Exploring the Robustness of Current Development Directions of Zwolle Region in Distant-Future Sea Level Rise Scenarios

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Abstract

Foresight used in the current developments of the Zwolle region limits itself to short-and-medium term foresights. Based on the hypothesis that prioritizing decision-making based on short-term, risks and opportunities may inadvertently omit crucial factors, while a focus on longer-term perspectives enables a more comprehensive understanding of complexity and uncertainty, questions the robustness of the developments. Therefore, this thesis conducted a case-study to assess the durability of current and novel development directions of the Zwolle Region focussed on distant-future sea level rise scenarios to amplify anticipatory consciousness, and therefore broadening the scope of policy directions for decision makers. For this, this thesis turned to the question: *How robust are the current proposed development directions of the Zwolle Region compared to Sea Level Rise scenarios up to 2300?* Based on a systematic grey literature an overview of the novel development directions of the region have has been created. According to a Dynamic Adaptive Policy Pathways analysis, the developments were compared to distant-future sea level rise scenarios that were based on interim KNMI sea level rise scenarios and semi-structured expert interviews. Following the analysis, it was determined that the proposed development directions assume the existing condition of the regional water system. Given the projected rise in water levels due to SLR, which is expected to significantly impact the regional water system, leading to increased moisture and frequent flooding, this thesis asserts that the current proposed developments lack robustness.

Key words: *Case study, Scenarios, Sea level rise, Urban development, Spatial planning, Climate change, Climate adaptation, Decision making, Long-term thinking, Distant Future.*

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1. Introduction

1.1 Climate Change Beyond 2100: a call for long-termism

We are living in the Anthropocene; "*the era that is completely influenced by man*" (van Hattum, 2022, p. 48). The impact of humans on the climate and environment are evident (Eyring, 2021; IPBES, 2019), and planetary boundaries are being globally encountered (Steffen, et al., 2015). The impact of humans on the landscape is clearly apparent in the Netherlands. Since about a thousand years ago, they have been modifying the landscape to their own advantage; resulting in a densely populated and prosperous delta. However, the intensive utilization and modification of the landscape is finding its boundaries (Deltares et al., 2021). Continually growing demands and external influences such as the changing climate exert even more pressure on the natural and thus our man-made systems. Increasing weather extremes, including droughts, extreme precipitation, and heatwaves, along with sea-level rise, economic development, population growth, and changes in land-use driven by these developments (such as the energy transition and urbanization) further push the current system to its limits, with in particular the very basis of our environment: the water and soil systems (*Parliamentary paper II,* I E NW/BSK-2022/283041*,* 2022).

In recent years, researchers, strategic policy advisors, and designers have been active in sharing their visions and views of possible futures of the Netherlands (i.a. Hamers et al., 2023; van Hattum, 2022; Kuiper Compagnons, 2021; LOLA Landscape Architects, 2020). Also, within the Dutch government, more elaborate future planning has been introduced. With the Environment and Planning Act (to be implemented on January 1st, 2024), the Netherlands aims to anticipate the current and future challenges. National, regional, and local governance have developed or are developing a long-term strategic vision for the entire physical environment (consolidated version Environment and Planning Act, article 3.1, October 4th, 2022). Within the visions of different governmental bodies, climate change is a central reoccurring topic that is directly related to other challenges (e.g., energy, housing). The climate change foresights primarily rely on the KNMI climate scenarios (Koninklijk Nederlands Meteorologisch Instituut [KNMI], 2014), which extend their projections up to the year 2100.

However, consequences of climate change such as sea level rise (SLR) are expected to further develop beyond 2100, especially when greenhouse gasses are not rapidly and significantly reduced (Lyon, et al., 2021). Lyon, et al. (2021) argue that foresights based on a scale of a century are short sighted. They advocate for *"more sophisticated climate and Earth system modelling beyond 2100"* as these *"longer-term projections are critical to preparing the way for a peaceful and habitable Earth in the coming decades and centuries"* (p. 357). In addition, according to Haasnoot et al. (2021), adapting to the changing climate has become inevitable. Overlooking (long-term) adaptation commitment for climate impacts beyond 2100 "*could lead to different, possibly high-regret, decisions"* (p.10) (e.g., costly retrofitting of infrastructure, generating stranded assets, less time adapting at greater costs). Moreover, the decision-making process, development of new technologies or implementations can take up decennia before they are realized (Hermans et al., 2023).

Yet in practice, current governance is still largely influenced by established short-termism such as political and cooperate interests tempting benefit more from short-term gains (e.g., re-election, quarterly reports) than long-term sustainability (Krznaric, 2021). In addition, by extending the time horizon, decisionmakers and politicians must deal with various stakeholders' interests that develop over time and may compete, increasing the complexity of decision making and the uncertainty of its outcomes. Thus, comfort can be found in short-term decisions (Marchau et al., 2019).

Nevertheless, decisions made today will translate into future situations. Long-term thinking pushes people to think beyond their own lifetime (*"inheritance mentality"*) whilst facing the challenges of today, forming a tug-of-war between long- and short-term thinking (Krznaric, 2021, p.12). Moreover, considering 'the future' amplifies anticipatory consciousness and therefore the opportunity to develop *"more creative strategies,* [...] *new product opportunities and create and share vision for organizational change"* (Giaoutzi & Sapio, 2013, p.4) to deal with these uncertainties.

Therefore, this thesis hypothesises that prioritizing decision-making based on short-term, risks and opportunities may inadvertently omit crucial factors, while a focus on longer-term perspectives enables a more comprehensive understanding of complexity and uncertainty. This, in turn, empowers individuals and entities to better anticipate and navigate future situations, thereby gaining a strategic advantage in adapting to developing circumstances. To test this hypothesis, research is conducted using the development of Zwolle Region as a case study.

1.2 The Region of Zwolle: Towards a Climate-Proof, Attractive and Economically Prosperous Delta Region

The Region of Zwolle is formed by an administrative collaboration network of 22 municipalities from 4 provinces and is located in the IJssel-Vecht Delta. In the coming years, the region aims to develop an economically attractive, liveable, accessible, and climate adaptive delta region (Regio Zwolle, 2022; 2023). In 2021, the region was accepted as program area for the 'National Strategy on Spatial Planning and the Environment' (Nationale Omgevingsvisie [NOVI]). Together with 4 waterboards, 4 government departments, research institutions, education and social institutions, forces are joined to tackle national and regional challenges.

The region of Zwolle, the IJsselmeer, Zwarte Water, Vecht & Sallandse Weteringen form the main water systems. It contains a variety of wet, dry, elevated, and low laying areas. Forest, brook- and river, polder, and meadow landscapes make up its natural landscape characteristics. At the centre, the city of Zwolle can be found, being the most urbanized area of the region. Other medium-sized urban centres and villages make up for the rest of the residential areas. Furthermore, the region experiences an above average growth in economic activity, employment, and population (Regio Zwolle, 2023). At the same time, the region is undergoing various developments: Due to national housing demands, a minimum of 50.000 newly build dwellings are planned to be realised until 2040; its growing broad economy must keep up with larger transitions such as circularity, the energy transition and digitalisation. Moreover, aging and dejuvenation in the region pressure the required labour; The region plays a central role in the mobility network of the Netherlands, connecting the northern provinces with the rest of the country; the water systems of the region reaching its limits and is sensitive to the changing climate. To ensure the sufficient water supply throughout the region and flood safety, the ballans of the water- and soil-systems should be recovered (Regio Zwolle, 2023).

Like other governance bodies in the Netherlands, the region has been exploring strategies for its development to deal with these challenges. These current environmental visions and plans on spatial planning and the environment are still in a developing and exploratory phase as the Environmental Act has yet to come into effect at the time of writing this thesis. Therefore, in this thesis, these visions and plans will be referred to as *(novel) development directions* rather than policies. With current (novel) development directions, the region aims to strengthen and further expand its economy as 4th economic region of the Netherlands (Regio Zwolle, 2022). With this ambition, current plans focus increasing the number of dwellings in the region and future-proving its mobility network, whilst adapting to climate change in anticipation to 2040 (Regio Zwolle, 2023). However, as discussed in the previous section, would only looking at 2040 not be shortsighted? KNMI foresights that look beyond

2040 up to 2300 do not exclude the probability of 2 to 5m SLR (KNMI, 2021). In contrast to the current situation, figure 1 presents a quick visualisation of how the Netherlands would look with 2 and 5m SLR without its flood defences. Considering the Region of Zwolle in these scenarios, would the current proposed development directions still be a rational strategy for the region's development?

Figure 1

Areas flooded with a sea level of 2m and 5m.

Note: Areas within the Netherlands that would flood when no flood defences are in place based on land elevation: A) Map of the Netherlands (red: areas <2m NAP; light green: areas <5m NAP; dark green: areas >5m NAP). B) Map zoomed in on the Region of Zwolle.

1.4 Problem statement

Rapid developments such as urbanization, economic growth, and its key role in the national motility infrastructure in combination with its climate change sensitive deltaic location are introduced as the main challenge in the region. It is noticeable that used foresights are ranging from the years 2030 to 2075. However, as mentioned in the previous section, there can be argued that this timeframe is short sighted (Lyon et al., 2021). Interim insights on climate change developments of the Netherlands present SLR-scenarios along the Dutch coast up to the year 2300. These SLR-scenarios are ranging from 0,3 meters in low scenarios up to 17 meters in highly extreme and uncertain scenarios (KNMI, 2021). In addition, explorative research into the behaviour of the Dutch delta at a sea level of 2 and 5 meters argues that with the current situation, the risk of flooding and inundation in the areas of Kampen and Zwolle significantly increases (+2m) or are completely inundated (+5m) (assuming the current flood defences in place) (Schra et at., 2022). Neglecting such scenarios could therefore question the durability and robustness of proposed development directions and limit the range of new policy options and solutions. Therefore, this thesis introduces the following problem statement:

Current exploratory research into the development of Zwolle Region limits itself to short- and medium-term foresights (2040-2075). Yet, there is argued that this limited foresight could lead to narrow policy options for decisionmakers to deal with the uncertainties. This raises the question whether the current proposed development directions (based on these foresights) about the development of Zwolle Region are forming a sufficient baseline for decision-making in anticipation of distant- future Sea Level Rise scenarios.

1.5 Aims and Objectives

This research aims to assess the durability of current and novel development directions of the Zwolle Region in distant-future sea level rise scenarios with the objective to amplify anticipatory consciousness, and therefore broadening the scope of policy directions for decision makers. This will be done by providing: 1) providing an overview of proposed development directions of Zwolle region; 2) creating three sea level rise scenarios for the Zwolle Region in 2300; 3) discussing the robustness of proposed development directions in distant-future climate scenarios to identify possible lock-ins and/ or regret-decisions.

1.6 Research Questions

This thesis concludes its findings by answering the main research question: *How robust are the current proposed development directions of the Zwolle Region compared to Sea Level Rise scenarios up to 2300?*

In answering the main research question, the following sub-questions were addressed during this thesis:

1. How would current proposed development directions shape the region of Zwolle?
2. How would different sea level rise scenarios influence the water systems of Zwolle region towards 2300?
3. What is the robustness of current proposed development directions compared to SLR scenarios up to 2300?

1.7 Relevance

1.7.1. Acedamic relevance

As mentioned in section 1.1, climate change can well continue beyond 2100, yet little research has been conducted to project the impacts of climate change beyond 2100 (Lyon, et al., 2021). They therefore advocate that "*climate change research and action must look beyond 2100".* Looking at current proposed development directions in the region of Zwolle and similar developments in other local and regional governments (e.g., strategies on spatial planning and the environment), such an approach to look beyond 2100 is not included. As a result, there is insufficient knowledge of what the added value of this long-term thinking could be at a regional level. Let alone the possible impacts of climate change in the long term. With this research, climate impacts beyond 2100 are be explored while discussing the relevance of extending the foresight beyond 2100 for the regional level.

1.7.2. Social relevance

The societal environment is, to some extent, shaped and guided by decisions (regulations, actions, plans, design, etc.). It is therefore crucial that these choices are comprehensively evaluated, aiming to contribute to the socio-ecological environment. Decisions have implications for both the present and the future, where current challenges must be addressed while also proactively mitigating and preparing for potential future challenges, thus averting them before they emerge or adapting in time. Broadening the timeline offers a more comprehensive vision of the future, stimulating public debate about socio-ecological environment and the desired future state: What (new) uncertainties can be anticipated? What kind of problems might these uncertainties bring in the future? How do we intend to address them now and in the future? What defines our long-term identity? These are questions in which society can actively participate. Through this societal debate, expertise (from society itself and scientific the scientific community), societal needs, and governance can be effectively bridged. This approach presents valuable opportunities for a comprehensive perspective for decision-making and monitoring, ultimately aiming to make a positive impact on society.

1.8 Outline of this thesis

Section 2 of this thesis outlines the concepts used in this thesis and is explained how they are applied in this research.

Section 3 elaborates on the methods that were used in answering each sub-question.

In **sections 4, 5, and 6** the results of this research are presented. Section 4 addresses SQ1, providing an overview of the current proposed developments in the region of Zwolle. Section 5 addresses the first part of SQ2, presenting four selected SLR scenarios. In section 6, the remainder of SQ2 is answered, exploring the impacts of the selected SLR scenarios on the water systems in the Zwolle region. Additionally, section 6 simultaneously addresses SQ3 by estimating the robustness of the current development directions in the context of the four different scenarios.

Section 7 contains the discussion of the results, elaborating on the interpretations, implementations, and limitations of the research.

Section 8 concludes the research and provides recommendations for further research and implementations.

2. Conceptual framework

This section provides and overview of the concepts related to the main research question.

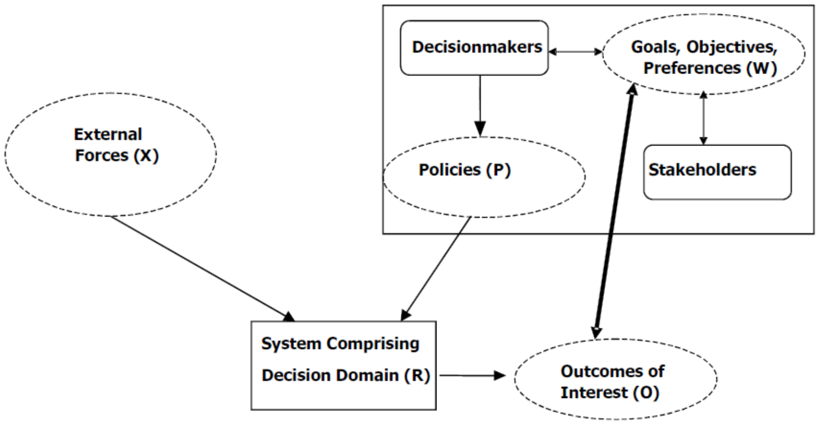
2.1 Decision making and uncertainties

2.1.1 Decision making

According to Marchau et al. (2019), Decision-making involves the selection of alternatives with the aim of influencing desired outcomes within a system; referring to alternatives as "*the means by which it may be possible to achieve the objectives*" such as policies, strategies, plans, designs, actions etc.. (p.4) or the *development directions* discussed in this thesis. It is therefore argued by Marchau et al. (2019) that "*Decision making requires an integrated and holistic view of various alternatives, their possible consequences, and conditions"* (p.4). Adapted from Warren (2000), Marchau et al. (2019) present a framework for decision support (see figure 2), forming a context in which these alternatives are presented and considered.

Figure 2

A framework for decision support. Reprinted from Decision Making under Deep Uncertainty, by Marchau, et al., 2019, p.5, Springer Nature. Copyright 2019 by Marchau, et al.



Note: Central to this framework is the system (R), consisting of interaction of both human and physical elements. The system is influenced by external forces (X) (outside the control of decision makers) and policies (P) (specification of chosen policies/ alternatives to influence the system with the aim of reaching desirable outcomes). The interactions within the system, the external forces, and policies will result in the system's outcomes (O) and are included for further (e)valuation (W) within the decision-making process (Marchau et al., 2019).

2.1.2 Uncertainty in decision-making

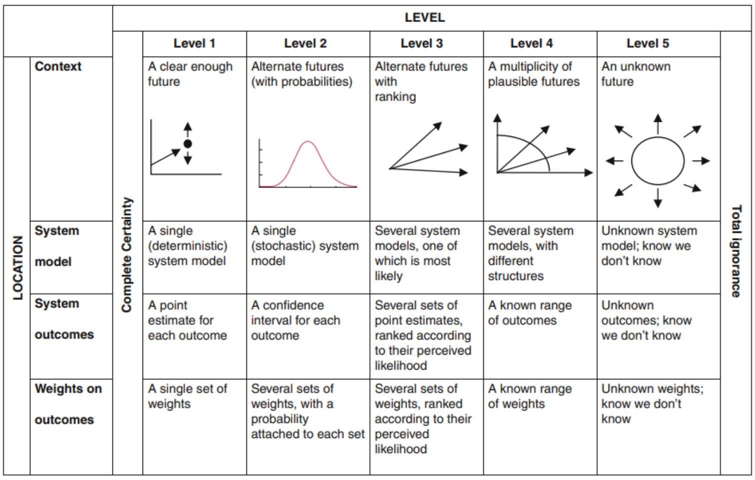
In decision-making, uncertainties will be encountered. We often don't know the exact outcome of a decision at the time of making one. Uncertainty, in its simplest form, is defined as "*limited knowledge about future, past or current events"* (Walker et al., 2013 p. 395) and touches upon *"the gap between available knowledge and the knowledge decisionmakers would need in order to make the best policy choice*" (Marchau et al., 2019 p. 2). Within the framework (figure 2) presented in Marchau et al. (2019), two areas in which uncertainties could occur are identified. Firstly, uncertainties can arise from the external forces (X). These are identified as *scenario uncertainties*; uncertainties about the development and impact of external changes (e.g., climate change, the economy, technological developments, etc..). Secondly, uncertainties arise from the system (R), and are identified as *structural uncertainty*; uncertainties about the system's response to external forces and/ with the implementation of policies/ alternatives (Marchau et al., 2019). Dealing with uncertainties is therefore a fundamental part of decision-making.

2.1.3 Levels of uncertainty

Ranging from complete certainty to total ignorance, Walker et al. (2013) distinguishes 5 levels of uncertainty (shown in figure 3) The first level acknowledges that there is no absolute certainty. However, the degree of uncertainty is not clearly measured and is mainly based on a point estimate and its sensitivity. The second level recognizes alternate futures (a single or multiple forecasts) with its probabilities. These can be clearly explained in statistical terms. In third level, these probabilities are able to be ranked on likelihood and are often based on trends. In level 4 multiple plausible futures can be recognized. However, due to limited knowledge one is unable to rank- or cannot agree upon the ranking of the futures based on likelihood. Lastly, level 5 covers the deepest level of uncertainty; "*recognized ignorance*" (Walker et al., 2013, p. 397). It takes into account events that have are considered to have a low probability or are not expected, and yet have a high impact (so called Black Swans). In their article, levels 4 ("*cannot agree upon*") and 5 ("*do not know*") are referred to as deep uncertainties.

Figure 3

Levels of uncertainty. Reprinted from Deep Uncertainty (p. 396), by Walker et al., 2013, in Gass, S.I., Fu, M.C. (eds) Encyclopedia of Operations Research and Management Science. Copyright 2013 by Springer Science+Business Media New York.



LOCATION	LEVEL: Level 1	Level 2	Level 3	Level 4	Level 5
Context	A clear enough future	Alternate futures (with probabilities)	Alternate futures with ranking	A multiplicity of plausible futures	An unknown future
System model	A single (deterministic) system model	A single (stochastic) system model	Several system models, one of which is most likely	Several system models, with different structures	Unknown system model; know we don't know
System outcomes	A point estimate for each outcome	A confidence interval for each outcome	Several sets of point estimates, ranked according to their perceived likelihood	A known range of outcomes	Unknown outcomes; know we don't know
Weights on outcomes	A single set of weights	Several sets of weights, with a probability attached to each set	Several sets of weights, ranked according to their perceived likelihood	A known range of weights	Unknown weights; know we don't know

Note: The transition of levels of uncertainty from complete certainty to total ignorance.

2.1.4 Dealing with uncertainties

Scenarios serve as an analytical instrument to portray and address uncertainties. It offers descriptions of potential future conditions of the system. However, it is important to note that scenarios do not predict future events or the future state of a system, but instead signify potential outcomes. In addition, scenarios solely encompass elements that could significantly influence the outcomes of interest rather than encompassing a full portrayal of a future system (Walker, 2000). According to Börjeson, et al. (2006), scenarios can be approached in different ways. They can be *predictive* in nature; what will happen? *Explorative*; what could happen? and *Normative*; how can a specific future be realized? (Maier et al., 2016. Adapted from Börjeson, et al., 2006).

