The Spatial Relation Between the Hinterland and Water Works

Envisioning a Future Where Dikes Become Dams in Hoedekenskerke, Zeeland

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Abstract

The Netherlands, with its intricate history of battling water, faces a pivotal moment as rising sea levels challenge traditional water defenses. This research navigates the intricate landscape of water management, focusing on the vulnerable region of Hoedekenskerke in Zeeland. The central thesis proposes adopting the Living with Water strategy posed by Deltares, urging a paradigm shift towards a symbiotic relationship with nature. The study employs a funneling methodology, ranging from a regional risk analysis to a nuanced exploration of the spatial relationships between the hinterland and water infrastructure. Through a detailed examination of dike failure probabilities and consequences on an urban scale, Hoedekenskerke emerges as a key focal point for urgent adaptation. Beyond their structural function, dikes are revealed as multifaceted elements, representing landscape features, cultural heritage, and symbols of trust. The research concludes with a call to embrace a more adaptive and mindful coexistence with water. And to work towards a future where the Netherlands can chart a resilient course—one that relocates its vulnerable hinterland to the higher ground that the waterworks provide while honoring the intricate legacy of hydraulic engineering that defines its identity.

Key concepts/words

Living with water, waterworks, flood defense, dikes, adaptation, spatial relation.

1. Introduction

1.1 The Netherlands' Ongoing Struggle with Water

The Netherlands has been shaped over time by the dynamic interplay of the sea, rivers, precipitation, and the forces of the wind. The ever-changing interfaces of land and water, shaped by sediment deposits, define the natural landscape, and offer inherent advantages. However, these regions are also particularly vulnerable, facing challenges such as flooding, land subsidence, and severe storms (Meyer et al., 2017). Throughout history, the Dutch have engaged in a relentless battle against water, resulting in the current landscape being a product of extensive human intervention. Centuries of hydraulic engineering, including the construction of dunes, dikes, and dams, have sculpted the land and controlled water within defined boundaries (Bobbink, 2016).

While the Netherlands has thrived and achieved prosperity through its historical water management practices, safeguarding the landscape with water infrastructure, the nation is once again grappling with a complex water challenge. The once advantageous areas, where water served as a source of nutrient-rich soil and a conduit for economic activities, are now under threat (Renaud et al., 2013, Ibáñez et al., 2019). Rising water levels exert escalating pressure on the landscape, undermining the very benefits it once provided. Accelerated sea-level rise, driven by rapid climate change and the alarming melting of the West Antarctic Ice Sheet, has surpassed initial predictions (Haasnoot et al., 2020). The imminent high-water levels are already revealing their consequences, as witnessed in the closing of storm surge barriers in the final weeks of 2023 (Rijkswaterstaat & Ministry of Infrastructure and Water Management, 2024).

The continuous challenge with water represents an ongoing struggle against the forces of nature. The fundamental question that arises is whether it is worthwhile to continue this battle or if there is a risk of succumbing to submersion by Mother Nature.

1.2 Problem Statement

The Ending Life Cycle of Water Defence Systems

The Netherlands is renowned for its innovative hydraulic designs that shield the nation from water. However, with rising water levels and increasing pressure on water infrastructures, water safety has become a daily concern. The Netherlands has an extensive network of water defense systems, with around 18.000 kilometers of dikes inspected annually for damages (Pleijster et al., 2015, p. 18). On average, water defense requires major maintenance every ten to fifteen years (Rijksoverheid, n.d.). To ensure water safety, it is legally mandated that primary barriers, such as dunes, dikes, dams, and storm surge barriers, undergo an assessment against safety standards every twelve years (Rijksoverheid, 2023). The current safety standards have been heightened in response to the findings of the scientific report KNMI National Climate Scenarios 2023. The projected sea-level rise is 34 to 38 centimeters by 2050 and 74 to 124 centimeters by 2100 (Figure 1). However, the upper limit of sea-level rise around 2100 could reach up to 2.5 meters if uncertain processes, such as the destabilization of the West Antarctic Ice Sheet, occur before 2100 (Dorland et al., 2023). According to the most recent assessment, more than half of the primary water defense systems do not meet the new safety standards (Rijksoverheid, 2023).

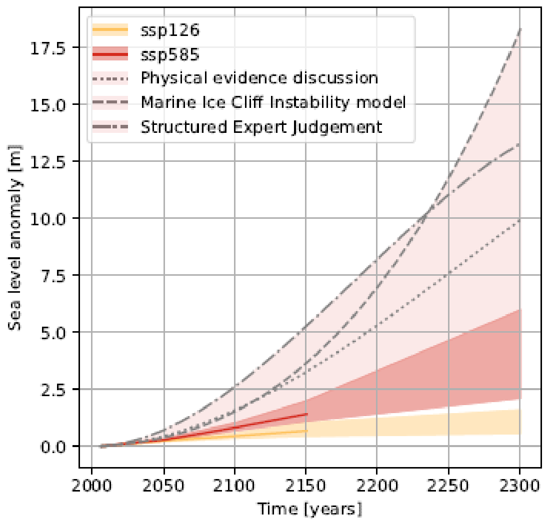

Figure 1: Sea-level scenarios on the Dutch coast (Dorland et al., 2023, p. 170)

Given the current backlog in dike maintenance and over half of the primary water defense systems failing to meet the safety standards, maintaining water defense systems is a losing battle. Sustaining all water defenses across the Netherlands proves impractical in the long term, prompting the need for future strategies addressing sea level rise and water management.

Adaptation Strategy: Living with Water

The Dutch Delta is under pressure as the lifespan of water defense systems comes to an end. The Netherlands needs adaptation strategies concerning the future of water management in the prospect of sea level rise. The independent knowledge institute Deltares specializes in applied research in the field of water and subsurface. Its expertise encompasses various aspects of water management, hydraulic engineering, coastal and river engineering, environmental studies, and geotechnical research. Deltares plays a key role in developing knowledge and solutions related to water safety, infrastructure resilience, and sustainable water use (Deltares, n.d.). In 2019, it initiated the knowledge program on sea level rise. The knowledge institute explores the potential consequences of sea level rise and investigates measures to prepare the country for these impacts in the future. Deltares proposes the following adaptation strategies as long-term solutions for sea level rise: Protect-closed, Protect-open, Seaward Expansion, and Living with Water (Haasnoot et al., 2019).

