PARADIGM SHIFT IN COASTAL PROTECTION?

Understanding the implementation of nature-based solutions: A case study on the Lower Saxony Coastal Protection Agency (NLWKN), Germany

By Marvin Olbrich

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Understanding the implementation of nature-based solutions: A case study on the Lower Saxony Coastal Protection Agency (NLWKN), Germany

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Declaration

This thesis is the result of my work and includes nothing, which is the outcome of work done in collaboration except where specifically indicated in the text. It has not been previously submitted, in part or whole, to any university or institution for any degree, diploma, or other qualification.

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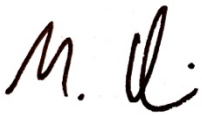
Signed: 

Date: 22.11.2023

Marvin Olbrich (B.Sc. Maritime Technologies)

Abstract

This thesis analyses the current state of coastal protection in Lower Saxony by examining the integration of nature-based solutions (NBS) for climate change adaptation, focusing particularly on the perceptions of the heads of planning within the Lower Saxony Coastal Protection Agency (NLWKN) and the influencing factors. By analysing the legal framework, strategic plans and interviews, the study shows that traditional engineering solutions prevail, in particular the dyke structures prescribed by the Dyke Act and the Master Plan for Coastal Protection. While historical practices characterise the current discourse, the East Frisian Islands offer a more balanced perspective that combines natural features with engineered solutions. The climate adaptation strategy signals a shift towards nature-based coastal protection that emphasises resilience and sustainability. The attitude of NLWKN heads of planning shows strong support for NBS, emphasising sustainability, adaptation to natural processes and contextual approaches. However, there are still challenges related to uncertainty, spatial planning and stakeholder coordination. Several factors that impact the implementation of NBS, including funding, legal complexity and potential future resource constraints were revealed by the the analysis of perceived behavioural control. The influence of dyke associations and legal frameworks, in particular the Dyke Act and the Master Plan for Coastal Protection, prove to be significant hurdles. In conclusion, the study argues in favour of a paradigm shift towards integrated and nature-oriented coastal protection. Recommendations include awareness strategies for greater awareness of NBS among the population, clearer definitions of NBS in climate adaptation strategies and the promotion of cooperation dialogues.

Keywords

Nature-based Solutions, Coastal Protection, Institutions, Path Dependency, Theory of Planned Behaviour

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List of Abbreviations

BMEL	Federal Ministry of Food and Agriculture
EbA	Ecosystem-based approach
EC	European Commission
Exp_Aur	Expert Aurich
Exp_Bra	Expert Brake
Exp_BraOl	Expert Brake-Oldenburg
Exp_Nor	Expert Norden
Exp_Sta	Expert Stade
Exp_Wil	Expert Wilhelmshaven
GAK	Joint Task for the Improvement of Agricultural Structures and Coastal Protection
GAK-G	GAK Act
GPK	Master Plan for Coastal Protection in Lower Saxony
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
NBS	Nature-based Solutions
NLWKN	Lower Saxony State Agency for Water Management, Coastal Protection and Nature Conservation
RQ	Research Question
SQ	Sub-question
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
UNESCO	United Nations Educational, Scientific and Cultural Organization

Chapter 1: Introduction

Coastal areas are dynamic and complex ecosystems that are constantly influenced by various natural and anthropogenic factors (Crossland et al., 2010). Sea level rise and extreme weather events caused by anthropogenic climate change are among the greatest threats facing coastal communities (Griggs & Reguero, 2021). These challenges have increased pressure on traditional coastal protection measures, which rely mainly on hard solutions such as dams, dykes and groynes fields (Temmerman et al., 2013). Such solutions, designed to keep water away from the inhabited coastline, have proven effective in the past (Schoonees et al., 2019). However, their limited adaptability to changing circumstances and high maintenance costs make them increasingly unsustainable in the long run (ibid.).

In response to these challenges, nature-based solutions (NBS) have gained considerable attention in recent years as an alternative to the traditional approach to coastal protection. NBS is considered an umbrella term (Seddon et al., 2020) and can be found in the literature under many names, such as nature-based solutions, building with nature, green or natural infrastructure, natural and nature-based features, ecological engineering (van der Meulen et al., 2022). What distinguishes these approaches from the traditional ones is their multifunctionality: they are not only meant to protect against flood risks but also to provide for the ecological health of the region and accordingly enhance biodiversity and provide recreational space for people (ibid.). These new views of coastal protection pose new challenges for coastal protection, which require more integrated planning and management (ibid.).

The federal state of Lower Saxony in Germany continues to adhere to traditional, linear coastal protection measures, even though scientific evidence supports the viability of NBS for climate adaptation. The water and coastal protection management in Lower Saxony has been criticised for adhering to the motto of business as usual

(Bauer & Steurer, 2014) and failing to implement innovative changes in its coastal protection master plans since the 1970s and 1990s (Ahlhorn, 2009). Scheve (2017) notes that coastal protection authorities in Lower Saxony still stick to their linear safety paradigm, despite the availability of alternative approaches such as NBS.

While the potential benefits of NBS are widely acknowledged, the specific dynamics influencing their implementation within the planning realm, particularly by the heads of planning within the Lower Saxony Coastal Protection Agency, NLWKN, remain underexplored. As coastal protection agencies face increasing climate-related challenges, ranging from increased storm surges to changing coastal dynamics, a comprehensive understanding of the factors influencing their decision-making processes in climate change adaptation is essential. As Steinmo (2001, p. 7557) points out, „We need a better understanding of the role of endogenous variables in the change process," which underlines the need to explore the internal factors that shape these agencies' strategies.

At the interface of climate change adaptation, environmental protection and coastal management, this research problem represents a particular knowledge gap in the field of planning. The lack of knowledge on the determinants of NBS implementation by key stakeholders is an academic deficit that deserves attention. Moreover, this gap is of significant societal relevance, as the effectiveness of NBS deployment can significantly affect the resilience and sustainability of coastal regions, impacting both human communities and the valuable ecosystems they inhabit (Seddon et al., 2020).

1.1 Goal and Scope of this Thesis

This study aims to examine the current approach to coastal protection in Lower Saxony, with a particular focus on the implementation of NBS as a climate change adaptation strategy. The study intends to gain a deeper understanding of the attitudes and perceptions of the heads of planning of the NLWKN regarding the

implementation of NBS in coastal protection. Furthermore, the study aims to identify and analyse the multiple factors that influence the decision-making processes of these key actors when it comes to implementing NBS. The case study on coastal protection in Lower Saxony includes an analysis of the existing laws and strategies, in addition, the history of coastal protection in the region is explained to embed the topic in a broader context.

Ultimately, this study aims to improve understanding of how these influential actors, namely the heads of planning, navigate the evolving landscape of climate change adaptation and provide valuable insights for planning theory and practice.

To achieve these goals, this thesis adopts a qualitative research approach that aims to gain an in-depth understanding of the complex landscape of coastal protection in Lower Saxony. By researching the social dynamics, the aim is to unravel the diverse aspects that characterise the strategies and practices of coastal protection in the region.

The study will involve conducting document research and semi-structured interviews with the heads of planning in the responsible agency of NLWKN to gain insight into their perceptions and attitudes towards nature-based solutions as a means of climate change adaptation and the factors influencing their decision-making.

A single case study approach is applied to the coastal region of the German federal state of Lower Saxony (see Figure 1). The regional boundaries along the North Sea coast of the German federal state of Lower Saxony have been defined as the geographical boundaries for this work. The scope is therefore justified as the NLWKN operates within these geographical boundaries.

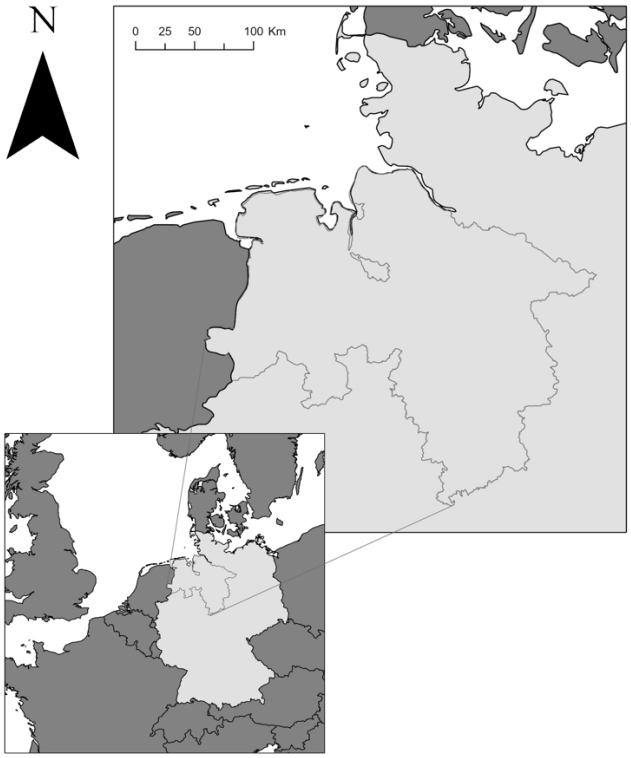

Figure 1: Geographical research scope for the German state Lower Saxony.

This thesis covers the period from December 2022 to November 2023, with the first four months spent on the research proposal and the remaining months on data collection, analysis and discussion. It was written alongside and after the regular courses of the Master's programme in Environmental and Infrastructure Planning at the University of Groningen.

1.2 Presentation of Research Questions

Based on the context described in the previous sections, the following research question will serve as a guideline for this thesis:

What is the current approach to coastal protection in Lower Saxony, including the integration of NBS for climate change adaptation, and what factors influence the decision-making processes of the heads of planning within NLWKN in this context?

To answer this question, a division was made into four sub-research questions that provide the necessary foundation and depth.

SQ1 *What is the current approach to coastal protection in Lower Saxony, specifically regarding the implementation of NBS for climate change adaptation?*

SQ2 *What are the attitudes and perceptions of the heads of planning within NLWKN concerning the implementation of NBS for coastal protection?*

SQ3 *What factors influence the decision-making processes of the heads of planning within NLWKN when considering the implementation of NBS for coastal protection?*

1.3 Framework and Outline of Thesis

Following the introduction in, section 2 explains the theoretical background and the conceptual model. The methodology used for this study is described and justified in section 3. Section 4 presents the results of the case study on coastal protection in Lower Saxony, which are orientated towards the sub-research questions. Section 5 goes on to discuss the sub-research questions, answer the main research question and formulate recommendations. Finally, section 6 summarises the work, while section 7 reflects on the study.

Chapter 2: Theoretical Background

This chapter deals with the theoretical framework on which this study is based. Section 2.1 serves as an introduction and examines climate change and adaptation. Section 2.2 explores the evolving water paradigm and highlights the changing perspectives. The focus of this study is explained in more detail in section 2.3. Section 2.4 then looks at institutions, while section 2.5 examines the application of the Theory of Planned Behaviour, which serves as a guide for the interviews. Section 2.6 illustrates all of this in the conceptual model.

2.1 Coastal Climate Change Adaptation

Coastal areas are dynamic and ever-changing ecosystems that have a long history of natural adaptation and human inhabitation. Given climate change, coastal regions are particularly vulnerable to the impacts of rising sea levels, increased storm intensity, and coastal erosion (Wright et al., 2019). As a result, coastal climate change adaptation has become a critical area of focus to safeguard these valuable ecosystems and human communities (Tubridy et al., 2022). This chapter provides insight into the inherent adaptive capacity of coasts, the resulting changes in settlement, and the need for effective climate change adaptation strategies.

2.1.1 The Coast's Natural Adaptation and Inhabitation

The coast, a dynamic interface where the powerful forces of water and land intertwine, is subject to constant change as water shapes its contours. Over the millennia, the coast has proven capable of adapting to changes caused by sea level rise, as witnessed by the transgression of the North Sea during the Holocene. Over the past 12,000 years, gradual sea level rise has led to the formation of barrier islands, notably the Frisian Islands in the Netherlands, Germany, and Denmark, and the shifting of

coastlines (Oost et al., 2012). This demonstrates the natural ability of the coast to adapt to the challenges of rising sea levels and underlines its natural resilience.

As the coast exhibits its remarkable adaptability to changing sea levels and shapes through natural processes, the interaction between people and the coast becomes increasingly significant. Human settlements have long been established in coastal areas, drawn to the coast's resources, economic opportunities, and natural beauty (Small & Nicholls, 2003). As populations grew, the need to protect these settlements from the forces of water became apparent. This led to the development of coastal protection measures and the formation of a paradigm that sought to control the water (Schoeman et al., 2014).

Coastal protection measures, such as the construction of dykes and other engineered structures emerged as a response to the perceived threat of flooding and erosion. These measures aimed to create a sense of security and stability, establishing a belief that human intervention could control and tame the unruly forces of the sea. This paradigm, commonly referred to as the ‚fighting the water' approach (Wiering & Arts, 2006), has prevailed in many coastal regions, including Germany's Lower Saxony, where traditional hard engineering solutions, such as dykes, have been dominant (Ahlhorn, 2009). The ‚fighting the water' paradigm has been deeply ingrained in coastal protection practices and policies, shaping the mindset and decision-making processes of coastal authorities and the perceptions of local communities (ibid.). However, this type of coastal protection is being challenged in the context of anthropogenic climate change.

2.1.2 Coastal Climate Change Adaptation

Anthropogenic climate change, as a persistent and global challenge, has far-reaching consequences across various ecosystems and environments. Terrestrial, freshwater, coastal, and marine ecosystems are affected by degradation, loss of biodiversity, and

increased risks due to warming, extreme events, and sea level rise, which poses socioeconomic consequences (IPCC, 2022).

Coastal areas are particularly vulnerable to the impacts of climate change (Wong et al., 2014), necessitating adaptation efforts for coastal ecosystems and communities (Cooley, 2022). In the following sections of this chapter coastal adaptation solutions and adaptation design options will be discussed.

2.1.2.1 Coastal Adaptation Solutions

Responding to and adapting to climate change is a complex undertaking that depends on society's ability and willingness to proactively anticipate change, recognise its impacts, and adapt to its consequences through appropriate planning (Cooley et al., 2022). The latest assessment report of the IPCC summarises the climate change adaptation solutions for oceans and coastal ecosystems and their services in three adaptation solutions: 1) Socio-institutional, 2) built infrastructure and technology, and 3) marine and coastal nature-based solutions (ibid.).

1) Socio-Institutional Adaptation

Social and institutional adaptation are essential components of an effective solution portfolio for climate change. Social responses depend on warming levels and institutional constructs, while both social and institutional transformations are needed to address power structures and bring about changes in marine ecosystems. Ideally, they should work together to sustain knowledge systems, enhance participation, support livelihoods, provide economic instruments, and implement effective governance.

2) Built infrastructure and technology

Engineering and technology play a crucial role in supporting marine and coastal adaptation. Built infrastructure encompasses both hard engineering solutions like seawalls and soft engineering approaches such as beach and shore nourishment. Technological tools include early warning systems, improved forecast and hindcast models, and environmental monitoring, which facilitate informed decision-making. Emerging adaptation technologies like habitat development, active restoration, and assisted evolution aim to accelerate ecosystem recovery and promote ecological adaptation to climate change.

3) Marine and coastal nature-based solutions

Marine and coastal NBS form an integral part of the ocean and coastal adaptation portfolio. These ecosystem-based adaptations harness the functions of marine ecosystems to restore, protect, and sustainably manage them in the face of climate change impacts. NBS not only benefit social systems and human security but also supports biodiversity. They are expected to contribute to global adaptation and mitigation goals by protecting coastal areas from sea level rise and storms and by sequestering carbon dioxide.

2.1.2.2 Coastal Adaptation Design Options

Sea level rise, and thus the risk of intensifying storm surges, is the most important factor in the context of anthropogenic climate change for coastal regions. Therefore, several coastal adaptation design options are proposed, based on Oppenheimer et al. (2019) (illustrated in Figure 2):

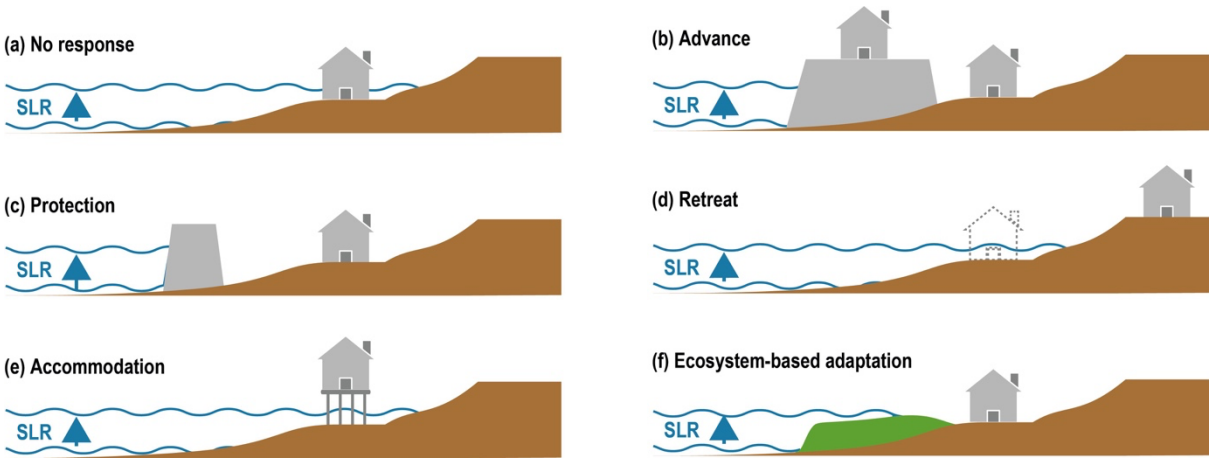

Figure 2: Coastal adaptation design options on sea level rise (Oppenheimer et al., 2019).

a) No Response

The no-response approach refers to the spatial arrangement of a given area that intentionally accepts periodic flooding, except for areas protected by other strategies (b-f). It recognises that these areas are vulnerable to flooding and emphasises the importance of considering non-design factors, such as effective risk communication strategies, as part of the overall approach.

b) Advance

This strategy involves seaward development that results in the creation of new land, effectively reducing coastal risks to both the hinterland and the newly filled areas. This approach includes a variety of techniques such as land reclamation above sea level through filling with pumped sand or other materials, as well as the selective planting of vegetation to support natural land accumulation and the construction of levees in surrounding low-lying areas. For this discussion, the primary focus is on cases that occur beyond the primary levee line, typically in waterfront redevelopment projects or in former waterfront areas.

c) Protection

The protection strategy aims to mitigate coastal risks and minimise the impacts of moderate or extreme sea levels by impeding their spread inland. This approach focuses on reducing the likelihood of flood events and includes both hard and soft protection measures. Hard protection measures include levees, dams, breakwaters, barriers, and barrages that protect against flooding and erosion. Soft protection measures, such as beach and shoreline accretions or dunes, use sediment-based strategies. Occasionally, ecosystem-based adaptation (EbA) measures may also fall under this category, and a combination of these three subcategories is often used as hybrid measures.

d) Retreat

The Retreat design strategy aims to mitigate coastal risks by relocating individuals, assets, and human activities away from hazardous coastal areas. This approach encompasses various forms of migration, displacement, or relocation. In the context of this thesis, the focus is on relocation as a proactive measure taken before the occurrence of flooding events. Managed retreat and realignment, which involve the planned relocation of small sites or communities, are typically initiated and overseen by governmental bodies at national and local levels.

e) Accommodation

Accommodation strategies encompass a range of biophysical and institutional measures that reduce vulnerability and mitigate coastal risks. These measures aim to ensure the habitability of coastal zones despite increasing hazards. Examples of accommodation measures include building codes, house elevation, floating structures, land use changes, and institutional responses such as early warning systems, emergency planning, insurance schemes, and setback zones.

f) Ecosystem-based adaptation

Ecosystem-based adaptation (EbA) involves the sustainable management, conservation, and restoration of coastal ecosystems like wetlands and reefs. EbA measures protect coastlines by attenuating waves, acting as barriers to storm surges, and stabilising coastal sediments. EbA is also referred to as Natural and Nature-based Features, Nature-based Solutions, Ecological Engineering, or Green Infrastructure.

