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RESILIENT CLIMATE ADAPTATION FORMED BY THE DEEP STRUCTURES

A research experiment of how resilience can inform strategic climate adaptation of socio-ecological systems, within urban design and planning

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Ill. 1 Frontpage and this page: Water in the North Sea at spring (NASA 2020)

RESILIENT CLIMATE ADAPTATION FORMED BY THE DEEP STRUCTURES

A research experiment of how resilience can inform strategic climate adaptation of socio-ecological systems, within urban design and planning

AUTHOR/ I am driven by a curiosity to understand the complex urban context, and hereby make changes that can improve both human and non-human life. My approach to urban design is strategic and process oriented. I am interested in the interdisciplinary knowledge that we base our discissions on in relation to urban transformation and development. In my opinion the urban fabric is an interplay between social and ecological systems that must be integrated in the best possible way to create better cities.

Signe Hald

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SUMMARY

The Anthropocene era acknowledge humanity as a geophysical force, that due to a dominance of nature has contributed to climate change. We will experience more frequent and extreme weather which will challenge both our urban landscapes and planning practice. This master thesis sets out to challenge the current planning and design practice, where *the deep structures* often are ignored. By exploring climate adaptation in the interface between ecology and urban design and planning it seeks to refine the integration of both social and ecological systems and hereby apply a more ecological sensitive approach that can contribute to address climate change.

In recent planning practice the term 'resilience' has emerged, as an effort for climate adaptation plans, but the definition of the term appears dissimilar and unclear, which leaves resilience as a buzzword. However, resilience as a concept has a great potential to bridge urban design and ecology. Based on this potential, this master thesis is an experiment aiming to develop a 'road map' that can inform and assess resilient climate adaptation of socio-ecological systems.

To develop such a road map, entails an in-depth understanding of resilience in relation to climate adaptation. Thus, the project review theory of resilience from the ecological field, collecting several concepts, principles, and ideas. These have been translated into urban design language, through a case specific study of Ribe, which has led to a *Road Map for Resilient Climate Adaptation*. The road map concretizes resilient elements and actions, for the benefit of initial urban analysis and following decision-making processes. To discuss the findings of the specific case, as well as evaluating the road map itself, three scenarios showing different directions of climate adaptation in Ribe are developed. The scenarios reveal interest of conflict and dilemmas in Ribe that are important for urban planners to consider when making long-term strategic plans, and they help to highlight the potential and challenges of the road map.

← *Ill. 2 Water in the North Sea at spring* (NASA 2018)

ACKNOW-LEDGEMENT

I would like to thank my supervisor Lea Holst Laursen for her time, inspiration, support, and guidance throughout the master thesis. Also, thanks to Jes Vollersen, who gave technical knowledge and inputs about hydrology and climate adaptation – this has been valuable to the interdisciplinary approach. I also appreciate the time that Jan Ove Petersen from Esbjerg Municipality spent discussing climate adaptation in Ribe.

Mange tak! / Tank you!

→ *Ill. 3 Water in the North Sea at spring (NASA 2018)*

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1. CONTEXT

↓ Ill. 4 The human dominated surface is characterized by urban areas and complex infrastructure. The picture shows the highway Santa Ana Freeway in Los Angeles (Burtynsky 2017)

CONTEXT

CHANGING GLOBAL THREATS

The last 100 years we have faced several crises, from World War One to Covid-19. Common for all the crises is the fact, that they have seemed insoluble in their present. The financial crises in 2008, the energy crises in 1970, and the IT crises in 2000, all arrived unexpected and let to a serious fallout in the financial sector worldwide. Other crises such as the 9/11 terror attack in 2001, and the HIV/Aids pandemic in the 1980, made it clear that crises can be a matter of life and death, and not only strike us financially.

In common for all prior crises, is the fact that they have hit us unexpected and in a short period of time, they have been the number one priority to be solved worldwide. The immediately visibility made it clear that we needed to act, to address the situation. None of these crises were possible to solve nationally, thus made it clear that the world is combined, and that huge crises needed to be fixed and solved globally. International cooperation, innovation, research, and science has been the solution to these global threats.

2020

COVID19

CLIMATE CHANGE

2010

THE FINANCIAL CRISIS

THE CONSUMER PARTY

11. SEPTEMBER

2000

THE IT CRISIS

1990

HIV AND AIDS

1980

THE COLD WAR

THE ENERGY CRISIS

1970

WORLD WAR II

1930

↑ *Ill. 5 Oil sand in Canada is an example of a human made production that promotes climate change (Burtynsky 2007)*

CLIMATE CHANGE: HUMANITY AS A GEOPHYSICAL FORCE

What happens when crises cannot be seen immediately with the naked eye, like all the prior crises we have faced so far? And what happens when crisis affects local areas differently? That is exactly what we are facing now with climate change. Humanity has become a geophysical force, known as the Anthropocene, where climate change is a by-product of our dominance of nature as a resource.

The emissions of fossil fuels have been slowly and steadily rising since the 1960's (Our World in Data 2019), and the demand for energy is still increasing along with the developing economies. Researchers has even stated that the ongoing climate changes are irreversible, which means that no matter of current reduction, climate change will occur (Oppenheimer et al. 2019).

The changing climate do also correlate with urbanization which brings further stress to our cities. Countries such as India that currently undergo urbanization and industrialization, will bring further new demands on manufactural goods. As inequality is offset, underdeveloped countries will strive for a level of welfare equal to that of the Western world. This testifies that we as humans have arranged ourselves incorrectly in relation to the inequality effect it creates.

CLIMATE ADAPTATION

The global ocean covers 71% of the Earth surface which human both directly and indirectly are dependent on. In Denmark the ten largest cities are located on the coasts, as well as half of the hundred largest cities. All these areas are exposed to climate change, but also inland areas will face challenges of extreme weather events. We are to expect warmer weather, instability, rising groundwater and seawater levels, and more frequent extreme events with extreme precipitation and storm surge (DMI 2020; DMI 2014; Kystdirektoratet 2016; Arnbjerg-Nielsen & Löwe 2019; Kystdirektoratet 2018). The changes in the hydrological cycle entailing an increased waterbody and changed waterscapes, that will affect our urban landscapes and bring new demands to urban design and planning in the form of climate adaptation.

It has become clear that the green transition must accelerate in the coming years, both in terms of energy transition but also the transition of urban development. If balance is to be created, a greener and more sustainable way of living must be more efficient than the one we have today. Within urban planning and design, we have the opportunity to contribute to the green transition. We should prepare for the climate changes that we already know will affect us in short and long term, and we must learn from our previous mistakes.

↑ *Ill. 6 Mumbai in India is one of the densest cities in the world, and is an example of urbanization (Burtynsky 2016)*

CONTEXT
MOTIVATION

INSPIRATION THROUGH STUDIES

Through my studies at Aalborg University, I was introduced to landscape urbanism and ecological urbanism, that works with urban design in a large scale, approaching it as a complex interdisciplinary field. Since then, I have been interested in working with urban design with a focus on 'what it can do', rather than 'what it looks like'. In the large scale we can work interdisciplinary with the landscape and urban fabric, to solve some of today's largest problems. At Aalborg University, we have learned to integrate technical knowledge into classic urban design and planning practice, which is a perfect platform to let urban design contribute to a larger agenda. In this regard, this master thesis aims to explore how urban design method can contribute to climate adaptation planning through the lens of ecology.

IGNORANCE OF THE DEEP STRUCTURES

It is possible to imagine a world without people. Seen in a geological perspective, we as a human species have only inhabited the earth for approx. 6 million years out of the Earth's 4.5 trillion years lifespan. On the other hand, it is harder to imagine people without nature. We are dependent on the earth, acting as an ingredient in it. This fact has been overlooked since the industrialization. Thus, the current geological period is termed, the Anthropocene.

Within urban design and planning, the Anthropocene is an expression of a practice that has ignored natural conditions and potentials, also known as 'the deep structures' (Spirn 1993; 2013) which Ian McHarg among others introduced back in the 1960's (McHarg 1969). Besides missed opportunities of developing with nature, large areas of the built environment have come into even greater risk of flooding, as natural systems in relation to hydrology (waterscapes) are blocked. This appears as land reclamation, land expansion, piped streams, buildings that block natural watercourses, and settlement in high-risk areas both near the coasts and in depressions (Wiberg 2018; Spirn 1993; Spirn 2013).

My motivation for this master thesis is driven by a will to change the tendency to ignore the deep structures. Previous mistakes must be avoided, and a new direction must be taken. Thus, this master thesis can be seen as a search for new values. Values addressed as a polemic against nature and human dichotomy. Instead values of co-existents, unity and partnership with nature must be cultivated. As the 2016 manifesto by Laboratory Bâle, Laba, at the Swiss Federal Institute of Technology Lausanne (EPFL) in Basel, formulate:" *We want to imagine an "ecology without nature," where clean energy and environmental management embrace human and non-human needs in ways that go beyond an economy of preservation in terms of "visual impact"*" (Laboratoire Bâle 2016). This points in the direction of a more ecological sensitive approach, that this project seeks to apply. It will address hydrology in relation to climate adaptation, and reinforce water's historic cruciality to settlement, and furthermore to generate urban development.

"If landscape architecture is to concern itself with the "ecological crisis" and other difficulties of human life upon the earth, then it must recognize expeditiously how the root cause of environmental (and spiritual) decline is buried in the complex foundations of modern culture, particularly its political-economic practices, its social institutions, and the psychology and intolerance of much of its citizenry."

- James Corner
(Corner 1997, p. 265)

"Deep structure can be masked, but it cannot be erased. When surface structure obscures or opposes deep structure, it will require additional energy, materials, and information to sustain. If these resources cease to be applied, the deep structure will reassert itself."

- Anne Winston Spirn
(Spirn 1993, p. 10)

"Up through the 20th century, we became technically more skilled at building. Somehow, we lost respect for the natural conditions when we built, which meant that we have built close to the water..."

- Gertrud Jørgensen
(Jørgensen 2019) (Author's translation)

Anne Winston Spirn about Mill Creek, where her students and herself studied different environmental challenges; *"Hills were cut down and valleys filled during the mid 1800s. The current grade above the Mill Creek sewer is now 40 feet or more above the original level of the creel. The old alluvial deposits on the former floodplain buried deep beneath the current surface of the city are a resource for absorbing stormwater and indicate where subsidence may occur."*

- Anne Winston Spirn
(Spirn 201, p. 52)

"Our eyes do not divide us from the world, but unite us with it. Let this be known to be true. Let us then abandon the simplicity of separation and give unity its due. Let us abandon the self-mutilation which has been our way and give expression to the potential harmony of man-nature."

- Ian McHarg
(McHarg 1969, p. 5)

2. FOUNDATION

↓ Ill. 7 Holland is as an example of how increasing amounts of water and flooding are addressed, in a country where 2/3 parts is below the water table (Burtynsky 2011)

AIM AND OBJECTIVES

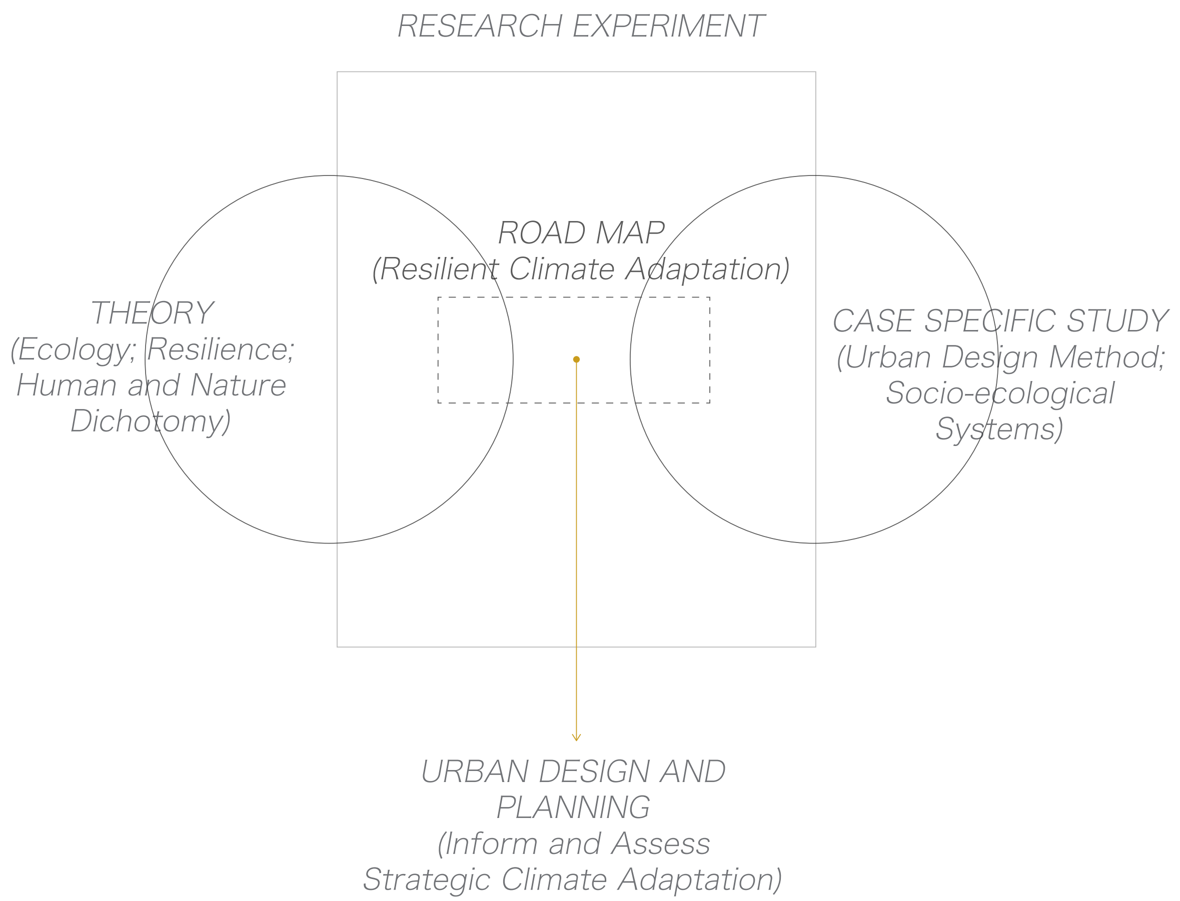
THIS MASTER THESIS IS A RESEARCH EXPERIMENT WITH THE

AIM TO DEVELOP A ROAD MAP THAT CAN INFORM AND ASSESS RESILIENT CLIMATE ADAPTATION OF SOCIO-ECOLOGICAL SYSTEMS, WITHIN URBAN DESIGN AND PLANNING.

1.
Review the theoretical relationship between human and nature dichotomy, ecology in urban design, and resilience.

2.
Explore how urban design method can read and translate concepts of resilience through a case-specific study, to create a road map for resilient climate adaptation.

3.
Discuss and evaluate how the road map for resilient climate adaptation can inform strategic urban design and planning of climate adaptation.



Ill. 8 The intension of this project is to conduct a research experiment that explore resilient climate adaptation through theory and a case specific study. Based on the two components a Road Map will be created, seeking to inform and assess resilient climate adaptation made by urban designers and planners. The experiment will follow the professional context of urban design, and hereby use classic urban design methods in the case specific study. The theory will be a mix from both the ecology and the urban design field, as it aims bridge resilience and urban climate adaptation (Made by author)

METHODOLOGY

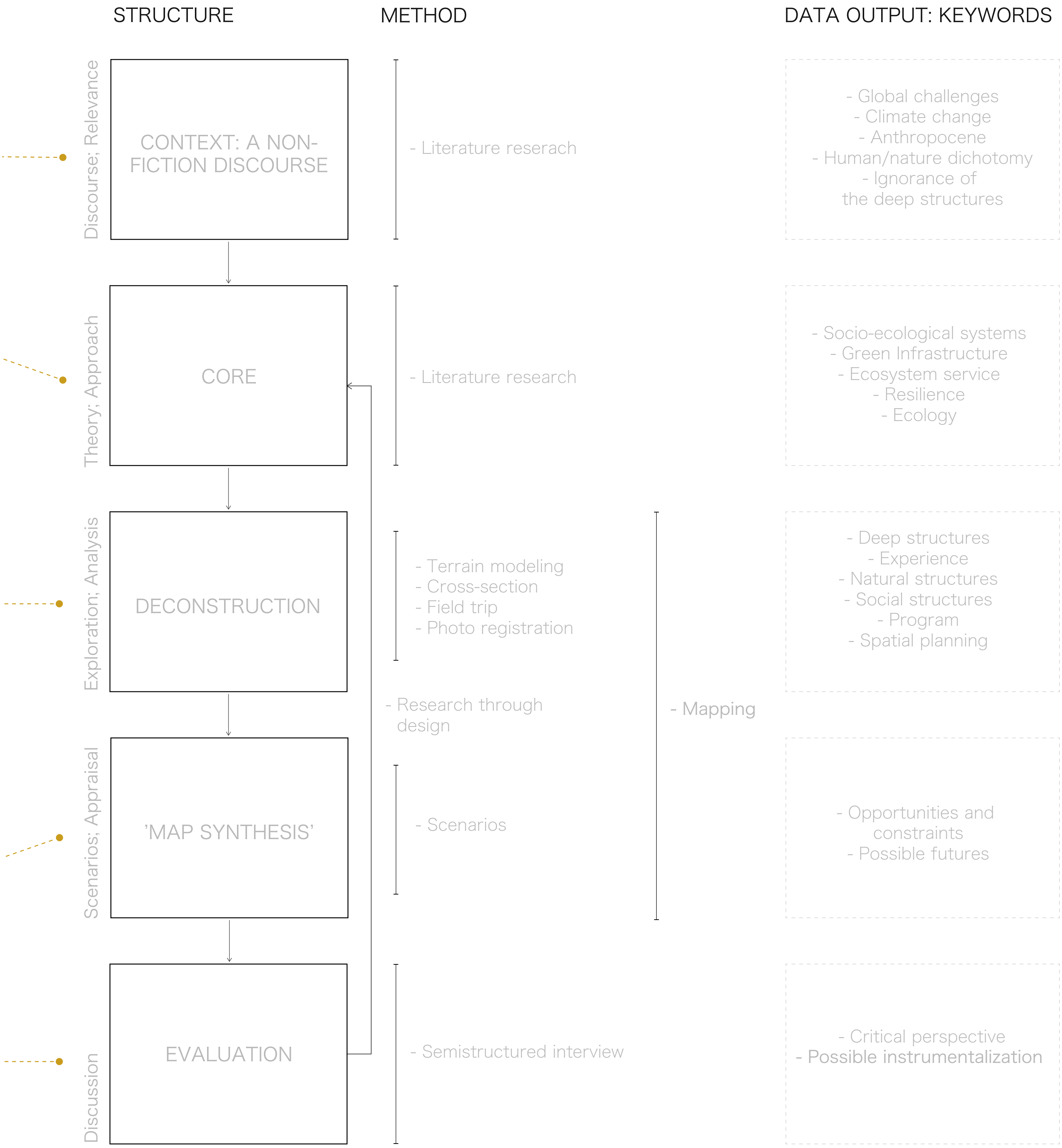
OBJECTIVES

- Review the theoretical relationship between human and nature dichotomy, ecology in urban design, and resilience.

- Explore how urban design method can read and translate concepts of resilience through a case-specific study, to create a road map for resilient climate adaptation.

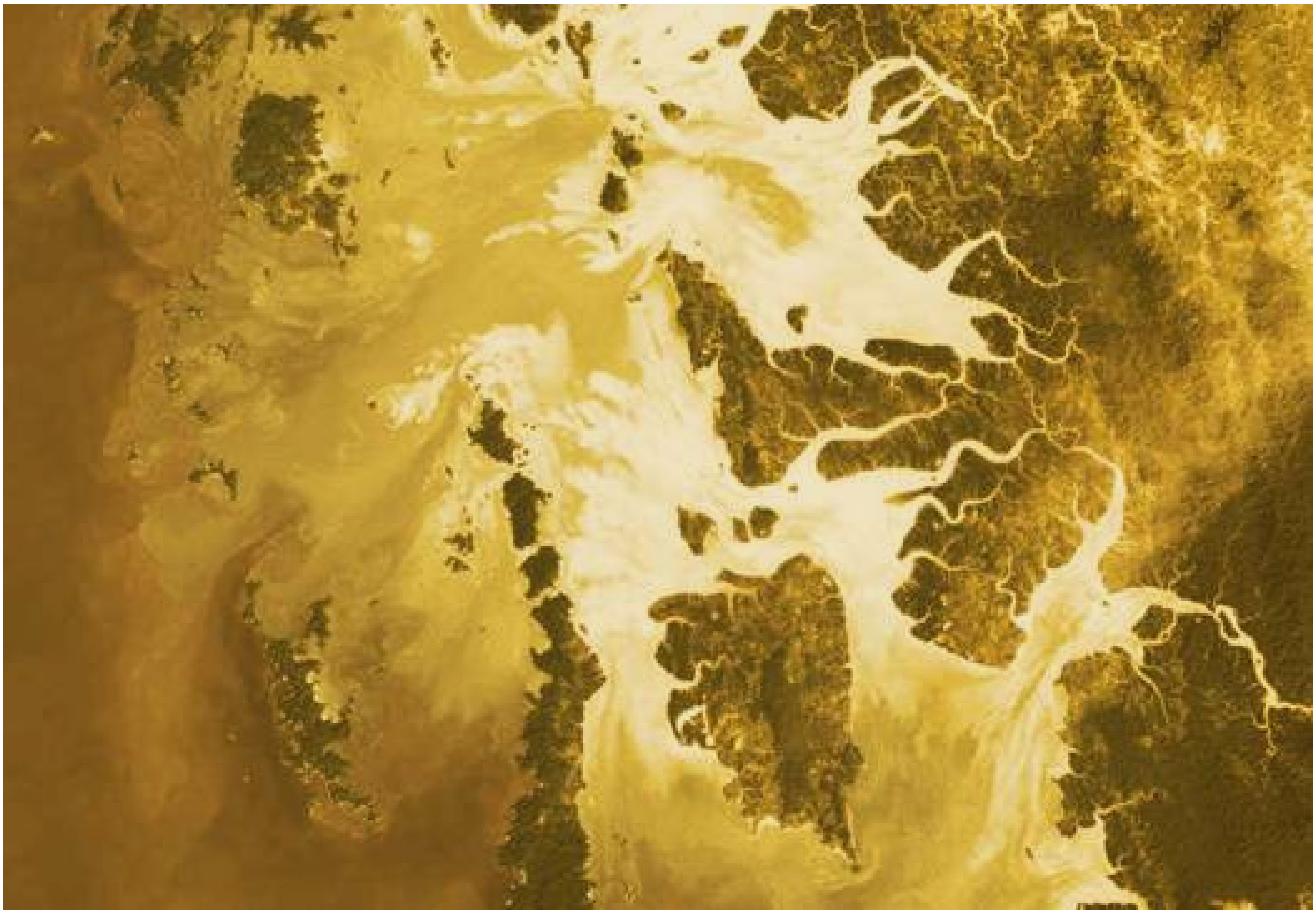
Discuss and evaluate how the road map for resilient climate adaptation can inform strategic urban design and planning of climate adaptation.

Ill. 9 The methodology shows the structure of the project, and the applied methods to each phase. The expected outputs are described as keywords that summarize the sub-findings (Made by author) (Made by author)



3. CORE

↓ Ill. 10 In Mergui Achipelago, Southeast Asia, the water dynamics becomes clear.
The coast is more a dynamic zone than a fixed line
(NASA 2019)



CORE THEORY: HUMAN AND NATURE DICHOTOMY

Is human a part of nature or not? What is nature? And how can urban planners and designers work with it to solve some of today's complex climate related issues? The relation between human and nature has evolved through history. It is relevant to outline the shifting dichotomy between the two, as ecology within several disciplines, approaches issues differently depending on their understanding of nature. Ecology in urban design is not objective but is based on specific nature views, as James Corner describes; "*Ecology is never ideologically (or imaginatively) neutral, despite claims of its objectivity*" (Corner 1997, p. 259). Therefore, the theory takes point of departure in the Human and Nature Dichotomy closely followed by theory of Ecology in Urban Design.

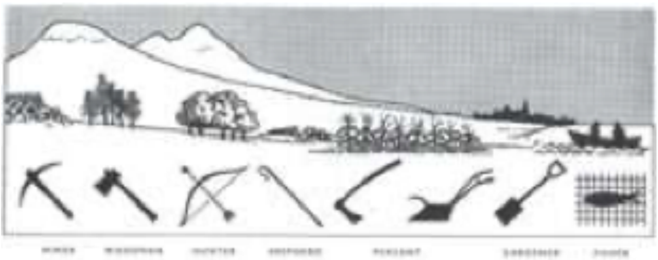
IS HUMAN A PART OF NATURE OR NOT?

From the beginning of urban civilization in the classical Greece there were contrasting notions of human and nature relation. While the philosopher Aristotle (384-322 BC) believed that nature existed for human exploitation, the philosopher Plato (422-347 BC) highlighted the importance of understanding nature before taking advances of it (Ndubisi 2014, pp. 13-14). In general, all settlement and physical space was originally bound to health condition, to support human life (Spirn 2013). Logics of sun orientation, water access, terrain etc. was important parameters there was considered. Human relation to nature was even from the beginning characterized by outer extremes, and the dichotomy of human and nature as well as urban and rural has dominated.

Urban and rural

TThrough history the city has been built as a dichotomy to nature. Already in the ancient Roman cities such as Pompeii (600 BC) the city was surrounded by massive walls creating a hard barrier to the surrounding rural landscape. The division of urban and rural was further strengthened in the philosophical development. Both Platon and Aristotle understood urban life as forming of philosophical thoughts. Aristotle did even claim that citizens were the intellectual while the disadvantaged lived at the countryside (Aristotle, 1328b, Book 7).

Several years later, cities were built as fortresses, as the danish city Fredericia from the 17th century is an example of. Also in the later modern era, the concentric urban model was embraced, dividing the city into different functions. It was first around 1900 that understandings that breaks down the dichotomy between urban and rural were presented. The biologist Patrick Geddes did at the beginning of the 1900s demonstrate a landscape understanding that ties culture, settlement, and landscape together, which is illustrated in his 'Valley Section' (see illustration 11). The section connects the natural conditions with urban settlement in a regional context, seeing all parts as a landscape.



Ill. 11 The Valley section by Patrick Geddes connects culture, settlement, and landscape (Wikimedia n.d.)

Another contributor to the understanding of urban and rural as interconnected are landscape architect Anne Winston Spirn with her book *The Granite Garden: Urban Nature and Human Design* from 1984 (Spirn 1984). In the book Spirn relates the city to natural science and breaks down the city and nature dichotomy when she claims that city is a part of nature.

"*The city must be recognized as part of the nature and designed accordingly. The city, the suburbs, and the countryside must be viewed as a single, evolving system within nature, as must every individual park and building within that larger whole. The social value of nature must be recognized and its power harnessed, rather than resisted*" (Spirn 1984, p. 5).

She further presents ecological principles and approaches that can be used to design the city accordingly with the natural foundation, which will be elaborated in the following theoretical section (see Theory: Ecology in Urban Design, p. 34) (Spirn 1984). In both Geddes' and Spirn's perspectives the human and non-human world are interacting and shaping each other, meaning that every physical environment both city and rural are a part of the same fabric - landscape and nature.

Human and nature

In the book *To Heal the Earth* the landscape architect Ian McHarg describes two opposing views of human and nature relation:

"*Conceptions of man and nature range between two wide extremes. The first, central to Western tradition, is man-oriented. The cosmos is but a pyramid erected to support man on its pinnacle, reality exist only because man can observe it, indeed God is made in the image of man. The opposing view, identified with the Orient, postulates a unitary and all-encompassing nature within which man exist, man in nature*" (McHarg 1963, p. 12).

The first view argues that human is placed outside of nature, even dominates nature, which Aristotle also implied. The second, opposite view argues that human is a part of nature and hereby collaborate with nature. Through history, this dualism has been present through different trends - even religion mark itself in this matter. Christianity has been criticized by both McHarg and the historian Lynn White Jr. in their writings from the 1960's, to be environmental degrading and man-oriented (Steiner 2016, p. 168).

The danish philosopher Hans Fink, argues that to figure out if human is a part of nature or not, and further be able to discuss e.g., nature politics, the notion of *nature* must be clarified (Fink 2003). What is considered good or bad for either nature or human depends on the conception of nature. He distinguishes seven different conceptions of nature, *the untouched*, *the wild*, *the rural, the green, the physical, the earthly*, and *the everything.*

The first six conceptions are all placing human outside of nature in different ways (Fink 2003). *The untouched nature* is everything that hasn't been influenced by humans and herby hasn't become culture. *The wild nature* is areas that hasn't been cultivated, looking as before the agricultural revolution. *The rural nature* is both the wild and cultivated which characterizes the danish rural landscape. Nature is the countryside in contrast to the city. *The green nature* is also a part of the city, as it is understood as everything organic and low-tech, which includes gardens, plants, pets, and nature materials opposite 'grey', high-tech, and synthetic. *The physical nature* is "*...the natural statutory, which consist of time and space, particles and fields, mass and energy. Nature is the objective existing. Opposite to nature is the subjective, psychical, symbolic, conventional, social, and cultural*" (Fink 2003, pp. 33-34) (Author's translation). It follows the laws of physics which includes both the environment as well as human physics, but whereas human physics is a part of nature, culture stands outside of nature. *The earthy nature* is more abstract, as it is the created work of a supernatural God, thus human is a part of the creation and nature which stands in contrast to the supernatural and divining. Humans are both a part of nature but also outside of nature, as the soul is immortal. The last conception is *nature as everything*, which stands in contrast to the other conceptions. Here, humans are fully a part of nature: "*Nature is what connects all that is diverse*" (Fink 2003, p. 35) (Author's translation).

Fink's different conceptions of nature are well known in a danish context, and each conception holds its own issues. The different perceptions and understandings of nature is always dependent on the subject and often the cultural determination (even though all Fink's conceptions can be visible at the same time within a single culture). One could say that the dominant perception and understanding of nature has developed through history along with the civilization's material entanglement, which today is expressed as the Anthropocene (see previous Chapter 1, *Changing Global Threats*, pp. 14-15).

NATURE AS A CULTURAL CONSTRUCTION

NOTE/ Scientists and thinkers such as Descartes, Newton, Galileo, and Bacon were some of the forerunners of the modern era.

In western Modernity dating from the 16th century, belief in technological development as a solution and as a means of increasing prosperity became widespread. Align with human progression the capitalist market economies were rising, which all together breed a belief that nature could be controlled (Corner 1997, p. 263). This development and attached nature view - perceiving nature as a machine and human as dominant over nature - has brought many benefits, but it has also led to some of today's largest issues. The landscape architect and urban designer James Corner perceive nature and culture as interrelated, thus he breaks down the opposition between culture and nature. In his essay *Ecology and Landscape as Agents of Creativity* (Corner 1997) he describes the consequence of human dominance over nature as follows:

"*In sum, the belief in human progress and mastery over Nature, for all of its good intentions and successes, has at the same time promoted an often brutally mechanistic, materialistic, and impersonal world, a domain in which the potential creativity of both Nature and culture is diminished to dull equations of utility, production, commodity, and consumption*" (Corner 1997, p. 264).

The dominance of nature, the environmental degradation, and human-oriented nature view are all objectifying nature as a reserve. Corner spends much time opposing the purely scientific approach to fully understand nature. He outlines two kinds of natures. The first is the *concept of nature* and the second is the *'actual' cosmos of nature*. He explains:

"*The first "nature" refers to the concept of nature, the cultural construction that enables people to speak of and understand the natural world, and that is so bound into ecological language; the second "Nature" refers to the amorphous and unmediated flux that is the "actual" cosmos, that which always escapes or exceeds human understanding*" (Corner 1997, pp. 259-260).

The *'actual' cosmos* of nature is impossible for human mind to understand, but it can spark the imagination and creativity for professions such as landscape architects to re-construct and renew the *concept of nature*. The 'unsaying' objects are essential to imagination and creation of new understandings.

Similar to Corner's notion the *concept of nature* is Spirn's description of nature as an idea. "*[Nature is an idea] ...not a place or a thing, and, furthermore, it is a set of ideas for which many cultures have no name*" (Spirn 2012, p. 8). The set of ideas that Spirn refers to cannot be fully covered by the naming of nature. It is not a full description of the concept itself, but through language we are able to relate our mind with nature and to give nature meaning, as we understand and perceive it. In this way, nature and culture are interwoven and affects each other, which implies that several natures exist, and that nature is a cultural construction through language.

THE CONCEPT OF 'LANDSCAPE' TO OVERCOME HUMAN AND NATURE DICHOTOMY

It is not only through language that nature is a cultural construction. It is also in the way that humans have physically changed the natural environment. The landscape architect Malene Hauxner states:

"*What we call nature, is often culture, a human-made, societal, historical phenomenon. It has been a long time since we have recognized that heath, common, and spruce forest are a result of a particular form of cultivation. Realizing that nature is usually man-made is a simple necessity*" (Hauxner 2011, p. 10) (Author's translation).

NOTE/ The Earth as Modified by Human Action was already stated by George Perkins Marsh in the last half of the 19th century (Marsh 1864; Spirn 2013)

Nature is also culture in the way that human has cultivated, influenced, and changed it through history. The line or dichotomy between culture and nature is therefore not existing, as culture and nature constitute each other. However, this perspective challenges the original definition of *nature*:

"*The phenomena of the physical world collectively, including plants, animals, the landscape, and other features and products of the earth, as opposed to humans or human creations*" (Oxford University Press (OUP), 2020).

Following this definition, nature is everything non-artificial and everything human hasn't influenced, which is similar to Hans Fink's conceptions of the *untouched nature*. Consequently, this means that there is very little nature left as most of the earth's surface has been either directly affected by human through cultivation or indirectly through e.g., anthropogenic climate change (Fink 2003). This leads to the question, is the term *nature* comprehensive in relation to urban planning and design?

If nature is to be used in urban planning and design, the concept must include the man-made nature. Nature must be re-defined to make that possible. Alternatively, nature must be replaced by another term. Philosophy Bruno Latour uses the term *hybrid* to merge the social and nature sphere (Latour 1991). His Actor Network Theory, where everything is moving together in a network and where all objects are put on the same level with no distinction between natural and artificial substances, is an expression of hybrid. For Latour, hybrid doesn't distinguish between the natural and social, instead he breaks down the dichotomy between the two (Latour 1991). In this way nature is not passive to human action but appears as dynamic. It even equals human and non-human actors, so instead of objectifying nature, it acknowledges human as an actor within it. Hybrid entails that human is nature or reversal that nature is human. Thus, hybrid describes everything that breaks down this dichotomy, as e.g., the Anthropocene era, that recognize human as a geophysical force.

Another example is the term *super-nature* used by the architect Rem Koolhaas (Koolhaas 1994) and in his later work he uses the term *landscape*. The last-mentioned term, *landscape*, is very useful, firstly because it acknowledges that nature is a cultural landscape formed by human interaction, and secondly, as it covers both human and non-human features of an area of land, thus overcome the dichotomy between culture and nature.

Landscape has been medium for several scholars through time. The genre origins from the sixteen-century paintings and became in the following century "...*a way of seeing or experiencing the world*" (Waldheim 2016, p. 3). It was first in the eighteen-century that Landscape Architecture became an academic profession, even though Landscape Gardening had existed since medieval times. Today, landscape covers many things, which in itself holds great potential, especially as a medium to address and solve complex challenges. In architect Charles Waldheim's book *Landscape as Urbanism* (Waldheim 2016), he reflects on several different meanings of landscape. He also points at the potential of landscape thinking applied to urban form - commonly known as the concept of *Landscape Urbanism*, which will be further elaborated in the following chapter. Waldheim describes that landscape as a medium of urbanism;

"...*has often been invoked to absorb and in some ways mitigate various impacts associated with social, environmental, and economic crisis. It has equally been found relevant for thinking through sites at the intersection of large, complex ecological and infrastructural systems*" (Waldheim 2016, p. 4).

He even points at landscape as relevant to "...*questions of green infrastructure in the informal city, and in response to questions of risk and resilience, adaptation and change*" (Waldheim 2016, p. 4), which points directly into the scope of this project. *Landscape* as an umbrella covers both ecological and social systems, where nature would in some cases only cover the ecological systems (understood as the non-human). Hereby landscape can be used as a strategic field.

"...*landscape no longer refers to prospects of pastoral innocence but rather invokes the functioning matrix of connective tissue that organizes not only objects and spaces but also the dynamic processes and events that move through them. This is landscape as active surface, structuring the conditions for new relationships and interactions among the things it supports*" (Wall 1999, pp. 233).

LET'S EXPLORE THE SOCIO-ECOLOGICAL SYSTEMS

"*Ironically, the more we learn to control nature, the less nature we have, and the more we change nature, the more complex, strange and unknowable it appears*" (Laboratoire Bâle 2016).

Although we have increased our knowledge of nature and biophysical processes, is seems that nature appears more and more complex and unknowable to us. This challenge is also noticed by Hans Fink within the conception of *the physical nature*. He emphasizes the importance of using natural science, but at the same time he claims that the knowledge we have today is insufficient and has created many of our problems.

"*[It]...calls for a general precautionary principle, and also for the importance of natural science that must focus on helping to solve the problems that we already face many of, and which are due to a short-term and ill-considered use of scientific results*" (Fink 2003, p. 37) (Author's translation).

A part of the solution could be to use the landscape as a medium, and hereby explore and learn from the urban socio-ecological systems within. This project aims to do so.

A socio-ecological perspective looks at both social and biophysical factors, and socio-ecological systems consists of those factors in a complex interrelation within a spatial boundary. Instead of exploring ecosystem dynamics as isolated from social factors, socio-ecological systems equals both social and ecological forces acting in both domains. This project follows the definition of socio-ecological systems as:

1. a coherent system of biophysical and social factors that regularly interact in a resilient, sustained manner;

2. a system that is defined at several spatial, temporal, and organizational scales, which may be hierarchically linked;

3. a set of critical resources (natural, socioeconomic, and cultural) whose flow and use is regulated by a combination of ecological and social systems; and

4. a perpetually dynamic, complex system with continuous adaptation

(Redman et al. 2004, p. 163)

This project will emphasize the importance of breaking down the human and nature dichotomy, seeing the whole landscape as consisting of both social and ecological systems that are interwoven (and hereby hybrid). It will merge the conception of *the physical nature* and *nature as everything*. In this way humans and culture play a role in the laws of physics, which has already been evident through the Anthropocene.

From clear distinction towards hybrid, from nature objectification towards interwoven socio-ecological systems, and from human dominance to collaboration with nature. These are some of the major development trends that has now been unfolded. Landscape and socio-ecological systems are keywords that speaks into a more sensitive ecological awareness. This is exactly what ecology in urban design seeks to apply, even that it is not always the norm.

CORE THEORY: ECOLOGY IN URBAN DESIGN

The human dominance of nature is widely criticized by many of the pioneers of ecology in urban design. Key figures are Ian McHarg, Anne Winston Spirn, George Perkins Marsh, Ebenezer Howard, Frederic Law Olmsted, Patrick Geddes, Lewis Mumford, and Kevin Lynch. In different ways they are all advocating a more ecological sensitive approaches that takes nature into account and builds on the perceiving of the landscape as hybrid, consisting of socio-ecological systems. This section will firstly present the starting point for ecology in urban design and the entry of ecology in landscape architecture, which will be followed by an elaboration of the concept Ecological Urbanism. Lastly, the practice of Ecological Urbanism will be advanced and linked with resilience, which is a promising tool to solve issues within climate adaptation. The direct connection between resilience and climate adaptation will be unfolded in the last theoretical section *Adaptation through resilient socio-ecological systems*.

ENTRY OF ECOLOGY IN URBAN DESIGN

"*Landscape ecology, human ecology, urban ecology, applied ecology, evolutionary ecology, restoration ecology, deep ecology, the ecology of place, and the unified theory of ecology (also called neutral theory of ecology) are but a few of the specialized areas of ecologically oriented research that have emerged over the past decades and continue to inform our thinking about the various interrelationships between plants, animals, and the physical, biological, cultural, and experiential world in which we live*" (Reed & Lister 2014, p. 16).

Ecology has flourished at the turn of the twentieth century, along with urbanization and an increasing focus on environmental challenges (Reed & Lister 2014; Spirn 2012; Mostafavi 2016). Different approaches and modes of ecology has unfolded within several disciplines, to better understand socio-ecological systems and hereby address urban and global issues. This has also been the case within the urban field, where knowledge and thoughts from ecology has been brought in. The interface between ecology and urban design became especially interesting since humans were recognized as components in ecological systems. The ecological approach breaks with the past tradition's dichotomy of human and nature, and urban and rural, which has been outlined in the previous theoretical section (see *Theory: Human and nature dichotomy*, pp. 26-33).

Much of the past and current research within ecology and urban design stem from Harvard Graduate School of Design. Their master program Urbanism, Landscape, Ecology describes the emergence of ecology into the urban field:

"*Over the past decade, longstanding disciplinary divides between the urban and the ecological have given way to more fluid, polyvalent and potentially more productive relations. The challenges of the built environment have rarely, at any time, corresponded to traditional discipli-*

nary or professional boundaries. Today, contemporary practices of urbanism are shaped by thinking from subjects as diverse as landscape architecture, geography and economics, while increasingly being informed by sensibilities and stores of knowledge broadly associated with the study of the natural world" (Harvard GSD master program n.d.).

As the description tells the division of the disciplines, architecture, landscape architecture, urban planning, and urban design are limited to address contemporary challenges. Interdisciplinarity with integration of other disciplines into urban design is a key element of an ecological approach. Therefor interdisciplinarity that deals with or use ecology is a key when approaching urban development - blurring the lines between disciplinary territories.

Through history, several pioneers that understood natural conditions as supportive and vital for human life, has worked with the integration of different disciplines from both the social and ecological arena. Different approaches have been advanced and refined, through time, which has led to the current development of ecology in urban design, that has been called the *third tide* by Pickett and Mary L. Cadenasso (Cadenasso & Pickett 2013). The third tide is characterized by four things:

"*First, it attempts to unify social and biological knowledge, concerns, and approaches... Secondly, it acknowledges and exploits spatial heterogeneity and fine-scale dynamics as a feature and cause of urban change... Thirdly, it seeks to understand the controls of biogeochemical processes throughout urban systems, including retention, fluxes, and leakage of limiting nutrients and pollutants. Finally, the hybrid nature of the systems is acknowledged, so that cities are seen as neither fully human nor fully natural entities. Rather, they are inextricably both human constructions and biophysical features*" (Cadenasso & Pickett 2013, pp. 41-42).

From traditional equilibrium paradigm to non-equilibrium paradigm

The reason for the high prevalence of ecology can be fined in the scientific field, that has undergone a change or a shift over time from a discourse focused on determinism, reductionist, stability, and order towards a "*...more contemporary understandings of dynamic systemic change and the related phenomena of adaptability, resilience, and flexibility*" (Reed and Lister 2014a, p. 15; Reed and Lister 2014b). In the past when ecologist examined dynamics in an ecosystem, the changes was assumed to be fixed with a stabile equilibrium, but current practice acknowledge that influence can happen outside of the studied ecosystem boundaries, and that several systems in different scales are interconnected. There has also been a shift from excluding human impact when examine systems to include human influence and explore both social and ecological systems at the same time (Pickett et al. 2013).

As an isolated discipline, ecology explore the relation between living organisms and their environment. Along with the change in the ecological science, the plant ecologist Steward T.A. Pickett suggest a new definition of ecology: "*The scientific study of the patterns and processes influencing the distribution and abundance of organisms, the interactions among organisms, and the interactions between organisms and the transformation and flux of energy, matter, and information*" (Pickett et al. 2013, p. 18). This definition includes an evolutionary, organismal, and energy flow perspective, that focuses on processes and dynamics, and it allows different scales from micro to regional as well as temporal, which corresponds to the new understand or discourse of ecology.

"... *mounting evidence from ecological research in the past few decades indicates that nature is not in constant balance, but rather in eternal flux. This recent discovery has led to a fundamental transformation in ecological thinking from emphasizing equilibrium, homogeneity, and determinism to non-equilibrium, heterogeneity, and stochasticity – or a shift from the balance of nature/ equilibrium paradigm to the hierarchical patch dynamics paradigm*" (Wu & Wu 2013, p. 212).

In James Corner's essay *Ecology and Landscape as Agents of Creativity* (Corner 1997) he argues that creativity and imaginative should be rooted in the alignment of landscape and ecology. Several times, Corner express that creativity, landscape, and ecology as metaphor or ideology holds a huge potential. A potential to "... *profound agency in the world, effecting change in a variety of material, ideological, and experiential ways*" (Corner 1997, p. 258). In this way ecology, creativity and landscape architecture as cultural ideas can affect nature, human environments, and the interactions therein.

In the essay Corner gather different new theories of ecology. Among several, he distinguishes between two types, the *scientistic / instrumentalist ecology* and the *metaphorical / cultural animate ecology*. While the scientistic / instrumentalist ecology follows the Newtonian world view, that support a static and linear approach, the metaphorical / cultural animate ecology builds on cultural ideas and supports a dynamic, everchanging and a nonlinear world view acknowledging complex socio-ecological systems. The first one, understand ecology as disconnected from culture which induce certain limitations, as designers and planners are left to only address nature environments. It excludes the influence of culture and hereby "... *fail to understand how the metaphorical characteristics of ecology inform and construct particular realities*" (Corner 1997, p. 260). Instead, by acknowledging how the metaphorical characteristics of ecology can influence cultural process and evolutionary transformation, the space for opportunity is expanded. This is an ecology rooted in a "... *culture's mode of relating to Nature*" (Corner 1997, p. 262) and it prepares the ground for work and imagination of process and evolutionary transformation. Corner states that instead of looking to ecology for "... *techniques of description and prescription*"(Corner 1997, p. 262), one should look to its

"... *ideational, representational, and material implications with respect to cultural process and evolutionary transformation*" (Corner 1997, p. 262). For Corner, ecology within landscape architecture prepare the ground for working with evolutionary principles - initiates processes that function "... *as agents, as processes, as active imbroglios and ever emerging networks of potential*" (Corner 1997, p. 279).

History of ecology in urban design

Even though ecology has flourished within the last couple of years, ecology in urban design has existed for decades. Some of the first ecological thoughts within urban planning was correlated with settlement and physical space. The Greek philosopher Hippocrates, bound health conditions together with the specific location, water, and air for about 2000 years ago (Spirn 2013, p. 2). Also, the roman architect Vitruvius (100 BC) defined street layouts, and the later architect Leon Battista Alberti advocated in his book *On Architecture* from the 15th century that "...*the siting of cities and the design of streets, squares, and buildings should be adapted to the character of their environment so that cities might promote health, safety, convenience, dignity, and pleasure*" (Spirn 2013, p. 2). In more resent time, through the 19th century Frederic Law Olmsted approached a collaboration with nature, in his design of urban areas such as parks and neighborhoods. His focus was to improve urban conditions for residents, by increasing health and safety (Spirn 2012). Another prominent practitioner was Patrick Geddes. Along with his landscape understanding that breaks down the city and nature dichotomy (see *Theory: Human and nature dichotomy*, pp. 26-33), he tried to integrate an ecological approach in urban planning, by introducing a regional survey method in 1915 (Geddes 1915). Regional survey before planning is well-known by all designers and planners today, but Geddes made it into a problem-solving practice for the first time (Spirn 2013). Geddes' method was further elaborated by his student Lewis Mumford who was an American historian and philosopher. Whereas Geddes integrative approach worked to create a synthesis that reached a final and definitive goal, Mumford worked with a more process oriented and flexible perspective. He explains that a new image of the city;

"...*must include the form-shaping contributions of nature, of river, bay, hill, forest, vegetation, climate, as well as those of human history and culture, with the complex interplay of groups, corporations, organizations, institutions, personalities... Yet once a more organic understanding is achieved of the complex interrelations of the city and its region, the urban and the rural aspects of environment, the small-scale unit and the large-scale unit, a new sense of form will spread through both architecture and city design*" (Mumford 1968, p. 164).

Both Geddes' and Mumford's perspectives and ideas became a huge inspiration for later landscape architects and urban planners who broad the environmental movement into practice. Many of the first practitioners who brought ecology into practice was motivated by an increasing environmental awareness and climate related concerns. These issues were already addressed concurrently in the natural science, that has gained new knowledge and a deeper understanding of the role of urban areas in the natural systems and of how human and the environment is connected (Spirn 2013). Science and approaches from the ecological field are used and applied first in landscape architecture and latter in urban design and planning. The landscape architects Chris Reed and Nina-Marie Lister term this intertwining between ecology and design profession for *Projective Ecologies*.

"*Projective Ecologies... is an explicit recognition of plurality of ecological theories and applied research underpinning contemporary understandings of cultural and natural living systems*" (Reed & Lister 2014, p. 16).

The notion *projective* should be understood as the creative representation of "*... ecologist's models for the physical world and dynamic aspects of the natural world*" (Reed & Lister, p. 16), that architects and designs can produce. Through these representations, ecological ideas are tested and specified, which normally would not be tested. Projective ecologies articulate the potential to use and project ecological models into design practice. Ecology then works both as a medium, model, and metaphor to understand cultural, social, and natural living systems also known as the socio-ecological systems (Waldheim 2016).

ENTRY OF ECOLOGY WITHIN LANDSCAPE ARCHITECTURE

Different practitioners have contributed to the emerging of ecology within landscape architecture. One of them is Ian McHarg, who was a forerunner for introducing and use ecological science in landscape practice and regional planning, to address environmental issues through the medium of landscape. In many ways McHarg is a leading example of the ecological thoughts and approaches that still today can be a part of the solution to climate change. He aimed to protect lives, the environment and "*... to achieve savings from appropriate ecological planning, to improve prediction and placement, and to improve the human condition*" (McHarg 1998, p. 83). McHarg's book *Design with Nature* (McHarg 1969) is introduced by Mumford with the words:

"*Here are the foundations for a civilization that will replace the polluted, bulldozed, maschinedominated, dehumanized, explosion-threatened world that is even now disintegrating and disappearing before our eyes*" (Mumford 1969, p. 8).

NOTE/ *But if the approach has been out there for almost 70 years, why hasn't it been more used and refined in standard practice? This wonder has also been put forward by the Danish landscape architect Katrina Wiberg in her PhD: "A fundamental question is how the knowledge and relationally-based methods of ecological approaches to urban development and ecological planning have not yet been implemented on a larger scale" (Wiberg, p. 517).*

McHarg developed a method that included all sorts of environmental experts such as geologists, hydrologists, biologists, ecologists and so on. In a cross-disciplinary collaboration they make a layer-cake of information of a region, that works as a basis for suitability suggestions of land use (McHarg 1969). An example of the method can be seen in the section, *Approach: Urban design method to de-construct*, pp. 80-83. In more contemporary terms, McHarg's method explores the socio-ecological systems at the specific location, and suggest suitability not only to please humans, but also to optimize natural conditions through preservation.

"*McHarg seeks the intrinsic carrying capacity of land through a design process that respects, integrates, and facilitates multiple ecosystem processes, functions, and services*" (Yang & Li 2016, p. 22).

Landscape ecology

Based on the knowledge and ecological approaches that McHarg and other practitioners developed and performed within landscape architecture, several ecological concepts emerged. One of the more important ones from the 1980's was *landscape ecology* (Spirn 2013). The concept was an answer to deal with major issues such as climate change, that goes beyond the scale of local urban areas or individual entities. It became a promising tool for both ecologists and urban designers, as it works through the medium of landscape that deals with several scales (Pickett et al. 2013; Spirn 2013). Landscape ecology expands the spatial scale and focus on spatial heterogeneity consisting of both biological and social structures and functions of the ecosystem (Spirn 2013; Pickett et al. 2013; Forman 2008). Hereby the socio-ecological systems play a virtual role when studying ecology of the landscape. Different methods are used to examine and explore spatial variables or elements and their interrelationship, which are related to ecological processes.