In both 'Protect' strategies, the focus is on reinforcing the existing water defense system. The Seaward Expansion strategy aims to create new land along the coast and involves abandoning high-risk areas. The Living with Water strategy embraces adaptation to the changing climate and seeks new ways of living in a country where humans harmonize with nature (Timmerman, 2022). The strategy envisions a future where nature shapes the landscape, and humans move in harmony with it. Living with Water, for the Dutch delta, entails migration to higher areas. Primary water defenses are maintained but not strengthened or expanded, meaning that the low-lying landscape will eventually be submerged (Haasnoot et al., 2019).

Over the years, the Dutch have tightly controlled the water within a rigid framework. Recent events indicate that this places stress on the dike network, and it is only a matter of time before a major accident occurs (Delta Urbanism Interdisciplinary Research Group et al., 2023). Due to the deferred maintenance of the failing dike network, it is not wise to continue building on water protection. Instead, this is the moment for the Dutch to choose to return to basics and embody the symbiosis between humans and nature. Therefore, the only solution is to let the Living with Water adaptation strategy guide the future of the Netherlands.

Figure 2: Caricature of the adaptation strategy Living with Water (De Beer et al., 2023)

While the adaptation strategy guides themes such as sea level rise, water safety, and societal feasibility on a national and regional scale (Haasnoot et al., 2020), there is a lack of implementation examples on an urban and architectural scale. The adaptation strategy does not indicate the consequences the approach will have on society.

1.3 Objective & Research Questions

In a past where water and the Netherlands coexisted in harmony, primary water defenses now stand as barriers against the encroaching seawater. However, the changing climate brings a rising sea level, intensifying the pressure on these defenses. It is concerning that over half of the Dutch primary water defenses fail to meet the current safety standards. Additionally, while adaptation strategies offer guidance on themes like adjusting to sea-level rise, they do not delineate the potential consequences on an urban and architectural scale. This marks a pivotal moment, demanding to change course and save the sinking ship that is battling against Mother Nature.

The Dutch landscape will undergo significant changes according to the adaptation strategy Living with Water, as the primary function of water defenses is expected to decline in the future scenario. While water washes away the low-laying urban areas, residents are forced to move to higher areas. To obtain insights into the future of Living with Water, this study examines a single overarching question: **Since the sea levels are rising and the life cycle of water infrastructure is ending, is there a new way in which we can adapt hydraulic infrastructure to live in harmony with water?** Subsequently, through research by design, the graduation project addresses the pivotal question linking it all together: How can the future role of water infrastructure be adapted concerning the hinterland of Hoedekenskerke, Zeeland?

Zeeland, located in coastal southwestern Netherlands, provides an ideal region to examine the consequences of the adaptation strategy Living with Water, as it is highly vulnerable to the results of climate change. Positioned at the mouth of the river delta, the province of Zeeland faces heightened vulnerability to sea level rise, as rising water approaches from two directions. From the North Sea, the sea level rises, allowing saltwater to penetrate further into the province. Inland, the rivers Rhine, Meuse, and Scheldt contribute substantial volumes of water during peak moments. This dual onslaught accentuates the challenges faced by Zeeland, increasing the pressure on water infrastructure (Van Duinen et al., 2014).

As maintenance of primary water defense systems halts, low-lying areas within the Netherlands will eventually become submerged, transforming dikes into dams. The pressure on the primary water defense systems is increasing, consequently elevating the risk of flooding in the hinterland. The repercussions of a breach caused by failure of primary water defense can be monumental, encompassing physical and economic damages, as well as potential loss of lives (Rijksoverheid, 2023). Investigation into the application of the adaptation method Living with Water is necessary to proceed. To address the overarching question of this research, the following sub-questions are raised:

- Which parts of Zeeland are more at risk of flooding based on the probabilistic method?
- What are the consequences of flooding on an urban scale?
- What is the spatial relation between the hinterland and water infrastructure in Hoedekenskerke, Zeeland?

The research offers insights into the prevailing probabilistic water management approach, where the government mitigates flood risk by maintaining water infrastructure. However, the project takes a distinctive perspective, focusing on minimizing the consequences of a flood. This shift in perspective highlights the challenges stemming from the existing political framework.

2. Methodology

The research methodology is both quantitative and qualitative and primarily based on a funneling approach. This method systematically narrows down information through levels of refinement, considering scales from regional to human. The input for the quantitative approach is derived from datasets of the Dutch government and water management institutions, focusing specifically on the province of Zeeland. The findings are presented in the form of diagrams and critical mapping. Additionally, the research takes a qualitative approach to defining the spatial relation between the hinterland and water infrastructure for the case study of Hoedekenskerke. This is done by descriptive research of fieldwork analysis.

Layer 1: Risk Analysis of Dike Failure on a Regional Scale

In Chapter 3.1, the following question is addressed at a regional scale: Which parts of Zeeland are more at risk of flooding based on the probabilistic method? Various quantitative research methods are applied, including data analysis, critical mapping, literature review, and risk analysis.

To evaluate the risk of a dike breach, it is crucial to first establish a knowledge base regarding the most common dike failures, as described by Pleijster et al. (2015). Subsequently, a diagram is generated using data on flood probabilities from the National Water and Flood Information System to pinpoint dike rings susceptible to failure (Rijkswaterstaat; Ministry of Infrastructure and Water Management, 2022). Thirdly, an assessment of dike rings at higher risk of flooding is conducted to identify potential breach locations using the dataset provided by the Legal Assessment Instrumentation for safety assessments of primary water defenses (2019). Subsequently, the same dataset is used to examine the area affected by a potential breach. Based on this evaluation, four urban areas are singled out as being particularly susceptible to flooding in the event of a breach. These areas are selected for a more detailed assessment of the consequences of potential dike failures in Chapter 3.2.

