Surmounting the polder

MSc Thesis

Rafael Gridelli

Creating land above sea by reversing subsidence processes in the Dutch peat polder
by implementing the concept of a growing terp

Master Thesis report
Rafael Gridelli - 5869749

Colophon

Author : Rafael Gridelli

Mentors:
Dr. ir. I. Bobbink
Dr. Arch. L. Iuorio

The Delegate of Examiner:
Prof. dr. ir. arch. Sevil Sarıyıldız

October, 2024

Landscape Architecture
Flowscapes Studio - Circular Water Stories Lab Faculty of Architecture and Built Environment

Delft University of Technology Delft, The Netherlands

AI free

Circular Water Stories

LANDSCAPE ARCHITECTURE

TU Delft Delft University of Technology Faculty of Architecture and the Built Environment

Abstract

This master thesis aims to turn the tide regarding current water management in the peat polder. To reverse a century old habitude to drain land for agricultural purposes, causing subsiding land below sea level. Climate is changing with increasing temperatures, higher peak precipitation in winter, draught in summer and rising sea level. Peat polders in the Western part of the Netherlands are subsiding due peat oxidation as water levels are kept low. Polders have subsided below sea level and need to be pumped out as an annual surplus of precipitation causes the polder to fill up. In coastal zones pressure from the sea causes salt water to seep to the surface. These problems in combination with climate change, questions a livable future in the polder.
The primary objective of this research is to critically examine and propose alternative water management practices of polder ecosystems. By examining methods for tolerating presence of water within our living environment. The terp proves to be an interesting way of living in harmony with water of the past. Elements of the terp such as fluctuating water levels, following soil characteristics, adaptable housing, and use of waste as building material, provide solutions for an alternative water system in the polder. Implementation of these elements are illustrated by an animation, showing a variety of possibilities to grow out of the polder. A zoom in on a small portion of the Noord-Kethel polder is used as a test ground for a masterplan to show how conceptual ideas from the animation would be implemented in practice.
In the Design a new water system is implemented to allow bigger fluctuation, decreasing peat oxidation. Then, the concept of the terp is implemented into a design which consist of two phases. The first phase shows an increase of one meter in water level resulting in the adaptations to landscape elements. The second phase of the design is a continuation of the first, as a next meter of water level increase is implemented. In the second phase, current polder changes from a green open landscape to a blue open landscape with meandering green strings, creating a resilient landscape, ready for future changes. The design implements a change in mentality, in which inhabitants need to be willing to adapt.

The Design is an addition to the 'adapt' scenario of the Delta Program. By proposing a graduate change to current polder landscape, resilient land above sea level is created, providing new forms of housing, cultivation, and nature within the Dutch Delta. The approach is an anticipative way of interacting with water, similar to the Dutch approach in the Golden Age. The change of mentality in current polder landscape towards an adaptive landscape is a challenge that needs more research to accomplish the design.

Fascination

Growing up in the city center of Amsterdam, resulted in a disconnection with the rural world. Weekend trips and holidays made my appreciation for the world outside of the city grow. The disconnection between nature and the city has always be apparent for me. Why is the city so artificial and why are natural processes limited. Can they be integrated?
My fascination for landscape architecture started one year before going to university. Cycling through the city of Amsterdam, I discovered the city does not solely consist of beautiful places. I wanted to discover why such places where generally classified as ugly and what a person could do to improve these areas. From then, I decided to study the discipline of landscape architecture.

Motivation

Growing up in the Dutch delta, water has always been nearby, from the canals of Amsterdam and Delft to the Rijn along Wageningen. I have always lived close to it. Water is the most important element of life. Without, humans would not exist. Since civilization started, water has become more than a source of life. It has religious purposes, facilitates economic activities, creates boundaries, and influences politics. Human interaction with water has become a fascination mine. Therefore, I want to express this interaction through landscape architecture design and have chosen the Circular Water Stories lab.

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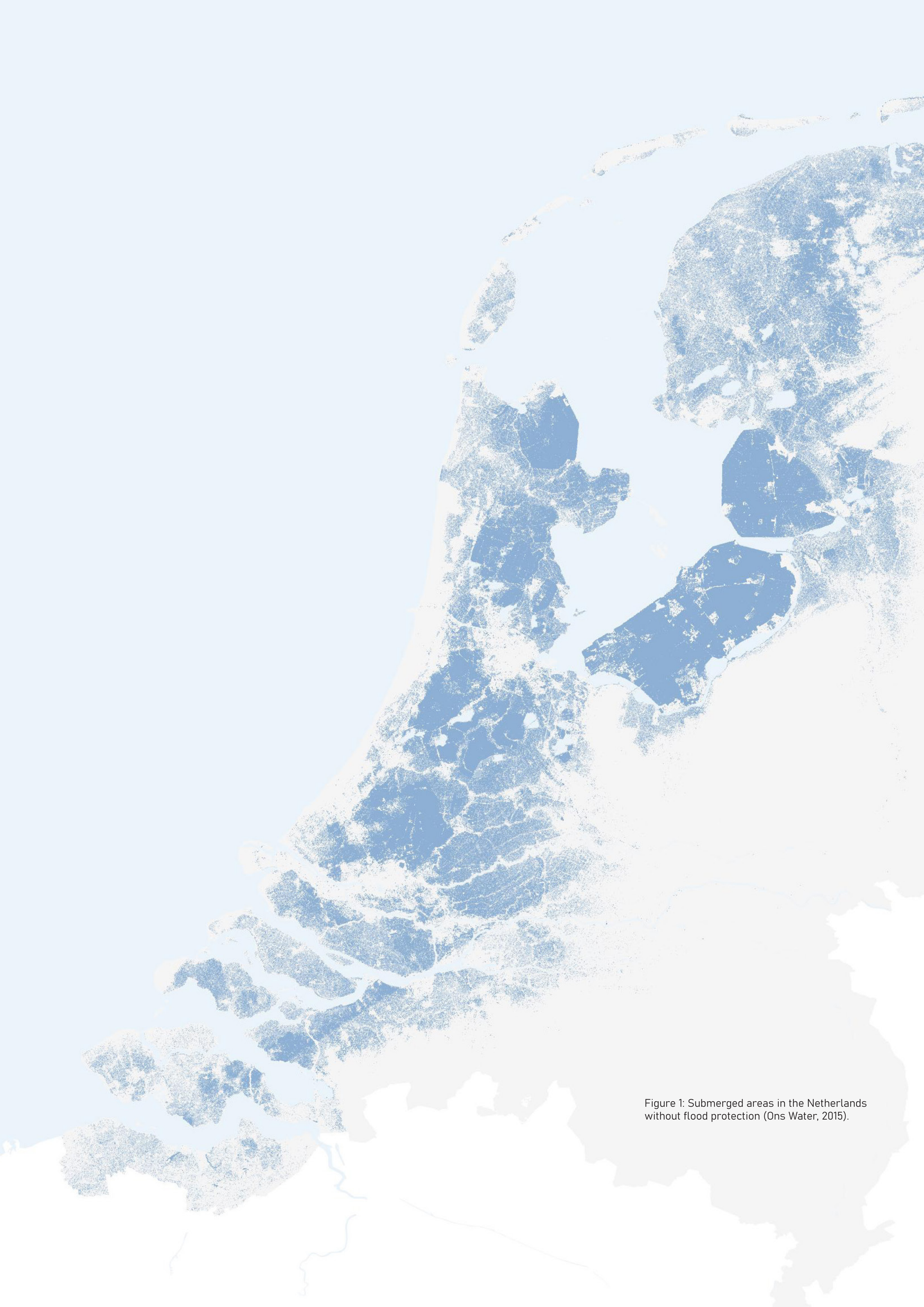


Figure 1: Submerged areas in the Netherlands without flood protection (Ons Water, 2015).

THE NETHERLANDS
Sea level, density and housing shortage

The Netherlands is known for its low-lying geography. Without water protections, 60% of the Netherlands would regularly flood (Ons Water, 2015). Over 4 centuries, the Dutch have lived in areas below sea level,with the first reclamation dating from 1532 (Oneindig Noord-Holland, 2012). The classic Dutch windmills were responsible for discharging all surplus precipitation that fell. Since then, the Dutch polder continued to evolve as peat areas sank below sea level. The polder has become a complex connected system ensuring stable water levels regulated on the centimeter. Living on land behind dikes below sea level has placed inhabitants of the Netherlands in a vulnerable position, as continuous monitoring of water protection measures is essential to ensure the safety of the Netherlands. With changing climate conditions, this pressure increases, putting the safety of the Netherlands at risk. For a long time, the task of the Netherlands has been to protect its inhabitants from water. In the future this will become an even bigger topic and alternative solutions must be found. Especially with most of the Dutch population living in coastal zones, below NAP (Allecijfers, 2021) and being in the top 20 of world's most dense countries (theGlobalEconomy.com, n.d.), space is therefore limited as every square meter is classified. All new interventions will therefore interact with existing practices.

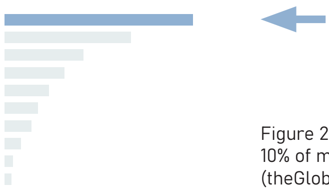


Figure 2: The Netherlands is in the top 10% of most dense countries of the world (theGlobalEconomy.com, 2023)

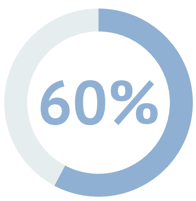


Figure 3: Percentage of the Netherlands that would be regularly flooded without water protection (Ministerie van Infrastructuur en Milieu, 2015)

CLIMATE CHANGE
Temperature, precipitation, draught and sea level rise

Climate has never been constant as warm and cold periods alternated. Since the last ice age, the Weichselian epoch, current warmer geological period the Holocene started. The last 2000 years climate has become warmer, but since the industrial revolution temperature started to rise quicker than ever (IPCC, 2021). The KNMI released an updated climate report with 4 scenarios elaborating on a quicker changing climate.

Temperature
The Dutch climate has changed as temperature has increased over 2°C since the start of measurements in 1901 (KNMI, 2023). This is almost twice as much as the increase in global average temperature since the pre-industrial period (1850-1900); which is 1.2°C (2022). In winter, this is partly caused by warmer wind from the west. Due to increasing solar radiation, decreasing cloud cover and decreasing air pollution, spring and summer warm up more. Half of the temperature increase in the Netherlands since the beginning of the last century took place in the past 30 years. According to all KNMI'23 climate scenarios, temperatures are still rising in the Netherlands. The increase of temperature will be greatest around 2050 as well as around 2100. (KNMI, 2023).

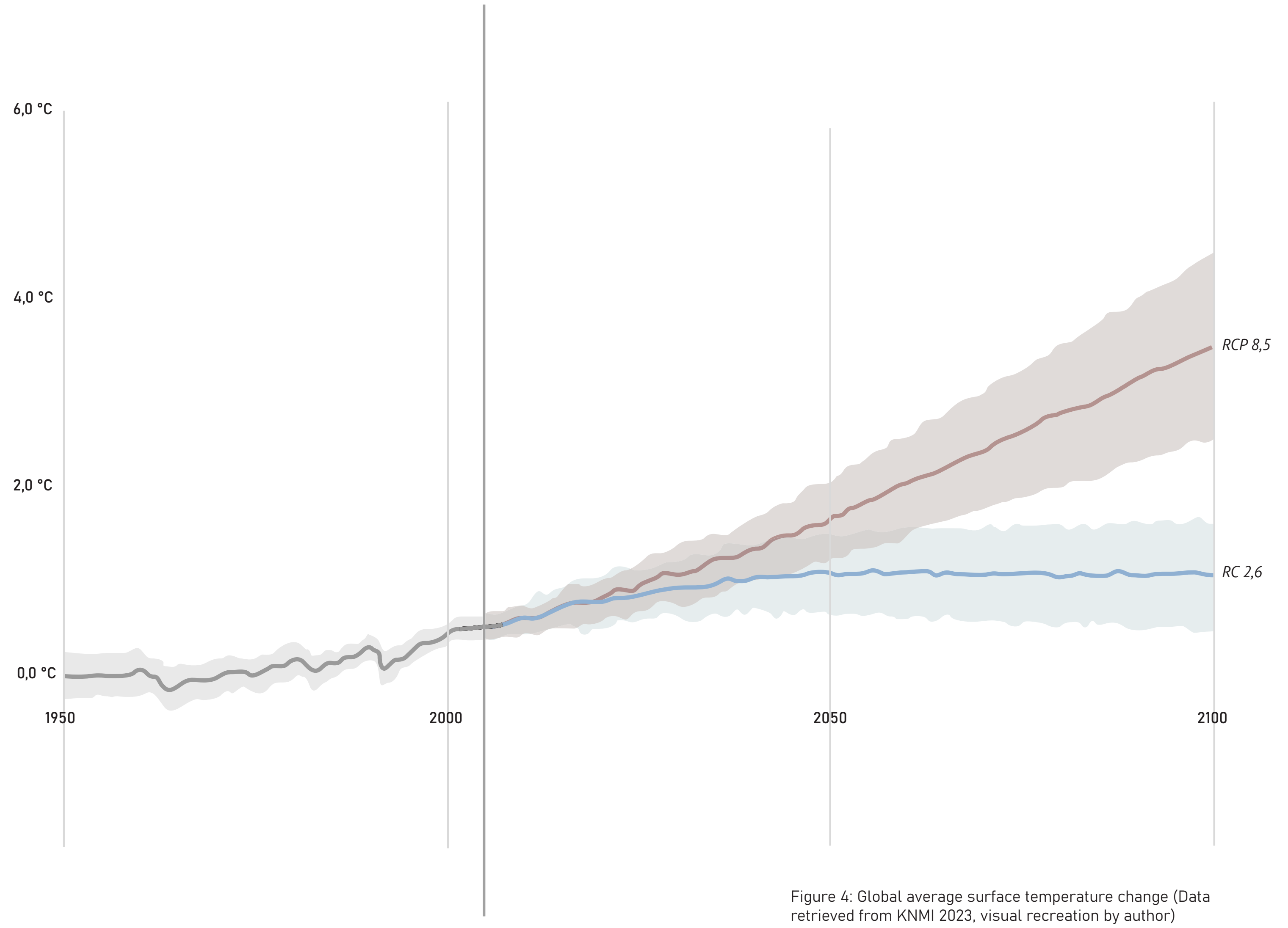


Figure 4: Global average surface temperature change (Data retrieved from KNMI 2023, visual recreation by author)

Precipitation
Since 1906, annual precipitation in the Netherlands has increased by approximately 20%. All seasons have become wetter, especially winter. Current precipitation in winter is 204mm (Homan, 2023), with KNMI's Hn scenario precipitation in winter would increase by 24% (Bessembinder et al, 2023). In summer, current precipitation is 84mm (Huiskamp, 2023), with KNMI's Hn scenario precipitation would decrease by 12% (Bessembinder et al, 2023). In all four climate scenarios, precipitation continues to increase in winter. Precipitation increases in spring and autumn, but less compared to winter. In three of the four climate scenarios, summer precipitation decreases. This decrease is caused by dry, continental air is being supplied from the east more often. The fact that wind blows more often from the east has two causes: changes in sea water temperatures west of Ireland, and strong warming in southern Europe. The number of light summer showers will decrease in the future. The number of heavy showers with high rainfall increases. There is a shift from light to more intense showers (Bessembinder et al, 2023).

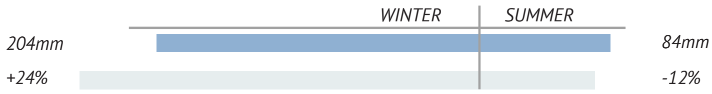


Figure 5: precipitation prognosis 2100 (Data retreived from KNMI 2023, visual recreation by author)

Draught
Drought occurs when there is less precipitation than normal or when more water evaporates than usual. This will result in a water shortage with problems for safety (drying/weakening flood defenses), agriculture, inland shipping, living environment, water quality and nature (KNMI, 2023). Long-term droughts in particular, cause such effects, such as in 2018, 2019, 2020 and 2022 (KNMI, 2023).
In the Netherlands, the risk of (extreme) drought is increasing, especially at higher emission scenario. In such a dry scenario, an average summer in the future will be about as dry as an extremely dry summer now.

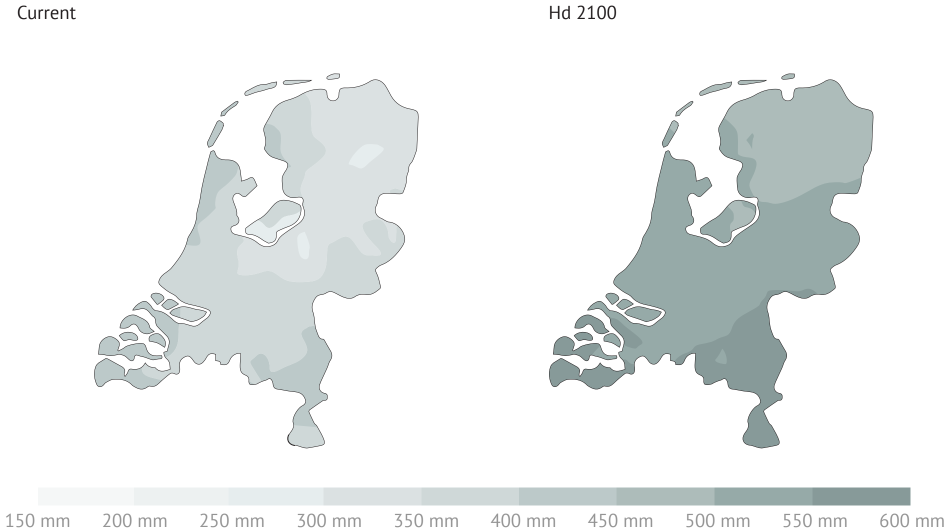


Figure 6: Maximum precipitation shortage (Data retreived from KNMI 2023, visual recreation by author)

Sea level rise
Since the beginning of the Christian calendar, global sea levels have hardly changed until they began to rise during the 19th century. Since 1900, the rise has been approximately 20 cm (1.7 mm/year) (Bessembinder et al, 2023). There has been an acceleration in the last 50 years: approximately 2.3 mm/year in the period 1971-2018, and 3.7 mm/year in the period 2006-2018. Sea level rise is still accelerating. Since 1890, the sea level has risen compared to the Normaal Amsterdam Peil (NAP) by 25 cm (KNMI, 2023). Current prognosis by the KNMI is a sea level rise of 80 centimeters in 2100. In the high emission scenario, sea level would rise 2,5 meters (Bessembinder et al, 2023).

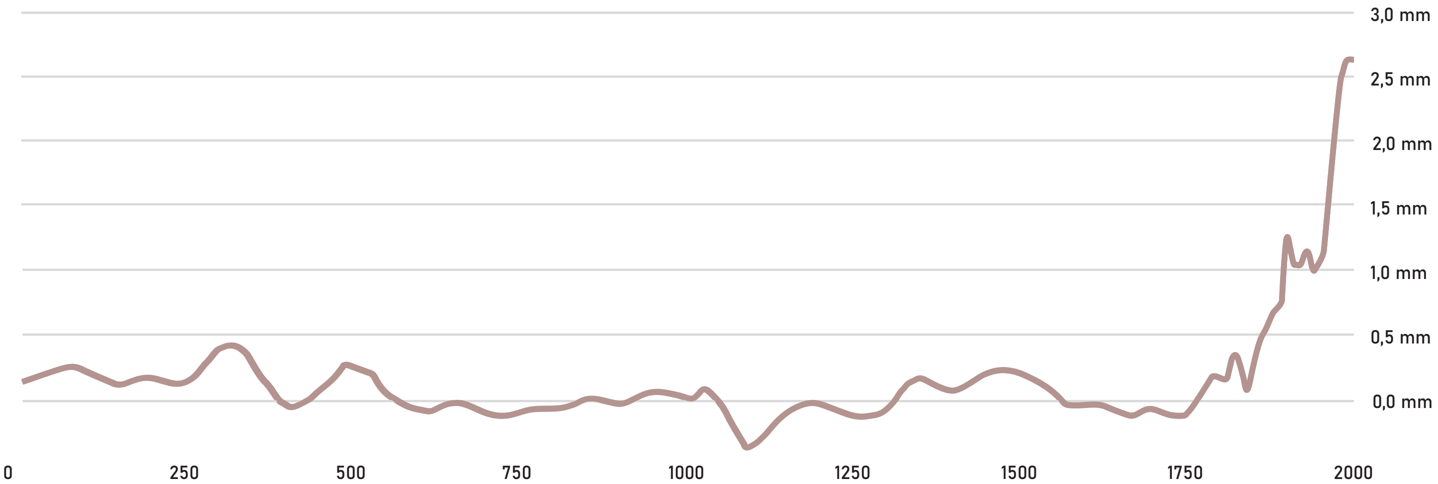


Figure 7: Sea level rise European coast (Data retreived from KNMI 2023, visual recreation by author)

Conclusion
Climate is changing faster than predicted, according to the KNMI'23 report, and has an impact on temperature, precipitation, drought, and sea level rise among other factors. This change will impact natural processes affecting the landscape and life on the planet Earth.
Low lying peat areas in the Netherlands will experience disadvantages from changing climate. With rising temperatures and increased drought in summer, evapotranspiration increases, resulting in lower water levels that expose more peat. This peat oxidizes, leading to greater soil subsidence. In winter, more precipitation is expected putting pressure on pumping stations risking floods in the polder. A rising sea level results in more pressure in the polder leading to an increase of (salt) groundwater seepage. Saltwater intrusion is harmful for agriculture as crop growth is compromised by presence of saltwater. The overall impact of climate change will influence or aggravate certain processes which will be elaborated on in the next chapter.

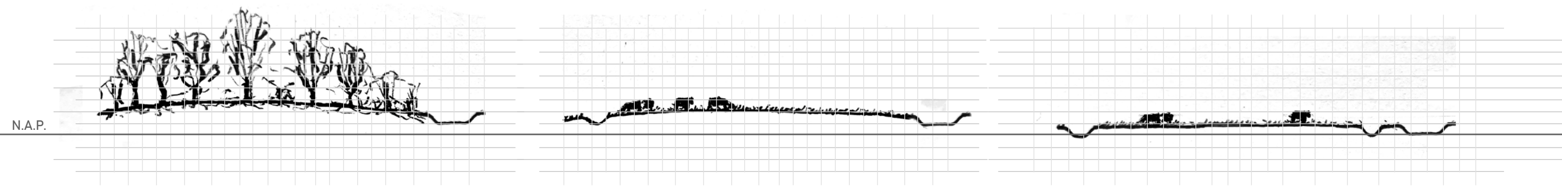
THE POLDER
Low lying land

Figure 8: Schieveen polder

LOW LYING LAND
Oxidatoin, subsidence and seepage in the polder

The Dutch have the saying: God created the world; the Dutch created the Netherlands. Since the Middle Ages, the Dutch have found a way to cope with water in swampy areas. An artificial system, draining water from land by controlling water levels has led to the evolution of the polder. The peat landscape, on which the polder developed, evolved during the Subboreal, about 5000 years ago. Shallow water behind the sea walls of Holland gradually became sweet, and swampy woodlands began to grow in the previously deposited sea clay (Polderatlas, 2009). As water levels in these lagoons rose, these woodlands died off, giving way to the growth of peat moss on their remains. This peat cushion increased in height and ultimately rose so far above water level that it was fed, only by rainwater.

Figure 9: Development of peat polder



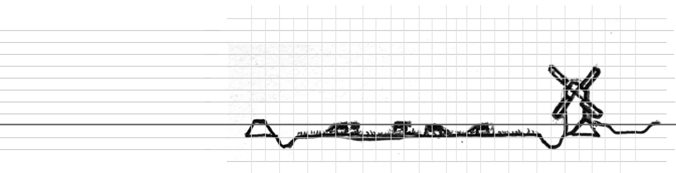
Natural phase, no interventions

Defensive phase: the natural landscape rules over the cultural

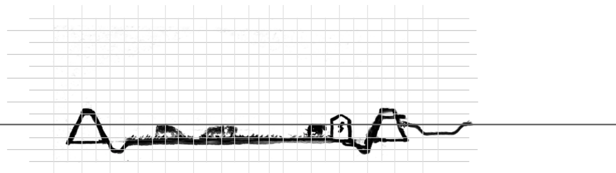
Adaptive phase: working with the natural system

Until 1000 AD The Dutch had a *natural approach* to the landscape, nature was ruling over culture (Hooimeijer, 2011). The first dams, dikes and drainage ditches mark the genesis of the polder land. That probably happened gradually, and not everywhere at the same time, because the interventions for water management were always adaptations to locally changing circumstances (Polderatlas). In this way the various building blocks of the polder system, and later the polder-boezem system, were slowly created. Trenches and drainage ditches carried off surplus rainwater in cases of rising ground water, and the land subsided more quickly. The construction of ring dikes to protect land against outside water, was perhaps the most decisive step because it necessarily meant that efforts had to be made to regulate the drainage of water inside the dikes, via a boezem system, to the outside water. It was the start of the Fine Dutch Tradition.

This relation with nature ended by the invention of the windmill, by draining water from lower areas. Water could be managed as large bodies of water could be moved. Slowly the drainage systems within the dike rings were coordinated with one another to become one water management system. At the same time, the system of dikes and dams created a framework in which the land that had been lost could be recovered. During the 16th century a start was made for this, creating the first lake-bed polders. The *defensive* positions of the Dutch became an *Anticipative* position. Inhabitants behind the dike had responsibility to keep the land safe and succeeded. This success was translated to the dominant position the Dutch had in the Golden Age.



Offensive phase: manipulating land



Abolute control

With the industrial revolution the *anticipative* approach of the Dutch changed to an *offensive* phase. With the steam engine more processes were systemized, allowing stricter control. With this sense of control the relation between geology and site got lost as the feeling of control grew. Peat areas continued subsiding below sea level. By creating lake-bed polders, areas emerged up to six meters below NAP, with the Zuidplaspolder as the lowest at -6,76m below NAP (Holland – Land of water n.d.).

From 1890 to the end of the twentieth century the Dutch gained *absolute* control. After the second world war, the Dutch feeling of Maakbaarheid (Humans can make everything possible) excelled. With technical innovation and progress in civil engineering, larger protective structures, like the Delta works could be created, protecting the Dutch against water. Parts of the former Zuiderzee, now IJselmeer were drained creating Flevoland. The Fine Dutch tradition of mitigating between land and water got lost.

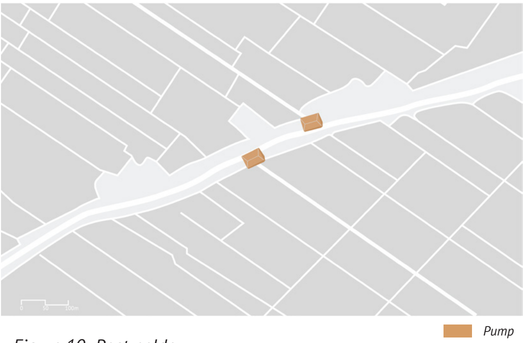


Figure 10: Peat polder

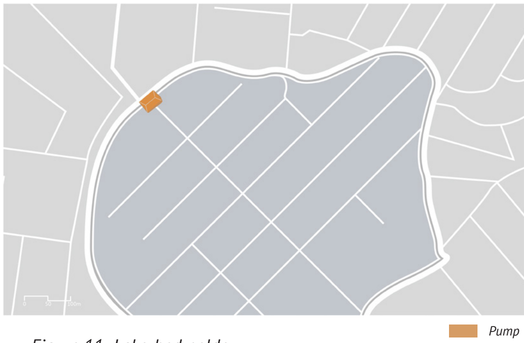


Figure 11: Lake-bed polder

The polder has become a complex system in which water levels are precisely controlled by waterboards. Low lying peat polder must be continuously drained as the Netherlands has a surplus of annual precipitation and these polders lie below sea level. In coastal areas, groundwater seepage can become salt, as low-lying polders create a high supply of groundwater. In this way, salt water from the sea is sucked into the system, harming vegetation. This salinization process can make a polder less productive and in the long-term useless for agricultural purposes.