2.2 Robustness

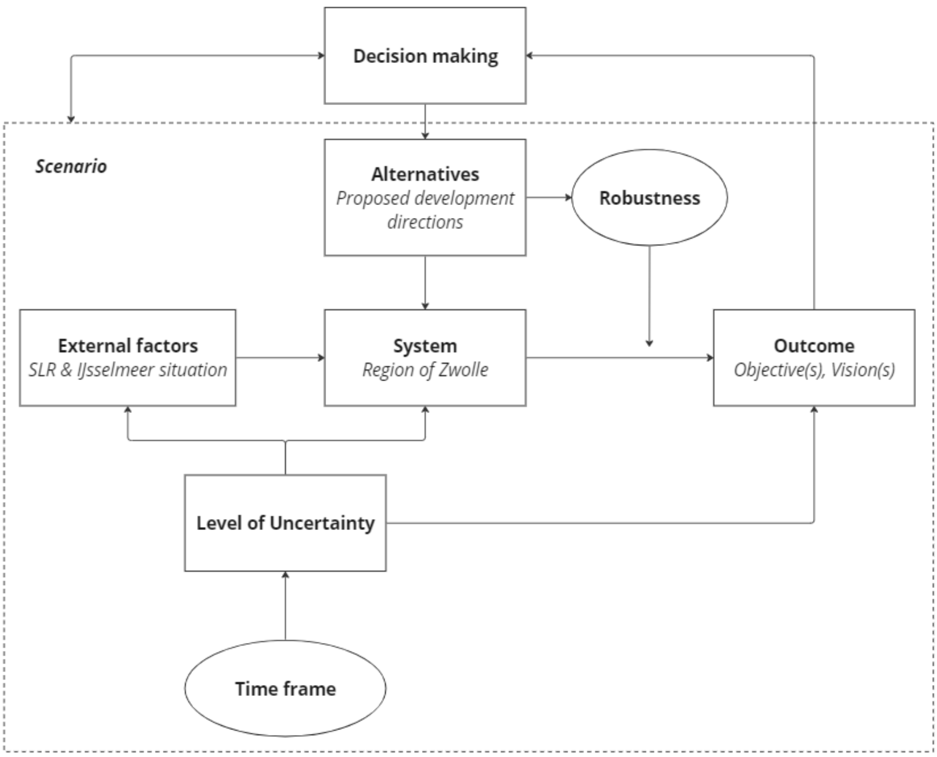
The term "robust" is widely used term in scientific literature and defined in various ways. Within different disciplines, robustness is generally referred to as the ability to withstand shocks or disruptions, maintaining the ability to keep fulfilling its function (Capano & Woo, 2017). In (Gilberto & Gallopín, 2006), robustness is referred to as the opposite of vulnerability. This concept can be used to determine: the robustness of decisions; assessing their ability to withstand uncertainties or a variety of conditions, and the robustness of systems; assessing the functioning of a system during disruptions (Mens et al., 2011). Moreover, in a strategic sense, it can be used to keep track of the need for alternations in a system, decision, or policy (Haasnoot et al., 2012).

2.3 Application of concepts

The applications of the concepts in this thesis are illustrated in figure 4. Central in this thesis are the current proposed developments directions in the region of Zwolle and how they unfold in sea level rise scenarios extending up to the year 2300. Based on this, the hypothesis within this thesis is tested by examining whether the current development directions, stemming from decisions based on near-future scenarios, can address uncertain situations that may arise in the distant future. To further elaborate on this, the framework for decision support by Marchau et al. (2019) has been adopted.

Figure 4

Applications of concepts within this thesis



Note: This framework is based on 'A framework for decision support' by Marchau, et al., 2019, p.5

Based on the framework of Marchau et al. (2019), the alternatives in this thesis refer to the current proposed development directions, that are as mentioned, based on a timeframe of 20 to 80 years. The system is in this thesis refers to the Region of Zwolle. As external factors, this thesis choses to focus on SLR developments and the Ijsselmeer situation[1]. Outcomes refer to the aims and objectives of the proposed development directions, the vision of the region of Zwolle. Argued in this thesis, the level of robustness of the alternatives influences the systems' outcomes; when an alternative is not able to withstand, a, or multiple situation(s) induced by external factors and the system itself, it fails to meet its objectives and thus influences the outcomes.

[1] This thesis recognises other external factors, but for research purposes and framing it limits itself to the SLR scenarios and Ijsselmeer situation.

As mentioned in Marchau et al. (2019), uncertainty can be found in the system and the external factors influencing this system. To deal with this uncertainty, scenarios are used to portray and address uncertainties. Therefore, this thesis argues that this framework can be used by decision-makers to simulate different scenarios and provide information for decision-making. As mentioned in Börjeson, et al. (2006), there are different approaches for these scenarios. This thesis will use an exploratory approach for the scenarios. In the scenarios used, this thesis limits itself to the uncertainties related to the external factors, leaving out the system uncertainties.

The hypothesis in this thesis adds the dimension of time to this framework, arguing that the timeframe used for these scenarios has an influence on the level of uncertainty within these scenarios; extending the timeframe increases the amount and diversity of possible futures and outcomes. Considering the current chosen development directions considering uncertainties that have not been recognized in a short timeframe, insights are expected to be generated to assess the durability of these developments and to determine whether they ultimately lead to undesirable outcomes by evaluating the robustness of the developments in these scenarios.

Based on this framework, the first question sub-question (SQ1) aims to create an overview of the current proposed development directions of the Zwolle Region (alternatives). The second sub-question (SQ2) aims to explore 4 distant future sea level rise scenarios (external factors). Lastly, with the third sub-question (SQ3), the robustness of the development directions (SQ1) will be assessed in the context of the 4 distant-future sea level rise scenarios (SQ2) in the region of Zwolle (system).

3. Methodology

This section offers an overview of the research methods employed and their implementation. As mentioned, this research focusses on a single case study. The use of a case study for this research and the choice to use the region of Zwolle as a case study is justified in 3.1. Sub sections 3.2, 3.3, and 3.4 elaborate on the used methods in addressing the sub-questions, and the data collection process. 3.5 elaborates on discussions conducted with regional experts in order to verify the results found during this research.

3.1 The region of Zwolle as Case Study

The research in this thesis is based on a single case study. According to Flyvbjerg (2006), a case study is "*a necessary and sufficient method for certain important research tasks in the social sciences, and it is a method that holds up well when compared to other methods in the gamut of social science research methodology*" (p. 241). It focusses on context-dependent knowledge and recognizes unpredictabilities that are difficult or cannot be captured in predictive, context-independent theories (Flyvbjerg, 2006). This thesis will focus on a critical case with the purpose of obtaining information that enables logical deductions in order to confirm or reject the hypothesis of this thesis. As already mentioned, this thesis selected the developments within the region of Zwolle as a case study.

The region of Zwolle has been selected as a case study based on the criteria that: it is a developing region in which (spatial) decisions are made within a time frame of 20 to 80 years and the region is (indirectly) influenced by SLR developments. Based on these criteria, the case study is initially relevant to other areas within the IJsselmeer region. Around the IJsselmeer area, similar developments are taking place (such as the strategies on spatial planning and the environment [including climate adaptation, housing, mobility et al.]) in which the water level of the IJsselmeer (which, in turn, is influenced by i.a. SLR) affects the current situation and developments. In the second instance, the region of Zwolle forms a unique case within the Ijsselmeer area because of the presence of two rivers that flow into the Ijsselmeer (the rivers Vecht and IJssel); making it a small delta area. Therefore, argued in this thesis, findings within this case study can also relate to SLR situations in Dutch delta in its whole.

3.2 SQ1: How would current proposed development directions shape the region of Zwolle?

Answering SQ1 was done on the basis of a grey literature review to create an overview of the current development directions. The literature has been retrieved based on a systematic search using a combination of the methods. The structure of this method was followed based on Pursell & McCrae (2020), highlighting the importance of eligibility criteria for and screening of the literature. The search strategies of the literature were based on suggestions by Godin et al. (2015), and the backward snowball sampling method presented in Wohlin (2014). To verify the summarised findings on the development of the Zwolle region (resulting from the literature research), findings were presented to experts involved in the developments of the region of Zwolle (see section 3.5).

At the start of the search, eligibility criteria were set as input for the search strategy and literature selection. The following eligibility criteria were used to determine whether literature was included or excluded from the research:

- Policy research, directions, programmes, plans and strategies;
- Relation to spatial developments in the physical living environment;
- Future oriented;
- Regarding or located within the study area (Zwolle region).

After selecting the eligibility criteria, search strategies were selected from suggestions in Godin et al. (2015) (see box 1). The fist search strategy used in this research was conducted with a customised google search engine. According to Godin, et al. (2015) it can be an efficient strategy in locating published (grey) literature by organisations on specific topics and provides a benefit in including recently published literature on the internet. The customised google search engine in this research provided the top 100 most relevant articles related to a given search term; significantly narrowing down the amount of search results (e.g., by using "Regio Zwolle" as search term, the normal google search engine provides >8 million results). However, in using this strategy, it is important to note that the ranking of relevant articles is based on unknown algorithms of Google. With the second strategy, literature was obtained in consultation with experts/ developers. Besides these two strategies, already known policy documents were also included within this research.

Box 1

Search strategy systematic grey literature review

Search engines
Google (costume search engine)

Search terms:
Regio Zwolle, Klimaat adaptatie Regio Zwolle, Omgevingsvisie Regio Zwolle, Mobiliteit Regio Zwolle, Energie Regio Zwolle, Zeespiegelstijging regio Zwolle, Woningbouw regio Zwolle, Landbouw Regio Zwolle.

Literature in consultation with regional experts/ developers
Literature was suggested by experts from: Twente University, Waterboard Drents Overijsselse Delta, and the Municipality of Zwolle.

Central literature (already known)
- Urban development: Regional strategy on Spatial planning (Urbanisation strategy)
- Rural development: Provincial programs rural area (PPLGs) [n=4]

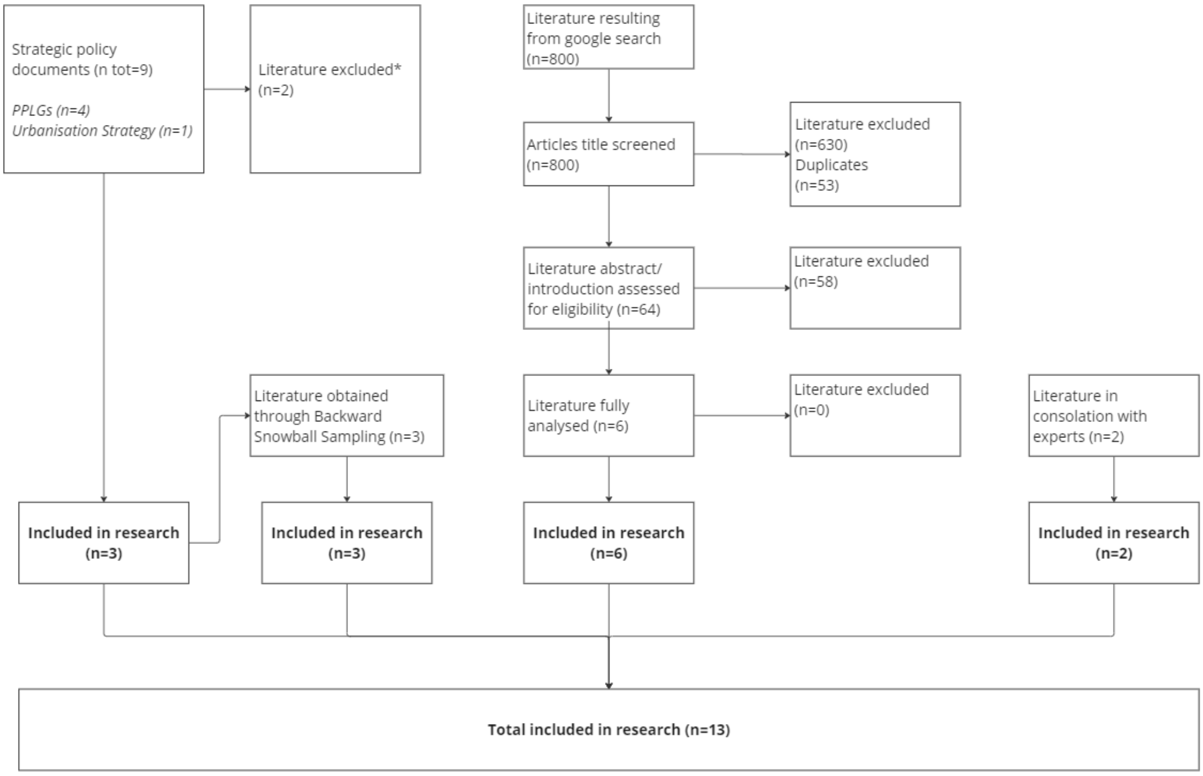
Note: Overview of the search strategies used in the systematic grey literature review, its sources/ means and input.

Literature obtained during the search was screened based on the eligibility criteria. During the search a first screen was conducted based on the title, after which also duplicates were removed. A second screening was conducted by reading the abstract and/ or introduction of literature. A third screening was conducted after a full read of the article. Figure 5 presents an overview of the conducted screening process in this thesis.

In a last step to expand the grey literature for this research, a backwards snowball sampling method (Wohlin, 2014) was used on the central literature (literature synthesising a wide range of developments). This was done because these reports contain pre-research that further elaborates on the information given in the central reports. The included literature is presented in table 1.

Figure 5

Literature screening process



Note: Overview of the screening process conducted to select grey literature to include in this research.
** From the central literature, the PPLGs of Gelderland and Drenthe were excluded as there were no concrete documents available at the time of writing this thesis.*

Table 1

Included literature in answering sub question 1

Topic	Sources
Economy	• Regio Zwolle Stapt Door: Meerjarige Agenda 2023-2028. (Regio Zwolle 2023) • Toekomstbestendige Arbeidsmarkt Regio Zwolle: Human Capital Agenda 2020-2023. (Regio Zwolle, 2020) • Warme Harten in een Klimaatadaptieve Delta: Verstedelijkingsstrategie Regio Zwolle. (De Zwarte Hond & Studio Bereikbaar, 2023)
Urbanisation	• Perspectievenboek: Verstedelijkingsstrategie & MIRT-traject Regio Zwolle. (Regio Zwolle et al., 2021) • Warme Harten in een Klimaaradaptieve Delta: Verstedelijkingsstrategie Regio Zwolle. (De Zwarte Hond & Studio Bereikbaar, 2023)
Mobility	• Gebiedsgericht MIRT-Onderzoek Bereikbaarheid Zwolle en Omgeving. Ministry of the Interior and Kingdom Relations. (Ministry of Infrastructure and Water Management, et al., 2023) • Perspectievenboek: Verstedelijkingsstrategie & MIRT-traject Regio Zwolle Zwolle. (Regio Zwolle et al., 2021) • Warme Harten in een Klimaaradaptieve Delta: Verstedelijkingsstrategie Regio Zwolle. (De Zwarte Hond & Studio Bereikbaar, 2023)
Rural development	• Concept Ontwerp-PPLG Overijssel: Provinciaal Programma Landelijk Gebied Overijssel: Toekomst voor ons platteland. (Province of Overijssel (2023) • Conceptontwerp: Flevolands Programma Landelijk Gebied: voor een toekomstbestendig landelijk gebied waar het goed wonen, werken, recreëren en voedsel produceren is. (Province of Flevoland, 2023) • Landbouw- en voedseltransitie: Onderzoek naar provinciale bijdrage aan landbouw- en voedseltransitie Provincie Flevoland. (Randstedelijke rekenkamer, 2022) • Landbouwvisie Provincie Overijssel. (Province of Overijssel (2022)

	• Voortgangsrapportage Landbouw Meerdere Smaken. (Province of Flevoland, 2022)
Energy	• RES 1.0: Samen naar een opgewekt Overijssel. In reswestoverijssel.nl. Regionale Energie Strategie West-Overijssel. (RES West-Overijssel, 2021)
Climate Resilience	• Klimaatadaptief ruimtelijk ontwikkelen Regio Zwolle: Uitgangspunten voor de verstedelijkingsopgave vanuit het bodem- en watersysteem en klimaatadaptatie. (Hekman & Ter Horst. 2022) • Regio Zwolle laat Nederland klimaatbestendig groeien: Een plan van doorpakken om als NOVI-gebied te bouwen aan de delta van de toekomst. (Regio Zwolle, 2022) • Stroomgebiedsanalyse Sallandse weteringen: Klimaateffecten en handelingsperspectief. (Sweco, 2023) • Warme Harten in een Klimaatadaptieve Delta: Verstedelijkingsstrategie Regio Zwolle. (De Zwarte Hond & Studio Bereikbaar, 2023)

Note: Overview of the literature used per topic in answering the first sub question.

3.3 SQ2: How will different sea level rise scenarios influence the water systems of Zwolle Region in 2300?

The second research question aims to give an indication of how sea lever rise would influence the water system of Zwolle region. This question is answered based on the KNMI sea level rise scenarios, expert interviews. During the execution of this thesis, additional literature on the (future) situation(s) of the Ijsselmeer was obtained in the preliminary research of this thesis and via the interviewees. Based on the information acquired by researching this question, 4 scenarios were developed[2]; determining the adaptation commitment for each scenario.

3.3.1 KNMI’21 scenarios as basis

This thesis used the KNMI SLR scenarios presented in the KNMI’21 climate single report (2021) as a starting point in the interviews and the further development of the scenarios within this thesis. In this report, new interim insights from the IPCC reports (since 2014 [when the last KNMI climate scenarios were presented]) and research conducted by the KNMI are presented; explaining how these developments will play out on the Dutch national and regional level(s). It is important to note that this report does not represent the latest climate scenarios for the Netherlands but focusses on “*observed trends and changes in insights* […]” (KNMI, 2021 p. 7) done in the period since the latest KNMI scenarios in 2014. Nevertheless, with new insights, the KNMI’21 report does provide initial insight into the new KNMI climate scenarios that will be presented in autumn 2023 (after submitting this thesis). Based on these arguments, the interim insights of the KNMI’21 report are used in this thesis instead of the KNMI 2014 climate scenarios.

3.3.2 Semi-structured interviews and obtained reports

To explore how the different sea level rise scenarios would influence the region, semi-structured interviews were conducted with experts (see box 2); thorough one-on-one interviews designed to produce qualitative information, following a structured set of guiding questions (Shackleton, et al., 2022) (see Appendix I: guiding questions semi-structured interview). These interviews were conducted to obtain information about possible future situations of the Ijsselmeer in the context of SLR. During the research, additional literature was obtained on suggestions from the interviewees and in the preliminary research phase of this thesis. In table 2, the additional literature included to answer sub-question 2 are presented.

[2] Arguments for selecting these scenarios is explained in section 5.3 of this report.

Box 2

Overview of interviewees sub-question 2

Organisation	n people interviewed	Background(s)
Rijkswaterstaat	1	- Advisor Climate Resilient infrastructure
Deltares	2	- Expert Climate change adaptation and water management - Coastal structures specialist
Staff of the Delta Programme Commissioner	1	- Senior advisor Strategy and Expertise

Table 2

Included literature in answering sub question 2

Sources
• Lange termijn oplossingsrichtingen zeespiegelstijging IJsselmeergebied: Eindverslag regioateliers kennisprogramma zeespiegelstijging spoor IV. (Defacto Stedenbouw, 2023) • Mogelijke gevolgen van versnelde zeespiegelstijging voor het Deltaprogramma: Een verkenning. (Haasnoot, et al., 2018) • Peilbesluit IJsselmeergebied. (Rijkswaterstaat, 2018) • Strategieën voor adaptatie aan hoge en versnelde zeespiegelstijging: Een verkenning. (Haasnoot, et al., 2019) • Verkennende systeemanalyse IJsselmeergebied. (Van Ginkel et al., 2022) • Wat wil de Delta? Uitzicht met inzicht: neogeografische kaarten van het Nederlandse laagland in een toekomst met zeespiegelstijging. (Schra et al., 2022)

Note: Overview of the literature included from preliminary research and on the suggestion of the interviewees (see box 2)

3.4 SQ3: What is the robustness of current proposed development directions compared to SLR scenarios up to 2300?

To answer the third and final sub-question, this research focused on the first 4 steps of the DAPP policy analysis shown in figure 6 (Haasnoot et al., 2013). This method aims to create a dynamic adaptive policy with an awareness of the range of plausible futures and can be changed over time when new information becomes available (Walker et al., 2013). This is done by conceptualizing a series of actions over time (pathways). Under different circumstances or scenarios, the adaptation tipping points (ATP) together with alternative policy directions can be identified. It provides an overview whether current policy directions are still on track, and whether direction needs to be changed to adapt- and what direction next should be taken (Haasnoot et al., 2013). With the use of the DAPP, this sub-question further builds on- and combined the information gathered in SQ1 and SQ2.

Figure 6

The Dynamic Adaptive Policy Pathways approach. Adapted from Dynamic adaptive policy pathways: A method for crafting deeply uncertain world, by Haasnoot et al., 2013, p. 489.

Note: Overview of the literature included from preliminary research and on the suggestion of the interviewees (see box 2)

The first 3 steps of the method are already covered by SQ1 as it provides: 1) a *description of the study area*; 2) *a problem analysis as described in current development documents*; 3) *Current proposed development directions*. Therefore, SQ3 focused on the fourth step of the method: To evaluate the *actions* (in this thesis referred to as the proposed development directions). Different to the initiated method, this research replaced the scenarios used in current proposed developments with SLR scenarios up to 2300 (SQ2).

The ATPs of the proposed development directions (SQ1) were identified by estimating its robustness in each SLR scenario (SQ2) to identify its tipping point; 'Will development X be considered robust in scenario Y?'. These assumptions have been made based on previously formulated assumptions in reports, expert assumptions, and literature on the robustness of certain proposed development elements. Additionally, the sell-by dates (timing tipping points) were estimate based on the adaptation commitment over time per scenario; 'When will development X not considered to be robust?'.

