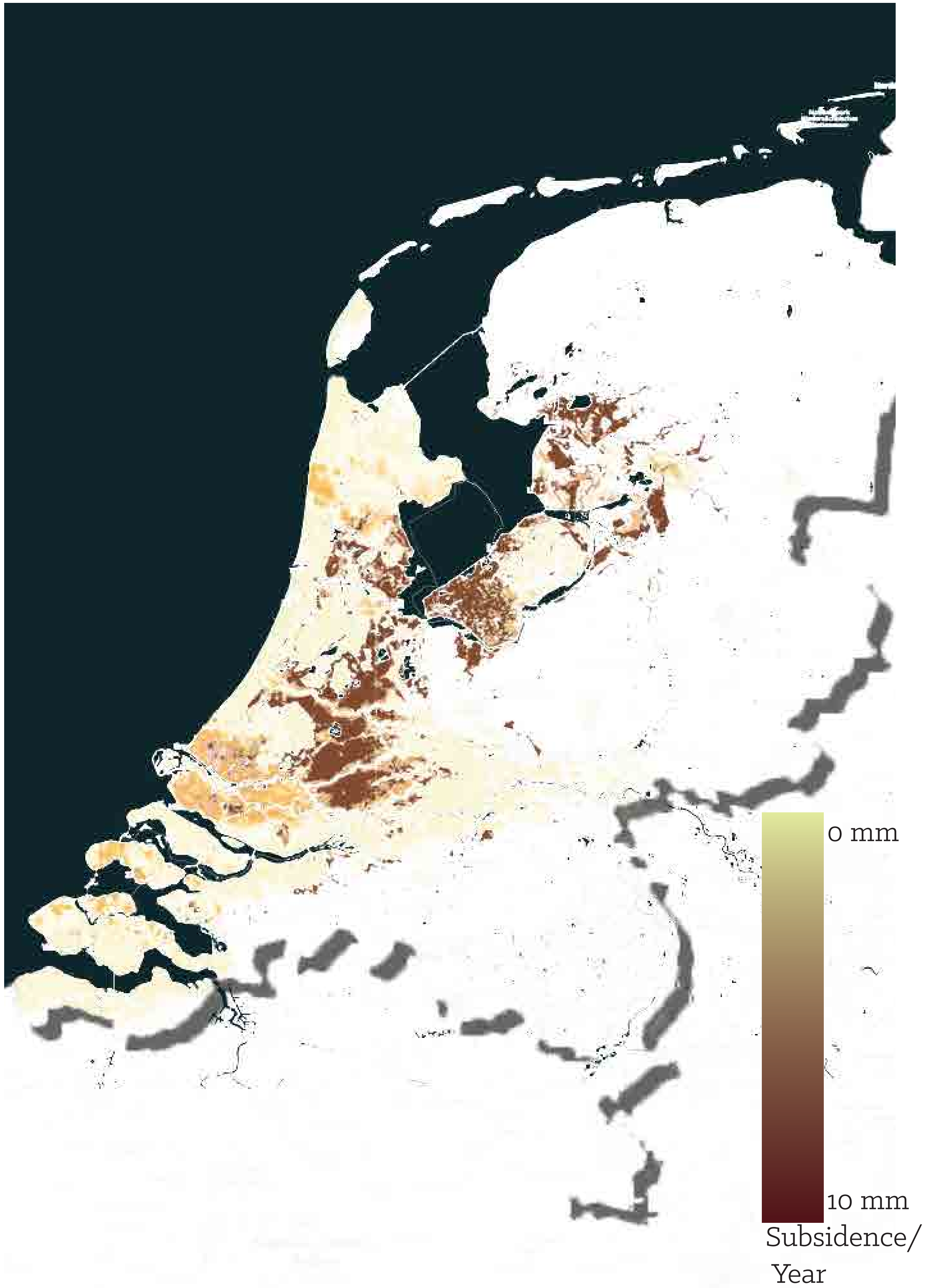


Figure 2.8: Soil subsidence in the Netherlands. Image: by Author. Source: https://zuid-holland.klimaatatlas.net/

2.4 The urgency of dealing with soil subsidence and its effects

Soil subsidence has been going on for a very long time, and it is therefore not a new problem. The effect are, however, getting stronger, and soils are subsiding faster. This makes that soil subsidence is more and more becoming an urgent problem worldwide. Dalende bodems, stijgende kosten (Van den Born et al., 2016)shows that moving the problem forward is definitely not an option. This platform is a collaboration of Dutch provinces, water boards and municipalities that already work together to look for innovation and collaboration when it comes to securing the future of the Dutch unique landscapes, historical inner cities and agricultural areas. They state the urgency of tackling this problem by showing that the soil subsidence is currently between 0.5 and 2.0 cm each year. This means that the soil is subsiding faster than the sea level is rising (0.2 cm each year) (Oldenbeuving & Dautzenberg, 2018). Much of the research into soil subsidence is however not yet finished. this leads to uncertainty surrounding the soil subsidence. It is not yet clear how much soil subsidence can be expected in the future, or how big the impact of the effects of soil subsidence will be. The problem regarding soil subsidence is therefore not only the soil subsidence itself, but also the uncertainty that still surrounds the future of soil subsidence. This and the previously described causes and effects of soil subsidence make it difficult to determine what the spatial impact and strategical requirements of soil subsidence, its effects, and dealing with them will be for Delfland. The following problem statement is therefore taken as the main problem that is researched within the report:

The spatial impact of dealing with soil subsidence and its effects within Delfland are still unknown and difficult to predict, due to uncertainty, the different landscape on which it has an impact, the large variety of involved stakeholders and the reciprocal relation that soil subsidence has with its causes and effects

How dealing with this problem has been researched throughout this thesis will be described in the upcoming chapters, by looking at the research aim and questions, the theories that are required to be able to research these question, and the research approach.

3. The Spatial Implications Of Soil Subsidence

Project Aim

The problem statement has revealed the urgency to deal with soil subsidence and its effects in delta cities, and their hinterlands. Delfland is a good example of an area where soil subsidence occurs within a densely urbanized delta region. Soil subsidence can in some cases be stopped or even reversed, while other cases of soil subsidence are difficult to counter. This research will therefore take a look at the possibilities to stop soil subsidence where possible, but also at the possibilities of dealing with the effects of soil subsidence when stopping it is not an option or possibility. Some technical solutions to soil subsidence have already been researched, while others are still in development. The spatial impact of the these solutions, and the strategical consequences of implementing the solutions, is however still very much unknown. A few reports that focus on the spatial impact of soil subsidence, its effects and the actions to counter them, have been published over the last year, such as "Ontwerpend onderzoek groene hart "(Plambeck, P., & Wijnakker, R., 2019). There was, however, very little information on the spatial and strategical impact of dealing with soil subsidence when this research started. The aim of this research is therefore: to explore the spatial consequences of dealing with the soil subsidence and its effects, in Delfland. It is hereby important to take the different stakeholders into account as well, since there are many different stakeholders in Delfland that are impacted by soil subsidence and its effects, or that could be impacted by the actions that are required to counter them. The role of these stakeholders will have to be defined within this research, to determine how they should be involved within the process of dealing with soil subsidence and its effects within Delfland.

3.1 Research Questions

The research will have to be separated in to more specific goals to be able to find an answer to this question. One of these goals is to further research the causes and effects of soil subsidence, to be able to create an overview of the further implications of soil subsidence, in peatlands, on other systems, flows and (natural) phenomena. Another goal is to explore which stakeholders have, or could have, an influence on soil subsidence and its effects. These stakeholders could all play a role in the decision-making process when it comes to dealing with soil subsidence and its effects. Uncertainty plays a big role within the research, and adaptation to soil subsidence. All lot of research into soil subsidence and its effects is still ongoing, which results in uncertainty about future impact and development of soil subsidence and its effects at this moment in time. Exploring ways to deal with uncertainty, now and in the future, should therefore be one of the goals within the larger aim of this research as well. The dynamic adaptive policy pathway method offers a model that is directed at dealing with soil subsidence and its effects. This model will be used within this research to be able to review different possible outcomes, while taking the uncertainty about the future of Delfland in general, and the future of soil subsidence, into account. The final goal of this thesis is, therefore, to explore the possible spatial and strategical consequences, for Delfland, when dealing with soil subsidence and its effects through the use dynamic adaptive policy pathway. This has led to the following research question:

What are the spatial and strategical consequences of dealing with soil subsidence, its effects, and the uncertainties that come with them, within the Delfland region, through the use of dynamic adaptive policy pathways?

This research question has four clear components that play an important role in answering this question. This first one is the spatial component that focusses on the spatial impact of interventions that are directed at soil subsidence and its effects. The second aspect is the strategical component. This strategical part of the research should focus on the, possibly, involved stakeholders and entities that could play a role on the regional scale. Finding answer to this question would, however, be impossible without doing further research in to the consequences of soil subsidence and the uncertainty that still surrounds this topic. This is represented in the third and fourth component of the research question. The regional scale is the fifth component. this component focusses on the possible reciprocal relation between different interventions, on a local scale, and how they could work together and enhance each other on a regional scale. The different components of the main questions can be separated in five sub-questions. These sub-questions have their own sub questions that reveal the underlying, more basic, questions. The five sub-questions that come forward out of the main question can be found on the next page

What are the spatial and strategical consequences of dealing with soil subsidence, its effects, and the uncertainties that come with them, within the Delfland region, through the use of dynamic adaptive policy pathways?

1. What is the impact, of the effects, causes and uncertainties of soil subsidence, on the Delfland region?
   a. Where and when does soil subsidence occur within Delfland?
   b. What is the impact of the causes and effects of soil subsidence on rest of the Delfland region?
   c. Who are the main stakeholders in the region that could play a role when it comes to dealing with soil subsidence and its effects?
   d. What are the main uncertainties, related to soil subsidence and its effects, that the Delfland will have to deal with, now and in the future?

2. What is the impact, of possible interventions on soil subsidence, its effects, and Delfland?
   a. Which interventions could be used to counter soil subsidence and its effects?
   b. How could the different interventions influence each other?
   c. How could the different interventions cope with the uncertainties that are related to soil subsidence and its effects?

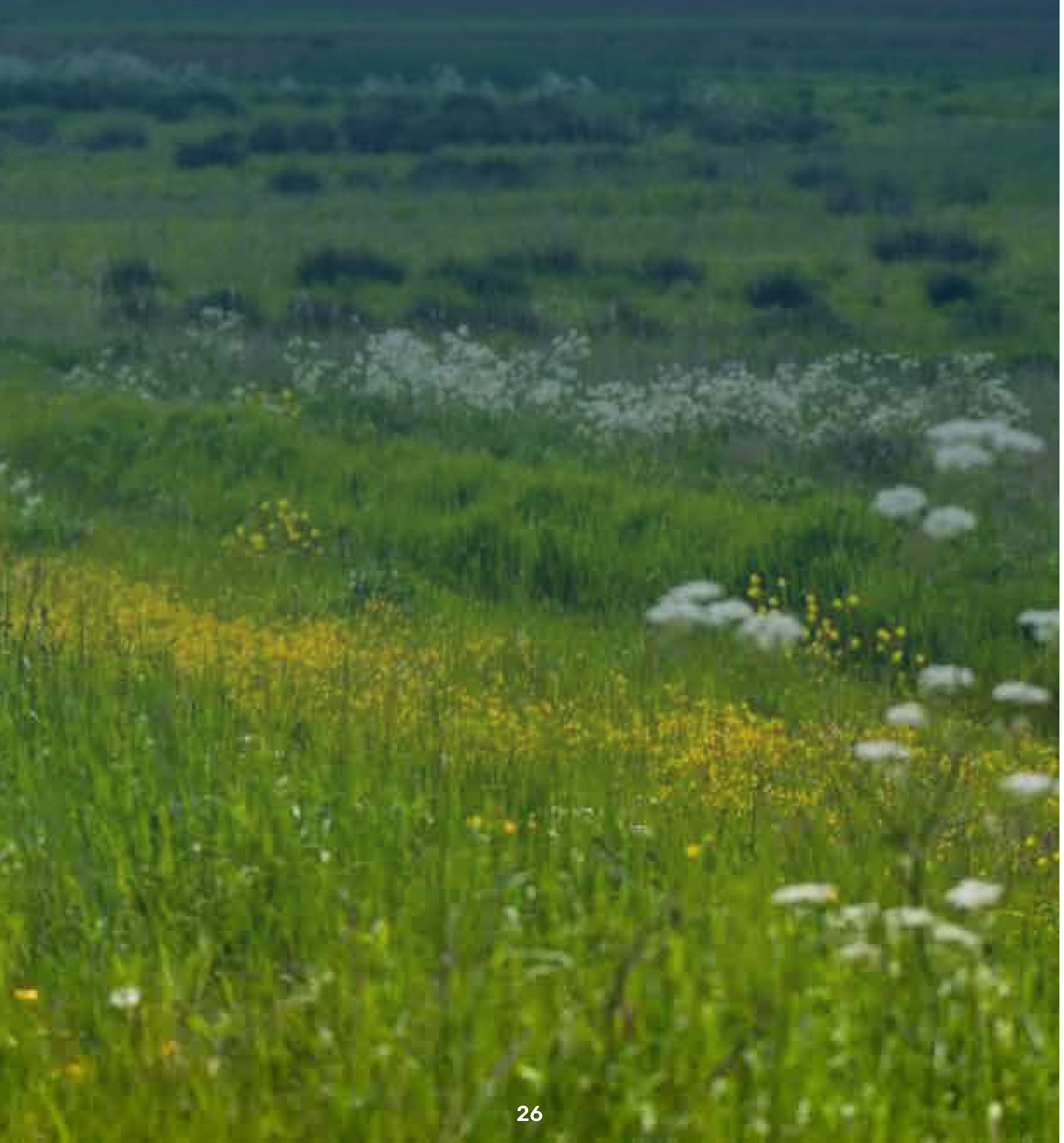
3. What is required of the stakeholders in Delfland, when pathway are developed and actions against soil subsidence and its effects are taken?
   a. Who are the involved and effected stakeholders?
   b. What is impact of the interventions on the stakeholders within Delfland?
   c. Which parties should be involved in the decision-making process and what should be their role, when it comes to dealing with soil subsidence and its effects.

4. How could the Delfland region become adaptable to the effects of soil subsidence and the related uncertainties, through dynamic adaptive policy pathways and what would be the spatial consequences?
   a. How can the different spatial interventions work together, within dynamic adaptive policy pathways, towards making Delfland more resilient to soil subsidence and its effects.
   b. What would be the consequences of the different pathways for the Delfland region from a spatia perspective?
   c. What would be the impact of the different pathways on a more local scale?

4. Analysis, Adaptation In Regional Scenarios

Theoretical Framework

This chapter will give an insight in how the research framework is developed. This is done by first taking a look at the concepts of climate change and uncertainty. These concepts play an important role within the problem field, and it is therefore important to have a good understanding of these concepts. The third part of the chapter will take a closer look at the dynamic adaptive policy pathway(DAPP) method and how it can be used within this research to deal with uncertainties. This method will be used as the basis for the research framework, that will be described in the fourth part of this chapter. This research framework will give an insight in the steps that have been taken throughout this research .



4.1 Climate change

Climate change is has become one of the most important factors that play a role within Urbanism and it is a key element in almost all urban developments over the last decades (Chu, Anguelovski & Roberts, 2017). Adaptation to climate change is, however, something that has been going on for a very long time. Human societies have been adapting to changes in the climate all throughout history. The reason that the attention for climate change has grown over the years is that future climate change could very well push beyond the limits of reversibility and adaptation (Adger, 2005). The fluctuations, in climate change, can make it difficult convince people of climate changes since they are not consistent and could therefore be written off as natural occurrences more than a systematic change in the climate. This is also one of the factors that make it difficult to predict climate change and to express it in numbers (Dessai, Lu & Risbey, 2005).

That is why different scenarios have been developed by instances like the KNMI. These scenarios should help to create an insight in possible future changes and effects based on current research results.
The scenarios of the KNMI (2015) give different insights in different effects of climate changes like: temperature, rainfall, wind, extreme weather, and the rise of the sea level. The problem statement revealed that: draught and water stress are the climate change effects that play the biggest role within this research.

4.2 Uncertainty

Uncertainty can be a very vague and general concept. This makes that researcher find it often difficult to define uncertainty. Abbott (2005) does, however, state that: "Something is uncertain if it is unknown or cannot be known"(Abbott 2005, P.237). This is the case for almost any research project, and uncertainty will therefor almost always occur during a project. The uncertainties that urbanist will have to deal with should, however, be manageable by focussing on the less turbulent and extreme uncertainties (Stafford Smith et al, 2011). This does however still leave two types of uncertainty that could be encountered within the project, according to Christensen (1985). The first type of uncertainty that could be encountered is: the lack of knowledge on how to tackle the problem. This means that the way to get to preferred outcome is unknown. The second type occurs when the preferred outcome is undefined. This could be caused by disagreement between the different parties that have is say in the final outcome. It could also be the result of the changing stakeholders, which makes it difficult to give certainty about long term goals. This is for example caused by political changes that have a change in policies or goals as a result. This is just one of the factors, that could influence a change in direction in the future, which causes more uncertainty for long term projects (Stafford Smith et al., 2011).

4.2.1 Dealing with uncertainty

Christensen (1985) shows that, dealing with uncertainty is not something new, and people are aware of the fact that they need to cope with it for a long time. The inclusion of uncertainty within planning projects has however been avoided for a long time. This is mostly caused by the fact that urban designers and planners chose to work towards a final goal that was defined by the knowledge that was available at the time of the project. Uncertainty has been getting more attention, and there are several attempts to integrate it within projects. This is done through different strategies that are developed to fit different types of projects. These strategies help create awareness among planners within projects, but, still, very few adjust their plans to incorporate uncertainty within their plans (Woodruff, 2016). Integrating uncertainty within a project is made difficult by the fact that there is no general agreement or scientific bases that states how uncertainty should be integrated within a project (Stafford Smith et al., 2011). A method, that is often considered to research uncertainty within projects, is the use of different scenarios that should give different insights in possible future solutions. This helps to create an overview of the different uncertainties that come into play during the development of a project or strategy (Woodruff, 2016). Haasnoot et al. (2013) does, however, state that there is also a downside to the use of scenarios, since many designers will try find a way, to combine the different scenarios in a perfect solution that is adjusted to the most likely future.

The complexity and uncertainty of soil subsidence and climate change, in combination with the large scale of the project, the uncertainty on the stakeholders and their roles, and the political changes that could take place within the Delfland, requires the project to deal with uncertainty, to make sure that the current and future effects of soil subsidence dealt with regardless of changing conditions in Delfland.

4.2.1 Dynamic Adaptive Policy Pathways

This research will make use of the Dynamic Adaptive Policy Pathways (DAPP) method to deal with the uncertainties within the project. This is a very structured method that is developed to deal with uncertainty through dynamic adaptive planning. This method is the outcome of the combination of two different adaptive methods. Those methods are: the adaptation pathways method and the adaptive policymaking method. The strengths of the two methods come together in DAPP while, it tries to overcome the weaknesses within the two methods. DAPP focusses on dealing with long time uncertainty over time by keeping the different proposals adaptable. While it also offers insight in how uncertainties could change over time, adaptation pathways, and monitoring systems with designated interventions to make sure that the favoured pathway is followed throughout the process. The different steps, of DAPP, and their order can be found in figure 4.1. (Haasnoot et al., 2013).

The first step in the DAPP method is all about assessment of the context in which the project will take place. This does not only include the assessment of current situation, but also a definition of the requirements that are desired to make the project a success. These requirements could be different elements, for example: which indicators will be used to evaluate the different pathways and when how is determined which actions take place at what time? The assessment of the context does also require a first overview of the largest uncertainties, at this moment or in the future of the project, that could affect the decision making process. (Kwakkel et al., 2010b).

The second step takes a deeper look at the outcomes of the first step by analysing the different problems. This is done by taking a closer look at expected future scenarios and comparing them with the present situation. Weather action is needed or not is determined by finding the gaps between future scenarios and the objectives that are stated in the first step. These gaps can be an indicator ofproblems, but they could also indicate the existence of new opportunities that should be seized.

The goal of the third step is to determine what the potential interventions are. This should in the end result in a wide range of interventions that could be used to reach the same or different goals within the project. These interventions can be shaping, mitigating, hedging, and capitalizing just like the actions from the adaptive policymaking method.

The scorecard from the adaptation pathways methods plays an important role in the fourth step. The score card is an a table that helps to evaluate the impact of the different possible actions by evaluating their positive or negative impact. An example of a score card can be found in figure 4.2. This score card helps to determine which actions will have to take place at what moment in time. This helps to figure out when the different actions will have to be prepared to make sure that the results are in place at the right time. The score has a validating function is well. It helps to identify the effectiveness, of the different interventions, to be able to make a final shifting after which only the effective interventions will be left.

The interventions from the forth step are used to research the different possible pathways in step five. The different combinations and the order of the different interventions will lead to collection of pathways that could be followed to achieve the pre-determined goal that has been defined in the first step. Theses pathways together form the pathways map in which only the most reasonable pathways will have a place. Has to be determined by the stakeholders. An example of a pathway map can be found in figure 4.3.

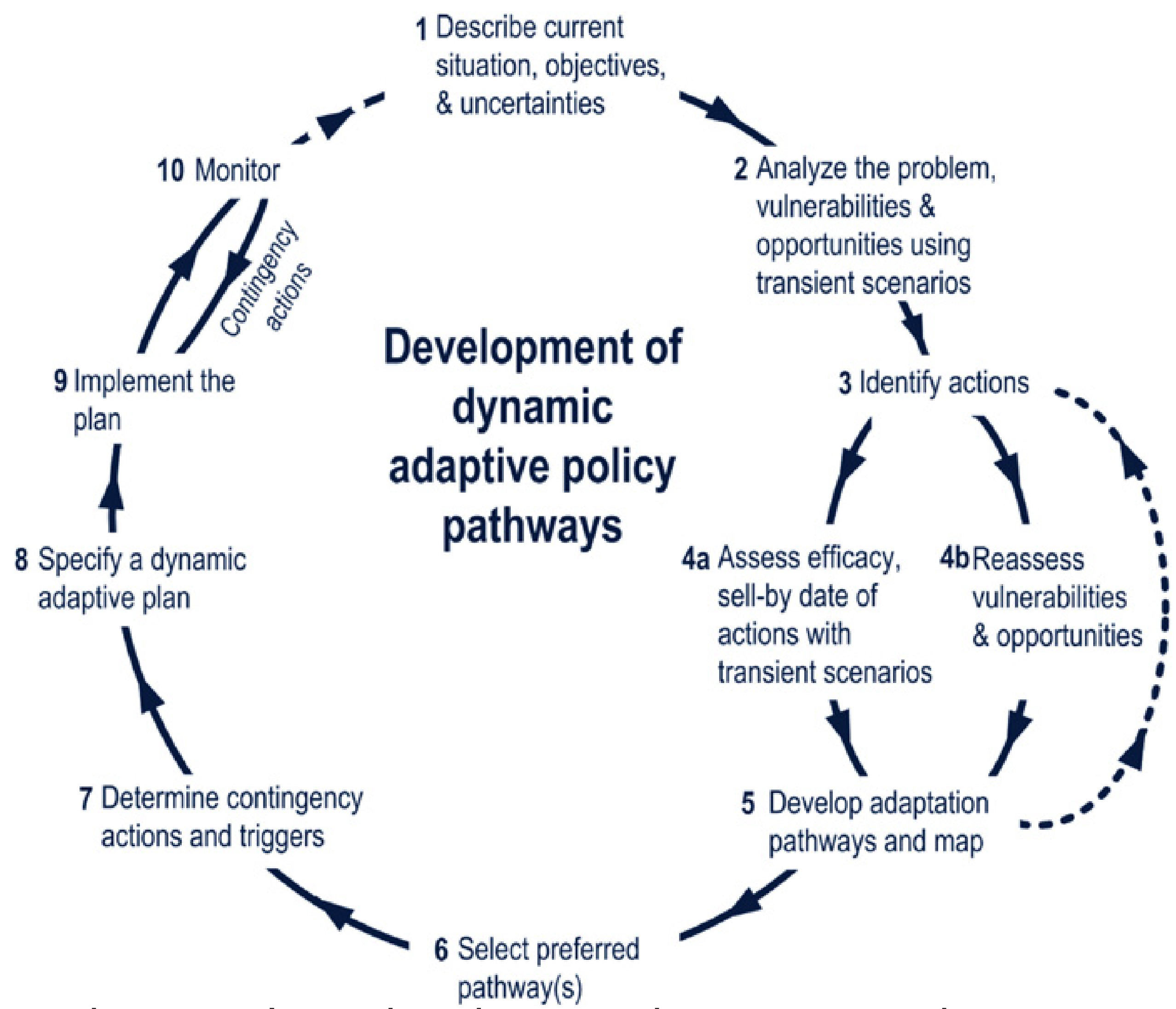


Figure 4.1: The Dynamic Adaptive Policy Pathways approach. Source: Haasnoot et al., 2013 p. 289

The most reasonable pathways are not necessarily the most favoured pathways. This is why the sixth step helps to uncover the favoured pathways. Which of the reasonable pathways are favoured or not can depend on a lot of different things like for example: the preferences of the different stakeholders. It would therefore be preferable to come up with several pathways that take diverse perspectives in to account. This should produce pathways that are not just robust from a spatial or technical perspective, but also from a social perspective (Offermans et al., 2011).

Finding the preferred pathways is not enough to make sure that they will be followed throughout the project, or that they will lead to the preferred final result. These pathways will have to be kept on track and they might need extra steering to deal with unexpected changes in the future. The seventh step will, therefore, prepare the pathways for these uncertainties. This is done by preparing actions the steer the process back in to the right direction, when something threatens to lead the process away from the favoured pathway. This could be a simple as not making definitive decisions for as long as possible, but it could also require more direct action like bringing interventions forward or delaying them to cope with unexpected threats.

This is where the eight step comes in. by developing a dynamic adaptive plan out of the first seven steps. Such a plan should determine what interventions should take place at this moment and what interventions could take place later. All of these interventions should, of course, fit within the favourable pathway that is determined in the sixth step.

The ninth step of the process is put in place to keep control over the dynamic adaptive pathways plan by setting up a monitoring system. This systems is activated once the first interventions are put in to place. The monitoring system will collect data to determine when, a trigger is activated and an action is required. Using this monitoring systems is seen as the tenth and final step of DAPP.

All of these steps together form the process of the DAPP. The method deals with uncertainties by analysing the context and problems within the context in to find the gaps between a future scenario and the desired future outcome of the project. Security is built in by finding, spatially, technically, and socially, robust pathways that should be followed to reach the favoured end result. A monitoring system with tipping points determines when action is required to deal with threats and uncertainties. These actions could be predetermined and part of the chosen pathway, but they could also be corrective actions that are needed to make sure that it stays possible to follow the chosen pathway. All of this together results in a model where the interventions will not have to change when the future turns out differently than expected. Uncertainty and unexpected future changes will only lead to speeding up or slowing down along the chosen pathway. Short term interventions can, therefore always take place without losing the possibility to connect them work towards the long term goals. (Klijn, Kreibisch, de Moel & Penning-Rowsell, 2013).

	Path actions	Relative Costs	Target effects	Side effects
1		+++	+	0
2		+++++	0	0
3		+++	0	0
4		+++	0	0
5		0	0	-
6		++++	0	-
7		+++	0	-
8		+	+	- - -
9		++	+	- - -

Figure 4.2: Scorecard example Source: Haasnoot et al., 2013 p. 289

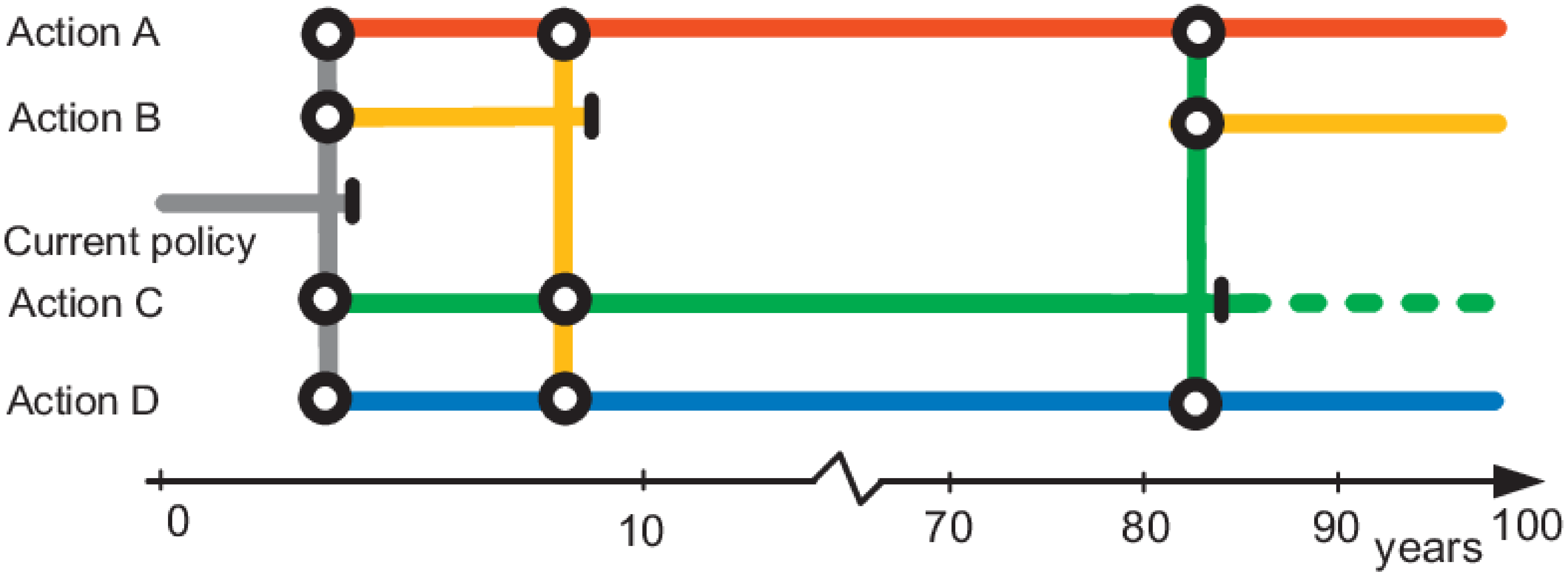


Figure 4.3: Pathwaymap exmaple. Source: Haasnoot et al., 2013 p. 289

4.4 Research Framework

The different steps of the DAPP model are used to structure the research. Not all the steps of DAPP can be taken within this research and some steps have been added to be able to apply DAPP to the complex problem of soil subsidence, and to be able to translate the chosen pathways into spatial projections that give an insight in the spatial impact of the chosen pathway. Figure 4.4 shows the research framework and the DAPP steps that are used within this research. The first five steps of DAPP have been used to be able to develop a pathway map. The problem statement in the beginning of this research could be seen as the first step of the DAPP method. The second step of the DAPP method is used to gain a better insight in the Delfland region and the occurrence of soil subsidence and its effects within this region. The identification and assessment of the actions is used, to determine which actions could be used to counter soil subsidence and its effects, as well as, to review where these actions could be used within Delfland. These actions are used to develop a pathway map that shows the different possible combinations of actions that can be used to make Delfland more resilient to soil subsidence and its effects.

The DAPP steps that come after the development of the pathway map are not part of this research, since these steps should be taken once the decision makers of Delfland have come to a consensus about the preferred pathway. These decision makers will have to determine what the preferred pathway for Delfland is. Other steps in the DAPP method can only be taken once a preferred pathway has been chosen. New steps that are not part of the DAPP method have been added to the research framework, after the development of the pathway map, to be able to research the different spatial outcomes of the pathways. There are currently no steps in the DAPP method that take the spatial impact or possibilities of the actions into account.

The pathway map should be used as a tool by the decision-makers. This research will therefore take a closer look at those decision-makers and how they should work together when pathway decisions are made. This will help to get a better insight in the strategical consequences of use of the DAPP method, as well as, the strategical consequences of dealing with soil subsidence and its effects. The spatial consequences will be reviewed by looking different pathways that can be taken on the pathway map. These pathways will be translated in to spatial projections for Delfland. This will give an insight in the spatial impact of different pathways as well is the spatial impact of the actions that can be used to deal with soil subsidence and its effects.

These research steps have to result in: an overview of the possible actions that can be used to deal with soil subsidence and its effects, a pathway map, spatial projections, insight in the required involvement of stakeholders . All of these elements together are required to be able to answer the main research question.

The upcoming chapters will describe the methods that are used within the different steps of the research framework and the outcomes of those steps. Chapter five will describe the methods that have been used and how they are connected to the different sub-questions, aims and outcomes of this research.

The sixth chapter, and second step of the DAPP method, will analyse Delfland in general to get a feeling for the context in which the design part of the research will take place. The analysis will also describe soil subsidence and its effects in Delfland, and the strengths, weaknesses, opportunities, and threats within the Delfland region that could come into play when dealing with soil subsidence and its effects. The seventh chapter will describe the outcomes of the third and fourth step of the DAPP method. This chapter will therefore contain the action assessment, that is required for the development of the pathway map in the fifth step of the DAPP method. The pathway map and its use within this research will be described in the eight chapter. This chapter will also take a closer look at how this map can be used when researching the strategical and spatial implications, of dealing with soil subsidence and its effects in Delfland. The decision-making requirements and spatial consequences are further described in chapter nine and ten.

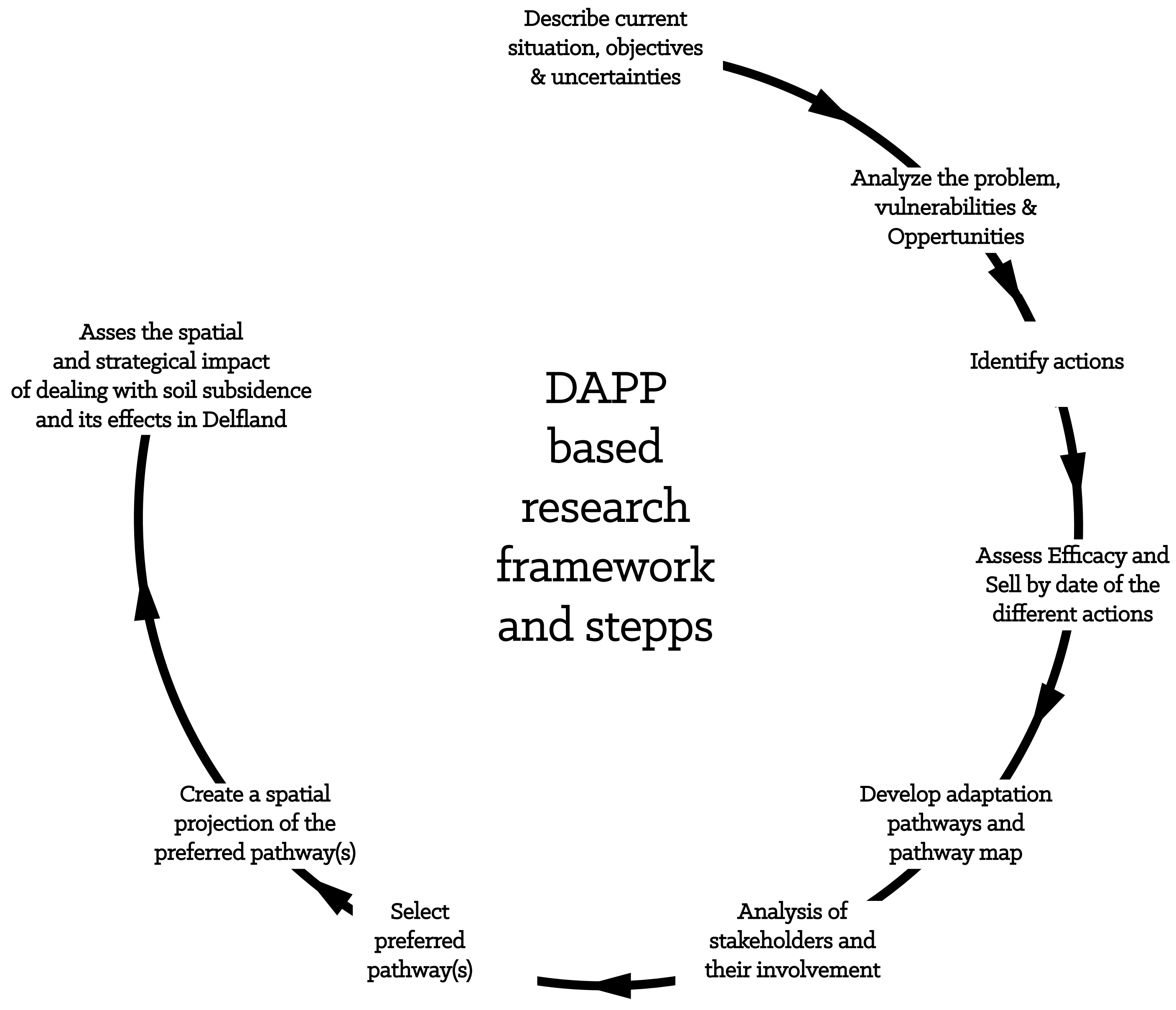


Figure 4.4: Research Framework. Source: by Author

5. A Regional Soil Subsidence Approach

Methodological approach

The methodological research scheme (figure 5.1) shows the setup of this setup of this research and the relation between the different parts of the research. This paragraph will explain the methods that are being used to research the main question and sub-questions. This is done by further explaining the different methods and their uses, while also taking a closer look at the theories. These methods and their relation to the research questions are brought together in the analytical framework, to further explain the methodology behind the research.

Different methods will be used within this research, to review and use quantitative data, but also the review the more qualitative aspects of the project. The different governmental entities, and research organizations in the Netherlands offer a lot of accessible data that could be very useful within the project. Different methods are, therefore, required to create an overview of all this data. This is not only required to find relevant information for the project. The methods will also help to organize and relate the different data sources to find new possible relations within all this information. The main methods and their uses can be found in the analytical framework (figure 5.2), and then be further explained.

Literature study
Addressed questions 1, 2, 3, 4,

Methods' objective:
This method will be used to research the different theories, to get a better insight in the different available sources and their possible value for the rest of the research. These theories are there to make sure that a well-informed start to the project is made. There are five major theories that will play a big part within this research. Those are:

1. Vulnerability: "Vulnerability is the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt"(Adger, 2005: 268). This research focusses on the vulnerabilities, of changes in the climate and environment, and the challenge, to integrate vulnerably within different domains like resilience and adaptation.

2. Dynamic Adaptive Policy Pathways: This is a strategy that combines adaptive policy making and adaptation pathways. This done by creating pathways that connect different interventions to each other, to make them work together towards a goal that could not be achieved through one intervention alone. These pathways can help in dealing with uncertainty while still offering the opportunity to implement short term interventions (Haasnoot et al., 2013).

3. Integrated water resource management: This is a process that coordinates the management and processing of resources related to water and land. This process is used to optimize the economic and social gain from these resources, without endangering crucial ecosystems (Agarwal, et al., 2000).

4. Diagnoses of barriers in climate change: This theory helps to determine which barriers could occur on the path towards climate change adaptation. The theory focusses on the foreseen barriers that could still be avoided (Moser & Ekstrom, 2010)

Policy analysis
Addressed questions 1, 3

The main policies, that influence the project area and problem field, are to be collected, researched and analysed within this method. This is done to find the gaps within the current policies that might have negatively the soil subsidence problem, or that might lack some requirements to be able to really tackle the problem. Analysing the different policies could also help in finding opportunities within these policies that could be related to, or strengthened within, the project.

Mapping & Spatial analysis
Addressed questions
2, 3, 4

A lot of information and open source (geo-)data is already available for most cities in the Netherlands. However, more detailed maps and quantitative research is needed to give a good oversight of information, specifically related to soil subsidence and water systems. This method will therefore help to combine different sources of information within readable maps that will help to create a better insight in the spatial impact of soil subsidence and its consequences for the project area. These maps will, meanwhile, also help to get a better understanding of the area, and the possible relations between the different elements within this area.

Stakeholder analysis
Addressed questions: 2, 3, 4

The main goals of this method is to find the different stakeholders that could play a role within the project. This will help to determine the influence, possibilities and opportunities that the different stakeholders bring to the table. It is important to review the level at which different stakeholders operate to determine when they could or should be useful and when not, but also to determine which parties should be involved at different times and scales throughout the project.

Research by design
Addressed questions: 2, 4

Research by design will be used to develop a strategy on a regional scale at first, while it will also be used to explore the impact of the regional strategy on a more local level. The method will help to research the different possibilities when it comes to combining spatial-, strategical-, and technological aspects within the same proposal. The design that are formed throughout the process, could be seen as tools to test whether or not it is possible to bring the different elements together. Designing will meanwhile also bring new questions forward that might still have to be answered. The research by design method is therefore also crucial to be able to reflect upon the project.

pathway based design
Addressed questions: 1, 3, 45

Pathway based design is a translation from actions along a pathway into a spatial projection. These spatial projection will give an insight in the spatial impact that choices between pathways can have on a region.

