Adaptive Frameworks

Resilient Strategies in Water-Dominated Landscapes

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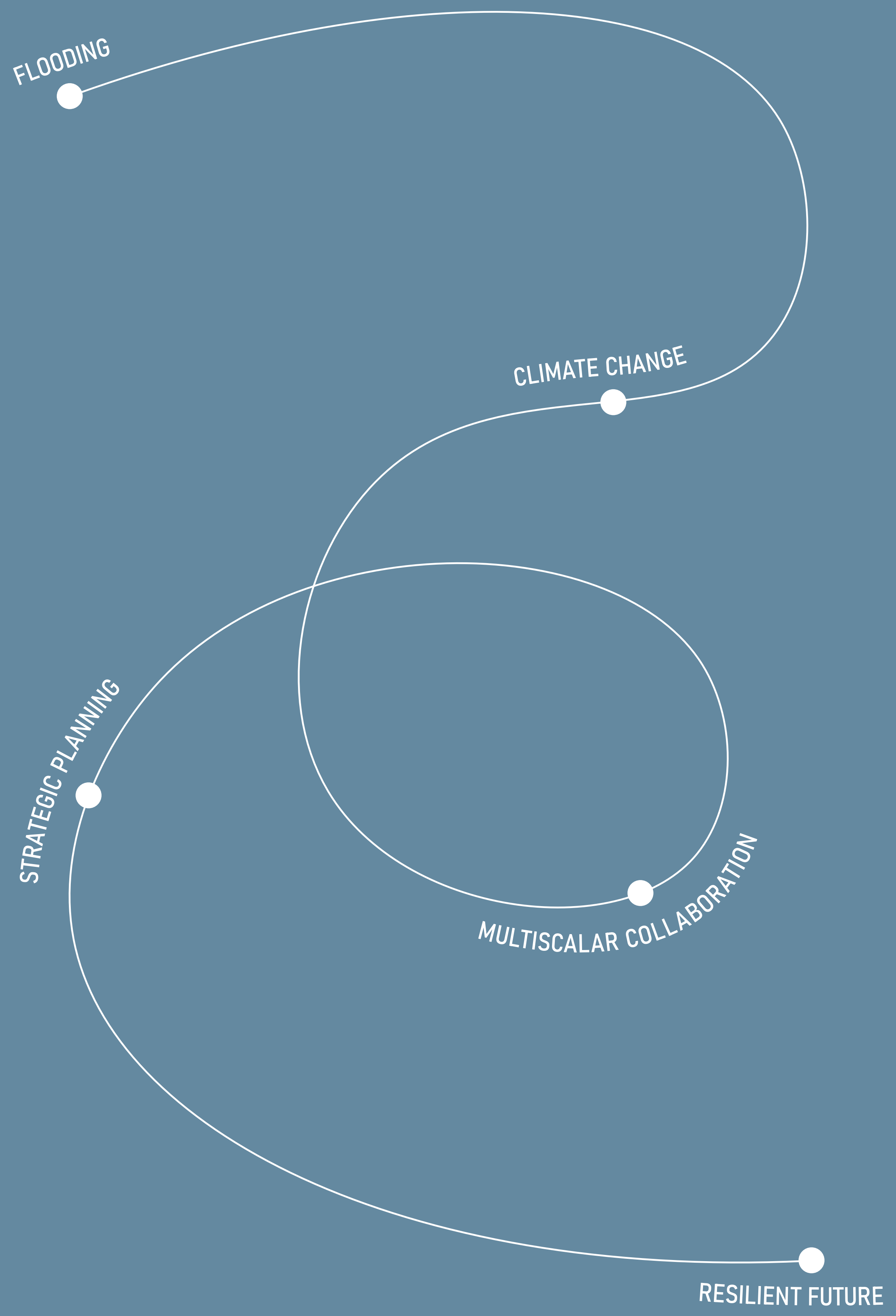

Abstract

This master thesis explores how to design and plan for flooding caused by sea level rise and climate change. With a focus on improving current design practices for flood protection and implementing a phase-based approach, the thesis presents how a series of local interventions can work in tandem at a larger scale to improve the level of protection and efficacy.

The project revolves around the Limfjord, located in the Northern part of Denmark, which is a large hydrological system spanning from the Western Sea to the Kattegat Sea. Due to its large size and the complexity of designing for such an area, a multiscalar approach is introduced. By analysing the entire system and the local areas of intervention, the multiscalar approach acts as a bridge between the strategic knowledge gained form the large-scale analysis and the designs which are adapted for the local landscape.

The development plan illustrates how protective interventions can be implemented at critical areas along the Limfjord system to ensure important landscapes and communities, while allowing flooding in selected areas to mitigate flooding further along the system. By aligning with the three pillars of sustainability and certain eco-urbanism principles, the design will also support the ecosystem while providing new opportunities for income and for building resilient communities.

While the proposed design is adapted for the Limfjord system, the thesis also includes a toolkit of strategies and interventions. The toolkit is to be used by stakeholders, lawmakers, and planners in order to ease the process of planning and designing for flood protection in other large-scale projects. Likewise, the thesis uses the categories - strategic, environmental, social, and economic - to better select which areas are beneficial to protect and where flooding can be advantageous. These categories and the adjacent methodology are also proposed as a tool to be used in other similar projects, intended to facilitate the decision-making processes and the stakeholder's work.

Preface

The idea behind this thesis first came in the form of conceptually abstract ideas of working with an imminent future with more water dominating our landscapes. Having collaborated before, we had discussed overarching topics previously, and our discussions would frequently end up in one way or another on the importance of designing for co-habitating with the water.

Initially, when throwing around ideas for our joint thesis, we'd mention mostly localised, small-scale interventions such as aquaculture farming facilities and green infrastructure acting as both protective measures and public space (subsequently, both of these ideas were incorporated into the final result of this thesis as parts of a more extensive water system).

However, the more we discussed, the more we realised that water cannot simply be considered at a limited, small scale. As a part of nature, water knows no human-made bounds; it comes from above, from below, from the sea, from the sky, from the ground, in parts, or all at once. It is, in its own right, a force of nature, and in our aspirations to work with it as designers and planners, we cannot simply consider it as a controlled mass within limits. Instead, we ought to anticipate the changes that might happen over time, and to do so we could look at the broader picture: namely, at the entire system to which the body of water belongs.

With this in mind, we shifted our focus to the entire system of the Limfjord in Northern Denmark, enlarging our project boundaries to a truly large scale, encompassing two national regions, a large number of municipalities, and a multitude of settlements under the influence of the waters of the Limfjord. As both of us lived in Aalborg at the time, the system's most major city, the Limfjord constituted a daily presence in our lives, and our witnessing of the changes it would go through over time was an additional motivation for its selection as our case study.

Such a large scale brought with itself the need for a different approach to our work as designers and planners. We had to implement a multiscalar methodology, often shifting between the limited view of the localised and the overarching perspective of the entire system in order to achieve the most optimal results in first our analysis, and then our proposed interventions. We then developed a methodology involving four categoric values (strategic, environmental, social, and economic) to facilitate the process of selecting which locations along the entire system would be most beneficial for the entire system to intervene at, as designing strategies for each single square metre along the Limfjord system was unfortunately beyond the time-frame of this work. And this resulted in the creation of a toolkit summarising the proposed interventions, allowing for it to be utilised by all involved stakeholders in the planning processes of other projects focusing on flood management in various locations in order to facilitate the decision making and ensure the best results possible.

Despite this thesis being a highly ambitious endeavour, we believe that the results achieved are an important step towards the creation of a more resilient future of co-habitation with water. The interventions and processes as presented within this thesis are intended to be re-analysed and re-adapted once again in the far future, as the natural environment and the socio-economic conditions will likely be vastly different from the current ones and would require a new approach to planning and designing for flood management at the time. Nevertheless, this thesis is meant to constitute a foundational basis for this future planning to be built upon, and we look forward to taking part in the creation of this resilient future.

Acknowledgements

I would like to extend my deepest gratitude to my family and partner, to our supervisor Hanna Mattila, and most importantly to my colleague Tsveta – without whom this thesis would never have been possible.

Firstly, to Tsveta: Many thanks for the opportunity to collaborate again and the incredible knowledge and growth you have inspired in me. I feel incredibly lucky that we started the master program together and I got to learn what a wonderful and driven person you are. It would bring me such joy to have more chances to work together in the future.

Secondly, to our supervisor, Hanna Mattila: Many thanks for being our supervisor through this master thesis and believing in our project vision. Your many insightful suggestions and questions sparked the most interesting discussions. Without your academic expertise and creative mind, our thesis would not have been so enriching.

Lastly, to my family and partner: My deepest love and thanks for supporting me through this project and my academic venture. Thanks, for always having my back, for showing such interest in my work, for always believing in me. You all have allowed me to experience such wonderful things and see the most incredible scenes that I will never forget.

Celine Janne Larsen

Above all else, endless gratitude to Celine for the collaboration on this work. It has been nothing but inspiring to work together, not only on this thesis, but also on our previous project. I sincerely hope that this is not the last time in which we get to create something together!

Without the support of Hanna Mattila as our supervisor, some of the themes within this work might have been overlooked. So, many thanks to Hanna for all the suggestions and inspiring feedback during our supervisions. They often showed us completely different perspectives towards our ideas which then grew into integral parts of this work and led to making it more complete.

Finally, heartfelt gratitude to my partner, without whom I would not have been in Denmark, and would have never gotten to collaborate on this work. Thank you for listening to my longwinded explanations of the concepts in this work, and for the endless support and encouragements at all the various times it was needed. Hopefully, now that his work is complete, the ramblings are a little more sensible.

Tsveta Atanasova Stoeva

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01

WATERS ON THE RISE

AND WHAT OF THE TIDES?..

As global warming continues to reach new highs, the threat of climate change and extreme weather incidents becomes more pressing (World Meteorological Organization, 2024). Increased periods of drought and record amounts of rainfall will become more frequent and storms more intense due to increased evaporation (IPCC, 2023). The polar ice caps will melt further causing sea level rise and higher rates of flooding (IPCC, 2023). For a low altitude country like Denmark, which is defined by its vast coastline and many bodies of water, climate change and water poses a particular problem (CONCITO, 2024). The threat of rising sea levels, storm surges, and increased downpour in addition to near-surface groundwater, results in the country struggling to manage water from multiple directions (CONCITO, 2024). The results are already seen in multiple reports of flooding and destruction of property, the need for pumping groundwater, moving housing further and further away from the coastline and rivers, and months of waterlogged areas - with more incidents happening each year (CONCITO, 2024). Thereby, people's lives and livelihoods are tragically displaced, causing massive economic losses for the whole country (CONCITO, 2024).

To manage this threat and the uncertainty of the future, it is necessary to learn; to protect people and what can be protected, to manage the situation especially in case of extreme weather situations and emergencies, to coexist with the increased water in the future and benefit from it. Such is the important topic that will be explored in this thesis. Many helpful interventions already exist, however there is a pressing need for more sustainable and resilient options that will add to the ecosystem and human experience. Denmark is in great need of national and regional strategies and collaboration between human-made municipal borders when dealing with extreme weather emergencies, as well as long term protective measures which can adapt to the increased amounts of water that might be seen in the future. To aid in the investigation of this complex topic, a problem statement is formulated to focus the project and guide the theoretical frame and topics of analysis. The goal is to develop several protective interventions at key areas along the hydrological and ecological system of the Limfjord, which will protect locally and work in tandem to mitigate large scale flooding.

ill. 01. Water level measuring, Østre Anlæg

WAIST-DEEP IN THE WATER

Problem & Motivation

The most common notion when engaging with design and architecture, is to design for the site. This means analysing and understanding the site in depth while being mindful of the context. However, the consideration for the context often ends at the sites neighbourhood or city the site is located in. Rarely does the concept of the context extend regionally or nationally. This becomes problematic when designing for flood protection, as a lack of understanding of the bigger context can mean ineffective or failing structures as water rushes in from a critical point located outside the local context. Especially when designing with long timeframes does the larger context become key, as the flow of water through a system changes as areas become affected by flooding. Therefore, this thesis works with flood protection, through the tools of urban design and planning, with a focus on sustainability and resilience with a multiscalar approach, where both the local and regional context are of equal importance. An emphasis is placed on the dynamic nature of the system and thus need for dynamic planning and interconnected interventions that improve the possibility of benefitting from flooded areas and increased water levels. These considerations have been condensed to the problem statement:

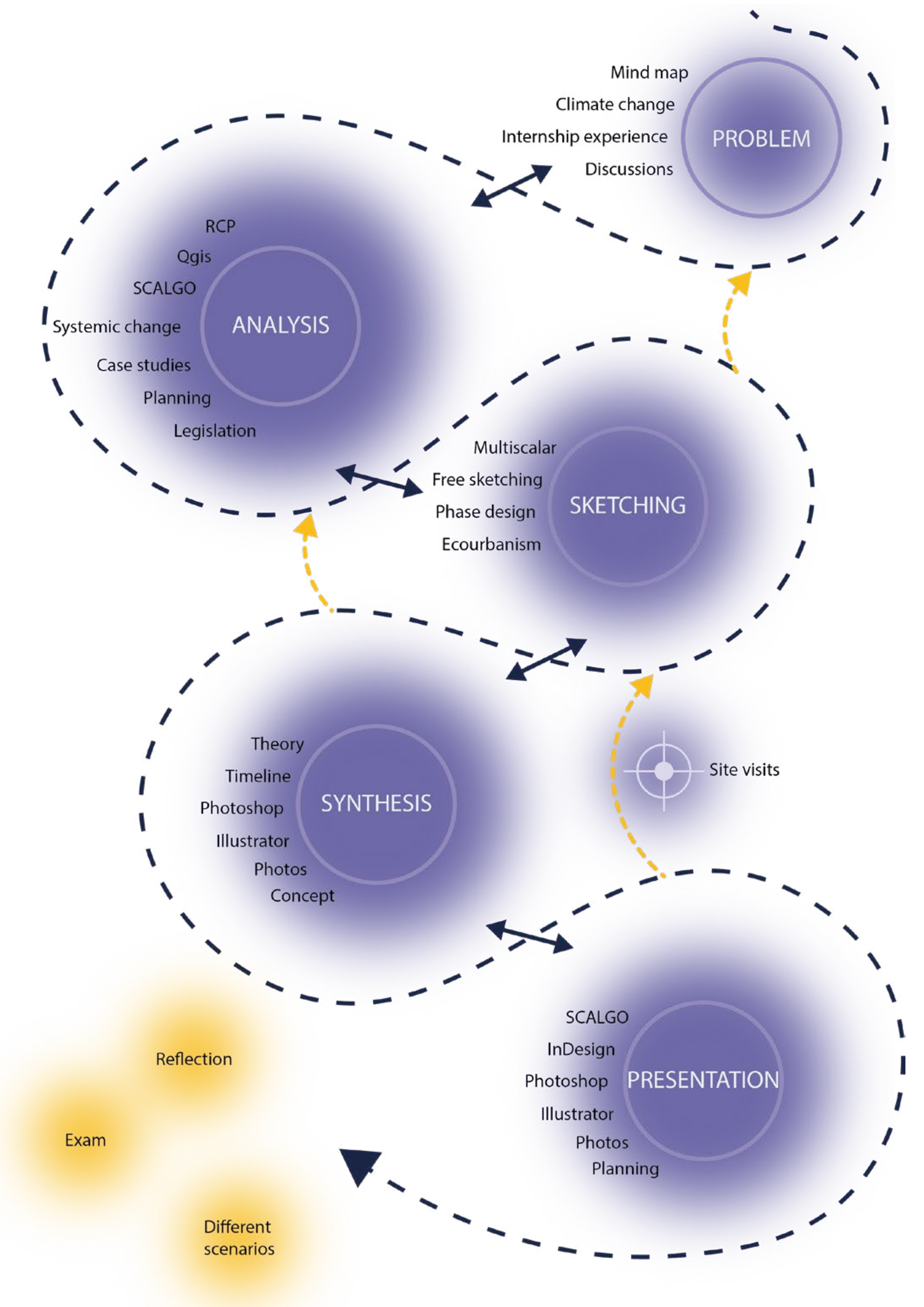
How can the threat of increased water and extreme weather caused by climate change, be managed through urban design and planning? How is a dynamic system, such as the Limfjord, impacted by multiscalar and interconnected interventions? And how can it be possible to live with water and benefit from the flooded areas in innovative ways?

Method

The integrated design process, IDP, was the main method used through the duration of the project. A holistic method meant to create a sustainable approach to design (Hansen and Knudstrup, 2005). By emphasizing collaboration between involved parties and especially interdisciplinary collaboration and communication, the method is used to achieve more innovative and sustainable design solutions (Hansen and Knudstrup, 2005). As this master thesis has a focus on improving sustainability of coastal and flood protection, the IDP method was essential to implement sustainable practices and concepts from interdisciplinary fields and effectivity of the internal collaboration in the group. Thus, ensuring the project meets the protective criteria while being as sustainable as possible and minimizing impact (Hansen and Knudstrup, 2005).

The IDP method is phase-based split between the phases of: Problem, analysis, sketching, synthesis, and presentation (Hansen and Knudstrup, 2005). Each phase governs a specific stage in the design process, where the design solution and knowledge of the problem becomes more specific as the process nears the presentation phase, however the method is circular meaning there is room to return to previous phases and further iterate as a result of progress and new knowledge (Hansen and Knudstrup, 2005). This project is similarly using Lawson's non-linear model which has enabled a multidirectional approach, where multiple scenarios and design interventions were investigated simultaneously (Lawson, 2005). Thereby testing new interventions and strategies parallel to the analysis resulting in more suitable design proposals (Lawson, 2005). Without a fixed start and end point, the method contributed to a more dynamic process, where each step led to new discoveries and questions as each phase was revisited (Lawson, 2005).

Due to the structure of writing the master thesis, the problem phase was started before the project period began. Thus, the project quickly progressed to the analysis phase where the system of the Limfjord and context was investigated while the theoretical frame was being formed. Initial sketching and design solutions followed and overlapped with the in-depth analysis conducted at the end of the analysis phase. Sketching led to the synthesis phase but also prompted new analysis and reassessment of the problem and problem statement. Likewise, the synthesis phase sparked new concept evolution, sketching, and expansion of the theoretical frame. Finally, the presentation phase sought to present the acquired knowledge and showcase the current most efficient design solutions and strategies.



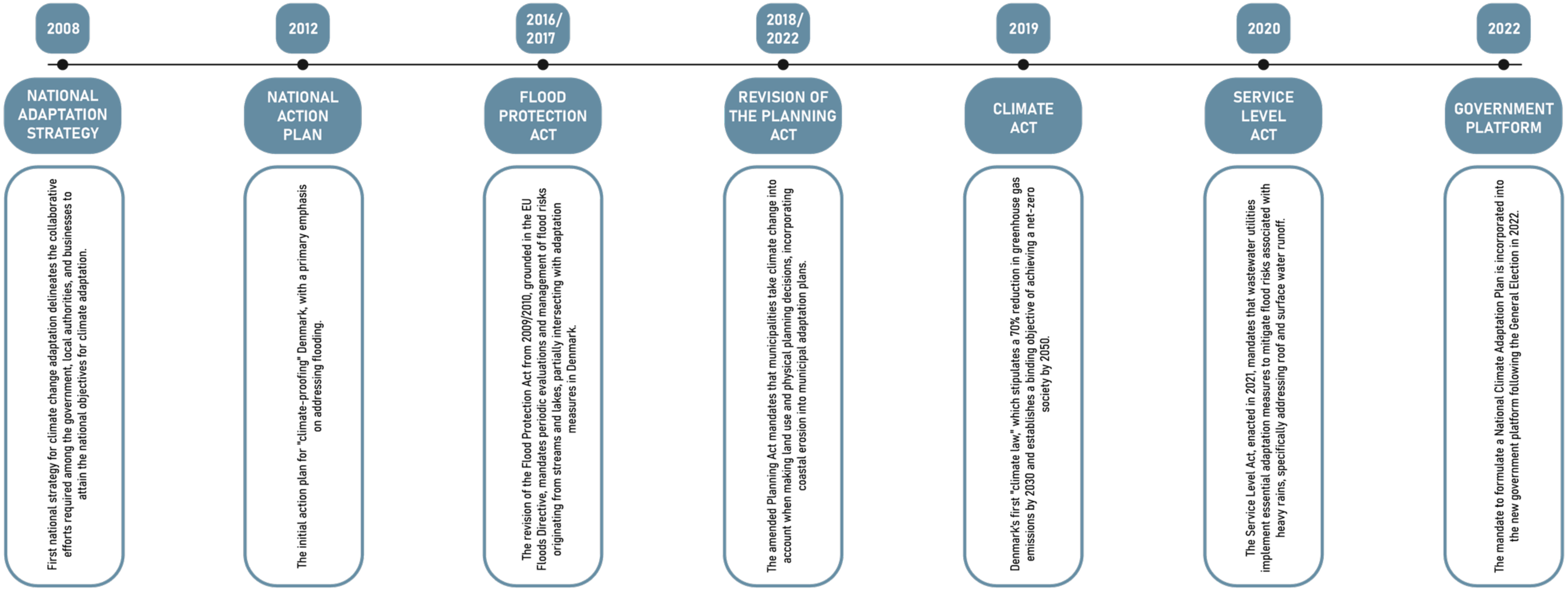
ill. 02. Method

AS FOR LEGISLATION...

From the point of view of governance, three levels are to be observed in Denmark: national, regional (5 regions), and local (98 municipalities). Each of these levels are responsible to a varying degree for the development and implementation of strategies regarding flood management (Sørensen et al, 2016). Yet, there is continuous collaboration between all levels at various points of the strategic processes, additionally supported by EU funds and directives on occasion (Sørensen et al, 2016).

At a national level, the government is tasked with developing overarching policies and legislation regarding climate adaptation and flood management, with coordinating implementation processes across regions and municipalities, with implementing international agreements related to flood management, with conducting nationwide risk assessments, and with developing nationwide climate adaptation plans (Gram-Hanssen et al, 2023).

ill. 03. Timeline of adaptation policies at a national level



The main responsibilities of the five regions regarding flood management are the coordination and support of municipalities in their application of climate adaptation strategies (Gram-Hanssen et al, 2023). Their role also extends to the provision of technical and financial assistance, and the monitoring and evaluation of the already implemented measures (Gram-Hanssen et al, 2023).

It is at the municipal level where the body of governance has the highest responsibility for the implementation of flood management strategies lies. By law, each municipality is obliged to plan for climate risks, flooding and coastal erosion when adapting their local plans (Gram-Hanssen et al, 2023). Following the DK2020 initiative, by 2021, 96 out of 98 municipalities had developed their local plans with a consideration for climate adaptation and flood mitigation (IEA, 2023).

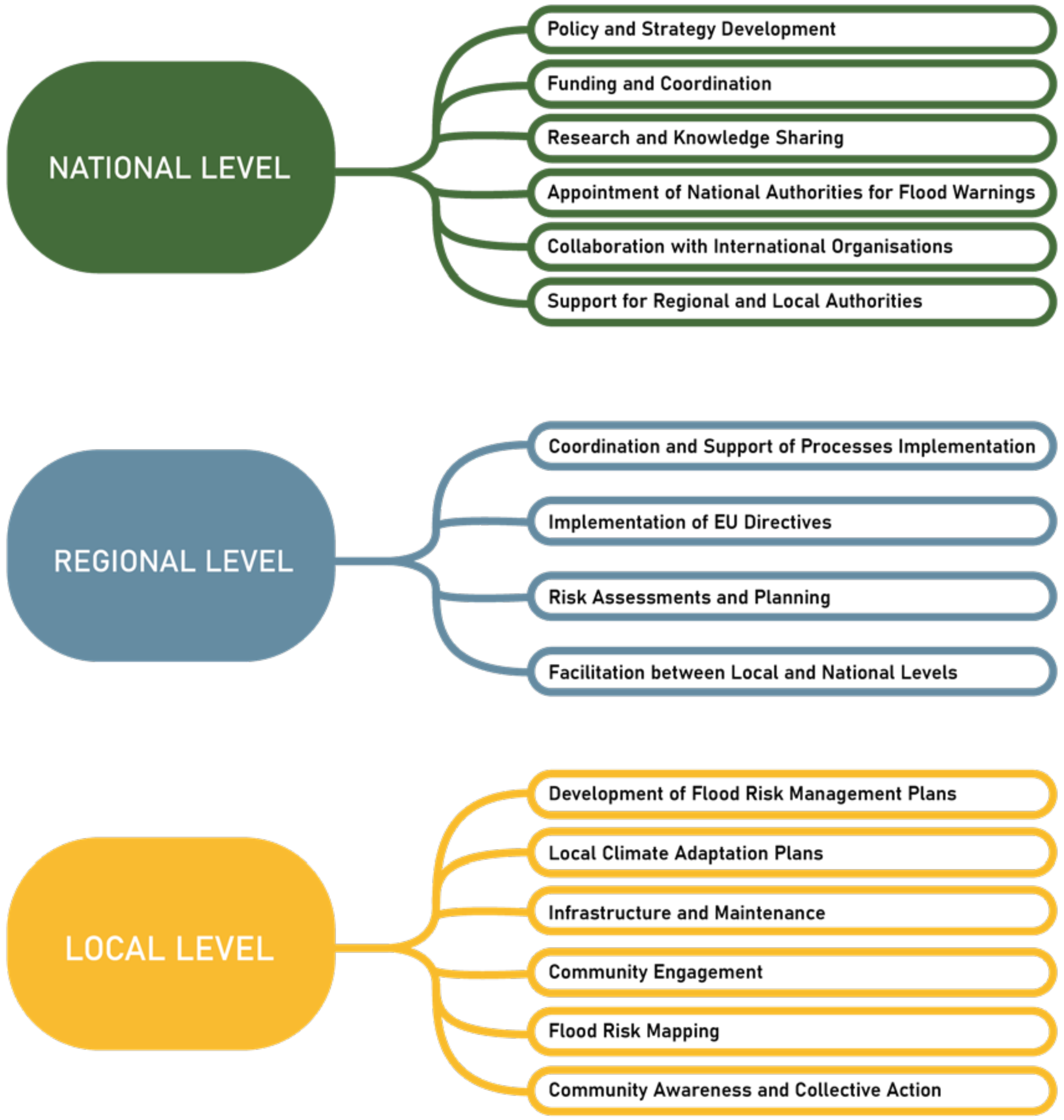
Furthermore, the municipalities are responsible for the delegation of the actual implementation works and their realisation by local wastewater utility services and private landowners (IEA, 2023). Being the body of governance which is tasked with the direct carrying out of the policies and strategies in the physical sense, the local municipalities take on a major part of the responsibility when it comes to climate resilience (Gram-Hanssen et al, 2023).