3.5 Verifying results and room for input

To test rationality of the interpretation of the development directions in- and the influence of a rising water level in the Ijsselmeer due to SLR on the region of Zwolle, the interpretations were presented to regional experts in the Region of Zwolle (see box 3).

The results and interpretations were presented and discussed in person with the use of printed maps. During the discussions, annotations (See Appendix III: Verification of results with experts) were made and included in the results of this research[3].

Box 3

Overview of regional experts approached to verify the interpretations of the results.

Organisation	n experts consulted	Background(s)
Municipality of Zwolle (1st interview)	1	- Spatial strategist
Municipality of Zwolle (2nd interview)	2	- Climate adaptation advisor (spatial planning) - (senior) Urban planner
Waterboard Drents Overijsselse Delta (separately approached)	5	- Water safety specialist; - Strategic director; - Strategic director; - Policy advisor on water safety; - Advisor on water safety & water systems.

[3] Because of the opportunity to write this thesis at WDOD, conversations about the results and interpretations with WDOD were often informal in nature and spread over the thesis period rather than set moments. Because of this, annotations were directly included in this thesis report and are referred to as 'WDOD, personal communication, 2023', and not included in Appendix III: Verification of results with experts.

4. Developing the Region of Zwolle

As mentioned in the introduction, due to various national and regional challenges and its own ambitions, the region of Zwolle is working on visions and plans to further develop the region into an economically attractive, liveable, accessible, and climate adaptive delta region. This section covers the regions ambitions and challenges, and its current development directions.

4.1 Ambition

With a growing population and economy (Regio Zwolle, 2022; Economic Board Regio Zwolle, 2022), the region has the ambition to distinguish itself by scaling up its economy and positioning itself (besides Mainports Amsterdam & Rotterdam, and Brain port Eindhoven) as the fourth economic growth region in the Netherlands (Regio Zwolle, 2022). Moreover, utilising its location, the region aims to serve as transition area between 'Randstad' and the eastern and northern parts of the Netherlands. Although the region can benefit from these developments, it is also aware that it increases more pressure on the already compact space use (De Zwarte Hond & Studio Bereikbaar, 2023; Regio Zwolle, 2022). National and regional space demands for housing, energy, mobility, water, agriculture in its low-lying deltaic area combined with climate change pose complex challenges for region. Therefore, the region is committed to addressing these challenges comprehensively with the goal to become a resilient delta area and an example for other delta regions.

4.2 Challenges and current developments

In recent years the region has been exploring strategies for its development to deal with the challenges being faced. Based on grey literature and interviews with experts involved in the region's developments, this section presents and overview of the main challenges and developments.

4.2.1 Economy

The region copes with an aging workforce and few graduates are entering the regional growing labour market (De Zwarte Hond & Studio Bereikbaar, 2023; Regio Zwolle, 2020; 2023). Because of the region's distance from other bigger cities, it cannot rely on their demands and facilities. It is therefore beneficial for both employers and employees to have job and employment nearby (De Zwarte Hond & Studio Bereikbaar, 2023). Furthermore, businesses are compelled to give shape to various transitions such as digitalisation, the circular economy, and the energy transition to support long-term economically sustainable position (De Zwarte Hond & Studio Bereikbaar, 2023; Regio Zwolle, 2023). This also gives rise to the need for certified personnel and an increase of businesses' innovative capacity (Regio Zwolle, 2023).

To maintain its economic growth, it is important for the region to maintain its attractiveness for people to live, work, and undertake business activities here. Therefore, the region plans to further develop towards a sustainable and agile economy, working on a future-proof and flexible labour market. This will be done by improving the entrepreneurial climate and creating room for business and employee development, as well as innovation with a focus on the region's sectors and ongoing transitions (Regio Zwolle 2023).

Even though foreseen, these developments are however not yet specifically manifested as spatial changes in the region. Yet, other developments discussed in this section do contain some focus on the economic developments. Spatial aspect comes into play with the fact that the region's economic system depends on large commuting distances. As already touched upon, besides Hoogeveen, a significant proportion of the region's residents have to travel to Zwolle to work. Moreover, there is a strong spatial demand for work facilities in various environment (read: offices, industrial areas etc..).

Yet, a coherent spatial-economic vision is still to be expected (De Zwarte Hond & Studio Bereikbaar, 2023).

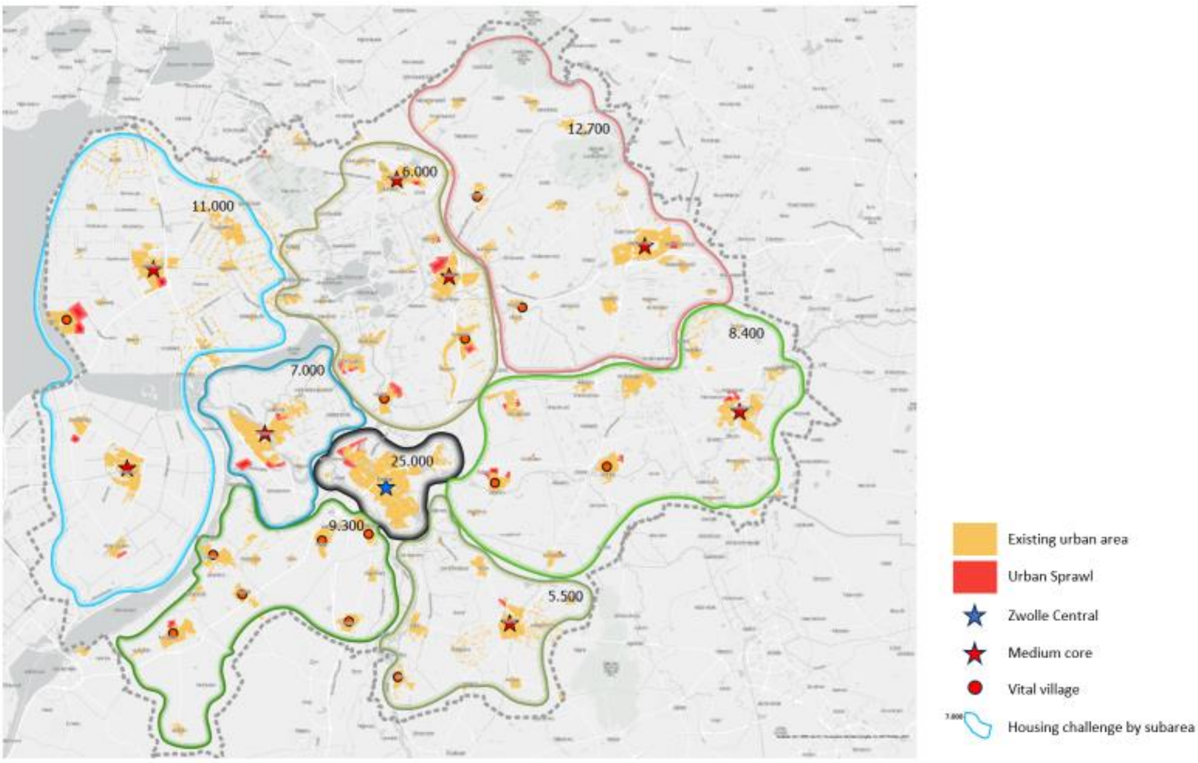
4.2.2 Urbanization

Due to local and national housing demands, a minimum of 50.000 and a maximum of 84.900 dwellings are planned to be realised in Zwolle Region until 2040 (De Zwarte Hond & Studio Bereikbaar, 2023) (see figure 7). With the maximum number of dwellings, the region considers dwellings that possibly need to be created to help other regions that are not able to adhere to their housing challenge (Regio Zwolle et al., 2021).

The urbanisation strategy emphasises on the agglomeration of the city of Zwolle whilst including the surrounding centres in the subregions to fulfil the housing challenge (De Zwarte Hond & Studio Bereikbaar, 2023). The surrounding centres can be categorised in medium-sized city centres (Hoogeveen, Meppel, Kampen, Dronten, Hardenber, and potentially Emmenloord, Raalte, and Steenwijk) and 'vital villages' (village centres). The medium-sized centres form (besides the city of Zwolle) another central point in the region, providing daily facilities (such as: education, work, groceries and healthcare). Moreover, they can facilitate additional housing growth (extra housing on top of the region's ambition). In the vital village centres housing developments are focussed to maintain and strengthen the liveability and living quality. There is no focus for additional housing growth in these areas (De Zwarte Hond & Studio Bereikbaar, 2023).

Figure 7

Urban developments within the region of Zwolle



Note: Urban developments within the Zwolle region, showing: Development areas for present and planned urban sprawl; highlighting each city/ village characteristic (Zwolle central, medium cores, vital villages); Housing challenge per subarea (Flevoland: 11.000; Kop van de Veluwe: 9.300; Salland: 5.500; Vecht- and IJsseldelta: 7.000; Vechtdal: 8.400; Southwest Drenthe: 12.700; Kop van Overijssel: 6.000). These developments are based on maps from De Zwarte Hond & Studio Bereikbaar (2023) and Hekman & ter Horst (2022) and tracked in district plans available on ruimtelijkeplannen.nl for verification.

Building new housing locations are prioritised (see table 3) to be realised in the existing build environment, focussing on the densification and infill of the centres. This will partly be done by the construction of new housing in the existing build environment, but also retrofitting existing buildings. Already, 80% of the (50.000) dwellings are built. When this not an option, the developments can[4] expand outside the existing build environment (De Zwarte Hond & Studio Bereikbaar, 2023).

Table 3

Prioritization and criteria of housing developments, adapted from Perspectievenboek: Verstedelijkingsstrategie & MIRT-traject Regio Zwolle, by Regio Zwolle et al., 2021.

Priority housing constructions	**Criteria**
1. Use of existing housing stock	- Vacant reuse - Rooftop extension - Dividing/ splitting dwellings
2. In and around the city centre	- Densification in and around the city centre
3. Within the built-up area of cities/ villages	- Close by public transportation networks - Transforming and invest in run-down neighbourhoods
4. Outside the built-up area	- Close by a public transpiration network - A new development must have no impact on the existing living environment while meeting the latest standards for development. Furthermore, the development must contribute to addressing one and ideally more societal challenges in the immediate area (such as mobility transition, climate-resilient urban planning, energy transition, improving liveability, and addressing housing market challenges).

Note: Priority for housing developments ordered from 1: use of existing houses to 4: outside the built environment (last), and the proposed criteria for each development approach.

4.2.3 Mobilization

Because of its location and strong mobility network, the city of Zwolle holds an important position at the centre of the region, attracting a significant portion of commuting activities of the surrounding municipalities. Moreover, it forms an important node in the national transportation network that joins the Randstad region with, in particular, the north of the Netherlands. Notably, Zwolle stands as the sole node in the national train network that connects the rest of the Netherlands with the north. Besides its important location, this also exposes a vulnerability for the train network. Outside the municipality of Zwolle, the region is not heavily urbanised, leading to cars being the main mode of commuting with the A28 as a crucial part of the road network, connecting the region with the Randstad. Additionally, the provincial roads are of importance for facilitating longer-distance regional and extra-regional commutes (via the A28) (Ministry of Infrastructure and Water Management et al., 2023).

Currently, the mobility network grapples with several intertwined challenges. Small problems at different points along the A28 cause often traffic jams. Also, the N50 between Kampen and Hattemerbroek frequently gets jammed. Housing developments and an increase in economic activities in the future are expected to notably increase in the movement of goods and people, posing pressure on the mobility network. In a high economic growth scenario (2040), commute time is expected to increase further as roads become more crowded, especially on key roads like the A28, A50, N50, N35, and A6. This high-growth scenario combined with cars being the primary mode of transportation (as predicted in the prognoses), results in substantial further losses in commute time. This impacts among other the number of jobs in a reasonable travel radius. However, in this high-growth scenario, the train

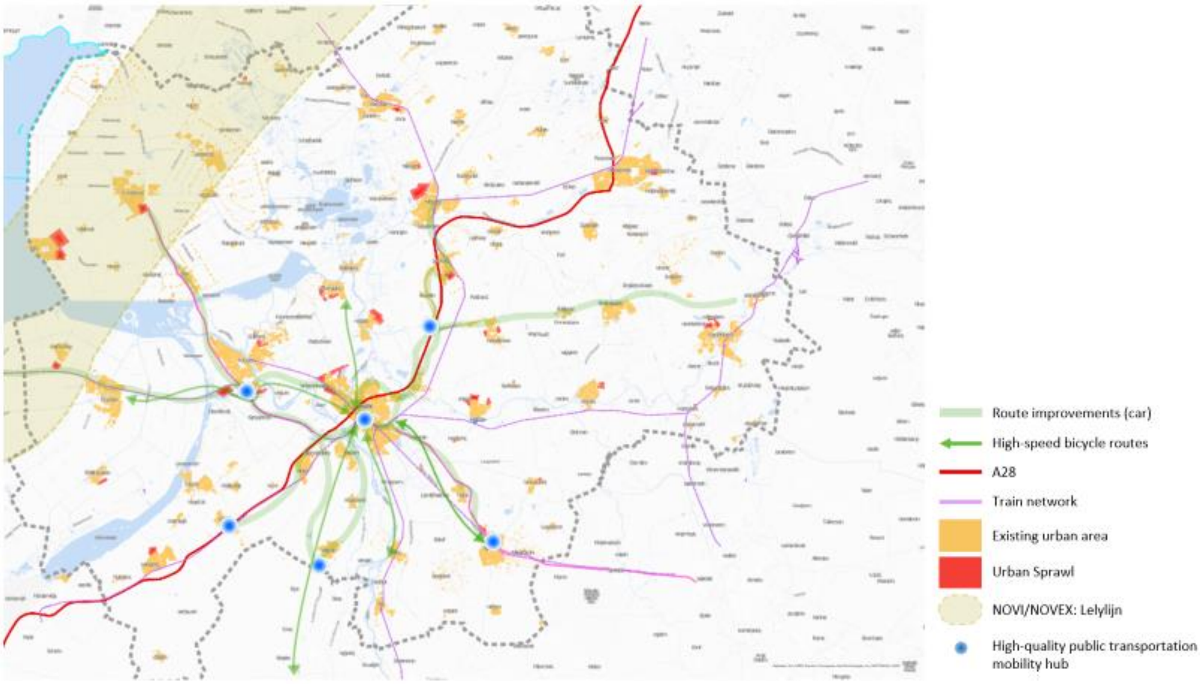
[4] Under the conditions that is has an added value to: the climate, climate adaptation, and the surrounding living environment (De Zwarte Hond & Studio Bereikbaar, 2023).

network is able to mitigate some of these issues as it is expected to have some rest capacity for commuters (Ministry of Infrastructure and Water Management et al., 2023).

To deal with these and future challenges, together with the urbanisation strategy, the Region of Zwolle aims to transform its mobility network (see figure 8). This will be done by focussing on the linked opportunities of urban planning and transforming the mobility system of Zwolle region (Ministry of Infrastructure and Water Management et al., 2023).

Figure 8

Mobility measures, adapted from Gebiedsgericht MIRT-Onderzoek Bereikbaarheid Zwolle en Omgeving, by Ministry of Infrastructure and Water Management, et al., 2023.



The mobility strategy aims to minimize unnecessary commuting. By offering people a range of amenities in their living environment, and encouraging remote work, it is expected that his will contribute to a decrease in travel congestion. Complementary to the mobility strategy, the urbanization strategy focuses on urbanizing in multimodally accessible locations. Proximity is considered as a guiding principle to limit current and future traffic congestion. This is achieved, among other things, by developing housing and work locations around public transport nodes, constructing in areas with available network capacity. The aim is to reduce the reliance on private vehicles and encourage sustainable transportation options (Ministry of Infrastructure and Water Management, 2023; De Zwarte Hond & Studio Bereikbaar, 2023; 2021). Therefore, a main focus for urbanisation measures is on boosting the train station areas of the city of Zwolle and the medium-sized centres (De Zwarte Hond & Studio Bereikbaar, 2023). Locating living, working, and consuming within this area would strengthen the use of new mobility modes. (re)Developments of areas, (alternative) mobility modes, and investments will be based on the STOMP principle, prioritising modes of transportation in the following order: Steps (walking), Bicycles, Public Transport, Mobility as a Service, and Private Car. To connect different scales of commuting, there will be invested in transfer nodes where commuters can easily transfer from different commute modes (e.g. [regional] mobility hubs combined with distant car parking) (Ministry of Infrastructure and Water Management, 2023). Nevertheless, despite this shift in mobility strategy, it was indicated during the interview with the municipality of Zwolle that a full transition of the mobility system in the region are not likely to happen. It is argued that a strong reliance on cars for commuting will be maintained. Given the region's modest size and low population density (compared to Randstad), substantial investments in a mobility transition are not seen as feasible (Municipality of Zwolle, personal communication, 2023, Appendix: III).

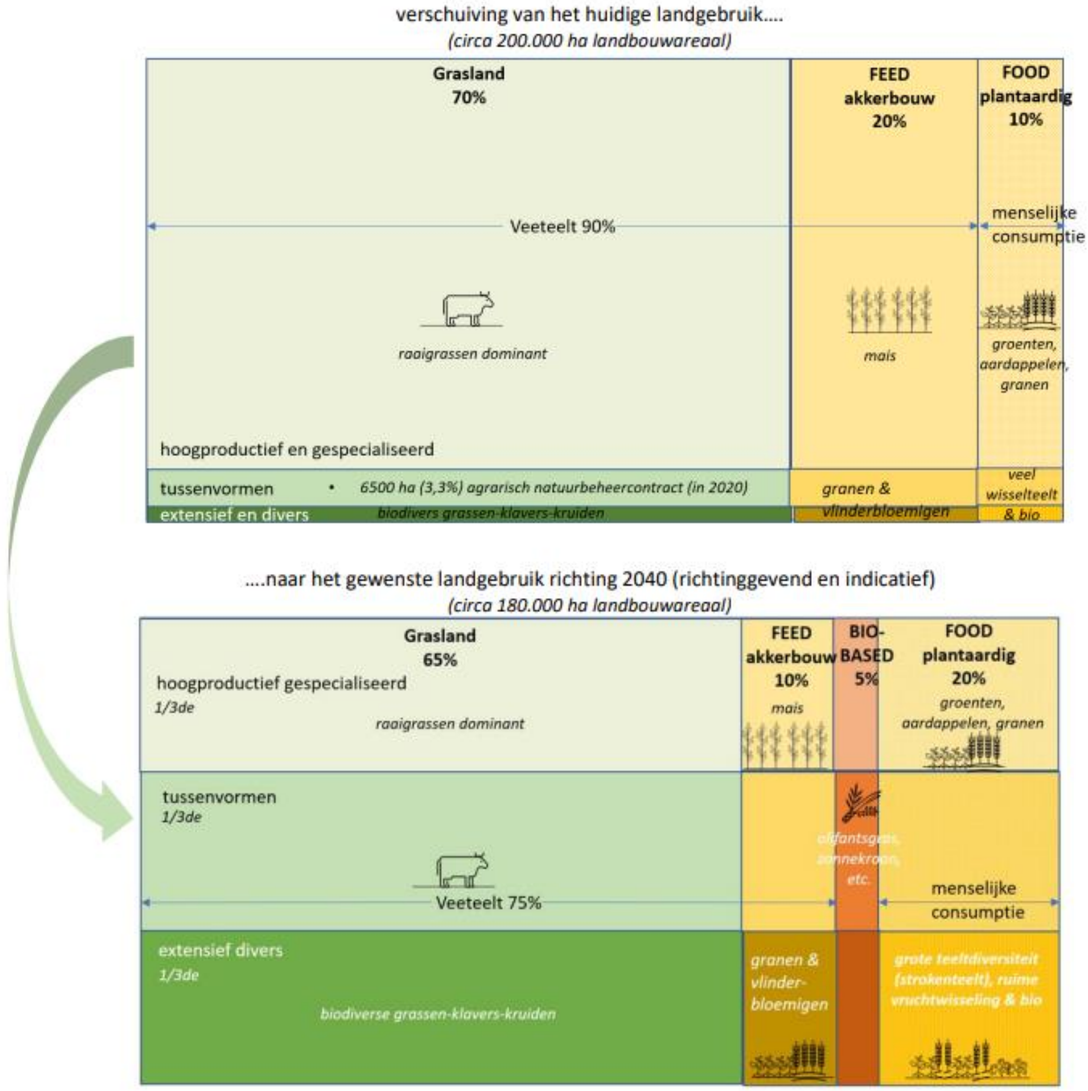
4.2.4 Rural developments

A significant portion of the land area in the Zwolle region consists of agriculture. A large part consists of grasslands. This is especially the case within the province of Overijssel. In contrast, the province of Flevoland is mainly characterized by arable farming (potatoes, corn, grains, and other crops). Both provinces have their own agricultural ambitions.

For instance, Overijssel is looking towards a transition in land use. Currently, within the province, grasses mainly intended for cattle are dominant, with 90% of plant products designated for livestock farming and 10% for human consumption. Additionally, a high-productivity and specialized form of agriculture prevails. However, this system puts pressure on regional ecosystems (including soil degradation, water and air quality, emissions, and loss of biodiversity in both flora and fauna). Moreover, the system heavily relies on external inputs like imported (e.g., animal feed, pesticides, medicines, etc.) and is less dependent on the local soil and water system. The province aims to reverse these two aspects in their agricultural vision (see figure 9). In the future, a better balance will be struck between high-productivity usage, diverse and extensive usage, and combinations thereof. Furthermore, more room will be created for plant-based food for human consumption and bio-based agriculture. In this transition, the vision of Overijssel centralizes the concept of circular agriculture (Province of Overijssel, 2022).