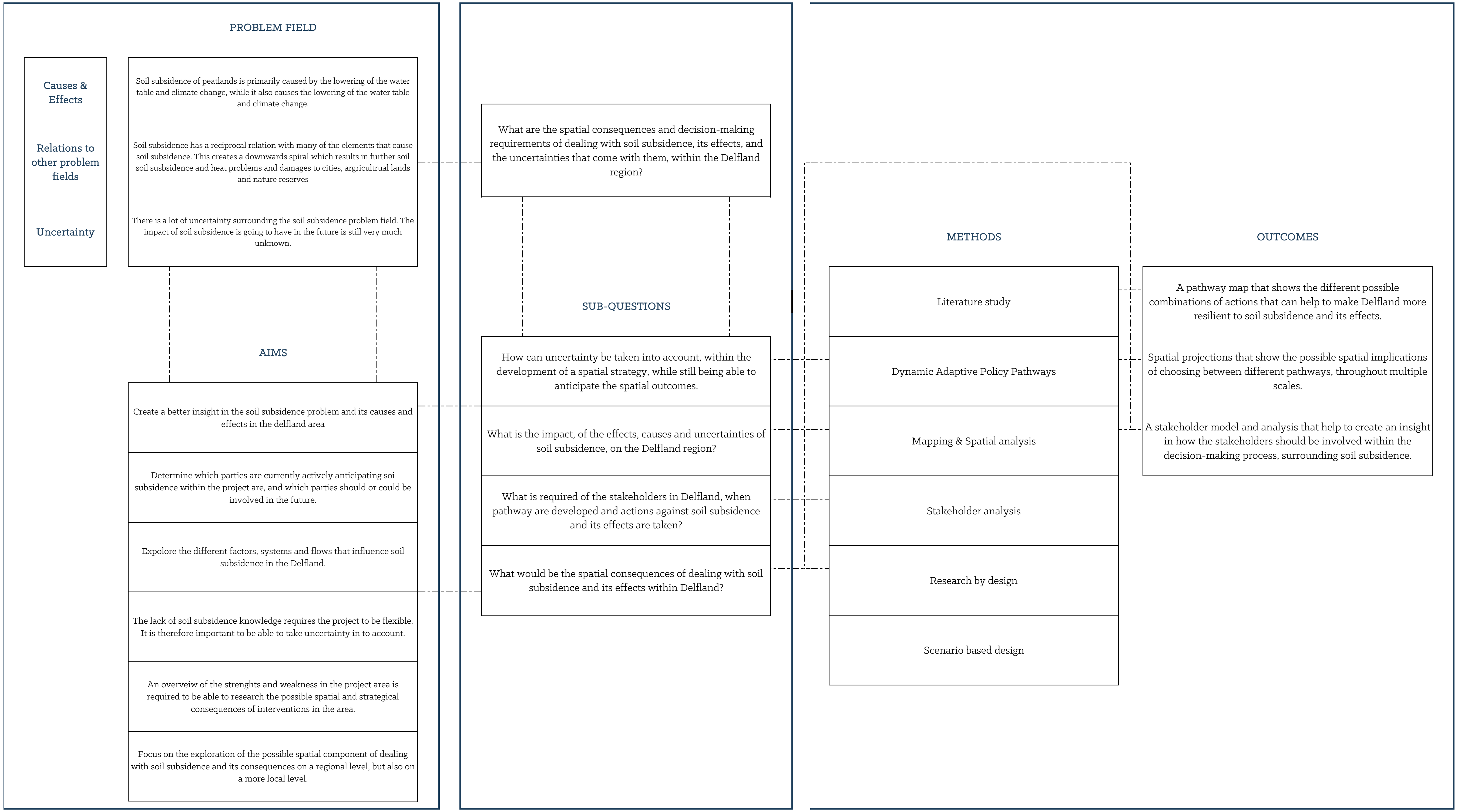


Figure 5.1: Methodological flowchart. Source: by Author

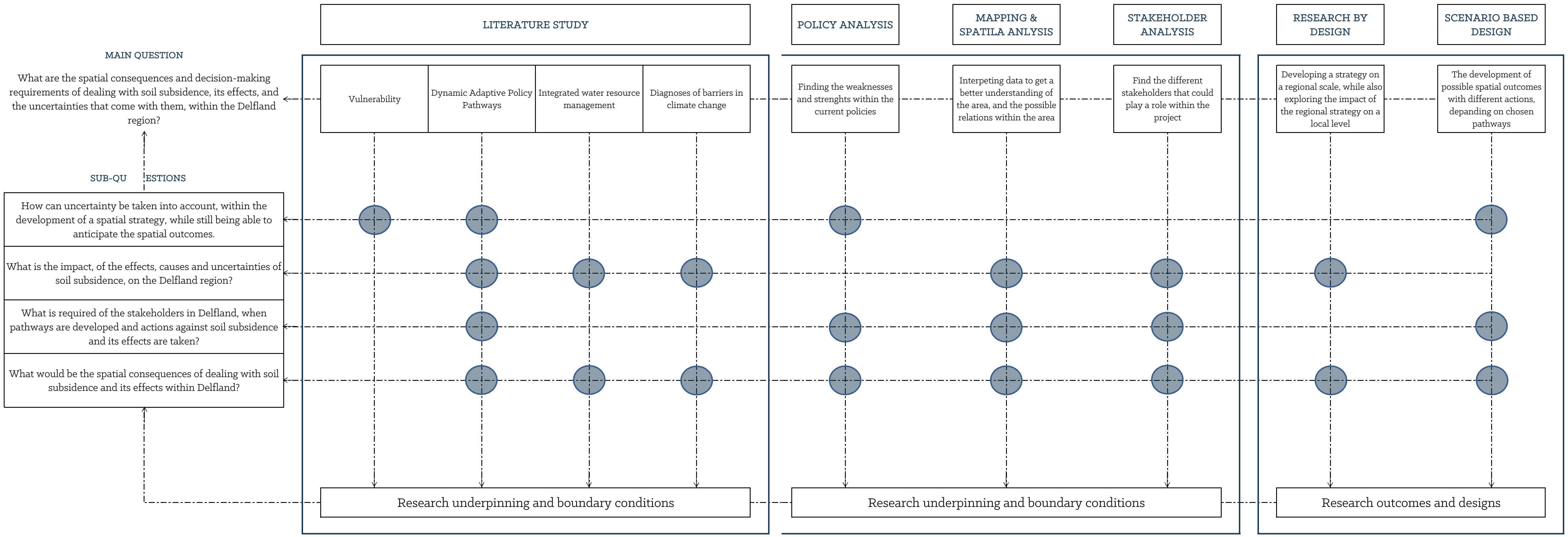


Figure 5.2: Analytical framework. Source: by Author

6. The Spatial Consequences of Soil Subsidence

Analysis

The previous chapters have explained how the DAPP method could be used to create dynamic adaptive plans to deal with soil subsidence and its effects now and in the future, while still taking uncertainty in to account. Dynamic adaptive plan are created by developing pathways of actions. These possible pathways are made up out of a combination of actions. A better understanding of Delfland and its conditions is required, to get an insight where actions would have to take place and what the effect of the actions should be. That is why an analysis of Delfland is a crucial part of the DAPP method. This analysis will help to reveal which actions are relevant for Delfland.
The conditions in Delfland, that are relevant when it comes to dealing with soil subsidence and its effects, will be analysed within this chapter. This is done by taking a look at the most important fields that are influenced by soil subsidence and its effects. These fields can be found in the problem scheme. The first aspect that will be reviewed is the subsidence itself. Looking at the subsidence alone is however net enough since many of the effects and future subsidence could occur in other places, outside of the areas that are currently subsiding.. The water system could play a big role in countering soil subsidence and its effects, when it comes to maintaining a groundwater table that is beneficial to the peat soils, but also when effects like floodings and droughts have to be dealt with. The water systems is therefore the second aspect that is reviewed. The third field that will be reviewed is the ecological systems, to see how soil subsidence and its effects influence the local ecology. The impact of soil subsidence and its effects will also be described for the urban areas in Delfland and the agricultural lands.

Figure 6.1: Delfland base map Image: by Author

6.1 Soil and subsidence in Delfland

There are three types of soil subsidence that can be observed in Delfland. The first one is the subsidence caused by oxidising peatlands. The second type is an increased subsidence in, mostly, clay soils during periods of drought. The third type is subsidence in urban environments which is a result of the pressure from buildings on the soil and this type of subsidence is further enhanced and influenced caused by a combination of factors: the settling of the ground, the soil conditions, the groundwater table and the type of foundations that are used to build on.

Figure 6.2 shows the measured subsidence in Delfland between 2015 and 2018. Most of the subsidence can be found in the peatlands. These peatlands have been subsiding for a very long time, and they can therefore be found on the lowest places in the landscape. Figure 6.4 and 6.5 show where subsidence is caused by other factors. Figure 6.4 Shows increased subsidence during long periods of drought. Subsidence as a result of drought can be found in 2 places. The first one are low places in the landscape where it is difficult for water to infiltrate in to the soil, due to the high groundwater table or the building density. The second one are higher places in the landscape where water seeps away to lower parts of the landscape, making it harder to retain water in those places. Figure 6.5 Shows soil subsidence as a result of anthropogenic loading. Future predictions for Delfland (figure 6.6) show that the subsidence will probably spread much further through the Delfland region if nothing changes.

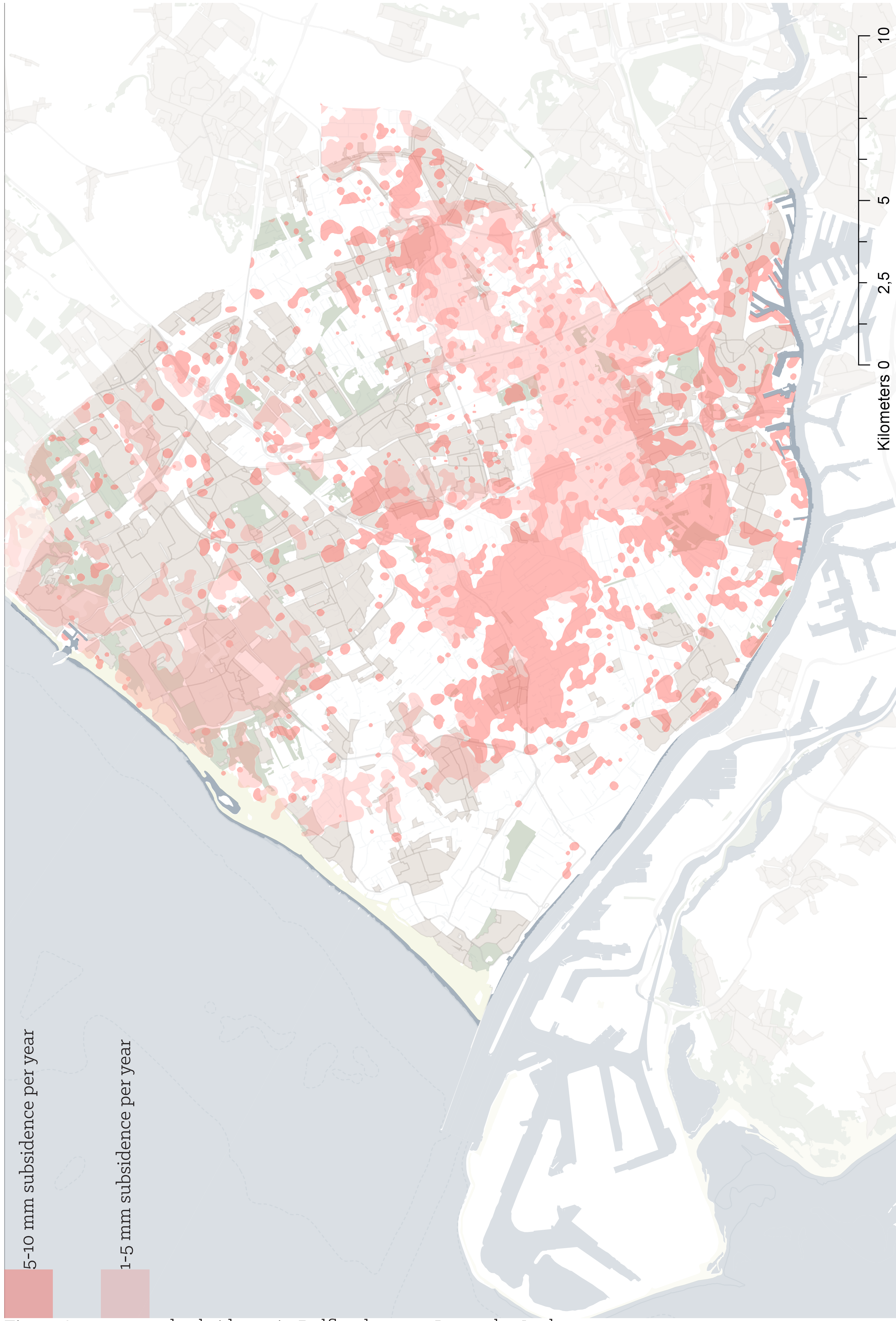


Figure 6.2: measured subsidence in Delfland Image: by Author

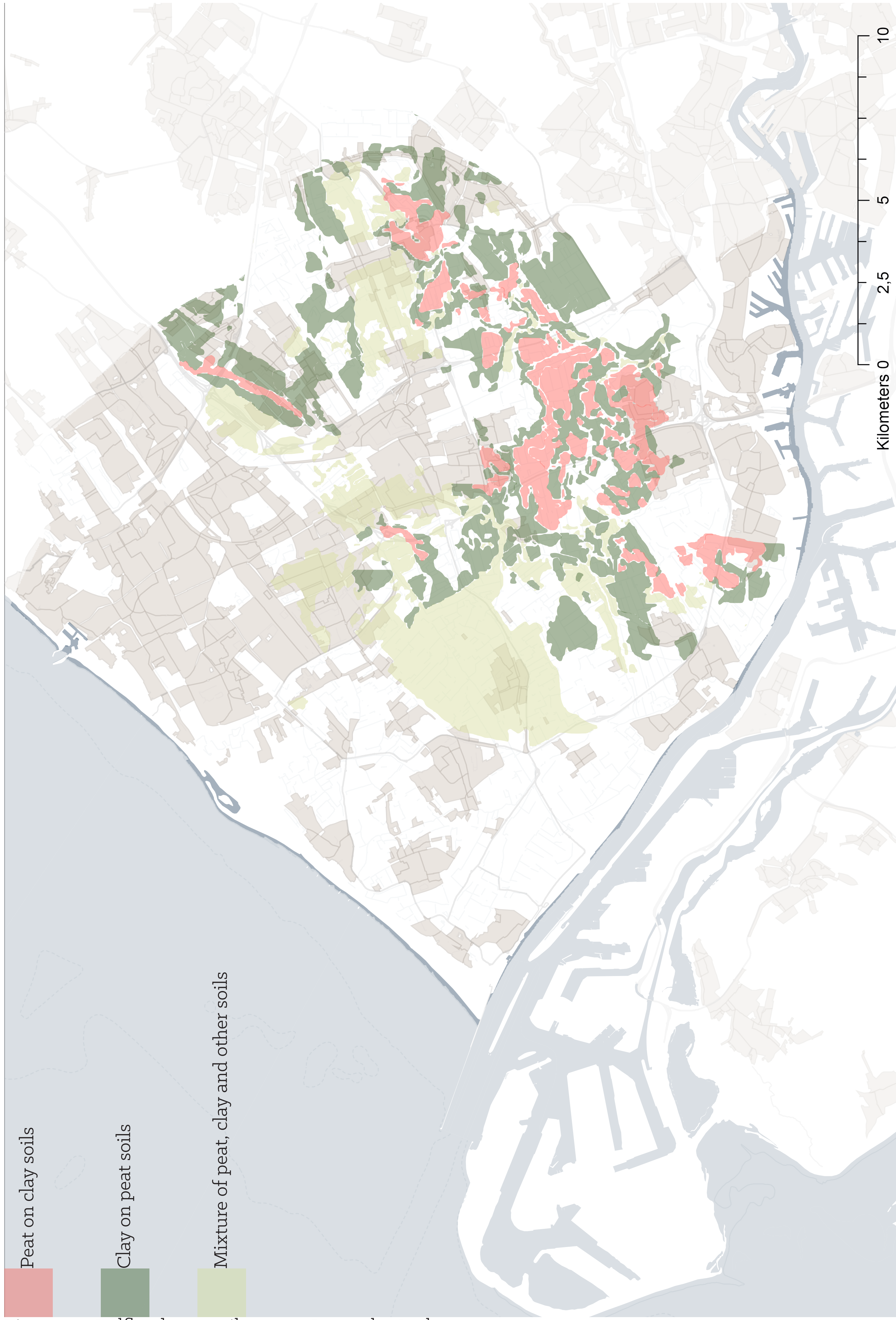


Figure 6.3: Delfland peat soils Image: by Author

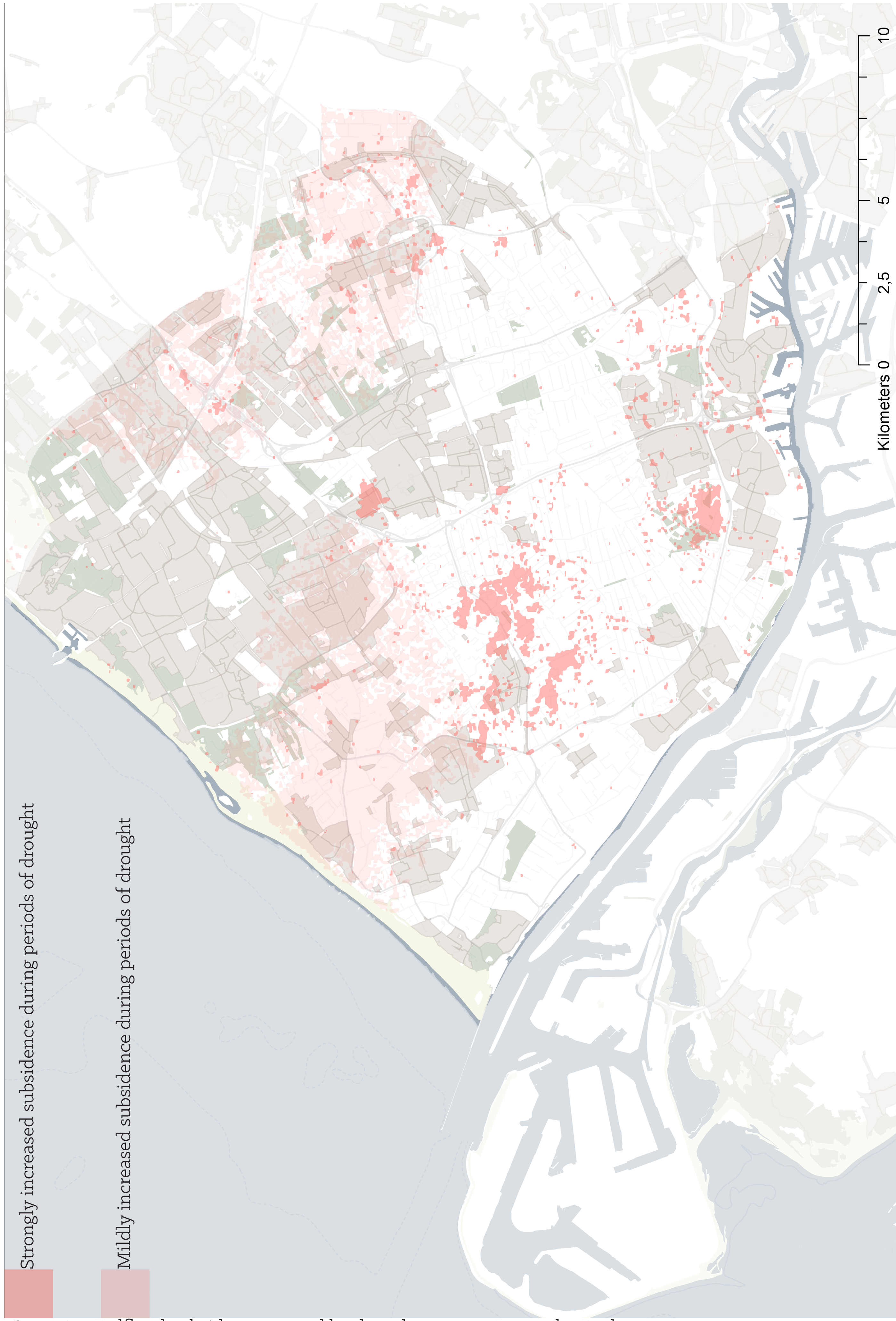


Figure 6.4: Delfland subsidence caused by draught Image: by Author

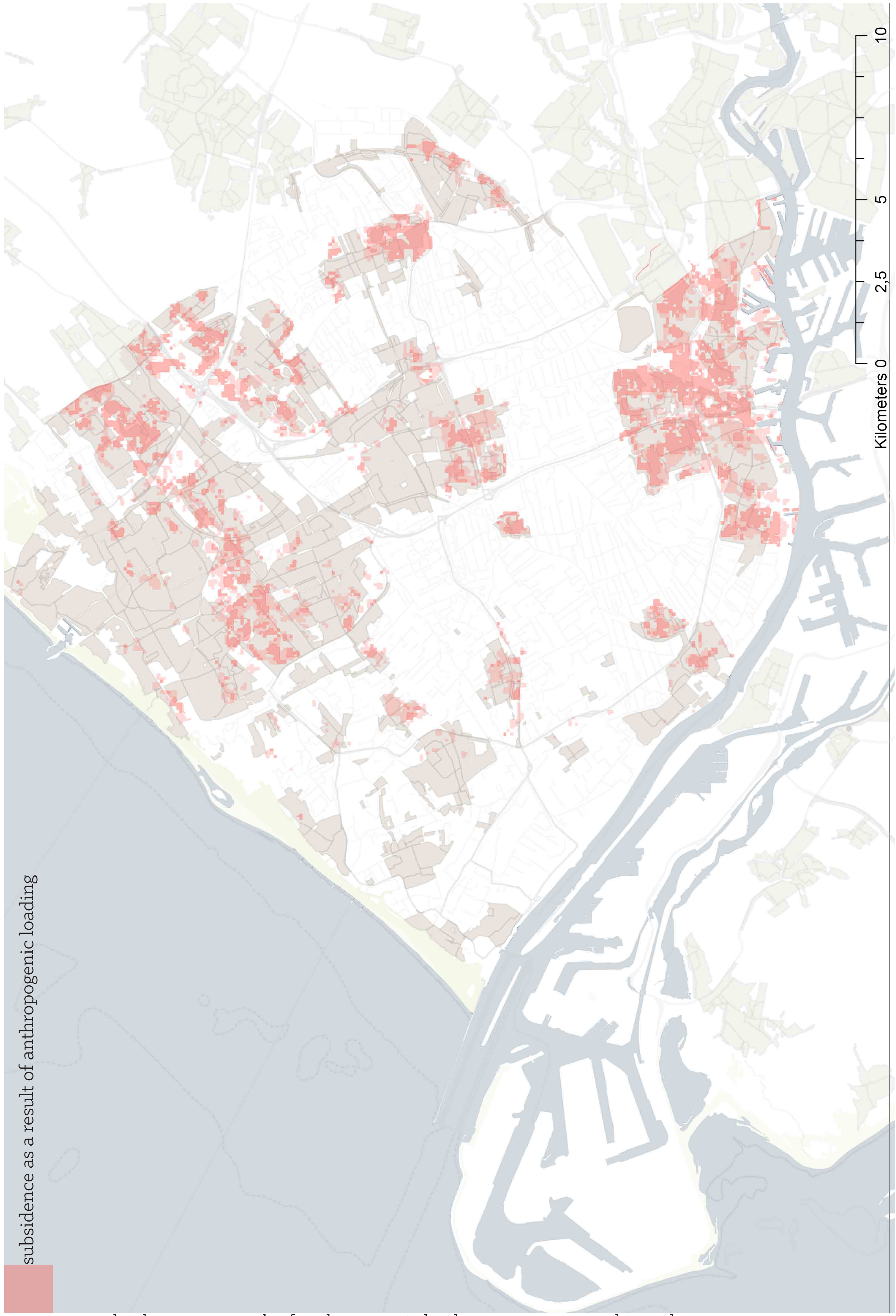


Figure 6.5: subsidence as a result of anthropogenic loading Image: by Author

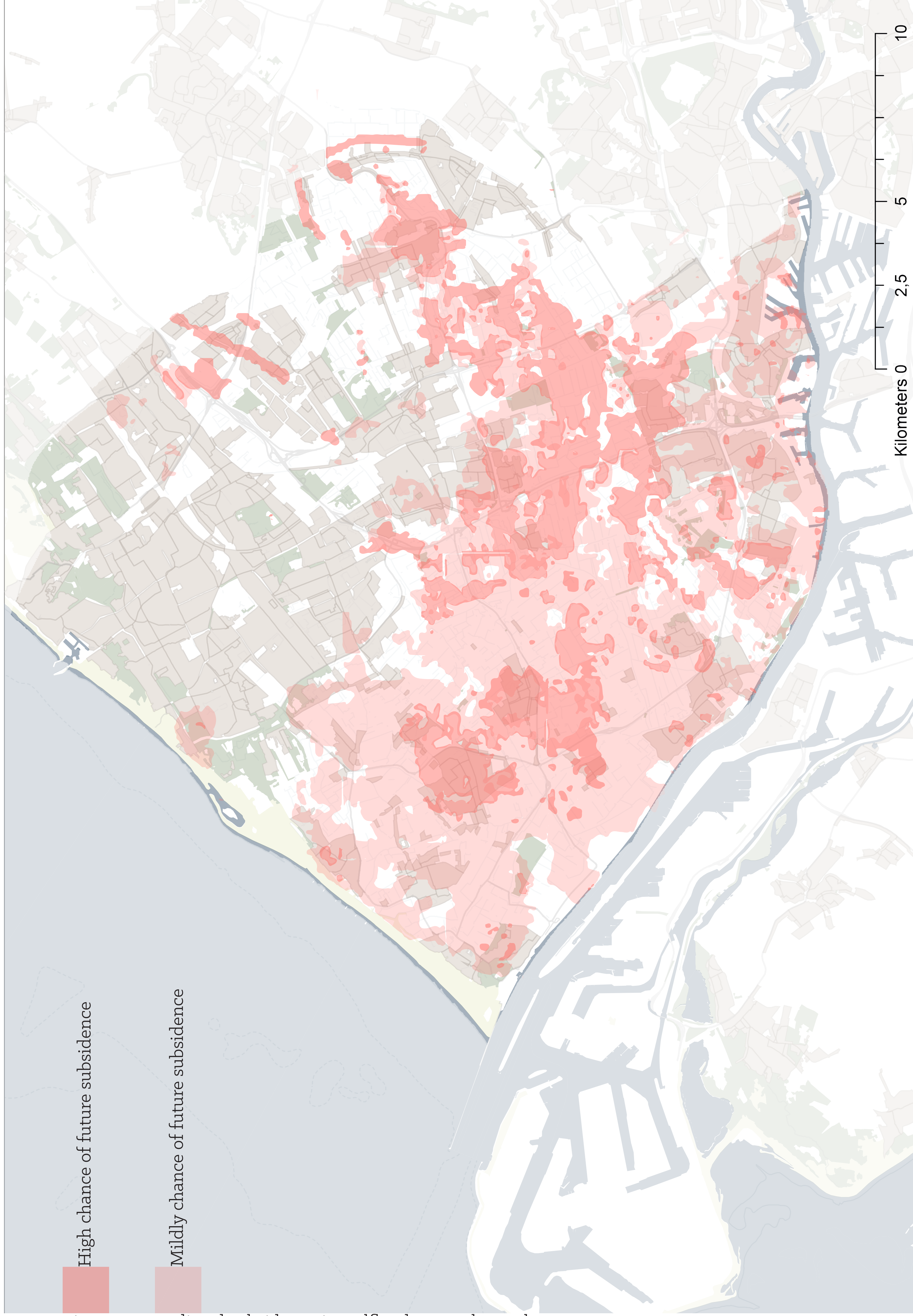


Figure 6.5: Predicted subsidence in Delfland Image: by Author

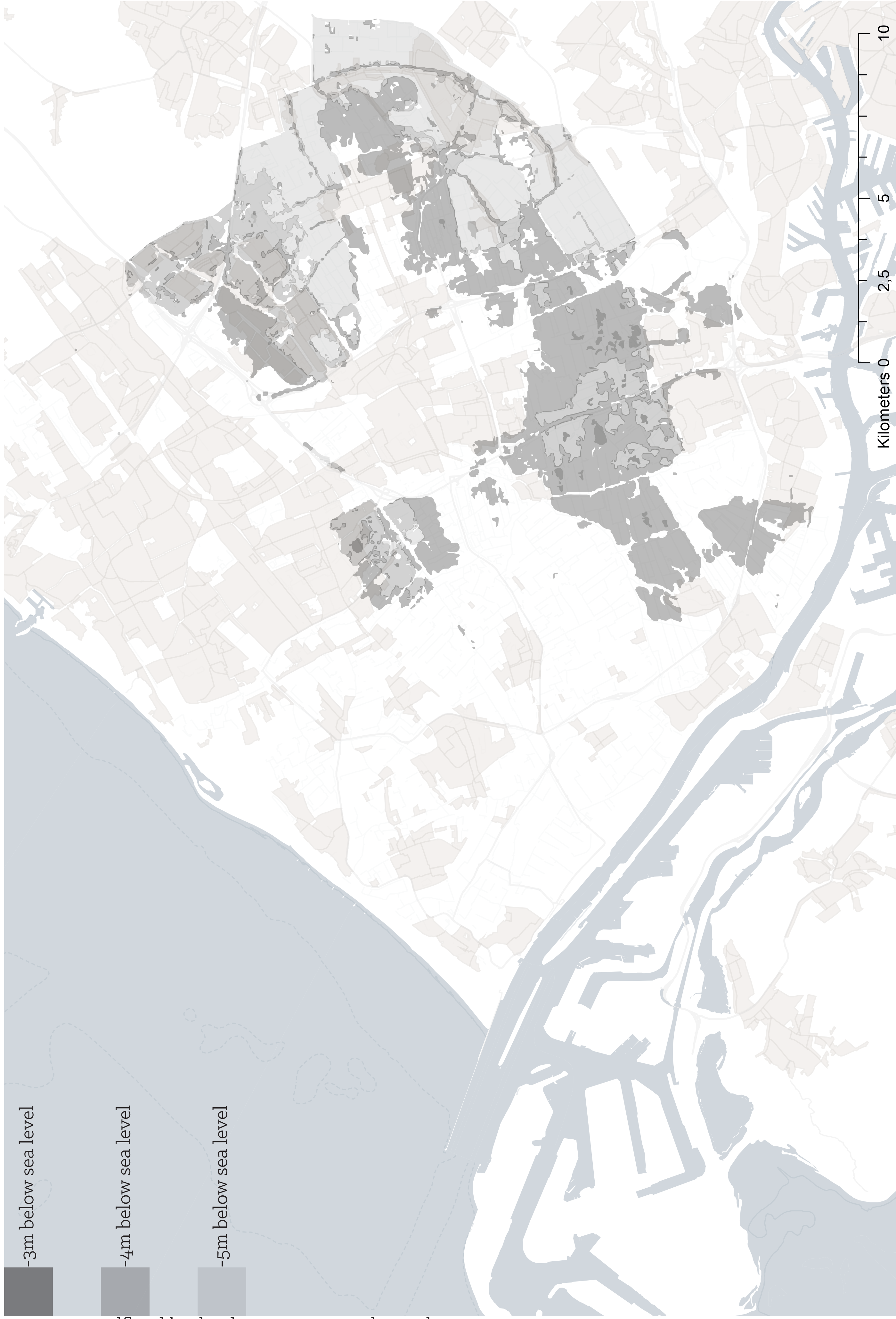


Figure 6.7: Delfland lowlands Image: by Author

6.2 Delfland water system

The Delfland water system is used to control the groundwater table within the different parts of Delfland. These parts are separated by Boezems that move water from and to the different areas within Delfland. The groundwater table plays an important role in dealing with soil subsidence and its effects. A relatively high groundwater level would keep the peat wet, and it will therefore prevent oxidation of the peat. The high groundwater table does pose a flood risk, since the water cannot absorbed by the soil during heavy rain showers. Another downside of a high groundwater level is, however that the soil has a small water baring capacity. This result in a small water buffer for the soil during periods of drought, causing the soil the dry out quickly during longer periods of drought. The peatlands are therefore very vulnerable to drought and oxidation when the groundwater level is high. This is shown in figure 6.8 and 6.9. Figure 6.9 shows that the groundwater level can drop fast in Delfland during periods of drought. Only a few spots in Delfland can maintain a relative high groundwater table during periods of drought.

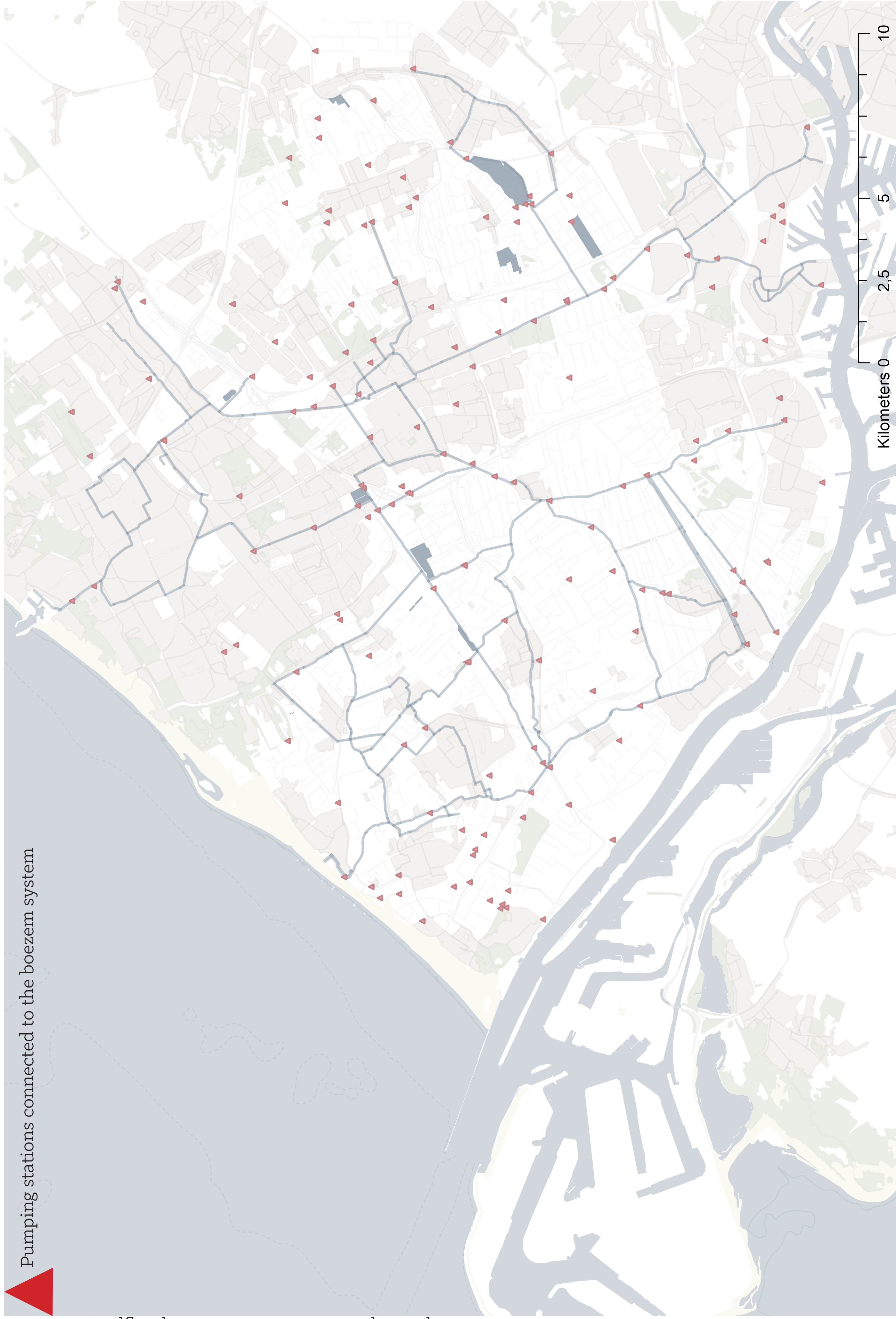


Figure 6.8: Delfland water system Image: by Author

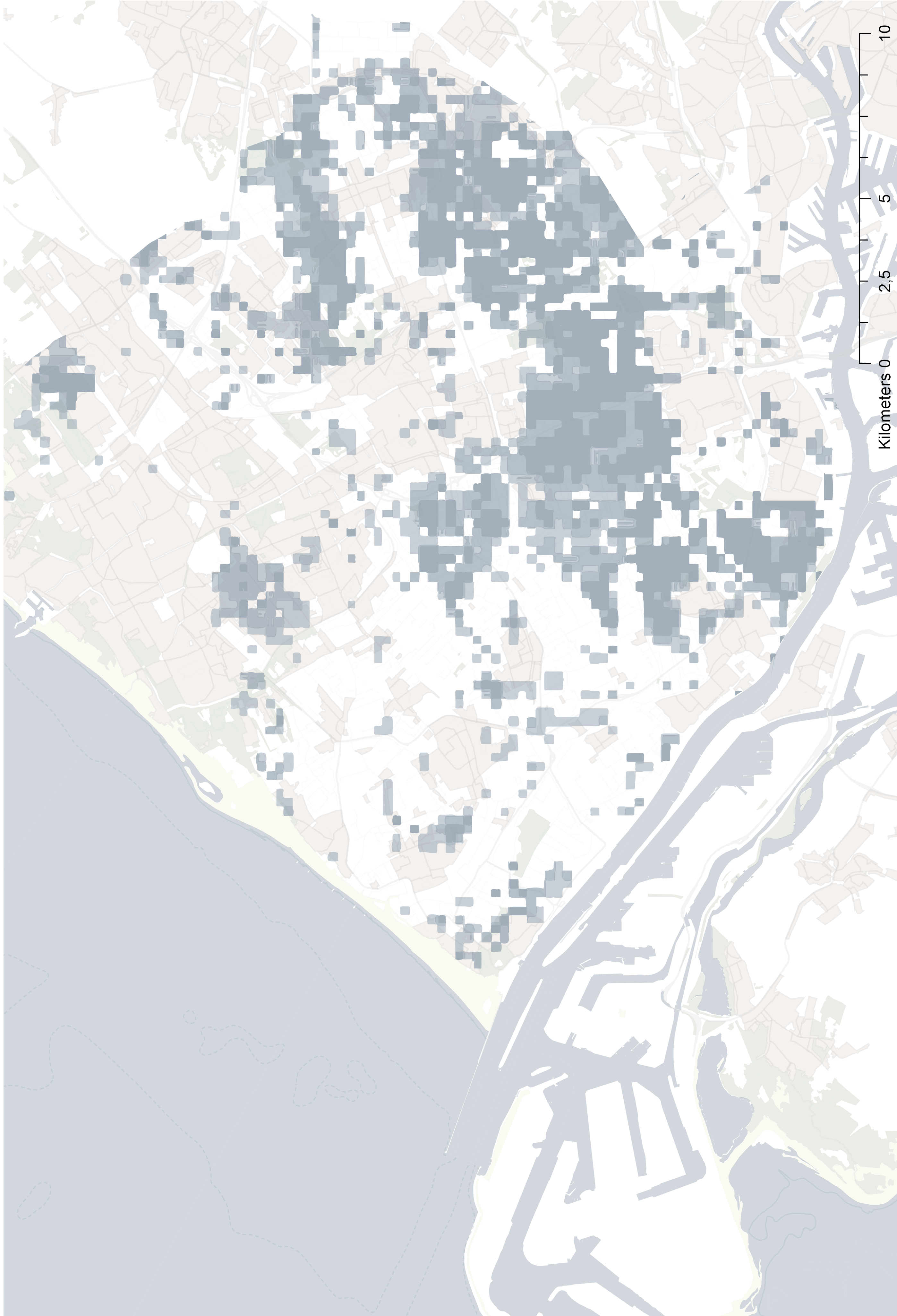


Figure 6.9: High groundwater tables during the winter period Image: by Author

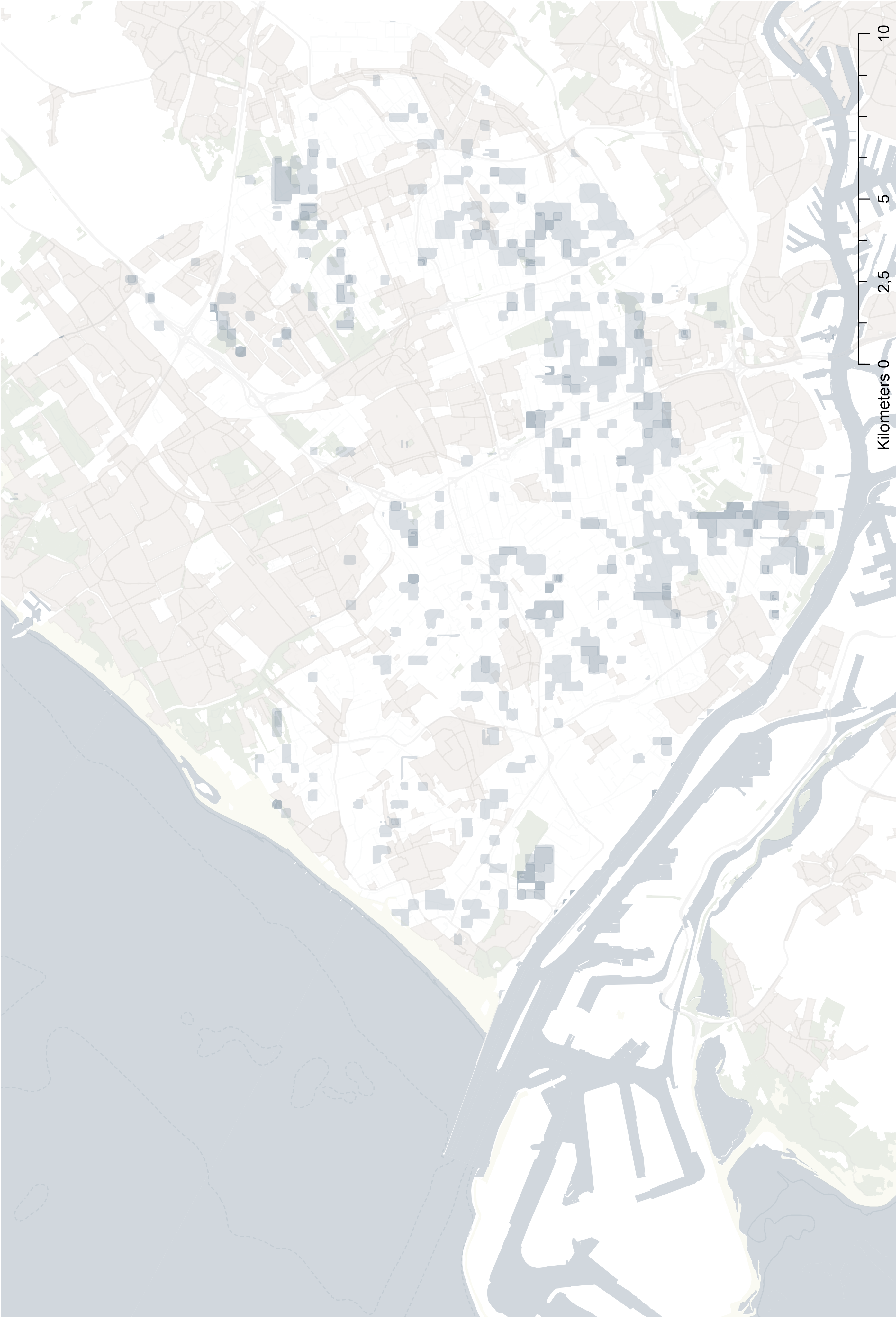


Figure 6.10: Areas where a high enough groundwater table can be maintained   Image: by Author

6.3 Ecological aspects

There are some ecologically vital areas in Delfland that will have to be protected from soil subsidence and its effects. Many waders mate in the peatlands during the summer. These waders and other animals require an ecosystem that offers a variation in plant and animal species, as well as, clean water and fertile soils. The ecosystems in the peatland are under pressure from eutrophication and salinization. Eutrophication will lead to uneven advantage for some plants, which results in them growing too fast. These plant will then quickly cover a large parts of the Delfland water surfaces. The oxygen levels in the waters will be reduced as an effect. This will eventually kill fish and other animals in the water, while other water plants get no chance to grow.