Having taken this into account, however, a more extensive role of the regional bodies of governance is either severely limited, or non-existent. This leads to the question whether a development of a toolkit presenting adaptive strategic proposals for flood management strategies to facilitate their applications at multiple levels would contribute substantially to the climate resilience state of Denmark. Within this thesis, this question will remain as a foundational stone throughout the elaboration of the strategic proposals and will serve as a criterion of the resilience of the given proposals from a strategic point of view.

Using the Limfjord system as a case study, an opportunity to suggest a trans-regional collaborative approach to design interventions are investigated. Located between the regions of North and Central Jutland, the Limfjord system's management falls into both regions' jurisdiction. Therefore, any policies regarding the entirety of the system must be a result of a collaborative agreement, as any interventions made at one point within the system would impact the entire system as a result, as investigated further in this thesis.

As such, this thesis operates with the idea of advocating for a further development of the legislative system when it comes to cross-regional large-scale projects, such as in the case of the Limfjord. Not only would collaboration lead to the benefit of all regions involved, but would also allow for a fairer process where regions with more resources collaborate with those with less for the benefit of the society and the nature in not only the regions involved, but in the extended surrounding areas as well, if not even at a nation-wide or global level.

ill. 04. Responsibilities at different governance levels



02

THE LIMFJORD CASE

A DYNAMIC SYSTEM

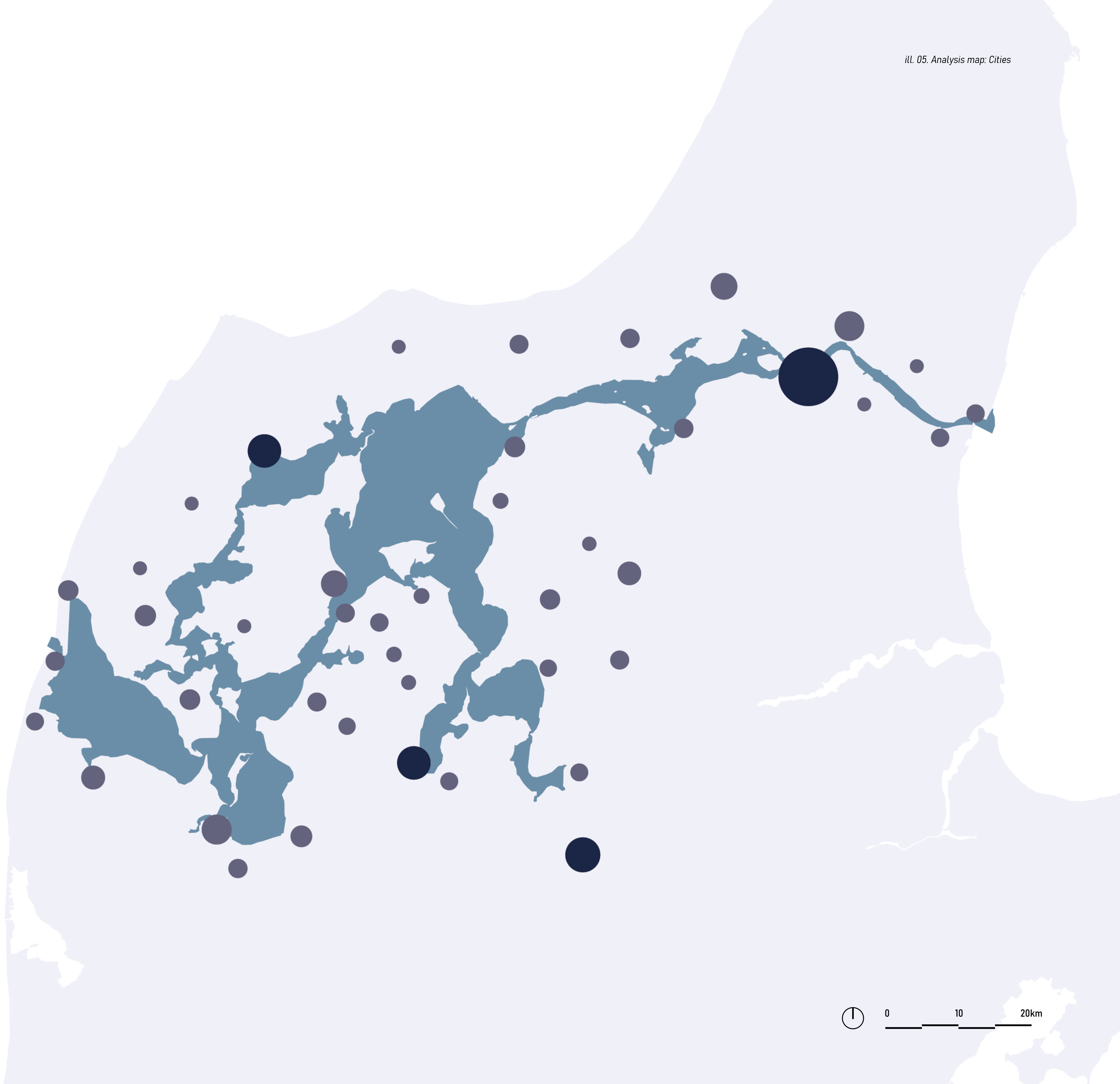
This project has chosen to work with the hydrological system of Limfjorden located in northern Denmark, stretching from the western sea and Thyborøn in the west to the Kattegat Sea and Hals in the east, splitting the landmass of Jylland in two.

The system transports vast volumes of water a day and serves an important role in both the surrounding ecosystem, landscape, human culture and logistics. Unfortunately, it also poses the risk of flooding, threatening habitats and settlements – a risk which becomes more pressing at the pace of climate change.

Being students at Aalborg University, the Limfjord has been part of our lives for multiple years, and we have become aware more of its challenges and potentials. We have seen the incidents of flooding and how new protective measures have occasionally been ineffective due to being limited to a single site. Therefore, we chose the whole system of the Limfjord as our project site, as we believe it is exceedingly important to consider the whole context, even when designing for the local.

Cities

Many cities are located near or right on the coast of Limfjorden and thus in high risk of flooding and water damage. The cities range from small villages to mid-sized villages with important industry to cities, with the largest being Aalborg with about 225.000 inhabitants (Aalborg Kommune, 2025).



ill. 05. Analysis map: Cities

Infrastructure

Mapped are the most important systems of infrastructure; the international E45 motorway, the national main roads, and train connections.

The E45 connects north to south, with the main roads connecting major and mid-sized cities across. The train connections are more sparse near the Limfjord, and only comes near or crosses the fjord at Thyborøn in the west, Oddesund 45km further east, and Aalborg to the far east.

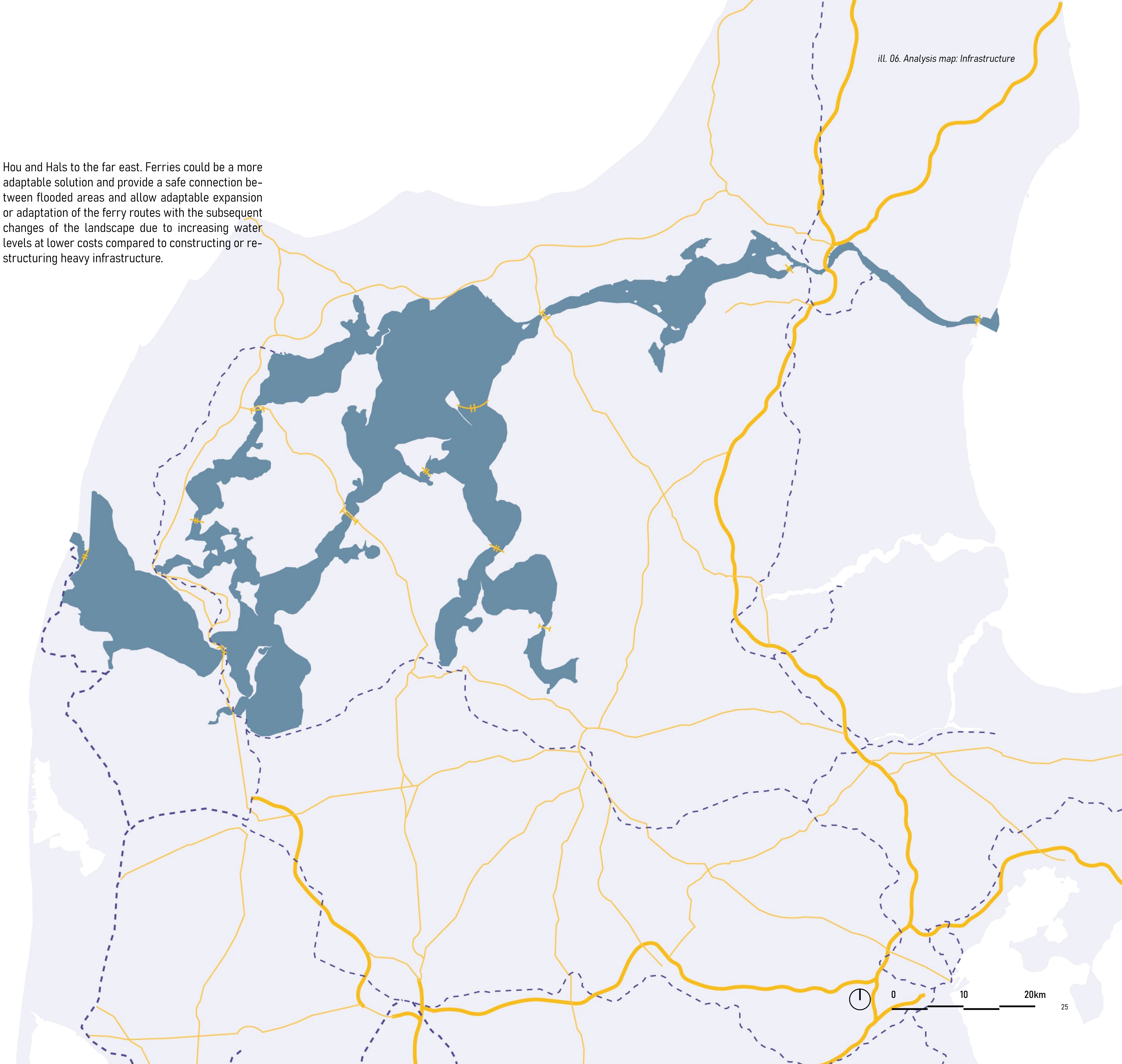
When compared to maps of predicted flooding due to sea level rise, it is generally seen that the majority of the important infrastructure will remain, as it is not located near the shores. However, Thyborøn, large areas of Jammerbugt municipality, and Aalborg see risk to the infrastructure.

At Thyborøn, the issues are in relation to the train connection to the city, as the city faces severe flooding, the train tracks will be lost. As the city is the end station for the train line, the issue is not deemed to cause issue for the remaining train connections.

In Jammerbugt municipality, the flooding is located between the smaller cities and therefore mainly affects the connecting main roads in the area. This could potentially harm the connection between the bigger cities of Thisted and Aalborg and affect the people living in Jammerbugt and commuting through the area. The main road may be moved, or a reliance be put on the smaller local roads in order to preserve connectivity.

Aalborg is the main area of concern, as much infrastructure coalesces there, and the area sees much flooding. Both the E45 and train connections cross the Limfjord at this location and serve as the main connection point between the areas north and south of the fjord. Much traffic also passes through every day as many people live and work on different sides of the fjord. Therefore, the infrastructure in this area must be protected or adapted to future water challenges, to ensure the connectedness of the country.

With future flooding, many connections and bridges across the Limfjord may be threatened. The traditional solution may be to build taller and more robust bridges, but if the water levels continue to rise, it may be a futile endeavour. Instead, it is suggested to rely more on ferry connections, which are already present at certain points of the Limfjord, such as between Hou and Hals to the far east. Ferries could be a more adaptable solution and provide a safe connection between flooded areas and allow adaptable expansion or adaptation of the ferry routes with the subsequent changes of the landscape due to increasing water levels at lower costs compared to constructing or restructuring heavy infrastructure.



ill. 06. Analysis map: Infrastructure

Nature

Multiple areas of habitat and species protection are located along the Limfjord, which should be secured and protected in the future. These areas have been defined by the EU as part of the NATURA2000 mapping of Europe (Styrelsen for Grøn Arealomlægning og Vandmiljø, 2025). This means that nature areas of particular importance to species of flora and fauna have been registered and are to be protected and not to be disturbed (Styrelsen for Grøn Areaomlægning of Vandmiljø 1, 2025).

However, as these are natural systems, it may not be advisable to protect them from flooding but instead expand their areas so the specific habitat can develop on the new areas next to the new shoreline. This way, the prior habitat can exist, albeit slightly moved, while new unique habitats can emerge from the now flooded areas. Furthermore, this provides areas for allowing flooding, which can help mitigate some flooding further along the system, as the water has more space.

ill. 07. Analysis map: Nature

Sea Level Rise

Sea levels are on the rise globally and will likely continue to rise as humanity continues to emit large amounts of CO2, resulting in areas near rivers and coasts being at an increased risk of flooding, coast erosion, and inundation due to increased groundwater levels (Schiermeier, 2018). This describes many areas in Denmark and along the Limfjord. As the future is uncertain and how much and how fast the sea level rise is coming is unknown, this thesis will rely on the different scenarios and predictions presented by the Intergovernmental Panel on Climate Change (IPCC) regarding carbon emissions and global warming (IPCC, 2023). The worst-case scenario of RCP 8.5, which represents emissions remaining at a current high value, is utilized at critical points along the system, as the DMI suggests appropriate for highly sensitive projects (DMI, 2018). In relation, the middle scenario of RCP 4.5, which represents a limited but still high amount of emissions, can be applied to less affected areas of the site, though it still assumes more extreme weather. The thesis does not work with the best-case scenario of RCP 2.6, which represents a limit on carbon emissions that does not exceed current levels for more than a few years, as it is a very optimistic scenario, and it has been deemed better to design for more hazardous scenarios.

Considering these factors, it is necessary to analyse multiple flood risk scenarios to assess the areas at risk at the necessity for different strategic interventions. Especially as most Danish cities currently only protect and plan for a 1.5m sea level rise, even as new studies suggest the design standard should be 3m (Dahl-Jensen et al., 2025).

2m

At a 2m sea level rise major flooding is already seen in the Jammerbugt area around Løgstør and Nibe Bredning. This causes some areas to become islands, and wetlands to expand. Most of the affected areas are open land nature or agricultural plots, with a few cities being at risk of flooding. While sea level rise is at this height, little action is required but it would be advisable to educate inhabitants and implement temporary protective measures for 10-20 years while relocating and compensating the residents in affected areas.

ill. 08. Analysis map: 2m flooding

3m

At a 3m sea level rise an expansion of the flooding in Jammerbugt is seen as more of the flooding reaches further inland. New areas of major flooding are seen in the west cutting of Thyborøn, and in the east around Langerak. At this level many coastal cities begin to face risks and flooding, especially in Jammerbugt and along Langerak. Furthermore, the flooding isolating Thyborøn will be detrimental to the city, as its infrastructure becomes inaccessible, and resources would not be able to reach the city. Therefore, the cities that become isolated or located at areas that have become islands will need to be supported, and resources shipped to them. It would be most advisable to vacate such cities, as new transportation system would take time, resources, and money to set up, though areas cut off by slim bodies of water may benefit from new bridge constructions or ferry connections. Any existing protective structures can be expanded to accommodate the increased water levels, but careful consideration for their lifetime should be made as water levels may continue to rise.

ill. 09. Analysis map: 3m flooding

5m

At a 5m sea level rise, which is a worst-case scenario with current emission rates, the flooding reaches a point where the region becomes unrecognizable. The flooded areas from before have expanded further, and new affected areas have opened up as many streams begin to experience the sea water push up their deltas. The northern part of Aalborg, Nørresundby, will also be cut off from the rest of the area north of the Limfjord, which will cut off the entire region due to the important infrastructure in the area becoming inaccessible. Large new bridges or vast reliance on boats and ferries will become a necessity to support inhabitants in the northern region, as many conventional protective structures may not be viable or become too grand and expensive at this level of flooding.

ill. 10. Analysis map: 5m flooding

10m

At a 10m sea level rise, the absolute worst case which may only happen if carbon emissions accelerate and natural systems breaks down, the flooding is vast and would cause multiple islands to form in the northern region. This would isolate many communities and challenge resource distribution unless a transportation system relying on water vessels is in effect. Furthermore, many cities will have been lost to the water masses, and the landscape greatly altered as the east coast is moved a great distance inland. Such a scenario would require far more resources and interventions to make the area habitable and should be avoided for the sake of both the population and the environment.

Implications

There exist both an immediate and future risk of flooding due to sea level rise in multiple locations along the Limfjord, especially at Thyborøn, Jammerbugt, Aalborg and along Langerak. These areas will be part of the main areas of intervention which this thesis will work with.

While cities currently protect and plan for a 1.5m sea level rise, new research suggest we should plan for a 3m increase instead (Dahl-Jensen et al., 2025). Regardless, both the 2m and 3m sea level rise scenarios see major flooding and put cities and people at risk. Some flooding can be protected against with protective structures, while open areas benefit more from allowing the flooding to minimize the impact further downstream. However, it is more advisable to focus on relocating people and industries for their long-term safety, especially as sea levels may continue to increase as long as the ice caps continue to melt. While the 5m sea level rise scenario is unlikely to occur in the next 100 years, it can become reality further in the future and considering the flooded areas at this sea level should be taken into account when placing protective interventions as they may be expanded upon at a later date.

While the flooding in some areas is major and will alter the landscape, it luckily will not happen immediately but rather gradually increase over the span of multiple years, maybe decades. This means that there is time to plan and enact new policies and strategies to properly protect important areas, cities, and infrastructure, as is the aim of this thesis.

ill. 11. Analysis map: 10m flooding

Flow

The flow map shows how many smaller streams, rivers and water structures are part of the greater system of the Limfjord – these will also be impacted by the flooding and increased water levels in the Limfjord. Therefore, it will be important to consider their deltas and catchment areas. These areas also carry great potential for aquatic agriculture as the salinity level will be far less in the streams and rivers, in addition to where they meet the Limfjord.

Waterflow in the Limfjord flows from the Vesterhavet to Kattegat, meaning a west to east direction (Styrelsen for Grøn Arealomlægning og Vandmiljø 2, 2025).

ill. 12. Analysis map: Flow

Ecological State

As stated by the EU law, Water Framework Directive boradly enforced since 2020 (European Parliament, 2024), it is mandatory to evaluate the water quality of bodies of water and coastal waters, with the goal to improve the conditions for challenged areas. This is determined by certain indicators categorized into ecological and chemical factors (Styrelsen for Grøn Arealomlægning og Vandmiljø 2, 2025).

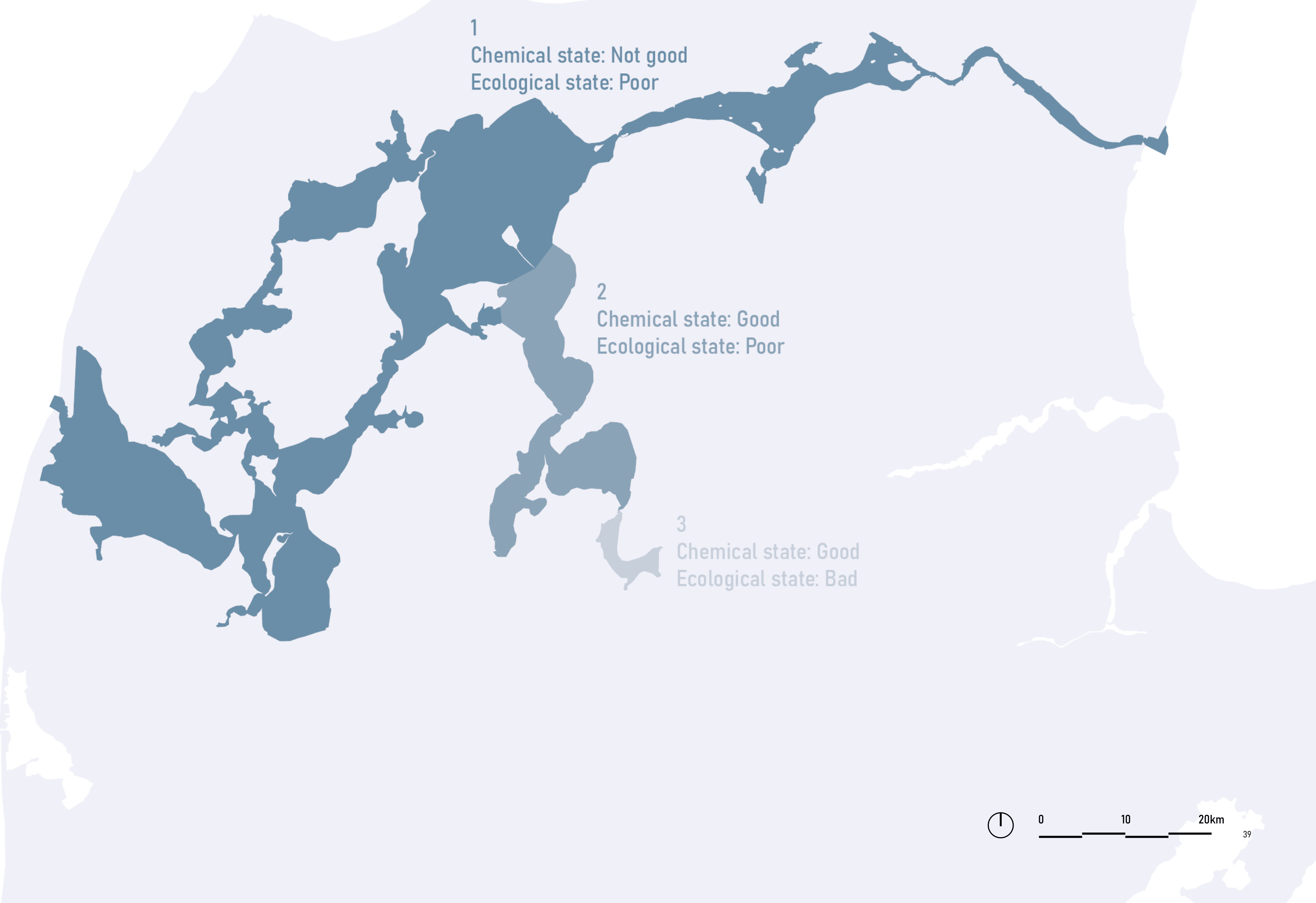
The ecological condition is based on measurements of concentration phytoplankton, bentick invertebrates, macroalgae and angiosperms – the biodiversity in the body of water, and is rated: High, good, moderate, poor, or bad, with the factor rating the lowest determining the overall rating (Styrelsen for Grøn Arealomlægning og Vandmiljø 2, 2025).

The chemical condition is based on the presence and concentration of 21 chemicals, appointed environmentally harmful by the EU, and is rated: Good or not good (Styrelsen for Grøn Arealomlægning og Vandmiljø 2, 2025).

The mapping of the water quality data shows widespread poor and bad conditions, as seen on illustration 13. The central part of the Limfjord, around Thisted Bredning, Løgstør Bredning, Skive Fjord, in addition to Nibe Bredning, is evaluated to the worst water quality of bad conditions meaning that flora and fauna will struggle to survive in these areas. The western and eastern ends of the system are of poor quality, which provides marginally better survivability. While the bad water conditions are highly problematic and will require much consideration when implementing interventions as to not further the problem, they also provide a substantial potential for improving the conditions while planning for sea level rise and flood risks.

Any intervention is required to either keep the water quality the same or improve it, which the Vandområdeplan for Limfjorden defines as reducing nitrogen in the system. The plan includes some focus areas which can improve water quality in the Limfjord, if used strategically (Styrelsen for Grøn Arealomlægning og Vandmiljø 2, 2025). The main focus area is to reduce agricultural runoff containing nitrogen originating from fertilizer use. This runoff can physically be limited, blocked or diverted, but it is also suggested to improve biodiversity on agricultural land and in the edge-zones in order to soak up excess nitrogen (Styrelsen for Grøn Arealomlægning og Vandmiljø 2, 2025). Other strategies include limiting wastewater runoff and establishing more forests to secure groundwater purity (Styrelsen for Grøn Arealomlægning og Vandmiljø 2, 2025).

ill. 13. Analysis map: Ecological state



Focus sites

The analysis of future flooding showed several impacted areas, which are both at great risk of flooding and are important for the system as a whole. Therefore, these areas have been chosen as focus sites, where the design and planning interventions will be concentrated. In order to investigate these focus sites, they were visited on different occasions. The visits explored the landscape and current impact of the systems water on the sites, while assessing the local communities and experiencing the sites at a human scale. These observations are crucial in the process of choosing what areas to protect and where to let nature be, in addition to design process for each site and the relation to the whole system. Each focus site will be described and showcased through the photos taking during the visit.