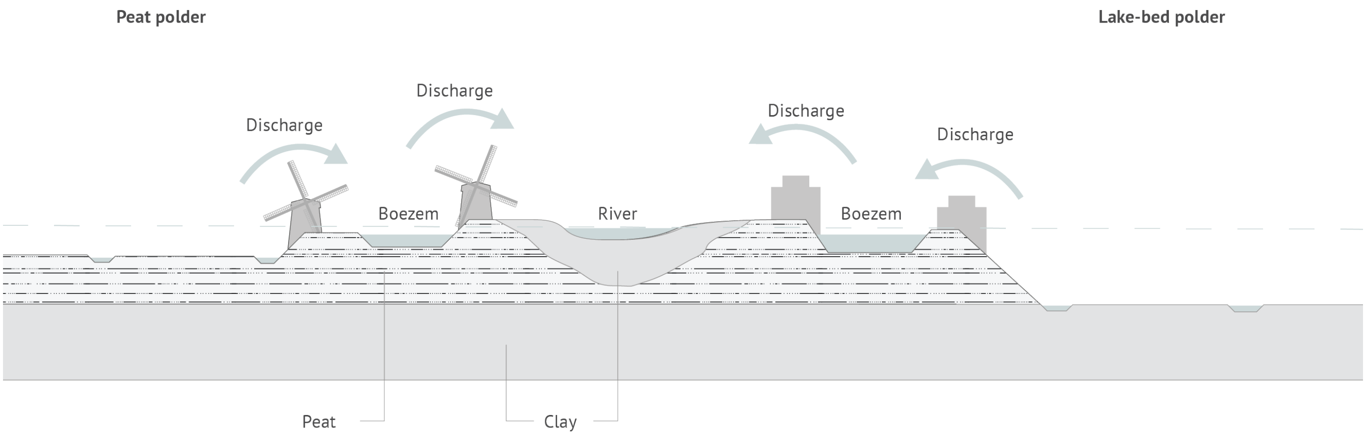


Figure 12: Functioning of the polder boezem discharge system

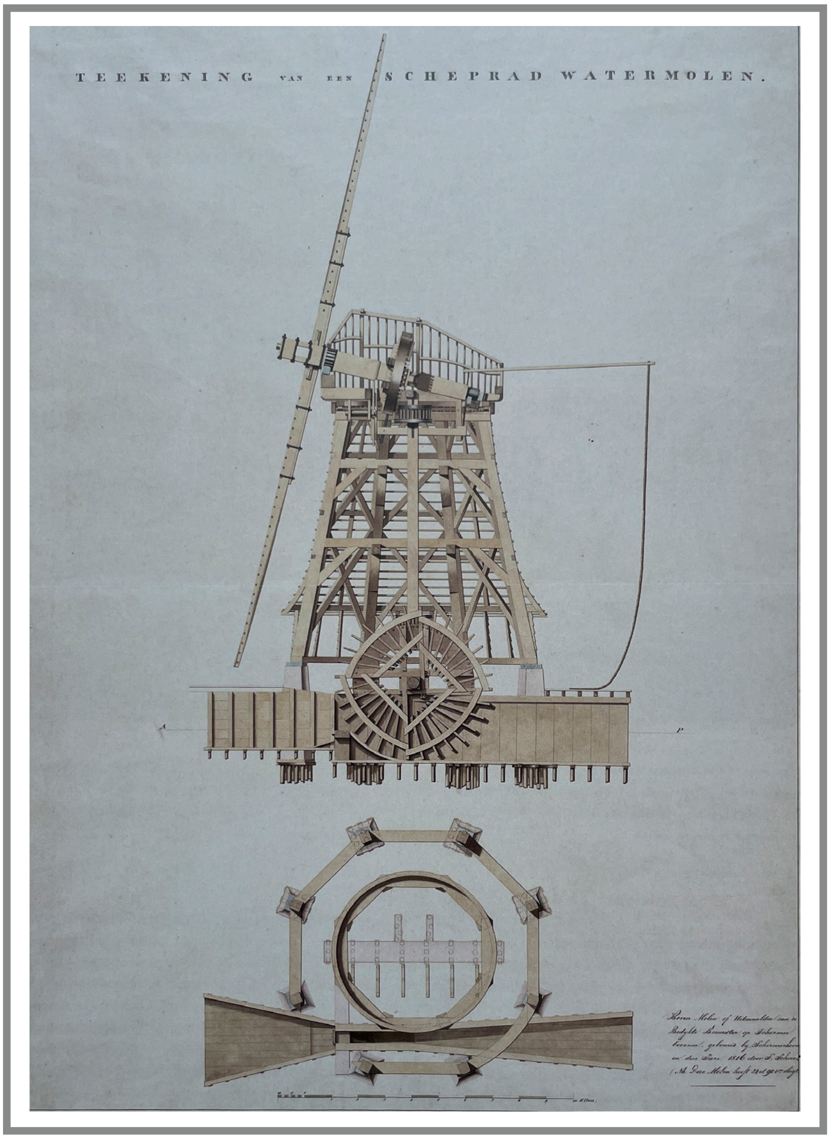


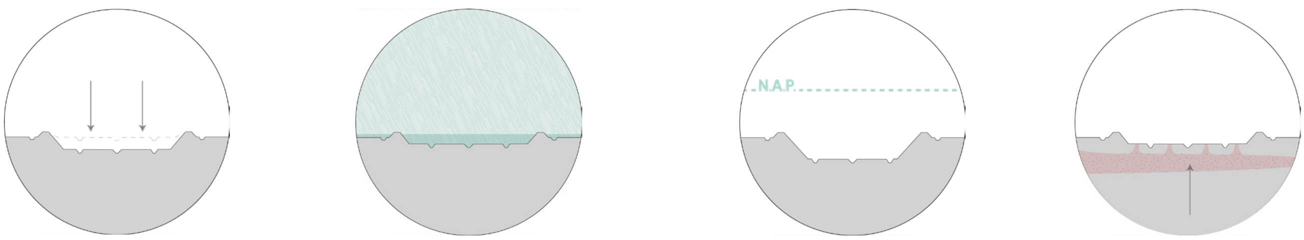
Figure 13: Darwing of a paddle wheel windmill, North Holland Archive, Collection Technical Drawings)

PROBLEMS IN THE POLDER
Oxidatoin, subsidence and seepage in the polder

Since the invention of the windmill, the Dutch have started to work against the natural process of water flowing from high to low. It resulted in a complex and intertwined system with strict regulations per polder to secure a fixed water level. The technical approach has led to an artificial water system that cannot deal with the increase of rainfall and drought. With changing climate conditions, even more pressure is put on this complex polder system. Energy consumption of such pumping stations will increase as sea level and peak precipitation increases, to pump water out of low-lying areas. Higher water levels provide bigger pressure on pumping stations as more energy is needed to discharge precipitation surplus. The Dutch have become dependent on this fixed drainage system as almost 50% of the Dutch population lives in these low-lying areas (AlleCijfers.nl, n.d.).

Example:
The IJmuiden Gemaal is responsible for draining a large part of Western Holland, its energy consumption is comparable with the annual energy consumption of 3.000 households (Van Weissenburch, 2005), which will continue to grow as the climate continues to change.

Figure 14: problems of the peat polder



Soil subsidence due to peat oxidation

a surplus of anual precipitation causes the polder to fill up

Peat polders are often located below sea level

Polders in coastal areas suffer from salt water seepage, harming agricultural vegetation

Compared to the lakebed polder the peat polder is in higher need of radical change. With poorer soil land is less productive than the more fertile clay soil in the lakebed polder. Increasing drought in summer causes a decrease in groundwater, uncovering a layer of peat in the polder. As peat is exposed to oxygen, a degradation process is started, expelling emissions like CO_2, CH^4 and N_2O. Next to increased emissions, degradation of peat strengthens soil subsidence in the polder.
Water shortage will occur more often, deteriorating water conditions. Rising temperatures provide higher evaporation. This in combination with higher summer drought, water shortage can occur in the polder uncovering a larger layer of peat, having an increased effect on subsiding soil.
In coastal areas, pressure is put on the saltwater bubble as the sea level rises. This results in saltwater seeping through soil in low lying polders providing brackish conditions in which agricultural plants cannot survive.

PROBLEM STATEMENT
Current water management

Roughly half of the Netherlands lies below sea level. The country has a high population density and limited space, especially in combination with an increasing demand for space per inhabitant. With rapidly changing climate conditions, the increase of temperature, wetter peak precipitation, longer periods of drought in summer and rising sea water level, the water management in the Netherlands is under high pressure. The lower polders face more water pressure from the sea and rivers, rain, and seepage. In the long term, current water management cannot guarantee future living in the lowlands. Therefore, improvements of current measures need to be taken. Rising dikes, improving discharge capacity of pumping stations and high-tech solutions against saltwater intrusion will have an impact on the landscape. The Dutch face a dystopic future in which they will have to live behind walls to protect belongings and valuable land.

Figure 15: Increasing sea level and subsiding soil threatening the polder

RESEARCH ASSIGNMENT
A new concept for the polder

Objective
The primary objective of this research is to critically examine and propose alternative water management practices of polder ecosystems. By examining methods for adapting to the presence of water in our living environment, a more resilient polder can be ensured that is capable of responding to future changes.

Figure 16: Concept of living with water, tolerating water in our living environment

RESEARCH ON FUTURE STRATEGIES

Attempts regarding an alternative future of the polder

Since 1990 the Dutch have total control over the landscape and got detached from the Fine Dutch Tradition. The Netherlands is stuck in a complex system with little to no flexibility. The problem statement questions continuation of current water management in the polder. With climate change and persistent problems in the polder, a shift in paradigm has started towards an increasing adaptive position. Different authorities have started looking for solutions regarding the future of the polder. Different solutions have been examined from small interventions to large scale transformation of the country.
From small to big:
Closing off salter water wells to prevent saltwater intrusion in coastal areas: Using hardening fluids or bio-sealing close off soil layers in which salt water arises. Field research from Deltares (Louw et al., 2012), proved it not to be promising.
Heightening dikes providing more safety against floods: The simplest solution to a growing problem, continuing what has been done for the past few centuries. Despite providing more safety, the core problem is postponed as problems aggravate over time.
Measures against peat soil subsidence: The National government organ 'Planbureau voor de leefomgeving" have concluded billions of euros are needed to renovate existing buildings in peat areas. Technical measures as underwater drainage can help reduce soil subsidence. On the larger scale, current way of cattle farming is questioned, and benefits of aquatic farming are explored.

Visions for the future of the Dutch metropolitan area are being research by the professional world. Magazine *De Blauwe Kamer* took up the gauntlet and presented the professional world's view of whether the Netherlands as we know can be maintained. Alongside future scenarios from Deltares, the WUR and studies from the Ministry of the Interior, led to a picture of a capricious and very complex task. Mark Hendriks reduced the harvest of *De Blauwe Kamer* to four strategies: attackers, land consolidators, radical poets and doomsayers.
Deltares published Four future strategies for the Dutch delta in 2120 Deltares, 2022), created by researchers, urban planners, landscape architects and engineers.

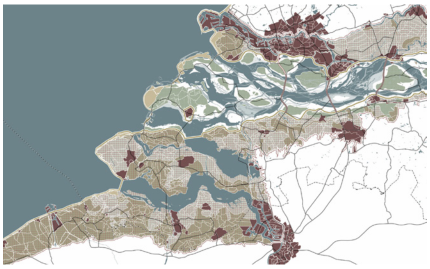


Figure 15: Project Zeelandia.

Zeelandia from Studio Hartzema, Feddes-Olthof and Witteveen & Bos
Zeelandia proposes a new symbiosis between land and sea. Housing, nature, ecology, agriculture, aquaculture, energy and other forms of land use find space in the mighty landscape of the Southwestern delta. The team sees the area as an ideal laboratory for this. Three different water scenarios were examined with a sea level rise of 3 meters and the implications for spatial planning were calculated. The Zeewaart scenario creates a large lake off the coast of Zeeland that protects the land and also helps generate energy. A Superdelta scenario was also designed in which space is given to water and the sea can penetrate our country up to the German border.

Figure 16: Project Rotterdam Sponge City.

Rotterdam as Sponge city from Urbanisten, Lola, Royal Haskoning DHV
In this design, Rotterdam becomes a sponge city with its own freshwater supply as the Maas becomes a fresh inland lake. The collected rainwater can be buffered locally in the city. This means that the city can provide for its own water needs. The port will be raised in the future, entirely in line with existing tradition, to keep the economic engine running. Every thirty years, a plot will be raised and redeveloped in balance with nature.

Figure 17: Project Midden-Delfland as National Productive National Park.

Midden-Delfland as National Productive National Park from Zus, Flux en Sweco
This team envisions Delfland as a National Productive Park. Midden-Delfland must become a green lung and a sponge for the liveability of the surrounding cities. This design assumes a simplified water system with fewer dikes, pumps and locks, with opportunities for increasing biodiversity, supplying raw materials such as wood and food and offers a solution against flooding, soil subsidence and the threat of salinization. The urban fringes of Rotterdam and Delft will form a high urban framework for Midden-Delfland and remain within this boundary to protect the area as a green lung.

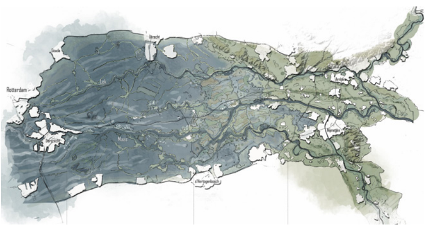


Figure 18: Project River Area, the Waal: Breaktrough!

River area, the Waal: Breakthrough!
The starting point of the team of the River Corridor Waal is an extreme scenario. They state that in the long term our water system with dikes and Delta Works will not work. Eventually the inevitable system crash will occur: the river system will return to its natural flow in an open route between hinterland and sea. The only thing we can do is to guide this 'crash', by already focusing on a semi-open system and to manage this disaster-in-slow-motion. The design includes evacuation scenarios, retreat strategies and ways of reconstruction in which we learn to live again with the seasons and the dynamics of the natural system, for example on sandy islands in seasonal houses.

Project information retrieved from Deltares (Deltares, 2022).

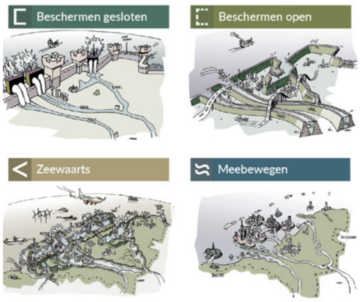


Figure 19: Deltares adaptation strategies

Delateres researched strategies for adaptation to high and accelerated sea level rise (Haasnoot et al., 2019), 4 scenarios were distilled: protection-closed: protecting the coast from floods and erosion with hard or soft measures such as water defenses, sand nourishment or wetlands. River arms will be closed off (with dams).
Protection-open: the same as Protection-closed, but rivers will continue to have open connections to the sea;
Seaward: the creation of new, higher and seaward land to protect the delta from the consequences of flooding;
Flexibility: the reduction of vulnerability to the effects of higher sea level rise by means of water- or salt-tolerant land use (such as floating buildings and infrastructure on piles), raising, spatial planning and/or relocation.

The National Delta program is currently investigating sea level rise in the Netherlands. Research will be published in 2026, but interim balance encourages continuation of current strategies for the short term and shows three main strategies for the long term:
Close river mouths and store river water in the South-Western Delta or discharge it through pumps.
River water is stored in a large lake off the coast, which also reduces salinization.
No more raising of dikes and adapting life to high water and salinization.

Figure 19: The National Delta Program adaptation strategies

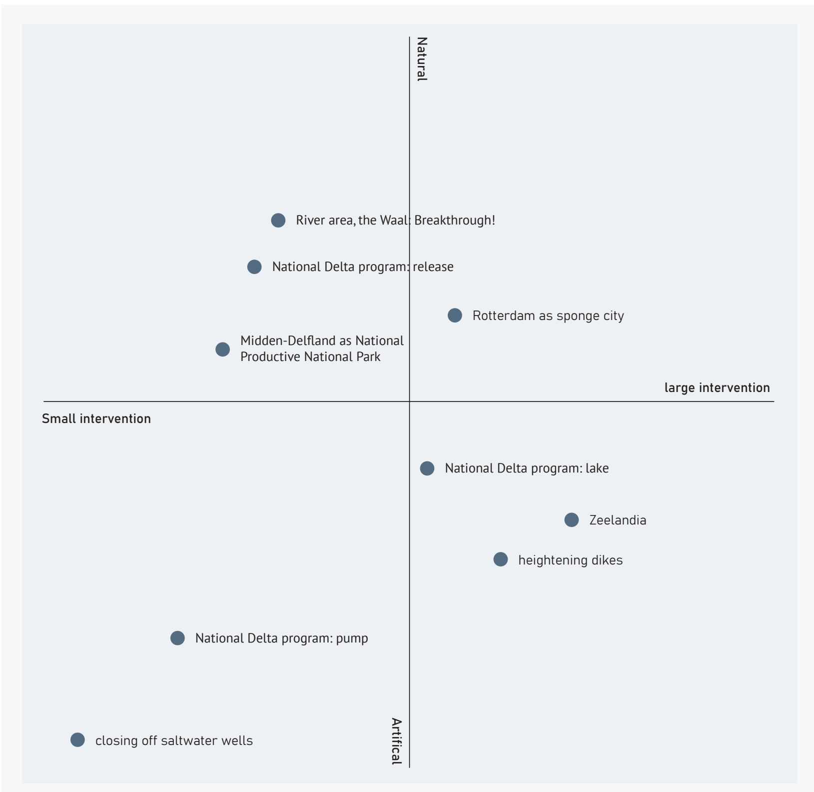


Diagram: Categorising future strategies for the coastal region of the Netherlands

The range of the above-mentioned research, visions and strategies vary from artificial to natural and from small interventions to large. Interventions like dampening saltwater wells or pumping river water to sea are relatively small measures that are artificial compared to natural processes. For a strategy such as Rotterdam sponge city, there is more space for natural processes, however large adaptation must be made to the city of Rotterdam. The National Delta Program, the lake, Zeelandia, and the raising of dikes, proves to involve significant interventions that require artificial measures to be implemented for these structures. River area, the Waal: Breakthrough! National Delta Program: release and Midden-Delfland as National Productive National park provide a relatively small intervention by allowing natural processes in the landscape of the future.
The goal of this research is to find a nature-based solution of the past which can be implemented in the landscape of today, aiming at a minimal intervention.

THE TERP
Safe without dikes

Figure 20: image retrieved from: Het geheugen van schagen, 2023

The terp

Before the Dutch dedicated themselves to the building of dikes, there was a place in the Northern part of the Netherlands, along rivers in which water was tolerated in the living environment. 600 BC first signs of settlements along the Dutch North Sea coast appeared on salt marsh ridges (Wiersma, 2018). By building houses on a small, elevated hill on top of the salt marsh ridges, settlers were able to make a living in this tidal landscape. This human-made elevation, called the terp, lasted for centuries in this area, until the early Middle Ages. After that period more elaborate dikes were constructed to keep the influence of the sea outside of the land. From this period, terps lost their function.

Figure 21: The Netherlands

Figure 22: Terpen in the province of Friesland

Origin and evolution of the Terp

During the last ice age, the North Sea was a polar desert. The soil was frozen, and no plant could grow (figure 23a). Eleven thousand five hundred years ago, the temperature increased, ice melted, and the North Sea level rose (figure23b). The northern part of the Netherlands developed into a salt marsh, as water gathered in the low, flat areas.

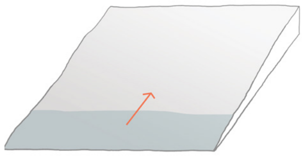


Figure 23a: 6000 BC Hunter & collectors

Six thousand years ago (Vos, 2000), not only did the sea level rise, but also the amount of sedimentation. The increase in sediment resulted in the creation of salt marsh ridges (figure 8).

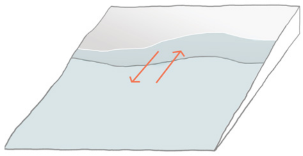


Figure 23b: Settlement on higher ground

These ridges developed during high water peaks, when floods reached inland areas where water was calmer, and sediment would settle, creating layers of sediment deposit. These salt marsh ridges eventually became high enough to only flood during storm surges (figure 23c).

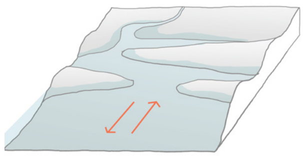
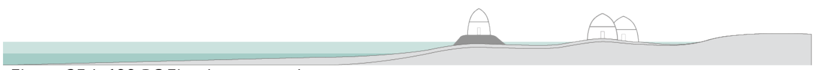


Figure 23c: 5000 BC Sedimentation

The hinterland of these salt marsh ridges contained fertile soil suitable for cattle to pasture. With it, first human settlement arose. A terp was created by artificially elevating these ridges with local (waste) material like sediment, earth, wood, and manure, protecting the settlers from storm surges (Nieuwhof, 2018).



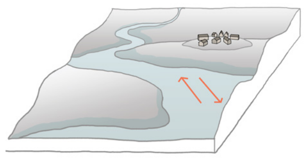
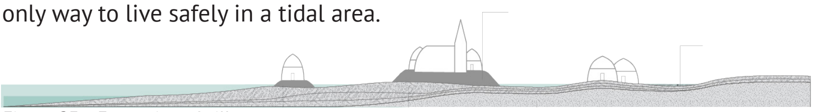


Figure 23d: 600 BC First human settlement

These settlements proved successful, and the hills started to expand. Single terpen agglomerated to neighboring terpen, creating terpen villages (figure 23d). The sea level continued to rise, as the amount of sedimentation did.

While villages were heightened to keep up with the rising sea level, sediment deposits continued, expanding the coastline towards the north (figure 9). This provided new salt marsh ridges where settlements could evolve (figure 23e). Until then, terpen were the only way to live safely in a tidal area.



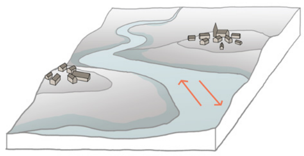
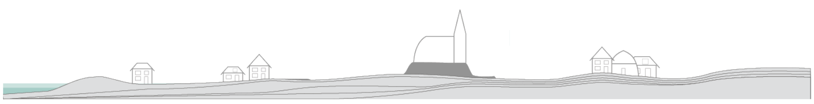


Figure 23e: Expansion of villages

Earlier attempts to create dikes did not prove to withstand the power of the sea. Towards the Middle Ages, dike systems became vaster and more elaborate. Lower-lying areas became safer for humans to settle in since dikes became more reliable. Villages evolved on lower grounds and prospered from their fertile soil (figure 23f). Terpen were only used as a safe zone during dike breakthroughs (Bakker 1995), as dikes did not meet modern-day safety standards.



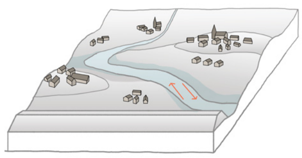


Figure 23f: Early middle-ages, built of sea dikes

Tidal dynamics

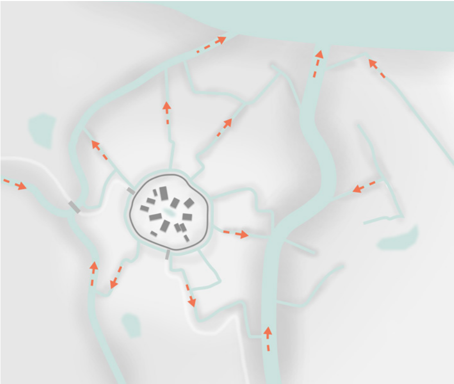


Figure 14: Ditch system, draining land after high tide floods

Low tide (*figure* 24)
Low tide occurs twice a day. During low tide, the salt march landscape is most accessible. Inhabitants could travel back and forth as lower-lying paths were accessible.

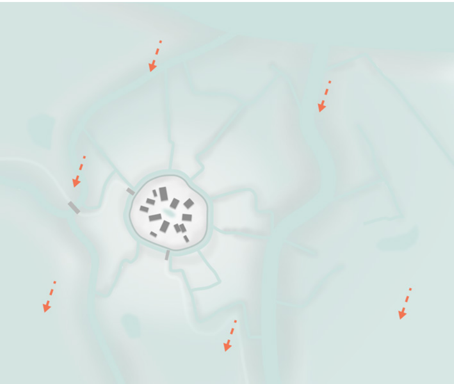


Figure 25: Periodic isolatoin during storm surges

High tide (*figure* 25)
Like low tide, high tide occurs twice a day. Water levels are, on average, two meters higher than during low tide (Rijkswaterstaat, 2024). At high tide, parts of the landscape become isolated.

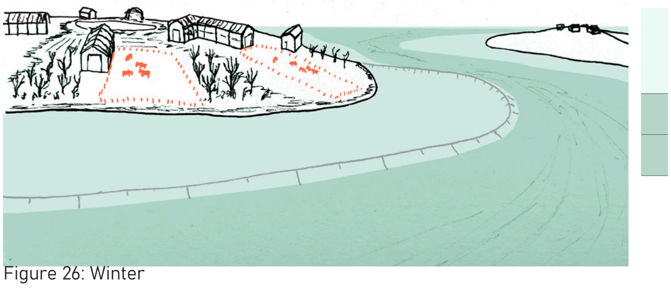


Figure 26: Winter

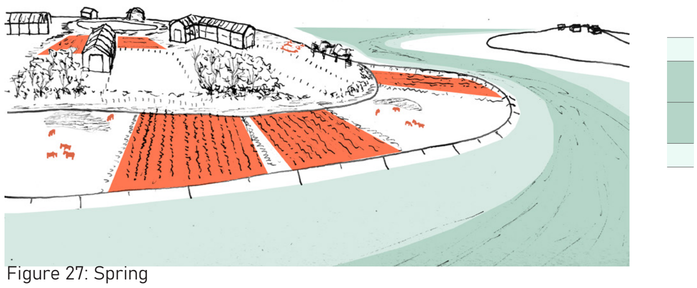


Figure 27: Spring

Winter
In winter, most severe storms occur. During these periods, terpen were the only places in the salt marsh landscape that stick out from the sea (*figure* 26). Cattle are brought in stables or small parcels (Nieuwhof, 2018).

Spring
In spring, cattle are released on the fields (*figure* 27). Parts of the terp and buildings are heightened if winter storms prove to be challenging. Manure is collected and used as a building material. Since manure contains gases, it is a highly isolating material (Nieuwhof, 2018). During this period, sowing takes place.

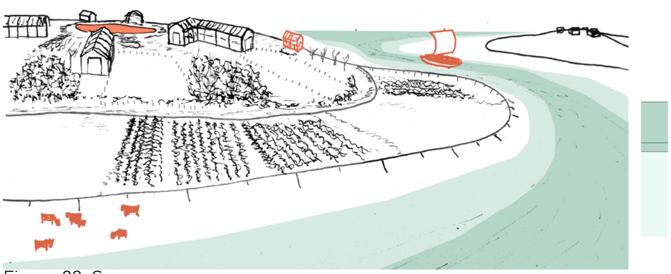


Figure 28: Summer

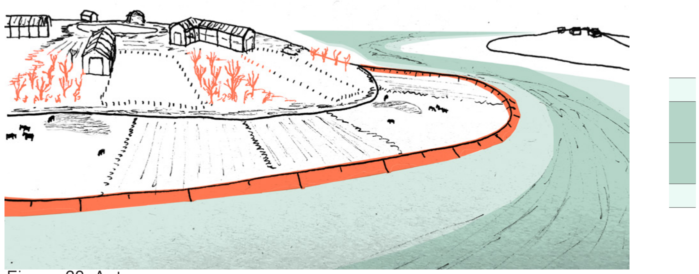


Figure 29: Autumn

Summer
In summer, dry periods challenge terp inhabitants as freshwater becomes scarce in this saltwater-dominated area. Boats filled with freshwater jugs originating from upstream creaks fill freshwater reservoirs on the terp (*figure* 28).

Autumn
In autumn, the last crops are collected. Summer dikes protect the crops and prevent floods from threatening their yield. When more severe tides accede in winter, floods surmount summer dikes, providing a new layer of fertile sediment and heightening these agricultural fields (Nieuwhof, 2018) (*figure* 29).

Terp as a system

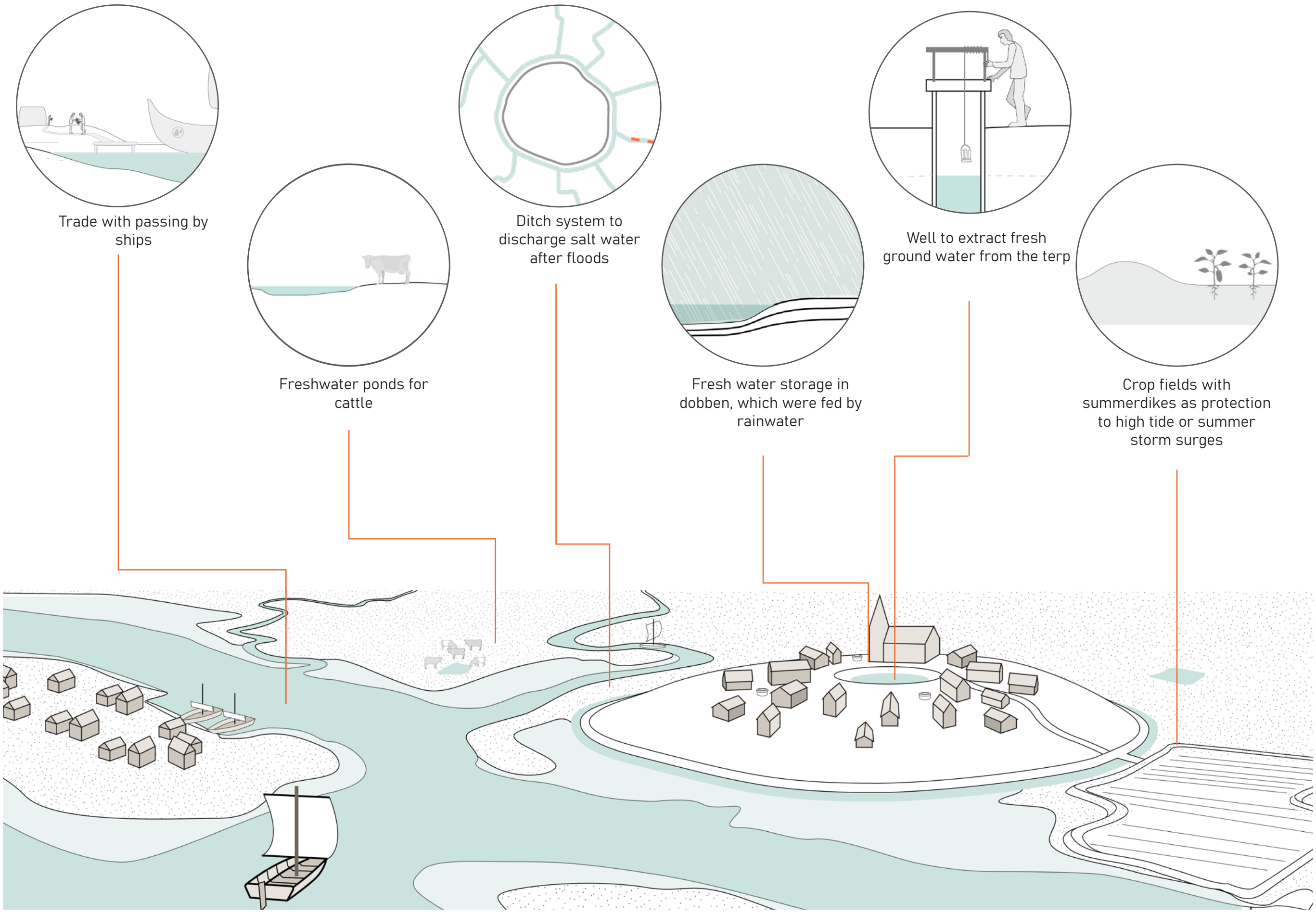


Figure 30: The system of a terp

The 800 AD terps landscape hosted an advanced way of living in harmony with the sea. It proved humans were able to prosper in a tidal area without dikes. This interaction has been lost with the current dike system, keeping the sea out of the landscape. Terps have become leftover dots in the landscape, many removed as they contained fertile soil which was sold to enrich the poor sandy soil inland (Nieuwhof, 2018).