Another risk to the Delfland ecology is seepage. Seepage poses a risk in two ways. Seepage is groundwater that flows from higher parts in the landscape to lower parts of the landscape. This means that higher parts of the Delfland landscape will dry out quicker, when water seeps away to the lower parts. Soil subsidence will enhance seepage, since it increases the height differences within the Delfland landscape over time.

Another threat that is posed by seepage is salinization. Water will not only seep from higher parts in Delfland to the lower parts, but is will also seep from the North sea to the lower peatlands, since many of the peatlands can be found below sea-level. The seepage from sea contains salt water that will end up in the lower parts of Delfland. This results in saltier soils that could eventual become so salty that they are no longer fertile for plants, animals and agriculture.

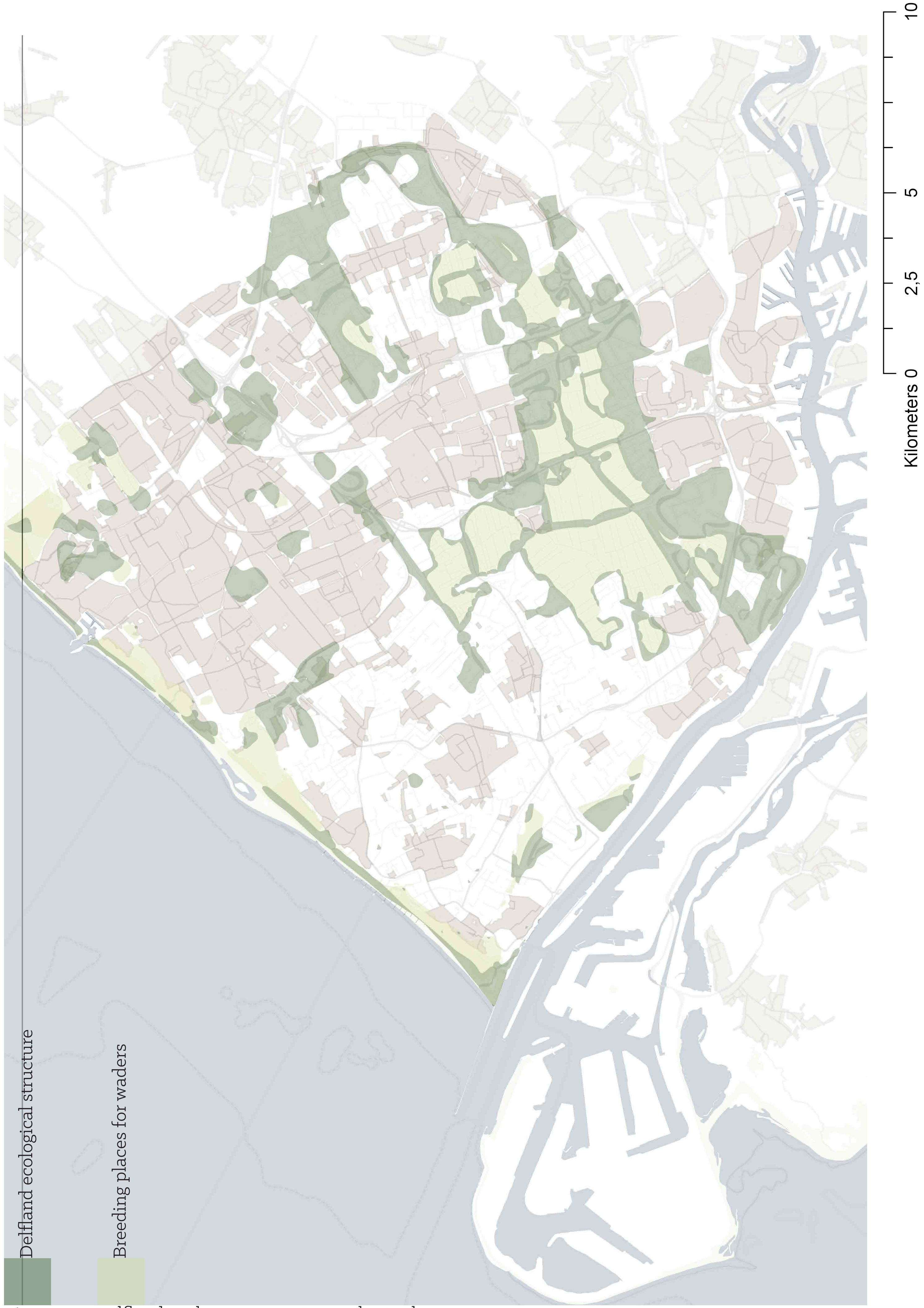


Figure 6.11: Delfland ecology Image: by Author

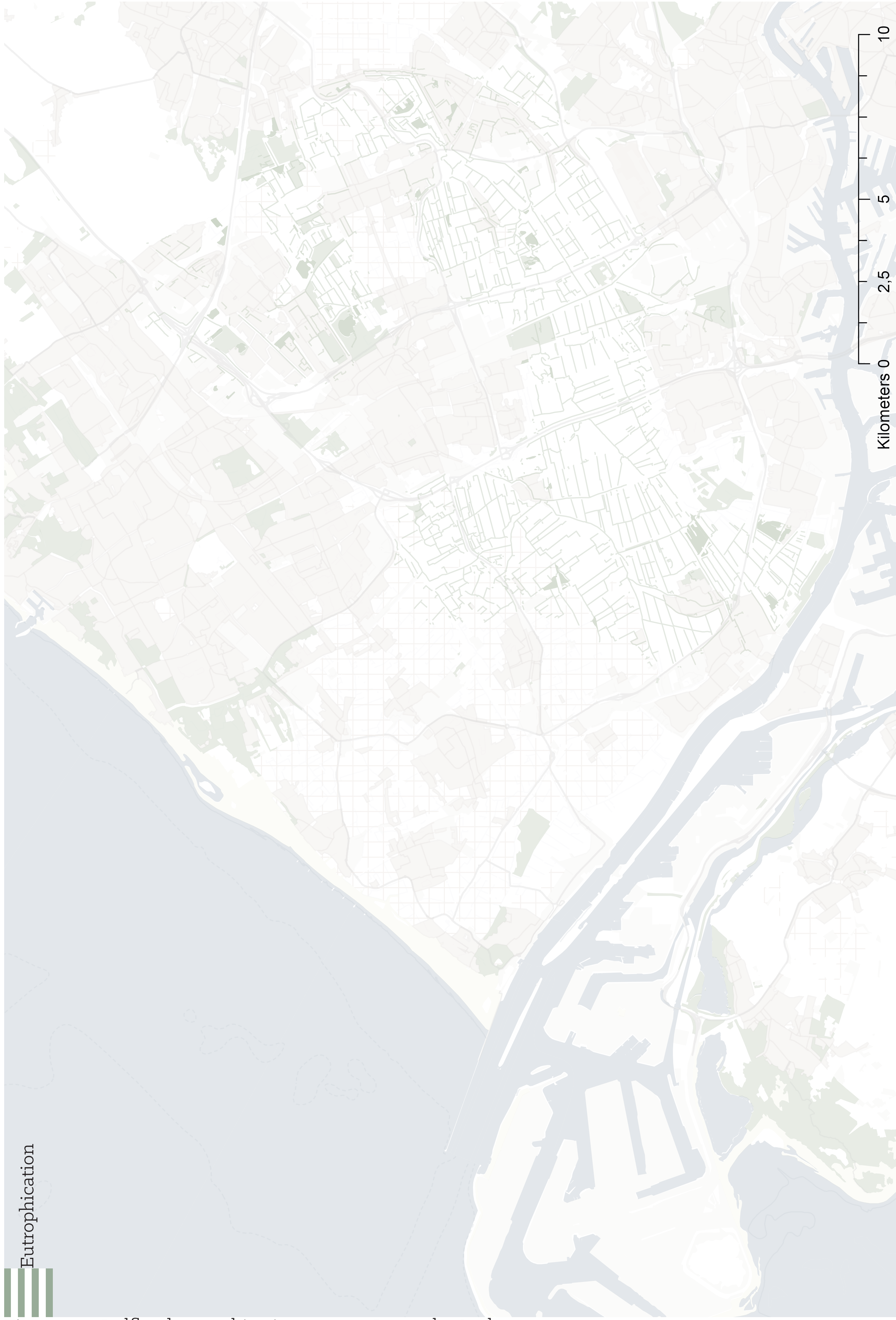


Figure 6.12: Delfland eutrophication Image: by Author

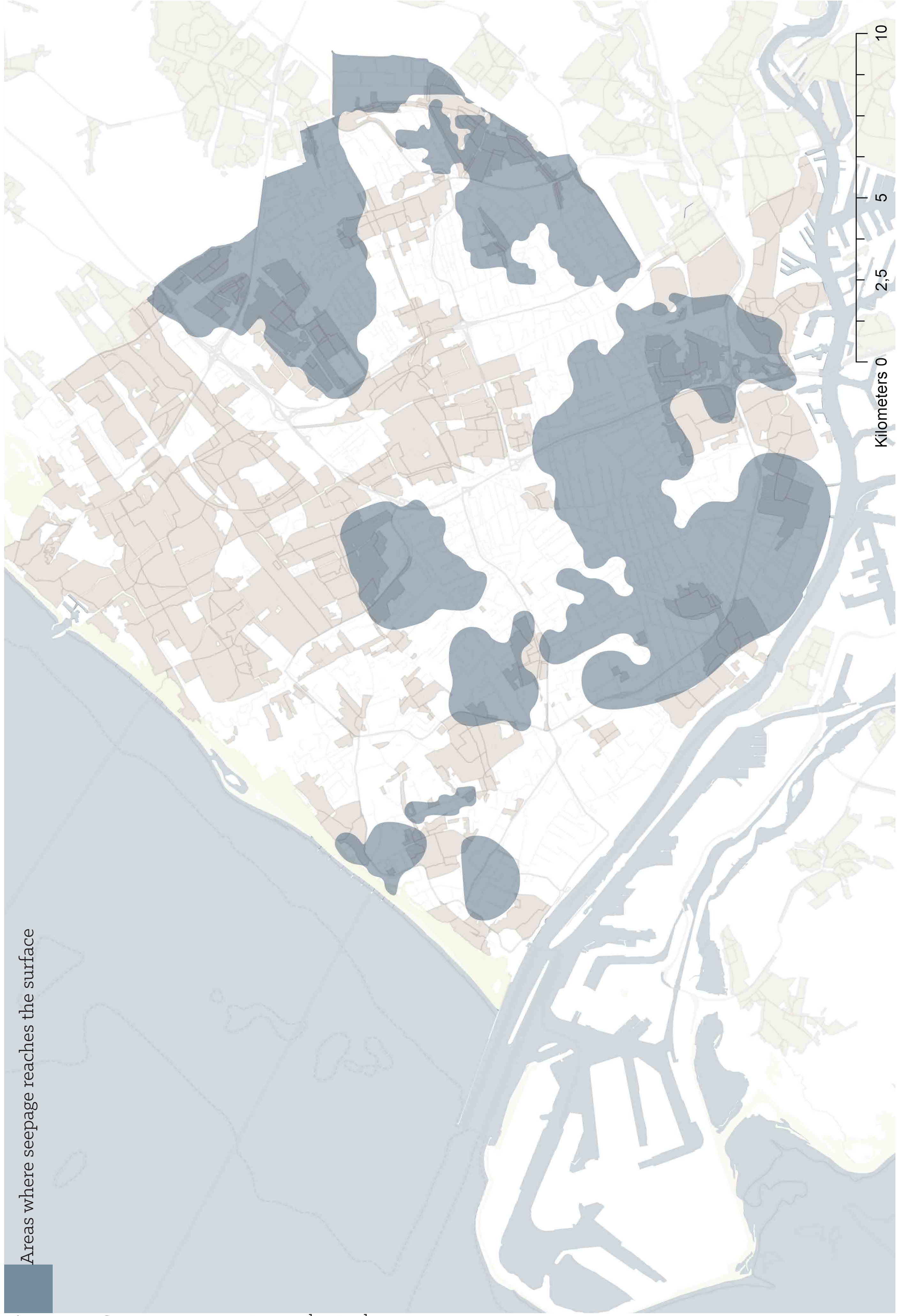


Figure 6.13: Seepage Image: by Author

6.4 Urban aspects

Constructional damages as a result of soil subsidence are not the only problems caused by soil subsidence and its effects in Delfland. Large parts of the historic cities in Delfland are built on wooden poles, which poses a risk when the groundwater table fluctuates too much. The wooden decay can damages the wooden poles when the groundwater tables falls and the poles are no longer kept wet. The poles will start to rot when the wet part of the poles is found above the groundwater table. Maintaining a high enough groundwater table is therefore crucial for the old city centres in Delfland. The pole decay could cause buildings to collapse, which would not only from a threat to the safety of the buildings and the people in it, but also to the monumental inner cities of Den Haag, Delft and Rotterdam that could be drastically changed under the influence of pole decay. Maintaining a high groundwater table within the cities poses a threat to the city as well. Lower parts of the city will be more prone to floodings, especially that parts where a large portion of the soil is covered by pavement or buildings. The water cannot infiltrate in to the soil when large parts of a city are paved. The high groundwater table makes it so that there is a very small water buffering capacity in the soil in the places where water is able to infiltrate the soil.

Figure 6.14: Risk of pole decay Image: by Author

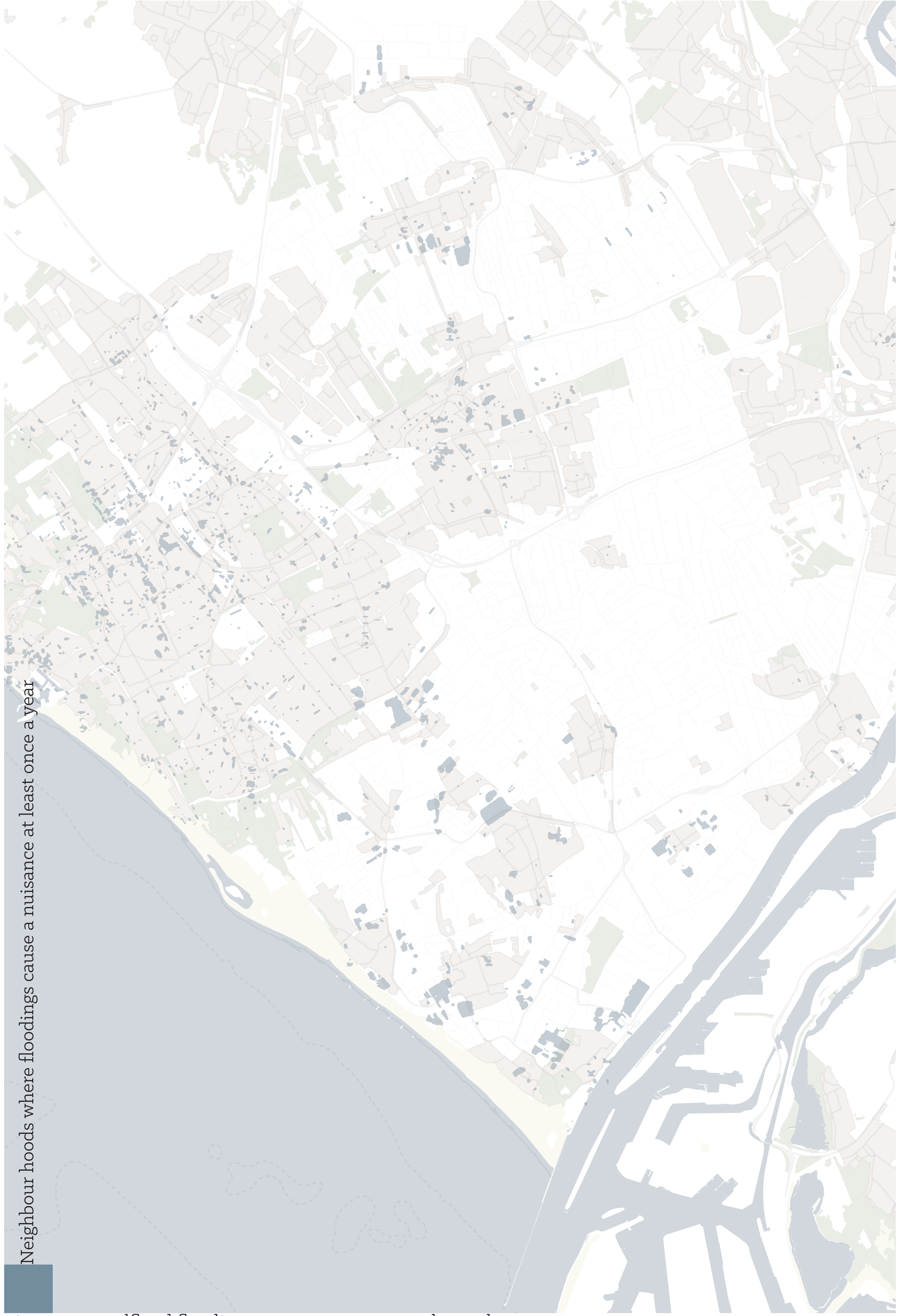


Figure 6.15: Delfland floodings Image: by Author

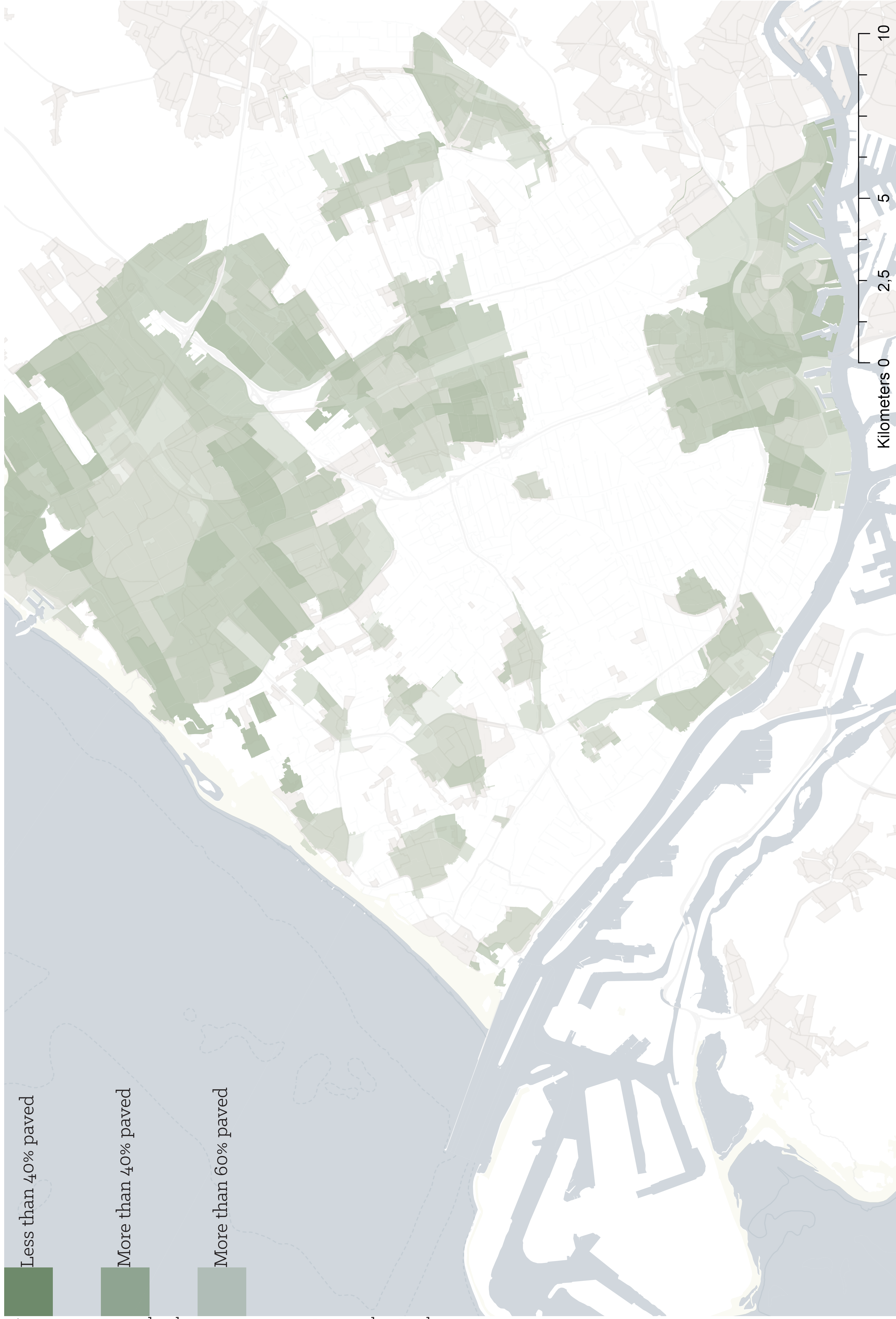


Figure 6.16: Paved urban areas Image: by Author

6.5 Agricultural landscape

Most of the agricultural lands in Delfland can be found on the peatland. This means that these lands have to endure a lot of subsidence. The subsidence of the peatlands is for a large part caused by the agriculture, since farmers require a low groundwater table to be able to use the soil. The water board has assisted the farms by lowering the groundwater table, to fit their needs. Continuing on that path is however not an option. Further oxidation of the peat will result in the peatlands completely disappearing over time. This would uncover the soils below the peatlands, which are much less fertile. The agricultural lands could, therefore, become worthless to the farmers once the peatlands have disappeared. Peat oxidation is not the only threat to the agricultural lands. The salinization from seepage, as is explained before, will make the soils infertile as well. The salinization is therefore not only a threat to the ecology of Delfland, but to the agricultural landscape of Delfland as well.

Figure 6.17: Delfland Agriculture Image: by Author

6.6 Conclusions

The analysis has shown that soil subsidence from peat oxidation has the biggest impact on Delfland. It has already subsided till a few meters below the surrounding soils. The oxidation of the peat results in eutrophication and the uncovering of infertile soils. This is harmful for the ecology and agricultural lands within Delfland.
The height differences that as a result of subsidence result in seepage towards the lower peatlands. This causes salinization in the lower lands and drought in the higher parts of Delfland. The groundwater table throughout Delfland is hard to maintain. Periods of drought cause the peatlands to dry out quickly, while seepages moves groundwater from higher parts of the city towards the lower peatlands. This lowers the groundwater table in those cities, which can result in pole decay on wooden pole foundations. Urban areas that are built on lower and weaker soils are not so much under threat from drought, but floodings and subsidence as an result of anthropogenic loading do pose a threat to those lower urban environments. The next chapter will describe and validate the actions that could be taken to deal with the soil subsidence and its effects within the different landscapes of Delfland.

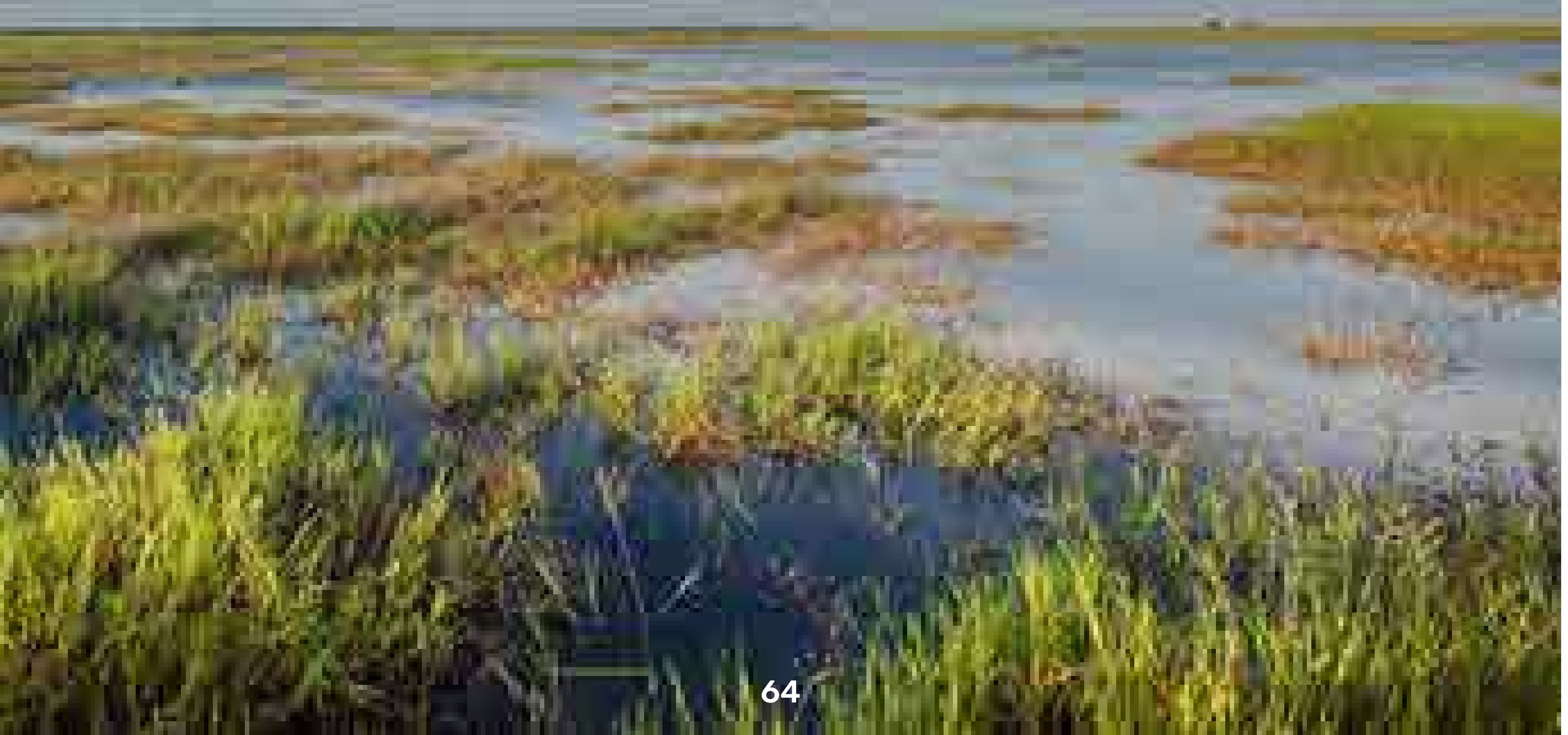
7. Action identification and assessment

Actions dealing with soil subsidence and its effects

The last chapter has shown where soil subsidence and its effects occur within Delfland, and in what from and intensity. This has revealed where soil subsidence and its effects should be counter. The analysis does however not give an insight in what can be done to deal with the different forms of soil subsidence and its effects that occur throughout the different landscapes of Delfland. This chapter will take a closer look at the actions that could be used to deal with the problems that have been revealed in the previous chapter. The description and validation of the possible actions is part of the third an fourth step of the DAPP method. The problem statement has shown that there are a lot of different influences and effects that come in to play within the soil subsidence problem field. The analysis has shown that these influences and effects occur, in many different forms, all over the Delfland region, in many different landscapes and urban environments. Countering soil subsidence and its effects would therefore require a lot of different actions for all the possible combinations of influences, effects and environments.

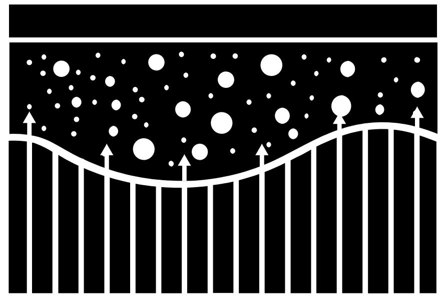
The possible actions, that could be applied to the Delfland area, are researched in three different steps. The first step is a literature study to find the different possible actions that are relevant for this research project. The actions are categorized in the second step, to create a better overview of where and when different actions could be applied. The third step is to validate and assess the actions by looking at: the impact on soil subsidence and its effects, their possible reciprocal relation, the spatial expected spatial impact, the different stakeholders, and the financial impact. The outcomes of these three steps are described in the upcoming paragraphs.
The major categories and their respective actions will be described first, before taking a closer look at the assessment of the actions. The four major categories that in which the actions have been divided are: Water management, Agriculture, Construction, and Ecology. The description for each of the actions will consist of a general description of the action, as well as, a assessment of: the effects on soil subsidence and its effects, the financial impact, and spatial implications of that action.

Further assessment of the actions consists of a description of the dependencies and possible collaboration between the different actions, and the sell by date for each of the actions. An overview of the actions, and the assessment of these actions, can be found in the action table at the end of this chapter. The assessment the actions provides the information that is needed to develop the pathway map in the fifth step of the DAPP method

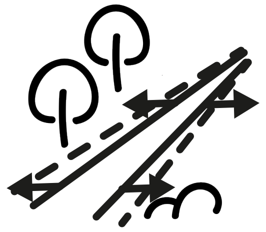


7.1 Water management actions

The main focus of the water management actions is: Expanding and adjusting the water system to make it better suited for dealing with soil subsidence and its effects. The actions will influence both the surface water system, and the groundwater system, since both have a strong reciprocal relation with soil subsidence. The goals of these four actions altogether is to help: maintain a higher groundwater table within the peatlands, make the water system more resilient to periods of drought, retain clean water within the Delfland water system, and prevent pluvial floodings in subsiding areas. The four actions, within this category, that could to achieve these goals are: passive waterlogging, broaden and expand watercourses, seasonal storage, and peak storage.

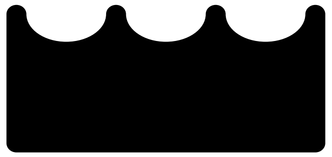


Passive waterlogging
Passive waterlogging (peilfixatie in Dutch) is an action that stops the lowering of the groundwater table. The groundwater table is currently being checked and lowered every few years to make sure that the groundwater table fits the land use within the polder. Stopping the lowering of the groundwater table would mean that peatlands are no longer pumped dry to facilitate agriculture or other functions on top of the peat soil. Passive Waterlogging can halve the soil subsidence (p13) since the peatland will no longer dry out. This would have a positive impact on climate change as well since the CO_2 production of the peatland will be heavily reduced. Applying passive waterlogging to all the peatlands in the Netherlands would lead to an emission reduction of about 1 million tons of CO_2 each year. There is however also a downside to passive waterlogging. A wet landscape is vulnerable to heavy rain showers since the storage capacity of the soil is lowered when the groundwater table rises. Waterlogging would also result in a wetter landscape to which the function upon the peat soil would have to adapt. This could result in higher costs for the current land users (van den Bron et al., 2016)



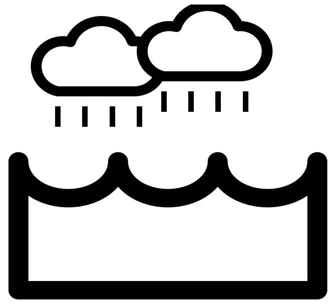
Broaden and expand watercourses

The current watercourses of the Delfland water system allows very little room for vertical and horizontal movement of water. Broadening and expanding these watercourses would offer the possibility to store more water within the system. Expanding the vertical water storage capacity is difficult since the water height is limited by bridges and other waterworks and the height of the groundwater table in the surrounding lands. It would also require new dykes. Horizontal storage would be easier. Broader watercourses or new watercourses can increase the capacity to move water throughout the landscape. The increased storage capacity of the watercourses would also means that water has more time to seep in to the ground, to supplement the groundwater table in the surrounding landscape. The watercourses are especially useful in the lower peatlands with a high groundwater table, since these areas require a lot of water to maintain the groundwater table during periods of drought. The low storage capacities of these peatlands requires water to be moved away during periods of heavy rainfall. New and broader watercourses will help to achieve this goal. The current Delfland landscape is already filled with a large amount of watercourses throughout the landscape. This action does however require new and broader watercourses throughout the whole peatland area of Delfland. Such a widespread action goes hand in hand with high investment costs (de Ruyter, P., & Plambeck, P., 2018) (van den Bron et al., 2016).



Seasonal storage

Seasonal storages are places where water can be stored throughout the season. These storages can be created in different ways and on different scales. Large scale storage to increase the region water storage capacity would mean expanding upon the water surface within the area. This is done by creating new ponds and basins or by enlarging them. These water bodies are preferably surround by dykes to increase their capacity and safety. The water level of these water bodies will differ throughout the year. The water level will be higher during wet periods and it will be lower during periods of drought, when water is needed elsewhere in the system. This water be used to maintain a high groundwater table in peatlands throughout periods of drought. The most sensible locations for these large scale seasonal storage areas would be on a lower place within the landscape where the water would flow naturally. This means that no new pumps or dykes are required to transport the water towards the seasonal storage basins. Seasonal storage is also possible on a smaller scale. This would means that the water is not stored in large ponds or basins but in smaller water tanks, for example on blue roofs or in smaller water bodies within streets or parks. These smaller scale interventions are most relevant for location with a high building density and little room for large interventions. Both forms of seasonal storage are used for the same goal. The water from these seasonal storage can be used to keep soil subsidence. The water can also be used to counter the effects of soil subsidence as well. It can help to counter drought, in higher locations throughout the landscape, that is caused by seepage from these areas to the lower peatlands. Another advantage of seasonal storage is the increased water storage capacity within the overall water system. This lowers the dependency of the water system on external water which can be polluted with phosphates or other materials that could be harmful for the local ecology. The spatial impact of seasonal storage can differ per location, depending on the form and scale of the storage. Small interventions can often be integrated within the existing environment, while larger interventions like new ponds or basins require a lot of space. This could mean that neighbourhoods, future developments, tillage, greenhouses, parks, or natural landscapes would have to make place to facilitate space for seasonal storage. The space that is used to create the larger waterbodies is however not useless since the water could be used to strengthen the local ecology, or it could be used for recreational purposes. (Pötz, H.,& Bleuze, P., 2009)



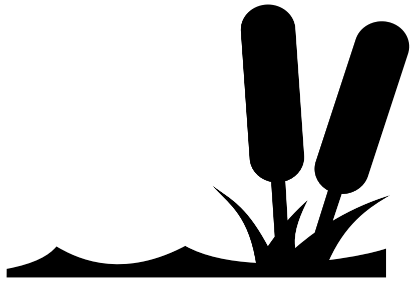
Peak storage

Creating a larger peak storage capacity for the area can be done in many different ways. But they have two main goals. The first goal is to prevent water nuisance that is caused by seepage or heavy rain fall. The peak storage will help to prevent floodings in the area surrounding the peak storage. The second goal is the retain water on higher places within the landscape, to make sure that not all the water flows to the lower areas at once. This would cause floodings in lower polders and peatlands. Peak storage can therefore be implement all throughout the project area. This means that it can also to take many different forms, depending on the landscape or environment in which the peak storage will be created. A good example of a larger scale intervention would be a summer polder.

The summer polders are places within the landscape will no longer be protected from floods during long wet periods. This means that the areas will flood if the system can no longer cope with the large amounts of water. These summer polders are often positioned on a low laying place in the landscape next to large watercourse. This allows the waterscape to overflow in the spot where the water will most likely flow naturally, without taking the risk of not knowing what part of the land is going to flood. These summer polders are completely dry during the drier periods and they can thus be used for different functions during these periods. For example: as agricultural land, recreational areas or urban parks. Smaller scale interventions within, for example, dense urban environments could be water squares, green roofs and Bioswales. These elements serve a similar purpose as the summer polders and the function in a very similar way, but on a much smaller scale.

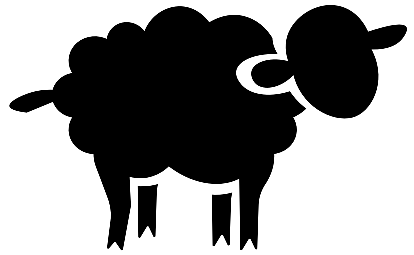
7.2 Agricultural actions

The Agricultural actions will have a focus on adapting the land use to the soil, instead of the other way around. This means that soil will no longer follow the function, but it will be the other way around. This is required to be able to adapt to soil subsidence, especially for agriculture on peat soils. Continuing the current forms of agriculture is not an option in the subsiding areas since they would require a lower groundwater table, which in its turn causes even further subsidence. This might not sound like a urgent problem for the local farmers that are not specifically interested in soil subsidence. The subsiding areas are, however, the lowest points in the landscape, which means that seepage from the north sea will flow towards these parts of the landscape. This causes salinization of the soil which could be make the soil worthless for future agriculture in any form. This is not even the only problem for the farmers. Continuous subsidence would also mean that all the peat in the soil could oxidise, resulting in exposing the soil layers below the peat. These soils are very dense, which makes it hard for roots to grow through these soils. The oxidation of the peat would therefor result unfertile lands There are four actions that can help to reduce, prevent, or even reverse soil subsidence. These actions are: Paludiculture, Sphagnum tillage, low weight agriculture and permaculture (de Ruyter, P., & Plambeck, P., 2018) (Plambeck, P., & Wijnakker, R., 2019).