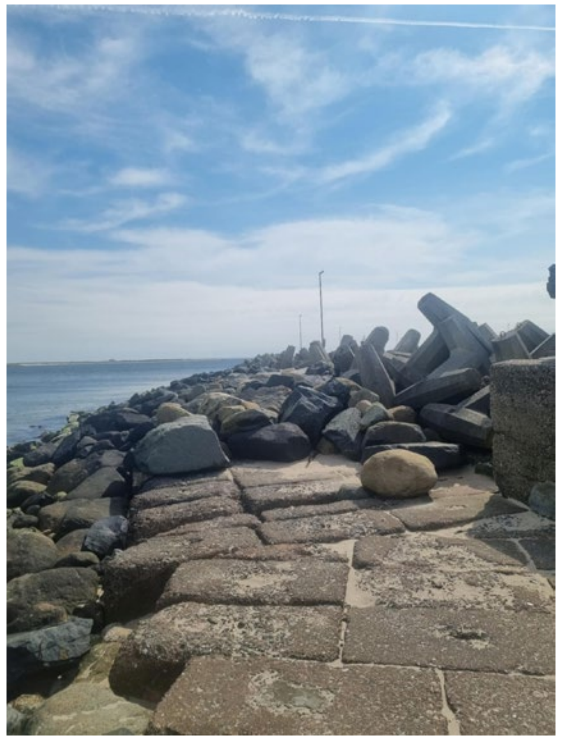
Thyborøn Kanal

The first site visit was to Thyborøn Kanal, located on the west coast marking the entrance to the system of Limfjorden. The channel is bordered by the city of Agger to the north and Thyborøn to the south, connected by a ferry line. When driving to Thyborøn, either by car or by train, water is visible on either side of the road, with the west sea to the west and the Limfjord to the east. The fact that this area is already heavily affected by coastal erosion and flooding (currently due to intense wind and tall waves) is quite apparent as extensive protective structures are visible along the western coast. Both tall sand dunes, large wave breakers and long corridors of revetments are visible and clearly weathered. These structures culminate at the northern part of the city, where the harbour is located, and here the city is further protected by a seawall, estimated to reach 3 m above sea level. Like the coastal protection, the local community was robust and centred around their connection to the sea as many inhabitants worked in the sailing or fishing industry and many houses were decorated with items related to boats. Multiple sea related attractions were also present, such as multiple museums, an aquarium, seal safari boat trips, and local seafood restaurants, which underlined this city as a destination, especially during summer vacation.

ill. 14. Thyborøn harbour

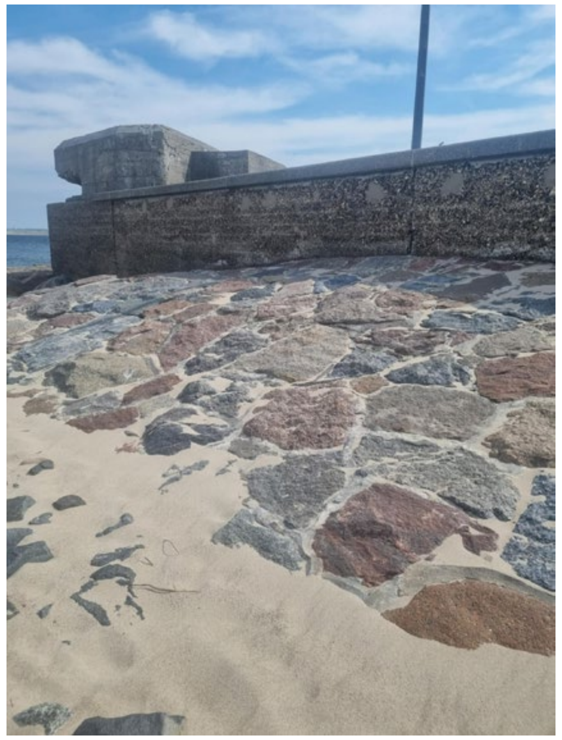
ill. 15. House with boat motif, Thyborøn

ill. 16. Thyborøn's weathered coastal protection

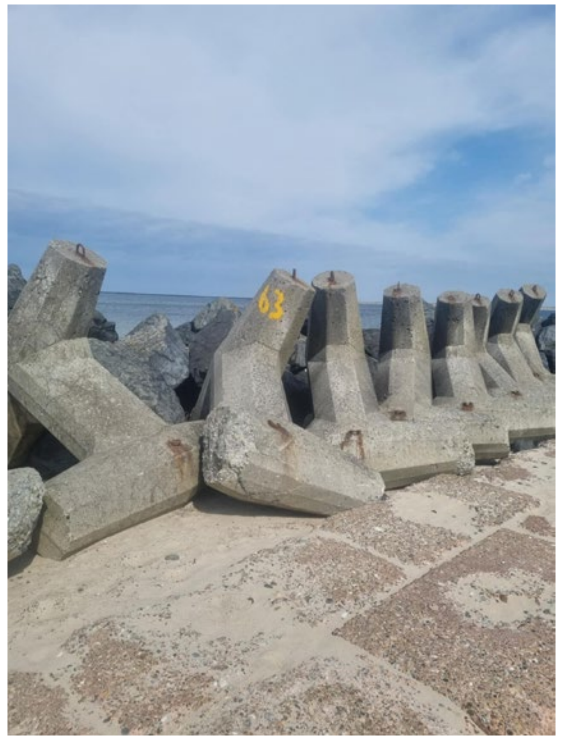


ill. 17. Thyborøn's coastal protection

ill. 18. Thyborøn's revetments



ill. 19. Thyborøn's wave breakers

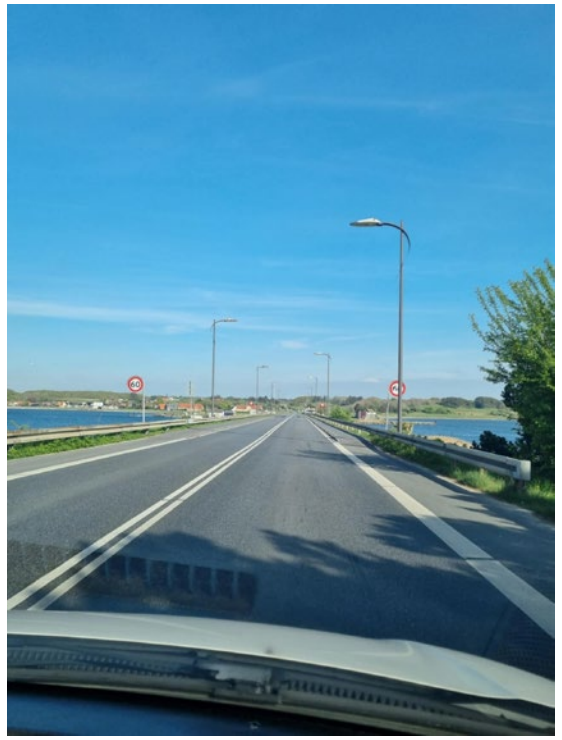


Lovns Bredning

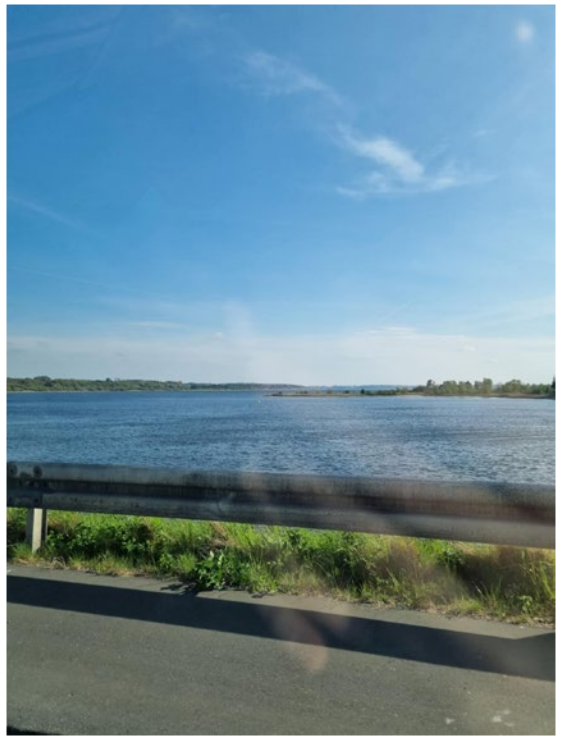
Next visit was to Lovns Bredning, one of the innermost reservoirs of the Limfjord situated between Skive Fjord and Hjarbæk Fjord. This site is located east of the city of Skive, in a relatively sparsly populated part of the country. Instead, this site is place to much open farmland and nature, with many aquatic and semi-aquatic plant species present. The surrounding landscape is perceived as flat with visual points of interest being the water, trees, and small settlements, especially as it is possible to see across the body of water to the opposite bank. Likewise, the seabed is experienced as rather flat and shallow as it is possible to see the bottom for a long distance. This area sees little flooding due to its sheltered location so far inland, but it has the valuable characteristic of having lower salinity making it a prime location for establishing aquafarms. The area already values bivalves as they hold yearly mussel festivals.

ill. 20. Access to water at Lovns Bredning

ill. 21. Low terrain at Lovns Bredning

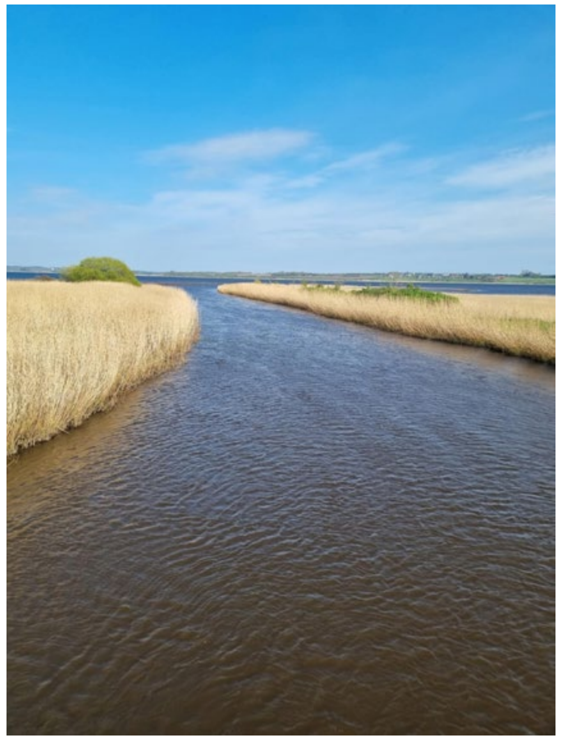


ill. 22. Other coast visible at Lovns Bredning



ill. 23. Semi-aquatic plants at Lovns Bredning

ill. 24. Vast nature at Lovns Bredning



Løgstør Bredning

The following visit was to Løgstør Bredning, located at the largest section of the Limfjord system. Part of Jammerbugt Kommune, this site sits between the fjord and the Western Sea. The especially flat terrain enables the area to flood easily and the landscape to vary depending on the tide. As the land use is focused around agricultural plots and unused natural habitats, the flooding is not of great concern. The sparse population, except for a few bigger villages located far inland, also means the flooding poses less risk to human life. The natural and protected habitats may even benefit from flooding as it contributes to the local species adapted way of living.

ill. 25. Coast at Løgstør Bredning

ill. 26. Inland stream at Løgstør Bredning

ill. 27. Coastal erosion at Løgstør Bredning

ill. 28. Varied landscape at Løgstør Bredning

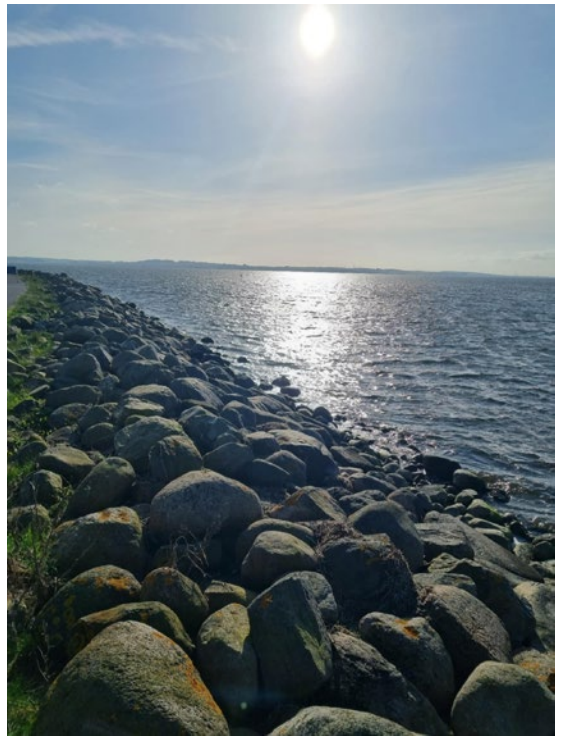
ill. 29. Nature at Løgstør Bredning

Nibe Bredning

Another visit was made to Nibe Bredning, which is part of a narrowing of the Limfjord system. This site is found just west of the city of Aalborg and its largest city is the city of Nibe. The areas low topography and vast fields of farmland define the landscape, which is split by the body of water. Nibe Bredning marks a pocket of the fjord with a shallow seabed, making it possible to wade a distance into the water, and an area with lower salinity due to the streams ending in the bay. The site is occasionally affected by flooding, both due to storms pushing water into the system and due to noticeable tide fluctuations cause by the low seabed. Therefore, some smaller protective structures are seen along the coasts of seaside cities such as Nibe. These structures are usually revetments and small dikes.

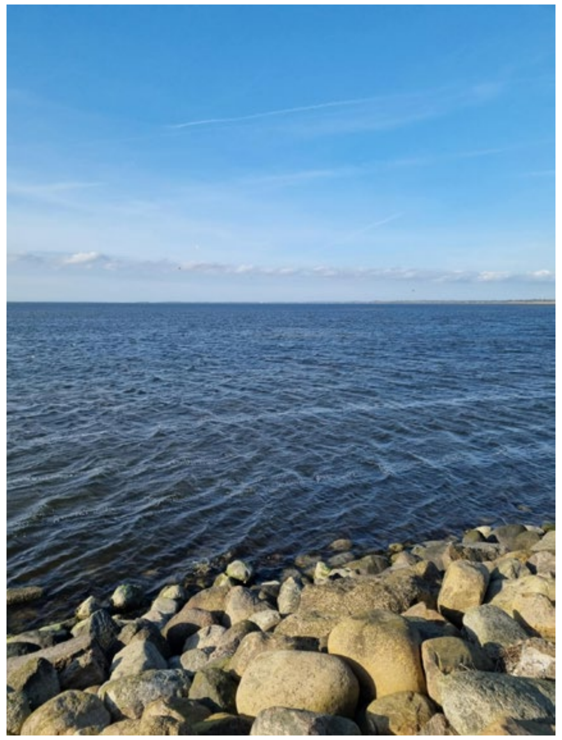
ill. 30. Water activities at Nibe Bredning

ill. 31. Other coast visible at Nibe Bredning

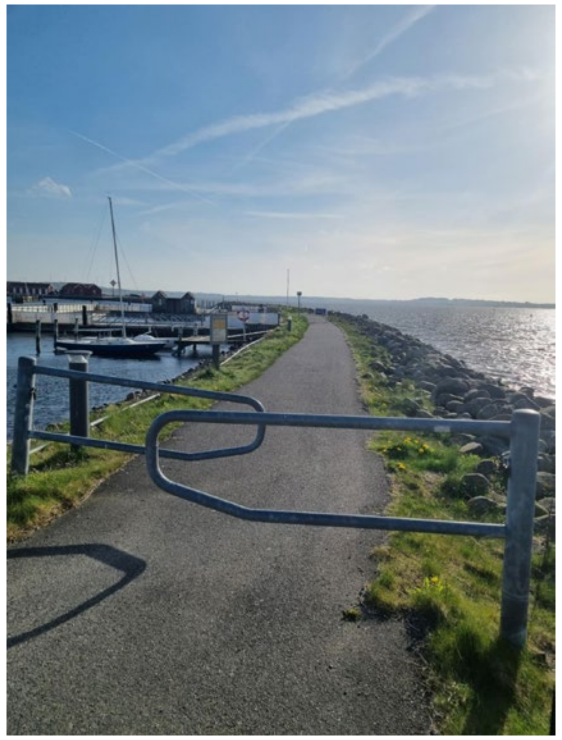


ill. 32. Revetment at Nibe Bredning

ill. 33. Shallow seabed at Nibe Bredning



ill. 34. Dike with path at Nibe Bredning

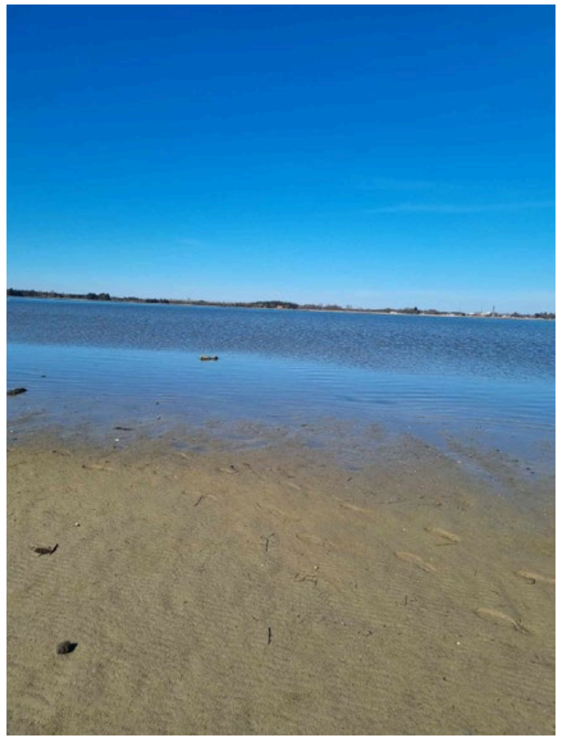


Hals Havn

The last site is Hals Havn located on the eastern shore, at the junction between the Limfjord and the Kattegat Sea. This site is defined by the cities of Hals to the north and Egense to the south, which are connected by a ferry line – much like Thyborøn and Agger. Due to the narrowness of the fjord in this area, it is possible to easily view the other shore. When standing in Hals it is noticeable that the southern shore's terrain is lower and flatter, with several areas where flooding has been allowed. On the contrary, Hals is rarely affected by flooding, both due to the slightly higher terrain and the protective structures in place. Multiple areas with revetments and wave breakers are seen, as well as a sea wall in place to protect the industrial harbour. The biggest threat of flooding for this area does not come from flooding earlier in the system, but rather from storms where the wind direction is from east to west, which pushes water from the Kattegat Sea into the cities. However, due to the offshore landmasses of Nordmandshage and Korsholmene, which act as natural wave breakers, impact is fairly limited.

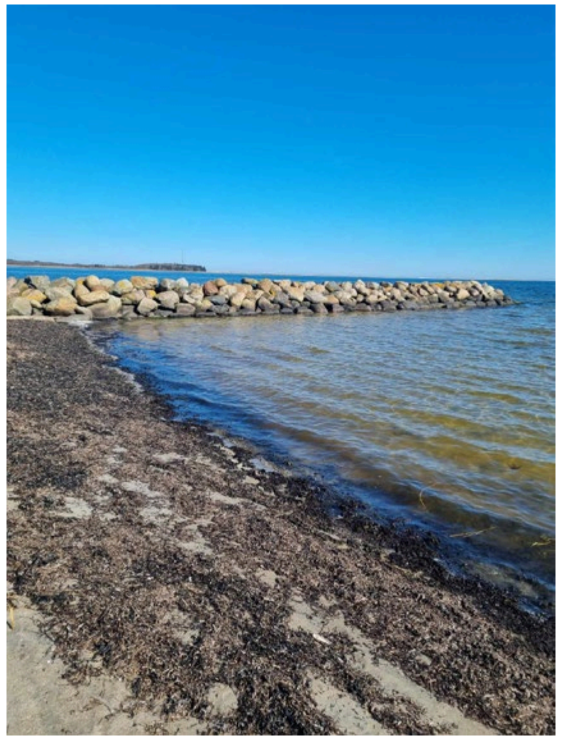
ill. 35. Cut-through dike at Hals Havn

ill. 36. Other coast visible at Hals Havn



ill. 37. Shallow seabed at Hals Havn

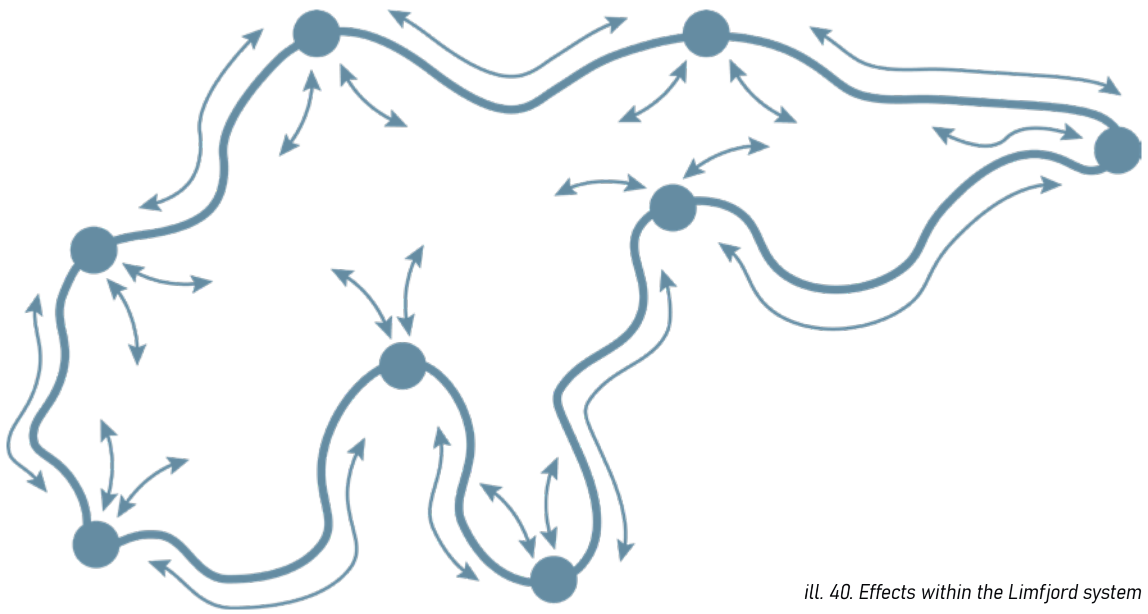
ill. 38. Wave breaker at Hals Havn



ill. 39. Ferry at Hals Havn

DEFINING IMPACT AREAS

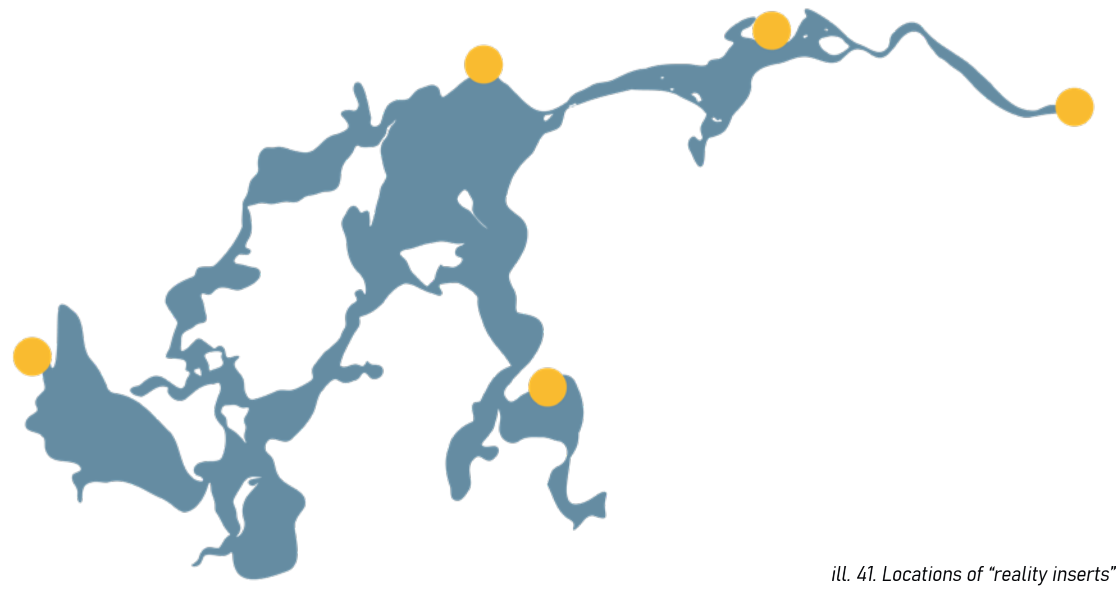
As any dynamic system, the inner workings of the Limfjord are greatly influenced by its composite pieces: the settlements along the coasts and their surrounding areas. And, although a common practice in the field of urban planning is to look at isolated places when developing projects, in the case of composite systems such as the Limfjord, any change in conditions in a certain point along the system would subsequently affect all other points throughout the entire system. Therefore, when designing interventions in such a case, a strategy with consideration for the entire system must be devised.



ill. 40. Effects within the Limfjord system

However, due to the urgency of implementing measurements against the rising threat of climate change and the resulting floods, developing an overarching, detailed strategy for the whole Limfjord would be greatly resource- and time-consuming; to the point where the impacts would be beyond the point of no return before any of the solutions could be put to practice. As such, the most sensible course of action would be to develop a catalogue of adaptable policies and strategies that can be translated to multiple locations along the system while working cohesively towards the overall resilience of the system. This thesis attempts to achieve precisely this, with the main goal being a robust framework which, after adaptation, could be utilised to strengthen the climate resilience of any similar area under threat.

To achieve this goal, the strategies must be able to perform well in a realistic situation and must be developed in a way which allows their further adaptation. As this is only a theoretical work at the time of its creation, such in situ testing is impossible. In order to go around this limitation, a simulative approach was taken in which five specific points of the system were chosen as "reality inserts" where the performance of the proposed strategies can be evaluated in a more realistic setting. Those five points are the Thyborøen Kanal, Lovns Bredning, Løgstør Bredning, Nibe Bredning, and Hals Havn.



ill. 41. Locations of "reality inserts"

Although it seems like this approach is no different from the typical "isolatory" one in the field, here the proposed interventions are not necessarily meant to represent a unique solution only applicable to that one specific site. Rather, the specific sites have been selected as the "reality inserts" after a careful consideration in relation to how representative each of them is of conditions that are applicable to multiple sites throughout the whole system. Additionally, all of the selected sites are at high risk of future floods, at both 3m and 5m sea level rise, which gives them a status of high-risk areas, and therefore in urgent need of a risk mitigation strategy.