Figure 9

Proposed agricultural transition Overijssel. Reprinted from Landbouwvisie Provincie Overijssel, by Province of Overijssel, 2022, p.11.



The province of Flevoland has the same ambition to turn to circular agriculture (Randstedelijke rekenkamer, 2022) but is less specific in the implementation. Currently the province is experimenting with pilots of different forms of agriculture and revenue models to boost innovation (Provincie Flevoland, 2023; 2022).

The developments above can be interpreted as the current goals and are yet to be approved upon (besides innovation pilots). Specific implementations of nature goals, governance of peak emitters and a perspective for the agriculture sector is still uncertain (Provincie Flevoland, 2023; Provincie Overijssel, 2023). Input from other explorative and impact researcher are still to be included, and so are the outcomes of the agricultural agreement that has failed during the writing of this research. Therefore, more thorough elaboration on both national and provincial level is needed to form a strategy and plans for the rural area.

4.2.5 Energy

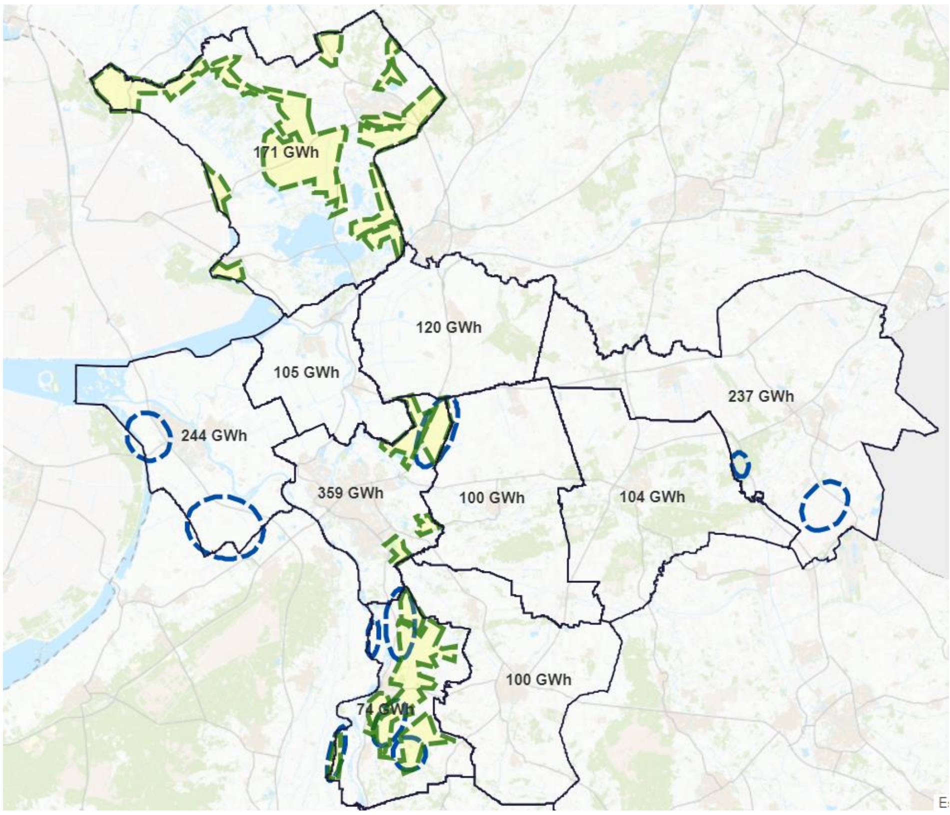
To adhere to the climate agreement to mitigate further climate changes developments, the region is undertaking an energy transition in the upcoming years. Currently, the most pragmatic options to produce sustainable energy lie in harnessing energy from wind and solar. Because of this, Regional Energy Strategy (RES) of West-Overijssel aims to deliver on 1,826 TWh of sustainable energy from 2030 onward. This will be achieved to yield 60% of the sustainable energy from wind and 40% from solar. The RES 1.0 has demarked search areas that have potential for the deployment of sun and wind energy facilities (see figure 10). The region is aware that these developments would reshape the region's landscape. Therefore, the search is governed by a set of fundamental design principles (Regionale Energie Strategie West-Overijssel [RES West-Overijssel], 2021).

- Utilization of opportunities within the build environment (e.g., solar on roofs);
- Synchronization of energy supply with localized demand;
- Consideration of synergies with other spatial challenges and developments in the area;
- Development along the existing main infrastructure (e.g., wind-mill development along the A28);
- Avoid valuable landscapes;
- Cluster installations in appointed suitable locations.

Elaborated details of project locations and the scope will be further outlined in RES 2.0. (RES West-Overijssel, 2021).

Figure 10

Search areas wind and solar parks. Reprinted from RES 1.0, by RES West-Overijssel], 2021, [ArcGIS online]: https://overijssel.maps.arcgis.com/apps/webappviewer/index.html?id=b0a1809ad333470f922ca8dfc04ca252



Note: Search areas for wind parks are indicated by the blue dotted circles. Search areas for solar parks are indicated by the green dotted, yellow areas.

4.2.6 Towards a climate-resilient region

Climate change is a recurring concern in all of the strategic domains. The region is facing challenges due to more frequent and extreme weather events, leading to both excess water in the lower laying areas and droughts in the higher sandy grounds. Technical innovations from the last decades have created a system in which human activities are somewhat disconnected from the water and soil systems and meeting its limits when it comes to cope with the changing climate (De Zwarte Hond & Studio Bereikbaar, 2023; Regio Zwolle, 2022).

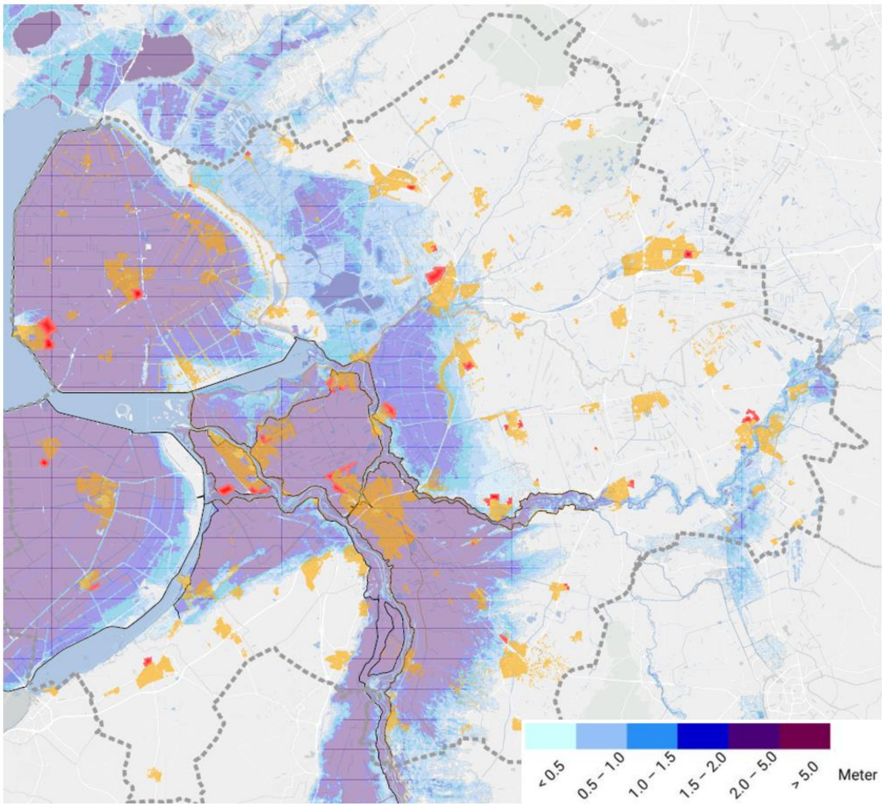
A renewal of the system is therefore needed to deal with the changing climate. The region does this on the one hand by taking climate mitigation measures to reduce its emissions. On the other hand, the region is working on climate adaptation measures which will be further discussed in this section.

Water and soil guiding in urban planning

When it comes to spatial planning, the region aims to follow the principles of water and soil guiding (Parliamentary paper II, I E NW/BSK-2022/283041, 2022). Within the urbanization strategy, the primary focus is on adaptively designing in the current development areas opposed to developments in climate-resilient areas. It is argued that further developing solely in climate-resilient areas would neglect the current situation (mainly located in climate prone areas) of which the transition to climate-resilience is already a significant challenge (De Zwarte Hond & Studio Bereikbaar, 2023; Regio Zwolle, 2022). As shown in figure 11 the build environment is largely located in floodable areas. Moreover, it is indicated that 81% of the existing housing development plans (24.674 dwellings) are located in floodable areas (Regio Zwolle et al., 2022).

Figure 11

Maximum flood depth in the region of Zwolle (NAP). Adapted from ESRI, n.d.



Note: Maximum flood depth in m -NAP in relation to present (orange) and planned (red) urban areas.

To realize climate resilience in urban planning, the following principles have been advised as guidelines (see table 4). These principles are further specified into fundamentals and requirements for climate resilience urban development in Hekman & ter Horst (2022) and constitute the minimum effort for climate-adaptive design.

Table 4

Design principles for urbanisation based on soil- and water systems. Adapted from Klimaatadaptief ruimtelijk ontwikkelen Regio Zwolle: Uitgangspunten voor de verstedelijkingsopgave vanuit het bodem- en watersysteem en klimaatadaptatie, by Hekman & ter Horst, 2022 p.6

"Avoid urbanization in areas that require significant measures (not connecting to the natural water system)"
"Urbanization follows the natural water system with natural and multiple solutions, considering the logic of the system and integrating them on-site"
"Urban developments always contribute to climate adaptation and also help the immediate surroundings"
"Think at a regional and system level: Act in a location-specific manner and choose natural and multiple-use solutions"
"Ensure that the projects contribute to addressing regional challenges"
"The sponge capacity of an area development always increases"
"Retain a droplet for as long as possible, at the highest possible level, and utilize it in a versatile manner before it is discharged into the sea or evaporates"

When selecting locations for new expansions, priority should be given to sites that maintain the flexibility and adaptability of the soil and water systems for the future. Developments should therefore always enhance the flexibility and resilience of the soil and water systems. This entails considering provisions for the future reinforcement of embankments, granting space for water and its associated ecology to naturally evolve. Developing in outer-dike areas should be avoided (only in exceptional cases). Development should not occur in areas designated for future dike reinforcement. Building heights and critical infrastructure should be aligned with potential flood depths to prevent damage and allow for evacuation if necessary (Hekman & Horst, 2022).

Sponge strategy

Currently the region is developing a 'sponge strategy' that focuses on redesigning the water system in order cope with excessive water due to pluvial events and droughts. Past developments have changed the water system in which (ground)water levels and water supply- and discharge have been designed to meet the demands for human activities (agriculture, urbanization, etc..). This has led at places to extensive dewatering, and other places to water nuisance (Sweco 2023; De Zwarte Hond & Studio Bereikbaar, 2023). In summary, attempts have been made to adapt the water and soil system to human activities. However, with the onset of extreme weather changes, these developments have now given rise to novel challenges. The sponge strategy aims to redesign this system in a manner that partially reverses some of these alterations and emphasizes on the natural water and soils systems. First directions of this strategy are currently explored in three different areas: 1) the build environment, 2) Sallandse Weteringen, and 3) Ketelmeer area.

The build environment

In the build environment (with in specific the city of Zwolle), green-blue networks are being enhanced and expanded. These networks are helpful as buffer for excess water during peak rainfall and being able to retain water for dry periods (De Zwarte Hond & Studio Bereikbaar, 2023).

Sallandse Weteringen

The Sallandse Weteringen play a significant role within the sponge strategy. Water from this area is flowing through the regional system via the city of Zwolle towards 'het Zwarte. This waterway is therefore also referred to as a 'bottleneck' (from a wide area the water accumulates at the city of Zwolle through which it continues its journey towards 'het Zwarte Meer'). Additionally, the area itself experiences waterlogging in the low-lying areas and valleys, and droughts in the higher sandy grounds (Sweco, 2023). With the development of the sponge strategy, efforts are being made to retain water on the higher sandy grounds and release it gradually. Around Zwolle, retention areas are being sought to capture water before it flows through Zwolle. Furthermore, research is being conducted into the possibility of creating an additional retention area for water flowing from Zwolle (relocating the Zwolle sluice gate towards the Vecht river). The potential diversion of water from the Weteringen around Zwolle towards the Zwarte Water is also being further explored (De Zwarte Hond & Studio Bereikbaar, 2023). In a first analysis (Sweco, 2023), both technical and spatial measures are explored that can be implemented to adjust the area towards a more robust system (see table 5).

Table 5

Potential spatial and technical measures Sallandse Weteringen. Adapted from Stroomgebiedsanalyse Sallandse weteringen: Klimaateffecten en handelingsperspectief, by Sweco, 2023

Challenge	Technical	Spatial
Drought	• Locations for above-ground water storage (relevant for: High sandy soils & relatively high, well-draining aeolian sandy soils). • Increase the capacity of water supply routes (widening and deepening waterways in relatively high, well draining aeolian sandy soils and water courses in lower laying areas)	• Store and retain water (heighten weirs in spring to store more water (relevant for relatively high, well-draining aeolian sandy soils). • Infilling of arteries (Channel Infilling at the top 300m of a waterway [reduces water drainage]) • Raising Streambeds (with 0.15-0.5m). • Increase infiltration and soil structure improvement (adjustments in agricultural land-use: reduced intensive land-use, use of lighter machinery, and soil improvement).
Excessive water	• Increase the capacity of pumping stations (additional pumping capacity of 5-45% needed) • Implementation of additional pumping stations (additional pumping capacity of 5-45% needed). • Strengthening and heightening of primary flood defenses and heightening and lengthening of regional flood defenses (to deal with increased discharges from the Vecht and IJssel river). • Increase peak discharge capacity of waterways (anticipating a 22-44% increase in extreme hourly rainfall [without the consideration of retention areas]). • Reserving space for dike reinforcements (approximately 100m around primary dikes and 30m around regional dikes)	• Lowest laying areas as inundation areas (collect and store rainwater in the lowest 10% of each water level control zone). • Differentiating Levee Norms - Primary Levees IJssel and Vecht (Allow controlled inundation of the waterways' embankments [formulizing the rare scenarios as this would be the situation in extreme cases already]). • Appoint inundation areas (retain and discharge water when discharge towards 'het Zwarte Water' is not possible). • Retain water in the waterways (create more room around the waterways of about 3-10m). • Reserving space for dike reinforcements or relocation (both primary and regional flood defenses). • Reduce watershed discharge (retain water as long as possible to manage save discharge via Zwolle into 'het Zwarte Water' [as the discharge flow is expected to be stalled downstream more often]). • Acceptance of wet areas/ seepage (radius of 1000m around the levee). • Flood adaptive housing developments in inundation areas.

		(when decided to develop housing in inundation areas, the design need to be adapted towards inundation events). • Reserving space for large scale retention areas (to cope with extreme events [heavy rainfall and/ or dyke failures])
Both	• Parcel water-level optimalisation (farm weirs, controlled drainage, rainwater reuse, and soil structure improvement). • Weir management (lowering weir heights allows water to drain, heightening weirs allows water to build-up).	• Acceptance of wet areas/ wet landscapes (mainly in natural low-laying areas and alongside waterways in relatively high, well-draining aeolian sandy soils) • Recover waterways (provide more space for streams to meander, restoring natural fluctuations to enhance water infiltration. Relevant for relatively high, well-draining aeolian sandy soils and low laying waterways)

With this first analysis of the Sallandse Weteringen, Sweco (2022) concludes after weighing spatial measures against technical measures that "spatial solutions are predominantly more future proof than technical solutions in the long term because they are better able to cope with weather extremes." However, the report also indicates that not all spatial measures will be suitable. With increasing water levels at 'het Zwarte Meer' (due in part to high drainage periods in the Vecht and IJssel rivers), drainage under gravity becomes difficult and sometimes not feasible. As a result, the area will still depend on pumping stations. In further research, combinations and synergies will be explored between the spatial and technical measures and modelled.

Ketelmeer
Mentioned in De Zwarte Hond & Studio Bereikbaar (2023) alongside the sponge strategy is the development of foreshores in 'het Ketelmeer'. This measure aims to inhibit wave buildup from the IJsselmeer area. However, there are no further specific implementation strategies or studies published about this yet.

Water safety

Since 2017, the Water Act has introduced new norms for flood defences. With these updated standards, a flood risk analysis is employed, focusing on the probabilities of flooding occurring, rather than just the exceedance probabilities of defences. This approach therefore not only evaluates the robustness of the defence structures, but also assesses the likelihood of flooding and the potential impacts on human life, the environment, and the economy. The flood defences are assessed against the standard every 12 years (Article 2.3, paragraph 2 of the Water Act 2017). The latest assessment rounds took place in the period 2017-2023. Within this round, the flood defences were assessed using the year 2050 as the reference point.

During this assessment, the majority of the primary barriers did not meet the new standard during the assessment round. Moreover, 180km of the regional dikes failed to pass the assessment. Therefore, flood defences not meeting the standard are strengthened in the coming years aiming to have all the defences according to standard by the year 2050. During the improvement of flood defences, projects look beyond 2050 and aim to prepare the structures for circumstance approximately 50 years from now. The current projects within the waterboard of Drents- Overijsselse Delta take into account foresight up to 2080. Notably, these projects use models that currently run on KNMI2006 scenarios and consider the current IJsselmeer water level management plan (WDOD, 2023, Personal communication).

4.3 Synthesis and reflection

The literature review highlights that a significant portion of the developments are still in a formative and exploratory stage. Observed in this thesis, the urbanization strategy in conjunction with mobility and climate adaptation is the most extensively developed, with interconnected relationships among these three domains already being sought. Plans and strategies concerning energy transition, rural land classification, and spatial economic development are less detailed but are in progress.

The development visions primarily concentrate on the near future (2030-2040), except for aspects related to flood safety measures (2080). Noteworthy is that despite the use of various scenarios in the preliminary investigations of different strategies, the ultimate visions adhere to only one scenario path, even though multiple potential future scenarios exist. Additionally, although long-term and continuous developments, such as sea level rise, are acknowledged, potential scenarios and their impact on the region remain unexplored. Furthermore, the current ambitions, emphasizing the objective of economic growth by 2040, lack comprehensive elaboration on the subsequent steps of this aspiration. Questions arise: Can the region continue to grow, where will growth be constrained, and can these growth plans harmonize with alternative potential future developments?

There are also strong substantial overlaps between the different developments, wherein they mutually impact each other in positive and negative ways. These interdependencies are recognised in the different development reports and, or visions. The development directions also considered incorporating these into their initial concepts where possible. Notably, the topic of climate change is integrated, if not named in all developments reviewed in this thesis. Nonetheless, argued by this thesis, there is a contrast between the growth plans and the vulnerability of the area in which these developments take place, with in particular the city of Zwolle. Despite the awareness of the region’s vulnerability, developments, and growth initiatives primarily centre around- and build upon Zwolle’s strong geo-economic position, which is simultaneously, as argued by this thesis, the most fragile location within the region. As the argument goes, the developments take place in an area where high maintenance is needed to allow these developments to happen.

5. Sea level rise developments and the IJsselmeer

To answer the second sub-question of this research: "How will different sea level rise scenarios influence the water systems of Zwolle Region in 2300"? This section focusses on listing SLR scenarios at the Dutch coast (based on the KNMI'21 predictions [KNMI, 2021]), and strategies for the Ijsselmeer area to anticipate these scenarios as the lake serves a direct link between the region of Zwolle and SLR (SLR is inflicted on the region through the Ijsselmeer). Based on this information, this section selects and presents 4 SLR scenarios that can be considered for the region of Zwolle; defining sea level rise scenarios in the main research questions and this sub-questions. The second half of this sub-question; 'how these scenarios influence the water systems of Zwolle Region?' will be answered in section 6.

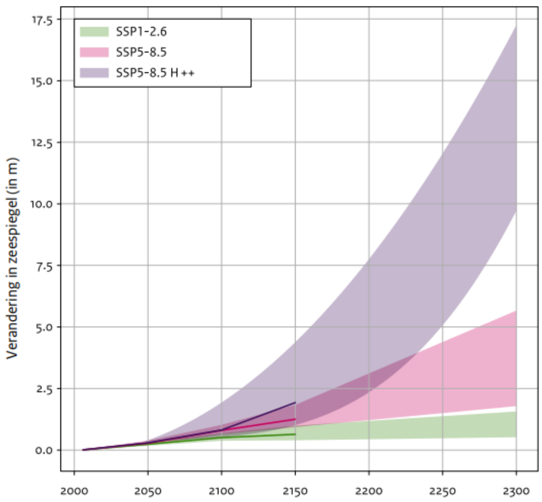
5.1 A view on SLR scenarios towards 2300

5.1.1 A view on SLR scenarios towards 2300 in the Netherlands

In KNMI Klimaatsignaal'21 (KNMI, 2021) a first insight is presented about updated climate scenarios for the Netherlands: KNMI'23-climate scenarios (to be published in October 2023). In this report distant-future foresight for SLR scenarios are presented up to the year 2300 (see figure 12). The foresight exclusively covers the low-end (SSP1-2.6) and high-end (SSP5-8.5) IPCC scenarios and a amplified version of the high-end scenario (SSP5-8.5++). Moreover, after 2150 a median of the developments cannot be calculated with the current models. Up to 2300 the foresights therefore present a estimated range (with a probability bandwidth of 67%) in which a scenario can exist. Due to the slow reaction of oceans on the already increased global temperature and the mass-loss of ice caps, the sea level will continue to rise in all scenarios. According to the scenarios currently shared the report, global average sea level is estimated to rise between 0,3m and 3m in the SSP1-2.6 scenario and between 1,5m and 7m in the SSP5-8.5 scenario by the year 2300 (KNMI, 2021, p.31).