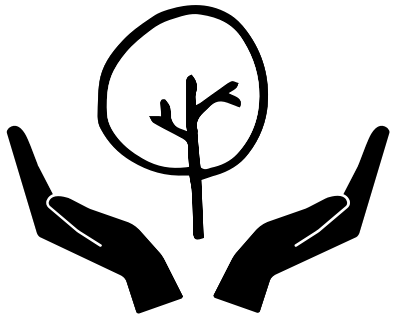


Paludiculture
Paludiculture is a form of agriculture that is appropriate for wet soil conditions. The crops that are used in paludiculture do not require a low groundwater table, since they prosper under wet conditions. This makes paludiculture a suitable form of agriculture for: places that are prone to flooding, or wet peat lands. Several types of crops can be cultivated in these wetlands with the use of paludiculture. There are multipurpose crops that can be used as silage, construction materials or fertilizers. These are corps like:: cat's-tail, sphagnum, sundew and cane. Crops with a more straightforward use, such as herbs or fruits, can be cultivated in wetlands is well. These are crops like: Water mint, cranberries, blueberries and cloudberries. paludiculture is a new form of agriculture that still needs to gain momentum. This means that the market and profits of paludiculture are still unknown at this time. It would therefore be sensible to start with smaller scale paludiculture to test out which crops could be profitable. The rest of the agricultural land does, however, not have to go to waste during this start up period. The wetlands could very well become profitable in other ways as well. For example by transforming agricultural lands in to floating photovoltaic power stations. This would no longer qualify as paludiculture, but it could be a valid alternate way to use to wetlands in a profitable way (Duursen, J., & Nieuwenhuijs, A., 2016(Plambeck, P., & Wijnakker, R., 2019).

Sphagnum tillage
The tillage of Sphagnum is the only way of land cultivation that can help to completely stop the soil subsidence and thus the greenhouse gas emissions from these peatlands. Sphagnum is a moss with unique characteristics. It is a moss that is naturally found in peatlands and it will help to regrow these peatlands when the groundwater table is maintained at a high level. The Sphagnum can create the rest of the required conditions to grow by itself. The moss is able to retain a lot of water and it can create its own ecosystem by adjusting the acidity of the soil. The moss is therefore able to retain water to prevent drought in the peatlands, while it also creates a new environment that allows new animals and plants to thrive. The sphagnum is also able to absorb large amounts of CO_2, which allows it to even further reduce the greenhouse gas emissions from peatlands. Sphagnum can be used as a soil conditioner in greenhouses, a water filtering product, a medical product or even as a conservative for food. It is however still unclear how profitable sphagnum can be. Switching to sphagnum tillage could therefore be a risk for the farmers (Plambeck, P., & Wijnakker, R., 2019).



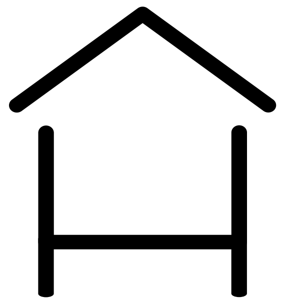
Low weight land cultivation
This form of agriculture takes the pressure, on the soil, from agricultural machines and kettle in to account, to protect the weaker soils. This means that crops that require heavy machinery will only be cultivated on soil that can bear the weight. The same is the case for heavy cattle like cows. Viable options for low weight land cultivation are Orchards and low weight cattle like sheep. Low weight land cultivation could be applied in places where the soil is currently subsiding as a result of high weight pressure on the soil. It is also suited for a landscape where the peat soils cannot be found directly at the surface but further down in the ground, since the groundwater table in these places could be maintained till just above the peat. This would prevent the transformation, of the top soil layers, into a wetland. These forms of land cultivation are already common in the Netherlands and will therefore not pose a large financial risk for the farmers, which would be the case if a transition towards a new type of land cultivation and a new market would be required (Plambeck, P., & Wijnakker, R., 2019).



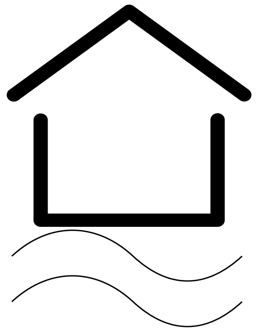
Permaculture
Permaculture is a nature inclusive way of land cultivation. This form of agriculture focusses on adapting, the land use and vegetation, to the surrounding climate and ecology. By using Permaculture design techniques, more water can be absorbed, held and made available to plants. Drought proofing, makes farms and its surroundings more resilient and able to withstand hotter temperature and drier weather it makes the soil able soak up larger amounts of rainfall in the rainy season. This is why permaculture could help to counter soil subsidence and, mainly, its effects, since permaculture can help to buffer water in the soil and nature surrounding the farms. This water will help to keep higher parts of the landscape supplied with water during periods of drought, while it will also help to refill the groundwater that is seeping away to the lower subsiding lands. The downside of Permaculture are the reduced incomes as a result of less intensive land use. The farmers that are involved in this land use change are therefore, again, the most important stakeholders. They would have to find other ways to increase the income from their land to compensate for the loss that is caused by the use of permaculture.

7.3 Constructional actions

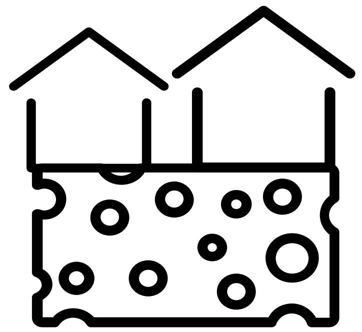
The constructional action will help to adapt the build environment to the subsiding soils, as well as the effects that are causes by soil subsidence in the landscape surrounding these subsiding soils. The build environment will have to change drastically in some places to be able to adapt to these new circumstances. The biggest challenge for the built environment is dealing with the soil that is subsiding below buildings, and the lower parts of the landscape that is slowly turning in to a wetland. Other challenges for the built environment are dealing with drought and pole decay because of seepage, and water nuisance in lower layer urban areas with a high groundwater table as an effect of passive water logging. The analysis has shown that a lot of different forms of built environments can be found in the Delfland area. This means the actions of the built environment should be suitable for urban expansions, inner cities, greenhouses, as well as individual buildings spread throughout the landscape. There are four actions that could help to make these urban environments adapt to the future changes caused by soil subsidence. These actions are: lifted constructions, floating constructions, low pressure constructions, and soil and height orientated planning and development.



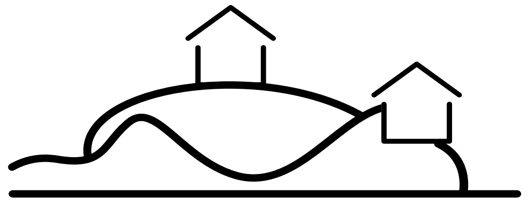
Lifted constructions
Raising buildings above the soil will help to deal with soil subsidence, as well as, its effects. The buildings are raised above the soil by poles that are founded on the stronger deeper soil layers. Houses and roads will no longer rest on the subsiding soils. lifted constructions will open up the soil that is normally covered by these buildings. This allows for more and better infiltration during heavy rainfall, while it also allows water to be evaporated from the soil, and its vegetation, during periods of drought and heat. Further subsidence of these soils would no longer impact the constructions above them since none of the constructions are built on these soils. A high groundwater level, that is required to prevent future subsidence, would not impact the constructions either, which allows the peatlands below the houses and walkways to stay wet throughout the year. This allows room for peatland regrowth below the new constructions in time, while the room space between the soil and the constructions also offers room for animals and plants. This will mean that the ecology in the peatlands does not have to suffer because of the construction of new developments above them. The downsides to building on poles are the higher costs and lowered accessibility of these neighbourhoods. The extra costs come from the raised infrastructure and foundations that can no longer be directly on top of the soil. They need separate constructions that are founded on lower stronger layers of soil. The accessibility of the houses is also reduced by this form of building, due to the walkways towards the houses that won't allow cars and other traffic to reach places beyond the main traffic routes through the neighbourhood. Public spaces and back gardens within these neighbourhoods will not look like any conventional open spaces since these functions will have to take place on top of the peat lands.



Floating constructions
Floating constructions mean that buildings are no longer built on sand or foundation poles. They are instead built on a float or pontoon that floats on the water. The buildings can therefore rise or fall with the surface water on which they float. Keeping the buildings afloat does require large enough upward buoyant forces. This has as a result that a large body of water is required. The seasonal storage areas in Delfland would therefore be ideal locations for floating constructions. The new buildings could float within these seasonal storage areas. The floating buildings would not reduce the water buffering capacity of these areas nor would it harm the local ecology since animals and plants that live in the water can continue to do so. Building on water has as an effect that neighbourhood is resilient to floodings, drought and heat. It is not yet possible to build a neighbourhood that is floating in its entirety. Infrastructure, like: roads and parking spaces, between the floating buildings should still be built on land or on foundation poles, since they would require a enormous floating foundation to be able to support cars and emergency vehicles. The costs for buildings a floating neighbourhood would be similar to a convention way of building according to the Veenetië report. This reports shows that the initial costs are higher, but the maintenance costs will be lower. A floating form of construction could therefore be a viable alternative for conventional forms of building, especially since cities in the Netherlands are running out of land to build on (Mankor et al, 2019).



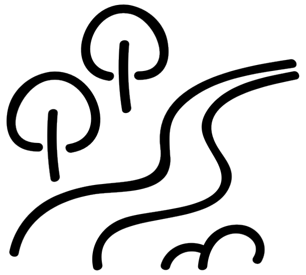
Low pressure (re)construction
One of the main cause of soil subsidence within an urban area is the pressure of the weight of the buildings on the soil. The pressure on this soil can be reduced by using light-weight materials in the preparation of the buildings site, instead of sand. Developing buildings and infrastructure on these low-weight materials does not only reduce the pressure on the weak soil underneath these constructions, it also allows the constructions to move along with the subsidence. This results in a neighbourhood with fewer height differences between houses and their surroundings and without broken infrastructure, like sewage and water pipes, because of local subsidence.



Soil and height orientated planning and development
The type of soil should dictate which functions can or cannot take place at a certain place. The current Delfland soil is modified to fit the land use that was required or planned. This makes that polders are pumped dry and the groundwater is lowered to benefit agriculture or for the construction of city expansions. This shows that the current form of planning is orientated in such a way that the soil has to adapt to the activity that has to take place upon it. Soil orientated planning will focus on planning from a soil perspective. This means that use of the land is adapted to the height of the landscape and the type of soil. Lower areas with weak soils should be used for functions that can cope with floodings or soil subsidence, for example sports fields or a park. Higher and stronger soils can be used to develop more vulnerable functions, like schools or hospitals. Making the soil dictate what happens on top of it could drastically reduce the impact that soil subsidence and its effects will have.

7.4 Ecological actions

The ecology of Delfland is under pressure from ever expanding cities and agriculture. Soil subsidence is a big threat for the ecology as well. The peatlands, that are crucial for the plants and animals in Delfland, are slowly disappearing as a result of peat oxidation. This oxidation does not only destroy the peat that is part of the historical Delfland landscape, it also releases phosphates and heavy metals in to the soil and water. These material will disturb the ecology even further. The ecology outside of the peatlands is influenced by the soil subsidence as well. Lower parts of the landscape will flood more quickly because of the reduced water retention capacity of the subsiding soils. Higher parts of the landscape will have to deal with drought as a result of seepage from higher areas to the lower subsiding landscapes. The water management actions can be used to help the Delfland ecology deal with issues like drought and water nuisance, but further actions are required to make the local ecology cope with the negative effects of soil subsidence. There are four actions that could help to strengthen the Delfland ecology and make it more resilient to soil subsidence and its effects. These four actions are: unrefined watercourses, Decentralized water treatment, underwater drainage, and environmental protection and conservation.

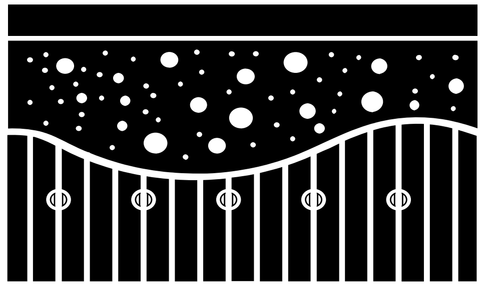


Unrefined watercourses

The landscape of Delfland is filled with canals and other watercourses that are dug by humans to transport water from and to the agricultural lands. These straight watercourses do however have some downsides. The straight water flows contain less water than unrefined watercourses that flow over the same distance. Water flows much faster through straight watercourses, which results in floodings at the end point of these water courses. Returning to a more natural water system, where possible, would therefore make sense in Delfland, especially for the benefit of local ecology. Unrefined watercourses allow the water to flow at different speeds to benefit different types of fish and plants, with different preferences. The same can be said for the different types of banks that are created by with a more natural water flow. Unrefined watercourses can offer a wide variety of small ecosystems to benefit birds, plants, fish and other animals (van Peteghem, M., 2016).

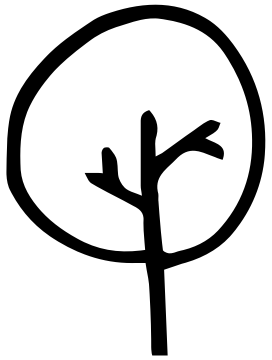
Decentralized water treatment

It can be difficult retain enough water in the system, to always be able to deal with drought. This is especially the case in areas like Delfland where a lot of water is required to maintain a high groundwater table in the peatlands. Water from outside the water system could be used to cope provide water for the system during these periods. This water is, very often, contaminated with phosphates or other materials that could be harmful for the environment. These same harmful materials are also released from the peatlands when the oxidise. A natural way of water filtering throughout Delfland could help to protect the local ecology from these material. Helophyte filters and the right water plants can help to keep filter the pollutants from the water, while they also offer a place for animals to live in (van Peteghem, M., 2016).



Underwater drainage

Retaining water within the system could eventually help to provide enough water throughout the scales to maintain a stable groundwater table within the water system. It is however questionable whether or not this can be achieved within the limited space of the Delfland. Drainage and irrigation systems could therefore be used to help maintain the preferred groundwater table. This intervention could be implemented on the short term and it allows water to be drained faster during periods of heavy rainfall. This could be useful in agricultural lands, but also in peatlands that can become vulnerable when they become too wet. The irrigation systems can help to provide water, that is retained within the system, for the peatlands to keep the groundwater table high enough to prevent the peat from oxidising during periods of drought. This means that underwater drainage can help to protect the wetland ecosystem from drought and floodings. (van den Akker, J.J.H., 2016)



environmental protection and conservation

The landscape of Delfland could change drastically as a result all the previously mentioned actions. This changing landscape should be well managed to make sure that it develops in a way that contributes to the ecology, as well as, the reduction of soil subsidence and its effects. This could be done in multiple ways. The historical wetlands landscape of Delfland could be recreated by letting nature take over in some places. This could happen in places where the landscape will change so drastically that it becomes hard to use it for agriculture or other functions. Nature would be left on its own in this case, to slowly return to its natural conditions. Another way of protecting and conserving the environment could be through Agricultural nature conservation. This would means that the land can still be used for agriculture, but the land cultivators would take the local ecology in to account when working the land. This could for example be done mowing the grass closer to the water to provide cover for animals that live in or close to the water. Another example would be to work the land in such a way that it is still possible for birds or other animals to nest on these lands (Plambeck, P., & Wijnakker, R., 2019).

7.5 Dependencies & collaboration

Some of the described actions may depend on other actions to be effective or to even work at all. Other actions could work on by themselves but they would strengthen each other when they are applied at the same time as some of the other actions. The dependencies and collaboration are relevant for two reasons. They will help to define the order in which actions should be places on the pathway map in the fifth step of DAPP. The dependencies and actions will also help in the decision-making between pathways in the sixth step of DAPP. Not all actions depend on, or collaborate with, other actions. The is paragraph will therefore give an overview of the dependencies and possible collaborations in three categories. The first category are the actions that do not depend on any other actions and could therefore be applied at any time throughout the project. The second category consists of actions that are dependent on other actions. The third category contains the actions that could collaborate.

Independencies

The independent actions do still require other actions to be taken throughout the process of adapting Delfland to soil subsidence and its effects. They are however not dependant on other actions to be applied in the most effective way. These actions could therefore be applied without depending on any of the other actions. These independent actions are: peak storage, low weight land cultivation, low pressure (re) construction, soil and height orientated, planning and development, and underwater drainage.

Dependencies

Paludiculture, sphagnum tillage, and lifted constructions do all depend on passive waterlogging being applied first, before these actions are taken. Sphagnum tillage and paludiculture depend on a high groundwater level. These actions could therefore only be applied once the groundwater table is no longer lowered to benefit other forms of agriculture. Lifted constructions are not dependent on a high groundwater level in the same way as sphagnum tillage or paludiculture, but it would be an unnecessary and ineffective action in an area where passive waterlogging is not applied. This is mostly the case because lifted constructions are built avoid water nuisance in areas with a high groundwater table. The lifted construction do also offer room for peatlands to regenerate, but this is only possible once the groundwater table is raised.

Collaborative

The collaborative actions could all function by themselves, but combining them with another action would mean that it could be implemented more effectively or that the action could have a greater effect in general. The first combination of actions that could strengthen each other are Passive waterlogging and broaden and expand watercourses. The extra water courses could help to maintain a more constant groundwater table throughout the area. This would help to easily spread the effects of passive waterlogging.

Combining unrefined watercourses, decentralized water treatment, and broaden and expand watercourses could lead to new more natural watercourses with clean water. This would mean that the new and broader watercourses are not only helping to store and spread out water. The new watercourses will also create a new and clean environment for animals and plants, while the unrefined watercourses allow more water to be stored in the new watercourses.

The transition from a more common form of agriculture to permaculture could very well be combined with environmental protection and conservation. The farmers would switch to a form of agriculture that takes the local climate in to account, while also actively facilitating breeding places and other facilities for animals and plants in the region. The final combination of actions that could help to strengthen each other are: seasonal storage, floating constructions, and decentralized water treatment. These action could easily be implemented at the same time and as one project to save costs. The seasonal storage would function as a new development location, while the urban green spaces could be arranged in such a way that they function as a green space for the neighbourhood and as decentralized water treatment facility.

7.6 Action table

The action table gives an overview of the different actions and their impact. The actions are rated by looking at their impact on soil subsidence and its effects. A "0" would mean that the action has no impact on that specific effect of soil subsidence. "+" and "++" indicate a respectively small or big positive impact. The "-" and "- -" indicate a negative impact on that effect.

The left side of the table shows the different action categories and their respective actions. For all of the actions is indicated whether they work in a mitigating or adapting way. The mitigating actions are the ones that stop or sometimes even reverse soil subsidence, while the adapting actions are focused on dealing with the effects of soil subsidence, that are already present at this moment or, that could occur in the future if soil subsidence continuous.

The top of the table shows the effects of the actions on soil subsidence and on three different categories. The climate category shows the effects that soil subsidence has on the climate or vice versa. The indicators in the table show whether or not an action can reduce the nuisance that is caused by that specific climate element .

The environment category shows the impact of an action on the location where it would take place and the impact of the action on the local ecology. The location impact is based on how much space is required for the actions, or how much an action will impact the current conditions and appearance of an area. The ecological effects show how big the impact of an action on the ecology could be. The expediency category shows the financial impact of an action, as well is the sell by dates of the actions. The financial impact is determined by the cost of the action or the reduction in profits that is caused by the action. The Sell by dates show when an action can take place at the earliest and when an action should be implemented at the latest.

The actions within this action table have been used to develop a pathway map. The development of this pathway map is the fifth step of the DAPP method. This step will be described in the next chapter.

Action	Effect	Subsidence	Climate				Environment		Expediency		
		Soil subsidence	Emissions	Heat	Drought	Water	Location impact	Ecological	Financial	Start date	End date
Water management	Passive waterlogging	+ +	0	+	+ +	0	- -	+	0	2025	2050
	broaden and expand watercourses	+	0	+ +	+ +	+ +	-	+	- -	2020	2080
	Seasonal storage	0	0	+ +	+	+	- -	+	- -	2020	~
	Peak storage	0	0	+	+	+ +	-	0	-	2020	2060
Agricultural	Paludiculture	+	+	+ +	+ +	+ +	0	+	- -	2030	2060
	Sphagnum tillage	+ +	+ +	+	+ +	+	0	+ +	- -	2030	~
	Low weight land cultivation	+	+	0	0	0	0	0	-	2020	~
	Permaculture	0	0	+	+	+	-	+ +	-	2020	2080
Constructional	Lifted buildings	+ +	0	+ +	+	+ +	-	+	-	2020	~
	Floating constructions	+	+	+ +	+ +	+ +	0	+	0	2020	~
	Low pressure (re)construction	+	0	0	0	0	0	-	-	2020	2050
	Soil and height orientated planning and development	+	0	+	+	+	-	0	0	2020	2070
Ecological	Unrefined watercourses	0	0	+ +	+	+	-	+ +	- -	2030	2070
	Decentralized water treatment	0	0	0	0	0	0	+ +	-	2020	2060
	Underwater drainage	+	0	0	+	+	0	+	-	2020	2050
	Environmental protection and conservation	0	+	+	+	0	- -	+ +	- -	2040	~

Mitigating

Adaptating

Figure 7.1: Action Table Source: by Author

8. Pathway map

this chapter to develop a pathway map. The development of this pathway map is part of the fifth step of DAPP. This chapter will describe the map and how it is used in the upcoming research steps to review the strategical and spatial outcomes of dealing with soil subsidence and its effects.

The pathway map consisting of the actions that have been described in the previous chapter can be found in figure 8.1. The map is show the different actions within their respective categories along a timeline. This results in a map that offers paths for four parallel pathways. This allows actions within different categories to be taken at the same time. Actions with the same goals or results are only found within the same category, to make sure that those actions are not taken in at the same time. The start end point for each of the actions indicate when an action can take place at the earliest and when an actions should be finished to still be effective. The map shows all the different possible paths that can be taken to create the pathways. All the different possible pathways can be seen as different strategies that will all help to adapt the Delfland region to soil subsidence and its effects. The different possible pathways will all work towards making Delfland more resilient to soil subsidence and its effects. The timing of the actions or choices within the pathways could however lead to different spatial outcomes for the Delfland region.
The timeline for the map is set to start in 2020 and end in 2085. The year 2085 is derived from the KNMI climate scenarios (KNMI, 2015) . These scenarios give an insight in the possible effects of climate change till 2085. These scenarios have been used in the analysis to analyse future change in Delfland when it comes to drought, floodings, soil subsidence, and other climate related effects. Predications beyond this date are limited or hard. The actions in the action table are therefore aimed at the predictions from these KNMI scenarios. The current map is there to offer the possible paths till 2085. Future actions and new horizons for the maps should be set once new research or actions have been developed. This will make it possible to keep using the map after 2085. The end date of this map is therefore not set as an end date on which all actions have to be finished and neither is a date on which the whole region should be adaptable to all forms of soil subsidence and its effect.
The map shows that some action can be applied at any moment on the timeline. Other actions have a specific timeframe within which they will have to be applied to work effectively. These sell by dates and how they are determined are described in the action assessment chapter.

The decision-makers in Delfland will have to decide which of the possible pathways is the preferred pathway to follow. The preferred pathway is the pathway that is most suited for Delfland according to the decisionmakers. That means that this pathway will be followed when possible. Future changes or events in Delfland could, however, influence whether or not an action should still be used. Some action could become irrelevant because they turn out to be ineffective at that time. New actions could be added to the map which could offer new pathway options. The Preferred pathway is therefore not necessarily the pathway that is taken in the end. Which preferred pathway along the pathway map will be chosen is up to the decision-makers in Delfland. The next chapter will give an insight in who the stakeholders in Delfland are and how they could be involved in the decision-making process when it comes to choosing a preferred pathways on the pathway map. The pathway map will also be used in the tenth chapter, to choose pathway along the map and review what their spatial impact on Delfland could be.

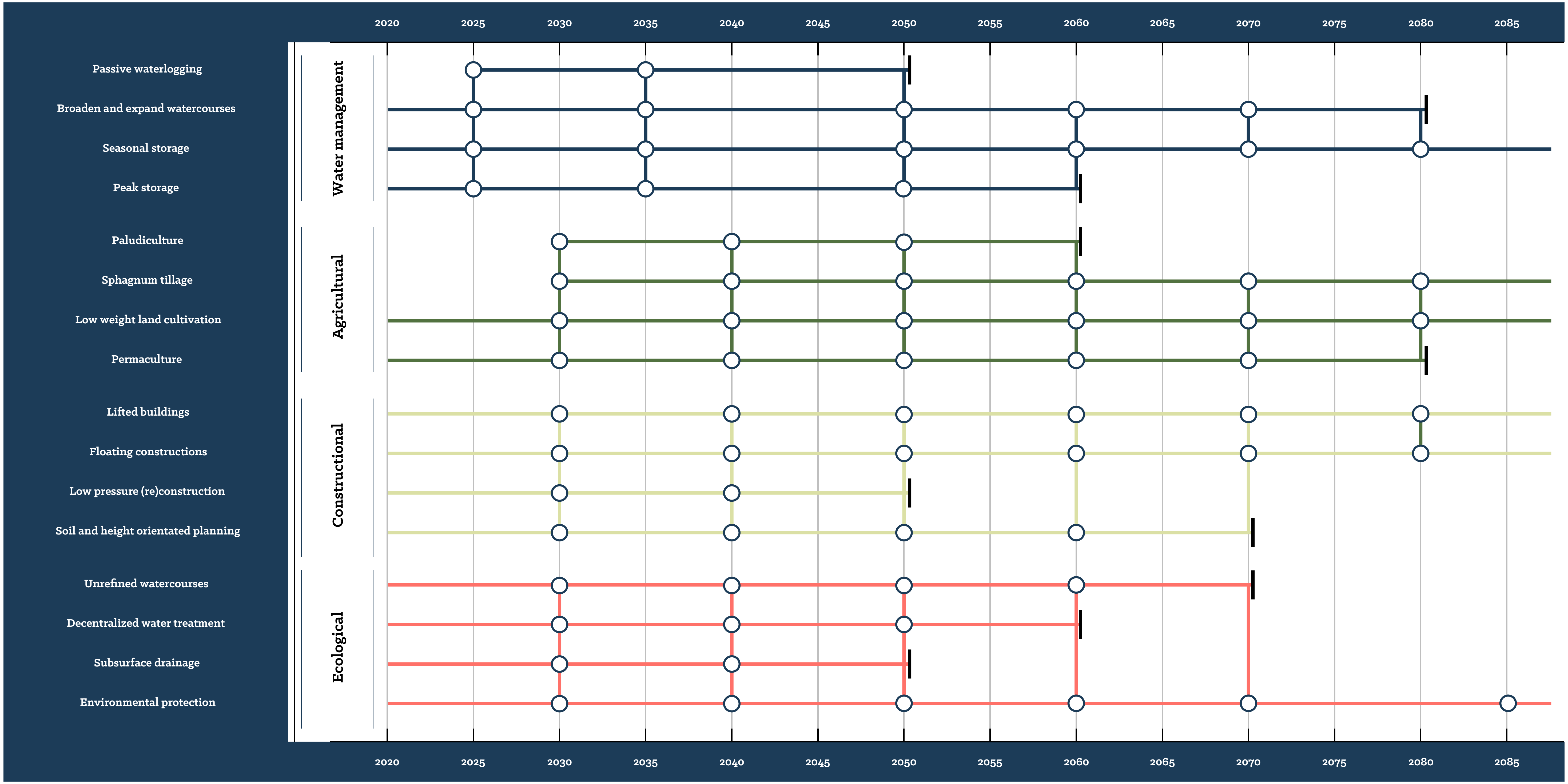
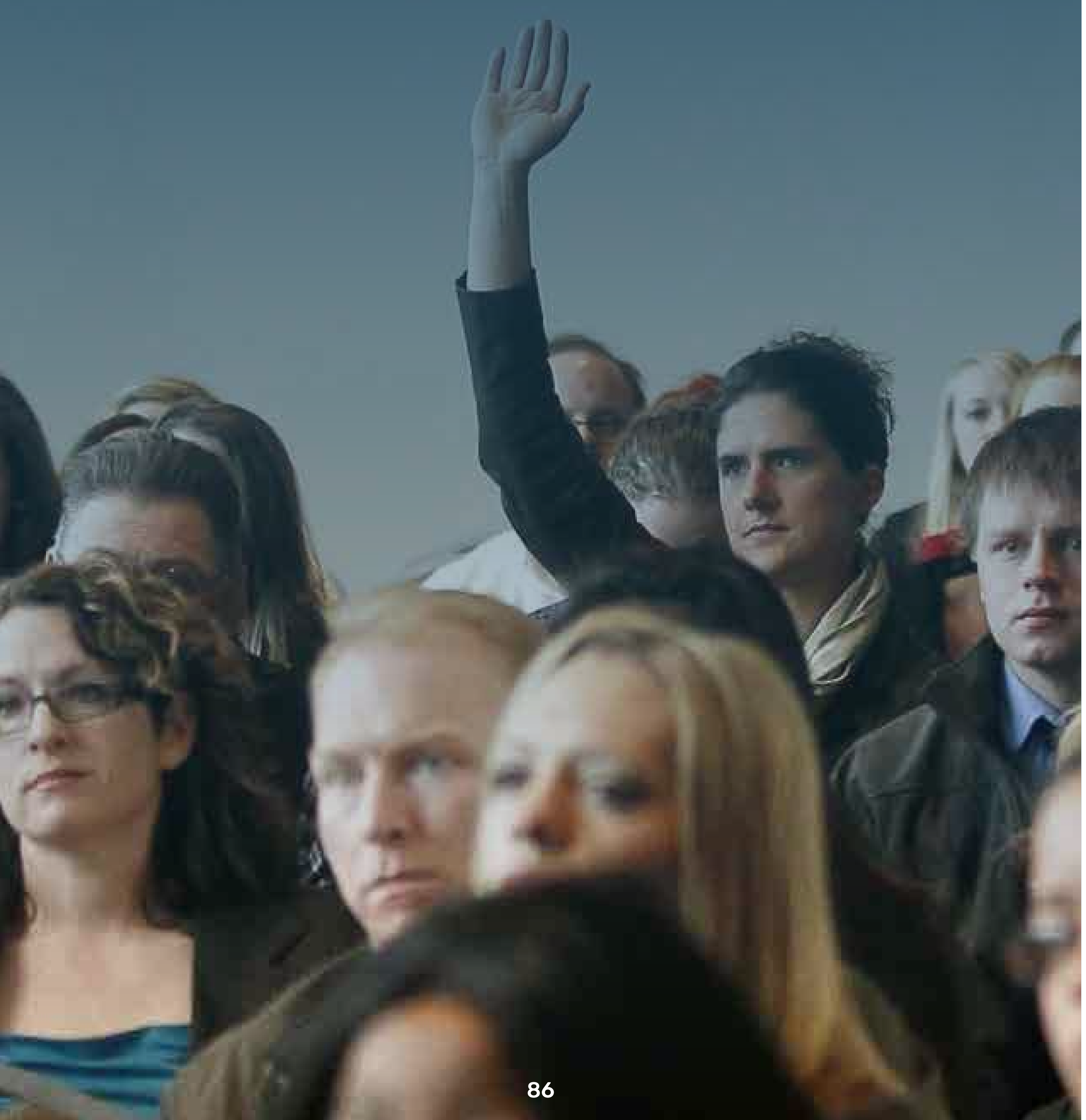


Figure 8.1: Pathway map Source: by Author

9. Stakeholders and decision making

Stakeholder analysis

The pathway map provides the different pathways that can be taken towards making Delfland more resilient to soil subsidence and its effects. A solid decision making process is required to be able to make a pathway choices that is supported by the different stakeholders throughout Delfland. This chapter will describe which parties should be involved in the decision-making process, as well as, their role within this process. This is described in three sections. The first paragraph will described the most important stakeholders and how they are the affected by soil subsidence, its effects, and the actions that could be taken to counter them. The second paragraph will describe the decision making model that could be used to involve the different stakeholders in the decision-making process. The third paragraph will focus on the role of the stakeholders within the decision-making process.



9.1 Stakeholders

The analysis and action assessment has shown that actions, to counter soil subsidence and its effects, will be implemented all around Delfland. The subsidence problem occurs throughout the scales and throughout different landscapes and environments. This has as a result that there are many different stakeholders that could be affected by the actions, as well as, by soil subsidence and its effects. The stakeholders that will be taken into account when it comes to the decision-making process are: The Delfland water board, municipalities, provinces, the national government, Farmers, Environmental Agencies and Organizations, and Inhabitants and Local businesses.

Delfland Water board

The water board bares the responsibility for the management of all the surface and groundwater within the Delfland region. This means that they have to facilitate a groundwater level that meets the requirements of all the different stakeholders in Delfland as good as possible. The water board can therefore not simply rise the groundwater table to counter soil subsidence. They need to collaborate with the other stakeholders to make sure that interventions in the water system will not harm those stakeholders. The water board is not per se affected by soil subsidence and its effects. The water board is, however, actively searching for possibilities to counter soil subsidence and its effects. The water board should therefore have a central role when it comes to decision-making surrounding the water management actions. Passive water logging for example is an actions that can only be taken by the water board, since they have control over the groundwater table. The water board is also involved in actions like the implementation of seasonal storages and broader watercourses. They will not only help to finance these actions, but they can also give an insight in the required water storage capacity or the location for these actions (Do, T., & Ellen, G.J., 2016)

Municipalities

The general role of the municipality is to maintain the public space and infrastructure within its borders. The influence of the municipalities is, however, limited to these borders. The soil subsidence problem in Delfland crosses the municipal borders, which makes it difficult for municipalities to counter the large soil subsidence and effects. They do, however, suffer much of the consequences. Municipalities that are located on weaker soils suffer the consequences of soil subsidence. These municipalities have to invest twice as much in the public space and infrastructure according to platform slappe bodems. The municipalities play an important role when it comes to implementation of actions, even though, their influence is limited outside of their borders. All of the actions within the action table influence at least one of the municipalities within Delfland. The actions that are chosen in the pathways should therefore be supported by the municipalities to make sure future implementation is made possible. This does not always mean that the municipalities bear the main responsibility when it comes to implementation actions. Some actions could be implemented on the municipal scale and could therefore be initiated by the municipalities themselves without needing support from other stakeholders. This are actions like: increasing the peak water storage capacity, creating seasonal storages, developing lifted and floating constructions, Low pressure (re)construction, and Soil and height orientated planning and development, decentralized water treatment, underwater drainage. These actions can sometimes be implemented on a municipal scale, but they do impact the larger scale. Municipalities should therefore be involved in the larger scale decision-making, to make sure that their actions fit within the Delfland scale plan to counter soil subsidence and its effects (Do, T., & Ellen, G.J., 2016).

Province

Provinces tend to focus on the long term vision for the region. They look at the regional requirements when it comes to development projects and the use of the soil. Large scale projects that cross municipal borders should be overseen and, for a large part, financed by the provinces, to make sure that there is conformity about the project throughout all the involved stakeholders according to platform slappe bodems. Reducing soil subsidence and its effects is one of the jobs of the provincial government (Meyer & Nijhuis, 2013). The provinces should therefore have a leading role when it comes to developing long term visions and policies on soil subsidence. Provinces should also be facilitating when it comes to connecting stakeholders, like municipalities and water boards, that are involved within these long term visions and policies. Actions that should be implemented on a provincial scale are focused making the whole of Delfland more resilient to soil subsidence and its effects. This are actions like: passive waterlogging, broadening and expanding water courses, large seasonal and peak storages, soil and height orientated planning and development, unrefined watercourses, environmental protection and conservation, and decentralized water treatment. The province does however still need the cooperation from the municipalities and other stakeholders to be able to implement the actions that take place within the jurisdiction of those stakeholders (Do, T., & Ellen, G.J., 2016).

National government

The national Dutch government is aware of the soil subsidence issues that are causing problems all around the country. Soil subsidence is not only causing physical problems for the Dutch population and the infrastructure. It can be damaging to the national cultural heritage as well. Soil subsidence can drastically change the Dutch landscape, it will negatively influence climate change, and it poses a threat when it comes to protecting to country from floodings and other water nuisance. This is why tackling soil subsidence is on the

agenda of the ministries for general affairs, agriculture and nature, economic affairs and climate policy, and the ministry of infrastructure and water management. Tackling soil subsidence, on a national level, would require an overall collaboration between all of these ministries and all of the affected provinces, water boards, municipalities, and Environmental Agencies and Organizations. A national program on soil subsidence could help to support and coordinate actions against soil subsidence and its effects on a national level. Staring a national program focused on soil subsidence has also been opted during the national congress on soil subsidence. The national program on Groningen has shown what the impact of a national program can be when it comes to tackling the problems, as well as, creating awareness. The impact of national program could help to tackle the soil subsidence problem nationally. The problem statement and analysis have shown that it is important to start such a program as soon as possible, before the soil subsidence problem gets out of control. The national government should in that case have a facilitating role when it comes to tackling soil subsidence. This can be done through subsidies or law change that could make some of the actions, on the pathway map, easier to implant in a region like Delfland. Passive waterlogging is currently made difficult by the fact that the water board should provide a groundwater table that fits the demands and wishes of the land use. Floating and Lifted constructions are currently difficult to realise because of the building restrictions. All three of these actions could be easier to achieve with support from the national government. Some other actions could require subsidies or other forms of support from the national government to kick start these actions. This could for example be said for paludiculture and sphagnum tillage. The financial risk is often too big from farmers to transition from a more traditional form of agriculture to a new form that could help to reduce soil subsidence and its effects (Do, T., & Ellen, G.J., 2016).

Farmers

A large part of the Delfland landscape and soil is currently occupied by the farmers. These farmers do already feel the effects of soil subsidence. It is harder to cope with periods of drought, the soil is sinking, and it is no longer possible to further lower the groundwater table to benefit agriculture. The financial impact, of the actions to counter soil subsidence and its effects, on agriculture will depend on the pathway choices that are going to be made. It is therefore hard to say whether or not the farmers will suffer or benefit financially. Some pathways could demand an investment from the farmers now that might benefit them in the future. The farmers would have to be willing to invest when that is case. The financial impact of the pathway choices will be reviewed for each of the pathway projections in the next chapters. It is however clear that a change is required from the land cultivators, no matter which choices are made. It is therefore important that the farmers and landowners are included in the decision-making process when it comes soil subsidence. The current protests, surrounding nitrogen regulations for farmers, show how much resistance is to be expected when the land cultivators are not included in the decision-making. Farmers should not only be involved when it comes to agricultural actions. Many of the actions require a lot of space, or a change in the Delfland landscape. The involvement and cooperation of farmers is therefore required when actions taken within these peatlands. This could be actions like: Passive waterlogging, broaden and expand watercourses, Seasonal storage, Peak storage, Floating constructions, Lifted constructions, environmental protection and conservation, and Decentralized water treatment (Do, T., & Ellen, G.J., 2016).

Environmental Agencies and Organizations

Environmental Agencies and Organizations represent the interests of the ecology of Delfland. Changes in the soil have a direct impact on the ecology, while pollutants disturb the natural balance even further. Seepage to these subsiding peatlands will have as a result that event the ecology outside of the subsiding areas are confronted with the effects of subsidence. The ecology and natural resources in Delfland have become vulnerable because of the pressure that is put on the available land by agriculture and urban expansions. It is therefore important that Environmental Agencies and Organizations are not only consulted when it comes to ecological measures. These agencies and organizations should be involved in the decision-making on all of the actions to make sure that they will not implement at the cost of ecologically valuable areas, by using up their space or by harming them in other ways. This is mostly the case when it comes to implementing: broaden and expand watercourses, seasonal storage, peak storage, soil and height orientated planning and development, unrefined watercourses, environmental protection and conservation, and decentralized water treatment (Do, T., & Ellen, G.J., 2016).

Inhabitants & local businesses

The inhabitants that live and work on the weak soils and in houses wooden pole foundation are currently most directly influence by soil subsidence and its effects. Other civilians in Delfland might already notice the effects of soil subsidence, but it is not always clear the these effects are (partly) caused by soil subsidence. the increased climate change will only enhance the rate at which the soil is subsiding. The effects of soil subsidence, such as drought, water nuisance and sub effects of those problems, will only become more intense and spread out further throughout Delfland. This means that more inhabitants and businesses will suffer the consequences of soil subsidence in the long term. Economic losses from damages, caused by subsidence, floods other effects, are the most direct effects of soil subsidence, but long periods of drought or floodings could influence the health of inhabitants as well. It is therefore important that the inhabitants are involved in the decision-making process concerning the actions to counter soil subsidence and its effects. This will allow the inhabitants to give their opinion on where actions should or should not take place within their municipality or the Delfland region. Involving the inhabitants will also help to create awareness among the inhabitants of Delfland, that might otherwise protest against the actions because of the costs or the location of these actions (Do, T., & Ellen, G.J., 2016)

9.2 Decision-making model

The mentioned stakeholders will have to collaborate to make sure that the chosen pathway takes all the different perspectives into account. Not all of them will have to be involved throughout the whole decision-making process. Some choices between actions do only influence a small group of stakeholders while others might influence all of them. A decision-making model is required that allows all the stakeholders to give input without necessarily involving them in every decision (Meel, J., & Bjørkeng Størdal, K. 2017) describes a model that is developed for the development of buildings where many stakeholders are involved. A similar model could be used on the Delfland scale where decisions are made on actions to counter soil subsidence instead of on the development of a building. The model created by Meel divides the stakeholders in four different groups that all have influence in the decision-making process. The model focusses on development of a solid guiding framework for that explains what the client wants from the project. Such a framework is similar to the preferred pathway that is chosen in the sixth step of DAPP. Both the framework and the pathway are there to steer and manage the project in the preferred direction. The four types of groups within this model are: a taskforce, a steering comity, work groups, and focus groups. These four groups will be further described in this paragraph to create an insight in their roles within the decision-making process.