Landscape urbanism

Landscape urbanism is another concept based on both the knowledge and ecological approaches applied in landscape architecture, and several ideas presented by different architects, among them Kenneth Frampton and Rem Koolhaas (Thompson 2012). It emerged at the turn of the century as a critique of the neotraditional urban design practice at the time, and it is concerned with environmental conditions in the wake of deindustrialization (Waldheim 2016). The concept was termed by Charles Waldheim, but it was already anticipated at the *Landscape Urbanism Symposium and Exhibition* that was held by the Graham Foundation in Chicago 1997 (Corner 2006). Much of landscape urbanism's legacy originate from North America, where the most influential practitioners are to be found at Harvard University and the University of Pennsylvania. Among these are Charles Waldheim, Mohsen Mostafavi, and James Corner, who also further developed the concept into the later *Ecological Urbanism*.

There are no exact methodology or definition of landscape urbanism, more it should be seen as a discourse consisting of ideas and a way of thinking of urban space. Architect Ian Hamilton Thompson tries to draw closer to a description of landscape urbanism through his list of ten tenets (Thompson 2012):

1. Landscape Urbanism Rejects the Binary Opposition between City and Landscape

2. Landscape Replaces Architecture as the Basic Building Block of Cities. Corollary: Landscape Urbanism Involves the Collapse, or the Radical Realignment, of Traditional Disciplinary Boundaries

3. Landscape Urbanism Engages with Vast Scales—Both in Time and Space

4. Landscape Urbanism Prepares Fields for Action and Stages for Performances

5. Landscape Urbanism is Less Concerned with What Things Look Like, More with What They Do

6. Landscape Urbanism Sees the Landscape as Machinic

7. Landscape Urbanism Makes the Invisible Visible

8. Landscape Urbanism Embraces Ecology and Complexity

9. Landscape Urbanism Encourages Hybridity between Natural and Engineered Systems

10. Landscape Urbanism Recognizes the Remedial Possibilities Inherent in the Landscape

Tenet number eight is of special interest when looking at ecology in urban design. Landscape urbanism has no exact way of working with ecology, but in much literature by both James Corner and Charles Waldheim, typical ecological terms are used, such as, *flow, self-organization, instability* and so on (Waldheim 2006; Corner 2006). Despite the lack of precision, landscape urbanism produces new ideas to include ecology in the urban field. Thompson describes:

"*We have learnt through the sciences of ecology and complexity that natural systems are dynamic, fluid, unstable, complex and indeterminate. A central insight of Landscape Urbanism, which it shares with Daoism, is that we must find ways to live harmoniously within this flux... Design and planning should not set themselves against natural processes in a misguided quest for permanence. Instead they should be responsive and catalytic, generating creative syntheses*" (Thompson 2012, p. 14).

James Corner do also try to describe landscape urbanism as a concept that holds together differences "*- difference in terms of the ideological, programmatic, and cultural content of each of those loaded and contested words "landscape," "urbanism"*" (Corner 2006, p. 23). Despite the many differences of the two terms, they work as a hybrid when brought together as one word. Corner emphasize the significant potential: "*...the ability to shift scales, to locate urban fabrics in their regional and biotic contexts, and to design relationships between dynamic environmental processes and urban form*" (Corner 2006, p. 24), which also corresponds to Thompson's description.

One of the characterizations of landscape urbanism is the principle to see the urban and all the artifacts within the physical space as landscape. An early example of this is OMA's Parc de la Villette (see more about the project in the section *Approach: Urban design method to de-construct*, pp. 80-83) (OMA n.d.). This project demonstrates the new understanding of landscape. Many architects did at the time, point out that *landscape* was lacking in the proposal. But if Parc de la Villette is seen through the lens of landscape urbanism the different buildings and objects termed *follies* are a part of the landscape as landscape elements with landscape functions. This understanding is based on the elimination of urban and rural or landscape and city dichotomy, as Spirn advocated in 1984 (Spirn 1984) (see previous section *Theory: Human and nature dichotomy*, pp. 26-33). Charles Waldheim do also describe this understanding as a key element within landscape urbanism:

"*Landscape Urbanism describes a disciplinary realignment currently underway in which landscape replaces architecture as the basic building block of contemporary urbanism. For many, across a range of disciplines, landscape has become both the lens through which the contemporary city is represented and the medium through which it is constructed...*" (Waldheim 2006, p. 11).

Another characteristic element of landscape urbanism is to address processes over time. Instead of focusing on processes of urbanization that creates spatial forms of urbanism, the focus is on processes that creates urban relationships. Corner describes that this element does not exclude spatial form "*... but rather seeks to construct a dialectical understanding of how it relates to the processes that flow through, manifest, and sustain it*" (Corner 2006, p. 28). This shift in focus emphasizes process's ability to shape the urban form, through multiple flows and forces, which is familiar with an ecological approach.

"*... the discipline of ecology suggests that individual agents acting across a broad field of operation produce incremental and cumulative effects that continually evolve the shape of an environment over time. Thus, dynamic relationships and agencies of process become highlighted in ecological thinking, accounting for a particular spatial form as merely a provisional state of matter, on its way to becoming something else*" (Corner 2006, p. 29).

A project that shows how various systems are set in motion is the project *Eastern Scheldt Storm Surge Barrier* by West 8 (West 8 n.d.). The project is a landscape design, located in the sea, and it is a storm surge barrier with infrastructural passage on top (see illustration 12). The 'island' has different plateaus with long sandy stretches covered with shells in black and white strips. At high tide, the black shells attract black sea birds, and the white shells attract white sea birds, which creates a dynamic landscape of camouflage. The project demonstrates how a dynamic process is created by the spreading of shells, and how the area of land furthermore has become a recreative area attracting humans. In this way landscape urbanism is "...*the development of a space-time ecology that treats all forces and agents working in the urban field and consider them as continuous networks of inter-relationships*" (Corner 2006, p. 30).

TOWARDS ECOLOGICAL URBANISM

Ecological urbanism builds on multiple traditions, ideas, concepts, and movements like landscape ecology and landscape urbanism. It gained currency around 2009, as Harvard University facilitated a conference named *Ecological Urbanism: Alternative and Sustainable Cities*

Ill. 12 Eastern Scheldt Storm Surge Barrier by West 8, showing the pattern of shells attracting white and black sea birds in a dynamic interrelationship with the tides (West 8 n.d.).

of the Future (Harvard University n.d.). It is also mainly Harvard University that has advanced and developed the concept over the years. Often it is directly correlated with the previous concept of landscape urbanism. In the book *Landscape as Urbanism*, Charles Waldheim (Waldheim 2016) expresses that there is a need to move from landscape urbanism towards ecological urbanism, to be able to address some of the major challenges in relation to sustainability. Ecological urbanism can be seen as stem or evolution of landscape urbanism that includes a more holistic approach and fine-grained use of ecology, to deal with environmental issues.

"*The emerging discourse of "ecological urbanism" has been proposed to more precisely describe the aspirations of an urban practice informed by environmental issues and imbued with the sensibilities associated with landscape. This most recent adjectival modifier of urbanism reveals the need for requalifying urban design as it attempts to describe the environment, economic, and social conditions of the contemporary city*" (Waldheim 2016, p. 179).

Ecological urbanism does enroll itself in the recent shift or change in the scientific field, as earlier outlined. It acknowledges the fundamental change going from perceiving ecosystems as equilibrium towards a non-equilibrium paradigm consisting of hierarchical patch dynamics. Spirn describes that Landscape Urbanism's idea of nature is that nature consists of a nexus of processes that create and sustain life, earth, and universe (Spirn 2012). To understand that nature is processes between social systems and ecological systems, is for Spirn fundamental to the ecological approach in urban design:

"*The idea of nature as consisting of the biological, physical, and chemical processes that create and sustain life, the earth, and the universe is fundamental to ecological urbanism. If one embraces this idea, then the false oppositions between city and nature, the given and the built, fall away*" (Spirn 2012, p. 8).

A way to deal with current challenges

Ecological urbanism clearly acknowledges that the current state of the world, with all its environmental problems is the epitome of the Anthropocene (see more at chapter 1, *Changing Global Threats*, pp. 14-15). It deals with problems that have been perceived as a 'design crisis' (Van der Ryn and Cowan 1995) and a result of ignoring the deep structures (Spirn 2012; Spirn 1993). Furthermore, the concept emphasize that human interventions, management, and designed ecosystems and landscapes has been unsustainable. "*In a broad sense, the state of the world is a consequence of the faulty design activities of humanity*" (Wu & Wu 2013, p. 211).

The main intention of ecological urbanism is to address major societal and environmental crises that threaten humanity and do so in a larger scale than has been typically undertaken by architects:

"*Ecological urbanism is critical to the future of the city and its design: it provides a framework for addressing challenges that threaten humanity, such as global warming, rising sea level, declining oil reserves, rising energy demands, and environmental justice, while fulfilling human needs for health, safety, and welfare, meaning and delight*" (Spirn 2012, p. 1).

In Mohsen Mostafavi's introduction *Why ecological urbanism? Why now?* to the book *Ecological Urbanism* (Mostafavi 2016), he faces several current global challenges such as, exploitation of the world's resources, mitigation from rural to urban areas, global warming, and growing population. He takes point of departure in these major challenges and ask the questions: "*What are we to do? What means do we have as designers to address this challenging reality*?" (Mostafavi 2016, p. 12). The response to these questions is Ecological Urbanism, that treat the urban as complex socio-ecological systems and with complex relations. Ecological urbanism can work as a framework that conjoin ecology and urbanism.

Mustafavi express the need for a new alternative design approach and suggest Ecological Urbanism as a way of turning global issues into "...*opportunity for speculative design innovations*" (Mostafavi 2016, p. 17). Ecological urbanism can be understood as a contemporary response to the ecological crisis:

"*The prevailing conventions of design practice have demonstrated a limited capacity both to respond to the scale of the ecological crisis and to adapt their established ways of thinking. In this context, ecological urbanism can be seen as a means of providing a set of sensibilities and practices that can help enhance our approaches to urban development. This is not to imply that ecological urbanism is a totally new and singular mode of design practice. Rather, it utilizes a multiplicity of old and new methods, tools, and techniques in a crossdisciplinary and collaborative approach toward urbanism developed through the lens of ecology. These practices must address the retrofitting of existing urban conditions as well as our plans for the cities of the future*" (Mostafavi 2016, p. 17).

Many cities worldwide are making sustainability policies and plans to obligate environmental challenges. Often these policies and plans result in 'ecological approaches' in the form of adding green spaces and focus on energy reduction. Mostafavi opens up the discussion of how ecological urbanism can expand this use of ecology, by asking the questions: "*Could such efforts be transformed by the approach of ecological urbanism? Couldn't the everyday elements, needs, and functions of the city be creatively imagined in new and unconventional ways that are not simply subjugated to the imperatives of the ecological*?" (Mostafavi 2016, p. 33). These questions imply that ecological urbanism expands the prevailing approach of ecology when address environmental issues.

To deal with the current state of the world, as urban designers and planners, ecological urbanism is suggested. To repeat Spirn's statement, ecological urbanism "*... provides a framework for addressing challenges that threaten humanity*" (Spirn 2012, pp. 1). Furthermore, ecological urbanism inspires urban designers and planners to design futures that are more sensitive to the environment, to challenge the established way of thinking (Mostafavi 2016). It adopts the new world thinking within the scientific field (introduced in the beginning), that has undergone a change or a shift over time. In other words, ecological urbanism seeks to advance the ecological approaches that designers may use to address global challenges. In this project the focus will be on urban climate related challenges in relation to hydrology.

ADVANCING THE PRACTICE OF ECOLOGICAL URBANISM

To advance the ecological approaches and hereby also the practice of ecological urbanism, three ecological concepts will be presented. The first concept is *spatial heterogeneity* and the second concept is *patch dynamic*. Both concepts are cornerstones to advance the understand of socio-ecological systems and they are by associated researchers suggested to bridge ecological principles and urban design (Wu & Wu 2013; Cadenasso et al. 2013). Furthermore, they provide a good insight into an ecological way of looking at the environment, that are necessary to know about when moving on to the last concept of *resilience*. In this project *resilience refers to the ability of complex socio-ecological systems to change, adapt, and transform in response to internal and externally generated hazards* (Davoudi 2012; Salata & Athene 2020; Pickett et al 2013; Walker & Salt 2006). To achieve this kind of resilience, this section will examine Anne Winston Spirn's idea of using ecological urbanism. Following her, ecological urbanism that advances ecological approaches is a way to design resilient cities. She presents six propositions and attached principles, that represent ecological urbanism. By following these propositions and principles, resilience through design can be achieved in urban socio-ecological systems (Spirn 2013).

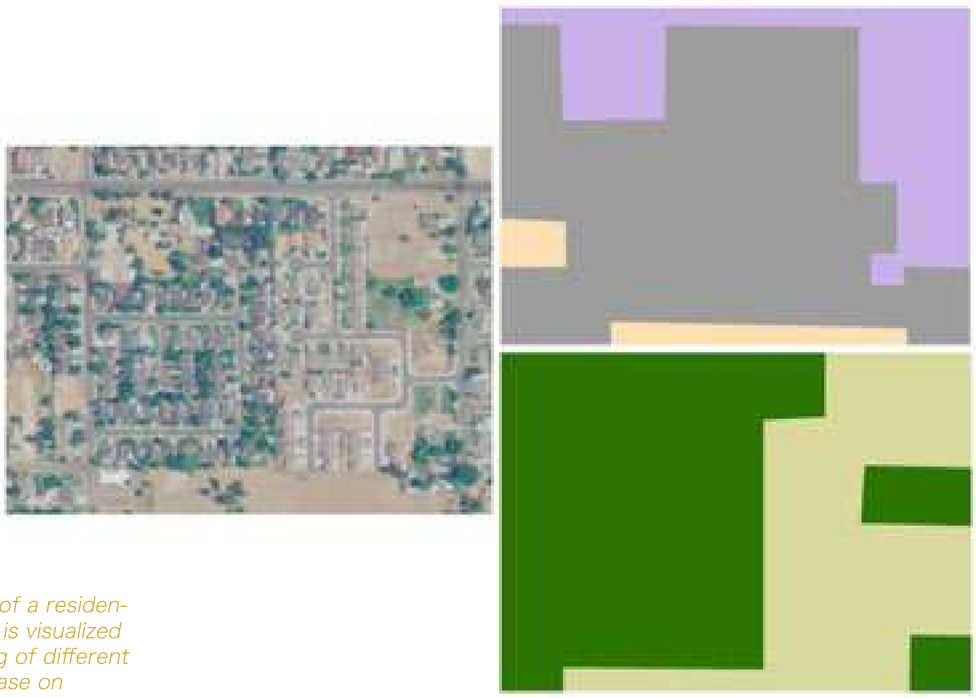
NOTE/ Resilience has been defined differently throughout literature. The used definition is a contraction of different phrasings.

Spatial heterogeneity and patch dynamic framework

Spatial heterogeneity is an ecological concept that describes the uneven distribution of elements in the spatial landscape. The application is relatively new to urban systems, but in best case it can be used to explore ecological functions of urban socio-ecological systems. In a research article, a team of ecologists and architects reflects on the use and understanding of spatial heterogeneity. They claim that the concept "*... serve as a bridge connecting ecology and urban design*" (Cadenasso et al. 2013, p. 108). It is a concept that enroll itself in the previously mentioned shift from the traditional equilibrium paradigm to a non-equilibrium paradigm. Previously traditionally ecologists have emphasized homogeneity in their experiments, but today spatial heterogeneity includes variations depending on the research focus (Cadenasso et al. 2013). Through the lens of ecology, heterogeneity can be mapped in different ways, but must often it appear as physical structures visualized as patches that differs in color and size, depending on specified variations within each patch. The interesting part is to find links between those patches or spatial heterogeneity (the structure) and ecosystem functions.

"*Such a link between structure and function suggests that a collaboration between ecologists and urban designers can fruitfully advance the understanding of urban areas as social-ecological systems and such a collaboration is imperative for designing resilient cities*" (Cadenasso et al. 2013, p. 108).

But what exactly forms the distribution of patches? As previously described each patch depend on specified variations. Those variations are defined by a chosen characteristic element of interest, that covers a spatial area. In urban design we are already familiar with different categories of variations such as land use or demographics in the landscape, that are often examined and visualized in multiple ways. These kinds of examinations can be understood as an examination of the spatial heterogeneity, that results in different patches in the landscape whose form, size and color depends on the variations of focus. An example can be seen at illustration 13, where the heterogeneity of a residential area in California is visualized as patches consisting of different size and color. The case on top examines the variations of building density, while the below examines the tree density.



Ill. 13 Heterogeneity of a residential area in California is visualized as patches consisting of different size and color. The case on top examines the variations of building density, while the below examines the tree density (Cadenasso et al. 2013).

When studying spatial heterogeneity, the medium of landscape, once again, becomes handy in the way that:

"*Landscapes are characterized by structure, function, and dynamics. Landscape structure describes the spatial arrangement of elements while landscape function refers to how ecological processes operate within that structure. Landscapes can also change through time as elements change through natural progressions or through disturbance and recovery processes*" (Cadenasso et al. 2013, p. 113).

It is the relation between structures and functions of the landscape that are interesting to explore, to get a deeper understanding of the socio-ecological systems, which again is "... *imperative for designing resilient cities*" (Cadenasso et al. 2013, p. 108). To overcome such an examination the spatial scale must be defined, as the concept of heterogeneity is not by itself scale depend. In theory the concept can be applied to study variations of bacteria in a soil sample, entailing a micro scale, or it could be a study of land use, which would typical be in means of kilometers. Within the defined boundaries the patches will occur.

Besides the determination of spatial scale, the temporal scale must also be determined. The temporal scale can cause changes in the variations within a single patch, which is termed *patch dynamic* (Pickett & White 1985). If a patch dynamic occurs it will cause either a change of the internal characteristics of the patch or a change of the boundaries of the patch (Cadenasso et al. 2013). As urban designers we can both analyze the current and historical patch dynamics of the landscape, but we do also affect it though design. By separating function from structure and to think of patch dynamics as a framework, is a way to apply an ecological approach. Wu and Wu present five key elements of patch dynamics, that summarizes what the concept is about (Wu & Wu 2013, p. 212).

1. Ecological systems are spatially nested patch hierarchies.

2. Dynamics of an ecological system can be studied as the composite dynamics of individual patches and their interactions.

3. Pattern and process are scale dependent.

4. Non-equilibrium and random processes are essential to ecosystem structure and function.

5. Ecological (meta)stability is often achieved through structural and functional redundancy and spatial and temporal incorporation of dynamic patches.

There is no exact model to visualize spatial heterogeneity. The example given here, uses patches but, it could be more creative mapping in line with urban design tradition. The important part is to determine the variations of focus, scope of research, and spatial and temporal scale. Based on these determinations the connection between structures and functions of the landscape can be explored. To conduct specific examinations of ecosystem functions would sometimes require an ecologist, as the knowledge level would exceed common urban design expertise. Despite this, it is a step towards interdisciplinarity and collaboration between urban designers and ecologists, that can advance the understand of socio-ecological systems and the application of the ecological approach in urban design. Also, the five key elements of patch dynamic are fundamental principles in ecological thinking, that are helpful to know before moving on to the concept of resilience.

NOTE/ This emphasize the importance of integrate knowledge and theories from different scientific fields into the urban design practice. Fortunately, this is also practiced in various architecture and design educations.

Ecological urbanism to design resilient socio-ecological systems

In Anne Winston Spirn's article *Ecological Urbanism: A Framework for the design of resilient cities* (Spirn 2013), she directly links ecological urbanism together with the concept of resilience. Spirn brings together studies within natural science and knowledge of the historical development of ecology in design practice, and hereby presents six propositions and attached principles that belongs to ecological urbanism. By following these principles and propositions resilience can be achieved.

NOTE/ Anne Winston Spirn's attempt to concretize urban design principles and concepts that can foster resilience, shares the same reflections as this project's research aim. Thus, this project will build on Spirn's prospections and principles, further explore concepts of resilience, and develop a Road Map that can inform and assess resilient climate adaptation of socio-ecological systems.

The first proposition is 'cities are part of the natural world,' which follow Spirn's earlier book *The Granit Garden, Urban Nature and Human Design* (Spirn 1984), where she made it clear that cities are a part of the natural world, consisting of ecosystems. Hence, the attached principal is to: "*Recognize cities as part of the natural world and design them accordingly*" (Spirn 2013, p. 8). The urban form can be adapted to natural processes, which becomes visible when thinking "... *in terms of the ways that human activities and urban form interact with natural processes of air (heat transfer and air flow), earth (geology and soils), water (water flow), life (reproduction, growth, and behavior), and ecosystems (flows of energy, information, and materials, succession of plant species and behavior of plants and animals)*" (Spirn 2013, p. 8).

The second proposition is 'cities are habitats'. Here the attached principles are: "*Design the city as a life-sustaining and life-enhancing habitat*" (Spirn 2013, p. 9) and: "*Celebrate the natural processes that shape the urban habitat and that sustain life, make them tangible and understandable*" (Spirn 2013, p. 10). The city must be managed and designed to sustain both the habitat of humans as well as non-humans. Each habitat has specific needs that must be considered. Human is attracted to life-processes, and they find purpose in the connection with nature (Lynch 1981), which can be made visible and tangible through the urban design.

The third proposition is 'urban ecosystems are dynamic and interconnected', which refers to the attached principle: "*Design the city as a whole, as well as every park, building, and district within that larger whole, as ecosystems that require minimal inputs of energy and resources to build and sustain*" (Spirn 2013, p. 11). Spirn points towards an optimization of ecosystems in the city, where all kind of waste from all our activities (e.g., consumption) should be a resource for another - seeking to make closed ecosystems at any ecosystem scale.

The fourth proposition is 'urban ecosystems are connected and dynamic,' with the first attached principle: "*Identify and portray the interplay of natural and social processes that shape and structure the city*" (Spirn 2013, p. 13). This principle refers to the communication through visual representations that designers must refine, to absorb the complexity of socio-ecological systems. Different mapping techniques are developed, and some those as well as the techniques used later in this project, is further elaborated in the section *Approach: Urban design method to de-construct*, pp. 80-83. The second principle attached to the proposition is: "*Address social and environmental challenges within appropriate boundaries at the appropriate spatial and temporal scales*" (Spirn 2013, p. 14). Ecosystems are interconnected, which means that one ecosystem can change another, thus it is important to address issues in the right scale, sometimes working with multiscale. Another principle is: "*Define multi-purpose solutions to comprehensively defined problems*" (Spirn 2013, p. 15). This principle is important and can be resources limiting, as several urban problems is addressed at the same time through integrative and multi-purpose solutions. The solutions should focus on both social, economic, environmental, and aesthetic dimensions. Here the concept of green infrastructure has proven to be efficient (the concept of green infrastructure will be further elaborated in the next theoretical section *Theory: Adaptation through resilient socio-ecological systems*, pp. 52-69). The last attached principle is: "*Take account of history*" (Spirn 2013, p. 16), which can help give a deeper understanding of the cultural landscape and its dynamics in a time perspective. It gives insight in social and cultural coherence with the landscape and its processes. Spirn suggest that urban designers ask themselves the question: *What is this place in the process of becoming?*.

NOTE/ Seeing places as processes of becoming is also expressed by the planner Simin Davoudi in her research of resilience.

The fifth proposition is 'every city has a deep structure or enduring context'. The first principle is: "*Adapt the physical shape and structure of a city – the infrastructure of roads and sewers, the buildings and parks – to its deep structure*" (Spirn 2013, p. 18), which is a principle that speaks into the heart of this project. The ignorance or opposes of the deep structures can cause unnecessarily amounts of energy, time, coasts, and materials. An example of this has previous been presented through the project of West Philadelphia's Mill Creek watershed and neighborhood (see quote at chapter 1, *Motivation*, pp. 16-17). Spirn does directly link the deep structures to resilience:

"*Deep structure remains crucial to the history and future of a place – why it was settled, its initial location, its transportation routes, its economic development and population distribution, the character of its buildings, streets, and parks, and the health and safety of its residents. The design of cities that are in agreement with the deep structure of a region, rather than counter to it, is essential to fostering resilient urban form*" (Spirn 2013, pp. 17-18).

The second principle is: "*Anticipate and exploit natural catastrophes*" (Spirn 2013, p. 18). Disturbances to the socio-ecological systems in the for of extreme events and hazards, can be hard to predict. The accuracy of future predictions increases in present time, especially regarding climate related flood. Designers must use the existing knowledge and let oneself be inspired by the ecological field that acknowledge unpredictable natural events and work with adaptation to change.

NOTE/ Is 'natural hazards' only product from environmental disturbances? Several researchers among these are Anuradha Mathur and Dilip da Cunha, enroll human activities to be a natural hazard, when the deep structures are ignored (Mathur & Cunha 2001 & 2009; Spirn 2013).

The last proposition is 'urban design is a powerful tool of adaptation'. Spirn states that every city at some point needs to adapt to certain circumstances. Her first principle is: "*Design resilient cities*" (Spirn 2013, p. 19). As the introduction to this section described, resilience refers to the ability of complex socio-ecological systems to change, adapt and transform in response to internal and externally generated hazards (Davoudi 2012; Salata & Athene 2020; Pickett et al 2013; Walker & Salt 2006). As some systems are more resilient than others, designers must investigate the specific site, and work with responds to natural hazards. As Spirn's previously principles suggest: "*Urban form that is congruent with the "deep structure" or enduring context of a city's natural environment will be more resilient*" (Spirn 2013, p. 19). The second principle that Spirn brings forward is: "*Act comprehensively and incrementally*" (Spirn 2013, p. 20). Learnings from the modernism has shown that large-scale plans can have unintended consequences, therefore Spirn proposes an incrementally approach that makes ongoing changes possible. However, she emphasizes that large-scale frameworks with goals for long-term change can strengthen the incrementally development.

There exist a lot of literature and research about both natural and social systems, as well as guiding models of ecological urbanism. Despite that, many recent studies dealing with ecological urbanism has been criticized to ignore the existing literature and research (Spirn 2013; Waldheim 2006; Mostafavi & Doherty 2010). Instead of extending the tradition of ecology in urban design, they reinvent models repeatedly, which seems irrational taking the amount of existing work into account. Hence, this project seeks to build on top of the existing ecological tradition within urban design, which has just now been described in the preceding.

The last part of theory will elaborate on resilience and further introduce interrelated concepts, that can be used to design resilient cities. Some of the concepts will reflect the thoughts and approaches already presented, which hopefully creates a common thread through the theory.

CORE

THEORY: CLIMATE ADAPTATION THROUGH RESILIENT SOCIO-ECOLOGICAL SYSTEMS

The concept of *resilience* has in recent years become widespread in several fields along with the increased awareness of climate change. It is claimed that the concept can deal with the perceiving of the world as more complex and uncertain (Davoudi et al. 2013; Davoudi 2012; Wu & Wu 2013; Holling 1973; Brown 2019). Seen from this perspective resilience holds a potential to be used in the context of climate adaptation, and act as a bridging concept between climate adaptation and urban planning and design. The question is then, how to translate resilience into the urban planning and design field? In the following the concept of resilience and the dynamic nature of resilience within socio-ecological systems will be unfolded. Thereafter, related concepts, principles, and ideas with relevance to urban designers and planners will be presented, to understand how a system's resilience can be built in relation to climate adaptation.

TYPES OF RESILIENCE

Resilience has existed in the ecological field since the 1960's but was first introduced and linked to social systems by Crawford Stanley Holling in 1973. Holling made resilience usable for other disciplines than ecology, including urban design as his concept of resilience seeks to understand and manage socio-ecological systems (Wu & Wu 2013).

In his article *Resilience and Stability of Ecological Systems*, he distinguishes between ecological systems being *stabile* or *resilient*. Whereas stability is "... *the ability of a system to return to an equilibrium state after a temporary disturbance*" (Holling 1973, p. 252) resilience "... *determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist*" (Holling 1973, p. 252). This distinction marks a shift from traditionally perceiving and examine ecological system's behavior in relation to one equilibrium state, towards include a system's resilience properties entailing multiple equilibriums (Davoudi et al. 2013; Davoudi 2012). In this way a system after a disturbance can either return to the same single equilibrium state as an expression of stability, or it can return to a new equilibrium state, adapting and absorb changes yet keeping the main structure of the system, as an expression of resilience. Today, the distinction is known as two different types of resilience. The first one is termed *engineered resilience*, while the other is termed *ecological resilience*. The current discourse has furthermore expanded Holling's definition of resilience to "... *include the system's abilities to self-organize and adapt to changes, and also contributions that make resilience more pertinent to social and social-ecological Systems*" (Wu & Wu 2013, p. 214).

SCOPE OF PROJECT

This project will explore urban areas that are complex socio-ecological systems, and it will delimit itself to only consider resilience in relation to disturbances from climate change. It is important to keep in mind that focusing on a systems response to only specific disturbances, can cause inattention on the system's general resilience (Wu & Wu 2013). Furthermore, the focus will be on biophysical factors that has an impact on the system's resilience, such as build environments, landscapes, climate change, and so on. It will also include some social factors, as e.g., culture, but other important factors such as law, economy, citizen involvement, and emergency preparedness will not be included (this will be elaborated in the later presentation of the Road Map, as well as in the evaluation).

In addition to engineered resilience and ecological resilience a third type of resilience, termed *evolutionary resilience* has been developed. All three types defer in relation to time and process of absorbing shocks or disturbances. In the following the three types are characterized:

Engineered resilience refers to a system's ability to 'bounce-back' to a steady state or equilibrium as fast as possible after an external disturbance. In this way the same system with its structures and elements will be re-established as it was before the disturbance, and hereby aim stability that keeps a system unchanged. Resilience is then a measure of "... *the resistance to disturbance and the speed by which the system returns to equilibrium*" (Davoudi 2012, p. 300).

Ecological resilience learns from a disturbance and implement changes that can increase resilience towards new external or internal disturbance, but at the same time remain the main structures of the system. For ecological resilience "...*resilience is defined not just according to how long it takes for the system to bounce back after a shock, but also how much disturbance it can take and remain within critical thresholds*" (Davoudi 2012, p. 300). It is a kind of adaptation that 'bounce forward' to a new equilibrium instead of bouncing back to a single one like engineered resilience. The intension is to sustain and improve a certain regime, thus the adaptive capacity becomes important (Ernstson et al. 2010).

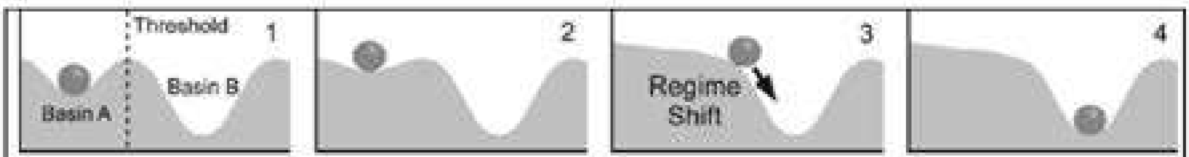
Evolutionary resilience (or socio-ecological resilience) is the last developed resilience type. Instead of working with one equilibrium state or several, this type of resilience goes beyond equilibrium as it understands systems as everchanging (Davoudi et al. 2013). The idea is to use either external, internal, or even no disturbances to make a transition. The main structure of a system is thus changed, as it 'transform-forward' to accommodate a new state, also known as a 'regime shift'. The transformative capacity is essential to be able to trigger a transition of the system towards a more preferable regime (Ernstson et al. 2010). This can also happen as a result of a system crossing a threshold that makes the system change with different feedbacks (Walker & Salt 2006) (the idea of *thresholds* will be further elaborated). Evolutionary resilience covers the "... *ability of complex social-ecological systems to change, adapt or transform in response to stresses and strains*" (Davoudi et al. 2013, p. 309). Hence, it shares the same perspectives with socio-ecology as they both revolve around several processes and ever-changing systems. Davoudi express that "... *evolutionary resilience, with its rejection of equilibrium, emphasis on inherent uncertainty and discontinuities, and insight into the dynamic interplay of persistence, adaptability and transformability, provides a useful framework for understanding how complex socio-ecological interdependencies work*" (Davoudi 2012, p. 306).

THRESHOLDS AND REGIME SHIFTS

Resilience in socio-ecological systems follows principles of change when a system moves from one stable state to another, as the resilience of the system decreases. Illustration 14 shows how a system with relatively high resilience and stability are located in basin A. As the system loses resilience the depth of the basin will decrease and the system will draw closer to a regime shift, which will occur when the threshold is crossed due to smaller or larger disturbances. When a system's resilience decreases a smaller and smaller disturbance will trigger the system to cross the system's threshold, leading to a state B (basin B) (Ernstson et al. 2010; Wu & Wu 2013).

The changes of a system leading to a regime shift, can be caused by a combination of both fast and slow variables (Ernstson et al. 2010). A slow variable such as sea level rise will move the system closer to its threshold, whereas a fast variable such as flooding will trigger the crossing of the threshold leading to a regime shift.

For urban designers and planners, physical changes and interventions can change the system's resilience. Some modifications can entail lower resilience, while other modifications can improve the resilience. Thus, it is relevant to first understand how the dynamic of socio-ecological systems work, and it is relevant to know about resilience theory and related concepts, ideas, principles, and knowledge that can enhance the designing and managing of more resilient socio-ecological systems (Wu & Wu 2013).



Real world examples:	Real world examples:	Real world examples:	Real world examples:
A healthy natural grassland ecosystem that is relatively resilient.	A degraded grassland due to overgrazing or prolonged droughts that is less resilient.	A grassland that is shifting into a desert-like system due to overgrazing or climate change.	A previous grassland has now become a shrubland or a desertified land.
A well-developed and managed city that is relatively resilient at present, but can shift into a different regime due to a disaster.	An urban system that has little resilience due to increasing environmental damage, social inequality, etc.	A city that is experiencing large-scale civil strife, escalating violence, hunger, or population crash.	An un-resilient city that has high poverty and crime rates and devastated natural environment, or a "ghost town."

Ill. 14 As a system's resilience decreases, smaller and smaller disturbances will trigger the system to cross the threshold, leading to a regime shift – illustrated as the ball rolling from basin A to B (Wu & Wu 2013, p. 215)

THE ADAPTIVE CYCLE

Urban areas consist of socio-ecological systems, that within resilience theory are understood as *complex adaptive systems*. Complex adaptive systems are defined as: "*... a system composed of a heterogeneous assemblage of types, in which structure and functioning emerge from the balance between the constant production of diversity, due to various forces, and the winnowing of that diversity through a selection process mediated by local interactions*" (Levin 1999). These systems are recognized to move through four phases illustrated by the *panarchy model of adaptive cycle* shown on illustration 15. 'Panarchy' refers to social or natural system's hierarchical structure, where each system is "*... interlinked in never-ending adaptive cycles of growth, accumulation, restructuring, and renewal*" (Holling 2001, p. 392), across temporal and spatial scale. In other words, the adaptive cycle shows the dynamic nature of complex adaptive systems or socio-ecological systems.

Davoudi describes that the adaptive cycle "*... does not in itself offer a framework for 'measuring' resilience, but rather it offers an evolutionary understanding of resilience as continually altering, as the system adapts and changes*" (Davoudi 2012, p. 310). Resilience capacity can be seen not as a being but as a becoming, (Davoudi 2012, p. 304) thus it is a process of change.

Each of the individual infinity curves is a system working at different scales, hence the adaptive cycle is based on a multiple-scale concept, that indicates interconnection where disturbances in the local scale can affect the above or below scale system. Each system is divided into four phases that are characterized by different functions, all together creating a change in the system's structure.

→ The *growth phase* (r) is characterized by rapid accumulation of resources (capitals), competition, seizing of opportunities, rising level of diversity and connections, and high but decreasing, resilience.

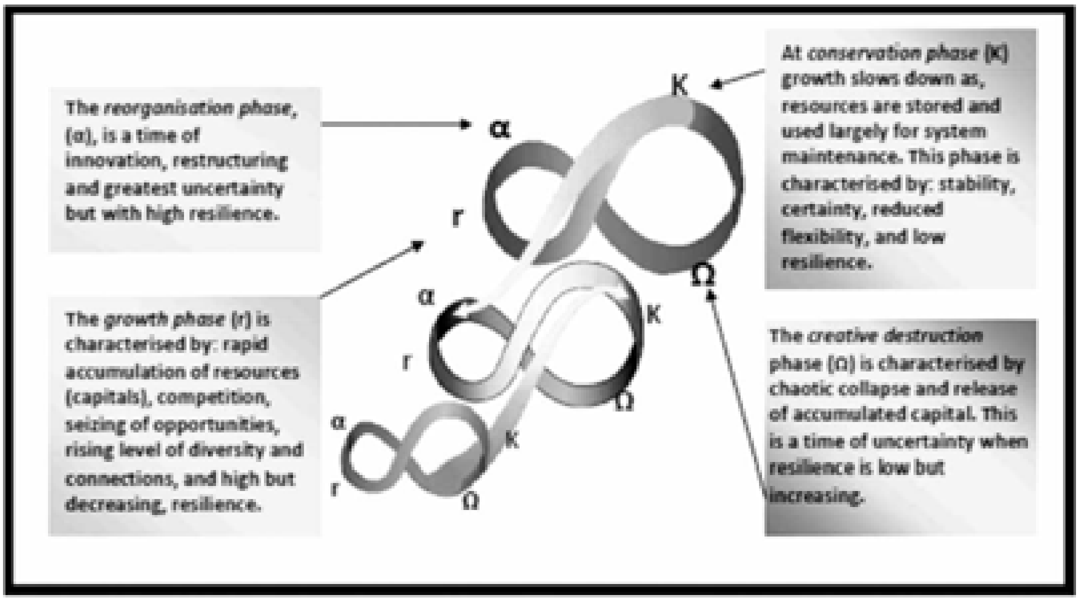
→ The *reorganization phase*, (α), is a time of innovation, restructuring and greatest uncertainty but with high resilience.

→ At *conservation phase* (K) growth slows down as, resources are stored and used largely for system maintenance. This phase is characterized by stability, certainty, reduced flexibility, and low resilience.

→ The *creative destruction phase* (Ω) is characterized by chaotic collapse and release of accumulated capital. This is a time of uncertainty when resilience is low but increasing.

(Davoudi et al. 2012, p. 303)

As presented in the previously section of theory (see *Theory: Ecology in urban design*, pp. 34-51) the relation between structures and functions are interesting to explore, to get a deeper understanding of the socio-ecological systems. This is exactly what the adaptive cycle can help urban designers to get. The spatial patterns (structures) are closely related to the system's processes (functions). As a simple example the process of optimizing infrastructure in cities has created structures of urban sprawl. Another example is the slow changes of rising sea water that creates flooding and might push/trigger the creative destruction (Ω) of the ecosystem. After the destruction the reorganization phase will enter (α) which will leads to the growth phase (r), that can either reach a similar or another conservation phase (K) with higher stability.



Ill. 15 The adaptive cycle (Davoudi 2012, p. 303)

RESILIENCE AND SUSTAINABILITY

As earlier mentioned, several cities are working with sustainability policies, with the intension to meet human and environmental needs without undermining future generation's opportunities to meet their needs (The World Commission on Environment and Development 1987). To achieve sustainability, it is widely recognized that actions and plans must focus and consider both the social, economic, and environmental realm. Within urban planning and design, sustainability is addressed through the notion of *sustainable cities*, which has gained significance as UN's sustainability goal number 11 is 'Sustainable Cities and Communities' (UN n.d.). It refers to one "... *in which an open social process articulates shared goals for achieving social, environmental, and economic norms, and in which mechanisms of resilience in each of the three realms are in place*" (Picket et al. 2013, pp. xxii). As the quote implies, sustainable cities and resilience are related concepts, whose relationship several scholars have indicated to hold a potential (e.g., Pickett et al. 2013: Wu & Wu 2013; Delgado-Ramos & Guibrunet 2017). A potential that can be transferred to climate adaptation, where sustainability may be achieved thorough resilience.

As previously mentioned, resilience refers to the ability of complex socio-ecological systems to change, adapt and transform in response to internal and externally generated hazards (Davoudi 2012; Salata & Athene 2020; Pickett et al 2013; Walker & Salt 2006). This definition defers from sustainability. Whereas sustainability refers to a set of socially constructed goals, resilience refers to a system's ability or capacity to change, adapt, and transform. Thus, resilience understood as a process of change, may serve as a guiding principle to achieve sustainability that formulate the outcome and desirable visions of the future (Wu & Wu 2013; Delgado-Ramos & Guibrunet 2017). Wu and Wu describe how sustainability should be understood in relation to the adaptive cycle:

"*From a resilience perspective, sustainability is not about maintaining a system at its equilibrium state by reducing the variability in system dynamics or optimizing a system's performance, but rather sustainability should focus on the system's capacity to create and test opportunities and maintain adaptive capabilities. Thus, resilience is the key to the sustainability in social-ecological systems... To achieve sustainability is not to get stuck in the conservation phase within an adaptive cycle, but rather to maintain proper operations of all four phases within each cycle as well as harmonic linkages between adjacent cycles across scales in space, time, and organization*" (Wu & Wu 2013, p. 219).

Even though systems follow the four phases in the adaptive cycle, the transformation itself should not be understood as an object of sustainability. Not all transformations are sustainable, some may even work against it. Therefore, Pickett enhance the importance of setting sustainability goals, and then identify how to reach the goals through right managing and designing of adaptive capacity (Pickett 2014).

BRIDGING RESILIENCE AND CLIMATE ADAPTATION PLANNING

In the end 1990's the complexity in flood risk assessment was understood and the term resilience emerged within flood risk management (Herath & Wijesekera 2020), simultaneously with the understanding of urban areas as ecosystems modified by human (see *Theory: Ecology in Urban Design*, pp. 34-51). In this regard, resilience became a promising concept to address uncertainty in relation to the external climate-related disturbances to urban socio-ecological systems. Especially evolutionary resilience that require forward thinking is interesting to deal with long-term perspectives, as uncertainty increases along with the expanded timeframe. It entails that the emphasis on 'short-term damage reduction' turn towards 'long-term adaptive capacity building' (Davoudi 2012). It also marks a shift in nature and world view "... *from mechanical and predictable to chaotic, complex, uncertain and unpredictable*," (Davoudi 2012) which climate change is further enhancing. Wu and Wu states that: "*Only by viewing urban regions as complex socio-ecological systems with feedback loops, cross-scale interactions, and inherent uncertainties can we design resilient cities*" (Wu & Wu 2013, p. 226), meaning that an understanding of the adaptive cycle is needed to increase resilience in cities, which are highly relevant for urban designers. Urban development can for instance cause depletion of ecosystem services (ecosystem services will be elaborated later) at a specific location, which will result in a decreasing resilience of the system. Other relevant examples for urban designers will be presented later.

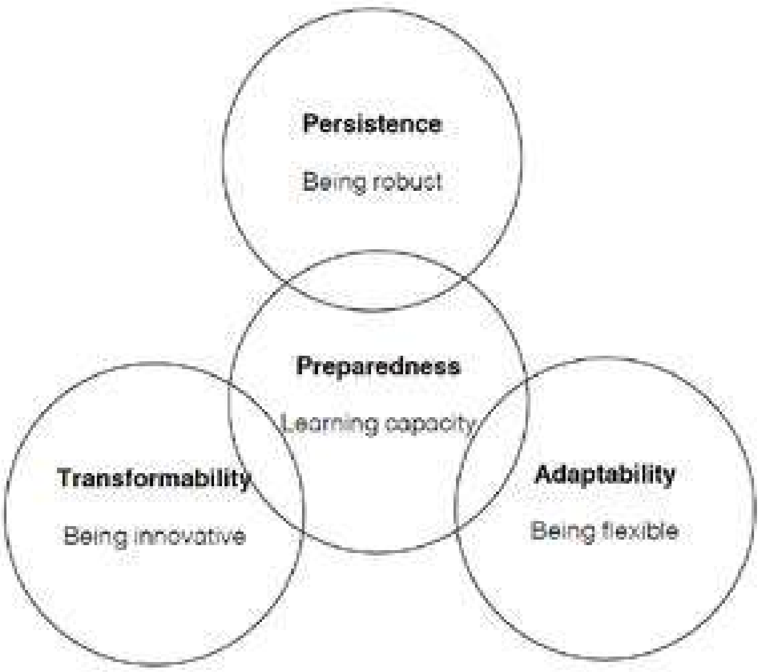
Within the climate change research, resilience is defined as: "*The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation*" (IPCC 2018, p. 557). This definition focuses on the ability to cope or adapt to disturbances and still maintain the system's main structure, which is similar to ecological resilience, but it does also enhance reorganization after a disturbance and maintain a capacity for transformation, which is similar to evolutionary resilience. Both types of resilience have by several researchers, been emphasized to contain a potential acting as a concept or tool within urban design and planning (Pickett et al. 2014; Wu & Wu 2013; Davoudi et al. 2013; Davoudi 2012).

Preparedness

In the adaptive cycle, the phase running from the creative destruction (Ω) to the reorganization (α) is a phase where disturbances or crises is turned to opportunities, thus it is a phase of innovation and transformation that "... *depends on the capacity to imagine alternative futures*" (Davoudi 2012, p. 303). But how do social systems increase the capacity to imagine these alternative futures? Davoudi et al., (2013) presents a *framework for resilience building* in relation to climate adaptation (see illustration 16). The conceptual framework consisting of four dimensions; *persistence, transformability, adaptability*, and *preparedness*. In particular preparedness is an interesting dimension, as it acknowledges human actions and interventions as a part of resilience. Opposed to non-humans, humans act with attention. Resilience is then dependent on the learning capacity in the form of preparedness, which imply that learning from history and earlier experiences resulting in specific interventions has an impact on the system's resilience.

"*The capacity to envisage and explore different futures suggested through a fuller examination of outcomes at different temporal and physical scales—with willingness to expose and address the 'information gaps' that emerge enroute— is an essential part of the preparedness, which our model places at the centre of Resilience*" (Davoudi et al. 2013, pp. 319-320).

The quote does imply that uncertainty in the form of 'information gaps' can be used and create value, when exploring possible futures. Furthermore Davoudi et al., states that it can sparks the creativity: "... *the emphasis is on the ubiquity of change and its inherent uncertainties, which can be a source of creativity*" (Davoudi et al. 2013, p. 320).



Ill. 16 Framework for resilience building consisting of four dimensions; persistence, transformability, adaptability, and preparedness (Davoudi et al. 2013, p. 311)

The framework highlights the importance of using history and uncertainties to create new futures. The whole framework differs from the ecological use of resilience, as preparedness is in contrast with systems' ability to 'self-organize'. Social-ecological systems has an opportunity to apply the learning capacity or preparedness when planning. If the social learning capacity increases the chances of enhancing persistence, adaptability and transformability are improved (Davoudi et al. 2013).

The presented framework for resilience opens a door for a new way of thinking, when planning for climate change, but it doesn't cover more specific implementation that physical planning handles. The potential of resilience has been tried out in many different adaptation strategies, that focus on 'resilience-building'. The Rockefeller Foundation established a network named, *100 Resilient Cities* that helps cities around the world to increase resilience to social, economic, and physical shocks or disturbances (Rockefeller Foundation n.d.). The danish municipality Vejle was a part of the network and committed themselves to create 'Vejle's resilience strategy' (2016-2020) (Vejle Kommune 2016). The strategy works with four different domains: *the co-creative city, climate resilience, social resilience*, and *smart city*. Focusing on climate resilience, Vejle aim to protect the city and use the water as an asset for urban and social capital, by e.g., developing a new urban area named Fjordbyen. The area will be a laboratory to explore innovative solutions in relation to flooding. Moreover, a new district, Rosborg, aims to develop as a green city with recreative areas and green connections to the surroundings. Another initiative in relation to mobility is the planning of a new 'cycle super-highway' through the center of Vejle. It should increase green mobility and move modes of traffic from cars to bicycles. Several of the initiatives in the strategy share principles with the concept of *Green Infrastructure*, which will be further elaborated later. New neighborhoods with the focus on developing green areas and mobility connections across the city similar with green corridors, can be referred to as green infrastructure.

Despite the increased emergence and use of resilience in climate adaptation strategies, there are no complete operational guideline of practice to build resilience. Resilience is an expression of the individual city's understanding of the term and different tools are used to reach it (Salata & Athena 2020; Beevers et al. 2021).

TENDENCIES, CONCEPTS, PRINCIPLES, AND IDEAS IN RELATION TO RESILIENT CLIMATE ADAPTATION

Since resilience isn't instrumentalized in climate adaptation planning and design the remaining text will examine different approaches and tools that can affect resilience-building. In the following the tendencies and strategies of climate adaptation will be outlined, comprising the approaches; *protect, accommodate, retreat*, and *avoid*. They represent different tools to reach resilience. Furthermore, concept, principles, and ideas in relation to resilience will be presented. *Green Infrastructure, Ecosystems, Diversity, Modularity, Connectivity, Redundancy*, and *Safe-To-Fail Design Experiments* will be elaborated.

Strategies: Protect, Accommodate, Retreat, and Avoid

In the past technical and engineered flood protection measures was isolated from spatial planning and design. Issues of increased flood risk due to climate change was solely seen as challenge only to be addressed by technical professions. This has changed in recent practice where several professions are involved, including spatial planners and designers. Flood risk are of course a concern for many, as it affects several units, authorities, communities, and locals.

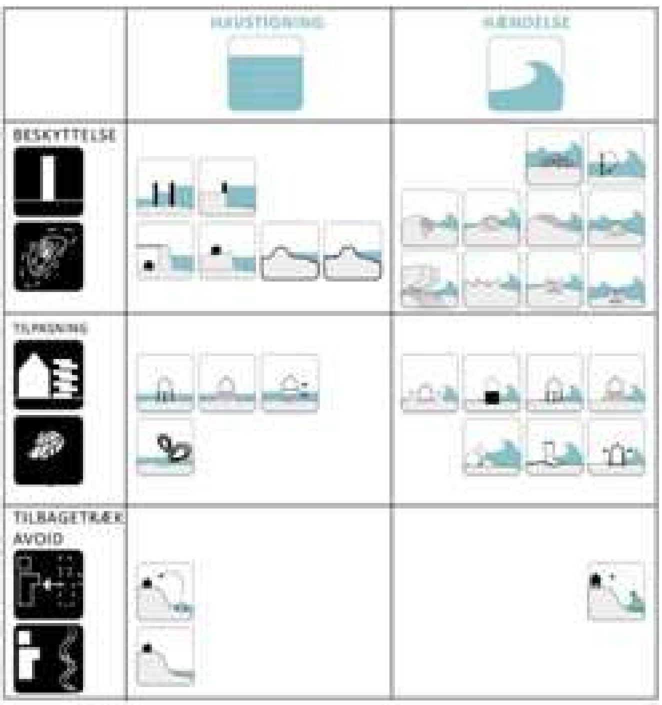
IPCC's climate change assessment report from 1990 outlines three approaches to managing increased sea level rise: *protect, accommodate* and/or *retreat* (IPCC 1990, pp. 146-150). In more recent research a fourth approach has emerged, termed *avoid* (Doberstein et al. 2018). Together these four approaches are seen as way to build resilience, not only to address rising sea water level but also to address the increased risk of flooding in general. The four approaches are illustrated at illustration 17. The first approach, *protection,* is the most used, often with a short-term purpose, with hard or soft protection such as sea walls, dikes, scour protection, dune building, beach nourishment and elevation of land. The aim is to reject the water and keep the build structures as they are. The second approach, *accommodation,* is linked to adaptation often understood as medium-term purposes in the form of, elevated homes, flood storage areas, or in general constructions that invite water into the city and finds alternative ways of living with the water. The third one is *retreat*, that refers to areas that due to flood risk or as an emergency response are phased out. This approach is long-term as it releases land to flooding and buildings are moved. The last one is *avoid*, *NOTE/ An avoid approach can prevent or avoid backfire in the long-term. In Katrina Wiberg's PhD she suggests that left-over-spaces can be kept free of buildings, so that future generations can use the areas to remedy flooding (Wiberg 2018).*

NOTE/ 'Retreat' often meets political opposition, as one has to compromise with the traditional habit of expanding land and thinking bigger.

which is also a long-term approach, that reflects both what we know and what we don't know in relation to future predictions. This approach comprehends keeping areas free of buildings, to remedy future needs (Fryd & Jørgensen 2019; Doberstein et al. 2018; Jørgensen 2020; Dansk kyst- og naturturisme 2020; IPCC 2019).