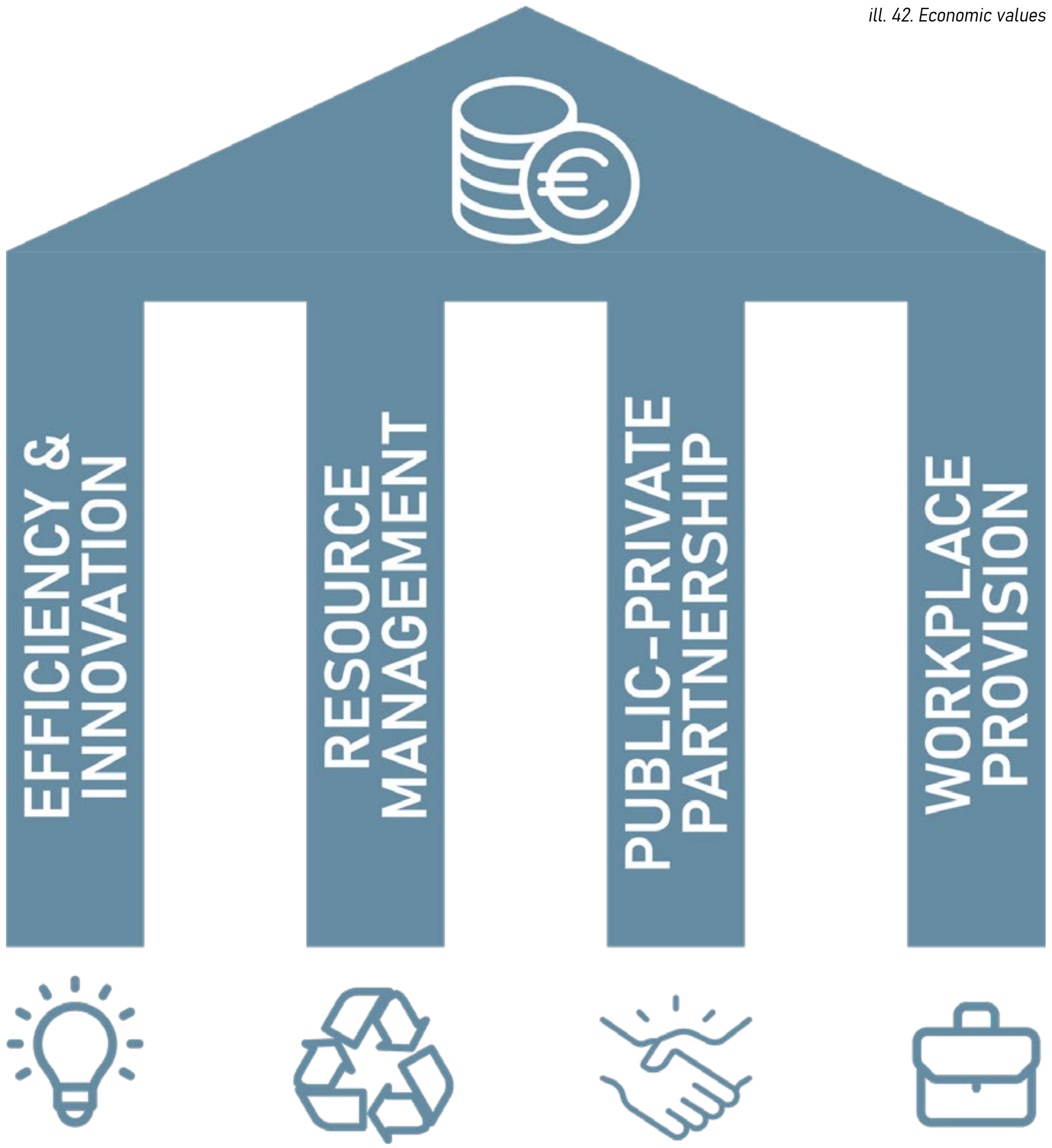
Furthermore, in order to select these specific sites, a more in-depth survey on the basis of the following four values has been conducted: strategic value, environmental value, social value, and economic value. So that misinterpretations are avoided, all of these values have been precisely defined and described as understood in this thesis.

Perceptively the most tangible out of the four, the economic value is usually the main focus of the vast majority of involved stakeholders when it comes to decision making regarding development projects. Generally presented in a numerical, mostly monetary format, it is easily understood, measured against, calculated, transformed into graphs and numeric tables, subdivided into components (commonly labour and resources), and seen as the "deciding factor" when it comes to the final decision regarding a new project. Concentrating before all else on profitability, most stakeholders understand the economic value of a project within the frame of a catalyst of "return on investment" (Sántha, 2023). In such a case, the project is a means-to-an-end; and the deciding factor is often the disparity between cost (preferably the lowest) and profit (the highest for the shortest time possible) (Christiansen, 2020).

This understanding, however, could be considered as progressively outdated, as the importance of resilient and robust practices becomes more and more urgent. As our available resources diminish, the insatiable drive towards economic growth must be reconsidered with the goal of stability at the forefront. That is not to say that economic growth must be completely disregarded, but instead approached in a more viable way, as suggested by E. B. Barbier in his fundamental theory on sustainable economic development (Barbier, 1987), which serves as the basis of the "Three pillars of sustainability" concept, later fundamental in the formulation of the UN's 17 Sustainable Development Goals (UN, 2015).

As per Barbier, economic sustainability is in place when economic growth, social equity, resource efficiency, and financial stability are in balance, and all economic activities are conducted with the scope of facilitating long-term economic well-being (Barbier, 1987). Subsequently, in this thesis, the economic value of a given site is understood as: a place with a capacity for efficiency and innovation of economic systems and businesses; a place where resources can be managed responsibly; a place with a potential high level of partnerships between the private and the public sectors; and a place with a capacity for the stable provision of workplaces.

ill. 42. Economic values



Following a similar approach, the definition of social value as understood in this thesis has been formulated with the concept of social sustainability in mind.

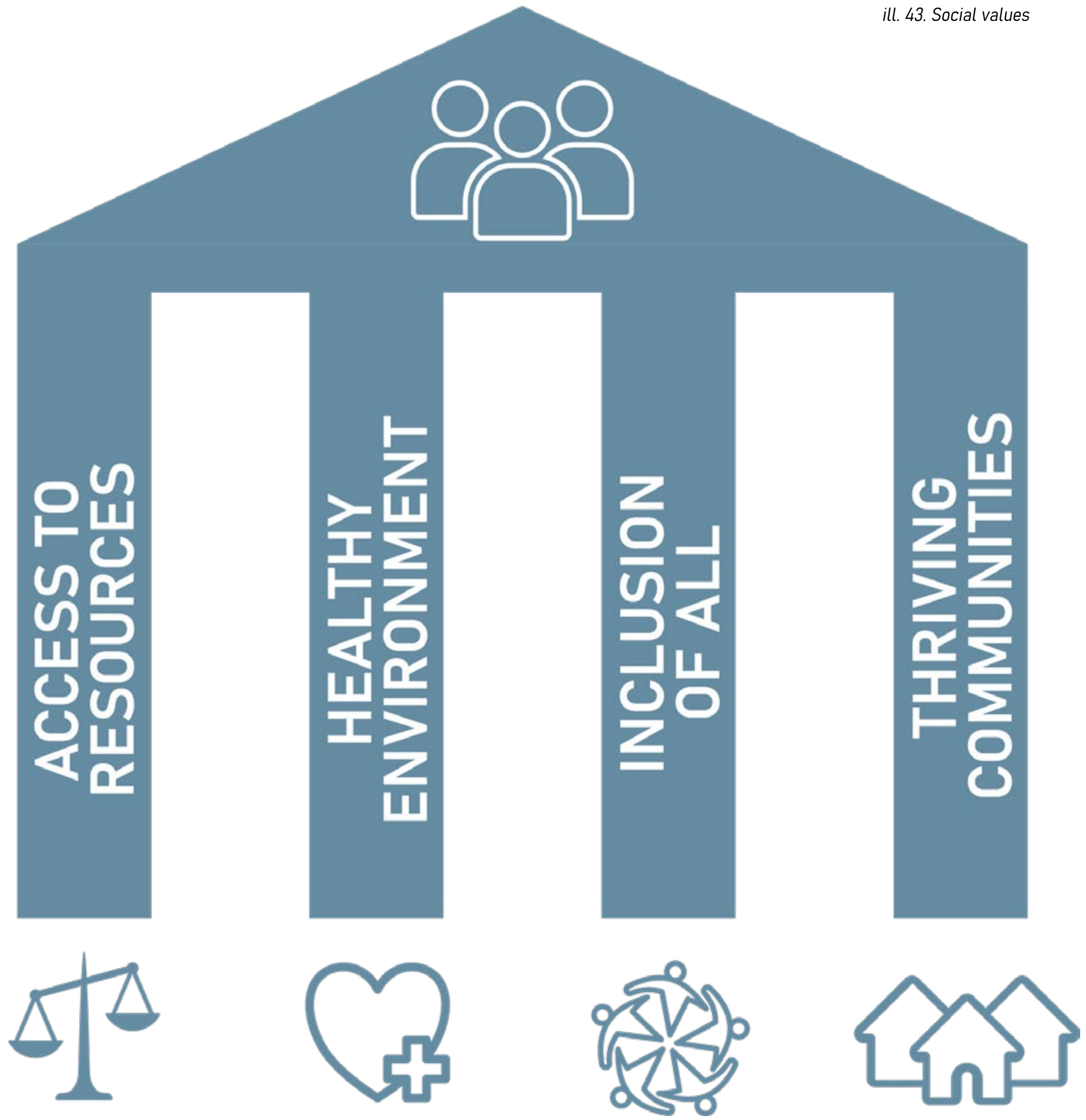
In the practice of urban planning and development, social sustainability is often a fundamental aspect in the project conceptualisation process from the point of view of professionals in the field. With a primary focus on the well-being of societies, a socially sustainable approach aims to promote equity and human rights, create inclusive communities, and ensure access to healthcare and education (Basiago, 1998).

Translated to the context of this thesis, the notion of a social value when it comes to a given site is defined as follows: a place with a secured equitable access to resources and opportunities for all; a place incorporating a beneficial environment for people's mental and physical health; a place which has adopted practices to foster the inclusion of all individuals; and a place where local communities have the opportunity to thrive.

Often colloquially referred to as simply "sustainability", the concept of environmental sustainability formulates the basis of the environmental value in this thesis.

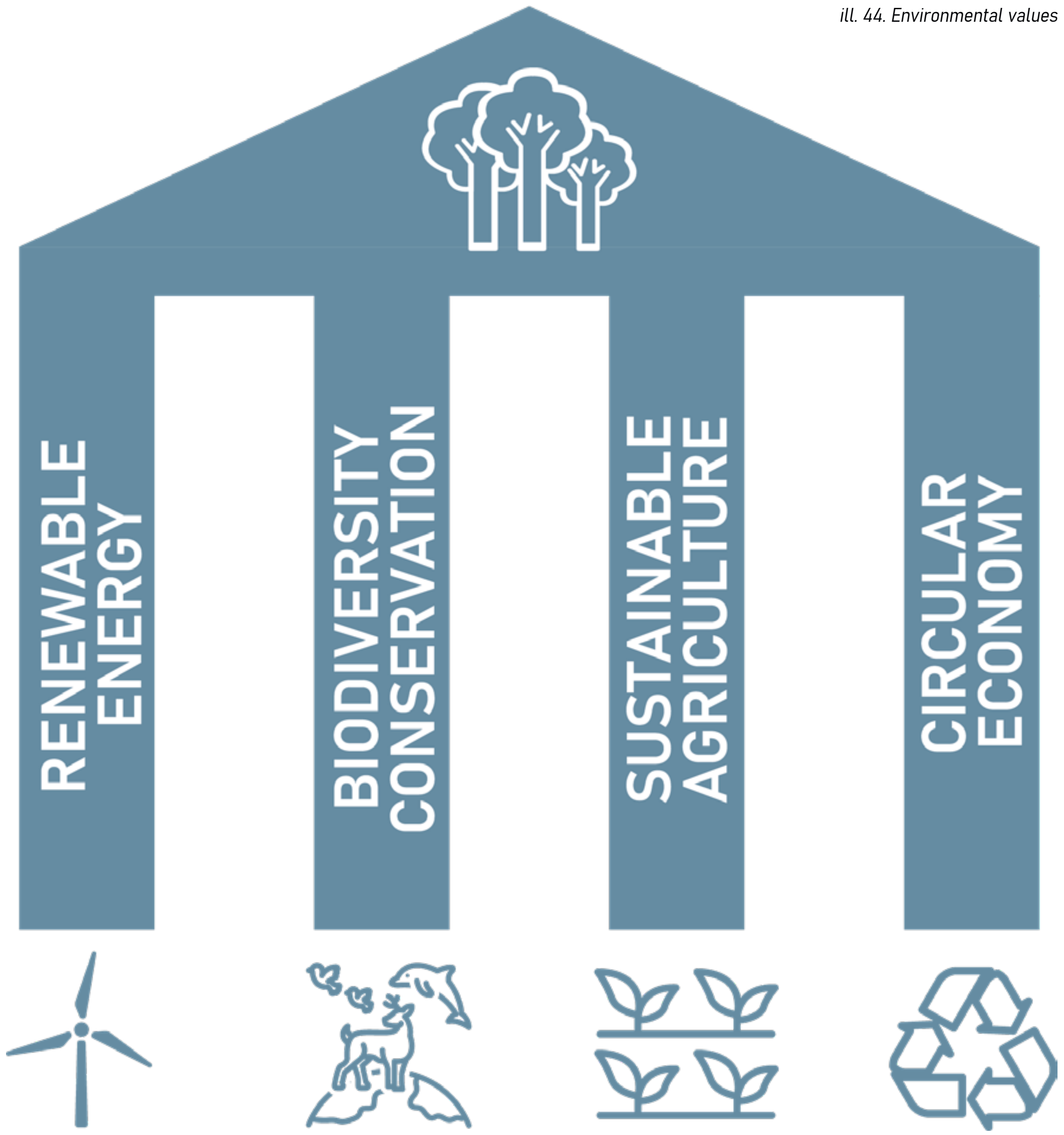
In the academic field, environmental sustainability commonly refers to the maintenance and safeguarding of the natural environment over time through effective practices and policies, ensuring that current needs are met without compromising future resource availability (Dryzek, 2005). Although much harder to concretise as tangible metrics than the economic value, the integrity of the environmental sustainability can be seen as influenced by several factors which in turn affect the ecological balance of the planet. Some of these indicators are: the loss of biodiversity; the pollution of air, water, and soil; the overexploitation of natural resources; the excessive amount of greenhouse gas emissions leading to climate change; and the economic models based on unsustainable consumption (Moldan et al, 2012).

ill. 43. Social values



Transferring this understanding of environmental sustainability to this thesis, the environmental value of the given site can be defined as: a place with a potential for energy production by renewable sources; a place where policies and practices to conserve biodiversity can be implemented; a place where sustainable practices in agriculture can be adopted; and a place with opportunities for promoting a circular economy.

However, analysing the sites only according to these three values ends up posing the same issue that is so common in the field of urban planning: perceiving places as isolated points, unaffected by their surroundings. As already explained, this approach is not ill. 44. Environmental values



suitable for the scope of this work, which aims to operate with the entirety of the Limfjord as a dynamic system, instead of picking off individual points along its flow.

Therefore, the criterion of the strategic value is introduced, where each of the sites is evaluated based on the sum of its impacts on the entire system.

To facilitate the understanding of what constitutes the strategic value, one might start with its most evident component: infrastructural systems and logistics. With their main feature being that of establishing physical connections between specific points along a defined route, infrastructural systems are a prime example of an important element of the strategic value of a location. In order to be of a particular value strategically, a location must at the very least be part of the points along the route comprising the infrastructural system, and ideally be a focal node along that route. It being a focal node could then be related to its importance in relation to logistics of goods (be it labour, resources, or both), and therefore its strategic value would increase in relation to the entire system of which it is a part.

However, the current reliance on long-range shipping of goods (and services) has been found to be progressively more damaging to the environment, despite the multitude of research done on the subject of carbon performance and management in relation to the logistics industry conducted in the last two decades (Herold & Lee, 2017). Spurred by the increasing trade competition due to globalization, the logistics industry has shifted its focus towards the global supply instead of the local (Martì et al, 2017). This has led to a growing out of the locally based systems, and thus has severed the relationship between the individual and the resource, thus concealing the actual impact that the access to this resource has on both the environment and the society (Plumwood, 2008).

In the advance towards a more resilient society, continuing to adhere to such practices would only result in further damaging the environment and all the communities related to the trade industry at a lesser or larger extent (Roth & Kåberger, 2002). As such, the scale of the logistics networks must be reconsidered, and the focus must shift towards the local communities within the range of a system which can be supplied primarily through self-sufficiency in order to obtain resilience (Roth & Kåberger, 2002).

Looking back towards the case of the Limfjord as a dynamic system, the approach towards logistics within it could be rethought to adapt a more traditional manner of trade: namely, the exchange of goods and services between the communities, constituting the given system. As such, the Limfjord itself becomes a part of the infrastructural network via the (re-)establishment of local trade routes between the interrelated communities. This would, in turn, lead to the designation of specific points (settlements) along the system as "trade hubs", consequently increasing their strategic value within the system.

In this thesis, the strategic value of a place is partially constituted by the prospects of the given place to be considered either a "trade hub" along the localised logistics system of the Limfjord, an "infrastructural node" composing an important point within the labour and resource mobility along the system of the Limfjord, or both.

Another constituent element of the strategic value of a place as understood in this thesis, is the nature and biodiversity factor.

Similarly to the interconnected and constantly flowing system of the Limfjord itself, nature (as in, flora and fauna) is also perpetually dynamic, and any small change at one point within its system would cause effects on the entire system (Amendolare, 2022). The Limfjord itself is, of course, also a part of the natural system, and it is subsequently affected by any shift in it (the opposite is, evidently, also true).

As such, areas along the system of the Limfjord with previously established natural environments or areas with the potential of establishing new natural environments are considered as places with a high strategic value in this thesis.

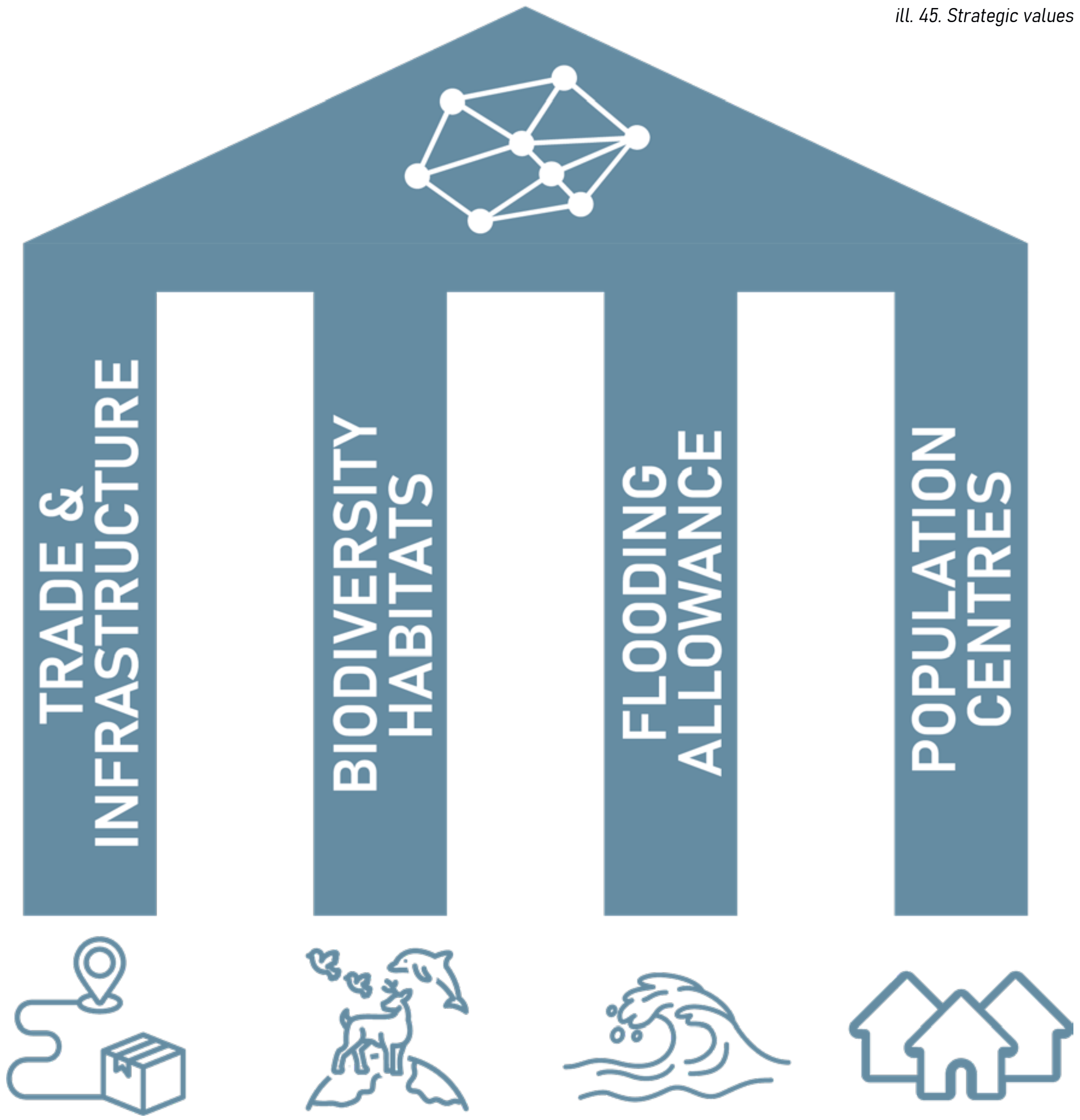
Seemingly counterproductive at first in relation to the strive towards preservation and resilience, a selective flooding allowance in some areas along the system of the Limfjord is also a composite element of the strategic value in this work.

It might, at first glance, appear as if the proposed strategies might not be functional in the scenario where certain areas are allowed to flood, while others are not. However, as multiple studies have shown over the last decades, at this point in time, flooding is inevitable, and the only truly sustainable course of action is to successfully mitigate it in areas where it is of the highest benefit, while allowing it in other areas where it would either be also beneficial, or of the least impact to the continued functioning of the system.

But how can a flood be beneficial? In the scope of this work, this has been observed on two different, yet related scales: in relation only to the impacted area itself; and in relation to the consequent impact on the entire dynamic system.

Firstly, there would be a localised impact within the area itself once flooded in relation to the local population, be it in regard to housing, or to land ownership from an agricultural standpoint. A completely flooded area would most likely lead to the land no longer being of use for these purposes, and therefore to a migration of the population to a different area. Of course, strategies as aquaculture and inhabiting water-based settlements could be implemented, but even in such a case a shift in the population is to be expected. Yet, the benefit in this case would be the development of new approaches of inhabiting such areas (such as the examples given here), which could later be of advantage at other points along the system (or elsewhere) once (and if) those other points are also impacted by floods.

A benefit observed at both the local and the system-wide scale would be the establishment of new natural habitats in the newly flooded areas. As already discussed, nature itself is a dynamic interrelated system, and any change along it would cause adaptations to the entire system. Thus, if some localised areas are allowed to flood, this would in turn be of an advantage to the local flora and fauna, as it would either expand their habitats, or designate new habitats along the system, sequentially contributive *ill. 45. Strategic values*



to the entire system.

Similarly related to the interconnected effects within systems, allowing a certain area to flood would in turn mitigate or entirely prevent the flooding of a different area along the system. In such a case, the flooded area would act as a vessel for the additional water now present within the system, and so would prevent the flow's need to make itself space further along the system. This, while not entirely beneficial to the local area itself, does bring an advantage to the entire system instead, by effectively enhancing the resilience of the overall system.

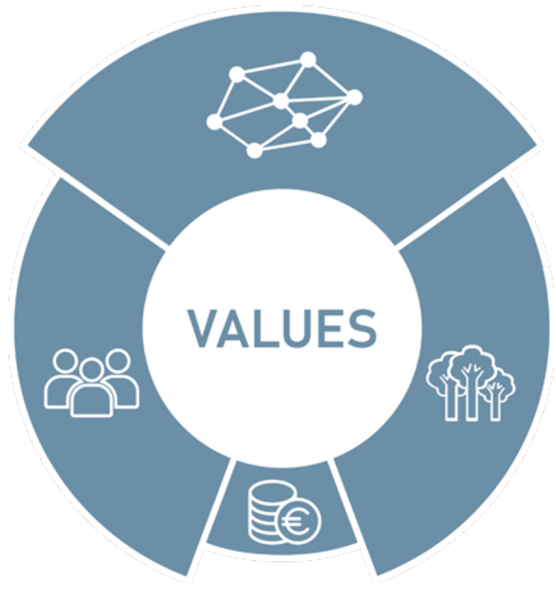
In an analogous way to flora and fauna being part of the natural system, the population is also a constituent element of the flow within the entire dynamic system related to the Limfjord. As such, the potential of locations as population centres along the system is another aspect of the strategic value of specific places. This is taken to also include the areas perceived as the hinterland of other settlements, as that is a factor of attractiveness in relation to the quality of settlements as seen by settlers (Vašíček et al, 2014). Therefore, places that could be considered as population centres are also of high strategic value.

To summarise, the strategic value of a place as understood in this thesis is such: a place that is a prospective "trade hub" or an "infrastructural node" in relation to the system of the Limfjord; a place with the potential of establishing new natural habitats or expanding existing ones; a place whose allowed flooding would be beneficial to the overall system of

the Limfjord; and a place which could constitute a population centre.

Within the scope of this thesis, the investigation of the sites has been approached via a ranking of these four values, created on the basis of each value's importance for and effect on the overall system of the Limfjord. In this ranking, the strategic value is placed first as the one bearing the most significant influence on the system. Then, the environmental value is seen as second, as the Limfjord itself is a part of nature, and to be able to continue co-existing with it, the approach towards inhabiting the areas surrounding it must be reconsidered. Third comes the social value, as the local communities are not only those who would be co-existing with the system of the Limfjord, but are also a composite part of the system itself. Lastly, and perhaps most controversially, the economic value has been ranked below the other three values.

ill. 46. Categories ranking



As pointed out earlier in this thesis, one of the main challenges which stakeholders face during the decision-making process of development projects is the ability to prioritise non-monetary values. More often than not, this leads to a focus on short-term or immediate (financial) gain, rather than long-term aspects which would be beneficial to not only the stakeholders, but also the environment and the local communities (Rochell et al, 2021). According to research, the main cause of this lies in the lack of tangible metrics when it comes to the other, non-monetary values (Rochell et al, 2021). Unlike financial returns, values such as environmental sustainability and community resilience are not measured via standardised metrics, and therefore pose a challenge when it comes to assessing their impact on a project (Jayasena et al, 2019). As such, one of the aims of this thesis is to facilitate the understanding of the four values (strategic, environmental, social, and economic), and thus allow stakeholders to make more informed decisions regarding resilient development that are based on more than just financial quotas, but rather on comprehensive benefits for both population and environment.

Another challenge when it comes to prioritising values by stakeholders, is posed by the competing priorities that the variety of involved stakeholders might have regarding a project. A simple example would be the discrepancy between the interests of the local community versus those of the involved institutions and political representatives. Often, projects are approved simply because they are a means-to-an-end of fulfilling short-term political goals, usually also seen as being an immediate source of revenue, rather than because of their significance in benefiting the long-term needs of the local community (Rochell et al, 2021). Analogously, the priorities of the involved institutions frequently end up competing against one another, which prevents the reaching of a consensus in regard to the specific project, leading to either a re-drafting of the entire project (costing even more time, labour, and resources), or a complete abandonment of the given project (Jayasena et al, 2019).