Steering comity
The steering comity is described as: "The steering committee (or 'project board') has the formal responsibility for the entire project. Part of this responsibility is to ensure that the project is underpinned by a clear and feasible brief. It has to appoint and set up a competent task force, allocate sufficient resources to it, and monitor its progress" (Meel, J., & Bjørkeng Størdal, K., 2017, P. 122). A steering team within the Delfland area would not make the decisions when it comes to finding the preferred pathway, it would set and check boundary conditions for this preferred pathway. The steering comity would have a monitoring role to control the taskforce that is appointed by the steering comity. The comity is also in place to resolve issues and conflicts between the other groups or stakeholders. The steering comity would therefore have to be impartial. Not only when resolving issues between stakeholders, but also when they set the boundary conditions and keep the taskforce in check. It would therefore make sense that the steering comity in the Delfland case would be formed by the governmental institutions that oversee the who Delfland area. These are: the water board, the province and the national government. The national government could especially have a role in the case of national program against soil subsidence as is discussed in the previous paragraph.

Taskforce
Van Meel describes the taskforce as a team of stakeholders that: "execute the briefing process and does the actual writing of the brief. Its members are responsible for all the briefing activities … "(Meel, J., & Bjørkeng Størdal, K., 2017, P.123). The taskforce in the Delfland case would not write a brief as is the case when developing a building. The taskforce would come up with a preferred pathway along the pathway map. This taskforce would make the choice between the different possible pathways to find the a preferred pathway that is fitting for all the stakeholders, for as far as that is possible. The taskforce does rely on the input from focus groups and work groups to gain information and knowledge that is required to choose between specific actions on the pathway map. The taskforce itself would therefore have to be impartial, to make sure that all the input from other groups is given the same weight in the decision-making process. The taskforce should consist of stakeholders that have knowledge of Delfland, as well as, soil subsidence and its effects. Van Meel (2017) states that the taskforce should consist of 2 to 4 stakeholders, to avoid long and elaborate discussions within the taskforce. It would therefore make sense the taskforce is made up out of the municipalities and water board, supported by impartial institutions with knowledge of soil subsidence and its effects.

Work groups
"Work groups can be set up to support the taskforce with the development of requirements for specific subjects areas" (Meel, J., & Bjørkeng Størdal, K., 2017, P 124). The workgroups do not have to be impartial and they can therefore represent the more specific interests of the stakeholders with a more personal agenda. The work groups give input to help the taskforce choose between possible pathways, but the work groups should not propose pathways themselves. The work groups will have a final say in the pathway decisions by evaluating the preferred pathways that are developed by the taskforce. There should be different work groups that can advise the taskforce on different aspects and themes within the subsidence problem. The groups do nog have to consist of stakeholders from within Delfland, they can also include external experts on the specific field of that work group. The soil subsidence problem in Delfland would require work groups on, at least, water management, agriculture, ecology, and construction.

Focus group
The focus groups are a means of giving a voice, to the inhabitant and users of Delfland, within the decision-making process. The focus groups are there to give input for taskforce, but also to check the taskforce. Input from the focus groups should help to make pathway decisions that are supported by inhabitants and businesses within Delfland. These focus groups should be open to anyone and the steering committee should strive for focus groups with all types of end users. It is important that sceptics and uninterested end users are involved in the process as well, to prevent future resistance once the plans have been completed. The members of the focus groups should, however, have a constructive attitude towards to project to be able to gain valuable information from out of these focus groups. It is also important that there is a balance between the users of the focus group to prevent one of the members from controlling the outcomes of the entire focus group. This could be achieved by having members from the taskforce or steering committee present at the focus group meetings, or by splitting up the focus groups. Inhabitants & local businesses would be the most important stakeholders in the focus groups, but municipalities, Environmental Agencies and Organizations, and farmers organisations could be part of these groups as well, especially when it comes to giving input on decisions outside of their field of knowledge (Meel, J., & Bjørkeng Størdal, K., 2017).

The advantage of focus groups and work groups is that these groups do not have to be involved throughout the entire decision-making process. This saves a lot of time and energy for the stakeholders within these groups. The job of the taskforce is also made easier because to amount of internal discussions is reduced because of this method.

The decision-making model in figure 9.1 shows the structure that could be used to find the preferred pathways to help Delfland become more resilient to soil subsidence and its effects. The local government organisations and main stakeholders should work together in a taskforce to choose the actions within the preferred pathways. The national government and provinces can support and steer these decisions from a national scale through a steering committee that offers guidelines and opportunities that would fit within a larger scale approach to soil subsidence. The workgroups are there to keep the taskforce in check, but also to make sure that all the stakeholders are heard and feel that they are involved. This could prevent future resistance to the chosen pathways, as is currently the case with the national nitrogen laws that are protested by farmers that were not involved in the decision-making process. The focus groups work in a similar way, but these groups are not there to steer the process by offering extra knowledge from their field of expertise. The focus groups will help to find the pathways or locations where interventions should take place, that are supported by the end users of Delfland, such as inhabitants and local business.

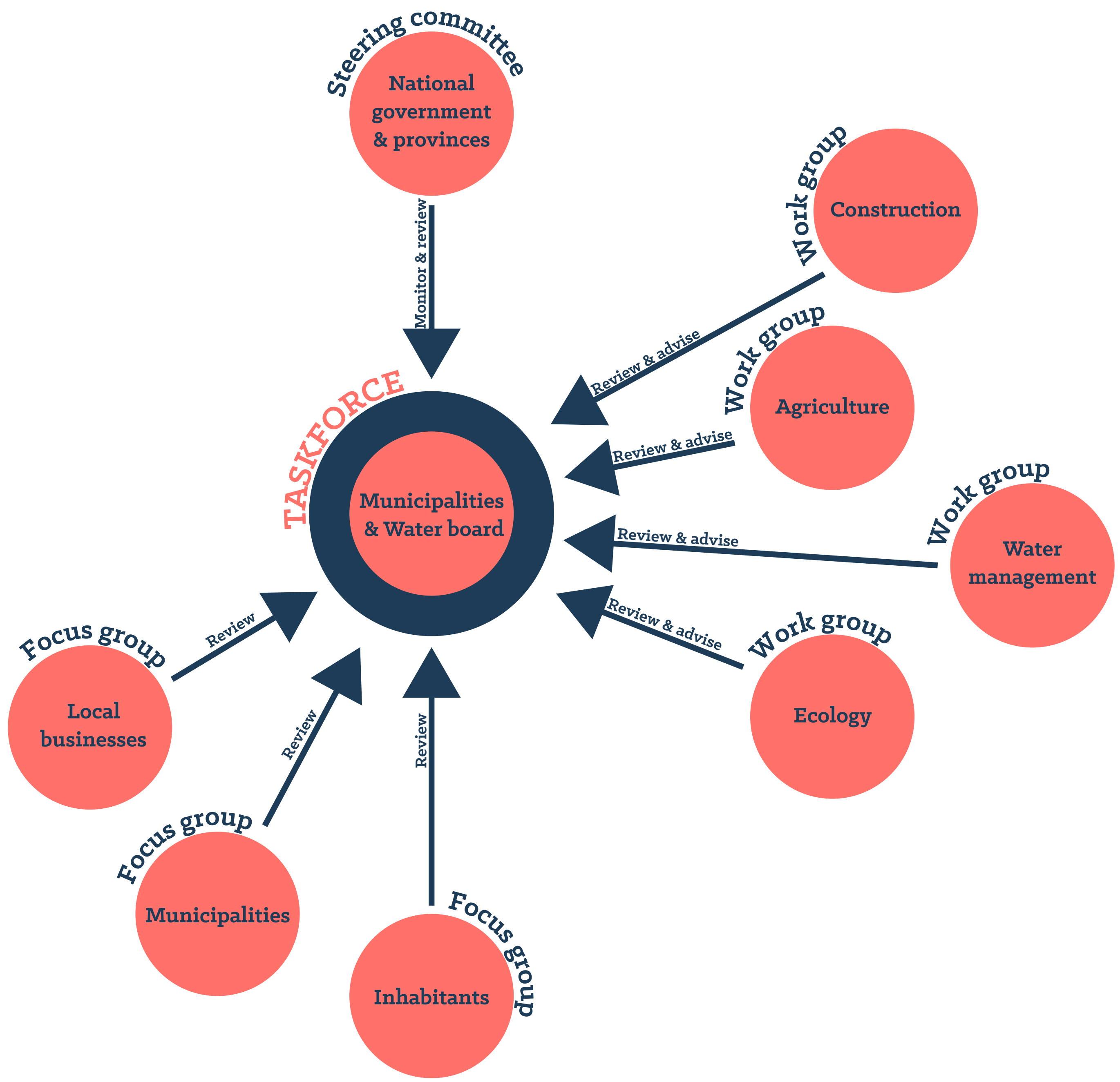


Figure 9.1: Decision-making model Source: by Author

10. Delfland pathway projections

Spatial impact

The previous chapters have created an insight in how the choices between different actions can be made, and by who. The pathway map shows the possible routes that can be taken towards making Delfland more resilient to soil subsidence and its effects. Finding the preferred pathway on this pathway map will be the task of a taskforce. This taskforce will have to take the demands, wishes, and expert knowledge of the different stakeholders in to account to determine which pathway would fit best for Delfland and the involved stakeholders. The pathway that is chosen by the taskforce is the preferred pathway. This preferred pathway shows which actions that will be taken, and when these actions will be taken.

Future events could however require that other actions are taken or that actions are taken at a different moment in time. This would mean that the preferred pathway is no longer relevant and a different path along the pathway map has to be chosen. Changing pathways does not affect the outcome of the pathway, since all pathways along the pathway map lead to the same goal: adapting Delfland to soil subsidence and its effects. Choosing a different pathway could however result in different spatial outcomes and in different outcomes for the stakeholders. A difference in the spatial outcome of a pathway is, mostly, created by the order in which the actions are taken in a pathway. Some actions could be applied to the same location or they could counter the same effect. Actions that are taken later on in the pathway will therefore only be used in places where they could improve upon earlier actions or in places where earlier actions could not be applied, due to the different conditions in which an actions is effective or not. This chapter will take a look at how different pathway choices could result in different spatial outcomes.

The possible spatial impact of different pathways is researched by choosing two different possible pathways on the pathway map. Both of these possible preferred pathways are projected on the Delfland region. This results in two pathway projections that give an insight in the possible spatial impact of two pathways and the actions that are chosen within these pathways. The first chosen pathway is focused on adaptation to soil subsidence and its effects. The second one is a pathway focussed mitigating soil subsidence and its effects as much as possible.

Both of the pathways and their spatial projections will be described within this chapter in five parts. The parts describes a scenario in which not pathway is developed and in which no actions to counter soil subsidence and its effects are taken. The second part will describe the adaptation pathway and the spatial projection of this pathway on the Delfland region. This is done by describing the pathway and the choices that are made within the pathway, before taking a look at where these actions would have to take place in the Delfland region. The second part will describe the same, but for the mitigation pathway. Both parts will give an overview of where actions within Delfland would be taken and how these actions would influence Delfland spatially from a regional perspective. The fourth part will compare the two regional projections to create an insight in the different spatial impacts, of the two pathways, on the Delfland region from a regional perspective.

The fifth part of this chapter will describe the small scale impact of the different pathway choices. This is done by looking at four locations that are characteristic for Delfland. The current situation and the possible changes, under the influence of the pathways choices, will be described for all these smaller scale location. This offers an insight in how the large scale pathway projections could influence specific parts of Delfland on a smaller scale.

Figure 10.: Current situation Delfland Source: by Author

Figure 10.: Impression current situation Delfland Source: by Author

10.1 Pasive projection

in the worst scenario if none of the actions are used to counter soil subsidence and its effects in Delfland. The problem statement has already shown that soil subsidence in peatlands could have an rigorous effect on the climate and surrounding landscapes. This paragraph will take a closer look at the problems would occur in Delfland of no counter actions are taken.

The most obvious problems that are caused by soil subsidence and its effects is continuous subsidence in the peatlands and other weak soils in Delfland. Most of the agricultural land we become unusable for agriculture due to barren soils that will be uncovered form underneath the peat, once all the peat has oxidised and disappeared. It is nog longer possible to reverse the process of peat oxidation once all the peat is gone. This is however not the only problem. The left over fertile soil could soon become less fertile as well. This is due to salinization as an effect of seepage that flows from the North Sea towards the lower landscapes in Delfland. This causes salinization and water pollution all around the region. This results in infertile lands and damages to the ecosystem. Seepage towards the subsided lands in general could cause problem all throughout Delfland. The water from higher places in the landscape will flow towards the lower subsided lands because of their groundwater table that has been lowered in these subsiding areas. This will slowly create a very contrasting landscape. The higher places will dry out while the lower places will be almost permanently flooded. The inner cities of Delft and Den Haag will dry out, making the cities prone to increase heat problems during periods of drought. Older buildings in these cities are often built on wooden poles. These poles are currently protected from decay by maintaining a high enough groundwater level throughout the year. This will keep the wooden poles wet, which prevents them from rotting away. This will no longer be possible when drought becomes a more urgent problem for longer periods of time. Many of the houses that are built on wooden poles can therefore no longer be protected from the drought, causing their pole to rot. The buildings will become hard to save when they are longer supported by the poles. The weight of the buildings will slowly push them in to the weak soil. This will cause dangerous situation in where the buildings will become crooked and they could even collapse in very dire situations.

Higher natural landscapes will suffer the consequences of seepage to lower lands as well. The Plants and soils will dry out while it will become difficult for animals to find fresh water. Many plant and animals will have to find a new place to live or they will die. This will leave very disrupted and monotonous ecosystem where only a few urban areas. These neighbourhoods will be prone to floodings during whenever it rains. These floodings will not only lead to water damages, but they could also be an instigator for the development of mildew in buildings. The mildew could become are serious threat to the public health. Pumping the water out of these neighbourhoods wood require a massive pumping capacity soil has completely subsided.

A projection in which none of the actions, to counter soil subsidence and its effects, are taken could be disastrous. The landscape and cities will for large part dry out or flood. Actions to counter these effects would be required after all, but in more extreme way than would be the case at this time. The ecology would be very disrupted and polluted by the salinization and organic materials, and heavy metals that are released in to the ecosystem during the oxidisation of the peat.

Figure 10.1: Passive scenario impression Source: by Author

10.2 Adaptation Projection

That pathway that is used for the Adaptation projection can be found in figure 10.2. The choices in this pathway are directed at adapting Delfland to soil subsidence as much as possible. The pathways are chosen in such a way that the current image of Delfland is maintained as much as possible. This means that the measures with the smallest spatial and financial impact on the Delfland region are prioritized. This results in pathways that are focused on only intervening were and when it is absolutely necessary. The pathway is therefore mainly focused on adapting to soil subsidence and its effects, and not so much on mitigating them. The choices that are made within the adaptation pathway will be explained in four steps of fifteen years.

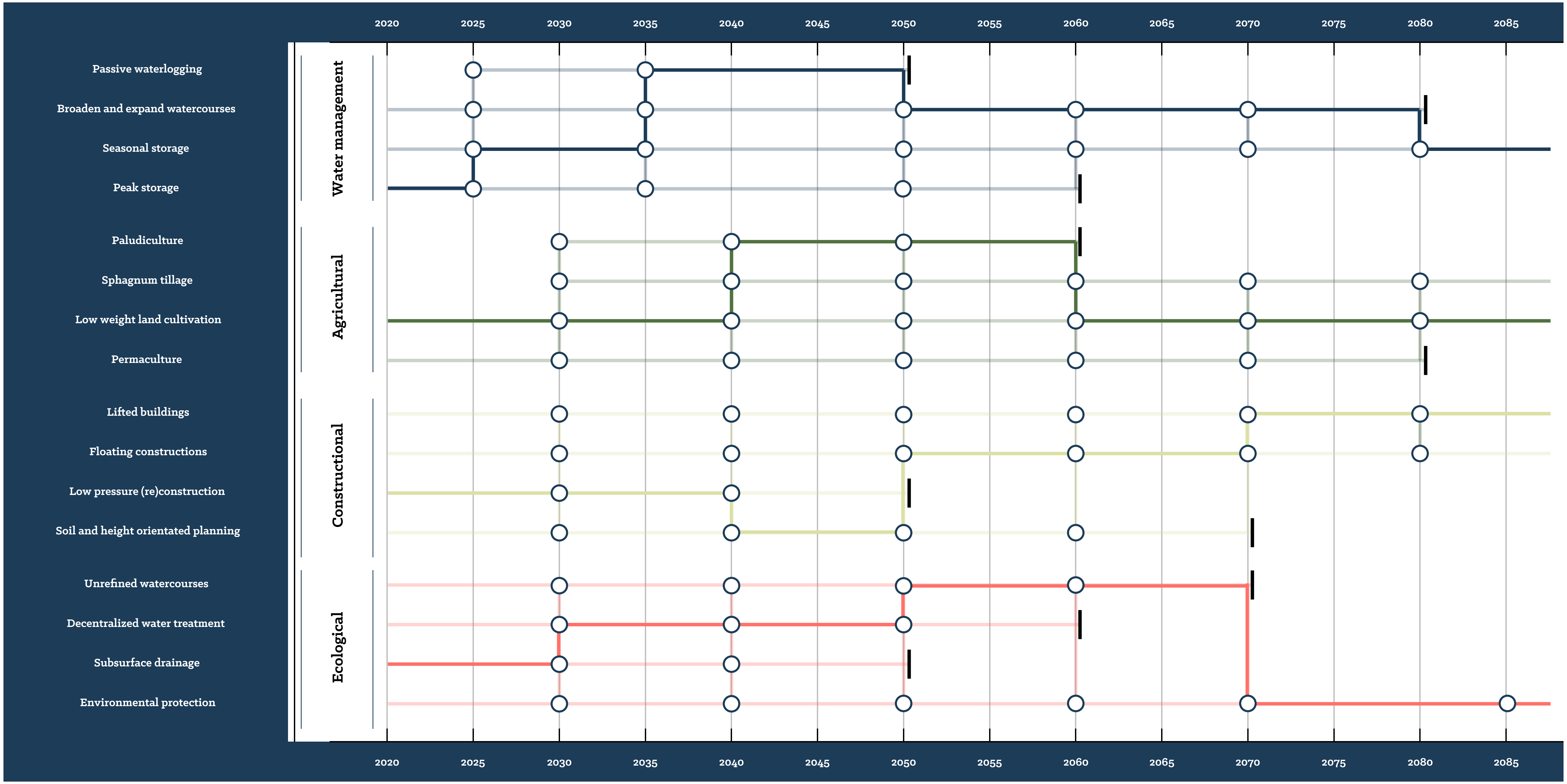


Figure 10.2: Adaptation Pathway Source: by Author

2035

The pathway for the first fifteen years is composed of actions with an immediate impact that are relatively easy to implement, since they do not depend on other actions to be taken, or because they have a relatively small spatial footprint. The pathway choices can be found in figure 10.3 and the location of the actions, in the Delfland region, can be found in figure 10.4.

Peak storages and seasonal storages are created to increase to water storage capacity of Delfland and to protected Delfland from flooding during periods of heavy rainfall. These actions together will help to protect Delfland from heat, drought and floodings. larger size buffers and water storages are created and implemented in open places on the lower parts of Delfland, to make sure that water flows towards these storages naturally. The peak storage location can therefore overlap with nature, or agricultural lands that are only used during drier periods. Smaller scale interventions to increase the peak storage and seasonal storage can be implemented almost everywhere in Delfland. These smaller scale interventions are therefore not shown on the Delfland map, but they will be described in the upcoming paragraph on the small scale pathway projections.

A transition to low weight agriculture is made to lower the pressure on the soil, and because low weight agriculture can be used in locations with a groundwater table up to 30cm below the surface. The transition towards low weight agriculture is made in place that have a weaker soil, and in places that will require a higher groundwater table in the future. Low weight agriculture will be applied to subsiding soils that don't contain peat. These soils are subsiding because of the pressure that is put on them by the conventional forms of agriculture.

Low weight agriculture will also take place on the 'clay on peat' soils, to prepare them for the passive waterlogging that is going to take place in the next fifteen years. The passive waterlogging will raise the groundwater table in the 'clay on peat' soils to 30cm below the surface, which is too high for conventional forms of agriculture. The low weight agriculture is applied before the passive waterlogging, to prevent future damages or nuisances once passive waterlogging is applied.

Low pressure reconstruction can be found on weak soils that are currently subsiding as a result of the pressure from the buildings, and on the 'clay on peat soils' as well. The constructions will help to reduce the soil subsidence in these areas. This action will not be applied to the areas with more intense forms of subsidence as a result of peat oxidation, since those places will require more other measurements, like constructions on poles or floating constructions, to be able to deal with the subsidence.

The peatlands with 'peat on clay' where the subsidence is very intense will be protected from further subsidence during the first fifteen years, by making use of subsurface drainages. The drainages allow the delay of other actions in the 'peat on clay' soils. This offers time to the users of the 'peat on clay' soils to prepare for future actions that will be applied to those areas.

Figure 10.3: Adaptation Pathway 2035 Source: by Author

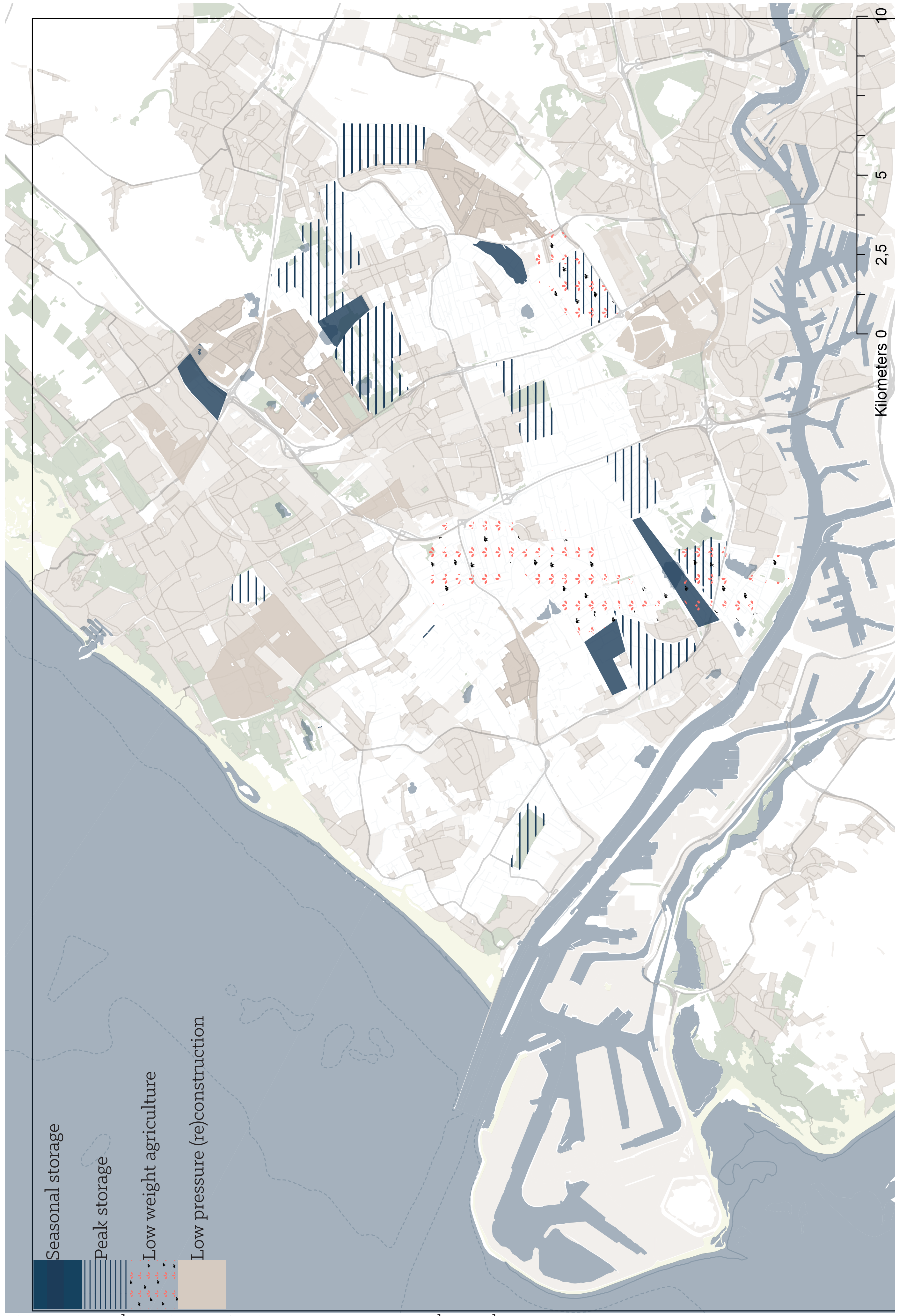


Figure 10.4: Adaptation Projection 2035 Source: by Author

2050

The actions in the pathway till 2050 are, mainly, chosen to counter soil subsidence and its effects in the areas where soil subsidence has the largest impact. The pathway choices that are made between 2035 and 2050 can be found in figure 10.5. The passive waterlogging is used to slowly raise the groundwater table in the peatlands.

This change the soil conditions in those peatlands, resulting a much wetter top soil. A transition to paludiculture is required for the farmers in those wetlands to make sure that they can still cultivate the land. Soil and height orientated planning is used to find new places for urban developments, outside of the areas that are effected by soil subsidence and its effects. Decentralized water treatment will help to filter the water in the newly created seasonal storages, to protect the environment from the pollutants in the water as a result of: peat oxidation and the input of external water.

Figure 10.6 shows where the actions, in the pathway between 2030 and 2050, will take place in Delfland. The passive waterlogging will be applied in the 'clay on peat' and 'peat on clay' soils. The boundaries for passive waterlogging are determined by the "boezem" system in Delfland, since this system regulates the groundwater table by transporting water from and to the lands that are confined by the "boezem" system. The groundwater table in the 'peat on clay' soils in these areas will fluctuate between 10cm below the surface and 20cm above the surface. That is the farmers in those areas will have to transition towards paludiculture once the groundwater tables starts to rise, as a result of passive waterlogging.

The height orientated planning and development locations can be found on higher places in the landscape where soil subsidence and its effects do not occur. A change in land use, or densification would be required to be able to develop in those areas. Decentralized water treatment interventions will be combined with the development of the seasonal storages, to filter the water that is stored there throughout the year.

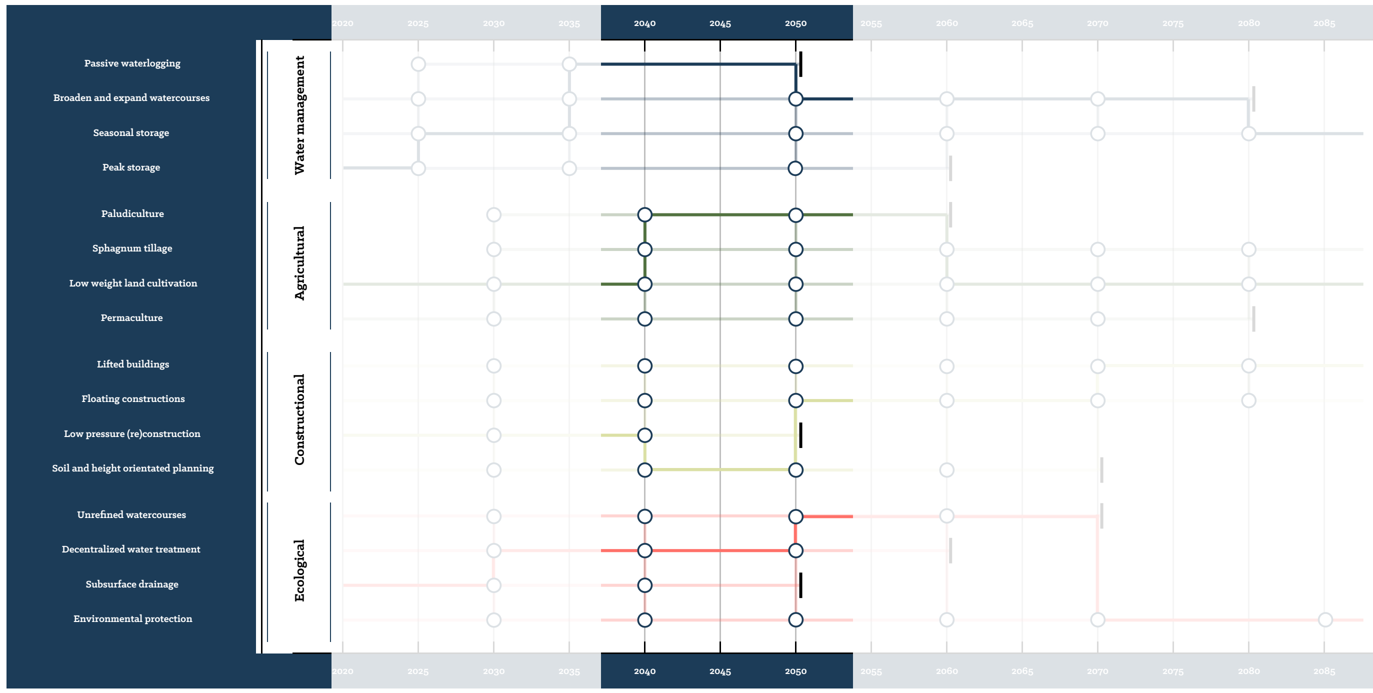


Figure 10.5: Adaptation Pathway 2050 Source: by Author

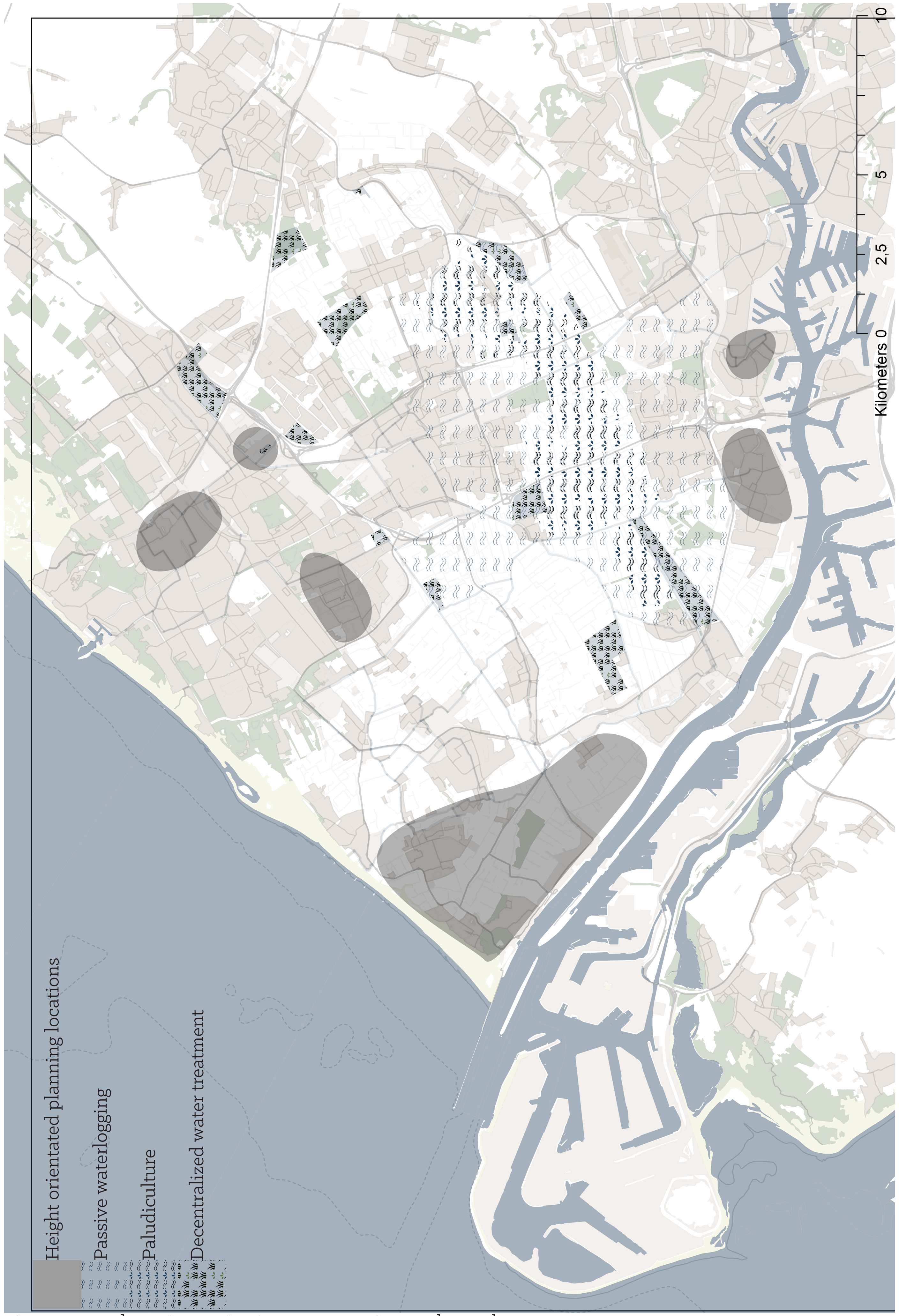


Figure 10.6: Adaptation Projection 2050 Source: by Author

2065

The pathway choices between 2050 and 2065 are made to further strengthen peatlands of Delfland against soil subsidence and its effects. The pathway map can be found in figure 10.7, and the locations of the actions are shown in figure 10.8. The watercourses in the peatlands areas, where passive waterlogging is applied, are broadened and unrefined to increase the transport of water from and to these peatlands. Create unrefined watercourses will not only increase the capacity of the watercourses, but is will also create new places for animals and plants to settle. Low weight agriculture applied to areas that are slowly subsiding. The agricultural lands, that can be found on higher places in the landscape and close to designated natural areas, will transition from conventional agriculture to permaculture. This well help to retain more water and prevent it from seeping away to lower parts of Delfland. Permaculture will also offer more room for ecology and it can thus strengthen local designated ecological areas.

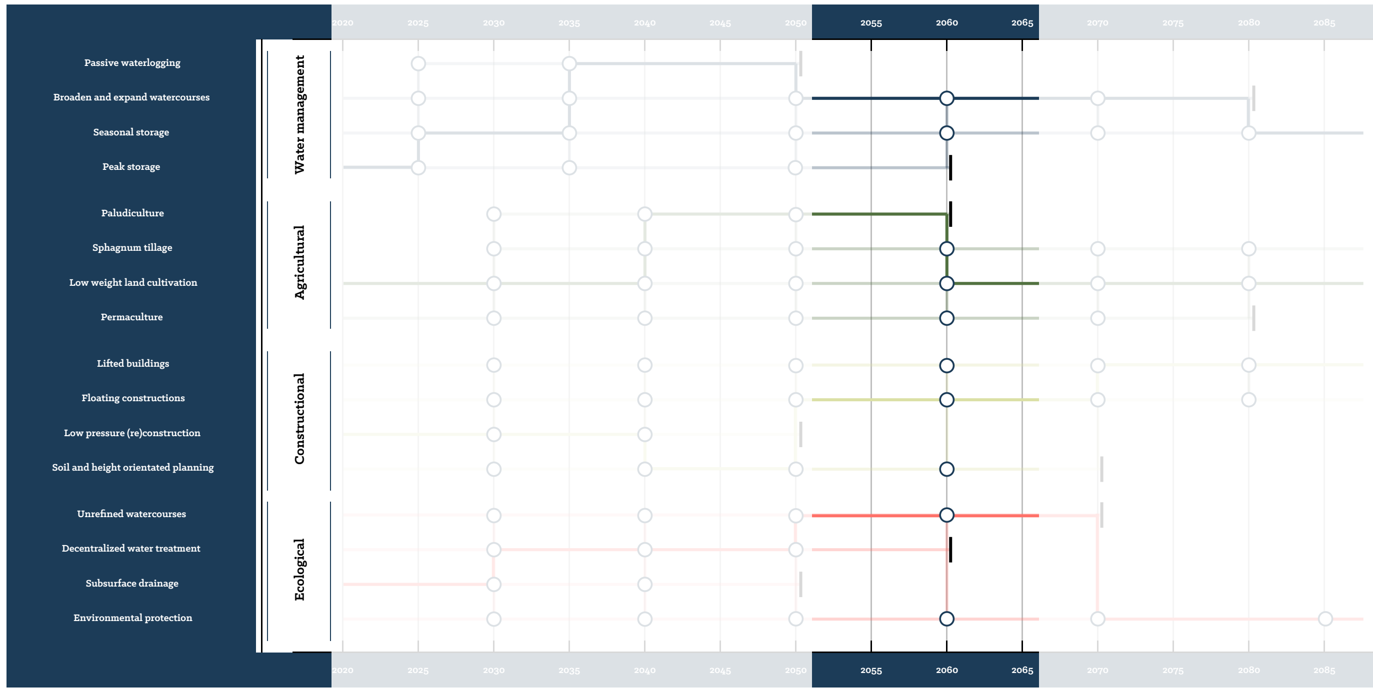


Figure 10.7: Adaptation Pathway 2065

Source: by Author

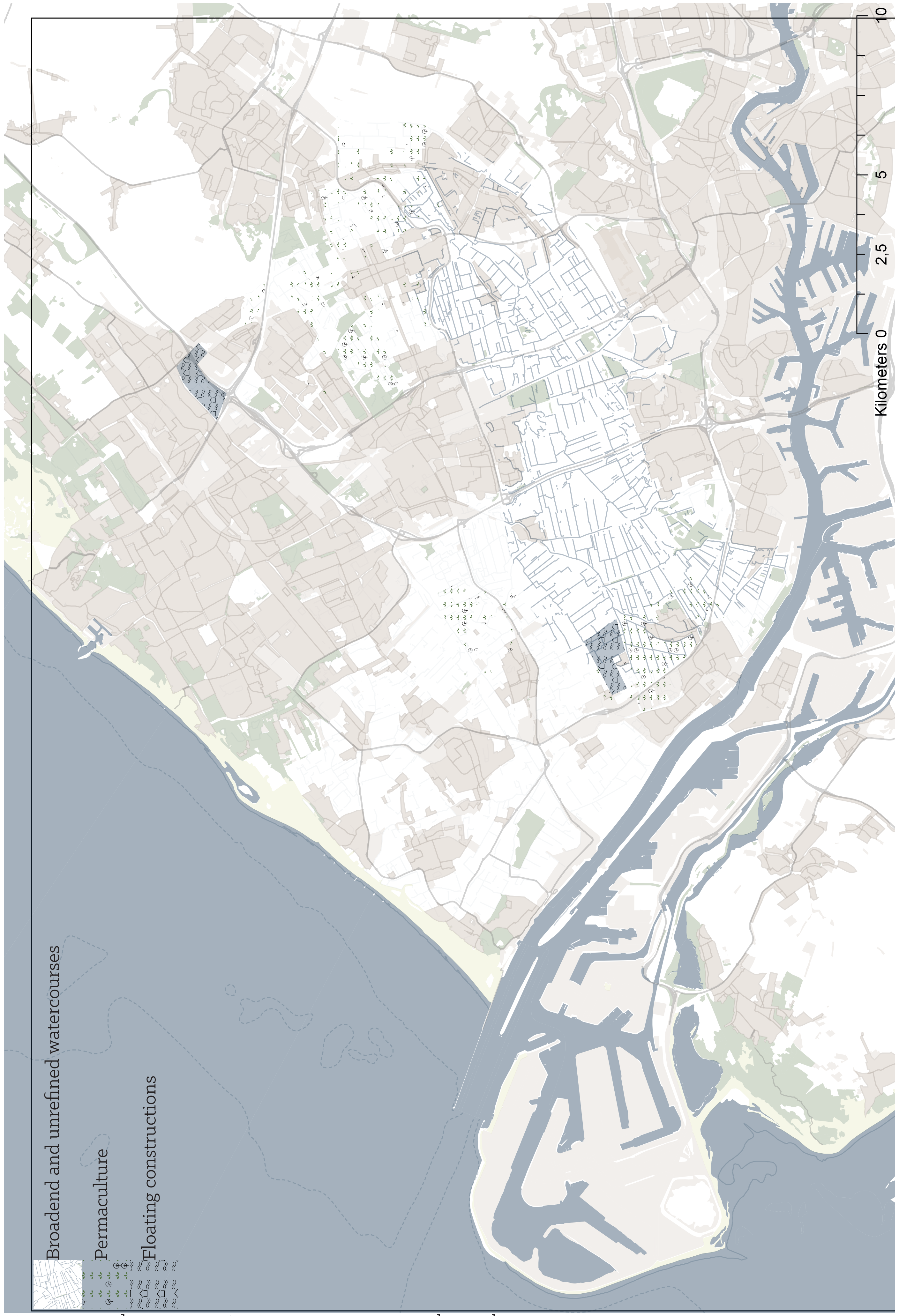


Figure 10.8: Adaptation Projection 2065

Source: by Author

2080

The final years of this pathway are directed at protecting neighbourhoods that are built on peat soils and on enhancing the ecology of Delfland. The ecology is strengthened to make sure that becomes more resilient to soil subsidence and its effects. Environmental protections can therefore be found in areas surrounding large designated natural areas, and in places with a 'peat on clay' soil where the subsidence is the fiercest. The natural areas will have to be protect from drought due to seepage, and the 'peat on clay' soils where much subsidence occurs will have to be monitored to make sure that peat wont oxidise much further. De neighbourhoods that are built directly on peat soils will transformed in neighbourhoods on poles. This projects the neighbourhoods from future subsidence, and it opens up the peat from underneath the houses, which will prevent future subsidence in those soils it will become accessible for plants and animals.