Given the urgent need for approaches to climate change adaptation in coastal areas, a paradigm shift is required (Davoudi et al., 2012): away from the traditional technical to a new water paradigm, which is discussed in the following chapter.

2.2 Shift in Water Paradigm

In the past, water-related sectors predominantly followed a traditional engineering approach characterised by a focus on sectoral and technical solutions. This approach, often referred to as ‚fighting the water,' involved building hard-engineered structures such as dykes, dams, and storm surge barriers to provide a sense of safety and protect the land and assets behind these structures (Burrel et al., 2007; Schoeman et al., 2014).

However, this approach to coastal protection has its limitations and unintended consequences. One of these consequences is the ‚levee effect,' in which reliance on hard-engineered structures can provide a false sense of security: levees continue to be raised, but this poses an even greater risk to the regions behind them in the event of failure (see Figure 3) (CRa, 2018). Moreover, the concept of path dependency reinforces the intractability of this approach, as established institutions, practices, and mentalities tend to perpetuate themselves since "preceding steps in a particular direction induce further movement in the same direction" (Pierson, 2000, p. 252), making it difficult to adopt alternative strategies.

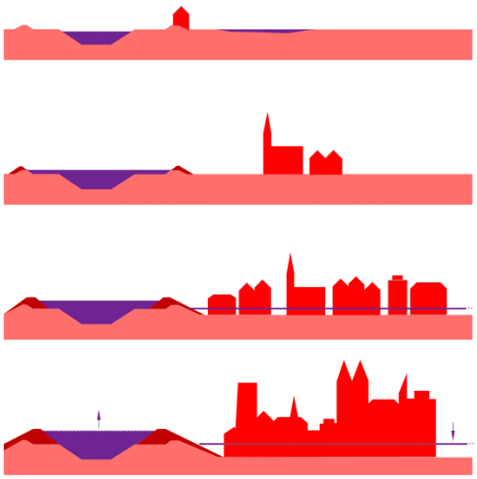

Figure 3: The levee effect (CRa, 2018).

Amidst the uncertain predictions of climate change, there has been a paradigm shift toward the ‚new water paradigm' (Schoeman et al., 2014). This paradigm shift recognises the need for a more holistic and multidimensional approach to water management that includes broader stakeholder participation and acknowledges a wider range of values, not only economic but also environmental and social (ibid.). The new water paradigm, therefore, includes recognition of the interrelationship between water systems and ecosystems and their services and the need to consider the long-term sustainability and resilience of water management strategies by advocating integrated water resource management, adaptive management, and ecosystem-based approaches (ibid.).

2.3 Nature-based Solutions

As discussed before, concerning the impact of anthropogenic climate change on the environment and thus on society and the economy, solutions are needed that do not only refer to the conventional technical paradigm but are closely linked to nature to adapt to the changes, reduce their impact and thus maintain and improve human well-being (Cohen-Shacham et al., 2016).

Initially introduced by MacKinnon et al. (2008) and Mittermeier et al. (2008), NBS aim to address climate change, protect biodiversity, enhance capacity, and foster resilience (Mandić, 2019). They prove valuable in tackling hydro-meteorological hazards like floods, storm surges, landslides, heat waves, and droughts, making them effective tools for climate change adaptation and disaster risk reduction (Ruangpan (Ruangpan et al., 2020). However, NBS is a collective term encompassing innovative approaches that tackle diverse societal and environmental challenges by leveraging natural processes and ecosystem services (Cohen-Shacham et al., 2016; European Commission, 2015).

2.3.1 The Umbrella Concept

As an 'umbrella concept' (Seddon et al., 2020, p. 2), NBS incorporates various ecosystem-related strategies and interconnected concepts (Ruangpan et al., 2020), providing an integrated approach that addresses multiple issues simultaneously (ibid.). Two of the most notable definitions come from the International Union for Conservation of Nature (IUCN) and the European Commission (ibid.).

The EC defines NBS as:

> *"Solutions that aim to help societies address a variety of environmental, social, and economic challenges in sustainable ways. They are actions inspired by, supported by, or copied from nature, both using and enhancing existing solutions to challenges as well as exploring more novel approaches. NBSs utilise the features and complex system processes of nature, such as its ability to store carbon and regulate water flows, to achieve desired outcomes, such as reduced disaster risk and an environment that improves human well-being and promotes socially inclusive green growth"* (European Commission, p.5, 2015).

The IUCN defines NBS as:

> *"Actions to protect, sustainably manage and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits"* (Cohen-Shacham et al., p.2, 2016).

Several underlying concepts with different names and definitions related to NBS exist, which makes the term somewhat ambiguous. These include (Ruangpan et al., 2020, van der Meulen et al., 2022): 'nature-based solutions', 'building with nature', 'natural infrastructure', 'green infrastructure', 'natural and nature-based features', 'ecological engineering' and 'ecosystem-based adaptation'.

All of these concepts use nature's elements and processes to achieve different goals, including reducing flood risk, enhancing ecology, and providing recreational opportunities (van der Meulen et al., 2022).

2.3.2 From Traditional to Natural Solutions?

As introduced in section 2.1 the predominant approach to coastal protection relies on traditional engineered solutions such as dykes, groyns and storm surge barriers to protect the hinterland's population and assets. Those solutions are referred to be hard or grey solutions in the literature (Livingston et al., 2019; Schoonees et al., 2019; Temmerman et al., 2013). Related to the change in the water paradigm (see section 2.2) a shift is noticeable in coastal protection measures as these traditional solutions contrast with green, nature-based solutions (Cheong, 2010; Schoonees et al., 2019). This change is also underpinned by slogans such as ‚from building in nature to building with nature' (EcoShape, 2023) and ‚from fighting water to living with water' (van der Brugge et al., 2005), which describe the general shift from traditional to natural solutions.

2.3.2.1 Traditional Solutions

Hard or grey solutions as the predominant approach to safeguard coastal areas (see Figure 4), defending against the water to protect properties date back to another management style, the old water paradigm (see section 2.2). These solutions were once believed to have the ability to control the forces of nature (Bruun, 1972). Some even achieved iconic status in the engineering world like the Scheldt storm surge barrier in the Netherlands, constructed in the 1950s. However, grey solutions are "alien" to the natural environment and have their disadvantages in the long run (van der Meulen et al., 2022, p. 3).

Figure 4: Traditional coastal protection structures (adapted from Schoonees et al., 2019)

The main disadvantages of hard structures are changes in the natural hydrodynamics and morphodynamics of the coast (Schoonees et al., 2019) that can result in alteration to wave regime (Dugan et al., 2011), disturbed or stopped sediment accumulation or degradation or destruction of natural habitat (Temmerman et al., 2013).

'Coastal squeeze' describes the phenomenon of loss of habitat: due to coastal development and the subsequent hard protection measures, rising sea level narrows down the shoreline between the waterline and the grey defence infrastructure (see Figure 5).

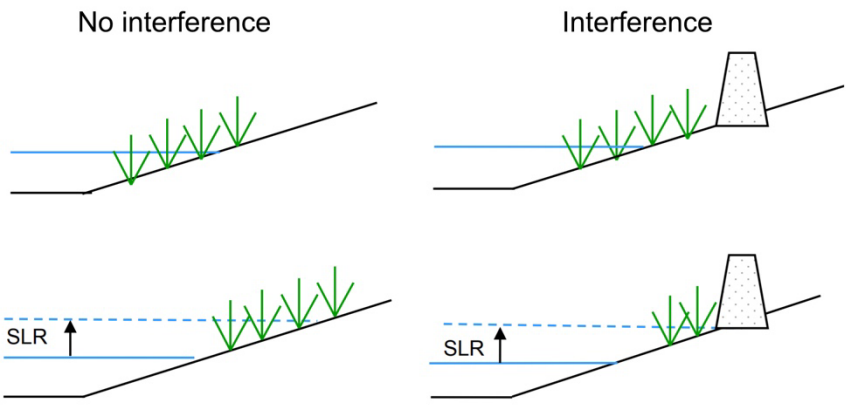

Figure 5: Coastal squeeze (adapted from (adapted from Zhu et al. (2010).

This leads to the loss of land that naturally functions in wave energy reduction (Morris (Morris et al., 2018) and habitat loss, which in turn contributes to biodiversity decline (Doody, 2013). Furthermore, hard structures in coastal protection are stated to be not cost-effective due to high maintenance efforts in the long run (see Table 1 in section 2.3.2.2) (Temmerman et al., 2013).

In general, it can be concluded that hard coastal protection is stated as not valuable for the challenges of climate change (Morris et al., 2018) and, over the long run, could potentially increase vulnerability for both people and ecosystems (Depietri & McPhearson, 2017). Consequently, the necessity of adopting greener solutions like nature-based solutions becomes more pronounced, offering a promising pathway to enhance coastal resilience while preserving the balance between human activities and the natural environment.

2.3.2.2 Nature-based Solutions

In contrast, grey solutions are the green alias nature-based solutions (see section 2.3.1). NBS are embedded in the new water paradigm (see section 2.2) and, since grey solutions are seen as increasingly unsustainable for the economy and the environment (Morris et al., 2018), NBS offer more valuable solutions regarding climate change as coastal protection measures (Schoonees et al., 2019).

The basic concept of NBS is based on the realisation that nature inherently provides solutions and that humans are an integral part of this interconnected system. Instead of fighting the forces of nature, NBS relies on harmonious coexistence and uses the wisdom of natural processes.

NBS stand out for their advantages, transcending the limitations of traditional solutions. By using local ecosystem-based solutions, nature's capacity is harnessed to mitigate the energy of storm waves and storm surges and to support sediment accumulation with rising sea level (Calliari et al., 2022). Unlike their singular protective counterparts, NBS provide far-reaching benefits. They create additional values such as mitigating biodiversity loss, sequestering carbon, improving water quality, creating recreational space and supporting other economic sectors such as fisheries (Temmerman et al., 2013). In addition, NBS is considered more cost-effective than hard solutions because nature renews and sustains itself (Masselink & Lazarus, 2019; Temmerman et al., 2013).

In general, NBS is considered to be a more resilient approach than hard solutions about the impacts of climate change on the coast. In the tangled web of definitions around resilience, Masselink and Lazarus (2019) have specifically attempted to find a definition for coastal resilience that relates to the natural and the socioeconomic system: "Coastal resilience is the capacity of the socioeconomic and natural systems in the coastal environment to cope with disturbances, induced by factors such as sea level rise, extreme events, and human impacts, by adapting whilst maintaining their

essential functions" (Masselink & Lazarus, 2019, p 10.). With regard to the resilience of natural systems, coastal landscapes like barrier islands and beaches, coastal dunes, tidal wetlands and coral systems or other submerged natural habitats like seagrass or mussel reefs naturally hold an intrinsic resilience (see Figure 6) (Masselink & Lazarus, 2019; Morris et al., 2018). Preserving or imitating these landscapes as nature-based coastal protection measures and allowing them room to adapt to rising sea levels is therefore crucial for coastal climate change adaptation (Morris et al., 2018).

Figure 6: NBS a) Barrier Islands and beaches (Freudenrich, n.d.), b) coastal dunes (BLM, 2021), c) tidal wetlands (NPS, 2016) and d) coral systems (GBRMPA, 2023).

Imitating such landscapes, harnessing their ecological functions for coastal protection, demands purposeful human intervention in ecosystem design and engineering. While ecosystem engineering creates ecosystems that use species such as mussel beds or mega-nourishment (see Figure 7) to integrate several functions (Borsje et al., 2011; Waterman, 2010), it is important to acknowledge some of its limitations.

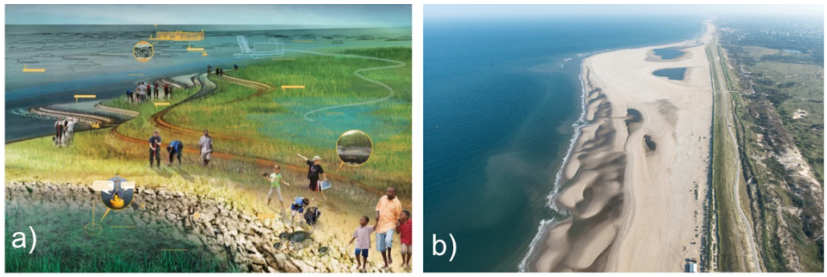

Figure 7: Caption: Examples of ecosystem engineering as nature-based solutions: a) Living Breakwater project off the coast of New York, USA (Rebuild by Design, 2023) and b) mega-nourishment Sand Engine off the coast of the Netherlands (TUDelft, 2021).

Notably, NBS can have high spatial requirements, necessitating substantial areas for implementation. Additionally, there may be challenges related to a lack of extensive experience in their implementation and uncertainty about their long-term effectiveness and societal acceptance. See Table 1 for a more detailed overview of the advantages and disadvantages of NBS compared to traditional solutions.

Table 1: Comparison of traditional and nature-based solutions in coastal protection (adapted from Schoonees et al., 2019, Temmermann et al., 2013).

	Traditional Solutions	Natural Solutions
Natural habitat	Degradation and destruction	Conservation and restoration
Sediment accumulation after sea level rise	Disturbed or stopped	Sustained
Long-term sustainability	Low: regular maintenance	High: self-maintaining
Cost-benefit appraisal	Moderate to high	High due to added benefits
Water quality	May degrade in closed-off estuaries	Improved and sustained
Climate mitigation through carbon sequestration	None	E.g. mangroves and marshes are important carbon sinks

Fisheries and aquaculture	Reduced	Improved
Human recreation potential	Negative perception	Positive perception
Spatial requirements	Low to medium	High
Design life	Long	Short to long
Existing implementation and experience	Substantial	Limited
Social and political acceptance	Widely accepted	Limited

2.3.2.2 Combining Traditional with Natural Solutions

Instead of relying solely on a single strategy, an integrated approach that combines traditional and natural solutions appears to be a more viable strategy for coastal protection (Cheong et al., 2013), considering the strengths and weaknesses of these solutions as summarised in table 1. On the one hand, the implementation of NBS is very place and space-dependent but promises many beneficial values. On the other hand, the strong reliance on traditional solutions due to path dependency (see section 2.2) underlines their current dominance and associated experience in implementation as well as social acceptance.

To leverage the benefits of both traditional and natural solutions Schoonees et al. (2019) advocate for sub-categories of nature-based solutions that combine the strengths of both approaches: (1) hybrid infrastructure as a concept that combines natural and traditional solutions like salt marshes and dykes and (2) environment-friendly grey infrastructure that accommodates the spatial circumstances by adapting green solutions to coexist with pre-existing grey structures by mimicking ecosystem functions or inducing or preserving connectivity to natural environment (Schoones et al., 2019, see Figure 8).

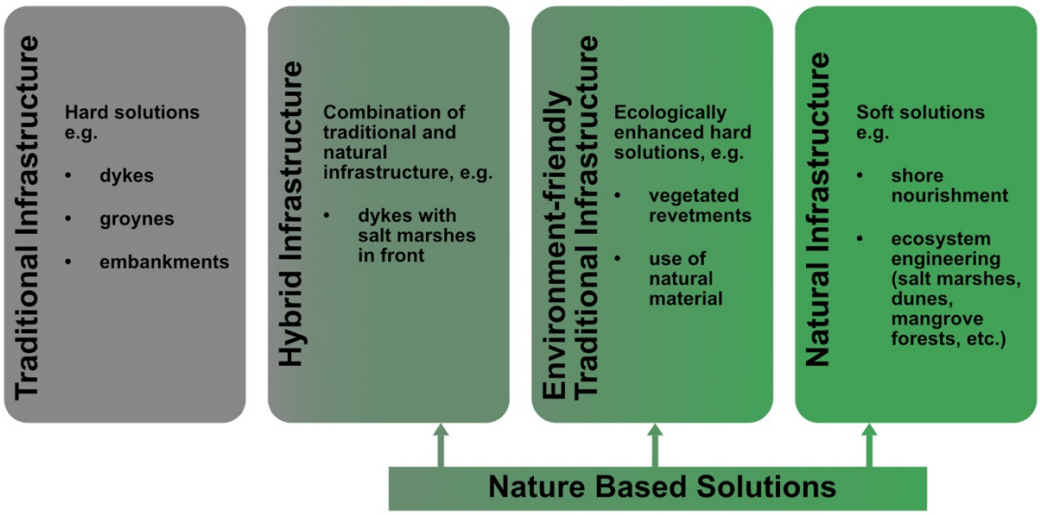

Figure 8: Classification of NBS and its subcategories in a grey-green spectrum (adapted from Schoonees et al., 2019).