Figure 12

Dutch coast SLR up to 2300. Reprinted from KNMI Klimaatsignaal'21: Hoe het klimaat in Nederland snel verandert, by KNMI, 2021, P. 31



Note: Dutch coast SLR for the SSPS-2-6, SSPS-8.5 scenarios. Besides these two scenarios, the SSPS-8.5 ++ scenario includes the uncertainties of ice cap processes (e.g., collapsing ice caps on the edge of Antarctica).

Box 4

Summary of the IPCC the Scenarios

IPCC Scenarios

SSP1-2.6
CO2 emissions globally are greatly reduced, reaching net-zero after 2050, accompanied by sustainable societal changes. Temperatures stabilize around 1.8°C higher by the century's end.

SSP5-8.5
CO2 emissions approximately double by 2050, propelled by rapid global economic expansion driven by fossil fuel exploitation and energy-intensive lifestyles. Reaching a average global temperature of 4.4°C by 2100

SSP5-8.5++
An amplified version of SSP5-8.5, considering the highly uncertain changes in ice streams and the destabilization of parts of the Antarctic Ice Sheet.

Estimated for the Dutch coast this results in a change of about 2m in SSP1-2.6 and about 5m in SSP5-8.5 (see figure 12). The models used in these scenarios do not account for processes that are hard to quantify (such as ice-cap processes) or have a hight level of uncertainty. When taking into account these uncertainties (SSP5-8.5++; low likelihood - high impact), sea level can increase up to 17m by 2300. (KNMI, 2022). Because SSP1-2.6 and SSP5-8.5 do not include these uncertain scenarios, a possibility exists that these scenarios evolve on the high end. Recent indications show that the chance in which a shift happens from a lower scenario towards a more serious scenario has increased (KNMI, 2022). Nevertheless, SSP5-8.5++ can be an overestimation due to its high uncertainty. Yet it does highlight the argument that the pace of SLR depends on whether crucial tipping-points are reached in which the Artic icecap becomes instable (KNMI, 2022). Therefore, these less susceptible processes, when occurring, could alter the course of the other scenarios. However, this last has not been scientifically proven and thus maintains an uncertain and controversial statement.

5.2 The IJssel lake in anticipation to SLR

With the construction of the Afsluitdijk, the Ijsselmeer has become a closed and regulated freshwater lake and forms the connection between water systems of the Zwolle Region and the Waddenzee. It is therefore not only SLR that will directly influence the water systems in Zwolle Region, but the robustness and decision-making in water management of the Ijsselmeer in anticipation to SLR. This makes it important to also discuss the different scenarios of the Ijsselmeer in anticipation of SLR before directly translating SLR developments to the Zwolle Region.

5.2.1 Current situation of the Ijsselmeer

In its present form, and also in the near future, the Ijsselmeer is of importance for the Netherlands of its three main functions (van Ginkel et al., 2022):

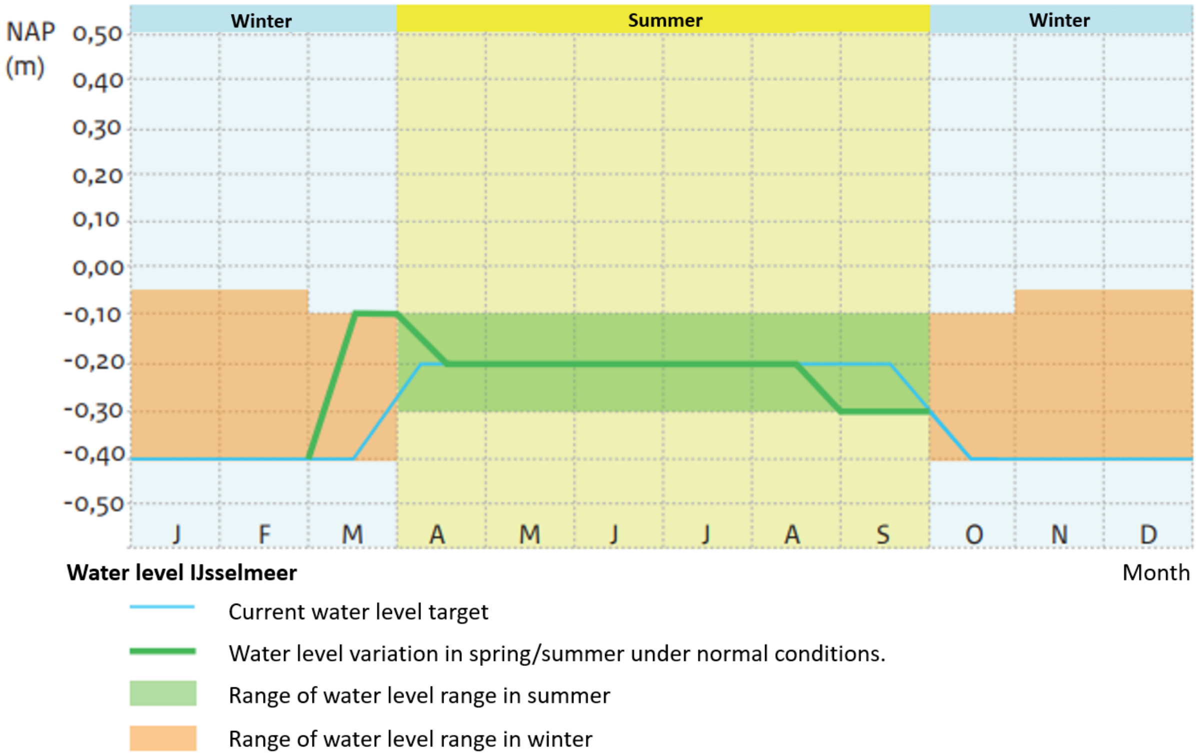
1. Excessive water storage (Water safety);
2. Fresh water storage (Water security);
3. Maintain a robust ecosystem (Healthy ecosystem/ biodiversity).

These functions have their own demands when it comes to managing the water level of the Ijsselmeer. In order to store excessive water due to peak discharges (common in winter periods), room is needed in the lake for storage, causing the lake to have a lower water level in the winter periods. On the other hand, a higher water level is preferred in the (dry) summer periods, as fresh water needs to be ensured for the activities in the area. A robust ecosystem benefits from a diverse, dynamic and connected water system (van Ginkel et al., 2022).

To meet these demands, the Ijsselmeer is managing a flexible water level. This was introduced with the Ijsselmeer water level decision (Rijkswaterstaat, 2018) (see figure 13). With this decision the water level in the Ijsselmeer is aimed to stay within -0,30m and -0,10m below sea level (Dutch Ordnance Datum [NAP]) in the summer period (creating a water storage of 400 million m3). In the winter period, the water level is aimed to be kept between -0,40m and -0,05m below sea level (NAP). In the transition from winter to summer, the water level is increased at the end of the winter period and will gradually lower over the summer. At the end of the summer the water level is lowered again, focussing on the lower side of the allowed bandwidth. Overall, it is aimed to maintain the annual long-term average of -0,25m below sea level (NAP) (Rijkswaterstaat, 2018).

Figure 13

Intended and current summer and winter (lake) levels in the IJsselmeer. Retrieved from Peilbesluit IJsselmeergebied, by Rijkswaterstaat, 2018, p. 32



This strategy is according to the decision (Rijkswaterstaat, 2018) adequate towards the year 2050 (including expected influences of climate change) and forms the basis for the current developments in the Ijsselmeer area. After 2050, the decision assumes a maximum compensation requirement for raising the water level of the Ijsselmeer by 60cm (assuming maximum sea level rise of 85 cm NAP by 2100). In this scenario, the Ijsselmeer's water level will partly and gradually ascend alongside the rising sea levels (Rijkswaterstaat, 2018). In short, the current way of managing the water level in the Ijsselmeer will be implemented until 2050, after which the water level will gradually increase with a maximum of 60 cm (in combination with extra sluice and pump capacity on the Afsluitdijk). These also form the guiding principles in the current development in the Ijsselmeer area.

5.2.2 Anticipating SLR beyond 2050

With the current decision there is a high confidence to proceed with the current way of managing the water level in the Ijsselmeer until. However, besides the option to increase the Ijsselmeer with 60 cm after the year 2050, it does not specify when a next tipping point is reached. The current decision, as mentioned, takes into account a sea level of max. 85 cm by 2100. However, as seen in the first insights of the new KNMI climate scenarios, a sea level rise of 1 m can already be reached in 2090 (SSP5-8.5 high end). Moreover, as mentioned before, sea level rise is most likely to develop way beyond the year 2100 (to put it in perspective: "*The expectation is that in 10,000 years, the sea level will be in equilibrium with the climate*" [KNMI, 2021 p. 31]). Up to the year 2050, the different SLR scenarios are located rather closely to each other (little difference in estimated sea level), yet after the year 2050, with the increase in possibilities and uncertainty, the scenarios become further apart. This is partly because the speed in which the sea level is rising differs for each scenario. For example, in the scenario in which the artic ice cap becomes unstable, "*the acceleration* [read: of sea level rise] *could significantly increase after 2050"* (KNMI, 2021 p. 28), whilst in lower scenarios the rise continues in a more gradually. Because of these uncertainties, this thesis argues that solely the option of gradually increasing the water level of the Ijsselmeer by max. 60 cm after 2050 would not be a sufficient perspective to anticipate future sea level rise. Nonetheless, even though it is included in the decision (Rijkswaterstaat, 2018), Dutch researchers and policy makers have not stood still and worked on further exploring options to anticipate a rising sea level in the future.

In a system analysis of the Ijsselmeer area, van Ginkel et al. (2022) introduce various development perspectives related to the three main function of the Ijsselmeer (see section 5.2.1 p. 37). Because of the frame of this thesis, it will mainly focus on the development perspectives related to the water level:

Maintaining winter water level during SLR by sluicing and pumping
A first option is to maintain the current water level management of the Ijsselmeer. With i.a. the Afsluitdijk, the Ijsselmeer stays a closed-off highly regulated system. With this option the current situation in the Ijsselmeer area stays the same; regional water can discharge in the Ijsselmeer under gravity and there is no direct need to further strengthen the flood defences along the Ijsselmeer.

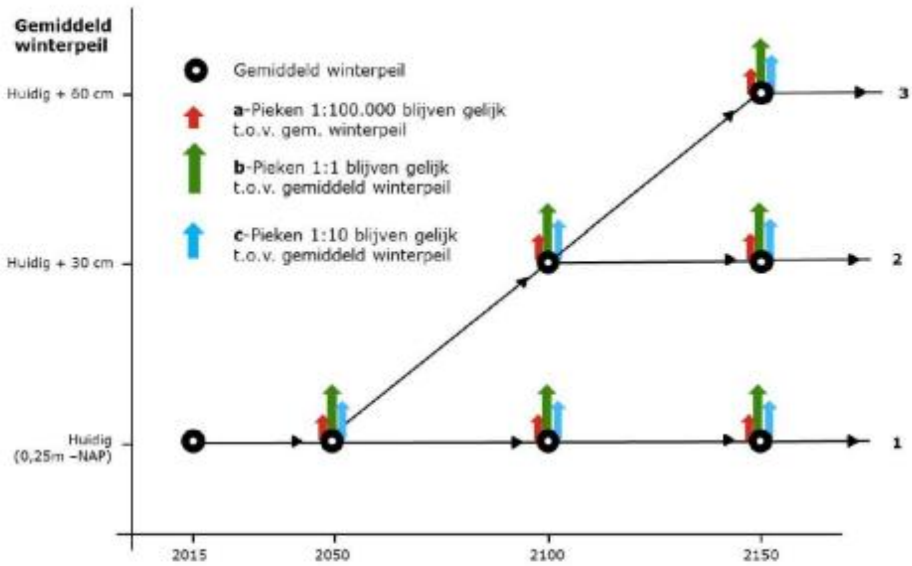
However, with a rising sea level, the gap between the water level of the Ijsselmeer and the Waddenzee increases over time; making it harder to discharge water from the lake into the sea under gravity (sluicing). In Deltares (2018), it is expected that the possibility of discharge under gravity meets its tipping point at a sea level of about +0.65m NAP. Because of this, the system will become more and more depended on pumps that are placed on the Afsluitdijk (van Ginkel et al., 2022). According to Rijkswaterstaat (2019), a pumping capacity is needed up to 3200 m3/s with a sea level of 1,75 m, and up to 3800 m3/s with a rise of 2,80 m (assuming strong control of the lake's peak water levels). In perspective, the Afsluitdijk would need a pump capacity of 6,4 to 7,6 times the world's largest pumping system in New Orleans (500 m3/s) or 12,3 to 14,6 times the pumping system in Ijmuiden (largest in Europe with 260 m3/s). Additionally, this strategy could result in a 'lock-in situation' (an irreversible situation) as more pump capacity would be needed over time whilst the gap between the two water levels increases (van Ginkel et al. 2022).

In addition to this scenario, besides sluicing an pumping, on and surrounding the Afsluitdijk there us room to further adjust the structure to future demands (Coastal structures specialist, interview, 2023, Appendix II D). Currently, scenarios are being explored in which the Wadden Sea is closed of, forming a second lake next to the Ijsselmeer. Senior advisor strategy and expertise, interview, 2023, Appendix II B; Delfacto Stedenbouw, 2023).

Limited gradually increase of the water level with SLR and strengthening of flood defences
A second option is to gradually increase the water level of the Ijsselmeer alongside SLR within certain limits. This strategy is also already discussed and referred to as optional by the water level decision (Rijkswaterstaat, 2018). It allows the Ijsselmeer to increase its water level with 60 cm after 2050. As shown in figure 14, the strategy aims on a 30 cm increase in 2100 and 60 cm in 2150 (Remmelzwaal et al., 2018 in van Ginkel et al., 2022). Gradually increasing the water level in the Ijsselmeer allows the activity of discharging the water by sluicing stays possible for a longer period; having to make less use of solely pumping.

Figure 14

Considered strategies for the average winter water level and higher water level peaks of the Ijsselmeer. Reprinted from Technische en economische analyse van langetermijnstrategieën voor peilbeheer in het Ijsselmeergebied. Eindrapport Integrale Studie Waterveiligheid en Peilbeheer IJsselmeergebied, fase 3, by Remmelzwaal et al., 2018, p. 13



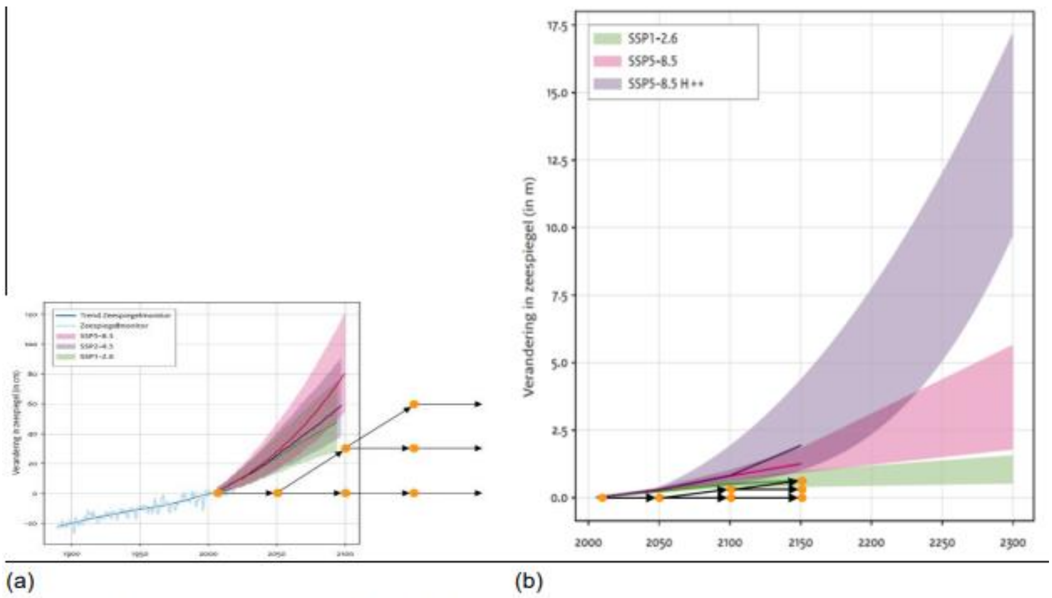
Note: This graph shows the strategies of increasing the water level in the Ijsselmeer with steps of 30cm (+30cm NAP in 2100 and +60cm NAP in 2150 from the current annual water level average of the lake).

Nevertheless, increasing the water level, does have large consequences of the spatial ordering of the Ijsselmeer area. Increased water depths can cause higher waves, the increased water level will affect the regional and up-stream water dynamics (e.g., water discharge from regional systems are less frequent to happen under gravity, back-water effect in rivers, outer-dike areas are more frequently inundated, increase of [inner-dike] seepage). Because of this, the existing flood defences need to be further strengthened and storm surge barriers are expected to close more frequently (van Ginkel et al. 2022; Haasnoot et al., 2018).

Noticeably of this strategy, as mentioned by van Ginkel et al., is that "*when we place these strategies in the context of accelerated sea-level rise, the degree of concurrent rise is very limited* […] *In many scenarios, the 'concurrent' water level will be much closer to the current IJsselmeer level than to the new sea level*" (2022, p. 49) (see figure 15). With this, the question can be asked whether, without any further decisions to increase the water level, this strategy will not turn into a similar lock-in situation on the long-term as the previous discussed strategy. Yet, as mentioned in the expert interview (Coastal structures specialist, interview, 2023: Appendix II D) this strategy in combination with a strategy that further rises along SLR could buy some time for the Ijsselmeer area to prepare for further increased water levels.

Figure 15

Limited gradual water level increase strategies for the Ijsselmeer compared to near-future SLR scenarios and extreme, long term SLR developments. Retrieved from Verkennende systeemanalyse IJsselmeergebied, by Van Ginkel et al., 2022, p. 48



Note: Considered strategies explored by Remmelzwaal et al., 2018 (see figure 14) in the context of regular sea level rise scenarios (a) and Considered strategies in the context of extreme sea level rise and the longer term (b).

Fully increasing the water level according to SLR and strengthening of flood defences

A third option is the fully increase the water level of the Ijsselmeer according to SLR. With this option, discharging water from the Ijsselmeer into the Waddenzee will remain possible. Also, it brings a more natural water dynamics back to the area and increases the storage capacity of fresh water. Nevertheless, as mentioned in the previous option, increasing the water level highly affects the connected inland water systems. Compared to the previous option, the consequences and the level of adjustment is far bigger. Large investments will be needed, not only in the Ijsselmeer area, but also upstream along the rivers. This expensive investment could be a valid reason to not consider this option. Especially considering that the costs will grow over time with an increasing sea level. However, "*Looking back from the future to the present, the transition costs to accommodate a rising water level in the IJsselmeer may now be lower than they will be in the future if spatial developments in or around the IJsselmeer area cannot be prevented*" (van Ginkel et al., 2022 p. 52).

Further compartmentalization of the Ijsselmeer

A fourth options is the further compartmentalization of the Ijsselmeer. With this strategy the Ijsselmeer will be further divided in compartments (like already the case with the Markermeer) that manage their own water level. This strategy would reduce the effects of drifting in combination with tilted water, and thus simplifying water safety measures. Moreover, salinisation events can be manged more easily. However, this strategy would also implicate more pumps to discharge the water between the compartments, increasing the dependence on pumping systems. Moreover, it would lead to fractured network for both human activities (such as boat routes), and nature (unnatural transitions between water systems) (van Ginkel et al., 2022).

5.3 Selection and elaboration on chosen sea level rise scenarios

To assess the resilience of the proposed developments, a selection of scenarios was made based on the information in this section. First, a decision was made regarding the selection of KNMI SLR scenarios. This thesis has deliberately chosen to exclude the SSP5-8.5++ and the SSP1-2.6 (low-end) scenarios for further analysis. The SSP5-8.5++ scenario with a SLR up to 17m is of such an impact for whole of the Netherlands, that the developments in Zwolle Region practically become insignificant, let alone the question whether Zwolle would still exist. The SSP1-2.6 (low-end) contains a light increase in SLR, that this thesis considers this scenario to have little influence on the Zwolle Region. By excluding these scenarios, this research will use the SSP5-8.5 (high-end) and SSP1-2.6 (high-end)/ SSP5-8.5 (low-end) KNMI scenarios for further analysis.

As the situation of the Ijsselmeer directly influences the water systems in the region of Zwolle, development scenarios of the Ijsselmeer are an essential part in the scenarios. As discussed in this section, the potential for an increase in the Ijsselmeer water level cannot be ruled out. Therefore, a deliberate choice was made to incorporate scenarios that account for both 'Limited gradually increase' and 'full increase' of the Ijsselmeer water level. The option of 'maintaining the current Ijsselmeer water level' was not included in this research because, in this scenario, the situation within the Zwolle region is presumed to remain unchanged.

