Future Challenges Of Kalmar City

Coastal adaptation strategy design in relation to sea level rise

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ABSTRACT

Sea level rise has steadily increased and is anticipated to rise further by the end of the century and beyond 2100. Low-lying coastal areas are affected by rising sea levels as they will be more susceptible to flooding and land loss. The main objective of this thesis is to design a holistic future proposal for Barlastholmen and Sylvanderparken in Kalmar City, Sweden. That considers adaptation to rising sea levels and emphasises green and public spaces. The thesis aims to explore how Flexmark coastal adaptation strategy could be utilised in coastal urban areas to adapt to rising sea levels and whether additional strategies would be needed. This is done using the Research by Design method and interactive processes; the work is based on a literature review and a site analysis. The literature review examines coastal adaptation strategies and their principles and structures. The site analysis investigates the current conditions and the identity of the selected areas for future values. The findings from the Literature Review chapter and Site Analysis chapter are the basis for the proposal. The project results show a holistic design proposal for the selected site in 2123. It shows how Barlastholmen and Sylvanderparken could be adapted to sea level rise and how it can create inviting and attractive green and public spaces. The results conclude that the Flexmark strategy can be utilised in the areas designated for recreation, where the site may be susceptible to flooding. However, the result shows that additional strategies are required as the Flexmark strategy was not suitable for the entire selected area. Therefore, additional strategies have been selected as they sufficiently protect specific structures and areas from flooding. The results show a comprehensive proposal combining research with a design to adapt to sea level rise.

Keywords: Coastal strategies, coastal structures, coastal principles, coastal urban area, Flexmark, sea level rise, public and green spaces, urban design

POPULAR SUMMARY

Coastal communities are dealing with severe issues like rising sea levels. As a result, adaptation strategies are becoming more necessary as they can help designers understand and adapt to the situation. Human activities have been the main global driver of sea level rise since 1970. The sea level rise is rising and will continue to do so beyond the year 2100, which means many coastal areas will be in danger of getting flooded if nothing is done to prevent it. This thesis is about how to adapt to sea level rise in Barlastholmen and Sylvanderparken; to develop a proposal for the selected areas in the year 2123 and utilise coastal adaptation strategies to adapt to sea level rise. Barlastholmen and Sylvanderparken are located on the east coast of Sweden in Kalmar City. Sylvanderparken is a park and the only green space near Barlastholmen, an industrial area developing as an urban area. Unfortunately, Sylvanderparken will be flooded and gone by 2123 because of the sea level rise. This means the only green area by Barlastholmen will be gone, making the area uninviting. During extreme storms in 2123, Barlastholmen is at risk of getting flooded, if nothing is done to prevent it. That is where the coastal adaptation strategies come in. These strategies are methods for controlling and lowering the risk of flooding in coastal communities. Coastal strategies are a tool that designers and planners can use to help them decide how to adapt to sea level rise. Examples of coastal adaptation strategies are abandoning the area, moving buildings to higher ground, and building coastal structures to protect certain areas from rising sea levels. The starting point of this work was trying out and utilising the new coastal strategy, the Flexmark strategy. The Flexmark idea is to use land that can be flooded, as flexible land, for purposes other than permanent buildings, such as using the land for recreation and habitat for species. This thesis examines the Flexmark strategy to determine whether urban areas could use it to adapt to sea level rise and if it is enough or if there is a need for other strategies. The results are that Flexmark coastal strategy can be utilised in the recreational areas. Recreational wetlands will add more life to the area by having suitable habitats for different species and recreation for people to enjoy the outdoors. However, the Flexmark strategy is unsuitable for the whole area, so other strategies are investigated to protect some of the urban areas from flooding. The strategies are Hold the Line and Move Seaward. Hold the Line strategy is about defending the existing coastline by building protection structures against the sea. The strategy is used for the urban area to protect it from flooding, and concrete seawalls and dike barriers (pyramid walls) are used to protect the urban area from flooding. Move Seaward is about constructing new coastal protections further out to the sea. The strategy is used along the existing seawall out to the sea, where small islands and wetlands are created to help reduce strong waves hitting the existing seawall. In the Flexmark strategy area, wetlands are established for the same reason by reducing strong waves and promoting new habitats for different species. Various public and green spaces are enhanced and created by utilising the new coastal structures to create inviting and attractive areas in Barlastholmen and Sylvanderparken. This is achieved by setting three objectives in the proposal: to enhance the accessibility to the mainland and accessibility in Barlastholmen and Sylvanderparken; enhance green areas and protect important buildings (landmarks) from flooding. These three objectives help create inviting spaces. This thesis can show other designers and planners how different strategies can be used and how to embrace them by creating welcoming spaces.

TABLE OF CONTENT

1. INTRODUCTION

This chapter introduces the topic and motivation for the project, which includes adaptation to sea level rise in a specific urban coastal area. The Flexmark adaptation strategy and other strategies are also presented to understand and adapt to sea level rise. Then the purpose of the thesis is introduced, followed by the research questions, a brief text about the project's structure, and the limitations are described. The chapter's main objective is to assist the reader in comprehending the significance of the project and its subject matter.

MOTIVATION

This master thesis deals with how to adapt to sea level rise in Barlastholmen and nearby areas in Kalmar City on the Swedish east coast (see figures 1 and 2). This thesis is based on the research project COALA which is investigating the concept of Flexmark (SGI 2023), a coastal adaptation strategy where Kalmar municipality is part of the research project, therefore, the selected areas are in Kalmar City. The work is a holistic design project investigating an industrial area developing as an urban area and how it is possible to adapt to sea level rise with an emphasis on public spaces. The design work follows an intuitive and iterative working methodology motivated by Research by Design Roggema's (2016) model. The work is based on a site analysis as well as a literature review of coastal adaptation strategies and their principles and structures. The design work is a specific case from which strategies cannot be withdrawn but can be part of developing a palette of different approaches in different situations, which might provide designers with ideas and solutions for their projects.

CLIMATE CHANGE

Climate change is the long-term shift of temperature and weather patterns (UN, n.d.). These changes may be natural, such as fluctuations in solar radiation (IPCC 2021). However, since the 19 century, human activities have been the primary cause of climate change. The most significant contributors to climate change are heat-absorbing greenhouse gases emitted by burning fossil fuels, deforestation, and agriculture (ibid.). Recent climate changes have been rapid and intensifying and are unprecedented over the centuries to the millenniums. Rising greenhouse gases concentrations are causing significant changes to the Earth's climate, including sea level rise, ocean acidification, global warming, and extreme weather conditions. These changes will intensify with each incremental degree of warming, with long-lasting, irreversible effects, and notably on sea level rise (ibid.).

SEA LEVEL RISE GLOBALLY

Over the past century, the global mean sea level has been steadily rising; it has increased about 21 cm from 1900 to 2020 (Levermann et al. 2013). It is anticipated to rise even further by the end of this century and continue to do so beyond the year 2100. Anthropogenic force has been the main global driver of sea level rise since 1970. The thermal expansion of ocean water served as the primary force at first (ibid.). However, starting around 2000, the impacts of thermal expansion have been outweighed by the melting of glaciers and the ice sheets in Antarctica and Greenland (Fox-Kemper et al. 2021). Even if greenhouse gas emissions are controlled, an extra 10 to 25 cm of sea level rise is predicted by 2050. The frequency and severity of extreme sea level occurrences along the coast, such as storm surges, wave inundation, and tidal floods, will increase due to sea level rise (ibid.). By 2050, independent of emissions, scientists predict that in some regions, extreme sea level occurrences that were previously predicted to occur once every 100 years will occur yearly at 20–25% of locations. Although the effects of sea level rise are global, its impacts vary between and within countries; local sea levels can be lower or higher than the average global rise (ibid.). Local sea level changes can result from variations in ocean circulation and wind patterns from year to year and location to location. One of the effects of sea level rise is that low-lying coastal areas will be more susceptible to flooding and land loss (ibid.). In addition, coastal areas frequently have dense populations, vital infrastructure, and biodiverse terrain, thus, it is projected that effects like floods or a lack of freshwater supply will put stability and security in danger (Cazenave et al. 2014). The annual damage from sea level rise is estimated to be 1.25 billion euros and is anticipated to reach between 93 and 961 billion euros by the end of the century, assuming no further expenditures are made for coastal adaptation (Vousdoukas et al. 2018). By the end of the century, it is anticipated that the number of persons vulnerable to coastal flooding will increase from 102,000 to 1.52-3.65 million annually (ibid.), therefore adapting to sea level rise is essential for future generations.

SEA LEVEL RISE AND THREATS IN KALMAR, SWEDEN

In Sweden, the postglacial land uplift reduces the impact of sea level rise. However, land uplift varies over Sweden; it is most prominent in the north along the coast of the Baltic Bay and smallest in the south (Vestøl et al. 2019). Due to Kalmar's location in the southeast, the land uplift is small. This means that sea level rise will be more significant there than in the north (ibid.). Furthermore, Kalmar is located in a low-lying area, making it vulnerable to sea level rise. Kalmar is one of the 25 cities in Sweden most vulnerable to flooding (MSB 2018). Numerous threats will arise due to rising sea levels, particularly in low-lying areas such as Kalmar City. The selected areas are Barlastholmen and Sylvanderparken; they are vulnerable to sea level rise, especially the park, as it has been estimated it will be submerged by water by 2120 (Hedfors 2023). Barlastholmen has its challenges; the area is a new urban development by the harbour that has relatively new university buildings, unfortunately, built on lower ground. Therefore, they will eventually be flooded unless something is done to protect them.

BARLASTHOLMEN AND SYLVANDERPARKEN, THE SELECTED AREAS

The selected areas Barlastholmen and Sylvanderparken are opposites, where Barlastholmen is grey and hard and Sylvanderparken is green and soft. The objective is to create a proposal for the site and provide solutions for rising sea levels. The aim is to create thriving and inviting green and public spaces in Barlastholmen and Sylvanderparken. Different strategies need to be reviewed to find solutions to the sea level rise.

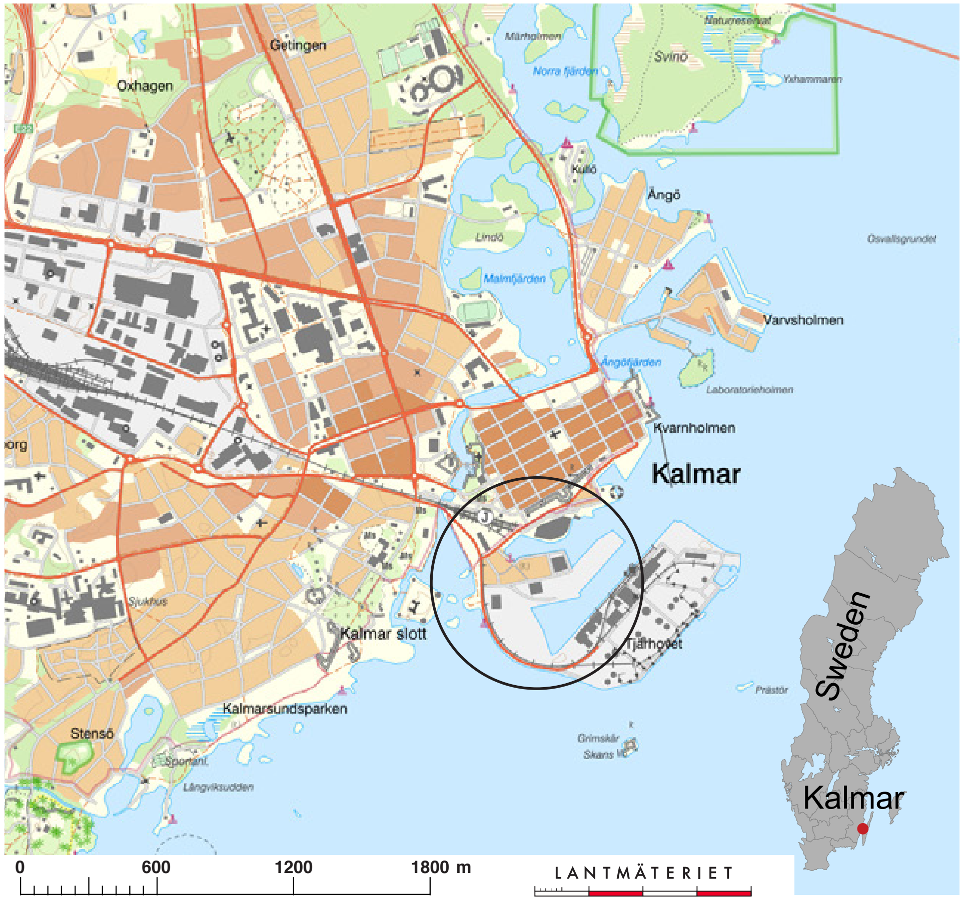


Fig. 1 & 2. Selected working area in Kalmar, and Kalmar situated in Sweden., (map from Lantmäteriet 2023; data for map of Sweden from SCB n.d.).

FLEXMARK ADAPTATION STRATEGY AND ADDITIONAL STRATEGIES

Flexmark is an adaptation strategy that declares some or all of the land as Flexmark/flexible (Göransson et al. 2022), a strategy resembling the Planned retreat strategy (SGI 2019; ICE 2010) (see Literature Review chapter). Flexmark implies that land could be designated as flexible land if it is susceptible to future sea level rise or frequent flooding (Göransson et al. 2022). This refers to land that can be abandoned when climate change's effects become too severe or expensive to protect. The land could be used for recreation, ecosystem services, temporary events, facilities or infrastructure, pathways and so forth, but is no longer suitable for permanent structures or infrastructure. Flexmark is viewed as a link between the present and the retreat time, where people need to move to safer ground. Flexmark demonstrates how the land can have values such as recreation before it is lost to the sea (ibid.). It is about seizing the chance to add value to an area that may one day be lost, accepting change, and realising how the land can be used for various purposes in the interim before it is lost. According to van Well et al. (2022 see Göransson et al. 2022), a flexible land use strategy could view water as a resource, embracing change and enhancing the value of the land.

My thought on using Flexmark in the selected area is to designate recreational areas for the Flexmark strategy. Göransson et al. (2022) suggest that the land susceptible to flooding could be used for recreation instead of permanent buildings. Since green and public spaces are the subject of this thesis, this will be the area of focus. Nevertheless, a part of the public areas need to be protected as they contain essential values. Therefore, additional strategies would need to be considered.

Additional adaptation strategies in my work include Do Nothing, Planned Retreat, Hold the Line, Limited Intervention, and Moving Seaward. These methods differ in how they approach sea level rise, from abandoning everything, to defending the current coastline, to developing towards the sea and in between. Thorough research on these strategies is done in the Literature Review chapter.

PURPOSE

This thesis will show a holistic design proposal of two urban areas impacted by sea level rise using the Flexmark adaptation strategy in conjunction with other coastal adaptation strategies. The proposal focuses on public spaces in Barlastholmen and Sylvnderparken in Kalmar City in the year 2123 when sea level rise becomes a problem.

RESEARCH QUESTION

How can a coastal urban design utilise the Flexmark coastal adaptation strategy to adapt to rising sea levels?

To answer the primary question another question is raised:
Is Flexmark coastal adaptation strategy enough, or is there a need for additional strategies?

STRUCTURE

The structure follows academic standards and is divided into an introduction, methodology, literature overview, site analysis, sketches, proposal and discussions. The first chapter introduces the main objectives of this project. The methodology is explained in detail in the second chapter. The Literature Review chapter is about reviewing several coastal strategies, principles and coastal structures. Next, the Site Analysis chapter goes through the current and future conditions in Barlastholmen and Sylvanderparken. The Research by Design Process Chapter is about testing various strategies and sketching out designs. Finally, the project results in a design proposal where previous findings are interpreted to create a future vision for Barlastholmen and Sylvanderparken, focusing on public spaces. The findings and results are then compared in the Discussion chapter, and the project is reviewed with a conclusion.

LIMITATIONS

Geographically, the work is limited to a coastal urban area, and the findings are related to Barlastholmen and Sylvanderparken in Kalmar City, Sweden, primarily focusing on public spaces. Most of the coastline in Kalmar municipality is low-lying and will be affected by sea level rise, but this thesis is limited to Barlastholmen and Sylvanderparken. The design defines itself through the year 2123 and does not go beyond. The knowledge gained from the project will benefit landscape architects and other professionals in developing future planning and design strategies for public spaces. Similar strategies could be adapted to other coastal areas. This thesis does not discuss policies, governance, financial aspects or land ownership.

2. METHODOLOGY

In this chapter the project's methods are thoroughly described, as well as the different stages of the work, including how empirical data was gathered and arranged to produce the results. A design proposal was made to address the questions of this thesis through a review of the literature and site analysis. The questions are interconnected and could not be resolved by either the site analysis or the literature review alone. As a result, both were required to provide the results.

RESEARCH BY DESIGN PROCESS

The method used for the thesis is Research by Design, motivated by Rob Roggema's (2016) model. Research by Design is a method where a design is explored to investigate and solve a problem through the design process. The design process starts in the early stage, where the design is the base for research through trial and error (Roggema 2016). An interactive process which is used throughout this project (see figure 3).
Roggema (2016) described three stages: the first phase is pre-design, the second phase is design, and the third and last phase is post-design (see figure 3).

The first stage is pre-design; the research is conducted before the design. As this stage helps the designer understand the basic knowledge that must be learned before the design can be conducted, the first stage focuses on what is there (Roggema 2016). To know the problems and what needs to be learned to adapt the design. It was crucial to comprehend the main topic to formulate the research questions for this thesis. Therefore it was necessary to understand sea level rise and the threat it poses and to learn about the COALA project, which forms the basis of this thesis. Furthermore, it was essential to begin researching and comprehending the various coastal adaptation strategies and their principles to start the next stage, which is the design stage.

The second stage, the design; it is described as the main phase of the method, the heart of the research (ibid.). The research and the design are closely connected, where the design process takes place through sketching and research by switching between the problems and solutions in an iterative process between inquiry and proposal. In the second stage, more knowledge was gained about the subject through a literature review covering the various strategies, principles and coastal structures. Then, parallel to the literature review, the site analysis began. First, the subject areas were selected and investigated by researching and visiting the site. Then I went back and forth from the site analysis to the literature review. Tested and explored future scenarios for 2123, different strategies and designs in the selected areas in the Research by Design Process chapter by sketching them until an idea came that I wanted to work with. Then, after some time, I began transferring the design into the drawing computer programme MicroStation. There, the design was continued, solving issues and coming up with solutions, as well as working with sections to get a better idea of how the place could look and sketching to help me visualise it. The Literature Review and the Site Analysis were as well being worked on throughout the design; always going back and forth, fixing and tweaking everything, including which things should be kept and what should be left out, what was essential and what not. Computer programs used were MicroStation for the design, with base maps from the municipality and data from Lantmäteriet. Sketchup, Photoshop, and Illustrator were used for diagrams and illustrations.

In the third and final stage, the post-design, the results are shown, the design is seen, and how the design will be; the final phase focuses on what will be there (ibid.). Finally, the design proposal is displayed, and the discussion and the conclusion; the last step is putting everything together.

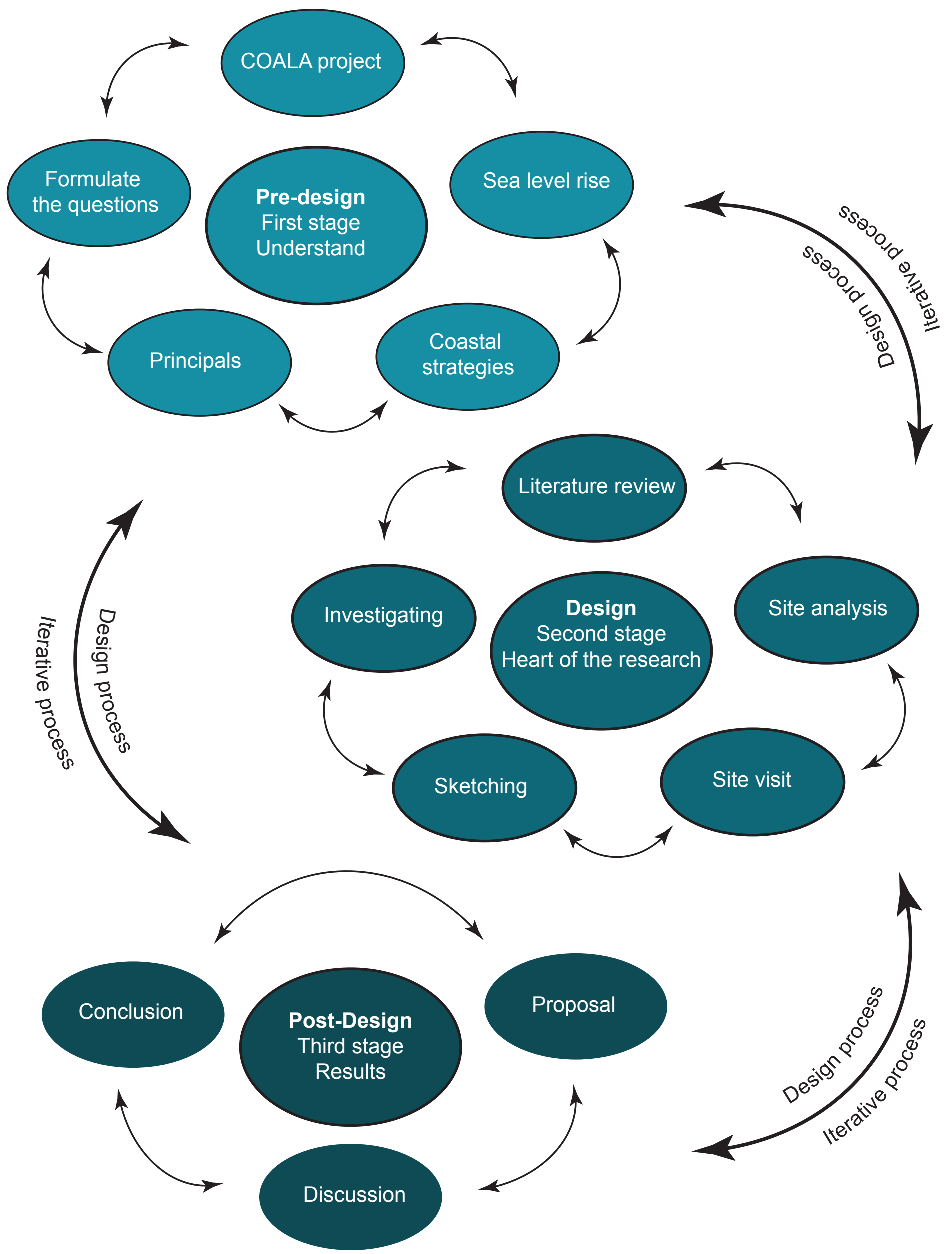


Fig 3. Shows the process, from the beginning to the end, (inspired by Roggeman's model 2016).

LITERATURE REVIEW

The Literature Review chapter focuses on gaining an overview of the state of knowledge through articles, books, and other literature. The literature is divided into two subchapters focusing on two related subjects. The first subchapter explores the adaptation strategies and their primary approaches. The second subchapter examines the differences between hard, soft, and hybrid structures and ecosystem-based adaptation (EbA) and the potential coastal structures such as seawalls, beach nourishment, and wetlands. The chapter was vital as it provided relevant information to start the design process by testing the different strategies in the selected areas through trial and error.

SITE VISIT

The site visit needed to be prepared as I would only visit once. Therefore, to make the most of the time available, it was crucial to make a plan. A guide map was created for the site visit (see figure 4). The map served as a guide but was only followed to a certain extent. For instance, some spots were altered, and others were deemed irrelevant. Figure 4 shows the route I took, the selected location, and the planned routes and locations. The most changes were in the industrial zone as those areas were restricted and therefore could not be accessed, and the route by Kalmar Slott was not walked because of time limitations. The Site Analysis chapter aimed to investigate the different coastline structures and identify important areas or buildings to protect from sea level rise, as well as analyse the public spaces in the areas and explore the identities of the sites. At each location, notes were taken of the sounds that could be heard, smells, and text describing what I saw in the context with the aims I set for the site analysis. Additionally, pictures were taken of the site during the visit to

Fig. 4. Site visit guide map (data from Lantmäteriet 2018).

analyse the area more thoroughly and aid in my memory since I only visited the locations once. Other tools included various maps, such as maps showing the sea level rise and scale-specific overview maps of Kalmar, Barlastholmen and Sylvanderparken. For example, the maps were used to investigate the coastlines, notes were written on one of the maps describing the type of coastal structures, and pictures were taken of them. The pictures were the most important element in the case of the coastline investigation as they showed the type of coastline. The materials, sounds and smells in the areas were analysed for the public spaces. Notes were taken to describe if the area had vegetation and if the areas were in shadow. The same analysis was done for the identity of the sites. After the site visit, the notes and the photos were reviewed. The Site Analysis chapter was continued, as well as the Literature Review.