In order to address these challenges, and aid in the prioritising of the values in project development beneficial to all stakeholders involved (including the local communities and the environment), this thesis presents a comprehensive explanation of those values and applies them to a proposed project to illustrate their future utilisation by the stakeholders. This explanation, combined with the subsequent specific strategies for flood mitigation, are meant to serve as the basis for the discussions taking place during the decision-making processes, and to contribute to the creation of a more resilient environment for the inhabiting communities of the future.

UNDER THE LENS

In the context of the Limfjord system's dynamic and interconnected nature, it is essential to carefully examine the potential sites where interventions would be suggested before their selection. This is done with the scope of choosing locations with a potential that is the highest when it comes to exemplifying the four values discussed above (strategic, environmental, social, and economic), and such that would best benefit the entire system of the Limfjord, not only the isolated surroundings of the given sites. Each of these sites, with its distinct characteristics and challenges, serves as a "reality insert" where the proposed strategies can be tested, evaluated, and adapted to contribute best to the overall resilience of the Limfjord system.

The selection of Thyborøn Kanal as a "reality insert" site within the Limfjord system is based on its multifaceted significance, which aligns with the four values delineated in this thesis: strategic, environmental, social, and economic.

Thyborøn Kanal occupies a pivotal position within the Limfjord system, serving as a vital infrastructural node that facilitates the mobility of both labour and resources. Its strategic importance is exemplified by its role as a focal point in the local logistics network, which is essential for the establishment of resilient trade routes. The canal's location enables it to function as a "trade hub," connecting various communities and fostering the exchange of goods and services. This interconnectedness is crucial for enhancing the overall resilience of the Limfjord system, as it promotes self-sufficiency and reduces reliance on long-range shipping.

Furthermore, Thyborøn Kanal's role as the "entry point" towards the system from the West, the location where more water is initially introduced within the system, makes it of utmost importance when it comes to regulating flooding throughout the entire system. By additionally securing Thyborøn Kanal, the amount of new water let into the rest of the system is controlled, and thus floodings further along the Limfjord are either lessened or entirely avoided.

The environmental value of Thyborøn Kanal is evident in its potential to support biodiversity conservation and sustainable practices. The canal's proximity to diverse natural habitats makes it an ideal site for implementing policies aimed at preserving and enhancing local flora and fauna. Additionally, the area's suitability for renewable energy production, such as wind and tidal energy, aligns with the principles of environmental sustainability. By adopting sustainable agriculture practices and promoting a circular economy, Thyborøn Kanal can serve as a model for environmentally responsible development. The selective flooding allowance in certain areas along the canal can also contribute to the establishment of new natural habitats, further enhancing its environmental value.

Despite Thyborøn Kanal's social value not being as clearly evident as the other value, it is still to be seen in its capacity to foster resilient communities. The canal's strategic location and economic possibilities can attract a diverse population, promoting equitable opportunities and a sense of belonging. By ensuring equitable access to resources and opportunities, Thyborøn Kanal can become a place where local communities thrive, and individuals' mental and physical well-being is prioritized. The implementation of inclusive practices and the provision of healthcare and education services can further enhance the social value of the site, creating a beneficial environment for all residents.

The economic value of Thyborøn Kanal is multifaceted, encompassing its potential for efficiency and innovation in economic systems and businesses. The canal's role as a trade hub and infrastructural node can stimulate economic growth by facilitating the movement of goods and services. This, in turn, can lead to the creation of stable workplaces and the development of partnerships between the private and public sectors. By managing resources responsibly and promoting sustainable economic practices, Thyborøn Kanal can achieve long-term economic well-being. The canal's economic value is further enhanced by its potential to attract investment and foster innovation, contributing to the overall prosperity of the Limfjord system.

Following the selection of Thyborøn Kanal, the discourse extends to Lovns Bredning, another site within the Limfjord system. The choice of Lovns Bredning is similarly predicated on its alignment with the four values that construct the framework of this thesis.

Lovns Bredning holds a significant strategic position within the Limfjord system due to its partial seclusion from the main flow of the Limfjord. As it is located more inland, the chemical composition of its waters differs from that found in the rest of the system, thus allowing for another type of intervention to be implemented, and namely that of aquacultural facilities. As aquaculture requires waters with a mixed salinity level (neither too high, nor too low), and waters which are not as disturbed by large scale seafaring transport, the location of Lovns Bredning composes an ideal opportunity for the establishment of such facilities. Furthermore, the establishment of an aquaculture plantation would have the added benefit of purifying the water and naturally producing nutritive sources, which would ultimately benefit the entire system by spreading throughout it via the waterflow.

As a subsequential result of the potential for aquaculture plantations, the environmental value of Lovns Bredning is evident in its potential to not only support but also contribute to biodiversity conservation and sustainable practices. The area's proximity to the diverse natural habitats within the waters makes it an ideal site for implementing policies aimed at enhancing local flora and fauna and contributing to the water quality in the entire system of the Limfjord. By adopting sustainable agriculture practices and promoting a circular economy, Lovns Bredning can serve as a model for environmentally responsible development.

Lovns Bredning's social value is reflected in its proximity to the border between the two regions of North Jutland and Central Jutland. This location, combined with the potentials of aquaculture farming, can attract a wider population to the area. The multitude of smaller settlements around the water allows for the creation of a cohesive community, founded on the principles of self-resilience through sharing and belonging. This, in turn, would immensely contribute to the physical and mental well-being of the population in this area, leading to a higher social value of the area.

The economic value of Lovns Bredning stems mainly from its cross-regional location and the potentials that come with the establishment of aquaculture facilities. This can lead to the creation of stable workplaces for the communities not only in the local area, but also from elsewhere, and the development of partnerships between the private and public sectors. There also exists the opportunity to then further invest in the area's development, thus contributing to the overall affluence of the entire Limfjord system.

Building upon the analyses of Thyborøn Kanal and Lovns Bredning, this chapter extends the examination to Løgstør Bredning. The focus of Løgstør Bredning is similarly based on the four values illustrating how it embodies the principles of systemic resilience and sustainability essential to the overarching objectives of this study.

Løgstør Bredning represents one of the areas along the Limfjord systems that is most significantly impacted by floods, even at current sea rise levels. Its landscape is home to a multitude of water bodies (lakes, rivers, and streams) which, combined with its relatively flat terrain, are the main reason for the frequent floods in the area. Furthermore, Løgstør Bredning is located precisely before the Aggersund Channel, which acts as the inlet towards the Eastern part of the Limfjord system. Therefore, if the area of Løgstør Bredning is allowed to flood in a controlled manner, this would subsequently lessen the flooding in the Eastern part of the system. This would benefit the rest of the system by lessening the impact on important locations such as Aalborg as the most major city along the system, and its hinterland in the Jammerbrugt municipality.

The environmental value of Løgstør Bredning is of an essential importance, as it currently houses several Natura 2000 natural habitats. This fact, combined with the opportunity of controlled flooding, comprises the exceptional significance of the area when it comes to the possibility of not only enhancing the current ecosystems in the area, but also creating new ones. As the chemical composition of the soil in the area would change due to the floods, new ecosystems would be established, and with them new and more life would be brough to the area, benefitting the entirety of the Limfjord system by bringing more biodiversity to it. Additionally, the area's proximity to the Thy National Park would allow for the extension of the protected natural areas, thus contributing to both human and environmental well-being in the area.

Løgstør Bredning's social value is reflected by precisely this proximity to thriving nature. It has been consistently proven that individual mental and physical well-being is dependent on the frequency and quality of the contact which one has to nature (Nejade, Grace & Bowman, 2022). With the extension of the natural areas at Løgstør Bredning, there will be more nature in the vicinity of other more populated areas, which would facilitate the direct contact that people throughout the Limfjord system have to nature, thus enhancing the social value not only of the location itself, but of the entire system.

The economic value of Løgstør Bredning is to be seen in the potential establishment of a research centre within the extended flooded natural area. This institution could be a branch of the Aalborg University, as the largest higher educational institution in the area, and thus act as an attractor of investment of both labour and resources, leading to the increase of economic value in the area. This research centre would not only create stable workplaces but would also establish the opportunity for an extension of the centre in the future throughout more of the system, thus leading to the economic benefit of the entire Limfjord system.

Continuing the comprehensive analysis of intervention sites within the Limfjord system, the selection of Nibe Bredning as an intervention site is also grounded in its alignment with the four values that exemplify its importance to the entirety of the Limfjord system.

Nibe Bredning's strategic value is distinguished by its unique geographical and logistical attributes. Unlike other sites within the Limfjord system, Nibe Bredning is characterized by its proximity to both urban and rural areas, making it a critical junction for integrating diverse economic activities. As Aalborg's hinterland, it is of high importance when it comes to it being a population centre, therefore also establishing its importance when it comes to connectivity. However, due to the very low terrain of the area, the danger of floods is high compared to other locations along the Eastern part of the Limfjord system. In order to safeguard the nearby population centres of Aalborg, Nørresundby, Aabybro, Brovst, Pandrup and Nibe, it is essential to allow for an occasional controlled flooding in the low parts of the Nibe Bredning area. This would then further enhance its strategic value, by contributing to the protection of other locations along the Limfjord system.

The environmental value of Nibe Bredning is particularly notable for its potential to act as a pilot site for innovative environmental conservation strategies. The area's diverse ecosystems, including wetlands and coastal habitats, provide a unique opportunity for implementing and testing aquafarming facilities and biodiversity conservation measures. Additionally, Nibe Bredning's location offers significant potential for the development of an interactive centre focusing on aquaculture and water farming. The implementation of selective flooding strategies in this area can also contribute to the creation of new habitats, thereby enhancing the ecological value and resilience of the entire Limfjord system.

Nibe Bredning's social value is primarily based on its proximity to the large population centre of Aalborg, and the role it plays as its hinterland. As the cost of living in large cities continuously increases, more and more people choose to instead move to the surrounding areas outside of the cities and commute to work as frequently as needed (Eliasson & Westerlund, 2023). The area of Nibe Bredning hosts a multitude of "commuter settlements", which in turn vastly increases its importance regarding the social value of the area.

Further coming as a consequence from the proximity to Aalborg, the economic value of Nibe Bredning is relatively high. Not only is there an economic boost to the area due to the vast available workforce as compared to that in the rest of the Limfjord system, but also the amount of goods and resources brought to the area due to the population is higher. Furthermore, the proximity to Aalborg as an industrial hub would play a major role in the potential of attracting investments of businesses and industry to the area of Nibe Bredning as resources and workforce is more spread out, further increasing the overall economic value of the area, and thus contributing to the economic value of the overall system.

Extending the analysis of intervention sites within the Limfjord system, the selection of Hals Havn as an intervention site is also in tune with the four values showcasing its importance to the entirety of the Limfjord system.

Hals Havn's strategic value is uniquely defined by its role as a gateway between the Limfjord and the broader North Sea region. This positioning not only enhances its importance as a logistical node but also amplifies its potential to facilitate international trade and cooperation. The strategic importance of Hals Havn is further strengthened by its capacity to integrate maritime and inland transportation networks, thereby fostering a more resilient and interconnected trade system. By leveraging its unique geographical advantages, Hals Havn can serve as a catalyst for regional economic integration and sustainable development. Additionally, its potential to act as a centre for maritime innovation and technology can further enhance its strategic value, contributing to the overall resilience of the Limfjord system.

The environmental value of Hals Havn is particularly notable for its potential to serve as a model for sustainable coastal management and marine conservation. The area's diverse marine ecosystems, including seagrass beds and coral reefs, provide a unique opportunity for implementing and testing innovative conservation strategies. Furthermore, Hals Havn's location offers significant potential for the development of marine renewable energy projects, such as offshore wind farms and tidal energy systems. By harnessing these natural resources, Hals Havn can contribute to the transition towards a more sustainable and low-carbon energy system.

Hals Havn's social value is based in the opportunities that come along with it becoming an important trade hub and maritime transport location. These developments would lead to the attraction of a wider population to the area, thus contributing to the societal development at the location. With the flow of goods and transport, the necessity of establishing services would also arise, and thus contribute to the foundation of a resilient society in the area. Furthermore, as a maritime port, the continuous flow of people would contribute to the diversity in the area, thus leading to a more inclusive and open society, further enhancing the social value of the area.

The economic value of Hals Havn encompasses its potential for fostering innovation and entrepreneurship in the maritime sector. The area's strategic location and diverse economic base provide a fertile ground for the development of new businesses and industries, particularly those focused on sustainable maritime practices and technologies. By promoting responsible resource management and sustainable economic practices, Hals Havn can achieve long-term economic well-being. The area's economic value is further enhanced by its potential to attract investment and foster innovation, particularly in the fields of marine biotechnology and renewable energy. By leveraging these opportunities, Hals Havn can contribute to the overall prosperity of the Limfjord system and serve as a model for sustainable economic development.

To summarise, this comprehensive analysis of the selected intervention sites within the Limfjord system exemplifies in depth the critical importance of strategic, environmental, social, and economic considerations in planning for systemic resilience and sustainability. Each site, with its unique attributes and potential, serves as a crucial "reality insert" where proposed strategies can be effectively tested and adapted. By carefully selecting and evaluating these sites, the interventions not only address localized challenges but also contribute significantly to the holistic enhancement of the entire Limfjord system. The integration of these multifaceted values ensures that the interventions are robust, adaptable, and beneficial to the entire interconnected system, thereby promoting a resilient and sustainable future for the Limfjord and its communities.

03

FRAMEWORKS FOR FLOOD RESILIENCE

CURRENT APPROACHES

When deciding to protect the coast and hinterland, an array of strategies is available to target challenges related to flooding and erosion. Thus, the strategies can be categorized into; flood control, erosion control, and defence strategies. Depending on the specific landscape and severity of the challenge, some strategies are more advantageous and thus a careful selection of the available strategies is key to achieving adequate protection and balancing the ecological concerns and human interaction. To decide what strategies will be appropriate for this project, and the landscape around the hydrological system of the Limfjord, the most common available strategies and their use cases will be discussed.

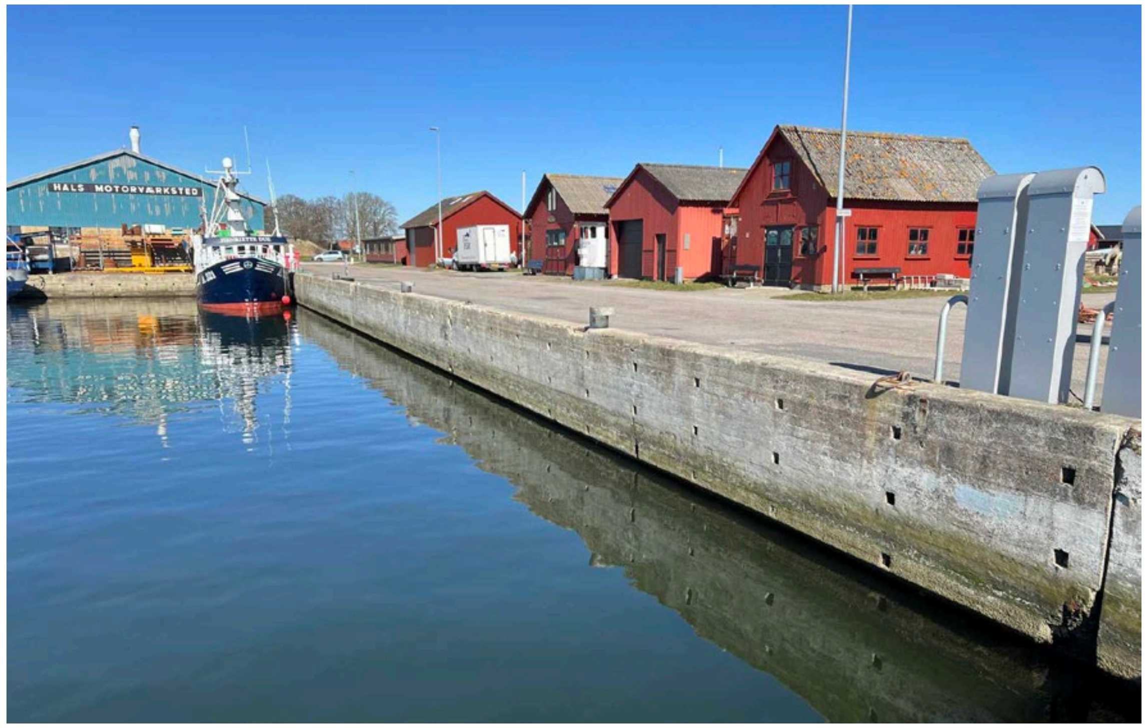
Dikes

ill. 47. Dike with path, Nibe

Dikes are an onshore strategy being both in the flood and erosion control group and are typically considered a last line of defence as they are designed to protect against a certain level of flooding. The shape and construction can also reduce and protect against erosion, as they are typically constructed by manipulating the terrain around a reinforced core or secured with stones in especially erosion prone areas (T. Schoonees et al., 2019). Dikes must be designed with a certain slope, usually between 1:3 and 1:7, in order to actively protect against waves, but an even more gentle slope could be considered in order to allow the dike structure to assimilate in the landscape and not be perceived as an artificial structure (T. Schoonees et al., 2019). Dikes require more space than other strategies, as the taller they are the wider they must also be in order to achieve the required minimum slope (T. Schoonees et al., 2019). However, dikes are well documented to be highly functional and can be designed in various ways that also benefit the ecosystem and be useable by the local community (T. Schoonees et al., 2019). This can be achieved by a gentle slope, and a green appearance with topsoil and local flora, while the dike can act be fitted with pathways and urban spaces making it interesting for human users (T. Schoonees et al., 2019). With pathways, the dike can also allow for a sustained connection and accessibility to the water, instead of separating, being highly attractive to both fauna and humans (Scheres & Schüttrumpf, 2019).

Seawall

ill. 48. Seawall, Hals

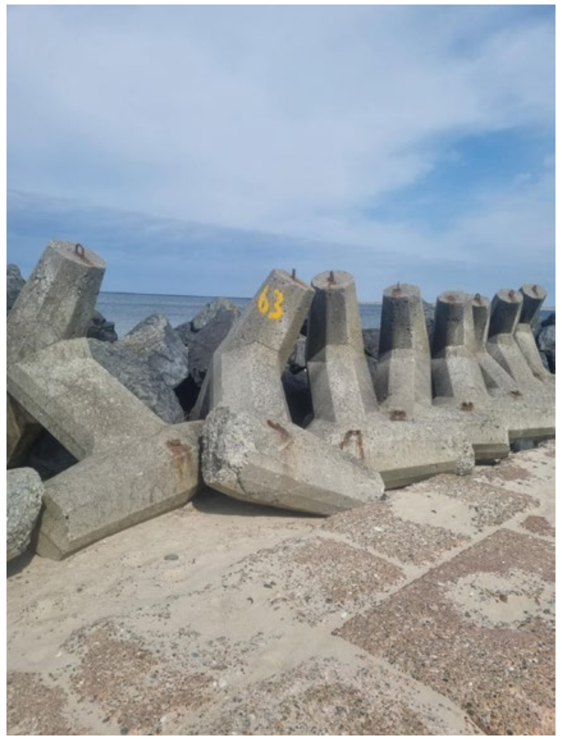


Similar to dikes, seawalls are onshore structures which function as both erosion and flood control and are also considered a last line of defence. Usually located next to the body of water, seawalls can be designed in various ways and at different heights, as to adapt to the specific location and flood threat (Hosseinzadeh et al., 2022). Seawalls are vertical or curved structures typically constructed of reinforced concrete or steel and are highly effective but must be carefully designed as they can produce wave reflection, which risks structural instability (Hosseinzadeh et al., 2022). Traditional construction practices result in seawalls being structures of separation, as they block access to the water, but modern practices tend to incorporate openings that can be closed during storms so the wall can be part of the urban space (Hosseinzadeh et al., 2022), such as the seawall in Lemvig (Nielsen et al., 2025). Modern adaptation to the structure can also support the ecosystem, with textures and crevices for aquatic animal to inhabit (Hosseinzadeh et al., 2022), (T. Schoonees et al., 2019).

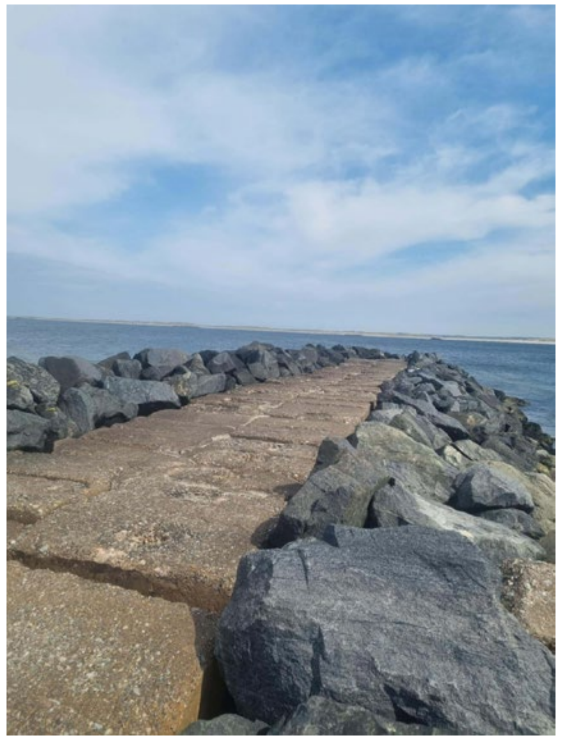
Wave breakers & revetments

Wave breakers and revetments are protective structures that function as erosion control, especially targeting coastal erosion. Placed either onshore or offshore, these structures are usually constructed of concrete or natural stone, with the biggest difference found in the placement (T. Schoonees et al., 2019). Wave breakers usually follow the coastline whereas revetments are placed in long corridors from the coast into the body of water, but both strategies act to reinforce the coast and minimize wave energy in effect reducing sediment loss (T. Schoonees et al., 2019). These structures can be very beneficial for the ecosystem as they add many opportunities for plants to grow and animals to hide (T. Schoonees et al., 2019). Likewise, if placed with care, they will not reduce the quality of and accessibility to the coast making them more favourable for the human experience.

ill. 49. Onshore wave breaker, Thyborøn



ill. 50. Wave breaker with path, Thyborøn



ill. 51. Revetment, Thyborøn

Beach nourishment

Beach nourishment is an onshore strategy targeting erosion control with a softer approach. This strategy does not try to limit coastal erosion, instead trying to restore the coast by periodically adding new sand and sediment to the beach (Peterson, C. and Bishop, M., 2005). It can also be used to restore previously damaged areas, for example places impacted by storms (Peterson, C. and Bishop, M., 2005). By adding more sediment, the coastal zone can be increased to further protect against waves, as a new slope angle can reduce wave energy (Peterson, C. and Bishop, M., 2005). However, this strategy can be expensive due to maintenance and its temporality, and it even risks harming the ecosystem if the wrong type of sediment is used or animals get trapped under the added sand (Peterson and Bishop, 2005).

ill. 52. In need of beach nourishment, Hals

Pumping

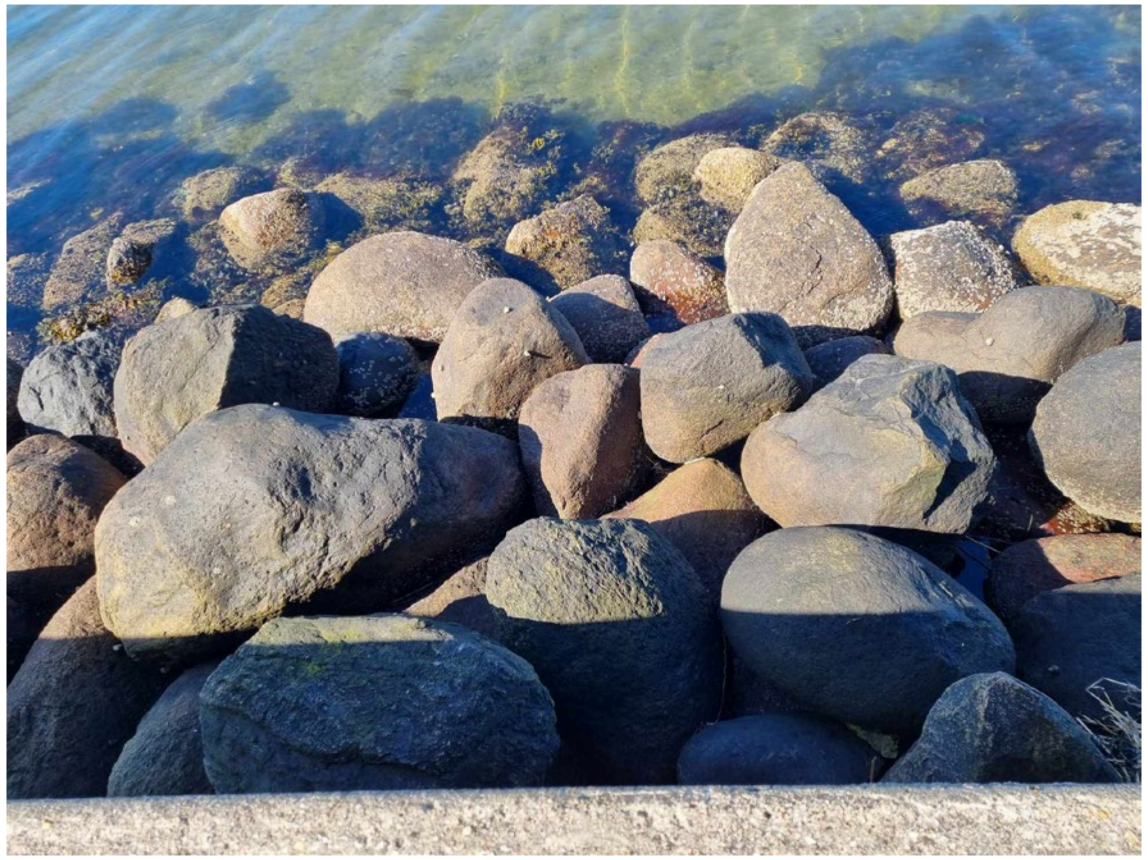
Pumping is an onshore strategy to move water from an undesirable location to a body of water, to target flood control (Leake & Barlow, 2013). A series of pipes and engines pump the water and can also handle surfacing groundwater. This strategy is costly and will emit CO_2 while the pump is in action, making the strategy non-sustainable (Leake & Barlow, 2013). Therefore, pumping is only recommended for short periods of time, for example in relation to construction of other structures and after storms where excess water is left in cities.