In conclusion, the chapter on NBS encapsulates the transformative potential these solutions offer in addressing climate change impacts, coastal protection, and ecological preservation. Defined as actions inspired or imitated by nature, NBS harness natural processes and ecosystem services to tackle multifaceted environmental, social, and economic challenges. NBS significantly differ from traditional 'hard' solutions, such as dykes and storm surge barriers, recognized for their limitations in long-term sustainability and ecological consequences. In contrast, NBS excel in providing resilience, cost-effectiveness, and multifunctional benefits, ranging from habitat restoration to improved water quality and recreational spaces. However, challenges related to spatial requirements, implementation experience, and societal acceptance persist, emphasizing the need for an integrated approach that amalgamates traditional and natural solutions for coastal protection. This integration, through concepts like hybrid infrastructure and environmentally friendly grey infrastructure, embodies the potential to harness the strengths of both approaches while mitigating their limitations.

2.4 Institutions

Institutionalism, a critical concept in social sciences, plays a pivotal role in shaping decision-making processes within various domains, including coastal protection. This institutionalist perspective provides valuable insights into the factors shaping institutional behaviour and responses to climate change adaptation strategies. Therefore, this chapter delves deeper into institutions and their theoretical foundations, exploring how they influence actors, such as the heads of planning at the coastal protection agency NLWKN, and shape their perceptions of and commitment to coastal protection measures.

2.4.1 Institutions and Institutionalism

Institutions, in the realm of social sciences, refer to the established rules, norms, and practices that guide and shape human behaviour within a society or organisation (Hodgson, 2016). These rules can be formal, such as laws and regulations, but also informal like deeply ingrained values, beliefs, and cultural norms that influence how individuals and groups interact and make decisions. (North, 1991).

Institutionalism is the theoretical approach used in social sciences primarily concerned with understanding how institutions shape and influence social and political behaviour (North, 1990). In contrast to the 'old institutionalism', which primarily focused on describing formal-legal and administrative arrangements of governments and the public sectors, the emergence of the 'new institutionalism', particularly in the post-World War II era, brought the society and informal practices or relationships into focus (Bell, n.d.). North (1990) goes further to argue that some of the most significant institutional factors are often rooted in informal interactions with others defined by codes of conduct, norms of behaviour and conventions.

Three main branches of the new institutionalism have emerged (Hall & Taylor, 1996):

Historical institutionalism

This approach emphasises the importance of historical legacies and path dependence in shaping institutions and their impact on contemporary behaviour. It posits that past events, decisions, and institutional structures significantly influence current practices and choices. Historical institutionalism is particularly relevant for understanding the persistence of certain institutional arrangements over time.

Rational Choice Institutionalism

Rational choice institutionalism focuses on the rational calculations of individuals and organisations operating within institutional frameworks. It assumes that actors seek to maximise their utility or interests while considering the costs and benefits of various actions. This approach is valuable for analysing decision-making processes within institutions and understanding how actors respond to incentives.

Sociological Institutionalism

Sociological institutionalism places a strong emphasis on cultural norms, values, and beliefs as drivers of institutional change and individual behaviour. It argues that institutions are deeply embedded within broader societal contexts and are influenced by shared cultural understandings. Sociological institutionalism is instrumental in exploring how societal belief systems shape actors' perceptions and actions within institutions.

2.4.2 Institutional Dynamics

As examined in section 2.4.1, institutions are the bedrock of societal organisation, providing a degree of stability and predictability to social interactions (Beunen & Patterson, 2016). However, this stability isn't immune to change, and understanding the dynamics of institutional change is crucial in the context of climate change adaptation and coastal protection.

Institutional stability often hinges on issues of path dependence, reproduction, and inertia (Beunen & Patterson, 2019). Path dependency, see also section 2.2, is central to this discussion, referring to the idea that institutions tend to perpetuate themselves by rewarding or incentivising behaviour along existing pathways (Pierson, 2000). In essence, once institutions are established, they become self-reinforcing and therefore hard to change.

Mahoney (2000) identifies several explanations for why institutional stability, or reproduction, occurs. These include utilitarian reasons, where institutions persist due to rational cost-benefit assessments; functional reasons, where institutions serve a useful societal function; power reasons, with elite actors supporting and maintaining institutions; and legitimation reasons, where institutions are perceived as morally just. Different hypotheses surround what might be required for institutional change to happen, including competition and learning (utilitarian view), exogenous shocks (functional view), altering power relations (power view), or changing values and beliefs (legitimation view) (Beunen & Patterson, 2019).

The dynamics of institutions are not solely determined by their inherent characteristics but are also shaped by the actions and interactions of actors within a governance system (Beunen & Patterson, 2019). Actors within coastal protection agencies, such as the heads of planning at NLWKN, play a pivotal role in influencing the meaning and relevance of institutions. They can maintain, alter, contest, or even fundamentally reject and replace institutions through their ongoing activities (ibid.).

In conclusion, the chapter on institutionalism illustrates its central role in understanding the impact on decision-making processes in coastal protection. Influential norms and dynamics within institutions significantly shape perception and behaviour. Embedded as societal guidelines, these institutions guide the NLWKN's actions in the field of coastal protection. Underlying theories, which include formal and informal norms, actively shape social and political behaviour, and underline the

importance of historical legacies, rational decisions and societal beliefs. The persistence of institutions is closely linked to their historical development and self-reinforcing structures, leading to resistance to change. To understand the interplay of institutions, actors and environmental pressures in the field of coastal protection, it is important to understand the institutional dynamics.

2.5 Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB) is a theoretical framework widely employed in social sciences to predict and explain human behaviour across various contexts (Ajzen, 1991). Its applicability extends to understanding the behaviours of actors within the coastal protection authorities, specifically their responses to climate change adaptation measures, particularly NBS. TPB is particularly relevant to this study as it helps illuminate the factors that influence the implementation of NBS as a means of climate change adaptation by the heads of planning within the Lower Saxony Coastal Protection Agency, NLWKN, and is used as a framework for the interviews with the heads of planning of the NLWKN (see section 3.3.3). This chapter delves into the foundations of TPB, its precursor, the Theory of Reasoned Action (TRA), and how TPB's constructs are interconnected and relevant to this research.

2.5.1 Foundations of the Theory of Planned Behaviour

Before delving into TPB, it is crucial to understand its precursor, the Theory of Reasoned Action (TRA). The TRA was developed by Fishbein and Ajzen (1975) and Fishbein et al. (1981) as a model to predict and comprehend behaviour that is under an individual's volitional control. TRA assumes that individuals are rational actors who systematically evaluate the information available to them before making decisions about engaging or not engaging in a particular behaviour (Fishbein & Ajzen, 1975). Figure 9 illustrates TRA with its key constructs.

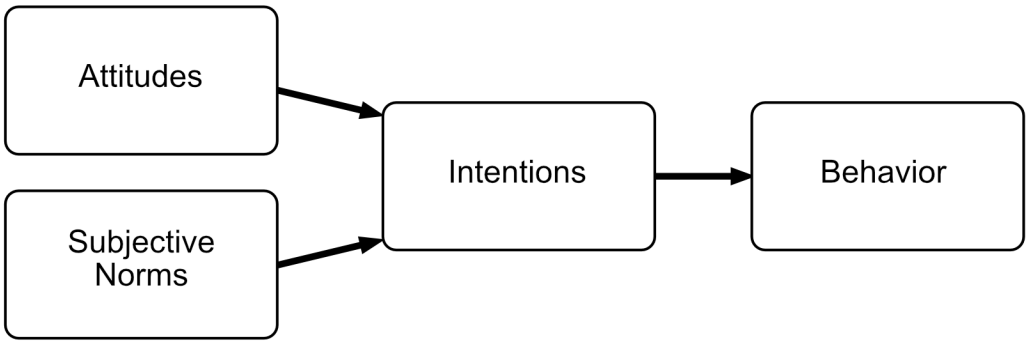

Figure 9: Scheme of Theory of Reasoned Action (adapted from Fishbein & Ajzen, 1975).

Behaviour represents the specific action or behaviour under investigation, in this study, the implementation of NBS as a climate change adaptation strategy by heads of planning in coastal protection authorities. TRA posits that an individual's *intention* to perform a behaviour significantly influences whether they will engage in it. Intention is shaped by two primary determinants: attitudes and subjective norms. *Attitudes* represent an individual's overall evaluation of a specific behaviour. In the context of this study, this relates to how the heads of planning within NLWKN perceive NBS as a climate change adaptation strategy. *Subjective Norms* refer to an individual's perception of social pressure or influence to perform or not perform a particular behaviour. This research relates to how the heads of planning perceive their colleagues and society's attitudes towards NBS.

2.5.2 The Theory of Planned Behaviour

While TRA was a valuable model, it assumed that all behaviours were under volitional control. This assumption doesn't always hold, especially in situations where external factors can limit or facilitate behaviour (Kan & Fabrigar, 2017). Recognising this limitation, Ajzen (1985); (1991) introduced TPB as an extension of TRA. The key innovation in TPB is the addition of a third determinant of intentions: *perceived*

behavioural control (see Figure 10). In essence, TPB acknowledges that the ability to perform a behaviour, or the degree of control one has over it, can vary across different situations. *Perceived behavioural control* refers to an individual's perception of the ease or difficulty of performing a specific behaviour (Ajzen, 1991). It recognises that even if someone intends to perform a behaviour, they may not always have the necessary resources, opportunities, or control to do so. Perceived behavioural control is shaped by an individual's beliefs about the presence or absence of factors that facilitate or hinder behaviour. These control beliefs may arise from past experiences, observations of others, or external variables that influence the perceived ease or difficulty of performing the behaviour (ibid.).

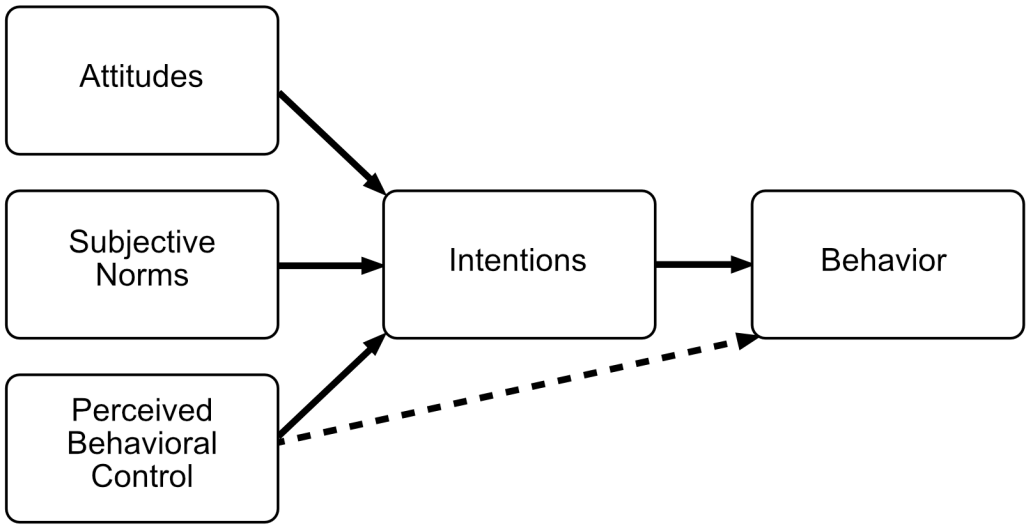

Figure 10: Scheme of Theory of Planned Behaviour (adapted from Ajzen, 1991).

Perceived behavioural control influences behaviour in two ways (after Ajzen, 1991):

1) Influence on Intentions: Individuals who perceive that they lack the necessary resources or opportunities to perform a specific behaviour are less likely to have high intentions to engage in that behaviour. Even if they hold a favourable attitude towards

the behaviour and face social pressure (subjective norms), perceived behavioural control can independently influence intentions.

2) Influence on behaviour: Perceived behavioural control can also directly impact behaviour, provided there is a high correspondence between perceived control and actual control. In situations where perceived control accurately predicts actual control, it serves as a proxy for actual control. However, in cases where perceived control is an inaccurate predictor of actual control (e.g., when individuals lack information, conditions change, or new factors emerge), the direct influence of perceived control on behaviour weakens.

In summary, TPB integrates attitudes, subjective norms, and perceived behavioural control to predict and explain human behaviour. Attitudes represent the individual's evaluation of the behaviour, subjective norms reflect social pressures, and perceived behavioural control accounts for factors that facilitate or hinder the behaviour. These constructs are interconnected, influencing intentions and, ultimately, behaviour. In the context of this research, TPB offers a valuable lens through which to examine the perceptions and decision-making processes of heads of planning within NLWKN regarding the implementation of NBS as a climate change adaptation strategy in coastal protection.

2.6 Conceptual Model

Figure 11 shows the conceptual model of this research. It illustrates the basic structure of this research by showing basic components and their relationship. Starting at the top, it shows how the central element, the decision-making process of NLWKN is embedded in the theoretical framework. The institutional environment and perceptions and behaviours of the heads of planning of NLWKN are the mediating factors of the central element that influence the outcome, and the implementation of NBS and are integral parts of this research. It is worth mentioning here that Attitudes,

Subjective Norms and Perceived Behavioural Control are the constructs of the TPB, which are determined with the help of semi-structured interviews.

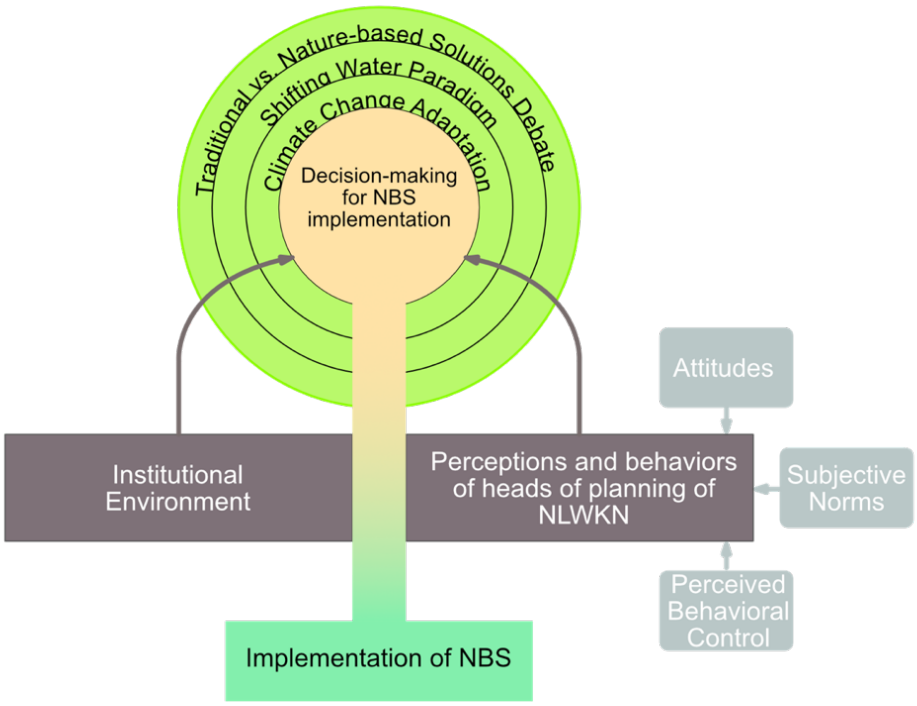

Figure 11: Conceptual model of this study.

Chapter 3: Methodology

This chapter outlines the methodology employed in this study, which aims to examine the current approach to coastal protection in Lower Saxony, including the integration of NBS for climate change adaptation. The study focuses on the factors influencing decision-making processes within the Lower Saxony Coastal Protection Agency, NLWKN. Insights into the attitudes and perceptions of key actors, especially the heads of planning, are essential for addressing the urgent climate-related challenges facing coastal protection authorities today. Section 3.1 details the research design, pointing out the choice of qualitative research method to describe this complex phenomenon. The single-case study approach, involving the coastal protection in Lower Saxony, is explained in section 3.2, along with the techniques employed for data collection, in section 3.3, and its analysis and interpretation in section 3.4. Furthermore, ethical considerations and study limitations are discussed in section 3.5 to ensure the rigour and validity of the research findings.

3.1 Qualitative Research Design

The overall objective of this study is to gain an in-depth understanding of "*What is the current approach to coastal protection in Lower Saxony, including the integration of NBS for climate change adaptation, and what factors influence the decision-making processes of the heads of planning within NLWKN in this context?*" To answer the research question a qualitative research approach was chosen.

Qualitative research examines phenomena in the natural context of individuals or groups and aims to explore people's experiences, perceptions and behaviours, as well as the meanings they assign to them (Moser & Korstjens, 2017). The focus is on understanding people's belief systems, experiences and meanings from their perspective (Mohajan, 2018). The qualitative approach follows a tradition of deep

understanding of the particular (Domholdt, 1993), and strives to provide detailed insights into human behaviour, emotions, attitudes and experiences (Tong et al., 2012).

Due to the nature of the research questions and objectives, qualitative research was given preference over quantitative research. Unlike quantitative research, which focuses on numerical data statistical analysis and generalisability to larger populations to explain phenomena (Creswell & Creswell, 2017), qualitative research collects and works with non-numerical data and seeks to interpret the meaning of this data to gain insights into social life within particular populations or contexts (Punch, 2013). Although quantitative features are valuable in certain research contexts, they do not fit the focus of the present study, which concentrates on understanding the complexity of decision-making within a particular organisation. The decision-making processes of the NLWKN, which are influenced by factors such as attitudes, beliefs and contextual nuances, are inherently qualitative and not easily quantifiable.

Within the realm of qualitative research, a descriptive research design was chosen. As defined by Kothari (2004), descriptive research involves the study of characteristics of people, groups, events or conditions in their natural state. In the context of this thesis, the aim is to comprehensively describe the perceptions, attitudes and behaviours of the heads of planning of the Lower Saxony Coastal Protection Agency (NLWKN) regarding the implementation of NBS for climate change adaptation. The primary aim is to provide an in-depth depiction of their views and actions as they naturally occur in the organisational setting. In contrast to exploratory research, which aims to explore new phenomena or create hypotheses (Lans & Van der Voordt, 2002), or explanatory research, which seeks to establish causal relationships (Blatter & Haverland, 2012), descriptive research aims to provide a detailed account of the existing state of affairs without manipulating variables (Siedlecki, 2020). Through the application of descriptive research, this thesis aims to contribute to a more detailed

understanding of the factors influencing the implementation of the NBS by the heads of planning of the NLWKN.