SITE ANALYSIS

Before selecting Barlastholmen and Sylvanderparken, two other locations in Kalmar City were also considered; all three had in common that the sea level rise would affect the sites, but the land uses were different. One was an open area used for recreation, and the other was a residential and sports area. Preliminary research was done to learn more about them before deciding on Barlastholmen and Sylvanderparken. The areas were selected because the sites were intriguing, as Barlastholmen is primarily a landfill and an upcoming urban development from an industrial area. And Sylvanderparken is the only place in the area that is covered in greenery. After selecting the areas, research on the sites was conducted for the Site Analysis chapter. The Site Analysis chapter was made to understand several aspects of the areas. Future predictions and assumptions were explored such as sea level rise in Barlastholmen and Sylvanderparken and to explore the various coastlines in the area to learn more about the current situation and potential future scenarios. After the sea level rise and coastline subjects, the chapter is divided into two subchapters, Hardscape (Barlastholmen) and Softscape (Sylvanderparken). These chapters explore the identity of the areas, the public spaces, and important landmarks, as well as the changes the areas have gone through throughout history. The site analysis was done to understand the area and to gain knowledge of public spaces. To enhance and create a thriving environment in Barlastholmen and Sylvanderparken, not only in relation to sea level rise but also to create a functional space where people want to be. These are essential elements for a landscape architect to consider. The Site Analysis chapter gathered data from the municipality, Lantmäteriet, and other sources and the site visit to formulate the findings in the Site Analysis chapter.

3. LITERATURE REVIEW

This Literature Review chapter investigates the various coastal adaptation strategies and their principles. Measures for adaptation must be taken as sea level rise will change the landscape around the coastline by permanently submerging it or occasionally flooding it and therefore disrupting coastal communities. That is why these subjects are selected, as there is a need to gain more knowledge about the various strategies and principles to design a proposal that adapts to sea level rise. As I have learned about public spaces in coastal areas through my education and work as a landscape architect, I have selected not to discuss them in this thesis. Instead, I will incorporate what has been learned through the years into the design proposal.

COASTAL ADAPTATION STRATEGIES

Coastal communities are dealing with severe issues like rising sea levels and increasing extreme storms (Temmerman et al. 2013). As a result, adaptation strategies are becoming more necessary as they can aid designers in understanding and adapting to the situation. Coastal adaptation strategies are approaches that manage and reduce flood risk in coastal communities (ICE 2010). Designers and planners can use coastal strategies as a tool to assist them in deciding how to adapt to sea level rise. If the area should be abandoned, if the buildings should be moved to higher ground or if there is a need for coastal structures to protect certain areas from sea level rise. These are examples of coastal adaptation strategies. In this subchapter, I will go further through the various adaptation strategies that have been developed and tested.

The Institution of Civil Engineers (ICE), the Swedish Geotechnical Institute (SGI), and the Intergovernmental Panel on Climate Change (IPCC) have all compiled various adaptation strategies throughout the years with the aim to adapt to sea level rise. The strategies these institutions have assembled have multiple names but are primarily the same. For example, ICE (2019) lists three strategies; Attack, Defend, and Retreat. SGI (2019) lists five strategies (translated to English); Do Nothing, Planned Retreat, Hold the Line, Limited Intervention and Move Seaward. IPCC (2019) lists six strategies; No Response, Protection, Accommodation, Advance, Retreat and Ecosystem-based Adaptation. These institutes were used as a reference for numerous strategies for several reasons, such as the strategies from ICE (2010) are well known, the strategies from SGI where selected as it is a Swedish institution, and the selected area is in Sweden, and IPCC is a well-known panel of the United Nations. A lecture about several coastal strategies (Almström, B. 2023) was also used to comprehend and compile these strategies.

ICE (2010)	SGI (2019)	IPCC (2019)
Attack	Move Seaward	Advance
Defend	Hold the Line	Protection
Retreat	Planned Retreat	Retreat
	Do Nothing	No Response
	Limited Intervention	Accommodation
		Ecosystem-based adaptation

Fig. 5. Shows the combined strategies, making it manageable to work with them.

After assembling the strategies, their similarities became apparent except for the Ecosystem-based Adaptation (EbA) strategy from IPCC (2019). After considering the various coastal principles, I conclude that the EbA should be a principle rather than a strategy because other strategies could use the EbA in addition to other principles, like hard protection, soft protection, and hybrid solutions. This is also concluded in the article by Bongarts Lebbe et al. (2021). Flexmark approach was not included in figure 5 as it is a new concept and only one strategy.

Next, I will explore the Do Nothing, Planned Retreat, Flexmark, Hold the Line, Limited Intervention, and Move Seaward strategies. Then, in the chapter, Research by Design Process, strategies will be applied to the site since these strategies have various angles and methods.

DO NOTHING / ABANDON

No direct investments or costs are made in coastal protection structures or measures to protect against erosion or floods, see figure 6 (SGI 2019). However, there can be high indirect costs, such as loss of properties, tourism, and loss of habitats (Almström, B. 2023).

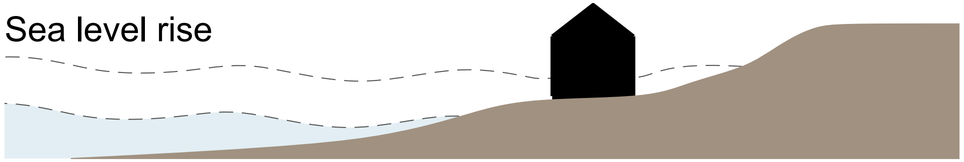


Fig. 6. Do Nothing strategy (based on Oppenheimer et al. 2019:386).

PLANNED RETREAT

Societies, infrastructure, and buildings are moved inland, and new coastal defences are arranged further from the coastline, see figure 7 (SGI 2019; ICE 2010). The planned retreat can lower the costs of defence structures but also be costly as significant investments need to replace the lost infrastructure.

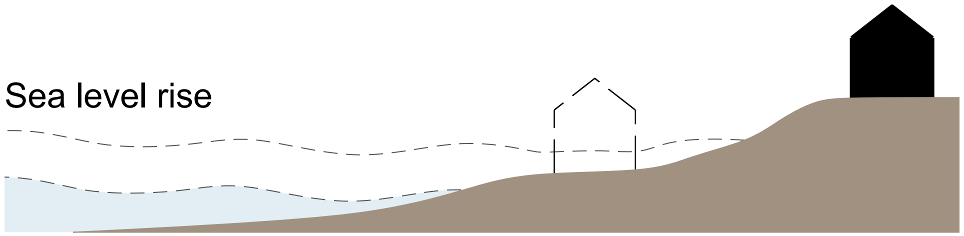


Fig. 7. Planned Retreat strategy (based on Oppenheimer et al. 2019:386).

FLEXMARK

As mentioned before, Flexmark is connected to Planned Retreat (Göransson et al. 2022). However, in the interim, the land that is vulnerable to sea level rise can be used for non-permanent buildings and infrastructures such as recreation, eco-systems, pathways and more, to add value to the area that will be lost to the sea, see figure 8. The areas with buildings and infrastructure would be moved inland, and new coastal defences would be arranged further from the coastline (SGI 2019; ICE 2010). The Flexmark/planned retreat can lower the costs of defence structures but also be costly as significant investments need to replace the lost infrastructure, as some of the buildings were built before the land was stamped as Flexmark.

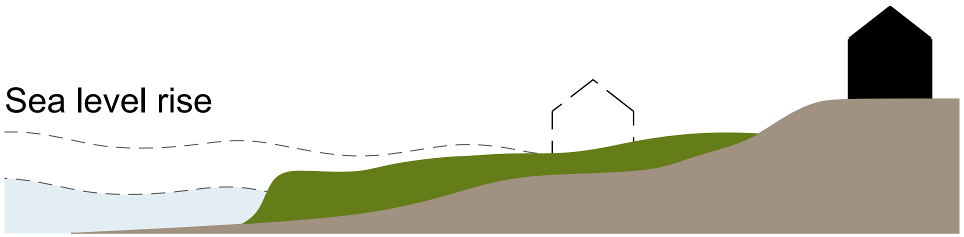


Fig. 8. Flexmark strategy (based on and modified from Oppenheimer et al. 2019:386).

HOLD THE LINE / DEFEND

Maintain and, if necessary, strengthen the current coastline, see figure 9. The strategy covers those situations where action can be taken in front of or behind the existing protections to improve or maintain the level of protection provided by the current protection line (SGI 2019). However, this plan can be expensive to adopt (ICE 2010), as the defences and upkeep can be costly.

Fig. 9. Hold the Line (based on Oppenheimer et al. 2019:386).

LIMITED INTERVENTION / ACCOMMODATION

Work with natural processes in a controlled manner by allowing erosion and securing and protecting identified values, see figure 10 (SGI 2019). Adapt buildings and infrastructure to avoid flooding and erosion damage; adapting existing structures can be challenging (Almström, B. 2023). In addition, the strategy allows opportunities for recreational spaces and access to waterfront areas.

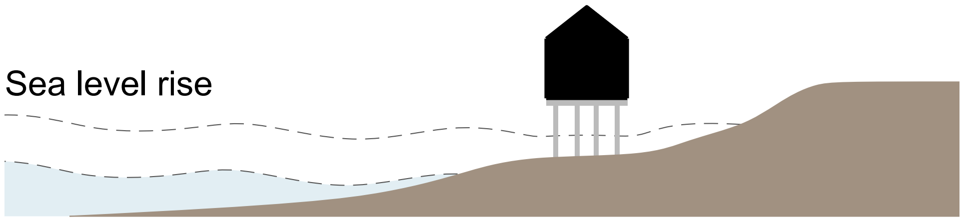


Fig. 10. Limited Intervention (based on Oppenheimer et al. 2019:386).

MOVE SEAWARD / ATTACK

New coastal protections are established further out to the sea; the existing protection line is moved forward by building new protection below the existing ones, see figure 11. Building out onto the water in coastal cities has development potential, such as preventing sprawl into the countryside (SGI 2019; ICE 2010).

Fig. 11. Move Seaward (based on Oppenheimer et al. 2019:386).

PRINCIPLES OF COASTAL STRUCTURES

This subchapter discusses examples of principles and their coastal structures in contrast to the previous one, which discussed coastal adaptation strategies. Principles can be applied to coastal strategies to support them in accomplishing their objective of adapting to sea level rise. For instance, if the Hold the Line strategy is used, which defends a specific area by protecting the current coastline. Principles and coastal defences would be required to protect the existing coastline from rising sea levels. For example, hard or soft protection principles can be applied to this strategy. Therefore the coastal structures that could be used are dikes (hard protection) and dunes (soft protection), as those coastal structures are under the principles of hard and soft protection.

Several pieces of literature on the various principles are reviewed in this subchapter; however, the main article that is used to find the relevant literature and comprehend the principles is an article by Bongarts Lebbe et al. (2021). The article provides an overview of the different principles that can be used with the various strategies and the diverse coastal structures categorised within each principle. Generally, the principles can be sorted into hard and soft protection, ecosystem-based adaptation (EbA) followed by hybrid solutions. These methods are applied in the Research by Design Process chapter with the strategies.

HARD PROTECTION / GREY SOLUTION

Hard protection, sometimes called the “grey infrastructure” approach, is widespread and primarily concentrated in deltas and densely inhabited areas like coastal cities in North-western Europe and East Asia (IPCC 2019). Hard protection has historically been the most popular approach, requiring significant investments while preventing land loss. Although popular, these measures are expensive and, in some cases, even unaffordable, but they take less space than soft protection (Hinkel et al. 2018). Seawalls can exacerbate erosion, affect the seabed and neighbouring coasts, and reduce the coastline’s capacity to respond naturally to changing conditions (van Rijn 2011). Dikes and static seawalls are also effective in stabilising the coastline but cause scour and can destabilise the beach. Hard protection may harm the coastal ecosystem and result in habitat loss or decreased species diversity (Bilkovic and Mitchell 2013). When hard protections are constructed, they can close off the sea, making it difficult for people to access the water (Hinkel et al. 2018).

DIKES

Dikes are earthen barriers built on riverbanks or coasts to prevent coastal and fluvial flooding in coastal and riverine environments (CIRIA 2013). These are often long, linear constructions that are part of more extensive flood protection networks, including floodwalls, gates, pumping stations, and other naturally occurring and artificial elements. Dikes can be natural, formed by the accumulation of sediments or artificial (EEA 2017). The core of an artificial dike is often made of masonry or sand and covered with impermeable materials like grass, pebbles and gravel, see figure 12.

SEAWALL

Seawall is a structure constructed alongside the coastline, between the shore and the mainland. Seawalls can be made of concrete, masonry, or sheet piles (Climate-ADAPT 2023d; UNEP-DHI 2016). It aims to shield the inland area from wave action and stop coastal erosion. A seawall is often a large structure built to withstand storm surges, see figure 13. The height of a seawall is often higher than the mainland to protect it against wave overtopping although sometimes the wall covers only the level variation from the shore and to the mainland (Climate-ADAPT 2023d). Seawalls are also utilised to stabilise collapsing cliffs and defend coastal settlements and roadways.

Fig. 12. One type of dike (Cormont 1995).

Fig. 13. Seawall (Oikos-team 2007).

SOFT PROTECTION

Soft protection, also known as sediment-based protection (IPCC 2019), is an approach that has been gaining popularity as people have become more conscious of the detrimental effects of hard protection on ecosystems, as well as on erosion and sedimentation patterns (van Rijn 2011). Soft solutions incorporate the mobility of the coastline and the littoral's inherent dynamics to work with nature. Dredging, dunes rehabilitation, barrier islands, beach nourishment, and beach scraping are some techniques used to prevent erosion and stabilise the coastline; they are reversible and have a finite lifespan (Buisson et al. 2012). These techniques are less disruptive to the natural coastal processes. Yet, it may have adverse physical and biological effects on beach ecosystem services (Fegley et al. 2020) and other ecological and socioeconomic effects. In addition, not every nation has an endless supply of beach-compatible sand (de Schipper et al. 2021).

BEACH NOURISHMENT

Beach nourishment is adding sand to degraded coastlines artificially to counteract natural erosion. Sandy beaches absorb wave energy and mitigate the effects of storm surges (Climate-ADAPT 2023a). The technique can involve spreading sand over the beach where erosion takes place (see figure 14), storing sand on the backshore, which is only exposed to waves during extreme events, or nourishing the shoreface near the water (see figure 15), where the decline of tidal energy can lead to improved accumulation at the beachfront (ibid.).

DUNES

Most sandy, less-developed beaches have dunes, which naturally shield the coast from erosion and prevent flooding in inland areas (see figures 16 and 17). In addition, they act as a natural barrier against the wind and the waves, absorbing some of their force (Climate-ADAPT 2023b). For dunes to continue protecting the coastline, they can be preserved, fortified, and repaired when necessary. This includes growing grass, dune thatching, and dune fencing (building fences along the seaward face) (Fernández-Montblanc et al. 2020). These complementing measures are frequently coupled with or used in addition to hard structures.

BARRIER ISLANDS

Barrier islands can form naturally when waves continuously deposit sediment parallel to the coastline (NOAA 2021). Barrier islands form a protective barrier around the mainland (see figures 18 and 19); they constantly move, erode, and grow as wind and waves shift (Feagin et al. 2010). The side of the barrier island that faces the mainland can consist of wetlands, tides, flats, and maritime forests; these areas are essential habitats for seabirds, fish, and shellfish (NOAA 2021). Barrier islands with grasses or dunes act like buffers, absorbing wave energy before it hits the mainland (ibid.), resulting in smaller storm surges and less flooding along the coast. The islands are also crucial for protecting the mainland and ecosystems from extreme storms.

Fig. 14. Beach nourishment (Ehardt 2006).

Fig. 15. Zandmotor (Rijkswaterstaat 2020).

Fig. 16. Natural dunes.

Fig. 17. Natural dunes.

Fig. 18. Barrier island (NCDOTcommunications 2011).

Fig. 19. Barrier islands and the mainland (NASA 2015).

ECOSYSTEM-BASED ADAPTATION

Ecosystem-based adaptation (EbA) responses offer a mixture of protective measures and advantages established on ecosystem conservation, restoration, and sustainable management (IPCC 2019). The preservation or restoration of coastal ecosystems such as wetlands, reefs, mangroves, and oyster beds are examples of EbA principles (Powell et al. 2019). EbA systems defend the coastline by reducing tides and storm surge flow in wetlands by functioning as a hindrance and providing retention space; they also raise elevation and lower erosion rates by capturing and stabilising coastal sediments (Shepard et al. 2011).

COASTAL WETLANDS

Coastal wetlands can act as buffers against coastal erosion as they reduce wave and tidal energy by improving the coarseness of the surface that the waves and tides cross over (Climate-ADAPT 2023c). Coastal wetlands are biodiversity hotspots; they have a variety of plants and animal species they support. They frequently serve as breeding and nursery habitats for fish, shellfish, birds, and mammals (ibid.). The ability of wetlands to protect coastlines from waves and tides and inland areas from storm surges and flooding depends on the characteristics of these ecosystems on both a significant and small scale. Mangroves and salt marshes are particularly good at preventing surges (see figure 20), while seagrass has an exceptionally high capacity to disperse wave energy (see figure 21), preventing beach erosion (Duarte et al. 2013).

Fig. 20. Coastal wetland (Fike (USFWS) 2010).

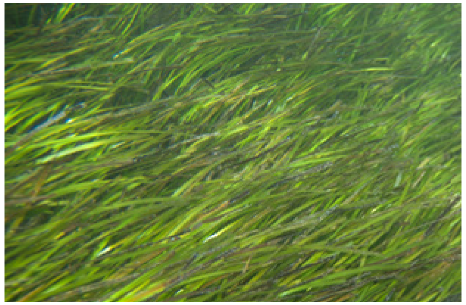


Fig. 21. Seagrass (Asman & Lenoble 2011).

HYBRID SOLUTIONS

As hybrid approaches become more prevalent and varied, coastal communities and territories have new, powerful potential to respond to sea level rise by combining measures. Sutton-Grier et al. (2015) define hybrid approaches as the combination of natural and built infrastructure to protect coastlines from erosion and flooding, intending to be more cost-effective in the long run than built infrastructure alone. The IPCC (2019) acknowledges that hybrid responses frequently combine hard and soft protection and EbA responses with numerous natural options, such as salt marsh restoration, rock groynes, and oyster restoration. Hybrid techniques, which seek to take advantage of the finest aspects of artificial and natural infrastructures, can offer higher security than EbA alone (Sutton-Grier et al. 2015). Some examples of hybrid solutions are a seawall with a marsh greenbelt in front of it (see figures 22 and 23) or a seawall with habitat-forming niches built into it. Co-benefits of the solution include strengthening the social, economic, and ecological resilience of coasts and coastal communities and minimising the loss of life and property (ibid.).

Fig. 22. Seawall and marshes (Lu et al. 2018:17).

Fig. 23. Seawall and marshes (Lu et al. 2018:17).

WHAT IS BROUGHT TO THE RESEARCH BY DESIGN PROCESS CHAPTER

- The majority of the listed strategies could be used to prevent flooding in the hardscape area (urban area).

- Use as many Eba principles as possible because they are more environmentally friendly and less expensive than hard protection. If that is not possible, use a hybrid solution, such as a combination of hard and soft protections or EbA principles, to mitigate the drawbacks of hard protections.

- Do not forget about the accessibility and connection to the water, as some coastal structures, like hard structures, may prevent that.

- In the Research by Design Process chapter, put the various strategies, principles, and coastal structures to the test.

4. SITE ANALYSIS

This chapter analyses Barlastholmen and Sylvanderparken's identities, and explores various facets of the area. First, a brief overview of Kalmar City is provided to help readers understand the city and its selected areas. The future predictions and assumptions are explored, such as the future of Kalmar and sea level rise. Furthermore, the selected areas are described briefly: Hardscape (Barlastholmen) and Softscape (Sylvanderparken). The threats posed by sea level rise are then examined, both now and in the future, along with the area's various types of coastline structures. This investigation is crucial in understanding the threats posed by sea level rise. After that, the site analysis is divided into two categories: Hardscape (Barlastholmen) and Softscape (Sylvanderparken). The identities and histories of both locations are examined in each chapter, understanding both areas is essential to design welcoming public spaces.

KALMAR CITY

Kalmar municipality is located in southeast Sweden, by Kalmarsund in eastern Småland and is part of Kalmar County. It is home to about 72,000 inhabitants in 2022; by 2050, the number is expected to rise to about 95,000 (Kalmar kommun n.d.a) and by 2123 it is estimated to be around 217,000 (1,011 present average by year) (Kalmar kommun n.d.b). Kalmar City is the central town in the municipality (see figure 24). One of Sweden's oldest cities, with mediaeval roots (Bengtsson & Magnusson 2014), the old town has cobbled streets and well-preserved 17th- and 18th-century buildings, and is known for the Renaissance-style Kalmar Slott. Today Kalmar City is a residential, academic, and commercial centre with a business scene and a centrally located port. In the summer, numerous tourists travel to Kalmar to enjoy the history and the coastal attractions.

Fig. 24. Kalmar city, Barlastholmen and Sylvanderparken (map from Lantmäteriet 2023).

SELECTED AREAS

The selected areas are Barlastholmen and Sylvanderparken; the sites differ from one another and serve different functions and uses. For example, although Barlastholmen is primarily an industrial area, it is developing into an urban area. The site is grey and has hard surfaces such as asphalt and slaps. Along the west coast is Sylvanderparken which is a green space. In contrast to Barlastholmen, Sylvanderparken is green with numerous plants and soft surfaces such as grass and gravel walkways. Because of these variations, the areas are divided into Hardscape and Softscape. Barlastholmen a Hardscape, and Sylvanderparken a Softscape; this is done to understand them better.

Fig. 25. The selected area, Barlastholmen and Sylvanderparken (data from Lantmäteriet 2022).

FUTURE PREDICTIONS AND ASSUMPTIONS

Given that this thesis aims to create a proposal for the year 2123, it is crucial to analyse future predictions and assumptions regarding different aspects, including sustainable future of Kalmar, social and technological change, climate change, ecological change, and sea level rise.

SUSTAINABLE FUTURE OF KALMAR

Kalmar municipality is part of The Climate City Contract, the Viable Cities (2022) It aims to enhance the pace of the climate transition in cities and enhance the level of ambition in sustainable urban development. The goal for Kalmar is to continue to be one of Sweden's most sustainable municipalities and be a role model regarding the environment. Kalmar's goal is to be climate-neutral by 2030. Along with Sweden and the rest of the world, Kalmar municipality will experience the effects of climate change. The impacts of climate change include flooding, high temperatures, water shortages, and an increase in the presence of pests, diseases, and invasive non-native species. The Climate Contract 2022 states that the long-term goal of Kalmar municipality is to be resilient in order to adjust to climate change. It also states that protecting human health, nature, cultural heritage, and economic interests against climate change is important. In the comprehensive plan for 2035–2050, Kalmar lays goals to achieve sustainable growth (ibid.).That Kalmar will be a socially, economically, and environmentally sustainable municipality and an attractive place for people to live, work, and visit (ibid.). It is reasonable to suppose that Kalmar will keep working towards these objectives well into the year 2123.

Kalmar municipality is also part of the 2030 agenda for sustainable development (Kalmar kommun 2023a). There are 17 global goals and 169 targets. The goals were adopted by the world leaders through the United Nations in 2015 and aim to achieve four main agendas by the year 2030: eradicate poverty and hunger, reduce inequalities and injustices in the world, promote peace and justice and solve the climate crisis. The 17 goals and targets for sustainability are interconnected and indivisible and balance the three dimensions of sustainable development: the economic, social and environmental (ibid.). It means that no goal can be reached at the expense of another and that the three dimensions must unanimously and mutually support each other and be weighed together when decisions are made. These objectives must still be pursued in the year 2123 to prevent them from becoming obsolete if they are accomplished by 2030.