The retreat and avoid approach both treats the long-term perspective, and they are notable in a long-term resilience perspective, that this master thesis address. They demonstrate an acceptance and acknowledgement of risk, pointing towards areas that are not well suited for long term investment and preservation. The concept of 'design to move up and in' is a way to transform these areas, by retreat flood exposed areas, often located in depressions, and move them upwards in the landscape (Harvard GSD 2019). Hence new futures must be considered in the same manner as evolutionary resilience advocates. The new futures gained through the retreat and avoid approaches can both be implemented through land-use regulations. Current role of spatial planning is to organize land use corresponding to future advantageous, thus flood risk in coherence with different types of land use becomes important. Land use as a regulating tool as well as an explorative tool in analyzing socio-ecological systems can help reaching resilience (Salata & Athena 2020).

"*The inextricable link between water and land use activities which plays a major part in the concept of evolutionary resilience causes chains of impacts and responses that are intertwined and interactive*" (Herath et al. 2020, p. 4).



Ill. 17 Principles of climate adaptation solutions collected in a matrix, shows how different solutions are connected to slow variables of sea level rise or fast variables of extreme events. The solutions are divided into three categories protect, accommodate, retreat and avoid (Wiberg 2019, p. 52)

Tendencies in planning

Planning practice has traditionally focused on engineered resilience, seeking to plan for 'spatial equilibrium' and 'bouncing back' to the known (Davoudi 2012). *Probability-based risk assessment* is used to rationally determine the right level of protection based on flood frequency and expected annual damage assessment (Herath et al. 2020). The most used type of resilience is hard climate protection to protect the existing build structures. When the hard defenses aren't strong enough and the structures are damaged, identical structures at the same location are rebuild, reaching the same stabile domain. "*In these assessments the parameters of flood events are considered as stationary and fixed and therefore, flood control structural measures had been designed assuming the stationary behaviour of hydrological system*" (Herath et al. 2020, p. 2). Perceiving probability-based risk assessment as stationary and fixed, strengthens the motive to build in flood exposed areas, because measures to a certain or 'fixed' level of protection appears as sufficient. In worst case this can create an "... *increase of flood damage potential as a result of a flood control infrastructure*" (Herath et al. 2020, p. 2).

NOTE/ The Levee-effect is an examples of flood control infrastructure that increases the flood damage potential. When levees are built, they create a false sense of security for residents, thus they invest more money in their housing which increases the damage potential.

Architect and researcher in city planning Gertrud Jørgensen explains that in Denmark during the 1900s, we increased our technical skills which somehow lead to losing respect for the natural foundation when building (Jørgensen 2019). An example is the worldwide strategy, transforming old industrial harbors into new attractive residential and business areas close to water. Defense measures based on probability-based risk assessment is used, but it only predicts flood events for a fraction of the area's total lifetime. In other words, we build in areas that we sometimes know for sure will be challenged by future climate, and we build in areas that contain a lot of uncertainty. Despite this fact we still pursue this kind of strategy today.

As earlier stated, planning practice is traditionally focused on engineered resilience implying hard, grey and single-minded solutions to solve climate related challenges. This approach contrasts with soft, green, and multifunctional solutions that is slowly gaining ground. At the webinar *Human Flood Interactions in a Changing Climate*, 2021, Professor Giuliano Di Baldassarre ask the question: "*It seems like we have gone from green systems to technical systems, but how do we go from technical systems to green systems?*" (Baldassarre 2021). Projects that are trying to answer his question is e.g., Holland's governmental design program named *Room for the River*, that demonstrates a shift from historical emphasis on technical and hard solutions towards embracing and making space for the water in the city. Holland has addressed water and flood challenges in many years, as 2/3 parts of the country is below the water table. Many water strategies and plans has been carried out. In general climate solutions and water management has been dominated by hard solutions with dikes and levees, that in recent years has turned towards more soft measures that embrace water and welcomes it into urban spaces as e.g., *The Sand Motor* in Ter Heijde (Resilient the Hague n.d.), shown on illustration 18 and Rotterdam Weather Wise Program 2018 (Gemeente Rotterdam et al. 2018), shown on illustration 19. Especially Rotterdam's approach to address water issues has changed significantly. The water is used as a recreative element in the city, local retention of water using buffer zones, green roofs and facades, water plazas, and infiltration ponds.

Other projects and initiatives do also work with innovative approaches that includes more hybrid, soft and nature based climate adaptation e.g., *Coast to Coast Climate Challenge, The cities and the rising sea water* (translation from Danish), *DNNK*, and the EU project *Building with Nature* (C2C CC n.d.; Realdania n.d.; DNNK n.d.; Inerreg North Sea Region n.d.) All the projects support the shift in approaches from soft to hard and back (Shannon 2013). The new tendency;

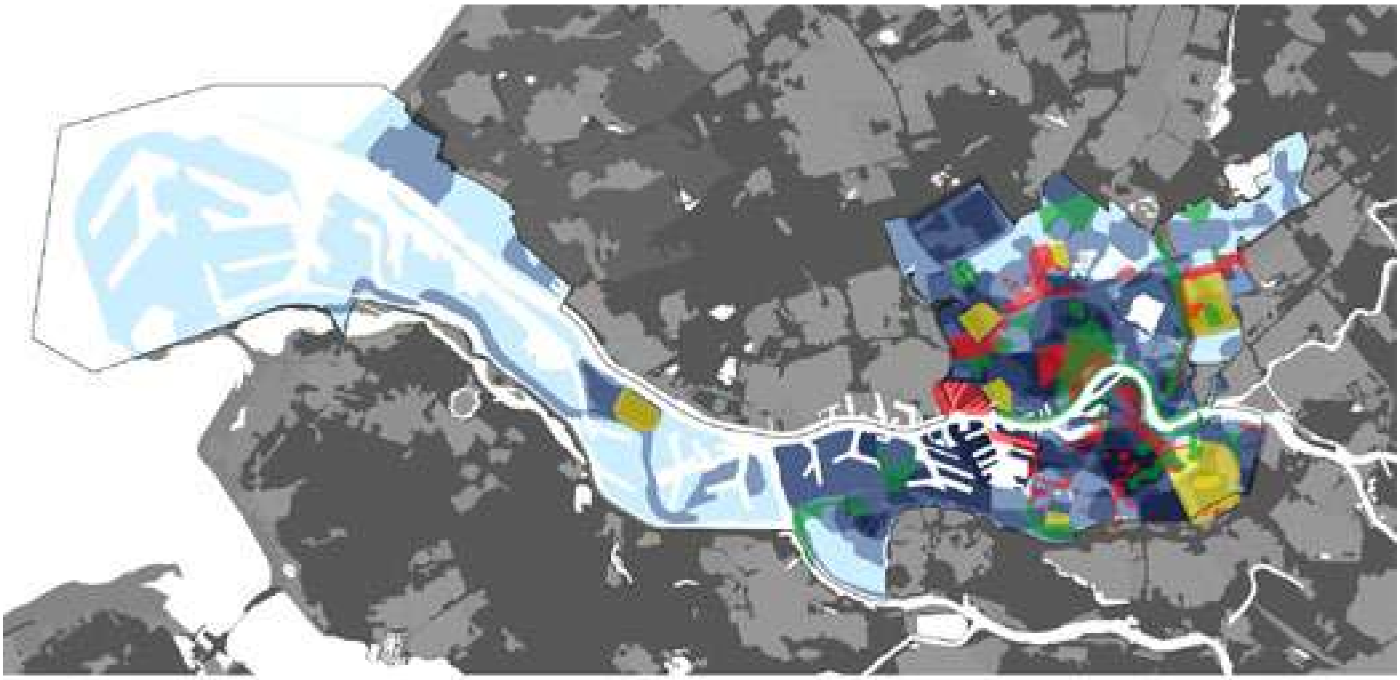
"*... reunite engineered and natural processes and strengthen existing logics of sites are becoming the base for new regional and urban forms. A "soft engineering" approach is advocated as a way to work with the forces of nature, in order to reduce or mitigate the likely impacts of natural disasters, while the revised development of cities is to be guided by new interplays of landscape, infrastructure, and urbanization*" (Shannon 2013, p. 165).

Ecosystem services and green infrastructures

"*Ecosystem services refer to the benefits that humans derive from the natural environment, including provisioning services such as food and water; regulating services such as regulation of floods, drought, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits*" (Wu & Wu 2013, p. 222).

Wu & Wu (2013) claims that urban development "... *can result in a significant loss of ecosystem services and thus a decrease in the city's cross-scale resilience*" (Wu & Wu 2013, p. 222). Human interventions can sustain or weaken the ecosystems. Seeing the deep structures consisting of ecosystems that can support and serve our social systems may increase a more sensitive approach, recognizing the importance of socio-ecological structures, as well as increase resilience.

Ill. 18 The Sand Motor in Ter Heijde, Holland is an experiment to defend the coastline from flooding. Huge amounts of sand are placed at the southern part of the coast, and the nature spreads the sand along the coast, which extends the foreland and creates barrier against flooding (Resilient The Hague n.d.)



Ill. 19 Rotterdam's climate change adaptation strategy named 'Rotterdam Weather Wise' presents challenges in relation to climate change, and it suggests the next steps forward for climate adaptation. The illustration shows opportunities in Rotterdam (Gemeente Rotterdam et al. 2018).

Sharing of structures and spaces to gain mutual advantages and co-benefits is also emphasized in the idea of *infrastructural ecologies* (Brown 2019). Brown defines infrastructural ecology as "... *a planning paradigm that emulates the closed-loop, sharing logic of natural ecosystems. It suggests that features of our power, water, sanitation, transport, and food systems may be strategically combined, collocated, or otherwise linked for mutual benefit*" (Brown 2019, p. 20). Brown points at the value of 'co-benefits' that ecosystems make achievable. The importance of co-benefits or multifunctionality con not be overemphasized. Solutions that solve more than one challenge and creates value for many at once, will always be a sustainable alternative to single-minded and mono-functional solutions (CONCITO 2017; Brown 2019; Fryd & Jørgensen 2019; Salata & Athena 2020; Ahern 2012; Ahern 2007).

NOTE/ Merværdi, Synergy, Sammentænkning, Sammenkobling, Integration, Multiple benefits, Plural values, Added value, Multifunctionality.

NOTE/ When climate adaptation solutions create multiple values for different users and functions it is also easier to get co-financing.

One of the ecosystem-based tools that incorporates multifunctionality is Green Infrastructures. "*It is commonly acknowledged that the promising ecosystem-based tool of GI [Green Infrastructure], essentially a spatial planning tool, provides multiple benefits and can reduce the vulnerability of cities, increase their resilience, and essentially facilitate their adaptation to climate change*" (Salata & Athena 2020, p. 14). Green Infrastructures builds in multiple ecosystem services in a green stretch which at the same time allows for different uses. Illustration 20 from Jack Ahern (2017) describes the many benefits that can be gained through abiotic, biotic and cultural functions of green infrastructures.

Green Infrastructure is a spatial tool that can support both social and ecological functions. Furthermore, it contains ideas from landscape ecology such as *multi-scales* and recognition of patch dynamics (Ahern 2007).

The multi-scale approach carries the potential to create transformation. Within spatial planning and urban design, transformation depends on scale of implementation or strategic assets. Implementations at a local scale will not be able to change the overall structure of a system to a sufficient degree. The measures must at least be considered on a municipal scale or with high intensity in order to transform the main structure of a system (Brown 2019). Green Infrastructures are a multi-scale approach that can take part in creating revolutionary resilience, as it "... *addresses the structure and behavior of systems that function simultaneously at multiple scales*" (Ahern 2007, p. 269). Hydrological processes that are nested at different scales can be treated in large green infrastructures (also known as 'blue-green infrastructures'). The multi-scale approach is also important to understand spatial heterogeneity, and the recognition of *pattern:process relationships* or patch dynamics. These patterns are crucial for the function of ecosystems and explorations of these might give a deeper understanding of the landscape.

NOTE/ In Katrina Wiberg's PhD she founds a connection between waterflows, green areas and ownership. She finds that natural waterflows runs through green stretches in the city, which convenient conjunct with public areas. This can be an advantage for the municipalities, as they can make use of the areas to extend and carry on the blue/green structures (Wiberg 2018).

Ahern (2007) suggest five guidelines for urban planners and designers to create green urban infrastructures based on landscape ecology principles.

1. Articulate a spatial concept, to build in innovation and to communicate the idea,

2. Strategic thinking, which can be either offensive, protective, or opportunistic,

3. The greening of infrastructure, to secure the multifunctionality storing multiple ecosystem services and functions in a single structure,

4. Plan for multiple use, as the third guideline it is important to think functions together especially in urbanized areas, where vertical integration of functions or innovative combinations may be a solution,

5. Learn by doing, as the implementation process is a learning phase it is important to be experimental.

(Ahern 2007, p. 273)

Abiotic	Biotic	Cultural
Surface:groundwater interactions	Habitat for generalist species	Direct experience of natural ecosystems
Soil development process	Habitat for specialist species	Physical recreation
Maintenance of hydrological regime(s)	Species movement routes and corridors	Experience and interpretation of cultural history
Accommodation of disturbance regime(s)	Maintenance of disturbance and successional regimes	Provide a sense of solitude and inspiration
Buffering of nutrient cycling	Biomass production	Opportunities for healthy social interactions
Sequestration of carbon and (greenhouse gasses)	Provision of genetic reserves	Stimulus of artistic/abstract expression(s)
Modification and buffering of climatic extremes	Support of flora:fauna interactions	Environmental education

Ill. 20 Abiotic, biotic and cultural functions of green infrastructures (Ahern 2007, p. 269).

Diversity, modularity, connectivity, redundancy and safe-to-fail design experiments

Across literature dealing with resilience is a general recognition that *diversity, modularity, redundancy*, and *safe-to-fail design experiments* are qualities that inextricably are linked to resilience (Fryd & Jørgensen 2019; Walker & Salt 2006; Wu & Wu 2017; Ahern 2012; Brown 2019). There is no universal model, but several researchers are enhancing different features of resilience, e.g., Walker and Salt (2006) who are listing nine 'resilient world values'. Some of these are highly relevant to urban planners and designers and are included in the above list. The five qualities presented here are enhanced as they have great impact on resilient ecological landscapes and urban design.

→ A system's **diversity** is based on the number of different constituent elements. The higher the diversity the higher the resilience of the system. Walker and Salt express that: "*A resilient world would promote and sustain diversity in all forms (biological, landscape, social, and economic)*" (Walker and Salt 2006, p. 145). Diversity is understood as an umbrella covering all elements in a system, where elements or structures such as buildings, functions, materials, landscape and even climate adaptation measures are interesting for urban planners and designers. An example in relation to extreme precipitation is the cover of diverse urban trees that has an impact on the infiltration (Walker and Salt 2006; Ahern 2012). Diversity can improve ecosystems and ecosystem services which can be a benefit for both human and non-humans, as presented in the section of Green Infrastructures.

→ **Modularity** is essential to maintain flexibility, as it relatively easy can be up scaled or down scaled. It consists of different typologies, such as specific adaptation measures or types of landscapes. Adaptation measures in the form of dikes, elevated buildings, greening patterns etc., can all be related to modularity, that can be downscaled or upscaled (Fryd & Jørgensen 2019). Connectedness between modules can negatively transmit disturbances from one module to another, thus resilience seeks to avoid over-connectedness (Walker & Salt 2006). Hence, modularity can prevent the spreading of risk (Ahern 2012).

→ Even though over-connectedness can be an obstacle for modularity, **connectivity** is important for many urban functions and services. Energy, transport, and swales are examples of structures that are depend on connectivity (Ahern 2012). One of the possible solutions that can incorporate and connect ecosystem services are the before mentioned Green Infrastructures.

→ **Redundancy** should be understood as a positive value. In the ecological field redundancy together with modularity can lower the risk (Ahern 2012). If several adaptation measures are used at once such as dikes together with extended foreland, the risk is spread as the dike will withstand a storm surge in case the extended foreland fails. Another example is when local infiltration of precipitation lowers the risk of sewer overflow.

→ Ahern (2012) presents the **safe-to-fail design experiments** as incorporated creative and innovative experiments in urban spaces. The concept is a response to the limited time to create comprehensive site-specific solutions, which often then becomes safe and common solutions instead of innovative and creative. When allocating areas for experiments, the implications and risk of failure is downscaled. These experiments will be pilot-projects that can be learned from and where status-quo can be expanded to include solutions that today seems too insecure.

NOTE/ The municipalities experience that they are taking a risk when using solutions which has not yet been used in a Danish context. Hard solutions, that engineers can calculate, often seems more reliable.

The previous theoretical sections, *Human and Nature Dichotomy, Ecology in Urban Design*, and finally *Climate adaptation through Resilient Socio-ecological Systems* has unfolded different perspectives, approaches and concepts. The human and nature dichotomy are the backbone of a new nature view that perceive human as a part of nature. Furthermore, *landscape* is introduced as a medium to explore socio-ecological systems.

The new nature view and interest in socio-ecological systems manifest itself as ecology in urban design, where social systems and natural systems are merged. The ecological approach in urban design has proven to be a key for urban designers, to explore socio-ecological systems, and herby come up with suggestions for possible futures that can help solve global issues, such as climate change. It can be used to design healthier, safer, and more life-sustaining futures for urban habitat.

Especially the presented propositions and principles by Anne Winston Spirn, are a huge step towards designing resilient cities using ecological urbanism. Together with the presented ecological concepts of spatial heterogeneity and patch dynamic, they suggest a way forward, to be included and implemented within urban design practice to promote resilience.

The last part of theory elaborates on *resilience* and further introduce interrelated concepts, ideas, and principles such as Green Infrastructures and Ecosystem Services that together with Spirn's propositions and principles, as well as the ecological concepts can be used to design resilient cities.

What is still unknown is how to concretize a practice that can inform and assess resilience within climate adaptation planning.

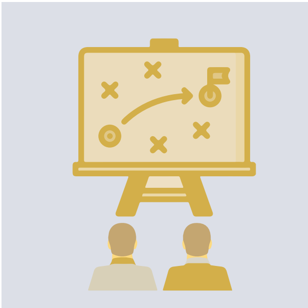
CORE IDEA OF THE EXPERIMENT

INTENTION

The intention of the experiment is, to increase resilient climate adaptation of socio-ecological systems by using a Road Map for Resilient Climate Adaptation, to ensures that decision-makers have the right information when making long-term decisions.

A. ANALYSIS BY USING THE ROAD MAP

The road map is a screening-tool intended for initial studies prior to a strategy, plan, or a design of resilient climate adaptation.



B. STRATEGIC DECISION MAKING

The road map can help strategic decision making, clarifying what kind of resilience that is desired, and what kind of climate adaptation that entails.

C. NEW DEVELOPMENT OF RESILIENT CLIMATE ADAPTATION

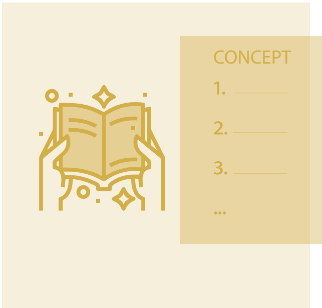
Ill. 21 (All illustrations: Made by author)

EXPERIMENT STEP BY STEP

The experimental part of this project is to concretize a road map that can inform and assess resilient climate adaptation of socio-ecological systems. A road map that works as a applicable screening-tool for urban designers and planners.

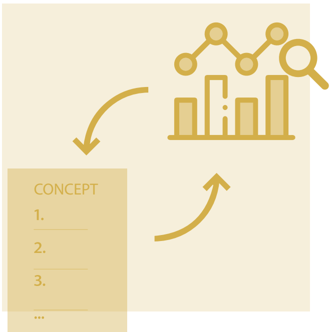
This project seeks to develop version 1 of the road map, by combining theory with case specific analysis of Ribe. Version 1 will be initially evaluated in this project, but to become an efficient screening-tool it needs to be evaluated and improved several times, which goes beyond the scoop of this project.

1. HOW CAN 'RESILIENCE' INFORM AND ASSESS CLIMATE ADAPTATION?



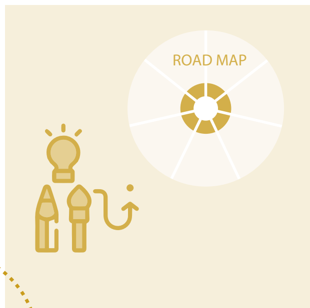
2. THEORY OF RESILIENCE

Theory studies of climate adaptation and resilient socio-ecological systems introduces different theoretical concepts, that can inform planning and design of climate adaptation.



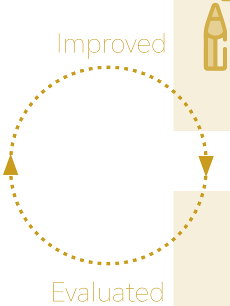
3. FROM THEORY TO PRACTICE

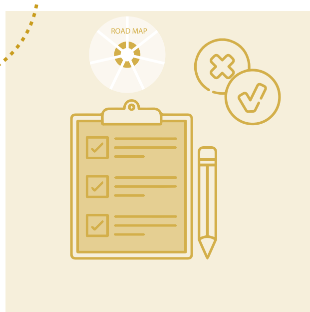
The theoretical concepts are translated into 'urban design language' by specifying interrelated urban design elements that can be identified and analyzed at a physical site.



4. ROAD MAP VERSION 1

The road map is a site-specific screening-tool, making 'resilience' applicable to urban planning and design practice.





5. EVALUATION 1

The road map needs to be evaluated and improved a number of times, to become an efficient screening tool.

CORE
ROAD MAP FOR RESILIENT CLIMATE ADAPTATION

WHAT IS THE ROAD MAP FOR RESILIENT CLIMATE ADAPTATION?

This section aims to present a road map that brings together; firstly, the concepts that repeatedly has emerged throughout the literature research of resilience and secondly, their interrelated urban design elements. The theoretical concepts have a potential to help planners and designers to understand and work with resilience, thus broaden the perception of resilience. Unfortunately, the linkage between these theoretical concepts and concrete and uniform implementation in urban planning and design practice is still missing. As earlier advocated, *resilience* used within several adaptation plans covers different understanding and practicalities. The ambiguity in the use of the term creates diverse practices that lack a common understanding and definition. In some cases, the term seems only to be used merely as a buzzword (Davoudi 2012; Salata & Athena 2020). The road map for resilient climate adaptation is an attempt to approach a common position and in particular make *resilience* applicable to urban planning and design practice.

The question is then, how to carry out the theoretical concepts as urban designers and planners? In this experiment the theoretical concepts are translated into 'urban design language' by specifying interrelated urban design elements. These commonly known elements are typically identified and analyzed at a physical site through classic urban design methods (see an elaboration of selected methods in chapter 2, *Methodology*, pp. 22-23). In this case, the specific urban design elements, as presented in the Road Map for Resilient Climate Adaptation, may inform us about key elements within resilience.

THE ROAD MAP AS A SITE-SPECIFIC SCREENING TOOL

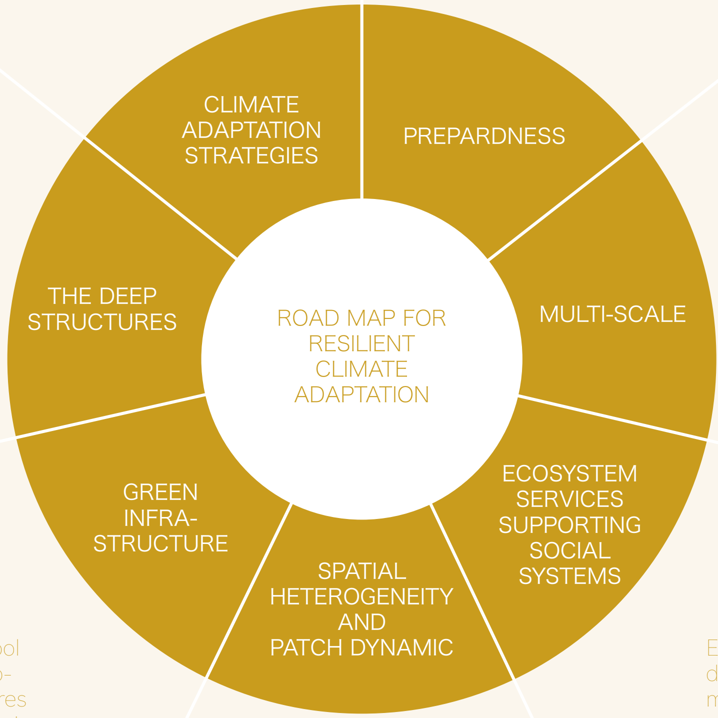
The final road map presented on these pages, is the first step in making a local rooted screening tool for urban planners and designers, that through mapping and descriptions reveal information about important elements of resilience. The screening tool is intended for the initial studies prior to an intervention, in the form of a strategy plan or a design. The road map can help strategic decision making or design to specify what kind of resilience that is desired at a specific location and what kind of climate adaptation that entails. Also, it seeks to draw closer to operationalizing or instrumentalizing resilience and hopefully it will contribute to reveal new urban development opportunities within climate adaptation.

First of all, the road map consists of seven concepts, that repeatedly has emerged throughout the literature research of resilience, thus they are understood as acknowledged and well-founded concepts to describe resilience. For each concept is a description that briefly summarizes the theoretical foundation and explains what the concept is about. On the following pages urban design elements are listed. These elements indicate what can be screened or analyzed to obtain a deeper understand of important site-specific key elements within resilience.

There exist four approaches of climate adaptation measures. The first one is 'protect', that often has a short-term perspective and is built with only one purpose, to protect the existing build structures. The second approach is 'accommodation' that has a medium-term perspective and seeks to adapt to the new reality. The third approach is 'retreat' that has a long-term perspective and seeks to transform the existing build structure by phasing out high risk areas, often following the design approach of 'design to move up and in'. The last approach is 'avoid' that has a long-term perspective. Through land use regulations, areas are kept free of buildings, to remedy future needs.

Preparedness is connected to the way we use and learn from history, precent as well as future predictions, which increases the learning capacity. The long-term predictions are often implicated by 'information gaps' that are important not to ignore and push in front of us for the future to deal with. Instead, acknowledgment of what we don't known can be useful and guide long-term strategic planning. Locations with high uncertainty should avoid permanent build structures, or be used for e.g., safe-to-fail experiments. In this way uncertainty can be used to create value and to spark the imagination of possible new futures.

Every site has a deep structure, that must be understood. The deep structures are the underlying ecological and geological conditions of the specific site. To design resilience the physical shape and structure must be adapted to the deep structures.



Ecosystems are interrelated, dynamic and work across different scales. To address a certain issue, the context must be addressed, thus the cross-scale implications and relations must be understood.

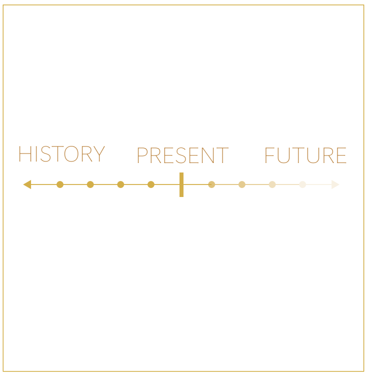
Green Infrastructures are a spatial tool that can support both social and ecological functions. Green Infrastructures builds in multiple ecosystem services in a green stretch which at the same time allows for different uses. In this way both abiotic, biotic, and cultural functions are taken into account, and multiple uses can be planed. The green infrastructures are sometimes termed blue/green infrastructures, refiring to hydrological functions that are built into the green stretch.

Ecosystem services are benefits derived from the natural environment to support humans. Sharing of structures, spaces, and resources to gain mutual advantages and co-benefit are essential to create resilient design. Thus multifunctionality, multi-purpose solutions, and connectivity must be emphasized.

Spatial heterogeneity is the distribution of different elements of focus. Through the medium of landscape, the spatial heterogeneity is examined. It is the relation between structures and functions of the landscape that are interesting to explore, to get a deeper understanding of the socio-ecological systems. The diversity of the different constituent elements is related to a system's resilience. The higher the diversity the higher the resilience of the system. Diversity can improve ecosystems and ecosystem services which can be a benefit for both human and non-humans, thus the identification of different elements is essential. Also, patch dynamics, that show changes in the spatial heterogeneity are relevant to explore. It can be used both to understand historical changes as well as future changes of the socio-ecological systems.

Ill. 22 Road Map for Resilient Climate Adaptation (Made by author)

PREPAREDNESS



A. Historical changes of the landscape (cultural landscape)
Focus on the following elements in a time perspective:
→ Settlement patterns
→ Hydrological modifications
→ Major historical events
→ Landscape changes
→ Social relation to the water

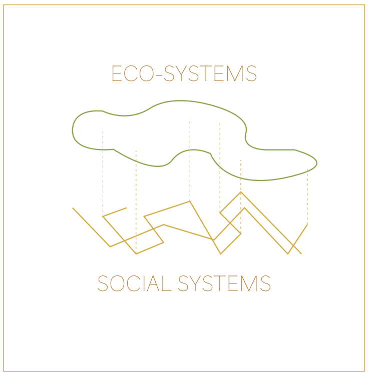
B. Vulnerable areas exposed to flooding
Identify the following elements exposed to flooding by using future predictions:
→ Cultural Heritage
→ Building Value
→ Population Density
→ Exposed areas to different scenarios of sea level rice and extreme events

C. Identification of uncertainties in relation to climate change
Clarify uncertainties in relation to scenarios of sea level rice and extreme events

NOTE/ Some of the elements belonging to one concept can as well be a element also unfolding another concept, e.g., historical changes of the landscape belonging to the concept of Preparedness, may also reveal possible co-benefits under the concept of Ecosystem Services Supporting Social Systems.

Ill. 23 Road Map for Resilient Climate Adaptation (All illustrations: Made by author)

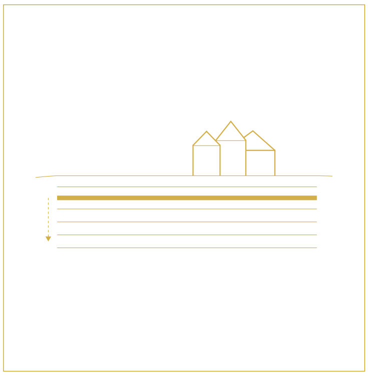
ECOSYSTEM SERVICES SUPPORTING SOCIAL SYSTEMS



A. Links between social and ecological systems (ecosystem services)
Identify the following elements and their interplay that shape the city:
→ Abiotic functions
→ Biotic functions
→ Cultural functions
→ Habitat
→ Vegetation
→ Soil conditions
→ Hydrology

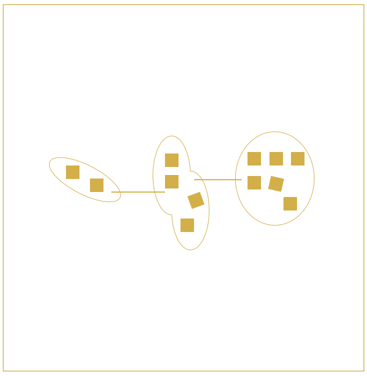
B. Other urban challenges
Identify other urban challenges e.g., within industry, decrease in population or connectivity

THE DEEP STRUCTURES



A. Deep structures of the site
Identify:
→ Significant features of the natural environment
→ City structures and physical shape that oppose the deep structures

SPATIAL HETEROGE-NEITY AND PATCH DYNAMIC

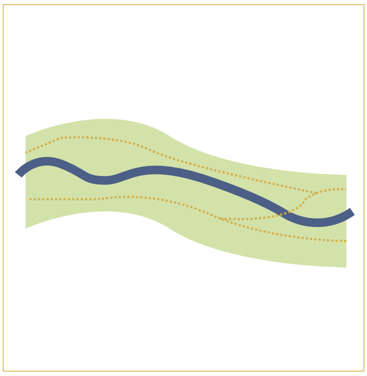


A. Diversity through identification
Identify different elements and their spatial distribution:
→ Functions
→ Build structures
→ Climate adaptation measures
→ Landscape elements
→ Cultural Heritage
→ Recreation
→ Infrastructure

B. Grouping of urban elements
The identified urban elements must be divided into:
→ Attractions
→ Sub-groups

C. Connectivity between the groupings
Identify the connectivity between:
→ The groupings of urban elements

GREEN INFRASTRUCTURE

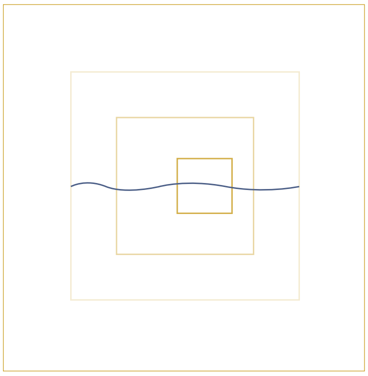


A. Waterflows and dynamics
Identify:
→ Waterflows
→ Dynamics affecting the waterflow

B. Green stretches
Identify:
→ Green stretches
→ Relation between green areas and ownership
→ Connectivity through the land-scape

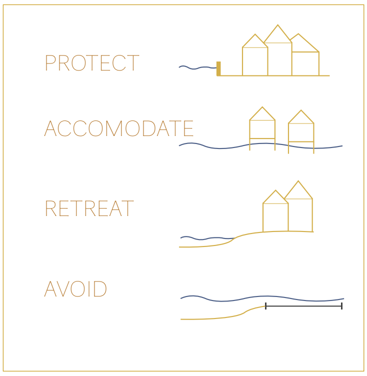
C. New green infrastructures
Assess possible new green infrastructures

MULTI-SCALE



A. Work in different scales
All urban elements and their relations e.g., the whole hydrological system, should be explored within appropriate different scales such as local, regional, and national

CLIMATE ADAPTATION STRATEGIES



A. Current climate adaptation measures
Identify:
→ Adaptation measures

B. Climate adaptation in relation to identified vulnerable areas
Assess the need and possibilities for climate adaptation in relation to identified vulnerable areas

C. Potential retrofitting areas
Identify high laying areas with little change of flooding

PROCESS OF EXPERIMENT

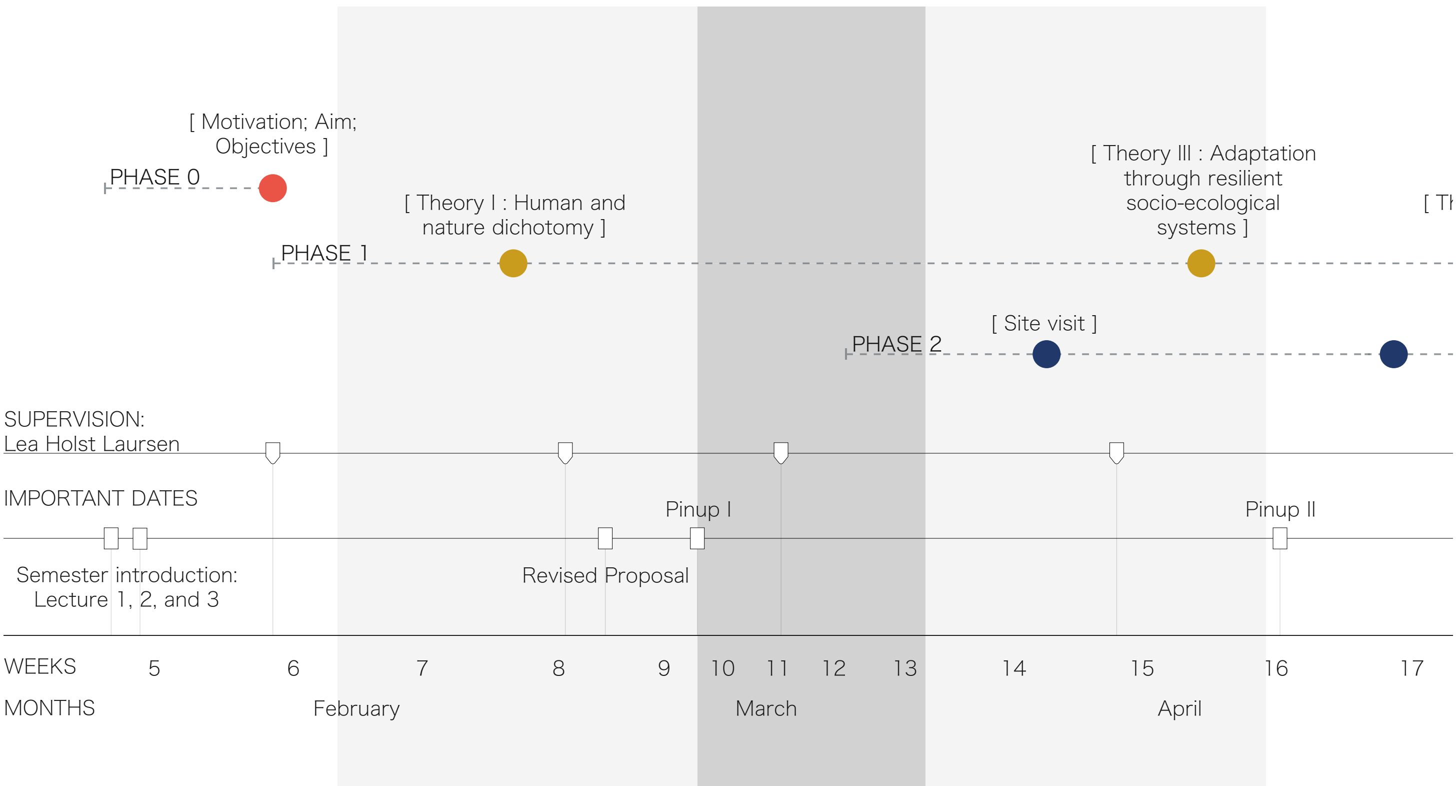
The research experiment consists of three phases, which are a connected to the project's three objectives (see chapter 2, *Aim and Objectives*, pp. 20-21). Firstly, a phase of theory, secondly, a phase of case-specific exploration, and thirdly, a phase of map-synthesis and evaluation (se illustration 24).

The first two phases of the working process have moved iteratively back and forth from theory to site explorations and resulted in the *Road Map for Resilient Climate Adaptation*. Thus, the road map is an expression of both the theory phase and case-specific exploration phase. The third phase of map-synthesis and evaluation has started when the first two phases were completed. In this phase findings from the case specific study are presented and three future scenarios are developed to discuss possible futures and evaluate the road map.

PHASE 1 AND PHASE 2: THEORY AND CASE-SPECIFIC EXPLORATION

NOTE/ Phase 1 is a result of objective number 1: Review the theoretical relationship between human and nature dichotomy, ecology in urban design, and resilience.

The road map for resilient climate adaptation contains an interrelationship between the theoretical concepts and urban design elements. The concepts listed in the road map has emerged through a theoretical literature research, here referred to as the phase of theory. At the



↑ *Ill. 24 Diagram of the process (Made by author)* same time the urban design elements are developed through phase two, the case-specific exploration of Ribe, where classic urban design methods have been conducted to analyze the site. In this way, the urban design elements have been more and more clarified along the process.

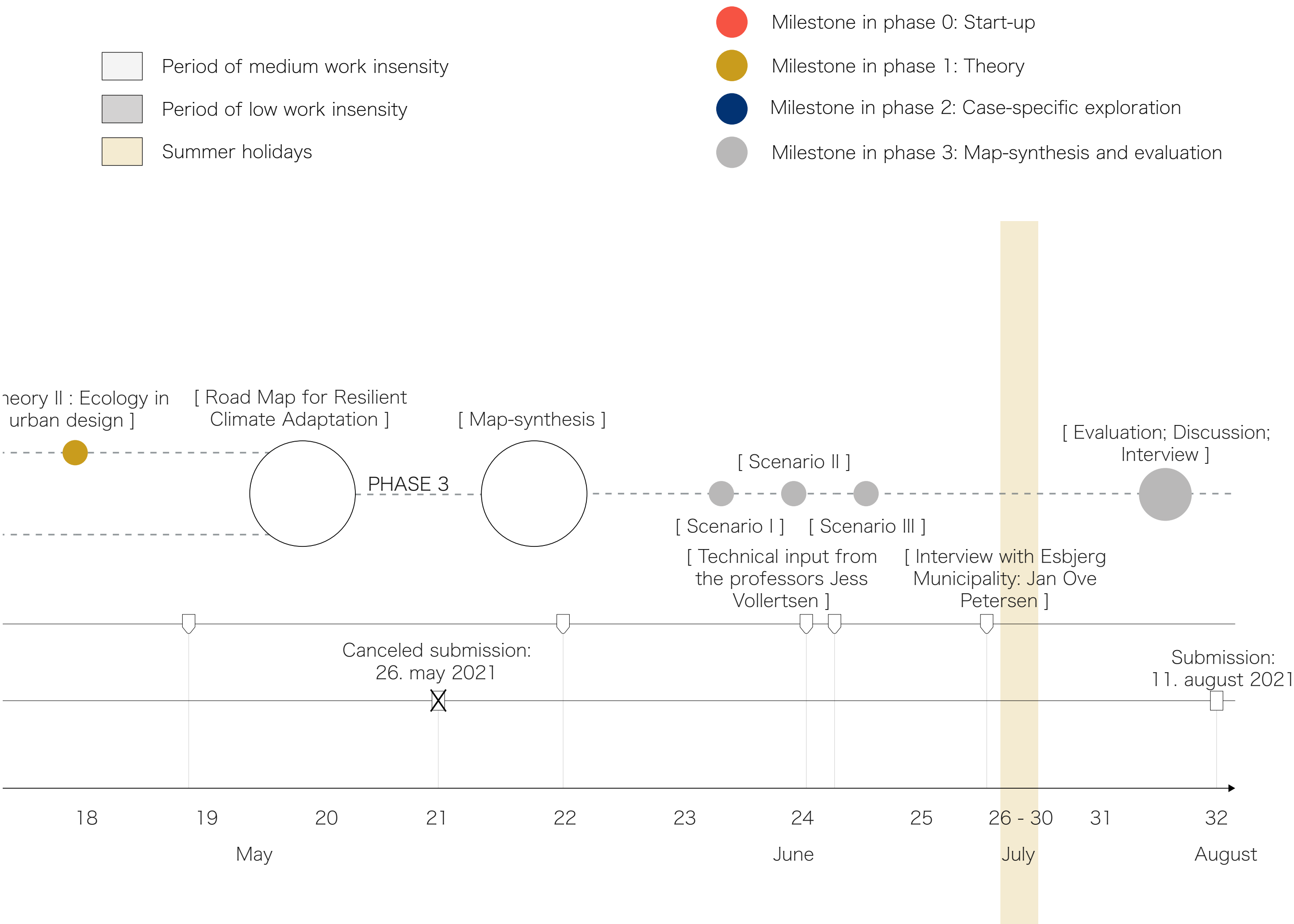
NOTE/ Phase 2 is a result of objective number 2: Explore how urban design method can read and translate concepts of resilience through a case-specific study, to create a road map for resilient climate adaptation.

PHASE 3: MAP-SYNTHESIS AND EVALUATION

The two first phases have led to a map-synthesis, that gathers the different findings from the case-specific exploration and indicates opportunities. This map-synthesis is an expression of the road map applied to the specific case of Ribe and it points in different strategic development directions, thus function as a help for decision making. The map-synthesis is hereby an application result of the road map for resilient climate adaptation.

Furthermore, three different directions of development are presented in the form of three scenarios. These three scenarios should not be seen as a solution, but as a tool to ask the 'what if' questions, that can open a discussion and broaden the evaluation. They are a 'discussion tool' for the evaluation used in an interview with architect, Jan Ove Petersen, from Esbjerg Municipality, to involve other perspectives.

NOTE/ Phase 3 is a result of objective number 3: Discuss and evaluate how the road map for resilient climate adaptation can inform strategic urban design and planning of climate adaptation.



FOUNDATION
APPROACH: URBAN DESIGN METHOD TO DE-CONSTRUCT

Urban design methods will be used in this project's phase two and three. In phase two they will be used to de-construct and explore Ribe. The selected urban design methods must contribute to broaden the perception of resilience, by exploring urban design elements that are interrelated with the theoretical concepts, ideas, and principles presented in the Road Map for Resilient Climate Adaptation (see pp. 74-77). Multi-methods are needed to comprehend the relevant urban design elements. The elements will give a deeper understanding of Ribe's socio-ecological systems and hereby display resilience. As presented in the methodology (see chapter 2, pp. 22-23), the methods used in phase two, which is the 'de-construction' are terrain modelling, cross-section, field trip, photo registration, and mapping. Especially mapping or cartography is important in this project, thus it will be further elaborated.

In phase three, three scenarios will be used as a method to discuss and evaluate possible futures. The scenarios illustrate three possible directions of Ribe's urban development. They will suggest different land uses and overall strategic directions, that indicate possibilities. In this way, analysis of the different scenarios creates the basis for dicission-making.

NOTE/ Site analysis methodologies are used across disciplines of architecture, landscape architecture, urban planning and urban design.

In general, site analysis in urban design is used to systematically build knowledge of a specific site (plot, district, or region). They help urban planners and designers to read and unfold a site, with the purpose of creating a physical intervention in the form of urban strategic plans or designed architectural structures.

The methods vary in both scope and scale depending on the specific site, and predefined type of intervention. Some methods are subjective while others are objective, and some are phenomenological while others are structural, all contributing to a deeper understanding of the site's condition. Each site contains multiple elements or properties that can be explored, such as typologies, connections, habitat, landscape elevations, functions, programs, materials, sounds, water flows, soil conditions, settlement patterns and so on. It is important to consider which analysis method, that are selected to obtain the needed knowledge depending on the specific project and intervention.

MAPPING / CARTOGRAPHY

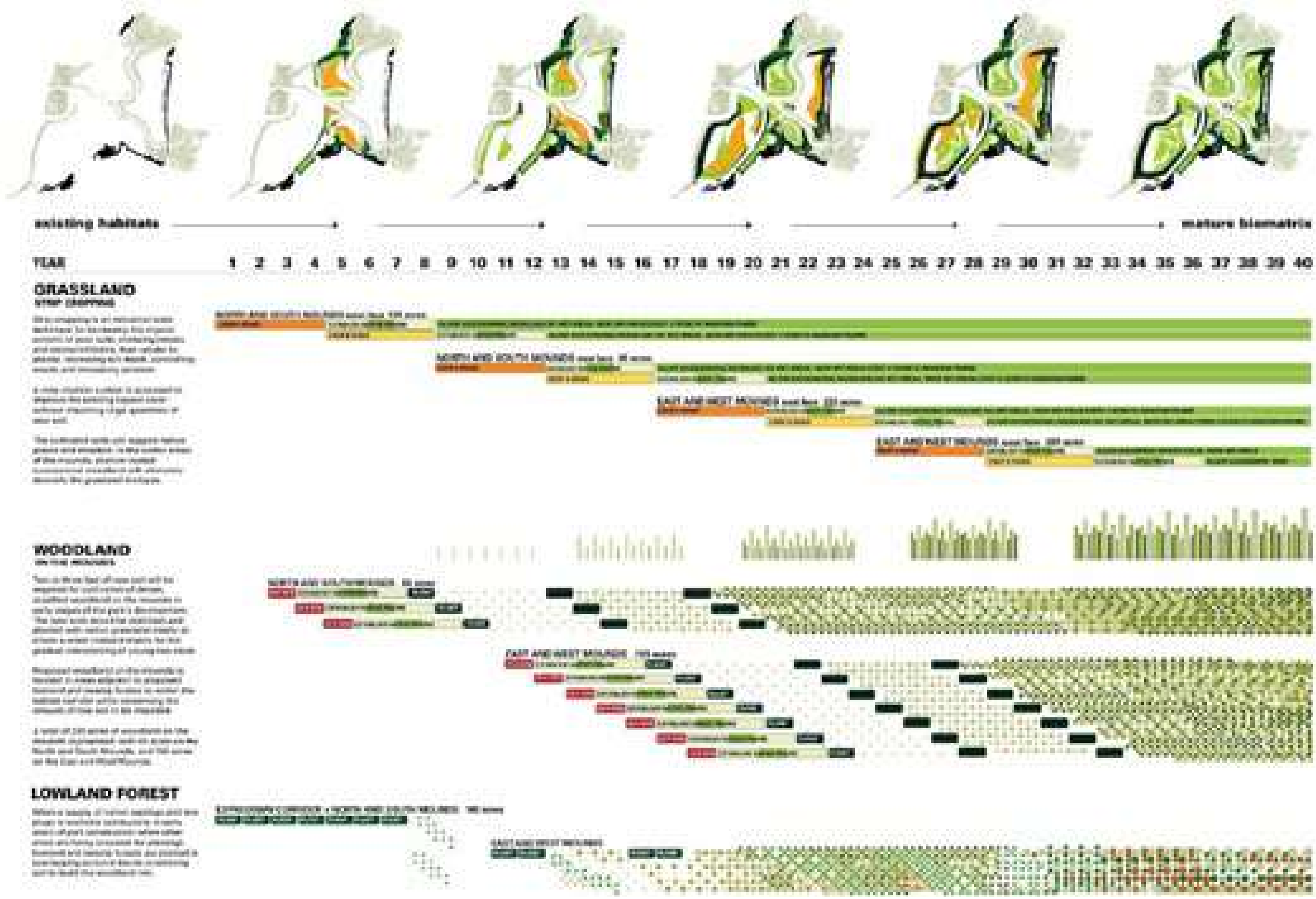
James Corner asks the question:

"... *how would one have to construe ecology and creativity in design practice? In what ways would they have to be appropriated for landscape architecture to function as a significant evolutionary agent - one that might develop greater diversity and reciprocity between the cultural world and unmediated Nature?*" (Corner 1997, pp. 258-259).

These questions are inspiring and relevant in relation to the choice of methods in this project. The methods designers use is often based on creativity, making new potentials or inventions in physical spaces visible. It is interesting how design method in this way can contribute to an ecological approach and how the connection between the two can be created. How can design methods absorb ecology? In this project mapping or cartography will be the main analysis method, that tries to absorb socio-ecological systems.

Cartography is the making of maps that through visual representation introduce systematically organized geospatial data. A common language has been developed over time, to draw closer to objective depictions of the world where e.g., accurate locations are defined as longitudes and latitudes, and where objective data repeatedly are visualized in the same way. We translate the world into maps. Even though, one aiming to keep the objectivity in the visual representation, it is a projection of the world through the eyes and hands of the human being.

"*With tools like Google Maps, the impression of realism has become so*



↑ *Ill. 25 The illustration shows the cultivation of new habitat over time from Field Operation's Fresh Kills Park project* (Field Operations 2006)

strong that one may be tempted to forget the constructed nature of the image of the earth that appear on our computer screens" (Picon 2016, p. 250)

There exists a balance between objective projections and subjective-intuitively projections of the world. The first one is often related to hardcore data, whereas the other is more creative in its nature, depending on the observer. Within urban design this balance is important, when using the method of mapping. In the classic essay *The Agency of Mapping* (Corner 1999) James Corner states that:

"*... the function of mapping is less to mirror reality than to engender the re-shaping of the worlds in which people live*" (Corner 1999, p. 213) ... "*Although drawn from measured observations in the world, mappings are neither depictions nor representations but mental constructs, ideas that enable and effect change. In describing and visualizing otherwise hidden facts, maps set the stage for future work*" (Corner 1999, p. 250).