Following the choice of a qualitative research design, a case study approach was considered most appropriate for this study. In the following section, the specifics of the case study research strategy chosen for this thesis will be explained by addressing the rationale and design used to explore the multiple factors influencing the implementation of NBS by the heads of planning of the NLWKN for climate change adaptation in coastal protection.

3.2 Case Study Approach

The case study approach is a fundamental research methodology employed to investigate complex, real-world phenomena in their natural context (Yin, 2018). It allows researchers to explore complicated relationships, contexts, and processes within specific cases, making it an appropriate choice to gain a differentiated understanding of factors influencing the implementation of NBS for climate change adaptation by the heads of planning at the Lower Saxony Coastal Protection Agency, NLWKN. According to Yin (2018), case study research can be categorised into two main approaches: single-case and multiple-case studies. The fundamental distinction lies in the number of cases examined. In a single-case study, as is the case here, researchers focus on a single, specific case to conduct a detailed analysis. In contrast, multiple case studies involve the examination of two or more cases to draw comparisons and identify patterns or commonalities (ibid.). While multiple case studies offer the advantage of cross-case analysis, single-case studies can provide valuable insights and in-depth knowledge about a unique phenomenon (ibid.).

The choice of a single-case study approach for this research is justified by several considerations. NLWKN, as the primary entity responsible for coastal protection in Lower Saxony, represents a distinctive and highly relevant case in the field of coastal

protection and climate change adaptation. The focus on a single case allows for an in-depth examination of NLWKN's decision-making processes and their complex interplay with factors influencing NBS implementation.

The unit of analysis, or case, is determined by setting spatial boundaries, theoretical scope and a specific time frame (Yin, 2003). The spatial boundary in this study comprises the Lower Saxony North Sea coast including the area of jurisdiction of the NLWKN. This geographical extent borders the Netherlands in the west and the federal state of Schleswig-Holstein in the northeast. Within this area, the studied population includes the heads of planning of five NLWKN field offices. These offices are strategically distributed along the coast and each has its spatial jurisdiction, making them eligible as study units (see Figure 12).

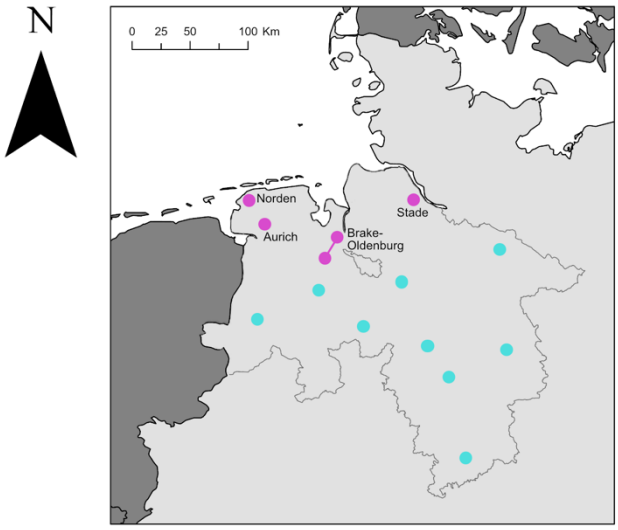

Figure 12: Distribution of 14 NLWKN offices in Lower-Saxony, illustrating the choice of five offices in charge of the Coastal Protection Department in the Planning and Construction Division (pink dots).

Theoretically, the case encompasses relevant theoretical concepts derived from the literature review for this study (see section 2). Climate change adaptation with its contextual factors, including the use of nature-based solutions as coastal protection measures and the mediating influences of institutionalism and the theory of planned behaviour, serves as the central element. As relationships between actors, their attitudes and policy frameworks may change over time, it is important to set a time

frame. This study covers the period from December 2022 to December 2023, with data analysis using the semi-structured interviews with NLWKN heads of planning conducted between May and July 2023.

3.3 Data Collection Framework and Techniques

The framework and data collection techniques used in this research are in line with the qualitative research paradigm, which emphasises a descriptive, inductive approach that deals with real-life situations in natural, non-manipulated settings (Mohajan, 2018). This methodological choice facilitates a holistic examination of the research questions and aims to provide a comprehensive understanding of the factors that influence the decision-making processes of heads of planning in NLWKN.

To enhance the validity and reliability of the results, a multiple-method approach is employed. This approach combines multiple data collection methods, including a thorough literature review, document analysis, and semi-structured interviews. Each method serves a specific purpose within the research process, in each of the sub-questions raised in this study is addressed with the corresponding method. An overview of the methods used to answer each sub-question can be found in Table 2. This approach ensures that the research questions are answered effectively and that knowledge about the influencing factors in the decision-making process is systematically collected and analysed.

Table 2: Applied research methods to answer sub-research questions.

#	Sub-Question	Applied Method
SQ1	*What is the current approach to coastal protection in Lower Saxony, specifically regarding the integration and utilisation of NBS for climate change adaptation?*	- Literature Review - Document Analysis

SQ2	*What are the attitudes and perceptions of the heads of planning within NLWKN concerning the implementation of NBS for coastal protection?*	- Semi-Structured Interviews
SQ3	*What factors influence the decision-making processes of the heads of planning within NLWKN when considering the implementation of NBS for coastal protection?*	- Semi-Structured Interviews

3.3.1 Literature Review

The research started with an in-depth literature review serving as the foundational element that provides essential background information on the key theoretical concepts central to the study. It serves to lay the groundwork for a comprehensive understanding of the research context, allowing for the development of a robust theoretical framework. To achieve this, a variety of information sources were accessed, including Google Scholar, SmartCat, relevant books and various articles discovered during the process. The literature review was conducted strategically, focusing on key terms such as 'climate adaptation/mitigation', 'nature-based solutions', 'coastal protection', 'transition', 'institutionalism' and 'theory of planned behaviour'. This targeted approach ensured that the literature review captured the most relevant and up-to-date knowledge related to the research questions, which ultimately formed the basis for this study.

3.3.2 Document Analysis

In this study, a comprehensive document analysis was carried out, focussing on the most important legal and strategic framework conditions for coastal protection in Lower Saxony. The specifics of the Dyke Act, the *Deichgesetz*, a fundamental legal document that characterises the approach to coastal protection in the region, were examined. In addition, an in-depth analysis of the Master Plan for Coastal Protection in Lower Saxony, the *Generalplan Küstenschutz* (hereinafter referred to as GPK), in

particular volumes 1, 2 and 3, provided insights into the overarching framework conditions for coastal protection, emphasising the prevailing strategies for the mainland and island regions. To broaden the perspective and gain insights into climate adaptation measures, the current Lower Saxony climate adaptation strategy was also analysed. This analysis aimed to identify explicit references or considerations to NBS in the context of climate adaptation.

3.3.3 Semi-Structured Interviews

The primary method of data collection in this study is semi-structured interviews. This method was chosen to gain in-depth and differentiated insights into the perceptions of NLWKN's heads of planning, who are central actors in the implementation of coastal protection measures such as NBS. The semi-structured nature of these interviews allows for a flexible yet focused examination of the factors that influence the implementation of NBS within the organisation.

To ensure a systematic approach, an interview guide was developed to guide the discussions (Appendix A). This guide is designed to address specific elements of the TPB, which serves as the overarching theoretical structure for this methodology. The TPB framework, and therefore the interview guide, includes three key components: Attitudes, Subjective Norms and Perceived Behavioural Control, which together provide a comprehensive lens through which to examine the decision-making processes of the heads of planning (see section 2.5).

The interviews were conducted individually with heads of planning from five NLWKN offices. From a total of 14 NLWKN offices spread all over Lower Saxony, the five offices in charge of the Coastal Protection Department in the Planning and Construction Division were selected (see Figure 12).

The process began with an initial email contact in February 2023, during which interviewees were provided with detailed information about the research, including

the purpose, interview process and measures to ensure privacy and confidentiality. Informed consent was obtained from each participant and assurances were given that the data would be anonymised. Each interview was conducted online via "google meet". Following, respondents were informed that interviews would be recorded to ensure the accuracy of data collection. These measures were taken to uphold ethical standards and maintain the integrity of the research process. An overview of the interviews conducted can be found in Table 3.

Table 3: List of interviews

#	Position	Operation Office	Territorial Responsibility	Date	Medium	Abbreviation
1	Head of Planning and Construction	Stade	Stade	23.05.2023	Google Meet	Exp_Sta
2	Head of Coastal Protection Department	Brake-Oldenburg	Brake	25.05.2023	Google Meet	Exp_Bra
3	Head of Planning and Construction	Aurich	Aurich	02.06.2023	Google Meet	Exp_Aur
4	Head of Coastal Protection Department	Brake-Oldenburg	Wilhelmshaven	06.06.2023	Google Meet	Exp_Wil
5	Head of Planning and Construction / Head of NLWKN	Norden	Norden, Frisian Islands	12.06.2023	Google Meet	Exp_Nor
6	Head of Planning and Construction	Brake-Oldenburg	Brake-Oldenburg	14.06.2023	Google Meet	Exp_BraOl

3.4 Data Analyses and Interpretation

In this chapter, the process of data analysis is addressed, a key phase in qualitative research that aims to gain insights into the factors influencing the implementation of NBS for climate change adaptation in the NLWKN. The process of data analysis involves several important steps, including data preparation, coding and pattern recognition. In addition, this chapter discusses how the theory of planned behaviour guided the categorisation and interpretation of the data from the interviews. The qualitative research data in this study are entirely descriptive and encompass various documents and interview transcriptions.

3.4.1 Data Preparation

To ensure the quality and reliability of the analysis of the collected data, a data preparation process was first carried out, which included both documents and transcripts of semi-structured interviews (Flick et al., 2004).

For the interviews, the initial step involved the careful reading and analysis of the fully transcribed interviews. It was essential to ensure the accuracy of these transcripts, and any potential errors or discrepancies were rectified through a process of corrective listening (Mayring, 2004). This methodical approach aimed to guarantee the fidelity of the interview data. Computer support by the software ATLAS.ti was utilised throughout this process to enhance efficiency and accuracy.

Similarly, for the documents, a systematic and rigorous reading process was undertaken. This phase involved the thorough examination of the documents to extract relevant information and themes, ensuring that the data was adequately prepared for analysis.

In the subsequent stage of data analysis thematic analysis was employed to extract valuable insights from the data sources.

3.4.2 Thematic Analyses

For the analysis of documents and policies, a method of thematic analysis was employed. This method involved an extensive search across the dataset to identify, analyse, and report on recurrent patterns within the documents (Braun & Clarke, 2006). The themes derived from the data actively construct the patterns of meaning to answer a research question (Javadi & Zarea, 2016).

A coding process was central to both content and thematic analysis. It involves systematically assigning codes to specific portions of the data to categorise and organise the information (Miles & Huberman, 1994). Codes served as markers or labels assigned to units of meaning in the data and enabled the efficient identification of segments about the research questions and emerging themes (ibid.). The coding process used in this research drew upon both deductive and inductive approaches.

Deductive Coding

Since the interviews conducted adhered to the framework of the Theory of Planned Behaviour (see section 2.5), the deductive codes were derived a priori on this basis. This set of deductive codes was constructed using the three main categories of the TPB: Attitudes, Subjective Norms and Perceived Behavioural Control.

Inductive Coding

In addition to deductive coding, inductive codes were developed during the analysis process. These inductive codes emerged organically from the data, capturing novel insights and unanticipated themes that arose during interviews and document analysis.

The next step after the coding process and developing themes, was crucial to look for emerging patterns. This includes checking whether the information collected from different sources converges to consistent results (Yin, 2018). Clear patterns and possible explanations were already identified during the data collection phase. These

early observations laid the foundation for a comprehensive case analysis that was guided by the research objectives and interests.

3.5 Ethics and Limitations

The issue of ethics in case study research is an important one for case study researchers (Priya, 2020). When conducting qualitative research that aims to gather insights and perspectives from individuals, it is crucial to give careful attention to the ethical aspects of data collection and management. This is especially true for methods such as interviews and surveys that require direct interaction with the participants. Since interviews were used as one of the research methods in this thesis, ethical considerations were an integral part of the methodological planning and realisation.

As outlined by Klopper (2008), ethical considerations involve safeguarding the personal rights of study participants and securing their informed consent for participation. These rights encompass several crucial aspects, including the right to self-determination, privacy, autonomy, confidentiality, fair treatment, and protection from discomfort or harm (Klopper, 2008, p. 71).

In line with ethical principles, participants in the interviews were explicitly asked for permission to record the interviews. Additionally, a document outlining the agreement to participate, approved by the Research Ethics Committee of the University of Groningen, was provided to participants. This document informed them about their rights, including the option to remain anonymous throughout the research process. The commitment to ethical research practices ensures the integrity and validity of the study's findings while respecting the rights and well-being of those involved.

Chapter 4: Research Results

This chapter looks at the results of the study on coastal protection in Lower Saxony, with a particular focus on the integration of NBS for climate change adaptation. The study led through the landscape of Lower Saxony's coastal system, its historical development of protection of this system and the complexity of coastal management. The aim was to shed light on the current approach to coastal protection and the decision-making processes of the heads of planning in the Lower Saxony Coastal Protection Agency, NLWKN, and to gain insight into their attitudes and perceptions regarding the implementation of NBS.

The case study of Lower Saxony's coastal protection (section 4.1) provides a unique background, shaped by its rich history of coastal protection, the dynamic characteristics of its coastal system and its elaborate coastal governance structure. Over the years, this region has faced numerous challenges, primarily due to its vulnerability to the effects of storm surges, but also the results of the continuing effects of sea movements. Furthermore, climate change, with its resulting rising sea levels, increase in storm intensity and accompanying increased coastal erosion, plays an exacerbating role. To address these issues, coastal protection strategies in Lower Saxony have evolved in response to the ever-changing natural and socio-political landscape.

The results presented in this chapter are structured in such a way as to answer sub-research questions one (section 4.2), two and three (section 4.3). First, the current approach to coastal protection in Lower Saxony is presented with a particular focus on the integration and use of NBS for climate change adaptation. The views of the NLWKN's heads of planning on the implementation of the NBS for coastal protection are then analysed to determine their insights, attitudes and possible reservations. The factors that influence the decision-making processes of these important actors in the NLWKN are also examined.

4.1 Case Study of the Federal State Lower Saxony, Germany

Coastal protection strategies in Lower Saxony have a long history, shaped by the dynamic forces of nature and adaptive human responses. Throughout contemporary history, the region has witnessed a progressive change in the coastline and approach to coastal protection, influenced by both natural processes and the socio-political landscape.

At first, it is crucial to understand the natural conditions of Lower Saxony's coast with its morphodynamics. Its natural system is not only characterised by its ecological diversity but also poses a major challenge in terms of vulnerability to sea level rise and increased storm events. A comprehensive understanding of the natural dynamics of the coastal system is essential to formulate effective strategies for its protection. Secondly, understanding the historical context of Lower Saxony's coastal protection efforts is crucial for comprehending the complex interrelationships that continue to shape its policies today. And thirdly, governance plays a central role in protecting Lower Saxony's coastal landscapes and inland areas. To understand how coastal protection decisions are made and implemented in this region, an examination of the governance system is essential.

4.1.1 Coastal System

The North Sea coast of Lower Saxony is located in the north-western part of Germany. This region is known for its remarkable natural landscapes and holds the title of being part of the Wadden Sea National Park, which has been declared a UNESCO World Heritage Site. To the west, it borders the Netherlands, while to the east it borders the German federal state of Schleswig-Holstein (see Figure 13).

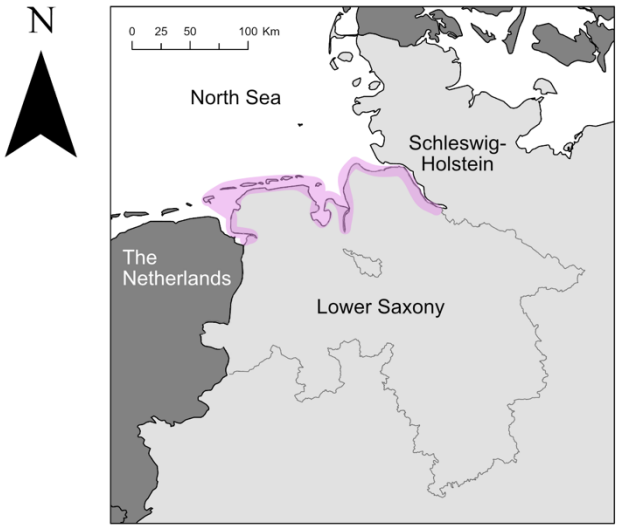

Figure 13: Illustration of the location of Lower Saxony's North Sea coast.

4.1.1.1 Its natural system

The North Sea coast of Lower Saxony has unique natural features that shape its distinctive environment. Seven dune islands, the East Frisian Islands, form a protective barrier of the coastline separated by tidal inlets. These islands are complemented by extensive tidal wetlands that cover the space between the islands and the mainland. In addition, the coast is shaped by the estuaries of tidal rivers such as the Ems, Weser and Elbe (see Figure 15 in section 4.1.1.3).

The sea has shaped the coastal landscape since time immemorial. To understand how it is important to look at the morphodynamics, i.e. the interaction of hydro- and sediment dynamics, of the region (Winter, 2011). Of particular importance is the wind-driven main current from the west in combination with the strong tidal currents in the tidal inlets, which influence sediment transport along the islands and within the tidal wetlands (see Figure 15 in section 4.1.1.3) (Fitzgerald et al., 1984). These natural processes play a crucial role in shaping the ever-changing coastal morphology, creating a complex and ever-changing landscape.

4.1.1.2 The mainland

The coastal region of Lower Saxony is characterised by marshes and lowland moors, which merge seaward into the tidal area and landward into the higher-lying Geest (see Figure 14).