SOCIAL AND TECHNOLOGY

Given the absence of scientific material regarding the state of our society in 2123, I will explore Kalmar's history and its evolution over the past centuries with some assumptions. Kalmar City was once a thriving trading centre and the site of numerous political gatherings (Bengtsson & Magnusson 2014). During the city's first 700 years, shipping and trade were the most important industries, but around 1870, the manufacturing industry took over (ibid.). But at the end of the 1990s, the municipality concentrated on developing as a university city (Kalmar kommun 2021a), replacing the decline in the manufacturing industry with increased public activities, research, education, and trade and service production. It can be assumed that Kalmar City will continue to evolve with the times as it has been doing so from the beginning. According to OECD (2015) 85% of the world's population is expected to reside in cities by 2100. By 2123, the inhabitants of Kalmar municipality will be around 217.000 (1,011 present average by year) (Kalmar kommun n.d.b). This would imply that additional building space would be required in the future. It is impossible to forecast what aspects of society will change and what will remain the same. Still, it is reasonable to anticipate that technology will significantly impact how our society develops by the advancements in transportation (Watkins 2021), education (Altinay 2022), reduction of working hours and work fields (Jain & Ranjan 2020) to name a few. Ameca, a robot, predicts that humanity will be in a far better place in 100 years (Ingle 2023). The robot imagines a world where great advancements in equality and sustainability have been made. It envisions a time when we have achieved a delicate balance between ecological preservation and human advancement (ibid.). This forecast aligns with the growing urgency and knowledge of climate change and the movement towards sustainable development in modern society.

CLIMATE CHANGE AND ECOLOGY

In the coming decades, climate change is expected to have a more significant role as a direct cause of natural oscillations and their effects on humans (IPBES 2019). Scenarios demonstrate that to achieve the Sustainable Development Goals, future goals and objectives must consider the impacts of climate change. In the coming decades, it is anticipated that climate change's effects will worsen, with relative effects varying by scenario and geographic area (ibid.). Most climate change consequences projected by scenarios are negative and have an exponentially declining influence on ecosystem health and biodiversity. Most terrestrial species are expected to diminish drastically, even with global warming of 1.5°C to 2°C. It is anticipated that nature-based solutions with safeguards will contribute 37% of the needed climate change mitigation through 2030 to achieve the target of limiting global warming to 2°C, with possible biodiversity benefits (ibid.). The Sustainable Development Goals, essential for ensuring global sustainability, can be achieved in cities at a reasonable cost using nature-based solutions. In addition to strengthening climate mitigation and adaptation, increased use of green infrastructure and other ecosystem-based strategies can enhance sustainable urban development (ibid.). In areas like flood protection, temperature regulation, cleaning of air and water, treating wastewater, and providing energy, locally sourced food, and the health benefits of being in nature, large-scale "grey infrastructure" can be supplemented by green infrastructure in urban and surrounding rural areas.

According to the Global Assessment Report on Biodiversity and Ecosystem Services (2019), ecosystem services and biodiversity have been declining quickly over the globe. The assessment found that the extinction rate of species worldwide is now at least tens to hundreds of times greater than the average rate during the last 10 million years and is accelerating. Coastal marine ecosystems exhibit historical losses in extent and condition and rapid continuous declines, demonstrating the influence of human activity on marine ecosystems. The impact of human activity on marine ecosystems can be seen in the coastal marine ecosystems' past losses in extent and condition and their rapid, continual decreases (IPBES 2019). Between 1970 and 2000, the area of seagrass meadows shrunk by 10% and 85% of the wetlands have disappeared. In the past 150 years, coral has almost drastically dropped in size, and over the last two or three decades, the reduction has been accelerated due to increased ocean acidity and water temperature interacting with and aggravating other loss-causing factors. These coastal ecosystems are among the most productive on Earth, and as a result, they are less able to shelter the coastlines and the inhabitants and other species from storms (ibid.). It can be predicted that it will continue beyond 2123 if nothing changes.

SEA LEVEL RISE RISKS NOW AND IN THE FUTURE IN BARLASTHOLMEN AND SYLVANDERPARKEN

Even though Sylvanderparken is lower than Barlastholmen, both Barlastholmen and Sylvanderparken will be affected by sea level rise, but not simultaneously. If there is an extreme storm (100-year storm) in 2023, the sea level could rise by 1 m during the storm (Hieronymus 2022). However, because the landfill is generally higher than 1 m, the extreme weather in 2023 would only slightly affect the area. For example, Barlastholmen is around 1,5-1,7 m above sea level, but Sylvanderparken is lower (see figure 26). Therefore, if the sea level rises by 1 m, Barlastholmen will not be inundated during a storm in 2023. Regardless, extreme storms might cause some parts of the park to flood and damage vegetation. The sea level rise will gradually happen, which means Sylvanderparken will experience the effects of sea level rise sooner than Barlastholmen. The water will gradually take more of the park until the whole park is submerged.

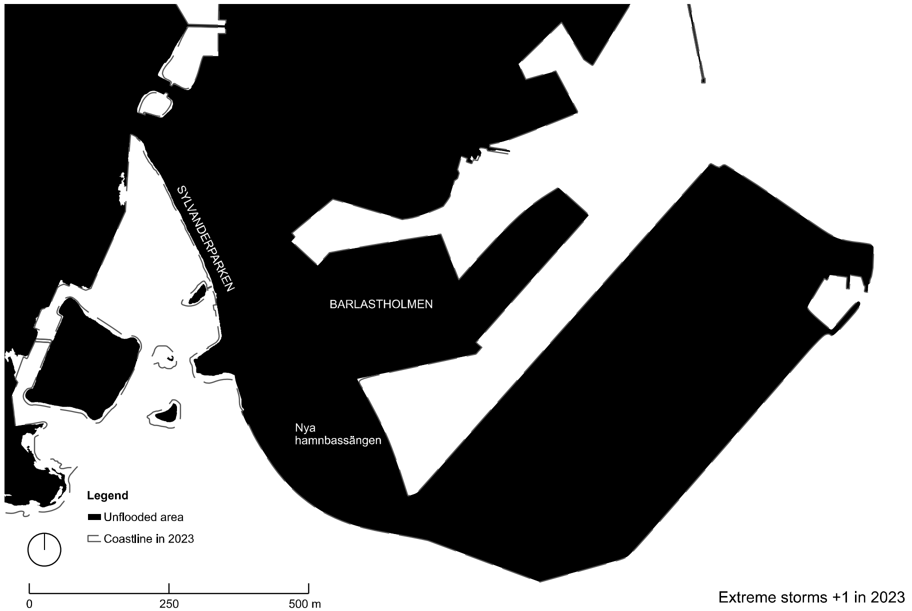


Fig. 26. Extreme storms in 2023 (data from Lantmäteriet 2021).

There are five "Shared Socioeconomic Pathways" (SSP)(SMHI 2022). These scenarios, which are used in climate models and describe various socioeconomic developments, provide scenarios for potential climate futures based on multiple emissions, increases in population, equality, and energy consumption. Each scenario has three projections: 5th percentile, median and 95th percentile. According to the 5th percentile in the SSP5-8.5 scenario, the sea level rise could rise about 0,45 m in 2120 in Kalmar (Hedfors 2023); for the median, it could be 0,97 m and then for the 95th percentile, the worst prediction it could rise about 1,77 m. SSP5-8.5 scenario and the 95th percentile were selected for this thesis since adequate data and information were available. Also, because it is the worst-case scenario, it is better to be more prepared. These scenarios are uncertain as they are future projections, but they can give us something to work with and aid in our preparation for the indefinite future.

The SSP5-8.5 scenario predicts approximately a +1,77 m sea level rise in 2120 (Hedfors 2023). The SSP5-8.5 predicts the worst case from the five SSP scenarios, where global emissions continue to rise, resulting in higher sea level rise (IPCC 2021). Furthermore, during extreme storms (100-year storms), the sea level will rise by an additional 1 m (Hieronymus 2022). It has been estimated that extreme storms will occur more frequently in the future (Fox-Kemper et al. 2021). Figure 27 shows the site with a +1,8 m sea level estimated in 2123. Most of the site will not be affected directly, as most land is higher. However, as seen in figure 27, Sylvanderparken will be submerged by 2123, and some of the area in Barlastholmen. Figure 28 shows the estimated sea level rise during extreme storms in 2123. As shown in figure 28, there will be a severe problem; the whole area will be in jeopardy of getting flooded during extreme weather.

Fig. 27 and 28. Sea level rise and extreme storms. The data for creating Fig. 27 and 28 came from Lantmäteriet (2021), the Terrain Model from 2021; the Nya hamnbassängen area became part of the Barlastholmen landfill after 2021; therefore, the data is not accurate in that area.

VARIATION IN COASTLINES AROUND BARLASTHOLMEN AND SYLVANDERPARKEN

An investigation has been conducted to examine the variation in the coastlines near Barlastholmen and Sylvanderparken to better understand the threat posed by sea level rise. As a result, two types of coastlines have been identified: hard and soft structures. This was also done to determine which coastal structures could be applied in the proposal.

Hard structures mainly consist of two types; concrete walls or fortified rocks. The concrete walls are clad with timber or tiers to prevent boat damage and can be found in Barlastholmen (see figures 29-31 and 36). The fortified rocks can be found in Barlastholmen and Sylvanderparken (see figures 32, 33 and 36)

Soft structures consist of sand and grass coastlines. Sylvanderparken mostly has a soft coastline; erosion is visible in those parts (see figures 34, 35 and 36).

Fig. 34 & 35. Soft structures consist of sand and grass coastline.

Fig. 29, 30 & 31. Hard structures; Concrete walls clad with timber or tiers.

Fig. 32 & 33. Hard structures; fortified rock coastline..

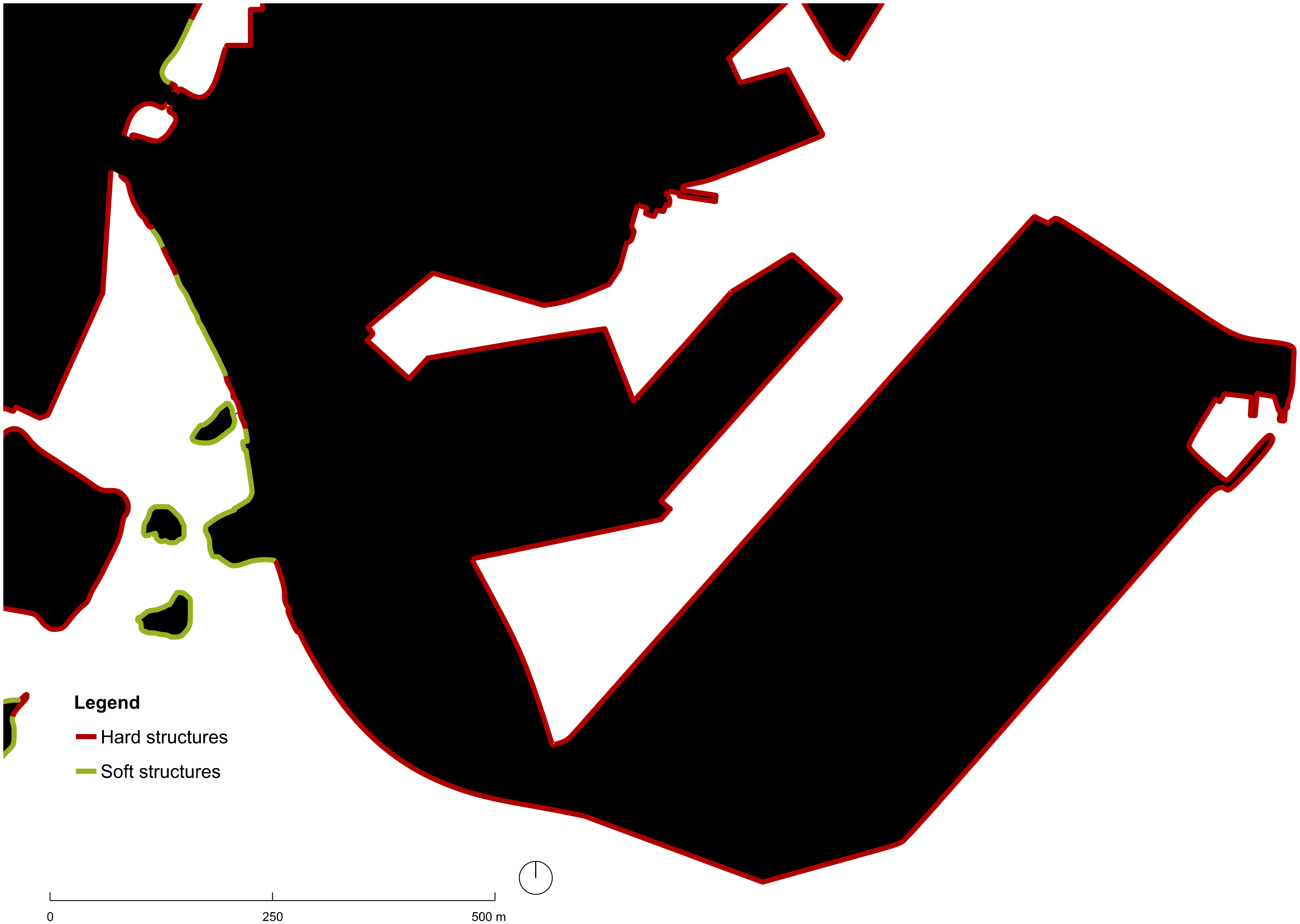


Fig. 36. Variation in coastlines, hard and soft structures (data from Lantmäteriet 2022).

HARDSCAPE - BARLASTHOLMEN

Barlastholmen is a part of the harbour by Ölandshamnen, see figure 38, an old industrial area that is changing by developing as an urban area. The Linnaeus University, Byteatern, guest harbour service, tourist office, marina, shops, harbour workshop, and timber export terminal are just a few of the many services currently available at Barlastholmen. The identity of the place is unique, as the area is both an industrial and an urban area. The municipality is updating its comprehensive plan for 2035–2050 (Kalmar kommun 2023b). The comprehensive plan was not yet implemented when this thesis was written, even so it was used. According to the comprehensive plan (see figure 37), the majority of the areas have the land use, mixed urban area. For Barlastholmen, the industrial area will be removed, and an urban area will be developed; the area might include commerce, services, offices, green spaces, and tourist attractions (Kalmar kommun n.d.c). According to the comprehensive plan (Kalmar kommun n.d.e), rising sea levels and erosion are two issues that must be dealt with in planning. In addition, new buildings and other structures are required to handle flooding up to +2,8 m above sea level.

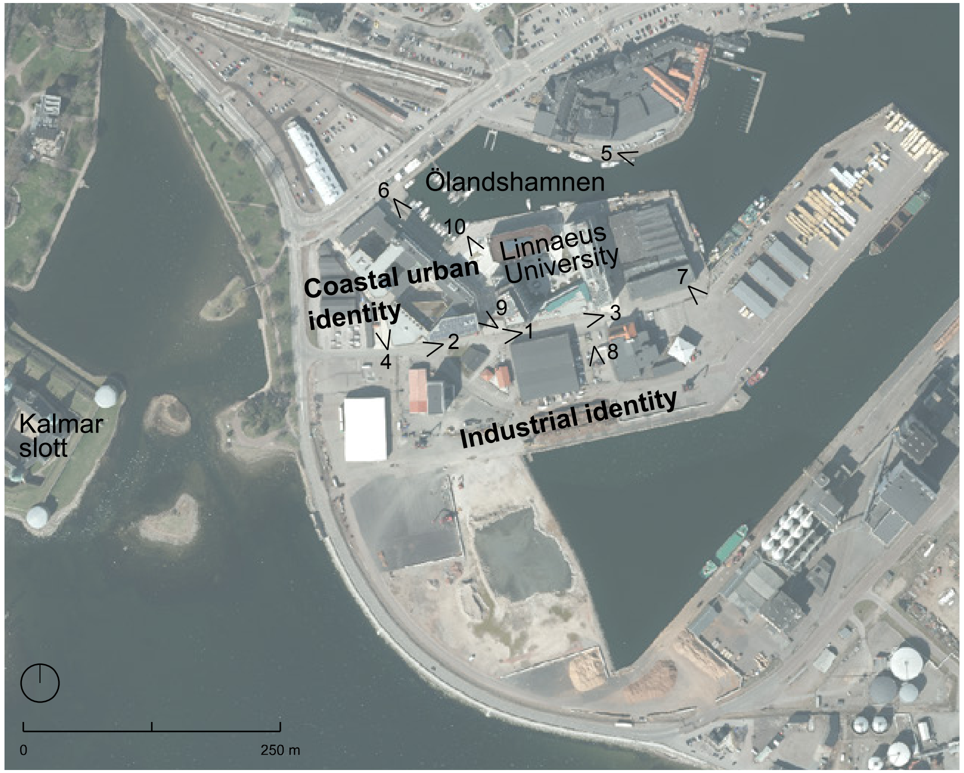


Fig. 38. Coastal urban identity as well as an industrial one (data from Lantmäteriet 2022).

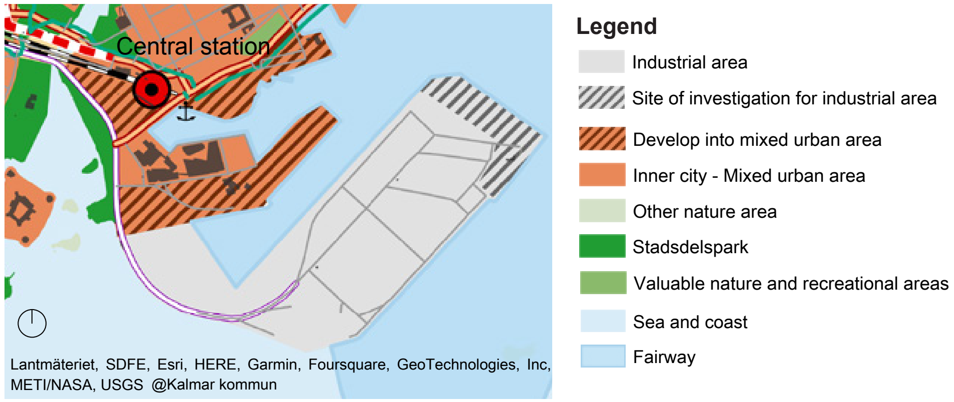


Fig. 37. Comprehensive plan for 2035–2050 (Kalmar kommun n.d.).

Fig. 39 & 40. Kalmar slott can be seen in the background.

As I walked around, I saw Linnaeus University and the guest harbour; the harbour had several small boats parked and made the place have a coastal urban atmosphere. However, the fact that I could smell sawdust and petrol as I continued to walk through the area, particularly behind the University buildings on the south side, made it clear that I was in an industrial area. Furthermore, I could hear heavy machinery loading and unloading timber (see figures 41-48). Industrial buildings make up most of the south side, but several businesses and offices are also there. Despite this, the area is grey and lacks vegetation, it is a hardscape. From the Barlastgatan, I could see the University from the south side; the buildings are reasonably new, and some of the areas by the University were unfinished as the area lacked sidewalks. Furthermore, from the street, I could see Kalmar Slott well (see figures 39 and 40).

Fig. 41-48. Different characteristics are in the area, from an urban atmosphere to an industrial one.

PUBLIC SPACES

Most of the public spaces in Barlastholmen are in shade during the autumn and winter months as they face north and are located in front of the University buildings. The sunniest areas are in the industrial zone (see figure 52), which is restricted to the public (see figures 49- 51). The only finished public spaces are on the north side of the University and there is little to no vegetation or green spaces in the area. Near the University, there are one or two trees here and there or a collage of ornamental grasses. However, the majority of the site is impermeable and grey, making the area uninviting (see figures 53-60). The ground surface edge of the marina is clad with a row of timber, emphasising the coastal character of the area. Aside from the roads and marina's edges, the ground surfaces are slabs or concrete made to look like large slabs (see figures with the numbers 5 and 9). The slabs vary in patterns and forms around the University, which gives the area character. Different types of seating can be found in Barlastholmen, with various materials and styles, which makes it incoherent (see figures 53-60). Most of the seating in Barlastholmen is found close to the University, as those areas are primarily finished and urban.

Fig. 52. Public spaces and restricted areas (data from Lantmäteriet 2022).

Fig. 49-51. The sunniest areas are in a restricted zone.

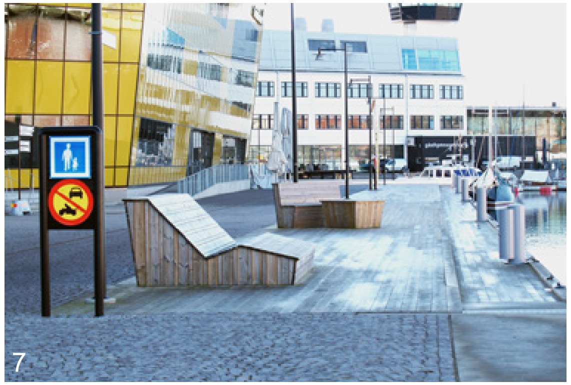


Fig. 53-58. Public spaces and vegetation in Barlastholmen. Different types of materials, wood, concrete and slabs.

Fig. 59. Grey public space by the University.

Fig. 60. Seating by the University. Ground covered with slabs.

LANDMARKS

After the site visit it was apparent there were two important buildings to preserve, Linnaeus University buildings and the Byteatern building; they can be seen as landmarks of the area. It is crucial to understand which areas are worth protecting from the threat of sea level rise, as the whole area will be in jeopardy.

LINNAEUS UNIVERSITY

The University buildings could be considered a landmark because they are the tallest structures in the area, and one has a distinctive yellow facade that adds some colour to the otherwise grey area (see figure 61). Linnaeus University buildings are relatively new; the construction on Kalmar's new campus began in 2016 and was completed in 2020 (Linnaeus University 2022). Unfortunately, sea level rise was not considered when the University buildings were constructed; they are at risk if no measures are taken. At Linnaeus University, roughly 16.000 students attend the Kalmar campus (Linnaeus University n.d.); if the buildings are not protected it will affect many lives.

Fig. 61. Linnaeus University by Ölandshamnen.

OLJEFABRIKEN / BYTEATERN

The Byteatern building can be seen as a landmark as it is the oldest building in the area and reflects the area's history. The Byteatern building was known as the Oljefabriken, an oil factory or oil extraction in the past (see figure 62). It began operating in 1918 in newly built facilities on Barlastholmen (Bengtsson & Magnusson 2014). They extracted oils from indigenous rapeseed and mustard seeds. Oljefabriken production ceased in 1957, by 1966 Kalmar City owned the structures and warehouses. In 1982, parts of the factory were rebuilt for Byteatern's needs (ibid.). Byteatern Kalmar Länsteater is a theatre that serves the entire Kalmar County and ensures that children and young people can access highly creative performing arts (Byteatern Kalmar Länsteater n.d.). In 2019, the property underwent additional renovations (see figure 63).

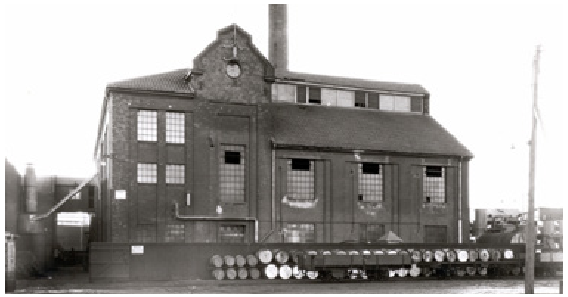


Fig. 62. Oljefabriken in 1931 (Olson & Kalmar Läns Museum 1931).

Fig. 63. Byteatern in 2023.

HISTORY AND CHANGES THROUGHOUT

Barlastholmen is made of three joined islets, Yttre Vedgårdsholmen, Barlastholmen and Lilla Kvarnholmen (Bengtsson & Magnusson 2014) (see figures 67-73), all of which were naturally occurring, but around the mid-19th century through repeating unloading of ballast from the ships, the islets had grown larger. Around the 1870s Barlastholmen was connected to Kvarnholmen by a bridge with a railway and extensive landfilling between Barlastholmen and the mainland was carried out during the 1930s and 1960s (see figures 69 and 70). In the 17th century the area was mostly used for storage and transport linked to harbour operations. Apart from a few buildings processing food and production facilities have mainly functioned for unloading and loading storage. Buildings have been erected as simpler sheds and larger warehouses (ibid.). During the 1920s many older sheds were demolished and replaced by buildings adapted to the street structure.