In this way Corner defines the act of mapping to be a representation of reality. In the essay he distinguishes between *tracing* and *mapping* (Corner 1999, p. 213). While tracing reproduce the existing, mapping uncovers potentials. Thus, mapping can be seen both as a tool to produce knowledge and at the same time it can function as a result to indicate potentials of re-shaping. For Corner mapping is a creative process that can be used to find potentials and 'latent relationships' across different elements (Corner 1999, p. 230). The agency of mapping consists of three operations, *fields, extracts,* and *plottings* (Corner 1999). *Fields* are the basic surface, table or ground where coordinates, scale, and measures are projected on. The creativity can be challenged by changing the framing, upscaling, or downscaling. *Extracts* are objects or elements that can be observed in the field. Corner's definition of extracts correspond to what is termed 'urban design elements' in this project. The elements can be data, speed, and directions, as well as waterflows, connections, habitat and so on. They can be de-territorialized and explored and studied as single or grouped elements that can be manipulated and put in new relations. The last operation is *plotting*, which is the re-territorialization, where latent relations between the elements or extract are found. It is a creative and strategic operation. Plotting will be used in this project's map-synthesis, where important elements are collected showing new potentials and possible directions of future strategic development.

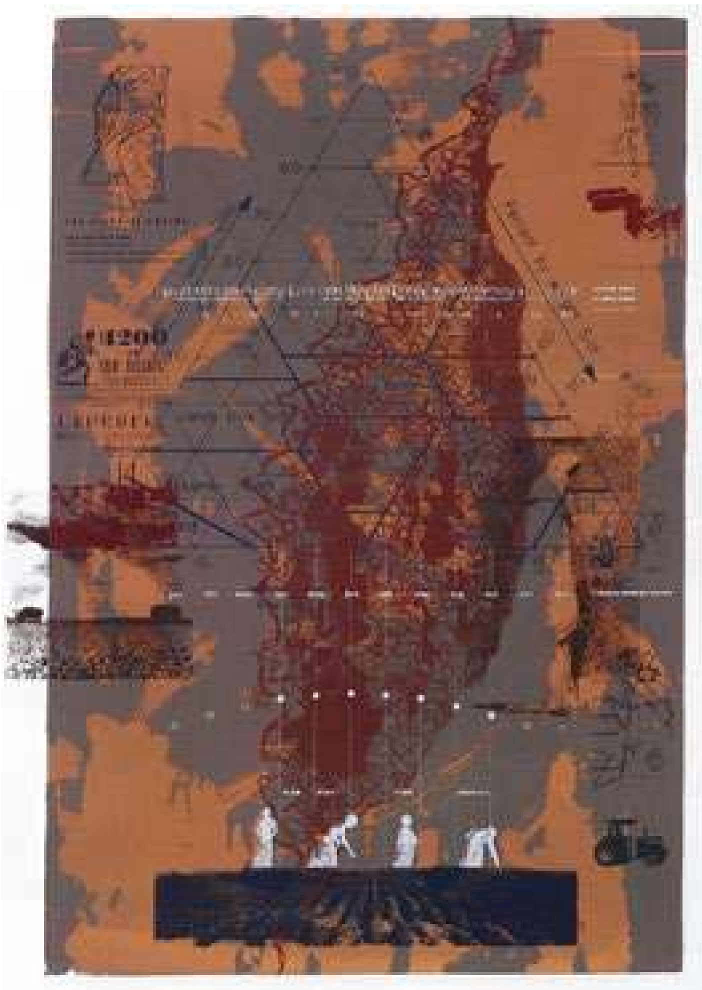
By the use of mapping, urban design elements, different scales, and time perspectives can be captured and reorganized to find potentials. A good example of a mapping technic that incorporates the time perspective is the landscape and habitat plan, shown on illustration 25, from the *Fresh Kills Park* project made by Field Operations (Field Operations 2006), whose founder is James Corner. Another inspiring mapping technique that incorporates processes, is Anuradha Mathur and Dilip da Cunha's used in their book *Mississippi Floods, Designing a Shifting Landscape* (Mathur and Cunha 2001). They use 'map-prints' to layer and erase information of the explored Mississippi mud, as it is shown on illustration 26. The map capture history, and dynamics of the flood landscape.

As stated in the beginning, mapping is a balance between objective projections and subjective-intuitively projections of the world. Whereas Corner's definition of mapping seeks to be intuitively, and creative, other types of mapping methods seeks to be objective, and data driven. Data driven analysis can give great insight to other disciplines such as ecology, hydrology, geology and so on. Ian McHarg is a classic example of this approach. In his work, he uses layering of different geospatial and interdisciplinary elements that all together gives important information to the determination of land use. In McHarg's book *Designing With Nature* (McHarg 1969), he describes his method in detail. There are several examples of how soil, drainage, vegetation, and other elements are identified, leading to suitability maps for lands use, as illustration 27 shows. His emphasis is on interdisciplinarity and his layering techniques was a huge step towards a more ecological sensitive approach within urban design in the beginning of the environmental movement, which has later been developed to GIS-tools. McHarg himself claimed that his method was rational and explicit:

"*In addition to being rational, the method is explicit. Any other persons, accepting the method and the evidence, is likely to reach the same conclusions as those demonstrated in the study*" (McHarg 1969, p. 105).

Often McHarg's use of layering method limits itself to be static and without imagination, as the time perspective lacks in the visual representation and the method is stripped for creativity. The overlaid maps that visualize different social and natural elements doesn't represent the dynamic relationship. Another example of how the technic of layering can be used in more creatives ways is OMA's competition proposal for *Parc de la Villette* (OMA 1983). As illustration 28 shows, layers are used to organize the site. The project follows its own organization principles where elements such as point grids, strips, access, circulation, and tress are used to create a program for the area.

The combination of data driven, and creative and imaginative mapping can be rewording. It is exactly that combination this project seeks to apply, to explore and explain socio-ecological systems of Ribe.

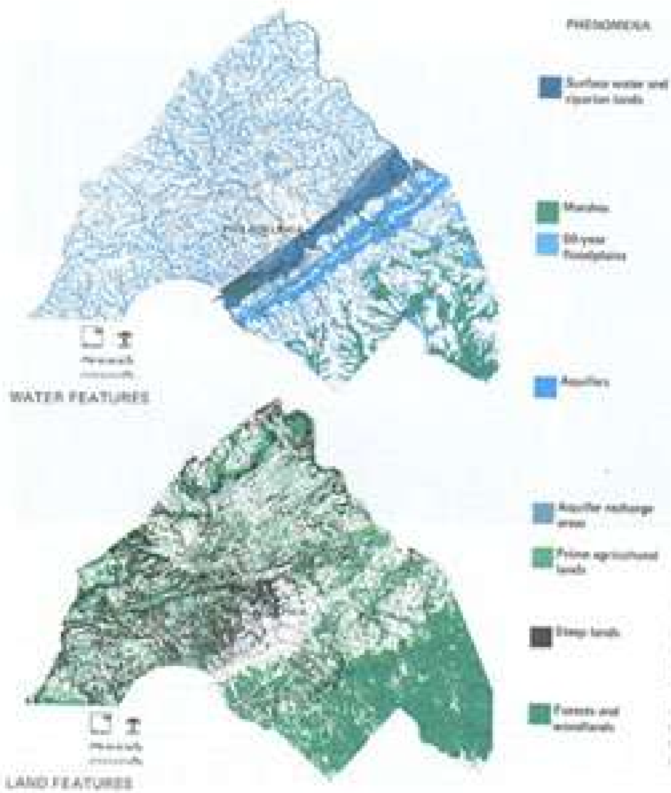


↓ *Ill. 26 Anuradha Mathur and Dilip da Cunha's use 'map-prints' in their book Mississippi Floods, Designing a Shifting Landscape. The map-print layer information of the historic cotton work and soil conditions* (Mathur and Cunha 2001)

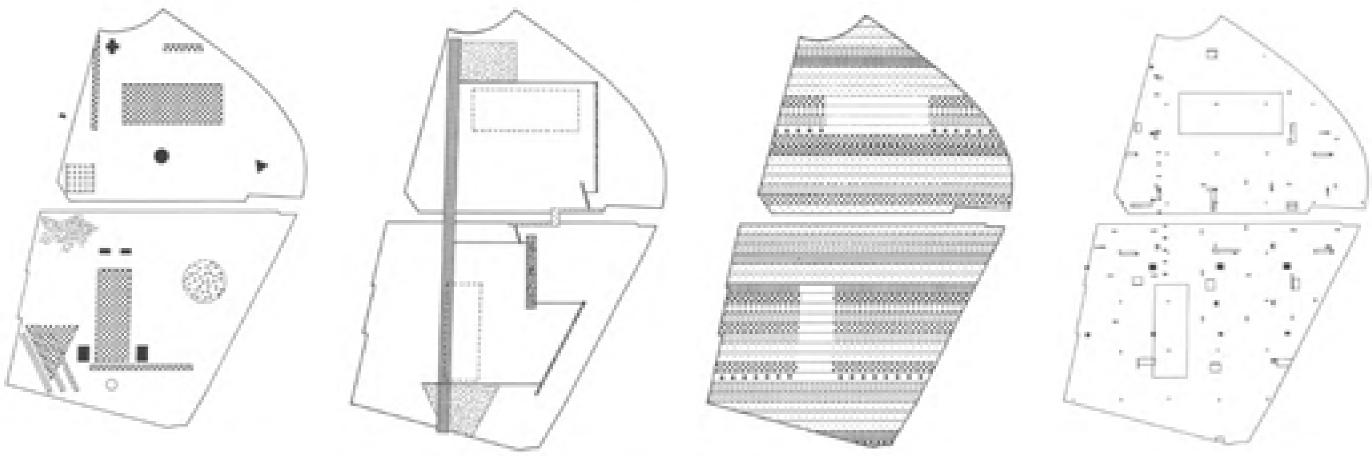
VISUAL OUTCOME

The different elements can be ordered and visualized in a variety of ways that makes it understandable for other professionals as well as for other interested such as citizens. It is a discipline in itself to translate and merge sometimes complex knowledge, so it is readable for others. When working with mapping, the representation will always be open for interpretation, as maps is not just reproduction of the existing but a selective process of what should be seen.

The Road Map for Resilient Climate Adaptation does not determine representation types of the analysis outcome. There are multiple types of visual communication that can be rewarding in their own way depending on the specific context. In this experiment the visual outcomes are varied to illustrate some of the possibilities, but they are much inspired by James Corner's definition of mapping, as well as Ian McHarg's eye for interdisciplinarity and his data driven layering.



↑ *Ill. 27 Ian McHarg's work with layers is used to first investigate different elements such as water and land features and finally the layers are gathered to indicate land use suitability* (McHarg 1969)



↑ *Ill. 28 OMA's competition proposal for Parc de la Villette shows the layering technic of different elements and organization principles* (OMA 1983)

4. DE-CONSTRUCTION

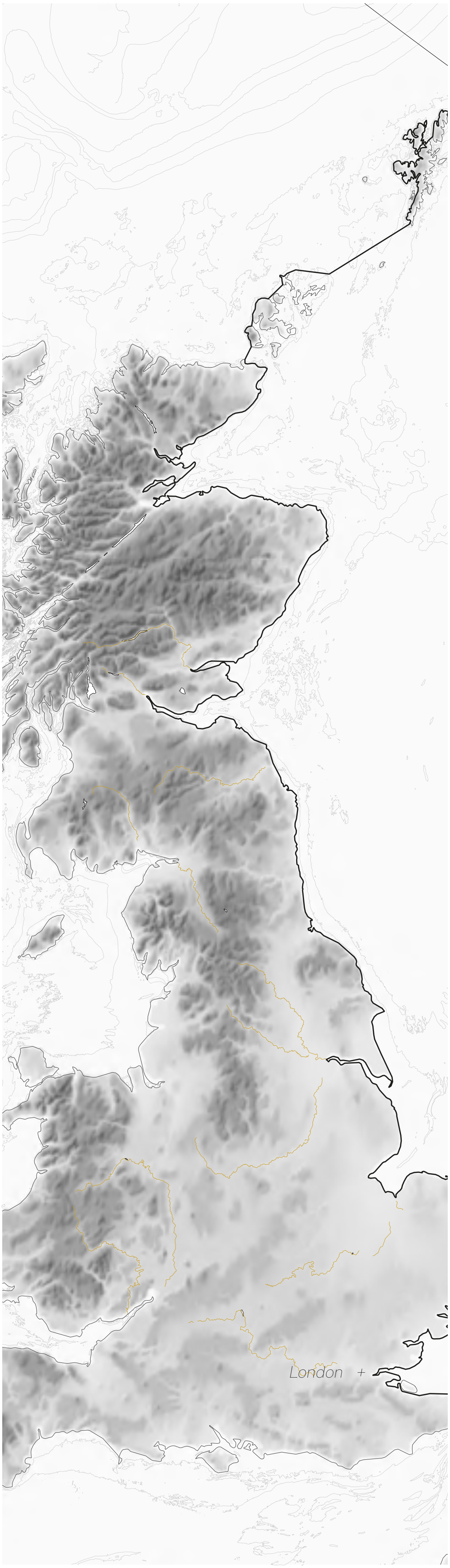
↓ *Ill. 29 Air photo of Ribe city and the surrounding flat marsh area (Kystdirektoratet 2020)*

DE-
CONSTRUCTION
LOCATION

In Denmark there is a large regional variation in the way flooding from storms emerge. The variations can be divided into three regions, the west coast affected by the North Sea and Skagerrak, the inland affected by Kattegat, and the southern part affected by the Baltic Sea (Hennequin et al. 2018). Along the west coast the storm surge height and frequency are above the national average. Especially in the southwestern part of Jutland, where Ribe is located, the storm surges are more extreme than in any other place. The southern part of Denmark that is affected by the Baltic Sea follows the inland water's frequency (Skagerrak and Kattegat), but when the rare storm surge strikes it will be almost as heigh as the once striking along the west coast (Arnbjerg-Nielsen and Löwe 2019).

	NORTH SEA	SKAGER-RAK	KATTEGAT	THE BAL-TIC SEA
Dimensions				
→ Length	960 km	240 km	-	1.601 km
→ Width	580 km	140 km	-	193 km
→ Max depth	700 m	200 m	-	459 m
→ Surface area	570,000 km2	47,000 km2	30,000 km2	30,000 km2
Climate				
→ Charac-terization affecting Denmark	High storm surge height and frequency	Low storm surge and frequency	Low storm surge and frequency	High storm surge, with medium frequency
Context				
→ Number of coastal populati-ons	185 million	-	-	85 million
→ Number of coastal countries	14	3	2	9

↑ *Comparison between seas around Denmark* *(Data from: Wikipedia 2021a; Wikipedia 2021b; Wikipedia 2021c; Wikipedia 2021d)*



→ *Ill. 30 Map of the North Atlantic Seas 1:4.500.000* *(Made by author)*


Oslo
Skagerrak
THE NORTH SEA
Kattegat
THE WADDEN SEA
RIBE
Copenhagen
The Baltic Sea
Amsterdam
Berlin
Brussels

DE-CONSTRUCTION FLOODWAYS

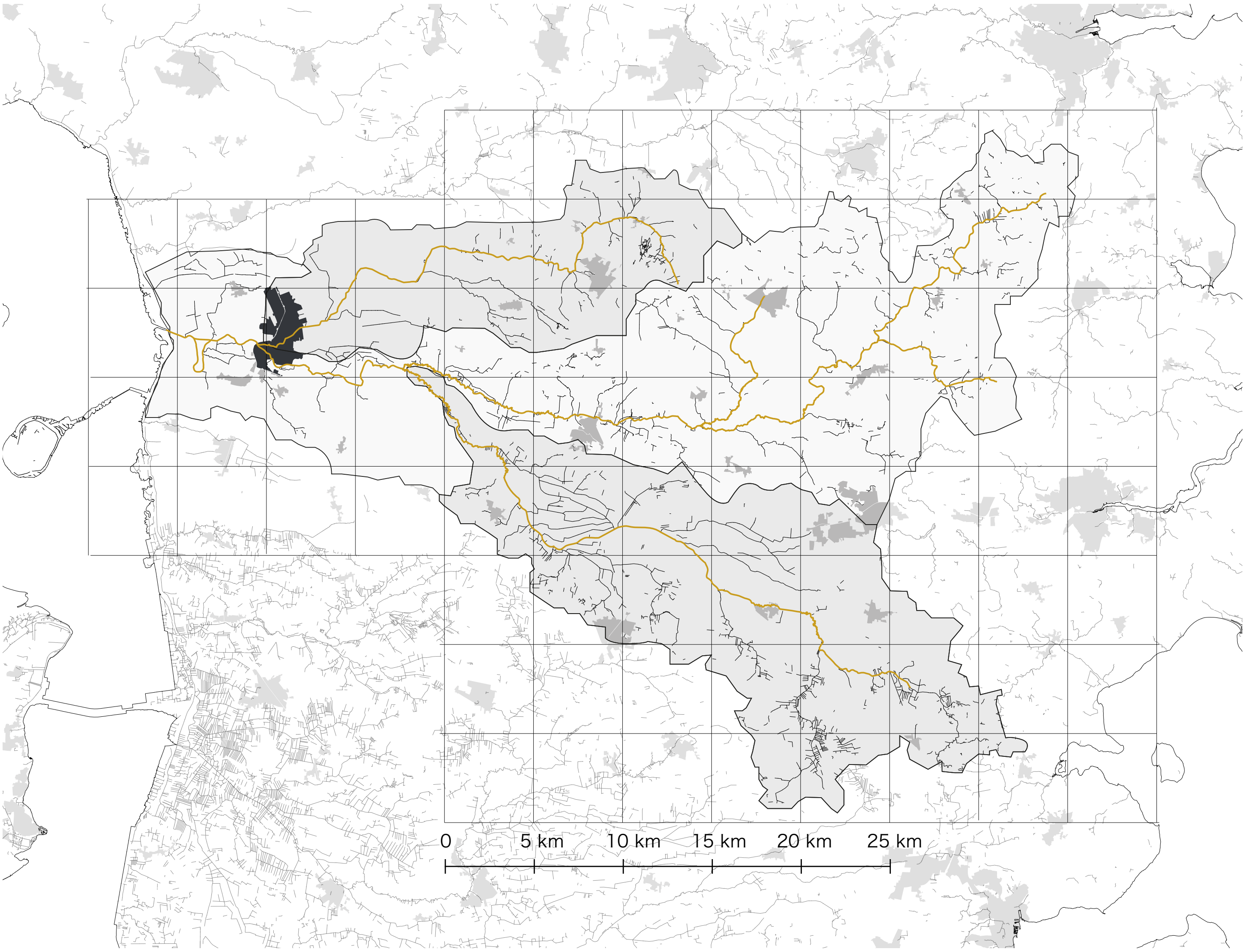
Ribe is located about 5-6 km inland away from the Wadden Sea. A dike along the coastline is separating the sea from the inland, and the area in between the dike and city is a marsh area, where Ribe Å runs through. Ribe Å is the 6th largest stream in Denmark with a length of 71km (Miljøministeriet et al. 2011). It collects water from five catchment areas with a total area of 962 km2 (Miljøministeriet et al. 2011).

To fully understand the whole hydrological system of Ribe Å a multiscale approach is needed. The up-stream areas have an effect on the water conditions in Ribe, thus the cross-scale implications of climate change implies that the disturbances must be understood in a dynamic relation to different scales.

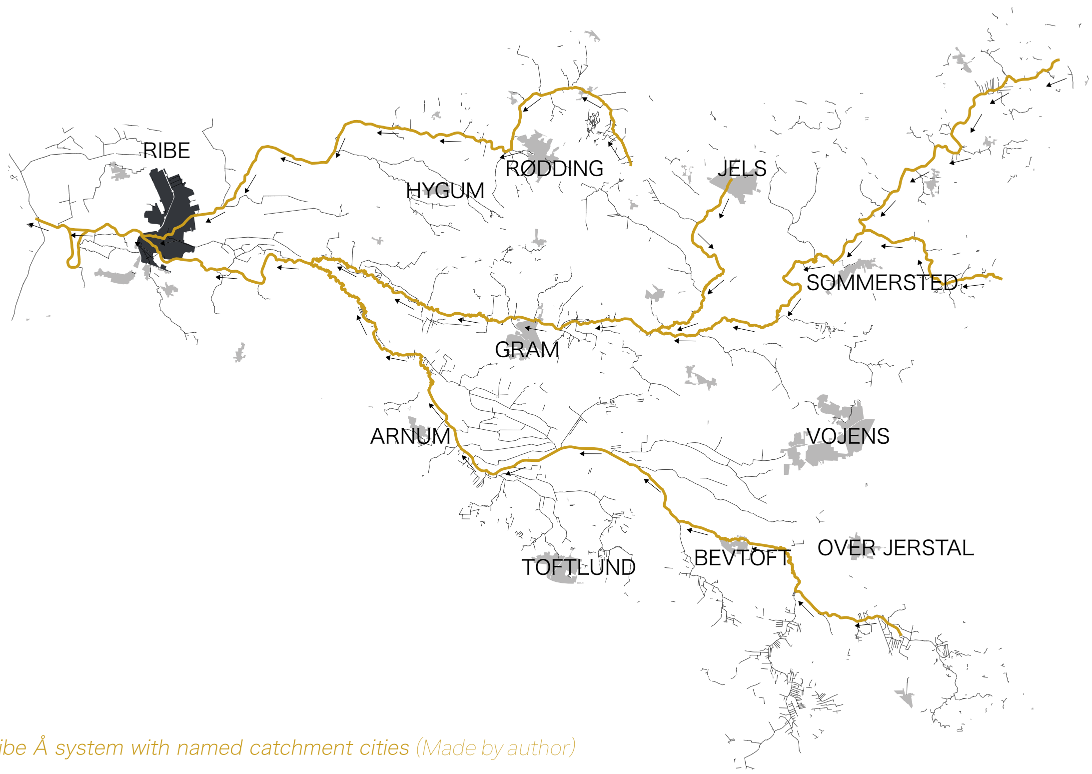
The most challenging type of flooding in the inner city of Ribe occur as a result of higher lying areas inability to handle rainwater local (will be further elaborated in the sections *Water Dynamics*, pp. 136-137 and *Watercourse Flood* 142-145, pp. 142-145). Ribe Å runs closely through the city, that is the last before the water is let out into the sea. The city act as a bottleneck for the large catchment area. The water should be handled as far upstream as possible, which requires collaborations with the neighboring municipalities. Nevertheless, Ribe is the city in the watershed that gets the biggest challenges with the water, thus the city must address and prepare for the coming disturbances.

Outlet	Through Kammerslusen to the Wadden Sea
Adjacent municipalities	Esbjerg Municipality, Vejen Municipality, Kolding Municipality, Haderslev Municipality
Size of catchment area	962 km2
Length of Ribe Å	71 km
Total length of Ribe Å system	449 km
Highest measured water flow rate	50.700 l/s
Highest measured water level	5,20 m
Area-specific runoff at a 100-year event	90 l/s/km2

↑ *Facts about Ribe Å system (Data from: Miljøministeriet et al. 2011; Ribe Å Systemet 2003)*



↑ *Ill. 31 Ribe Å system has a length of 71 km, consisting of five catchment areas (Made by author)*



↑ *Ill. 32 Ribe Å system with named catchment cities (Made by author)*

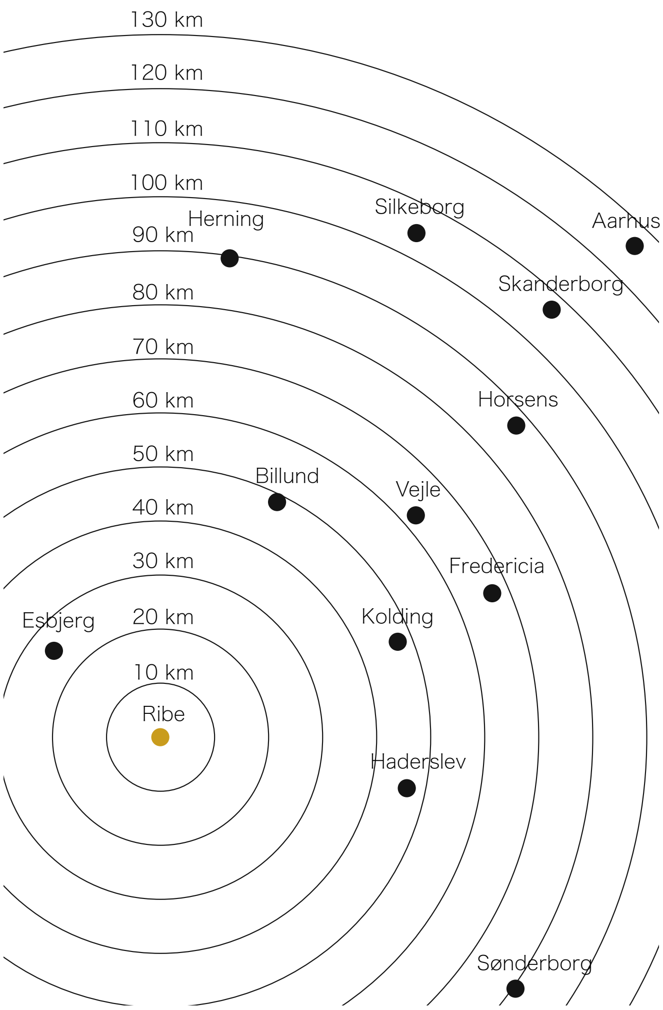
DE-CONSTRUCTION
REGINOAL CONNECTION

Ribe is located in southwest Jutland in Esbjerg Municipality with about 30 km to the main city Esbjerg. The city is well connected to Esbjerg in north and Kolding in east, and the railway station do also connect the city with the surrounding country. But the distances are long as illustration 33 and 34 shows, thus Ribe is geographically isolated with over 120 km to the larger city of Aarhus.

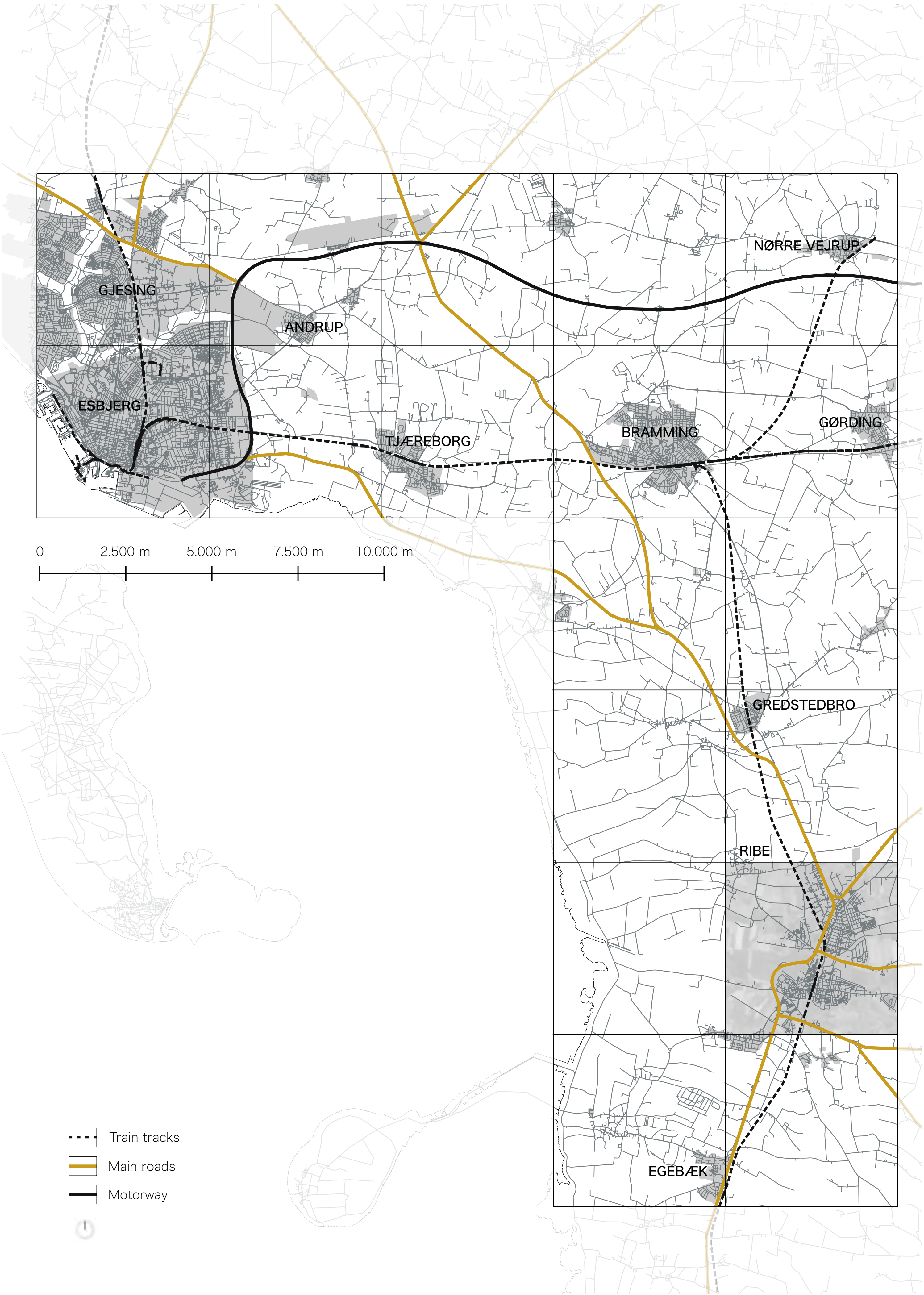
The city is also small with 8.287 inhabits compared to Esbjerg's 115.579 inhabits (Danmarks Statestik 2021b). The population has increased since 2015 but has slightly declined from 2020 to 2021 with 30 inhabits (Danmarks statestik 2021). The majority of the population is between 50-70 years old, which indicates that the city is struggling to attract families with children.

Ribe has a long history as the main trading city (will be further elaborated later), but when Esbjerg was later founded in the 19th century with its large port, Ribe's industry was outcompeted. Today the city is best known for its ancient medieval town and location near the Wadden Sea, which makes the town a major tourist attraction (Den Digitale Byport: Danmarks købstæder 2012). Ribe Cathedral attracts more than 90.000 visitors, but the Whadden Sea Center and Ribe Viking Center do also attract a lot of visitors (Welinder 2020).

↓ *Ill. 33 Distances to the surrounding main cities* (Made by author)



→ *Ill. 34 Infrastructural connections to the nearby cities* (Made by author)


GJESING
ANDRUP
NØRRE VEJRUP
ESBJERG
TJÆREBORG
BRAMMING
GØRDING
GREDSTEDBRO
RIBE
EGEBÆK
0
2.500 m
5.000 m
7.500 m
10.000 m
Train tracks
Main roads
Motorway

DE-
CONSTRUCTION
LOCAL CONTEXT AND CURRENT CLIMATE ADAPTATION PLANS

↓ *Overview of current principles and wishes in Esbjerg Municipality's climate adaptation planning (Data from: Esbjerg Kommune 2021; Esbjerg Kommune 2017; NIRAS 2013)*

Ribe can be divided into five main areas as shown on illustration 35. Ribe North is an area dominated by industry in northern part and residentials in southern part. The New Residential Area in east extends further east. Ribe East is an area with a lot of public service functions mixed with residentials. In Ribe South two schools are located. And in Ribe Old City and Center, the medieval city is located with a mix of retail, cultural functions, and residentials. The illustration does also reveal that Ribe Å is divided into four branches where the water flows through the city. The water is close to the built structures and everyday life.

Esbjerg municipality has ambitions to make independent climate adaptation plans for both Esbjerg, Bramming, and Ribe, which are the main cities in the municipality. Already today the Municipality Plan communicate general guidelines for the forthcoming climate adaptation. An overview of current principles and wishes in the planning is gathered in the table below.

Municipal Strategy (2022-34)	→ Climate solutions must contribute to green urban quality and increased biodiversity in urban spaces
Municipal Plan (2018-30)	→ Restrict settlement in the marsh → More green areas → Limit impermeable surfaces → Management of surface water → Existing risk mapping must be improved → Apply soft climate adaptation solutions rather than hard constructions in the area south of Esbjerg → Cooperation with neighboring municipalities to address water challenges → Strive towards innovative solutions with multifunctionality instead of pump and pipe solutions (in areas designated as 'manageable flood threat') → Do not plan for new buildings where the groundwater is close (including areas in the marsh) → It is not appropriate to restrain flooding in the marsh with isolated protection measures → New mappings of 100-years events in 2050 shows that large areas of Ribe is at risk of flooding
Climate Adaptation Plan for Esbjerg (phase 1) (2014-2026) *Avoid building in areas that will be at risk of flooding in the future. The plan has been prepared since Esbjerg was nationally designated as a risk area. On the basis of the designation, the municipality must prepare a risk management plan.*	→ Ambitions to make independent climate adaptation plans for both Esbjerg, Bramming, and Ribe in phase 2, as a part of the Municipality Plan
Initiated an examination of the cultural soil layers under the old city center of Ribe (2022-2025) *The aim is to understand the dynamics between agriculture, floods, water barriers in Ribe, and the entire marsh area.*	
Vision 2025 (in preparation) *Formulation of visions and objectives that the Municipal Plan will fulfill.*	

→ *Ill. 35 City of Ribe overview 1:20.000 (Made by author)*

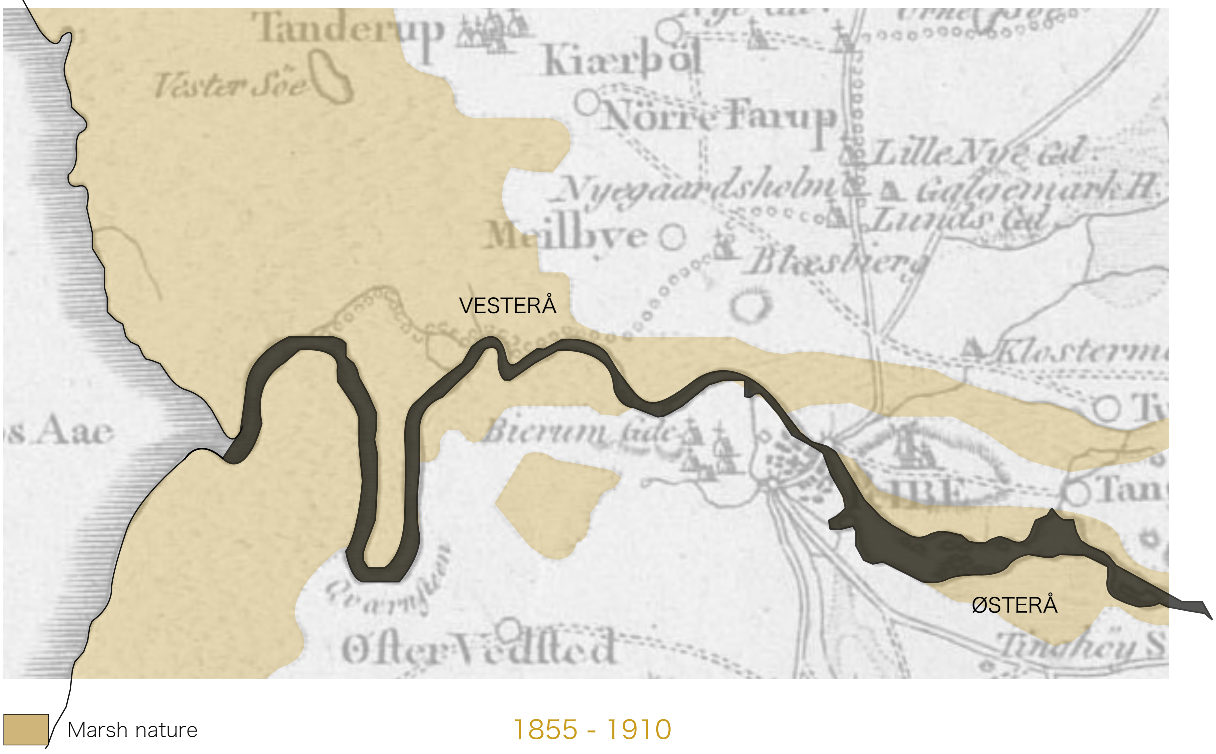

RIBE NORTH
The area is cut through by Trojelsvej. The northern part is industry and the southern part is residential area.
RIBE OLD CITY AND CENTER
Ribe's old city from around the year 700, is located on 'ge-esten' overlooking the marsh. The water is close as Ribe Å runs through the city centre.
NEW RESIDENTIAL AREA
New detached house area with extension to the east.
RIBE EAST
The area is dominated by villas and detached houses as well as public functions such as a doctor and specialist center.
RIBE SOUTH
The area primarily houses two schools.

DE-CONSTRUCTION THE CULTURAL LANDSCAPE

BEFORE 1855

Before Ribe Å was changed by humans, the natural watercourse wind was North Europe's longest. The first modification that was made, was in 1250, where the first dam over Ribe Å was built in the city center to utilize hydropower, which brought four mills along. The largest mill was *Kongens Mølle* today known as *Frislusen*. *Midtmøllen* and *Ydermøllen* were subsequently built in 1526 and finally *Stampemølle* in 1581. Today, the water level in Østerå is regulated by the four sluices in Ribe city center.

↓ *Ill. 36 Maps of the changing waterscape (Made by author)*

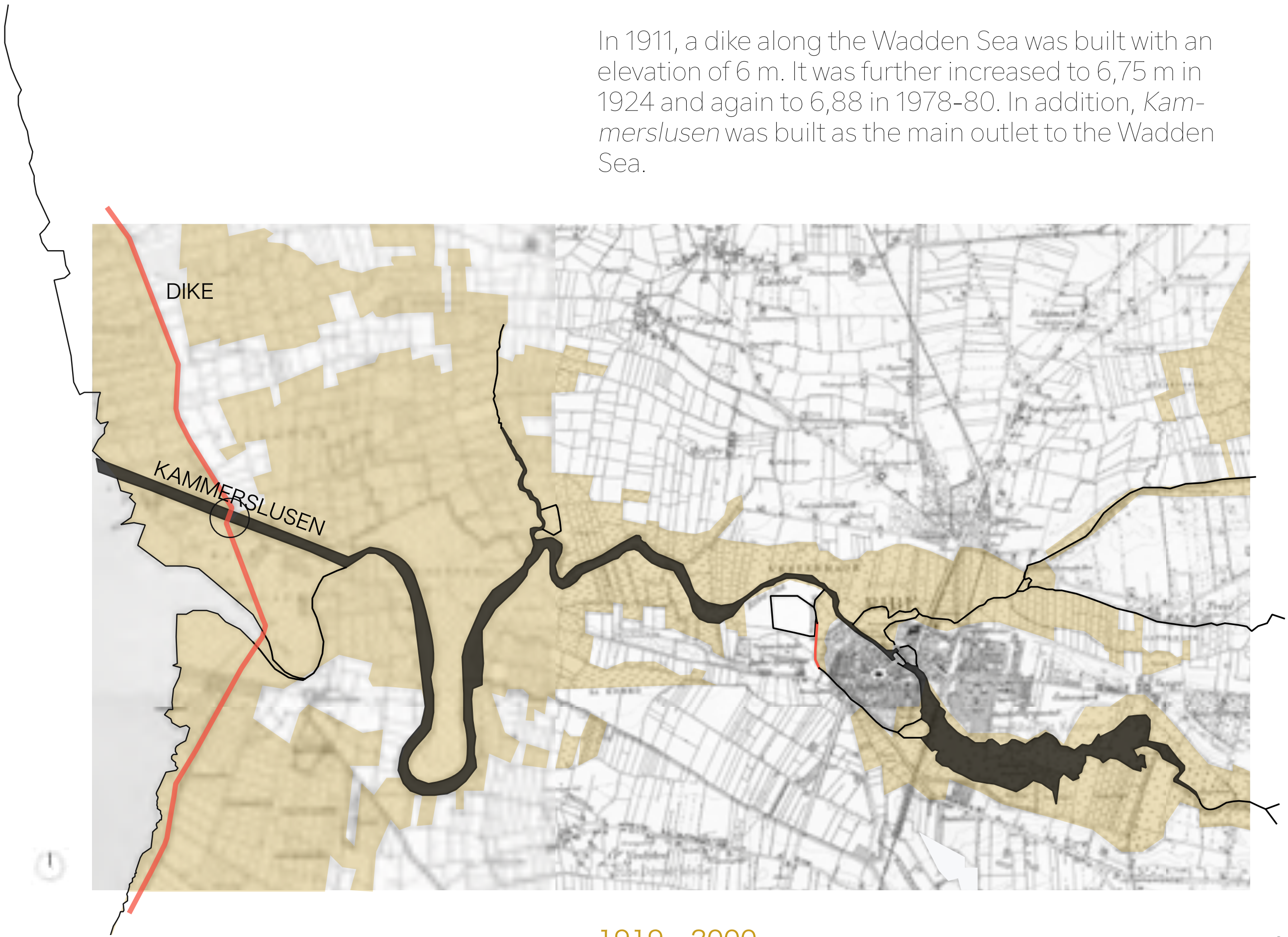


1855 - 1910

Already from the 16th century Vesterå had problems with sand deposits that made it difficult to enter Ribe Å. In 1855, a new canal was built towards the Wadden Sea, running through Fårup Meadow to ease the entry.

1910 - 1919

In 1911, a dike along the Wadden Sea was built with an elevation of 6 m. It was further increased to 6,75 m in 1924 and again to 6,88 in 1978-80. In addition, *Kammerslusen* was built as the main outlet to the Wadden Sea.



1919 - 2000

In 1919 an intersection of Ribe Å was built to make sailing easier. The intersections are named Ribe Holme and Peters Holme. Later, Ribe Å was made wider, which further increased drainage of the meadow and marsh area, which meant that agriculture became intensified and dominating in the marsh area.

(Data from: Kann 2001)

DE-CONSTRUCTION HISTORY

↓ *Ill. 37 Ribe in the Viking Age (Danhostel Ribe n.d.)*

700

Ribe is the oldest city in Denmark, founded in the early Viking age. The long history appears in the underground, as today's city center is built on top of 4-5 m layers of garbage deposited with organic material that can be traced back to around year 700. These cultural soil layers are termed *Kultursvampen* and reveal the history of an important trading city (Kann 2001; Askgaard & Folke 2017).

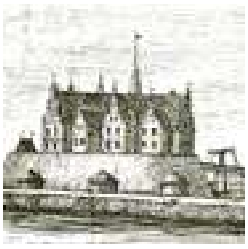
↓ *Ill. 38 The cultural layers in the soil (Danhostel Ribe n.d.)*

↓ *Ill. 39 Viking Ship in Ribe (Ribe Vikingecenter n.d.)*

1100

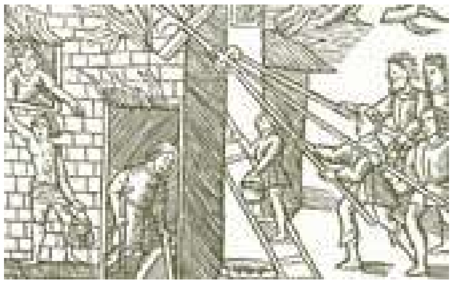
Ribe built momentum as the most important trading town up through the Middle Ages, where Ribe Å enabled sailing. Ribe Cathedral was built in the 12th century, which furthermore made the city an important church center (Askgaard & Folke 2017). The royal castle, Riberhus, was also built in the same years (Vadehavskysten n.d.). Only the ruins and castle banks can be seen today.

↑ *Ill. 40 Ribe Cathedral seen from the distance (Stamp n.d.)*



↑ *Ill. 41 Riberhus from around 1595 (Trap 1879)*

→ *Ill. 42 Ruins and castle banks from Riberhus (Skov 2019)*



↑ *Ill. 43 The large fire in 1580 (Agergaard n.d.)*

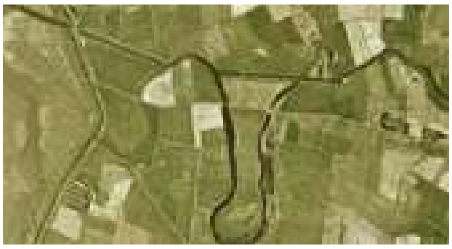
1500

In 1580, 213 buildings burned down in Ribe. The fire gave rise to a law that required all roofs to be made of stone. In 1600 all thatched roof buildings were rebuild (Agergaard n.d).

1600

In 1634 *The second Huge Man Drowning* flooded Ribe. With a water level of 6 m above normal, 10.000 people lost their lives and the whole city was ruined. In the following years Ribe was rebuild (Miljøministeriet n.d).

↑ *Ill. 46 Ribe Å after the new channel was built* (Geodatastyrelsen 2021a)



↑ *Ill. 47 Aerial photo of Ribe marsh* (Geodatastyrlsen 2021b)

↓ *Ill. 44 Entry to Ribe along Ribe Å* (Rasmussen 1869)

1800

In 1800 the new channel running through Fårup Meadow was build, which changed the waterscape.

↑ *Ill. 48 Intersection of Ribe Å* (Kulturministeriet 2020)

↑ *Ill. 45 Illustration of The second Huge Man Drowning* (Wikimedia Commons 2009)

↑ *Ill. 49 The dike along the coast* (Esbjerg Kommune & Nationalpark Vadehavet n.d.)

↓ *Ill. 50 Kammerslusen* (Karkov 2012)

1900

At the beginning of the twentieth century, the intersection of Ribe Å was made, the entire dike along the coast was built and Kammerslusen was established. All changes of great importance to the hydrological system, functions, and landscape (Kann 2021).

DE-CONSTRUCTION
LANDSCAPE ELEMENTS

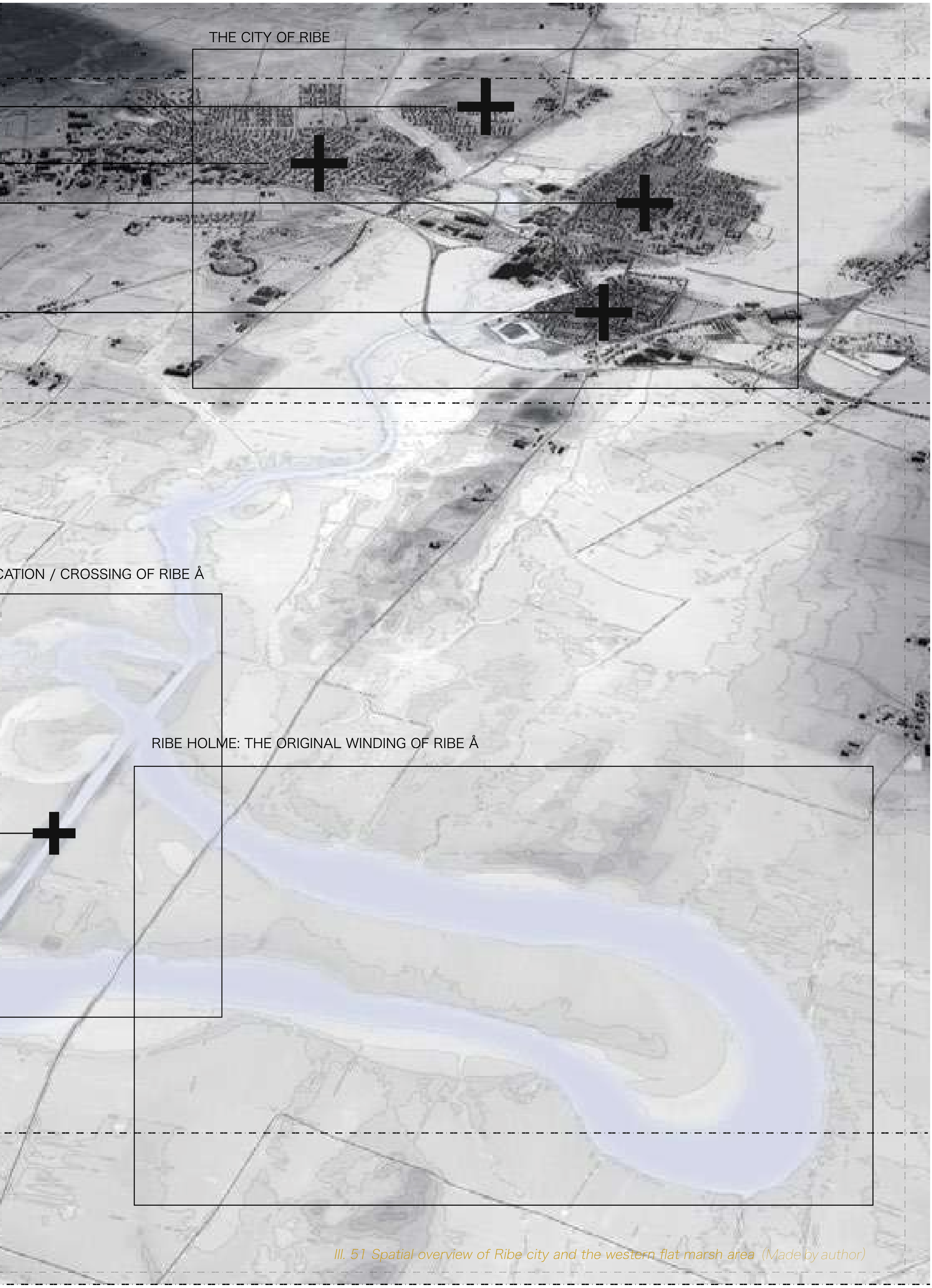
The city rises significantly in the landscape, as it is placed on hill islands withdrawn from the Wadden Sea. It creates a clear border between city and the open and flat landscape. Ribe Å runs close to the city, and winds its way between the hill islands. The city opens up to the surroundings and overlooks the flat marsh landscape.

The linear modification of Vesterå made passage by ship faster from the Wadden Sea to Ribe. With the modification the water level in the stream was lowered, which was an advantage for agriculture, that could more easily drain their fields.

Several years after the modification, attention was drawn to the consequences. The old town center struggled with subsidence as the lower water level in Vesterå causes lower groundwater level below the city. The cultural soil layers under the city dries out, which means that the organic material is metabolized more quickly and creates subsidence damage in the city (Kann 2001).

Ribe Marsh is a flat landscape with almost no vertical vegetation. The wide surface is transected by Ribe Å, that as a landscape element creates a connection between coast and city. In the past, before the modifications of the watercourse and the construction of the dike, the whole marsh was a dynamic area often flooded by salt water due to tide and storm surges. The marsh has transformed from being a saltwater marsh to be a freshwater marsh and from being rich in habitat and flora to be more uniform and less diverse.