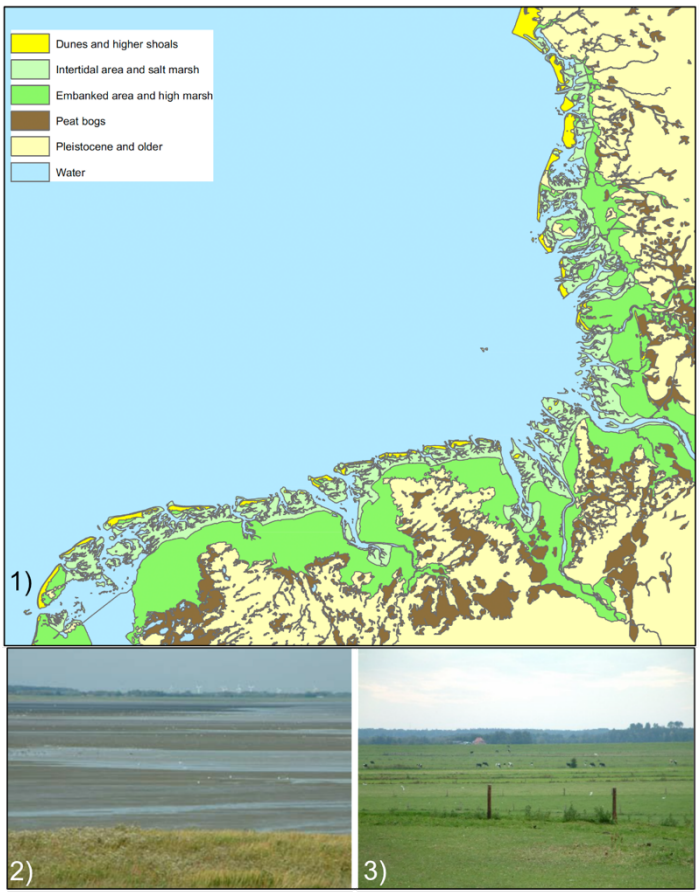

Figure 14: 1) Map of the Frisian Wadden Sea and its landscape features around 0 BP (Oost et al., 2012); 2) Salt marsh with adjacent tidal wetland sediments (Borman, 2010), 3) Typical higher marsh landscape (Borman, 2010).

The marshlands encircle the North Sea's shore by a varying-width belt ranging from 5 to 30 km (NLWKN, 2007). These marshlands extend far into the inland areas along the lower reaches of the tidal rivers Ems, Weser, Elbe, and their tributaries. The present formation was formed due to the advance of the North Sea, a consequence of various phases of sea-level rise.

4.1.1.3 The East Frisian Islands and Tidal Wetlands

The Frisian Islands, extending for approximately 1000 km, form a chain of barrier islands that parallels the coast (see Figure 15) (Eitner & Ragutzki, 1994). This island chain includes the West Frisian Islands, starting in Den Helder, Netherlands, and stretching to Germany, the East Frisian Islands, and the North Frisian Islands on the east side of the German Bight, reaching up to Skallingen, Denmark. These islands, along with the extensive tidal wetlands, serve as vital buffers protecting the mainland from the highly energetic conditions of the North Sea. In total, this coastal system encompasses an area of 10,000 km², constituting one of the largest tidal flats in the world (ibid.).

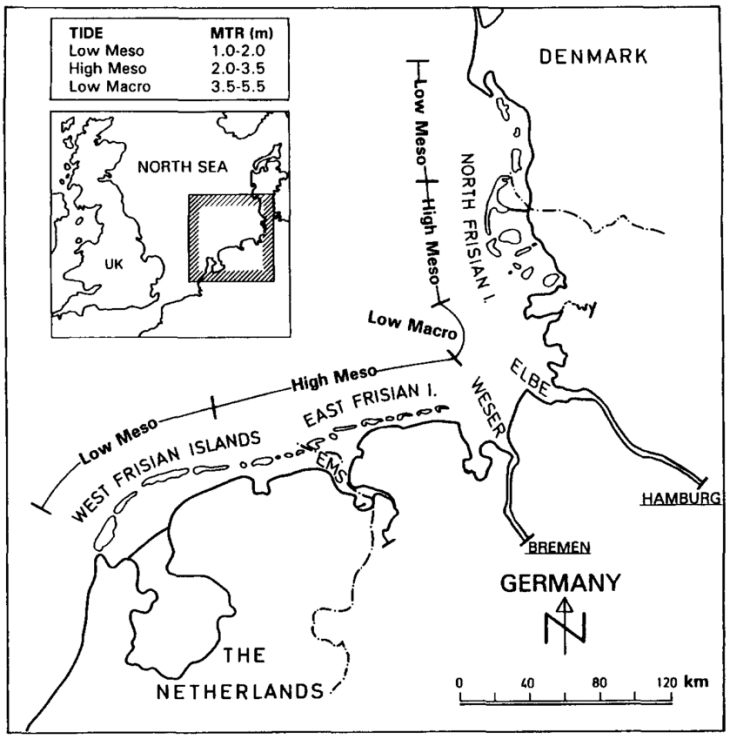

Figure 15: Map of Frisian Islands (Eitner, 1996).

The East Frisian Islands, situated off the coast of Lower Saxony between the mouths of the Ems and Weser rivers, were shaped as dune islands during the post-glacial sea level rise and transgression of the North Sea. This southward movement of the North Sea pushes sediments ahead of it, forming sand accumulations and tidal deposits

along the water's edge: the first precursors of these islands. However, the position of these islands was about 10 - 15 km northwest before that of the present islands (8000 BP) (Oost et al., 2012). The development of the dune islands transitions from a fragile, sandy plateau to mature dunes with a storm surge-proof core and is marked by changing environmental conditions and plant colonisation (ibid.). As a result, there is an island that shields the hinterland from storm surges and fosters the growth of salt marshes (ibid.).

Dune islands are inherently vulnerable due to their sandy nature and the pervasive influence of natural forces. The main currents responsible for the formation and constant change of its morphology include an energy current that moves sediments along the coast from the west and is deflected northwards by ebb currents in the tidal inlets between the islands, resulting in the formation of an ebb delta with shoals and a sandy reef arc spanning to the next island (see Figure 16) (Fitzgerald, 1984).

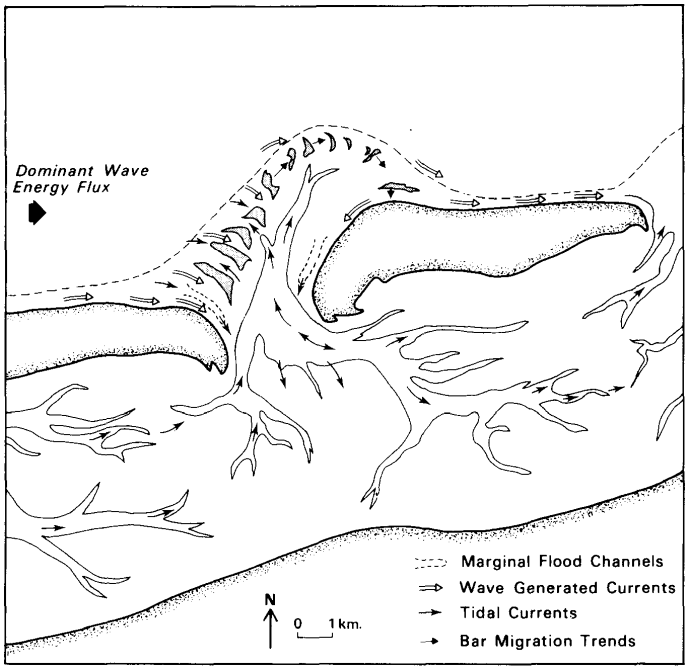

Figure 16: Complex current and sediment behaviour that shape the coast's morphology (Fitzgerald, 1984).

In the event of a storm surge, inundation processes can occur on the dune islands, with water and sediment flowing over the dune crests adjacent to areas of the dune

core, creating alluvial channels and depositing sediment in the back and mudflats, forming alluvial fans. This process is recurrent and responsible for the fact that islands have always adapted to the transgression of the North Sea.

A prototypical island has five significant morphological units (see Figure 17.1) (after Oost et al., 2012): (1) the island head is surrounded by strong currents, therefore mostly characterised by erosion, (2) stabilised dune arches (dune core) providing shelter from storm surges, (3) the washover complex, (4) the island tail with alternating dunes, washover fans and tidal marshes, and (5) the beaches and shoreline area along the north side of the island. These units overlap and interact throughout the morphological evolution of the island.

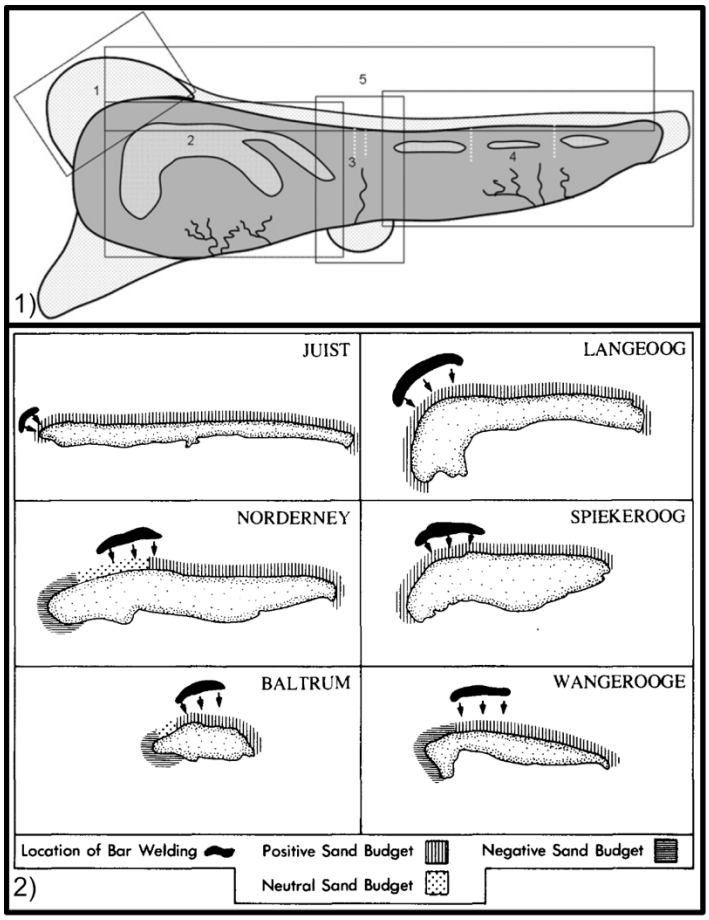

Figure 17: 1. Illustration of a prototype of a dune island with its morphological units: (1) head of the island, (2) dune core, (3) washover complex, (4) alternating island tail and (5) its seawards beach (Oost et al., 2012); 2. Illustration of the erosional-depositional shoreline trends of selected East Frisian Islands (Fitzgerald, 1984).

In reality, each island has its shape, which depends on the locally different morphodynamics. Figure 17.2 illustrates this with selected examples from the East Frisian Islands: The individually different positive and negative erosion areas of the islands can be seen, as well as the areas where new sediment is brought in from the west across the sand reef arc. Figure 18 shows a selection of the East Frisian island landscapes for illustration purposes.

Figure 18: Photographs of the East Frisian Islands' landscapes: 1) The uninhabited island Memmert, illustrating the natural form of dune islands without human intervention (Stroman, n.d.), 2) The inhabited island Norderney with settlements at the western head and its sandy tail to the east (New Wave, n.d.), 3) Overgrown dunes on the island Borkum (Weiss, 2021), and 4) The tidal wetland between the islands and the mainland during low tide, showcasing a section of a tideway (Temme, n.d.).

In summary, it can be concluded that the East Frisian Islands undergo continuous transformation due to locally driven morphodynamic processes. This variability is a significant factor contributing to the distinction in coastal protection measures between these islands and the mainland.

4.1.1.4 Importance of Coastal Protection

The coastal regions of Lower Saxony are characterised by extensive low-lying areas, with the rivers Ems, Weser, and Elbe, along with their tributaries, extending deep into the hinterland (NLWKN, 2020). By covering approximately 6,500 km² and being home to about 1.1 million people, this region faces a continuous threat from storm surges and even regular high tides (Thorenz et al., 2017). Remarkably, around 60% of the areas protected by dykes in Lower Saxony currently lie below the mean high tide, with some portions even below the mean sea level (ibid.). This area under the influence of high tides represents roughly one-twelfth of the entire land area of Lower Saxony. Situated in front of the mainland coastline, the Lower Saxony Wadden Sea and the East Frisian Islands are also vulnerable to storm surges and erosion (NLWKN, 2010).

The consequences of flooding due to storm surges are dire, posing threats to life and property, and causing significant economic and socio-cultural disruptions, potentially leading to the loss of livelihoods (NLWKN, 2010). In the protected regions on the mainland, assets valued at around €129 billion are at risk (NLWKN, 2018). Mitigating this risk and taking the necessary measures are therefore of utmost importance to protect not only the socio-economic factors but also the preservation of the cultural heritage and the distinctive and irreplaceable natural landscape (NLWKN, 2020).

4.1.2 History of Coastal Protection in Lower Saxony

As mentioned in the previous section (4.1.1), the morphology of the North Sea coast is subject to constant change. In particular, since the end of the last ice age (11,500 BP) and the beginning of the current Holocene, glaciers have been melting, leading to a transgression of the North Sea (Coles, 2014). During this general rise in sea level, there have been intermittent periods of regression where the North Sea has exposed large areas of land that were previously flooded (see Figure 19). It was

during these periods of changing sea levels that the settlement of what is now Lower Saxony began, constantly adapting to the sea level rise.

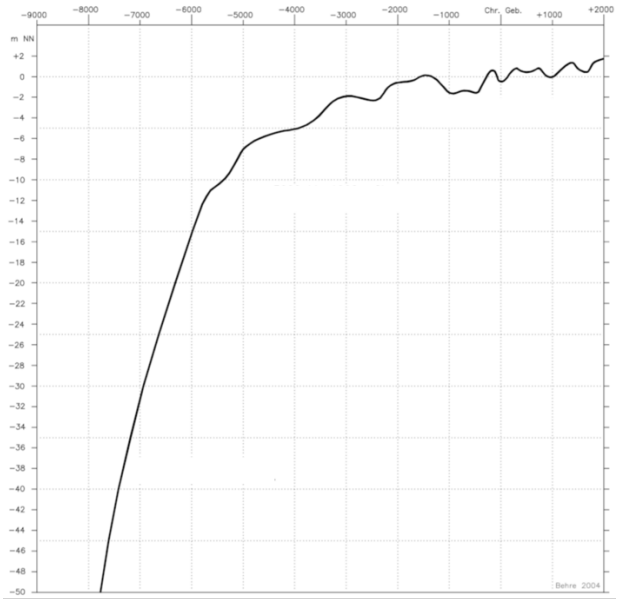

Figure 19: The rise in sea level in the southern North Sea since the last ice age also shows periods of decline and standstill (Behre, 2003).

In the Late Bronze Age, the first human settlements were established in Lower Saxony, especially in the German Clay Region (or marshland), in the Jemgum/Ems region and the Rodenkirchen/Weser area (Behre, 2004). These so-called *Flachsiedlungen* (flat settlements) (see Figure 20) were kept very primitive, without protection against possible storm surges. Only when the sea level rose again did these coastal settlements face the destructive forces of storm surges. In response to this natural challenge, the inhabitants of the region developed innovative strategies to protect themselves. They built their dwellings on artificially raised mounds, also called *Wurten*, which were the first form of early coastal protection (Behre, 2004).

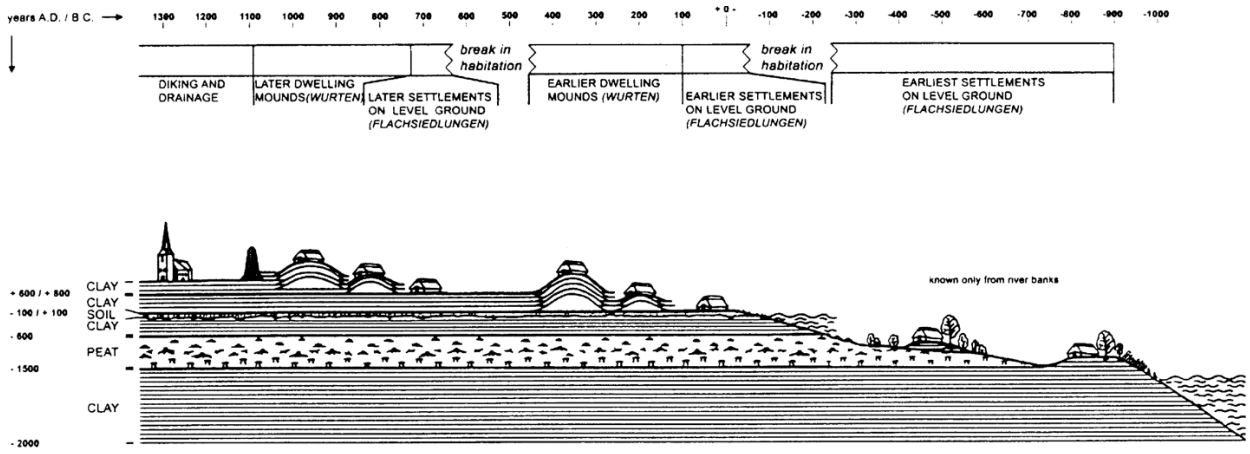

Figure 20: Schematic illustration of deposition and stages of inhabitation of the German Clay Region, the marshland (Behre, 2004).

The habitation of the North Sea coast continued and adapted to the progressive rise of the North Sea. As can be seen in Figure 20, after a break in settlement, the flat settlements and dwelling mounds were repeated until the construction of the first ring dykes for protection at the end of the 11th century (Behre, 2004).

In the 13th century, these ring dykes were connected and raised to adapt to recurring storm surges. Since that time, one speaks of a continuous dyke line that protects the area behind it from winter storm surges (NLWKN, 2007). However these developments of early coastal protection also had their disadvantages: they led to a higher storm surge level because the area to be flooded was smaller, which caused the water to flow into the estuaries and rivers and then flood the low-lying farmland (Behre, 2004). This led to devastating floods in the 12th and 14th centuries, such as that of the Julian Flood in the 12th century, the first concretely recorded storm surge, and the Marcellus Flood in the 14th century, which was the first storm surge of which there is an eyewitness account (Jensen & Müller-Navara, 2008).

In the 16th century, land reclamation began in the region, even though there were repeated setbacks due to severe storm surges. These efforts were finally successful after one polder after another was dyked. A central role in the land reclamation process was played by the improvement of dyke construction techniques, and the

dykes became essential elements of the landscape (Behre, 2004). However, the dykes hindered natural drainage, which led to the development of an artificial drainage system using windmills (and later electric pumps in conjunction with a ramified network of ditches and canals) (ibid). However, land reclamation had a disadvantage: the newly poldered clay areas near water are naturally at a higher level. Therefore, the newer polders were always higher than the older ones, making the older polder areas more prone to flooding (see Figure 21) (ibid.).