Layer 2: Consequences of Dike Failure on an Urban Scale

Chapter 3.2 addresses the following question: What are the consequences of flooding on an urban scale? Various quantitative research methods are applied, including data analysis, literature review, and risk analysis.

This chapter's objective is to investigate the repercussions of dike failure in the urban areas of Bruinisse, Yerseke, Hansweert, and Hoedekenskerke, commencing with the identification of the definitive probability of failure at potential breach locations. This determination relies on information sourced from the Legal Assessment Instrumentation for safety evaluations of primary water defenses (2019) and is complemented by flood scenarios provided by the province of Zeeland (2014). Once a clearer understanding of the flooded area is established, the consequences of dike failure can be evaluated.

Utilizing documents from Rijkswaterstaat detailing flood scenarios (Boon, 2012; Bart & Bossenbroek, 2011; Bossenbroek & Bardoel, 2014), the consequences of dike failure are assessed for each urban area based on the flood scenario with the highest probability of occurrence. These consequences are categorized into two aspects: economic damage and the number of casualties. The chapter concludes with a diagram illustrating the consequences of dike failure in the four selected urban areas, a visual representation of this diagram is available in Appendix 6.2. Based on this evaluation, one urban area is singled out with the most pressing need for an adaptation strategy. This area is selected for a qualitative assessment of spatial relations between the hinterland and water infrastructure in Chapter 3.3.

Layer 3: Spatial Relationship Between the Hinterland and Water Infrastructure on an Urban Scale

In Chapter 3.3, the following question is addressed considering the human scale: What is the spatial relation between the hinterland and water infrastructure? Various qualitative research methods are applied, including fieldwork and literature review.

This chapter aims to get an in-depth understanding of the spatial relation between the Hinterland of Hoedekenskerke and water infrastructure. Exploring nuances, complexities, and the context surrounding the question. This chapter analyses the dike as a spatial object, a reflection of history, and the faith between water infrastructure and the inhabitants of the hinterland. The dike is a landscape element with a spatial significance based on one's perspective (Hudig et al., 1928). Additionally, the dike embodies Hoedekenskerke's history concerning water management, bearing the imprint of calloused hands that adapted the dike to ever-changing demands. Moreover, the dike resembles the blind trust that inhabitants have in its water-protecting services.

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is there a new way in which we can **adapt hydraulic infrastructure** to live in **harmony with water**?

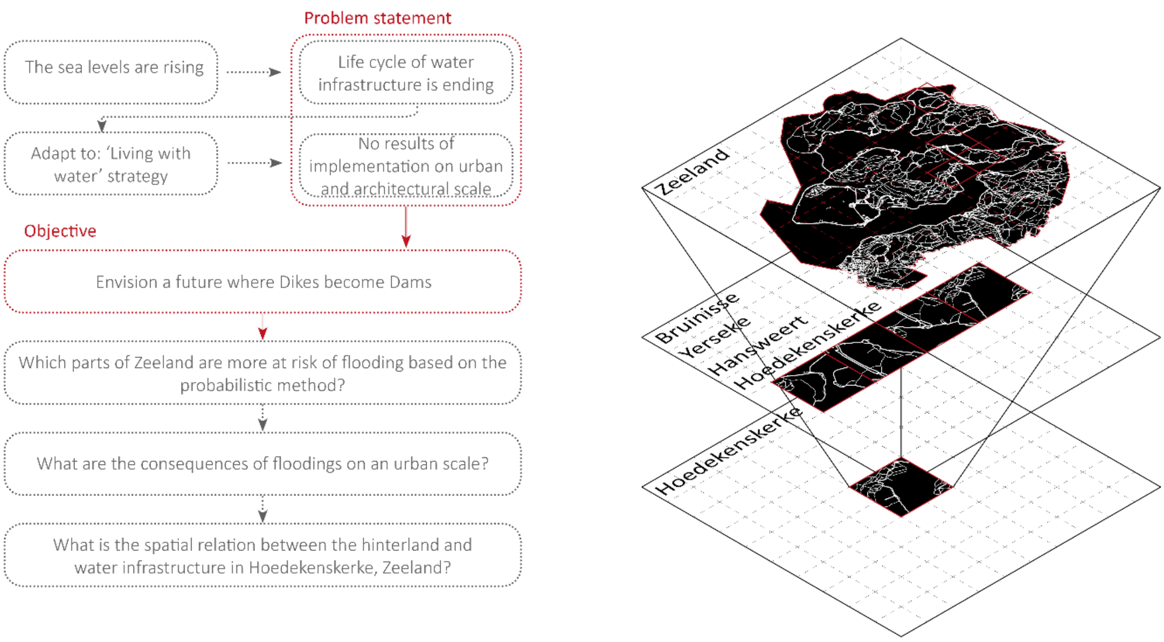

Figure 3: Representation of the Research Structure (Zuidmeer, 2024b)

3. Research

3.1 Risk Analysis of Dike Failure on a Regional Scale

To evaluate the risk of a dike breach, it is crucial to first establish a knowledge base regarding the most common dike failures, as described by Pleijster et al. (2015). Subsequently, a diagram is generated using data on flood probabilities from the National Water and Flood Information System to pinpoint dike rings susceptible to failure (Rijkswaterstaat; Ministry of Infrastructure and Water Management, 2022). Thirdly, an assessment of dike rings at higher risk of flooding is conducted to identify potential breach locations using the dataset provided by the Legal Assessment Instrumentation for safety assessments of primary water defenses (2019). Subsequently, the same dataset is used to examine the area affected by a potential breach. Based on this evaluation, four urban areas are singled out as being particularly susceptible to flooding in the event of a breach. These areas are selected for a more detailed assessment of the consequences of potential dike failures.