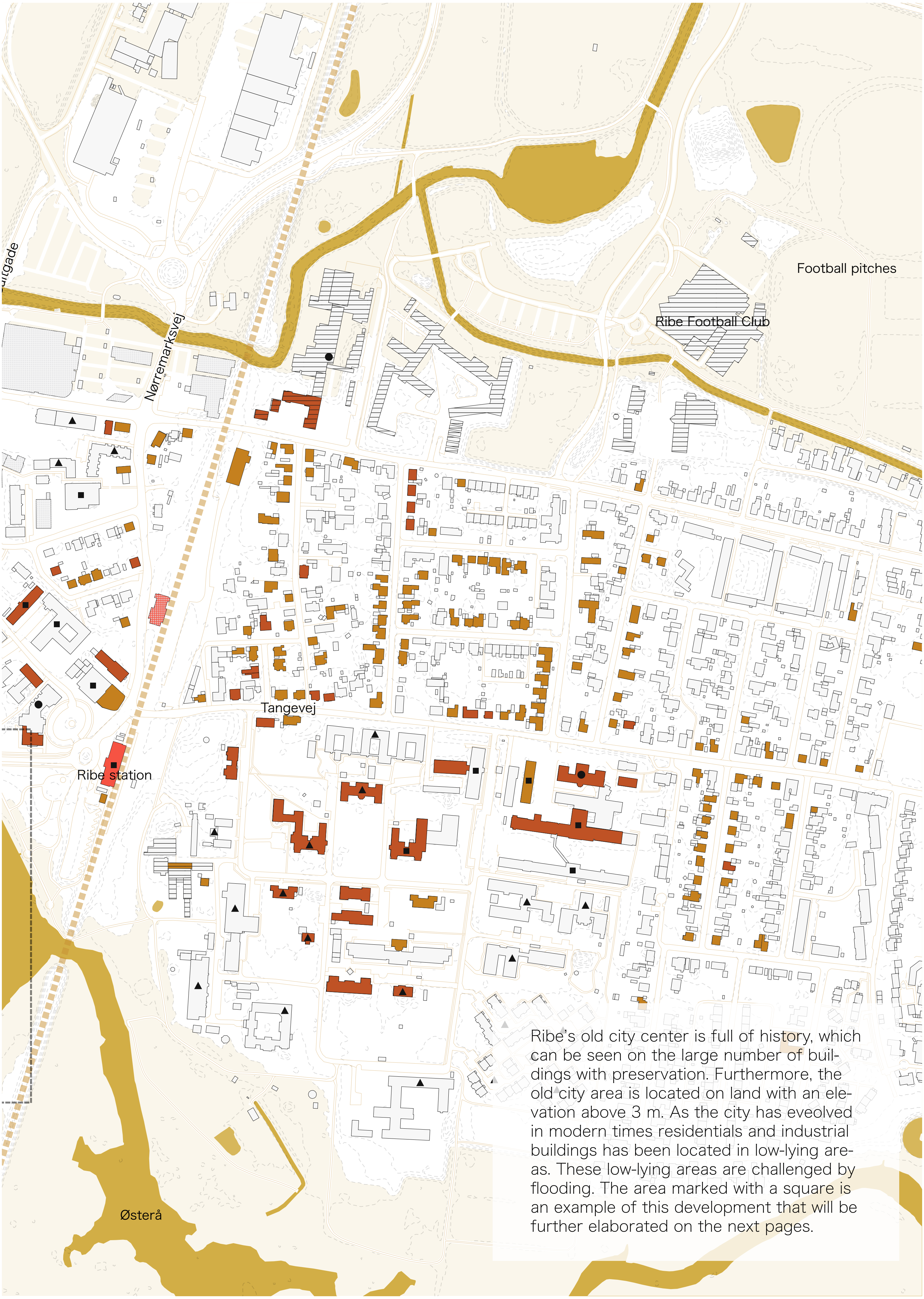
The outlet of Ribe Å has been modified to ease the entry by ship. Towards the Wadden Sea at the end of the new channel the outlet is controlled by Kammerslusen. At high tide the sluice is closed, and at low tide the sluice is opened and creates a flow.



Ill. 51 Spatial overview of Ribe city and the western flat marsh area (Made by author)

DE-CONSTRUCTION CITY CENTER

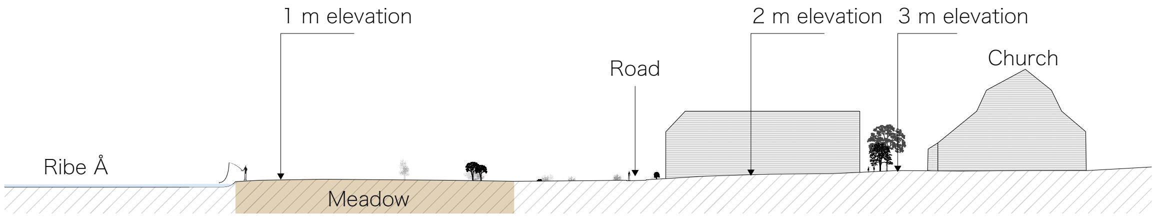
Ill. 52 Overview of Ribe city center showing build preservation 1:5000 (Made by author)



Ribe's old city center is full of history, which can be seen on the large number of buildings with preservation. Furthermore, the old city area is located on land with an elevation above 3 m. As the city has eveolved in modern times residentials and industrial buildings has been located in low-lying areas. These low-lying areas are challenged by flooding. The area marked with a square is an example of this development that will be further elaborated on the next pages.

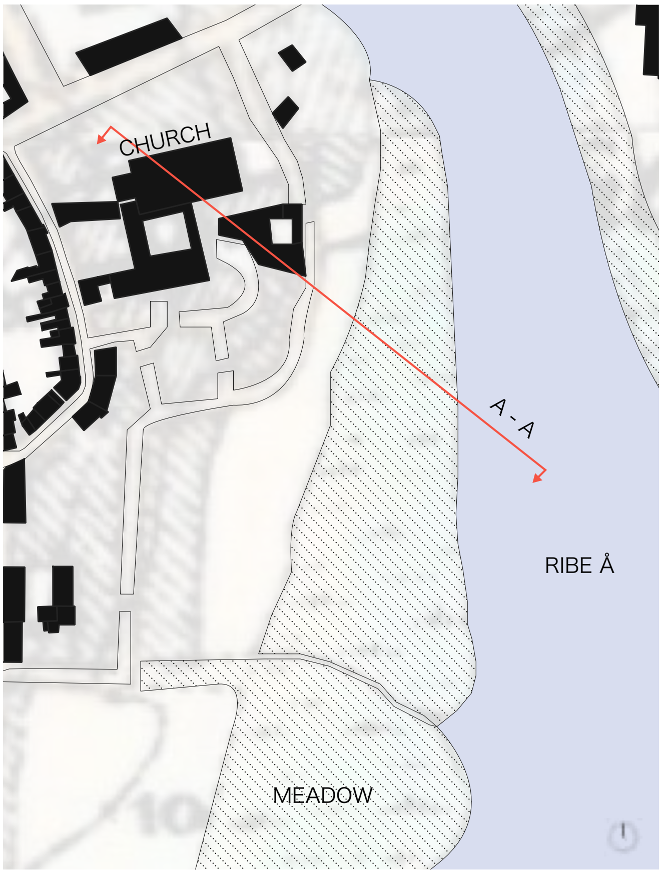
DE-
CONSTRUCTION
SETTLEMENT IN DEPRESSIONS

The area shown on illustration 53, 54, 55, and 56 is an example of how city development has ignored the *deep structures* or natural conditions at the specific site. Up until 1899 the meadow along Ribe Å has been kept free from build structures, as the area is low-laying, and the soil conditions are bad for constructions. Nevertheless, in recent years, houses have been built in the meadow area. All the houses have been built around 1910, including infrastructure in the form of the road Kurveholmen. The cross-section at illustration 57 shows how the church was built in 3 m elevation away from Ribe Å and the meadow. When looking at the cross-section at illustration 58, the built structures has later exten-



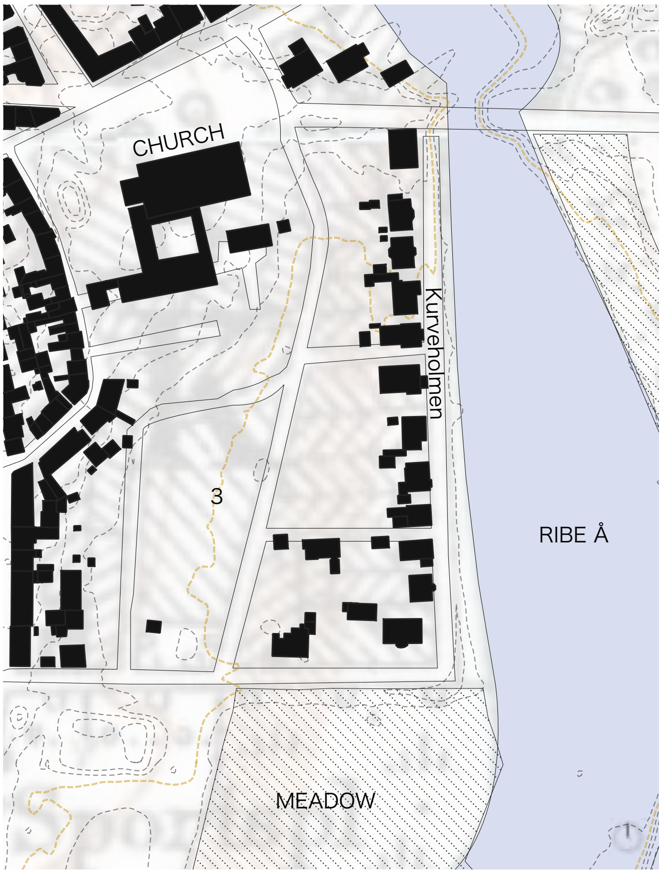
↑ *Ill. 57 Cross-section A - A from 1842 - 1899 1:1500 (Made by author)*

1842 - 1899



↑ *Ill. 53 1842 - 1899 1:3.000 (Made by author) (Data from: Høje Målebordsblade)*

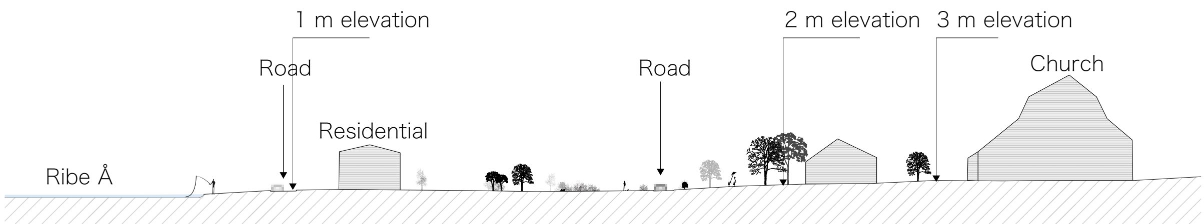
1901 - 1971



↑ *Ill. 54 1901 - 1971 1:3.000 (Made by author) (Data from: Lave Målebordsblade)* ded downwards to 1-2 m elevation. In this way the build structures have taken over the natural meadow area and the dry city has been prioritized higher than the wet city.

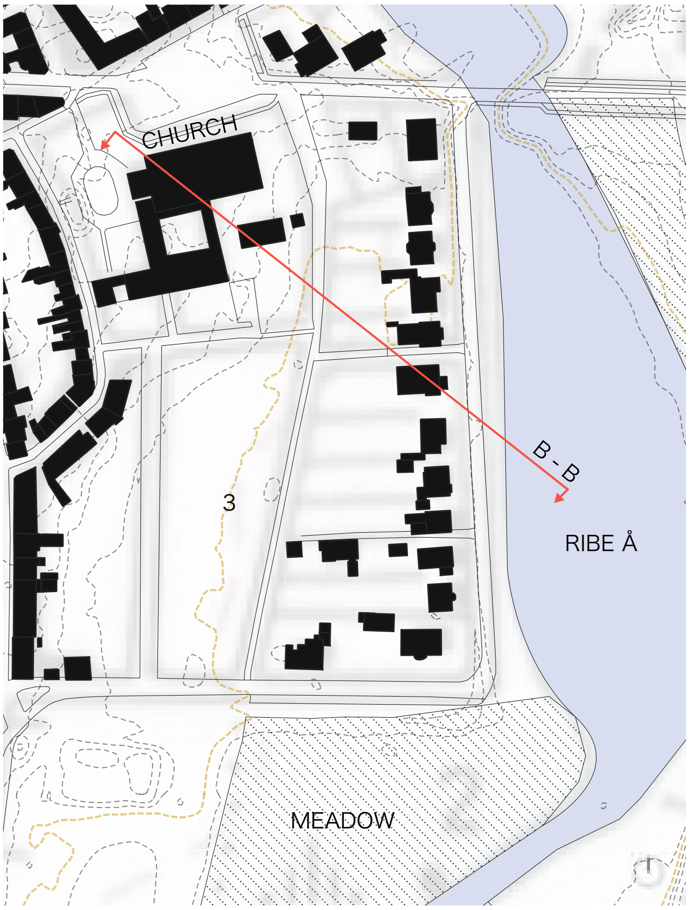
Furthermore, illustration 56 shows the blue spot pattern with 15 mm water. Clearly it shows how the area of Kurveholmen will be challenged by major rainfall events. When looking at future climate predictions, areas like the example, will be in high risk of flood, not only by precipitation but also by watercourse floods and storm surge, which will be further elaborated in the sections *Storm Surge*, pp. 140-141 and *Watercourse Flood*, pp. 142-145.

NOTE/ As earlier presented, Katrina Wiberg's PhD indicates how settlement has been placed in former green and blue stretches through the city. In this way build structures opposes the natural conditions, and these areas will be challenged by future climate (Wiberg 2018).



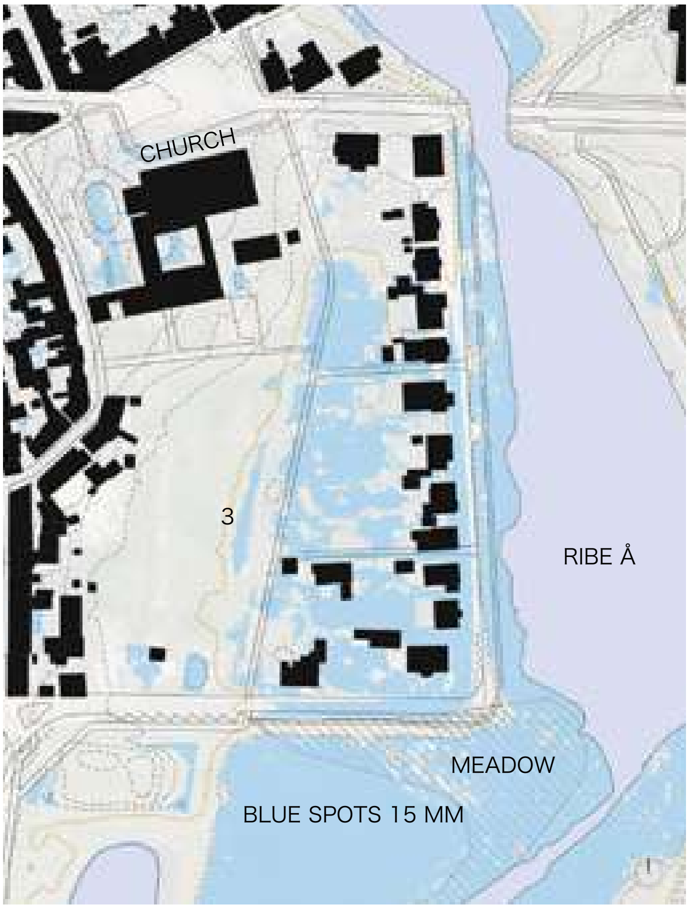
↑ *Ill. 58 Cross-section B - B after 1901 1:1500* (Made by author)

1980 - 2001



↑ *Ill. 55 1980 - 2001 1:3.000* (Made by author) (Data from: DTK/4cm)

2021

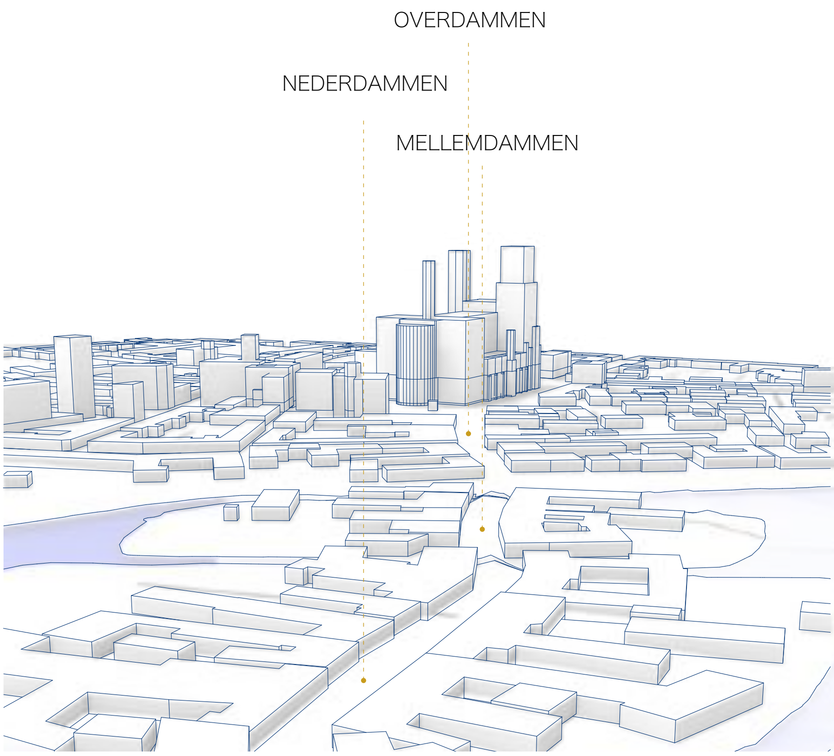


↑ *Ill. 56 2021 1:3.000* (Made by author) (Data from: GeoDanmark)

DE-
CONSTRUCTION

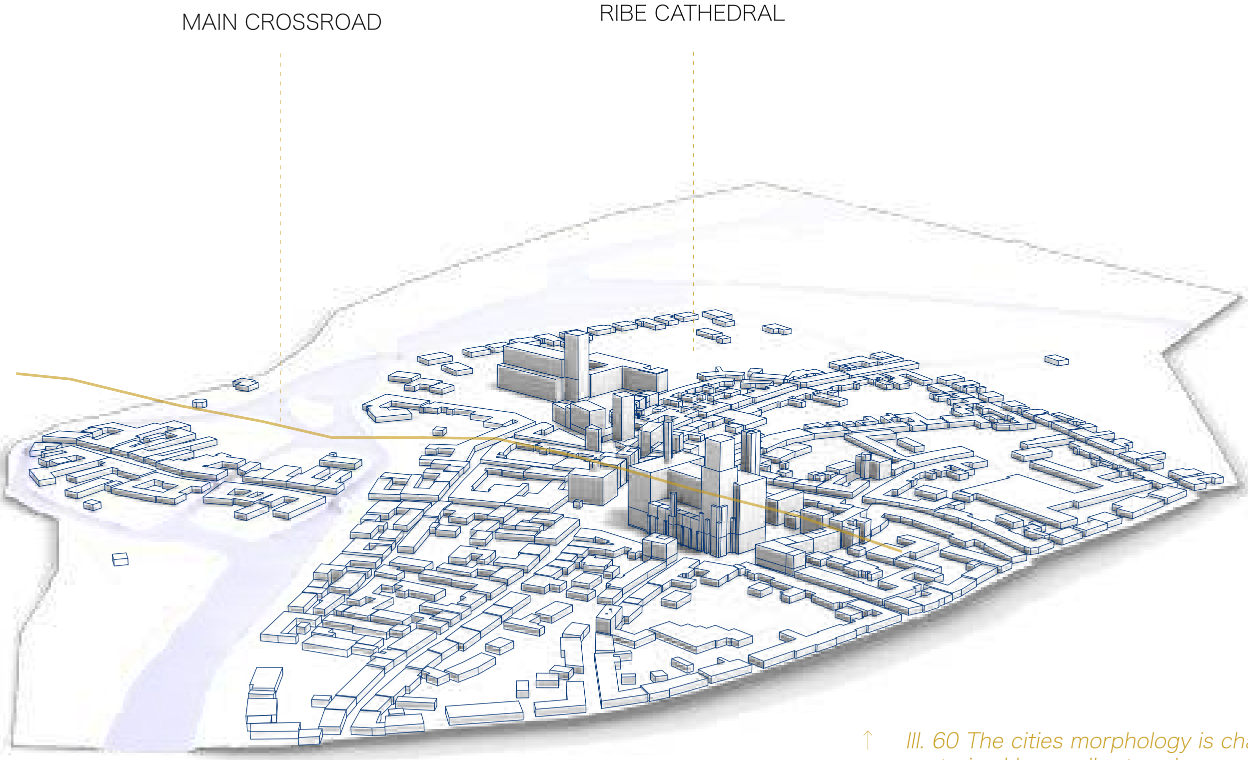
CITY MORPHOLOGY

As the oldest city in Denmark, Ribe's city center is characterized by its classic medieval structure. Here, the cathedral is located in the center of the city where it enthrones among the smaller city houses as illustration 59 and 60 clearly shows. The main crossroad consisting of Overdammen, Mellemdammen, and Nederdammen runs through the city center, and has minor informal streets. Illustration 61 shows a view down through the main crossroad with the dominant cathedral at the end. Furthermore, the city is dense with small gathering spaces and the water is close to the city. Typically, medieval cities have had city walls, but Ribe is an exception. Instead, they protected themselves behind the many moats.



← *Ill. 61 The 3D model shows a view down through the main crossroad (Made by author)*

↑ Ill. 59 Aerial photo of Ribe's old city center. The volume of the cathedral stands in contrast to the smaller town-houses (Vadehavskysten n.d)



↑ Ill. 60 The cities morphology is characterized by smaller townhouses connected by irregular streets (Made by author)

↑ *Ill. 62 Ribe Cathedral and the square is an important landmark in Ribe. The pavement marks an urban space that unifies the surrounding buildings and makes them accessible for people (By author)*

The urban space surrounding Ribe Cathedral is the main square. Up until 2010 the square suffered from an increased number of cars in the city center. Esbjerg municipality made a new plan for infrastructure and the square was redeveloped between 2010-2013 (Ribe Domkirkeplads 2020). Today the square together with the Cathedral is an important landmark in the city.

↓ *Ill. 63 Ribe Cathedral calls for attention with its location in the center of the square (Stamp n.d.)*

The historic city is an important evidence of the Danish history and a well-preserved example of the classic medieval city structure. The small streetscapes, irregular street structure, and several listed and preserved buildings attracts many tourists every year.

In this project, the case specific study of Ribe is unusually as the city's cultural heritage has not only local value but also national value. Furthermore, the location in the landscape nearby the Wadden Sea makes the case study special. This will be further elaborated in chapter 6, *Reflection / Critic*, pp. 180-181.

↑ *Ill. 64 The streetscape reflects Ribe's long history (By author)*

↑ *Ill. 65 The half-timbered house at Præstegade 15 is the old chapel residence. It was one of the few buildings that didn't burn in 1580 (By author)*

↓ *Ill. 66 Minor informal street connected by the crossroad (By author)*

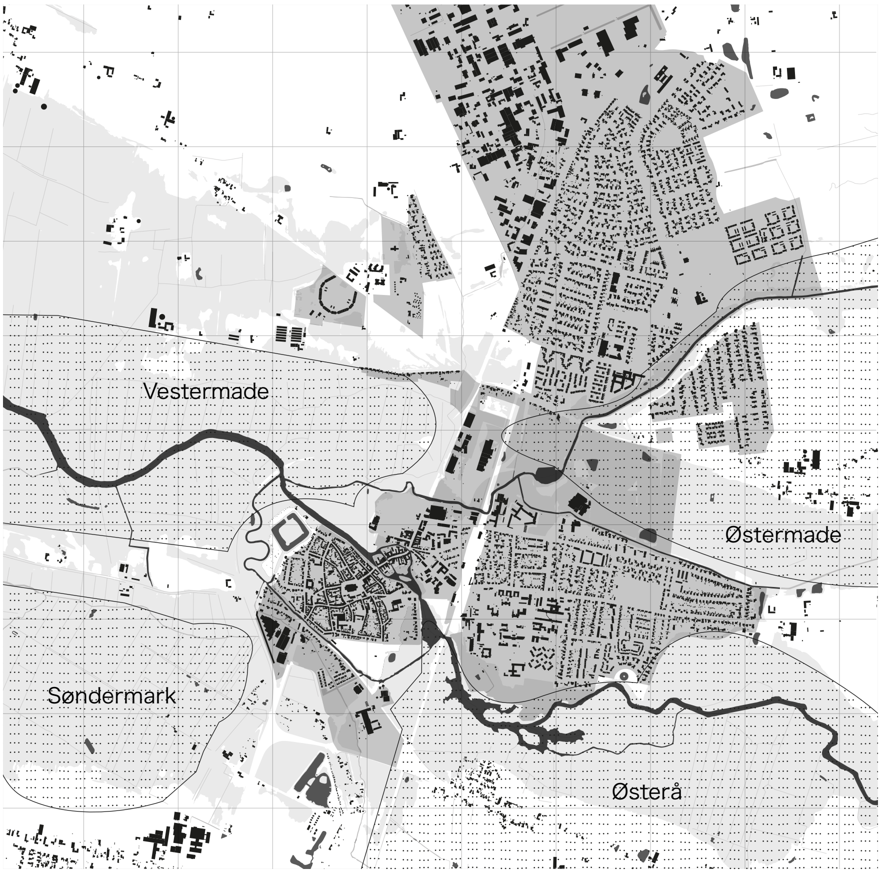
SURROUNDING LANDSCAPE

NOTE/ What kind of nature do we strive towards? Is it restoration back to a certain time or is it a new kind of nature that considers the present and the deep structures? This will be further discussed in chapter 6, Reflection / Critic, pp. 180-181.

The meeting between city and landscape is a characteristic element in Ribe (see illustration 67). The city is built on top of minor landscape elevations, and it is surrounded by the flat and open marsh and meadow with no buildings. The landscape reveals the long cultural entanglement, where settlement in relation to the changing waterscape, was limited to the smaller sandbanks in the landscape. Thus, the edge between city and landscape are sharply defined. This character is important to maintain by limiting the planting in the marsh area and further strive for the historic landscape character of the area. It should not be an attempt to return to the past, instead the attempt should be to let the inherent conditions of the place have a voice.

When looking at Ribe from the distance the skyline is significant. The city is compact and the Cathedral tower dominates the view. The skyline slightly changes when moving around the city in the flat landscape. Illustration 68 shows the variation. Especially the view from Ringvejen, shows a characteristic skyline of the city.

The surrounding landscape can be divided into four areas as illustration NO shows. The areas are connected by Ribe Å, but the green stretch through the city could be further enhanced.



← Ill. 67 Four different landscape areas surrounds the city of Ribe (Made by author) (Data: Miljøministeriet Planstyrelsen 1990)

↓ Ill. 68 The profile of the city seen from the flat landscape. The below picture shows the city from Ringvejen, the upper left picture shows the city from Vestermade, and the upper right sketch shows the city from Riberhus (By author)

DE-
CONSTRUCTION

RIBE Å, THE MARSH AND THE WADDEN SEA

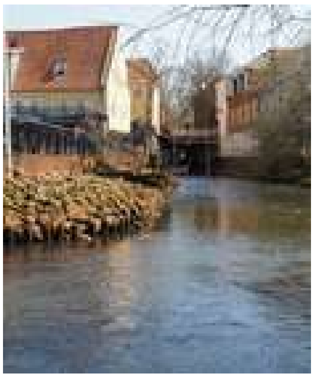
↓ *Ill. 69 Ribe seen from Riberhus, which marks the former military position (By author)*

Ribe is located 5 km away from the Wadden Sea, that is a UNESCO World Heritage site and the largest national park in Denmark. Ribe Å runs through the marsh area between the city and the sea and is an important area for abiotic and biotic functions. The Wadden Sea and the marsh area is a large area of habitat for migratory bird, mammals, and the area function as a corridor for fishes that mitigate inland through Ribe Å. Especially the interest of the migratory birds are important to support and enhance. On the East Atlantic Flyway over 12 mio. birds fly from north to south and the Wadden Sea function as a recovery area on the route (Nationalpark Vadehavet 2013).

LOSS OF NATURAL VALUE

Before the watercourse regulations in 1919, the whole area contained even greater natural values. Due the regulation and the lowering of the water level in Ribe Å, the moist meadow, specialist plants, insects, and birds, including the stork, has decreased. Instead, agriculture has gained ground, as the marsh area has been drained, by means of excavations and ditches.

↓ *Ill. 70 Ribe Å runs close to the city through dams. This testifies the city's cultural relation with the water (By author)*



↑ *Ill. 71 The cultivated marsh area contains a large network of ditches* (By author)

↑ *Ill. 72 Kammerslusen marks the entry to Ribe Å from the Wadden Sea* (By author)

DYNAMIC TIDAL AREA

The Wadden Sea is a tidal area that is everchanging and dynamic. Future climate will bring even more water to the area, which will contribute to the changing landscape. Twice a day the water level rises and falls about 1,5 m. In the past the marsh was often flooded along with the tidal dynamic, but the transition from sea to marsh is today defined by the high dike. Thus, the marsh has changed from being flooded by salt water, to the current state where the marsh is drained and only flooded by fresh water.

↑ *Ill. 73 Areas close to Ribe Å has stronger natural value than areas further away* (By author)

↓ *Ill. 74 View of the Wadden Sea National Park* (By author)

← *Ill. 75 When migratory birds take a break in the Wadden Sea area, they gather in large flocks that form the natural phenomenon 'black sun'* (Vadehavskysten n.d.)

DE-
CONSTRUCTION

CONNECTIONS AND ATTRACTIONS

Ribe is well connected to the nearby cities, but the transverse connections from the city to the Wadden Sea is poor. There are no recreational paths for people to enjoy the nature.

Ill. 76 Map of connections and attractions (Made by author)


RIBE NORTH
Varde Hovedvej
Koldingvej
Farupvej
Trojelsvej
RIBE OLD CITY AND CENTER
NEW RESIDENTIAL AREA
RIBE SOUTH
RIBE EAST
Haderslevvej
RIBE VIKING CENTER
(MUSEUM)

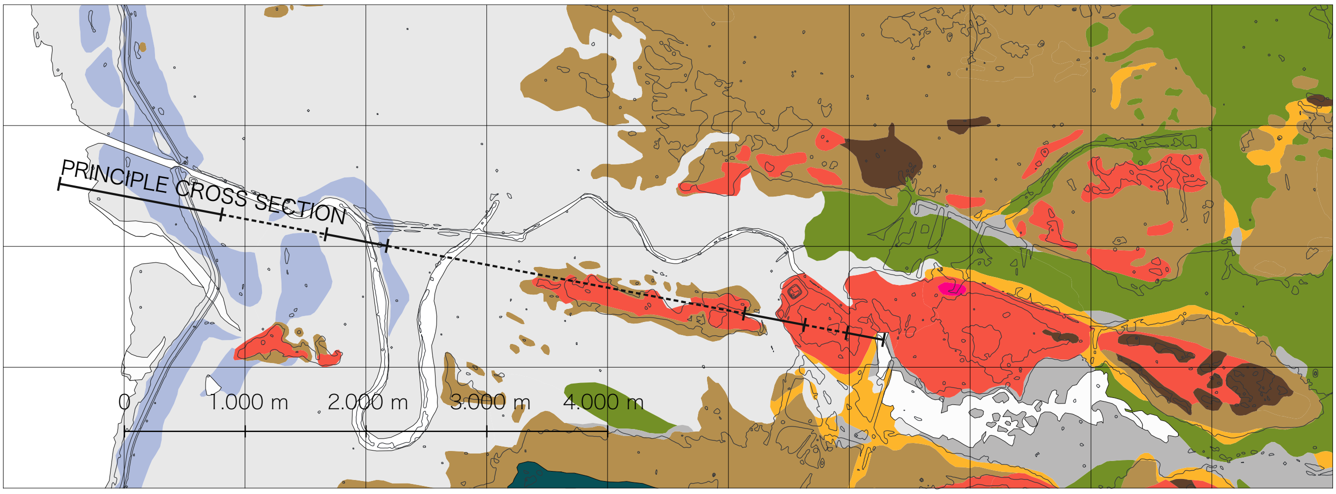
DE-
CONSTRUCTION
LANDSCAPE FORMATION

Ribe marsh covers an area of 2.500 hectare (see illustration 77) and extends all the way up to the city in east. The landscape is formed by the two glacial periods. At the first glacial period, Saale, the whole country was covered by ice, which formed the area like a hilly landscape. The last glacial period, Weichel, did only cover half of Denmark with a defined line down towards Jutland. The southwestern area of Denmark where Ribe is located, was not covered with ice, but as the ice began to melt it ran towards the Wadden Sea in west and created the large outwash plains (Jelnes et al. 2006). The highest areas are classical hill islands, and minor elevations are areas filled with sand from later times. These areas are moorland plains consisting of meltwater sand. Ribe is located on a moorland plain with sand sedimentation (see illustration 78). The marsh itself consists of soil with a typical mix of sand, organic sediments and clayey (Bartholdy & Pedersen 2019).

The meeting between the flat marsh and moorland plains is termed 'geest'. Geesten is typically at a height of 2.5 m, which makes settlement possible without the risk of major floods. This explains the settlement pattern in the whole marsh area, where build structures are located high in the terrain (see illustration 79).

Ribe Marsh

→ *Ill. 77 Boundary of Ribe Marsh covering 2.500 hectare 1:90.000* (Made by author)



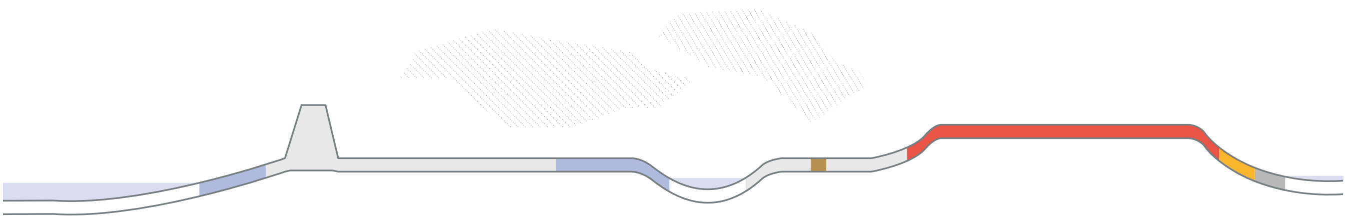
↑ *Ill. 78 Geological map - soils near the surface* *(Made by author) (Data from: GEUS 2020)*

- Freshwater sand (Postglacial)
- Freshwater peat (Postglacial)
- Sand
- Aeolian sand (Postglacial)
- Meltwater sand (Glacial)
- Freshwater gyttja (Postglacial)
- Meltwater sand (Postglacial)
- Saltwater sand (Postglacial)
- Alternating thin saltwater beds, marsh (Postglacial)

COAST LANDSCAPE

THE MARSH LANDSCAPE

CITY ON THE GEEST / HILL ISLANDS



Salt meadow formed by ocean currents, tides, wind, and wave erosion. These dynamics has also formed the large marsh area in the lowland behind the dike.

Meltwater valleys formed by large meltwater streams from the second Weichsel-glacial period. The flat valley consists of fine sand and alternation thin saltwater beds.

Outwash plains formed by melting ice from the second Weichsel-glacial period, followed by sand disposits.

↑ *Ill. 79 Principle cross section of the case today (The colors refers to the soil types at illustration 78)* *(Made by author)*

DE-CONSTRUCTION THE GREEN LANDSCAPE

→ *Ill. 81 Cultivatet fields and designation of lowland areas ('lavbundsarealer') 1:90.000*
(Made by author) (Data: Erhvervsstyrelsen n.d. and Miljø- og Fødevarministeriet Landbrugsstyrelsen n.d.)

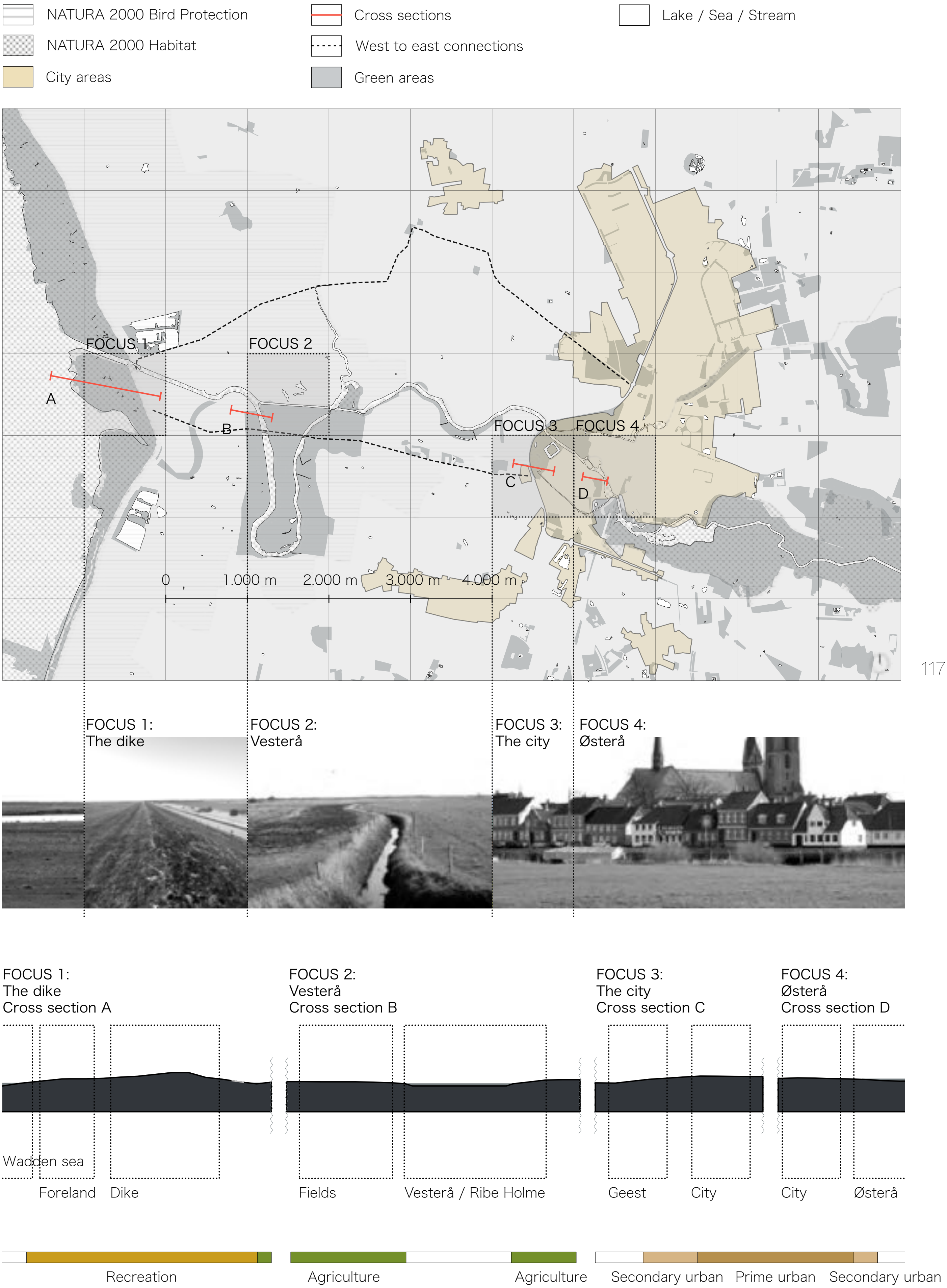
Ribe's landscape has high natural value. Large parts of the landscape are protected. The entire coastal zone as well as Vesterå and Østerå is a NATURA 2000 habitat area, and a large part of the marsh is an area of NATURA 2000 Bird Protection. As the map on illiustration 80 shows the stretch from the sea to the city varies. It consists of the coast, dike, marsh, Vesterå, geesten, the city, and Østerå. Once again it becomes clear that a recreational route that captures the landscape variations is missing in an east-west going direction. The coast area invites to great nature experiences, while the marsh area including Vesterå is mainly used for agricultural functions.

THE CULTIVATED LANDSCAPE

NOTE/ The removal of cultivation in low-lying areas has in recent years played a significant role in the desire to reduce agricultural emissions of greenhouse gases, reduce emissions of nitrogen to the sea, and restore or improve nature. For Ribe, this will be a relevant consideration to make. This will be further discussed in chapter 6, Discussion: Perspectives and outcomes, pp. 172-175.

Parts of the marsh area are permanent grass used for grazing, while other parts are used for cultivation of oats, potatoes, corn, barley, wheat, etc. (OBICON 2015). The cultivation makes the soil impermeable to water, which entail that the water must evaporate or run to the nearest ditch. In winter periods where precipitation is high, the water remains as basins in the area, to the inconvenience of farmers, while in the summer periods all the water will evaporate (OBICON 2015). To secure runoff and drainage of the fields there is a fine masked ditch system in the marsh area, as shown on illustration 81.

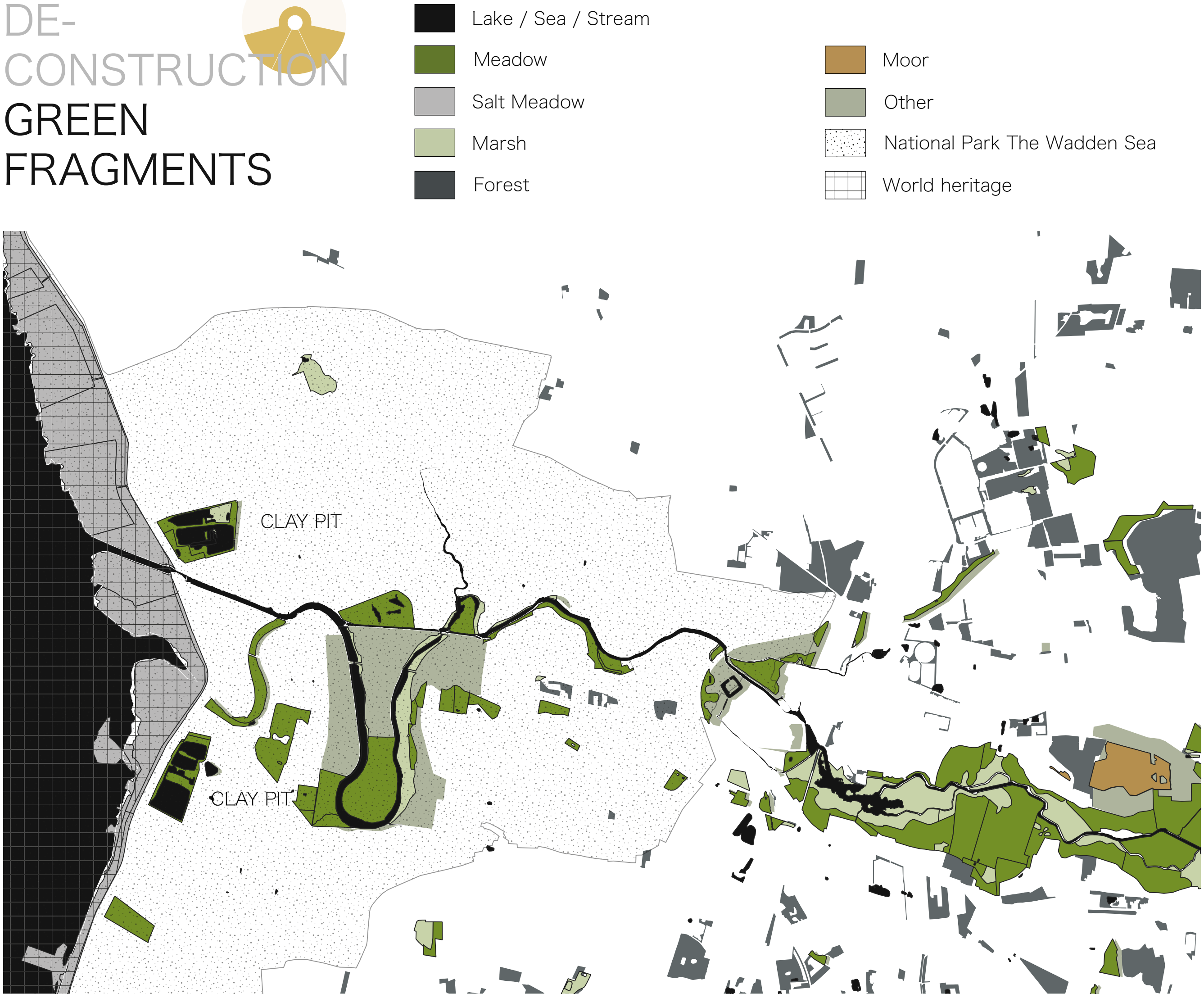
With the rising sea water level, the marsh area will be below sea level, which makes the drainage harder. The groundwater level will also increase, which will entail that the soil under the current conditions, will be moister over time. Furthermore, large parts of the marsh area are lowland areas ('lavbundsarealer') which also indicate that the soil is moister. To maintain agriculture in the area further drainage will be needed.



↑ *Ill. 80 Map (1:60.000), pictures, principle cross section and functions from The Wadden Sea to Ribe city (Made by author)*

DE-
CONSTRUCTION

GREEN FRAGMENTS



↑ *Ill. 82 Different protected nature types exist in Ribe's surrounding landscape 1:60.000 (Made by author)*

The landscape around Ribe contains various protected nature types, such as meadow, salt meadow, marsh, and moor, as illustration 82 shows. The different nature types are centered around Ribe Å, and the two clay pits are examples of new nature areas with great significance for bird life.

↓ Ill. 83 The blue and green structures surrounding Ribe are fragmented 1:60.000 (Made by author)

Even though the Wadden Sea National Park has the largest number of different habitat types in Denmark (Nationalpark Vadehavet 2013), the nature types are fragmented. Illustration 83 shows how the green and blue structures are incoherent spots in the marsh. There is a potential for connecting the fragmented blue and green structures in the west-east going direction. This stretch would also provide an opportunity to integrate recreational connections into the landscape and in this way activate the existing natural values for people to use and enjoy.

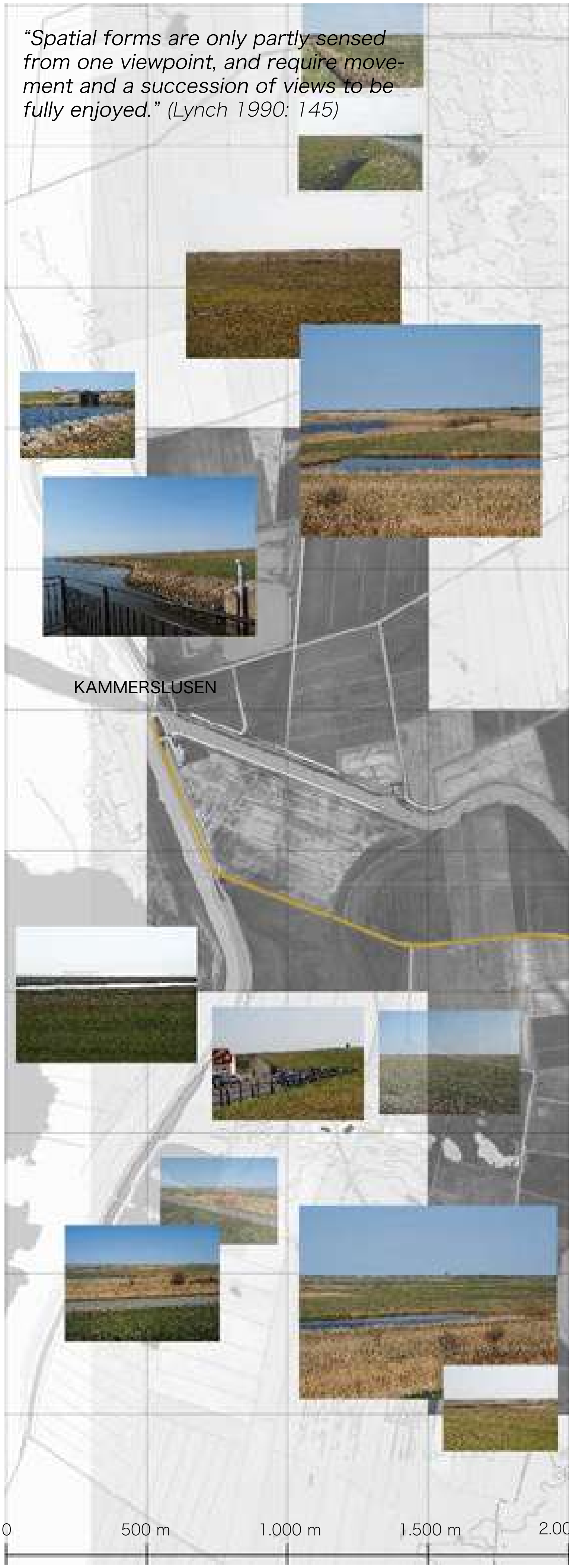
DE-CONSTRUCTION THROUGH THE LANDSCAPE

SITUATIONAL EXPERIENCE OF A RIDE THROUGH RIBE MARSH

Date: 17.04.2021
Time: 11.00
Road: Bjerrumvej

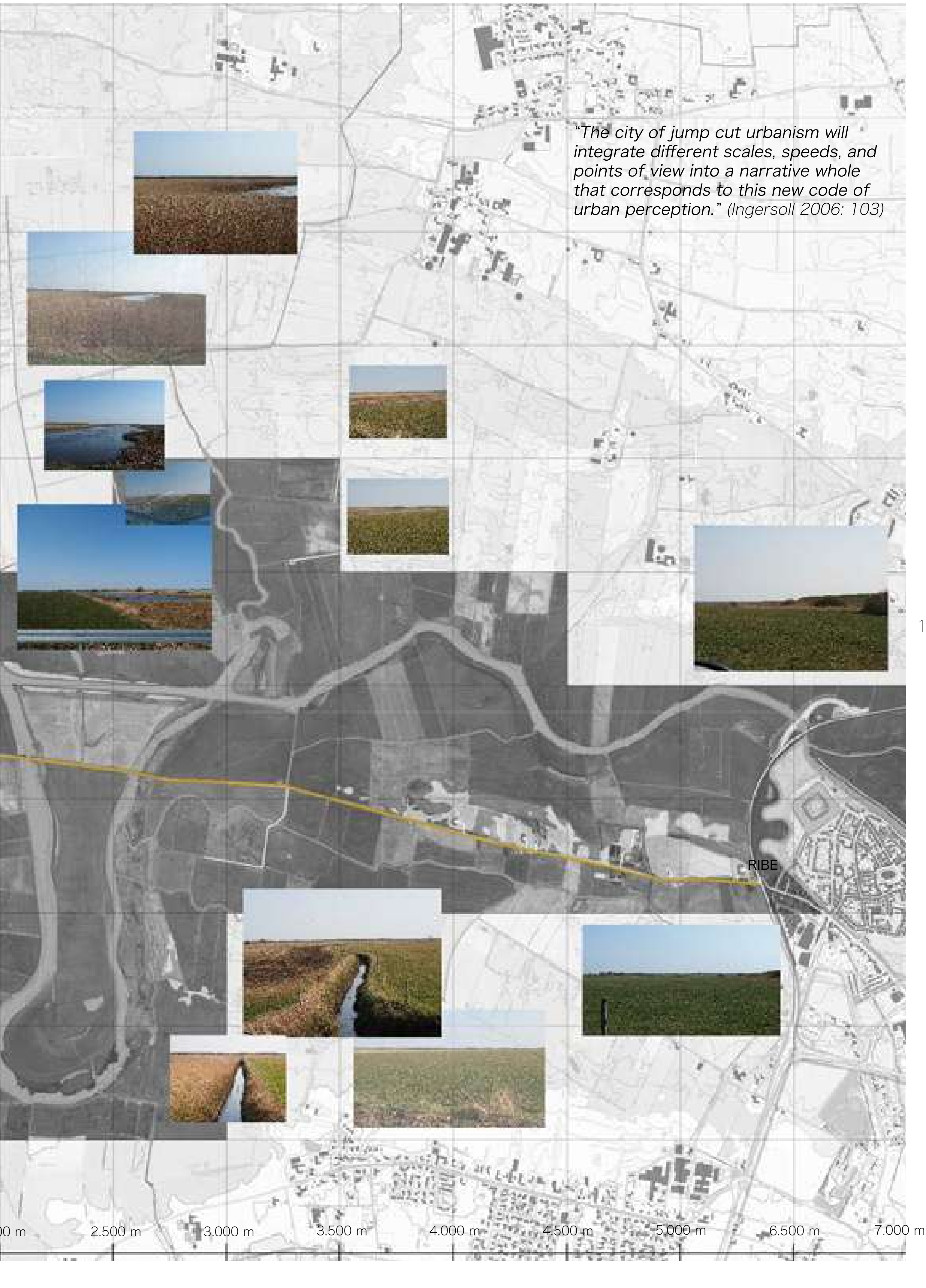
The ride with car from Ribe city to the Wadden Sea is a situational experience depending on the day, time, and person. The visual perception is documented in photos, that gives a sense of the landscape. The marsh area is a scenic place with a flat open marsh outlined between the city and the dike. The area does not invite to stays, but the road leads one out to Kammerslusen and the Wadden Sea, which can be further explored as an attraction in the area. As previously stated, the area has a great potential to be activated for people to use and strengthen the existing character and functions.