Barlastholmen has undergone significant changes as seen from the orthophoto from 1960 (figure 66) and compared to the orthophoto from 2022 (figure 65). In addition, sheds can be seen in the exact location of Linnaeus University in 2023; the sheds are seen in figures 64 and 66. The area's transformation will continue to change throughout the years to come.

Fig. 64. Barlastholmen 1927, the sheds were located where Linnaeus University is today (Kalmar Läns Museum 1927).

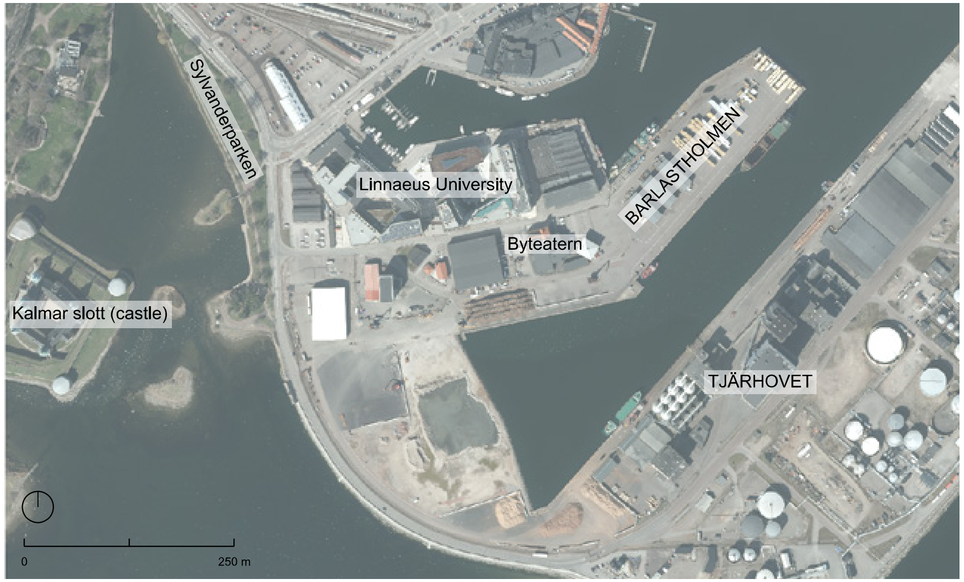


Fig. 65. Barlastholmen and neraby areas in 2022 (data from Lantmäteriet 2022).

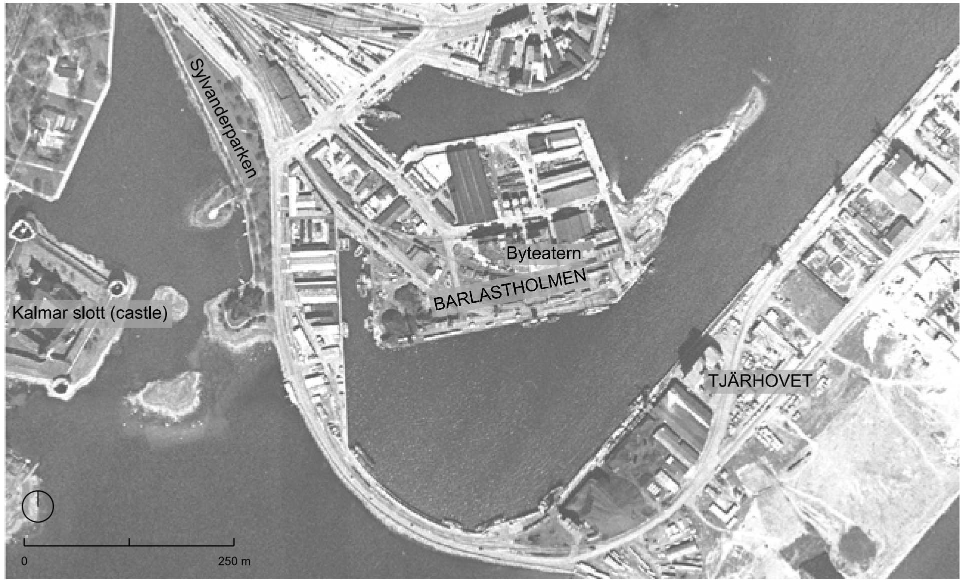


Fig. 66. Barlastholmen and nearby areas around 1960; from the figure from 2022, significant changes can be seen throughout Barlastholmen (data from Lantmäteriet 1960).

The coastline of Barlastholmen and nearby areas have undergone significant changes over the years. From 1650 (see figure 67), when Barlastholmen was a small islet, but grew more prominent over the years through unloading ballast. Between 1868 and 1960 (see figures 69-71), during which time the majority of the noteworthy changes took place, where Barlastholmen became known as Barlasholmen and Tjärhovet industrial area became and grew even larger between 1939 to 1960 (see figures 70 and 71). Between 1960 and 2022, small landfill extensions have been made, but not as significant as before (see figures 71-73). These changes have not occurred consistently throughout the years. These figures show years when considerable changes have occurred over a short period and then years when few changes have been made. All of these coastline changes are artificial.

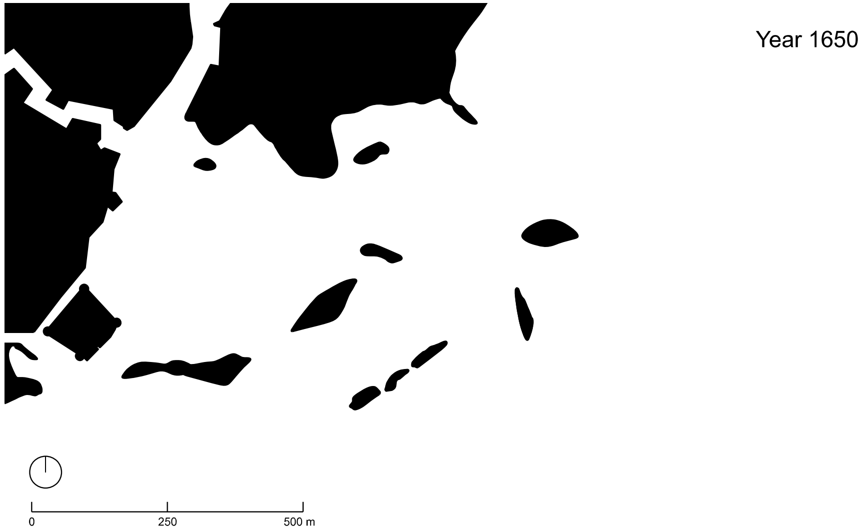


Fig. 67. Coastline in 1650 (data from Lantmäteristyrelsens arkiv 1650).

Fig. 68. Coastline in 1854 (data from Lantmäteristyrelsens arkiv 1854).

Fig. 69. Coastline in 1868 (data from Lantmäteristyrelsens arkiv 1874).

Fig. 70. Coastline in 1939 (data from Rikets allmänna kartverks arkiv 1943).

Fig. 71. Coastline in 1960 (data from Lantmäteriet 1960).

Fig. 72 & 73. Coastlines in 2002 and 2022 (data from Lantmäteriet 2002 and 2022). These years were selected as it was possible to obtain maps or orthophotos of those years.

SOFTSCAPE - SYLVANDERPARKEN

West of the train station and by the coast is where Sylvanderparken is located. The park is a softscape with lawned grass, gravel pathways and tall trees (see figures 74-85). Unfortunately, the park will be submerged in water by the year 2123. Therefore, it is essential to transform Barlastholmen into a serene and welcoming space by bringing some of Sylvanderparken's essence.

As I walked to Sylvanderparken from Barlastholmen, I immediately felt the difference in the atmosphere. Sylvanderparken is soft and serene. Even though I was there in spring and the trees had no leaves or flowers, it was still welcoming. Despite the park's length and relatively narrow diameter, I was unaware of loud traffic noises from the nearby roads. As I walked through the park, I could see people walking their dogs and I saw a man in a kayak. Near the tall pine trees are two laidback benches in the southwest of the area. I tried one of the benches, and enjoyed the view of the ocean and the castle. I could have spent all my day there relaxing and listening to the birds and the waves.

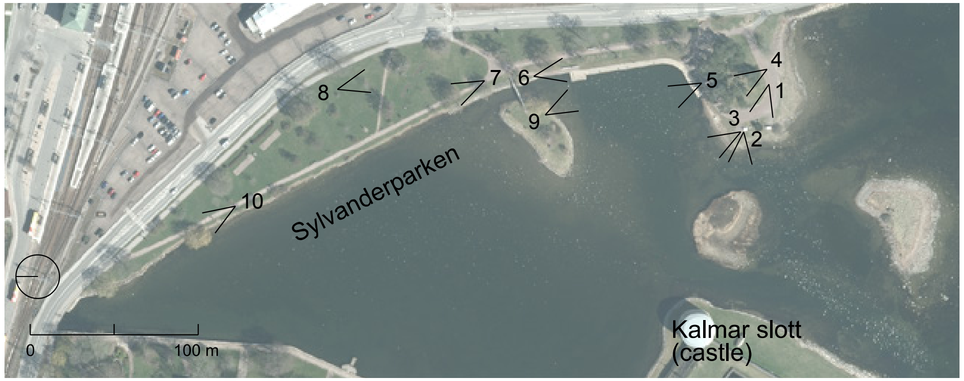


Fig. 74. Sylvanderparken (data from Lantmäteriet 2022).

Fig. 75-85. With old trees and stunning views of the castle, serence and welcoming.


Water sounds
5


Soft textures
9


Gravel pathways
10


Serene
6


Walking a dog
7


Connection to the water
9


Old trees
8

HISTORY AND CHANGES THROUGHOUT

The Sylvanderparken was established at the end of the 19th century on a landfill in Slottsfjärden (Kalmar kommun n.d.d). The park was named after Gustaf Volmar Sylvanders (1816-1882), a teacher and researcher who is most known for his monumental work "The History of Kalmar Castle and City" (Kalmar Slotts och Stads historia) (Bengtsson & Magnusson 2014). The park has mostly stayed the same since the photograph from 1936 (see figure 86), but some vegetation has been changed and removed, and some areas are simpler today (see figures 87 and 88). The southwest area by the coastline and the pine trees has also changed. For example, today (2023), the site has wooden decks along the coastline where people can dock boats (see figure 90). But in figure 89 from 1932, the wooden decks are non-existing.

Fig. 86. Sylvanderparken in 1936 (Kalmar Läns Museum 1936).

Fig. 87. Island in the park, from 2023, some vegetation has been changed.

Fig. 88. Island in the park, from 1920, different vegetation and a pathway (Winell et al. 1920).

Fig. 89. Wooden deck is non-exsiting in 1932 (Olson & Kalmar Läns Museum 1932).

Fig. 90. Wooden deck in 2023.

WHAT IS BROUGHT TO THE RESEARCH BY DESIGN PROCESS CHAPTER

- Due to sea level rise and severe storms, coastal structures must withstand a sea level rise of 2,80 metres.
- Enhance and add green spaces in Barlastholmen, as there are few of them and because Sylvanderparken will be submerged in water by 2123.
- There is a need to find a way to use Sylvanderparken as a recreational area and how to embrace the changes after it is submerged.
- Barlastholmen will no longer be an industrial area by 2123, but retaining some of its industrial identity is important.
- Protect important landmarks from flooding; protect Linnaeus University and Byteatern buildings.
- Create a dedication to connect the area to its history.
- Create a future scenario for the selected areas in 2123.

5. RESEARCH BY DESIGN PROCESS

This chapter is divided into four: Predictions and Assumptions for 2123, which created a scenario for the areas in 2123. The second Scenarios and Testing Coastal Adaptation Strategies, which investigates the various strategies. The third is Holistic Design Sketching, where several design sketches are presented. The fourth, The Design Proposal in 2050, is about showing the design in 2050, 70 years before the design proposal in 2123. These processes are a fundamental part of this thesis, where scenarios, different strategies and designs are applied through trial and error until the results are satisfactory.

PREDICTIONS AND ASSUMPTIONS FOR 2123

The future predictions and assumptions from the site analysis are used to create a future scenario for the selected areas Barlastholmen and Sylvanderparken in the year 2123.

FUTURE SCENARIO FOR 2123

It is hard to predict the future, especially 100 years from now, but if I consider the evolution in the last 100 years and people's predictions of the next 100 years,, I can envisage the future. Since my design is holistic, some elements may alter, but they will not impact it as the design does not go into depth. Additionally, technology will advance, which may render the design obsolete in 2123; yet, since we cannot forecast the future, we must make educated guesses and do our best. In this instance, doing nothing is far worse than creating anything requiring updating. To decide on the design idea and what is needed, I will make a future scenario for the selected areas of Barlastholmen and Sylvanderparken.

It can be assumed that the effect of climate change on the environment by the year 2123 will be severe as the climate will be warmer than today. Most climate change consequences projected by scenarios are negative and have an exponentially declining influence on ecosystem health and biodiversity (IPBES 2019). It is anticipated that most terrestrial species will dramatically decrease. Nature-based solutions with safeguards can help mitigate the climate, and they will be at the forefront of mitigating the changes we will face. From this perspective, it is essential to have green spaces to reduce the heat and for biodiversity, as it has been decreasing over the years and adding wetlands and ecosystems will help mitigate climate change (IPBES 2019). Sea level will certainly rise by 2123, even if greenhouse gas emissions are controlled; an extra 10 to 25 cm of sea level rise is predicted by 2050 and will get even higher past 2050 (Fox-Kemper et al. 2021). As I selected the worst case scenario, which estimated approximately 1.8 m rise in sea level by 2123, this could mean that the effects will not be as severe as the worst case scenario predicts, which would be positive. Scenarios are predictions that consider several things but can only take some as we can only anticipate some things. Still, we need to make assumptions to be resilient about the future. It might imply that some coastal structures will be smaller or constructed later than anticipated by design. At the same time, wetlands and EbA solutions can be implemented immediately as they benefit various species. Considering that the sea level will be higher and the ocean warmer and more acidic in 2123 (IPBES 2019), flooding and severe storms will happen more frequently (Fox-Kemper et al. 2021). By 2123, these occurrences may cause changes in ocean species and plants, but this will not impact the holistic design as those things are not the main focus. It is reasonable to suppose that people will continue to use the ocean for social activities like toe-dipping, swimming, fishing and using it as a mode of transportation.

It is assumed that Sweden and Kalmar Municipality will both acknowledge by the year 2123 how crucial it is to change human behaviour for the sake of the environment and other species. To slow down the loss of biodiversity and ecosystems, they will concentrate more on adding wetlands and providing habitats for various species, which will also establish recreational areas. Green areas can mitigate the effects of climate change. By 2123, the weather may need us to use plants that can withstand drought better than those we are accustomed to in Kalmar. However, as this is a holistic design, the plants are not the focus, as they can be changed fairly easily.

By 2123, Kalmar's population is projected to be around 217 thousand (Kalmar kommun n.d.b). This means that there could be a demand for buildings with various functions, including places for businesses, services, entertainment, and recreation.

Jain & Ranjan (2020) suggest that the work life in the future will be similar to today. Although certain occupations have been replaced by technology or robots, people will work less than they do now (ibid.). As a result, people could have more free time to engage in enjoyable and productive activities, making recreational spaces even more important. Some buildings could have a different use than we think we have today. Buildings need to be flexible to be able to change their services. For example, the universities could have different programs than we are used to. Or the buildings could be used for something completely different. But as there were universities 100 years ago, I do not see it changing as knowledge is power.

In 2123, transportation could differ from today, from self-driving cars to shared rides (Watkins 2021) or the same, such as using bicycles or our feet. We may also utilise other means of transportation, but in my opinion, we will still need roads and pavements, just as we did 100 years ago. We may continue to use automobiles and buses, but renewable energy or something entirely new will require roads or structures. The proposal will include streets and pedestrian walkways.

SUSTAINABLE FUTURE OF KALMAR

I see the future for Kalmar to be more sustainable than before as they will need to be as they are part of The Climate City Contract, the Viable Cities (2022). It can be assumed that Kalmar municipality will continue to work with the sustainable development goals and focus more on the environmental and social aspects and less on economics to find the balance between the subjects (Kalmar kommun 2023a). It can be assumed that Kalmar will focus more on sustainable transportation than cars to make new urban areas more sustainable for humans and by adding valuable green spaces for humans and other species (Viable Cities 2022). Kalmar could see the sea level rise as an opportunity to make its coastal areas greener and more livable to people and other species.

SCENARIOS AND TESTING COASTAL ADAPTATION STRATEGIES

The adaptation strategies from the Literature Review chapter are applied to the selected site since they all have various angles and methods. This was done in order to apply each strategy to the selected site to see which strategies, principles and coastal structure could be effective, not just Flexmark strategy. This is my interpretation of these methods.

DO NOTHING / ABANDON

If nothing is done several buildings will be in danger of getting flooded and all the buildings in Barlastholmen will be flooded during extreme storms (see figure 91). According to predictions, the sea level rise will rise 1,77 m in 2120 (Hedfors 2023), and during storms the sea level will rise an additional 1 m (Hieronymus 2022). There are better choices than abandoning everything for this area; several different values would be at stake, such as the university's value, the area's history, and the harbour.

Do Nothing: No direct investments or costs are made in coastal protection structures or measures to protect against erosion or floods, see figure 92 (SGI 2019). However, there can be high indirect costs, such as loss of properties, tourism, and loss of habitats.

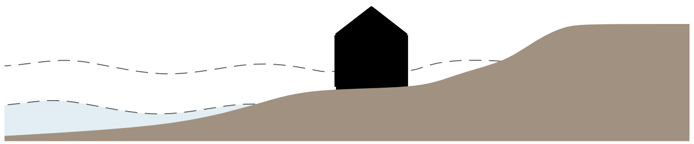


Fig. 92. Do Nothing strategy (based on Oppenheimer et al. 2019:386).

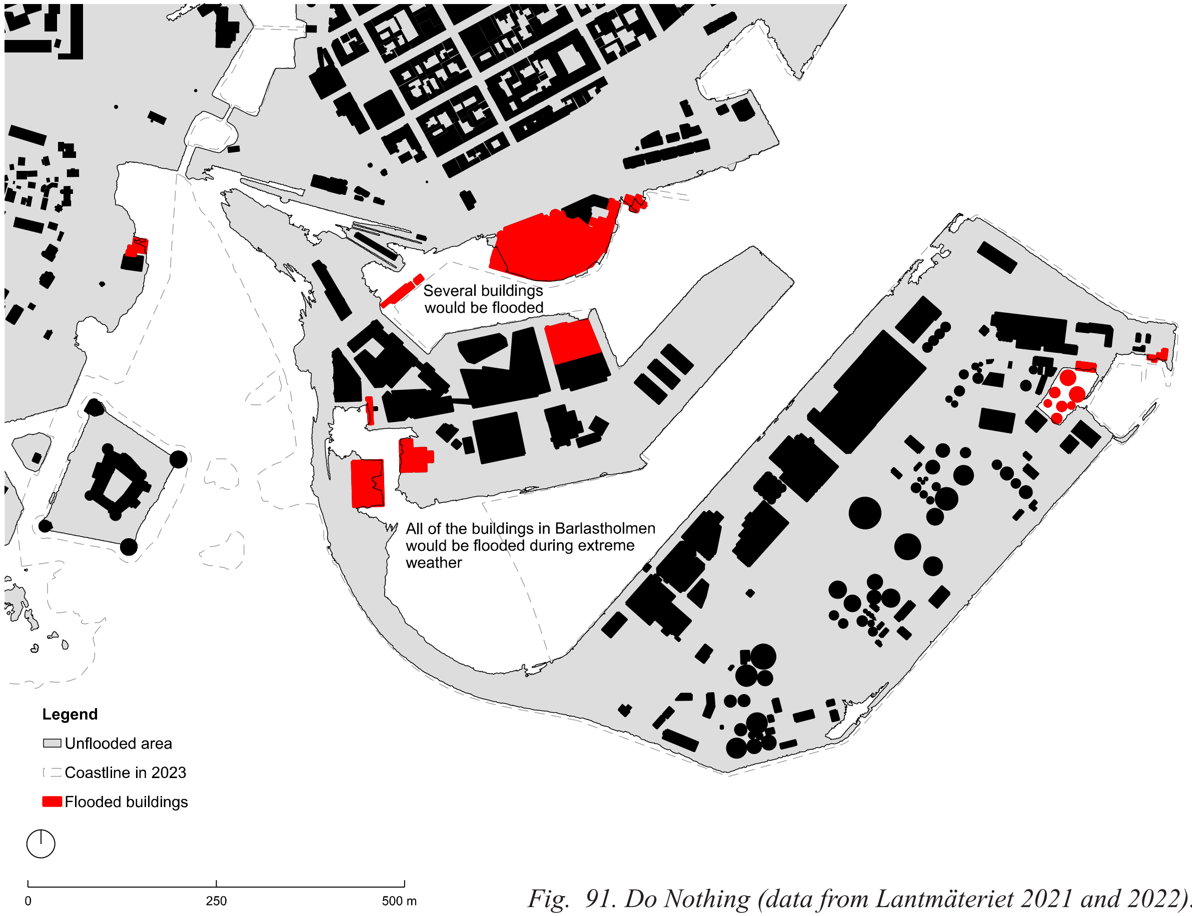


Fig. 91. Do Nothing (data from Lantmäteriet 2021 and 2022).

PLANNED RETREAT

The train station would be relocated to the west-north and structures that were in danger of being damaged would be moved or demolished (see figure 93). The area could be developed into a recreational space with tide buffer wetlands and some of the landfill could be removed. Further inland coastal defences, such as seawalls and dikes, would be constructed if needed.

Planned Retreat: Societies, infrastructure, and buildings are moved inland, and new coastal defences are arranged further from the shoreline, see figure 94 (SGI 2019; ICE 2010). The Planned Retreat can lower the costs of defence structures but also be costly as significant investments need to replace the lost infrastructure.

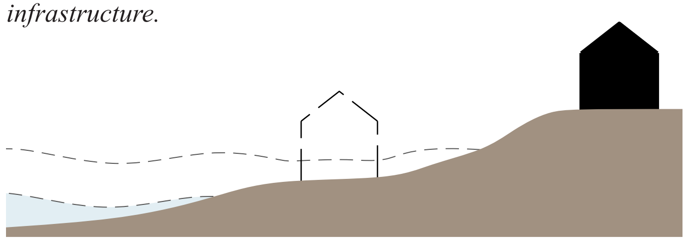


Fig. 94. Planned Retreat strategy (based on Oppenheimer et al. 2019:386).