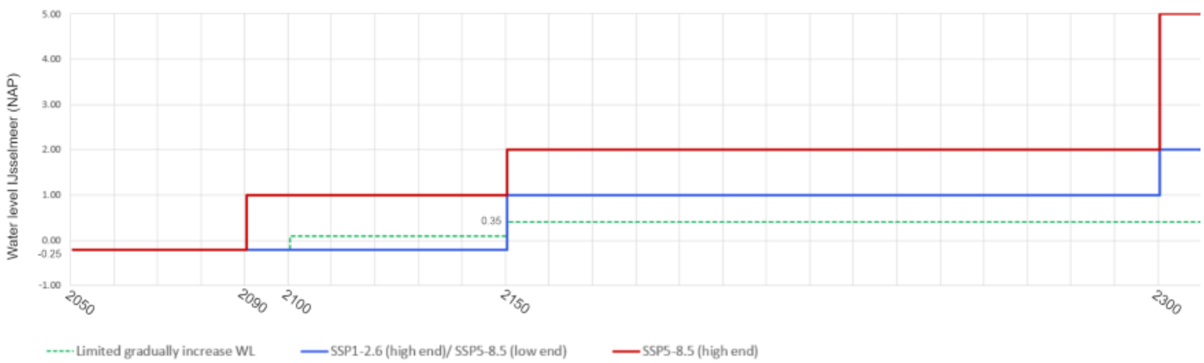
Based on this selection, the following 4 scenarios were established to assess the robustness of the proposed development directions[5]:

- The Zwolle region at a Ijsselmeer water level of +0.35m NAP (Limited gradually increase WL);
- The Zwolle region at a Ijsselmeer water level of +1m NAP (Full increase WL to SLR + SSP1-2.6 (high) & SSP5-8.5);
- The Zwolle region at a Ijsselmeer water level of +2m NAP (Full increase WL to SLR + SSP1-2.6 (high) & SSP5-8.5);
- The Zwolle region at a Ijsselmeer water level of +5m NAP (Full increase WL to SLR + SSP5-8.5).

The estimated timeline in which these scenarios can occur is depicted in Figure 16.

Figure 15

Scenario pathways used by this thesis plotted in time



[5] Due to the absence of precise values in the KNMI report's graph, it has resorted to approximating these figures by rounding them to the nearest whole numbers. Given the abstract and primarily qualitative approach of this research, this thesis contends that these approximate values are reasonable for conducting the analysis.

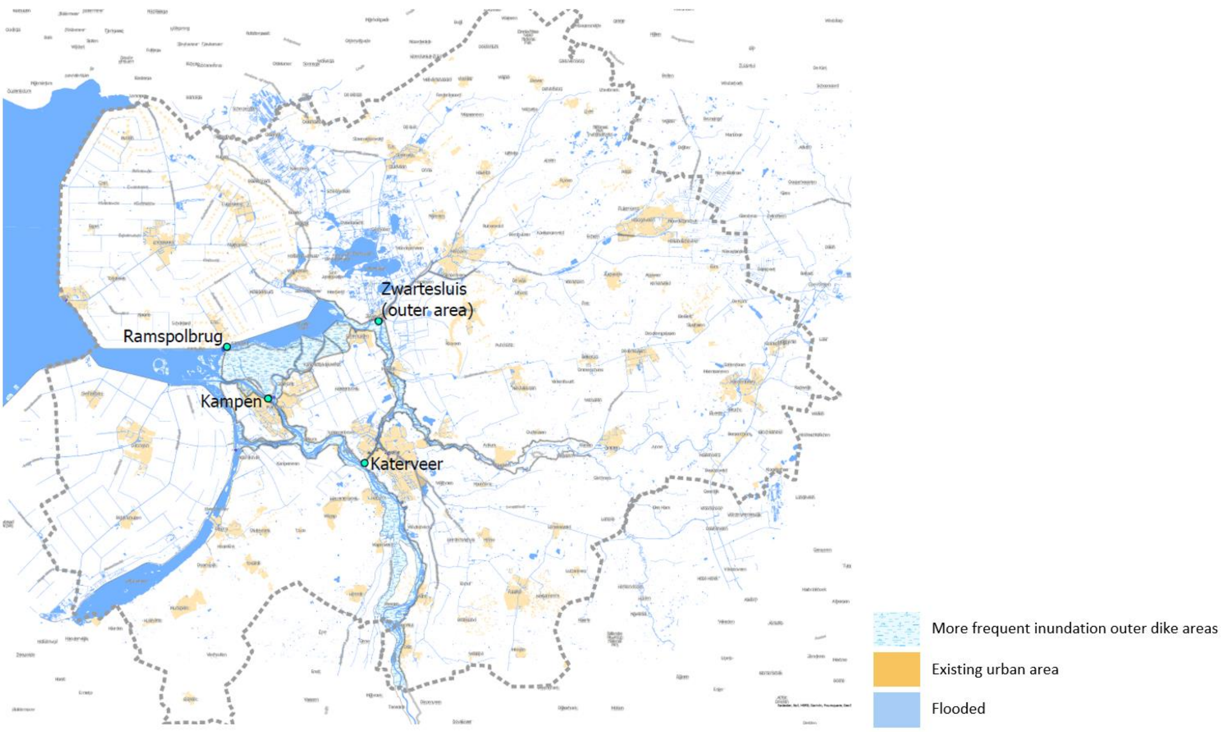
6. The robustness of current proposed development directions in possible water level scenarios.

In the previous section, various climate scenarios and policy options for Lake Ijssel are explored. Based on these findings, this section will present 4 scenarios of water levels that will be further explored in this thesis. In order to analyse the robustness of the region's developments, this section will first discuss how the different water levels could influence the water systems in the region (in the current situation). After this, the development directions will be placed in these scenarios to test its robustness in the given situation. The findings are based on the earlier done research of Schra, et al. (2022) and the input from interviews. It is important to note that these are highly abstract estimations. Moreover, the estimation does not include the backwater effect in rivers that comes with the increased water levels. For its analysis it copies the water level of the Ijsselmeer given in each scenario.

6.1 Scenario: Ijsselmeer water level of +0,35m NAP (Limited gradually increase of the water level with SLR)

Figure 17

Estimated situation water system Zwolle region with an average Ijsselmeer water level of +0,35m to +1m NAP



Note: Estimated in this scenario: 1) Floodplains undergoing more frequent inundation; 2) Slow and increasing development of seepage along the flood defences and within the build environment; 3) Decrease in periods for water discharge under gravity into main water systems. At the scenario of +1m, these events are estimated to occur more frequent and become more intense.

Table 6

Present day water thresholds compared to a +0,35m Ijsselmeer water level scenario. Retrieved from Waterinfo.nl. Rijkswaterstaat, n.d.

	Present day water level thresholds					
Measuring station	Reduced water level (cm)	Normal water level (cm)	Slightly elevated water level (cm)	Elevated water level (cm)	High tide /Storm surge (cm)	Extreme high tide (cm)
Katerveer	< -15	**-15 to 155**	>155	>195	>280	>360
Kampen	<-45	**-45 to 50**	50 to 70	> 70	>175	>260
Zwartesluis (outer area)	<-50	-50 to 50	**>30**	>47	>150	n/a
Ramspolbrug	<-55	-55 to 20	**>20**	>40	>70	>110

Note: Present day water level thresholds. Colored cells indicate the water level NAP at the measuring stations shown in figure 17 with an Ijsselmeer water level of +0,35m.

In table 6 the water level thresholds used in present day are given of 4 measuring stations in the region. (see figure 17) With colour it is indicated which of the current thresholds are exceeded with the water level presented by each scenario (in this case +0.35cm NAP). At the stations Katerveen and Kampen, the water level with an 60cm increase of the current water level of the Ijsselmeer still can be considered as normal water level for this area. Yet for the locations Zwartesluis and Ramspolbrug, the new 'normal' water level would be what is now considered a slightly elevated water level.

However, a water level of +0.35m NAP is close to what is considered an elevated water level in the waters close to the estuary (Ramspolbrug & Zwartesluis). With the increase in the new normal water level, it is also likely that this will impact high water levels (high water will become higher). Therefore, it is reasonable to assume that this increase will result in the more frequent inundation of floodplains (incl. Kampereiland). It is assumed that the elevated water level will lead to increased seepage (Municipality of Zwolle, Appendix: III; Defacto Stedenbouw, 2023), and the regional water drainage towards the major water bodies (Zwartemeer, Rivers Vecht, and IJssel) will less frequently be in free flow (Defacto Stedenbouw, 2023).

6.1.1 Climate adaptation developments at an Ijsselmeer water level of +0,35m NAP

Water safety

With the increased water levels dikes surrounding the Ijsselmeer need to be further strengthened. For the region of Zwolle this mainly concerns the primary flood defences surrounding the Flevo polders (dike rings: 7-2; 8-3; 8-4), and the dike surrounding Kampen (dike ring: 11-2). Alongside the other primary flood defences space needs to be reserved for further strengthening the dikes (Defacto Stedenbouw, 2023); this is already considered in the existing development reports (see: Hekman & ter Horst 2022).

The increased water levels also cause the Ramspol storm surge barrier to close more frequently (closes at +0,5m NAP combined with a strong northern-western wind [Ministry of Infrastructure and Water Management, 2023]). Argued in Defacto (2023), the closing conditions of the barriers need to be updated according to the new water level, causing higher water level in the Zwartemeer.

Additional to strengthening flood defences, pump capacity in the region needs to be increased as water is less frequently able to be discharge naturally (under gravity). To meet the demands, and to maintain the current situation in the inner-dike areas, pumping capacity needs to be expanded to facilitate water drainage (Delfacto Stedenbouw, 2023).

Sponge strategy

The built environment

Because the situation stays unchanged as seen earlier, the current sponge strategy within the build environment is considered to fulfil its objectives.

Sallandese Wetering

The interventions presented in the sponge strategy of the Sallandese Wetering (Sweco, 2023) align are in alignment to deal with this scenario. The measures already take into account the further wetting of the Sallande Wetering; considering already the additional pump capacity needed in this scenario to maintain the current spatial situation within the dikes. Creating additional inundation zone also helps alleviate the pressure on the pumps. As indicated in the report (Sweco, 2023), there can still be considered what the desirable balance is between technical and spatial measures are fitting for this scenario. As will be discussed in the other scenarios, long-term considerations will be important because under increased pressure on the water system, technical and spatial solutions will each have their own way of handling it.

6.1.2 Urban developments at an Ijsselmeer water level of +0,35m NAP

According to Delfacto Stedenbouw (2023), the increased water level does not impact the current urbanisation strategy, but room needs to be reserved for further strengthening the dikes. This falls in line principles that are presented in the guidelines of Hekman & Horst (2022) for the urbanisation strategy. However, in conversation with the municipality (Appendix III), there are concerns that because of the increased water levels, seepage in the urban environment will slowly intensify. It was pointed out that already in the current situation seepage causes problems in especially post-war neighbourhoods. Intensified seepage is seen as a threat, a silent and insidious process that affects the quality of dwellings and living (e.g., dampness in dwellings, increased water nuisance in neighbourhoods). By this decrease in quality and thus living quality, neighbourhoods become less attractive. This raises the question: What are the societal consequences of this?

Nonetheless, as discussed in 'water safety' (see 6.6.1), it is assumed that in this scenario, the pump capacity in the region will be increased to maintain the present situation in the polders and therefore prevents intensified seepage in urban areas. This again shows a strong connection between the two development domains, as the urban situation and developments highly depend on flood safety, yet also become a demand for the flood safety system.

6.1.3 Mobility at an Ijsselmeer water level of +0,35m NAP

Because the inner-dike situation stays unchanged, the mobility strategy is expected to develop without any complication.

6.1.4 Rural area at an Ijsselmeer water level of +0,35m NAP

Because the inner-dike situation stays unchanged, current agricultural practices can continue. However, outer-dike agricultural practices must deal with more frequent inundations events (Defacto Stedenbouw, 2023).

6.1.5 Energy at an Ijsselmeer water level of +0,35m NAP

Because the inner-dike situation stays unchanged developing the plans for wind- and solar projects are not conflicting with any spatial changes in the landscape. However, from a demand perspective, the increased pump capacity will require more (sustainable) energy from the grid. Nonetheless, comparing this with other energy demands in the region makes it debatable whether it would have a significant impact on the energy-grid. The impact of this still needs to be researched.

6.1.6 Economy at an Ijsselmeer water level of +0,35m NAP

Because the unchanged situation within the region's inner-dike area, and thus allowing among others urban and mobility developments to create a more excessive and attractive region for work and living, there can be argued that within this scenario the set goals to develop economically are met. However, outer-dike economic developments (Defacto Stedenbouw, 2023). Activities such as ports and leisure do have to deal with the increased water levels; leading to amongst others: more frequent inundation of low-laying ports, spatial conflict between small ports and strengthened flood defences, and less accessible leisure locations due to inundation or strengthened flood defences.

6.2 Scenario: Sea level +1m NAP

Besides Katerveer, a 1m increase of the water level in the Ijsselmeer is experienced with the present thresholds as elevated water levels (see table 7). At the Ramspolbrug it even matches what is currently preserved as 'high tide'. It is estimated that this scenario further increases the pressures on the water system as mentioned in 6.1: Floodplains are more frequent inundated, and Kampereiland is expected to function more often to retain excessive water; seepage further increases groundwater levels, causing more water nuisance in the build environment; Natural was of water drainage become more difficult (see figure 17).

Table 7

Present day water thresholds compared to a +1m Ijsselmeer water level scenario. Retrieved from Waterinfo.nl. Rijkswaterstaat, n.d.

Measuring station	Reduced water level (cm)	Normal water level (cm)	Slightly elevated water level (cm)	Elevated water level (cm)	High tide /Storm surge (cm)	Extreme high tide (cm)
Katerveer	< -15	**-15 to 155**	>155	>195	>280	>360
Kampen	<-45	-45 to 50	50 to 70	**> 70**	>175	>260
Zwartesluis (outer area)	<-50	-50 to 50	>30	**>47**	>150	n/a
Ramspolbrug	<-55	-55 to 20	>20	>40	**>70**	>110

Note: Present day water level thresholds. Colored cells indicate the water level NAP at the measuring stations shown in figure 17 with an Ijsselmeer water level of 1m.

6.2.1 Climate adaptation developments at Ijsselmeer water level +1m NAP

Water safety

Assuming that the primary flood defences meet the new standard, WDOD expect (based on a broad estimation) that with a water level of +1m NAP, 50% - 60% of the primary flood defences would not pass assessment according to the new standards (WDOD, personal communication, 2023). Because of the complex process of assessing the flood defences on failure (due to the variety in constructions, situation, and that fact that in practice assessment and measures are deployed on every 60 metres in length of the defences), an expert of WDOD has been asked to make a broad estimation on the dominant failure mechanisms with the premiss of water hight as main hydraulic pressure. With the increase of the water level, the waterboard expects the current dikes fail because of bursting, heave and piping; Erosion of grass coverings on the crown and inner slope; or Inward Macro stability. (important to note that in these estimations more complex calculations have been used to determine these mechanisms).

Within the case of a water level of 1m, the waterboard would consider strengthening dikes as main option (WDOD, personal communication, 2023). As mentioned in the previous section, further strengthening of dikes comes with increased space requirements for the barriers. It is roughly estimated that with a one-meter elevation of the dikes in Flevoland, an additional 18 meters in width will be occupied, and along the Ijssel an additional 15 meters width, covering about 800 ha of land in the IJssel valley (Haasnoot, et al., 2019). Moreover, with this scenario this thesis expects that the water level also increases upstream. Taking this into consideration, flood defences further up along the IJssel and Vecht need to be strengthened as well. Strengthening the dikes as strategy to deal with the previous (water level of +0,35 NAP), and this scenario (water level of +1m NAP), is not seen as a tipping point in this thesis. It is true that with the increased water levels the dikes are assumed not to meet the required standards, but further strengthen the dikes as a strategy is still considered a valid option in this scenario (WDOD, personal communication, 2023).

Looking at Ramspol storm surge barrier, this scenario would cause the barrier to be permanently closed according to the present closing conditions. Argued by this thesis, the Ramspol storm surge barrier finds it tipping point in this scenario as it can no longer operate as intended (an open barrier from which water from the Zwarte meer flows into the Ketelmeer, and a closed barrier to protect the Zwartemeer region against storm surges). To further adapt to this scenario, two options arose from the conversations with the waterboard (WDOD, personal communication): 1) adjusting the closing conditions by which the water level would increase beyond the barrier with 1m; 2) Permanently closure of the barrier with additional pumps to discharge the water (coming from the Vecht river) into the Ketelmeer and maintaining the current water level beyond the barrier.

These two options illustrate how the pressure on the Ramspol storm surge barrier system impacts other systems within the region. The first option would result in the water level in the Zwarte Meer the Zwarte Water up to the Vecht to increase by approximately 1 meter (this is an assumption). Consequently, the barriers along these water bodies would also need further reinforcement, and the regional water flowing from the polder can no longer be naturally discharged into the Zwarte Water and Zwarte Meer. This would make the regional system dependent on pumps, and further expansion of the current pump capacity is needed. This means that water from the Sallandse Wetering, that normally flows through Zwolle into het Zwarte Water, can also happen naturally; causing the city of Zwolle to become dependent on pumping systems, and zones might be allocated within the city and in the Sallandse Weteringen to buffer excessive water that could accumulate because of this new situation.

In the second option, the situation described in the first option is essentially shifted to the Ramspol barrier, which would now function as a closure dike. By pumping the entire discharge towards the Ketelmeer, the situation around the water bodies can continue to exist in its current state. However, it would still be advisable to reinforce the barriers behind the Ramspol closure dike as a secondary safety measure should the new closure dike system with pumps fail. To provide an idea of the pump capacity, this thesis utilizes the increased water discharge at the Genemuiden measuring station (Rijkswaterstaat, Waterinfo, n.d.). Based on an increased discharge from the "Zwarte Water" to the Ketelmeer, a maximum pump capacity of 250m3/s is required, which is roughly equivalent to the capacity of the pumping station in IJmuiden (260m3/s).

Sponge strategy

The built environment

Considering the situation at the Ramspol storm surge barrier, the change on high water levels within the build environment (with in particular, the city of Zwolle) could cause complications. Firstly, with increased water levels in the water systems within cities, groundwater levels might also increase; making it more difficult for water infiltration measures, such as swales, to operate as saturated ground makes it more difficult for the water to infiltrate. Because of this, above-ground water storage can become a better option for water storage within the build environment. Considering this wet situation within the build environment, the 'green network' should also be considered. When more wet environments (or blue networks) are to be created within the build environment, vegetation should also be adjusted to this. Additionally, sewage systems within the build environments should be considered in such a situation. Especially increased water levels in combination with heavy rain events raise the question whether sewage overflow into surface waters is still possible (this was not researched in this thesis). When this is not possible, the chance exists for the sewage system to get clogged and causing water nuisance.

With some slight adjustments in the strategy, this thesis argues that using blue and green networks as sponge structure within the build environment is still a valid strategy as it creates space to direct and store excessive water. However, the storage capacity highly depends on the available space and the speed in which water can be discharged into the main water systems of the region (this balance needs to be further researched).

Sallandese Wetering

Just like in the previous scenario, the sponge strategy of the Sallandse Wetering plays a significant role. With this strategy, the water that could potentially accumulate in Zwolle in the new situation can be retained for Zwolle. In contrast to the other scenario, this thesis expects that the water from the Wetering will be less quickly discharged through the city of Zwolle. As a result, the designated inundation zones of the strategy are expected to be underwater more frequently and for longer periods.

The possible option to divert the water from the Sallandse Wetering around Zwolle could also alleviate the pressure on the city. However, consideration must be given to potentially higher water levels in the drainage area, especially if the closure conditions of the Ramspol barrier are raised to 1 meter.

Shifting the sluice gate from Zwolle towards the Vecht to create a catchment area for water from Zwolle could provide additional space to handle peak discharge so that it does not accumulate in the city of Zwolle. Here too, it is important to consider higher water levels in the drainage area, and this approach only works if the water can be discharged quickly enough to handle any potential subsequent peak discharge from the Wetering and Zwolle.

6.2.2 Urban developments at Ijsselmeer water level +1m NAP

Considering that the strategy of using flood defences and drainage systems to maintain the current situation within the inner-dike areas as a likely ‘go to’ strategy in this scenario, urban developments as presented can proceed. However, the pressure on the inland water system has increased, leading to an elevated risk of increased water nuisance. This thesis considers the concerns raised by the municipality (see Appendix III) in Section 6.2.1 to be more relevant for this scenario. Additionally, this thesis anticipates that extra consideration must be given to spatial planning, with a stronger emphasis on accommodating the space required for the sponge strategy in creating residential opportunities.

6.2.3 Mobilisation at Ijsselmeer water level +1m NAP

Because the inner-dike situation is aimed to stay unchanged, the mobility situation is expected not to be influenced. However, as indicated in 6.2.2, due to the increased pressure on the water systems within the inner-dike area, increased water nuisance can occur. As the mobility strategy is mainly build on the already existing network, this thesis expects water nuisance to increase in places where this is already common (mostly low-laying or located where water discharge is low). Moreover, mobility networks in outer dike areas such as Kampereiland, can be less frequently used as the area is more frequently inundated, making the area less accessible.