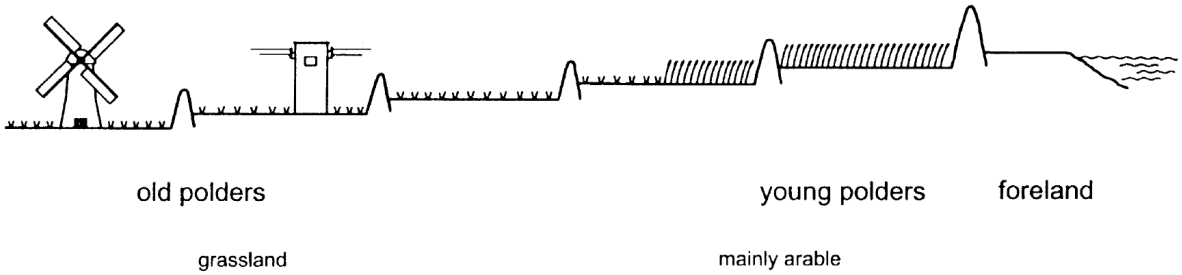

Figure 21: Schematic representation of a polder landscape showing differences in age, use and elevation of polders (Behre, 2004).

The interplay between peaceful times and devastation by the sea continued. But thanks to the advancing technical development of mankind, coastal protection also improved. The foundation stone for coastal construction was laid in the 18th century by Albert Brahms of Lower Saxony, based on the experience of the Christmas storm tide of 1717, in his book "*Anfangsgründe der Deich- und Wasser- Baukunst*" (The beginnings of the art of dyke and water construction (NLWKN, 2007).

Following the devastating Holland Flood on February 1, 1953, which caused substantial loss of life and property damage in the southern Netherlands, the "Lower Saxony Coastal Program" was initiated in 1955. This program laid the groundwork for enhancing coastal protection in the storm surge-prone regions of Lower Saxony. The catastrophic flood of February 16/17, 1962 along the German North Sea coast, claimed more than 340 lives and caused significant property damage. This disaster prompted a review of dyke construction regulations by establishing the Lower Saxony

Dyke Act and led to an expansion of dyke and other coastal protection infrastructure. In 1973, the Lower Saxony Minister for Food, Agriculture, and Forestry published the GPK, detailing the measures to be implemented at that time (NLWKN, 2010, 2020). Since then, the GPK has been regularly adapted. Today it comprises three volumes: for the mainland, the East Frisian Islands and for protective dykes. These developments laid the foundation for the current coastal protection efforts in Lower Saxony.

4.1.3 Organisation of Coastal Protection

Coastal protection in Lower Saxony is not only a regional concern but a matter of national and international significance. This chapter provides an insight into the multi-layered organisation of coastal protection in Lower Saxony by looking at the distribution of responsibilities between the federal, state, regional and local levels, as well as influential international agreements. A graphic overview can be found in Figure 22.

Federal level

The division of responsibilities in coastal protection is rooted in the German Constitution, known as the *Grundgesetz*. According to the *Grundgesetz*, the responsibility for coastal protection falls under the concurrent legislative competence of the German Federation and the *Länder* (states). This means that the *Länder* can legislate on coastal protection matters unless the Federation has exercised its legislative competence through federal law. To date, the Federation has not legislated in this domain, giving the *Länder* the agency to regulate coastal protection through Land laws. Furthermore, Article 91a(1) of the *Grundgesetz* allows the German Federation to participate in tasks of national importance when such participation is deemed necessary to improve living conditions. Coastal protection is recognised as one of these joint tasks (*Gemeinschaftsaufgabe)*. The GAK (*Gemeinschaftsaufgabe zur Verbesserung der Agrarstruktur und des Küstenschutzes* – joint task for the

Improvement of Agricultural Structures and Coastal Protection) is the principal national funding instrument for a resilient, future-oriented, and competitive agricultural and forestry sector, coastal protection, and the vitality of rural areas and is regulated in more detail in the Act on the Joint Task (GAK Act – GAKG). The constitutional objective of GAK is to establish equality of living conditions in Germany. To achieve this, a joint framework plan is periodically developed for the *Länder*, as prescribed in §4 GAKG. In the context of coastal protection, §10(1) No. 2 of the GAKG stipulates that the Federation reimburses each *Land* for 70 per cent of the expenses it incurred as part of the framework plan (BMEL, 2020).

State level

At the state level, coastal protection in Lower Saxony is regulated by state law, the Dyke Act (*Deichgesetz*). With the *Deichgesetz*, Lower Saxony is the only state in all of Germany to have a law that establishes the legal definitions for coastal protection facilities, defines principles for their dimensioning, establishes responsibilities, contains standards for the use and utilisation, and expansion and modification as well as the control of coastal protection facilities (MU, 2014).

The central agency involved in state-level coastal protection is the *Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz* (Lower Saxony State Agency for Water Management, Coastal Protection, and Nature Conservation, NLWKN). This agency, based in Norden, operates under the purview of the Lower Saxony Ministry of Environment, Energy, Building, and Climate Protection. Within the NLWKN, there is a division of the business units, which are among others responsible for the planning and construction of coastal protection measures. The specialised tasks in the field of water management, flood protection, coastal protection and nature conservation on site are implemented in regional branch offices.

Regional level

The execution of local tasks is decentralised to NLWKN's branch offices, spread across Lower Saxony, ensuring regional presence. These branch offices are located in Aurich, Brake-Oldenburg, Cloppenburg, Hannover-Hildesheim, Lüneburg, Meppen, Norden-Norderney, Stade, Sulingen, Süd (Braunschweig and Göttingen), and Verden, whereby the responsibilities for the performance of tasks are adapted to local conditions.

Local level

As stipulated in the *Deichgesetz*, flood protection in Lower Saxony is the responsibility of the dyke associations (also called water and soil associations), the *Deichverbände*. A *Deichverband* is an association of property owners and other members of a certain area protected by the dyke. Membership as a landowner, if his land is protected by the dyke, is obligatory. The respective dyke association is responsible for the maintenance of flood protection dykes, which includes both dyke maintenance and dyke construction. The *Deichverbände* are established as self-governing public corporations. Each *Deichverband* is headed by a board of directors, which is presided over by a dyke count. This board, democratically elected by the association members, oversees the administration of the association's affairs. To ensure compliance with the law, the districts also exercise legal supervision and monitor compliance with the relevant regulations. In Lower Saxony, 22 dyke associations are responsible for maintaining the dyke (NLWKN, n.d.).

International level

At the international level, the field of coastal protection is also linked to international agreements. The importance of such interaction becomes clear by considering the recognition of the Wadden Sea by the United Nations Educational, Scientific and Cultural Organization (UNESCO). This globally recognised organisation declared the Wadden Sea a biosphere reserve in 1986 and added the Dutch and German regions

to the World Heritage List in 2009, followed by the Danish part of the Wadden Sea in 2014.

At the European level, the area of coastal protection overlaps with various biodiversity and water management frameworks. These multiple frameworks include the Water Framework Directive, Natura 2000, the Birds Directive and the Habitats Directive. In addition, cooperation between riparian states is actively promoted through the INTERREG programmes for the North Sea, especially in the Trilateral Wadden Sea Cooperation between the Netherlands, Germany and Denmark. These initiatives promote approaches to address environmental issues, which are an important additional stakeholder for coastal protection.

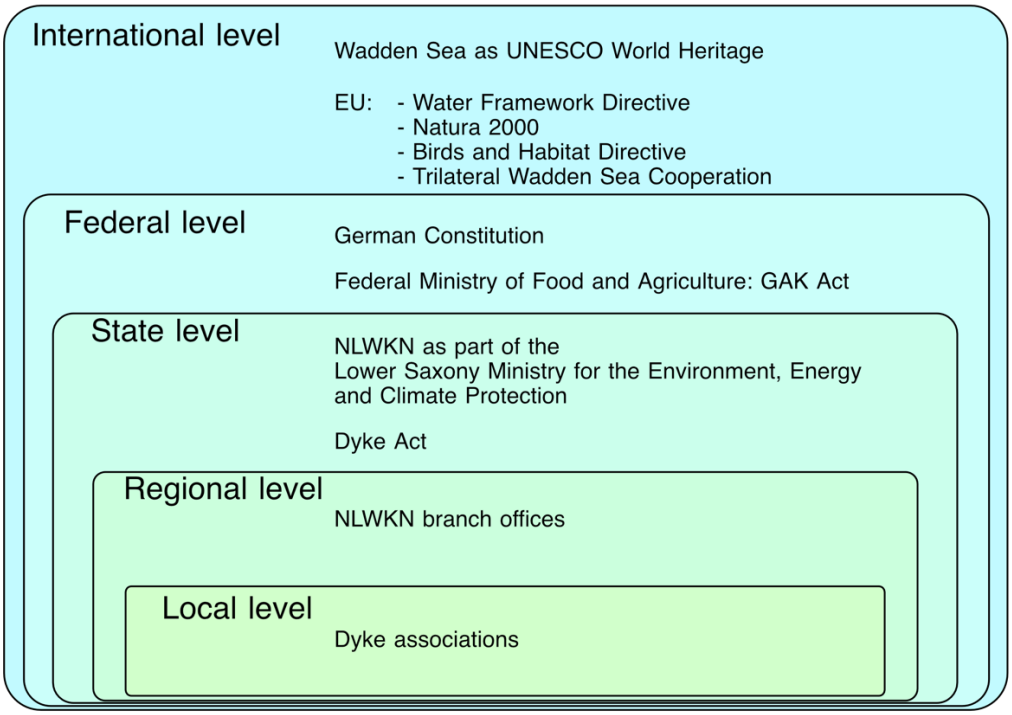

Figure 22: Graphical overview of the distribution of responsibilities in the field of coastal protection in Lower Saxony from the federal to the local level and how this is embedded in the international level with important international (EU) agreements.

4.2 Findings SQ1

This section presents the findings regarding the current approach to coastal protection in Lower Saxony, focusing on the integration and utilisation of NBS for climate change adaptation. The study is mainly based on document research in which currently valid laws such as the *Deichgesetz (dyke act)*, fundamental coastal protection strategies as described in the three volumes of *GPK* (Volume 1: mainland, Volume 2: East Frisian Islands, Volume 3: Protective dykes) and the current *Klimaanpassungsstrategie* (climate adaptation strategy) of the state of Lower Saxony are analysed in the context of coastal protection in Lower Saxony.

A summarised comparison of the results is presented in Table 4 at the end of this section.

4.2.1 Deichgesetz

As explained in section 4.1.2, the *Deichgesetz* (Lower Saxony Dyke Act) is the legal framework that defines the responsibilities, regulations and procedures for coastal protection in the state of Lower Saxony and thus forms the basis for the current approach to coastal protection in Lower Saxony.

It stipulates that the main element of coastal protection is the dyke. The Dyke Act mainly uses technical terms and formulations such as "*Anlagen*" (facilities), "*Schutzbauwerke*" (protective buildings) and "*Sperrwerke*" (flood barrier).

The only nature-related terms are "*Schutzdünen*" (protected dunes) or "*Vorland*" (foreshore), whereby the "*Vorland*" is mainly described to be used to protect the dyke as "*Deichvorland*" (dyke foreshore).

No definitions for adaptation to climate change were found.

4.2.2 Generalplan Küstenschutz

Volume 1: Mainland

The first volume of the GPK, which was published by the NLWKN in 2007, provides a comprehensive overview of the coastal protection strategy for the mainland of Lower Saxony. It names "*Deiche*" (dykes) and "*Sperrwerke*" (barrages) as the central elements and "Sturmflutwhere" (storm surge barriers), "*Buhnen*" (groynes) and "*Deckwerke*" (revetments) as further important elements of coastal protection on the mainland coast of Lower Saxony. The main dyke forms the first dyke line, which is reinforced by a second dyke line inland. Furthermore, the coastal protection strategy is described with a majority of technical words such as "*Anlagen*" (installations) and "*Bauten*" (structures).

Regarding nature-related aspects, the plan recognises the importance of "*Vorland*" (foreshore) and "*Lahnung*" (natural embankment) as protective elements that contribute to ensuring the functionality of the main dykes. In addition, the term "*Grüne Deiche*" (green dykes) and their "*Grasnarbe*" (grass sod) appear in the plan: The grass sod, therefore, helps to stabilise the physical conditions of the dykes, protect against erosion and improve the overall protection of the dykes.

In the face of climate change, the plan recognises that technical protection is still necessary in the face of climate change: "*Der technische Küstenschutz ist heute unersetzlich und wird es auch in Zukunft sein*". In this context, the plan identifies the dyke as the most important element and considers "*Vorsorgemaß*" (precautionary measures) to increase dyke heights as a means of adapting to rising sea levels and coping with the effects of climate change.

Volume 2: East Frisian Islands

The second part of the GPK relates specifically to the East Frisian Islands and was published by the NLWKN in 2010.

In the East Frisian Islands, although the coastal protection strategy relies significantly on natural elements and utilises "*naturnahe Prozesse*" (natural processes), it is often formulated in technical terms similar to volume 1 such as „*Werke*" (buildings) and „*Bauten*" (structures) to describe the coastal protection system

The East Frisian Islands play an important role in the overall strategy of coastal protection in Lower Saxony, as they act as barrier islands in the natural coastal system, i.e. they buffer storm surges from the sea due to their exposed location. However, the protection approach on the islands differs from that on the mainland due to the different natural conditions and morphology, which makes the use of protection measures very place-specific. The natural features of the islands, especially the beaches and the dunes behind them, are recognised as key features for the protection of the islands and receive great attention and care. This is not only about protecting the inhabitants but also about preserving the tourism and economic value.

The protection system on the islands follows a ring system, with the naturally formed dunes (see section 4.1.1.3) serving as the central element facing the sea to protect against storm surges. For this reason, the protection of the dunes is given high priority and nature-based measures are carried out using the natural material on site. It is recognised that the protective dune consists of important parts such as the foreshore, the island's beach in general and the peripheral dunes, which together form a dynamic overall system. To protect the dunes from wind erosion, the sand is caught by bush fences and biological engineering measures such as the planting of erosive dune sections with marram grass are practised, which has long been common practice on the islands and serves to stabilise the dunes and ultimately protect the island. Since the 1950s, the negative erosion balances on the islands have been balanced out with the help of sand nourishment to support the dynamic system of the protective dune. This practice is described as a measure with a "*naturnahem Charakter*" (near-natural character), as it is adapted to the natural hydromorphological and sedimentation environment. Sand nourishment not only stabilises the dunes but

also plays a crucial role in maintaining hard solutions such as groynes. Groynes are strategically placed in highly erosive areas and without regular sand nourishment, their foundations would gradually erode, making continuous maintenance essential.

The general approach to protecting the „*Schutzdüne*" (protective dune) is that if the protective dune were not protected by hard solutions, its sand body would be subject to the forces of nature.

For this reason, engineered/hard solutions are used as additional ring system elements. Hard solutions are generally used to combat erosion problems and stabilise beaches and dunes. For example, groynes are used on erosive beach sections to reduce sediment loss, such as on the erosive western side of Norderney. The ring system is closed by a dyke on the side of the island facing away from the sea and towards the mudflats.

Volume 3: Protective Dykes

The third part of the GPK was published by the NLWKN in 2020. This represents an inventory of the protective dykes and provides a comprehensive overview of the entire 600-kilometre-long dyke line of all protective dykes in Lower Saxony and Bremen.

In terms of the explanations of coastal protection in Lower Saxony, this volume is very similar to the previous volumes, but above all to Volume 1, with a majority of technical words such as "*Anlagen*" (installations) and "*Bauten*" (structures). Here, too, the dyke plays a central role in the coastal protection system, whereby the protection of the dyke continues to be ascribed to great importance, which is also shown in Volume 1.

Another similarity is that the mention of the "*naturnahes Element*" (near-natural element) comes in connection with "*Schutzdünen*" (protective dunes) and "*Deichvorland*" (dyke foreshore). The concept of the "*Grüne Deich*" (green dyke) with a covering grass layer is also mentioned again in Volume 3 but without any recognisable change in its description.

No natural or near-natural solutions are mentioned in connection with climate change and climate adaptation. Only the possibility of raising and widening the dykes with its "*Vorsorgemaß*" (precautionary measure) as an adaptation strategy plays a role here.

4.2.3 Klimaanpassungsstrategie Niedersachsen

The Lower Saxony Climate Adaptation Strategy was published in 2021 by the Lower Saxony Ministry for the Environment, Energy and Climate Protection and comprises 17 fields of action that will be affected by climate change along with the necessary adaptation strategies. Chapter 3.3 presents the adaptation strategy for coastal protection measures. The central elements of coastal protection in Lower Saxony are the dykes, dunes and barrier islands, which are protected by protective elements. The natural protective elements of the dykes include the dyke foreshores and the beaches for the dunes. Other important protective elements for dykes, beaches and dunes are technical elements such as revetments and groynes. All these elements work together and form a cooperating coastal protection system.

An important component of coastal protection is the „*naturnahes*" (near-natural) concept of "*Deichvorländer*" (dyke foreshores). These are natural elements that reduce the impact on the dykes during storm surges, as they act as a natural buffer and therefore help to protect the dykes. The benefit of dyke foreshores lies in the fact that they reduce the need for hard structures to protect the foot of the dyke. Dyke foreshores are recognised as having ecological value and are present in more than 75% of the area in front of the dyke line. They are considered an integral part of coastal defence, particularly in adapting to sea level rise.

The basis for the climate adaptation of coastal protection and the measures to be taken is the GPK, which includes determining the required construction heights and ensuring the functionality of the protection system. Overall, the aim is to implement

these measures in a "bauwerksspezifisch" (structure-specific) manner. Accordingly, *"erforderliche Ausbauhöhen"* (required expansion heights) and a "*Vorsorgemaß*" (precautionary measure) of the dykes are essential for climate adaptation.

In addition, the climate adaptation strategy recognises the importance of natural measures to preserve and improve natural and near-natural coastal protection elements such as dunes and salt marshes with their valuable ecosystem services. The main focus is on the integration of nature into the protection of sandy coasts, such as the concept of "*Bauen mit der Natur*" (building with nature), with particular attention being paid to practices such as sand nourishment. In this context, "*zukünftige Entwicklungen von resilienten und nachhaltigen Strategien*" (future developments of resilient and sustainable strategies) are to be taken into account. No further additional explanation for potential variations of the grass layer of the dykes was found.