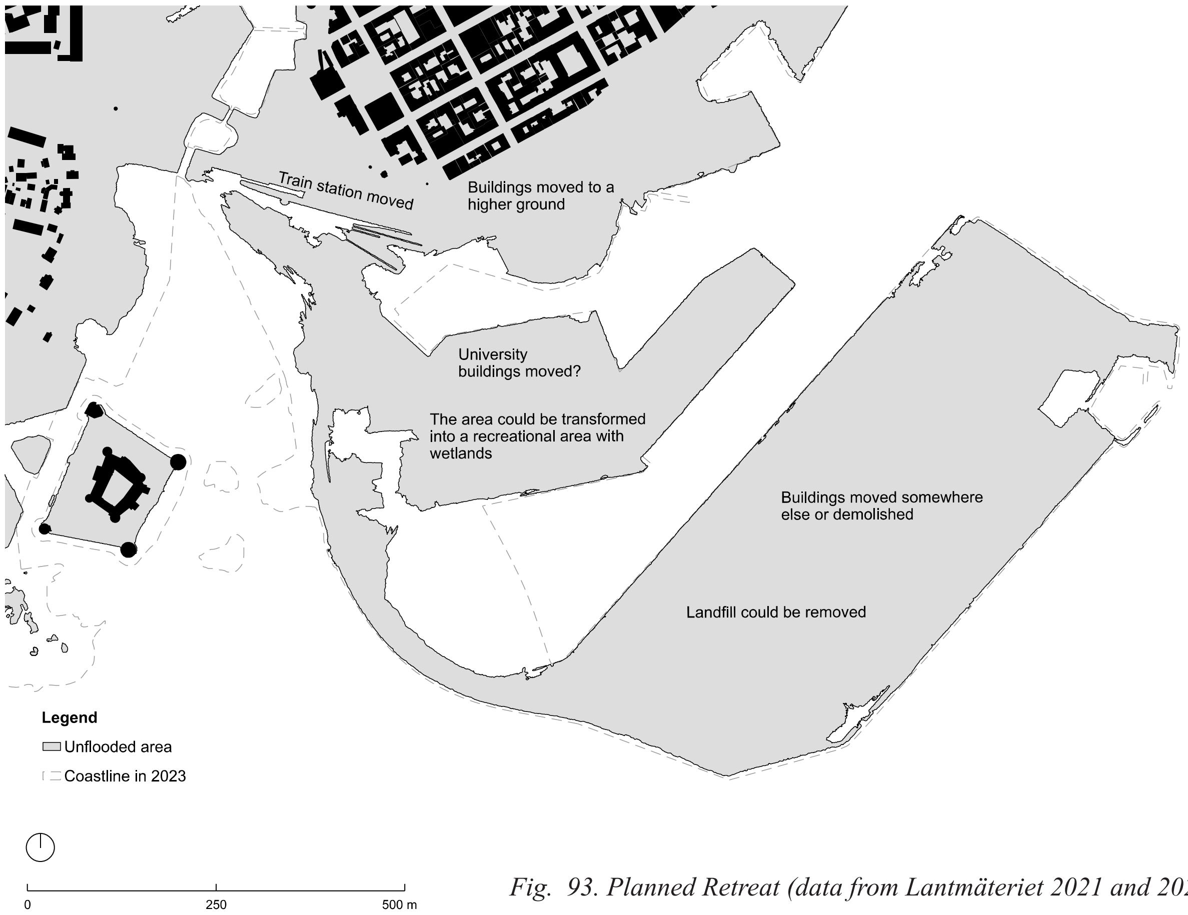


Fig. 93. Planned Retreat (data from Lantmäteriet 2021 and 2022).

FLEXMARK

Similar ideas as in the planned retreat, wetlands and recreational areas would be the primary values in the area (see figure 95). The train station would need to be relocated to the west-north, and structures that were in danger of being damaged would be moved or demolished. New buildings or structures would not be built in areas susceptible to flooding.

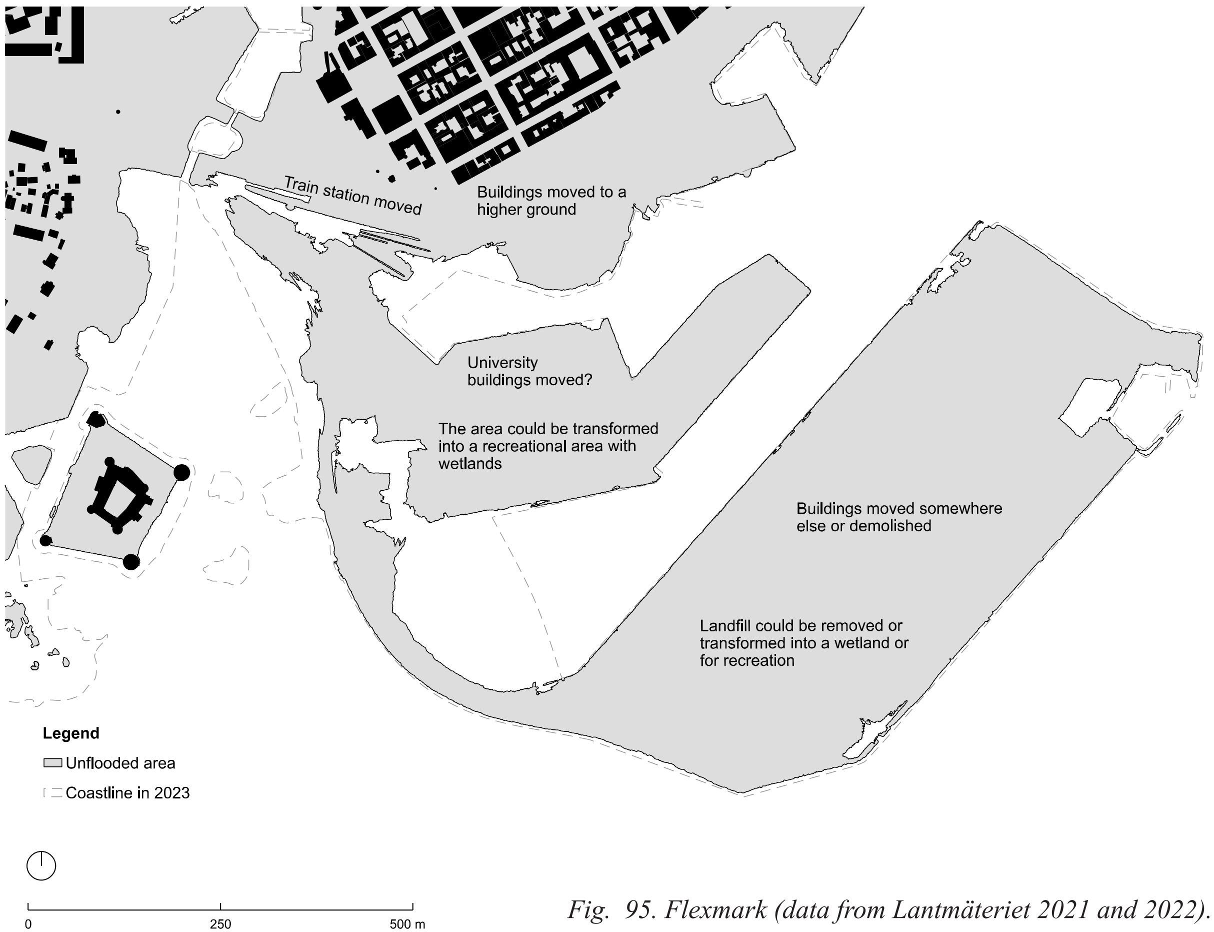


Fig. 95. Flexmark (data from Lantmäteriet 2021 and 2022).

Flexmark: Is connected to Planned Retreat (Göransson et al. 2022). However, in the interim, the land that is vulnerable to sea level rise can be used for non-permanent buildings and infrastructures such as recreation, eco-systems, pathways and more, to add value to the area that will be lost to the sea (see figure 96). The areas with buildings and infrastructure would be moved inland, and new coastal defences would be arranged further from the coastline (SGI 2019; ICE 2010). The Flexmark/ Planned Retreat can lower the costs of defence structures but also be costly as significant investments need to replace the lost infrastructure, as some of the buildings were built before the land was stamped as Flexmark.

Fig. 96. Flexmark strategy (based on and modified from Oppenheimer et al. 2019:386).

HOLD THE LINE / DEFEND

Various techniques, such as seawalls, dikes, wetlands, beach nourishment, and dunes, can protect the existing coastline. Seawalls could be used in the industrial area and areas with limited space (see figure 97). Where sufficient space exists, such as south of Barlastholmen, dikes could be used to prevent flooding. Beach nourishment could also be used in Sylvanderparken and west-south of the area where a beach exists. Wetlands could be established in a few places by the castle and along the landfill coastline in the west-south. There are many ways to approach the problem.

Hold the Line: Maintain and, if necessary, strengthen the current shoreline, see figure 98. The strategy covers those situations where action can be taken in front of or behind the existing protections to improve or maintain the level of protection provided by the current protection line (SGI 2019).

Fig. 98. Hold the Line (based on Oppenheimer et al. 2019:386).

Fig. 97. Hold the Line (data from Lantmäteriet 2021 and 2022).

LIMITED INTERVENTION / ACCOMMODATION

Adapt existing buildings to severe storms, but there would be a need for barriers around the existing buildings from sea level rise. Due to pollution at the industrial site and difficulty adapting the structures to sea level rise, the area would need barriers such as seawalls (see figure 99). New buildings would be on stilts, meaning they would not get flooded and would not be damaged. In addition, there might be an issue with the raised building's accessibility; a solution would be needed.

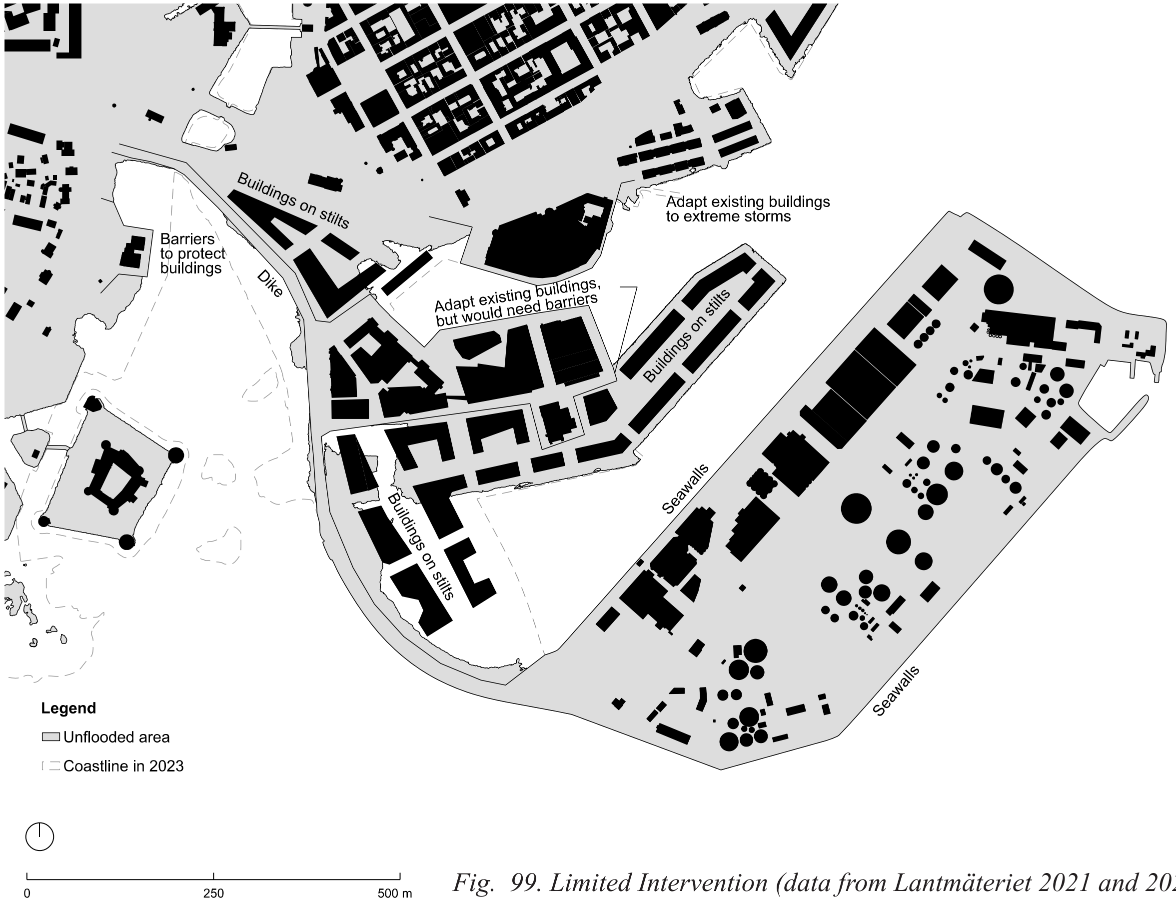


Fig. 99. Limited Intervention (data from Lantmäteriet 2021 and 2022).

Limited Intervention: Work with natural processes in a controlled manner by allowing erosion and securing and protecting identified values, see figure 100 (SGI 2019). Adapt buildings and infrastructure to avoid flooding and erosion damage.

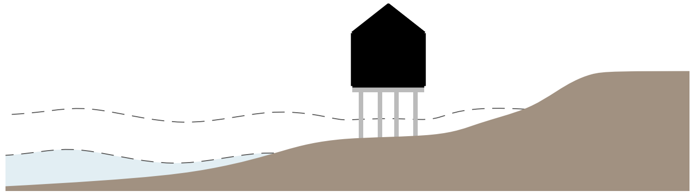


Fig. 100. Limited Intervention (based on Oppenheimer et al. 2019:386).

MOVE SEAWARD / ATTACK

Move Seaward: New coastal protections are established further out to the sea; the existing protection line is moved forward by building new protection below the existing ones, see figure 102. (SGI 2019; ICE 2010).

The attack tactic is the most extreme; landfills are expanded, an artificial island is added, and water levels are managed in one location. Rented cottages are on the artificial island which can be used as a recreation area (see figure 101). A beach has been added to Sylvanderparken, and the location has controlled water levels, so the sea level rise would not impact there. Two landfills are added by Barlastholmen and the industrial area; the sites are fortified with seawalls and dikes. Barlastholmen would be entirely constructed, new buildings near the central station, and the central station would not need to be relocated. Although this approach would be the most expensive, it would also add several values to the area, such as the beach in Sylvanderparken, which can control the water level and the new recreational area on the artificial island.

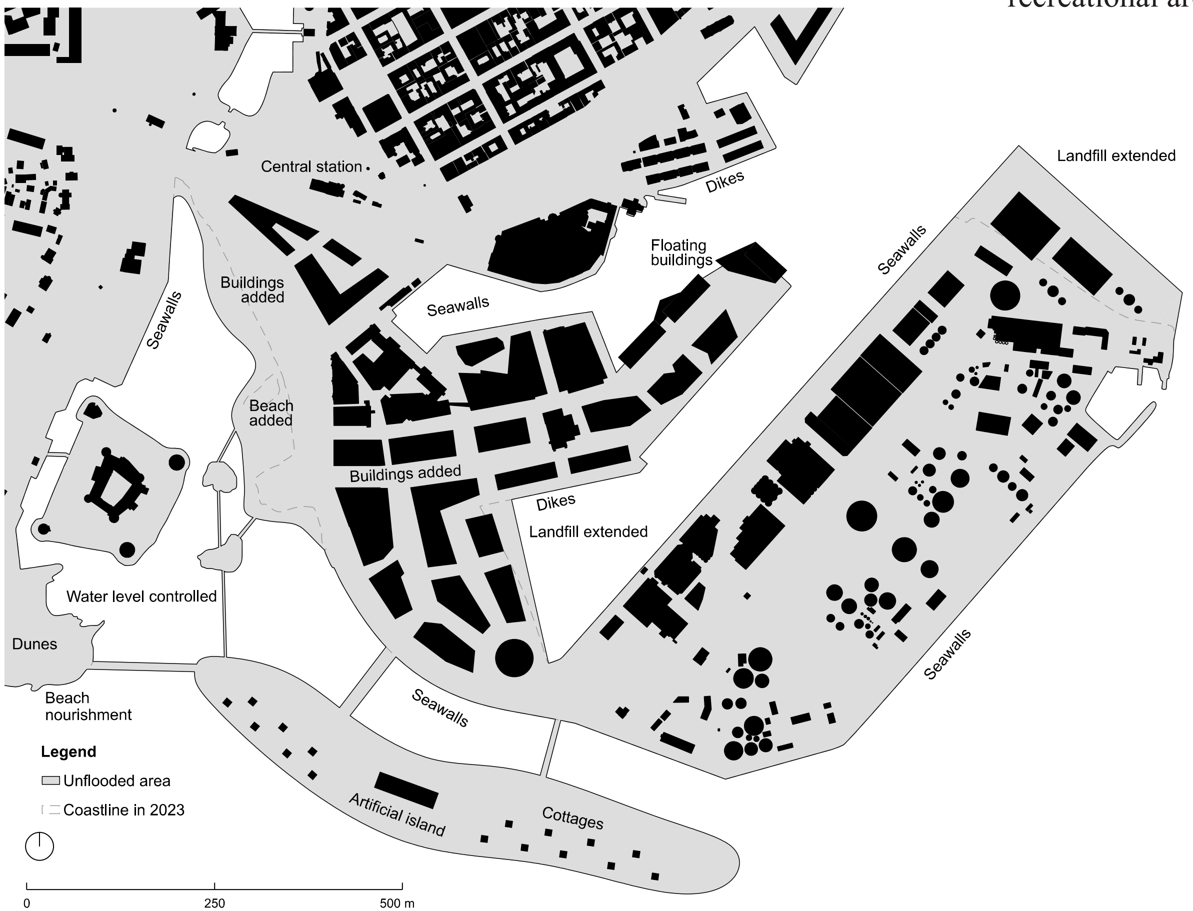


Fig. 101. Move Seaward (data from Lantmäteriet 2021 and 2022).

Move Seaward: New coastal protections are established further out to the sea; the existing protection line is moved forward by building new protection below the existing ones, see figure 102. (SGI 2019; ICE 2010).

Fig. 102. Move Seaward (based on Oppenheimer et al. 2019:386).

HOLISTIC DESIGN SKETCHES

Several design sketches are presented in this chapter; the designs incorporate different designs as well as the various coastal structures and strategies that I tested out.

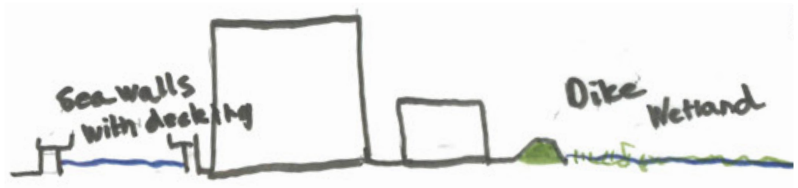
BARLASTHOLMEN AND SYLVANDERPARKEN

Figure 102 illustrates several strategies such as Hold the Line, Do Nothing and Flexmark. A wetland could be created in the southern area where the Flexmark strategy has been applied.

Fig. 102. The red area is Hold the line (protect), and the green hatched areas are Flexmark and Do nothing in the site's northeast. The yellow line is pathways (data from Lantmäteriet 2022).

Figure 103 and section A1-A1 show various coastal structures, such as seawalls and dike in the protected area (Hold the Line strategy) and wetlands on the other side of the dike (Flexmark strategy); hard structures and EbA can work well together.

Fig. 103. The red area is Hold the line (protect), and the green hatched area is Flexmark. The yellow line is pathways and blue line is car roads (data from Lantmäteriet 2022).



Section A1-A1shows the area with various techniques, such as seawalls, dikes and wetlands. The section is not in scale.

Figure 104 is one of my earliest sketches showing different strategies, which areas I wanted to protect, and which areas could be flexible. For example, flexible spaces could have wetlands and green spaces instead of permanent structures. In addition, flexible space could be used for recreation or to increase the site's biodiversity. The Limited Intervention strategy was also used in one of the areas, the buildings are on stilts making them higher and to prevent the buildings from getting flooded. Hold the Line, Limited Intervention, and Flexmark strategies are used in this sketch.

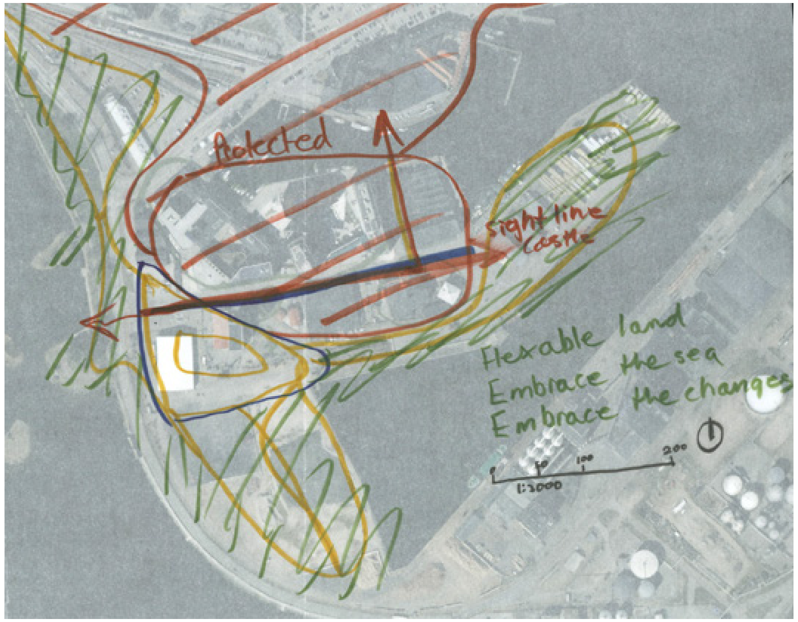
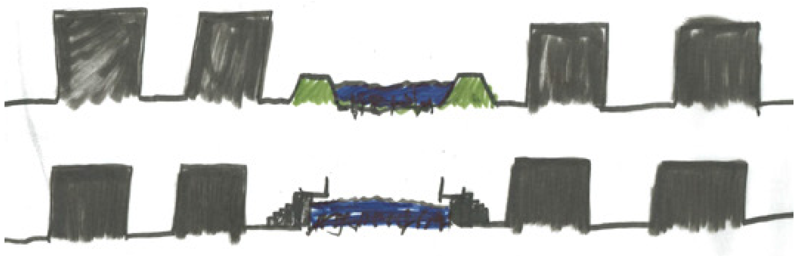


Fig. 104. The red area is Hold the line, The green hatched area is Flexmark, and the blue triangle area is Limited intervention. The yellow line is pathways or decks(data from Lantmäteriet 2022).

The sections A-A show two techniques; a dike and a seawall with a deck. These methods can be a part of the Hold the Line strategy. The section is not scaled or positioned in a particular location instead, it was made to visualise how the methods could look.



Sections A-A show two techniques; the section on top shows a dike, and the section below shows a seawall with a deck.

Figure 105 continues with the ideas in figure 104. Here buildings are added and they are on stilts see sections 2B1-2B1 and 2B2-2B2. The Flexmark areas would be transformed into wetlands and recreational areas, with three decks, one beside the building by the harbour, another between the elevated buildings and the last south of the urban area. Ultimately, I decided not to go further with the idea because of accessibility; it would have been too complicated to make the stilts buildings accessible for everyone.

Fig. 105. The purple area is Hold the line (protect), and the green hatched area is Flexmark. The yellow line is pathways, and the red line is roads (data from Lantmäteriet 2022).

Section 2B1-2B1 shows the stilts buildings, with a deck area separating them and an opening in the middle; a dike would still be required to protect the existing structures from flooding. Section 2B2-2B2 shows how the dike could be used to access the elevated buildings. Unfortunately, that idea does not work for everybody. The sections also show the connection to the existing urban area and how it would look.

Section 2B1-2B1 shows the elevated buildings with a deck between them, the section is not in scale.

Section 2B2-2B2 shows how the dike could be used to access the elevated buildings, the section is not in scale.

Figure 106. has a large area of elevated buildings added and a wetland between them and the urban area; the area is protected from flooding. Again, Hold the Line, Flexmark and Limited Intervention strategies were used. Since the stilt buildings were too far from the urban area, this idea was also abandoned.

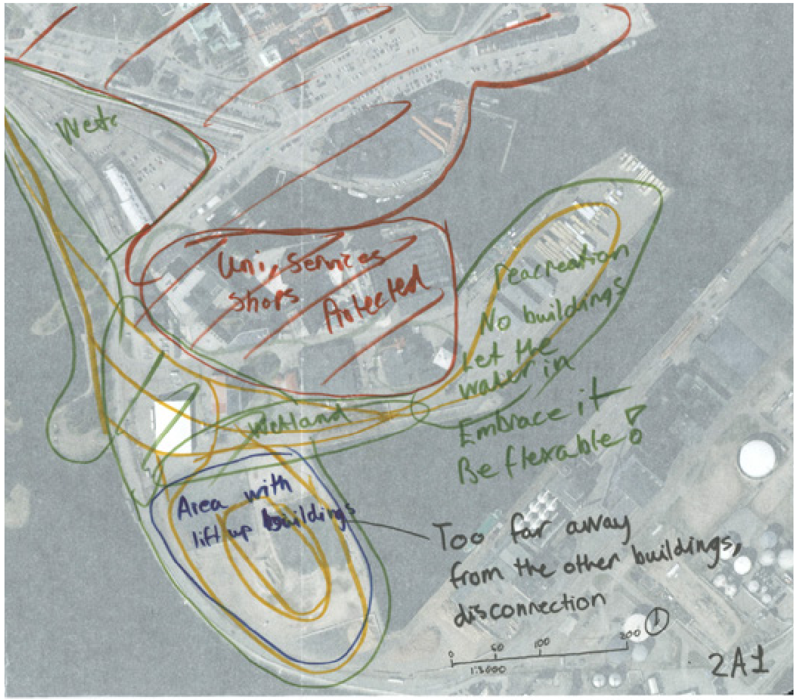


Fig. 106. The red area is Hold the line, The green hatched area is Flexmark, and the blue area is Limited intervention. The yellow line is pathways or decks (data from Lantmäteriet 2022).