6.2.4 Rural area at Ijsselmeer water level +1m NAP

As proposed in various strategies, such as the sponge strategy, retaining and holding water in rural areas becomes important for water management. This means that certain pieces of land must be designated to be frequently and for longer durations underwater. In locations designated as large retention areas by the sponge strategy, there are currently (and likely in the future) farms and fields with ryegrass and livestock. When these areas are designated as retention areas, the current situation will undergo significant changes. Farms are built directly at ground level without elevation (such as a mound). Additionally, crops like ryegrass do not tolerate prolonged inundation well (Ecopedia, n.d.). In this case, the retention area will either need to be constructed in a clever manner, or the rural area will need to adapt, allowing for both functions to be combined (building on mounds, introducing water-resistant crops), or the current land use will cease entirely and transition to a new land use (e.g., nature conservation).

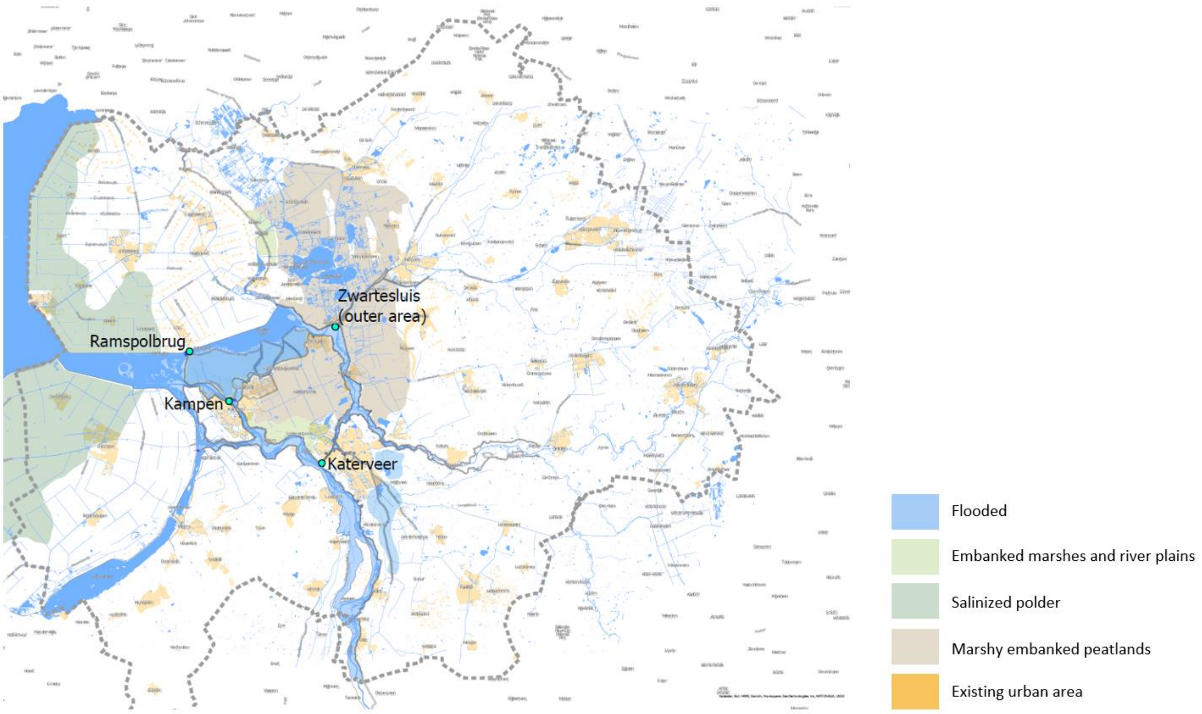
6.2.5 Energy at Ijsselmeer water level +1m NAP

Little specific information is given about the development of the energy system in the region. However, search areas for solar and wind parks have overlap with areas that are also considered in the sponge strategy as retention areas. Similarly, to the rural developments, generating renewable energy, whether it is wind or solar should adapt to this new situation. However, considering that floating solar panel fields and windmills placed on water are already introduced in the Netherlands, this thesis does not see big obstacles to realise energy generation in these areas. Yet, with this information it needs to be safeguarded that both developments are aware of each other so integration between the two can happen in an efficient way.

6.3 Scenario: Ijsselmeer water level of +2m NAP

Figure 18

Estimated situation water system Zwolle region with an average Ijsselmeer water level of +2m NAP



Note: Estimated in this scenario: 1) Floodplains are permanently underwater (IJssel up to Deventer; Vecht just past Zwolle); 2) Increased seepage along the flood defences and within the build environment; 3) Water discharge under gravity from inner dike areas into the main water systems is downstream not possible anymore; 4) Inner dike areas have become wetter (marshy peatlands, embanked marshes); 5) Increase in salinization due to autonomous salinization process in the Flevo-polders.

Table 8

Present day water thresholds compared to a +0,35m Ijsselmeer water level scenario. Retrieved from Waterinfo.nl. Rijkswaterstaat, n.d.

Measuring station	Reduced water level (cm)	Normal water level (cm)	Slightly elevated water level (cm)	Elevated water level (cm)	High tide /Storm surge (cm)	Extreme high tide (cm)
Katerveer	< - 15	-15 to 155	>155	**>195**	>280	>360
Kampen	<-45	-45 to 50	50 to 70	> 70	**>175**	>260
Zwartesluis (outer area)	<-50	-50 to 50	>30	>47	**>150**	n/a
Ramspolbrug	<-55	-55 to 20	>20	>40	>70	**>110**

Note: Present day water level thresholds. Colored cells indicate the water level NAP at the measuring stations shown in figure 18 with an Ijsselmeer water level of +2m.

At a water level of +2m NAP, floodplains are permanently inundated until Deventer (IJssel) and just passed the city of Zwolle (Vecht) (See figure 18). In this scenario the current flood defences are expected to barely yet still able to resist the hydraulic pressures. But the probability of a dike failure has increased significant. The water levels can now be experiences as elevated in Katerveer, high tide in Kampen and Zwartesluis, and even extreme high tide at the Ramspolbrug. What is currently considered a regular high-water situation, and a 1-in-10-year recurring high-water event, leads to circumstances that are regarded as 'extreme high-water' in the present scenario (Schra et al., 2022).

Besides the inundated floodplains, autonomous salinization processes are expected to take place in the Flevo-polders (Schra et al., 2022) and are even estimated to occur around Kampen (Defacto Stedenbouw, 2023). Kampereiland is considered to inundate, and inner-dike mashes and marshy peatlands are formed (Schra et al., 2022). Based on the situation discussed in 6.2.1, the lower parts of Sallandse Weteringen are expected to inundate as water accumulates in the area; not able to efficiently discharge on the bigger surrounding waterbodies.

6.3.1 Climate adaptation developments at an Ijsselmeer water level of +2m NAP

Water safety

Assuming that the primary flood defences meet the new standard, WDOD expect (based on a broad estimation) that with a water level of a water level of +2m NAP, 95% - 100% of the flood defences are expected to not pass the assessment. Strengthening the dikes would be a consideration in this scenario, however, because of the scope of the assignment, other options would also be considered here. From 3m onwards, further strengthening the dikes is not assumed to be realistically feasible and other solution pathways need to be discovered from that point onwards (WDOD, June 8th, personal communication).

Out of conversation with the waterboard (WDOD, personal communication), besides further strengthening the flood defences, one option is to decrease the hydraulic pressures along upstream flood defences. Like the situation at the Ramspol storm surge barrier, a similar structure could be proposed for the IJssel river. By maintaining a water level such as in the current situation, less investments are needed to strengthen all the dikes along the IJssel river. In place, an investment needs to be made for the large pumping station needed to discharge the water coming from the IJssel towards the Ketelmeer. This would require a pumping system with a maximum requirement of 1150 m3/s, or about 4.5 times the pumping station in Ijmuiden (260 m3/s). It is also possible to create a closure at the mouth of the Ketelmeer to the Ijsselmeer in which both the pumping capacity at Rampol and the IJssel are combined (capacity of about 1400 m3/s). Another option is to stop investing in the further strengthening of the flood defences, in which the last implemented hight is maintained. With this, the region allows water to overtop the dikes, causing (controlled) inundation of the inner dike areas (excepting wetting of the region). In this case, the question could also ask, when these large pumping systems are needed, if it wouldn't be more efficient to move these measures to the Afsluitdijk, where an increased pump capacity maintains lower water levels as proposed in 6.1.1. A third option, in anticipation of this scenario, could be the option to develop on higher grounds (>+2m NAP).

In the conversation with the Municipality of Zwolle, they consider this scenario as a different world than the one we know (see Appendix: III). In their view, it will take a lot of effort and dependency on a highly technical regulated system to maintain the current- and situation expected in the near-future (2050). In this scenario, the municipality also raised the question whether it is still worth to invest in the region, and whether there is a regional or national investment available to cope with this situation. At the same time, they point out that these question in how to develop and cope with these possible changes is as much of a social debate as it is technical. Residents and entrepreneurs of the Zwolle Region need to decide how they want to identify themselves as a delta region (e.g., closed and highly regulated system to maintain the current situation vs an open adapted version of the delta containing new ways of living, working, and traveling).

Sponge strategy

The built environment

The scope of the current sponge strategy, which is mainly focused to cope with heavy rainfall events, -is argued in this thesis not sufficient to cope with accumulating water within the inner-dike area. This thesis argues that it is likely in this scenario that the water will persist in the built-up area for an extended period of time rather than an event. Small infiltration or water storage measures would not be sufficient to deal with the larger amount of water that needs to be managed. Instead, this thesis assumes more space within the build environment should be further dedicated to store water; further increasing space for blue-green networks, but with a focus on long-term accumulating water in the build environment, rather than shorter-term heavy rainfall events.

Sallandese Wetering

Additionally of what already was mentioned in the previous sub-sections, more inundation is expected within the area as water becomes more difficult to discharge in the main water systems. With the option to stop further strengthening the dikes along the IJssel river and the Vecht, larger areas surrounding the dikes also further inundate. As already mentioned in the report (Sweco, 2023), technical system such as pumping are not sufficient on its own. More and more spatial adaptation is needed to accept are more wet landscape. In this scenario this thesis expects a transformation in the landscape of the Sallandse Wetering, in which, as proposed in the report (Sweco, 2023), especially lower-laying areas, areas surround dikes, areas along water way, and appointed retention areas become more and longer inundated.

The measure of increasing the water supply for the area could be considered again, as with the increased inundation in the area (primary expected to build-up in the winter periods), and thus the storage of water in the area, could be sufficient to meet the water demands in the summer period (this water balance is yet to be research).

This thesis assumes that with this scenario, groundwater is becoming harder to manage as souls, especially in low-laying areas become more saturated, and thus activities in these areas (such as agriculture) have to adjust to higher ground water levels. Groundwater on the higher sandy soils are expected to be managed with more ease.

6.3.2 Urban developments at an Ijsselmeer water level of +2m NAP

Existing but also newly developed urban areas are expected to experience more prolonged water inundation in this scenario. Especially when the decision is made to allow water (in a controlled manner) to pass over the dikes (and therefore the decision to not further reinforce the dikes), the lower areas of the region will become wetter (Schra, et al., 2022). Area developments for housing, such as in Grafhorst, Stadshagen, Hasselt, Genemuiden, Zwartesluis, and Meppel, are taking place in areas that are considered to become swampy at a water level of +2m NAP.

When looking at the measures and principles for new construction, it is noticeable that the measures to deal with water nuisance are based on the assumption of dealing with temporary water inundation or flood events or being prepared for flooding in the event of a dike breach. This thesis interprets that these measures aim to manage short periods of water inundation (minimizing damage) and provide safe escape routes in case of a possible flood, but both strategies are not designed to accommodate prolonged wet conditions in the living environment. It raises the question whether, in such situations, the liveability of the residential area will deteriorate (will prolonged wetness damage homes? Will the roads remain easily accessible for coming and going from home?).

Within such situations, new development directions could arise to make inner-dike urban areas more robust to situations in which water and/ or swampy landscapes are allowed to develop in the inner-dike areas. A concept mentioned by one of the experts (Expert Climate change adaptation and water management, Interview, 2023, Appendix: II A) is the 'achteroever' concept ("*a water storage area behind the dike where, with flexible water level management, water can be stored from a nearby national waterway*" [Doef & van Ek, 2021 p. 32]). According to Doef & van Ek (2021 p. 35), *"The concept of the backshore offers a wide range of opportunities for integrating water management with other functions on the land side of the dike. This could include activities such as residential and commercial development near and, on the water, provision of drinking water, natural habitat conservation, recreational activities, and sustainable (wet/floating) circular agriculture or fishing. In essence, this makes it possible to transform backshores into sustainable living and working areas, thereby generating new prospects for the regional economy".* Instead of keeping low-lying wet areas dry, it is now accepted that these areas are naturally wet. Instead of pumping or draining the water away, there is now a greater emphasis on adapting to the natural flow of water. This is also mentioned in the exploration of the sponge strategy (Sweco, 2023). The suggestions of Doef & Ek (2021) could be considered to shape, give a social purpose to these wet areas.

6.3.3 Mobilisation at an Ijsselmeer water level of +2m NAP

Due to the inundation of certain areas in the region, there is a chance that road networks and possibly train connections (e.g., Zwolle - Kampen) in these areas may become less accessible. As indicated in the previous scenario (6.2), with a waterlevel of +2m NAP, Kampereiland will be difficult to nearly impossible to reach via the road network. Furthermore, it also raises the question whether the long-term inundation will have and impact on the road and rail infrastructure.

6.3.4 Rural area at an Ijsselmeer water level of +2m NAP

From, among other things, the sponge strategy, it becomes clear that rural areas can offer a lot of space for the storage and retention of water. However, with current agricultural activities (where the groundwater level is kept around -40cm below ground level), there is a conflict between these activities and the wetting of rural areas. As mentioned earlier, at a water level of +2m NAP or more, the wetting of the rural area is inevitable. Unless there will be invested in stronger dikes and greater pumping capacity, this thesis expects that parts of the rural areas will become marshy, as indicated in Schra et al. (2022).

In this scenario, rural areas start to meet its tipping points. As no concrete plans were presented at the time of this thesis, the current situation of the rural area is considered as the situation in the near future. Therefore, this scenario will negatively affect the current crops that are being cultivated as these will not develop and even fail to fully grow in wet circumstances (Weterhof, 2018). Besides, wet grounds are also not preferred for grazing cattle. Therefore, this thesis argues that a transition in rural activities is needed in which wet, swampy landscapes are considered. At the same time, such a transition could come with new opportunities. By allowing the rural landscape to become more wet, land subsidence within the polders could be tackled (Geurts & Balkema, 2023). In this case, agriculture can adapt and transit to other crop types that are more resistant to wet circumstances (Paludiculture) Catall (Typha sp.), Reed (Phragmites australis), Peat moss (Sphagnum sp.), Grasses like reed canary grass (Phalaris arundinacea), and Alder (Alnus sp,) (Geurts et al., 2019 p. 7).

6.3.5 Energy at an Ijsselmeer water level of +2m NAP

See answer 6.2.5

6.4 Scenario: Ijsselmeer water level of +5m NAP

Figure 19

Estimated situation water system Zwolle region with an average Ijsselmeer water level of +5m NAP

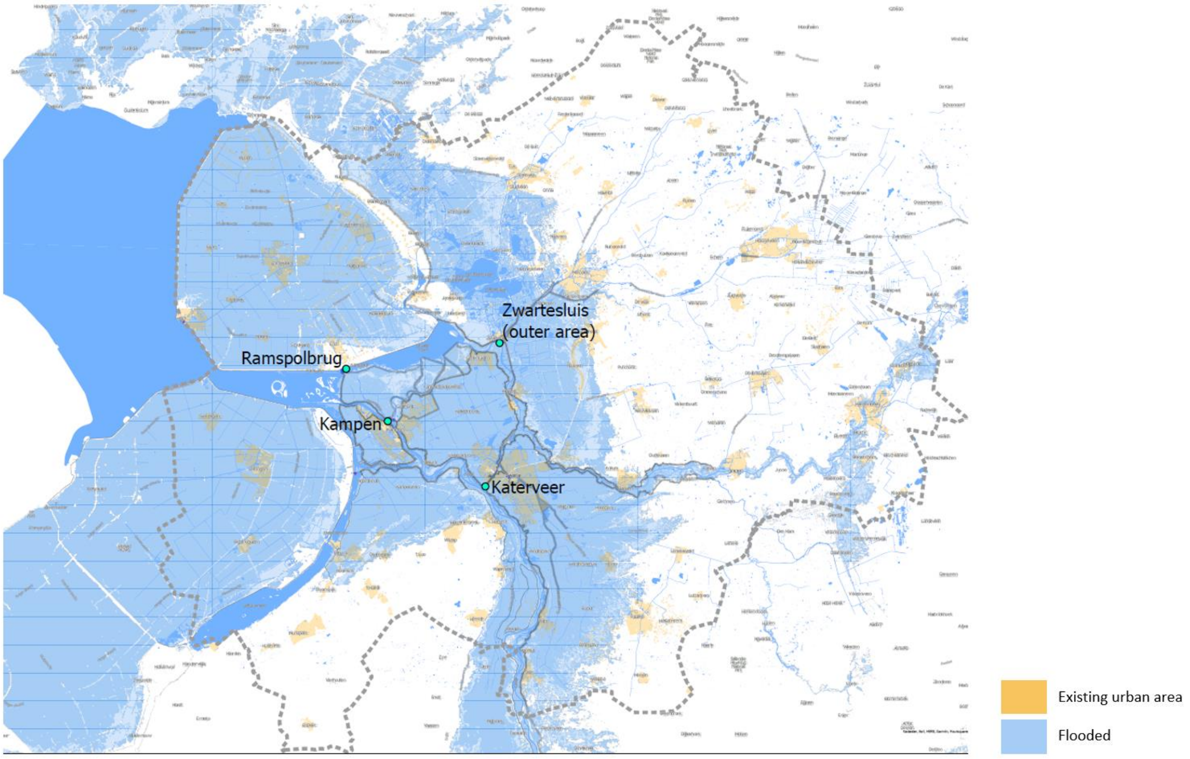


Table 9

Present day water thresholds compared to a +5m Ijsselmeer water level scenario. Retrieved from Waterinfo.nl. Rijkswaterstaat, n.d.

Measuring station	Reduced water level (cm)	Normal water level (cm)	Slightly elevated water level (cm)	Elevated water level (cm)	High tide /Storm surge (cm)	Extreme high tide (cm)
Katerveer	< - 15	-15 to 155	>155	>195	>280	**>360**
Kampen	<-45	-45 to 50	50 to 70	> 70	>175	**>260**
Zwartesluis (outer area)	<-50	-50 to 50	>30	>47	**>150**	n/a
Ramspolbrug	<-55	-55 to 20	>20	>40	>70	**>110**

Note: Present day water level thresholds. Colored cells indicate the water level NAP at the measuring stations shown in figure 19 with an Ijsselmeer water level of +5m.

At +5m NAP, the floodplains experience permanent inundation extending up to Westervoort (Ijssel), and considerable sections along the Vecht River are submerged up to beyond Ommen. The Ijssel Delta becomes submerged: the surrounding area of Kampen is inundated, and both Kampen and Zwolle face flooding with the existing flood defences (Schra et al., 2022).

In both conversations with the waterboard (WDOD) and the municipality of Zwolle, this scenario is almost unthinkable in nowadays reality. Whereas the municipality at 2m already points out, a totally different mindset is needed to deal with that scenario, WDOD indicates that already at a water level of +3m, it would consider different strategies than strengthening the flood defences; assuming the costs to strengthen and maintain would be unrealistic to invest in (WDOD, personal communication, 2023).

When the flood defences are not considered anymore, this thesis argues this to be the tipping point for a more closed, compartmentalized system; when flood defences are not sufficient, water will enter and pumping would become irrelevant. In this case, this thesis argues that it would be more logical to implement this option at the Afsluitdijk, as there is more room available to strengthen the flood defences and the instalments of large (world record breaking) pumping systems (Expert Climate change adaptation and water management & Coastal structures specialist, Interview, 2023, Appendix: II A, D). Especially when other regions within the Ijsselmeer area and upstream rivers that connected to the Ijsselmeer did not implement any adaptation measures for this high-water level scenario.

To adapt to this situation, this thesis argues that only options of adaptive land-use planning (in more extreme and innovative forms such a floating cities) and retreat are possible to deal with such scenario. The only situation in which this thesis sees it somewhat plausible to have a closed system, is when there is chosen to protect the main and large cities of Kampen and Zwolle, transitioning these cities into islands within the Delta[6].

6.5 Developments over time

In the previous sub-sections, various scenarios that revolve around the changing water level of the Ijsselmeer due to SLR were discussed. In this last sub section, these scenarios will be place in time towards 2300 to discuss and estimate the sell-by dates of possible development directions.

6.5.1 Anticipating an Ijsselmeer water level of +1m NAP

Starting from the current situation[7], the system meets the first big change in water level with an increase of 1,25m[8] in 2090 (SSP5-8.5 high end scenario). At a water level of 1m, the artificial islands in the Ketelmeer are argued not to be effective anymore as with 1m it is expected by this thesis that these islands would have been submerged by at least 1m. Therefore, the tipping point for the artificial island are in this thesis to happen in 2090. However, in the SSP1-2.6 (high-end) and SSP5-8.5 (low-end) scenarios, the sell-by date is expected in 2150.