Landscape values
The specific conditions of a mix of sea level rise and sediment depositions facilitated the naissance of the terps landscape. The artificial hills were a source of cultural, social, and natural significance. Beside some human intervention, the salt marsh landscape was untouched as the sea periodically leveled the landscape out.

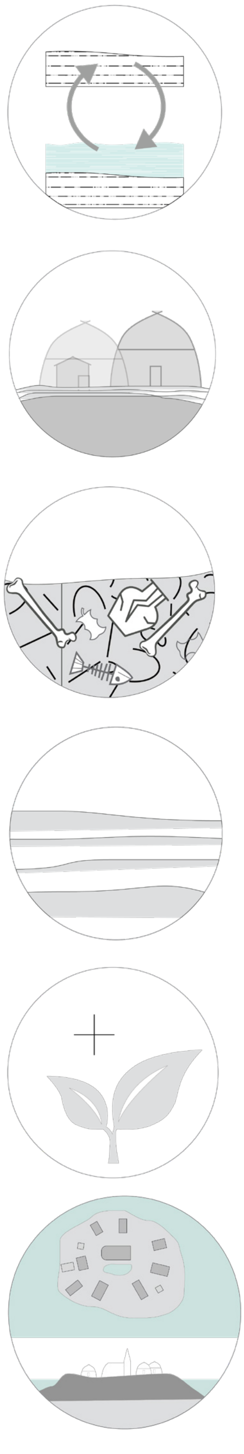
Functionality values
The concept of a terp is to use surrounding land and waste material to heighten parts of the landscape which ensures a dry area to live on and bring the cattle on to, during high tides.

Sustainability values
Inhabitants of terpen villages were remote, located on pioneer soil further away from the inland villages. With annual floods during storms, terpen became utterly isolated. Material and goods brought in or produced on the terp were used to its full extent. Expanding buildings used foundations and materials from demolished houses. Even waste material served a purpose: to heighten parts of the terp and cope with the rising sea levels. Life on the terp was majorly circular with a high sustainability level.

Lessons to learn.
The terpen proved to be a way to live with the tidal dynamics of the sea. Since the Middle Ages, the Dutch became dependent on a rigid and energy-consuming polder system. By draining land for agricultural purposes, parts have subsided below sea level. Low lying land needs to be protected against the sea by dikes and drained with pumps to prevent it from drowning. Over the centuries the complexity has increased, water levels have no, to little fluctuation and the system has become energy consuming due to mechanical pumping. With changing climate conditions and subsiding land, the question arises if today's water management in the Netherlands is sustainable. The terp proved to be a successful way of living with fluctuating water levels, providing safe ground for inhabitants in a dynamic landscape, able to adapt to extreme weather events.

ELEMENTS OF THE TERP

The terp is more than just a human made artificial hill to keep dry feet during floods. It is the development of this hill through centuries, adapting to rising water levels, and development of wealth. From simple huts in search for freshwater to flourishing settlements with trade connections over all northern Europe.



Fluctuating water levels
With high and low tide marching in, land use needed to be flexible. The highest parts were for living, the higher parts were used for crop growth and high parts for cattle pastry. During high tide, parts of the land were not passable. During winter floods the whole land flooded, terps were the only parts which did not submerge by water. With the arrival of dikes, this flexible use of the landscape was lost, but stability was gained.

Adaptability of houses
Since sea levels were rising, terps needed to be raised to manage higher water levels. Houses were taken down and rebuilt, with parts of the old house used to elevate the terp as needed. The rest was reused to build the new house.

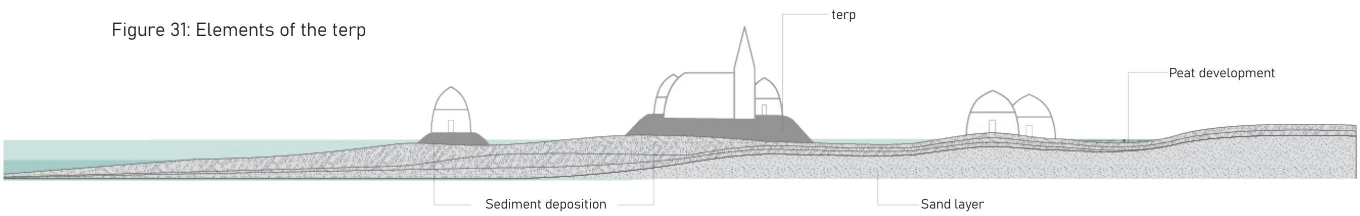
Built with waste material
During the heightening of the terp to protect inhabitants from sea level rise, every available material was used to gain height. From animal manure to household waste, build material and sediment.

Sedimentation
With the rising sea levels along the North Sea coast, sediment deposition resulted in salt marsh ridges which expanded the coast towards the North. Humans made use of this sediment by using summer dikes to trap sediment in winter when floods were more severe. Water calmed behind these small dikes, in which sediment could settle. This accelerated the land reclamation process.

Increase of biodiversity
Human activity enriched biodiversity in the salt marsh of the North Sea. In these saline conditions, a limited amount of fauna could develop. With human activity, new species were introduced, manure of cattle enriched the soil and provided nutrients for more species to exist.

Social Cohesion
Small villages emerged from single terps. These small communities provided a "we" feeling as they were together in this tidal area. Social cohesion was higher than in regular villages as they had to cope with the same problem of periodic isolation. Towards the Middle Ages, terp villages connected dikes in-between the villages to secure agricultural land from the sea. Before this incision the villages had a "we" – "Them" feeling. By this connection, villages shared an equal responsibility of maintaining the dikes to secure safety of crops from sea water (De Ruyter, 2020).

Figure 31: Elements of the terp



WHY TERPEN DID NOT EXIST IN THE POLDER

The aim to use the concept of the terp in the polder raises the question why the terp was not already present in the polder. Terpen appeared in areas with fluctuating water levels along rivers and coastal areas. The most characteristic feature of the polder is controlling water levels. Therefore, settlers did not have to live on an elevated area, as water fluctuations did not occur. Precipitation was pumped out to maintain a fixed level. People settled along the highest parts in the landscape: sand ridges or directly on and along dikes, where houses were built on ground level using a foundation. Another argument is the material: by making a hill out of peat, the oxidation process starts vanishing the hill that was created.

With the research question proposing alternative water management, dynamic water levels are expected in the polder. The concept of the terp could therefore be implemented as a solution to fluctuating water levels. In this research there will be elaborated on the concept of the terp to investigate what benefits can be applied when water dynamics are allowed to grow out of the polder. As the terpen cope with fluctuating water levels and use stable soil to build on.

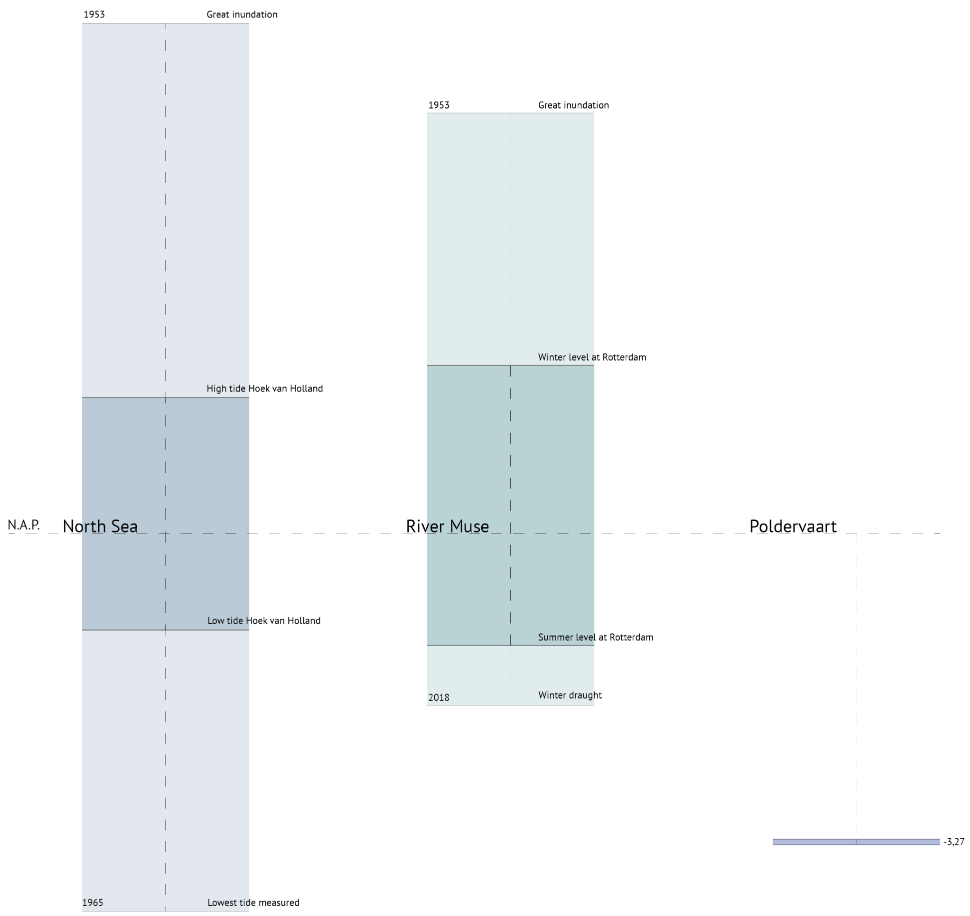
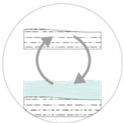


Figure 32: Water levels and fluctuation of the North Sea, the River Muse at Rotterdam and the Poldervaart South Holland

MODERN ELEMENTS OF THE TERP

Translating the concept of the terp to the polder

To implement interesting elements from the terp in the polder conversion or adaptation of these elements is needed as circumstances are different as our way of living has developed.



Water fluctuations

In the terp landscape water fluctuations were caused by tidal movement of the sea. Twice a day, the tide changed from high to low tide. In the polder, tidal movements are not part of the process since the design location is not in direct connection with the sea. Fluctuations would take place throughout the year as precipitation occurs in winter and evaporation in summer.

Figure 33: from a twice a day tidal movement to a yearly fluctuation.

Building with waste material

Once a terp had to be raised to cope with the rising sea, everything which was at hand was used to gain height. Salt marsh material and human waste is different from the waste of today. All materials used on the terp were biodegradable. With current consumer society, humans produce a lot more waste, which is often not degradable or harmful for the environment (Marín Beltrán, 2021). The range of waste has also expanded, as a greater variety is now available (Marín Beltrán, 2021).

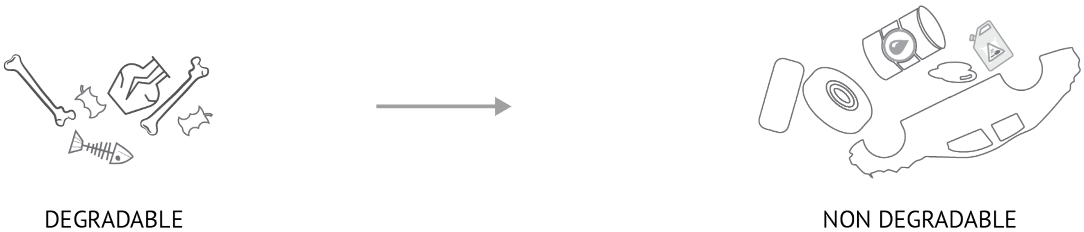


Figure 34: from simple organic waste to complex types of waste.

Adaptable houses

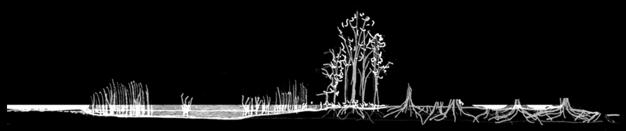
In the terp landscape, houses were remote. They were built from simple and light material, big enough to ensure one family. In modern times the building process has become more complex, and houses have become bigger and heavier, hosting many more households.

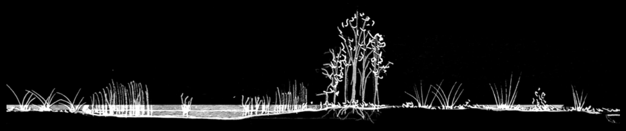
Figure 35: from remote homes to elaborate houses.

RISING OUT OF THE POLDER
Animated concept

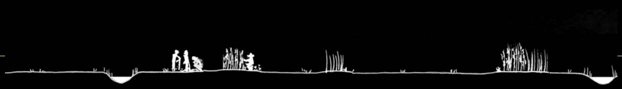
Rising out of the polder illustrates how elements of the terp can possibly contribute to a gradual transition of the landscape creating land above sea level. Showing adaptations to the built environment, changes in agriculture and increase in biodiversity, creating a resilient landscape which adapts to increasing water levels.

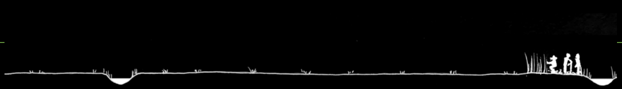
Frame 1: Making land suitable for agriculture



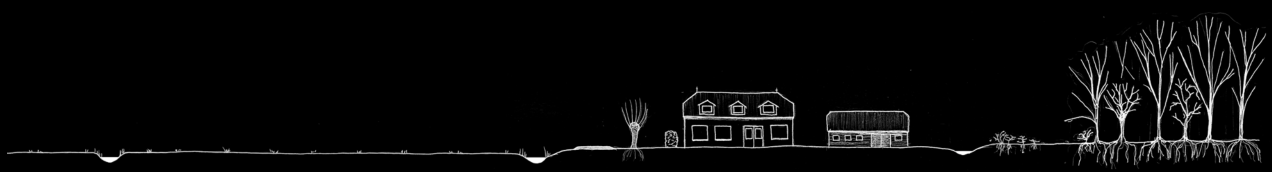


Frame 2: Soil subsidence due to drainage





Current situation



Change of seasons

Winter

Spring

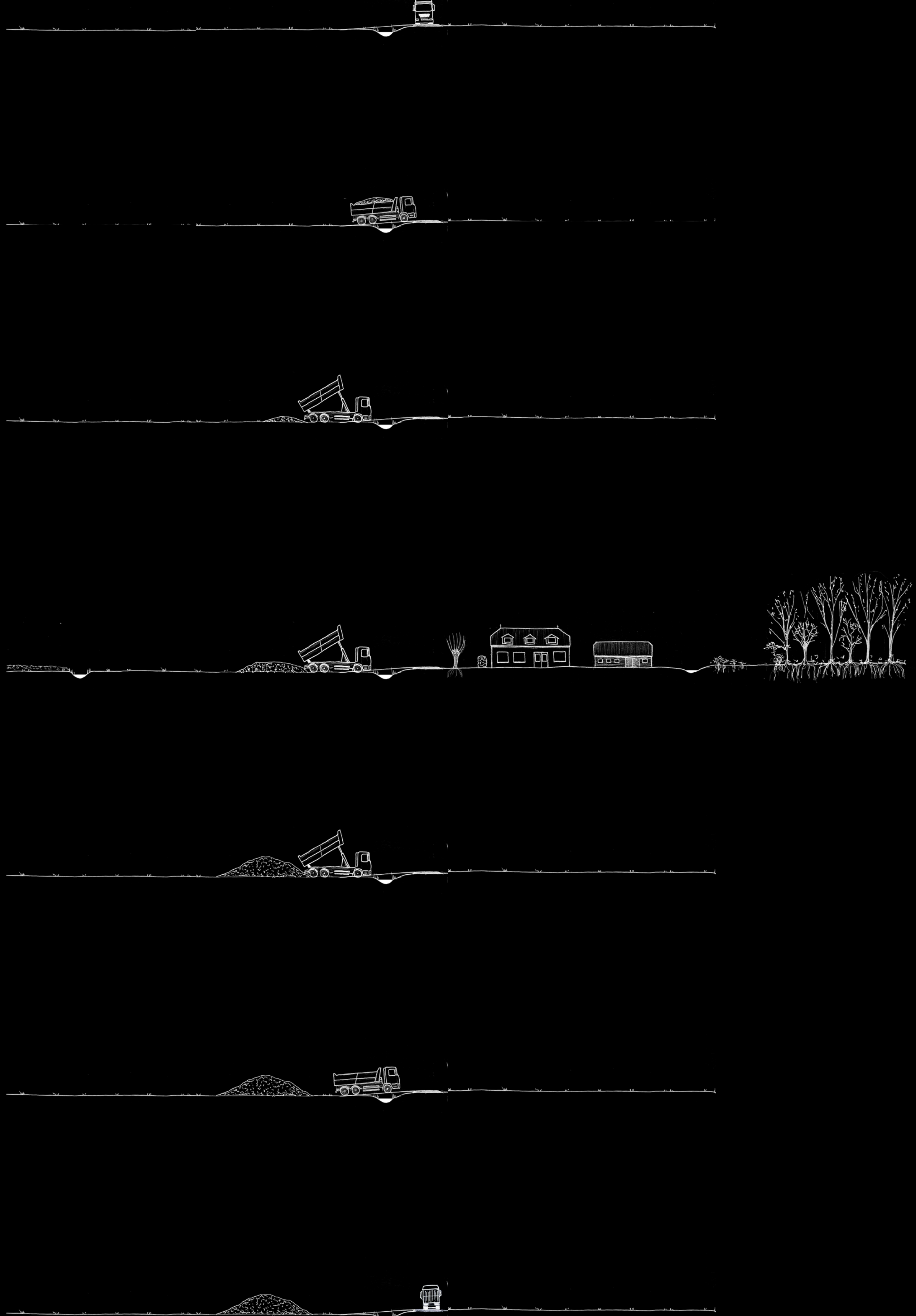
Summer

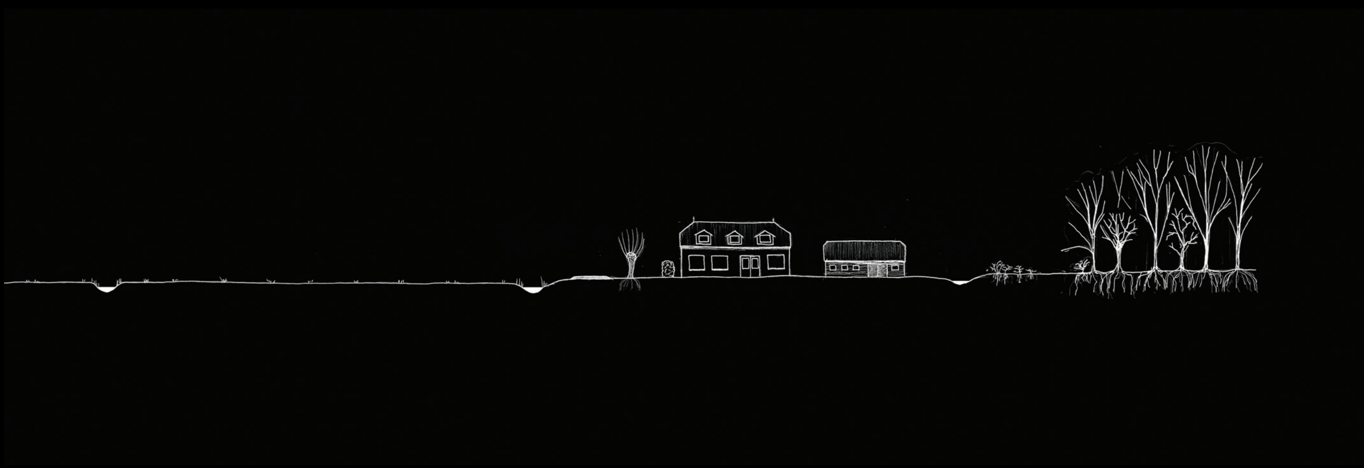
Autumn

Frame 4: Allowing water fluctuations in the polder

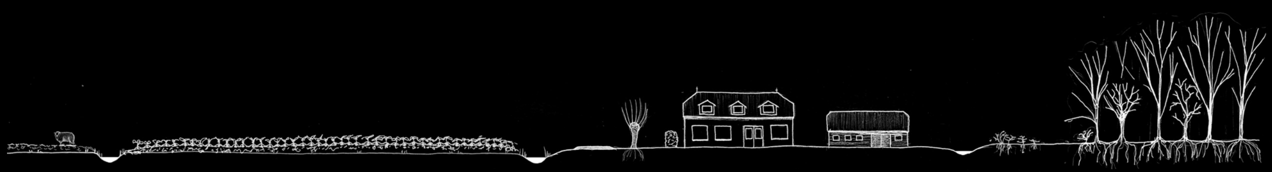
Frame 5: By pumping less precipitation out of the polder

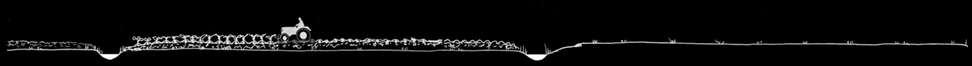
Frame 6: Increasing flood resistance by heightening land



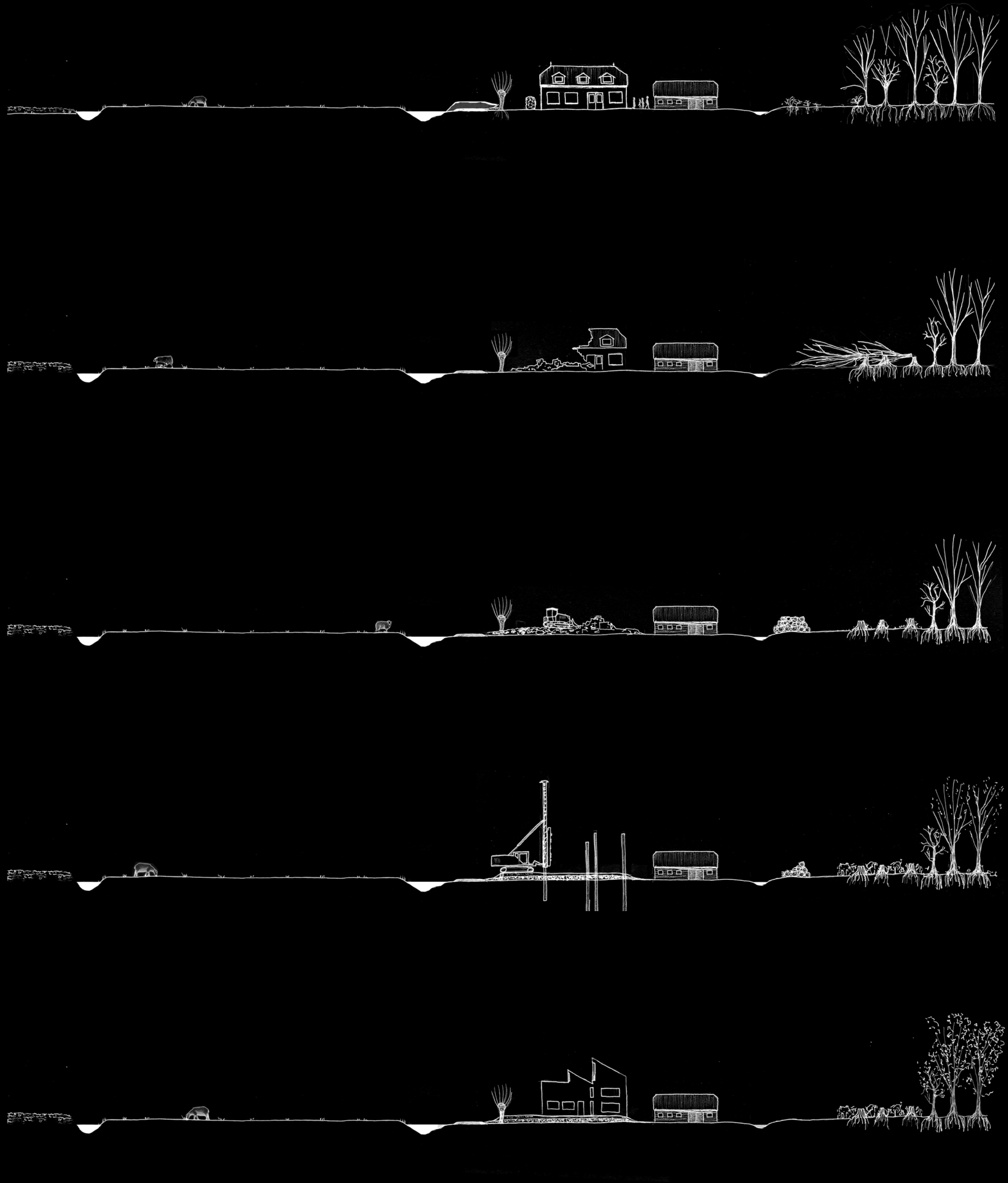


Frame 7: Crop growth due to increased soil conditions





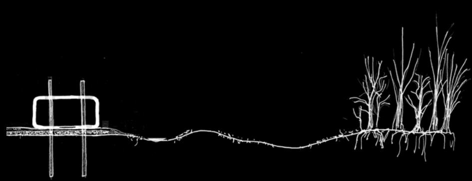
Frame 8: Homses have to adapt to heightened water level + Local material can be used as resource

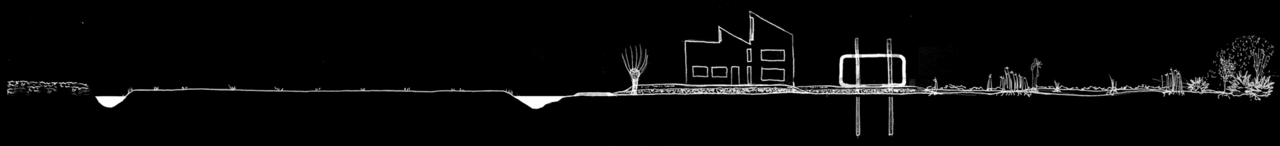


Frame 9: Nature areas are uesed as temporary storage places for material

Frame 10: increasing biodiversity

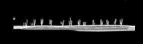
Frame 11: Material gets re-distributed to heighten parts of land



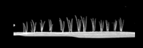
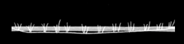


Frame 12: Stimulating peat groth in recreational areas

Frame 13: Alternative forms of agriculture due to increase of water levels



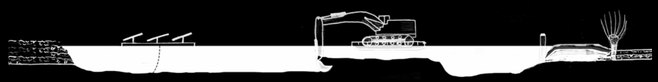



Frame 14: Solar farming

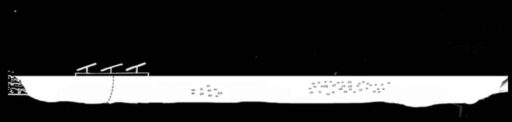
Frame 15: Wet cultivation

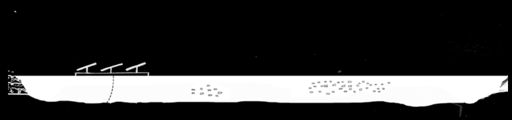
Frame 16: Aquatic cultivation

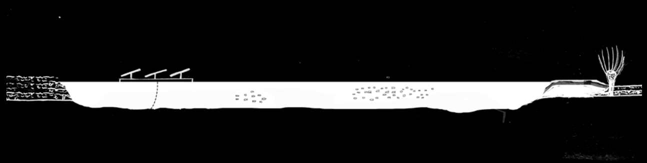




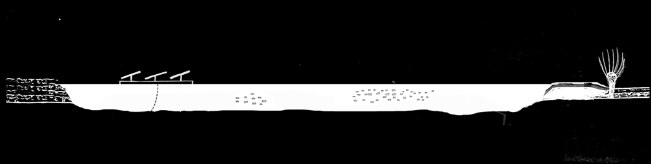
Frame 17: Re using fertile top soil layer



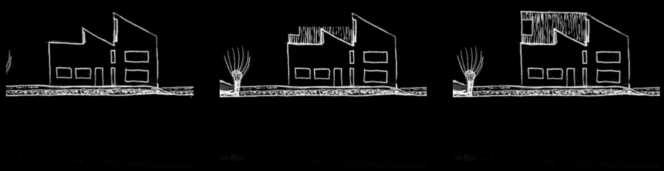




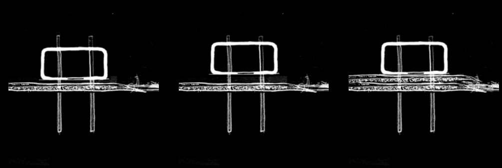
Frame 18: Alowing aquatic forms of agriculture



Houses have been adapted to be modified

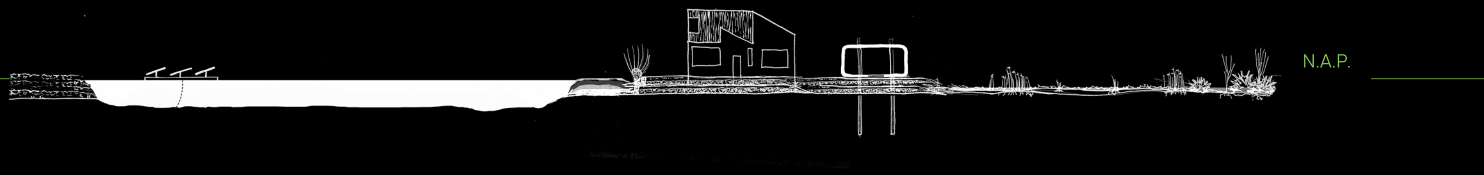


Frame 19: Build can be continued



Frame 20: or can be elevated

Land has been developed above sea level


N.A.P.