The Principle of Dike Failure

The water defenses in the Netherlands do not constitute a waterproof system. Safety standards against floods are defined per dike ring in the Water Act. This legislation focuses on preventing or mitigating floods, waterlogging, and water scarcity, while also protecting and improving the quality of water systems to fulfill various societal functions. (Water Act, 2024). Each dike ring has a specified exceedance probability that the water defenses must withstand by law. The norm frequency depends on the nature of the threat, the area to be protected, and the value the area represents (Water Act Article 2.2 – 2.7). The water defense system fails when the water load surpasses the strength of the defense (Rijkswaterstaat Project Bureau VNK, 2014). Failures can occur through various mechanisms, with the most common being overflow and wave impact, sliding of the inner slope, and erosion due to damage to the lining, and piping (Pleijster et al., 2015).

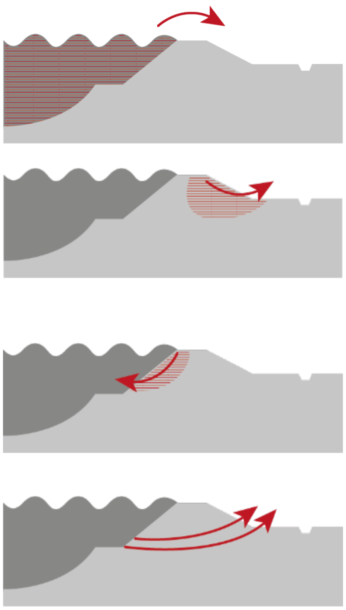

Figure 4: Dike Failure Mechanisms (Zuidmeer, 2024a)

Overflow and wave impact can cause damage to the inner slope of the dike. If this results in the exposure of the dike core, erosion may occur, potentially leading to a dike breach (Pleijster et al., 2015 p. 181).

The inner slope of a dike can slide under the influence of water pressure during high water. The likelihood of this happening is significantly dependent on the substrate; in the case of soft clay or peat layers, the risk of sliding increases (Pleijster et al., 2015 p. 181).

Damage to the lining can lead to erosion. This failure mechanism is particularly relevant in areas with powerful waves, such as along the coast. In the River Area, the likelihood of damage and erosion is less due to less powerful wave action (Pleijster et al., 2015 p. 181).

During prolonged high water, water can flow beneath the dike. If the water flow carries sand, it creates pipes that undermine the dike. The dike will then subside, losing its water-retaining capacity (Pleijster et al., 2015 p. 181).

Identification of Areas at Risk of Dike Failure

The Netherlands is protected against high water by multiple dike rings, forming a safety system to prevent the entire country from being submerged in the event of a dike breach. The dike ring is comprised of primary water defenses designated in the Water Act. The dataset on flood probabilities from the National Water and Flood Information System is used to generate a diagram posing the risk of dike failure per dike ring (Rijkswaterstaat; Ministry of Infrastructure and Water Management, 2022) (Appendix 6.1). The results in Figure 5 show the probability of a dike failure per dike ring. Consequently, the dike rings of Schouwen-Duiveland, Zuid-Beverland West, and Zuid-Beverland East are further considered in this research.

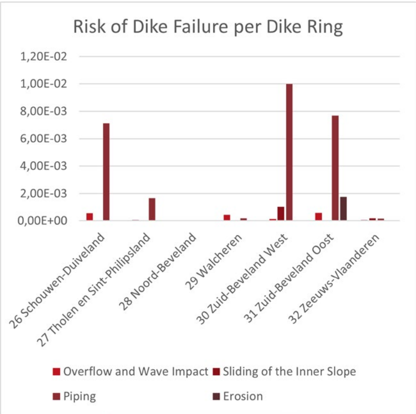

Figure 5: Risk of Dike Failure per Dike Ring (Rijkswaterstaat; Ministerie van Infrastructuur en Waterstaat, 2022)

The analysis of dike rings is extended using the dataset supplied by the Legal Assessment Instrumentation for the safety evaluations of primary water defenses (2019). This dataset indicates the norm frequency of dike segments, revealing those segments within the primary defense system that fall short of current safety standards. In the event of a dike breach, water permeates the hinterland at the breach location. How water traverses the area is contingent upon the breach's location, size, and elevation of the area. This determination influences the susceptibility of the hinterland to flooding (Rijkswaterstaat Project Bureau VNK, 2014). Figure 6 illustrates the areas at the highest risk of flooding based on information from the Legal Assessment Instrumentation for Safety Evaluations of Primary Water Defenses (2019).

For the ongoing research, it is imperative to identify areas with a heightened probability of dike breaches to comprehensively assess the repercussions of such an occurrence. Consequently, four urban areas are chosen for further investigation into the consequences of a dike failure. The cities of Bruinisse, Yerseke, Hansweert, and Hoedekenskerke, identified as the urban areas most vulnerable to flooding, serve as specific case studies in the following sections of this paper.

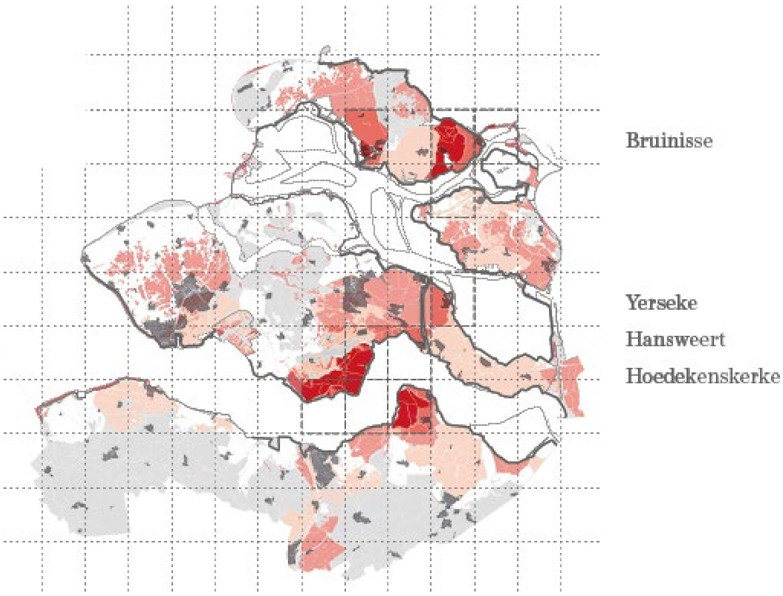

Figure 6: The Risk of Flood in Zeeland (Zuidmeer, 2024e)