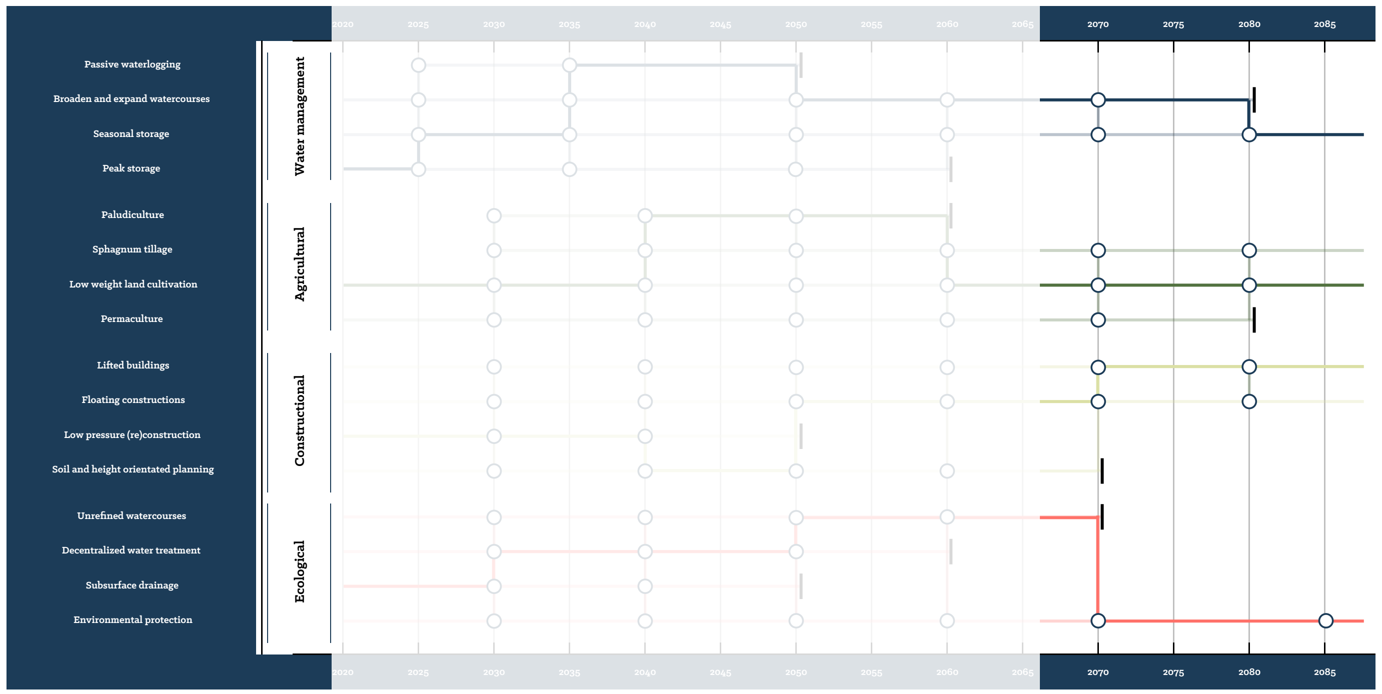


Figure 10.9: Adaptation Pathway 2080 Source: by Author

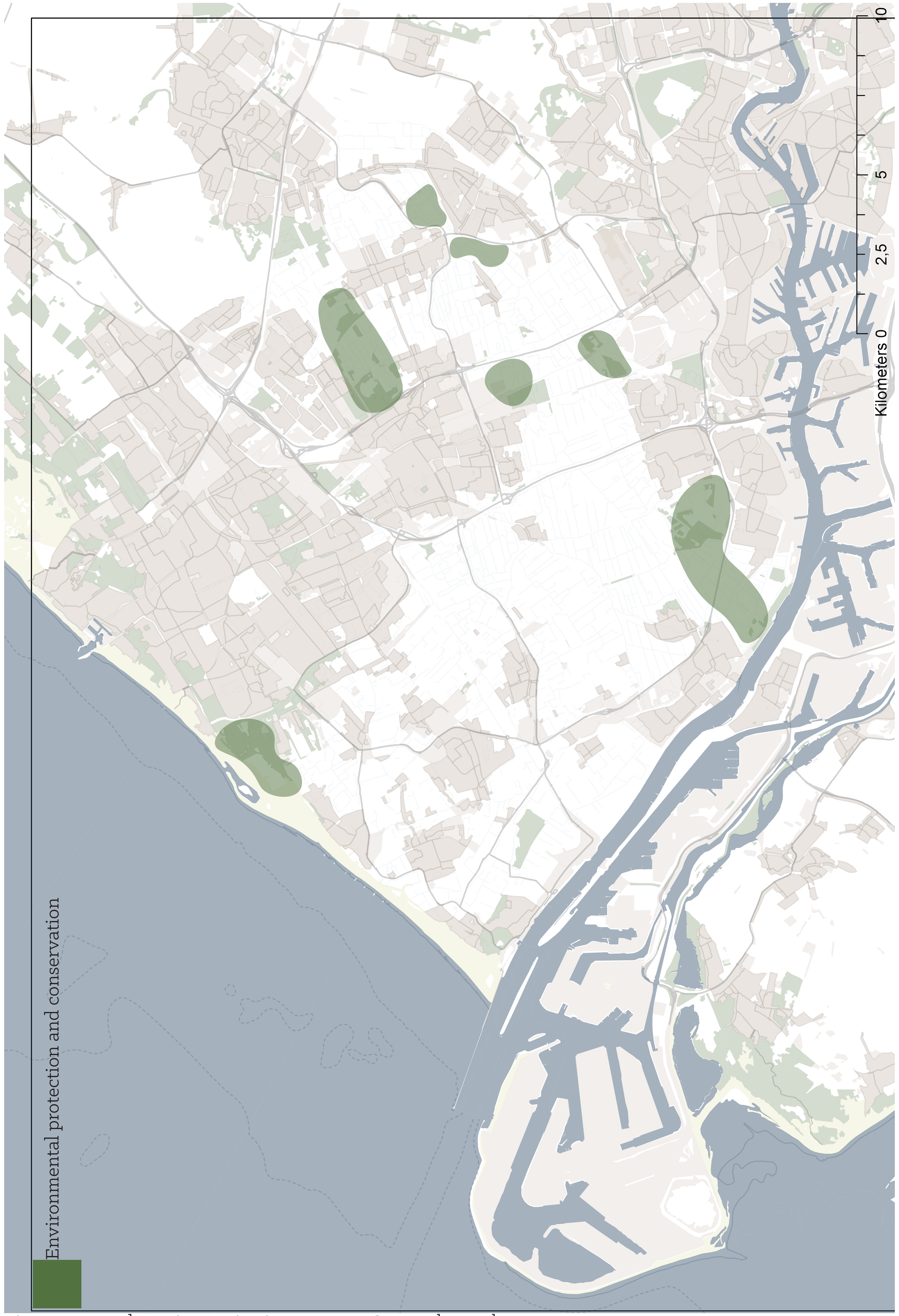


Figure 10.10: Adaptation Projection 2080 Source: by Author

2085

The Adaptation pathway will in the end result in a Delfland projection where the mild forms of soil subsidence are tackled by reducing the pressure on top of these soils. This is done through low weight agriculture and low pressure reconstruction. This is also the case for the neighbourhoods and agricultural lands on the 'clay on peat' soils. These soils are further protected in this projection through the use of seasonal storages that offer water during periods of drought. Passive waterlogging and paludiculture will only be applied in areas with a peat on clay soil, and where the soil subsidence is at its fiercest. The ecology of Delfland is mostly strengthened through the use of decentralized water treatment to filter out the pollutants from the water and soil. Unrefined water courses and environmental protection can be found in the peatland that are most threatened by soil subsidence and its effects. figures 10.11 and 10.12. give an impression of what the Delfland region would look like when the adaption pathway would be projected upon the Delfland region.

Figure 10.11: Adaptation Projection 2085 Source: by Author

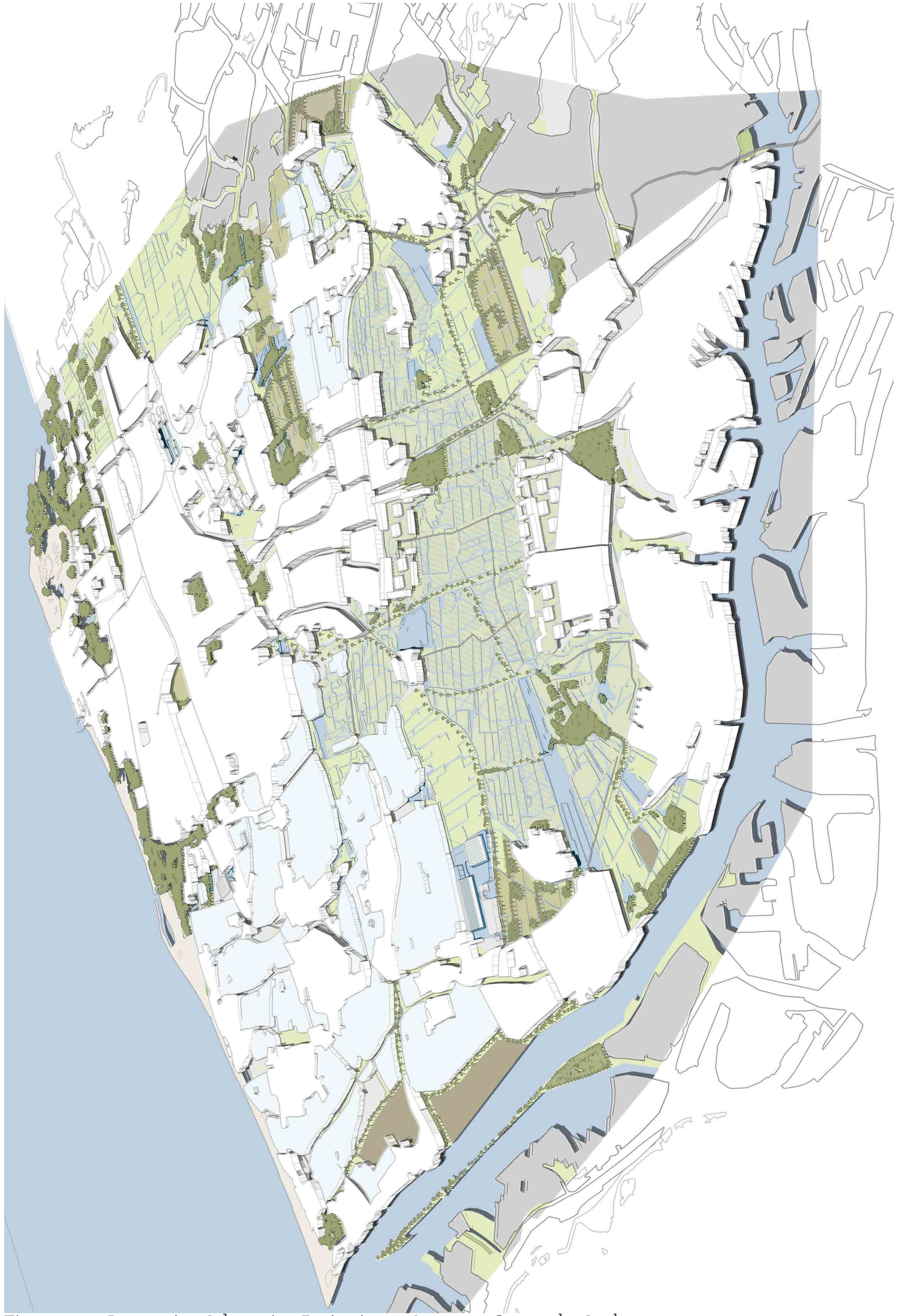


Figure 10.12: Impression Adaptation Projection 2085 Source: by Author

10.3 Mitigation Projection

The choices in the mitigation pathway map are made to mitigate the soil subsidence problem, in Delfland, as much as possible. This is done by giving priority to the actions that have a mitigating effect on soil subsidence. This means that mitigation actions will first be applied wherever this is possible in the pathway projection. The actions that are focused on adapting Delfland to soil subsidence will only be used to support the mitigating actions, or they will be used to adapt to soil subsidence and its effects in places where mitigating actions cannot be applied. The pathway choices and their projection on Delfland will be described in the same steps of fifteen years as before. Figure 10.13 shows the complete mitigation pathway map that is used to create the mitigation Delfland projection.

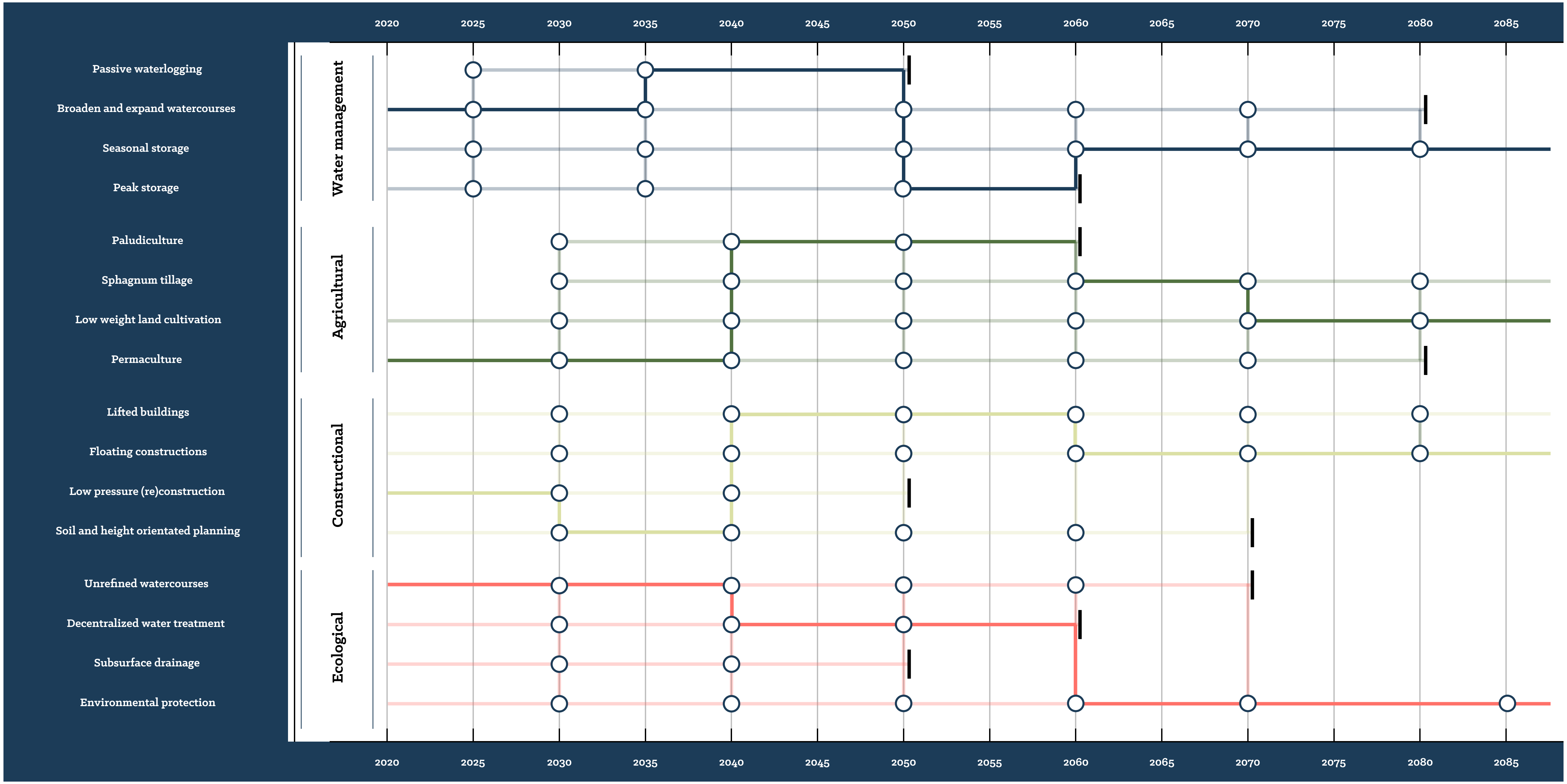


Figure 10.13: Mitigation PathwaySource: by Author

2035

The first fifteen years are used to prepare implement mitigating actions that can be implemented right from the start. Pathway steps during these fifteen years can be found in figure 10.14. The actions in this period are also used to prepared Delfland for passive waterlogging, which is one of the most important actions to mitigate the soil subsidence in the peatlands. The watercourses in all the peatlands are broadened, unrefined and expanded at the same time. This is a combination of actions that both require changes to the watercourses, it does therefore make sense to implement them at the same time. These actions will improve the water movement from and to the peatlands, and they offer new territories and conditions for animals and plants to settle in. The watercourses will also allow more water to be stored throughout the whole peatland area, which makes it easier to maintain a constant groundwater level in these peatlands. Maintaining a groundwater table makes it easier for passive waterlogging to be effective during the next fifteen years. The agricultural lands, outside of the peatlands, that are affected by subsidence and drought, will make the transition towards permaculture. Subsidence in these areas is, mostly, caused by periods of drought. Permaculture will lead to a less intensive use of the soil, to be able to offer room to more natural elements throughout these agricultural lands. This will help to retain more water, protect the soil from heat, and it will strengthen the local ecology by offering more space for plants and animals live within these agricultural lands. Low weight (re)construction is used to stop the soil subsidence, due to pressure on the soil, as much as possible. Low pressure (re)construction is applied to all subsiding urban areas that are not built on peat lands. The urban areas that are built on peatlands are most likely subsiding as a result of peat oxidation underneath the urban developments. This cannot be countered by low pressure reconstruction, since the weight on the soil is not the main cause of the subsidence.

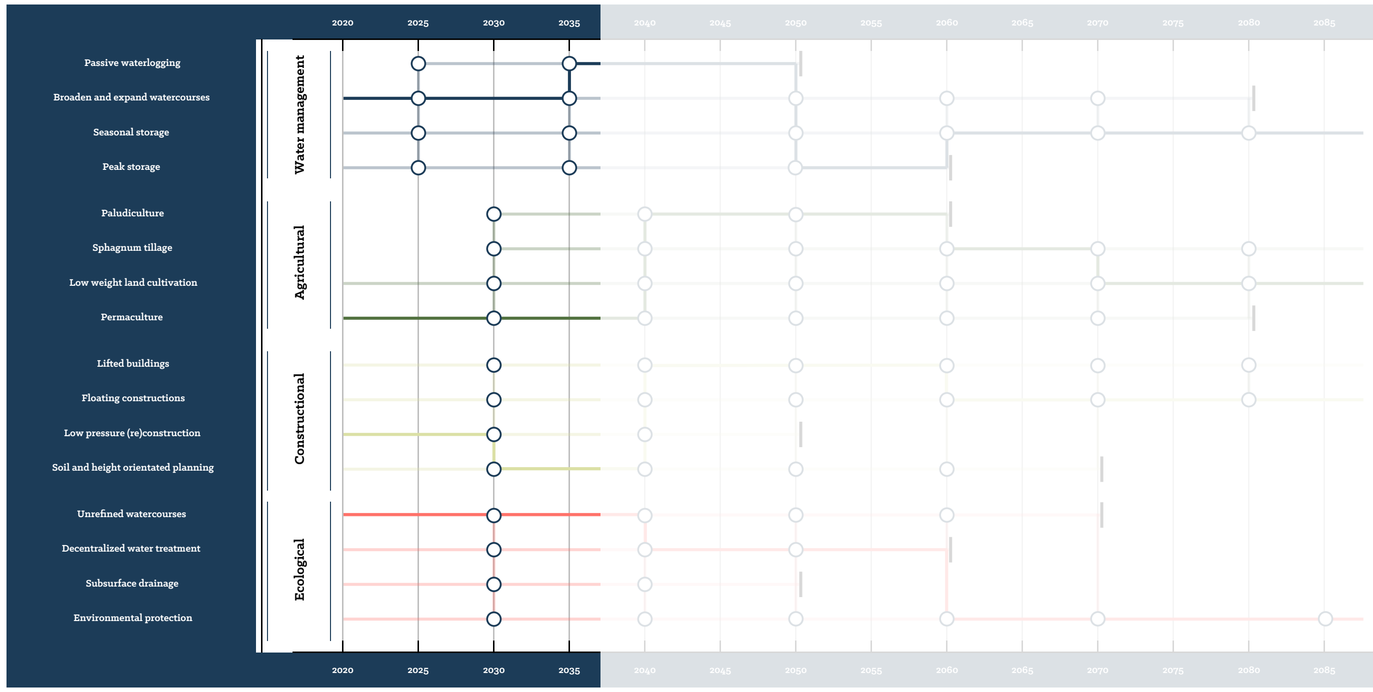


Figure 10.14: Mitigation Pathway 2035 Source: by Author

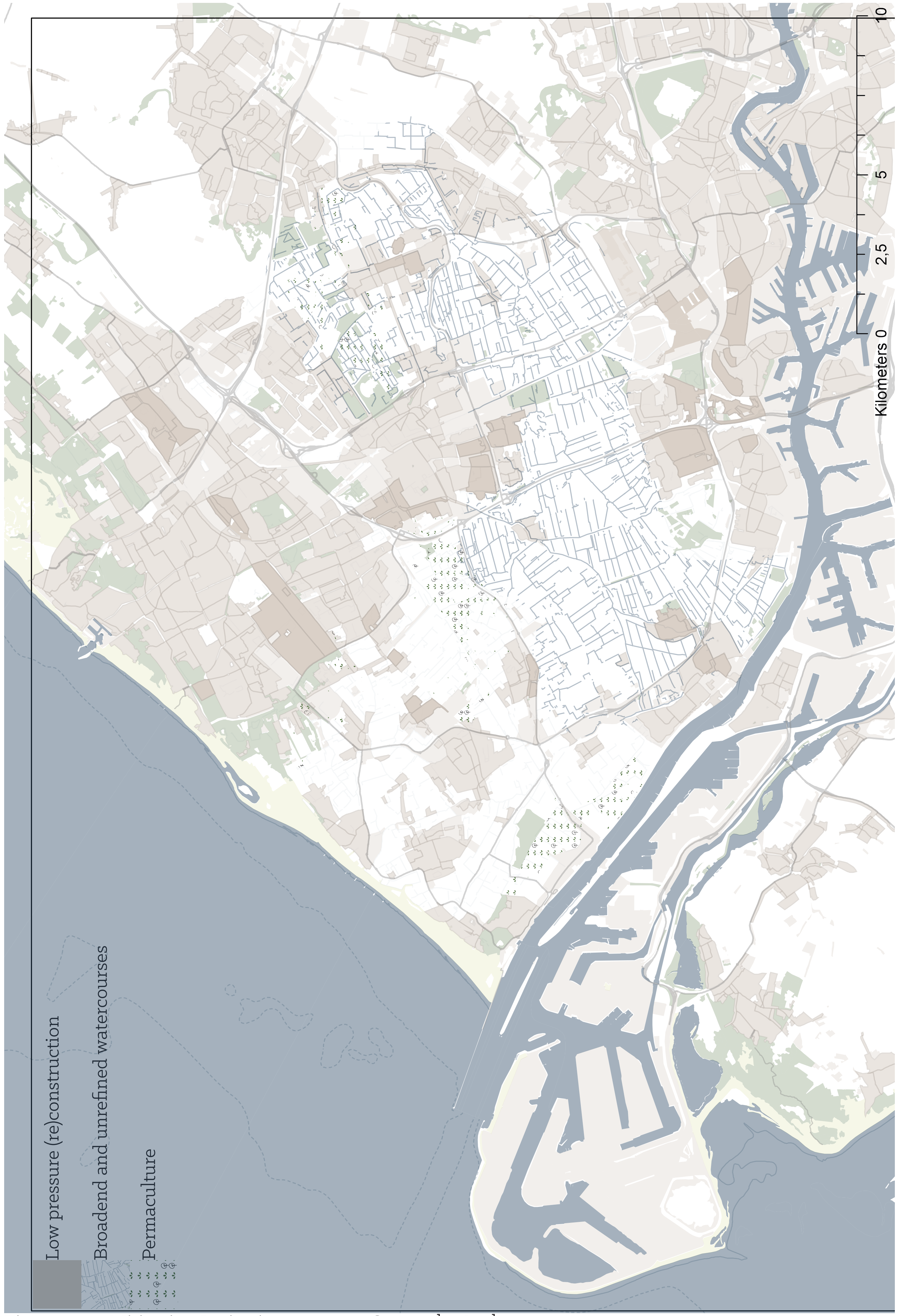


Figure 10.15: Mitigation Projection 2035 Source: by Author

2050

The second phase of the mitigation pathway is directed at stopping soil subsidence through passive waterlogging. This action is applied all over the peatland areas of Delfland. It is not possible to apply passive waterlogging to just the areas where peat can be found in the soil, since the groundwater table is regulated within the boezems of Delfland. This means that the passive waterlogging is not confined by the soil type, but by the boezemsystem of Delfland. The areas where passive waterlogging is applied will become much wetter over time, due to the groundwater tables that are rising as an effect of passive waterlogging. This requires a change in agriculture and in the form of construction that is used to build in those areas. The agricultural lands will have to switch from conventional agriculture to a form of paludiculture to make the cultivation of the wet soils possible. The neighbourhoods that are built on the peatlands will have to deal with the rising groundwater tables as well. The rising groundwater table could cause floodings in these neighbourhoods, but this could be avoided by building on poles. This will rise the buildings above the soil, to avoid water problems in those neighbourhoods, and to free up the peat soil underneath those neighbourhoods. This will allow the peat to regrow under the right conditions and the peatlands will become accessible to plants and animals that live in those peatlands. The local ecology is further strengthened by developing decentralized water treatment in the watercourses that run through peatlands. The decentralized water treatment plants will help to filter out the pollutants from the water and soil throughout the whole peatlands.

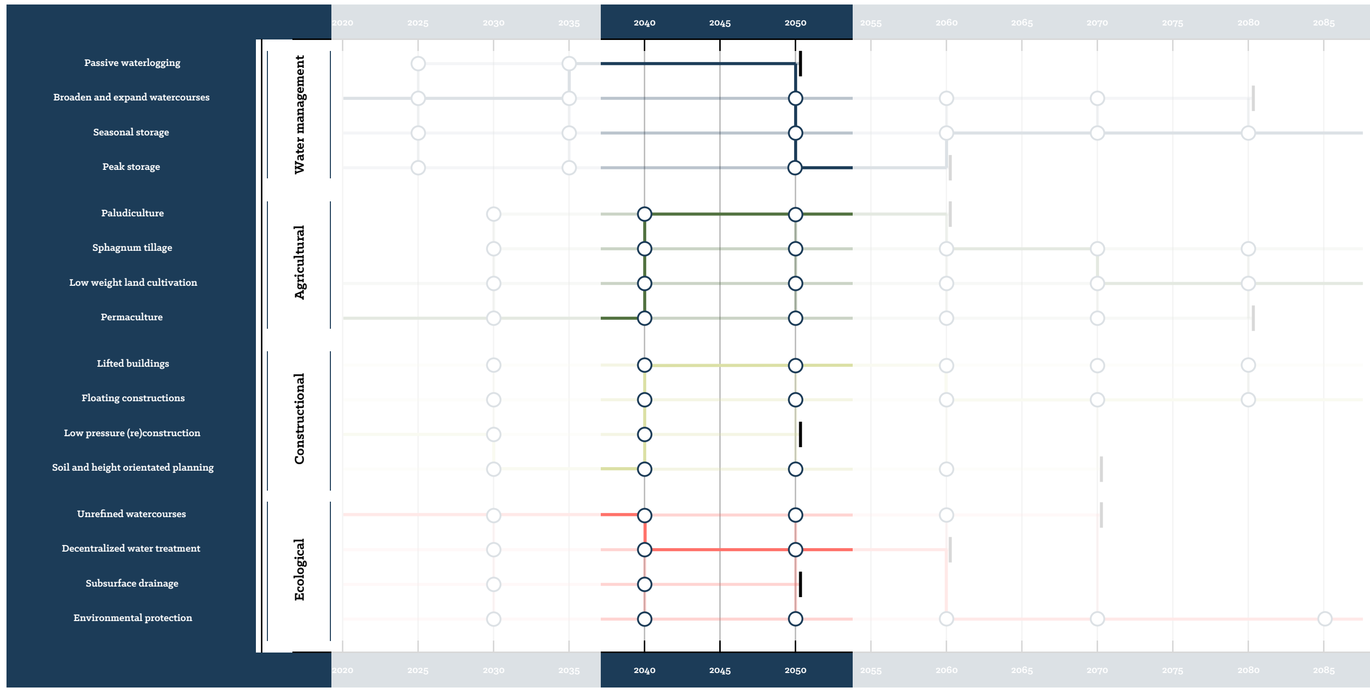


Figure 10.16: Mitigation Pathway 2050 Source: by Author

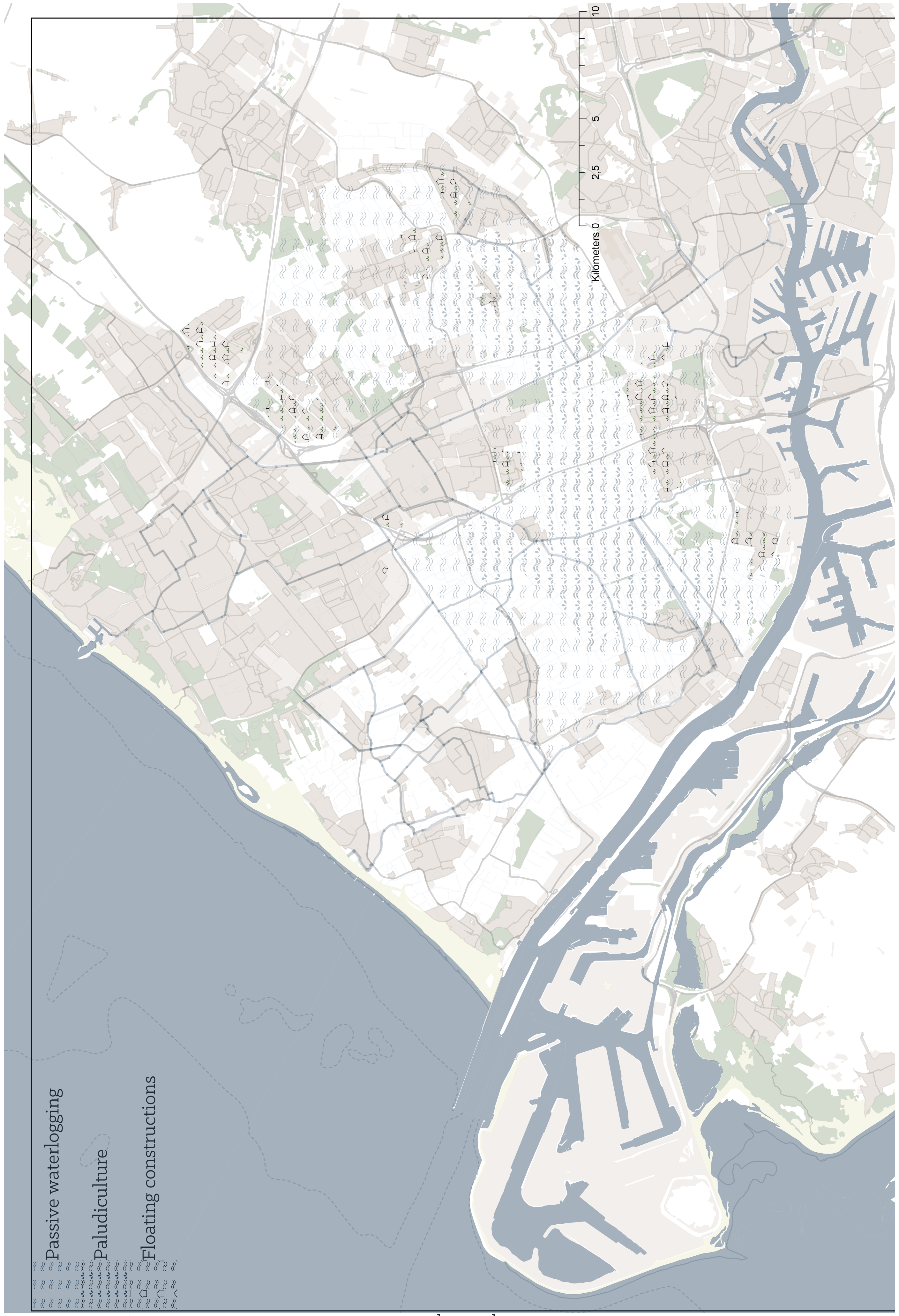


Figure 10.17: Mitigation Projection 2050 Source: by Author

2065

Most of the actions from the previous fifteen years are extended during the third phase of the mitigation pathway. The new steps that are taken during this timeframe are chosen to further mitigate the subsidence problem and to protect the lower parts of Delfland from floodings. The chance that floodings will occur will rise due to the passive waterlogging. The groundwater table will rise and the water storage capacity of the soil is reduced due to this higher groundwater table. These floodings will be prevented or redirected by creating peak storage locations throughout Delfland. The map in figure 10.19. shows the designated floodings areas that can be found on low places in the landscape that are already prone to floodings. Redirecting the water to these areas during periods of heavy rainfall will protect the surround landscape from flooding. Smaller scale interventions to increase the peak storage capacity of Delfland will be described in the smaller scale projection paragraphs. Further mitigation of the soil subsidence problem is achieved by making use of sphagnum tillage. This will reverse the soil subsidence by re-growing peat on top of the existing peat lands. Sphagnum tillage can be applied to the same agricultural lands as paludiculture. Transitioning to sphagnum tillage alone would however pose a financial risk, since the market for sphagnum is unknown. It would therefore make most sense to start with sphagnum tillage on a smaller scale. The lowest peatlands with a lot of subsidence and peat oxidation would be the best locations to start with sphagnum tillage, since reversing the subsidence would have the largest effect in these areas.

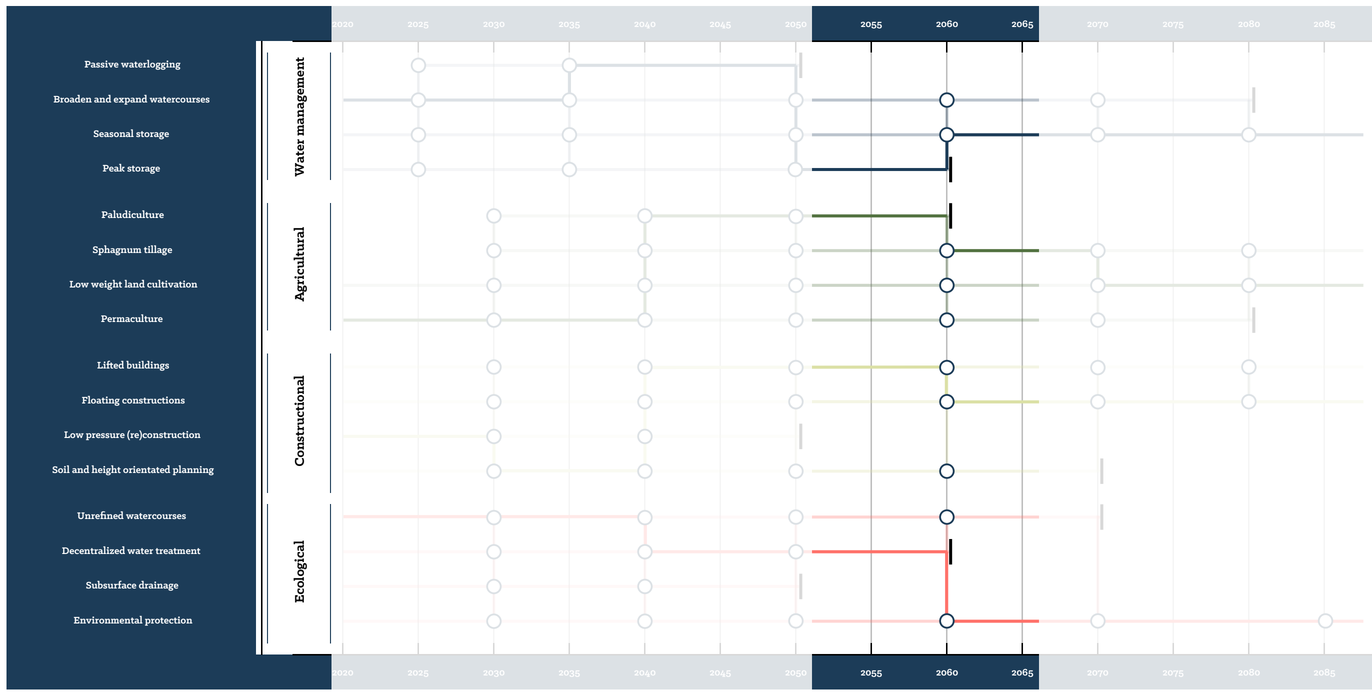


Figure 10.18: Mitigation Pathway 2065 Source: by Author

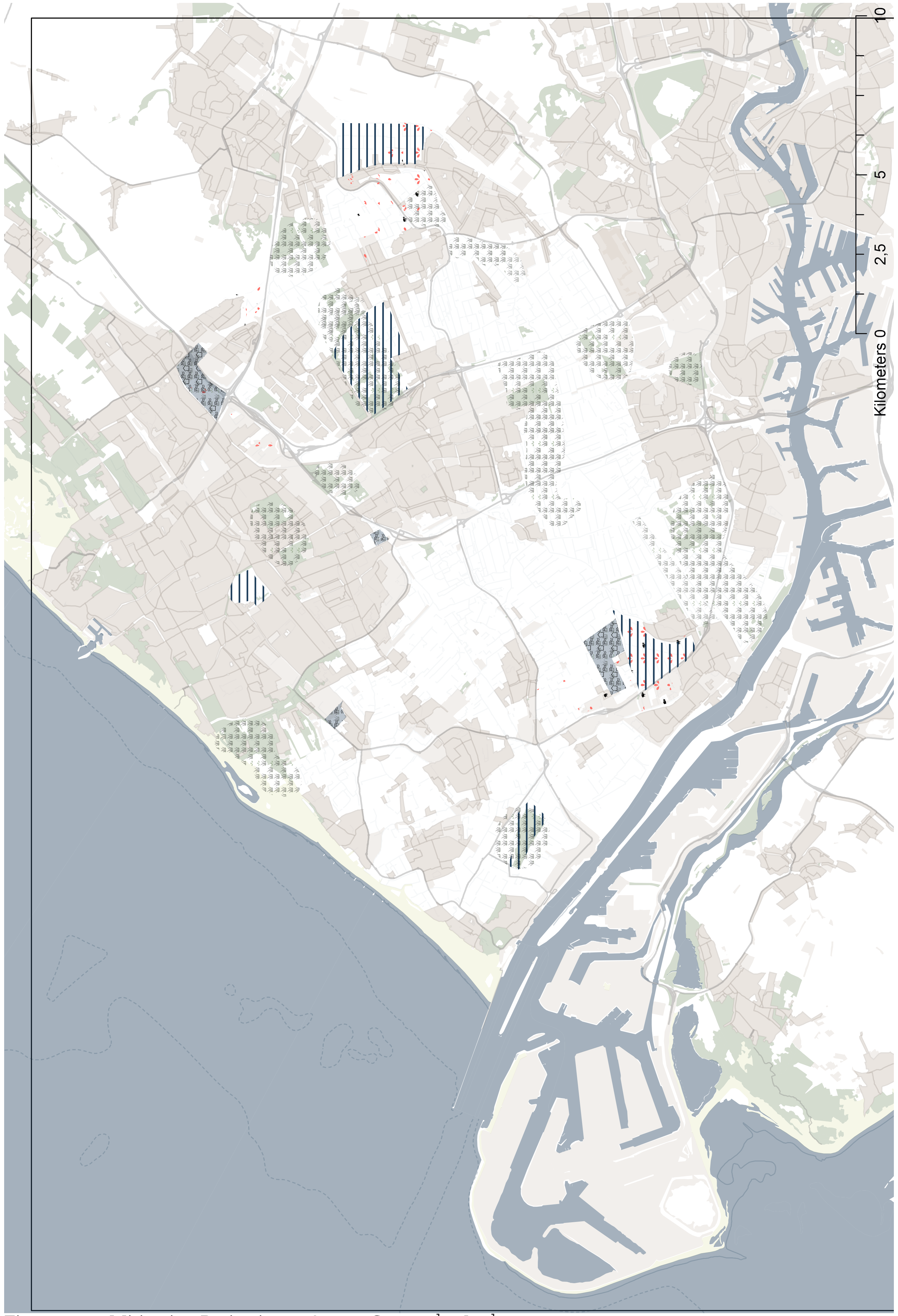


Figure 10.19: Mitigation Projection 2065 Source: by Author

2080

The final part of the mitigation pathway is made up of actions that adapt the Delfland region to soil subsidence and its effects in areas where mitigation is not possible. This results in seasonal storage areas in the areas surrounding the peatlands and in urban areas with subsidence problems. These seasonal storages will help to maintain a constant groundwater table in urban areas where subsidence occurs or where the buildings or built on wooden poles. Buildings on poles or with floating constructions is often not an option in old city centres, since these new forms of construction would change the historical image of these city centres. The seasonal storages are also used to supply water to higher parts in the landscape that have to deal with drought due to seepage to the lower parts of Delfland. This is, mostly, a problem in the designated natural areas of Delfland where the ecology will suffer during periods of drought when too much water seeps away. These natural areas will be further protected through environmental protection in the agricultural lands surrounding these natural areas. Room for environmental protection should also be reserved within the peatland to ensure that the peatland re-growth and restoration as an result of passive waterlogging can be ensured. The implementation of seasonal storages will be combined with the construction of new floating neighbourhoods on top of these seasonal storage areas. The agricultural lands can deal with this rising groundwater table, as a result of passive waterlogging, by transitioning from conventional agriculture to low weight agriculture. This form of agriculture puts less stress on the soil and is better capable of dealing with higher groundwater tables. Low weight agriculture will therefore take place the subsiding soils surrounding the peatland areas. The rising groundwater table will raise the chance of floodings in the lower parts of Delfland due to the reduced water storage capacity of the soils with a high groundwater table.