Figure 107. Adds new buildings along Barlastgatan and a green space along them that could be used for recreation; the wetlands could also be used as a recreational area. In the wetland south of the urban area, hills have been created to give the place a dimension and create various species' habitats. In addition, barrier islands have been added west of the site as wave buffers. Strategies used are Hold the Line, Flexmark and Move Seawards.

Fig. 107. The red area is Hold the line, The green hatched area is Flexmark, and barrier islands are Move seawards strategy. The yellow line is pathways (data from Lantmäteriet 2022).

These three figures 108, 109 and 110, contain the ideas described in the proposal. The concept was then further developed by drawing it out in MicroStation, combining the figures into a single proposal, and adding more detail. Therefore, these figures will not be described in detail as some will be repeated in the proposal.

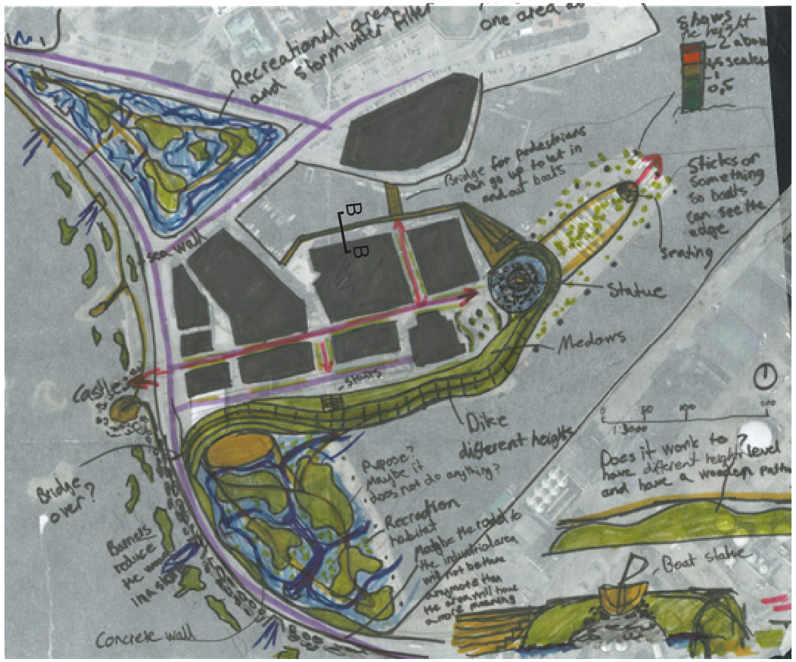
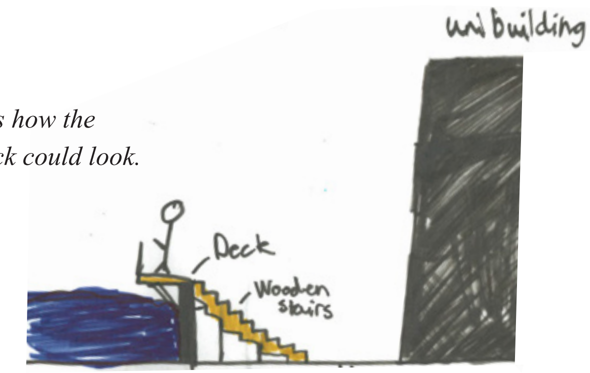


Fig. 108. *Sightlines to the castle are meaningful; the boat ballast statue is on the opposite side. A snake shape dike along the urban area protects it from flooding (data from Lantmäteriet 2022).*

Fig. 109. focused more on the green space of Barlastholmen, various types, wetlands, street beds, barrier islands, a park and other green areas (data from Lantmäteriet 2022).

Section B-B shows how the seawall with a deck could look. Not in scale.



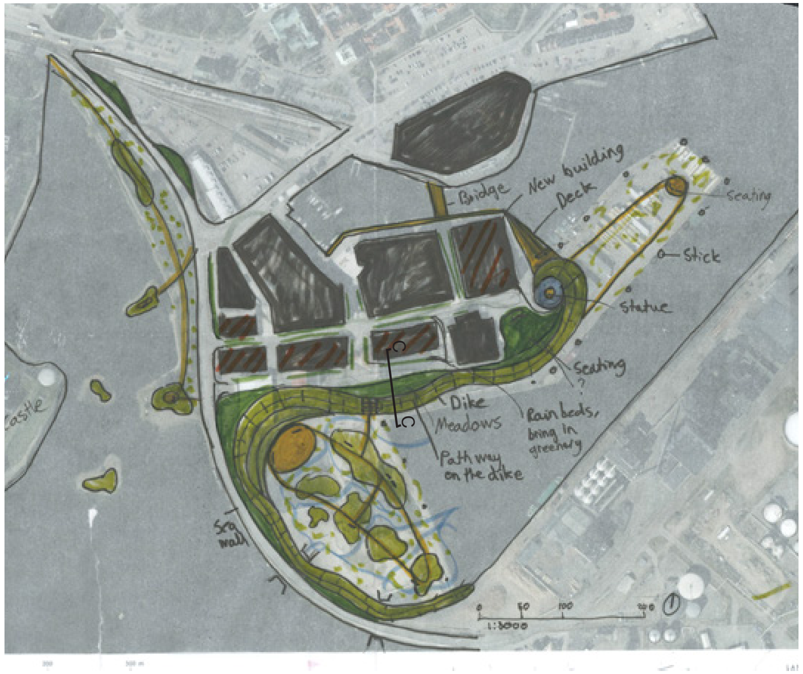
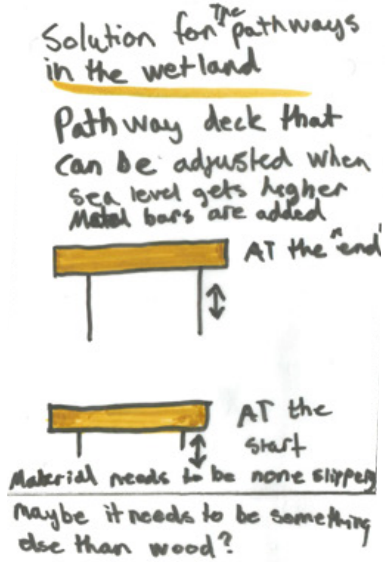
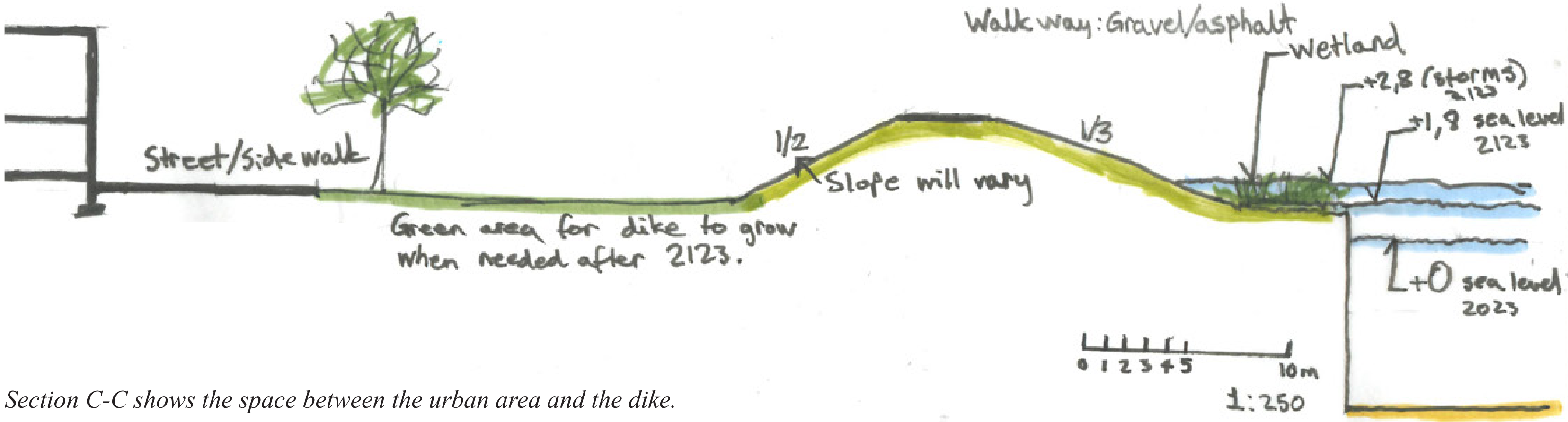


Fig. 110. New green and public spaces will add value to the area (data from Lantmäteriet 2022).

Fig. 111 shows one way the wooden pathways could be adjusted in the event of rising sea levels to adjust the height of the paths.





Section C-C shows the space between the urban area and the dike.

THE DESIGN PROPOSAL IN 2050

Although the design proposal is designed for the year 2123, it can be beneficial to consider the design phases by considering it almost 70 years prior, or the year 2050. Several aspects, though uncertain, have been considered for the design: the rise of sea levels, the effects of climate change on the area, and societal and technological changes. The design will show my predictions of these effects in the year 2050.

In the SSP5- 8.5 scenario it is estimated that the sea level rise will have risen by 0.54 m in 2050 (Hedfors 2023). Due to its elevation of 1.5 - 1.7 metres above sea level, Barlastholmen will continue to be protected from sea level rise in 2050, but in the event of extremely strong storms, certain parts may be inundated (Hieronymus 2022).

In 2050 all the new buildings will be constructed, and the industrial sheds will be gone. To minimise the effects of sea level rise on the urban area, the height of the concrete seawall in the north has been raised and the deck above the seawall has been built.To accommodate for rising sea levels, the seawall and deck can be built even higher.

On the south side is a green area in 2050, with trees and bushes to hide the industrial area in the background and a pathway along the area. Since the south side is around 1.7 m, there should not be any significant flooding in the event of a storm. The surrounding green space might flood, but the south urban area's buildings will not as they are further away and the ground floor is higher. Coastal structures can be added later where the green space is when the rising sea levels will be a problem.

The secret place will be under construction; young trees and plants have been planted in the open asphalt areas, and in the cut channels, vegetation has been planted. Since the site will not be inundated, wooden paths have yet to be built. The secret place can be seen from the green area.

The recreational wetland has started to be constructed as the barrier islands have been formed, and wetland plants have been planted, as well as some trees and bushes. Wooden pathways have yet to be constructed to let the habitats be established first.

By 2050, Sylvanderparken will not be underwater, although some parts of the park have been lost. Wetlands have been planted, and some of the barrier islands have been formed at the end of the park. This is done to minimise the pressure on the seawall along the Tjärhovsgatan (road).

Due to societal demands and sea level rise, the area will continue to change after 2050, which could result in the addition or expansion of some coastal constructions.

Fig. 111.1. Design proposal in 2050, (data from Lantmäteriet 2022; Samhällsbyggnadskontoret Kalmar kommun 2023).

WHAT IS BROUGHT TO THE DESIGN PROPOSAL CHAPTER

THE OBJECTIVES

The main objective is to find a solution for the area for sea level rise by using coastal strategies, but because of this few additional objectives need to be kept in mind: to improve connectivity to the mainland, add green spaces and save important landmarks from sea level rise.

COASTAL STRATEGIES

In relation to sea level rise the strategies used in the proposal are Flexmark, Hold the Line, and Move Seawards. From these strategies, the underlying principles are: hard protection, such as dikes and seawalls, soft protection, such as barrier islands, and ecosystem-based adaptation, such as wetlands. Each coastal structure is covered in each part it is related to (see figure 112).

CONNECTIVITY

Barlastholmen feels disconnected from the mainland, as there is only one way for pedestrians to go to the mainland, on the west side of the area. Therefore, one of the goals is to improve connectivity to Barlastholmen from the mainland for pedestrians (see figure 113). Furthermore, this objective is also to keep in mind the accessibility and connectivity in the design, as there will be physical barriers such as dikes, seawalls or sometimes dry and wet areas. Therefore, several solutions will be needed to make the majority of the parts accessible to everyone; thus, connectivity is vital to make the proposal work.

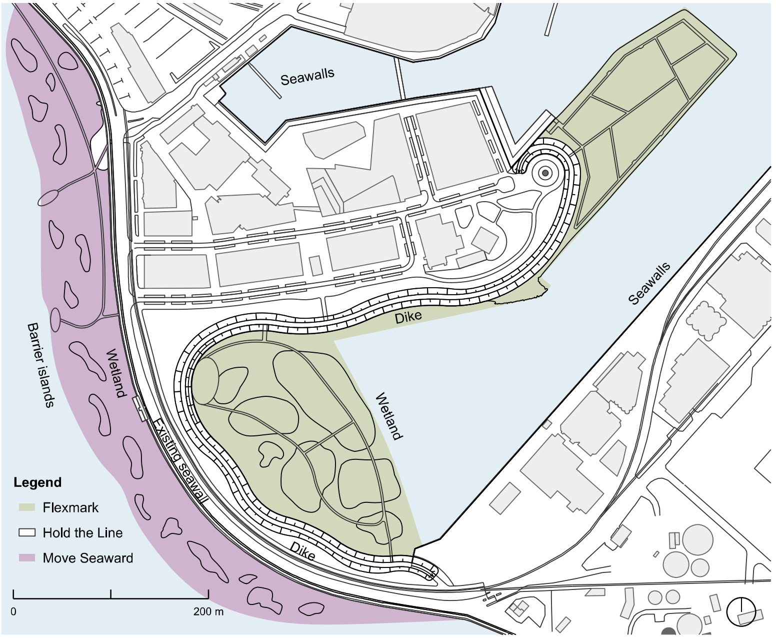


Fig. 112. Flexmark, Hold the Line and Move Seaward strategy, (data from Lantmäteriet 2022; Samhällsbyggnadskontoret Kalmar kommun 2023).

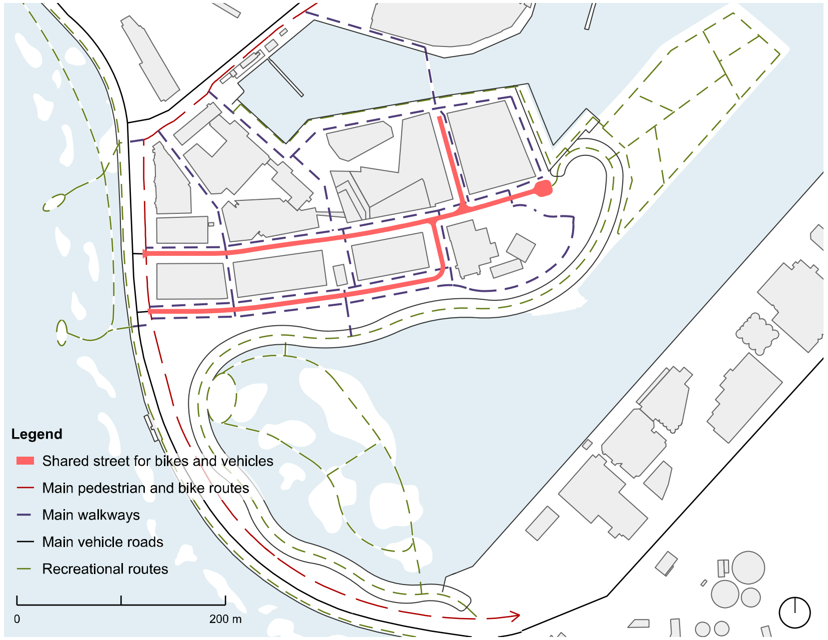


Fig. 113. Main pathways (data from Lantmäteriet 2022; Samhällsbyggnadskontoret Kalmar kommun 2023).

GREEN SPACES

As the whole area was once industrial, there are only a few green spaces to be found on the site; therefore, one of the goals is to add more green spaces (see figure 114) . The main green spaces that are focused on are the wetlands, as they are a part of the Flexmark strategy that is the basis of this thesis, as well because they are hotspots for biodiversity but can also protect the coastlines from waves and reduce tides and storm surges (Climate-ADAPT 2023c). In addition, some wetlands could be used as recreational areas.

Fig. 114. Wetlands and other green spaces (data from Lantmäteriet 2022; Samhällsbyggnadskontoret Kalmar kommun 2023).

IMPORTANT LANDMARKS

Important landmarks are the University and the Byteatern building (see figure 115). The University buildings are relatively new and add significant value to the area from educational, research and social values. The Byteatern building is essential to preserve, as it has significant cultural and historical values. Now it is a theatre that serves the entire Kalmar County; however, before it became known as the Byteatern, it was known as Oljefabriken, an oil factory that began its operations in 1918 and ended in 1957. Therefore, this objective was chosen as it is important to preserve those buildings as I find them important for the future of Barlastholmen. They are worth saving and protecting due to sea level rise from social, cultural, and historical aspects.

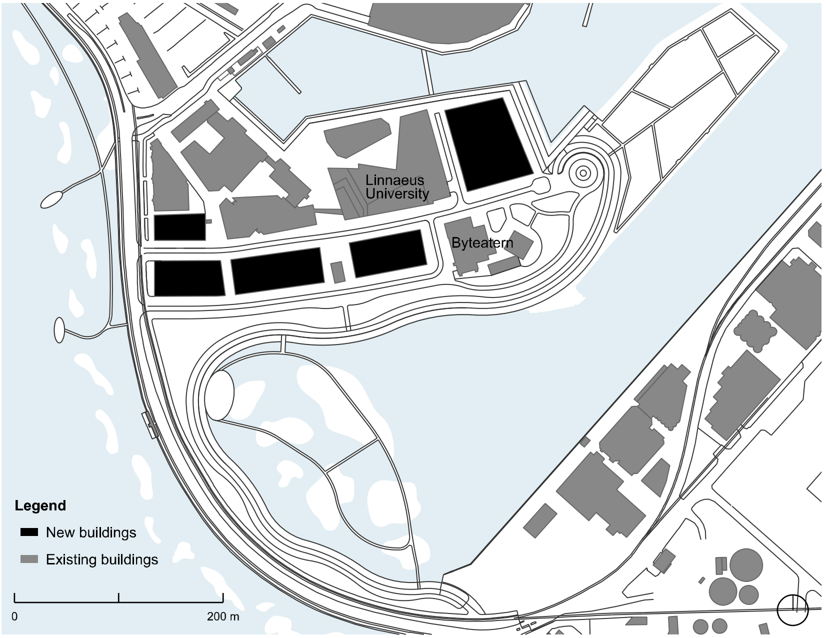


Fig. 115. Linnaeus University and Byteatern are important landmarks (data from Lantmäteriet 2022; Samhällsbyggnadskontoret Kalmar kommun 2023).

6. DESIGN PROPOSAL

The final design proposal is presented in this chapter. It is based on the knowledge that has been gained through this project. Literature review, site analysis, site exploration, and the design process have all been part of developing this design. The proposal seeks to create inviting public spaces in Barlastholmen and Sylvanderparken that are both attractive and functional; to use the coastal structures to enhance those spaces by seeing the structures as an opportunity to improve the area and the spaces that will be flooded now or in the future. The proposal is designed for the year 2123, a future vision for Barlastholmen and Sylvanderparken.

DESIGN PROPOSAL OVERVIEW

The year is 2123, and you have decided to spend the day in Barlastholmen. You ride from your home and have decided to go over the bascule bridge from the mainland to Barlastholmen as that is a shortcut. You go over the bridge, bring your bike down the deck, and park your bike in Barlastholmen. You continue to walk towards Barlastparken, where you meet your friends for a picnic to have fun and relax. After some time, you want to cool down as it is sunny. So you and your friends have decided to go to the stair deck, where you can sunbathe and go into the water to cool off. After some time, your friend decides to take a stroll in the secret place to enjoy the scenery and admire the view. After that, you and your friends decided to have some food, the café by Barlastholmen was chosen, and you and your friends enjoyed your meal outside the terrace. From the table, you can see part of the dike covered in wildflowers and grasses, and along the dike are various trees and bushes. After the meal, you and your friends decided to go to the concert playing on the deck in the recreational wetland area. You and your friends start walking toward the wetland. You go through the park, which smells like newly mowed grass and walk towards Finngrundsgatan. Then you go up the stairs of the dike, sit in the formed dike seats above the deck in the recreational wetland and watch and listen to the musician playing on the deck below. After the concert, you grab your bike and ride along Sylvanderparken to see the birds on the islands and in the wetland, and then you say goodbye to your friends and go home.

Fig. 116. Design proposal (data from Lantmäteriet 2021 and 2022; Samhällsbyggnadskontoret Kalmar kommun 2023).

HARDSCAPE

PRESENTED PUBLIC SPACES ARE:

SPACES BETWEEN THE BUILDINGS

THE DECK & THE BRIDGE

THE STAIR DECK

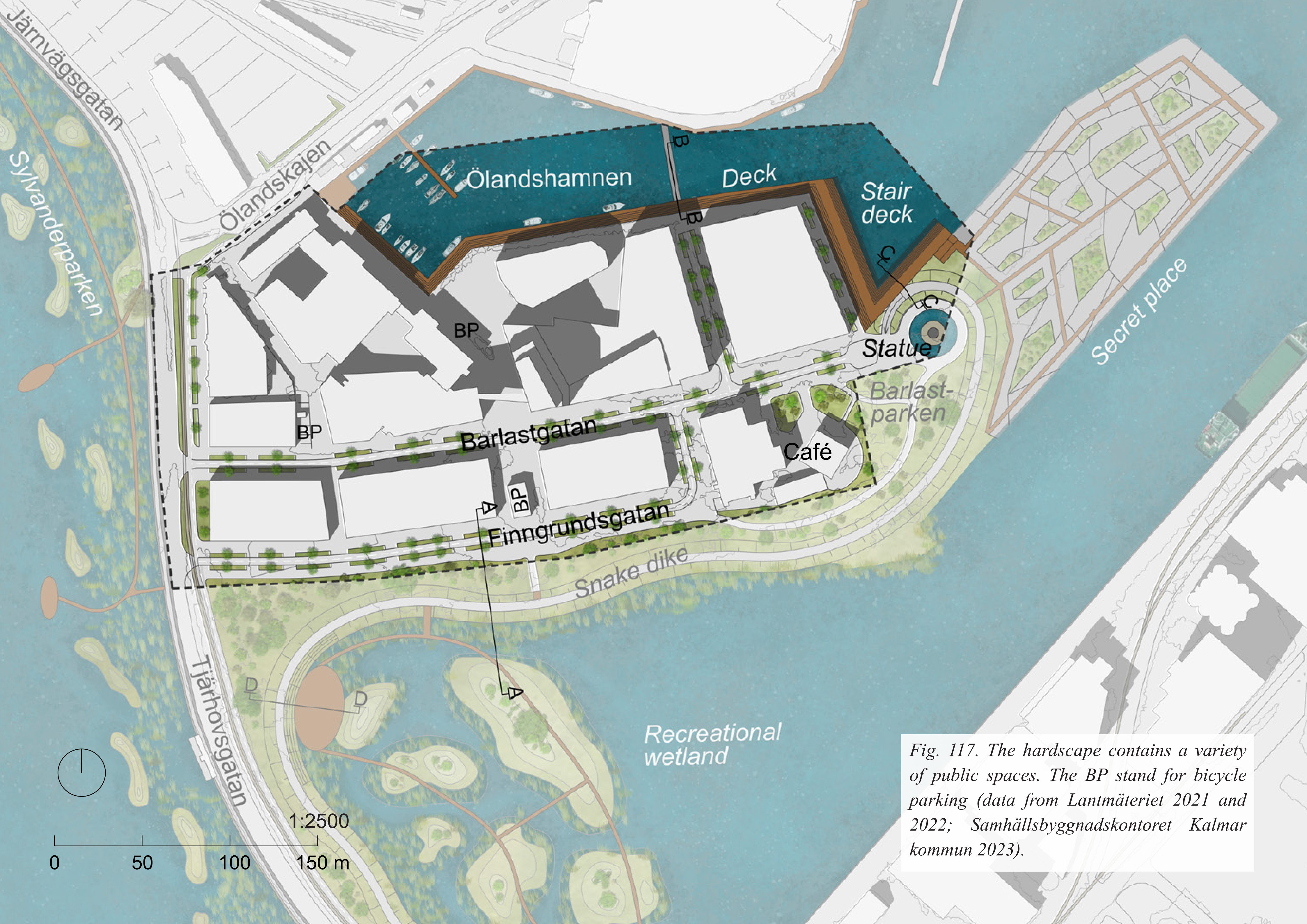


Fig. 117. The hardscape contains a variety of public spaces. The BP stand for bicycle parking (data from Lantmäteriet 2021 and 2022; Samhällsbyggnadskontoret Kalmar kommun 2023).