3.2 Consequences of Dike Failure on an Urban Scale

In the preceding chapter, the villages Bruinisse, Yerseke, Hansweert, and Hoedekenskerke were chosen based on their geographical location within a high-risk flood area. This chapter's objective is to investigate the repercussions of dike failure in these urban areas, commencing with the identification of the definitive probability of failure at potential breach locations. This determination relies on information sourced from the Legal Assessment Instrumentation for safety evaluations of primary water defenses (2019) and is complemented by flood scenarios provided by the province of Zeeland (2014). Once a clearer understanding of the flooded area is established, the consequences of dike failure can be evaluated.

Utilizing documents from Rijkswaterstaat detailing flood scenarios (Boon, 2012; Bart & Bossenbroek, 2011; Bossenbroek & Bardoel, 2014), the consequences of dike failure are assessed for each urban area based on the flood scenario with the highest probability of occurrence. These consequences are categorized into two aspects: economic damage and the number of casualties. The chapter concludes with a diagram illustrating the consequences of dike failure in the four selected urban areas (Figure 7), a visual representation of this diagram is available in Appendix 6.2. Based on this evaluation, one urban area is singled out with the most pressing need for an adaptation strategy. This area is selected for a qualitative assessment of spatial relations between spatial objects and water infrastructure.

Bruinisse

Bruinisse, a village with 3.790 inhabitants situated in dike ring 26, also known as Schouwen-Duiveland (CBS, 2024a), faces a significant flood risk primarily from the failure mechanism of piping. The calculated flood probability for the most probable breach location affecting Bruinisse is once every 520 years (Boon, 2012, p. 49). In the event of a flooding occurrence in the dike stretch adjacent to the Bruinisse polder, the resulting damage is estimated to be between 300 - and 370 million euros. This damage is attributed to the destruction of buildings and the main road N59 adjacent to the village (Boon, 2012, p. 103).

A flooding event would pose a threat to the residents, with a minimum of 40 victims and a maximum of 195 (Boon, 2012, p. 103). The evacuation possibilities are crucial in determining the number of victims during a flood. However, for Dike Ring Area 26, the effectiveness of preventive evacuations is hampered by the short warning time for high water during storm conditions. On average, only 26 percent of the population can be evacuated preventively in the event of a flood (Boon, 2012, p. 14).

Yerseke

Yerseke, one of the larger villages in Zeeland with 7.140 inhabitants situated in dike ring 31, known as Zuid-Beveland East (CBS, 2024d), faces a significant flood risk centered around the Breedsendijk breach location. This specific dike segment has a calculated flood probability of once every 240 years, primarily due to the failure mechanism of piping (Bart & Bossenbroek, 2011, p. 37). In the event of a breach, the immediate consequence is the flooding of the polder directly behind the breach location, with water depths reaching almost four meters. The economic impact of a breach at Breedsendijk is substantial, with minimum estimated damage at 605 million euros and maximum damage at 765 million euros. This elevated economic impact is attributed to the extensive size of the polder behind this breach location, characterized by grasslands and a few agricultural areas. Additionally, a regional road, the N670, would suffer damages from the flood (Bart & Bossenbroek, 2011, p. 55).

Despite the economic implications, damage to the buildings in Yerseke is limited as the village is situated at a higher ground level compared to the surrounding area. However, a flooding event would pose a threat to the residents, with a minimum of 40 victims and a maximum of 375 (Bart & Bossenbroek, 2011, p. 55). The number of residents at risk varies based on evacuation scenarios, with the highest casualties projected in an unexpected flooding situation where zero percent of the residents can be evacuated, and the least number of casualties occurring in a scenario where 72 percent of the residents can be evacuated (Bart & Bossenbroek, 2011, p. 47).

Hansweert

Hansweert, a village with 1.725 inhabitants located in dike ring 30, named Zuid-Beveland West (CBS, 2024b), faces a considerable flood risk primarily attributed to the failure mechanism of piping. The calculated flood probability for the most probable breach location affecting Hansweert is once every 1.800 years (Bossenbroek & Bardoel, 2014, p. 47).

In the event of a flooding occurrence in the dike stretch adjacent to the Hansweert polder, the water flows directly toward Highway A58, resulting in estimated damages ranging between 330 - and 390 million euros. The variability in these numbers is influenced by the water level in the moment of flooding. Higher water levels would lead to the overflowing of the area behind the A58, causing additional villages to incur economic damages (Bossenbroek & Bardoel, 2014, p. 64). The maximum water depths in Polder Breede Watering range from 5.6 to 6.4 meters, contributing to a high number of victims estimated between 265 to 1.760 victims. The primary cause of casualties is attributed to high water ascent rates combined with substantial water depths (Bossenbroek & Bardoel, 2014, p. 64).

However, it is essential to note that in 2023, construction commenced on the dike to structurally enhance its water-retaining function (Rijkswaterstaat, 2023). Consequently, the current structural status of the dike is unknown. As there is no other dike area posing a threat to the village, Hansweert will not be considered for further research.

Hoedekenskerke

Hoedekenskerke, a small town with 715 inhabitants located in Dike Ring 30, named Zuid-Beveland West (CBS, 2024c), confronts a significant flood risk centered around the Baarlandpolder breach location. This specific dike segment has a calculated flood probability of 1/100 per year, primarily due to the failure mechanism of piping (Bossenbroek & Bardoel, 2014, p. 48).