Specialized plants

Introducing more specialized plants and increasing green structures near the coasts can be used for flood and erosion control, even though it is a limited strategy. This means that it can only protect to a certain threshold, that is lower than many other strategies (T. Schoonees et al., 2019). Onshore, certain plants will tolerate occasional flooding and slightly higher salinity levels, where their roots will protect against coastal erosion (T. Schoonees et al., 2019). Offshore, aquatic plants such as eel grass will help reduce wave energy and sediment loss, reducing coastal erosion (T. Schoonees et al., 2019). These plants and green structures are essential for the ecosystem in these areas and must be implemented, however it should more so be used in conjunction with other protective strategies in vulnerable areas (T. Schoonees et al., 2019).

ill. 53. Specialized plants, Lovns Bredning

ill. 54. Ecological activity, Nibe



ill. 55. Supporting the ecosystem, Hals

Retreat settlement

Retreating settlements is a defence strategy to be used in areas where continued habitation proves too risky to human health (Siders, Hino & Mach, 2019). Settlements to be abandoned result in a displacement of people and a loss of structures and resources. This is considered an invasive strategy as communities are lost and people forced to relocate, requiring many resources (Siders, Hino & Mach, 2019). However, this is occasionally necessary and as sea levels rise, may become more relevant. Therefore, it is important to plan properly for this strategy, as areas must be identified early to give inhabitants adequate time to relocate and be compensated for their loss (Siders, Hino & Mach, 2019).

Allow flooding elsewhere

Allowing flooding means accepting the flooding, which can be considered a soft strategy dealing with flood control. Areas suitable for flooding can be identified, either by being far from settlements, too difficult to avoid flooding, or a nature type that would benefit from the flooding (Lamond and Proverbs, 2009). Through careful planning these areas can be left alone to naturally flood, and the displaced water will be stored and lessen the impact of flooding on areas further along the water system (Lamond and Proverbs, 2009). As this strategy can greatly impact the environment where the flooding occurs, it must be done with caution and be allowed to happen gradually, so the area has time to adapt (Lamond and Proverbs, 2009). In effect, the new flooded areas can benefit the local ecosystem and protect the hinterlands without any new built structures (Lamond and Proverbs, 2009).

ill. 56. Allowed flooding, Hals

Aquaculture/Aquafarming

Aquaculture can be used as coastal protection, specifically as erosion control, as the structures can act as wave breakers reducing the wave energy (T. Schoonees et al., 2019). This strategy can be highly beneficial as it both protects the coast and provides a habitat for aquatic species (T. Schoonees et al., 2019). Especially structures focusing on bivalves are desirable as the animals can improve the water quality as they filter the water and eat algae, while providing food for the human communities nearby (T. Schoonees et al., 2019).

Implications

A wide array of strategies is available, and each has different use cases. Many traditional protective measures are 'grey' structures, such as seawalls, which solely focus on being functional and often have low useability for both flora, fauna, and humans (T. Schoonees et al., 2019). Newer strategies, such as using plants and beach nourishment, focus more on 'green' and 'soft' structures, which rely on using nature as the protective structure and support the ecosystem (T. Schoonees et al., 2019). Certain hybrid structures have been developed, which add modifications to the 'grey' structures to better accommodate flora and fauna. Likewise, modern protective structures are often designed to be multifunctional and incorporate urban spaces and function to support the local community (T. Schoonees et al., 2019). Therefore, this project will focus more on the green and hybrid structures, while still designing protective structures that will be safe for a design period of 100 years, to accommodate the uncertain future.

ill. 57. Hybrid structure erosion control, Nibe

Flodbyen Randers

Location: Randers, Gudenåen
Established: 2010 – 2025
Expected finish date: 2075
Client: Randers Municipality

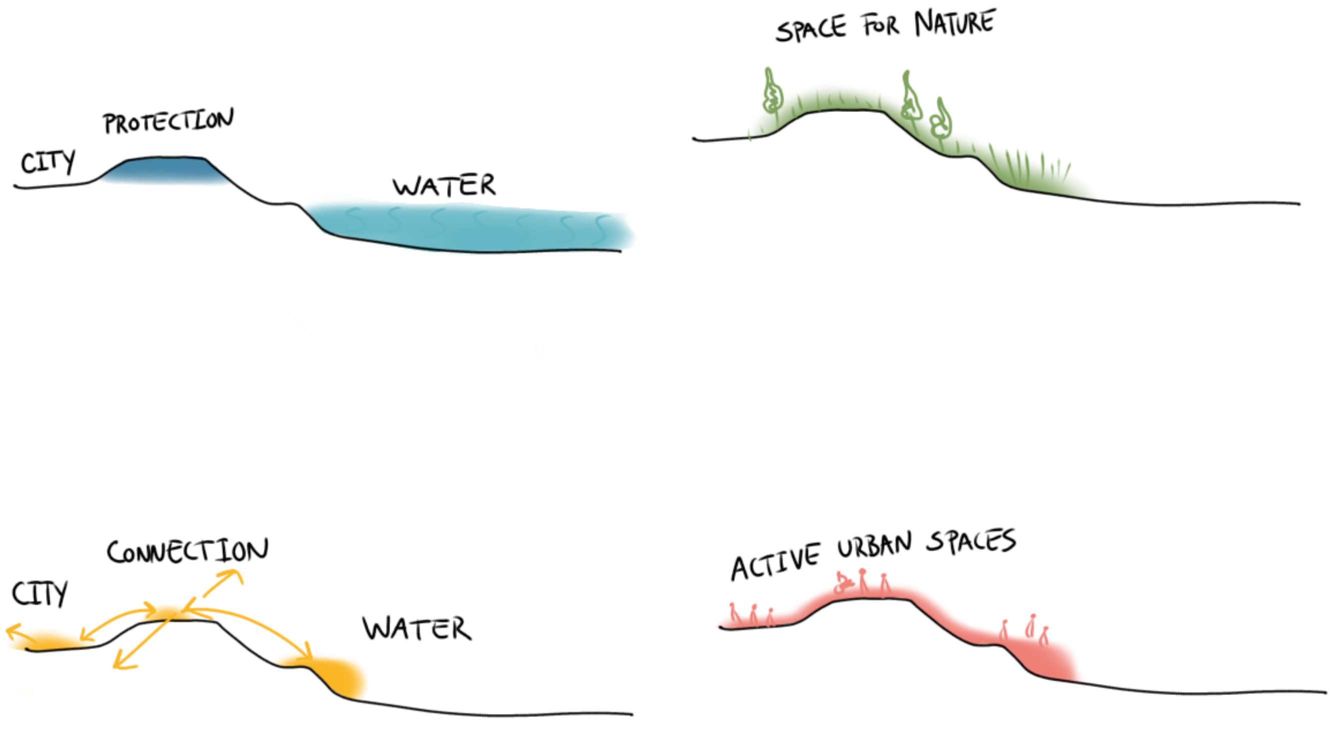
Starting in 2010, with the city council decision to transform the harbour, Randers Municipality has been working on a new development plan for the city centre (Randers Kommune, 2025). The plan focuses on balancing climate-proofing the city centre and making space for nature while strengthening urban spaces and creating stronger connections between city and water (Randers Kommune, 2025). As the city is divided by the Gudenå, the city has tradition for being connected to the water and it once served as the 'main road' and this coexistence with water is a main goal of the plan which has been named Flodbyen Randers (Randers Kommune, 2025). The plan serves both as a development plan, design manual, and management tool to sythesize a tanglible and cohesive strategy for the large area which is robust and flexible as it developped in stages (Randers Kommune, 2025).

Flodbyen Randers seeks to experiment with city development and climate-protection in a balancing act between water and city (Randers Kommune, 2025). The vision is to create sustainable urban development that encompasses both the dreams of the average citizen and innovative buisnesses that ensure economic viability (Randers Kommune, 2025). The plan works with 6 main strategies meant to steer the development phases (Randers Kommune, 2025). To climate-proof the city, there will be made more space for nature in the city and certain areas will allow flooding as blue urban spaces, but most importantly is the inclusion of a dike, called the climate ribbon, which will protect the city from sea-side flooding and storm surges while being a new urban room connecting the city and water with new paths and recreational spaces (Randers Kommune, 2025). Nature and water is to be felt and used (Randers Kommune, 2025). Likewise, new urban areas and housing will invigorate the city and engage the citizen to create active spaces (Randers Kommune, 2025). As the plan will take many years to finish, multiple new experiences will gradually open up to the citizen, increasing the interest in the area.

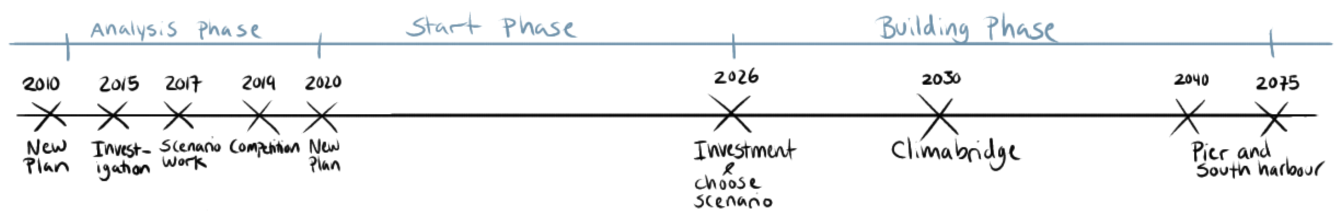
The plan is developped across 5 main phases, 0-4, with a few main projects and areas for development in each (Randers Kommune, 2020). Starting in the west with phase 0, the plan will progress to the north for phase 1 and 2, and finally move south and east for phase 3 and 4 (Randers Kommune, 2020). phase 0 is currently under construction, with 1 out of 2 projects finished as of 2025 (Randers Kommune, 2025). The plan is expected to be fully built by year 2075, meaning the plan works with a timeline of 60 years which is far longer than many other Danish development plans (Randers Kommune, 2020). The phase-divided plan creates a more flexible and robust framework for the development, as there is time and space for changes (Randers Kommune, 2025). Additionally it ensures an economy in balance, where the contruction expenses can be earned back before the onset of the next phase, as well as time to test new urban spaces, to ensure quality and efficacy, and create comprehensive areas which function regardless of the following phases (Randers Kommune, 2025).

While Randers Flodby is not situated along the Limfjord, many of the challenges and potentials the plan tackles are comparable. The low-lying landscape and challenges caused by water are in many ways alike what is seen in many locations along the Limfjord, and especially the city of Aalborg is similarily divided by a body of water. As such, the strategies for climate-protection and urban development can be adapted to the locations for intervention in this project. The plans hollistic approach of integrating urban development and nature is much aligned with the theoretic frame of eco-urbanism partly employed in this project, and serves as an example of how it may be executed in a modern Danish context. By not thinking of water as a mere challenge and threath, new valuable recreative and educational spaces may be created and get citizens more involved and connected to the land. While this project will work with the entire hydrologic system of the Limfjord, so interventions may be more spread out, this is neccessary as no one location can be seen in isolation.

The strategic and phase-based approach of Flodbyen Randers is highly beneficial when working with large and complex projects spanning many decades as it allows for adaptability and time to react. This results in a certain robust quality as the plan is more likely to be viable and functional. Therefore, such a method of planning and design will form the foundation of this project's logic and be utilized to form a comprehensive strategy and design interventions.



ill. 58. Strategy approaches for Flodbyen Randers



ill. 59. Timeline for Flodbyen Randers

Eco-Urbanism

Originating in the 1960's and 70's, the idea and initial concept of Eco-Urbanism sought to restructure the way cities are planned and built in order to improve living conditions in the industrial cities. However, it was not until the 1980's that the architect and environmental activist, Richard Register, coined the term 'Eco-City' and formally defined it as: "an urban environmental system in which input (of resources) and output (of waste) are minimized" (Register, 1987). As this definition is rather open, the concept has seen many uses through time and such lack one concise and accepted definition to date (Rapoport, 2014).

Initially the movement was focused on local projects, led by citizens and architects trying to improve the environmental conditions and both old and new sustainable technologies and practices (Rapoport, 2014). During this time, the focus was on simple and communal living in self-sufficient 'eco-villages' which was in line with the trends and environmental discourse of the 1970's (Rapoport, 2014).

The 1990's saw an increased interest and importance of environmental consciousness with important progress made towards the modern understanding of sustainability. Especially the Brundtland report of 1987 was fundamental in shaping sustainability and linking both the economic, environmental, and social aspects. This time saw more of a focus on experimenting and utilizing new technologies (Rapoport, 2014).

At the time of this report, the movement has seen increased interest as the climate crisis has progressively worsened. Sustainable practices and interventions, such as solar panels, rainwater management and cleaning, low carbon emissions, sustainable materials, and much more, have become a part of the majority of new urban projects. Multiple large-scale projects have been planned and begun construction, with several completely new eco-cities have emerged across multiple continents (Rapoport, 2014). Especially across Asia, such large-scale city projects are emerging as impressive feats of engineering, design and planning (Caprotti, 2014).

These new eco-city projects are often located on 'reclaimed' land which were previously deemed unsuitable for habitation, such as deserts, swamps, and flooded land areas (Caprotti, 2014). Advances in technology has made it possible to alter such areas and force them closer to a more comfortable environment for humans, with ready access to resources such as clean water, food, and electricity (Caprotti, 2014). Projects on a smaller scale focus more on transforming parts of pre-exiting cities to improve the quality of life and sustainability of the area while introducing more greenery and nature – as modern eco-urbanism is often about thinking the city and nature in coexistence (Rapoport, 2014). However, eco-projects can never be seen in isolation as they will always be part of the larger socio-economic scale both regionally, nationally, and globally in the same way as nature is always part of a bigger structure spanning across human-made borders (Carprotti, 2014).

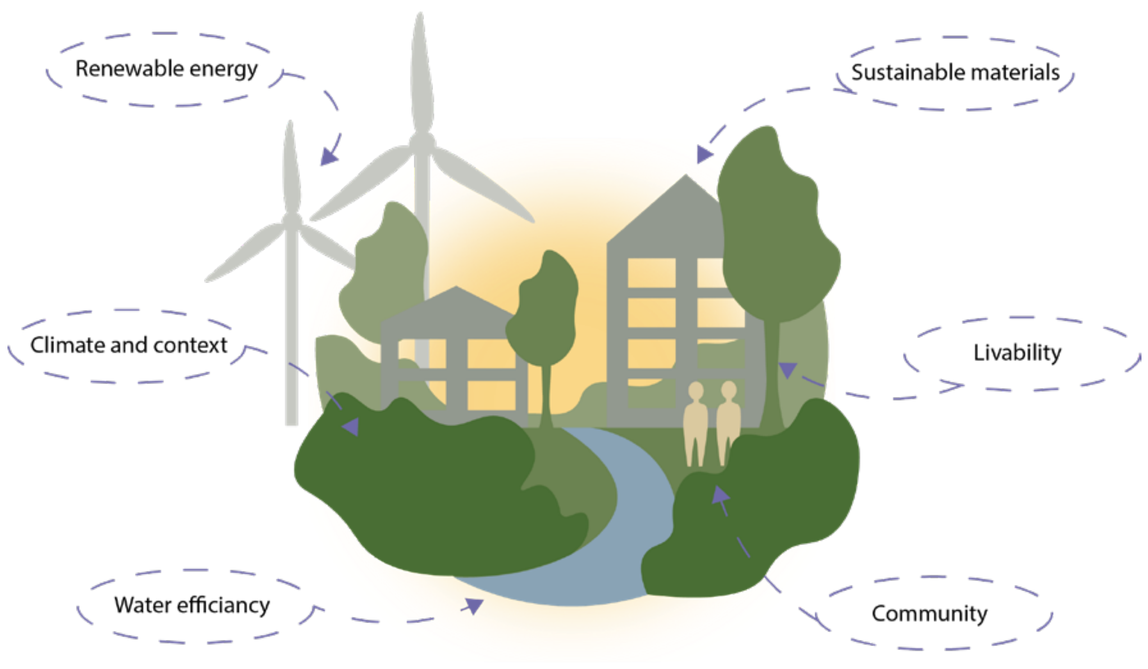
With the modern focus on new eco-cities and new technology making it possible to build in previously unhabitable areas, means a new focus on building and planning completely new cities where there was previously only nature (Carpotti, 2014). But is this truly the most sustainable approach? A large amount of built environment already exists, and the natural resources are gradually being depleted – so why are we using even more resources to build completely new cities and taking away even more undisturbed nature? Even in the case of environmental change and global warming, why must we continue to protect and create settlements in areas that are becoming dangerous instead of relocating to more safe and suitable cities? Very critically, it could be speculated if this is fuelled by money and potential profit as new modern projects are more attractive and can be sold at a higher price to future inhabitants when compared to smaller transformations to old buildings (Carpotti, 2014).

It is also important to be critical of the condition under which such projects are being built, as they require a lot of construction workers who are often transient workers (Carpotti, 2014). These workers may be working under dangerous conditions for minimal pay and will never be able to afford to live in the cities they are building, creating a stark class division of the rich living in new clean and sustainable cities with the poor living in the old and resource challenged cities (Carpotti, 2014). Such problematic practices have especially been seen with the construction of several eco-city projects both in China, with Tianjin eco-city, India and the Middle East, with Masdar in Abu Dhabi and The Line in Dubai (Human Rights Watch, 2024), although the practice is most likely more common (Carpotti, 2014). While such a scenario may have improved upon the environmental and economic sustainability, it will severally harm the social sustainability and lead to more suffering (Carpotti, 2014).

"For example, a recent survey uncovered the fact that while urban climate change experiments are not confined to any one region of the world, 52% were located in the global North, while 46% were situated in emerging economies. Only 2% were located in the world's least developed states (Castán Broto and Bulkeley 2013). This opens up real and pressing questions about the spatial inequalities which are starting to be constructed in an age of climate change: when 1.2 billion people live in extreme poverty (World Bank 2010), and when it has long been recognised that the world's poorest will suffer disproportionately as a result of the impacts of climate change (OECD, 2003), it is staggering to realise that 98% of the world's urban climate change experiments are aimed squarely away from the globe's poorest citizens." (Carpotti, 2024).

With the eco-urbanism approach, multiple environmentally aware and sustainable interventions along the natural system of the Limfjord, can benefit both the people living in the area and support the species and nature at the same time. Such interventions could protect important cities and natural habitats if placed strategically and designed with an appropriate awareness for the surroundings and landscape. It will additionally be of importance to design for the future and ensure an appropriate lifetime of the intervention as less environmental benefit is to be had, if the intervention has to be re-made every couple of years. However, this project will advocate for limiting the amount of completely new built structures and instead focus on transforming what is already built and reusing as much as possible in order to further limit the environmental impact.

ill. 60. The concept of Eco-Urbanism



Climate Centre Lemvig

As Denmark is a country defined by the seas, it has a long-standing connection to the water and living by and using the coast. As the effects of climate change has exacerbated the challenges related to water, a greater interest has emerged regarding the effects of environmental challenges affecting Denmark and how new technologies can be used to mitigate them. A major development in this field was made when the Climatorium (Danish: Klimatorium) was established in 2020 in the western city of Lemvig, right at the harbour where the effects of the sea are clearly visible and experienced (Klimatorium, 2025). The centre was built to create a meeting point between the civil society, private companies, the government, and research and education, where new innovative climate solutions are created (Klimatorium, 2025). The goal of the Climatorium is to develop these new solutions in their defined fields of: Coastal Climate Challenges, Green Energy, Circular Economy, and Water and Environment – with a focus on multiple scales ranging from the local, regional, national and international (Klimatorium, 2025).

The centre acts partly as an educational facility to visitors and schools, as a research facility to those working there and visiting scientists and professionals, and as an event hall for lectures, seminars, and other events (Klimatorium, 2025). These functions combine to educate the people about climate change challenges and how we may find solutions for them, in addition to further research and innovation in the field (Klimatorium, 2025). One particularly interesting aspect of the centre is their 'Living Lab' which is an area of 508 km2 around the centre, where new technologies and solutions are tested in practice. As the world's largest area for climate experimentation and innovation, it also serves to strengthen the interaction between nature and society as it showcases the challenges and climate solutions in a tangible manner (Klimatorium, 2025).

ill. 61. Climatorium at Lemvig with a seawall

TOOLKIT FOR REGIONAL STRATEGIC FLOOD MANAGEMENT

Timeline

With the slow progression of climate change and the time-consuming process of planning and construction, it is essential for this project to design with a long timeframe. Therefore, this project is divided into 3 different phases, with different protective strategies being enacted as they are imagined becoming necessary. This approach is to ensure adequate protection where needed while being flexible to the ever-changing climate and uncertain future. As the timeline nears the year 2100, the strategies become more vague and open-ended as to allow for adaptation and new technologies. Because perhaps the future is less impacted by climate change than expected, perhaps it is worse than expected, and even so perhaps the areas identified in this project will not be affected in the way analysis show.

2025-2050

The first phase is targeting areas that need protection immediately and strategies that should be implemented sooner rather than later. A focus is put on strengthening the coastal protection in Thyborøn and establishing a dike on the east coast, as this area is already affected by floods and erosion. For the remaining areas this phase is centred around preliminary work, setting up for future interventions, such as examining the natural habitat at Løgstør Bredning and the water quality at Lovns and Nibe Bredning. These assessments will determine the effects of the future flooding and if the areas are suitable for the future interventions. Conducting such assessments sooner allows for more time to improve the situation and interventions if needed.

2050-2075

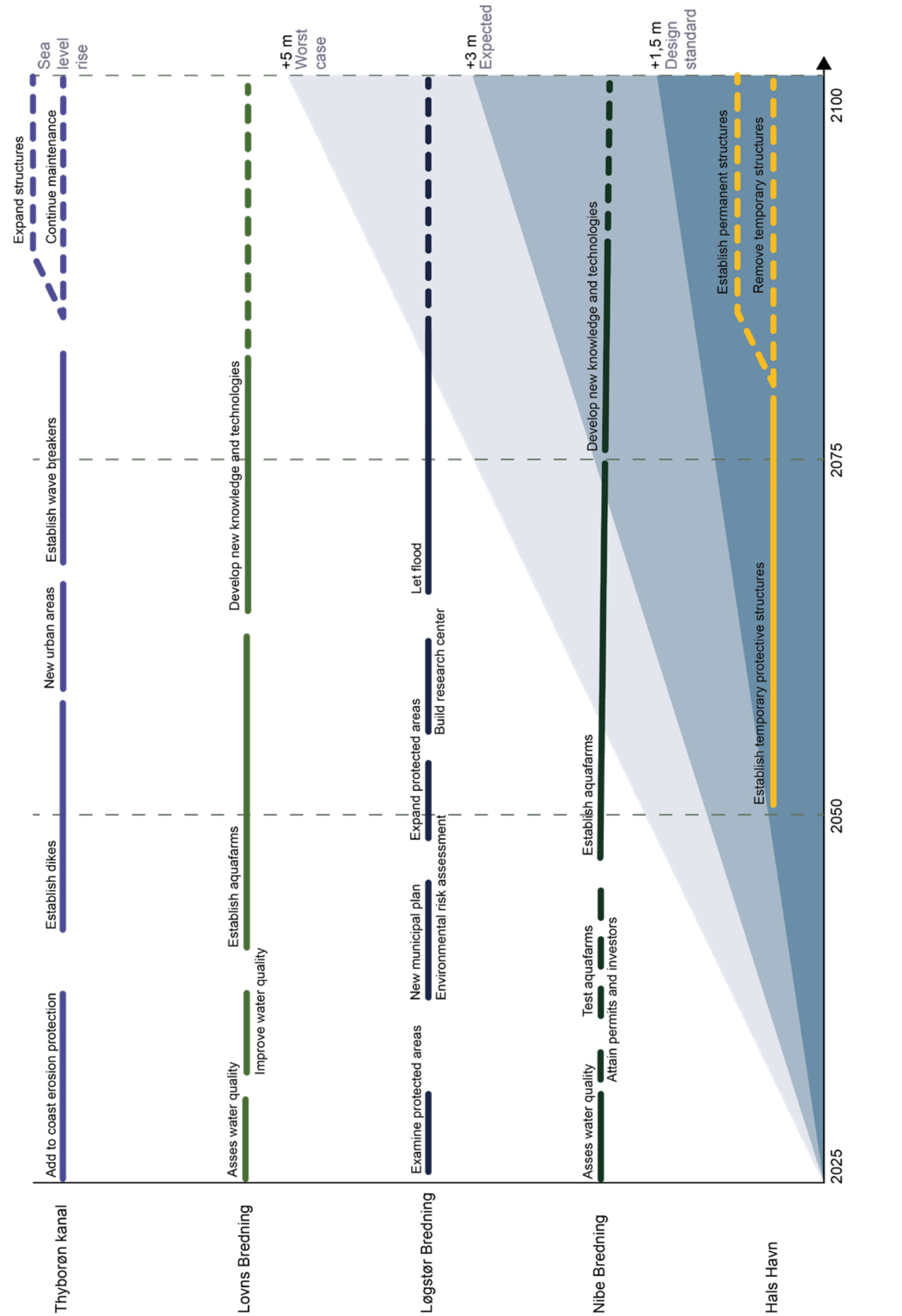
This phase is focused on implementing many of the proposed strategies and structures, as it is expected that this timeframe is when the effects of sea level rise will begin to surface and flooding worsen. The 25 years should be adequate time to both plan, attain permits, finance, hold competitions, and finally construct the interventions before an area is severely impacted by flooding.