Design Assignment

The goal of this research is to reverse the process of subsiding soil in peat polders, by growing land above sea level using the concept of the terp. Current water management leads to subsiding soil in peat areas, polders are flushed to minimize salt intrusion and nutrition saturation. As the Netherlands face an annual precipitation surplus, an energy consuming system of pumps prevents flooding, pumping out water to keep a steady water level. The aim is to implement a design that incorporates elements of the terp, creating a resilient landscape capable of coping with the gradual rise in water levels, similar to the terpen landscape 1500 years ago.

Strategy

To accomplish the design assignment, elements of the terp are bundled together and shown in an animation. The concepts that are used in this animation are implemented in an existing polder where problems are poignant. First a region is analyzed before a location within the region is chosen. The location and its landscape elements are analyzed to which the concept of the terp is applied. Water management is changed to minimize peat oxidation. A larger change in water level occurs as parts of the polder approach sea level. A system is implemented facilitating supply of waste material to heighten parts of the polder. Geological deposition is used as the foundation of growth. Landscape elements like houses, farms and agricultural land become adaptable and water levels can be increased. Cut and fill takes place to make farming possible, creating a diverse pallet of agricultural activities compared to the monogamous use of dairy farming. Along creek ridges, fertile organic waste is deposited on the more solid clay layers providing heightened soil for crop farming. Water levels are equalized, creating height differences in ground level, improving biodiversity as gradients from wet to semi dry to dry circumstances arise. These interventions are bundled in a master plan map, which aims to give an overview of a resilient landscape. Diagrams explain landscape design changes and a zoom-in visualization shows the practical implementation of all elements mentioned above. With these products the design strategy aims to give a complete overview of the design for the future peat polder.

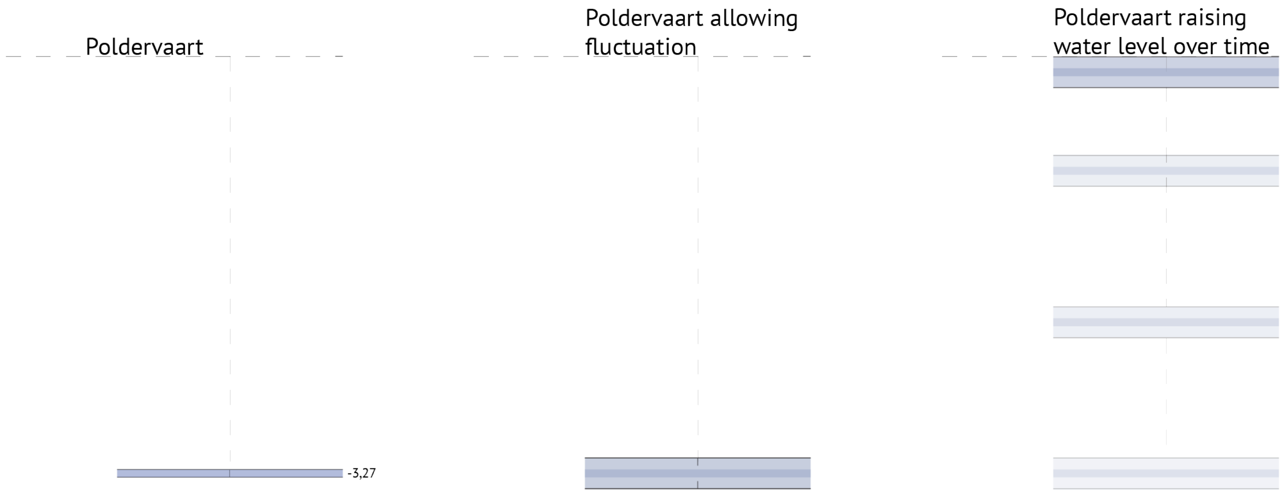


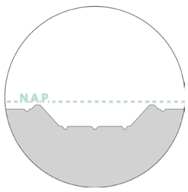
Figure 36: Design stages of water level in the Poldervaart

Location
Implementing the concept of the terp in the polder

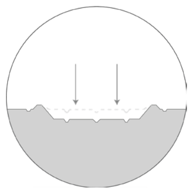
COASTAL PEAT POLDERS
Design region

Testing the new concept for the polder would logically take place in an area where problems are most poignant. Peat areas can mostly be found in the western part of the Netherlands. As most of the land is drained for agricultural purposes, peat oxidates, and land subsides. As can be seen in figure 38, peat areas overlap with subsiding areas. Areas with salt intrusion can be found along the coast in the western part of the Netherlands. Testing the research question would naturally take place in an area where peat, soil subsidence and salt intrusion overlap. The design location is not bound to specific requirements as the research question aims at a larger outcome, applicable to multiple places with similar conditions.

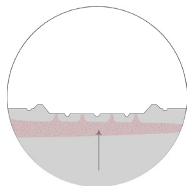
The green patch between Delft, Rotterdam and Hoek van Holland meets the above mentioned requirements and is an interesting location due to the variety in land use. It borders urban expansion areas and consists mostly of peat. Water is discharged through a boezem system which connects different areas with each other. Dairy farming is the main agricultural use in this area, but also a wetter nature area can be found in the Poldervaart recreational area.



Polders below sea level



Subsiding areas



Salt intrusion

Figure 38: Peat areas in the Netherlands

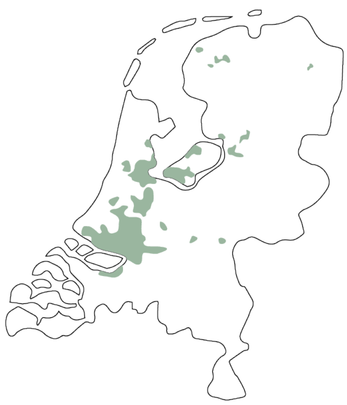


Figure 39: Subsiding areas in the Netherlands

Figure 40: Salt intrusuion areas in the Netherlands

Figure 40: Information derived from AHN, edited by author using Qgis

Elevation map: All blue areas lay below sea level. In the Rotterdam-Delft area polder vary from - 0m N.A.P. towards the coast to - 5.5m inland eastwards.

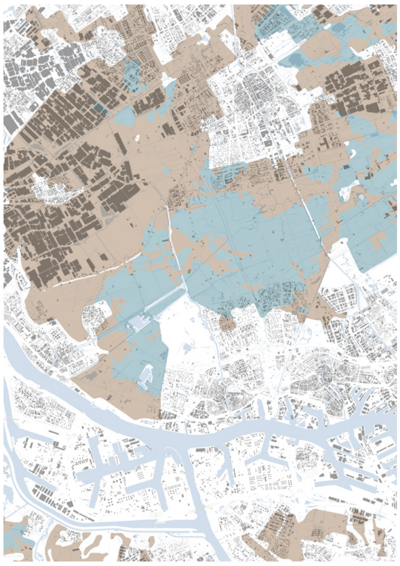


Figure 41: Information derived from bodemdata WUR, edited by author using Qgis

Peat – Clay map: In blue showing the peat areas, in orange showing clay areas with creek ridges. Most of the soil in this region is based on peat, as parts of Delft and Rotterdam are built on peat.

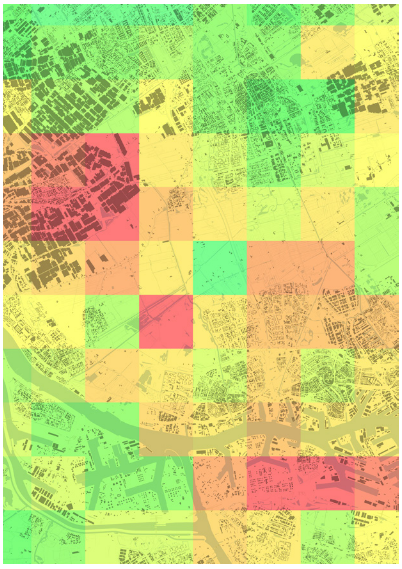


Figure 42: Information derived from atlas van de leefomgeving, edited by author

The red/orange areas in the region of Rotterdam-Delft has subsiding soil. Derived from satellite measurements areas are assigned where subsidence takes place.

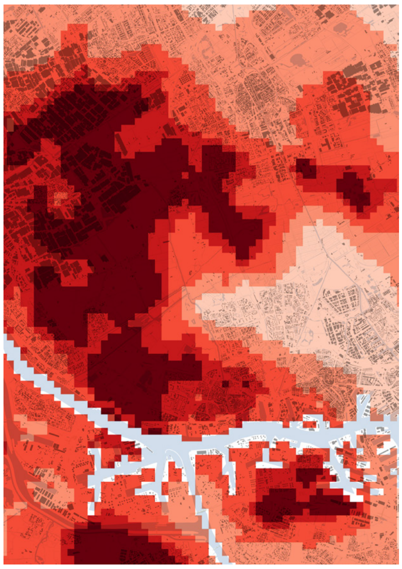


Figure 43: Information derived from STOWA, edited by author using Qgis

Salt intrusion is a problem along a large part of the Dutch coast, The darker red areas represent bigger chance of salinization through ground water

NOORD-KETHEL POLDER
site analysis

The design location will serve as a testing ground to implement elements of the terp in any low-lying Dutch peat polder, to create land above sea level. Zooming in further on the Noord-Kethel polder, the green patch between Delft and Rotterdam stands out due to the variety of landscape elements. The polder mainly consists of peat. The boezem Schie connects Delft with Rotterdam and the sea, which is an interesting line through the landscape. A system of dikes prevents the higher located boezem water level from flowing into the lower polder. The North area consists mostly of grassland used for dairy farming, the middle part is a recreational area Poldervaart which hosts a biodiverse area. The area is rural, with the village Kandelaar on the dike along the Schie and an area along the train track with about 50 households.

The Noord-Kethel polder is an interesting location to implement different elements of the terp, as illustrated in the animation, to help solve the problems mentioned in the problem statement. The location is a suitable testing ground but certainly not the only ground in which these elements can be implemented. The design aims to show an implementation of the concept of the terp in the polder to solve current water management problems. These design interventions are intended to work in similar locations.

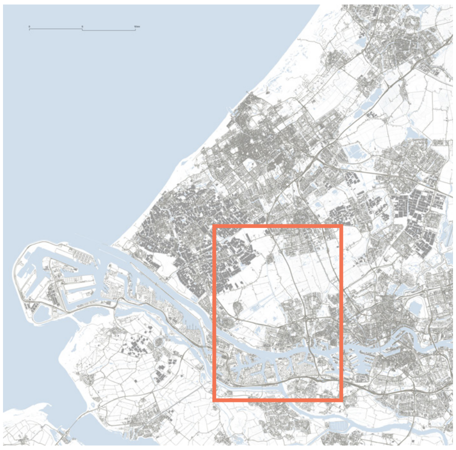


Figure 44: Design region

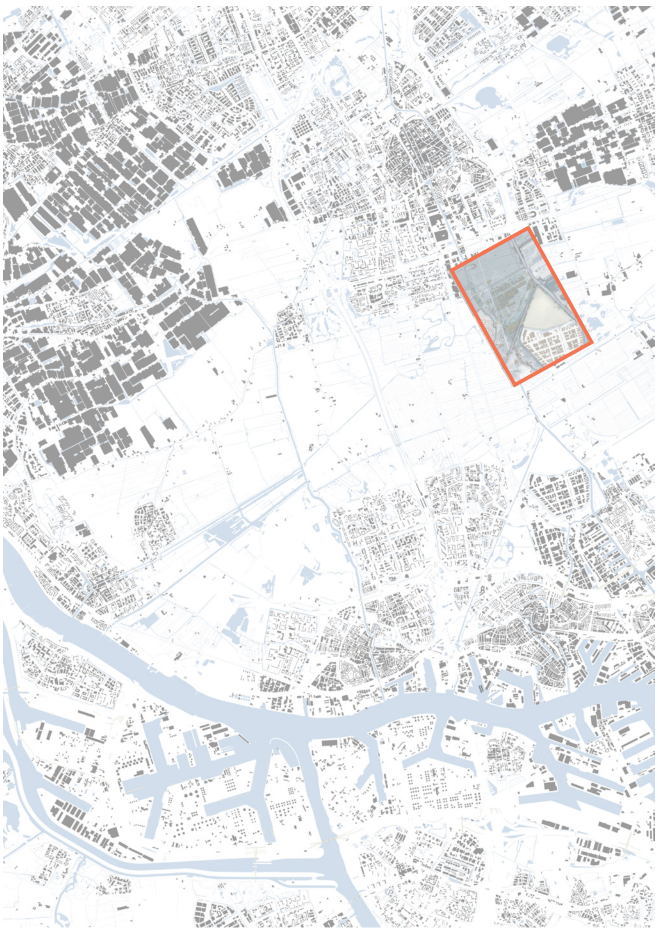


Figure 45: Design location

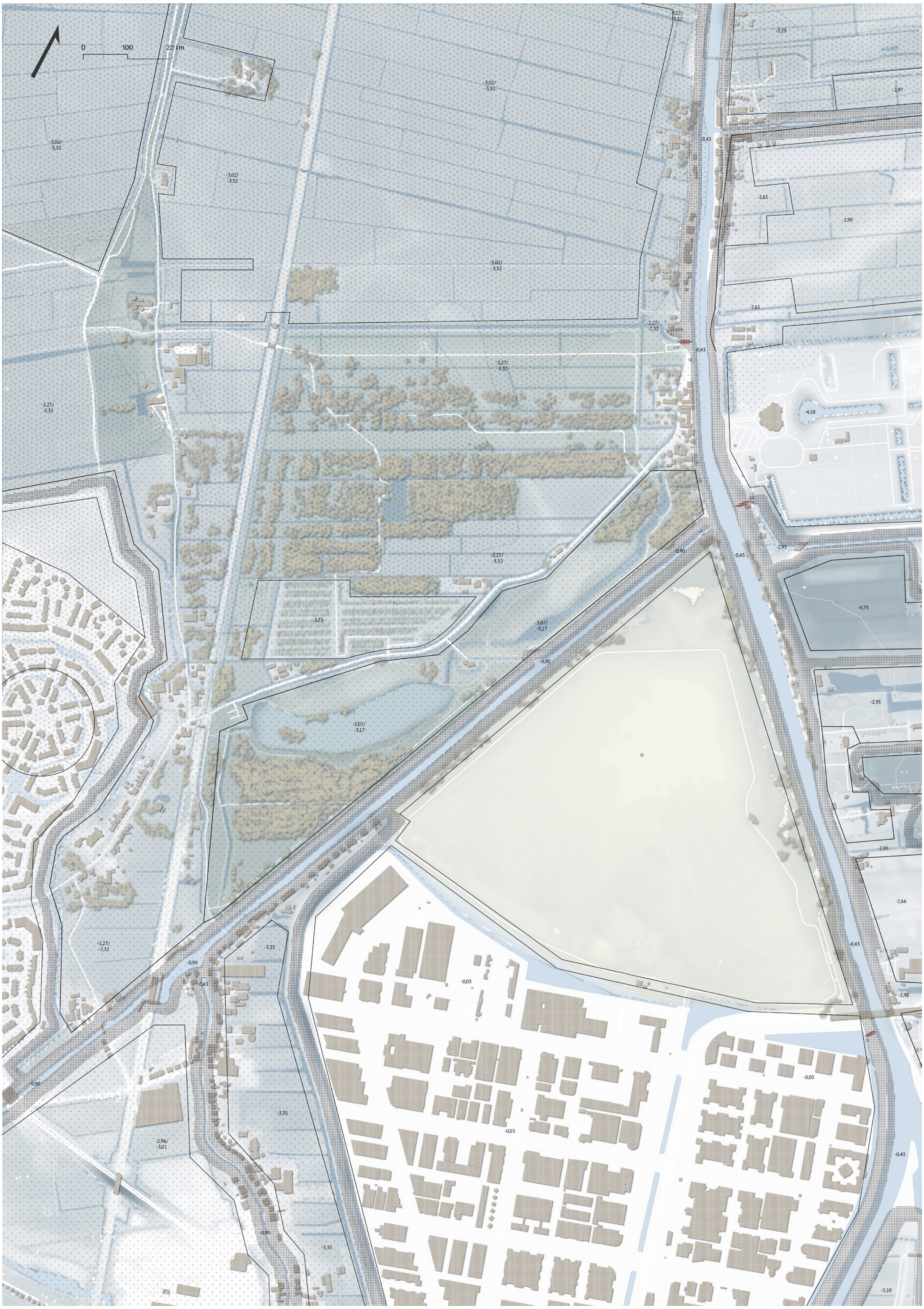


Figure 46: Map of design location

LANDSCAPE

GEOLOGICAL REMAINS IN THE PEAT POLDER
soil analysis

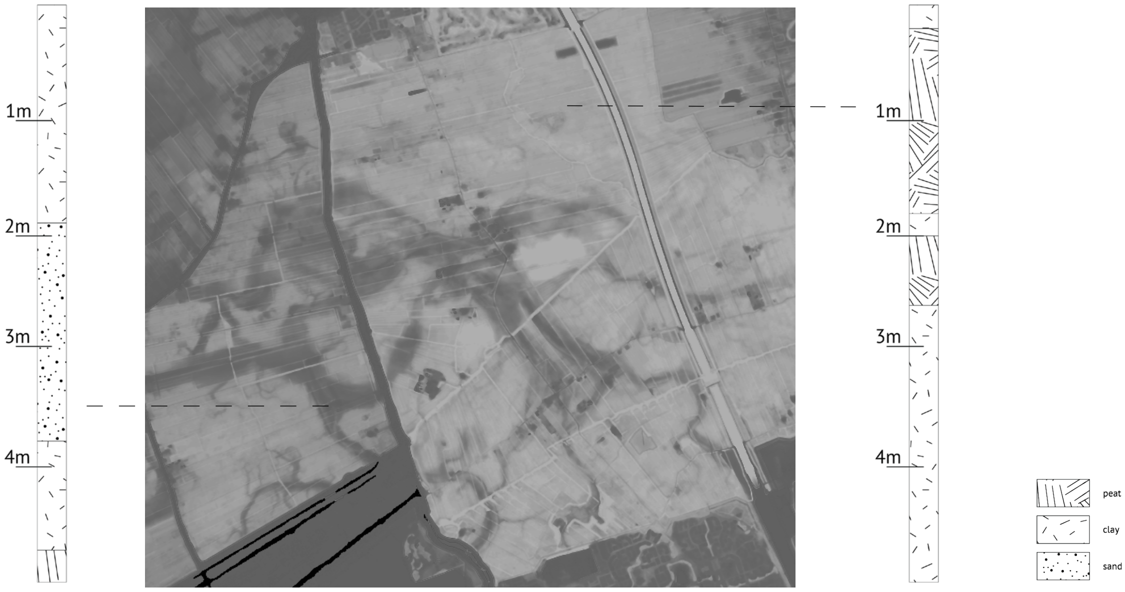


Figure 47: Creek ridges occuring in peat areas. Information derived from AHN, edited by author using Photoshop

Throughout the Dutch low-lying peat polders, remnants of peat creeks can be found (figure 47). These darker flowing lines were naturally responsible for discharging water from the higher peat lands. Since land was reclaimed for agricultural purposes, peat was drained and started to oxidate resulting in subsiding soil. Peat creeks accumulated clay deposition creating clay soil ridges. These ridges would be more stable and less vulnerable for subsidence. From the eye level these height differences cannot be seen, but by using a height level map these small changes in height can be measured as can be seen in figure 48. In the peat landscape, the top layer consists of a few meters of peat. A creek ridge in a peat area mostly consists of clay. In the design location, hereafter called the Poldervaart, these creek ridges can also be distinguished. Comparing them with the soil map, clay areas overlap with creek ridges. In the Poldervaart they can be found along the canal (Poldervaart) and towards the north where the hamlet is based.

Figure 48: representation of a peat polder in South-Holland

Figure 49: Information derived from AHN, edited by author using Photoshop

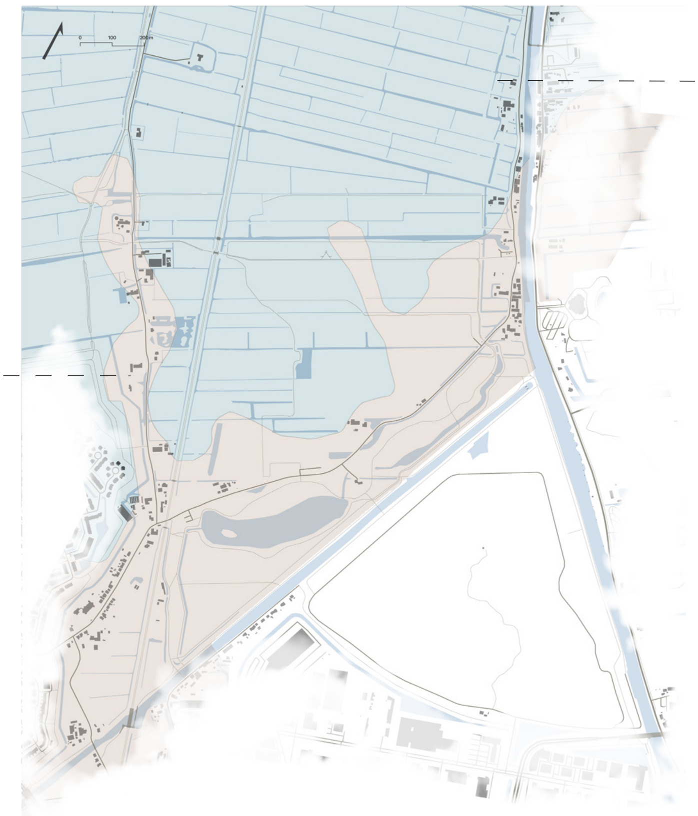


Figure 50: Soil analysis map in the Noord-Kethel polder

POLDERVAART AND NOORD-KETHEL

Nature and recreation with historical elements

The Poldervaart recreation area is named after the canal which was originally connected with the Schie. It was constructed in 1280 as a new waterway and was used for the drainage of the eastern crafts of the Hoogheemraadschap van Delfland: Vrijenban, Hof van Delft, Berkel, Kethel and Pijnacker. Near the Schie, the restored locks are still a relic. The Poldervaart is now closed off from the Delftsche Schie by a dam. The recreation consists of plots which still follow the geometry of agricultural subdivision. Rectangular ditches discharge the water. A gravel path is constructed which leads the recreational user through the area. Along the Kandelaarweg which cuts the Poldervaart recreational area in two, a helophyte filter is installed aiming to filter nutrients from agriculture in the north. A remains of a windmill can be found which has been converted to a residential home. The windmill originally pumped out water from the polder into the Poldervaart. The discharge ditches surrounded by dikes still can be distinguished in the landscape. Next to the recreation area the hamlet of Noord-Kethel is located. An historic group of houses with the *Sint Jacobus de Meerdere* chruch with high historic value.

Figure 51: The historic hamlet of Noord-Kethel with the tower of the Sint Jacobus de Meerdere church

Figure 52: Helophyte filter at the poldervaart recreational area

Figure 53: Small pond in the middle of the recreation area

WASTE HILL
superficial terp with profound potential

Figure 54: Aerial view of northern part of waste dump (dS+V, 2010)

Between 1967 and 1985 the former agricultural Oos-Abspolder is claimed to Rotterdam. The polder is heightened with sludge originating from the harbor and the Overschiese Plassen. The southern part of the area will become a business district. The Northern point of the former Oost-Abstpolder becomes a storage area for polluted soil. The soil is sealed and closed off in 2003 when plans are made for a Golf Course.

With a superficial view, the waste hill can be seen as a modern terp. But heightening land with waste, building above sea level would only agree from a visual perspective. In the end such a hill is static and once sea levels rise, the hill is no different than other land. Therefore, the storage area is a missed opportunity to create a dynamic place which is adaptable and can provide land by means of storage area for low lying polders with subsidence and salt intrusion problems.

Figure 55: Soil egalisation for the golf course.

Figure 56: Nature development on the hill

THE DUTCH PRECIPITATION SURPLUS
Climate in the Netherlands

The Noord-Kethel area has a temperate maritime climate and an annual surplus of precipitation. On average, a yearly total of 915 mm of precipitation falls in this area of the Netherlands (KNMI, 2024), compared to a yearly evaporation of 612mm. The yearly surplus is therefore 303mm per year. From January to March, precipitation surpasses evaporation. Water levels can rise up to 134,5 mm before evaporation overtops precipitation bringing water levels back towards 26,5mm from April to July. From August to December precipitation surpasses evaporation rising water levels to 303mm which can be seen as the yearly surplus.

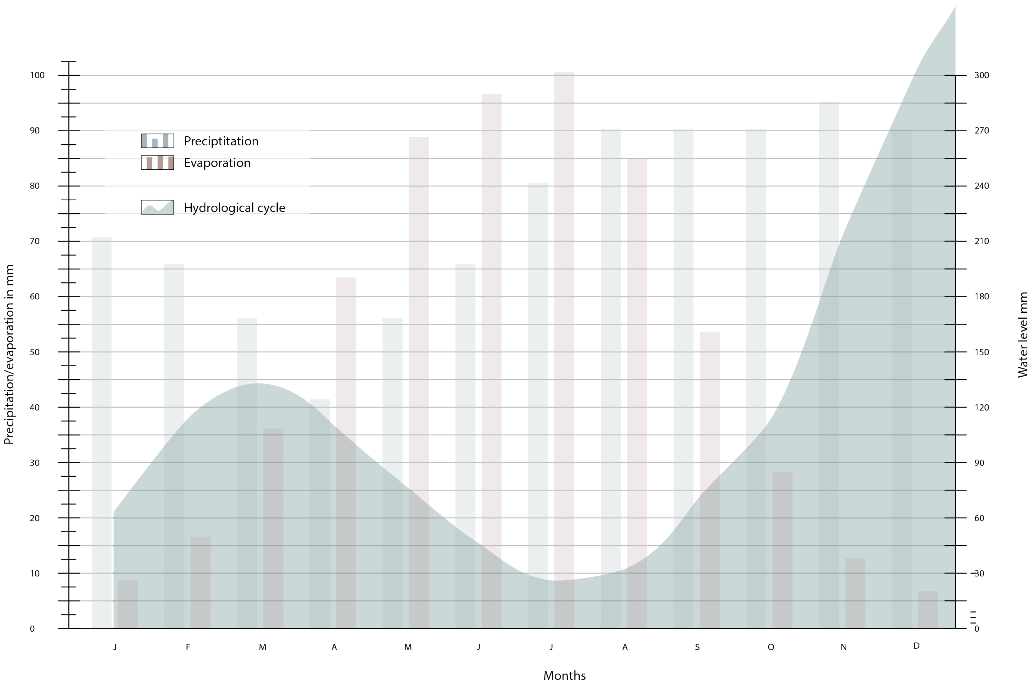


Figure 57: Graph of precipitation and evaporation (Created by author, data retrieved from KNMI).

The Noord-Kethel polder has a fixed water level of – 3,32m during winter and – 3,27m during summer. If no water management occurs, the polder would fill up before the end of 2035.