SPACES BETWEEN THE BUILDINGS

Barlastholmen's buildings serve various purposes, including those of hotels, restaurants, shops, and universities, but there is no housing in the area. The area has the same land use as in the comprehensive plan, and it would also be irresponsible to build housing there given that the land could be prone to flooding in the future. Figure 118 shows that the proposal keeps the sightlines from Barlastgatan to Kalmar Slott, as it is an important sightline (see also figure 120). In addition, a statue dedicated to unloading ballast is opposite the Castle at the end of Barlastgatan. Another important sightline is from the bascule bridge to the Byteatern, where the building can be seen from the mainland. It is the oldest building in Barlastholmen (see figure 119).

The proposal has several existing buildings, not just the university and the Byteatern, see figure 118. The removed buildings were mainly warehouses and did not blend in with the area's urban development; these structures could be relocated elsewhere. Three new buildings have been added by the Finngrundsgatan. The new buildings are only two to three stories tall, which allows more light to enter the Barlastgatan and prevents the new structures from casting shadows down the entire street. Additionally, the sidewalks are wider on both south sides of the streets as most pedestrians want to enjoy the sun while walking. The map's BP symbols, shown in figure 117, show three main locations where bicycles can be parked. Two are existing and are near the University, and the third is between the streets and is new. Parking is facilitated in one of the existing buildings, where people can park their bicycles indoors and outside.

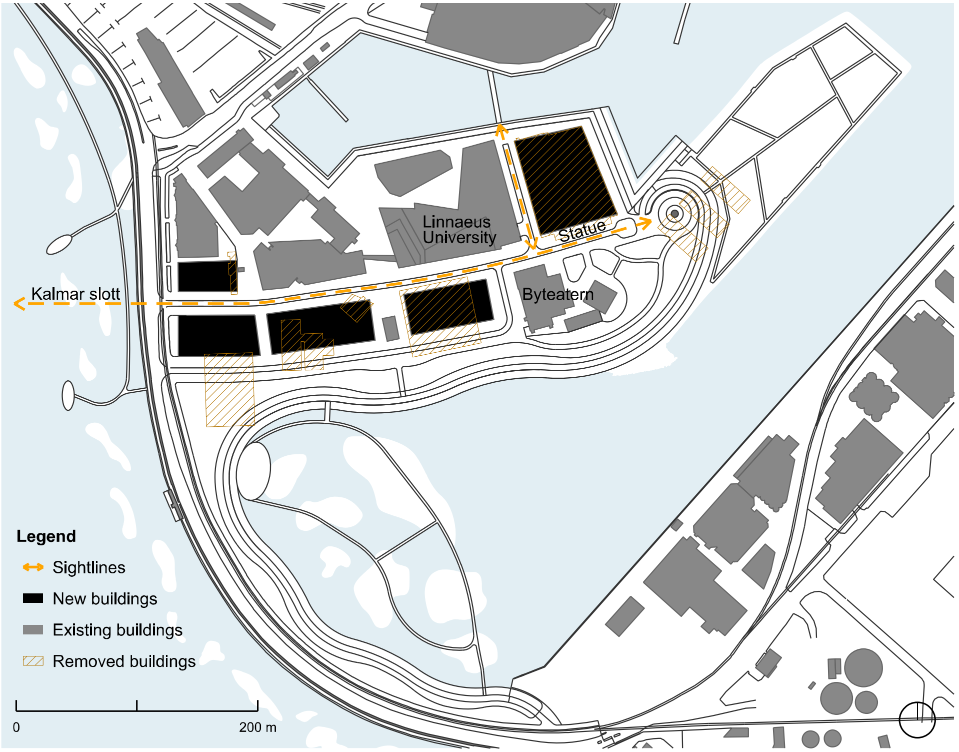


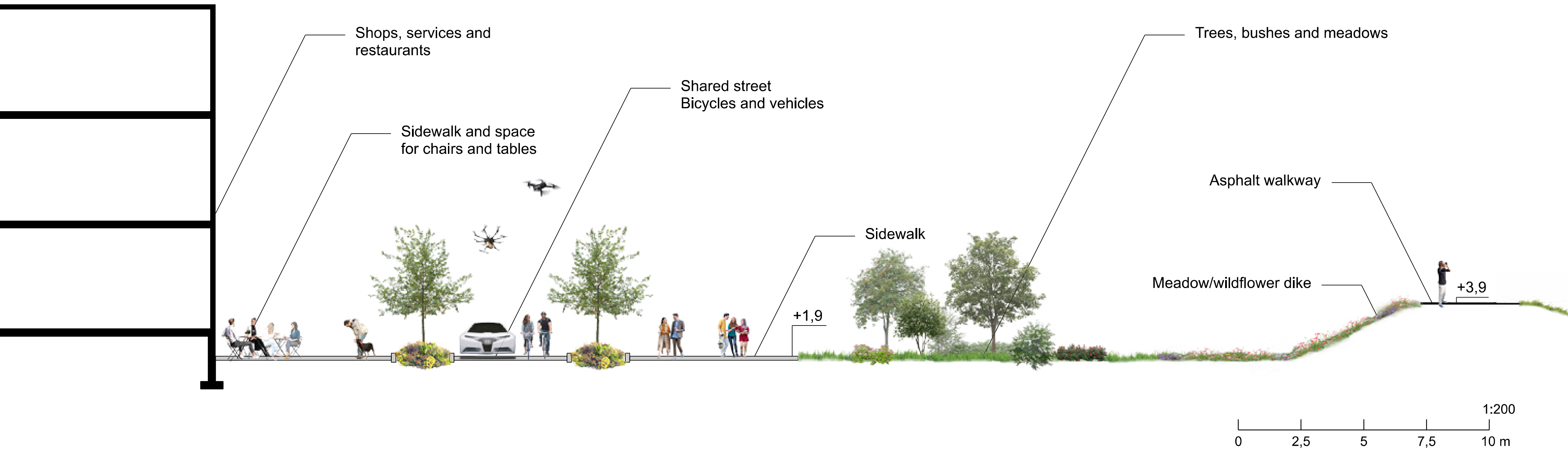
Fig. 118. Existing, removed and new buildings (data from Lantmäteriet 2022; Samhällsbyggnadskontoret Kalmar kommun 2023).

Fig. 119. Byteatern building can be seen from the bridge.

Fig. 120. Kalmar slott can be seen from the street at Barlastholmen.

The proposal adds a new street called the Finngrundsgatan, the street name was there before, but the street layout was different. Both Barlastgatan and Finngrundsgatan have rain beds along them; the beds will bring vegetation to the area while filtering the grey water. The street structure comprises sidewalks, rain beds and shared space (see section A-A). However, the car is given a shared space with the cyclists. As Barlastholmen is an almost car-free zone, there are no car spaces in Barlastholmen except for parking spaces for people with a disability and a parking lot underneath the university, where parking is permitted. The shared space (street) is mainly for cyclists, deliveries, taxis, and emergency vehicles. The shared space is thought to separate pedestrians and cyclists, giving each one a broader space they do not need to compete with. Further, the shared space is believed to provide more space on the sidewalks; thus, in the summertime, tables and chairs may occupy a significant portion of the sidewalk, giving the street additional life.

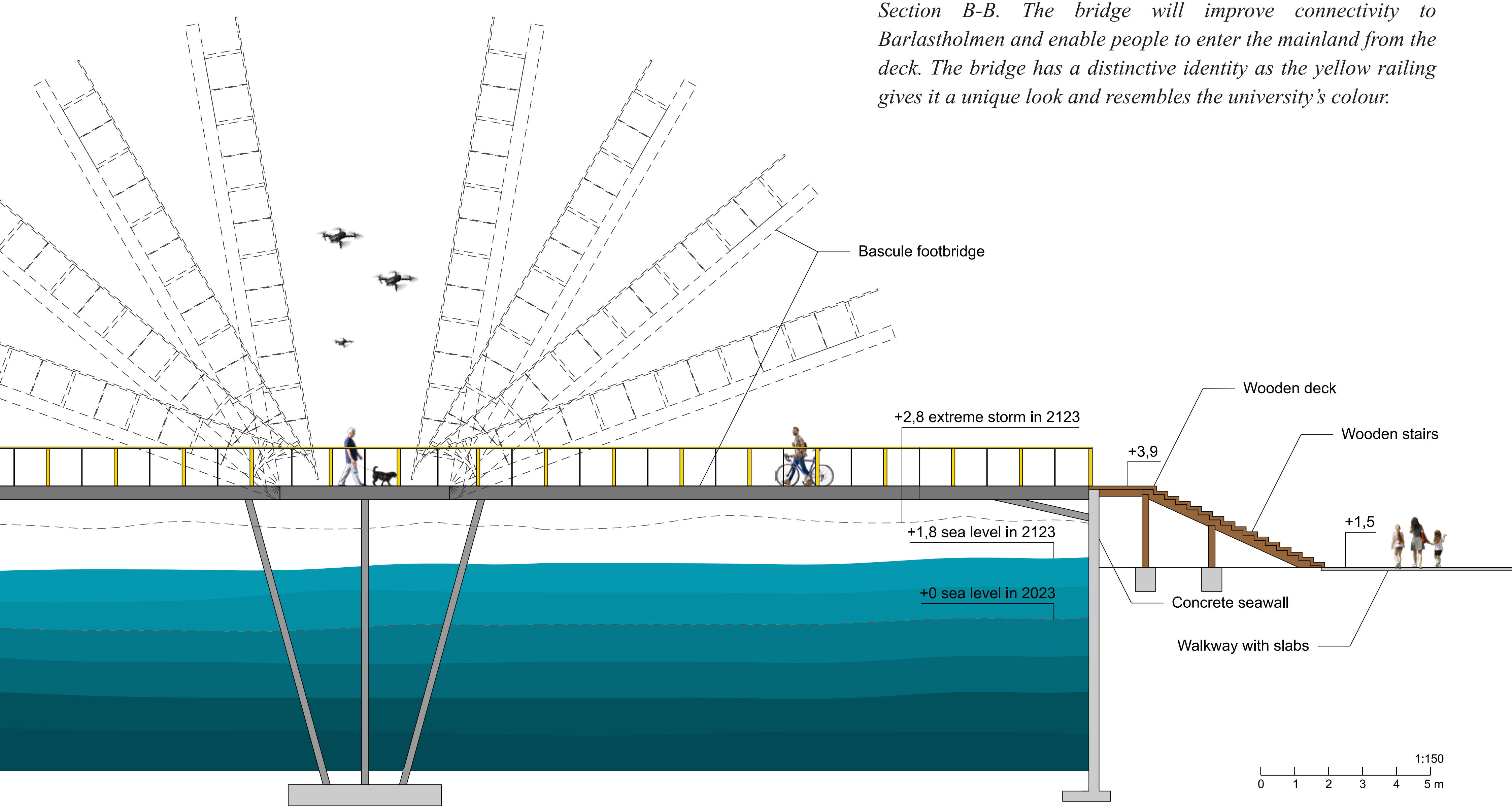
Section A-A shows the street layout and the area between the street and the dike.
The section is longer, see the section in Snake Dike chapter to see the other side.



THE DECK & THE BRIDGE

North of Barlastholmen, seawalls defend against rising sea levels and extreme weather, making rising sea levels not an issue in 2123 (see figure 117 and section B-B). A deck is built over the seawalls where people can walk and view the harbour. This is done to embrace the changes and make a distinctive public space. There are steps and ramps leading up to the deck along the seawalls to allow everyone to access the deck. The deck will let people see the harbour at a higher elevation, and the timber will soften the surroundings. The combination of ramps and steps gives the area a uniform appearance, and the stairs can be used for sitting as well. Access to the deck is crucial as a bascule footbridge goes to the mainland; the bridge lifts itself in the middle to allow boats to enter the harbour (see section B-B). The bridge will improve connectivity to Barlastholmen and enable people to enter the mainland from a different location. The bridge has a distinctive identity as the yellow railing gives it a unique look and resembles the University's colour.

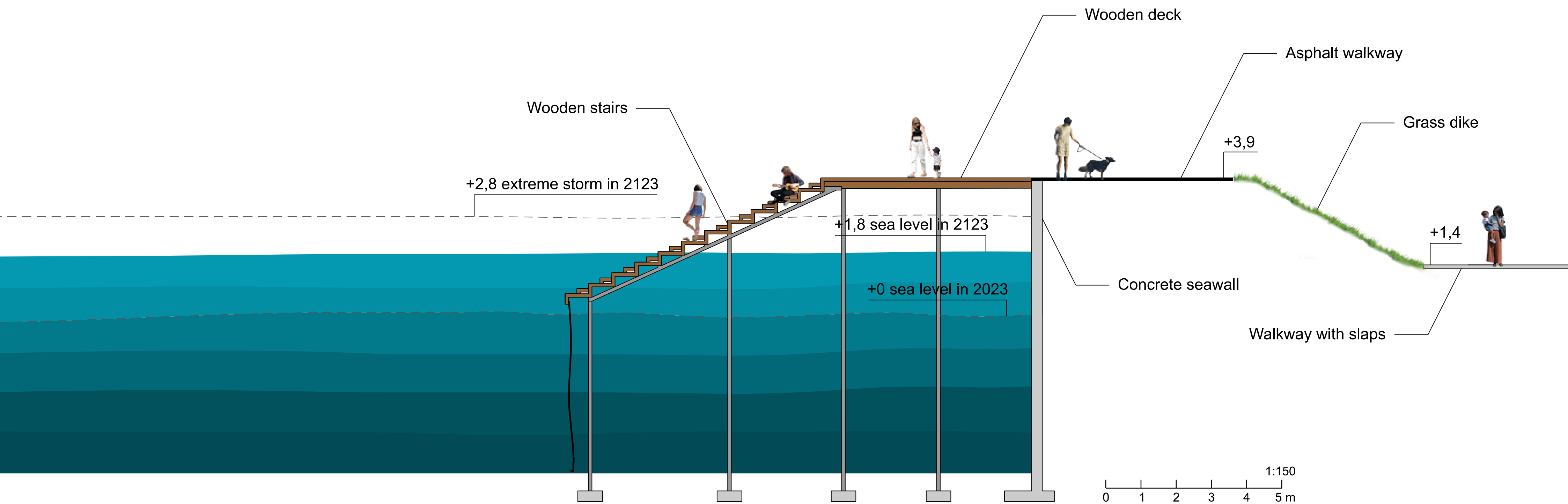
Section B-B. The bridge will improve connectivity to Barlastholmen and enable people to enter the mainland from the deck. The bridge has a distinctive identity as the yellow railing gives it a unique look and resembles the university's colour.



THE STAIR DECK

Northeast of the seawall deck is a sizable stair deck that descends into the ocean (see figure 117). When hard structures, like seawalls, are constructed, they occasionally close off the sea, making it difficult for people to access the water (Hinkel et al. 2018). That is one of the main reasons for creating the stair deck, where visitors can dip their toes into the water, to take in the scenery and hear the waves crash against the deck's wooden surface. Section C-C shows the deck with the steps, but the traditional steps are only present in a few spots along the deck. The other areas have broader and higher steps to create places for people to sit and have additional space, therefore, every other step is taken out. After the year 2123, the water will continue to rise and cover more of the stairs. Raising the seawall and the deck a few decades after 2123 is possible, but that decision would be made later. People can also access the walkway along the dike from the deck and vice versa.

Section C-C. The sections show a the traditional steps, they are only present in a few spots along the deck; the other areas have broader and higher steps to create places for people to sit and have additional space; therefore, every other step is taken out. People can also access the walkway along the dike from the deck and vice versa; the deck may be the final stop at Barlastholmen.



SOFTSCAPE

PRESENTED PUBLIC SPACES ARE:

SECRET PLACE

BARLASTPARKEN

SNAKE DIKE

RECREATIONAL WETLAND

SYLVANDERPARKEN

Fig. 121. The softscape contains a variety of public spaces, (data from Lantmäteriet 2021 and 2022; Samhällsbyggnadskontoret Kalmar kommun 2023).

SECRET PLACE

The northeast side of the area, behind the head of the dike, is a secret place. The area has no buildings, but the ground is covered in vegetation that burst from the asphalt in some areas as the asphalt has been cut and formed channels and batches throughout the site. This area resembles a long-gone industrial area by fusing asphalt with nature and allowing plants to grow where asphalt is generally present. Since the area is higher than the expected sea level rise in 2123, it will not be submerged underwater. However, extreme storms will cause the sea level to rise and cover the site, so the vegetation will reduce the tidal energy as the vegetation will act as buffers and this will help protect the dike from extreme storms (Climate-ADAPT 2023c). A few decades after 2123, the area could be submerged under water; during that time, the vegetation will change, and turn it into a wetland. The vegetation for the year 2123 needs to tolerate fluctuations in dry and wetness; the vegetation can be bushes, trees and plants, creating spaces within the area, making it more private and intriguing (see figure 123). An investigation needs to be done for this area, as well as all the industrial areas in Barlastholmen to find out how polluted the surfaces are and what can be done to help clean up the contaminated surfaces, especially given that this area will eventually be submerged underwater. The site has wooden paths to direct people where to go and keep the path dry except during storms. In addition, there are places to sit along the routes where people can unwind and enjoy the scenery. Since the area should not be flooded in 2123, the wooden pathways could be installed later when the site is flooded. The area is accessible to everyone since there are two locations to enter the secret location: from the deck with stairs or ramp leading down to the site or from the dike with stairs leading down to the place.

Fig. 123. The Secret place has wooden pathways, guiding the visitor where to go (data from Samhällsbyggnadskontoret Kalmar kommun n.d.).

BARLASTPARKEN

At the end of Barlastgatan is Barlastparken where people can relax and enjoy in the summertime, under a tree for shade or the bare sun (see figure 124). West of the park is a café housed in one of the existing buildings where Kalmar Harbour authorities were once located. The café will add life to the area where visitors can sit by the café or visit the park's picnic tables.

At the end of the park is a place dedicated to ballast with a statue. According to history, the area used to be where ships would unload their ballast; over time, the islet grew and became Barlastholmen. The statue honours the location's history and how Barlastholmen began. The subchapter Holistic Design Sketches shows a sketch of an idea, however, an artist would design and create the statue.

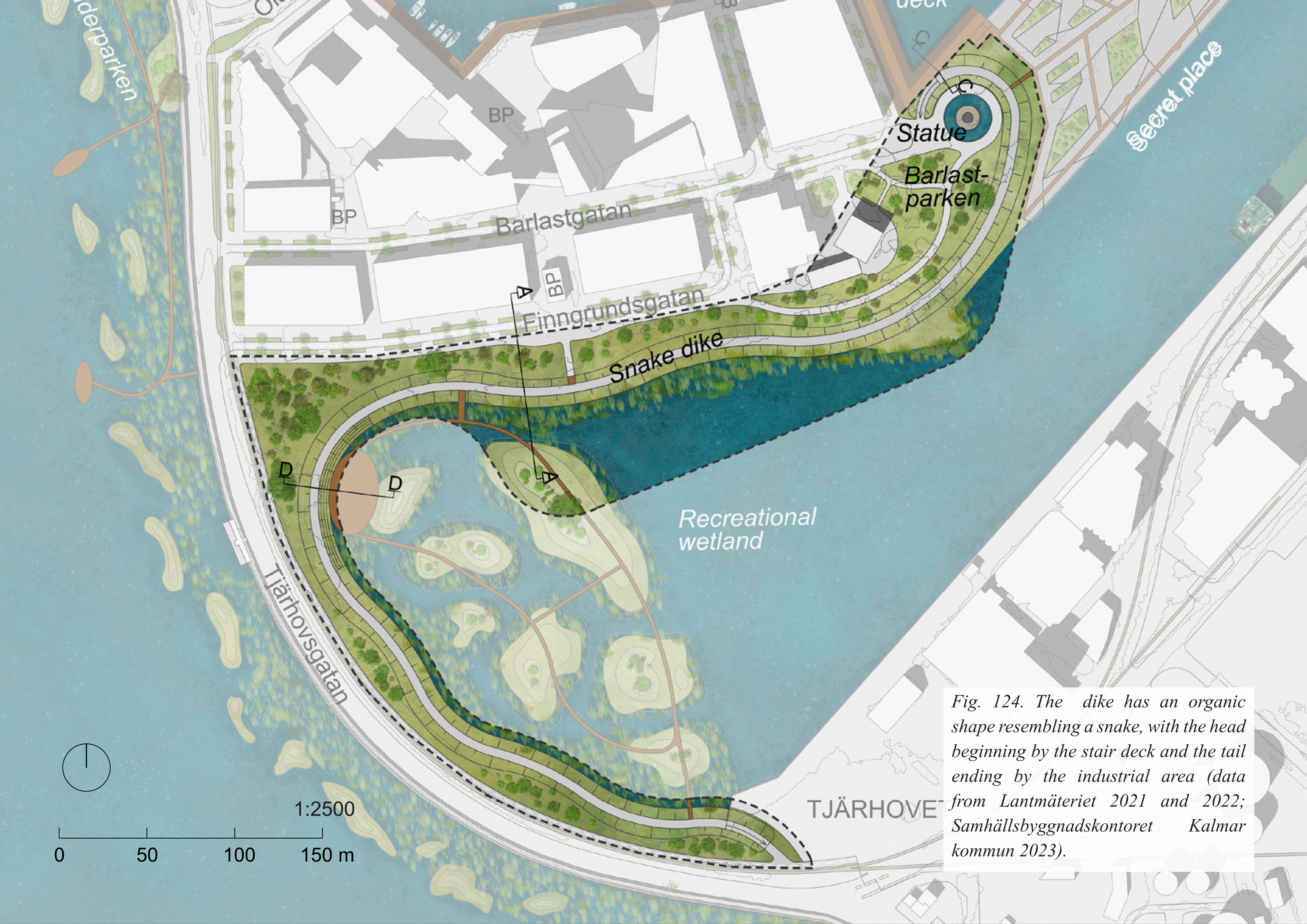
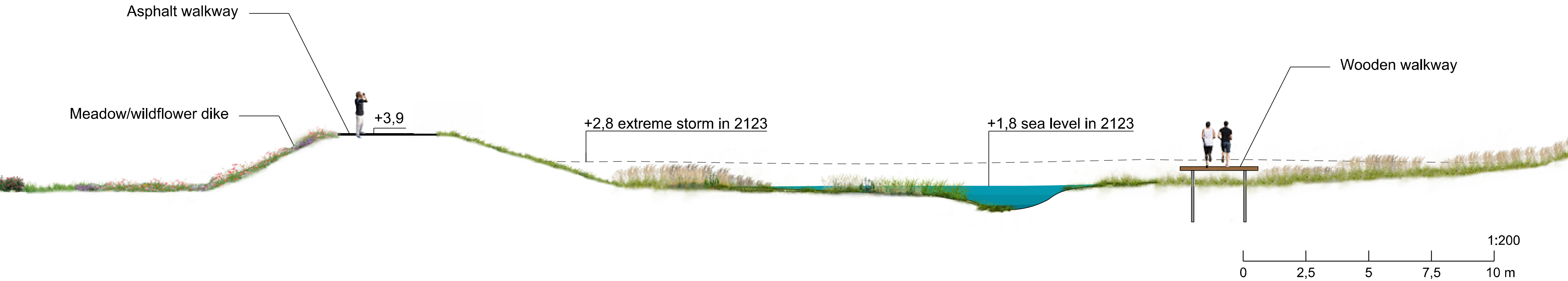


Fig. 124. The dike has an organic shape resembling a snake, with the head beginning by the stair deck and the tail ending by the industrial area (data from Lantmäteriet 2021 and 2022; Samhällsbyggnadskontoret Kalmar kommun 2023).