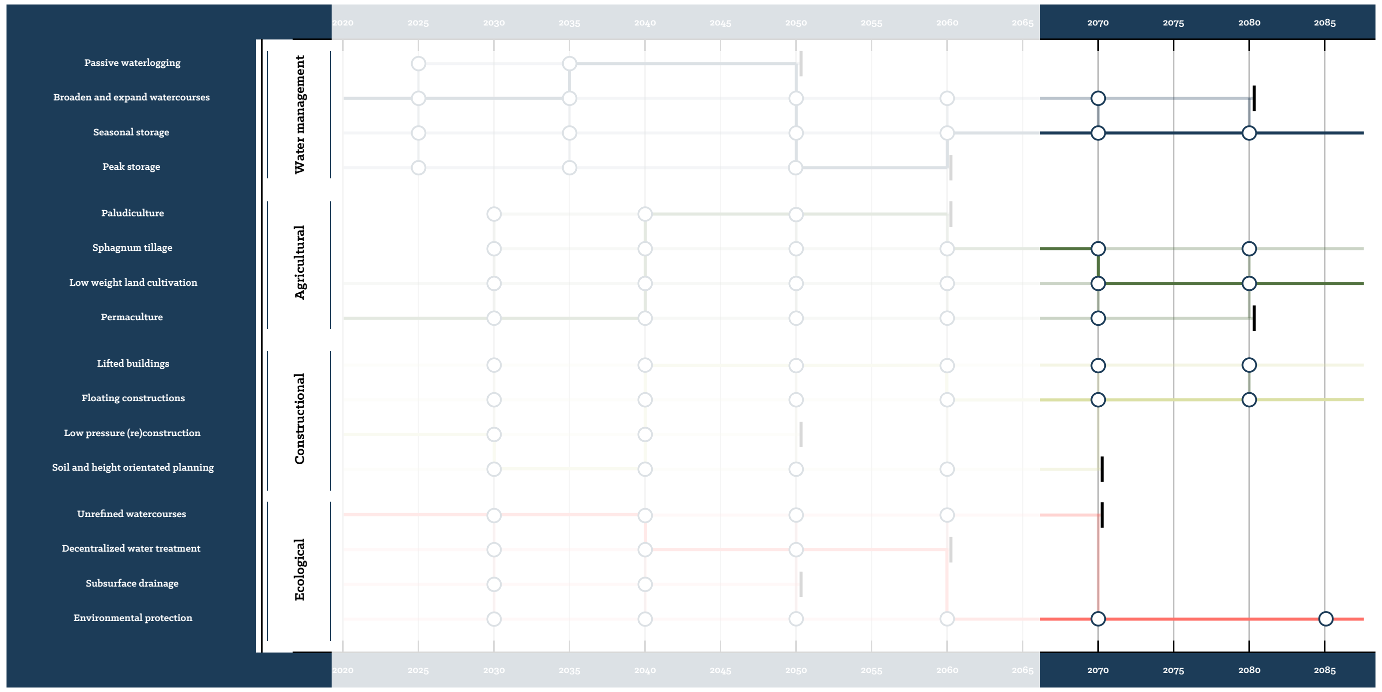


Figure 10.20: Mitigation Pathway 2080 Source: by Author

Figure 10.21: Mitigation Projection 2080 Source: by Author

2085

Following the Mitigation Delfland results in a Delfland projection, in which soil subsidence in the peatlands is stopped and in some parts even reversed. Figure 9.20 Gives an insight in what Delfland would look from a regional perspective when the mitigation pathway is projected on the Delfland region. This does however require a large part of the Delfland region to be transformed in to a wetland. This wetland requires most of the agricultural lands to make a transition towards a wet form of agriculture like paludiculture or sphagnum tillage. Neighbourhoods that are built on peat soils will are transformed in to floating neighbourhoods or neighbourhood on poles. These new constructions forms will require new construction techniques, but they will also offer a completely new form of public space. Much of the open space in these neighbourhoods will be water or wetlands instead of the conventional open space that are currently found in the urban areas of Delfland. The wetlands of Delfland will be filled with new unrefined watercourses and decentralized water treatment plants. This will clean the pollutants from the soil and water, while the unrefined water courses create new micro climates for plant and animals to live in. The wetlands with their unrefined watercourses will change the appearance of Delfland to look more like the wetlands that could be found in Delfland centuries ago. The local ecology could profit from these changes towards a more natural landscape in Delfland.

Figure 10.22: Mitigation Projection 2085 Source: by Author

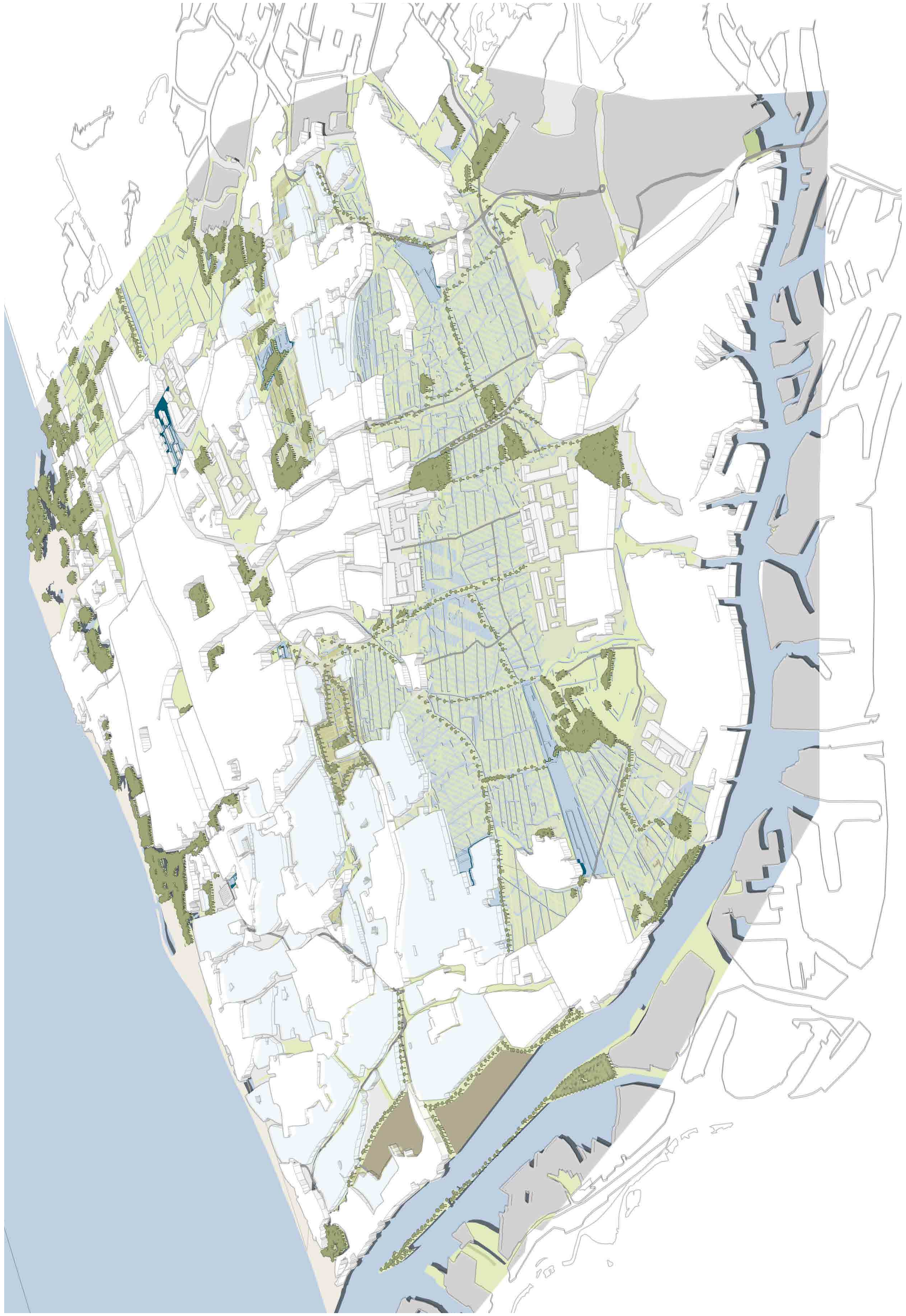


Figure 10.23: Impression Mitigation Projection 2085 Source: by Author

10.4 Small scale spatial impact

Three small scale locations are used to represent the spatial impact of the pathway projections on the smaller scale. The three locations that have been chosen can be found in figure 10.24. These specific locations have been chosen because the different scenarios have a different spatial impact on those locations. The three locations represent three different typologies that can be found in Delfland. All three of these typologies can drastically change when actions against soil subsidence are taken. The change that they will go through depends on the pathway choices that are made. The impact of these choices will be reviewed for each of the three locations, by looking at what impact actions from the different created scenarios will have on these locations.

Figure 10.24: Small scale projection locations Source: by Author

Urban

The first location a can be found on the border between Den Haag and the peatlands. It is currently used as an industrial area, but the area is slowly being transformed in to a residential area. This is an ongoing trend for the entire area surrounding the A4. These small scale will therefore show what impact, the choices that are made in the scenarios, will have on new urban developments. The current situation is represented in figure 10.25

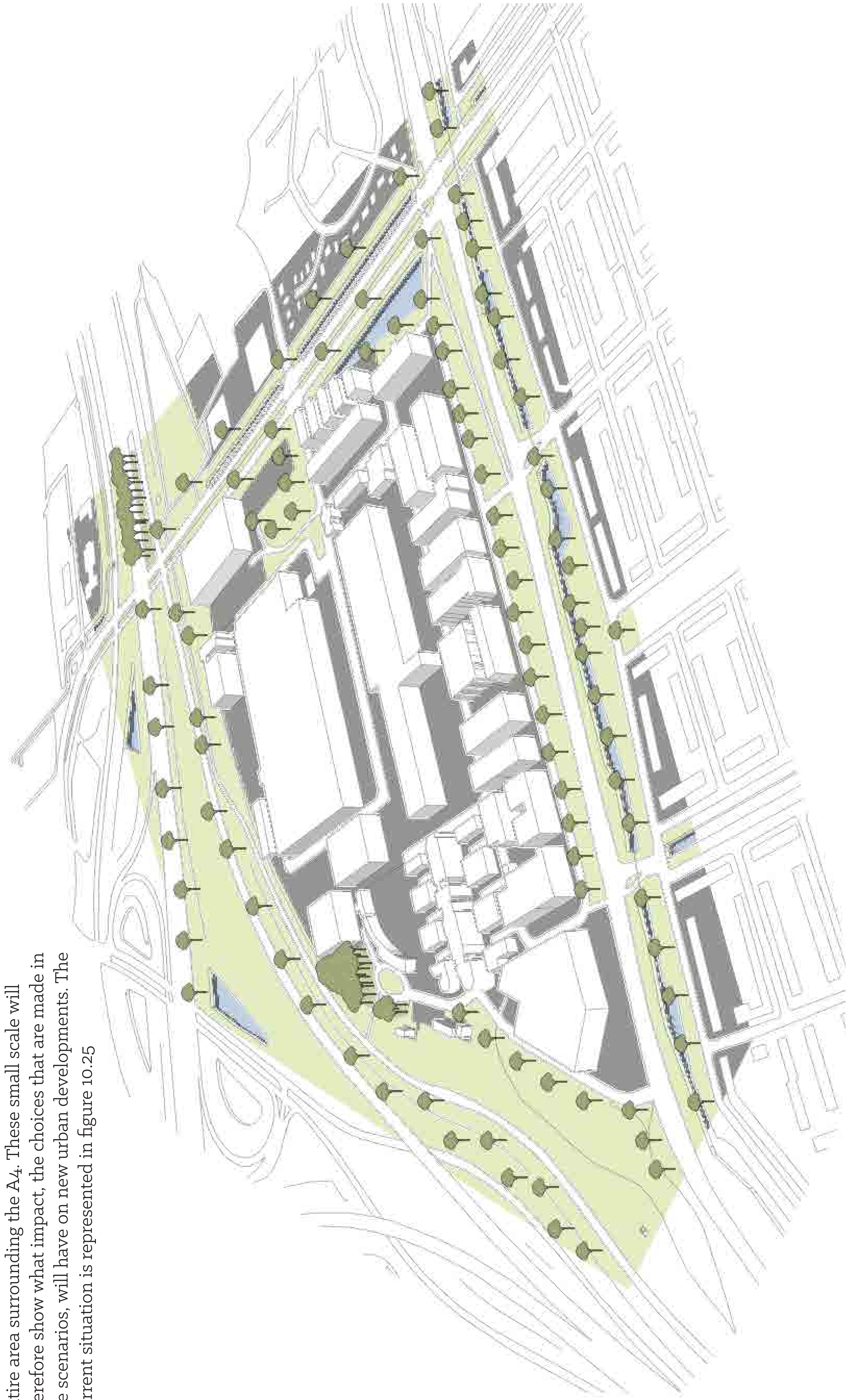


Figure 10.25: projection 2: urban location Source: by Author

The impact of the adaptation projection can be found in figure 10.24 and 10.25. It shows how the area has been transformed in to a seasonal storage area with floating houses. This allows water to be buffered while also developing new urban expansions. The water from the storage will be used to provide water for the peatlands during periods of drought, but it can also be used to cool down the surrounding neighbourhoods.

Figure 10.24: projection 1: urban location Source: by Author

Figure 10.25: Impression of a floating neighbourhood Source: by Author

The mitigation pathway requires all of the peatlands to be turned in to wetlands. Even in this case, where the peat can be found below the top clay soil layer. This means that new water courses have to be created to maintain the high groundwater table. This intervention is more wide spread than water buffering option from the adaptation projection. figure 10.26 and 10.27 give an impression of what this are and the surrounding neighbourhoods would have to look like to be able to live in these new wetlands. The houses are built on poles. This will prevent damages to the houses and roads if the soil would subside any further, but it would also allow the peat to regrow underneath the houses.

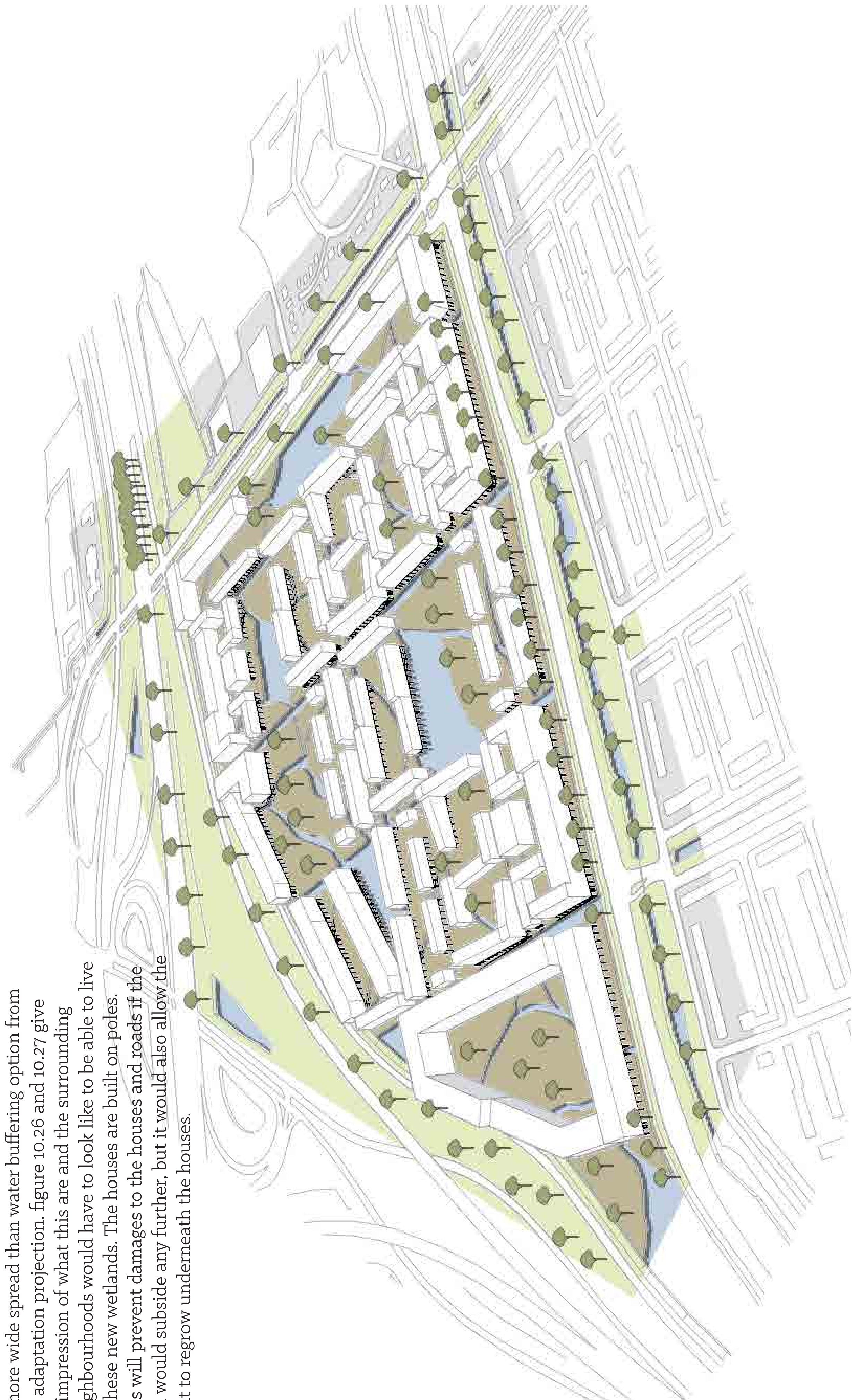


Figure 10.26: projection 2: urban location Source: by Author

Figure 10.27: Impression of a neighbourhood on poles Source: by Author

Natural

The more natural location can be found between Pijnacker and Nootdrop. This is one of the few designated natural areas in Delfland, since much of the landscape is urbanised or used for agriculture. This specific location is surrounded by peat soils that are fore the largest part covered with clay. Water is already being stored at this location, but both scenarios would still require changes to a location like this, when the pathway actions are projected on Delfland.

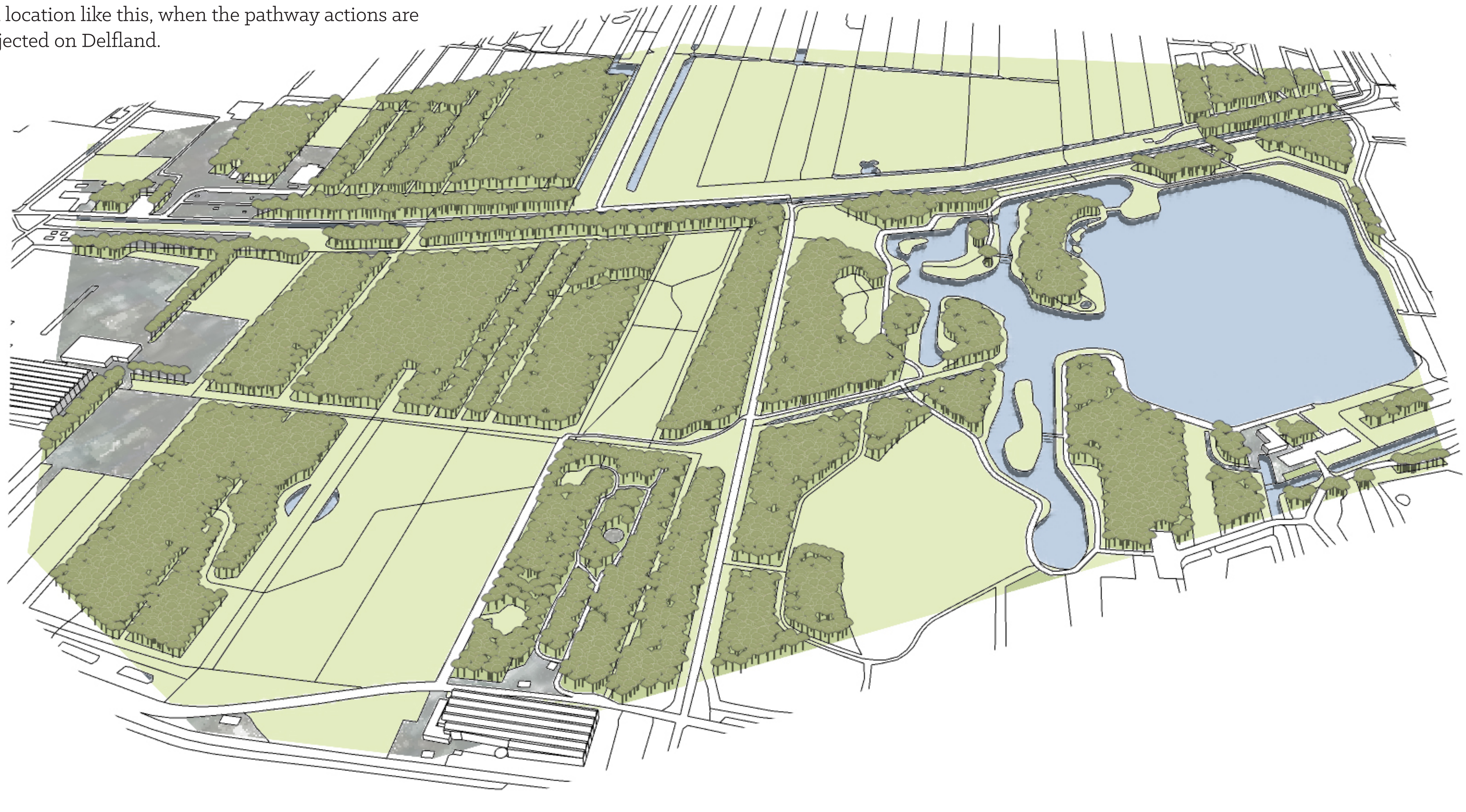
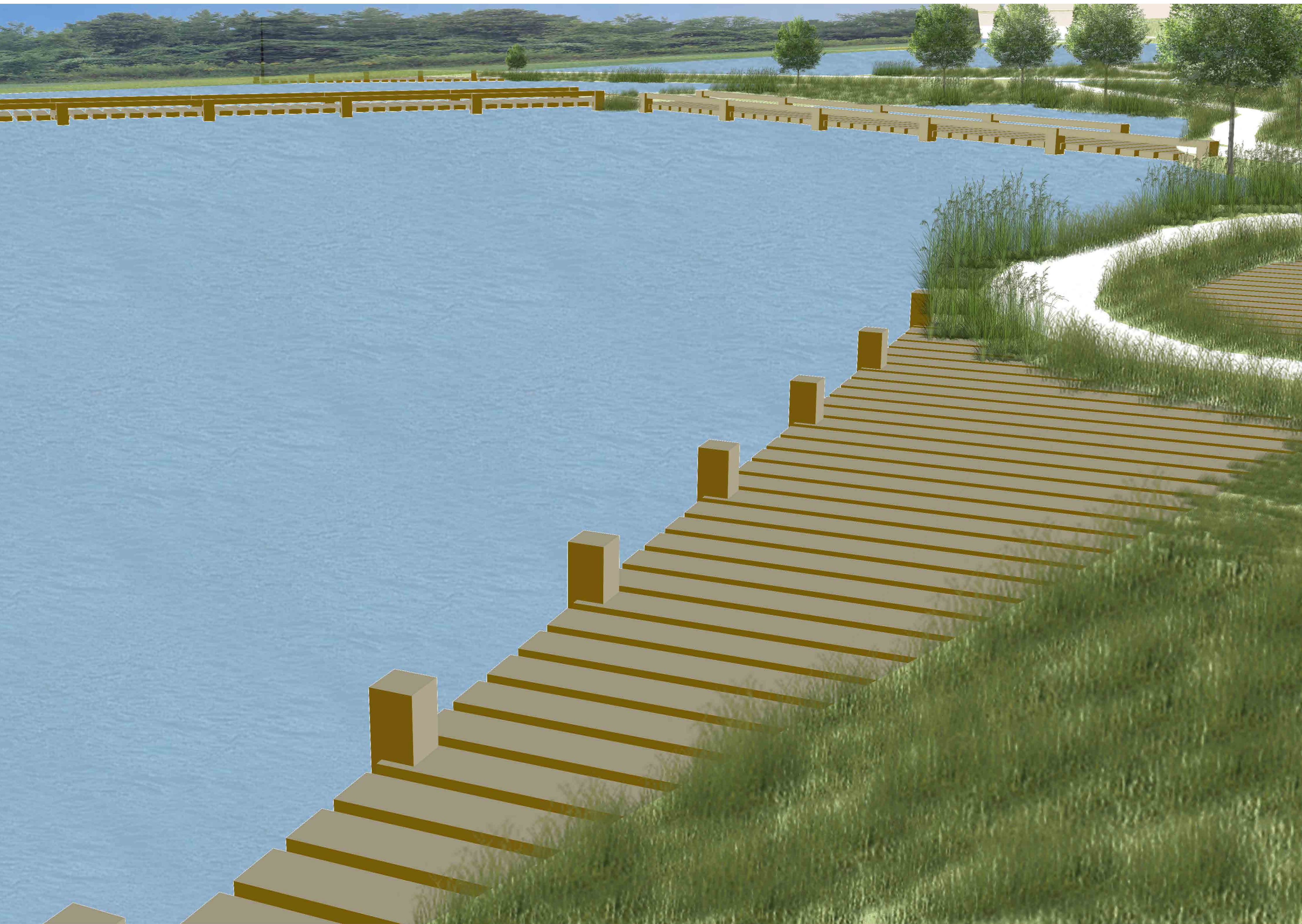


Figure 10.27: current situation: natural location Source: by Author

The adaptation projection would require an expansion of the water storage capacity to be able to buffer enough water throughout the year. This would mean that many of the grass lands, and even some of the more vegetated parts of the landscape, would have to make place for seasonal storage areas. The ecological structure is kept intact by making sure that the different island within the water surfaces are connected and still accessible for animals and plants.

Figure 10.28: projection 1: natural location Source: by Author



The mitigation projection would require the area to become part of the larger wetlands. This results in wetlands replacing much of the forestation on this location. The area would change from a densely filled green location to a more open wetland location. This would mean that the local ecology and living environments for animals and plants would change drastically as well. figure 10.29 and 10.30 give an impression of what these wetland would look like.

Figure 10.29: projection 1: natural location Source: by Author

Figure 10.30: Impression of a wetland park Source: by Author

Greenhouses

The greenhouse locations can be found in south of the Westland area. This location is right on the border between the greenhouse area and the agricultural lands. There is a lot of subsidence going on underneath these greenhouses, and many of them are built on peat or clay soils. The greenhouse are currently very close to each other and the cover a large area of the soil. This prevents water from infiltrating in to the soil. This enhances that subsidence rate during periods of drought.

Figure 10.31: Current situation: greenhouse location Source: by Author

The location is transformed in to a seasonal storage area in the first projection. This requires floating greenhouses in a much lower density than is the case in the current situation. The greenhouses could function as living machines that filter the water and thereby keep it clean. This would provide clean and fresh water for the local ecology and greenhouses in the area (Pötz, H.,& Bleuze, P., 2009).

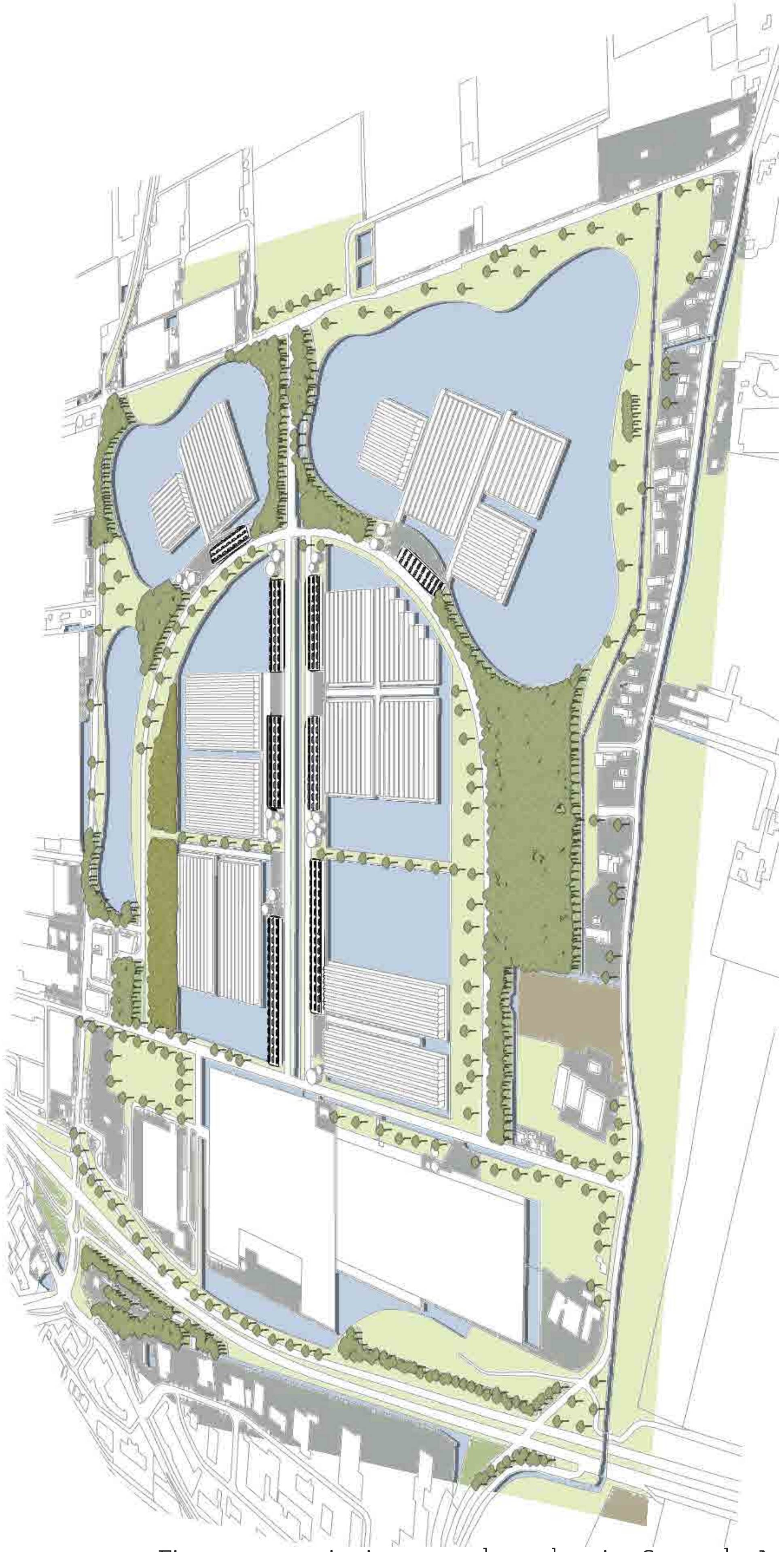


Figure 10.32: projection 1: greenhouse location Source: by Author

Figure 10.32: impression projection 1: greenhouse location Source: by Author

The mitigation projection would require this part of the Delfland to be turned in to wetlands as well. This will help to regrow the peat where possible. It would however also require a much lower density of greenhouses in this area and in the surrounding greenhouse areas.

Figure 10.34: projection 2: greenhouse location Source: by Author

Figure 10.35: impression projection 2: greenhouse location Source: by Author

11. Conclusions & reflection

The previous chapters have created an insight in how the choices between different actions can be made, and by who. The pathway map shows the possible routes that can be taken towards making Delfland more resilient to soil subsidence and its effects. Finding the preferred pathway on this pathway map will be the task of a taskforce. This taskforce will have to take the demands, wishes, and expert knowledge of the different stakeholders in to account to determine which pathway would fit best for Delfland and the involved stakeholders. The pathway that is chosen by the taskforce is the preferred pathway. This preferred pathway shows which actions that will be taken, and when these actions will be taken.

Future events could however require that other actions are taken or that actions are taken at a different moment in time. This would mean that the preferred pathway is no longer relevant and a different path along the pathway map has to be chosen. Changing pathways does not affect the outcome of the pathway, since all pathways along the pathway map lead to the same goal: adapting Delfland to soil subsidence and its effects. Choosing a different pathway could however result in different spatial outcomes and in different outcomes for the stakeholders. A difference in the spatial outcome of a pathway is, mostly, created by the order in which the actions are taken in a pathway. Some actions could be applied to the same location or they could counter the same effect. Actions that are taken later on in the pathway will therefore only be used in places where they could improve upon earlier actions or in places where earlier actions could not be applied, due to the different conditions in which an actions is effective or not. This chapter will take a look at how different pathway choices could result in different spatial outcomes.

The possible spatial impact of different pathways is researched by choosing two different possible pathways on the pathway map. Both of these possible preferred pathways are projected on the Delfland region. This results in two pathway projections that give an insight in the possible spatial impact of two pathways and the actions that are chosen within these pathways. The first chosen pathway is focused on adaptation to soil subsidence and its effects. The second one is a pathway focussed mitigating soil subsidence and its effects as much as possible.

Both of the pathways and their spatial projections will be described within this chapter in five parts. The parts describes a scenario in which not pathway is developed and in which no actions to counter soil subsidence and its effects are taken. The second part will describe the adaptation pathway and the spatial projection of this pathway on the Delfland region. This is done by describing the pathway and the choices that are made within the pathway, before taking a look at where these actions would have to take place in the Delfland region. The second part will describe the same, but for the mitigation pathway. Both parts will give an overview of where actions within Delfland would be taken and how these actions would influence Delfland spatially from a regional perspective. The fourth part will compare the two regional projections to create an insight in the different spatial impacts, of the two pathways, on the Delfland region from a regional perspective.

The fifth part of this chapter will describe the small scale impact of the different pathway choices. This is done by looking at four locations that are characteristic for Delfland. The current situation and the possible changes, under the influence of the pathways choices, will be described for all these smaller scale location. This offers an insight in how the large scale pathway projections could influence specific parts of Delfland on a smaller scale.

11.1 Conclusions

Soil subsidence as a result of peat oxidation occurs all over the world in deltas that are heavily urbanised and adapted to the needs the inhabitant of those deltas. The Dutch delta is one of those urbanised Deltas where soil subsidence is causing more and more problems. Few people are however aware of the impact that soil subsidence has on the Dutch cities and landscapes. The soil subsidence rate in the Netherlands is in some places higher than the rate at which the sea level is rising due to the effects of climate change. Delfland is a part of the Dutch delta where soil subsidence and its effects can be noticed in the cities, as well as, the landscape surrounding these cities. Parts of Delft, Den Haag and Rotterdam are slowly sinking in to the ground. The landscape surrounding those cities is filled with agricultural lands and ecologically viable landscapes. These landscapes and cities are under threat from soil and water pollution, floodings, drought, and salinization, as a result of peat oxidation. Cities will flood more often and the Delfland landscape could, for large parts, become infertile, if the oxidation and soil subsidence process is not stopped. The peat oxidation process has a reciprocal relation with its effects and causes. Such as drought, floodings and climate change. This means that the oxidation is strengthening its own downwards spiral toward further oxidation.

There is a lot of uncertainty about the impact of soil subsidence and its effects, due to external factors such as climate change. The research into soil subsidence and its effects is also still ongoing, which means that a lot of new information about the effects and counter actions of soil subsidence can still be discovered over the coming years. Delfland is however already under threat from soil subsidence and its effects which means that actions to counter soil subsidence should be taken as soon as possible, to stop the downwards spiral before it is too late. The DAPP method has been used to be able to take uncertainty in to account. This method is developed to deal with uncertainty in water management. DAPP is however not designed to deal with complex problems like soil subsidence. Dealing with soil subsidence through DAPP required a change in the development of the pathway map. The DAPP method is normally used to develop a pathway map that consist of actions that can all be used to tackle the same problem. The pathway map that has been developed to make Delfland more resilient to soil subsidence and its effects consist of actions that target four different problem fields. The actions within these four different problem fields will have to work together to be able to deal with soil subsidence and its effects in Delfland. Using the actions within the four different fields at the same time will speed up the process and it allows spatial planners to create an design in which multiple actions can be implemented at the same time. This has led to a pathway map for Delfland that makes use of four different parallel pathways for the four different problem fields that are related to the soil subsidence problem. The four pathways work within different fields where soil subsidence and its effects causes problems or where solution to soil subsidence can be found. Making sure that actions are taken in all four of the fields at the same time, will ensure that all the different problems and aspects of soil subsidence are taken into account within the pathwaymap Using all four of these pathways simultaneously is required to be able to achieve the goal of the pathway map, which is: adapting Delfland to soil subsidence and its effects.

The DAPP method is not directed at involving a large group of stakeholders, since the method is developed to deal with water management problems that only require decision-making from a water management perspective. This is however not the case for soil subsidence and Delfland. Many different stakeholders and users come together within the Delfland region and the four different related problem fields. Tackling soil subsidence and its effects does therefore require a decision-making model that helps to determine how the pathway choices should be made. It is important to create an overview of the different stakeholders before their role within the decision-making model can be determined. The problem analysis and the action assessment , as a part of the DAPP method, can be used to determine which stakeholders are involved and affected by the soil subsidence problem and the actions that that are used to counter the problem. Tackling the soil subsidence problem in Delfland requires decision-making model that includes stakeholders from all four of the problem-fields to make sure that knowledge from the four different problem fields is taken in to account, but also to create acceptance and understanding within the different stakeholder groups. This should lead to less resistance against the chosen pathways. The decision-making model developed by (Meel, J., & Bjørkeng Størdal, K., 2017) will help to achieve this goal. This decision-making model is centred around one impartial taskforce that is made up out of a small group of stakeholders. This taskforce should make pathway decisions by collecting input from the different knowledge fields and end users. These end users and the stakeholders within the knowledge fields should review the decisions made by the taskforce, to make sure that that made decisions are acceptable for all the involved stakeholders.