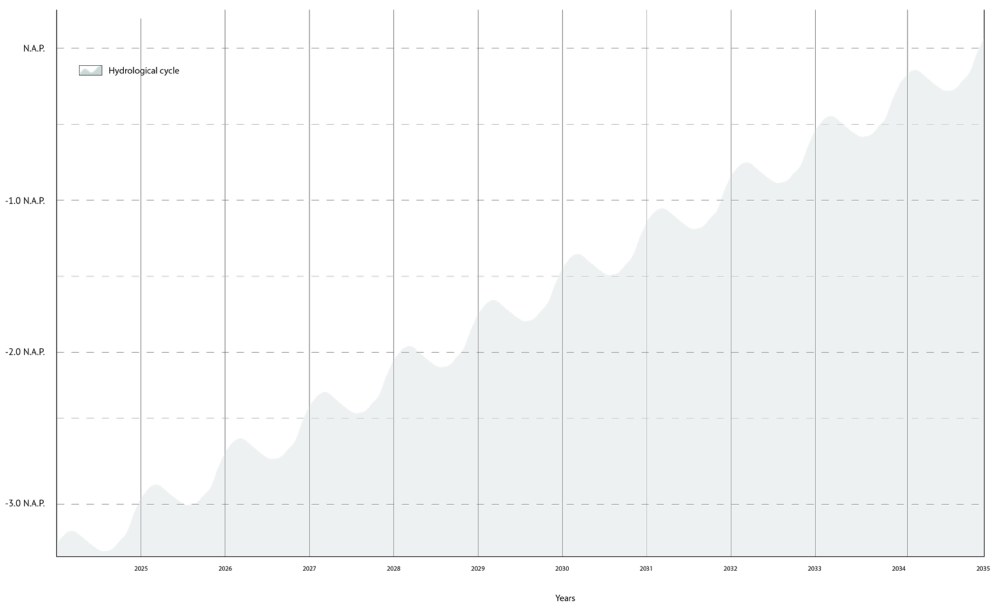


Figure 58: Graph of waterlevel if no water discharge would take place in the Noord-Kethel polder (Created by author, data retrieved from KNMI).

PUMPING IN WINTER AND SUMMER
Current water management

To prevent filling up of the polder, pumping stations, baffle's and dams (formerly windmills) regulate water all year long maintaining a fixed water level in 5 different areas (figure x).
Up until March, water is pumped out by the Noord-Kethel polder pump to manage the main winter water level of – 3,32m. In summer, water is pumped in the polder to keep the water level up to – 3,27. Maintaining this accuracy means that pumps are almost constantly working to maintain this fixed level in an area of 3 square kilometers.

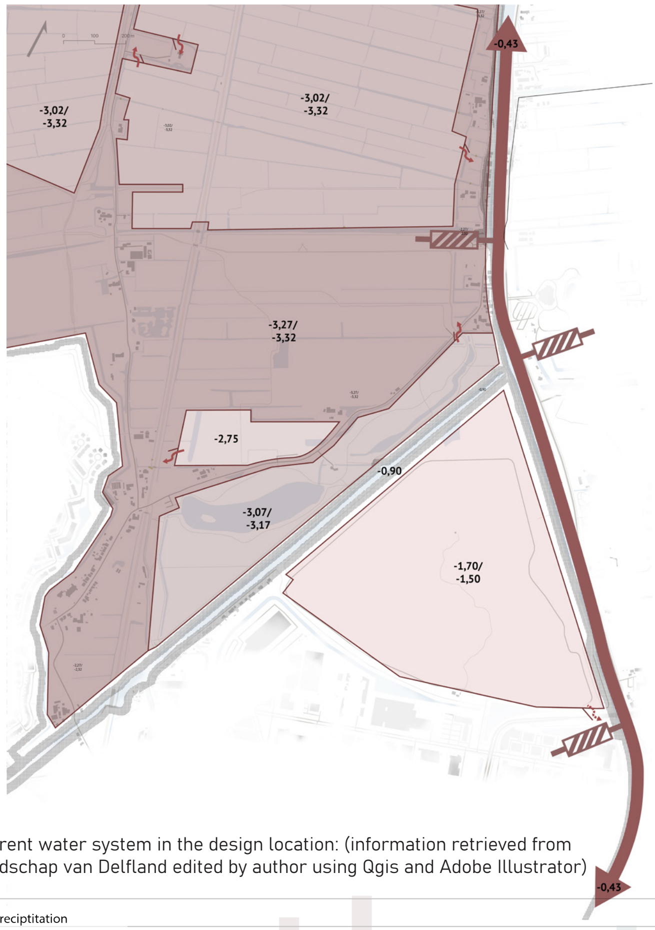


Figure 59: Current water system in the design location: (information retrieved from Hoogheemraadschap van Delfland edited by author using Qgis and Adobe Illustrator)

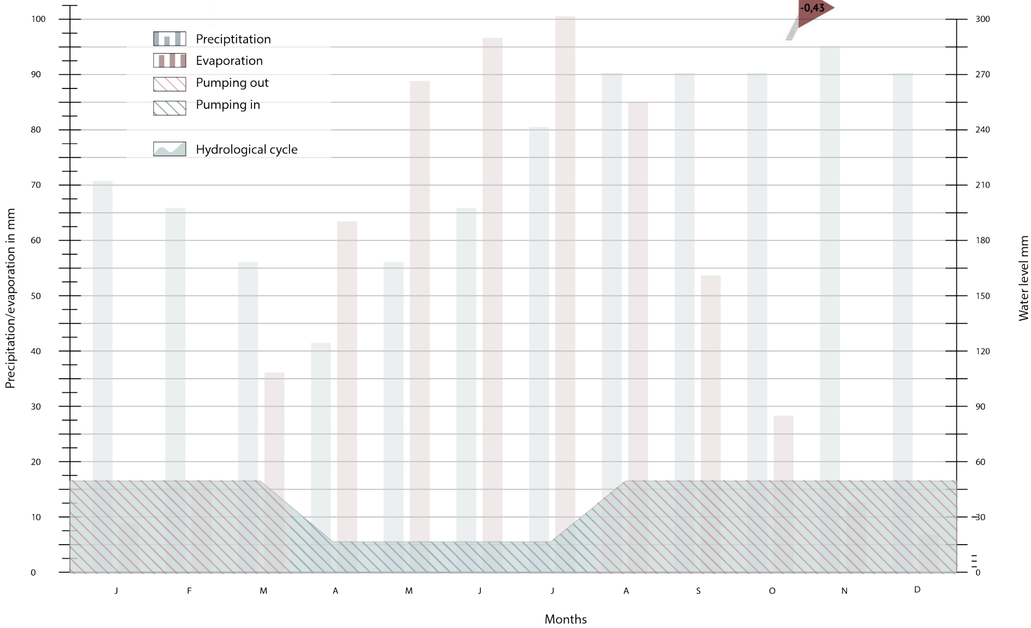


Figure 60: Graph of current water management in the Noord-Kethel polder (Created by author, data retrieved from KNMI).

INTRODUCTING FLEXIBILITY
new water management proposal

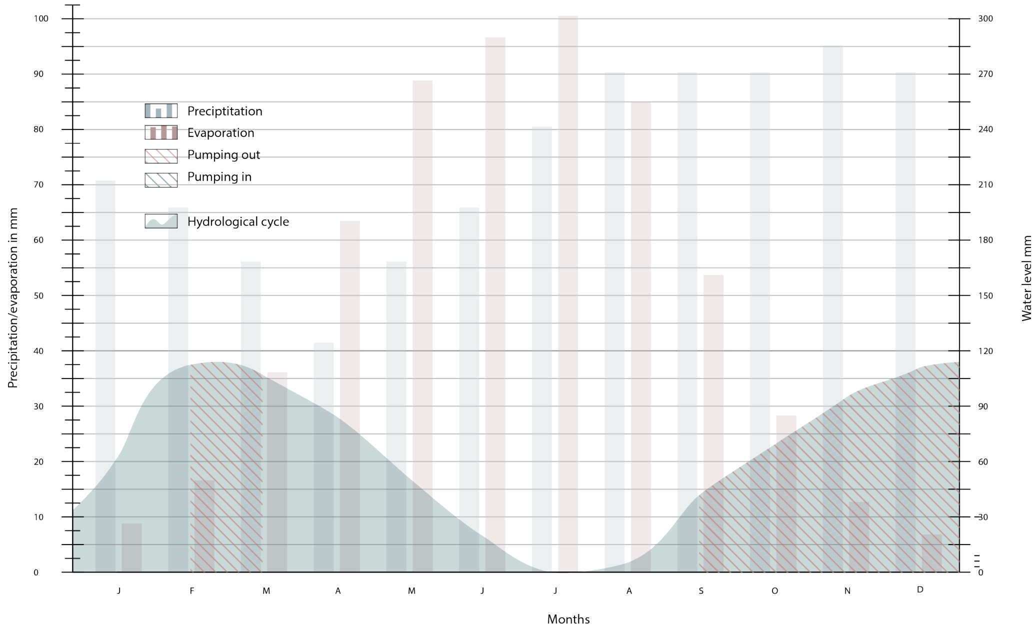


Figure 61: Graph of water management change in the North-Kethel polder (Created by author, data retreived from KNMI).

This design aims to heighten land gradually using the concept of the terp, so water levels can rise eventually to sea level, and water discharge happens naturally. Therefore, water management needs to change. The first implementation is to allow more water fluctuation in the polder. From January to March, precipitation that falls in the polder is discharged less. Water levels rise to 108 mm. From April to July, water levels decrease to the current water level as 108mm evaporates on average. No water needs to be pumped in the polder. From August to December, some water is pumped out to manage a maximum rise of 108 mm so it can evaporate during summer. As retrieved data is based on an average, pumping water in and out can vary according to the yearly excesses. With changing climate, more precipitation can be expected to fall in winter (+24%) and drought will cause higher evaporation creating a bigger change in water level. Current measurements will be used for the purpose of this research, to produce a linear design. Allowing for greater water fluctuations can be implemented immediately, as a fluctuation of 10.8 m will not endanger housing. Farmers will notice wetter ground level during winter, which is a negative side effect. Allowing more water in winter will help reduce peat oxidation contributing to a decrease in soil subsidence.
Over the first 10 years, the landscape is prepared for a bigger change: a graduate rise of + 1m.

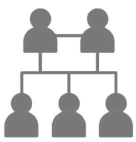


Figure 62: an intervention aimed to stay for1.5 generation

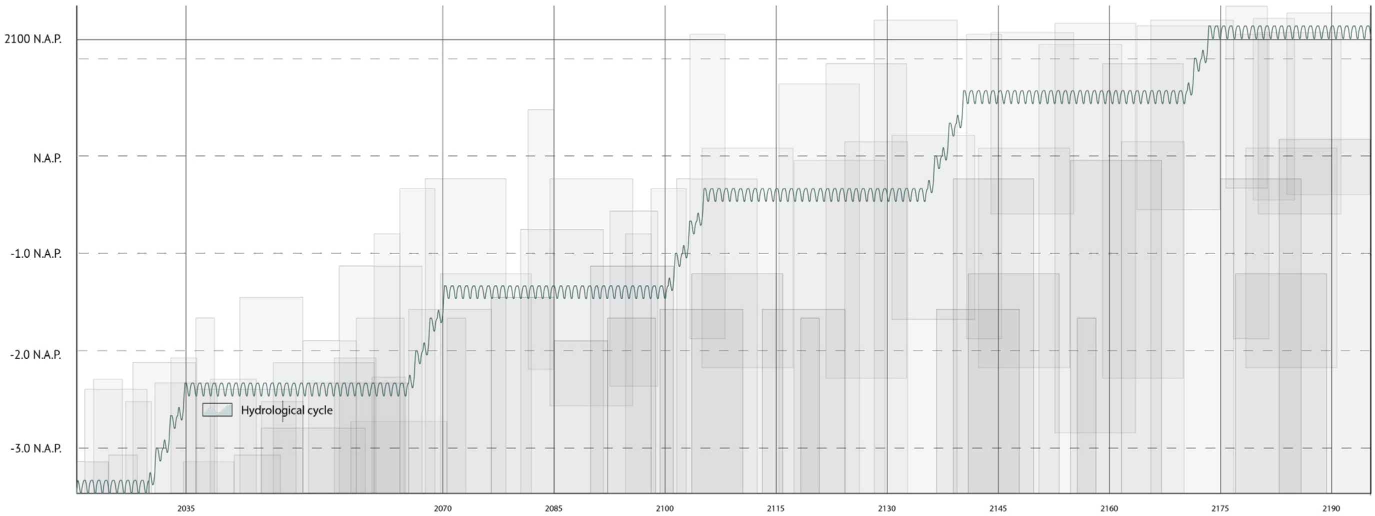


Figure 63: Water level in the North-Kethel polder over years with adapting soil levels to future water level change (Created by author).

This change in water level is the start of bringing water levels up to sea level while the landscape gradually adapts and curves with this change. + 1m increase intervals occur every 1,5 generation. In this way inhabitants can settle in-between these intervals building up their surrounding landscape without seeing it washed away. The start of this graduate change is a project with no end date. After 160 years, parts of the Noord-Kethel polder would rise above sea level. The landscape is set up to adapt to future changes of sea level as the concept of the terp is maintained.

The Noord-Kethel polder is an interesting location to implement different elements of the terp, although certainly not the only ground in which these elements can be implemented. The design aims to show an implementation of the concept of the terp in the polder to solve current water management problems. These design interventions are intended to work in similar locations.

PART ONE

The first part of the design shows a masterplan map (masterplan 1) of the future landscape of the Noord-Kethel polder, if water levels are increased +1m and elements of the concept of a terp are implemented in areas which are affected by the meter water level rise. The ensemble results in renovating houses to make them adaptable, heighten (parts of) roads, new forms of agriculture. With the design cut and fill principle to maintain current dairy farming, but also crop cultivation and paludiculture is introduced. The existing nature adapts, finding a new equilibrium in the wetter conditions. The waste collection hub will be a new feature in the location area, currently closed off, but in the design future a pop-up nature area. Further design interventions are discussed in zoom in plans, sections, impressions, and bird eye view, aiming on an integral understanding of the implementation of the terp in the design location of the Noord-Kethel area.

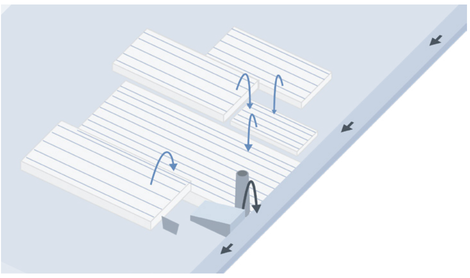


Figure 64: From different water levels, one type of soil condition

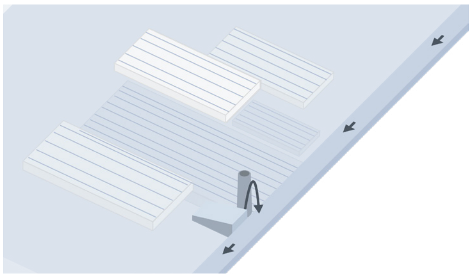
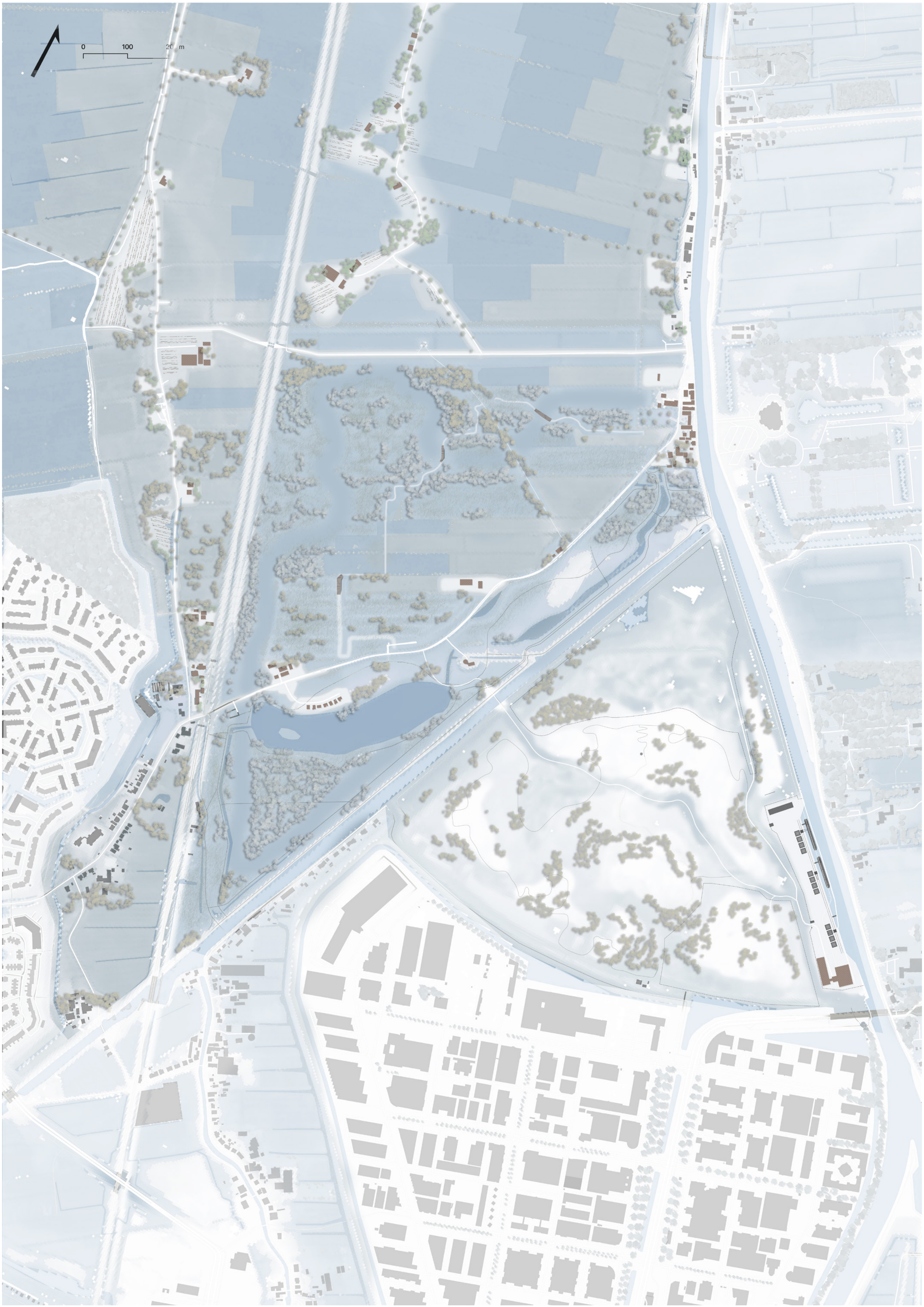


Figure 65: to One water level, different types of soil conditions

With the implementation of a meter increase of water level, different areas in the polder are equalized. Current division of polders create a uniform landscape at different water levels. Each area hosts a different water level to have similar conditions for farming. As the water levels are raised, a uniform water level is reached. On the contrary, soil levels have more variation. Some areas become submerged, other areas become wetter and other areas remain dry. The landscape becomes more diverse in this way, hosting different landscape characteristics.



Masterplan 1 of design location with +1m water level rise

ONE METER RISE
Letting in + 1m of precipitation

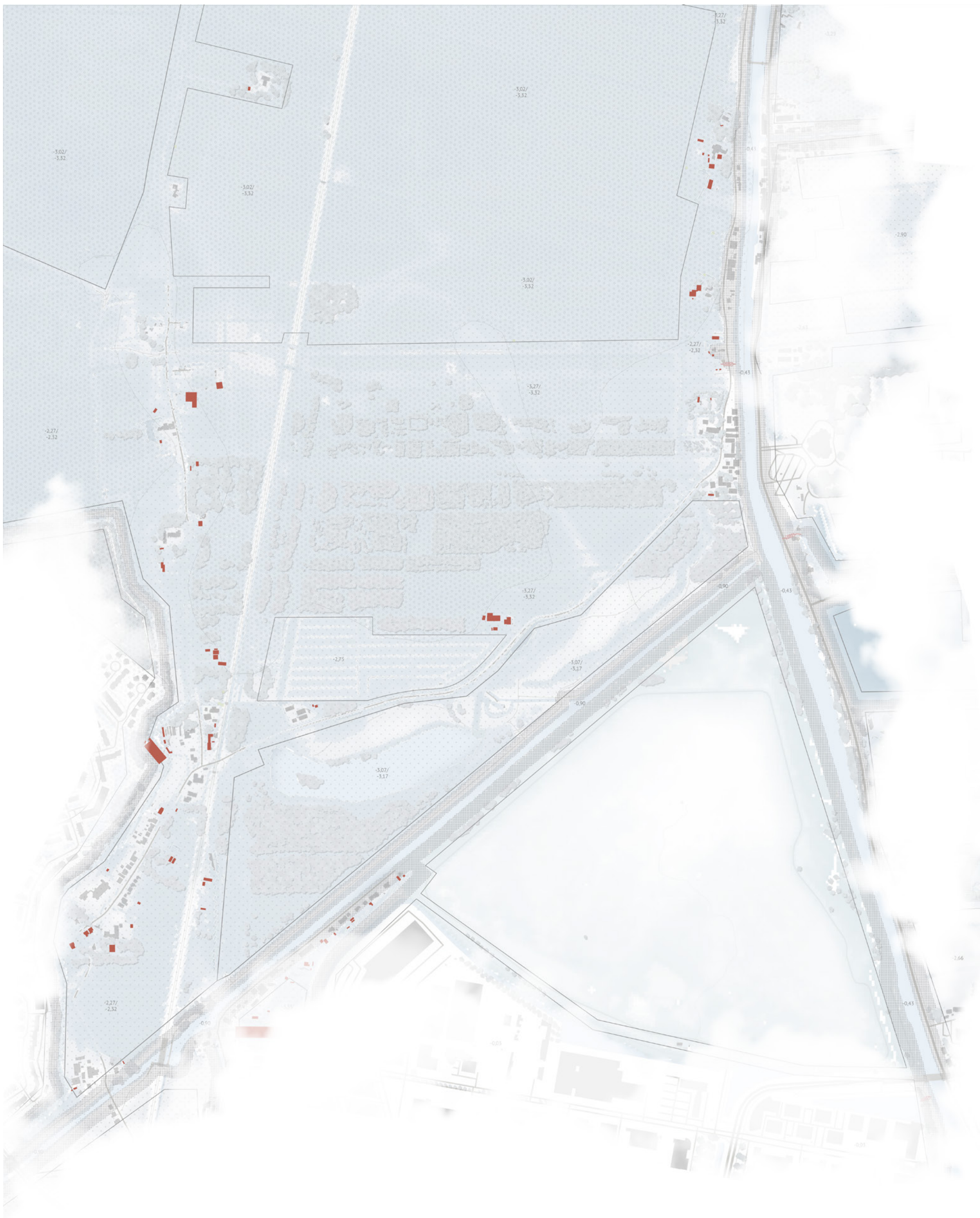


Figure 66: Buildings and roads which need to be heightened (Created by author using Qgis and Psd).

By allowing water levels to rise by one meter, from - 3,27m/ - 3,32m to - 2,27m/ - 2,38m N.A.P, the landscape changes significantly. Most of the agricultural and recreational land is submerged. Most of the houses have one meter clearance but some houses and roads need to adapt or be heightened to cope with the water level rise (map above).

ADAPTABLE HOUSING
from static buildings to a modifiable environment

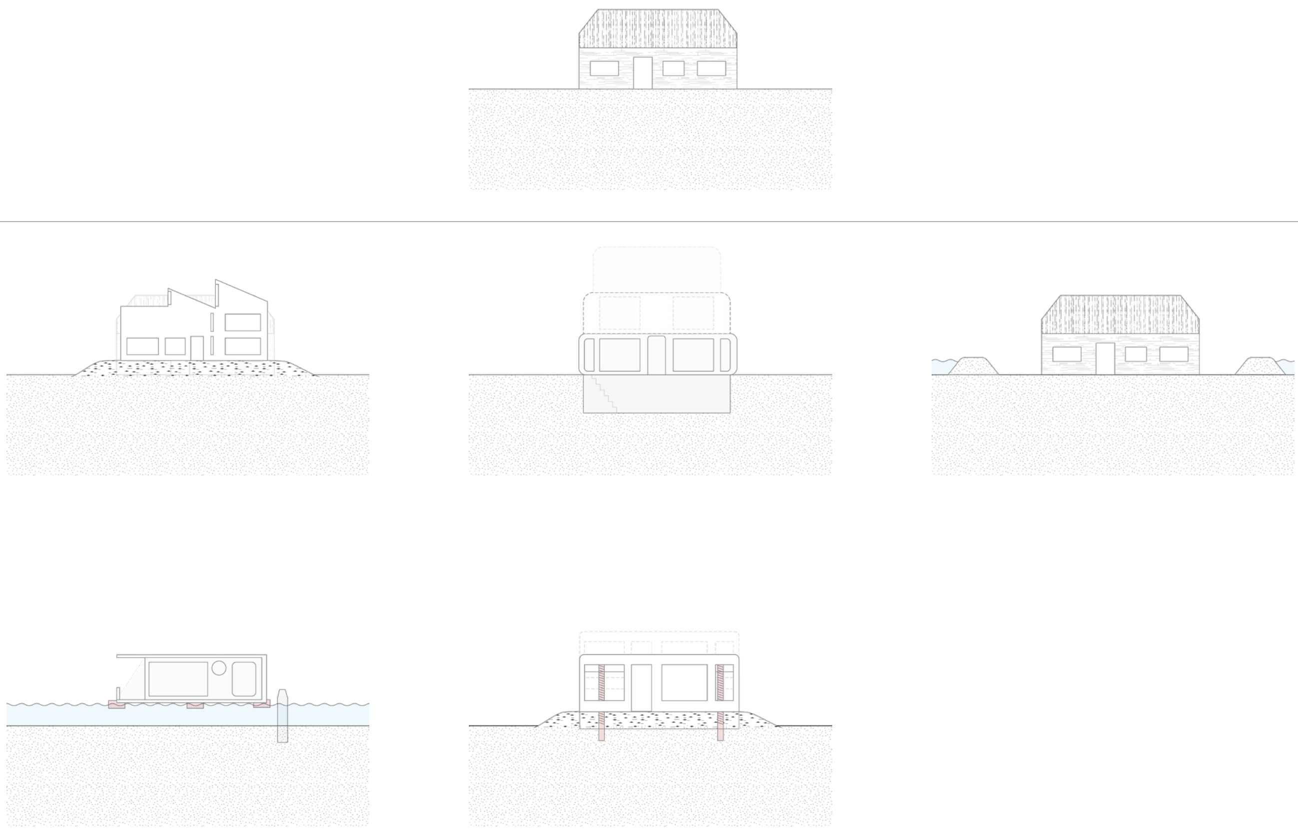


Figure 67: Range of adaptable housing options

Current housing is not built to adapt. Instead of heightening houses to meet new standards, houses need to be become adaptable, so changes can be made over 1.5 generation, when water levels are increased again. Houses can be rebuilt on old remains, by using demolished material as foundation (figure 67). Since demolished material is not enough, a different supplement is needed to create enough ground above the water level. Another option is to create buildings which are strong enough to support continuing to be built on top. The ground floor becomes the basement, the first-floor ground floor and a new layer can be added on top (figure 67). A third option is to have floating houses which continue to rise with changing water levels. When a home is not built on a stable high ground like a dike or a creek ridge, this type of house can be an option. A fourth option is to build a house on a foundation which can be heightened. Before water level is risen and soil is added to heighten ground, a house can be tilted using its adaptable foundation. As a last suggestion, applicable at cultural heritage or areas with high historical value, a dike can be laid around a home protecting it from high water levels.. As water levels rise, the vulnerability of the traditional polder is exposed, with high water levels surrounding such places.

As seen in the previous map, some roads need to be heightened at some places to reach above water. Interventions might be less drastic compared to the adaptations made to homes. Enlarging the structure by putting a layer on top of the low laying areas secures enough clearance from high water (figure 68).

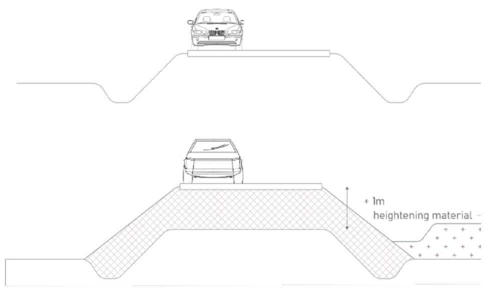


Figure 68: Heightening roads by enlarging the carrying structure

CREEK RIDGE ZOOM IN

Figure 69: Zoom in on top view of creek ridge (current situation)

Figure 70: Zoom in on section of creek ridge (current situation)

The Groeneweg located on the left part, running from North to South is an interesting part of the design, as the road is located on a creek ridge. The ridge is separating two water different levels: (-3,02 and -3.27 N.A.P). Behind the settlements soil levels decreases, hosting dairy farming. Enough root clearance between the soil and ground water level results in a variety of trees. Houses in this peat area are often build on a pole foundation, reaching to the stable sand layer. The small road has ditches on both sides, and with its elevated position it gives insight into people their gardens.