Table 4: Comparative summary of the results of the document analysis

Aspect	Dyke Act	Masterplan Coastal Protection (GPK)	Climate Adaptation Strategy
Legal Framework	Defines responsibilities, regulations for protection	Provides comprehensive coastal protection strategy	Outlines adaptation strategies for coastal protection
Central Elements	Dykes	Dykes, barrages, storm surge barriers, groynes	Dykes, dunes, barrier islands, technical elements
Nature-related Terms	Protecting dunes, dyke foreshore	Dyke foreshore, natural embankment, dunes, green dykes with grass sod	Dyke foreshores, beaches, dunes, salt marshes, green dykes with grass sod
Climate Change Consideration	No mention of climate change adaptation strategies	Recognises need for technical protection measures	Considers nature integration for adaptation (adhering to GPK); Recognising ecosystem services of foreshore and dunes
Role of Technical Elements	Dyke maintenance,	Structures for coastal protection	Still significant, based on GPK

	protective buildings		
Nature-based Approaches	Limited, foreshore = protection of the dyke	Recognition of the importance of dunes (Vol. 2), foreshore and green dykes (Vol. 1 & 3)	Emphasis on nature integration, 'building with nature'
Coastal Protection Measures	Use of technical elements, dyke foreshores	Coastal strategies differ for mainland (dykes) and islands (dunes)	Focus on dykes and dunes based on GPK
Adaptation Strategies	Focus on dyke heights (precautionary measures)	Emphasis on adapting to sea level rise, focus on raising dykes (precautionary measures)	Integration of nature, sand nourishment; adheres to raising dykes (GPK)
Ecosystem Preservation	No emphasis on ecosystem services	Emphasizes the preservation of natural elements	Recognition of ecological value
Future Strategies	No explicit mention of future resilient strategies	Consideration for future sustainable approaches	Focus on resilient and sustainable strategies

4.3 Findings for SQ2 and SQ3

In this section, the results of the semi-structured interviews of the heads of planning of the NLWKN are presented to answer sub-research questions 2 and 3 (section 1.2). These interviews aimed to investigate and shed light on their attitudes, subjective norms and perceived behavioural control about the implementation of NBS for coastal protection.

Before turning to the differentiated analysis of the individual sub-questions, it is important to mention a common feature that was identified during the data collection: All heads of planning have a degree in civil engineering. This common educational background forms the basis for a comprehensive understanding of their perspectives and decision-making processes in the field of coastal protection.

A summarised comparison of the results is presented in Table 5 at the end of this section.

4.3.1 Attitudes

When analysing the interviewees' responses, several key themes emerged regarding their perception of NBS as coastal protection measures. These responses reveal a complex landscape of attitudes and considerations.

Support for NBS

Whilst the majority of interviewees expressed support for NBS, Exp_Sta stands out by describing himself as a "*großer Anhänger*" (strong advocate) of NBS and is strongly in favour of the growth of foreshore: "*wir sollten alles tun, damit das Vorland aufwächst*" (we should do everything we can to grow the foreshore). In his opinion, NBS should be used wherever possible. He firmly believes that NBS is a better alternative to the overuse of concrete. In addition, although Exp_BraOl is satisfied with the current coastal protection strategy and mentions the foreshore in particular as a near-natural element in this context, she emphasised the advantages of NBS, especially its potential to reduce dependence on non-natural building materials, which leads to less land sealing. This approach is seen as cost-effective, making NBS a resource-efficient choice. In addition, several benefits were recognised through the implementation of NBS: Exp_Sta recognised that these solutions go beyond coastal protection and offer significant benefits for tourism and recreation, while Exp_Nor even sees a synergy between coastal protection and nature conservation. Similar to Exp_Sta and Exp_Bra, Exp_Wil also sees the foreshore as an important natural component and categorises it as a "*schützenswertes Gebiet*" (area worth protecting).

Emphasis on Sustainability

Sustainability is a recurring theme among the interviewees. Exp_Wil argues that traditional dyke construction fits seamlessly into the local ecosystem due to its

historical context: "*Die Art des Deichbaus aus der Historie passt perfekt ins Ökosystem und wenn man das heute weiter so betreibt, ist das nach wie vor nachhaltig*". Additionally, Exp_Bra also argues in favour of "*nachhaltige Lösungen*" (sustainable solutions) instead of NBS. In this context, she considers the construction of a storm surge barrier in the Weser estuary to be more sustainable to counter spatial constraints.

Alignment with Natural Processes

Several interviewees emphasised the importance of aligning coastal protection measures with natural processes. So did Exp_Wil advocate learning from nature and adopting a holistic ecological perspective. Additionally, Exp_Wil emphasised how important it is to gain knowledge from nature and "*die Sichtweise des Ingenieurs zu erweitern*" (to broaden the engineer's perspective), i.e. to adopt an ecological perspective in addition to the engineering perspective. Exp_Wil goes on to explain that the utilisation of natural processes will also help to save resources

Context-Dependent Approaches

Some interviewees adopted context-dependent approaches, favouring NBS where feasible but acknowledging the need for harder solutions in specific locations or situations. Some respondents take a contextual approach, favouring NBS where possible but recognising that more stringent solutions are required in certain locations or situations. Exp_Nor therefore speaks of "*keine pauschale Sichtweise*" (no blanket view) that NBS is always the better solution. For example, the sedimentation processes on the East Frisian Islands are very individual and require different measures. Exp_Aur also recognises the site-dependent implementation of NBS and even goes so far as to acknowledge a combination of both, i.e. NBS and hard solutions.

Concerns and Challenges

Although respondents are generally in favour of NBS, they also expressed concerns and challenges related to NBS. Exp_BraOl, for example, is concerned about the uncertainties of the effectiveness of NBS and believes that there is more certainty in the calculation of the stability of a spit wall than in the calculations of sand accumulation due to natural sedimentation processes. Exp_Bra mentions requirements in connection with spatial planning: the space in their area of jurisdiction is very limited. Exp_Bra also emphasises the challenges of coordinating all relevant stakeholders. This ties in with the statement by Exp_Wil, who calls for greater dialogue between the stakeholders.

In conclusion, the analysis showed strong support for NBS amongst the heads of planning, particularly from Exp_Sta, who is in favour of its broad application. Exp_BraOl emphasises several advantages of NBS, such as reducing dependence on non-natural building materials and less soil sealing. Exp_Wil emphasises sustainability in the context of the existing coastal protection system, stating that traditional dyke construction fits seamlessly into the ecosystem. At the same time, he argues in favour of coordinating coastal protection with natural processes. Context-dependent approaches are advocated, recognising that NBS is not always the best solution. Concerns include uncertainties about the effectiveness of NBS and challenges in spatial planning and stakeholder coordination. Overall, NBS is favoured, but some challenges still need to be overcome for successful implementation.

4.3.2 Subjective Norms

When analysing the subjective norms of the heads of planning surveyed, several notable trends and patterns emerge that provide insights into the prevailing attitudes within their professional and social environment. Participants' perceptions of colleagues, stakeholders and societal expectations provide valuable perspectives not

only on the factors influencing heads of planning' actions but also on acceptance and the potential challenges associated with NBS in coastal protection.

Open-mindedness and Supportive Colleagues

A recurring theme among all participants is the positive and open-minded attitude of colleagues towards NBS. There is a general recognition of alternative methods in coastal protection. Exp_Bra refers this to her „*junges Team*" (young team), while Exp_Aur emphasises that „*es keine Vorbehalte gegenüber NBS gibt*" (there are no reservations about NBS) and that „*man der Sache dienen möchte, egal mit welchen Mitteln*" (we want to serve the purpose (of coastal protection), regardless of the means). Although Exp_Wil also sees positive support from his colleagues, he nevertheless makes it clear that the dyke paradigm is strongly present.

Interest Group Dynamics and Political Divides

NBS is perceived differently by the various interest groups. Conservation organisations are mentioned most frequently, as they are generally in favour of NBS when it comes to land conservation. However, Exp_Sta makes it clear that these organisations are quick to oppose a measure as soon as it is intended to intervene in the area. Exp_Bra expresses a similar view and takes a somewhat stronger stance: "*Der Naturschutz ist maßgeblich am Mitgestalten des Küstenschutzes beteiligt, mit seinen Verboten*" (nature conservation is significantly involved in shaping coastal protection with its prohibitions).

The second most frequently mentioned and most important interest group is the dyke associations, although no clear position towards NBS can be recognised. However, Exp_Sta makes clear that the adoption of NBS is involved in a broader political and interest group dynamic, as the dyke associations "das lokale politische Meinungsbild widerspiegelt" (reflect local political opinion) due to their organisation.

Other influential interest groups mentioned are tourism and agriculture. Exp_Bra frequently mentions "land use pressure" in the interviews and takes a strikingly critical

stance, particularly towards agriculture. This negative perception is based on the fact that she recognises agriculture as a major factor in the general land use pressure. Exp_Nor, on the other hand, makes it clear that the tourism industry can only find a high level of acceptance through continuous dialogue.

Societal Expectations and Fear-Driven Narratives

The views of the heads of planning on social expectations in connection with NBS and coastal protection show a uniform picture: there are no predominant expectations to change the existing coastal protection, dyke construction is favoured. Rather, there is a fear of dyke breaches, particularly in connection with rising sea levels, as Exp_Sta states. Exp_Bra goes even further and reports on a torchlight march as a protest by the population when it came to a dyke relocation project to give nature more space and implement ecosystem-based solutions: "*die Bevölkerung hat den Deich mit eigenen Händen gebaut*" (the population built the dyke with their own hands). Despite that, Exp_Wil states that he sees a high level of trust in the NLWKN among the population and concludes that any methods would be accepted. Exp_BraOl makes it clear that the population is mostly unaware of the measures taken to date, such as foreshore reclamation and conservation. Only Exp_Nor states that there is awareness among the population and, due to a long tradition of dune management and sand nourishment on the East Frisian Islands, these measures are also highly accepted as NBS.

In conclusion, the analysis of subjective norms among heads of planning reveals a positive and open-minded attitude within professional circles towards NBS in coastal protection. The support of colleagues is recognised as generally encouraging, with an emphasis on alternative methods. However, the pervasive dyke paradigm remains influential, as acknowledged by Exp_Wil. Interest group dynamics present a varied landscape, with conservation organisations generally supporting NBS for land conservation, while dyke associations reflect local political opinions, illustrating a

broader political and interest group dynamic. Tourism and agriculture, notably perceived as a source of land use pressure by Exp_Bra, also play pivotal roles. The views of the heads of planning on societal expectations demonstrate a prevailing fear of dyke breaches, emphasising the challenge of altering existing coastal protection approaches. Exp_BraOI highlights a lack of awareness among the population regarding implemented NBS measures, whereas Exp_Nor notes acceptance on the East Frisian Islands due to a tradition of dune management.

4.3.3. Perceived Behavioural Control

The following section presents the factors such as funding, the complexity of legislation and power dynamics, resources and personnel constraints, as well as the perception of their ability to implement NBS, which lead heads of planning to feel (un)constrained in their behaviour when implementing NBS and present potential challenges.

Funding

The majority of interviewees spoke of sufficient financial resources in coastal protection, and therefore see no restrictions regarding the implementation of NBS. Only Exp_Sta and Exp_BraOI see financial constraints. Exp_BraOI states that there was too little funding for NBS last year and that the foreshore, for example, is not given enough priority in the funding guidelines.

Complexity of legislation and power dynamics

A recurring theme is the complexity of legislation, which influences the actions of the heads of planning about the implementation of NBS. While Exp_Sta and Exp_Nor see no restrictions, Exp_Bra and Exp_BraOI cite challenges in connection with legal frameworks and bureaucratic processes. Exp_Bra feels restricted by all framework conditions, both nationally and internationally. For example, the planning approval procedures in the NLWKN are very lengthy. She also explains that each of the various

stakeholders tries to operate within its legal framework, which makes it extremely difficult to achieve the actual goal of coastal protection. Accordingly, she also sees the coordination processes as a hindrance. In general, there is little room for innovation, which is also hindered by EU directives such as the Water Directive. Exp_BraOl holds a similar view. She points out that the Dyke Act carries less weight "*das Deichgsetz ist kein scharfes Schwert*" (the Dyke Act is not a sharp sword) than international laws such as European nature conservation laws, the Habitats Directive, Natura 2000 or UNESCO, which restricts coastal protection measures. In general, nature conservation directives are often mentioned in connection with restrictions on the implementation of current coastal protection measures.

Another recurring term for regulatory restrictions is the dyke association. For example, Exp_Sta sees itself restricted by the organisation of coastal protection in Lower Saxony, as the NLWKN only works as a planning office and submits a proposal for the coastal protection measure to the dyke association, which can also reject the planning. Accordingly, he sees a lack of power to ultimately implement NBS.

Furthermore, Exp_Sta points out a significant limitation related to the public's potential for protest: "*In Deutschland haben wir das Problem, dass es oft eine unmittelbare Reaktion in Form von Bürgerinitiativen gibt*" (In Germany, we face the challenge that there is often an immediate reaction in the form of citizens' initiatives).

Resource and Personnel Constraints

Future resource shortages and labour shortages were only mentioned as challenges by a small number of respondents. Although the majority stated that there is currently no shortage of resources such as building materials, Exp_Nor and Exp_BraOl look to the future and believe that sand in particular will soon be a problem. Exp_Bra, Exp_BraOl and Exp_Wil, on the other hand, emphasise an impending shortage of skilled workers, with Exp_Bra being more explicit and referring to the demographic change in the Brake region.

Individual Abilities

In general, all respondents see themselves in a position to implement NBS as a coastal protection measure in their area of jurisdiction. However, as described above, Exp_Bra and Exp_BraOl in particular feel restricted by the prevailing regulatory framework.

In summary, it can be said that the perceived behavioural control in the implementation of NBS for coastal protection is characterised by various factors. While the majority of respondents express confidence in sufficient funding and acknowledge no financial constraints, some cite financial constraints and a lack of prioritisation for NBS in funding guidelines. The complexity of the legislation and the power dynamics are proving to be a major challenge, both in terms of implementing existing approaches and in terms of hindering innovation. The legal framework, especially at the international level, and the influence of dyke associations are seen as an obstacle to the current goals of coastal protection. In addition, a possible future shortage of resources and personnel, especially skilled labour, is cited as a challenge.

Table 5: Summary of the results of the interview analysis

Themes	Sub-Themes	Key Findings
Attitudes	Support for NBS	Exp_Sta strongly advocates for NBS, emphasizing the growth of foreshore as crucial. Exp_BraOl sees advantages in reducing dependence on non-natural building materials. Several interviewees recognize benefits of NBS beyond coastal protection, such as tourism, recreation, and nature conservation.
	Emphasis on Sustainability	Sustainability is a recurring theme; Exp_Wil suggests traditional dyke construction fits into the local ecosystem. Exp_Bra advocates for sustainable solutions over NBS.
	Alignment with Natural Processes	Interviewees emphasize aligning coastal protection with natural processes. Exp_Wil stresses learning from nature and broadening the engineer's ecological perspective.

	Context-Dependent Approaches	Recognized the need for context-specific approaches; not viewing NBS as a universal solution. Exp_Nor emphasizes individuality of sedimentation processes on East Frisian Islands, requiring different measures. Exp_Aur acknowledges the potential for a combination of NBS and hard solutions based on site conditions.
	Concerns and Challenges	Despite support, concerns exist: uncertainties in NBS effectiveness, spatial planning limitations, stakeholder coordination challenges. Exp_BraOl notes concerns about lack of funding prioritization for NBS, while Exp_Bra worries about spatial planning requirements and stakeholder coordination.
Subjective Norms	Open-mindedness and Supportive Colleagues	Positive and open-minded attitude of colleagues towards NBS noted by interviewees. Exp_Aur emphasizes serving the purpose of coastal protection regardless of means.
	Interest Group Dynamics and Political Divides	Differing perceptions from various interest groups; conservation organizations generally favor NBS, dyke associations reflect local political opinions. Exp_BraOl mentions restrictions from international laws and nature conservation directives affecting coastal protection measures.
	Societal Expectations and Fear-Driven Narratives	Fear of dyke breaches among the population noted; Exp_Sta highlights this concern. Exp_Bra reports on public resistance in a dyke relocation project for nature-based solutions.
Perceived Behavioural Control	Funding	Majority perceive sufficient financial resources, while a few express concerns about limited funding for NBS and foreshore prioritization in funding guidelines.
	Complexity of Legislation and Power Dynamics	Complexity of legislation and bureaucratic processes hinder innovation in coastal protection; legal frameworks at national and international levels restrict measures. Exp_BraOl cites various international laws affecting coastal protection, while Exp_Bra notes challenges with planning approval procedures and stakeholder coordination.
	Resource and Personnel Constraints	Potential future resource and labor shortages are mentioned, especially for sand and skilled workers. Exp_BraOl and Exp_Wil highlight an impending shortage of skilled labor and resources.
	Individual Abilities	Heads of planning generally perceive themselves capable of implementing NBS; some feel restricted by prevailing regulatory frameworks. Exp_BraOl and Exp_Bra feel constrained by existing legal frameworks.

Chapter 5: Discussion

In the previous sections, the results of this study on the current approach and implementation of the NBS for coastal protection in Lower Saxony were presented. In this chapter, these results are critically analysed and interpreted according to the sub-research questions (sections, 5.2 and 5.3) to decipher the implications of our research in the broader landscape of climate-adapted coastal protection strategies. The results are then summarised to answer the main research question (section 5.4): "What is the current approach to coastal protection in Lower Saxony, including the integration of NBS for climate change adaptation, and what factors influence the decision-making processes of the heads of planning within NLWKN in this context?" Following, recommendations are given (section 5.5).

5.1 Current Approach and Implementation of NBS

The study found that the coastal protection strategy is predominantly anchored in traditional engineering methods, which is reflected in the importance of the Dyke Act and the GPK. The legal framework, in particular the Dyke Act, emphasises a strong reliance on dyke structures with minimal integration of nature-related concepts or explicit climate adaptation measures. Although nature-related elements such as "foreshore" and "protective dunes" are recognised, the main task of the foreshore appears to be dyke protection.

Volumes 1 and 3 of the GPK reinforce this tendency towards technical language by emphasising the importance of hard structures and preventative measures such as dyke heightening. Volume 2 of the East Frisian Islands, on the other hand, offers a more balanced perspective and emphasises a symbiotic relationship between technical and NBS. Measures such as sand nourishment and sand trapping as part of

dune management and for the stabilisation of implemented hard structures already have a long tradition of implementation.