In the event of a breach, the immediate consequence is the flooding of the polder directly behind the breach location and the village of Hoedekenskerke. The economic impact of a breach at the Baarlandpolder is substantial, with minimum estimated damage at 70 million euros and maximum damage at 410 million euros. This elevated economic impact is attributed to the large amount of agriculture situated behind the dike and the railway infrastructure that would suffer severe damage (Bossenbroek & Bardoel, 2014, p. 66). The village is also impacted, causing the number of victims to vary from 5 to 160 (Bossenbroek & Bardoel, 2014, p. 67).

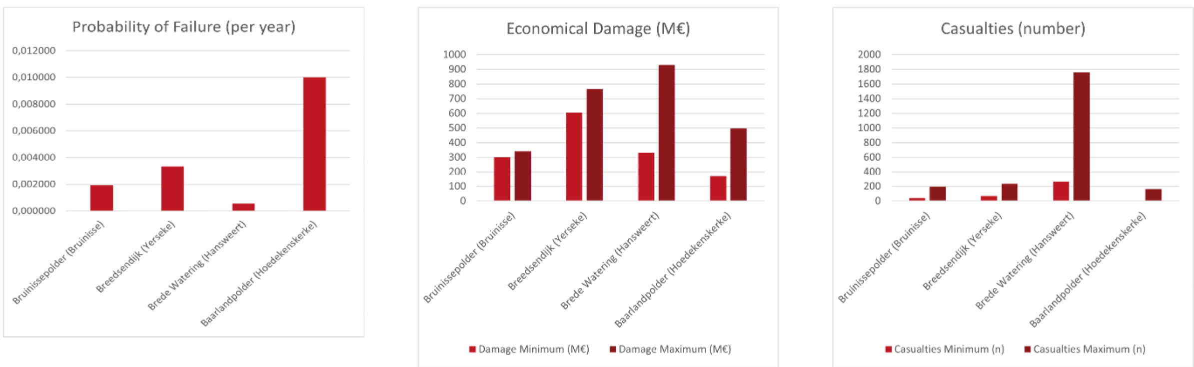

Figure 7: Results of the consequences of Dike Failure in four Urban Areas (Rijkswaterstaat; Ministerie van Infrastructuur en Waterstaat, 2022; Provincie Zeeland, 2014; Boon, 2012; Bart & Bossenbroek, 2011; Bossenbroek & Bardoel, 2014)

For the ongoing research, it is crucial to pinpoint the area with the most urgent need for the implementation of an adaptation strategy. Urgency is determined by combining the probability of a dike failure and the resulting consequences. Figure 7 presents the insights obtained in this chapter (Appendix 6.3). Hoedekenskerke emerges as the urban area with the highest likelihood of a flood. While Hansweert faces the highest economic damage and casualties. However, the dike segment posing this threat is currently under construction, leading to the exclusion of this village from further consideration.

Yerseke follows closely as the second highest in terms of economic damages and casualties. However, given Yerseke's population size, this outcome is not unexpected. When considering casualties as a percentage of the current inhabitants, Hoedekenskerke significantly outpaces others. Given the village’s high probability of a flood occurrence and its higher percentage of casualties, the urban area of Hoedekenskerke is the primary focus of the subsequent chapter in this research.

3.3 Spatial Relationship between the Hinterland and Water Infrastructure in Hoedekenskerke, Zeeland

This chapter forms an in-depth understanding of the spatial relation between the Hinterland of Hoedekenskerke and water infrastructure. Exploring nuances, complexities, and the context surrounding the question. This chapter analyses the dike as a spatial object, a reflection of history, and the faith between water infrastructure and the inhabitants of the hinterland. The dike is a landscape element with a spatial significance based on one’s perspective (Hudig et al., 1928). Additionally, the dike embodies Hoedekenskerke’s history concerning water management, bearing the imprint of calloused hands that adapted the dike to ever-changing demands. Moreover, the dike resembles the blind trust that inhabitants have in its water-protecting services.

The Dike as a Landscape Element

The dike serves as a multifaceted landscape element, defining the spatial realm and connecting areas. Its spatial significance varies based on one's perspective, as described in the influential publication ‘The Future Landscape of the Zuiderzee Polders' (Hudig et al., 1928). Approaching Hoedekenskerke by car from the north (Appendix 6.4), the sea dike rises eight meters above ground, forming a spatial boundary grazed by sheep. Across the road lies the marshy natural landscape, the ‘inlaagpolder,’ excavated as a precautionary measure for a secondary dike in case of a breach. Following along, the dike takes a sudden curve—a remnant of an old creek, the Ee—where the initial settlement of the current village began. (Eshuis & Brader, 2020, p. 12). Today, this bend in the dike connects sea and inland waters. At the dike's base stands a pumping station that has been redirecting water from the polders around Hoedekenskerke back to the sea since 1952 (Netherlands Pumping Stations Foundation, n.d.). The road leads to a junction, with the village entrance to the right and the ‘Nieuwe Veerweg’, established during the relocation of the ferry pier in 1914, to the left. This road ascends gently to the dike's highest point, altering the perspective. On one side, the view of the sea; on the other, the village partially enclosed by dikes. The dike, once a landscape division, now serves as a connecting element, making landscape coherence visible and linking the local to the regional.

Figure 8: Changing Perspectives of the Sea Dike in Hoedekenskerke (Zuidmeer, 2023)

The Dike as Heritage

Heritage intertwines the past, present, and future, preserving traces deemed significant from the past in the present and striving to preserve them for the future. Dikes embody poetry in a land shaped by human effort. Unlike mountainous landscapes formed by powerful glacial forces, the Dutch landscape emerged through the physical toil of people wielding shovels and wheelbarrows to keep water at bay and reveal the land beneath. Over time, dikes adapted to new demands, bearing the imprint of calloused hands. Rising water and sinking land necessitated higher dikes. While the earliest sea dikes defended the land, more dikes emerged to reclaim new agricultural ground. The most historic remnants date back to 1250 (*Nationale Basisbestanden Primaire Waterkeringen*, 2017).