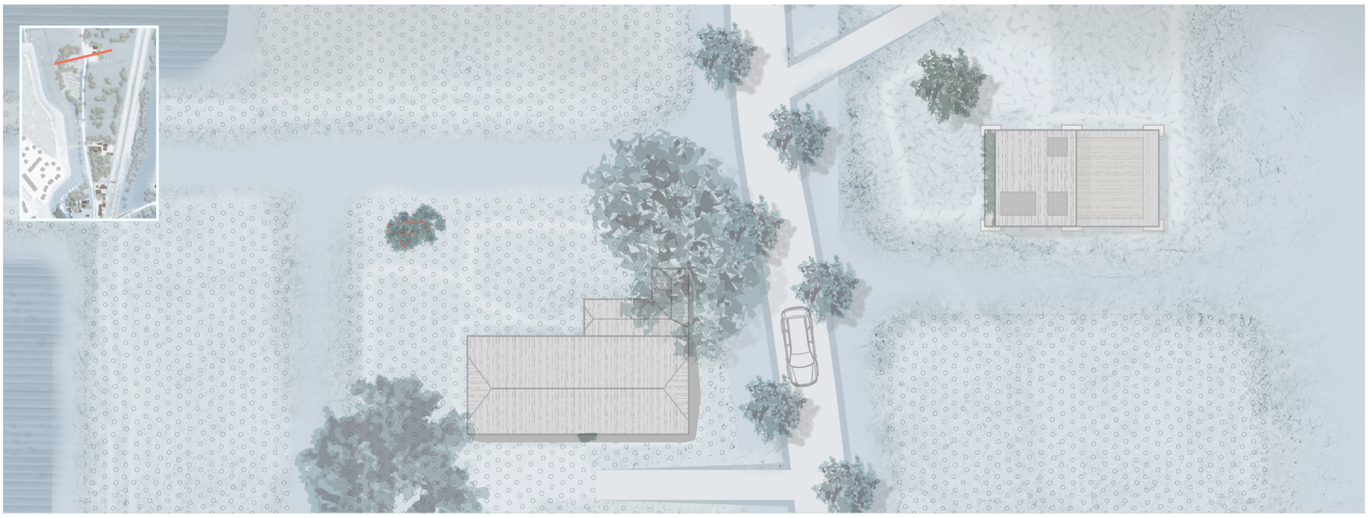


Figure 71: Zoom in on top view of creek ridge (design part ONE)

Figure 72: Zoom in on section of creek ridge (design part ONE)

In the Part ONE of the design water levels are made uniform and increased by one meter.
By using a cut and fill strategy parts of agricultural landscape is maintained as two parcels are combined to one. The opened parcel can be used for paludiculture. Existing trees will have to adapt to the heightened water level which is in some cases not possible. Older trees will suffer while younger trees can still adapt. Most houses on the Creek ridge are located above the increased water level of -2,27 and can be maintained for another 1.5 generation. Houses which are affected by the increase in water level need to be renovated and made adaptable. Landowners have had 1.5 generation to adapt. In this zoom in, the house located on low lying weak peat soil, can best become a floating home, built on the remains of the former home. The area host new species as the aquatic habitat has been enlarged.

PRESERVING CULTURAL HERITAGE

The hamlet of the Noord-Kethel has historic value with the Sint Jacobus de Meerdere church. The area is surrounded by the Train track in the East, a dike along a modern neighborhood of Schiedam in the West and the dike of the Noord-Kethel polder in the South. Closing this area off is relatively easy by prolonging the height of the road after the train track. In this way a small, isolated polder is created. With the design in place the road becomes the border between the futuristic polder and the low-lying hamlet as can be seen in the impression of figure 74. With this clear border the vulnerability of the lower lying polder becomes more evident as the little dike is the only barrier, holding back the waterbody of the Noord-Kethel polder.

Figure 73: The isolated hamlet of Noord-Kethel

Figure 74: an impression of the design in place, with the kerkweg road protecting the Noord-Kethel village.

WASTE LAND HUB

storing future land combined with nature and recreation

In the South-East of the location a waste hill in the form of a triangle can be found. Current stored soil needs to be measured as the soil is polluted. After remediation of the soil, new soil can be distributed. In the Netherlands 65% of organic waste material is collected, totaling 1762 kton (1kton = 1 million kg) (Rijkswaterstaat, 2020). The first parts of the composting material are fermented, emitting gasses which can be reused as biofuel. After fermentation and composting 40% of the original weight remains. 1 cubic meter of compost equals 750kg. The content capacity of the waste hill is 3600,000 cubic meters. Which means 27,000 kton of compost can be stored. As compost is extremely fertile, it can be mixed with other less fertile materials and still be fertile (Hanegraaf 2021). To fill the waste hill with 50% of organic material 1350 kton needs to be collected over 30 years (1.5 generation). This means 45 kton of organic material needs to be collected equaling 1,6% of the total annual Dutch organic waste production.

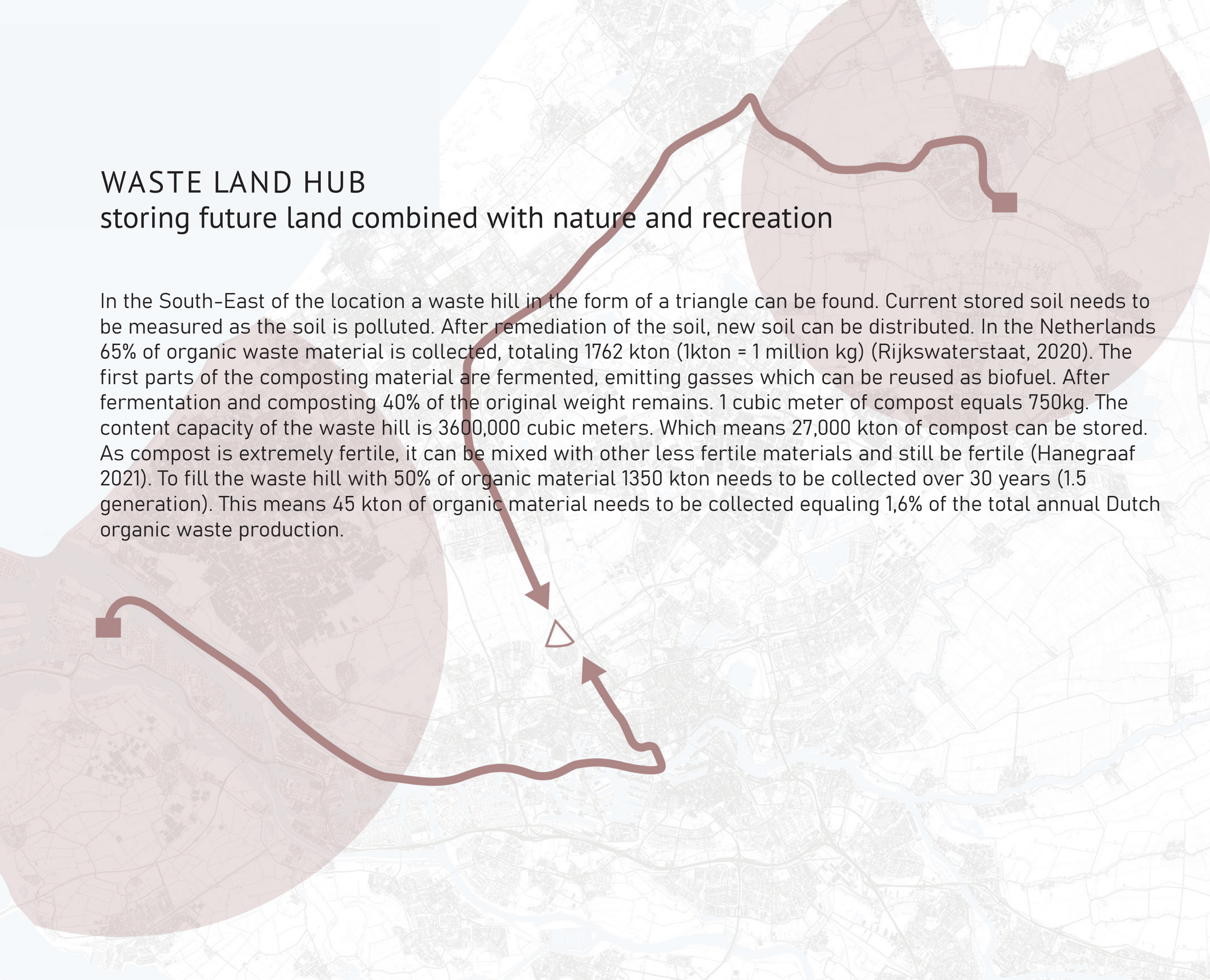


Figure 75: Waste collection in the port of Rotterdam and Alphen aan de Rijn, transported over water to design location.

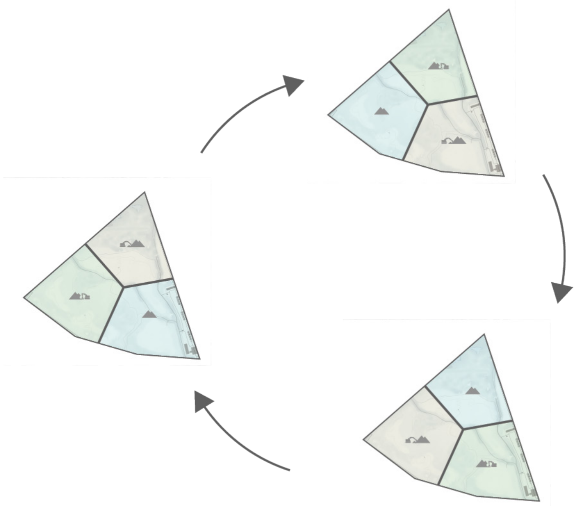


Figure 76: Alternating system of waste collection hub.

Material stored at the hill can be spread out over the land once water levels are heightened. The hill consists of three parts: an area where incoming material is stored. A resting part in which vegetation filters part of the waste material and is combined with recreation. And finally, a disposal area in which land is dispersed over the Noord-Kethel polder providing heightening material for houses, agriculture, or nature areas. These three areas alternate over time, providing an alternating scenario for recreational users.

WASTE COLLECTION HUB

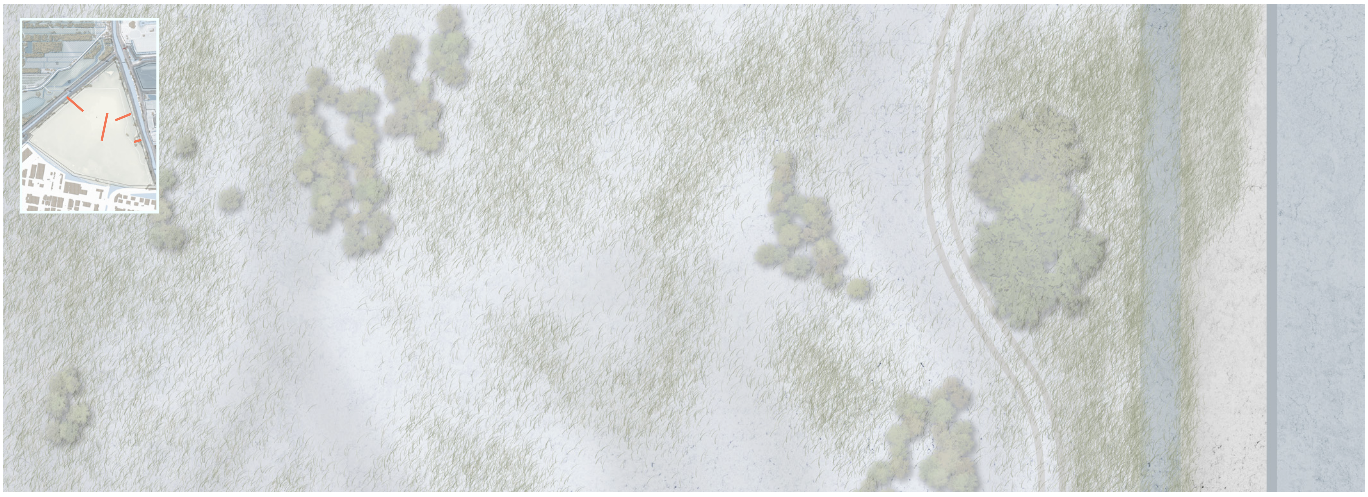


Figure 78: Zoom in on top view of waste collection hub (current situation)

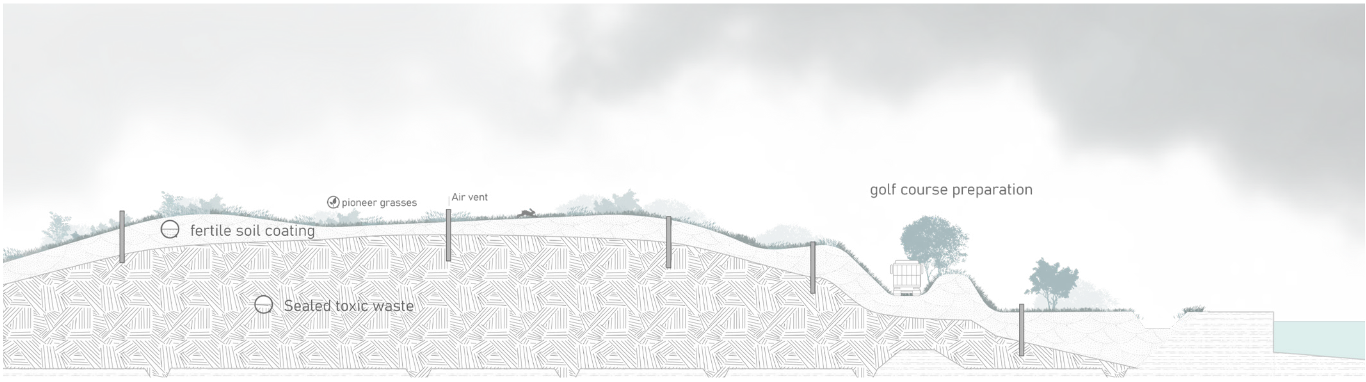


Figure 79: Zoom in on section of waste collection hub (current situation)

The current sealed of waste hill is planned to become a golf course. Toxic waste material is encapsulated, sealed off and a fresh layer of soil is placed on top. Tubes emitting gasses and monitoring the toxic waste. The last two decades, the hill is being prepared for a golf course.
One can imagine that within the scope of this thesis the golf course does not fit the design approach. Therefore, the hill is transformed to a usable hill which can provide fertile material to heighten parts of the polder. Toxic waste is dismantled and (fertile) waste material is collected.

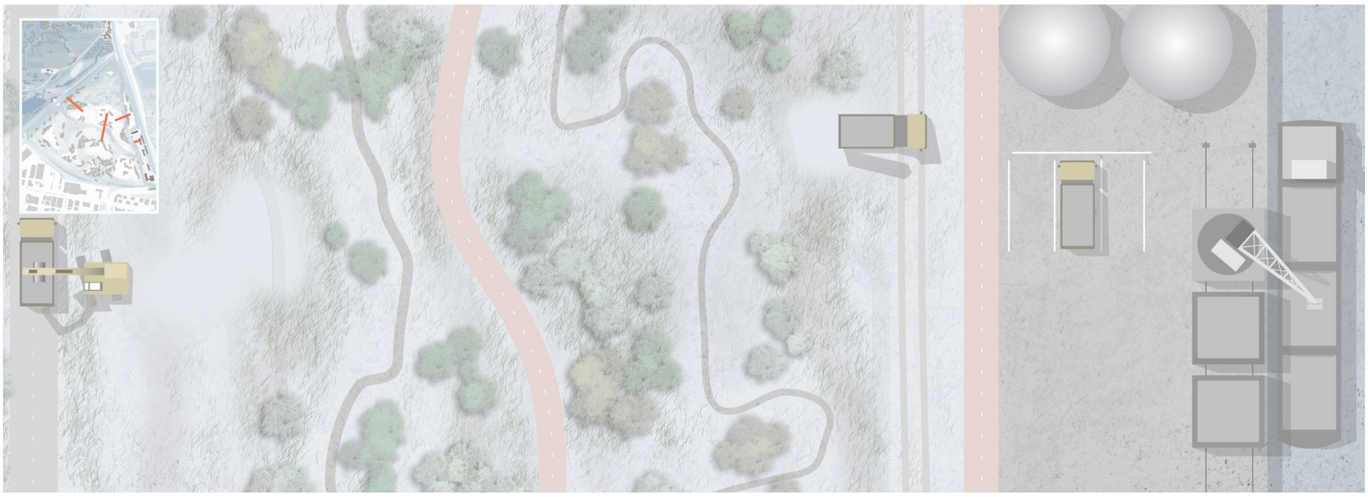


Figure 80: Zoom in on top view of waste collection hub (design part ONE)

Figure 81: Zoom in on section of waste collection hub (design part ONE)

To create this future land storage, a hub is put into place along current jetty. Waste can be brought in by boats using biogas emitted by composting organic waste material. Material is collected or incorporated for further composting. Trucks place material in the storage area where waste is collected. Areas which have been completed can be opened to public. Ecological process takes place, providing place for drier species as the oak, poplar birch and ash tree. New types of flora provide simultaneously new habitats for fauna. A pop up desing of this area creates paths lasting for 1.5 generation, when the collection cycle of the hill is change. This results in a main road around the hill, one cutting through the middle, which is connected to different cycling routes in the area. The hills can be the playground for MTB routes or forest strolls, with places to sit and overview the polder landscape, as the elevated point of view of the hill is benefitted.

AGRICULTURE ZOOM IN

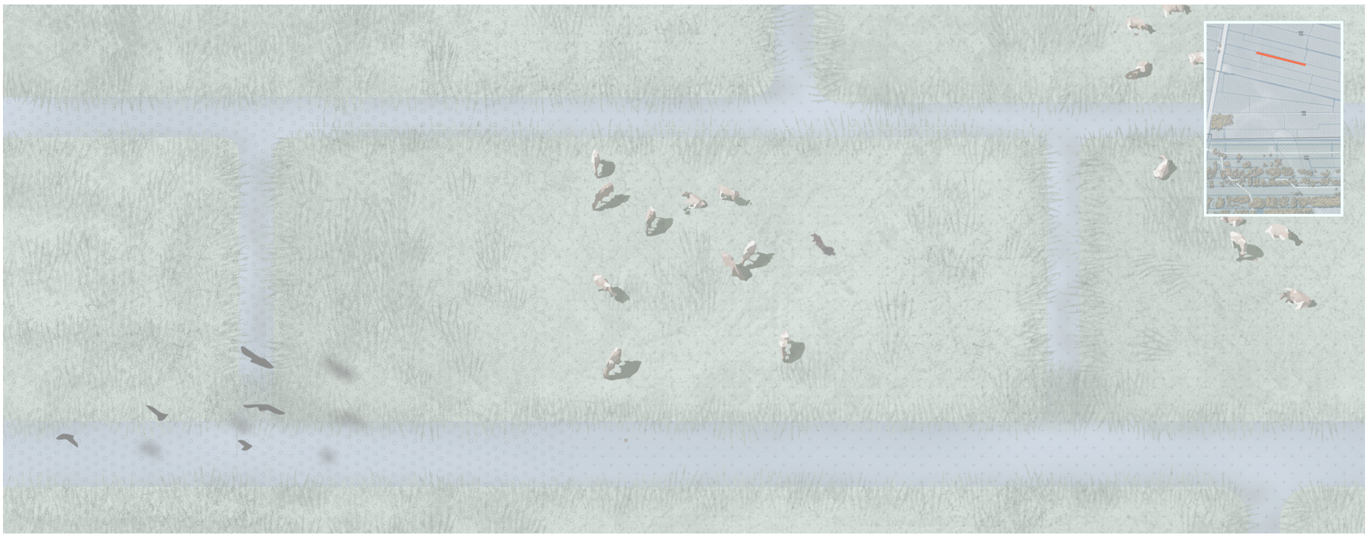


Figure 82: Zoom in on top view of agricultural land (current situation)

Figure 83: Zoom in on section of agricultural land (current situation)

Current agricultural land is mostly used by dairy farming. The oxidating peat soil is usable for grass cultivation. The wide landscape gives a serene view over green meadows reaching the horizon. Birds can be seen flying, grazing, and resting. Cows pasture in spring and summer. The open horizon is a big contrast with the surrounding cities of Delft and Rotterdam.

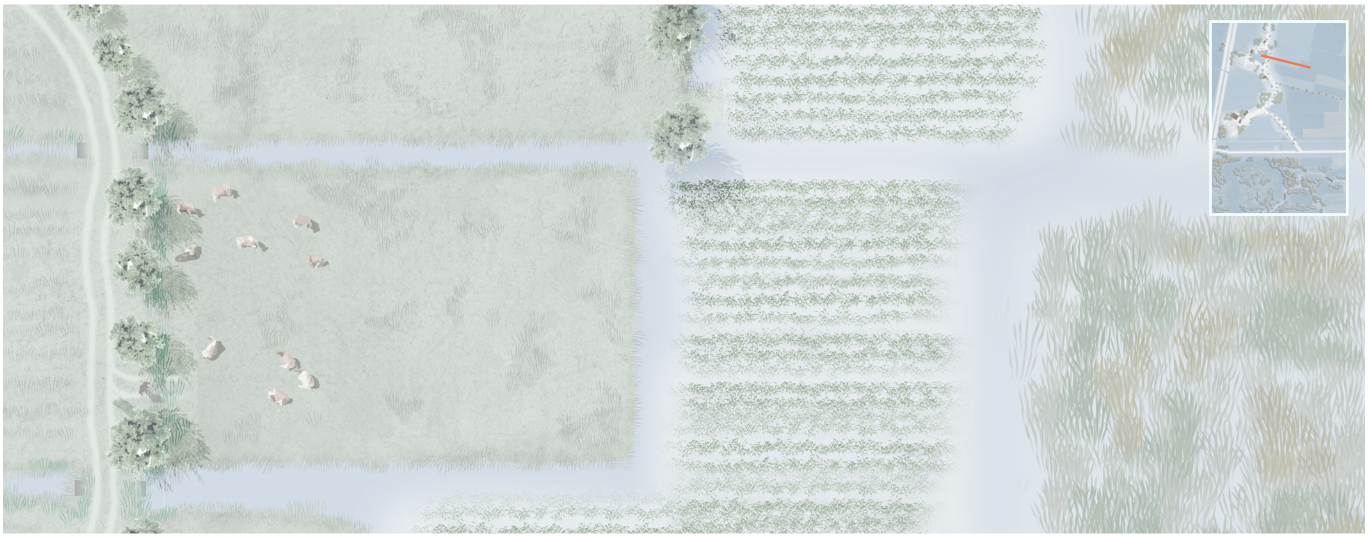


Figure84: Zoom in on top view of agricultural land (design part ONE)

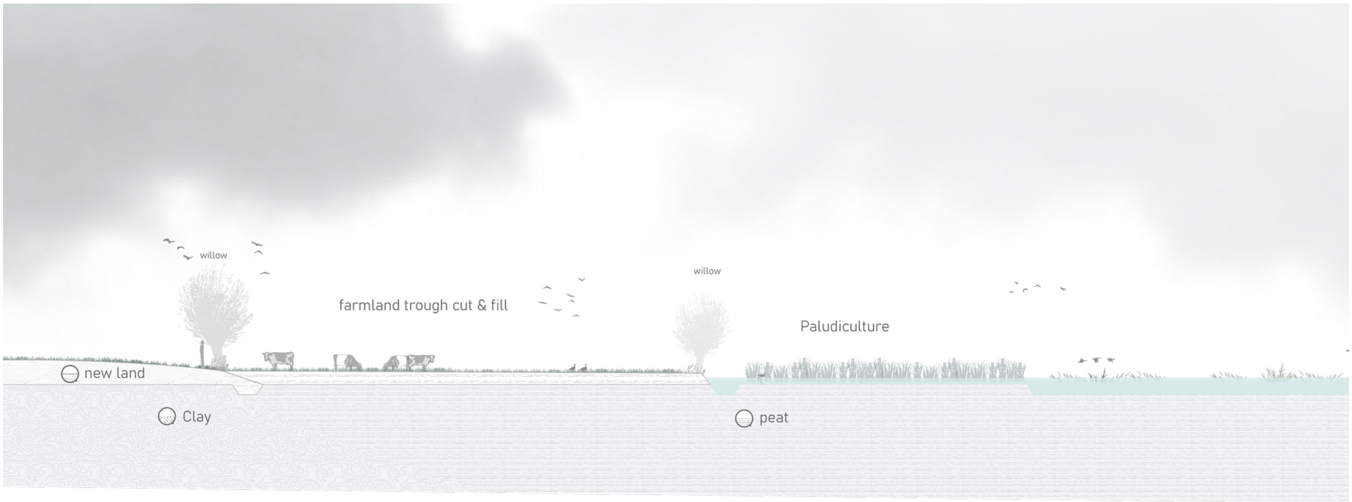


Figure 85: Zoom in on section of agricultural land (design part ONE)

Current ground level has on average 40cm of clearance with the water level. With a rise of +1 meter, most agriculture will need to adapt. Initially, efforts must be combined. By using the cut and fill principle, some areas of the treated top soil layer are removed and added to another parcel. In this way, a part of the land remains usable for cattle farming, the wetter parts can be used to develop paludiculture. By using nitrogen filtering crops, water quality is improved. On the stable ground of creek ridges, organic waste material can be laid out forming a base for crop cultivation. Using organic waste material to heighten parts of farmland, creates more fertile soil conditions compared to the traditionally poor peat soil. Crop vegetation increases a farmers income, as crop cultivation is almost 40% more valuable than cattle farming (Plambeck, 2019).

ECOLOGICAL GRADIENTS

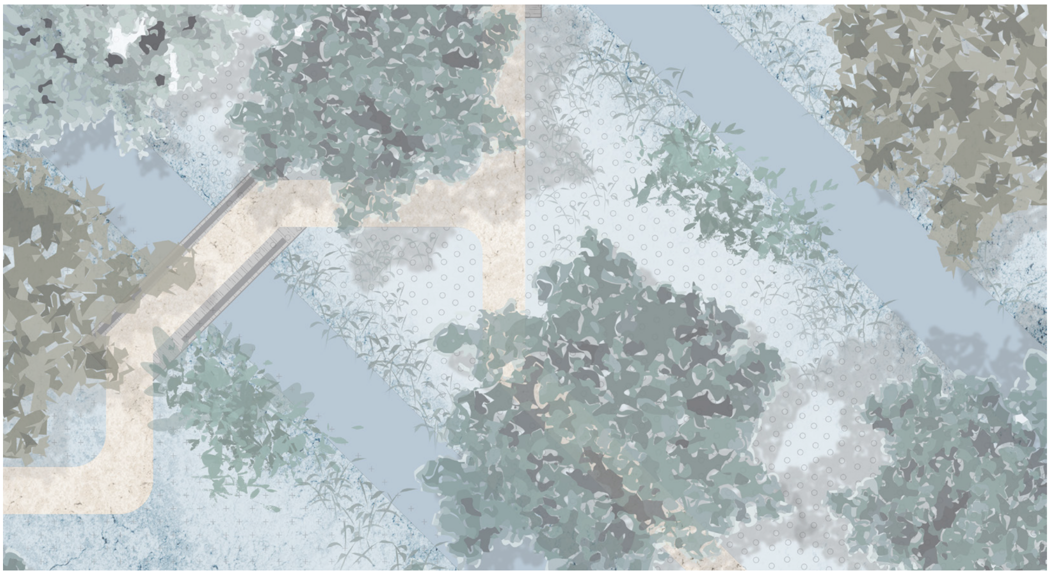


Figure 86: Zoom in on top view of recreational area (current situation)

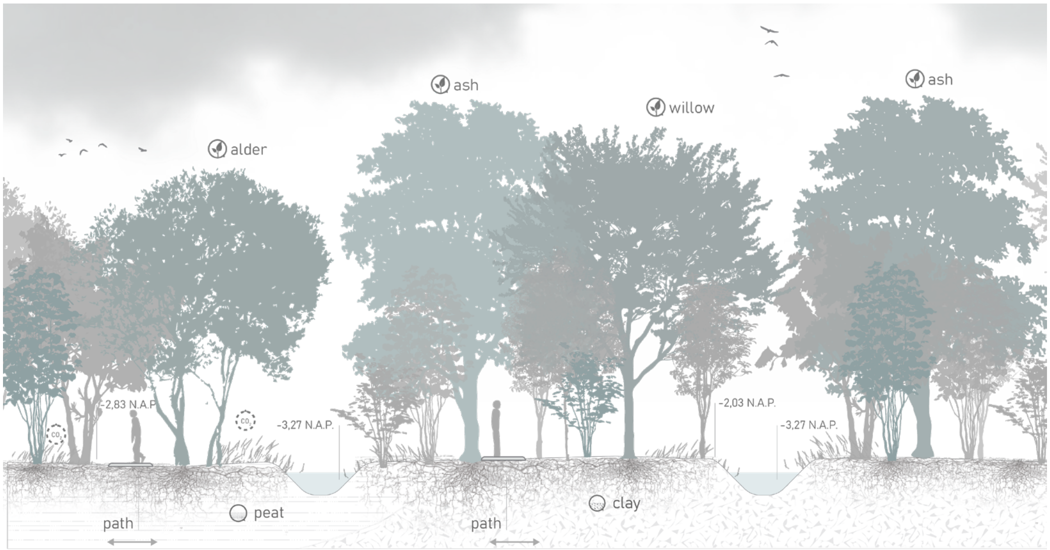


Figure 87: Zoom in on section of recreational area (current situation)

Current recreation area of the Poldervaart hosts dense vegetation. With a variety of dense grasses, Ash, Alder, Elm and Willow trees. Different water levels provide similar soil conditions as root clearance is the same. This results in a monotonous forest of the Poldervaart. Ditch pattern of the former polder farmland is maintained giving the impression no maintenance was done after the creation of the nature area resulting in current vegetation growth. Co_2 still emits, as water levels are maintained as low as the surrounding parts of this area.