"Spatial forms are only partly sensed from one viewpoint, and require movement and a succession of views to be fully enjoyed." (Lynch 1990: 145)



→ *Ill. 84 Situational experience of a ride through Ribe marsh (Made by author)*

“The city of jump cut urbanism will integrate different scales, speeds, and points of view into a narrative whole that corresponds to this new code of urban perception.” (Ingersoll 2006: 103)



HABITAT AND VEGETATION

Ribe Å's large river system is of great importance to a number of vulnerable plants and animals. The list on these pages as well as the next pages, gives an overview of the large amount of animal and plant species. One of them is the salmon species, Snæblen, that has international attention as it is endangered. Snæblen lives in the Wadden Sea and swims into Østerå along Ribe Å where it spawns (Nationalpark Vadehavet 2013). Another species of special interest is the stork. The stork lives in wet and humid areas along Ribe Å and the marsh. Both the stork and snæblen have had challenges with the intensified agriculture and water regulations (Kann 2001). Snæblen has had unfavorable conditions due to blockages in the water system as well as decreasing water quality, and the stork suffers under the increased drainage of the marsh. A diverse plant and animal life are increasingly being replaced with monocultures of agricultural crops. Several reports state the loss of natural value, and suggest improvements (see e.g., OBICON 2013 and OBICON 2015). One improvement is to establish natural hydrology by creating more wetland with retention ponds in the area (OBICON 2013). These areas would attract birds in the same way as the clay pits. Another improvement is re-winding of Ribe Å, that would improve the natural conditions for the area's birds (OBICON 2015). Both proposals should be considered in relation to agricultural interests.

THE SALT MEADOW OUTSIDE THE DIKE AND THE WADDEN SEA

- Sæl
- Odder
- Marsvin
- Strand-annelgræs
- Kveller
- Almindelig vadegræs
- Strand-kogleaks
- Strand-asters
- Stilkløs kilebæger
- Strand-vejbred
- Strand-trehage
- Smalbladet kællingetand
- Harril
- Rød svinge
- Almindelig rajgræs
- Lav ranunkel
- Ager-tidsel
- Almindelig kvik
- Almindelig rajgræs
- Kryb- hvene
- Græsning af kvæg
- Ederfugl
- Vibe
- Strandskade
- Stor præstekrave
- Rødben
- Klyde
- Dværgterne
- Almindelig ryle
- Gæs
- Ænder

↓ *Ill. 85 Animal and plant life are intensified in different areas* (Made by author)

The animals and plant species are listed in Danish (Data from: Nationalpark Vadehavet, 2013; Søndejyllands Amt et al. 2005; Jelnes et al. 2015)

THE CLAY PITS

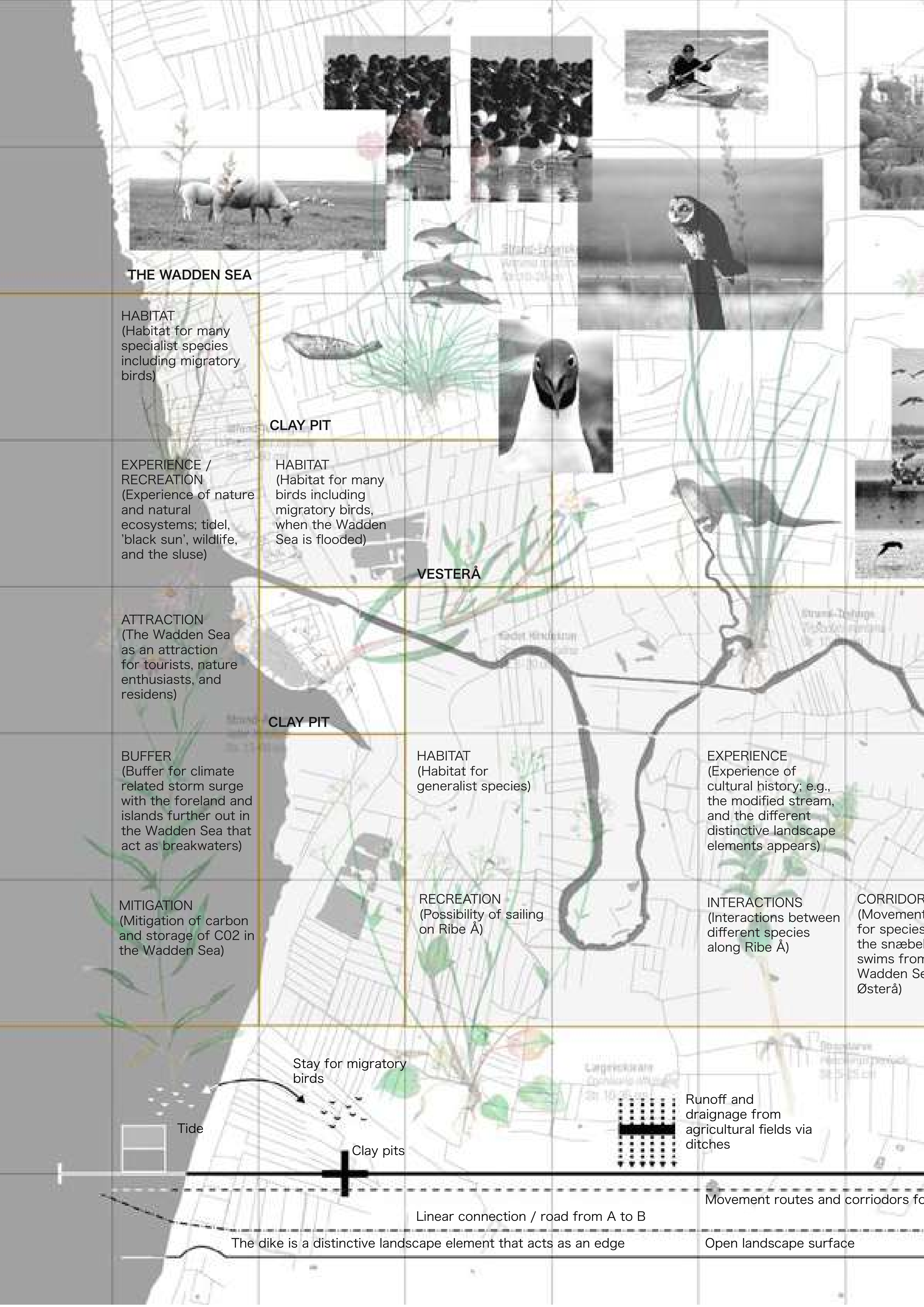
- Toppet lappedykker
- Knopsvane
- Grågås
- Gravand
- Knarand
- Krikand
- Gråand
- Atlingand
- Skeand
- Taffeland
- Troldand
- Blishøne
- Strandskade
- Klyde
- Vibe
- Stor kobbersneppe
- Rødben
- Hættemåge
- Fjordterne
- Gul vipstjert
- Brushane
- Mosehornugle
- Grågås
- Pibeand
- Krikand
- Gråand
- Spidsand
- Vibe
- Brushane
- Stor regnspove
- Rødben
- Hvidklire
- Grøn mosiakguldsmed
- Krebseklo

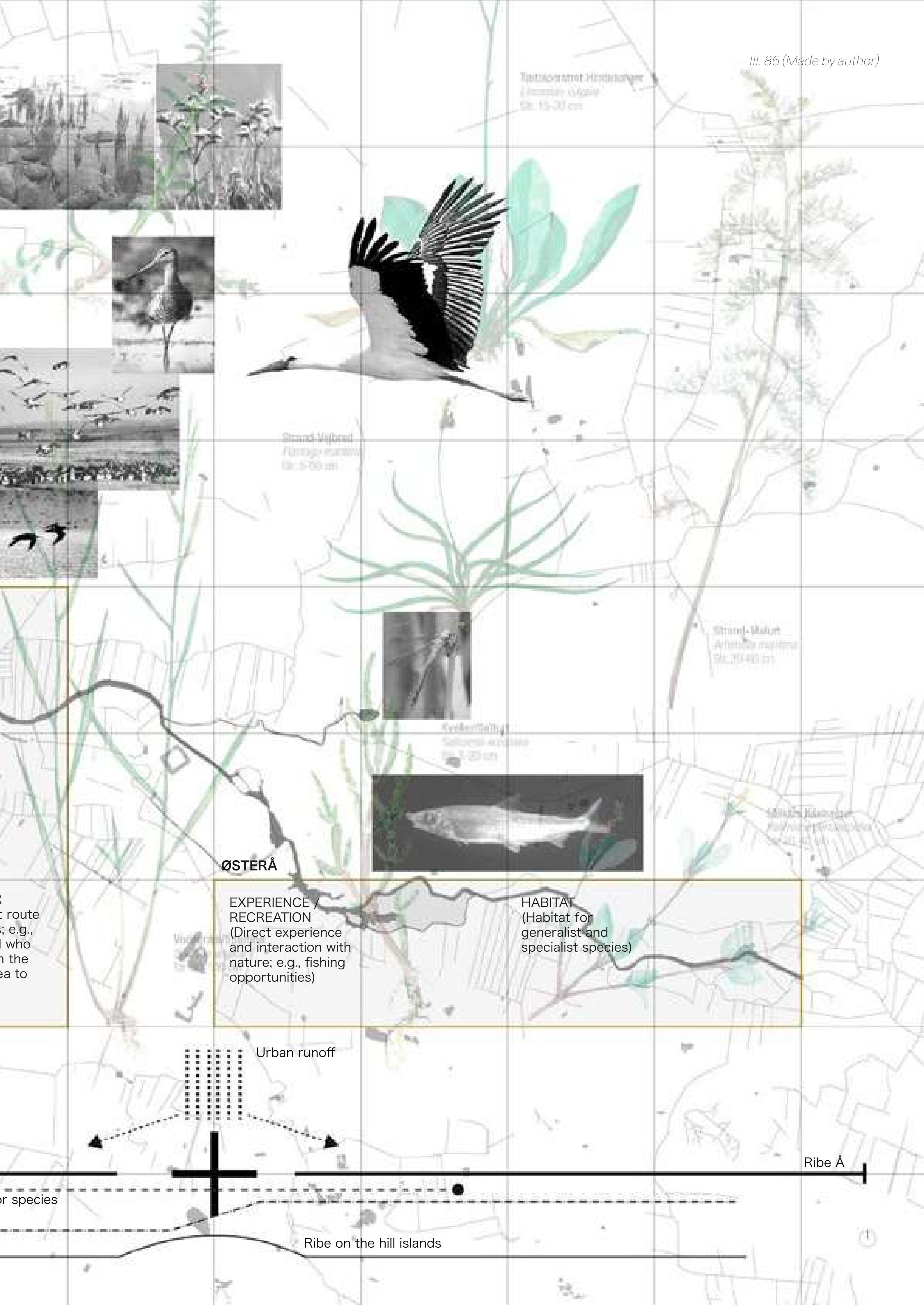
VESTERÅ

- Tagrør
- Rørgræs
- Brudelys
- Kalmus
- Nikkende star
- Ager-tidsel
- Lav ranunkel
- Kruset skræppe
- Eng-kabbeleje
- Eng-for- glemmigej
- Kær-snerre
- Smalbladet kællingetand
- Stor kobbersneppe
- Gul vipstjert
- Vibe
- Dobbeltbekkasin
- Rødben
- Toppet lappedykker
- Gråand
- Blishøne
- Strandskade
- Vibe
- Rødben
- Mosehornugle
- Pibesvane
- Sangsvane
- Sædgås
- Kortnæbbet gås
- Bramgås
- Canadagås
- Pibeand
- Krikand
- Vibe
- Hjejle

ØSTERÅ

- Stalk
- Flodlampret
- Bæklampret
- Snæbel
- Laks
- Odder
- Tagrør
- Høj sød- græs
- Rørgræs
- Gul iris
- Eng-rørhvene
- Almindelig mjødurt
- Krybende baldrian
- Gifttyde
- Gul frøstjerne
- Brudelys
- Kalmus
- Nikkende star
- Mosebunke
- Lav ranunkel
- Fløjlsgræs
- Almindelig hvene
- Eng-kabbe-leje
- Trævlekrone
- Smalbladet kæruld
- Djævelsbid
- Mose-troldurt
- Maj-gøgeurt
- Vellugtende festgræs
- Hjertegræs
- Kær-fladbælg
- Gul frøstjerne
- Eng-troldur


THE WADDEN SEA
HABITAT
(Habitat for many specialist species including migratory birds)
CLAY PIT
EXPERIENCE / RECREATION
(Experience of nature and natural ecosystems; tidel, 'black sun', wildlife, and the sluse)
HABITAT
(Habitat for many birds including migratory birds, when the Wadden Sea is flooded)
VESTERÅ
ATTRACTION
(The Wadden Sea as an attraction for tourists, nature enthusiasts, and residens)
CLAY PIT
BUFFER
(Buffer for climate related storm surge with the foreland and islands further out in the Wadden Sea that act as breakwaters)
HABITAT
(Habitat for generalist species)
EXPERIENCE
(Experience of cultural history; e.g., the modified stream, and the different distinctive landscape elements appears)
MITIGATION
(Mitigation of carbon and storage of C02 in the Wadden Sea)
RECREATION
(Possibility of sailing on Ribe Å)
INTERACTIONS
(Interactions between different species along Ribe Å)
CORRIDOR
(Movement
for species
the snæbel
swims from
Wadden Se
Østerå)
Stay for migratory birds
Tide
Clay pits
Runoff and draignage from agricultural fields via ditches
Movement routes and corriodors fo
Linear connection / road from A to B
The dike is a distinctive landscape element that acts as an edge
Open landscape surface



Ill. 86 (Made by author)

DE-
CONSTRUCTION
WATER STATUS

Ribe has a long history with the water, with its location in the middle of Ribe Å. On the one hand, the water has been a value in relation to settlement and transport, but on the other hand, the water has been a threat to the city with several floods. The city on the hill islands is an expression of this duality.

CURRENT ADAPTATION MEASURES

To keep the city safer different water regulations has been built, as shown on illustration 87. The dike along the coast was built 1911 and has been further elevated several times to the dike height of 6,88 m (Kann 2001; Piontkowitz et al. 2011). The cross section on illustration 88, shows how the dike is constructed with a layer of 0,5 m clay and with a flat foreland towards the Wadden sea. The dike has an important role as a hard protection keeping the marsh area and city safe from both rising sea water level and storm surges. This has transformed Ribe marsh into a polder area. Along the construction of the dike, Kammerslusen has been built to let the inland water out, and let ships and habitat inter Ribe Å.

In the inner city, Ribe Å is divided into four streams that flows between the hill islands. These streams are regulated by three sluices, Frislusen, Midtmøllen, and Ydermøllen, and the stream in south flows freely through Stampemølle (see illustration 87). The three dams in the city regulates the water level in Østerå. The water level is lowest in the summer and highest in the winter and vary approximately 80 cm (Esbjerg Kommune n.d.).

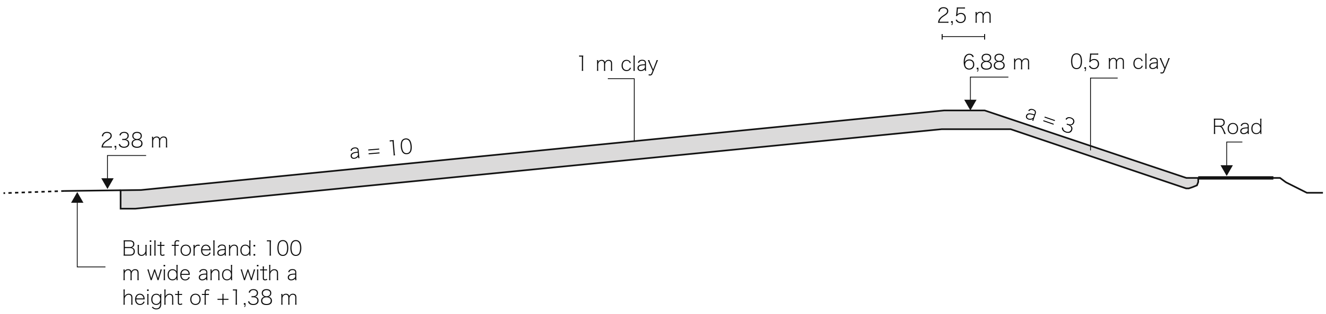
Two minor infrastructural dikes run on each site of the city center. In west it is Ringvej and in east it is the railway.

→ *Ill. 87 Current flood protection structures1:30.000 (Made by author)*

Minor infrastructural dike

Main dike

Sluice or dam



↑ *Ill. 88 Principle cross section of the sea dike (Made by author) (Reproduction from: Piontkowitz et al. 2011, p. 50)*

DE-CONSTRUCTION VALUES UNDER PRESSURE

Risk assessment is based on three parts: *exposure*, *vulnerability*, and *hazards* (see illustration 89).

Exposure is the number of values and people who are potentially subject to a risk (Arnbjerg-Nielsen & Löwe 2019). Thus, exposure is a variable that changes along with increasing, decreasing, or moving populations and changes along with the city development.

Vulnerability refers to the extent to which exposed values and people are affected by a flood (Arnbjerg-Nielsen & Löwe 2019). A vulnerable area is characterized by large exposure, that will cause large loss in case of flooding. However, the valuation and statement of damages suffers from great uncertainty. Often the hazards have incidental expenses such as industrial recession, traffic disruption, health coasts etc. Thus, the degree of vulnerability depends on different parameters that is beyond physical loses – also local emergency level and capability is important parameters.

Vulnerability is also dependent on which climate adaptation strategy that is used. A study by Di Baldassarre et al. (2015) compare hard protection in the form of dikes with a soft accommodation approach in the form of green adaptation measures. The comparison reveal that soft accommodation approaches expose inhabitants to minor floods more often. By experience these minor floods, the inhabitants maintain their collective memory, by which ongoing adaptation occurs. In case of hard protection, the floods happen less frequently, by which the collective memory decreases after each single flood. This can present challenges with the collective will to action, which also influence an areas vulnerability.

NOTE/ Risk assessments do also depend on the spatial and temporal scale. What may look like huge coasts in a local scale, can be quite small seen from a national perspective. This feeds into the contemporary debate that raises the question: Is climate adaptation the local's and individual's responsibility or a collective social responsibility? (will be elaborated in chapter 6, Discussion: Perspectives and outcomes, pp. 172-175).

→ *Ill. 89 Risk is based on three parts: exposure, vulnerability, and hazards (Made by author)*

→ *Ill. 90 Water from the upland was hold back by the dike along the coast, bringing the water close to the city in febuary 2020 (Detlevsen 2020)*

The last part on which risk is based is **hazards** or more specific, flood hazards. Flood hazards is based on future predictions of climate. In other words, it describes the event that needs to be considered, the return period, and the frequency (see also the section *Water Challenges*, pp. 134-135). In consequence of climate change, we are to expect warmer weather, instability, rising groundwater and seawater levels, and more frequent extreme events with extreme precipitation and storm surge (DMI 2020; DMI 2014; Kystdirektoratet 2016; Arnbjerg-Nielsen & Löwe 2019; Kystdirektoratet 2018).

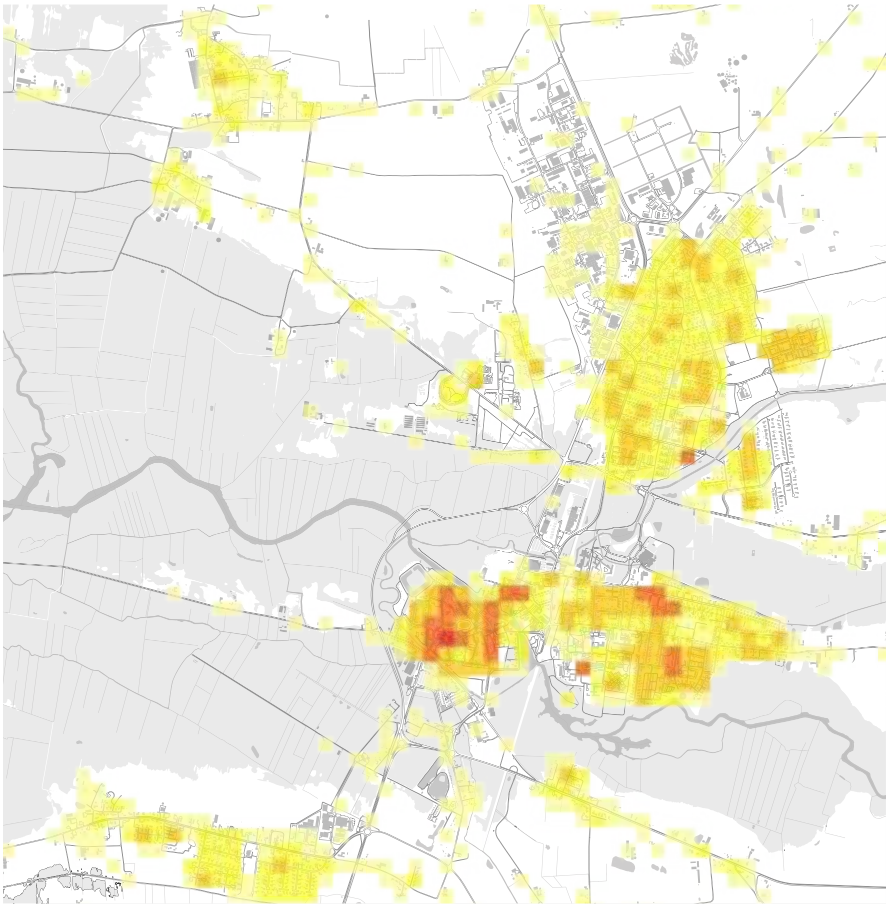
The hazards do also emerge as simultaneous events. This could be a case where a 100-year extreme precipitation event and a 50-year storm surge event happen at the same time, which would increase the coast of damages. Simultaneous events are relatively underexposed, and hereby hard to visualize and map.

RISK ASSESMENT IN RIBE

Risk assessments are complex to calculate, as both exposure, vulnerability, and hazards are taken into account. Illustration 91 and 92 shows that Ribe's old city center is the area with highest exposure, due to population density and build value. Furthermore, Ribe is a special case as the city has a long culture-historical identity that manifests itself in the large amount of building heritage. This should play a role when assessing the area's vulnerability. Ribe is an example of the complex risk assessment, where the direct value is difficult to determine. The city holds a national historical interest, that is beyond the economic losses.

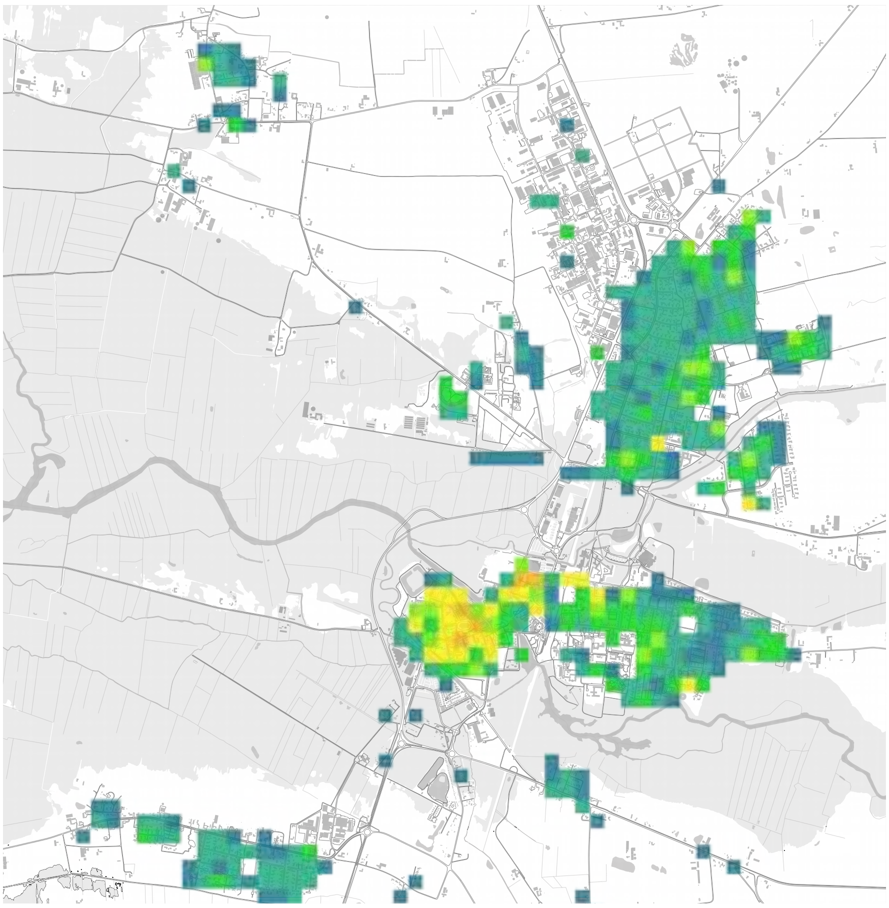
Another, vulnerable element in Ribe is the marsh area where much agriculture is located. As the following pages will reveal, the huge marsh area and associated agriculture is in high risk of flooding. This would entail large local loss for agriculture and the single farmer. Based on these considerations, the following analysis will focus on flooding of Ribe city center and marsh.

NOTE/ The valuation of cultural-historical values reflects the complexity of vulnerability assessment. How should cultural heritage be valued in a risk assessment? Should we provide extra funds to protect these parts of the city?



← *Ill. 91 Population density (Made by author) (Data from: Miljøministeriet 2010)*

Less than 10 inhabitants
10 - 25 inhabitants
25 - 50 inhabitants
50 - 100 inhabitants
Over 100 inhabitants



← *Ill. 92 Building value (Made by author) (Data from: Miljø-ministeriet 2013)*

Less than 5 million
5 - 10 million
10 - 15 million
15 - 20 million
20 - 40 million
40 - 100 million

WATER HISTORY

↑ *Ill. 93 The Second Huge Man Drowning* (Wikipedia n.d)

↑ *Ill. 94 Storm surge in 1911* (Fyns Frimærke Service n.d)

1634

The flood in 1634, The Second Huge Man Drowning, had a water level that was about 6 meter over normal sea level, which flooded the whole marsh area and city center. Around 10.000 people lost their lives, and several lost their houses and farms, as well as livestock and profit from cultivated areas. In Ribe Cathedral, a marking tells how high the water was in the cathedral itself - 170 cm above the floor. A royal letter from 1635 testify that citizens of Ribe was excluded from paying taxes for three years in order to rebuild the city and the area around Ribe.

1825 and 1911

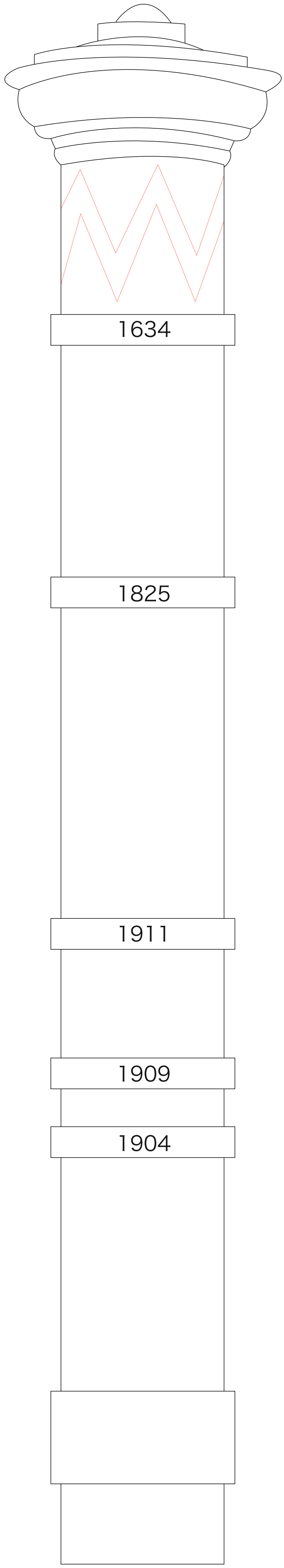
The water level was 5.33 m over normal sea level in 1825 and 4.4 m over normal sea level in 1911.

1976 and 1981

The current dike was built in 1912 along the west coast from Tjæreborg to Vester Vedsted, which has secured Ribe from storm surge flooding since then. However, citizens in Ribe still experience floods, as water from the hinterland stagnate when Kammerslusen is closed due to high sea water levels outside the dike. The water level was around 4.7m over normal in 1976 and in 1981 the water level was around 4.7m over normal.

(Data from: Miljøministeriet n.d.; Mit Vadehav, n.d.; Danhostel Ribe, n.d.; Moesgaard 2020)

→ *Ill. 96 The storm surge column is located in the city of Ribe. It shows how high the water level has been through history (Made by author)*



↑ *Ill. 95 Flood of Ribe marsh in 2020 (Hestehave 2020)*

1999

In December 1999 the most powerful hurricane hit Denmark. In Ribe the water gauge broke at the water level of 5.12m. The water level is estimated to have exceeded 5.5m over normal. If the event had hit at high tide the water level would have exceeded the dike height, and the sea water would once again have flooded the marsh and city.

2020

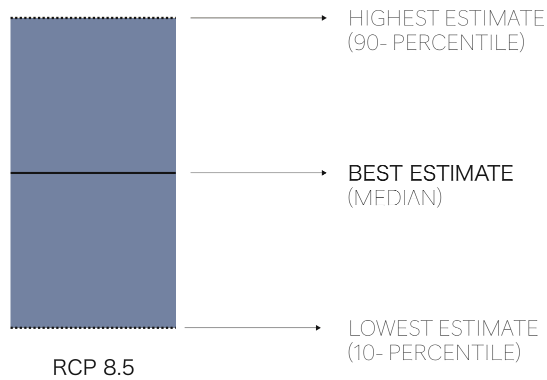
After a record wet autumn followed by a record wet winter with 135mm precipitation in February, several areas in Denmark were flooded. When the water level peaked, it was equivalent to a 100-year event. In Ribe the upland water was retained as the sea water level was too high. This event demonstrate how water-course flood can create a bathtub effect

USED CLIMATE PROJECTIONS

The most used future scenarios of climate projections are IPCC's *Representative Concentration Pathways* (RCP) (IPCC 2014). There exist four scenarios inferred by how much additional greenhouse gas that will be emitted in the coming years and associated surface temperature changes. All scenarios are predictions until year 2100. RCP 4.5 is a scenario where we reduce the emission and balances the climate impact towards 2100, whereas RCP 8.5 is the 'worst case' scenario where the emission will continue as it is today also after 2100. This project is focusing on resilience building in a long-term perspective, therefore working with the worst-case scenarios RCP 8.5 by 2100.

In this project the used projections are from the Danish Meteorological Institute's (DMI) Climate Atlas (DMI 2020b). The data is based on DMI's own data, international collaborations, FN's climate report, and it uses the different RCP scenarios. In this way DMI translate global climate models to a Danish context.

All predictions rely on uncertainty; thus, every RCP scenario has a 'best estimate' in the middle of an uncertainty interval (see illustration 97). On the following pages there will be referred to the level of uncertainty following either the lowest, best, or highest estimate.

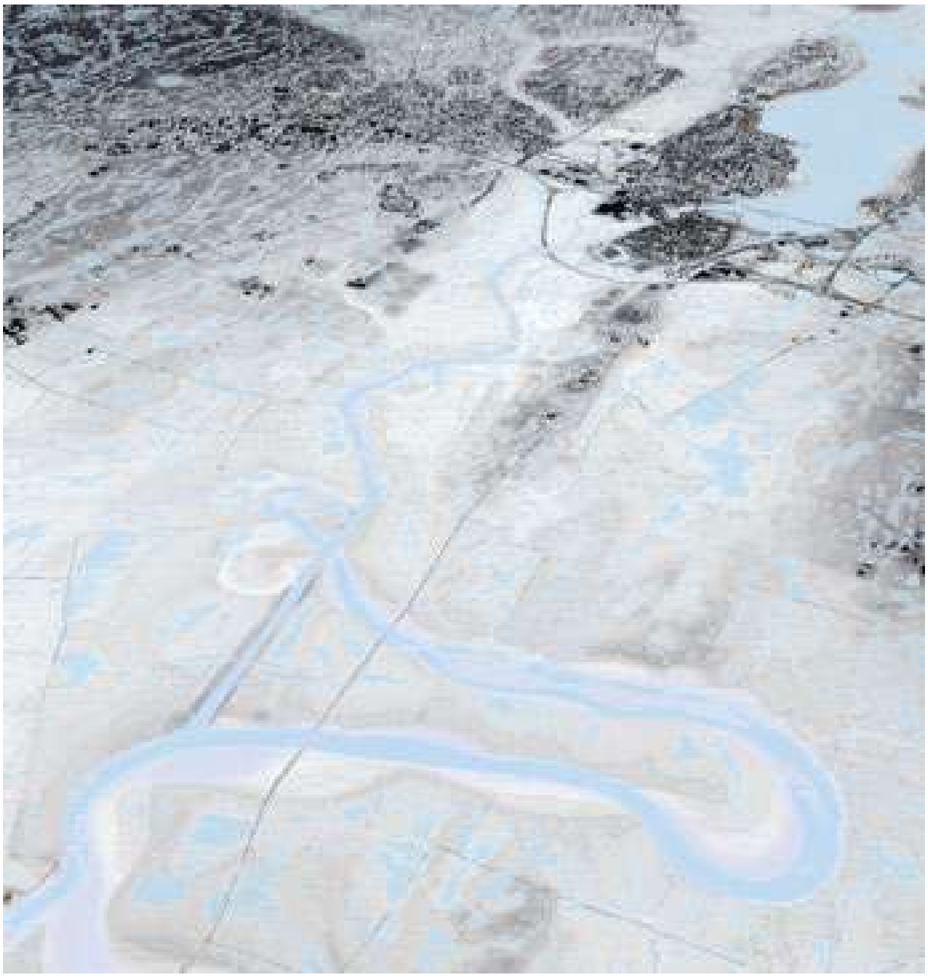


→ *Ill. 97 Risk is based on three parts: exposure, vulnerability, and hazards (Made by author) (Reproduction from: DMI 2020b)*

TYPES OF FLOODING

Ribe is in risk of three kinds of floods; storm surge, watercourse flood, and extreme precipitation – and these types of floods can occur simultaneously. Additionally, the rising groundwater level may challenge the low laying marsh area.

To give an initial indication of how flooding will affect Ribe illustration 98, shows a case of extreme precipitation defined as 15 mm / half an hour. Blue spots indicate all the minor depressions in the marsh area. Illustration 99 shows a 100-year event where the watercourse will be flooded. The whole marsh area is flooded and the hill islands where the city is located, looks like islands in the water. On the following pages, the water challenge will be further elaborated.



← Ill. 98 Extreme precipitation bluespots (15 mm/half an hour) (Made by author)

← Ill. 99 Watercourse flooded 100 year event (Made by author)

DE-
CONSTRUCTION
WATER DYNAMICS

The three principle cross-section and attached principle on the opposite page (illustration 100, 101, 102 and 103), show the water dynamics that affects the waterflow in the stretch from the Wadden Sea to Østerå. The waterflow dynamics has been changed through history, along with human made modifications and climate change, as previously stated (see section *The Cultural Landscape*, pp. 94-95). In the following, the three main problems are outlined.

THE CULTURAL LAYERS / KULTURSVAMPEN

In Ribe the groundwater level is of great importance for the old city center, which due to its long history has been built on top of meter thick cultural layers - Kultursvampen. These layers consist of organic materials that hasn't been metabolized. They need to be moist to slow down the metabolism process. If the material dries out, the air will speed up the process which can create subsidence in the old city center. In this regard, the groundwater level plays a crucial role, to maintain the moist beneath the city surface.

The groundwater flows in the sandy layers underneath the cultural layers in the city (Kann 2001) and the water level beneath the city follows the water level in Vesterå and Østerå. In the past it was only regulated by the natural dynamics in the Wadden Sea (see illustration 100), but after the modifications of Ribe Å, and the construction of the dike and sluices in the city center, the water level in Vesterå was lowered, which led to a lower groundwater level (see illustration 101). Some of the largest damages from subsidence in the old city center, happened in the same period where Ribe Å was traversed (Kann 2001). Today Ribe Å is regulated to maintain a certain water level to keep Kultursvampen moist.

THE MARSH AND CULTIVATION

Besides the changed dynamics of the groundwater level, the modifications of Ribe Å, the dike, and the sluices has changed the marsh area. After the changes was made the whole marsh area's abiotic, biotic, and cultural functions were changed. From being an area with high abiotic and biotic value, the cultural functions became dominating, as the area could now be cultivated. Today + 85% of the marsh area is used for agriculture (OBICON 2015).

Farmers in the area are challenged by floods, as their fields are located in the low laying landscape. As previously stated, the cultivated marshland is impermeable to water, which makes them dependent on the fine masked ditch system to drain (see section *The Green Landscape*, pp. 116-117). Several farmers that deal with floods, suggest further excavation of the ditches and Ribe Å (Grahndin 2020).

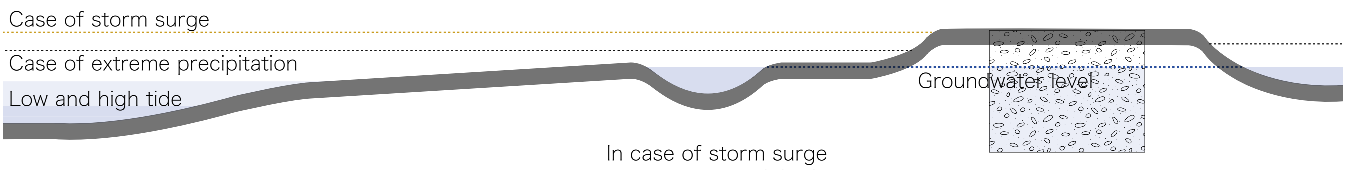
THE BATHTUB EFFECT

The water level in Vesterå is controlled by two factors, the sea level in the Wadden Sea and the upland waterflow. The tide itself cause the rising water level in Vesterå by approximately 60 cm from highest to lowest (OBICON 2015). When the outer sluice has been closed in longer amounts of time, due to high sea levels in the Wadden Sea, the inner marsh area becomes flooded, which in extremes brings flood risk to the city. What becomes most challenging for the city, is combinations of storm surge and extreme precipitation occurring at the same time. In this case, the dike and the closed sluice will create a bathtub (see illustration 102). Originally the dike was built with the single function to provide protection from the sea, but as the climate changes, the dike can be vulnerable as it does not take the water on the inside into account. Hence, the largest problem in Ribe is the huge catchment area, that brings all the water to Ribe. The most logic solution for Ribe, would be to deal with the water as long upstream as possible, but in reality, the solutions must be found in the area of Ribe.

THE WADDEN SEA

VESTERÅ

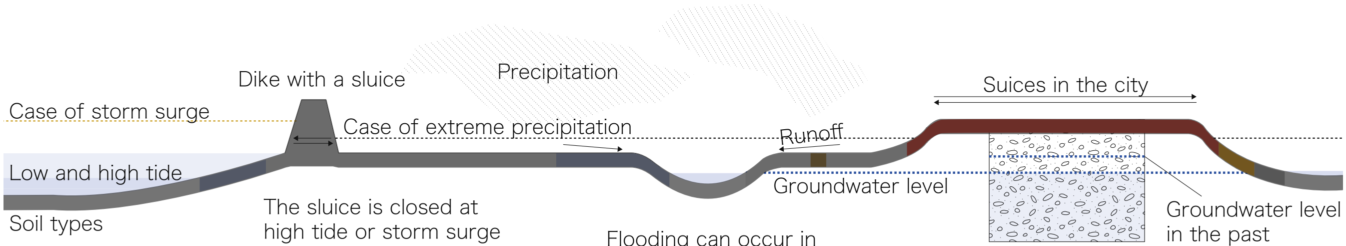
THE CITY OF RIBE



In case of storm surge or extreme precipitation the marsh area was flooded.

In the past the groundwater level was higher underneath the old city, which ensured that the cultural layers was moist and the rate of metabolism of the organic material was slowed down.

↑ *Ill. 100 Principle cross section of the past before 1900 (Made by author)*

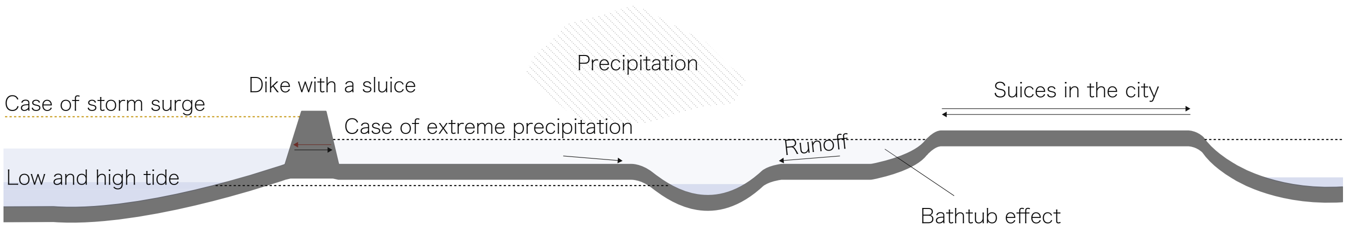


The sluice is closed at high tide or storm surge and opens at low tide or extreme precipitation. The dike and modification of the Ribe Å lowered the water level in the stream.

Flooding can occur in simultaneous extreme events, where the lock is closed and water on the inside of the dike accumulates.

The groundwater level follows the water level in Vesterå and Østerå. The lowered water level in the stream and hereby also groundwater level underneath the city surface expose the cultural layers to metabolize quicker, which causes subsidence in the old city center.

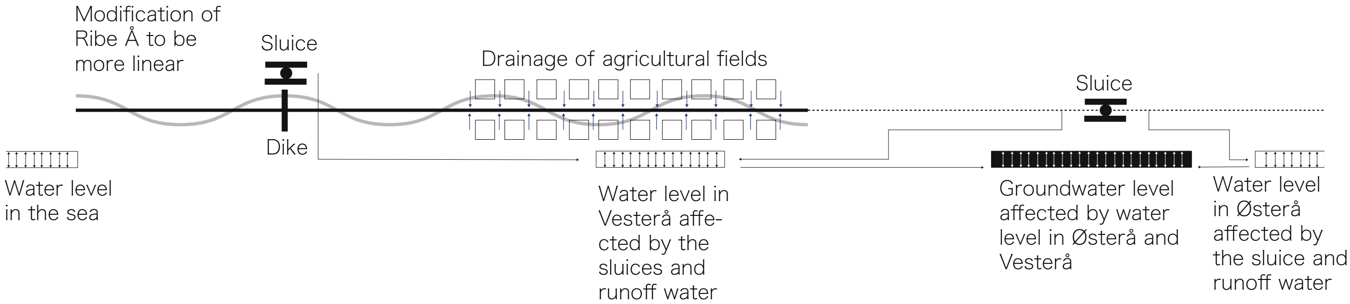
↑ *Ill. 101 Principle cross section of the case today (Made by author)*



In Denmark the sea level rise is predicted to rise 5-103 cm towards 2071-2100 (RCP4.5 and RCP8.5) depending on the chosen IPCC's scenario.

With the rising sea water level the water level differences between Ribe Å and the sea will be more and more leveled out. This will further stress the ability to open the sluice and let water out from the inland. In worst cases the dike and closed sluices will create a bathtub effect, leading to flooding of the marsh and city.

↑ *Ill. 102 Principle cross section of future challenges (Made by author)*



↑ *Ill. 103 Principle of current climate adaptation and mutual hydrological significance (Made by author)*

DE-
CONSTRUCTION

EXTREME PRECIPITATION

Ribe and Ribe Å's water catchment area is located in the area with highest annual average precipitation in Denmark. In the period from 1971-98 the annual average precipitation was 950-1050 mm per year (DMU 2000). It indicates that Ribe will only be further challenged with precipitation in the coming years.

The three maps illustrate a 100-year event of extreme precipitation as a best estimate (see illustration 104), the lowest estimate (see illustration 105), and the highest estimate (see illustration 106). The change is small as the depth shows. In all three cases there are local depressions that collects the water. This risk is less pronounced as the vulnerability is local dependent where smaller depressions are located. Nevertheless, the depressions in Ribe are worth paying attention to, as they can be incorporated in small scale planning solutions.

In the old city center the water is collected around Ribe Cathedral, and in the backyards of surrounding residential blocks (see illustration 104). In Ribe east and north residential areas may struggle with the water, as the housing itself will be flooded.

Solutions could be implemented into city spaces that uses the water or increases the infiltration ability. It can be as recreative elements working as buffer zones that stores the water. The football pitches in Ribe east could be transformed to contain the water from surrounding residentials. Another solution is the greening of residential roads and squares with build in ponds or bassins ('faskiner') underneath the soil.

Seen in a long-term perspective, extreme precipitation would only affect minor areas, thus this type of flooding shouldn't get the main attention, when making long-term strategic decisions.

→ *Ill. 104 Extreme precipitation 100 year event. The map shows a best estimate of 111 mm/day 1:10.000 (Made by author) (Data from: DMI 2020b; SCALGO n.d.)*

Minimum 50 cm depth

Minimum 25 cm depth

Minimum 0 mm depth

Above 3 m elevation

Below 3 m elevation

↑ *Ill. 105 Extreme precipitation 100 year event. The map shows the lowest estimate of 91 mm/day 1:10.000 (Made by author) (Data from: DMI 2020b; SCALGO n.d.)*

↑ *Ill. 106 Extreme precipitation 100 year event. The map shows the highest estimate of 130 mm/day 1:10.000 (Made by author) (Data from: DMI 2020b; SCALGO n.d.)*


FOOTBALL
PITCHES
RIBE CATHEDRAL
BACKYARD
BACKYARD
RESIDENTIAL

DE-
CONSTRUCTION
STORM SURGE

In Ribe, storm surge is a risk in cases where the height of the surge exceeds the dike or the existing dike breaches. With a dike hight of 6,88 m the inland would be protect in most cases.

With the changing climate, the sea water level will rise of predicted 58 cm (14 - 103 cm) up until 2021 (following RCP 8.5) (DMI 2020b). This stresses the water level when storm surge hid, putting new demands to the dike.

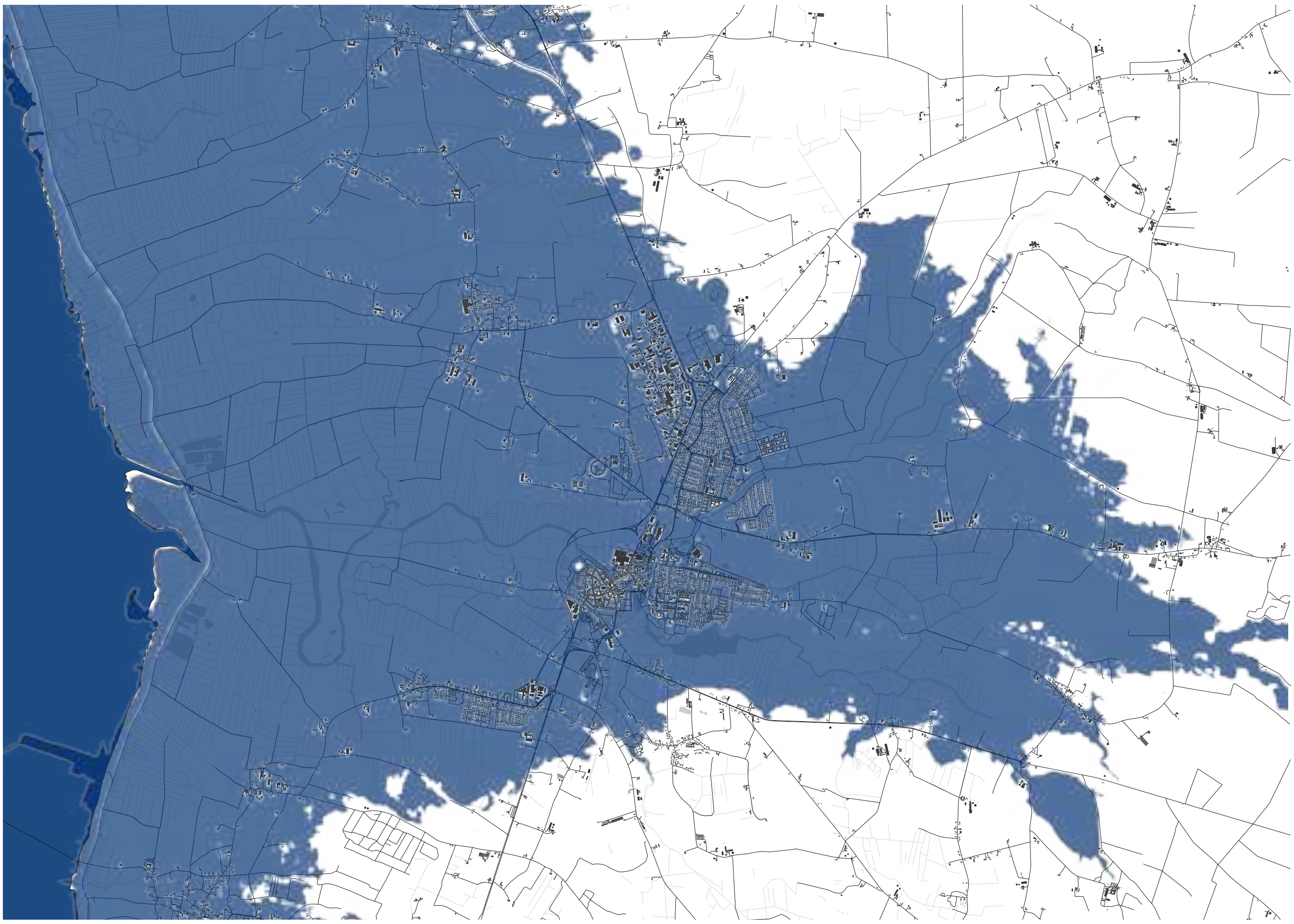
In Ribe, flooding above 3 m would have a huge impact on developed urban areas. Especially it would create huge damage to the historical city center. Looking at historic reference data of sea water levels from 1981-2010, the water reaches 365 cm once every 5 years, which indicates a need for protection already today, not just in the long term. Future predictions shows that flooding above 3 m will occur once per year between 2041-2070 following an RCP 4.5 middle case scenario (DMI 2020b).

Altogether, it becomes clear that based on current needs and future predictions, the existing dike is important and highly recommended.