SNAKE DIKE

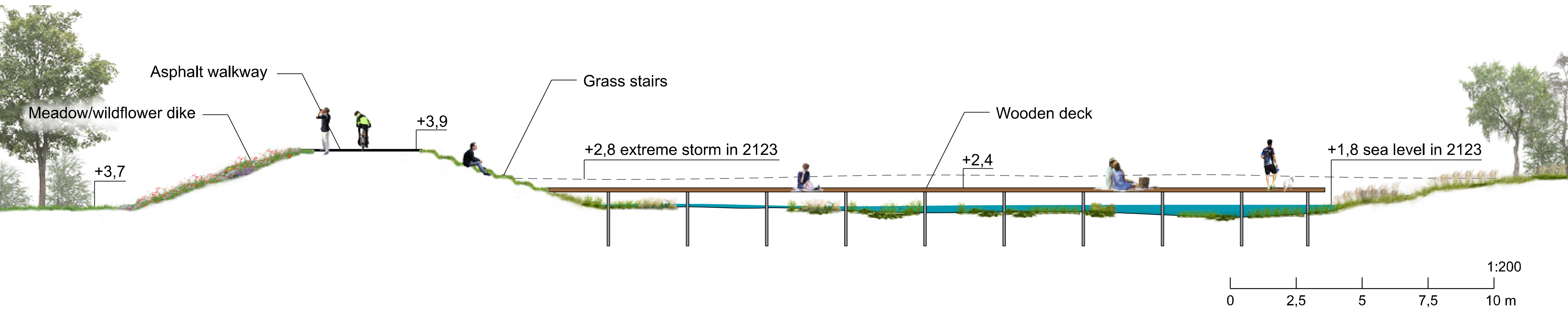
In the northeast of the area, a dike has replaced the seawall; it has an organic shape resembling a snake, with the head beginning by the stair deck and the tail ending by the industrial area (see figure 124). The slope along the north side of the dike changes, as does its width; this is done to give the dike more dimension. The side of the dike facing the ocean is covered with grass. On the side facing the hardscape area, it is covered with wildflowers (see section A-A). By the dike's head, it is covered with cut grass next to the statue. Wildflowers and meadows will increase biodiversity in the area. Closer to the urban area, small trees and bushes line the north side of the dike, and the grass is cut more frequently; this will give it a different character. After 2123, the dike could be expanded in these areas to accommodate rising sea levels; the dike's height and width must increase if the sea level rises. The green space with trees and bushes is added along the entire dike and ends where the dike slopes down to the sidewalk in the south. There are several locations where people can access the asphalt walkway on top of the dike, both stairs and slopes, with the intent that everyone can enjoy the castle and sea view.

Section A-A shows the dike and the surroundings; the dike side facing the ocean is covered with grass, and the other side facing the urban area is covered with wildflowers. The section is longer, see the section in the Hardscape chapter to see the other side.



RECREATIONAL WETLAND

A recreational wetland with reed or marsh vegetation is located south of the dike. The area has islands that will be formed using the landfill material from the place where channels were made by excavating the landfill (see figure 125). The intent is to have a deeper water channel and create islands for diverse species' habitats; further, some areas will continuously be wet or dry while others will fluctuate. Numerous trees and bushes are on the islands' highest point, which will create spaces in the area and increase biodiversity. Wooden pathways go along the islands with stairs on both ends that lead up to the dike; the wooden pathways are higher than the sea level in 2123 to ensure they are dry in most conditions. A deck is located west-north of the site; above the wooden deck, the dike forms stairs and goes down to the deck (see section D-D). The stairs are designed for people to relax and sit, where entertainment could be placed on the deck, and the audience could sit on the dike and watch (see section D-D). In addition, the wetland will promote biodiversity and serve as a storm buffer (Climate-ADAPT 2023c).



Section D-D shows the dike and the recreational wetland; a place to relax and enjoy.

SYLVANDERPARKEN

Sylvanderparken is very low compared to other sites in the area and will be submerged by 2123 (Hedfors 2023); the park is transformed into a wetland area with wooden walkways and seating decks (see figure 125). The wetland and the barrier islands were created to be used as storm buffers (Climate-ADAPT 2023c; NOAA 2021), but regardless, a structure would be needed to prevent extreme flooding. In this project, a concrete wall is extended from the existing wall at the end of Sylvanderparken, which goes to the industrial area. Even so, the existing concrete seawall might be too low for extreme storms. However, it should be adequate as it is all right for the road to flood during powerful storms; after all, there will not be any traffic in an extreme storm. However, there might be a need for a solution for the hardscape area from the road so that the water will not flood the areas. The solution could be to build a non-permitted structure, which could be temporarily piled up sandbags, that would prevent the water from flowing into the hardscape area.

Fig. 125. The recreational wetland has islands formed using the landfill material from the place where channels were made by excavating the landfill. The wetland and the barrier islands in Sylvanderparken and along the road were created to be used as buffers for storms (data from Lantmäteriet 2021 and 2022; Samhällsbyggnads-kontoret Kalmar kommun 2023).

7. DISCUSSION

In this final chapter, the design proposal is discussed, from the strategies in the proposal to the possible consequences of the choices made, discussion on sustainability and resilience. Followed by the method used for this thesis, a discussion of limitations, further research and investigations and reflection about the project and landscape architecture. Finally, the chapter ends with the conclusion, which answers the research questions concisely and summarises the main objectives.

REFLECTION AND ANALYSIS

Sylvanderparken in Kalmar City that addresses adaptation to sea level rise, with emphasis on public spaces in the urban areas by developing them in relation to sea level rise. Geographically, the work is limited to a coastal urban area, and the findings are related to Barlastholmen and Sylvanderparken in Kalmar City, Sweden. The thesis is divided into an introduction, literature review, site analysis, sketching, proposal and discussion. The Literature Review chapter analysed the various coastal adaptation strategies, principles and structures. The Site Analysis chapter is conducted to understand the threats of sea level rise, various types of coastlines and the identity of the areas. The Research by Design Process Chapter is about testing various strategies and sketching out designs. Finally, the proposal is developed using the site analysis findings, the literature review, which visualises Barlastholmen and Sylvanderparken in the year 2123, where the area is adapted to sea level rise through various strategies and coastal structures. The thesis addressed the following research questions:

How can a coastal urban design utilise the Flexmark coastal adaptation strategy to adapt to rising sea levels?

Is Flexmark coastal adaptation strategy enough, or is there a need for additional strategies?

The results indicate that Flexmark strategies can be utilised in the recreational spaces in Barlastholmen and Sylvanderparken. Furthermore, the results suggest that the Flexmark strategies can be applied to create and enhance the area's green spaces by taking the opportunity to create an inviting and thriving environment at Barlastholmen and Sylvanderparken. However, the Site Analysis chapter concludes that additional strategies are required to protect particular landmarks in Barlastholmen. As a result, the Flexmark strategy is not enough for all areas. The other strategies are Hold the Line and Move Seaward. The Hold the Line strategy is selected to protect some urban areas from flooding (SGI 2019), thereby saving important landmarks. The Move Seaward strategy is used for Sylvanderparken and along the existing seawall, as it could help prevent flooding and create new species habitats (NOAA 2021).

THE SELECTED COASTAL STRATEGIES AND STRUCTURES

It soon became apparent that other strategies in addition to the Flexmark strategy were needed. For example, Flexmark was not enough for the entire area because it would have meant letting it be flooded. Instead the recreational areas were chosen to implement the Flexmark strategy. In addition, it was important to protect a few of the infrastructure and buildings from flooding. After conducting a literature review and experimenting with the various strategies on the site, it became more apparent that it would be necessary to combine the Flexmark strategy with other strategies. I wanted to have as much of the Flexmark strategies in the proposal as possible. However, it was not realistic, as I knew that the area is important to the municipality and the community as the University is there. Therefore, I decided to look at additional strategies and find which sufficiently served the goal of protecting specific landmarks and areas from flooding and which did not. The strategies not chosen were Do Nothing, Planned Retreat and Limited Intervention

The Do Nothing strategy was not chosen as it called for doing nothing (SGI

2019), abandoning everything. Therefore, losing the essential infrastructure to the sea was not an option. I found that unrealistic and could not see the municipality keen on that.

As it was important to protect several buildings, the Planned Retreat strategy was too similar to Flexmark; the structures susceptible to flooding would have needed to be removed or moved inland (SGI 2019; ICE 2010). Undoubtedly, this strategy can lower the cost of defence structures, but it can also be expensive as new infrastructure and buildings must be replaced (ICE 2010). As a result, this approach failed to achieve the goal I had laid out.

From the standpoint of accessibility, a Limited Intervention strategy was not chosen; new structures would have needed to be on stilts, which would have required raising the decks and terraces, and it would have been challenging to have ramps and stairs everywhere to make sure to have good accessibility for everyone. Also, the existing buildings would have needed to be modified to allow water to flow through the ground floor or hinder water from getting in, which is possible but can be tricky (SGI 2019). For those reasons, the strategy was not chosen.

The selected strategies were Flexmark, Hold the Line, and Move Seawards (see figure 112). From these strategies, the underlying principles are: hard protection, such as dikes and seawalls, soft protection, such as barrier islands, and ecosystem-based adaptation, such as wetlands. However, these could be shown to be hybrid solutions because EbA works with hard protection, such as the dike and existing seawall (Sutton-Grier et al. 2015),

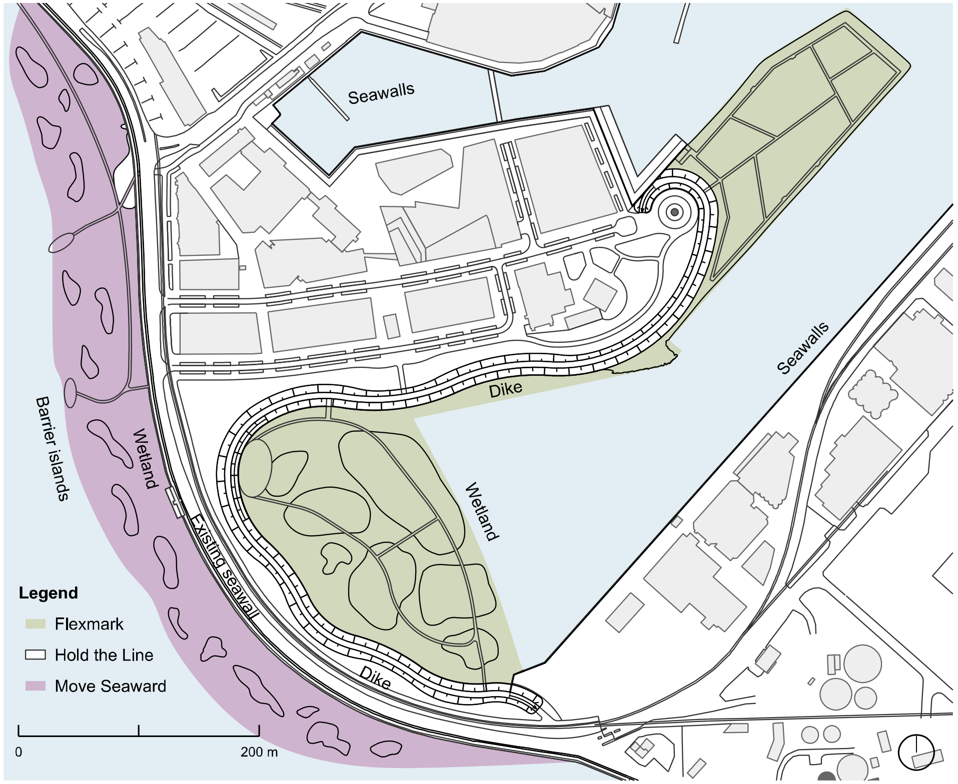


Fig. 112. Shows Flexmark, Hold the Line and Move Seaward strategy, (data from Lantmäteriet 2022; Samhällsbyggnadskontoret Kalmar kommun 2023).

as the EbA cannot stand alone in this project due to the proximity of the existing structures to the sea. Each strategy completes the others; if one is lacking, the others make up for it.

The Flexmark strategy is an interesting concept to designate areas susceptible to flooding as flexible land (Göransson et al. 2022). Where those areas could be used for recreation and ecosystems services to link biodiversity protection to adaptation to sea level rise; it could be one of the main objectives why Flexmark strategy should be used. Principles such as EbA (Powell et al. 2019) and hybrid solutions were applied to the site (Sutton-Grier et al. 2015). Coastal structures are wetlands which will add ecological and recreational values to the area (Climate-ADAPT 2023c).

Hold the line strategies were used around the urban area to protect the infrastructure and buildings where water is not allowed to enter; the principles are hard structures, such as seawalls and dikes (Climate-ADAPT 2023d;CIRIA 2013). The Hold the Line strategy was also applied to the areas near Barlastholmen and Sylvanderparken that were not the focus of this proposal to take a comprehensive approach. The Hold the Line strategy was chosen as it maintains and strengthens the current coastline (SGI 2019). As there is sufficient room north of the University, there needed to be a strategy that would strengthen the existing coastline.

Move seaward strategy was used in the west where the barrier islands and wetlands are located; both have been added. The barrier islands are categorised in the Move Seawards strategy, as they were not there initially. The Move Seaward strategy was chosen because new coastal protection could be established further out to the sea (ICE 2010). Additionally, there would be a requirement for additional storm defences, and the barrier islands could assist in safeguarding the current seawall and protecting wetlands surrounding the barrier island, which would also act as wave buffers (Climate-ADAPT 2023c; NOAA 2021). The strategy is used to increase defences against extreme weather by creating barrier islands and creating wetlands, not to build farther out to sea.

PRINCIPLES AND COASTAL STRUCTURES

Seawalls have been used when there is insufficient space for dikes or ecosystem-based defences against sea level rise (Hinkel et al. 2018). Additionally, seawalls were chosen because they occupy less space and permit access to and docking of boats in the harbour. Dikes would not have worked by the Ölandshamnen because they would have prevented access to the harbour. Seawalls have challenges, though, as they must be tall to withstand extreme storms (Climate-ADAPT 2023d). A deck was designed over the seawalls where people can walk and view the harbour and the surroundings; this was done to create a new and different public space. An existing sea wall is along the Tjärhovsgatan that goes to the industrial area.

Dikes can be superior as they can be constructed with an outer grass layer (EEA 2017), which softens the structure, as these structures are sizable, making it more ideal to have a prominent green structure than a grey one such as a seawall. The dike was chosen for the south of the area, as there was sufficient space. Dikes are adequate for protecting sites from flooding (Climate-ADAPT 2023d), both from sea level rise and extreme storms that will occur more frequently in the future (Fox-Kemper et al. 2021); although a wetland was also chosen for the area.

Wetlands are added in two locations; they act as buffers against coastal erosion as they reduce wave and tidal energy by improving the coarseness of the surface that the waves and tides cross over, and they are biodiversity hotspots (Climate-ADAPT 2023c). Wetlands support various plants and animal species; they frequently serve as breeding and nursery habitats for fish, shellfish, birds, and mammals (ibid.). Unfortunately, the wetland could not solely be chosen to protect the areas, as the wetlands required more room to be sufficient enough to protect the site entirely from sea level rise and extreme storms (Shepard et al. 2011). Therefore, a dike was chosen to provide greater security for the urban area. The structures offer higher protection than alone (Sutton-Grier et al. 2015), and they can be considered a hybrid solution. The wetlands can also be used for recreation and protect the seawall and dike from storms.

Since the west side of Barlastholmen is open to the sea, barrier islands were created. The barrier islands were chosen as they act as a storm buffer for the existing seawall and shield the wetland from extreme storms (NOAA 2021), which is essential when the wetland is establishing itself. In addition, the barrier islands add habitats for species in the area. Finally, barrier islands create a new recreational area where Sylvanderparken was, and the park will live on in another form.

POSSIBLE CONSEQUENCES OF THE CHOICES MADE

The design can be interpreted as controversial, as several elements were added that were not there before, such as the wetlands, barrier islands and the dyke, and transforming two places in the urban area for recreation, with no buildings. However, it can be assumed this land is valuable to the municipality for new urban development, and they would want to use as much of it as they can. These new recreational areas and the urban area will add value; social, ecological, and economic. The site has a potential to be popular amongst various companies, services, and offices, as the public and green spaces will entice people to stay there for an extended period and as a result, the area will be full of life and an excellent place for various companies, services and offices.

Most of the coastline is constructed, however, some of Sylvanderparken's coastline is composed of soft structures such as sand and grass, and other landfill coastlines are made of hard structures. As such, adding seawalls and dikes should not have any additional detrimental effects on the area, but further research would be required. Hard protection like seawalls can exacerbate erosion, impact the surrounding coastlines and the seabed, and limit the coastline's ability to adapt naturally to changing conditions (van Rijn 2011). However, since the nearby coastlines are also hard structures, they should not have an impact on them. According to Bilkovic and Mitchell (2013), hard protection may damage the coastal ecosystem and cause habitat and species loss. However, since this is a built area and the effects have already materialised, I assume the seawalls and dike should not decrease the habitat or species diversity. The impact of the barrier islands is unknown and requires further research, they are less disruptive to the natural coastal processes because they are soft protection, are reversible and can have a finite lifespan (Buisson et al. 2012). Therefore, a specialist would need to conduct a thorough investigation of each of these structures to gain a better understanding of the consequences.

FLEXMARK

Most municipalities are working to make their cities denser; therefore, Flexmark could be a great tool to ensure that some areas are left undeveloped for recreation, ecosystem services, or both. Perhaps areas near the coast could be developed into these areas in order to increase recreational spaces and ecosystem services while lowering the likelihood of flooding in populated areas. Communities need to be flexible as we have no idea what the future holds for us. As the weather changes and Sweden gets warmer, a flexible land could be a solution for cooling some of the areas by having more green spaces and lowering the sea level rise with natural solutions, either soft solutions or EbA. Municipalities can benefit from Flexmark by adopting a new perspective on their land and recognising the opportunities presented by the sea level rise.

SUSTAINABILITY AND RESILIENCE

This project is about sustainability, adapting to sea level rise and enhancing and creating a better environment for people and other species. The project follows social, ethical, cultural and ecological values to enhance or give existing values more space to improve the urban and natural areas. The proposal pushes to preserve as many existing buildings as possible with sustainability in mind. Some structures however, needed to be moved or demolished. Most of the buildings in Barlastholmen are modern industrial buildings with no significant value, which is why several of them are not included in the proposal. An ethical viewpoint was to have no housing in the area as it would be irresponsible to build housing there given that the land could be prone to flooding in the future. Forcing people to move somewhere else is not acceptable, as it can be unattainable to protect the areas from climate change decades after 2123. This thesis has a resilience approach since the Kalmar community is adapting to new threats such as sea level rise. My interpretation of Flexmark is that it can be viewed as a resilient approach, as being flexible means being resilient. To be ready for potential obstacles, to be equipped with a plan of action and a way to bounce back from an obstacle that is flexible and resilient.

METHOD

Research by Design method's key component is the design process, which combines a literature review with site analysis and sketching to deal with a wicked problem like the sea level rise. The design process was a key component of this thesis because it assisted in understanding the issues and allowed me to test various strategies, principles, and structures. In addition, the design process greatly aided my ability to visualise the solutions by sketching them; this was done through trial and error until I was satisfied with the results. Therefore, the Research by Design method was suitable for this thesis as it helped solve and communicate the issues. In my opinion, a design proposal was the best way to determine where and how the Flexmark strategy could be used and where it could not. The proposal helped me visualise the problem and the solution; writing a report about it would not have sufficed; it needed to be seen by presenting a design proposal.

LIMITATIONS, FURTHER RESEARCH AND INVESTIGATIONS

This thesis is about a holistic design proposal and does not go into detail. The project instead demonstrates various strategies that could be used to prepare an urban coastal area for sea level rise. It also takes the opportunity to embrace the changes and create new public spaces. Because of time limitations and lack of resources there would be need for additional and more detailed research and investigation for the areas. A thorough analysis of the storm, wind and wave height in the area would be required to make better assumptions of what will be needed to protect the area from sea level rise. There would also be a need for a detailed investigation of where the coastal structures need to be. For instance, I assumed that since the area is open to the sea on the east side, the barrier islands would need to be situated there in order to protect the urban area from extreme storms. Further research would be required to comprehend better the positive and negative effects of the various coastal structures as well as the technical aspects of the structures; how high and wide do the dikes and the seawalls need to be? Assumptions were made about their height and width, but this would need to be calculated by a coastal engineer.

Due to the decision to focus only on Barlastholmen and Sylvanderparken, there is a need for solutions for surrounding areas and the mainland as the sites are low-lying; strategies would be required for the sites. In this thesis, I presupposed that seawalls would be the main form of adaptation on the mainland. Although this project's focus area is another, I decided to apply the seawall structures for all the non-focus sites, as these areas would affect Barlastholmen. If the surrounding areas are not protected Barlastholmen becomes an island surrounded by water. There would be a need to implement several strategies and principles for the mainland and as far as the sea level rise affects the land. Therefore, it would be beneficial to do an investigation with the thesis area to get a holistic view of all the sites together. Then the other urban areas could then be designed with this proposal in mind to create a coherent urban design and strategies for the rural areas to embrace the future and not see it as a problem but as an opportunity.

The vegetation was not covered in detail in this thesis. However, it is necessary to study the trees, bushes, and other plants that will be planted in the area, particularly in the secret place, as the vegetation must be able to withstand changes in water levels from semi dry to wet. There would also be a need for specialists for the wetlands, how to establish them and make them thrive, and which vegetation to use.

This thesis can show designers and planners how to use various coastal adaptation strategies in a coastal urban area and how Flexmark could be used.

THE PROJECT AND LANDSCAPE ARCHITECTURE

This project was very ambitious for one person, but I have learned a lot from it, from coastal strategies to coastal structures and how Flexmark can be defined to learning about sea level rise. As a landscape architect, many factors must be taken into consideration, especially when making a design proposal for the year 2123. Given the many uncertainties surrounding the future, a lot can happen in 100 years while remaining the same. Climate change will continue to affect the environment, but we still do not know how bad it will be in 100 years or how much the sea level will have risen. Nevertheless, when planning for the future, we must create a scenario because taking action is better than doing nothing. As a result, my design proposal is based on the scenario I created using predictions and assumptions made by others about the future. As we design for the future, the design cannot be set in stone; the design is created with the information and predictions of today, but that information might change in the future. It must be reevaluated to see if it still applies or if any changes are required due to technical advancements, social aspects, and climate change-related factors like sea level rise. This project needs to be looked at through a planning sector lens. The design would be developed in phases, with each phase being assessed to determine whether it is still applicable or needs to be updated. The project needs to allow for changes to be a successful design.

The profession of landscape architecture serves as the project's binding agent. If this were a genuine project, a team of experts from multiple fields, such as engineers, ecologists, and building architects, would collaborate. The landscape architect would act as the glue, connecting all the ideas from creating an environment for various species to designing a liveable and vibrant environment for people and balancing out all the factors while mitigating climate change as we live in uncertain times.

CONCLUSION

This thesis aimed to know how Flexmark coastal adaptation strategy could be utilised in a coastal urban area to adapt to rising sea levels. Based on the literature review and site analysis through a Research by Design method, it was concluded that Flexmark strategy can be utilised in the areas which are designated for recreation or ecosystem services, where the site may be susceptible to flooding with coastal structures such as wetlands. However, the results indicate that Flexmark strategy was insufficient for the whole subject areas, and additional strategies were needed. The selected strategies were Flexmark, Hold The Line and Move Seawards; the last two strategies were selected as they sufficiently protected specific structures and areas from flooding. The coastal structures used were wetlands, seawalls, dike and barrier islands; they all work well together to protect the urban area from flooding. This thesis was also about public spaces, which meant creating inviting spaces by introducing three objectives to the proposal: improve connectivity, enhance green spaces and protect important buildings. Combining these objectives with the coastal structures and strategies created a holistic proposal. The basis of this thesis was the COALA project which is researching the concept of Flexmark and how it can be used. This thesis was used to learn about sea level rise, how it affects coastal communities, what Flexmark is, how to implement it and if coastal urban areas need additional strategies. Combining research with a design to solve wicked problems such as sea level rise resulted in comprehensive and visualising results. Based on these conclusions, designers should consider the Flexmark strategy in their design in relation to sea level rise, as EbA structures can reduce waves and tidal energy by improving the coarseness of the surface, and the area may be used for recreation. In addition, to better understand the implications of these results, future studies could address how these strategies can be implemented slowly and steadily regarding the coastal community's needs in adapting to sea level rise. As the Flexmark strategy concept is new and has not been implemented with a design proposal before, this thesis could help other designers and planners envision how the Flexmark could be executed and how it may be combined with additional strategies.

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