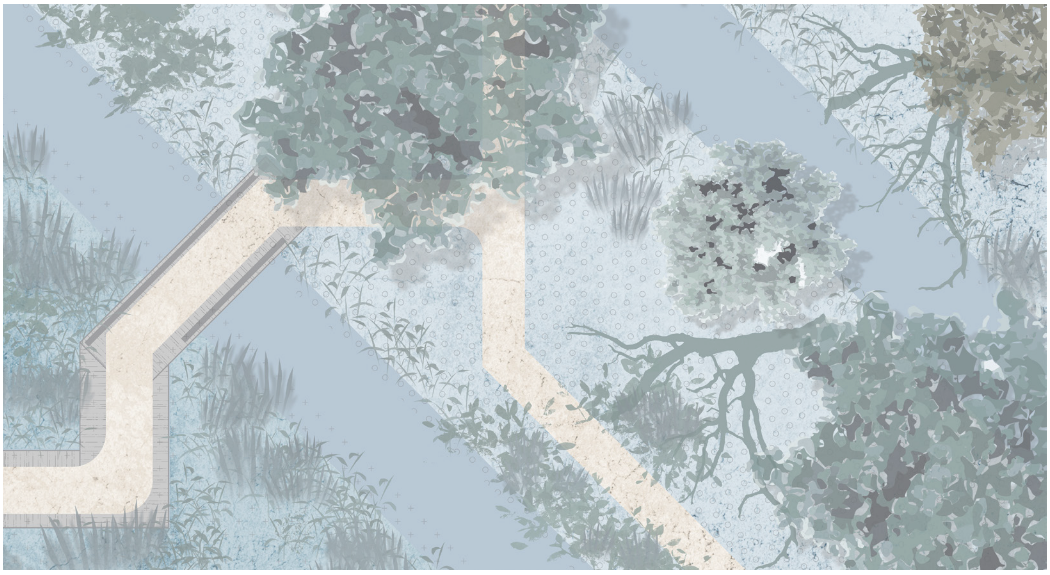


Figure 89: Zoom in on top view of recreational area (design part ONE))

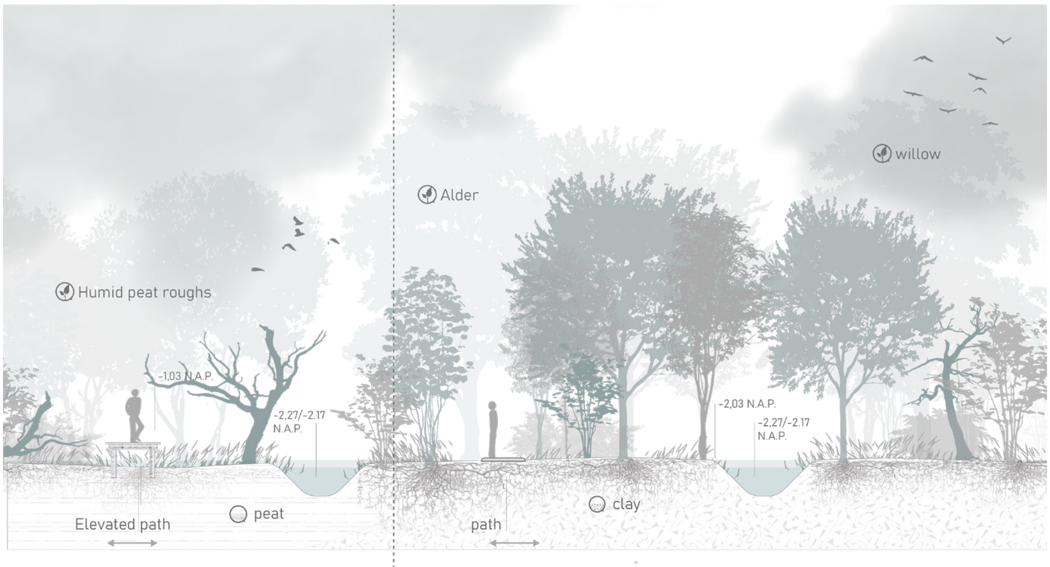


Figure 90: Zoom in on section of recreational area (design part ONE)

With a more flexible water level, Ash trees on the lower grounds will have difficulty to survive. With a meter water level rise, many trees can not survive in their current shape. After implementation of the first part of the deisgn, the area undergoes a significant transformation. Organic remains will serve as a fertile base for new forest development. In the wettest and thus lowest parts a Birch-Alder forest develops. On the higher grounds Ash trees will be found. The grounds containing clay will mostly be covered by Willow trees. The recreational area becomes wetter, providing different gradients for ecological developments. Current recreational paths need to be revised and in lower parts adapted by implementation of an elevated walk, creating a new experience for visitors as this area can be seen from a different point of view.

PART TWO

The second part of the design shows a continuation of the first part of the design. Within the approach of surmounting the polder and creating land above sea level the second meter of water level increase is implemented in this phase. Wherein phase one, landscape elements could handle the meter increase, a second meter increase effects even the higher parts.
In this second phase a clearer structure of the elements of the terp come forward. The design is shown in masterplan two, illustrating the continuation of implementing elements of the terp into the Noord-Kethel polder area. Creek ridges start to form the landscape as they become one of the few places which are located above the water. Houses continue to become adaptable, and on or around creek ridges. Creek ridges provide extra space for housing increasing the number of households in the area. A shift in strict division of function is put into action. Segregation between buildings, agriculture and nature is minimized. Houses are prioritized and build on creek ridges, also in the former Poldervaart recreation area. With increased water levels more space is given back to nature, making up space which was lost in the recreation area. Agriculture hosts a wider range of activities. The dryer creek ridges provide space for crop cultivation providing higher income compared to traditional dairy farming. Paludiculture is rolled out in the wetter areas and in aquatic areas fish farming takes place. The system of a whole become more intertwined and less segregated as housing is in close contact with agriculture, and nature is present in all facets of the new polder. The waste storage hub provides a former unknown landscape type in the polder. Height differences are used for the new temporary design of the recreational routes over the hill.

The green polder changes to a blue polder with green strings located on former creek ridges. The open landscape is maintained and future developments on water and sky can take place, providing new forms of mobility. In the next part of the design, previously covered zoom in areas will be analyzed again, showing continuation of implementation of adaptable landscape elements following the concept of the terp.

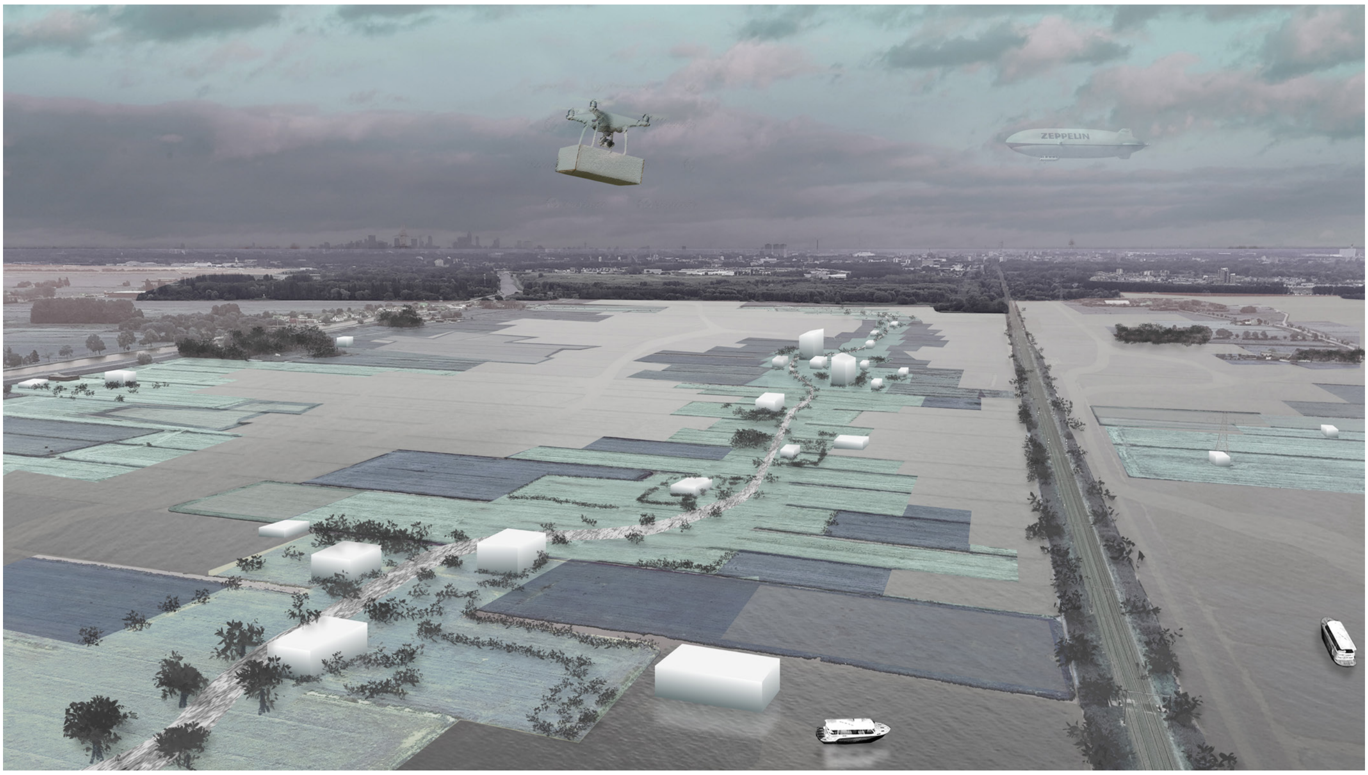
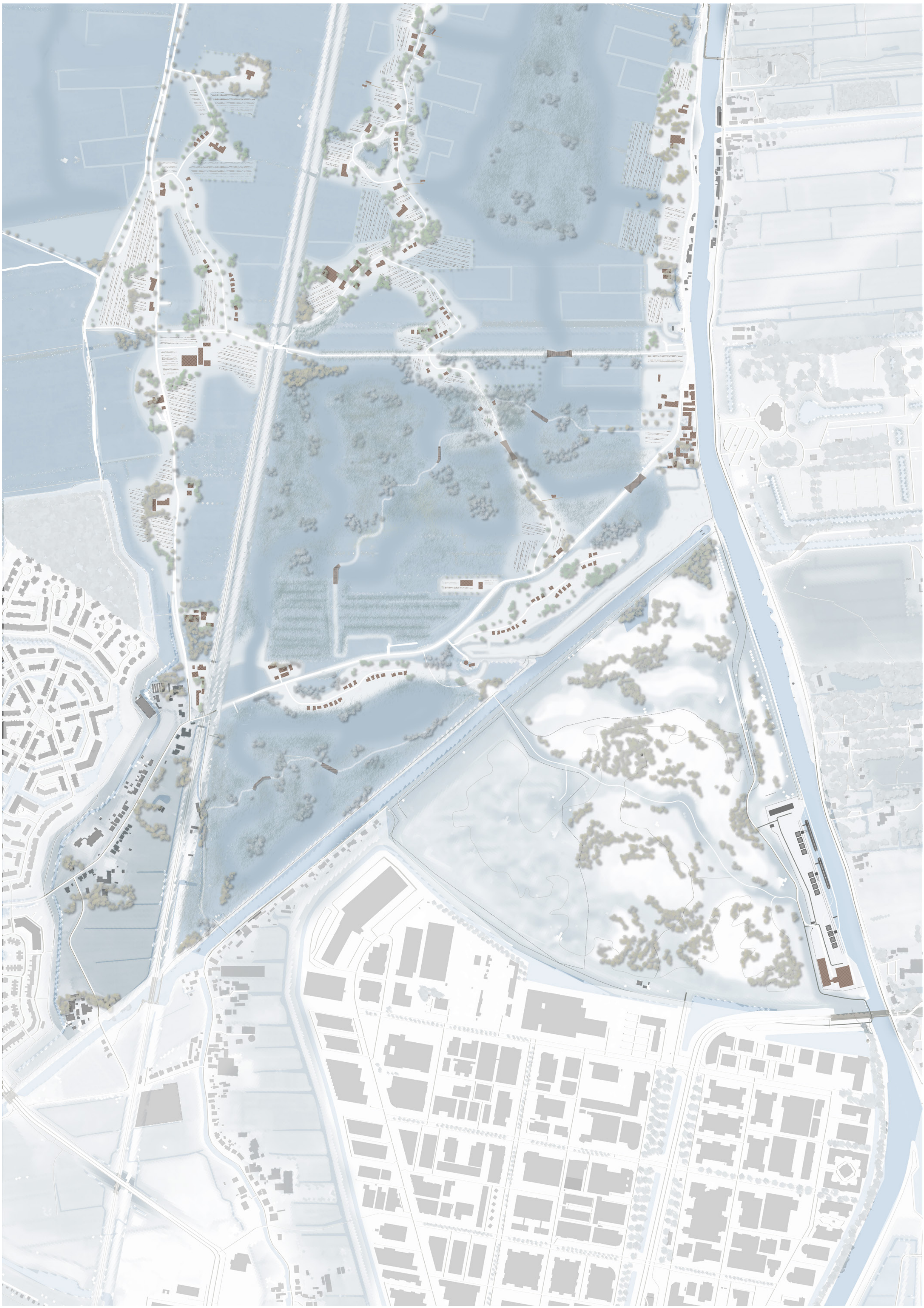


Figure 91: Birdeye view impression of the future Noord-Kethel polder



Map 2: Masterplan of design location phase II

CREEK RIDGE ZOOM IN

Figure 92: Zoom in on top view of creek ridge (design part ONE)

Figure 93: Zoom in on section of creek ridge (design part ONE)

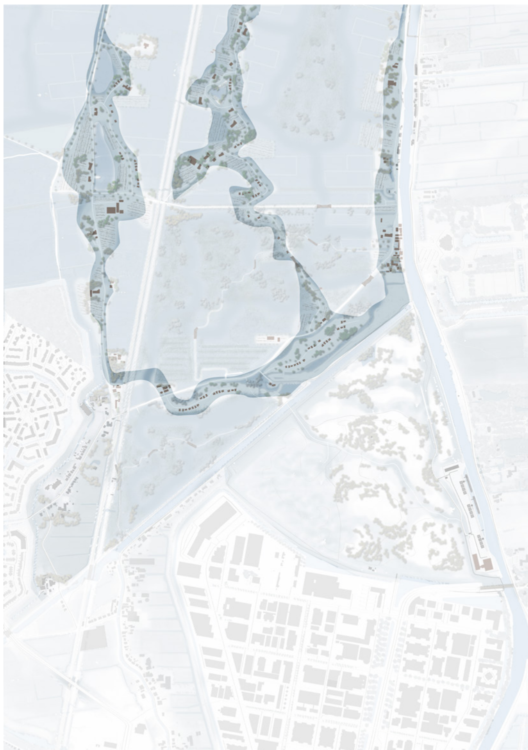


Figure 94: map overview of creek ridges

Compared to the first part of the design the creep ridges start to emerge from the polder (figure 94). In this next phase all houses have become adaptable. The new house in the middle is built on an adaptable foundation (figure 95 and 96). The house to the right, on the other side of the road has started floating with the increased water level. The Creek ridge has been heightened with waste material provided by the waste collection hub. Precipitation has a natural runoff, to which the ditches have been removed. The fertile ground provides space for new species. Crop cultivation can take place providing bigger income for farmers. Increased water levels result in too wet conditions for paludiculture, new forms of aquatic cultivation like duckweed growth and fish farming are implemented. Creek ridges become reachable over water as can be seen in the far right where an amphibious bus drives out of the water.

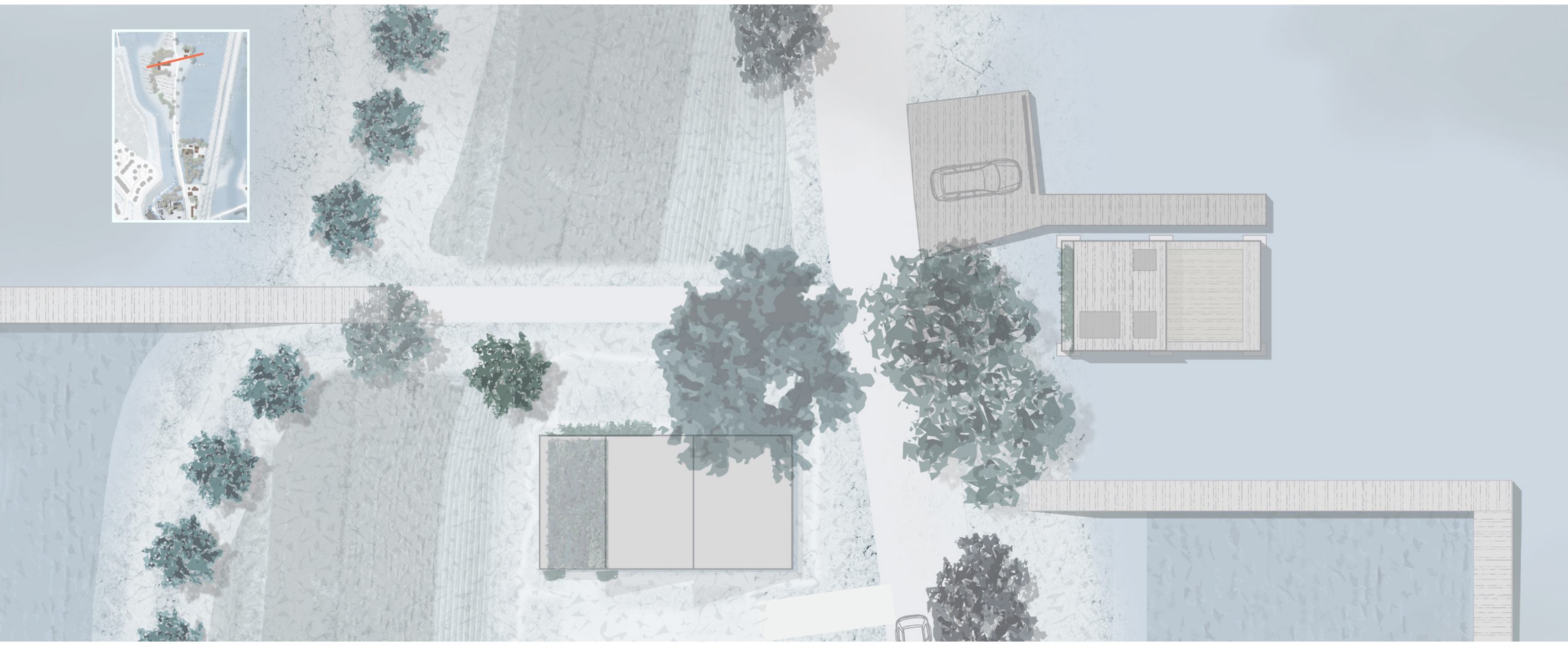


Figure 95: Zoom in on top view of creek ridge (design part TWO)

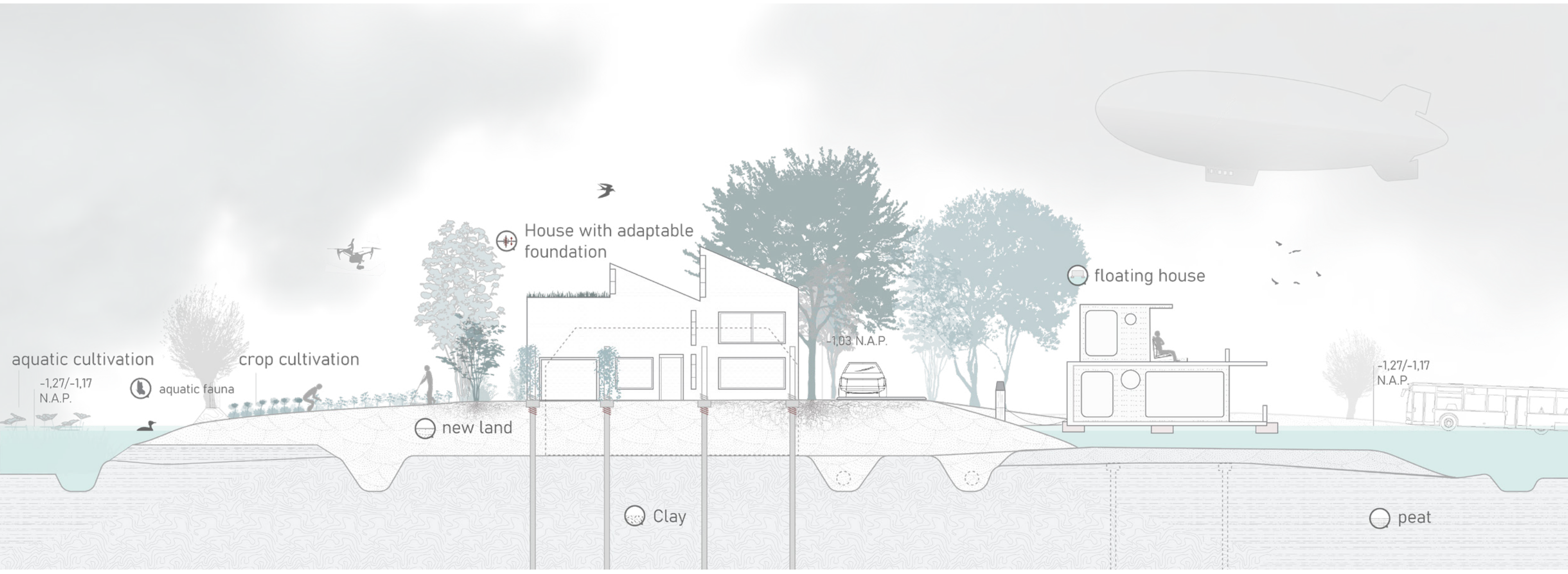


Figure 96: Zoom in on section of creek ridge (design part TWO)

WASTE COLLECTION HUB ZOOM IN

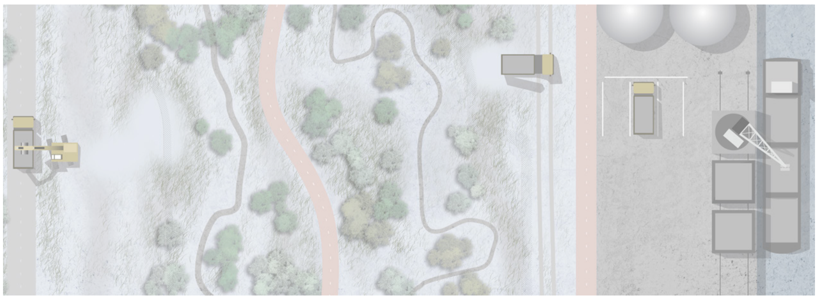


Figure 93: Zoom in on top view of waste hill (design part ONE)

Figure 97: Zoom in on section of waste hill ridge (design part ONE)

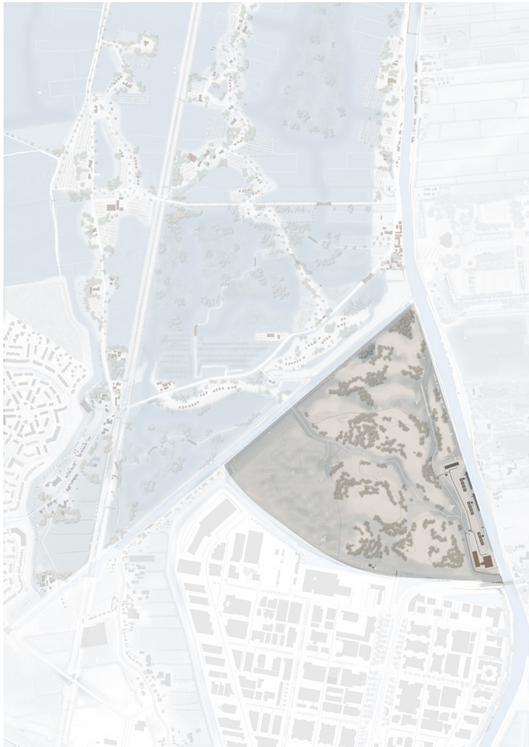


Figure 98: map overview of waste collection hub

The waste collection hub remains mostly the same although the contents switch. As land is spread out over the polder, empty parts of the hill can be refilled. The former deposition area becomes the recreational area as waste has settled, and a new design can be made to make this part of the hill publicly accessible., the recreational area becomes the takeout area and the former take out area becomes the new waste deposition area. New paths are designed through the new recreational area. Providing new view lines and recreational possibilities as somebody is sitting on a bench, looking over the waste collection hub (figure 100).

Figure 99: Zoom in on top view of waste hill (design part TWO)

Figure 100: Zoom in on section of waste hill (design part TWO)

AGRICULTURE ZOOM IN

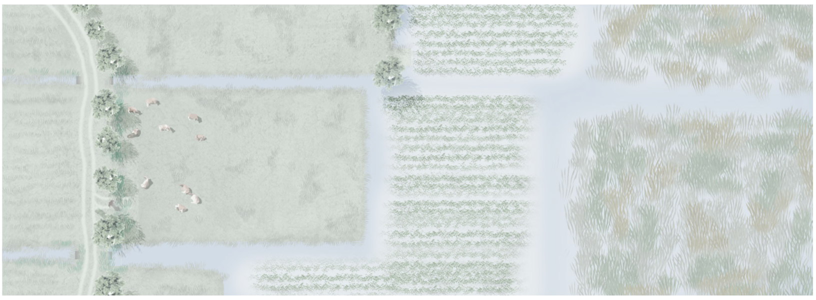


Figure 101: Zoom in on top view of agriculture area (design part ONE)

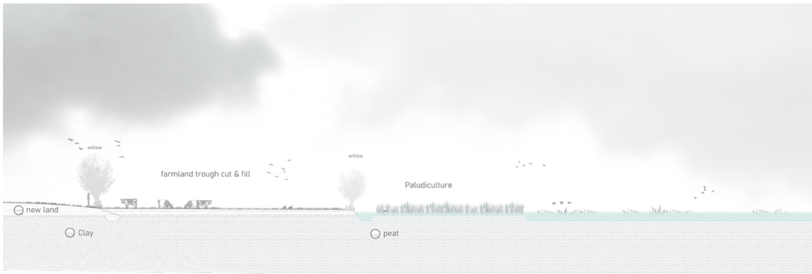


Figure 102: Zoom in on section of agriculture area (design part ONE)

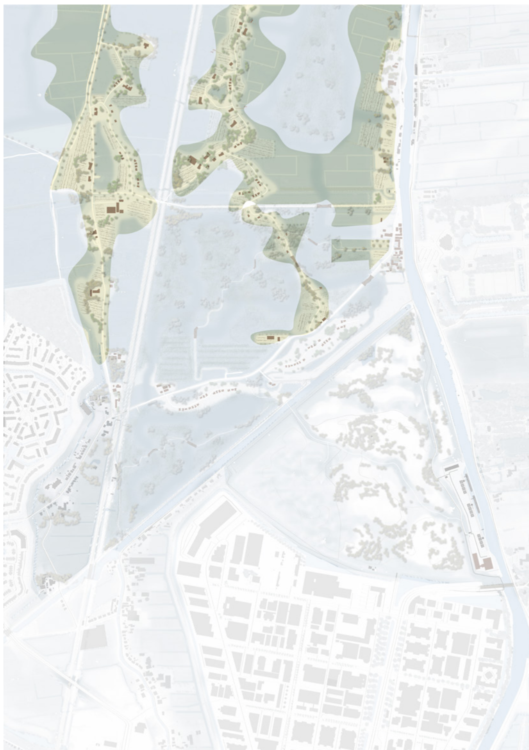


Figure 103: map overview of agriculture areas

In the second phase of the design farmland becomes more agglomerated to the creek ridges, the higher parts of the polder. Closer to the higher parts of the ridge, crop cultivation takes place, providing more profit compared to dairy farming, so smaller portions of land need to be covered. Only 73% of the original dairy farming space as crops cultivation is almost 40% more profitable. Away from the creek ridge land is less stable and other forms of agriculture appear. Aquatic cultivation like fish farming takes places towards the deeper polder areas. The dams providing space for historic landscape elements like pollard willow rows. The Extensive way of farming provides more interaction with recreation as more paths along agricultural fields can be found. Run-of ditches between the parcels provide space for aquatic transportation to dock. The parts to the right, further away from the creek ridge are abandoned from agricultural use as peat continues to develop in this area, fixating CO_2. The agricultural field have been scattered over the design location being implemented on a more local scale integrated with housing and nature.