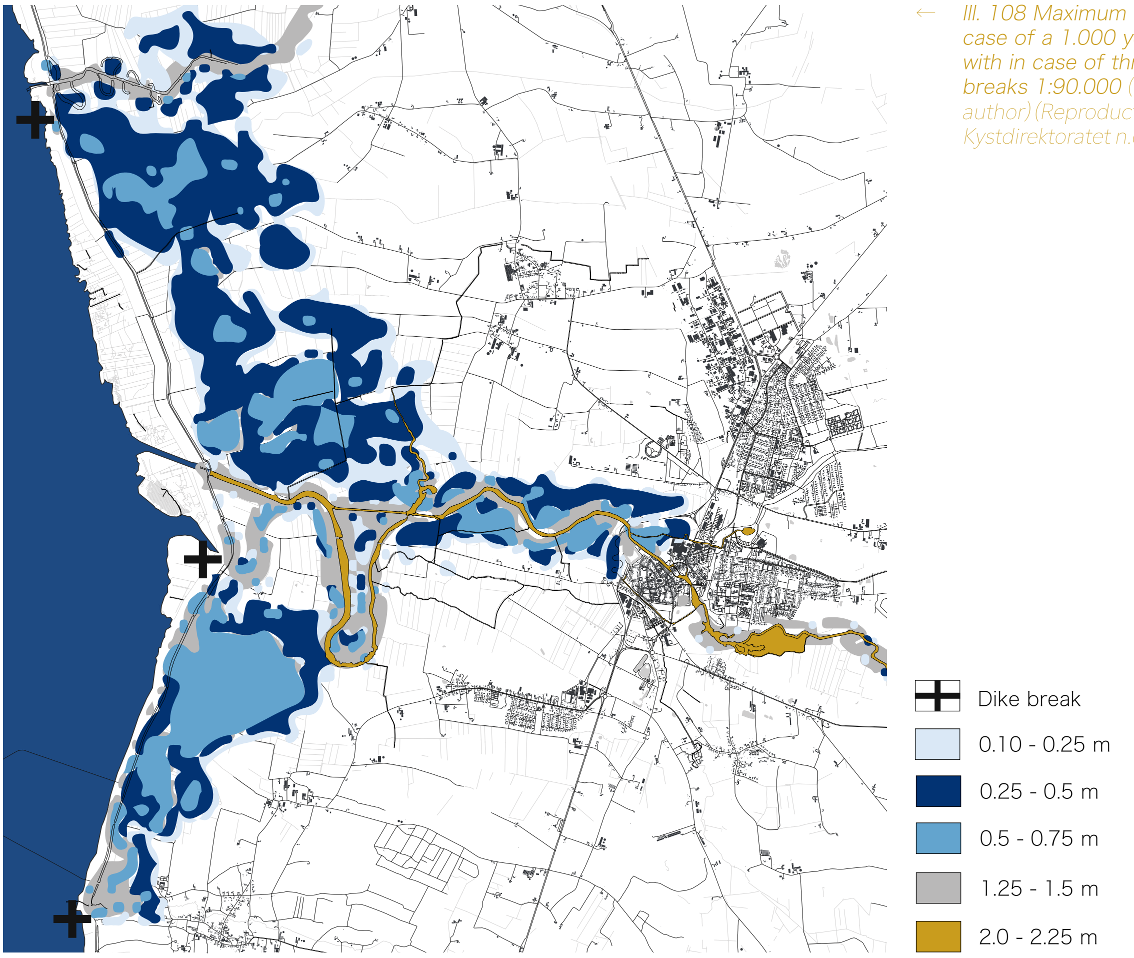
Illustration 107 shows how a storm surge exceeding the current dike height would flood the city. This would happen at the highest estimate for a 10.000-year event (DMI 2020b). The whole city would be flooded.

Another more important thing to consider is, how flooding would affect the marsh area and city if the dike brakes. The danish coastal authority have constructed dynamic computational models to simulate how the water would behave in case of three dike breaks at a 1.000-year event (Kystdirektoratet, n.d.). Illustration 108 shows how the marsh would be filled with water at certain places, and illustration 109 shows the temporal spread of the flooding. The temporal spreading illustrates that the city of Ribe would be in risk of flooding in the example.

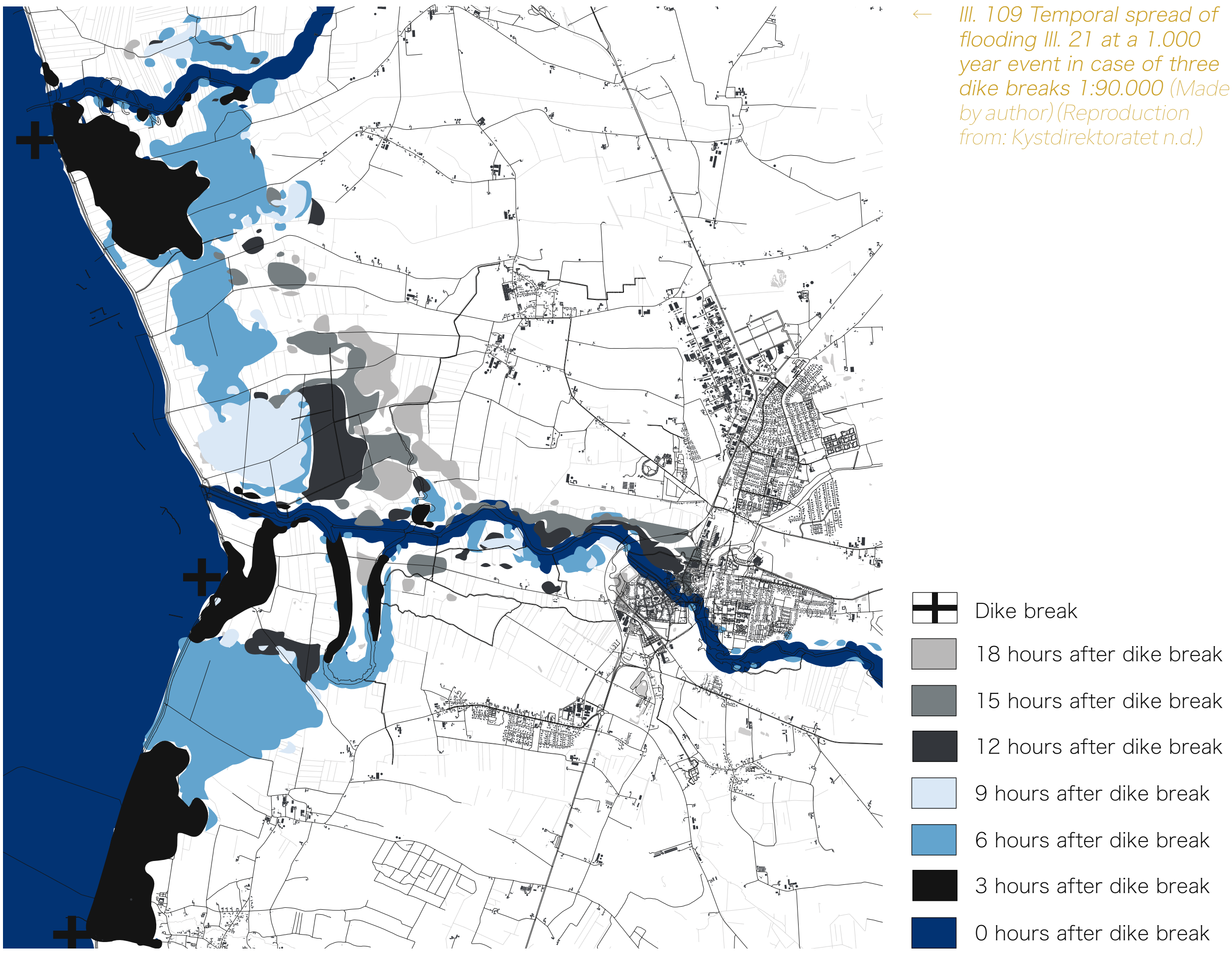
↓ *Ill. 107 Static simulation of storm surge exceeding the dike height of 6,88 m. This corresponds to the highest estimate for a 10.000 year event reaching 693 cm 1:90.000 (Made by author) (Data from: DMI 2020b; SCALGO n.d.)*



← *Ill. 108 Maximum depths in case of a 1.000 year event with in case of three dike breaks 1:90.000* (Made by author) (Reproduction from: Kystdirektoratet n.d.)



← *Ill. 109 Temporal spread of flooding Ill. 21 at a 1.000 year event in case of three dike breaks 1:90.000* (Made by author) (Reproduction from: Kystdirektoratet n.d.)



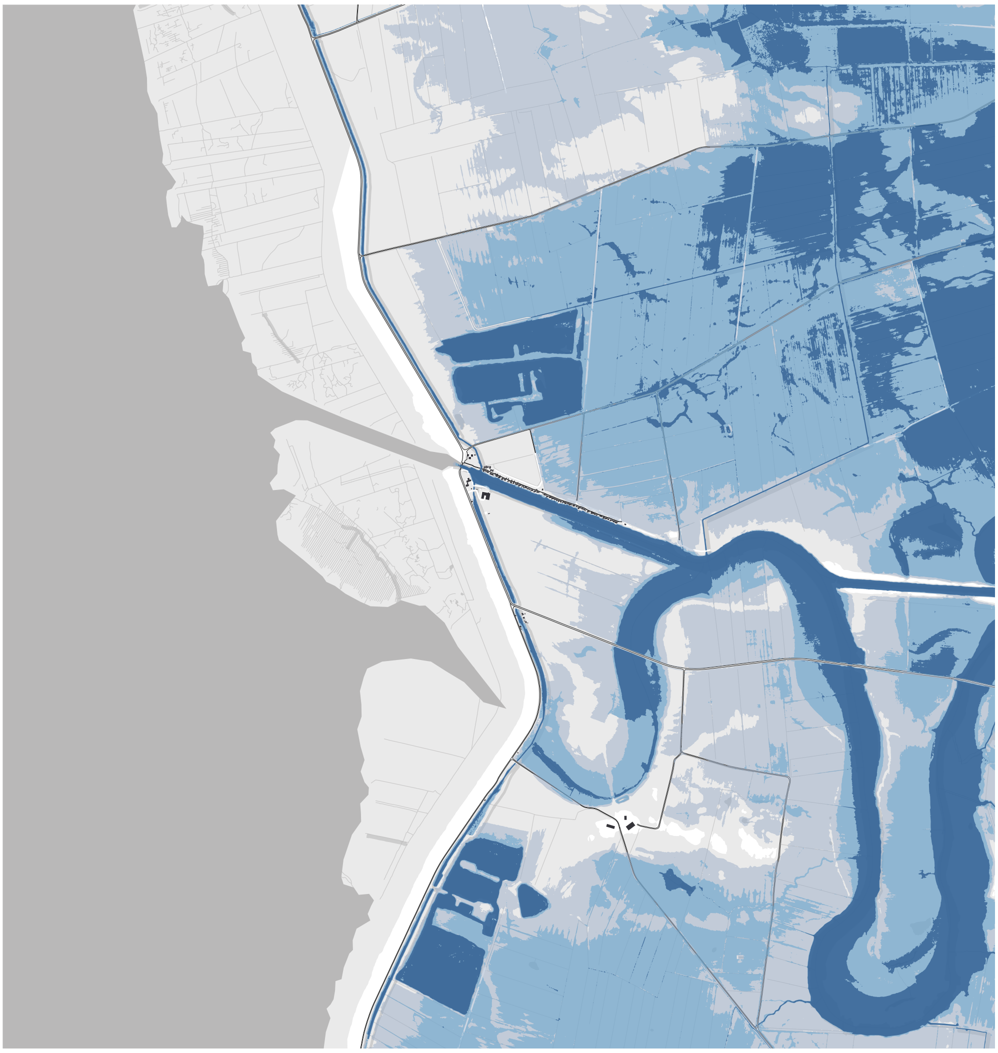
DE-CONSTRUCTION WATERCOURSE FLOOD

Ribe Å has a central function for the water catchment area of about 962 km2 (Miljøministeriet et al., 2011), as it drains of the entire upland. It brings the water through the city center, cultivated marsh, into the Wadden Sea though Kammerslusen. Both the flat marsh and the adjacent city that functions as a bottleneck in the stream system, are areas vulnerable to watercourse floods.

In cases of high sea water levels in the Wadden Sea the sluice is closed, which stops the outlet to the sea. This will automatically increase the water level in Ribe Å, as the inland water is hold back behind the dike. Normally it would not be a threat, but if the precipitation has been increased over long periods of time, the watercourse will flood (an example of this, was in Febuary 2020 (see section *Water History*, pp. 132-133)). The low laying marsh will be flooded to the inconvenience of farmers, and Ribe is also in risk of flooding with deep water levels surrounding the hill islands.

Illustration 110 shows a case of watercourse flood based on historical area specific run-off for Ribe Å. Here a 100-year event of run-off corresponds to 90 l/sek/km2 (Miljøministeriet et al., 2011). The map indicates large, flooded areas in the marsh, and the water gathers around the city on the hill islands. It changes the perceiving of landscape, from the hill islands in the open and flat landscape towards islands in a waterscape. Hence, the characteristic landscape elements change with the dynamic waterscape.

The rising sea water level is also a challenge for the stream, as it challenges the outflow of upland water that flows through Ribe Å – this has previously been refered to as the 'bathtub effect' (see section *Water Dynamics*, pp. 136-137). The water level differences between Ribe Å and the sea will be more and more



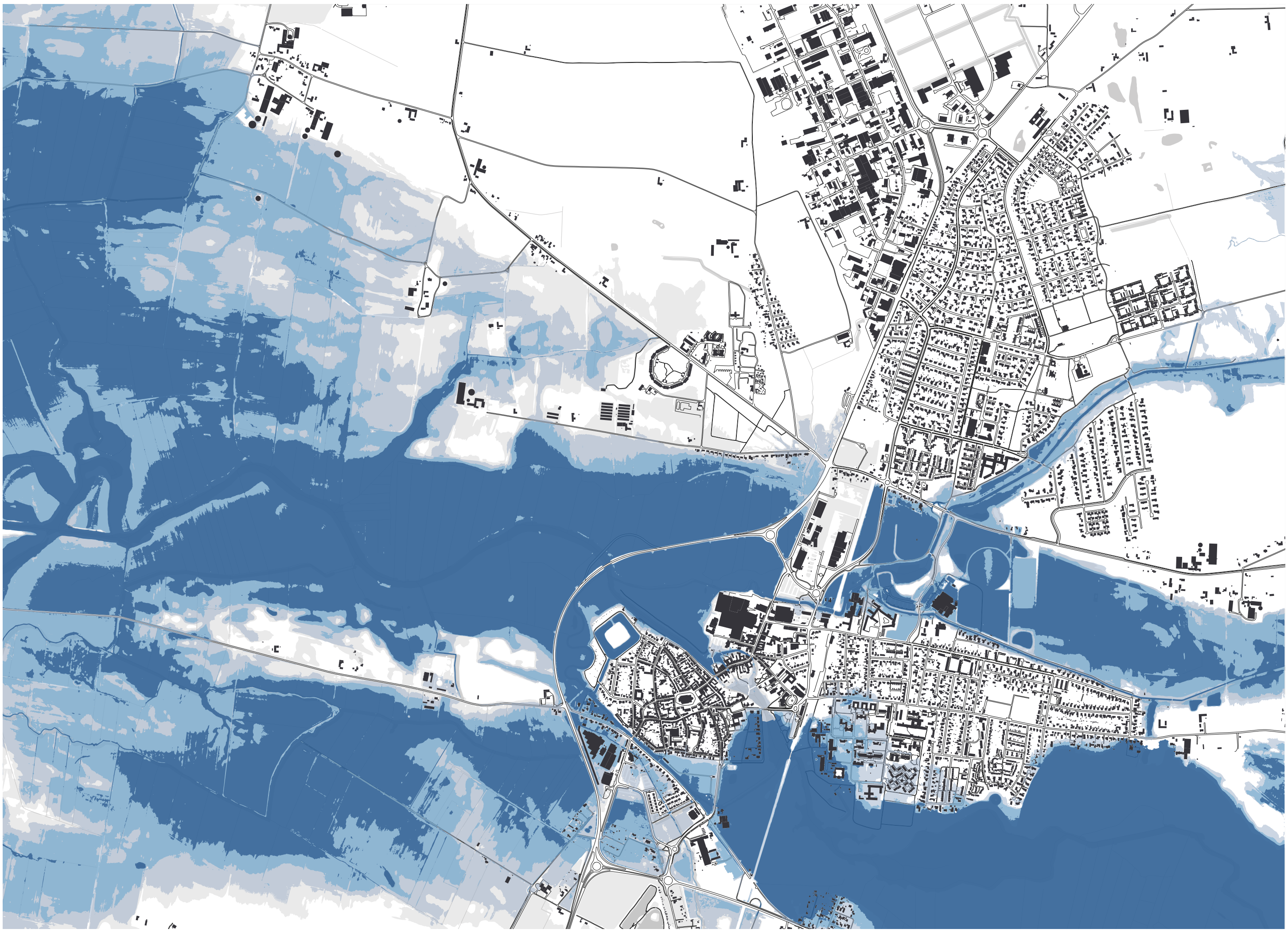
Minimum 1 m depth

Minimum 50 cm depth

Minimum 0 mm depth

→ *Ill. 110 Watercourse flood based on historical area specific run-off for Ribe Å which trigger a 100 year event of run-off corresponding to 90 l/sek/km². 1:30.000 (Made by author) (Data form: Miljøministeriet and Transportministeriet 2011; SCALGO n.d.)*

leveled out, which makes it harder to outlet the upland water. In addition, the rising sea water level also raises the groundwater level, which makes the whole marsh area moister, also stressing upward going flood.



Looking closer at the city there are certain areas that will be challenged by watercourse flood (see illustration 111). The eastern area of the old city near Kurveholmen will be flooded in case of extreme watercourse flood. This area has previously been highlighted as an example of settlement in a depression (see section *Settlement in Depressions*, pp. 102-103), which once again exemplifies how the ignorance of deep structures has future consequences. Another area build in a depression is the western part of the old city center, where Holmevej and Møllevej will be flooded. These roads have already been challenged by smaller watercourse floods as the one in February 2020 (Jørgensen 2020).

In Ribe East a large area in south is also vulnerable to flooding. In the area several public facilities are located (see section *City Center*, pp. 100-101). Additionally, when looking at land owned by the municipality this large area is included together with the green and blue stretch around Ribe Å. This supports the previously presented finding of Katrina Wiberg, who connects waterflows, green areas, and ownership (see chapter 3, *Theory: Climate Adaptation Through Resilient Socio-ecological systems*, pp. 52-69). These areas hold a potential to extend blue/green structures, or to perform experiments in relation to climate adaptation. Also, the football pitches will be flooded, which also happened in February 2020 (Sommerand 2020).

The largest focus must be on watercourse flood, as it will be the most widespread threat in Ribe. All the challenged areas with build structures should be addressed in relation to the future climate.

Municipally owned land

Minimum 1 m depth

Minimum 50 cm depth

Minimum 0 mm depth

→ *Ill. 111 Watercourse flood based on historical area specific run-off for Ribe Å which trigger a 100 year event of run-off corresponding to 90 l/sek/km². 1:7.500 (Made by author) (Miljøministeriet and Transportministeriet 2011; SCALGO n.d.)*


FOOTBALL PITCHES
SOUTHERN PART OF RIBE EAST

5. MAP SYNTHESIS

↓ *Ill. 112 The flooded meadow near Ribe city center* (Bruhn 2020)

MAP SYNTHESIS
FINDINGS

The de-construction of Ribe can be concluded in 14 findings, that highlight key elements, conflicts, and potentials. The findings are mapped at illustration 113 and 114.

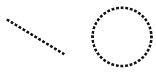
1

Must be prepared for storm surge height and frequency that is above the national average, coming from the North Sea.

2

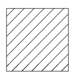
The Wadden Sea, the north and south clay pits, Kammerslusen, Østerå, and the old city and center are all areas with high value of attraction that must be remained.

3



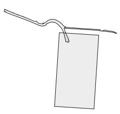
The dike is a characteristic historic landscape element, that together with Kammerslusen and the sluices in the city center, has an important role as they regulate the water level, which keep Ribe's city center safe from storm surge, as well as keeping Kultursvampen beneath the city center moist.

4



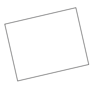
The marsh act as a bathtub during simultaneous events of watercourse flood of Ribe Å and high tide, where Kammerslusen is closed so inland water can't be let out.

8



The Wadden Sea, the clay pits, Ribe Holme, Vesterå, and Østerå are all important areas for habitat and vegetation with high natural value and preservation. These areas are challenged by agriculture and the modifications of Ribe Å.

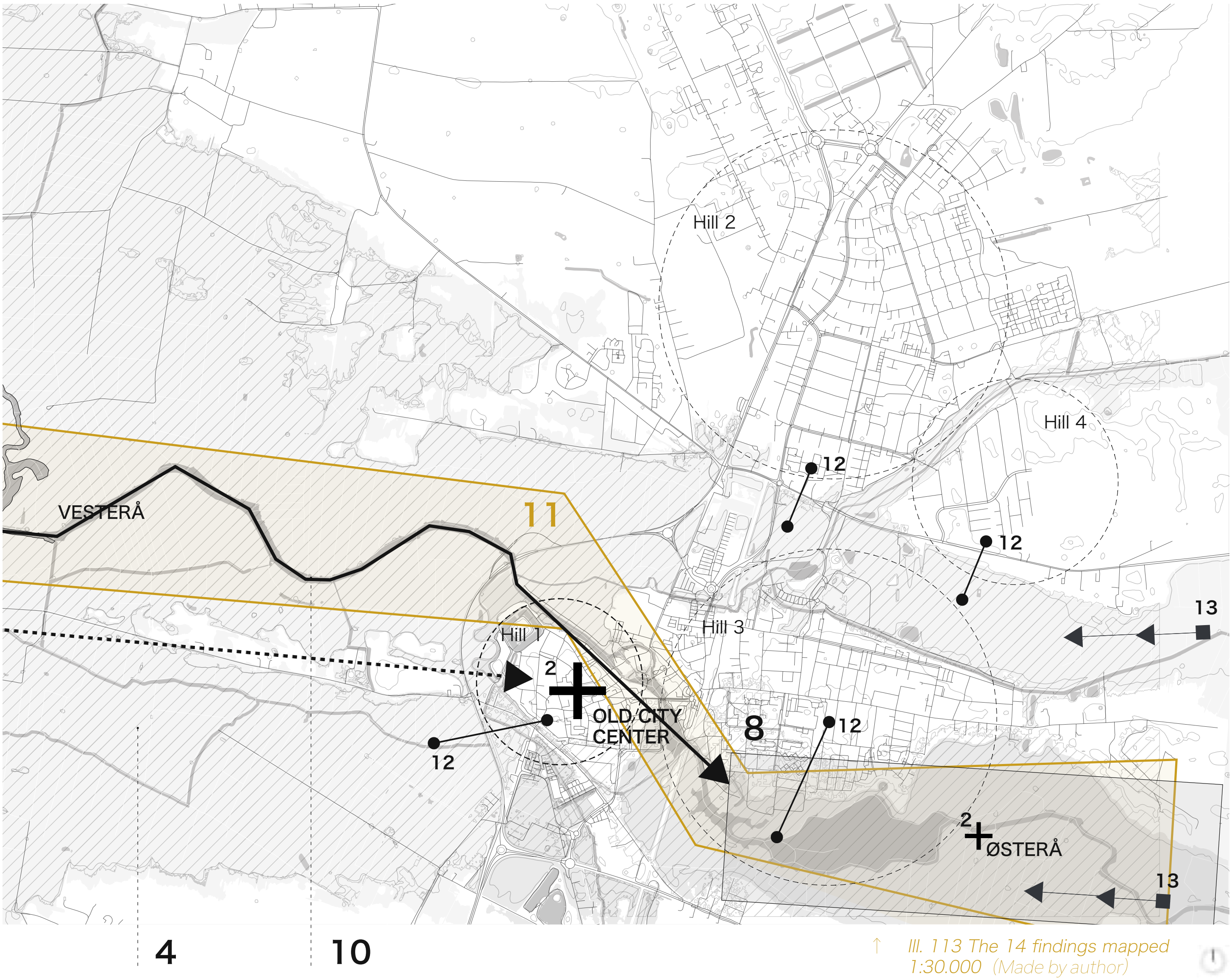
9



There is potential for strengthen the natural conditions around the clay pits, which today are important areas for bird life - this would increase the value of attraction and habitat.

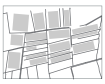
10

Vesterå is an important connection between the fragmented green areas and for migratory fish, such as snæblen.



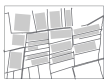
↑ *Ill. 113 The 14 findings mapped 1:30.000 (Made by author)*

5



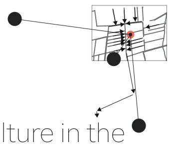
The cultivated fields are currently being challenged by flooding from Ribe Å, due to the low laying location in the marsh - even in 'lavbundsarealer'.

6



Further studies on the rising groundwater level, and its effect on the agricultural fields in the marsh should be accomplished, to clarify future challenges of agriculture.

7



Conflict: The agriculture in the marsh depends on the dike, ditches, and the excavation of Ribe Å - to maintain the agriculture the excavation of ditches are needed to ease surface runoff. At the same time watercourse are challenged by the amounts of runoff from the cultivated areas, which creates flooding.

11

The green areas with high natural value are fragmented in the east-west going direction. There is a huge potential for implementing a new green infrastructure along Ribe Å, which, among other things, will strengthen a poor connection between the city of Ribe and the Wadden Sea.

12

The meeting between the city on hills and the flat surrounding landscape is a quality that should be remained.

13

Ribe Å has a huge catchment area, which means that the upland villages have a responsibility to locally retain the water.

14

Parts of the city center and the eastern city will be challenged by flooding. In particular the cultural-historical values in the old city center are challenged.

→ Ill. 114 The findings related to the near city scale are mapped 1:7.500 (Made by author)

Hill 2
12
Hill 4
Hill 3
12
14
IØLLEN
14
14
12
2
ØSTERÅ

MAP SYNTHESIS
CHALLENGES AND STRENGTHS

Ribe is a city with a strong historical identity, that manifests itself both in the building heritage as well as in the cultural landscape. The city's location is scenic on the outwash plains forming minor hill islands. The history witnesses a long entanglement with the sea, where the dynamics of the Wadden Sea and the hydrology along Ribe Å is affecting Ribe both positively and negatively. With the changing water landscape, the city either appears as hill islands in the flat marsh or as islands in the flooded marsh. The hydrological issues, which are expected to be more intense, are related to the modifications of the natural hydrology. The drainage of the marsh area and the modification of Vesterå are elements with advantages for agriculture, but with disadvantages for the natural drainage and natural values. Lastly, Ribe's nearness to the Wadden Sea and the marsh area with biotic, abiotic, and cultural functions are a quality with a huge potential to enhance, create coherence, and connection thorugh. In this way the area would be better utilized for the benefit of both humans and non-humans.

The 14 findings are summarized in the following challenges and strengths.

STRENGTHS

- →Scenic setting of the city in the flat landscape on the hill islands
- →Strong historical identity and characteristic medieval city center with national interest
- →The Wadden Sea, Ribe Å, and the clay pits are valuable areas for birdlife and endangered species
- →Vesterå is an important corridor for habitat moving inland
- →The Wadden Sea, the clay pits, Ribe Holme, Vesterå, and Østerå are areas with high natural value and preservation
- →The cultural landscape and social entanglement with the sea is a valuable story revealed through the surrounding landscape

CHALLENGES

- →The marsh and the city are at risk of flooding when upstream water is caught in the marsh area – creating a bathtub effect
- →The cultivated fields in Ribe marsh will increasingly be challenged by flooding due to rising ground water level, low water capacity in the surrounding ditches and Ribe Å, and the low laying location
- →Drainage of the cultivated fields contributes to watercourse flooding and loos of natural value
- →The water level in Ribe Å affects Kultursvampen that needs to be moist in order to avoid subsidence in Ribe's old city center
- →Poor west-east going connection through the scenic landscape
- →Low laying areas in the city built in contradiction with the natural elevation of the terrain are challenged by flooding
- →The size of the upland catchment area puts pressure on Ribe city where large amounts of water pass and must be handled
- →Fragmented green areas in the east-west going direction

POSSIBLE FUTURES: THREE SCENARIOS

The analysis has given an overview and a holistic understanding of the hydrological situation in Ribe. It has given a stronger basis for strategic decision making. As an output the findings play a role in which direction of development climate adaptation can take. The summarized challenges and strengths can be addressed and utilized in different ways.

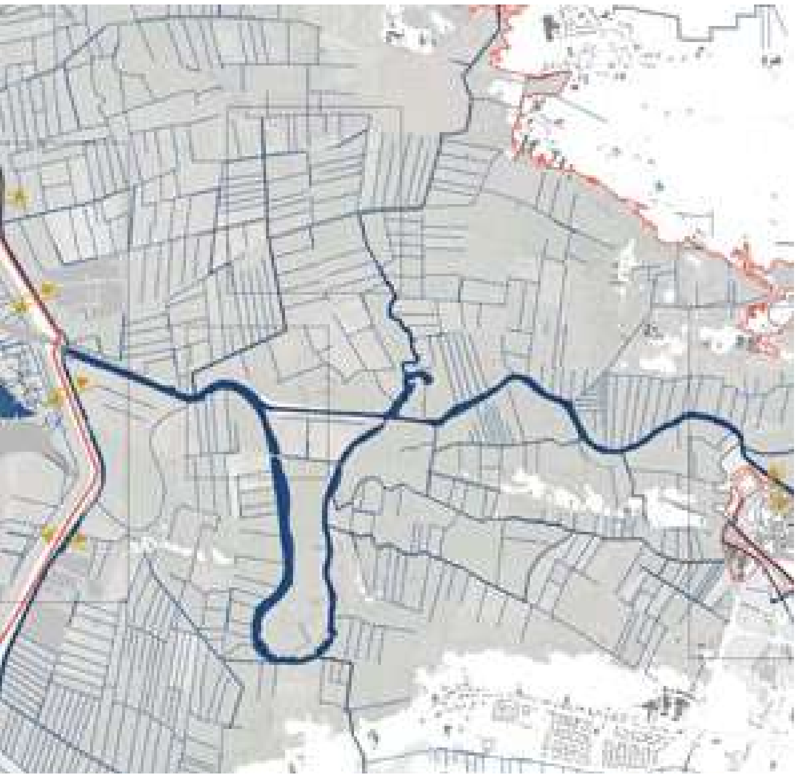
Three future scenarios are developed firstly, to show different directions of climate adaptation, and secondly, to be used as a discussion tool. The scenarios are also a way to analyze possible futures, thus they should not be understood as solutions but as a way to ask the 'what-if-questions'. In this project they are used as a tool in a interview with Ribe Municipality, where they have given new perspectives and further elaborated certain aspects.

NOTE/ The scenarios may also be used as a tool in processes of citizen involvement, as they visualize and concretize opportunities. This idea will be further elaborated in the section Reflection / Critic, pp. 180-181

→ *Ill. 115 Illustrations of the three scenarios (Made by author)*

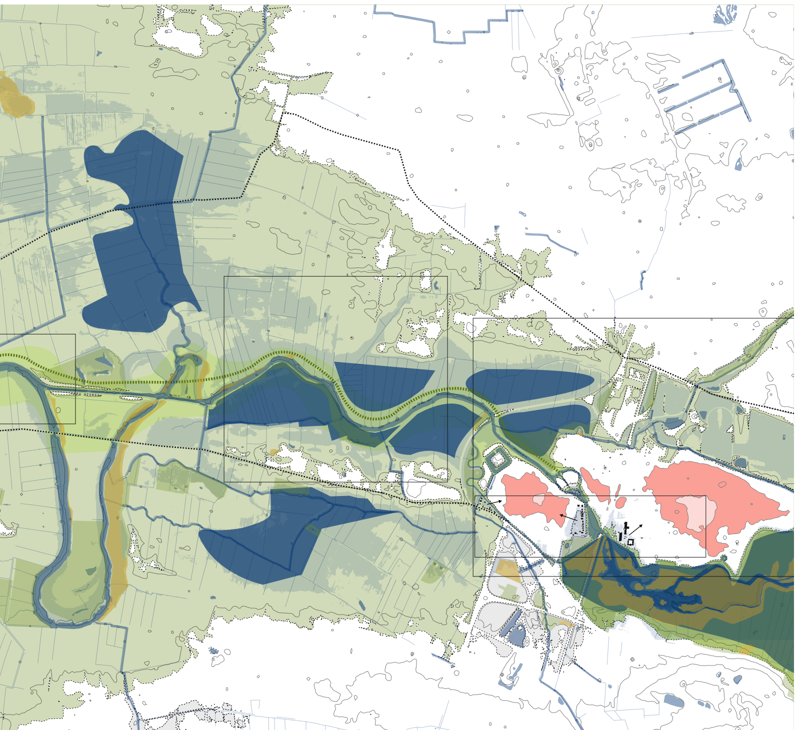
SCENARIO 1: REBUILD

Aim: Rebuild the affected structures after a disturbance
Time perspective:
Short-term



SCENARIO 2: THE HARD STRUCTURES

Aim: To keep the existing structures as they are
Time perspective:
Medium-term



SCENARIO 3: THE DEEP STRUCTURES

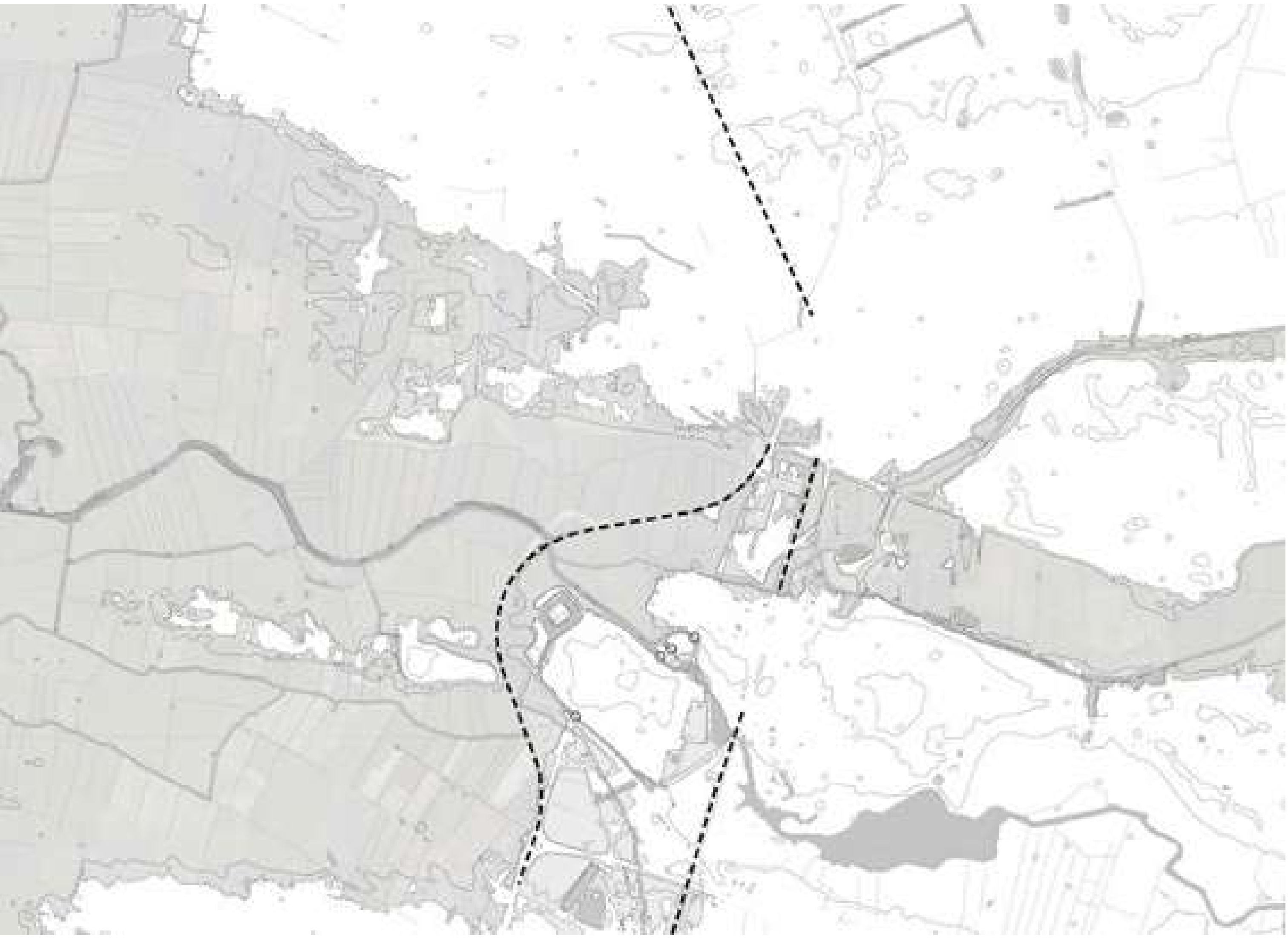
Aim: Use the deep structures to transform the existing system
Time perspective:
Long-term

MAP SYNTHESIS
SCENARIO 1: REBUILD

Minor infrastructural dike
Main dike
Sluice

→ *Ill. 116 The scenario of 'rebuild' 1:30.000 (Made by author)*

The concept of the *rebuild* scenario is to reach the same steady state of the socio-ecological system after a disturbance, as before the disturbance, by rebuilding the affected build structures after flooding. The choice to avoid climate adaptation measures is weighed against the financial costs. Here, reconstruction is emphasized rather that protection.



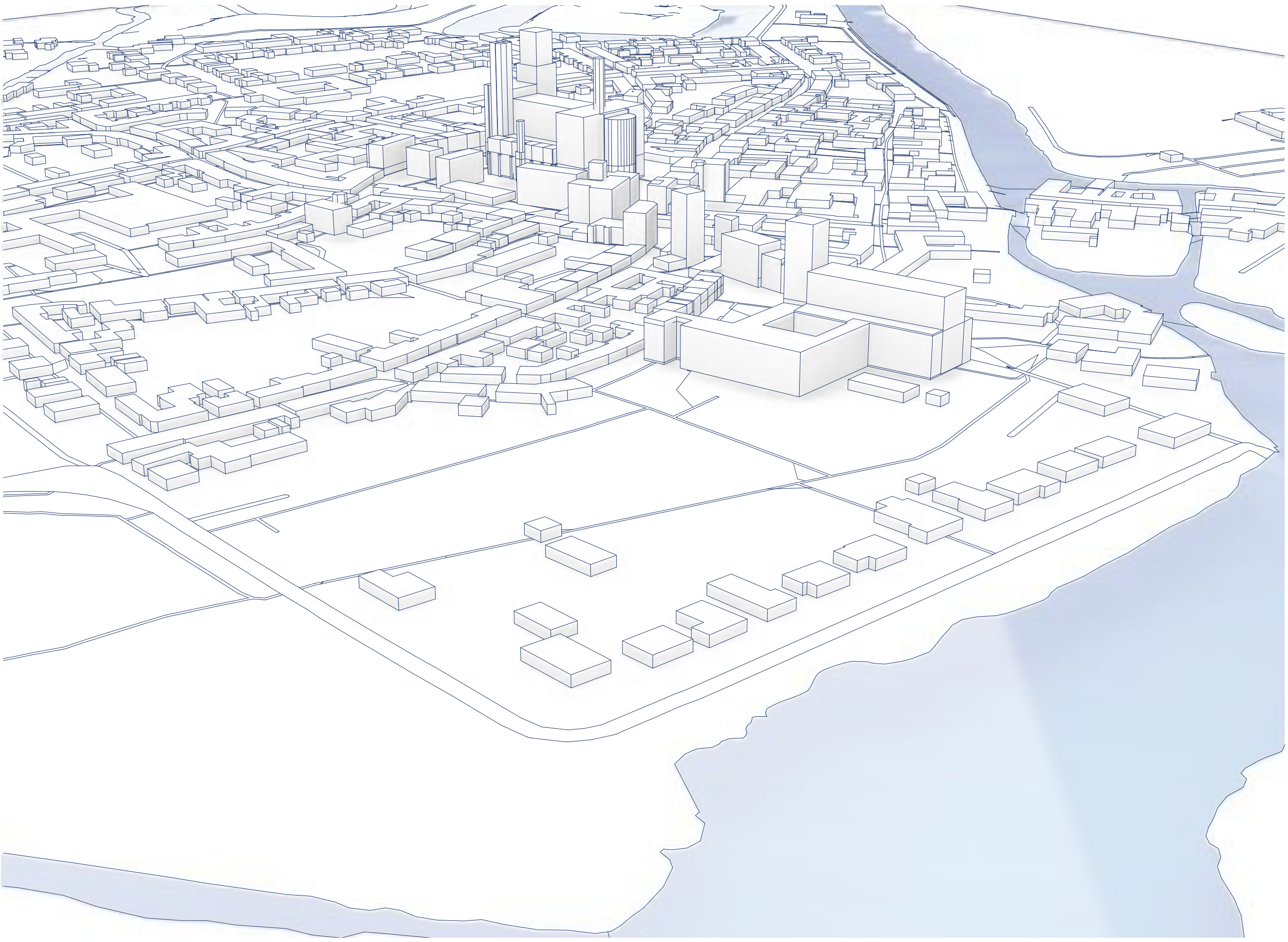
Instead of adapting to the changing climate, the price is paid for rebuilding the existing structures after a disturbance. In this way, the functions are maintained, such as agriculture in the marsh area and residentials in the depressions. Instead of investing in extensions of climate protection, the state of emergency preparedness can be increased and the damages that may occur, despite the emergency preparedness, are rebuilt.

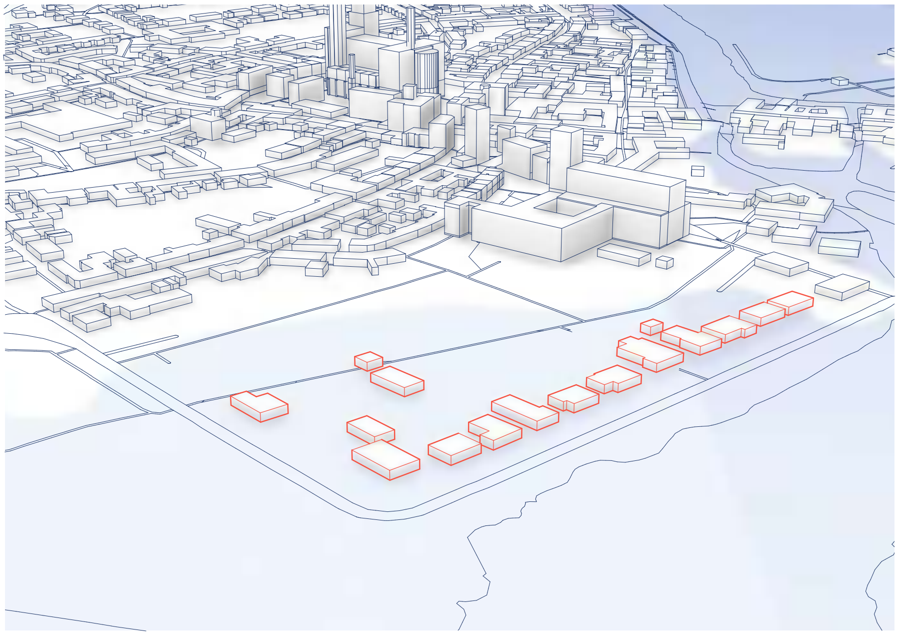
NOTE/ The Rebuild-scenario opens the discussion of who is going to pay for the possible damages? Is it an individual or shared responsibility? Furthermore, insurance issues must also be considered. This will be further discussed in chapter 6, Discussion: Perspectives and Outcomes, pp. 172-175)

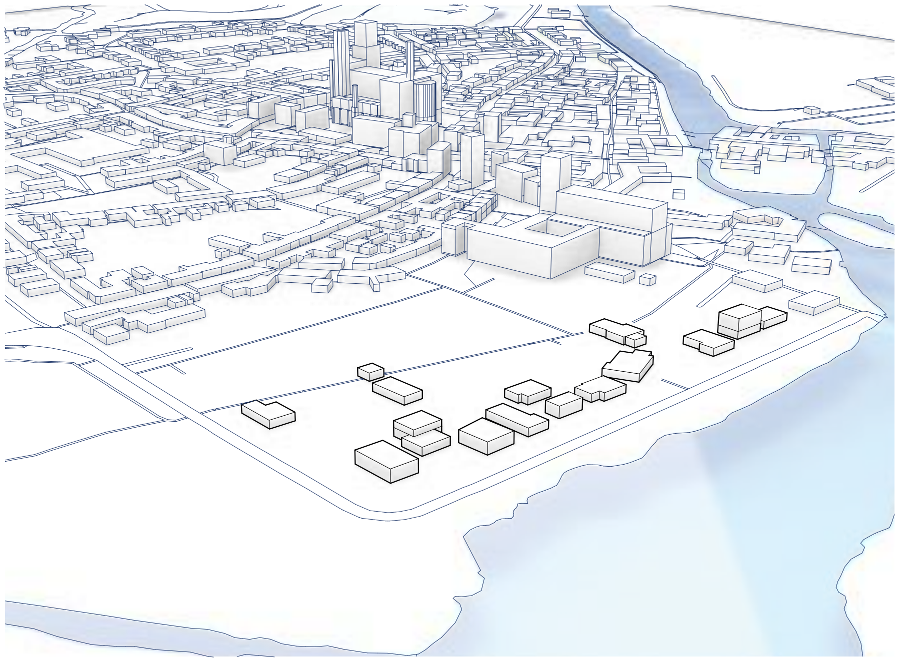
The strategy of 'rebuild' is used today. In the absence of a long-term strategy for flood-prone areas, the landowner himself pays the price for the damages (and the insurance). This is seen e.g., when the farmer's fields are flooded and the harvest is destroyed, or when homes are damaged by water after floods. The frequency and intensity of these events will increase in the coming years; thus, the financial coasts will also increase.

The district of Kurveholmen is an example of how current buildings, due to ignorance of the deep structures, are at risk of flooding (see more about the specific case in chapter 4, Settlement in Depressions, pp. 102-103). The location in a depression close to Østerå makes the area vulnerable (see illustration 117). When the watercourse floods the houses will be affected. The landowners who can withstand the water pressure by emergency preparedness experience less damage, while others experience greater damage. Common to all of them, is that their homes are renovated or rebuild as illustration 118 shows. When another event strikes again the same buildings and landowners will be affected once again.

↓ *Ill. 117 Kurveholmen district as it appears today (Made by author)*







↑ *Ill. 118 The top illustration shows how buildings are flooded in case of extreme events. After the disturbance the buildings are re-build as shown on the below illustration (Made by author)*

MAP SYNTHESIS
SCENARIO 2: THE HARD STRUCTURES

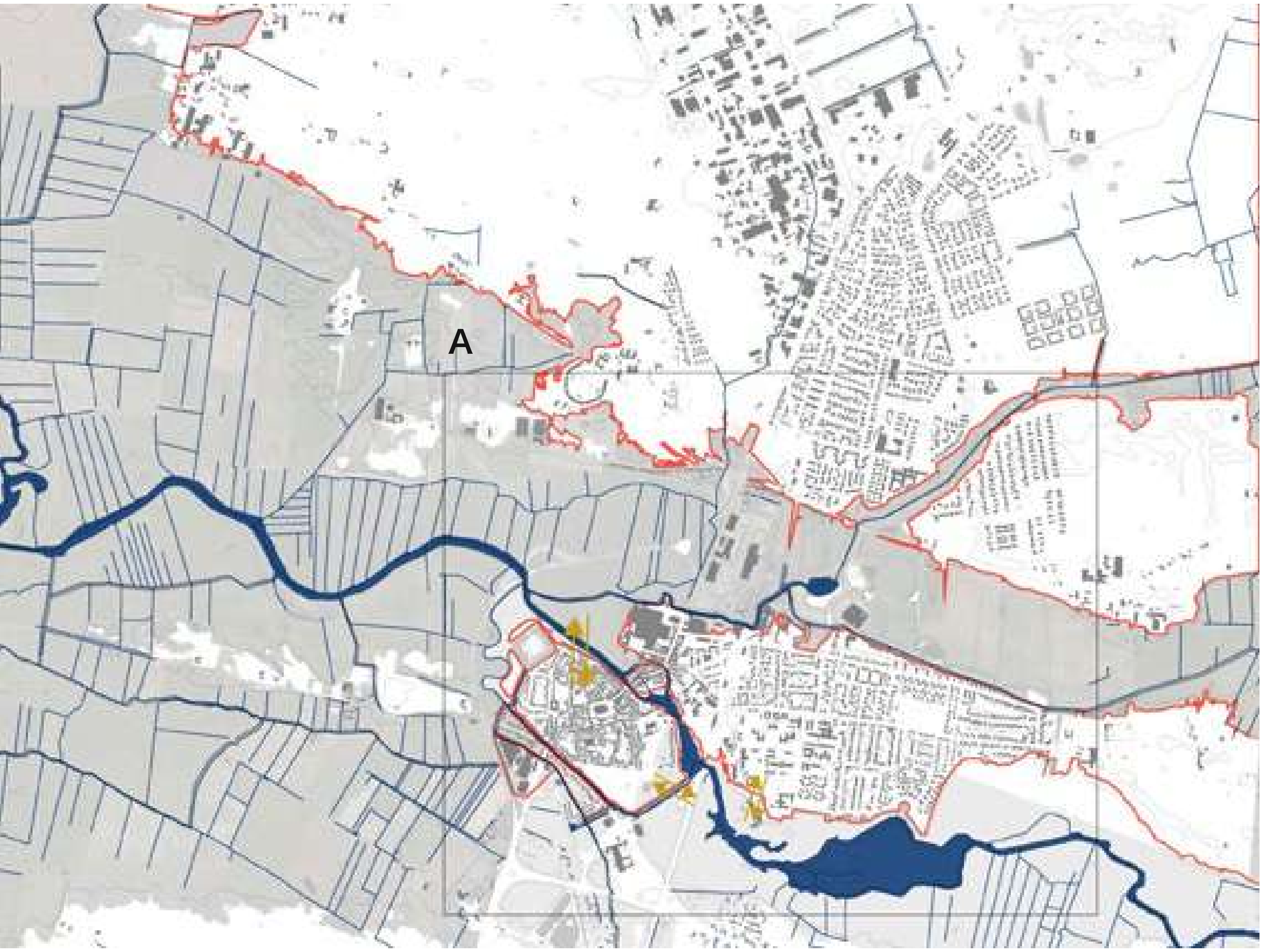
ditch
Pumps
Dike

→ *Ill. 119 The scenario of 'The Hard Structures' 1:30.000 (Made by author)*

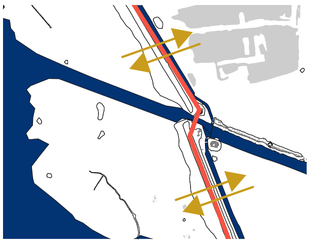
To keep the existing structures as they are, and hereby reach a steady state, four strategies are implemented. Together they protect the existing buildings, functions, and people in the area by the use of hard climate protection. Dikes and pumps are the main ingredients to keep flood-prone areas dry. Moreover, the marsh is further drained by excavation of the ditches and Vesterå, so that the function of agriculture remains the same. Linked to this scenario, is the ability to 'bounce back', which is similar with engineered resilience.

A DIKES AROUND THE CITY ON THE HILL-ISLANDS AND SUPPLEMENTARY PUMPS

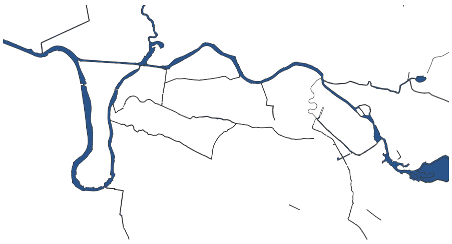
To protect the build heritage, functions, residential areas, people, and infrastructure in the city of Ribe, surrounding dikes are used. Additionally, extreme precipitation that undesirable would be hold back behind the dikes are let out by the use of pumps.