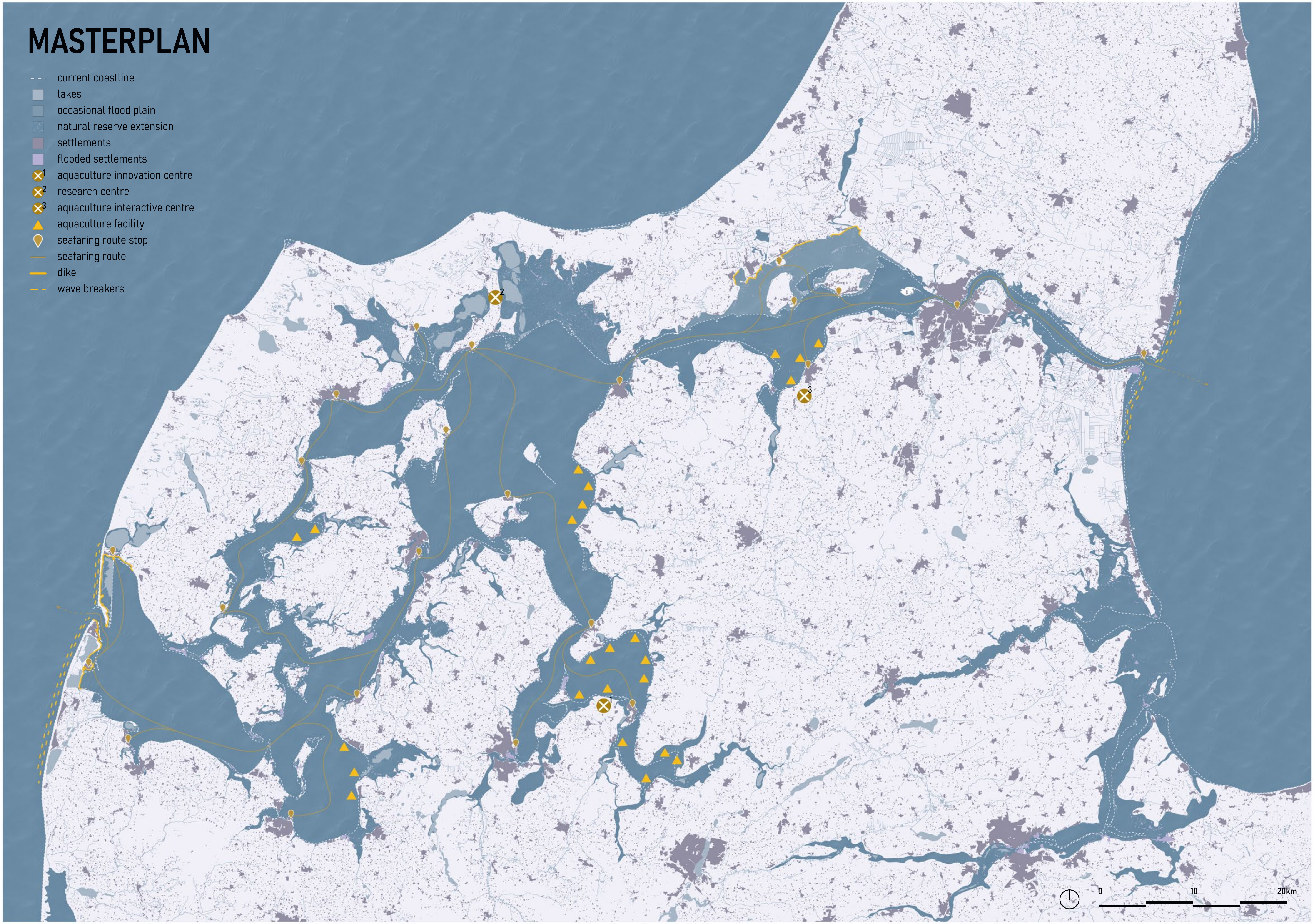
2075-2100

The final phase is the most vague and unclear, however that is on purpose. This phase will focus on adapting the built structures and strategies to the specific future scenario. Therefore, it includes the options to maintain structures or to expand them depending on what an area needs. Flexibility and room for further development are key, as the future situation is uncertain and new and better technologies and solutions may be available.

As the overall strategy is to create a resilient and multifunctional system of flood protection interventions, to simultaneously embrace the challenges of the system as a whole and the focus sites' specific challenges, a long-term design plan is key. The interventions must protect locally but work together to protect the whole system in a multiscalar process. One site's intervention should never simply move the problem elsewhere, instead lift the challenges in tandem with the remaining system.

ill. 62. Timeline of strategic interventions




MASTERPLAN
current coastline
lakes
occasional flood plain
natural reserve extension
settlements
flooded settlements
aquaculture innovation centre
research centre
aquaculture interactive centre
aquaculture facility
seafaring route stop
seafaring route
dike
wave breakers
0
10
20km

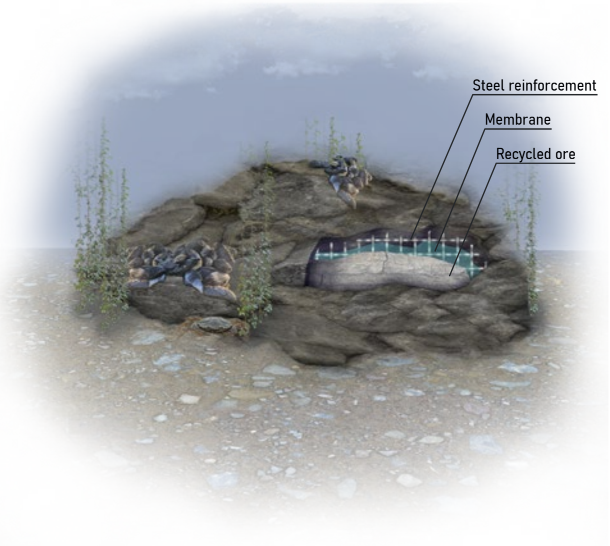
Thyborøn Kanal

Because Thyborøn Kanal marks the point where the water from the Western Sea enters the Limfjord system, it is very important to protect the area's landscape and prevent more water rushing into the system.

As this area is currently heavily affected by strong waves and wind, a large amount of coastal protection is already seen there. Therefore, the final design proposal for Thyborøn Kanal mainly focuses on a protection strategy, where wave breaker and dikes are the essential interventions. The designed wave breakers are placed offshore, to act as stony reefs, reducing potential wave energy while creating new opportunities for aquatic species to find food and shelter.

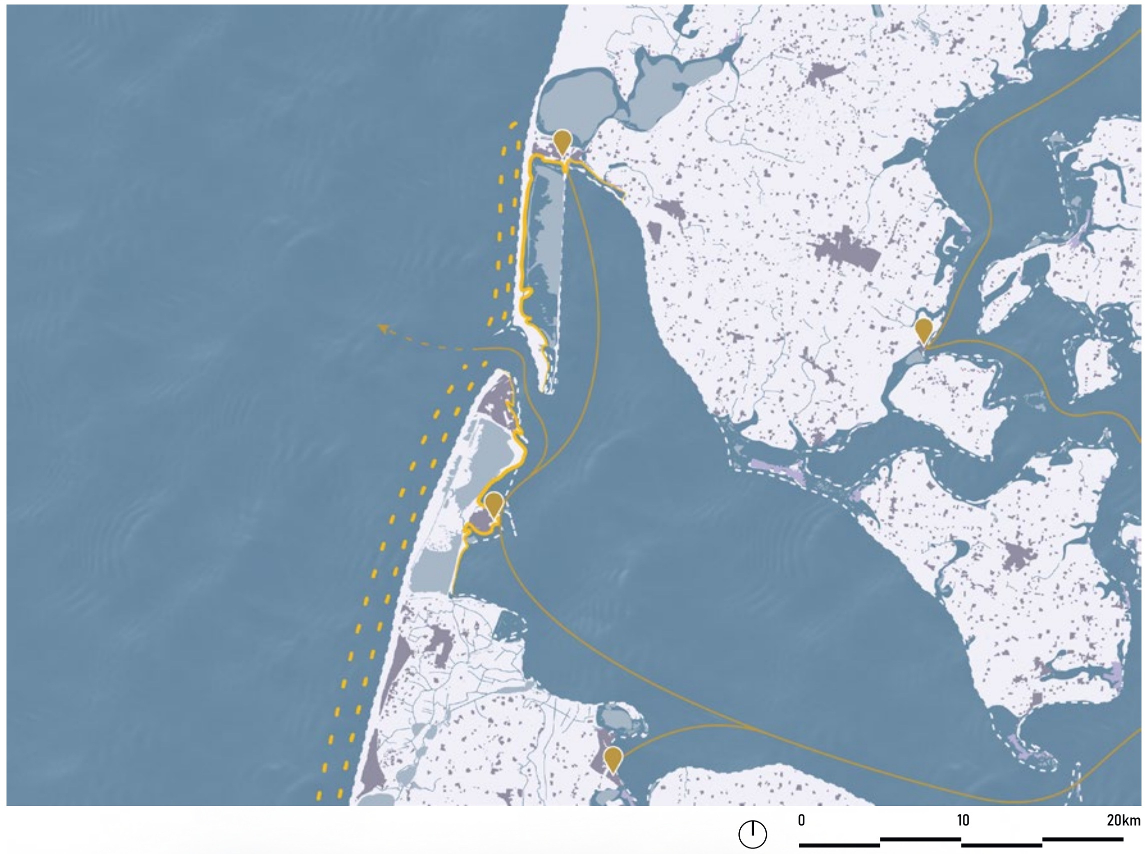
With the western coast secured, the flooding will mostly occur from the fjord on the eastern coast. To mitigate this flooding, dikes are placed near the coastline with a maximum height of 3 m. As the area features much open land, the dikes are designed with a wide base and thus gentle slope, helping them blend into to surrounding landscape. With a focus on green slopes, the plants will help protect the topsoil from erosion while benefitting the ecosystem of terrestrial and aquatic species. To accommodate the human experience, the dikes are designed to include paths and access points to the water, so they can be used for hikes and relaxing walks in nature, where the unique landscape and incredible fjord can be viewed. The new dike paths could also play a role in the area's tourism industry, as new scenic routes and bike-trails could be established along them.

ill. 64. Wave breakers: technical section



ill. 65. Dikes: technical section

ill. 66. Thyborøn Kanal: Plan of interventions



ill. 67. Thyborøn Kanal: View of interventions

Lovns Bredning

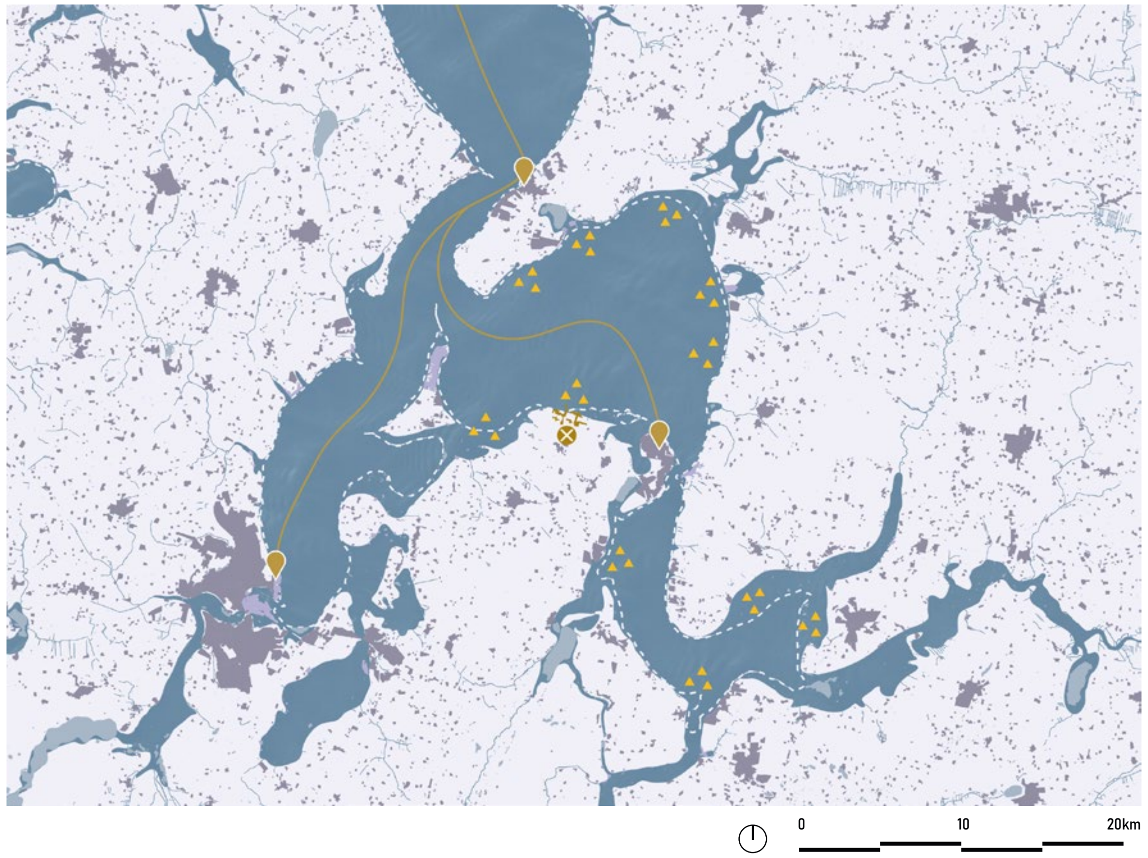
Lovns Bredning is on the inner most part of the Limfjord system, as it is the delta of several steams, resulting in water with lower salinity. The calm waters also feature a good chemical condition, but a bad ecological condition.

Therefore, the final proposed design focuses on implementing multiple aquafarm facilities, where mussels, oysters, and other bivalves would have good conditions for being grown. These facilities will be placed near the shoreline, where anchored floating platforms mark nets adapted for growing bivalves. The platforms allow for easy access to the nets and to examine their condition.

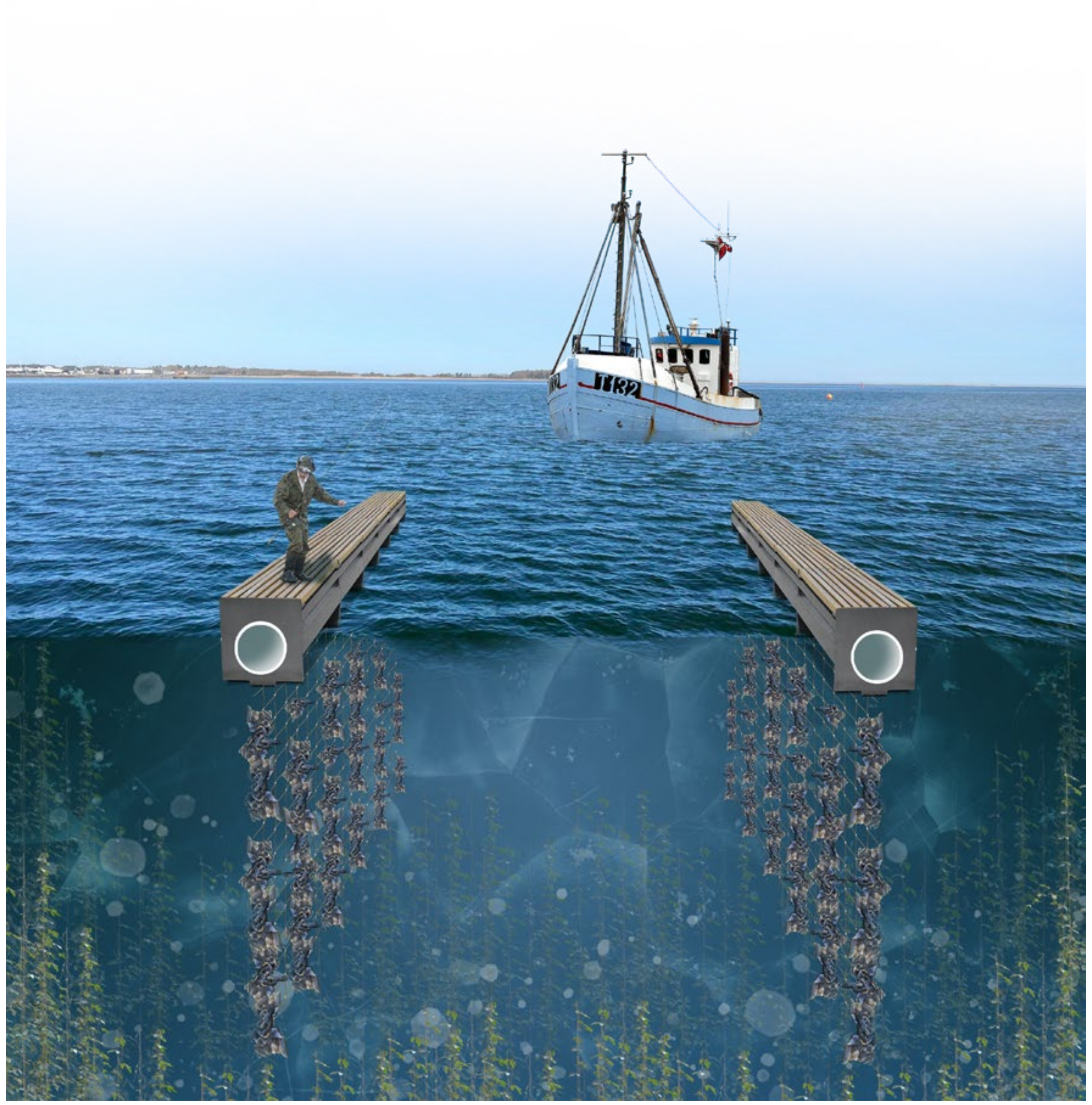
The benefits of farming bivalves are twofold: on the one hand the animals help improve the ecological state of the water as they filter the water for food, and on the other hand they will eventually mark a sustainable source of food for the local communities.

As this type of farming is not as common as other more widespread types, it would greatly benefit from further research and innovation. To accommodate this, the design proposal also includes a research and innovation centre to be established in the area. This centre could be placed in the city of Skive, but a better suggestion is to place it further east closer to Virksund, as a way to bring more revenue and activity to the lesser populated areas.

ill. 69. Lovns Bredning: Plan of interventions



ill. 68. Aquaculture farm: technical section



Løgstør Bredning

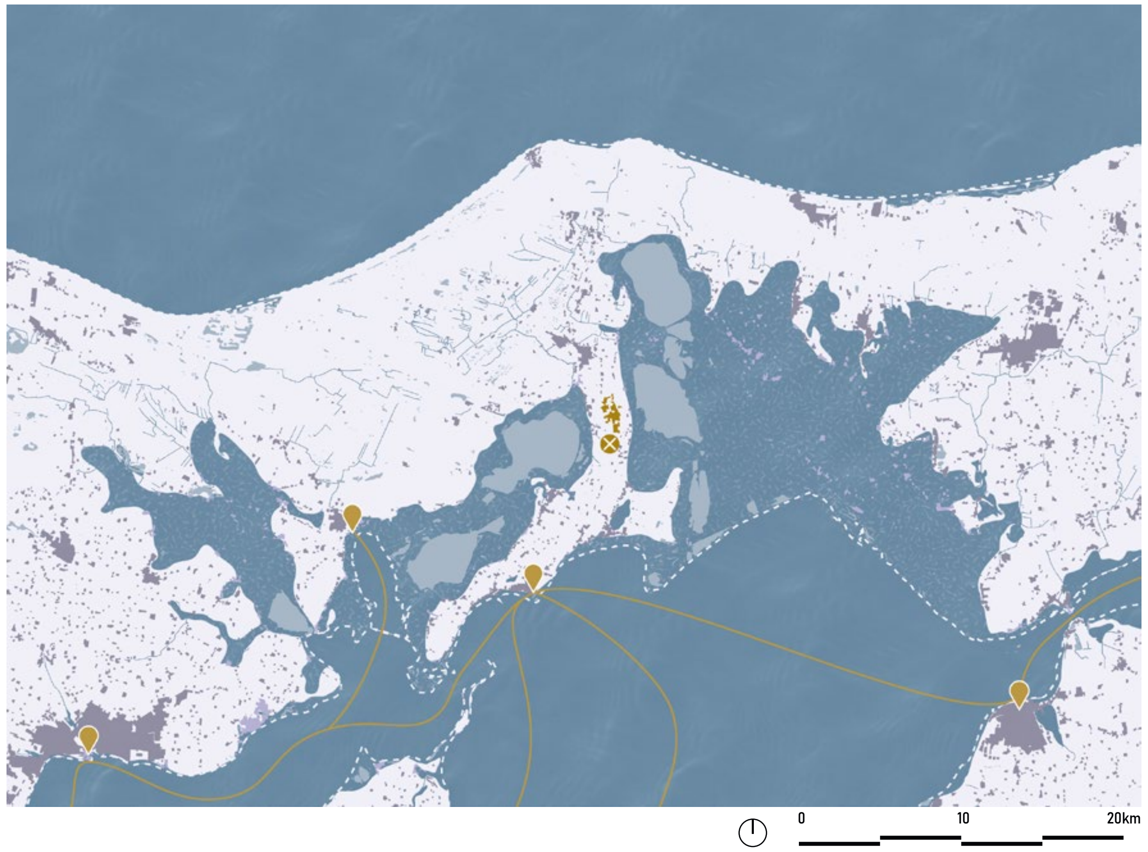
As an area defined by its beautiful nature full of agricultural plots and natural wildlife, Løgstør Bredning is full of potential. The present lakes are home to many species of birds and amphibians, and are designated NATURA 2000 protected nature areas.

To preserve these qualities, the final proposed design focuses on allowing the area to remain natural and to flood. As the local species are adapted to live in flooded and wetland areas, the gradual flooding which will occur in the future will benefit them as their unique habitat expands. As the animals occupy new areas and their habitat type expands, so should the borders of their protected zone.

By allowing this large area to flood as nature sees fit, less water is expected to flow further along the system. Therefore, the design proposal expects less flooding in the system east from Løgstør Bredning. Certain key areas must be allowed to flood for the benefit of the entire system.

To continue to support the area, the design proposal implements a research centre placed between the two new flood plains. This centre should study the effects of climate change and sea level rise locally, and use the surrounding areas as cases. The centre could be an extension of Aalbrog University or another similar facility, and is expected to bring new revenue and activity to the area, along with new job opportunities.

ill. 70. Løgstør Bredning: Plan of interventions



ill. 71. Løgstør Bredning: View of interventions

Nibe Bredning

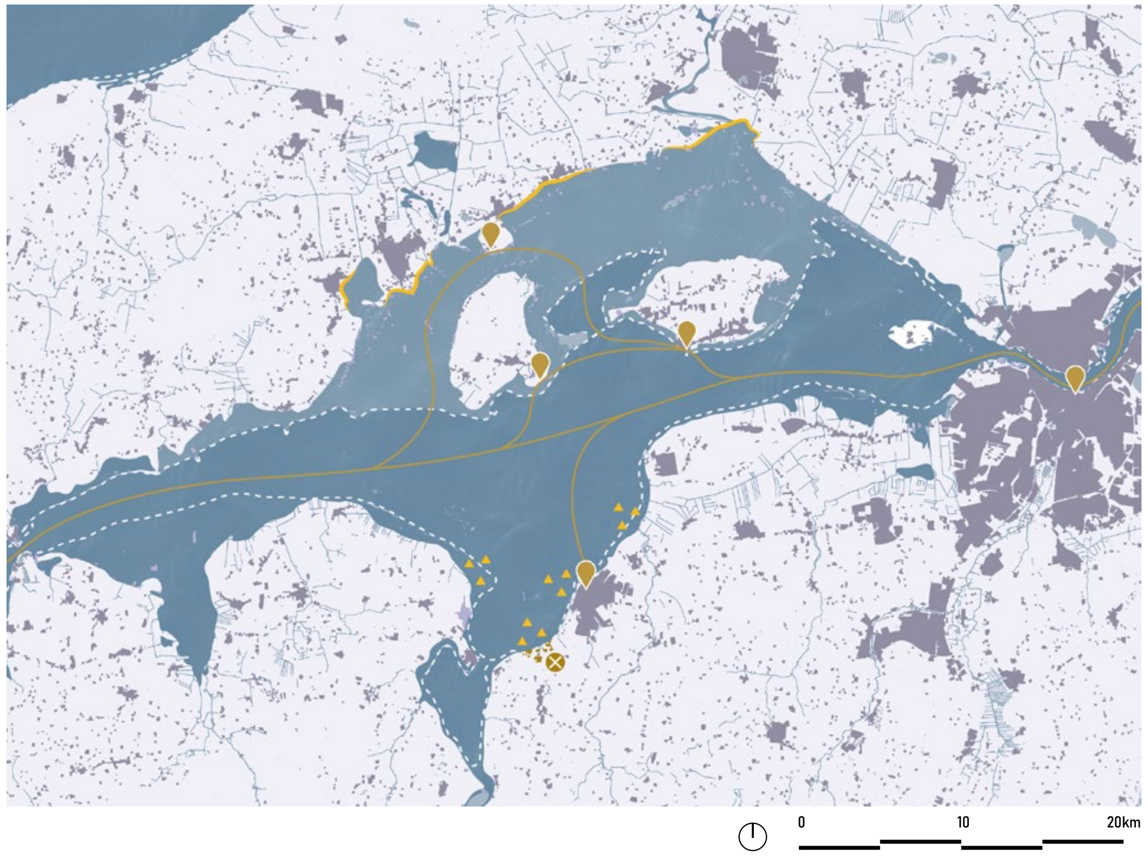
Nibe Bredning features a large delta where a stream meets the fjord, resulting in water with lower salinity much like Lovns Bredning. Due to this great quality, the final proposed design focuses on placing several more aquafarms in this area, with a similar construction as described on page 84.

As the northern shore of the site is more affected by flooding, with new islands forming, the design also focuses on establishing new ferry routes to preserve the accessibility of these areas and communities. The new flooded areas will experience very deep water to the north, and as such it could potentially only be an occasional flood plain.

However, as this is an unknown, the design proposal does implement a few smaller dikes near larger settlements. These dikes should only be implemented if or when they become necessary, estimated to be around the year 2075.

To establish a unique character to the area, the design places an activity centre near the city of Nibe, which invites all citizens to see the aquafarms, to learn about bivalves and help shift the public's habits to eat more bivalves and seaweed in the future. As the area has a far shallower seabed, it will be possible for people to visit the aquafarms and the improved ecological state will bring more life to the water, creating good opportunities for fishing for both children and adults.

ill. 72. Nibe Bredning: Plan of interventions



ill. 73. Nibe Bredning: View of interventions

Hals Havn

Hals Havn marks the point where the Limfjord system meets the Kattegat Sea, however this area is not heavily affected by the waters in contrast to Thyborøn Kanal.

Hals Havn will mainly experience flooding-affecting storms, where the wind direction changes to blow from the east causing water from the Kattegat Sea to push up into the fjord.

On the southern side, by the city of Egense, the low terrain means more flooding due to sea level rise, however this is greatly reduced due to the mitigating effect of allowing flooding at Løgstør Bredning and Nibe Bredning.