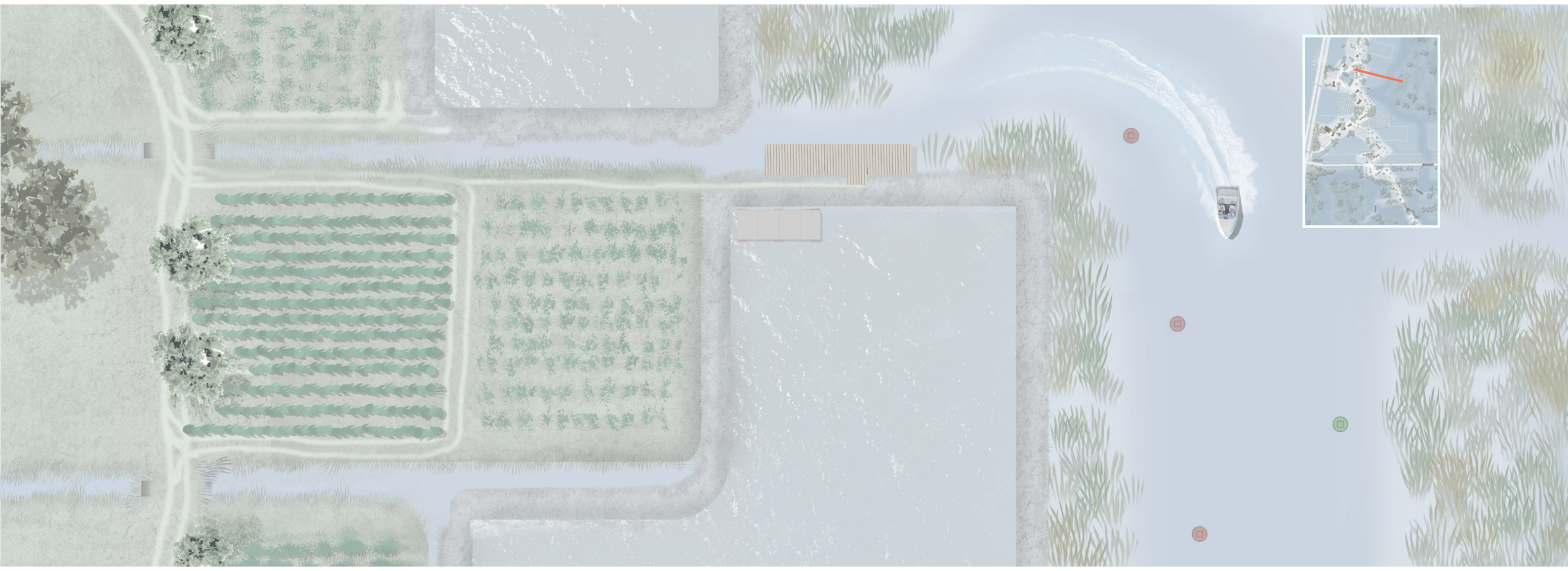


Figure 104: Zoom in on top view of agriculture area (design part TWO)

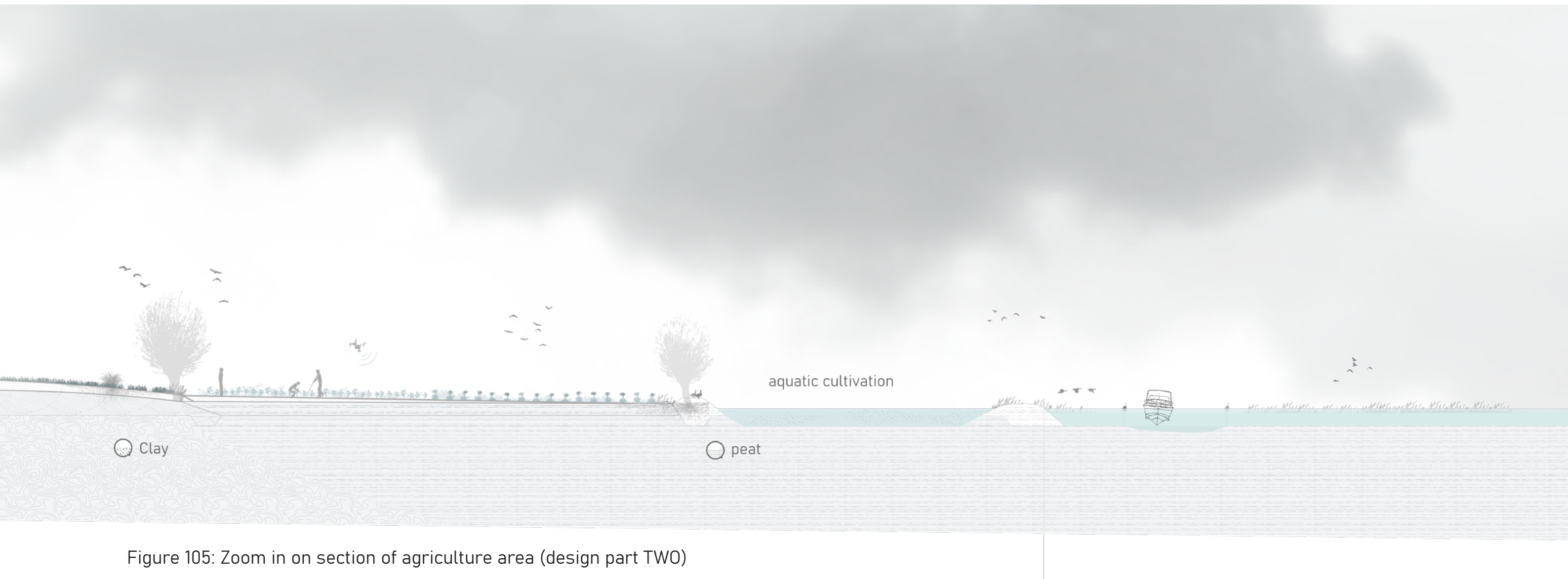


Figure 105: Zoom in on section of agriculture area (design part TWO)

POLDERVAART ZOOM IN

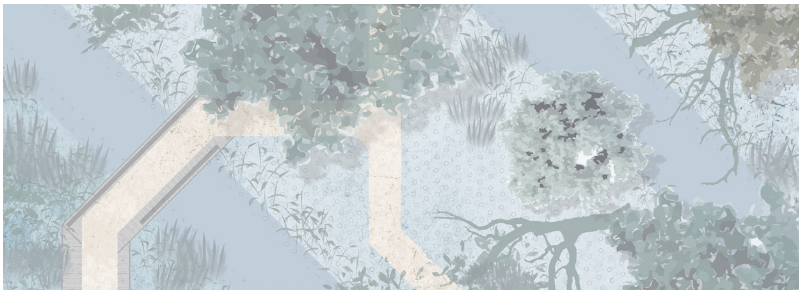


Figure 106: Zoom in on top view of Poldervaart (design part ONE)

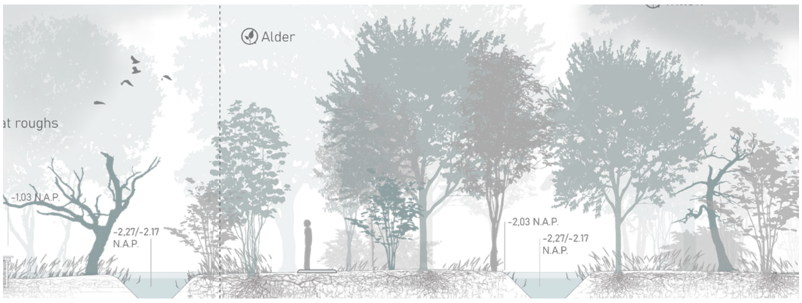


Figure 107: Zoom in on section of Poldervaart (design part ONE)

Figure 108: map overview of Poldervaart

During the first and second phase of the design the Poldervaart has handed in parts of its original surface as the recreational area was mostly placed on creek ridges, which have become precious in the design for allocating housing. On the contrary the nature area has spread over the Noord-Kethel polder area. Different gradients of nature can be found throughout the design. Wetter conditions provide canoeing routes and green corridors have been established (figure 108). Vegetation has 30 years to recover in between water level increase, within this period organic material is grown heightening soil level. Certain areas have become too deep for vegetation growth and are transformed to larger water bodies. Areas which are slightly submerged grow aquatic plants increasing peat and creating marsh forests. Along the higher parts willow forest will be found as the elevated creek ridges continue wet clay, which create suitable conditions for growth of willow trees.

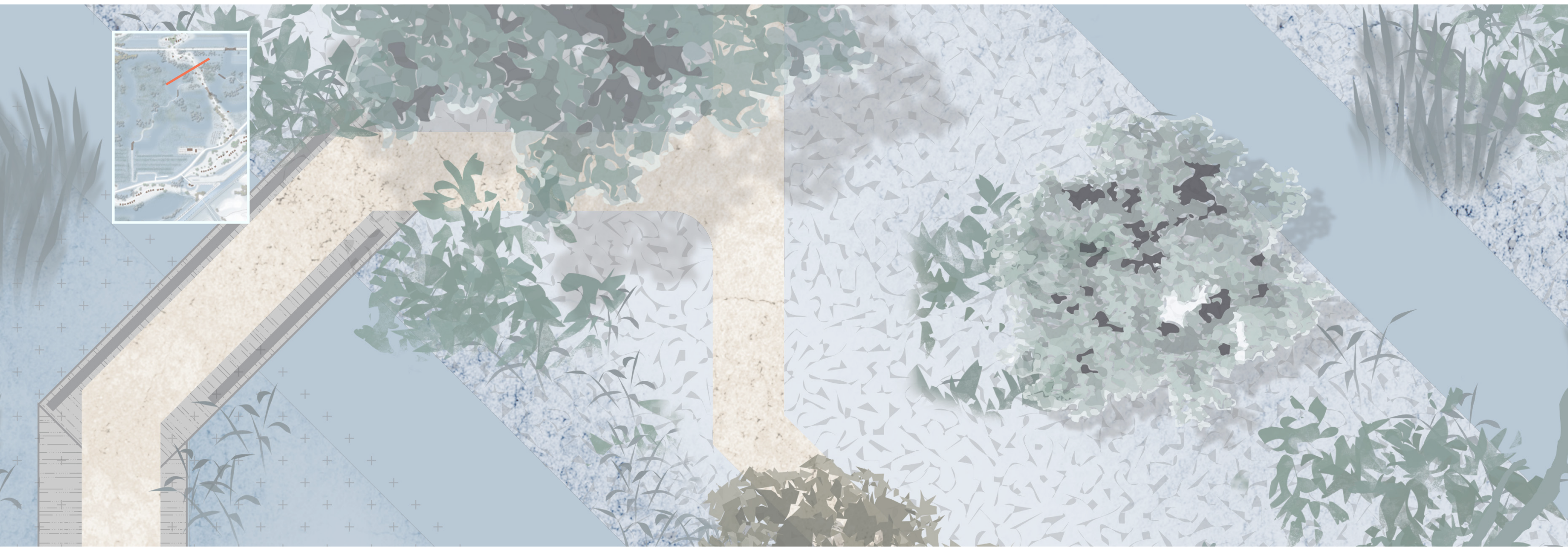


Figure 109: Zoom in on top view of Poldervaart (design part TWO)

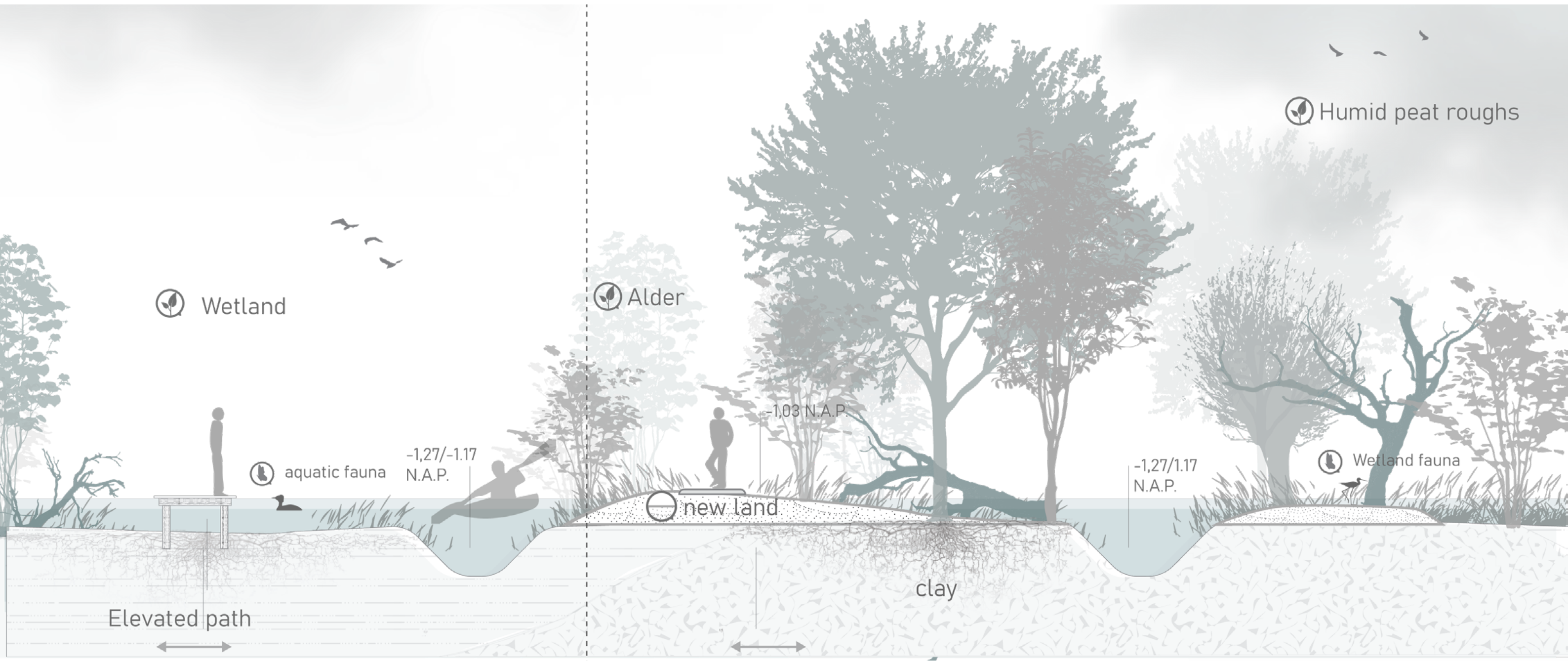
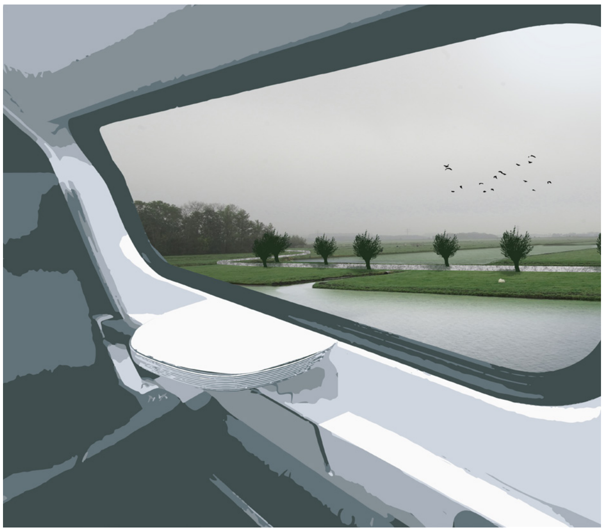


Figure 110: Zoom in on section of Poldervaart (design part TWO)

TRAIN RIDE TROUGH TIME

On a misty morning you take the train from Rotterdam to Delft. The gray concrete landscape flashes by until it opens up, and the horizon becomes visible. For a moment you float over endless misty green meadows alternated by ditches. Before you know, the horizon is gone, replaced by gray flashes of concrete. When the light disappears, you know it's time to get up.



Thirty years from now you take the same train ride, until then, the gray concrete flashes have become a bigger part of the ride. But when the landscape opens up, the green meadows have started sharing the horizon with blue/gray waters.

Two generations later the ride is not the same anymore, the train travels over water, as you leave the island of Rotterdam behind. The train carves through the mist, hovering over its reflection. From the window you are accompanied by green strings which meander through the landscape,
The horizon is endless, as endless as the polder has become.

CONCLUDING THIS RESEARCH

The aim of this research is to find an alternative water management system for current low-lying Dutch peat polder system. Current water management results in peat oxidation, saltwater intrusion and an energy consuming complex system of pumps is needed to regulate water levels. With climate change, problems in the polder are aggravated. An increase in precipitation means a larger capacity of water needs to be discharged. Draught in summer results in more evaporation oxidating peat, causing increased emissions, and subsiding soil. Rising sea level puts more pressure on the freshwater bell, resulting in saltwater leaks in coastal peat areas, causing brackish conditions which are devastating for farming.
The goal of this thesis is to find an alternative water management system to prevent further aggravation of the low-lying Dutch peat polder.

The terp
The terp proves to be an interesting alternative as an ancient way in the past of living without dikes, proposing solutions for current problems the polder is facing. The artificial hill was a way of coping with rising water levels. From the terp, multiple elements can be distinguished.

- Introducing a more dynamic water system, by playing with precipitation surplus in winter and a shortage in summer creates a more flexible water level.
- Using benefits of soil composition and topography to build on higher, more stable areas, such as creek ridges which can be found in peat areas.
- Using waste material serving as landfill or creating fertile farmland by using organic waste material.
- Introduce adaptable houses which can cope with changing conditions.

The flexible approach of the terp is interesting to design with, in a static environment of the polder. The animation: Rising out of the Polder shows the potential of implementing different elements of the terp in the polder.

The next phase of the design is to implement these elements in an area which problems are most poignant: The North-Kethel polder is a low-lying peat polder in South Holland serving as design location in my research. As the area is located below sea level, facing subsidence and salt intrusion. The design aims at transferability to other peat polders facing similar problems.

Design
The first step in the design is to dismantle current water management which results in current problems in the low-lying peat polder. By less pumping, bigger water fluctuation of 10.8 millimeters are created, resulting in a decline of peat oxidation. From then a plan is made to gradually increase water levels with steps of one meter, over a period of 1.5 generation to create a slow transition for people and landscape to adapt. The first two phases of raising water levels towards sea level are shown by a design.

First phase: graduate increase of one meter of precipitation.
With this implantation different water levels are equalized to a single water level of -2.27/-2.38 below NAP. The landscape is adapted to this water level raise. Some houses are heightened and improved by making them adaptable to higher water levels. Cultural heritage as the hamlet including the Sint Jacobus de Meerdere church is preserved by isolating it from the new system. Cut and fill of land is needed to preserve parts of current farmland. Beside dairy farming, new forms of agriculture arise as conditions become more wet through increased water levels and dryer by heightened land: aquatic cultivation and crop cultivation can be introduced. Land become more biodiverse through gradients as water is leveled, ranging from marsh lands to dry forests. Creating a waste collection hub at the former sealed-of waste dump is used as storage space for (organic) waste material.

In the second phase, after 1.5 generation, water levels are increased with another meter rise. (organic) waste material form the waste collection hub is used to continue heighten parts of the polder. Houses are renovated to become adaptable, different forms of agriculture like aquatic cultivation on lower areas are introduced as crop cultivation is continued on the heightened parts near the creek ridges. Marsh forests become marsh wetlands and water bodies enlarge which opens opportunities for transport over water.
The landscape becomes more diverse with all new elements in place. Compared to current prevailing green meadows, the landscape becomes wetter. Wide characteristics of the polder are preserved, the green meadows are replaced by blue water bodies with green strings meandering through the landscape.

A new mentality needs to be established to cope with an continues changing landscape. With the implementation of the concept of the terp, landscape elements become adaptable, making land less vulnerable to problems regarding climate change.

Bigger picture
The future of the polder will be decided over the next decennia. The tree solutions Rijkswaterstaat is proposing (protect in a closed environment, protect in an open environment, or adapt to higher water levels) will probably be implemented depending on the landscape condition. In polder areas which are given back to the water (third option), the concept of the terp is a way to cope with water, instead of resigning land. New forms of habitation, cultivation and nature can develop in this part of the Dutch Delta.
The design aims at an anticipative interaction with the landscape. The landscape reacts, adapts, and develops according to changes in nature. An approach prevalent in the Middle Ages when the Dutch experienced the Golden Age.

This research aims at a reverse of current water management, to go from subsiding land in the low-lying Dutch peat polder, to a growing landscape, eventually above sea level. Elements of the terp provide a good base to grown land in an adaptive way. But implementation of adaptable elements in a static system, result in conflicts. Change of mentality is needed to bring about change, and needs to be looked further into. Whether change is regulated top down by regulating water levels and forcing inhabitants to adapt or bottom up from local test ground to create an adaptive community. The focus is to reinvent the polder and create a landscape which stands closer to natural processes

Figure 114 current situation

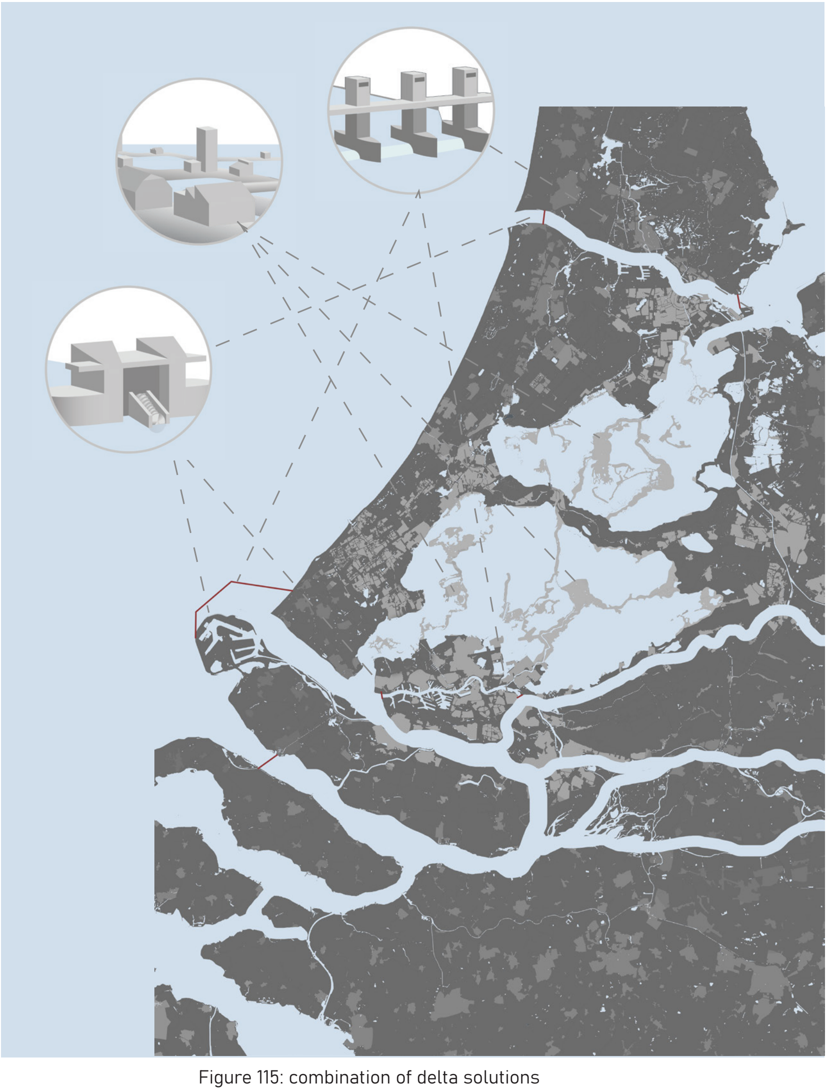


Figure 115: combination of delta solutions

REFLECTION

This research started by investigating the Netherlands, the place I'm most familiar with. Analyzing its low location, its dense use of land and its characteristic polder landscape. The poler landscape became a point of interest, as there is a lot to do around this topic. Problems in the polder have increased over the last decades and will continue to aggravate. This led to my problems statement of finding an alternative water management for the polder.

The next phase of the research was to look at available research regarding this topic. This provided inspiring solutions, but most solutions focused on a problem/solution approach.

Being part of Inge Bobbink's Circular Water Stories lab meant researching a traditional water system. This helped looking at the history of my research problems statement before the beginning, in times when dikes did not exist. The terp came into the picture and provided my design assignment: can the concept of the terp be implemented in the polder to solve current problems occurring in the lower parts of the Netherlands.

By extracting elements of the terp and translating them to current times, a set of elements came about, providing steppingstones for the design. These elements were illustrated by an animation showing how the concept of the terp could be implemented in the polder.
After analyzing low-lying Dutch peat polders, a suitable location was selected to test the concept of the terp in the polder. A landscape analysis gave guidance for design interventions. The discovery of creek ridges which consisted of stable ground compared to the surrounding soft marshy soil, provided a solid base on which the design could be rolled out on. A hydrological analysis of the area created a deeper understanding of the water system in play. By setting a higher water level, the design was further demarcated as consequences of the raised water level provided points of contact for implementing elements of the terp.

This resulted in the first phase of the design. As an addition to the master plan, zoom ins showed the polder in a more extended way, giving a more complete overview through the scales of the design. Since the first phase did not provide a full overview of implementation of the concept of the terp in the polder, a second design phase resulted in a clear understanding of its implications. Illustrated by a masterplan, zoom ins and additional visualizations providing a general understanding of the design.

The final phase of this research was linking the design back to the bigger picture. Comparing this thesis to existing research and positioning it in the context of current work field. The main outcome of fitting in the 'adapt' strategy of the Delta Program and providing a landscape based solution for the polder that insists on an anticipative way of working with the landscape.

The main approach of connecting a traditional water system as the terp to a modern problem worked extremely well. The compulsory part of the lab: the Traditional Water Story, provided a solid base to use in the design. Since my research abilities are less elaborated, compared to my fellow students, this lab approach suited me well. The structure of research methodology could have been improved, to give a better overview on this research. On the contrary a less systemic approach works well for me, as a too strict framework constrains my creativity.

Interaction between Inge Bobbink (first mentor) and Luca Iuorio (second mentor) evolved naturally. Regular meetings provided feedback on products made for this research. The feedback given was always reasonable and most of the time in line with my thoughts. My main comment received was to be more precise, showing my understanding of the system. This conflicted with my approach to simplify gained knowledge, which was often lacking depth, justifiably mentioned by my mentors. Reviewing sessions and gaining knowledge from similar research, resulted in more precise products.

This thesis can be divided in multiple parts: The initial problem statement of the polder, which was part of choosing my topic to work on for the rest of the academic year. The terp as a solution to the problems opposed in the polder. A strength of me of finding landscape-based solutions from the past/another field. Then, gaining more insight/researching both topics, my least favorite part as research seems endless. This obstructed the process for a while as it did not get off the ground. The next part was to create a toolbox of ideas, the animation helped visualizing the implementations of the terp in the polder. The design: a sticking point which costed me the first round of P4. Being decisive in the design was scary, but a breakthrough was found after some time off during the summer break. The next presentations forced me to position myself in the work field and describe the relevance of this research.

Within this year I made a few important steps regarding the design. To be less hesitant when it comes to the final design. Speak with people about your design, as it. Clarifies your train of thought.

Scope and relevance
The graduation year provided the chance to work one full academic year on a topic of your fascination. Joining a lab created a link with the master track. My research of surmounting the polder is in line with the master track of Landscape Architecture and MSc program, as the design focused on a landscape-based intervention. Studying Landscape Architecture during my BSc in Wageningen and MSc in Delft has taught me it's a way of combining knowledge from different disciplines to create an integral design. Within my research, it has not been different as the design is built on knowledge from water and waste management, architecture, agriculture, and ecology.

Research as a pile-up
All elements of the research have contributed to the outcome of the design, similar to a sum of numbers. The research by design approach resulted in going back and forth between research and design to create a coherent story. As mentioned early, this research by design method can be done in a structured way, keeping track of all steps to have a more coherent story. In my research less the case, as keeping track of all steps slows down my creative process. Keeping momentum throughout my process is important for the outcome of my design.

As mentioned in the conclusion of this research, a change in mentality is needed to implement this design. This change in mentality needs to be implemented on a different scale top down or bottom up as forcing inhabitants to change their way of living would not fit Dutch democratic standards.
To conclude: I'm happy with the outcome of my research as it provides enough points of contact for future research and sparks the future of the polder. Something which I'm willing to continue working on.

Personal Growth
The year brought me in different mind states, spending hours analyzing and developing myself. With mental and a little economic support from my parents Daniëlle and Sergio, advise from friends, roommates, and fellow students and my ever seeming enthusiastic and supporting girlfriend Yamila, I conclude this thesis. I'm thanking my main mentor, Inge Bobbink, for being flexible and allowing me to leave the beaten track and pulling me back in time. I also want to thank Luca Iuorio for his involvement, giving friendly but severe comments only to support me and extract the best out of me. The freedom university gives will be missed, but I'm looking forward to the next steps in life.

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