The economy owes its existence to the dike, shaping and protecting the land. Behind the dike lies Hoedekenskerke, thriving through agriculture and ferry services but also grappling with floods. After the ferry service closure in 1972, the village declined, with the population more than halving since 1970 (PSDnet, 2023; CBS, 2024c). Aging residents further accentuate the village's challenges. The dike’s shape and hidden layers narrate the history of the hinterland. Therefore, preserving old, non-functional dikes is crucial for the landscape's historical visibility.

The Dike and Blind Trust

The dike symbolizes resilience. People feel secure behind the dike, investing and residing in the hinterland. It underscores that managing risks and uncertainties is a human endeavor. The Dutch have a profound trust in the centuries-old water protection system and the authorities maintaining it. Evacuation plans are nonexistent, and there are no insurance policies against water-related issues. Living without fear of water is a luxury, as hinterland residents place blind trust in the dike's water safety. However, upon reviewing the current state of the primary water barrier (Wettelijk Beoordelingsinstrumentarium, 2019), it is challenging to determine whether it is trust or sheer ignorance.

4. Conclusion

In a past where water and the Netherlands coexisted in harmony, primary water defenses now stand as barriers against the encroaching seawater (Bobbink, 2016; Delta Urbanism Interdisciplinary Research Group et al., 2023). However, the changing climate brings a rising sea level, intensifying the pressure on these defenses (Haasnoot et al., 2020). It is concerning that over half of the Dutch primary water defenses fail to meet the current safety standards (Rijksoverheid, 2023). This marks a pivotal moment, demanding to change course and move with water instead of fighting against it.

The central proposition of adopting the Living with Water adaptation strategy emerges as a compelling and transformative solution. Rather than persisting in an unsustainable battle against the forces of nature, the strategy advocates for a paradigm shift, a return to a symbiotic relationship between humans and the environment. This approach recognizes that primary water defenses are maintained but not strengthened or expanded, meaning that the low-lying landscape will eventually be submerged (Haasnoot et al., 2020).

The funneling methodology employed in this research spans risk analysis for the province of Zeeland. Followed by an analysis of the consequences posed by flood on an urban scale, culminating in the identification of Hoedekenskerke as a focal point for urgent adaptation. By evaluating the probability of dike failure and assessing potential consequences, this study results in the choice of Hoedekenskerke as a case study for the last chapter (Rijkswaterstaat; Ministerie van Infrastructuur en Waterstaat, 2022; Provincie Zeeland, 2014; Boon, 2012; Bart & Bossenbroek, 2011; Bossenbroek & Bardoel, 2014).

The final layer of analysis delves into the spatial relationship between the hinterland and water infrastructure in Hoedekenskerke. Beyond their physical function, dikes are revealed as multifaceted elements: landscape features, repositories of heritage, and symbols of trust. The dike's historical significance emphasizes the importance of finding the future function of these structures, even though their water retaining function will be lost in the future, for both cultural and landscape visibility.

In conclusion, the Living with Water adaptation strategy is not merely a theoretical proposition but a practical, sustainable path forward for Hoedekenskerke and analogous regions. This research advocates for a holistic understanding of the spatial, historical, and cultural dimensions intertwined with the water challenge. By embracing a more adaptive and mindful coexistence with water, the Netherlands can chart a resilient course into the future, one that relocates its vulnerable hinterland to the higher ground that the waterworks provide, while honoring the intricate legacy of hydraulic engineering that defines its identity. This thesis invites stakeholders, policymakers, and communities to consider this adaptive strategy as an integral part of the nation's evolving narrative in the ongoing battle against water.

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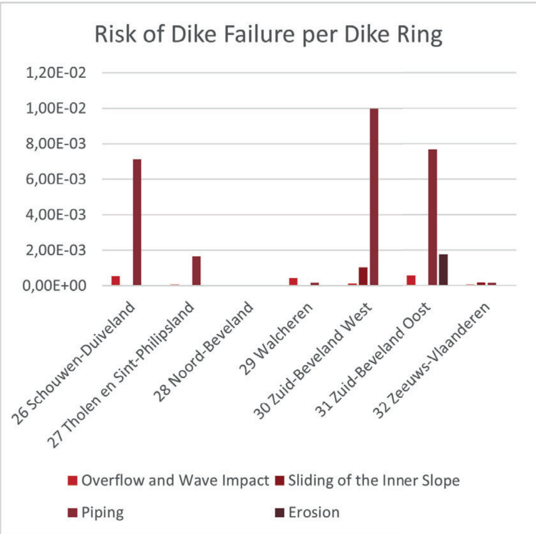
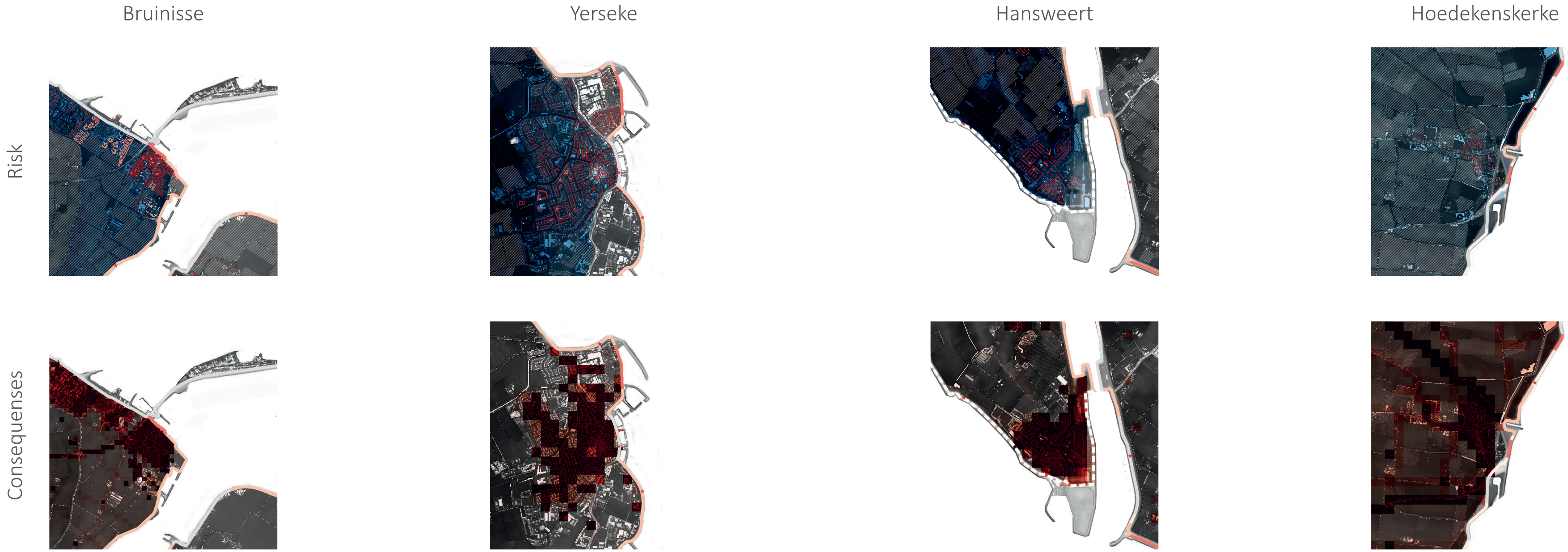
Appendix 6.1