Only Lower Saxony's current climate adaptation strategy shows a greater recognition of the value of natural elements. Accordingly, it recognises the ecological value of the dyke foreshores and mentions the importance of resilient and sustainable strategies, signalling a possible evolution of the coastal protection paradigm.

The dyke is therefore the centrepiece of Lower Saxony's current coastal protection paradigm, around which everything revolves - either in connection with it or for its protection. This central role is enshrined in the Dyke Act and the basic protection strategy of the GPK.

What is striking is the lack of climate change adaptation measures for ecosystems; instead, the identified adaptation measures mainly revolve around raising and widening the dykes. The Lower Saxony Climate Adaptation Strategy is somewhat different. Ecological values are recognised there for the first time and concepts relevant to NBS, such as "building with nature" and the "need for resilient strategies", are mentioned. This indicates a shift in coastal protection. However, the strategy lacks detailed elaboration, leaving the reader with considerable room for interpretation regarding the meaning, application and implementation of these concepts. Furthermore, at the beginning of the strategy for climate-adapted coastal protection, strong reference is made to the GPK and the Dyke Act as the basic references. This implies that there is no substantial change and that climate adaptation is aligned with the existing system: the raising and extension of the dykes.

A look at the historical development of coastal defence can provide some clarification. The construction of the first dykes in the 11th century (see section 4.1.2) created a paradigm that has endured to this day. Technical progress has subsequently improved the safety of such systems even further. Looking at the roots of the Dyke Act (1963) and the GPK (1973), two important observations stand out. Firstly, they

conform to the old water paradigm, which prioritises technical solutions and does not include the wider values of water and ecosystems (Schoeman et al., 2014). Secondly, these frameworks were developed after devastating storm surges and shaped the regional narrative. Both aspects are closely related to path dependency - the tendency to stick to established paths that are characterised by existing values and collective memories. As Tubridy et al. (2022, p. 2) aptly note, „the collective social memory embedded in organisations and reflected in institutions can be a barrier to the adoption of new approaches".

Furthermore, the introduction of NBS is highly dependent on specific contextual factors (Temmerman et al., 2013). This context dependency is particularly evident in the discrepancy between the prevalence of NBS approaches on the East Frisian Islands compared to the mainland and between the individual islands. It is due to the differences in natural conditions and morphodynamics that need to be taken into account when applying NBS.

A remarkable and debatable observation is the mention of the green dyke and its grass cover in Volumes 1 and 3 of the GPK. As the name suggests, this dyke is covered with grass. According to the definition of Schoones et al. (2019), it falls into the category of 'environmentally friendly grey infrastructure' due to the inclusion of vegetation (see Figure 8). However, in Volumes 1 and 3, vegetation is only mentioned to protect the dyke from erosion through root systems. Surprisingly, there is no indication that their potential role in restoring, maintaining or mitigating the loss of ecosystem services is recognised. Furthermore, the Climate Adaptation Strategy does not mention or clarify that these dykes could be planted with diverse seeds, which would be one way to counteract biodiversity loss. This lack of recognition in the strategy raises important considerations about the broad ecological potential of these green dykes and the need for a more holistic approach to their implementation.

5.2 NLWKN's Heads of Planning Attitudes towards NBS

Examining the attitudes of heads of planning towards NBS in coastal protection reveals a differentiated landscape. While there is overwhelming support for NBS, with notable enthusiasm from Exp_Sta, who classifies himself as a strong advocate, other interviewees also recognised the multiple, beneficial values. Emphasising sustainability is a recurring theme. Some interviewees are clearly in favour of NBS and emphasise the importance of the foreshore as a protective element. This support is based less on the natural qualities of the foreshore and more on its role as protection for the dyke. Others, such as Exp_Bra and Exp_Wil, emphasised the sustainability of traditional approaches. Exp_Bra sees a storm surge barrier as the most sustainable solution for their region, as the Brake region is characterised by spatial restrictions and offers little scope for innovation. Exp_Wil further stated that the existing protection system with dykes, due to its historical developments, is the most sustainable approach for their respective regions.

This observation reveals a remarkable pattern: those responsible for planning are deeply rooted in a coastal protection paradigm dominated by the dyke. This orientation can easily be explained by their professional background, as all interviewees are civil engineers who are naturally predisposed to a technical paradigm. The legal framework on which they are based, the Dyke Act and the GPK, also adhere to the dyke paradigm, as already mentioned, and restrict innovations. The interviewees therefore seem to be very well attuned to the path dependency of historical institutions, which is reflected in their responses.

The significance of these results is twofold. Firstly, the general recognition and support for NBS indicates a positive move towards more nature-based coastal protection. However, the views of the heads of planning are characterised by a dyke paradigm, which is primarily based on the existing coastal protection strategy. Furthermore, the concerns and challenges, such as uncertainty about the

effectiveness of NBS and the constraints of spatial planning, nevertheless point to areas where improvements can be made.

5.3 Factors Influencing the Implementation of NBS

5.3.1 Subjective Norms

The subjective norms of heads of planning regarding NBS in coastal protection reveal a generally positive and open-minded attitude within professional circles. Colleagues are seen as supportive, with a recognition of alternative methods. Interest group dynamics present a diverse landscape, where conservation organisations generally support NBS as long as there is no interference in the protected area, while dyke associations reflect local political opinions with much power. Tourism and agriculture, particularly perceived as a source of land use pressure, also play pivotal roles. Societal expectations, however, lean towards a fear of dyke breaches, indicating challenges in altering existing coastal protection approaches.

Although overall support is positive, the influence of the prevailing dyke paradigm is recognised as a potential barrier to the widespread adoption of NBS. The diverse landscape of stakeholder dynamics highlights the complexity of political and social factors influencing perceptions of NBS. Fear-driven narratives about dyke breaches in the past make it clear that changing existing coastal protection concepts is a major challenge.

A certainly crucial aspect is the perspective of society and how it influences the heads of planning. Exp_Sta mentions potential citizen initiatives as slowing down the implementation of measures, not specifically addressing NBS, but seeing it as a potential issue. This can be confirmed by the example of the torchlight protest mentioned by Exp_Bra during the implementation of the nature project "Langwaader Grooden." The project envisaged the relocation of dykes to make room for salt marshes, which led to protests by the local population with torches. This indicates

that there is little support for the NBS as coastal protection, while adherence to the dyke is widespread among the population. As a result, the heads of planning feel restricted in their work, which in turn could hinder implementation. As Burrel et al. (2007, p. 347) state, "Past flooding affects the attitudes and willingness of people to adhere to measures intended to protect them and their property from flooding," showing that the population of Lower Saxony lives within the dyke paradigm, challenging efforts to break free from institutional inertia. Statements from the interviews also highlight another perspective: the population may not precisely know what the NLWKN is doing regarding NBS or what NBS entails. Is it a lack of awareness? A deficit in dialogue? Exp_Wil advocates more dialogue, especially with nature conservation. Here, too, it is important to take the spatial requirements into account. Exp_Nor, who is responsible for the islands, explains that the local population and tourism are very much in favour of the NBS there, as it has a long tradition due to the morphodynamic conditions.

Overcoming the influence of the dyke paradigm requires concerted action to emphasise the benefits and effectiveness of NBS. Differentiated strategies that take into account the specific priorities and concerns of different groups are needed to address the different dynamics of stakeholders. A positive perception of NBS by those responsible for planning offers the opportunity for joint efforts to promote and implement nature-based approaches. The challenges identified from a societal perspective underline the importance of comprehensive communication strategies, including increased dialogue, to close the awareness gap and promote understanding between planners and the public.

In conclusion, the subjective norms among heads of planning present a mixed landscape, with positive attitudes within professional circles but challenges stemming from the prevailing dyke paradigm and diverse interest group dynamics. The fear-driven societal expectations indicate a need for strategic communication to shift perceptions. The varying awareness levels among the population and the acceptance

of NBS on the East Frisian Islands underscore the importance of local context in shaping attitudes. Overall, the findings suggest a need for targeted interventions to foster a more widespread acceptance of NBS in coastal protection.

5.3.2 Perceived Behavioural Control

The investigation of the factors perceived by the heads of planning regarding subjective norms and behavioural control about the implementation of NBS in coastal protection shows a differentiated picture. While the majority of respondents have confidence in the availability of funding and do not feel financial constraints, others, such as Exp_Sta and Exp_BraOl, cite financial challenges and insufficient prioritisation for NBS. The complexity of legislation and power dynamics prove to be a major obstacle affecting innovation and coordination processes. Legal frameworks and the influence of dyke associations are seen as obstacles. In addition, a possible future lack of resources and qualified labour is cited as a challenge.

The complexity of the regulations, particularly about nature conservation, is presented by respondents as a burden on dyke construction. These strict regulations, especially about encroachments on nature conservation areas, represent obstacles to the smooth implementation of the existing concept. This raises a critical question: Can coastal protection strategies that focus more on NBS offer a more harmonious alignment with nature conservation objectives compared to traditional dyke construction? However, the problem with the already existing land use pressure from agriculture would also arise here.

In addition, the future scarcity of resources and an emerging labour shortage within the NLWKN for the implementation of structural measures are mentioned. These barriers are in turn influenced by local conditions and create a differentiated landscape in which the feasibility of coastal protection measures is closely linked to the specific context of each site. Understanding these barriers is crucial for assessing

the adaptability of the current approach and evaluating the potential for integrating NBS into the coastal defence strategy.

At an individual level, the perceived capabilities of staff do not appear to be a major constraint. Participants express a degree of confidence in their individual abilities. However, the broader structural and legal challenges suggest a collective struggle that goes beyond individual capabilities.

These results have two implications. Firstly, perceived control varies between heads of planning, suggesting that tailored approaches are required for NBS implementation. The challenges identified, particularly about legislation, point to areas that require particular attention. Secondly, the anticipation of future challenges, such as labour shortages, implies the need for proactive planning and strategy to ensure long-term success.

In summary, the behavioural control perceived by heads of planning about the implementation of NBS is shaped by various factors. Many express confidence, but the challenges identified emphasise the importance of dealing with financial constraints, complex legislation and external influences, all of which need to be seen in the context of local differences due to local conditions. The realisation that resource and staff shortages are potential future challenges underlines the need for proactive and adaptive strategies in coastal protection planning.

5.4 Answer Main RQ

Lower Saxony's coastal protection strategy is primarily anchored in traditional engineering, with dyke construction taking centre stage. The legal framework, particularly the Dyke Act, reinforces the reliance on hard structures and lacks the explicit integration of NBS or climate adaptation measures. Although certain natural elements such as foreshore, dunes and beaches are recognised, the current strategy is site-specific and mainly revolves around the dyke. Accordingly, Lower Saxony's

coastal protection approach can be characterised as a hybrid approach that considers both technical and nature-based solutions (Schoonees et al., 2019). However, the climate adaptation strategy also reflects the image of the dyke paradigm, which recognises the ecological value of natural elements such as salt marshes but does not contain any defined strategies for NBS. Here, too, the focus is on the dyke: it is to be extended and raised.

The NLWKN heads of planning show a positive attitude towards NBS in coastal protection and thus emphasise a possible shift away from traditional dyke-centred approaches. However, this positive attitude is associated with challenges that are rooted in historical paradigms. Despite the willingness to embrace NBS, there are still uncertainties about its effectiveness, which is a barrier to seamless adoption. The confluence of positive professional attitudes towards NBS and societal fears creates a complex dynamic. Citizens' initiatives and a general lack of public awareness are cited as potential barriers, emphasising the need for comprehensive communication strategies.

In addition, some respondents acknowledge financial challenges and emphasise the pragmatic constraints of implementing NBS. The complexity of legislation, particularly in the area of nature conservation, is cited as a major obstacle, emphasising the need to navigate a complicated legal landscape. Anticipating future challenges, such as resource and labour shortages, underlines the importance of proactive planning to ensure the long-term success of NBS implementation. In essence, while the move towards NBS is positive, the deep-rooted historical context and multi-layered challenges require strategic action for a more effective and comprehensive integration of NBS into coastal defence planning.

5.5 Recommendations

Navigating the complex landscape of coastal protection in Lower Saxony requires strategic efforts to address the persistent dyke paradigm. Historical and natural contextual factors anchor this paradigm and require targeted initiatives for gradual but substantial change. The continuation of a hybrid approach that recognises both engineered and nature-based solutions becomes a cornerstone. This recognition means a variation of coastal protection measures that only relate to dyke-centred strategies, but still serve to protect the dyke.

One of the key recommendations is to raise awareness of the inherent values of natural elements and emphasise the numerous benefits of NBS. Public awareness is crucial and targeted awareness campaigns play a central role in bridging the gap between technical knowledge and societal understanding.

To strengthen adaptation to climate change, there is an urgent need to concretise the term *resilience* within the existing framework. A clear definition of resilience parameters and their integration into strategies will improve the adaptive capacity of coastal protection measures. In addition, a careful revision of the climate change adaptation plan should focus on the concept of "grass sod" to not only prevent erosion but also actively promote biodiversity. This will harmonise strategies with ecological principles and ensure a more sustainable and harmonious coastal protection paradigm.

These recommendations essentially aim to strike a balance between historical continuity and adaptive development and to promote a coastal protection strategy that better fits the existing dyke paradigm while promoting Lower Saxony's ecological diversity.

Chapter 6: Conclusion

To summarise, the study of coastal protection strategies in Lower Saxony offers a nuanced understanding of the prevailing paradigms and the potential for transformative change. Deeply rooted in history, the dyke-centred paradigm is a robust guardian against the encroaching sea and has shaped policy and practice for centuries. This paradigm, enshrined in the Dyke Act and the GPK, has stood the test of time but requires critical reassessment in light of changing climatic challenges.

To summarise, the study of coastal protection strategies in Lower Saxony offers a nuanced understanding of the prevailing paradigms and the potential for transformative change. Deeply rooted in history, the dyke-centred paradigm is a robust guardian against the invading sea and has shaped policy and practice for centuries. This paradigm, which is enshrined in the Dyke Act and the GPK, has proven its worth but needs to be critically reassessed in light of the changing climate challenges.

The current coastal protection strategy is primarily based on traditional engineering expertise, with dyke construction taking centre stage. The legal framework, in particular the Dyke Act, reinforces reliance on hard structures without incorporating NBS or explicit climate adaptation measures. Natural elements such as foreshore, dunes and beaches are recognised, but they enclose the dyke and are overshadowed by its dominance. This established, dyke-centred approach, reinforced by historical legacies and legal foundations, is a powerful barrier to a seamless transition to more sustainable, nature-integrated strategies.

It is worth noting that those responsible for planning in the NLWKN show a positive inclination towards NBS, signalling a possible move away from traditional dyke-centric approaches. The clash between professional openness towards NBS and societal fears highlights a complex dynamic. The public's lack of awareness and potential resistance, expressed in possible citizens' initiatives and protests against

dyke relocations, illustrate the difficult path to a more diverse coastal protection paradigm.

Against the background of these findings, recommendations emerge as guides for gradual but meaningful change. Taking into account the historical and natural context that underpins the dyke paradigm, the thesis proposes a nuanced approach that recognises the intrinsic value of natural elements and the multiple benefits of NBS. Targeted awareness-raising campaigns are crucial to bridge the gap between technical knowledge and public perception. Improving the climate change adaptation plan requires a redefinition of the term *resilience* and an in-depth study of the *grass sod* to actively promote biodiversity.

Overall, this work makes an important contribution to existing knowledge by exposing the nuances of Lower Saxony's coastal protection strategies. It uncovers the remaining influence of the historical, dyke-centred paradigm and sheds light on the challenges associated with the decision-making processes. The identification of barriers, ranging from uncertainties about the effectiveness of NBS to societal fears and financial constraints, provides a nuanced understanding that is crucial for targeted interventions.

Chapter 7: Reflections

This study provides a deep insight into the perceptions of heads of planning of the NLWKN and represents a unique, agency-centred investigation of coastal protection strategies in Lower Saxony, Germany. The combination of in-depth interviews and thorough document research on fundamental strategies and law increases the credibility of the results and provides a nuanced understanding of decision-makers perceptions.

However, some limitations should be noted. Firstly, the findings are context-specific to the coastal protection strategies in Lower Saxony, limiting their generalisability to other regions. Secondly, during the interviews, it became clear that some participants may not have a comprehensive understanding of NBS, indicating a possible awareness gap. In addition, participants often framed their responses within the entrenched dyke paradigm, which made it difficult to gain direct insights into their views on NBS. Furthermore, the sample size of heads of planning within NLWKN, though diverse, might not fully represent the organisation's entirety. A quantitative study involving all NLWKN employees could provide a broader perspective and thus improve the overall validity of the results.

Although this study provides important insights into the views of heads of planning, it represents only one piece of the larger puzzle of NBS implementation in Lower Saxony. A more comprehensive study involving all staff and stakeholders would provide a more holistic understanding. Despite these limitations, the study provides valuable insights into the challenges and opportunities associated with integrating NBS into coastal protection strategies and provides a basis for future, more comprehensive research.

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Appendix

Appendix A: Interview Guide

1. INTRODUCTION

   1.1 Greeting (+ consent for recording)
   1.2 Introduction of myself and my research

2. DATA COLLECTION

   2.1 Introduction of the Interviewee
   • Their position, role, and responsibilities
   • Their background
   • Duration of their work for the NLWKN or in the field of coastal protection

   2.3 Theory of Planned Behaviour

   'ATTITUDES'
   1. What are your **opinions and beliefs** regarding nature-based solutions (NBS) as part of climate adaptation in coastal protection?
   2. How do you assess the **effectiveness and feasibility** of implementing NBS compared to traditional engineering approaches?
   3. What potential **benefits and drawbacks** do you see in the context of coastal protection when it comes to NBS?

   'SUBJECTIVE NORMS'
   4. Could you describe the prevailing opinions and attitudes of **your colleagues** regarding the implementation of NBS in coastal protection?
   5. How **influential are interest groups** such as government agencies, local communities, and experts in shaping the decision-making process for coastal protection measures?
   6. To what extent do you feel **social pressure or the expectations** of others to adopt NBS in your work?

   'PERCEIVED BEHAVIOURAL CONTROL'
   7. What are the main **challenges or obstacles** you see in implementing NBS in coastal protection?
   8. How do factors such as **resource availability, financial constraints, or legal and regulatory frameworks** affect your ability to adopt NBS?
   9. How confident are you in **your ability** to effectively implement and manage NBS?

3. CONCLUSION

Is there anything else you would like to add or discuss regarding the introduction of ecosystem-based solutions in coastal protection?