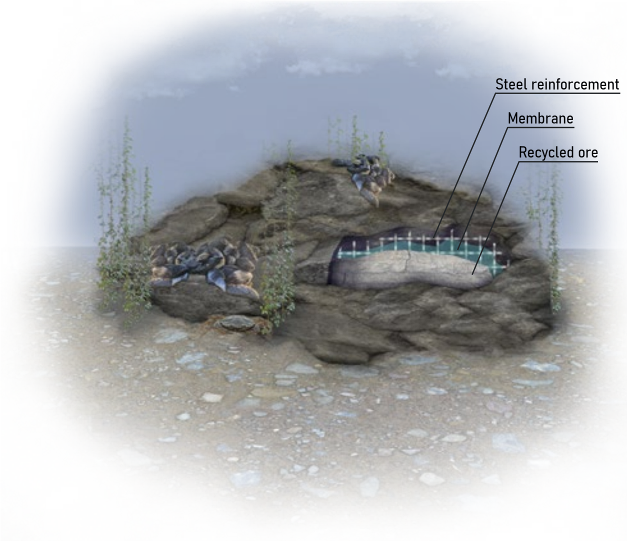
Therefore, the final proposed design for this area is focused around establishing wave breakers on the eastern coast and expanding the ferry routes.

Already established due to the operational port at Hals, the expansion of the ferry routes is meant to underline marine transportation as the most resilient form in a water-dominated future. As constantly reconstructing vehicular- and rail bridges becomes increasingly more costly as the coastal lines shift more and more inwards due to the increasing water levels, these modes of transportation are deemed unsustainable in the long term. With a functional network of seafaring vessels, however, such a problem does not exist as they do not rely on such expensive and expansive infrastructure in order to be operational. This type of transport also allows for the land-based and air-based logistical networks to be replaced by water-based ones, which, by utilising the same routes as the human transporting ones, would significantly lower the costs of logistics.

ill. 75. Hals Havn: Plan of interventions

ill. 74. Wave breakers: technical section

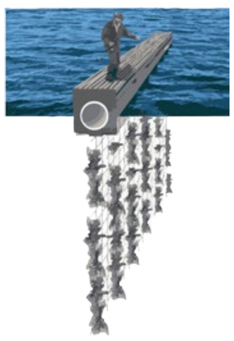
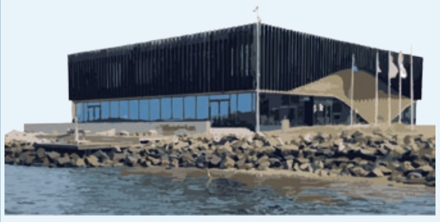
The wave breakers are designed to have a natural rocky appearance, to support the ecosystem with new opportunities for food and shelter for aquatic species while reducing wave energy. The structures are fitted with a heavy core of repurposed construction waste, such as concrete rubble and old bricks, too damaged to be recycled. Around the core is a membrane which will contain the core and any minor pollutants there may remain and attach to the outer layer of irregular rocks and concrete. These structures will help protect the coast from erosion while not obstructing the landscape or view.



ill. 76. Hals Havn: View of interventions

Toolkit

ill. 77. Toolkit for regional strategic flood management

Strategies	Description	Implementation steps	Applicable locations
Wave breakers 	Protective structures primarily used to control coastal erosion by following the coastline and reducing wave energy, thereby minimizing sediment loss. They are typically constructed from concrete or natural stone and are strategically placed to reinforce the coast while also providing ecological benefits and maintaining coastal accessibility for human use.	1. Site Assessment and Planning 2. Design 3. Permitting and Approvals 4. Construction 5. Monitoring and Maintenance 6. Adaptive Management	◦ Sandy beaches ◦ Coastal towns and cities ◦ Harbours and marinas ◦ Estuaries and lagoons ◦ Coastal wetlands ◦ Eroding cliffs and bluffs ◦ Areas with high ecological value
Dikes 	An onshore strategy for flood and erosion control by utilizing reinforced cores or stones to mitigate erosion and incorporating specific slopes to protect against waves while blending into the landscape. Designed to be multifunctional, providing ecological benefits and community usability through gentle slopes, greenery, pathways, and urban spaces.	1. Site Assessment and Planning 2. Design 3. Regulatory Approvals 4. Construction 5. Ecological Integration 6. Community Integration 7. Monitoring and Maintenance 8. Evaluation and Adaptation	◦ Coastal areas ◦ Riverbanks ◦ Low-lying delta regions ◦ Estuaries ◦ Lakeshores ◦ Urban waterfronts ◦ Agricultural lands ◦ Wetlands
Aquaculture farms 	Aquaculture farms employ structures that serve as wave breakers to control erosion and protect coastal areas, while simultaneously creating habitats for aquatic species. These farms, particularly those focusing on bivalves, enhance water quality by filtering algae and provide a sustainable food source for nearby communities.	1. Site Selection and Assessment 2. Design and Planning 3. Regulatory Approvals 4. Stakeholder Engagement 5. Construction and Installation 6. Species Selection and Stocking 7. Monitoring and Maintenance 8. Harvesting 9. Community Integration 10. Evaluation and Adaptation	◦ Coastal bays ◦ Estuaries ◦ Mangrove forests ◦ Tidal flats ◦ Lagoons ◦ Fjords ◦ Intertidal zones ◦ Delta regions ◦ Barrier islands
Facilities 	Involves creating research and innovation centres to advance aquatic farming and study the impacts of climate change, thereby generating revenue and job opportunities in underdeveloped regions. Also includes establishing activity centres to educate the public about aquafarms and promote the consumption of bivalves and seaweed, enhancing ecological engagement and local fishing opportunities.	1. Research and Planning 2. Stakeholder Engagement 3. Funding and Resources 4. Infrastructure Development 5. Programme Development 6. Construction and Implementation 7. Operation 8. Monitoring and Evaluation 9. Promotion and Outreach 10. Sustainability and Growth	◦ Coastal regions ◦ Delta areas ◦ Island archipelagos ◦ Estuarine systems ◦ Shallow seabeds ◦ Inland lakes and rivers ◦ Coral reef systems ◦ Regions with existing research institutions
Natural reserve 	Strategy focusing on preserving the habitat's natural state and allowing controlled flooding to support local wildlife adapted to wetland habitats. By expanding protected zones in tandem with the natural spread of these species, the approach aims to mitigate flooding in adjacent areas and maintain ecological balance.	1. Assessment and Planning 2. Stakeholder Engagement 3. Funding and Resources 4. Habitat Preservation 5. Flood Management 6. Monitoring and Adaptation 7. Policy and Regulation 8. Education and Outreach	◦ Wetlands ◦ River deltas ◦ Floodplains ◦ Lakes and ponds ◦ Estuaries ◦ Natural reserves and parks ◦ Agricultural lands with natural features ◦ Urban green spaces ◦ Restored habitats ◦ Coastal zones
Occasional flood plain 	Involves designating specific areas to naturally accommodate floodwaters, thereby reducing pressure on more vulnerable regions downstream. This soft flood management approach relies on careful planning to select suitable locations and allows gradual adaptation, ultimately benefiting both flood control and local ecosystems.	1. Site Identification and Assessment 2. Environmental and Social Impact Analysis 3. Stakeholder Engagement 4. Planning and Zoning Adjustments 5. Infrastructure Adaptation and Buffer Creation 6. Gradual Implementation and Monitoring 7. Maintenance and Policy Integration	◦ Agricultural lowlands ◦ Riverine forests ◦ Wetlands ◦ Abandoned or depopulated rural areas ◦ Nature reserves ◦ Protected areas ◦ Urban fringe zones ◦ Urban green belts ◦ Delta areas ◦ Estuaries
Seafaring transport hub 	Strategy focusing on expanding ferry routes to establish marine transportation as a resilient and sustainable alternative to land-based infrastructure increasingly threatened by rising water levels. By leveraging adaptable seafaring vessels that require minimal fixed infrastructure, the hub enables a cost-effective shift of both passenger and logistical networks to water-based systems.	1. Infrastructure Assessment 2. Planning 3. Fleet Procurement 4. Route and Network Design 5. Port and Docking Infrastructure Upgrades 6. Policy and Regulatory Alignment 7. Integration with Logistics and Transit Systems 8. Engagement and Promotion 9. Evaluation and Adaptation	◦ Fjords and coastal inlets ◦ Floodplains ◦ River deltas ◦ Coastal wetlands ◦ Estuarine zones ◦ Urban ports ◦ Archipelagos ◦ Tropical coastlines ◦ Ice-free polar coasts

REMARKS & RECOMMENDATIONS

Discussion

As the project period and this thesis comes to a close, the process of reflection and design continues. Many contemplations have been gathered throughout the project which relate to the challenging aspects of the problem and design solutions both present in the final design and alternative interventions. The complexity of designing for an uncertain future will also be discussed, as this thesis experimented with different methods of doing so, which ultimately are not presented in the final design.

Process

As a leading approach in concretising locations for the work in this thesis, the method of formulating specific categories via which to evaluate locations and then make a selection was implemented. It facilitated the process of precise location choice, as the system of the Limfjord is home to a vast amount of settlements and natural areas that are all unique when it comes to their characteristics. The application of the four categories – strategic, environmental, social, and economic – helped narrow down the selection pool, and brought to light the final five focal locations which would best serve the purpose of representative areas for the interventions discussed in this thesis.

In practice, stakeholders often find the categorisation of values difficult to understand and to implement in the planning and design processes due to the abstract, overlapping, and at times conflicting nature of the values themselves, particularly when translated into practice at the local scale. While the four categories are conceptually distinct, their boundaries frequently blur in real-world contexts, making it challenging for practitioners to distinguish them in a way that feels both accurate and actionable. This complexity is further convoluted by the differing priorities, expectations, and interpretations that various stakeholder groups bring to the table, which can hinder a shared understanding and thus compromise the coherence of the planning process. Moreover, the inherently site-specific character of place-based values resists easy categorisation, especially when local knowledge, historical uses, and emotional attachments come into play.

Nevertheless, the process of categorising places using these four values offers an adaptable methodology that could be replicated in other locations to support more transparent and inclusive approaches to flood management planning. By providing a structured yet flexible framework, it can help guide early-stage conversations among stakeholders, make implicit priorities explicit, and create a basis for collaborative decision-making. Replicating this process elsewhere could contribute to streamlining the complex and often contested procedures involved in the development and implementation of protection strategies, while still allowing for local characteristics to be acknowledged and integrated meaningfully.

Hydrological complexity

Early on in the process, it was decided to focus on the whole hydrological system of the Limfjord, as it did not make sense for the project to focus on a more local site due to the knowledge that a single site of intervention would still risk flooding in nearby areas. However, this decision meant increased work to analyse and understand the complex hydrological conditions due to the size and multiple connecting bodies of water adding to the whole system of the Limfjord.

The shift in site also brought a shift in mindset as the concept of the system became central to the thesis. Not only acknowledging the fjord as a system but also seeing the design interventions as working together as a system meant a more coherent strategy, where sustainability and multiscalar thinking became important tools to integrate the natural and constructed systems.

Design solution

As the thesis initially explored different design scenarios, with different extends of flooding caused by sea level rise, the intend was to include different design solutions that were dependent on the degree of flooding. Yet, as the project progressed and more analysis was concluded, it became clear that one scenario was far more plausible than the others and therefore it was decided to focus on this specific scenario for the thesis. That resulted in the presented design solution, with the flooding standard of 3 m in the western region of the Limfjord, and 1,5 m in the eastern region. By focusing on this scenario, it became possible to investigate how interventions in one area could affect and mitigate flooding in another, ultimately leading to more condensed interventions and room to experiment.

One such experimenting approach is seen in the interventions, where allowing flooding and more soft protective strategies are suggested alongside traditional grey structures, which are modified with more consideration for the ecosystem and sustainability. Waste materials, such as construction waste or even plastic waste, are repurposed as structural cores in both wave breakers and dikes to locally source leftover materials, reducing cost and climate impact. If done with care and tested properly, this experimental proposal could help create more resilient structures and reduce the impact of waste materials. However, these cores must be encased and prevented from leaking harmful substances to the environment and therefore only select waste materials should be used as to limit the risk of contaminates.

Another experiment was to create a toolbox of strategies, which can be applied to other locations making the proposed design and strategic formula more universal in an attempt to ease the process of securing other high-risk areas in a holistic and sustainable manner. This toolbox includes key strategies and how to implement them, so policy makers, stakeholders, planners, and designers can identify the best interventions for their area. It is an attempt to transfer knowledge and solutions in a more comprehensive way that saves resources by lessening the task of analysis and design, by standardizing key implementation processes. If such a tool could be realized and proven functional, it would let this project reach beyond the Limfjord system. But whether such a toolkit would be beneficial remains untested and so do its limitations. Due to this it would be interesting to do future research into such a tool and how generic or specific the tools within can be before it loses its efficacy and ability to be applied more universally or locally.

Other solutions

During the design process, multiple alternative design solutions were discussed and tested but ultimately cut from the final design. Most notably, the multiple scenario concept mentioned earlier, was a series of design solutions aimed at different future scenarios of flooding. This would see the same interventions as in the proposed design solution but utilized in different manners and to varying extends. As the current design solution, based on a middle scenario, began to form, it became clear that this was the most realistic one, and due to time constraints it was opted to focus on only this scenario for the thesis. Regardless, the insights gained from working with alternative scenarios benefitted the process and contributed to more developed strategies and interventions for the current design proposal.

Other strategies and designs were not included in the final design proposal due to not being appropriate for the areas of intervention or scope of this thesis. Most notably, the strategy of reforestation which many municipalities have been focussed on in recent years. This strategy was not included as it did not directly pertain to the hydrological system nor flood protection. Although plants are used to slow flooding and mitigate erosion, such plants are specialised to flood prone conditions and do not include the most common forest plants. It must also be mentioned that many municipalities already have plans for reforestation in works. However, as this thesis emphasizes more collaboration, especially across municipal and regional borders, it could impact these plans and suggest the systemic thinking of nature as systems in order to expand the reforestation areas to cross-municipal projects.

Conclusion

This thesis has explored how to design for flood protection with a focus on sustainability and interconnected interventions along a whole hydrological system. By identifying critical points along the Limfjord system, where the flooding risk was eminent and the potential to strengthen the area and benefit the entire system was the highest, the design interventions work in tandem as a multiscalar strategy for protection. Through an identification of the categoric values - strategic, environmental, social, and economic - the process of deciding where and how to protect areas was eased and resulted in the suggestion that a similar assessment method could be utilised by future projects to help make the difficult decisions. This thesis's strategy and design proposal has been condensed to a toolbox of processes and interventions, aimed at future projects, policy makers, designer, and stakeholders, to streamline the many flood protection projects likely to be crucial in the future while stating the need to think systemically and consider the whole hydrological system instead of a single local site.

Designing for flood protection is a difficult task, but designing for flood protection for an entire hydrological system posed a different challenge. While the hydrological conditions were more complex, the task of designing the interventions and where to strategically intervene was eased as the larger understanding of the system and its components were the steering factor. Therefore, this thesis advocates for a paradigm shift to a more multiscalar thinking where designers and planners put more emphasis on the larger context and interconnectedness of scales – especially when designing interventions that can greatly impact any system. A shift must also happen in the mindset of policy makers and planners, as climate change continues to progress and sea levels rise, we must come to terms with the fact that not all areas should be protected and some flooding must be permitted. If we do so, it is possible to mitigate flooding in other parts of the hydrological systems, in turn saving more lives, resources and benefitting the natural ecosystems along the shores.

While the thesis started with the goal of integrating the large scale and the system-based thinking, it was clear that the smaller scale was integral to the ability to design, not just strategize, and that the different scales are uniquely tied. Therefore, the focus has jointly been to create a large-scale strategy that incorporates a long timescale, and to place and design interventions that work across the context. The strategy is based on the ICPP's RCP 8.5 scenario and is split in 3 phases, ending in 2100, where each phase presents new interventions to the focus sites. The open end allows for assessing the uncertain future and choosing appropriate measure for the scenario faced. These interventions are primarily traditional protective structures, such as dikes and wave breakers, but have been carefully designed to improve their ecological function and sustainability. It is also proposed to use aquaculture facilities and part of the protective interventions as they can both function as wave breakers but also provide a stable source of food and income for the inhabitants, resulting in more resilient communities.

References

Aalborg Kommune. (2025) Nøgletal og Statestik. [Online]. [Accessed: 01-04-2025]. Available at: https://www.aalborg.dk/om-kommunen/oekonomi-og-statistik/noegletal-og-statistik

Amendolare, N. (2022). Cause & Effect Relationships Across Natural & Engineered Systems | Study.com. [online] Available at: https://study.com/academy/lesson/cause-effect-relationships-across-natural-engineered-systems.html [Accessed 2 Apr. 2025].

Barbier, E.B. (1987) 'The Concept of Sustainable Economic Development', Environmental Conservation, 14(2), pp. 101–110. doi:10.1017/S0376892900011449.

Basiago, A.D. (1998) 'Economic, social, and environmental sustainability in development theory and urban planning practice.' The Environmentalist 19, pp. 145–161. https://doi.org/10.1023/A:1006697118620

Caprotti F. (2014) Eco-urbanism and the Eco-city, or, Denying the Right to the City?, Antipode, 46, pages 1285–1303, doi: 10.1111/anti.12087

Christiansen, E. M. (2020). Tectonics and the city: In search of a critical perspective on assembling the city. Aalborg University Press. https://vbn.aau.dk/files/549572473/PHD_Elias_Melvin_Christiansen_E_pdf.pdf

CONCITO, (2024), Klimaforandringernes betydning for fremtidens arealanvendelse. [Online]. [Accessed 21-03-2025]. Available at: https://concito.dk/files/media/document/Klimaforandringernes%20betydning%20for%20fremtidens%20arealanvendelse.pdf

Dahl-Jensen, et al. (2025) Den skjulte klimakatastrofe. [Online]. [Accessed: 24-03-2025]. Available at: https://www.navigating360.dk/

Dryzek, J. S. (2005) The politics of the earth: environmental discourses, 2nd edn. Oxford University Press, Oxford https://books.google.dk/books?hl=en&lr=&id=sjVKEAAAQBAJ&oi=fnd&pg=PP1&ots=sVkOce56ce&sig=lAsA23rJm-6W8fpKR8JBEulqUWU&redir_esc=y#v=onepage&q&f=false

Eliasson, K., & Westerlund, O. (2023). Housing markets and geographical labour mobility to high-productivity regions: The case of Stockholm. European Urban and Regional Studies, 31(3), 259-280. https://doi.org/10.1177/09697764231210791

European Parliament. (2024) Water Protection and Management. [Online]. [Accessed: 24-03-2025]. Available at: https://www.europarl.europa.eu/factsheets/en/sheet/74/beskyttelse-og-forvaltning-af-vandomrader

Gram-Hanssen, I., Aall, C., Drews, M., Juhola, S., Jurgilevich, A., Klein, R.J.T., Mikaelsson, M.A. and Mik-Meyer, V.L. (2023). Comparison and analysis of national climate change adaptation policies in the Nordic region. [online] Copenhagen: The Nordic Council of Ministers. Available at: https://pub.norden.org/temanord2023-525/index.html.

Hansen, H. T. R. and Knudstrup, M. A. (2005) The integrated design process (IDP): A more hollistic approach to sustainable architecture, Action for sustainability-The..., page 27-29

Herold, D. M. and Lee, K.-H. (2017) 'Carbon management in the logistics and transportation sector: an overview and new research directions', Carbon Management, 8(1), pp. 79–97. doi: 10.1080/17583004.2017.1283923.

Hosseinzadeh, N., Ghiasian, M., Andiroglu, E., Lamere, J., Rhode-Barbarigos, L., Sobczak, J., Sealey, K. S., Suraneni, P. (2022) Concrete seawalls: A review of load considerations, ecological performance, durability, and recent innovations. Ecological Engineering, Volume 178.

Human Rights Watch. (2024) "Die First, and I'll Pay You Later" Saudi Arabia's 'Giga-projects' Built on Widespread Labor Abuses. [Online]. [Accessed: 17-03-2024]. Available at: https://www.hrw.org/report/2024/12/04/die-first-and-ill-pay-you-later/saudi-arabias-giga-projects-built-widespread

IEA (2023), Denmark Climate Resilience Policy Indicator, IEA, Paris https://www.iea.org/reports/denmark-climate-resilience-policy-indicator, Licence: CC BY 4.0

IPCC (Pbs.). (2023) Summary for policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assesment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland, p.2-34

Jayasena, N.S., Mallawaarachchi, H. and Waidyasekara, K.G.A.S. (2019). Stakeholder Analysis For Smart City Development Project: An Extensive Literature Review. MATEC Web of Conferences, [online] 266, p.06012. doi:https://doi.org/10.1051/matecconf/201926606012.

Klimatorium. (2025). [Online]. [Accessed: 17-03-2025]. Available at: https://klimatorium.dk/

Lamond, J. E. & Proverbs, D. G. (2009) Resilience to flooding: lessons from international comparison, Proceedings of the Institution of Civil Engineers, Urban Design and Planning volume 162 Issue 2, page 63-70. [Online]. [Accessed: 05-05-2025]. Available at: https://doi.org/10.1680/udap.2009.162.2.63

Lawson, B. (2005) How designers think | The Desing Process Demystified. Fourth edi.

Leake, S.A. and Barlow, P.M. (2013). Understanding and managing the effects of groundwater pumping on streamflow. Fact Sheet. [Online] doi:https://doi.org/10.3133/fs20133001.

Martí, L., Puertas, R. and García, L. (2014) 'The importance of the Logistics Performance Index in international trade', Applied Economics, 46(24), pp. 2982–2992. doi: 10.1080/00036846.2014.916394.

Moldan B, Janoušková S, Hák T (2012) How to understand and measure environmental sustainability: indicators and targets. Ecol Indic 17:4–13. https://doi.org/10.1016/j.ecolind.2011.04.033

Nejade, R. M., Grace, D., & Bowman, L. R. (2022). What is the impact of nature on human health? A scoping review of the literature. Journal of global health, 12, 04099. https://doi.org/10.7189/jogh.12.04099

Nielsen, K., Mernild, S., Holmegaard, L. N. (2025) Store vandmængder kræver nye løsninger. Aktuel Naturvidenskab, Nr. 1, page 18-21.

Peterson, C. H. & Bishop. M. J. (2005) Assessing the Environmental Impacts of Beach Nourishment, BioScience, Volume 55, Issue 10, Pages 887–896. [Online]. [Accessed: 05-05-2025]. Available at: https://doi.org/10.1641/0006-3568(2005)055[0887:ATEIOB]2.0.CO;2

Plumwood, V. (2008). Shadow Places and the Politics of Dwelling – AHR. [online] Australian Humanities Review. Available at: https://australianhumanitiesreview.org/2008/03/01/shadow-places-and-the-politics-of-dwelling/.

Rapoport, E. (2014) Utopian Visions and Real Estate Dreams: The Eco-city Past, Present and Future. Geography Compass, 8: 137-149. https://doi-org.zorac.aub.aau.dk/10.1111/gec3.12113

Register, R. (1987) Ecocity Berkeley. Berkeley, CA: North Atlantic Books.

Randers Kommune, (2025) Flodbyen Randers. [Online]. [Accessed 26-03-2025]. Available at: https://www.randers.dk/udvikling-by-og-land/byer-og-lokalsamfund/strategisk-udvikling-af-byer-og-omraader/flodbyen-randers/

Randers Kommune, (2020) Udviklingsplan for byen til vandet. Randers Kommune. [Online]. [Accessed 26-03-2025]. Available at: https://www.randers.dk/udvikling-by-og-land/byer-og-lokalsamfund/strategisk-udvikling-af-byer-og-omraader/flodbyen-randers/udvikling-af-flodbyen-randers/udbygning-i-etaper/

Rochell, K., Zhang, X.-Q., Fleck, L., Delbridge, V. and Harman, O. (2021). Financing Sustainable Urban Development. [online] UN-Habitat. Available at: https://unhabitat.org/sites/default/files/2021/06/FSUD%20report_web.pdf.

Roth, A. and Kåberger, T. (2002). Making transport systems sustainable. Journal of Cleaner Production, 10(4), pp.361–371. doi:https://doi.org/10.1016/s0959-6526(01)00052-x.

Sántha, E. (2023). CATALYST - Architecture as a catalyst for social and socio-economic value creation. 10.54337/aau588607952.

Scheres, B., & Schüttrumpf, H. (2019) Enhancing the Ecological Value of Sea Dikes. Water, 11(8), 1617. https://doi.org/10.3390/w11081617

Schiermeier, Q. (2018) Droughts, heatwaves and floods: How to tell when climate change is to blame. In: Nature, 560, p.20-22.

Siders, A.R., Hino, M. and Mach, K.J. (2019). The case for strategic and managed climate retreat. Science, 365(6455), pp.761–763. doi:https://doi.org/10.1126/science.aax8346.

Styrelsen for Grøn Arealomlægning og Vandmiljø 1. (2025) NATURA 2000. [Online]. [Accessed: 01-04-2025]. Available at: https://sgavmst.dk/natur-og-jagt/naturindsatser/natura-2000

Styrelsen for Grøn Arealomlægning og Vandmiljø 2. (2025) Limfjorden. [Online]. [Accessed: 21-03-2025]. Available at: https://sgavmst.dk/natur-og-jagt/naturen-i-danmark/novana-overvaagning-af-natur-og-vandmiljoe/guider-til-danske-vandomraader/marin/limfjorden

Sørensen, C. S., Broge, N., Molgaard, M.R., Schow, C.S., Thomsen, P., Vognsen, K., and Knudsen, P. (2016). Assessing Future Flood Hazards for Adaptation Planning in a Northern European Coastal Community. Frontiers in Marine Science, 3. doi:https://doi.org/10.3389/fmars.2016.00069.

Schoonees, T., Gijón Mancheño, A., Scheres, B., Bouma, T. J., Silva, R., Schlurmann, T. & Schüttrumpf, H. (2019) "Hard Structures for Coastal Protection, Towards Greener Designs". Estuaries and Coasts 42, page 1709-1729. [Online]. [Accessed: 05-05-2025]. Available at: https://link.springer.com/article/10.1007/s12237-019-00551-z#citeas

United Nations General Assembly (2015) Resolution 70/1: Transforming our world: the 2030 Agenda for Sustainable Development (25 Septemper 2015). [Online]. A/RES/70/1. https://docs.un.org/en/A/RES/70/1

Vašíček, O., Budina, M., Nehudek, T. and Česelský, J. (2014). Factors Affecting the Attractiveness of the Area for Individual Housing. Advanced Materials Research, [online] (1020), pp.680–685. Available at: https://www.researchgate.net/publication/280952569_Factors_Affecting_the_Attractiveness_of_the_Area_for_Individual_Housing.

WMO, (2024) State of the Global Climate 2023. [Online]. [Accessed 24-03-2025]. Available at: https://library.wmo.int/records/item/68835-state-of-the-global-climate-2023

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