Dike Ring	Probability of Failure (per year)			
	Overflow and Wave Impact	Sliding of the Inner Slope	Piping	Erosion
26 Schouwen-Duiveland	1/1.800	1/83.000	1/140	0
27 Tholen en Sint-Philipsland	1/6.300	1/200.000	1/600	0
28 Noord-Beveland	1/140.000	1/33.000	1/76.000	0
29 Walcheren	1/2.300	1/180.000	1/5.300	0
30 Zuid-Beveland West	1/7.300	1/960	> 1/100	0
31 Zuid-Beveland Oost	1/1.700	1/32.000	1/130	1/570
32 Zeeuws-Vlaanderen	1/15.000	1/5.300	1/5.900	0



(Rijkswaterstaat; Ministerie van Infrastructuur en Waterstaat, 2022)

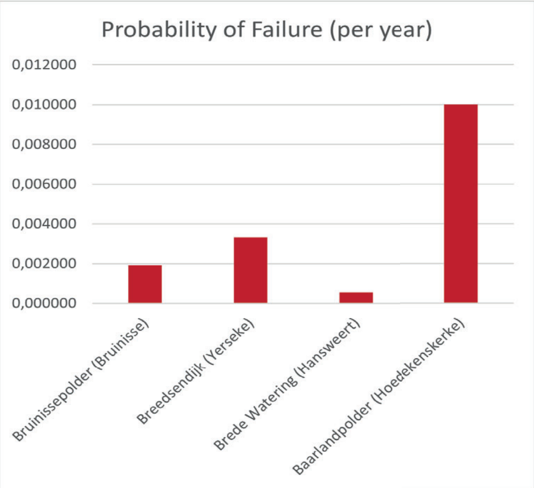
Appendix 6.2

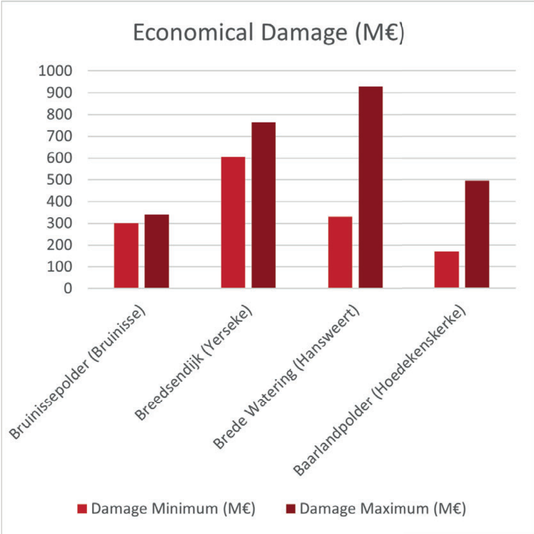


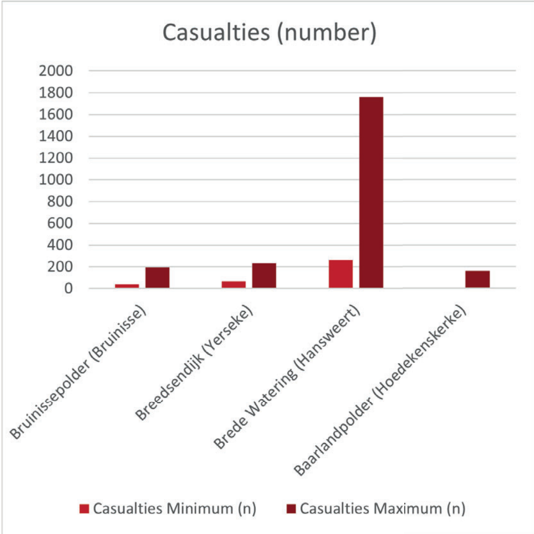
(Zuidmeer, 2024c)

Appendix 6.3

Breach Location	Probability of Failure (per year)	Damage Minimum (M€)	Damage Maximum (M€)	Casualties Minimum (n)
Bruinissepolder (Bruinisse)	0,001923	300	340	40
Breedsendijk (Yerseke)	0,003333	605	765	65
Brede Watering (Hansweert)	0,000556	330	930	265
Baarlandpolder (Hoedekenskerke)	0,010000	170	495	5







(Rijkswaterstaat; Ministerie van Infrastructuur en Waterstaat, 2022; Provincie Zeeland, 2014; Boon, 2012; Bart & Bossenbroek, 2011; Bossenbroek & Bardoel, 2014)

Appendix 6.4

(Zuidmeer, 2024d)