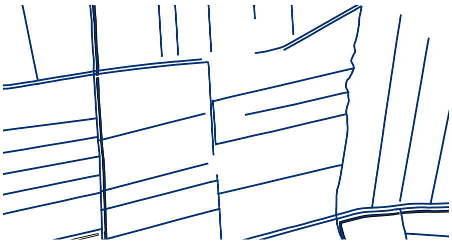
B ELEVATED DIKE WITH PUMPS



C EXCAVATION OF VESTERÅ



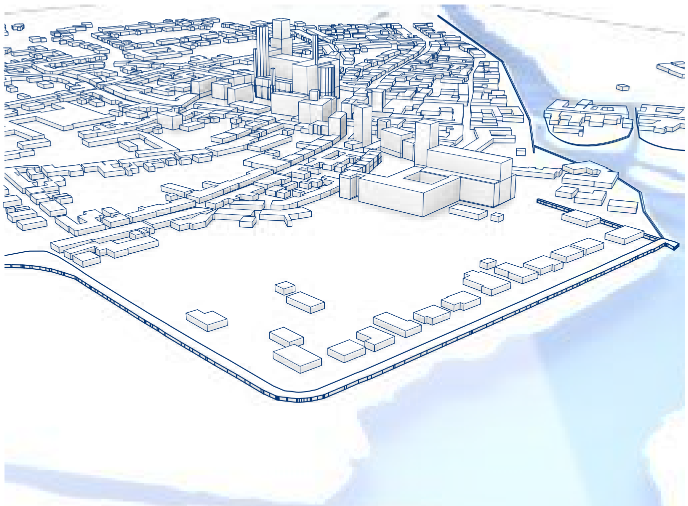
D EXCAVATION OF DITCHES

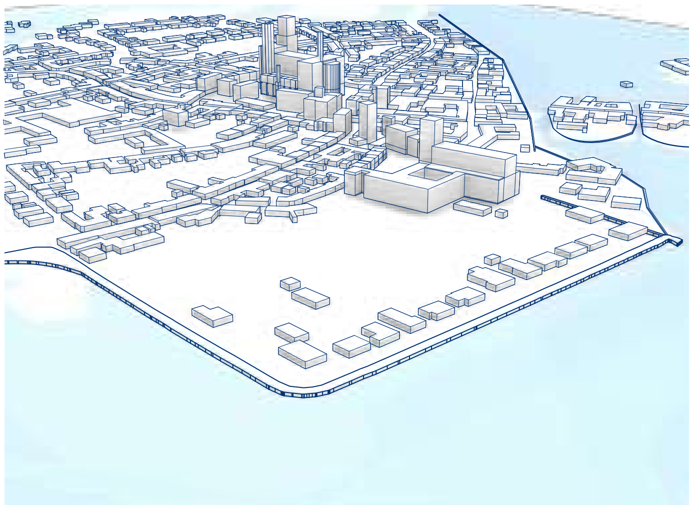


The existing dike along the coastline needs to be maintained and further elevated in the long-term. In the short-term, pumps must be integrated into the dike construction to outlet water in case of watercourse flood.

To provide the needed drainage of the cultivated fields in the marsh area, Vesterå is excavated. In this way, the water capacity is increased, which solves both a current need as well as a future need.

Drainage is increased by excavation of the existing fine masked ditch system in the marsh area. Thus, the function of agriculture can withstand the increasing amounts of water.





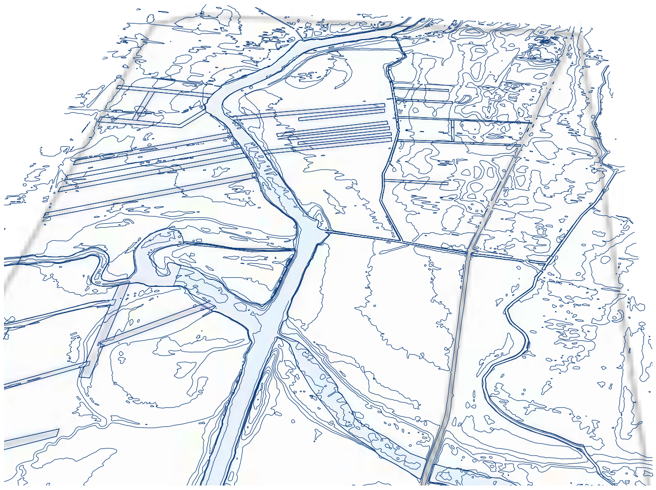
↑ *Ill. 120 Kurveholmen district with a surrounding dike as shown on the illustration to the left. The dike does also function as a road, to maintain the current function. The illustration to the right, shows a case of flooding, where the build structures and the city are protected (Made by author)*

The strategy to protect the existing build structures by the use of hard climate protection is already known in Ribe. The dike along the coastline, and sluices in the city center are examples of existing hard climate protection. In this scenario new dikes around the city on the hill islands clearly defines what should be protected and what areas can be flooded. The dikes near the city can be integrated as infrastructural elevations as illustration 120 is an example of. Here the low laying district, Kurveholmen, uses the existing road to integrate the protection. Depending on how much protection is desired, the dike can either enclose the city on the hill islands, or it could be integrated in the terrain, so that minor vulnerable areas like Kurveholmen will be protected with dikes. Often pumps will be needed to outlet the water that will be trapped behind the dike in case of extreme precipitation.

↓ *Ill. 121 The picture shows a local dike in Holland along a stream. Land subsidence makes the water level higher than the ground (Wordpress n.d.)*

NOTE/ The use of hard climate protection measures are built to perform a specific function, which often cause inattention to the experiential values. What do the high dikes mean for our urban experience? Does it disconnect the city from the surrounding water and landscape? Which architectural complication do they cause? These questions will be further elaborated in the discussion (see chapter 6, Discussion: Perspectives and Outcomes, pp. 172-175).

← *Ill. 122 The picture shows a dike at the Wadden Sea coast in Holland (MacLean 2016)*

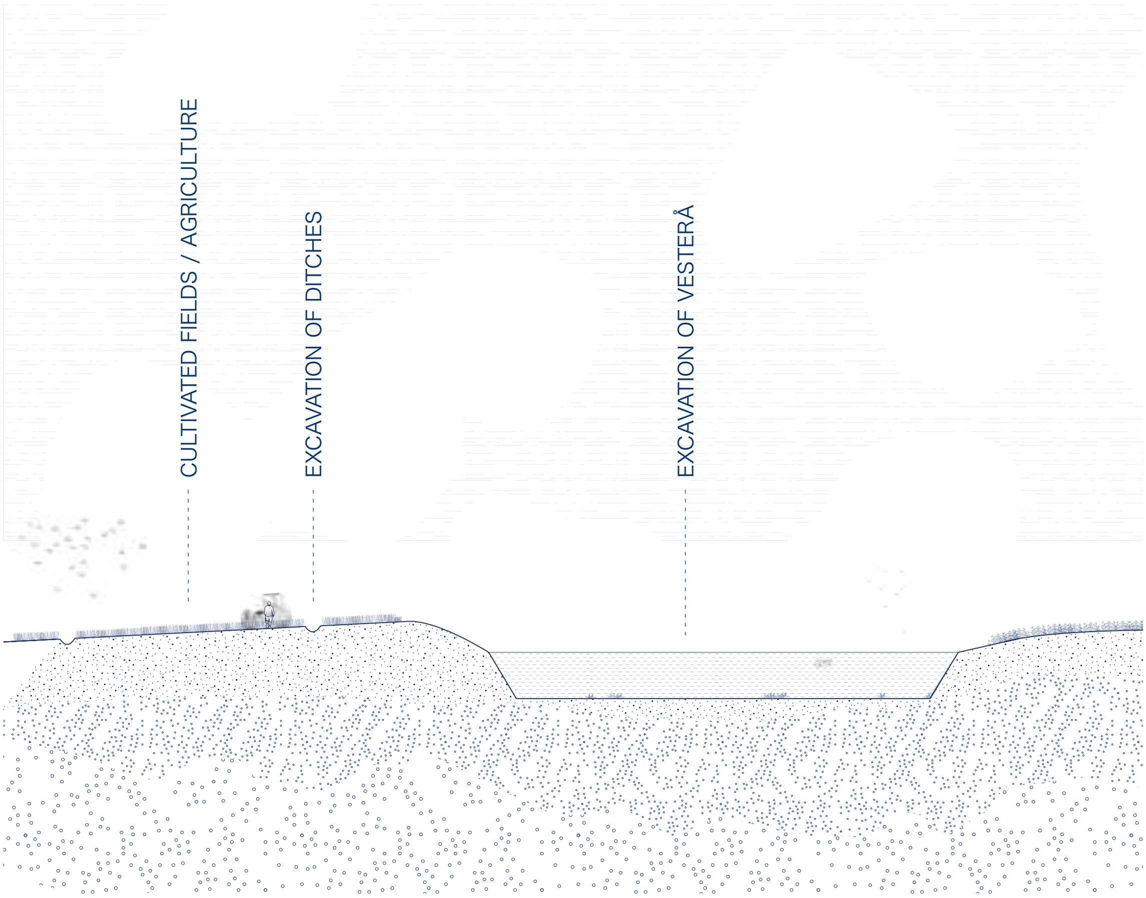


↑ *Ill. 123 In the marsh the ditches and Vesterå are excavated to increase the drainage, and hereby maintain the agricultural functions (Made by author)*

NOTE/ Legally, it can be almost impossible to be allowed to change the condition of protected areas, as a result of the Nature Conservation Act § 3. Excavation of ditches and streams in Ribe marsh can be hard to carry out, as the right of free drainage (Watercourse Act § 5) is not applicable to protected nature areas, as large parts of Ribe marsh are designated as. This leads to questions such as how would agriculture survive in the long term without changing the natural conditions in the area? And should the marsh areas even from the beginning, have been cultivated? This will be further discussed in chapter 6, Discussion: Perspectives and Outcomes pp. 172-175

In the marsh area, the climate solutions should protect the existing function of agriculture. It is proposed to build on the existing solutions, by further excavation of Vesterå and the fine-grained ditch system. In this way the capacity of the waterways will be increased, which would drain the cultivated fields (see illustration 123). The cross-section of Vester in illustration 124 shows how the atmosphere will be in the marsh area.

↓ *Ill. 124 Cross-section of Vesterå in the marsh area. The ditches and Vesterå are excavated to drain of the fields. The modified stream will be more angular than the natural stream and the landscape will appear as it is today 1:500 (Made by author)*



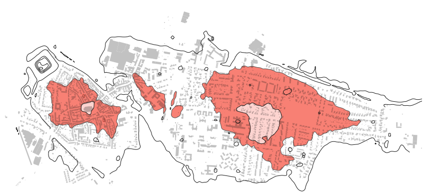
MAP SYNTHESIS
SCENARIO 3: THE DEEP STRUCTURES

- Retreat
- Densification
- New connection
- Road
- Green Infrastructure
- Marsh
- Meadow
- Ponds
- Bog
- Dike

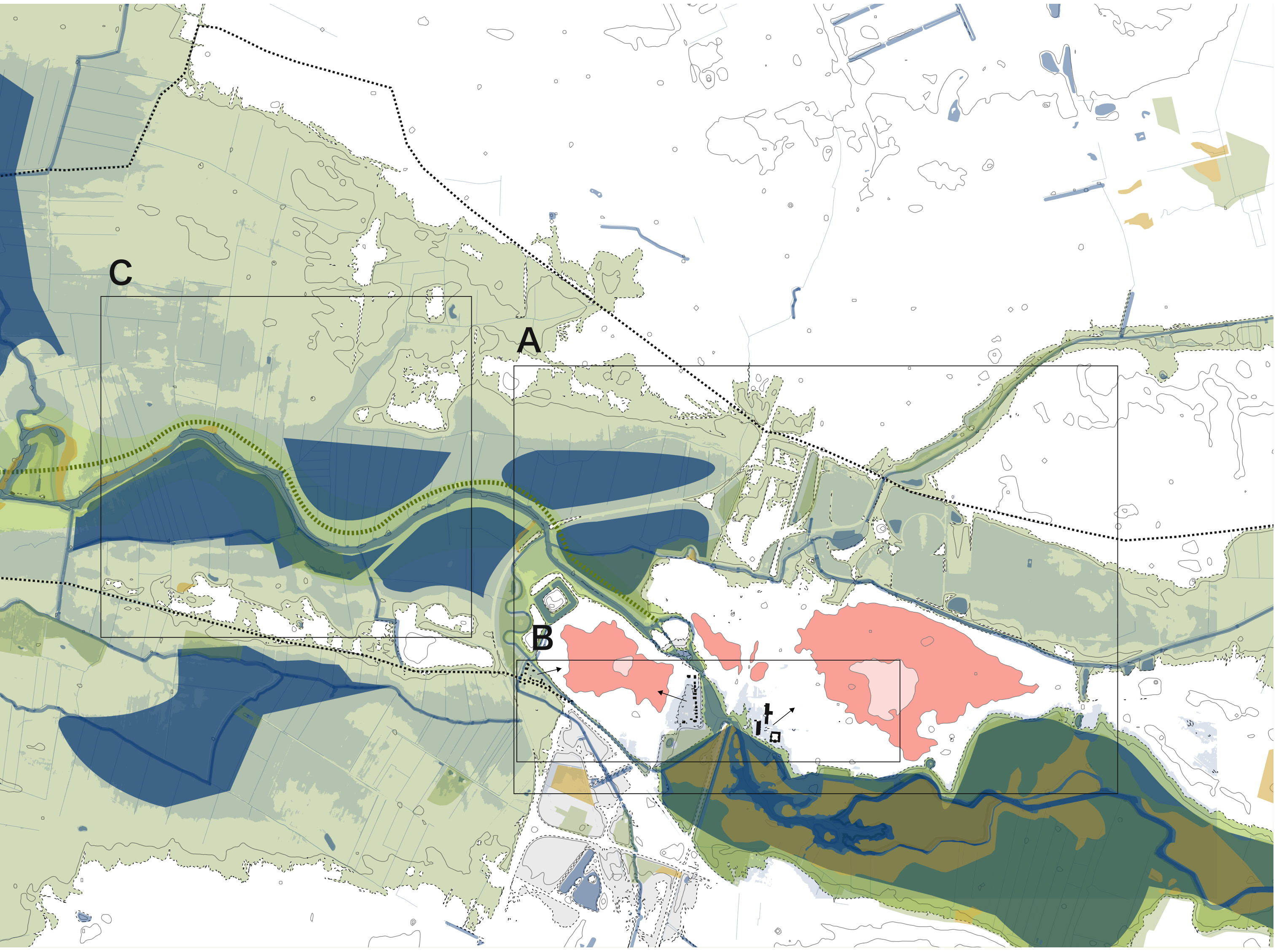
→ *Ill. 125 The scenario of 'The Deep Structures' 1:30.000 (Made by author)*

To use the deep structures to transform the existing socio-ecological system is a forward thinking and long-term vision. Different climate adaptation strategies are used. The first strategy is to retreat high-risk areas, following the design approach of 'design to move up and in,' which would densify the existing city areas following the elevation of the terrain. In the marsh area, retention ponds are established, and green infrastructure will connect the city with the Wadden Sea.

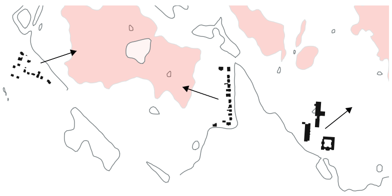
A DENSIFY ON TOP OF THE HILL ISLANDS



The densification will follow the elevation of the terrain, meaning that the top of the hill islands will be densified. This strategy is related to the strategy of retreat as the low laying areas are moved up and in. New residential areas will continue as planned on the areas east of Ribe.

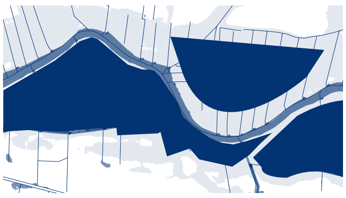


B RETREAT



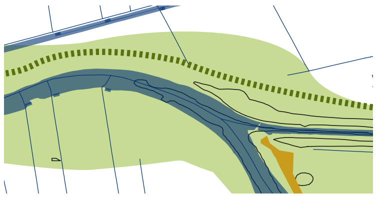
Build structures that are located in high-risk areas in contradiction to the natural conditions are retreated. The strategy works with a long-term perspective over the next 50-100 years and will be plan-driven, which ensure a strategic approach where other values can be incorporated.

C PONDS IN THE MARSH LANDSCAPE

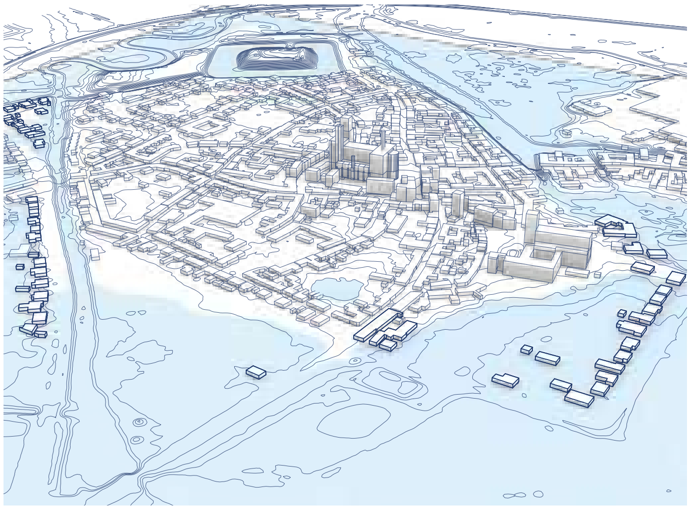


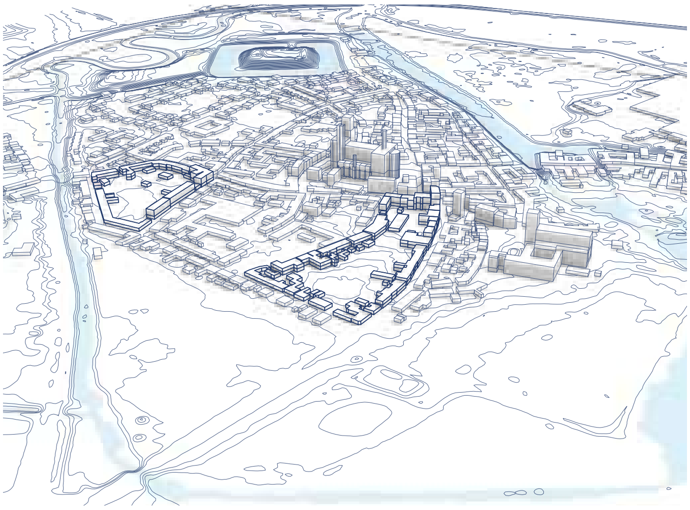
Retention ponds are located in the marsh area to both increase the natural values and help store the water in case of extreme events. With inspiration from the clay pits along the coast, new nature areas are established for the benefit of animals and plant life, including migratory birds. At the same time the existing ditch system will be a natural waterway leading water to the ponds to relieve the pressure on Ribe Å.

D GREEN INFRASTRUCTURE



The green stretch consists of multi-layered functions and ecosystem-services both biotic, abiotic, and cultural. Recreative paths connects the city to the Wadden Sea, which together with the flow of water, and improved wildlife creates new attractions, interactions, and experiences – all with multiple benefits. Furthermore, a conversion of the existing agricultural function could be implemented as a way to adapt land-based cultivation towards water-based.





↑ Ill. 126 Buildings in high-risk areas, as shown on the left illustration are retreated and the higher laying city is densified, as shown on the right illustration (Made by author)

In accordance with the natural conditions high-risk areas are given back to nature. Illustration 126, shows how the retreat strategy will leave new areas close to the water empty, as the long-term economic perspective will not include investments in hard protection systems. Instead of using the areas for permanent buildings, semi structures with low economic value can be located in these areas e.g., new recreative paths with moveable toilet buildings, small shops etc. Also, safe-to-fail experiments could be implemented in these areas.

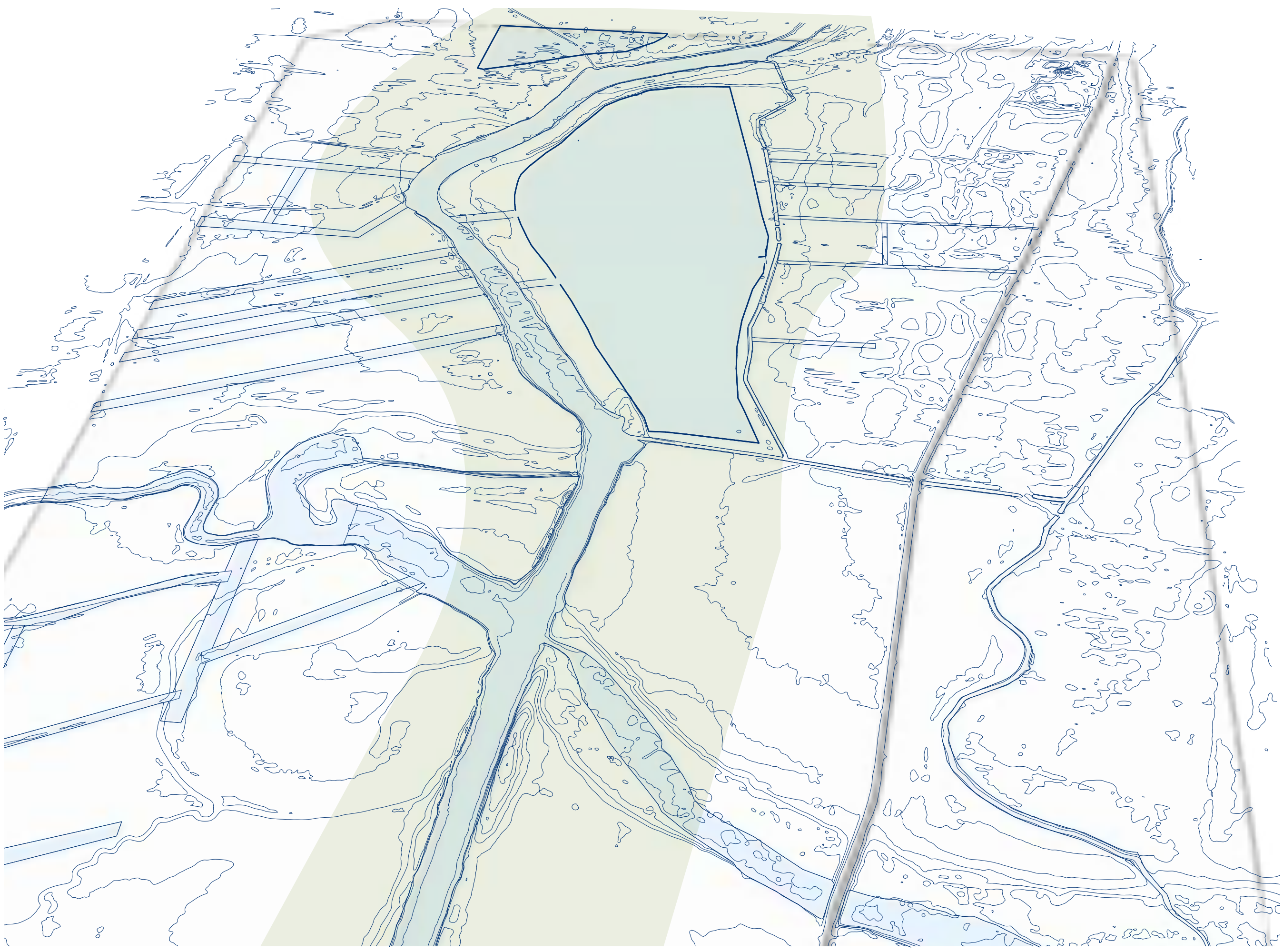
The strategy of Green Infrastructure connects the Wadden Sea with the city, which makes the area accessible for humans and non-humans. The whole stream system with its natural value will be intensified for the benefit of animals and plant life. It would also reinforce the existing natural qualities in the marsh area that are not accessible today, which could be a new tourist attraction in the Wadden Sea National Park.

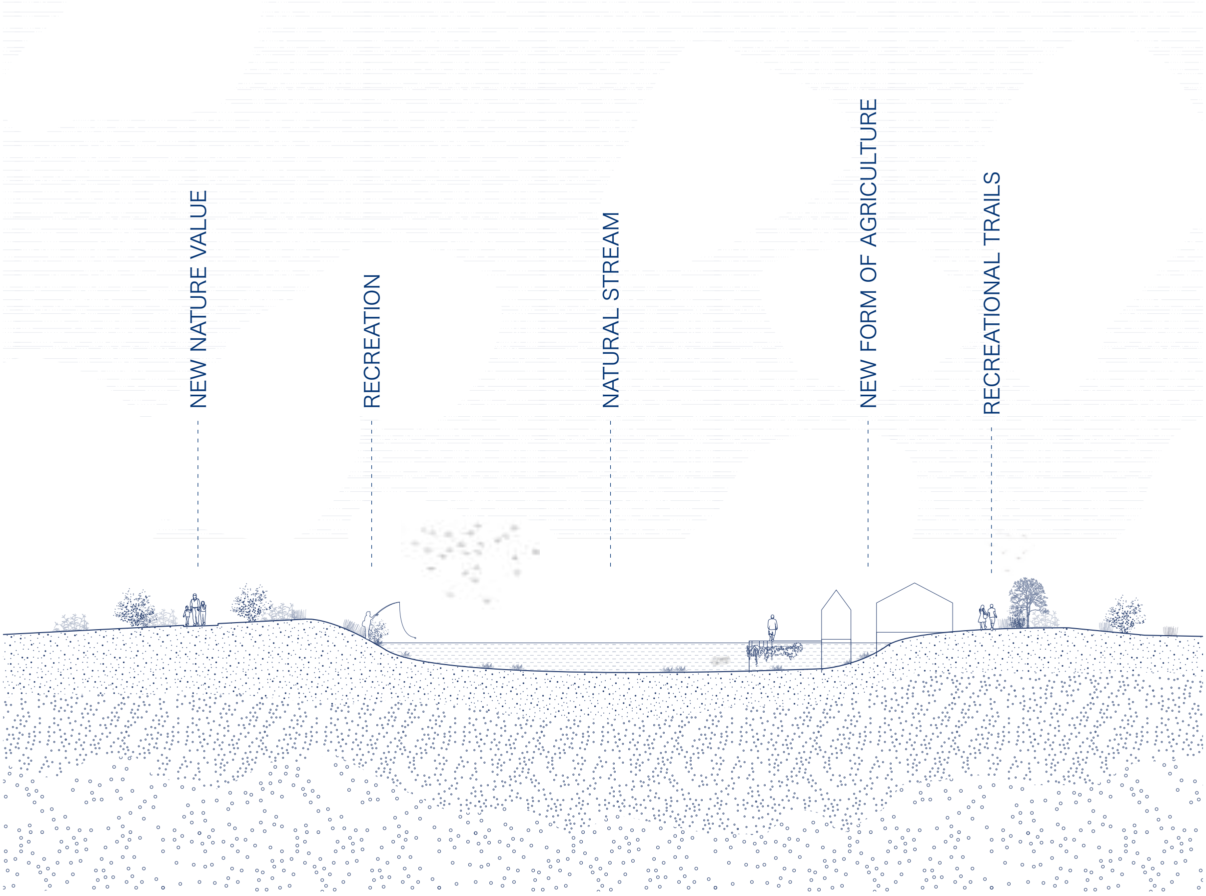
← Ill. 127 Dland Studios has made the project Bight: Coastal Urbanism that works with a retreat approach. The project in Jamaica Bay mixes different climate adaptation strategies, but focuses on nature-based climate adaptation (Dland-studio & Rafi Segal 2017)

The marsh is used as a vital part of the solution to address climate change. New retention ponds are established to collect overflow water from Ribe Å and the upland, so that the city of Ribe remains dry. With the catchment area of 962 km2, and a runoff of 90 l/sec/km2 in case of a 100-year flood event, more than 21 km3 of water must be distributed on the surrounding terrain. Currently, the area east of Ribe, will be able to store up to 9 km3 of water, by which the area west of Ribe, with the new ponds should store around 12 km3 of water. This corresponds to half of the marsh area will be flooded with 1 m of water. Thus, the ponds would create a large wetland area, that only rarely would reach its maximum capacity (depending on the selected return period). The terrain elevation in the marsh will dictate where to locate the new ponds, so that the existing ditch system will act as the waterway leading overflow water to the ponds. The meadow areas near the city are examples of low laying areas that should be used to the water.

NOTE/ The water should be handled as far upstream as possible, which requires collaborations with the neighboring municipalities. Ideally the ponds should be located east of Ribe as far upstream as possible, but often the reality leaves the lowest-lying cities with the problem.

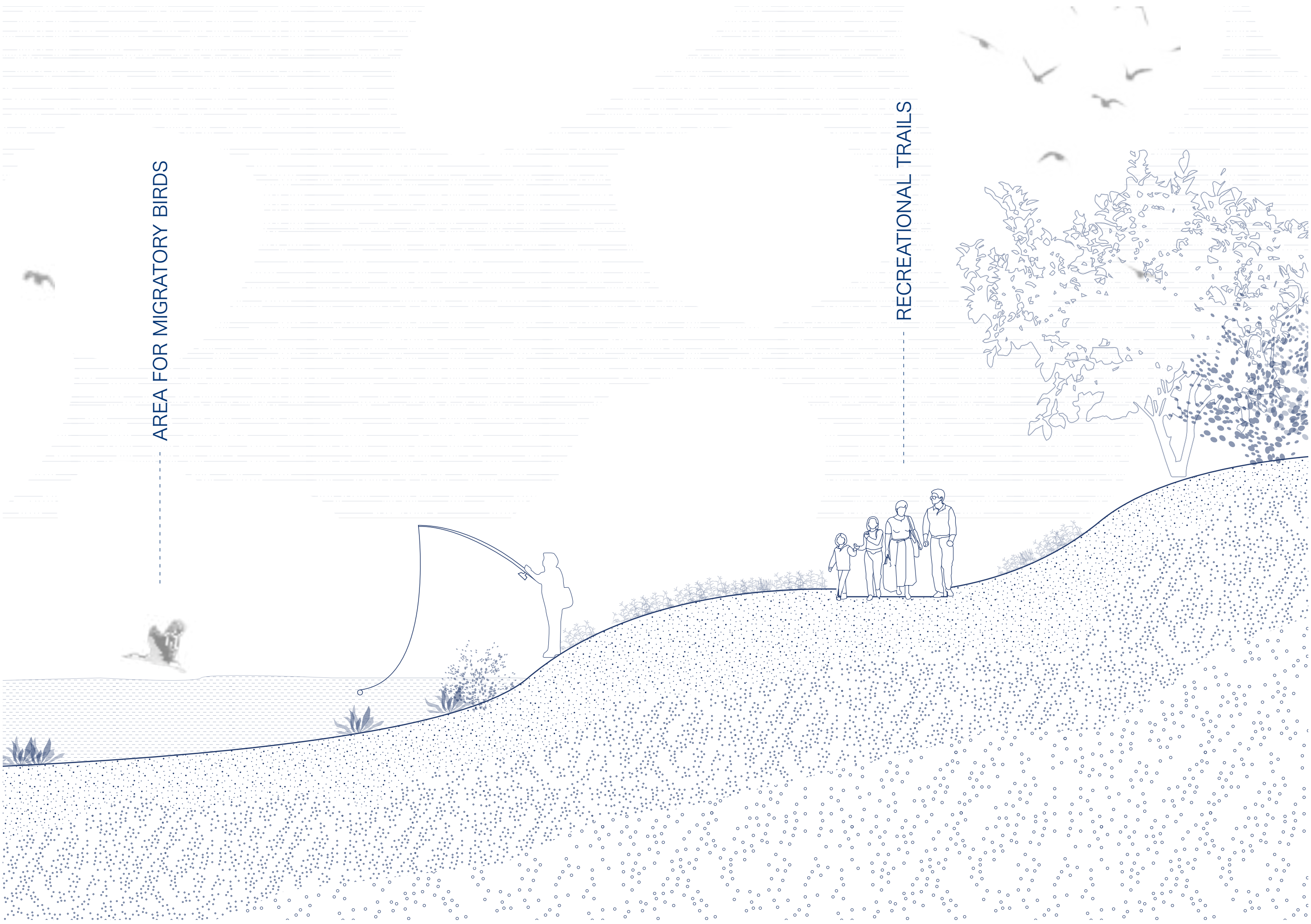
↓ *Ill. 128 Retention ponds are added into the marsh area and a new Green Infrastructure along Ribe Å supports both social and ecological functions*
(Made by author)





↑ *Ill. 129 Cross-section of Vesterå showing how the natural waterflow as a part of the green stretch intensifies the natural value, gives new recreational opportunities, and how new forms of agriculture could be established 1:500 (Made by author)*

↓ *Ill. 130 Cross-section of one of the new ponds in the marsh. The areas would attract mitigatory birds and be used for recreational purposes such as sailing, fishing, and nature walks 1:100 (Made by author)*



6. EVALUATION

↓ *Ill. 131 Air photo of Ribe*
(Lytt Architecture n.d.)

EVALUATION
DISCUSSION: PERSPECTIVES AND OUTCOMES

NOTE/ In the interview with Architect Jan Ove Petersen from Esbjerg Municipality, it became clear that no strategic climate adaptation plans have been made for Ribe jet. Many of the perspectives that emerged are therefore not based on experience gained in Ribe, but are general reflections that have opened up different discussions regarding Ribe.

The three scenarios presented, show three different directions of strategic climate adaptation, that works with different time-perspectives and strategies. The scenarios have worked as a tool to analyze the future of Ribe, and they have been used as a discussion-tool in an interview with architect Jan Ove Petersen from Esbjerg Municipality. In this way, different conflicts of interest and complications has been unfolded. In the following, four perspectives are presented. These are not exhaustive for all the perspectives the scenarios have revealed, but they cover the most distinctive ones. In this regard, it is important to emphasize, that many of the perspectives talks into a larger socio-political agenda, that goes beyond the authors field of study. Nevertheless, it shows how complex climate adaptation planning is, and it emphazise a previously presented theoretical point, that interdisciplinarity and collaboration are the alpha omega when working with strategic climate adaptation.

AGRICULTURE IN THE MARSH?

In Ribe there are several conflicts of interests regarding climate adaptation. The most prominent is the interest and desire of farmers to preserve their cultivation in the marsh area, which becomes more and more difficult with the increased amounts of water in the landscape. The previously mentioned bathtub effect is a major challenge for agriculture in Ribe. Also, the fields located in low laying areas ('lavbundsarealer') would be further challenged with the rising groundwater level.

Seen from a historical perspective, it is clear that the location of agriculture is in conflict with the natural conditions, also referred to as *the deep structures*. The constriction of the dike and the modifications of Vesterå was of great benefit to agriculture, but also at the expense of the natural value in the area, not to mention the unintended consequences for subsidence in the medieval city center. If agriculture function is to remain in the marsh area more drainage needs to be carried out (possibly pumps will also become a necessity), as scenario 2, *The Hard Structures*, implies.

The issue of agriculture in lowland areas ('lavbundsareler') is politically relevant today. In April 2021 the national government presented an agricultural proposal where the ambition is to take out 88.500 ha lowland areas. By phasing out agriculture in those areas and let them flood, around 0,5 million tons CO_2 can be reduced towards 2030 (Regeringen 2021). Scenario 3, *The Deep Structures*, follows the governments wish, and furthermore increases the natural value, and use the marsh as a part of the solution to address future climate changes.

When looking at the Road Map for Resilient Climate Adaptation, the concept of The Deep Structures is incorporated in scenario 3. The structures and functions that currently opposes the deep structures are adapted to the underlying ecological, geological, and hydrological conditions.

DYNAMIC SOLUTIONS

The three scenarios represent different climate adaptation solutions. Scenario 1, *Rebuild*, follows the current approach where destroyed buildings and structures are repeatedly reconstructed after a disturbance. Scenario 2, *The hard structures*, follows a protection approach with single minded mono solutions. Scenario 3, *The deep structures*, are more forward thinking as it combines different solutions including more nature-based adaptation approaches. The big difference is that scenario 3 is an everchanging and dynamic way of approaching climate change. The water landscape is used as an asset, which can contribute to increased nature value, recreation, and destination development. It may prove profitable to work integrated with water in urban development and use the challenges as a steppingstone to transformation and improvement of our cities. Another important quality of accommodation approaches including nature-based solutions is, the avoidance of doing either too much to protect, or too little, as those kinds of solutions are multifunctional with multiple purposes that can be more than just climate protection.

It is also unknown how hard protections such as dikes affects or urban spaces. In some cases, seawalls separate the city from the sea, creating a barrier between the two. The most vulnerable areas are often the most expensive ones, as they are located near the water, which has so far been perceived as the most valuable places. How would such areas response to high dikes that may remove the appreciated values?

Currently the hard protection structures are most used in a danish context; thus, experiences with nature-based solutions are lacking. This contributes to a degree of insecurity, when decisionmakers choose solutions. It can be difficult to financially defend solutions that are not 100 % secure and previously tested.

WHO HAS THE RESPONSIBILITY AND WHO IS GOING TO PAY?

Today the ones who benefit from the specific climate protection, often the property owner, are those who must pay for the solution. Dike-guilds ('dige-lav') are widely used to find common solutions and co-finance. In most cases there are several others who have interest in the protection, e.g., when infrastructure or recreative areas is for the benefits of all citizens. Hence, a wider circle of interest distributes the coasts. It is also common that municipalities, who has the overall responsibility for climate protection, act as a facilitator at larger citizen meetings regarding climate adaptation. In recent years, municipalities have become more aware of their role in climate adaptation issues, as solutions may have greater urban significance for larger parts of the city.

The time perspective has by several municipalities been pronounced as a problem in climate adaptation matters. The long-term perspective and decisions whose result will only be seen in 50-100 years are difficult to create political momentum around, as city councils are replaced every four years. Jan Ove Petersen do also address the need for holistic planning that goes beyond the scale of minor urban spaces. Long-term visions and guidelines need to be made, to secure a coherent and persistent urban planning.

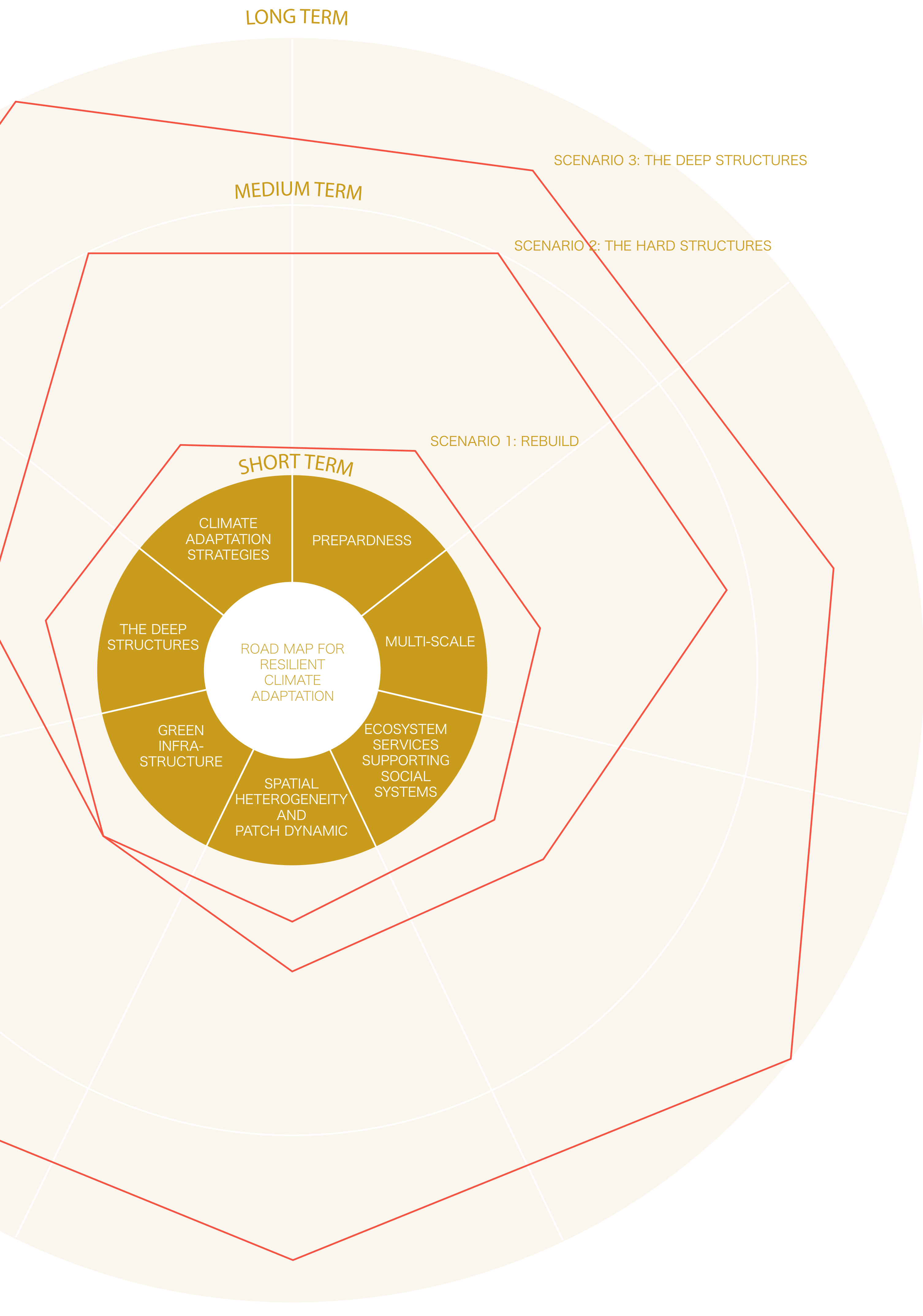
There is no legislation that ensure overall planning across municipal boundaries. The decentralization of policy responsibility regarding climate adaptation, leaves the decisions to the individual municipality, which contribute to a diverse an uneven practice across the municipalities. Seen from a nation perspective, it may as well not make sense to invest in large climate protection in some municipalities, while in other municipalities it may be of great economic benefit. Copenhagen is an example of the most vulnerable area, that for sure would demand protection, as our pension funds are located here. Also, cultural and build heritage which may have national interest and value could be areas that would need more protection. Ribe's medieval city center is a good example.

This issue has been debated by experts and politicians, who wants a national plan to avoid incoherent solutions (Frederiksen et al. 2020). Their wish has been granted; thus, the national government are in the making of a national climate adaptation plan expected to be completed in 2022. In this way, decisions can be made that strategically takes the specific location into account.

RESILIENCE

When analyzing the three scenarios in relation to The Road Map for Resilient Climate Adaptation, it becomes clear that the concepts related to resilience in different ways and levels are incorporated. Illustration 132 shows how the different concepts from the road map are thought into the individual scenario. The Road Map only indicates concepts of resilience and their interrelated urban design elements that are important for resilience (see chapter 3, *Road Map for Resilient Climate Adaptation*, pp. 74-77), thus it does not give an exact degree of resilience, as no scale has been set, that can assess the 'amount' of resilience. Nevertheless, a strategic future scenario that works purposefully with as many of the concepts as possible and incorporates interrelated elements can be interpreted as being more resilient. That is what illustration 132 seeks to show. Scenario 3, *The deep structures*, is the one with the longest perspective as its ability to continually adapt makes is flexible and dynamic, and it can be understood as the scenario with highest resilience.

→ *Ill. 132 The three scenarios are assessed in relation to each individual concept included in The Road Map for Resilient Climate Adaptation (Made by author)*


LONG TERM
SCENARIO 3: THE DEEP STRUCTURES
MEDIUM TERM
SCENARIO 2: THE HARD STRUCTURES
SCENARIO 1: REBUILD
SHORT TERM
CLIMATE ADAPTATION STRATEGIES
PREPARDNESS
THE DEEP STRUCTURES
MULTI-SCALE
ROAD MAP FOR RESILIENT CLIMATE ADAPTATION
GREEN INFRA-STRUCTURE
ECOSYSTEM SERVICES SUPPORTING SOCIAL SYSTEMS
SPATIAL HETEROGENEITY AND PATCH DYNAMIC

NEXT STEP: THE ROAD MAP FOR RESILIENT CLIMATE ADAPTATION

Climate adaptation design and planning is a complex matter, that holds a potential to transform our cities to be better and more sustaining. The Road Map for Resilient Climate Adaptation proposes urban design elements that can be analyzed or screened in the initial studies prior to a strategy, plan, or design to inform urban planners and designers and help assess future urban development in relation to resilient climate adaptation. The road map presented in this project is a first draft version, previously termed, *version 1*, (see chapter 3, *Idea of the Experiment*, pp. 72-73), that needs to by further refined and adjusted to work as an instrument within urban planning.

The evaluation of the road map in this project is limited to first, a map-synthesis that gives possible directions of urban development and reveal challenges and strengths. It shows that, by identifying urban design elements presented in the road map, decisionmakers can be guided. And second, the three scenarios concretize three possible directions of development that has been used as a discussion tool to broaden perspectives in relation to the specific case study. The research experiment shows a potential to guide decisionmakers and inform and assess resilient climate adaptation planning and design, but to further develop the road map, it must be practically tested in e.g., municipalities. The users can give critique, feedback, and verify the tool in a practical context. The iterative testing, evaluation, and improvement would help refine the draft version presented in this project.

EVALUATION
CONCLUSION: THE RESEARCH EXPERIMENT

The aim of this master thesis and research experiment was to *develop a road map that can inform and assess resilient climate adaptation of socio-ecological systems, within urban design and planning*. By combining theoretical litterateur research with practical site-specific explorations, a first draft version of the Road Map for Resilient Climate Adaptation has been developed.

To reach the overall aim, the process has taken its point of departure in three objectives. The first objective was to *review the theoretical relationship between human and nature dichotomy, ecology in urban design, and resilience*. Theory of human and nature dichotomy are the backbone of the new nature view that this project is based on, perceiving human as a part of nature, and using landscape as a medium to explore socio-ecological systems. Theory of ecology in urban design reveals approaches such as Ecological Urbanism that integrate ecological principles and concepts into urban design, thus the theory act as a bridge to integrate ecological theory of resilience into climate adaptation planning, which the last theoretical bit seeks to do. Whereas the first two topics are classic urban design theory, resilience that origins from the ecological field is relatively new within urban design practice and climate adaptation planning. Concepts, ideas, and principles of resilience that can be used within climate adaptation planning has been revealed. Together, the three theoretical parts creates one of the two pillars that the Road Map of Resilient Climate Adaptation is based on.

The second pillar is linked to the second objective. It seeks to concretize a practice that can inform and assess resilience within climate adaptation planning, by *exploring how urban design method can read and translate the found concepts of resilience through a case-specific study* of Ribe. Through classic urban design method, such as mapping, Ribe is analyzed guided by the theoretical concepts, ideas, and principles of resilience. This has helped to 'translate' the theory into 'urban design language' by specifying interrelated urban design elements that can be identifies and analyzed at a physical site.

Based on the two first objectives a draft version of the Road Map of Resilient Climate Adaptation has been developed. The last objective seeks to *discuss and evaluate how the road map can inform strategic urban design and planning of climate adaptation*. First, the findings from the analysis of Ribe presented in the map-synthesis reveals both strengths and challenges in relation to Ribe's urban development. The map-synthesis is an expression of the road map applied to the specific case of Ribe and it points in different strategic development directions, thus function as a help for decision making. The map-synthesis is hereby an applicable result of the Road Map for Resilient Climate Adaptation.

To further discuss and evaluate the road map, three future scenarios has been created to present three possible directions of development. The scenarios are used as a discussion tool to ask the 'what-if-questions'. This purpose has been used in an interview with Esbjerg Municipality, which has brought new perspectives into the spotlight. The perspectives of conflicts of interest in Ribe, differences of climate adaptation solutions, responsibility in relation to climate adaptation, and the measure of resilience are discussed.

Through the research experiment it has shown to be possible to create a Road Map for Resilient Climate Adaptation, that can inform and assess climate adaptation planning. Even though the road map is a draft version that needs further refinement, it shows a potential to broaden perspectives and start discussions, that are important in the creation of resilience. The project has narrowed the use and definition of resilience within urban design and planning, to overcome the buzzword-like use of the term resilience. Resilience is a strong concept that can be used within climate adaptation planning. It can secure an interdisciplinary approach, that takes the specific site's deep structures into account. Hence, urban design and planning working with climate adaptation have the opportunity to improve, transform, and work holistically with our cities and landscapes in a progressive way.

EVALUATION
REFLECTION / CRITIC

In the process of making the Road Map for Resilient Climate Adaptation certain aspect has been excluded or underexposed, as a result of time, complexity, as well as reflexive blind spots. Furthermore, the learning curve for this project has been steep, and a lot of new information have been revealed along the journey.

TYPES OF RESILIENCE AND SOCIAL ASPECTS

In the theoretical literature research of resilience, it became clear that resilience is not just linked to environmental systems, but it is also linked to social and economic systems, that all together are interrelated (socio-ecological systems). When a climate related disturbance strike, it affects all systems. Thus, when focusing on socio-ecological systems through the urban design profession and only address one type of disturbance it will cause inattention to other important aspects as well as other relevant disturbances that are fundamental for a systems total resilience.

In line with this, the economic aspects go beyond the scope of this project and is therefore underexposed, even though it is highly relevant. Economic resilience in relation to climate change are vital to consider. How much does disturbances coast, and what solutions are economically most sustainable in the long term?

Another fundamental aspect of resilient climate adaptation is social resilience. Even though the social elements are reflected into the urban design elements in the road map, such as cultural landscape and ecosystem services, the local citizens play a crucial role both in terms of decision making, and emergency preparedness. The local social resilience is not fully reflected into the road map. As an enhancement the three scenarios could function as a tool to involve and discuss different futures with the citizens, but unfortunately this has been challenging to establish due to COVID-19 in the project period.

RIBE IS A SPECIEL CASE

The Road Map for Resilient Climate Adaptation is a product of both theoretical literature research and the case specific study of Ribe. Hereby, the urban design elements reflect what is found in Ribe, which is not a fully encompassing representation. If the research experiment had included another location or multiple case specific studies, it may be more generally valid or representative. Furthermore, Ribe is a special case with its unique medieval city center and long history, which include national value. Hence, one must keep in mind that the urban design elements from the road map reflects this special case.

THE DEEP STRUCTURES

The motivation that has driven this master thesis is based on a wonder that the urban design and planning profession often ignore the deep structures of the specific site. From the beginning the assumption has been that by incorporating ecology into urban design and planning it is possible to create better and more sustainable cities for both humans and non-humans. The project has confirmed the assumption. It has become clear that previously ignorance of the deep structures is an obstacle for today's urban planning regarding climate adaptation. If we continue to make patchwork solutions and maintain the nature-dominant approach, we create basic problems for the future. Ecology in urban design, works exactly with this in-depth and interdisciplinary approach, that perceive the entire urban landscape as cohesive socio-ecological systems. The approach is becoming more and more relevant to use, especially when working with long-term climate adaptation plans. The aim is not to return to a romantic notion of nature by the use of restoration, instead it seeks to work with the natural conditions and use them to transform our urban spaces and landscapes to support both social and ecological systems.

When working with climate adaptation planning, the project shows how important it is to understand the natural conditions at the specific site, to be able to make long-term, sustainable, and holistic solutions. To understand the small scale, it is necessary to know the mechanisms and interrelated dynamics in the large-scale. Today, a lot of climate adaptation is made in minor project scales, such as the new area of Jernstøberiet in Ribe. Those kinds of projects only consider the local climate adaptation, but does not fit into a comprehensive, large-scale plan for the whole city or region, as such plans often doesn't exist. Nevertheless, strategic climate adaptation planning in a large-scale, that defines overall principles and visions, would potentially save money, and actions that may be obstacles for the future could be avoided. In addition to be a reaction to consequences, strategic climate adaptation has a potential to be a dynamo for progressive urban development.

Another perspective that has emerged in the work with Ribe has been the question of how deep we should work. Ribe's livelihood depends on the dike that runs along the coast. If the dike wasn't there, Ribe would risk massive floods. In this way, we have historically made ourselves dependent on hard climate adaptation solutions that opposes the dynamics of nature. If the deep structures are fully followed, one must ask the question if Ribe could maintain its existence. Should we continue to oppose the natural dynamics to secure the city? How much will it cost nationally to give up the protection? Maybe we should only follow the deep structures to a certain limit. Some historical initiatives cannot be remedied, but today's planning profession have the opportunity to improve and work holistically with our cities and landscapes.

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