It is difficult to determine the spatial outcomes when the DAPP method is used. It is however possible to develop a spatial plan for Delfland with the actions from the preferred pathway. It is not absolutely certain that this pathway will be followed, since future events could require changes in the pathway to make sure that the final goal is still achieved. The preferred pathway could however still be used to create a spatial design for the Delfland region. This design can then again be used to review the preferred pathway. Reviewing the spatial outcomes of a preferred pathway could result in different pathway choices being made, to be able to achieve a better spatial outcome. Reviewing the spatial outcomes of a pathway is not part of the DAPP method, but it would be very useful when developing a strategy on dealing with soil subsidence and its effects in Delfland. It could help to make choices between actions and pathways based on future spatial outcomes and not only based on the financial consequences or technical possibilities. A positive spatial outcome is crucial when dealing within soil subsidence in Delfland because it can heavily impact the way that Delfland will look in the future while it can also help to improve the acceptance and awareness of actions that are used to counter soil subsidence and its effects.

Using DAPP to develop a regional spatial strategy would therefore require an extra step that reviews the spatial impact of a pathway. A version of the DAPP development plan that includes large groups of stakeholders and a step that reviews the spatial impact of a preferred pathway has been made. This development plan can be found in figure 11.1. This image shows how different stakeholders can be involved in the pathway decision-making process by not just analysing the problems and possible actions, but by also analysing the different involved and required stakeholders. A spatial impact review step has been added once the preferred pathway has been chosen. This step is used to check whether or not the preferred pathway also has the preferred or demanded spatial impact on the region. A unwanted spatial outcome of a pathway could in this case lead to different choices within the preferred pathway.

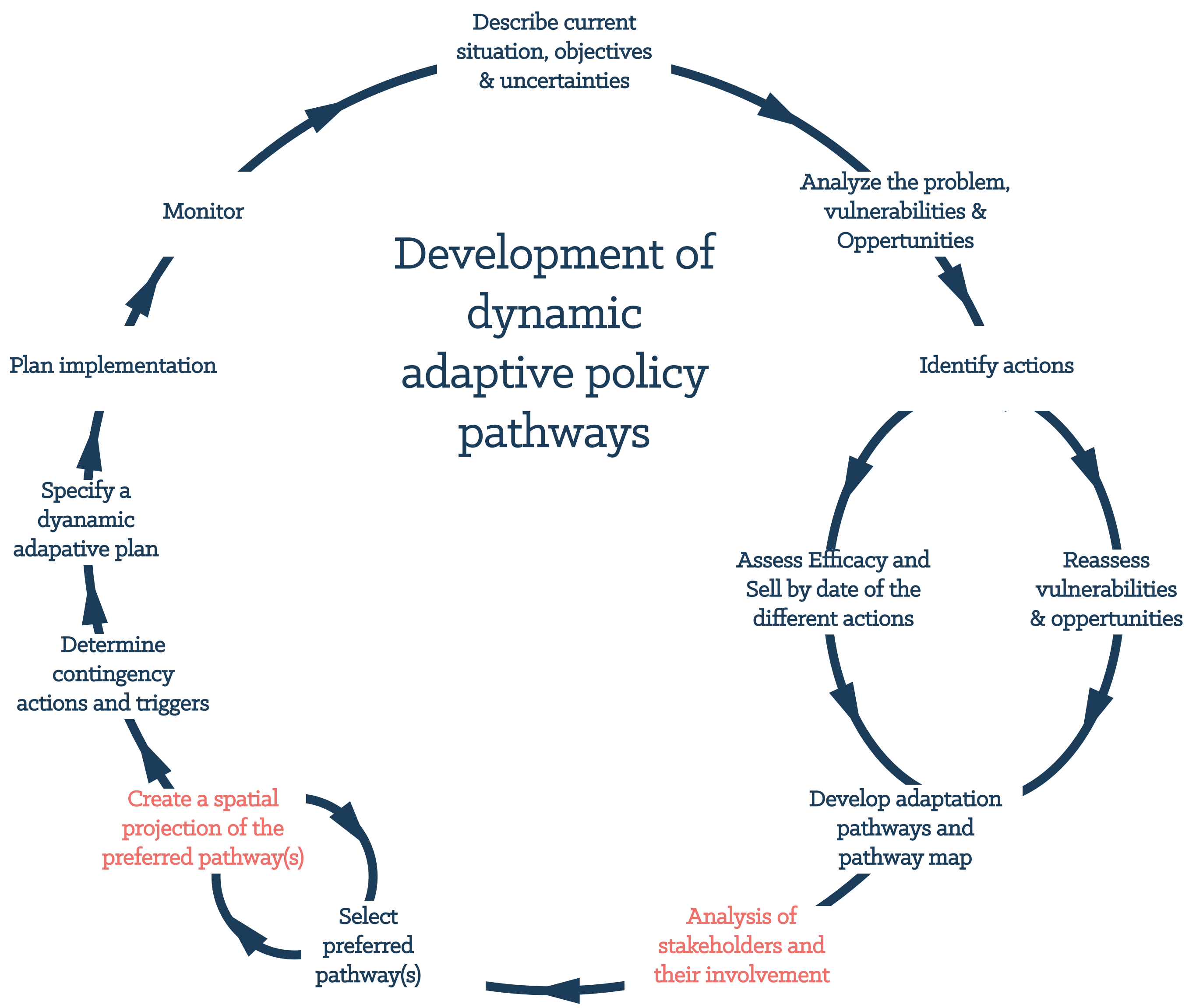


Figure 11.1: Adjustments to the DAPP development model Source: by Author

11.1 Reflections

the relationship between research and design.

The first research into soil subsidence did already reveal how complex the subsidence problem is, because of all the reciprocal relations between subsidence, its causes and its effects. This revealed the four major problem field that would have to be targeted during the design phase. The dynamic adaptive policy pathway theory offered clear steps the proved very helpful in giving direction to the research, as well as, the design steps. The action assessment step of the DAPP method helped to define the requirements that where needed for the development of an effective design. The assessment also helped to further define what was needed from the analysis, to make it useful during the design steps and implementation of the actions on the right locations. The dynamic adaptive pathways, that where eventually developed with the actions, gave direction to the design. The pathways gave an insight in the phasing of the design steps, and they determined which design steps were to be taken to develop that pathway in to pathway projection. The pathways are therefore the essential step that help to translate the design into required design steps, and eventually a design.

the relationship between the graduation topic, the studio topic and the master track

Urban metabolism is concerned with understanding the metabolism of urban environments and its relationship to landscape systems theory. It investigates the performance of infrastructures, environmental technology and systems in relation to spatial quality, environmental sustainability, livability and the social wellbeing of future cities. The research group is focussed on developing future urban systems that are less damaging to the environment and more resilient to future changes. We do that by making them more efficient in terms of energy, water, material and waste cycles and management and more adaptive to natural flows, such as storm water and heat. Metabolism tools can help to assess and aid the growth (and decline) of cities in developing regions towards more resilient systems based on reciprocal relations between cities and hinterlands, culture, nature and ecology.
This is how the urban metabolism was described in the first lecture that introduced us to the different possible studio topics. These themes can clearly be recognized within this research. Soil subsidence and its effects are part of the natural flows, which play a central role within these research. The research focusses on dealing with the negative effects of the natural flows in Delfland. This is done by looking at the future systems that were required to protected the cities in Delfland and their hinterlands form the negative effects of the natural flows. This is first of all done by looking at how the natural flows effect Delfland. Further steps in the research take a look at what is required to deal with these negative effects, and how actions to could help Delfland adapt to, or sometimes even mitigate the soil subsidence problem. The pathway projections helped to get a better understanding of how the different actions, that are required to counter soil subsidence and its effects, can impact the spatial quality and liveability of Delfland

The relation between the chosen method and the methodical approach of the graduation lab.

The methods of the urban metabolism studio are directed at analysing data and technical interventions, to see how they could influence, stimulate, steer or improve a spatial design. Methods like GIS have helped to create an insight in where soil subsidence and its effects occur. The DAPP method has played a clear role within the research as well. This method has helped to translate a combination of technical actions into a strategy that can be used to develop a spatial design.

Project and research transferability

The spatial projection of the pathways are very site specific for Delfland. These spatial representations of the implementation of the actions in Delfland could therefore not directly reveal the spatial impact of the action on another location. The same can be said for the action table and the pathways since they have been developed with actions that have been researched for Delfland. Some of the actions might work all around the world, while other are more site specific. The DAPP method can however be used to approach the soil subsidence problem in other locations as well. The complexity of the soil subsidence problem did require some adjustments to the DAPP method to allow it to deal with multiple problem fields at once. These problem fields can however variate within a project without compromising the possibility to use the DAPP method. A spatial review component has been added to the DAPP method within this research as well, to be able to deal with the technical aspects of soil subsidence, as well as, the spatial aspects.

scientific relevance

The climate change and all its impacts are becoming clearer and clearer all over the globe. The KNMI (2015) has shown that the climate change also has a big impact on the climate in the Netherlands. Extreme Rain showers and droughts are becoming more common and cities in the Netherlands will have to adapt to these changes.
Many cities have adapted to these changes in some way, but they could take it much further. Hallegatte (2009) states that many cities have only adapted to deal with the current issues that climate changes poses. Many of the interventions that cities have choses are very insensitive when it comes to future climate conditions.
Most interventions have been integrated on locations where there was still space available instead of integrating them in to the cities design.
Most of the current solutions for climate adaptation work best when there is space to integrate them within the existing structure. This space is very often no longer available in cities in the Dutch delta region, because the cities are limited to their current boarders and can no longer expand beyond those borders. The space for climate adaptation could become even more limited due to further densifications of most of the cities in the Dutch delta. All of this together means that interventions in these cities should take up as little space as possible and no space can be wasted.
It would therefore make sense to try and find as much opportunities as possible outside of the city on a regional scale. These large scale scenarios could then help to find the problems that need to be tackled within the urban design of the city and which problems could be solved by making city and landscape collaborate to find an evolutionary resilient solutions (Davoudi & Mehmood 2013).

societal relevance

Cities in Deltas all over the world are struggling to deal with water issues like: floods and droughts in combination and enhanced with soil subsidence. This is also the case for almost all of the cities in the Dutch delta. Even though most cities have a well thought out and functioning water system. Climate change will still require these systems to change and become adaptable to new and more intense weather conditions.

The Delta program 2018 has shown that these problems are taken in to consideration by the Dutch government and plans are made to deal with water and soil issues all over the Netherlands. This research will continue on that to try and create more depth when it comes to creating a specific regional vision and how such a vision could influence the quality and liveability of the city.

Ethical considerations

There are several ethical considerations that should be taken in to account and reviewed during the project. Working on such a large scale means that a lot of stakeholders will be involved that all have different priorities. Issues like lowering or raising the ground water level could also have possible effects in one part of the city or landscape while other parts of the could be damaged by interventions like these. Regional strategies could show that some areas would be better off when they would change the land use or policies, this could however create frictions on a smaller scale between for example municipalities, housing corporations or land owners. Changes towards adaptable cities could require people to change their way of live or it could have a heavy impact on the neighbourhood that they are living in this means that people have to be willing to adapt or maybe other solutions will have to be found.

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HOW TO TACKLE SOIL SUBSIDENCE WITH DYNAMIC ADAPTIVE PAHTWAYS

T. Claassen

KEYWORDS

Dynamic adaptive policy pathways, soil subsidence, adaptive Delta management, adaptive planning, delta regions

ABSTRACT

This paper will focus on the possible use of Dynamic Adaptive Policy Pathways (DAPP) in creating a strategy on soil subsidence and related water systems in the urban environment in a delta region. This is researched through defining what Dynamic Adaptive Policy Pathways are and by finding the strengths and weakness of this method. This will in the end lead to an advise on when and when not to use the Dynamic Adaptive Policy Pathways method.

The method of DAPP has a clearly structured approach. It combines elements from adaptive policy making and adaptation pathways within a strategy (Merrie et al., 2014). This is done by linking different proposals within pathways that include designated tipping points that indicate when new interventions are required. The different strategies should be monitored to unveil these tipping points (Haasnoot et al., 2013).

DAPP does, however, have some downsides. The model requires a very detailed approach, to be sure that all important factors are taken into account. The method should, however, also be quick enough to analyse a large amount of scenarios within an acceptable timeframe (Haasnoot et al., 2013). This most likely contributes to simplifications within the method when it comes to knowledge, institutions, and the underlying grid of values (Wise et al., 2014).

Other studies promote upgrades to the DAPP method, like toolkits and new models. These will have to reduce the required resources and make it easier to control all the different scenarios (Kwakkel, Haasnoot & Walker, 2015). This could also be achieved through avoiding implausible pathways and adding thresholds that have to be passed before pathway switches are accepted to prevent waste (Manocha & Babovic, 2017).

DAPP could be useful when it comes to creating a new strategy on soil subsidence but it would be important to be aware of the simplifications and downsides within the method (Zeff, Herman, Reed & Characklis, 2016). It is, furthermore, important to take the different improvements on DAPP into account to enhance the significance of the method for this specific strategy.

1. INTRODUCTION

This paper is part of a bigger research in to soil subsidence in delta regions. This research will focus on the possibility to deal with soil subsidence and its consequences within a regional spatial strategy. Soil subsidence (caused by peat oxidation) is a huge problem in deltas all over the world. Delatres states that: “A major rethink is needed to deal with the ‘hidden’ but urgent threat of subsidence” (Deltares 2013-P1). Soil subsidence is, however, very difficult deal with because, the amount of, soil subsidence, and the scale at which it will take place, are difficult to predict.

The regional and strategical approach of the research, in combination with uncertainty about the future, could require Dynamic Adaptive Policy pathways (DAPP), to steer the dissension making within the project in the right direction. DAPP is a method developed as a response to traditional decision making. (Haasnoot et al., 2013) This mehtod tries to prevent making the same mistake by developing adaptive plans that: ‘contain a strategic vision of the future, commit to short-term actions, and establish a framework to guide future actions’ (Haasnoot et al., 2013: 458)

It seems likely that the pathways methods that are used within water management could also play a role when it comes to developing a regional spatial strategy on soil subsidence. This is mostly so because of the reciprocal relation between soil subsidence and the water system. Changes in the water system like lowering the water table or extracting ground water have a negative effect on soil subsidence. Soil subsidence will, meanwhile, require changes in the water systems to slow down the subsidence. This makes is seem likely that the DAPP approach could also play a role when it comes to tackling soil subsidence. The hypothesis of this research is therefore: Dynamic Adaptive Policy pathways could play a role within the development of a regional spatial strategy on soil subsidence, when it comes to making sure that plans will be adaptable and open to future changes in the effects of soil subsidence.

This hypothesis will be researched by seeking the answer to the following research question: What role can Dynamic Adaptive Policy Pathways play within the development of a regional spatial strategy on the effects of soil subsidence?

This question will be researched by: first taking a deeper look at why and how the DAPP method is developed. How DAPP works and how it should be used is described in the second part of this paper. The third part of the paper will take a look at the downsides and critiques on DAPP. This will help to define the risks or possible problems that are involved in using DAPP. This part of the paper will also focus on the possible improvements or adjustments on DAPP, that have been promoted or used in the past, to make sure that the different possible uses of DAPP are explored before looking at the possible use within this research. The Fourth part of the paper will focus on this aspect, and takes a look at the possibility of using DAPP within a the development of a regional strategy on soil subsidence in deltas.

2. THE DEVELOPMENT OF DAPP

As is stated in the introduction: DAPP is developed in a response to static proposals and plans that could very well fail if the future doesn’t turn out to be as was expected when the first design was made. Traditional decision making is based on: developing the most optimal plan for the most likely future, or developing a very robust plan that is acceptable in most future scenarios. These ways of decision making are, however, vulnerable to unforeseen future developments. This means that many of the plans that are developed through traditional decision making will eventually fail because of unforeseen changes.

DAPP is developed by using the strengths of two different adaptation methods together. These methods are: Adaptation pathways and Adaptive policymaking. Both methods use similar concepts which offers the opportunity to use aspects of both methods together within a new method. The most import reason for combining both methods is the fact that both focus on the use of a trigger or tipping point. These are used to determines when a solution is no longer sufficient, when it comes to meeting the objectives that where set for the project. An intervention is required when these tipping points or triggers are reached (Haasnoot et al., 2013)

This paragraph will take a closer look at how DAPP is developed, by taking a closer look at Adaptation pathways and Adaptive policymaking, to see determine how the method works and when it could be used.

2.1 Adaptation pathways

The method of Adaptation is centred around the earlier described tipping points (Kwadijk et al., 2010). The method requires action when the tipping point conditions are met. The adaptation pathways offer possible actions that could be taken after a tipping point has been reached. A adaptation tree offers different choices for each the tipping points. Different pathways could formed, through this adaptation tree, depending on which choices are made once a tipping point has been reached (see figure 1 for an example) (Haasnoot et al., 2013). One thing that all pathways should have in common is that all they all end up the same, predetermined, final result. Parties that are involved within the decision making process, like stakeholders or clients, decide which action is taken at the different tipping points. “Decisionmakers or stakeholders may have a preference for certain pathways, since costs and benefits may differ” (Haasnoot et al., 2013: 478). A scorecard could be used to review the coasts and benefits of the different pathways. The adaptation tree, helps in making this decision, by offering an insight in the timing of the different actions. The tree can be used to see which actions should be taken at this very moment, and which actions should be prepared, to be ready of implementation at a later time.

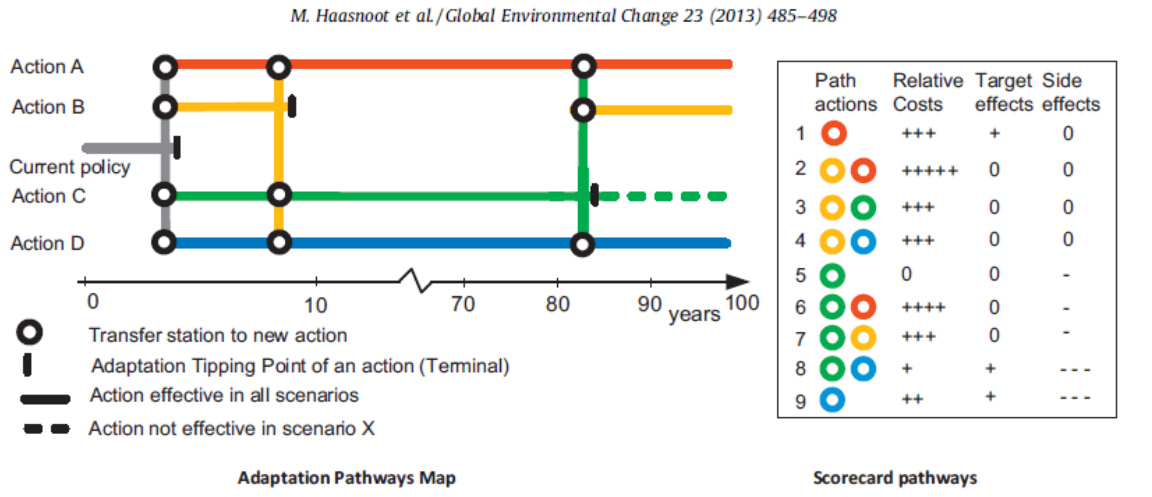

Figure 1: pathways and tippingpoints in a adaptation pathways map (Haasnoot et al., 2013)

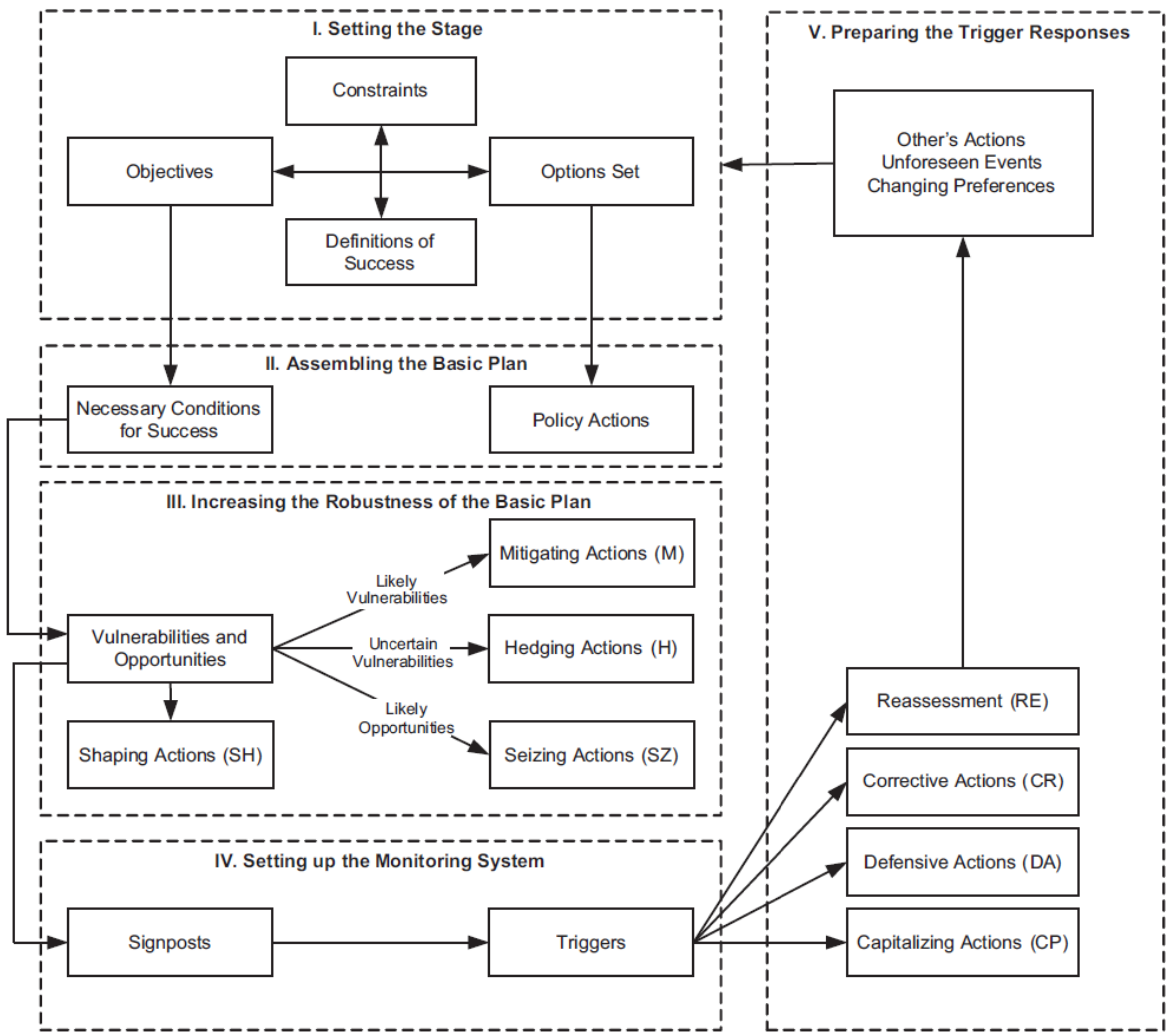

Figure 2: The five steps of adaptive policymaking (Haasnoot et al., 2013)

2.2 adaptive policymaking

The approach of Adaptive policymaking is organized around the ability to create robust and dynamic strategies and designs. (Kwakkel et al., 2010a). Adaptive policy making uses five steps that guide the user through the design process for a dynamic adaptive design. These steps of adaptive policymaking are shown in figure 2.

The first step is focussed on analysing the current conditions and the future objectives. These objectives are put together in a plan, in the second step of the process. The third step is to monitor this plan. This is done to make sure that the plan is robust enough trough mitigating, hedging, seizing and, shaping actions. The actions help to contain the possible negative effects while they also help determine where opportunities could arise. The fourth step helps to determine, whether or not, the plan is still on the right track. This is done through signposts that define what data should be analysed to make sure that the plan is heading towards a successful result. A trigger is activated when the plan is no longer on the right track. The response to these triggers is defined in step five. The responses in step five are not necessarily focussed on negative effects that are taking place. A trigger can also be activated because new opportunities arise that could or should be grasped. The plan is complete after step five is been completed. This means that the outcome of steps two and three can implemented, and the monitoring system can be put place. Information from signpost will then be collected which could active the triggers. These triggers will then determine which new actions will have to be taken to keep to process going in the right direction.

2.3 comparing both methods

The two previously mentioned methods have some clear similarities between the two of them, as well as some clear distinctions that make them clearly different approaches. One of the commonalities between both methods is the tendency to focus on dealing with long-term uncertainty by keeping plans and solutions adaptable (Haasnoot et al., 2013). This is probably the most important factor in both of these methods, because it makes it possible to implement new policies and changes, on the short term, while also maintaining the possibility to wait and see what the future has in store.

The main difference between both of the methods is the way, in which, both methods handle the decision making aspect. The adaptation pathways offer the possibility to review a large amount uncertainties, varying from system changes to more natural uncertainties. The quick and simple model allows to explore these uncertainties through different pathways in a fast way. The pathways map that is formed by exploring the different pathways does, however, not offer tools for the decision makers to turn the map in to an actual proposal. This is the biggest downside to this model, according to Haasnoot (Haasnoot et al., 2013).

Adaptive policy making handles the decision making aspect in such a way that it helps the decision makers in their search for an actual proposal. This is done through the steps that are specified within the method. The robustness of the plans, and the overview of changes and vulnerabilities, that adaptive policy making offers helps to make sure that a large amount of uncertainties can be taken into account. The method does, however, not offer ways to identify, what vulnerabilities might play a role, or how interventions should be prioritized. This means that method does not help to take the possible unknown uncertainties of the future in to account.

Taking a closer look at both of these methods shows the strengths on which DAPP tried to build. These are primarily the use of indicators and robustness within the method, to make sure that the plans that are developed with DAPP will be able to deal with long-term uncertainty. The risks that a combination of the two methods could bring forward is the possible lack of ways to turn pathways in to proposals, or difficulty whit taking future uncertainties in to account. These last two issues should be tackled when combining the two methods in DAPP. The next paragraph will therefore take a closer look at DAPP method and how it tries to avoid the weakness within its predecessors.

3. THE USE OF DAPP

Dapp has been developed by using the strengths and of the two previously mentioned approaches, while DAPP also tries to overcome the weakness that those methods bring with them. Has a focus on dealing with long time uncertainty over time by keeping the different proposals adaptable. While it also offers insight in how uncertainties could change over time, adaptation pathways, and monitoring systems with designated interventions to make sure that the favoured pathway is followed throughout the process. This paragraph will give in insight in how the DAPP method works to get a better insight in the possible uses of DAPP. This is done by taking a closer look at the different steps that are part of the DAPP method. Looking at the different steps separately will help to get a better insight in how DAPP could be used, while also, taking a closer look at the different elements within DAPP and how or when they should be used. The different steps, of DAPP, and their order can be found in figure 2. (Haasnoot et al., 2013).

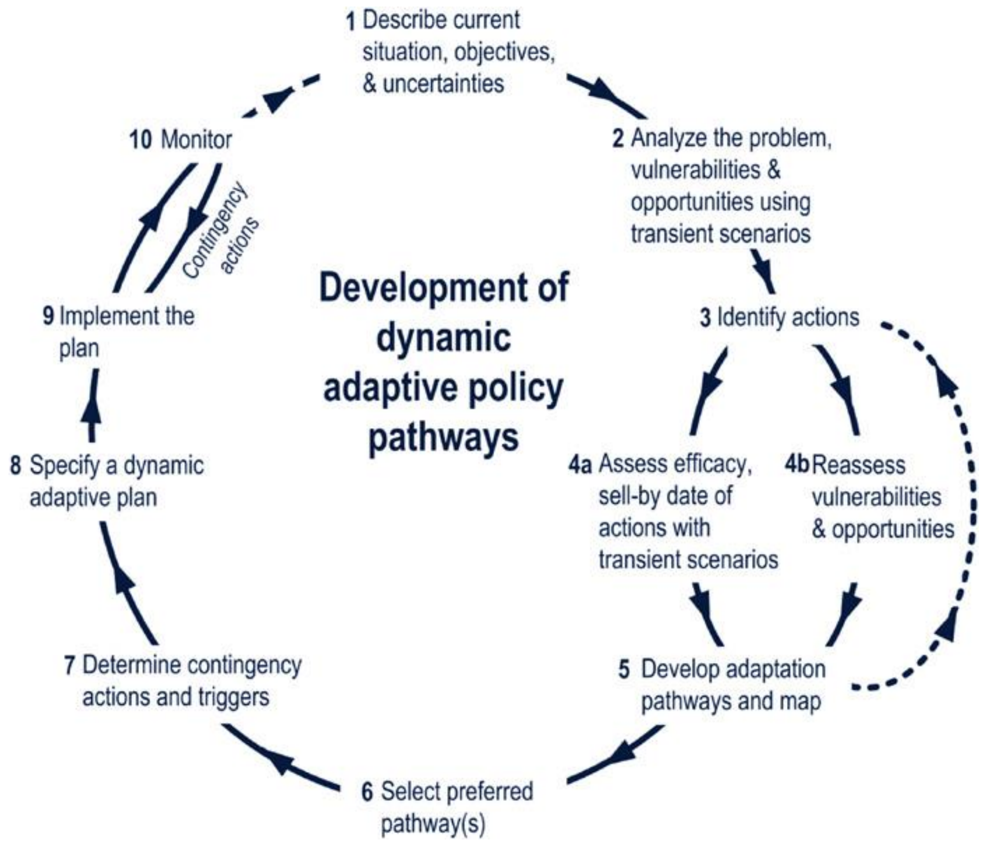

Figure 3: DAPP structure and steps (Haasnoot et al., 2013)

3.1 The DAPP process and steps

The first step in the DAPP method is all about assessment of the context in which the project will take place. This does not only include the assessment of current situation, but also a definition of the requirements that are desired to make the project a success. These requirements could be different elements, for example: which indicators will be used to evaluate the different pathways and when how is determined which actions take place at what time? The assessment of the context does also require a first overview of the largest uncertainties, at this moment or in the future of the project, that could affect the decision making process. (Kwakkel et al., 2010b).

The second step takes a deeper look at the outcomes of the first step by analysing the different problems. This is done by taking a closer look at expected future scenarios and comparing them with the present situation. Weather action is needed or not is determined by finding the gaps between future scenarios and the objectives that are stated in the first step. These gaps can be an indicator of problems, but they could also indicate the existence of new opportunities that should be seized.

The goal of the third step is to determine what the potential interventions are. This should in the end result in a wide range of interventions that could be used to reach the same or different goals within the project. These interventions can be shaping, mitigating, hedging, and capitalizing just like the actions from the adaptive policymaking method.

The scorecard from the adaptation pathways methods plays an important role in the fourth step. This score card helps to determine which actions will have to take place at what moment in time. This helps to figure out when the different actions will have to be prepared to make sure that the results are in place at the right time. The score has a validating function is well. It helps to identify the effectiveness, of the different interventions, to be able to make a final shifting after which only the effective interventions will be left.

The interventions from the forth step are used to research the different possible pathways in step five. The different combinations and the order of the different interventions will lead to collection of pathways that could be followed to achieve the final result, which is determined in the first step. Theses pathways together form the pathways map in which only the most reasonable pathways will have a place.

The most reasonable pathways are not necessarily the most favoured pathways. This is why the sixth step helps to uncover the favoured pathways. Which of the reasonable pathways are favoured or not can depend on a lot of different things like for example: the preferences of the different stakeholders. It would therefore be preferable to come up with several pathways that take diverse perspectives in to account. This should produce pathways that are not just robust from a spatial or technical perspective, but also from a social perspective (Offermans et al., 2011).

Finding the preferred pathways is not enough to make sure that they will be followed throughout the project, or that they will lead to the preferred final result. These pathways will have to be kept on track and they might need extra steering to deal with unexpected changes in the future. The seventh step will, therefore, prepare the pathways for these uncertainties. This is done by preparing actions the steer the process back in to the right direction, when something threatens to lead the process away from the favoured pathway. This could be a simple as not making definitive decisions for as long as possible, but it could also require more direct action like bringing interventions forward or delaying them to cope with unexpected threats.

This is where the eight step comes in. by developing a dynamic adaptive plan out of the first seven steps. Such a plan should determine what interventions should take place at this moment and what interventions could take place later. All of these interventions should, of course, fit within the favourable pathway that is determined in the sixth step.

The ninth step of the process is put in place to keep control over the dynamic adaptive pathways plan by setting up a monitoring system. This systems is activated once the first interventions are put in to place. The monitoring system will collect data to determine when, a trigger is activated and an action is required. Using this monitoring systems is seen as the tenth and final step of DAPP.

All of these steps together form the process of the DAPP. The method deals with uncertainties by analysing the context and problems within the context in to find the gaps between a future scenario and the desired future outcome of the project. Security is built in by finding, spatially, technically, and socially, robust pathways that should be followed to reach the favoured end result. A monitoring system with tipping points determines when action is required to deal with threats and uncertainties. These actions could be predetermined and part of the chosen pathway, but they could also be corrective actions that are needed to make sure that it stays possible to follow the chosen pathway. All of this together results in a model where the interventions will not have to change when the future turns out differently than expected. Uncertainty and unexpected future changes will only lead to speeding up or slowing down along the chosen pathway. Short term interventions can, therefore always take place without losing the possibility to connect them work towards the long term goals. (Klijn, Kreibisch, de Moel & Penning-Rowsell, 2013).

4. CRITIQUES AND IMPROVEMENTS ON DAPP

DAPP might seem to be the ideal method to tackle uncertainty within a project while maintain the possibility to implement short and long term proposals that all work together towards a long term goal. This is, however, not necessarily the case, because there are some critiques on DAPP as well. These critiques could give a good insight in to why DAPP might be useful in certain cases, or what the downsides to DAPP are. That is why this paragraph will take a closer look at the critiques on the DAPP method and the proposed improvements on DAPP.

4.1 Critiques on DAPP

One of the main focus points and strengths of the DAPP method could also be its weakness, according to Gersonius et al. (2015). This research paper show a further research in to tipping points and how the influence the ability to uncertainty of future changes in a proposal. This research has found that tipping points bring a danger with them when they are not implemented in the right way. Implementing these tipping points in the right way is not done by the model itself, but by the stakeholders that are involved. The tipping points are, therefore, dependant on the risks that the involved parties are willing to take or not. This could lead to tipping points that are to secure, which leads to a lot of unnecessary actions, or not secure enough, which will result in being able to reach predetermined final goal. The tipping points can therefore make or break a project that makes use of a method that is heavily dependent on the use of tipping points, like DAPP (Gersonius et al., 2015).

Another downside to the DAPP method has been discovered while researching the robust water infrastructure of London. This research has found that the lead up time before actions can be taken are taken in to account when DAPP was developed, however there is no implementation schedule included in the DAPP method that shows when actions should be prepared or how long the preparation of different actions could take (Huskova, Matrosov, Harou, Kasprzyk & Lambert, 2016).

The same research has also found that the DAPP method requires a very detailed model to be able to take all the different significant factors in to account. This means that the analysis of multiple scenarios would take up to much time. The models could be simplified to make them faster but that would lead to a less accurate end result. The users of the DAPP method should therefore be apprehensive of the simplifications, that are used when analysing the different scenarios (Zeff, Herman, Reed & Characklis, 2016; Jurgilevich, Räsänen, Groundstroem & Juhola, 2017).

Woodruff (2016) states that large scale projects have certain conditions that makes the DAPP method ideal to use. These are conditions like: a distinct goal long term, harmony between the different stakeholders, and sufficient assets. DAPP is for this reason almost exclusively used in larger scale case studies and not in projects on a smaller scale, in which the uncertainty approach becomes less practical.

4.2 Improvements on DAPP

Very few criticasters come with improvements on DEPP, apart from the simplification of the models to make the analysis of the different scenarios faster. This does, as is stated before, result in less accurate and reliable outcomes. The research in to the robust water infrastructure of London has shown that a implantation schedule would be needed to make sure that all the tipping points are active in time to be able to prepare the related required actions. The researches do, however, not come up with a way to implement this scheme (Huskova, Matrosov, Harou, Kasprzyk & Lambert, 2016).

Manocha & Babovic (2017) did come up with some imporovements on DAPP because they felt that use DAPP could lead to a waste of time or resources. This is mainly the case, according to them, when very resource intensive pathways are chosen by the stakeholders for some reason. Choosing these resource intensive pathways could be avoided by predetermining the minimum benefit that a pathway should have to avoid waste of resources of time. Setting a minimum gain level for pathways could in that case help to avoid illogical pathways that are not filtered out in the second and third step of the DAPP method.

DAPP & SOIL SUBSIDENCE

Subsidence is defined by the National Research Council (1991) as the sudden sinking or gradual downward settling of the ground's surface with little or no horizontal motion. This means that whether or not something is subsidence, is not defined by the pace or surface of the subsidence. Subsidence could therefore occur in many different forms and intensities. It can be caused by natural causes as well as by human interventions in nature. (National Research Council, 1991)

The largest natural causes for soil subsidence are: tectonic movement and sediment compaction. Subsidence caused by human interventions come in different forms and intensities. Extraction of oil, coal, gas, salt and groundwater can lead to subsidence in the deeper soil layers.

Shallow soil layers can be compressed by loading them with buildings, or as the result of water drainage and a lack of oxygen for organic soils. This compression would in most cases result in a subsidence of 0 to 20 meters. This form of subsidence is found in urbanized delta regions all around the globe. These areas are often full of peatlands and therefore prone to subsidence. (Deltares 2013)

This last form of subsidence will be the focus of this research project, since it is problem in all the large delta cities around the globe. Most of these cities are growing fast and they will continue to do so over the next decades. This means that the soil subsidence in these areas could have huge effects on human life all over the world (Meyer & Nijhuis, 2013).

The management of the water system is one of the main causes of soil subsidence in deltas. A good management of the water system could, however, also play a large role in tackling soil subsidence and its consequences. That is why the use of DAPP could be very useful within this project. DAPP is developed as a method for large scale water management projects. The water management aspect of DAPP and soil subsidence could therefore come together within this project. This is, however, not the only reason to use DAPP within a soil subsidence project. The research into soil subsidence is growing, but there is still of uncertainty when it comes to predicting and countering soil subsidence. Following the DAPP method could offer the opportunity to start with the first interventions right now, while being able to adjust them to future changes and uncertainty.

This doesn't mean that DAPP could always be used when it comes to tackling soil subsidence. Many projects that focus on soil subsidence are looked at from the smaller scale, because soil subsidence is very often a local problem. This means that the projects often lack: a distinct goal long term, harmony between the different stakeholders, and sufficient assets. Using the DAPP method would therefore be inadvisable according to Woodruff (2016) .

The main research, where this paper is a part of, tries to find a new regional approach to soil subsidence that will try to tackle soil subsidence trough, a regional strategy instead of, smaller scale unrelated and incoherent soil subsidence solutions. This means that DAPP could play a role in the development of the underlying regional strategy on soil subsidence by, relating the different smaller scale projects and by finding the right timing and configurations for different interventions through the use of guiding pathways.

CONCLUSIONS

SUMMARY OF MOST IMPORTANT FINDINGS

DAPP is developed out of two planning methods that are commonly used in water management as well is in other regional strategies. These most important element of these methods are their tipping points and indicators that help to determine when action is required to keep a long term strategy on track. Both of these methods are, therefore, very useful when it comes to planning with uncertainty. DAPP has been developed to continue on strength of the methods while trying to eliminate the weakness like: problems with translating pathway maps in to an actual proposal, or difficulties with taking unknown future uncertainties into account. Using DAPP for a research project would therefore offer more certainty and possibilities, than using its predecessors. This is mostly achieved, by DAPP, through the use of ten clear defined steps that guide the user through the process. The first three steps will help to determine the underlying conditions by: describing the current situation, analysing the problems and uncertainties, and coming up with actions to tackle to problems or seize opportunities that might occur along the way. The next three steps are about choosing the right pathways for the project. It is important to look at the pathways from different perspectives to make sure that the pathways are resilient from social, technical and spatial perspectives.   The final steps are implement the first actions while also implementing a monitoring systems for the future to make sure that: chosen pathways will be followed, and future uncertainties can be integrated. This Helps DAPP to overcome the problems within its predecessors, since the pathways are formed into definite plan instead of optional routes, while the monitoring systems allows the plan to respond to future changes and uncertainties.

The steps within DAPP makes it a resource intensive method that requires harmony between stakeholders and a clear defined goal. This can often be found in larger scale projects, while smaller scale projects lack these resources. DAPP could therefore be used in larger scale soil subsidence projects, especially if they focus on the relation with the water systems and water management aspects of soil subsidence. Soil subsidence projects that focus on a smaller scale would, however, be better of using less complicated methods like the adaptation pathways method. This would still be able to show when action is required without the need of forming a underlying strategy that requires more resources and a the integration of projects within the larger scale strategy.

Using DAPP on larger scale soil subsidence can definitely help in developing a strategy. There are, however, still some problems and downsides to the method that should be taken in to account. The user should be aware of simplifications in the models that are used to analyse the different scenarios. These simplifications are often required to make sure that the analysis take up to much time.

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