As estimated in the previous sub sections, with a water level of 1m, primary dikes need to be strengthened. Depending on the dike section, this could take 1-14 years, meaning that preparations for strengthening the flood defences already need to start earliest in 2070-2075. For flood defences completed in the middle of this century (2040) that are expected to last until 2120 (assuming a function lifetime of 80 years), this means that the defences might need to be strengthened again before it reaches the end of its expected functional lifetime if this scenario was not considered, risking stranded assets. In the SSP1-2.6 (high-end) and SSP5-8.5 (low-end) scenarios, this would not be the case, as functioning lifetime is met before preparations for such a scenario need to start. Therefore, this thesis argues that the current process of strengthening the flood defences is sufficient in this scenario (looking 80 years ahead).

In 2090, the Ramspol storm surge barrier will also reach a tipping-point. As discussed in 6.2.1, two decisions can be made: either to permanently close the barrier with a large pumping system to maintain the current or adjusting the closing conditions; accepting upstream water to rise, and thus more flood defence reinforcement is needed. This in its turn increases the possibility of water

[6] In the case of Kampen submerged islands that are separated from the water with high flood defences like a bathtub.

[7] In this situation, the proposed development direction as discussed in section 4 are in place.

[8] Difference between the current average water level of the Ijsselmeer (-0,25 NAP) and the Ijsselmeer water level in the SSP5-8.5 high end scenario (+1m NAP).

accumulation events in the inner-dike regions when water cannot be drained fast enough; risking water nuisance in urban and rural areas and might need to adapt.

6.5.2 The impact of flood defense strategies on land use

The latter situation is an interesting one, as there can be argued that by looking at this situation flood defences have a dominant influence on the spatial planning and activities in the region. It is argued that inner dike activities and developments depend on the flood defences in place: when the flood defence system starts functioning differently, inner-dike areas vulnerable to flooding might have to adapt as well. Because of this dependency, this thesis will further analyse the developments based on potential strategies instead of separate alternatives. These strategies are inspired by the Deltares solution pathways for the Netherlands (Haasnoot, et al., 2019) (see figure 10 and table 20).

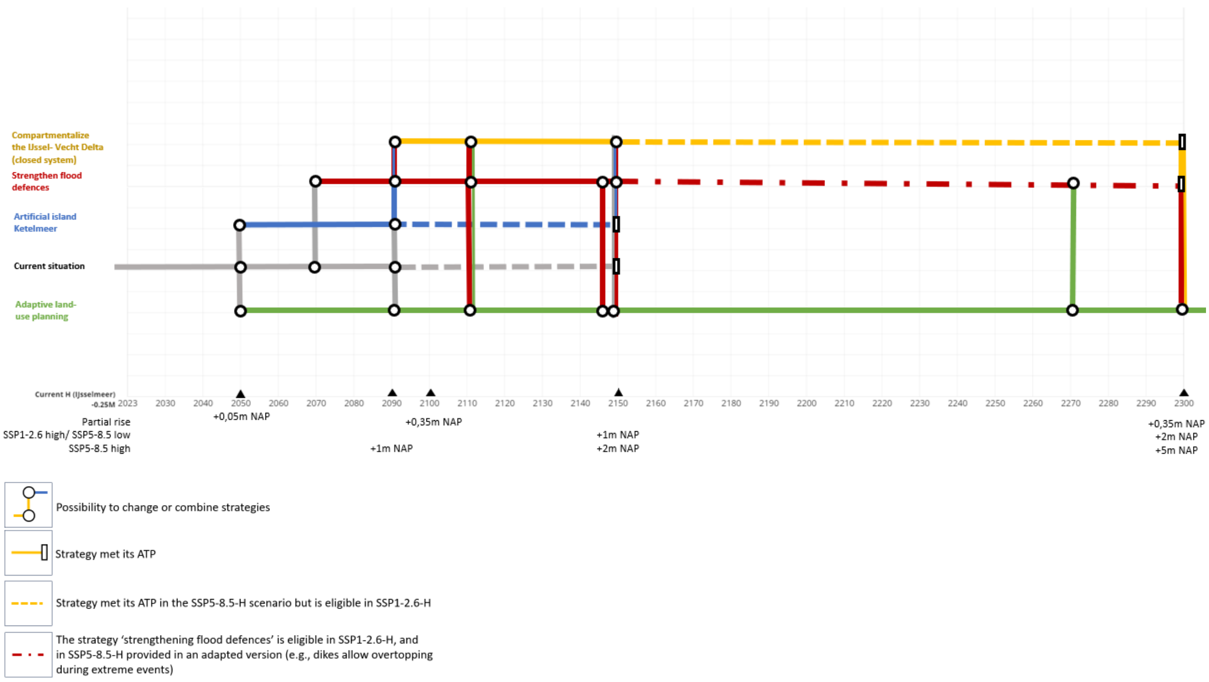
Table 10

Description of pathways showed in figure 20

Pathways	**Description**
Compartmentalizing of the Vecht-IJssel Delta (closed system)	Dike strengthening and combined with further compartmentalization of the Delta combined with large pumping systems.
Strengthening Flood Defences	Further strengthening of dikes.
Artificial islands in Ketelmeer	Sponge strategy focussed on Keterlmeer area
Current situation	Present situation of Zwolle Region.
Adaptive Land use planning ([semi-]open system)	Developments adapting to the changing water level (e.g., crop transition, adaptive building [e.g., terps], etc..).

Figure 20

Estimated adaptive pathway for the Zwolle region



Note: This figure shows the estimated pathways of strategies in time. Indicated when tipping points are met, and where decisions should be made to change or combine strategy.

Table 11

Lead time and functional lifetime of alternatives used in to determine the pathways in figure 20

Alternative	Lead time (year)	Functional lifetime (year)	Source
(Storm surge) Barrier	20-40	50-200	Haasnoot et al., 2020: table 1 p.9
Dikes and dams	Tens of km per year *HWBP WDOD: 180km in 31 years* *1-14 years depending on section*	50 - 80	- Haasnoot et al., 2020 p. 9 table 1 - WDOD, 2023
Pump	2-10	20-50	Haasnoot et al., 2020: table 1 p.9
Land reclamation	5-20	>100	
Flood-proofing building	2-10	30-150	
Planned retreat	Years to decades, short after flood event	>100	
House	-	At least about 100 years	Hekman & ter Horst, 2022
Windmill	-	+/-20	Milieudefensie, n.d.
Solar panel	-	+/- 25	Essent, n.d.

6.5.3 Anticipating an Ijsselmeer water level of +2m NAP

A water level of 2m can be earliest expected in 2150 in the SSP5-8.5 (high-end) scenario. To cope with this scenario, flood defences can be further reinforcement. However, options would likely to be considered here as well (WDOD, personal communication, 2023). This is where other strategies tend to arise.

Continuing with the current strategy of reinforcing, tends to move towards a strategy in which the IJssel-Vecht delta slowly becomes compartmentalised, as discussed with the situation of the Ramspol storm surge barrier, managing and maintaining the current water levels so the regional water system can operate in its present form. In return, strong flood defences in combination with a big pumping capacity need to be put in place (compartmentalising the delta as the main river systems are interrupted). Another option mentioned was to accept the increased water levels, which would or require the river dikes to be further reinforced combined with additional pumping capacity to drain the water from the inner-dike areas (closed dike system with emphasis on the regional systems). Preparations for this strategy are estimated to start around the year 2210.

Another strategy would be to allow inner-dike areas to become more frequently or permanently inundated (semi-open system in which flood defences still protect against large floods, but allowing water to enter they system [e.g., adjusted flood defences allowing water to overtop the dikes]). The latter one would require more spatial adaptation of the inner dike areas. In this case, the strategy of flood defences is adjusted by reframing its function from permanently keeping the water out to allowing water to, e.g., overtop during high water or extreme events. This strategy can be developed along the strengthening of flood defences. Starting early with inner-dike spatial adaptation for a wet environment, can make a switch from a closed system to a (semi-) open system easier.

6.5.4 Anticipating an Ijsselmeer water level of +5m NAP

The SSP5-8.5 (high-end) scenario is the only scenario consider in this thesis that has a water level of + 5m NAP and is expected in the year 2300. As discussed in section 6.4, maintaining the flood defences to protect the whole region is considered such a costly investment, that this is not considered to be realistic anymore. Therefore, this thesis argues that with 5m the strategies of a regionally closed system, and strengthening the flood defences, meet their tipping-points. In this extreme, only the strategy 'adaptive spatial land-use' is argued to exist in this scenario. However, these adaptations are of much larger and innovative scale (think about floating cities), which can be hard to realise, and one could argue with the current knowledge whether this is even a plausible option.

7. Discussion

7.1 Interpretation

This thesis started with the hypothesis that prioritizing decision-making based on short-term risks and opportunities may inadvertently omit crucial factors. longer-term perspectives enables a more comprehensive understanding of complexity and uncertainty, and therefore empowers individuals and entities to better anticipate and navigate future situations, thereby gaining a strategic advantage in adapting to evolving circumstances.

Based on the grey literature review to address SQ1, it becomes evident that current proposed development directions for the Zwolle region, with the exception of water safety developments, have a strong focus on present day challenges and how to address them in the near future (2040). In comparison to the hypothesis, it could be argued that this supports the proposition that the development directions are based on short-term risks. However, within these developments, there is an emphasis on 'how these developments can be addressed in a sustainable manner in the future'. Furthermore, in the implementation of new developments within the region, it is expected to be incorporated into the plans. Within this notion of 'sustainability', this thesis recognises an underlying emphasis on long-term foresight as it emphasises on making conscious choices in the plans, aiming to prevent the shifting of burdens onto other areas or generations. Particularly within the context of climate and water safety tasks, attention is given to the long term. It is customary, for example, to look 80 years ahead in dike reinforcement projects. Additionally, space is also being reserved for the further strengthening of dikes. Based on these findings, it appears that in the region, a longer-term perspective is being considered than was previously believed before this study.

However, when questioned what the long-term risks are for the region, it is argued by this thesis that the examined literature does not provide a complete picture of what these entail. So have models been used to assess current developments, such as mobility and socio-economic growth, and are based on trends derived from the current developments. Based on Börjeson, et al. (2006) these can be interpreted as scenarios being more predictive in nature. In theory there is argued that predictions have a tendency to over- or underestimate a situation (Marchau et al., 2019, p. 2-3; Sarewitz et al., 2000, p. 2). Predictions could make thinking about the future more familiar and comfortable. Doing it in such a way makes it "*unlikely to generate novel insights*" as the "*systems that affect the future are inherently dynamic and chaotic* [...] *the future will probably not be what most people predict. Foresight research is a tool to help us to acknowledge and address that fact*" (De Beer & Bannerman, 2010, p. 222). Argued in this these, it lacks to recognise a certain level of uncertainty, and in terms of Walker's et al. (2013) interpretating these developments being based on a level 3 uncertainty (Multiple system models from which one is considered the most probable).

In addition to the models, there is also a reference to the future, where ambitions and visions come to the fore, drawing inspiration from previously created visions such as van Hattum (2022). According to Börjeson et al. (2016), within this thesis, these are interpreted as scenarios that are primarily normative in nature. By using norms and values, a desired future vision is outlined. This is of added value because it recognizes the various interests within society and serves as a crucial benchmark in defining a future. However, by naming and visualizing values, norms, and a desired outcome, this doesn't say much about the uncertain factors that can influence them nor the long-term risks. In other words, a goal has been set on the horizon, but the journey toward it remains uncertain. This becomes clear when comparing the growth ambition of the region of Zwolle to its vulnerable location. In contrast to these SLR scenarios, the region shares the ambition to economically grow into the 4th economic region in the Netherlands, with an emphasis on further building upon the strong geo-economic position of the city of Zwolle. Keeping its vulnerable location out of consideration, this thesis would find this strategy logical. However, investing in a vulnerable located region with the incentive of growth seems in the opinion of this thesis risky. Argued in the proposed development directions, attracting investments to the region would benefit climate adaptation and mitigation measures as these investments can be used to finance them. As a counter arguments, this thesis points out that with increased investments in a region, the risk (in this case flood risk) therefore also increases because of the fact that the consequences of a flood event have been increased. Especially when the growth ambitions of the Zwolle region are meant to match those of the other three largest economic locations in the Netherlands, such as Brainport Eindhoven or the Randstad[9]. Moreover, the risk further increases when external factors such as SLR in combination with water level decisions of the IJsselmeer are considered, increasing the vulnerability of the region. This discussion is also recognised in the research of McGranahan, et al. (2023). Based on a global study on rapid urbanisation of low-elevated deltas, they found that under the appropriate conditions, the process of urbanisation has the potential to support and contribute to climate change. Yet they also recognise that urbanisation leads to spatial path dependencies that could last over centuries or even millennia.

The prediction and envisioning of a future can both be viewed as long-term reasoning. However, this thesis believes that within the case of Zwolle, little attention has been given to identifying future risks and uncertainties; scenarios and explanations that explore 'what could happen', referred to by Börjeson et al. (2016) as explorative scenarios. This can be substantiated with this thesis' focus on SLR. Within the proposed development plans, SLR is recognised as a possible challenge in the future for the region, yet no further elaboration on such scenarios have been explored or are considered in the development directions. Notably, these scenarios are being explored by the Dutch Delta Programme, even in consideration with the region of Zwolle. However, these findings, as stated, are not accounted for in the current development documents. Argued by this thesis, this indicates a gap between what is being discussed in the context of the larger Ijsselmeer region and what locally is discussed in the development of the region of Zwolle.

The proposed developments are based on the current water level decision of the Ijsselmeer, in which a margin is applied that the water level can rise with a maximum of 30cm after 2050. Whilst in answering SQ2, it has been found that a possible increase in the Ijsselmeer water level more than this 30cm cannot be ruled out. As found in SQ3, this could have major consequences for the Zwolle region, and therefore, argued in this thesis, not recognising these potential future risks could have major consequences for the region. Based on the results of SQ 2, there can be stated that a further increase in the water level of the Ijsselmeer, in addition to the already included 30cm in the water level decision, cannot be ruled out. Even with a rise of 60 cm compared to the current average Ijsselmeer water level, the pressure on the region will increase, leading to more frequent to permanent flooding of areas outside the dikes and wetting of areas within the dikes. Interpreted in this thesis, the current proposed development directions for urbanization and rural areas mainly rely on the flood defences in which the current situation within the dikes is assured, requiring little adaptation of the areas inside the dikes and land use. While climate conditions such as waterlogging and potential floods are taken into account, they are primarily based on events rather than permanent situations. However, for the sponge strategy, initial research has been conducted on possible inland climate adaptations, even though sea-level rise scenarios were not considered in this study.

Based on this, this research has identified two strategies for anticipating the changing water system. The first strategy involves strengthening and expanding the technical water system to maintain the

[9] The current literature does not specify on the exact extent of the region's growth ambitions, which makes it hard to validate this comparison.

current situation (especially present in urban and rural development), while the second strategy focuses on adapting to changing conditions and places less emphasis on water safety (especially present in the sponge strategy). By placing both strategies in different long-term scenarios, the option of gradual adaptation is considered the most robust. This is because it is believed that gradually adjusting to the water system makes it easier to anticipate changes than having to achieve this in the distant future under stricter conditions and within a shorter time frame. Moreover, by the scenarios covered in this thesis, starting from a 2m rise, questions can be raised about the efficiency of further strengthening and expanding the technical water system. In the most extreme scenario of a 5m rise, this strategy is deemed impractical for the Zwolle region due to the substantial investments and maintenance required, making the region less attractive to live in. Thus can be argued that with a short term perspective, a technical approach would be cost efficient approach to deal with the current challenges, as a spatial and land-use transition would be considered complex and expensive. Whilst on the other hand, based on the of Zwolle region in context of used scenarios, this strategy however, is not desirable in extreme or distant future scenarios.

Accordingly, this thesis argues that a prioritised or one-sided focus on short-term risks and opportunities without considering the implications in the future is short sighted. By placing these developments and potential long-term strategies into perspective, additional relevant information has been gathered within this research that can be incorporated into the further development of the region. In the context of rising water levels in the IJsselmeer, insights regarding the water management of the Zwolle region are particularly interesting. Since it has been found that relying solely on a reinforcement and defence strategy against a changing water system is not considered a robust choice, it becomes intriguing to further investigate the role of spatial planning in inland areas in the development direction. The sponge strategy has already taken an initial step in this direction.

As this thesis confirms the added value of this long term-perspective, another question arises of how far one must look into the future. In Lyon, et al. (2021), it is advocated for climate research to look well beyond 2100 up to 2500 to estimate its impact in the long term. As Lyon et al., mainly focusses on climate mitigation, using the foresights as an argument for urgent climate mitigation, this research's focus was mainly on climate adaptation. Based on the findings in this case study, this thesis argues that selecting a timeframe for foresight highly depends on the decision that will be made. In this, the lifespan of a decision or the extent to which it is expected to have an impact over the long term is important to consider. Decisions with a short lifespan and little influence within its surroundings do not need a distant future approach; temporary outer dike vacation home developments are less relevant in the long term than urbanisation developments. Considering decisions in a distant future perspective would be highly inefficient and costly. Therefore, in considering distant future, it is more efficient to apply this on slow and long lasting developments such as urbanisation. Reflecting on the case of Zwolle, the time frame up to 2300 was considered relevant for amongst other flood-safety planning. Here a long term overview helped to indicate when changes in strategy or design are desired. Especially in the context of extreme scenarios with an increased rate in which the water level accelerates in which new designs were required before expected lifespan was reached (SSP5.8.5-H scenario). The timeframe up to 2300 was considered less relevant for decision about windmill or solar panel parks because of there short lifespan.

7.2 Limitations

During the grey literature review, time constraints led to a focus on urban-economic developments. This limits the research by excluding other crucial developments in the region like nature, safety, industry, and more. As a result, the answering of both main and sub-questions is also restricted to these developments, making this research incomplete in practical sense. However, in addressing the hypothesis within this thesis, this limitation is considered less significant because the research has based on these developments gathered sufficient information to test the hypothesis; arguing that the research concept remains the same regardless of the developments being addressed.

Some of the grey literature analysed in this research lacked in detail as they provide the most recent status of continuously evolving plans. This particular level of abstraction causes a tendency towards an expectation bias of the researcher. In order to mitigate this bias, this thesis aspired to maintain as truthful as possible to the original text when summarizing/ placing the findings within the context of this thesis, and efforts made to identify information gaps within this thesis. However, it's important to note that complete elimination of this bias cannot be assured, especially when analysing qualitative information that inherently allows for interpretation by the researcher.

Because the explorative nature of this research, the impact of SLR on the region of Zwolle in this thesis is largely based on assumptions and rough estimations. This has limited the research in being precise on the exact occurrence and extent of the impacts of SLR in the region of Zwolle. Because of this, this thesis cannot fully justify its findings and more research and modelling will be needed to fully justify the findings.

The assessment of the robustness of the current proposed developments in the region of Zwolle lack a strong analytical framework. As a result, the findings are less effectively structured, thereby impacting the reliability of these findings.

In the verification of the results (as described in section 3.5) was done with a select group of people from WDOD and the municipality of Zwolle. Even though, involved in the developments of the Zwolle region, other organisations, stakeholders, and researchers have not been approach; limiting the verified results to a select group of actors within the case study. Therefore the results do not represent all viewpoints in this case study.

8. Conclusion and recommendations

This thesis focussed on the main research question: This thesis concludes its findings by answering the main research question: *How robust are the current proposed development directions of the Zwolle Region compared to Sea Level Rise scenarios up to 2300?*

In the approach to the year 2300, it is crucial to consider scenarios of SLR ranging from 2 to 5 meters, as they cannot be ruled out. These scenarios will significantly impact the Zwolle region, particularly by decisions related to the IJsselmeer water level. Over a 250-year horizon, the possibility that the water level in the IJsselmeer (party) increases alongside the SLR developments cannot be omitted. At the same time the region of Zwolle has the aspiration to develop into the fourth economic region of the Netherlands. In this, the city of Zwolle serves as the central focal point within the region where the majority of the housing challenge is addressed with a strong focus on infill. In surrounding mid-sized urban centres, the residential offerings are expanded, and in smaller towns, the emphasis is placed on fostering strong vitality instead of growth. The mobility network is also designed from both urban and rural centres, where a vital city or village centre will reduce the number of travel movements, and the use of public and shared transportation is encouraged. Within these developments there is also aimed to tackle climate related challenges, striving development in the region must contribute to climate adaptation, and or mitigation. With the sponge strategy plans are made to enhance the resilience of the water system against the effects of climate change, such as drought and heavy rainfall events. Water captured in the mainland is retained and drained over a longer duration. Noticed by this research, most of the current development directions did not consider possible developments of SRL, and are planned according to the current water system of the Zwolle region, and thus depending on the current water system of the region. The scenarios have shown that raising the water level exerts significant pressure on the water system, causing outer dike areas to flood more frequently or permanently, and inner dike areas are expected to become more wet. Even though current development take into account temporary water nuisances or floods, they are not designed for persistent flooding conditions. As the developments presuppose the present state of the water system, and the fact that increased water levels would have an significant influence on the water system of the region, resulting in a more wet and frequently flooded environment, this thesis concludes that the current proposed developments lack in robustness.

By applying a distant future perspective, this thesis has provided novel insights on the possible future challenge of increase water levels in the region of Zwolle. As this research is exploratory in nature and strongly based on rough estimations, it is recommended to further thoroughly explore the impacts of an increased water level of the Ijsselmeer to obtain more information about the exact vulnerabilities and consequences within the region for better informed decision making, facing its uncertainties. Moreover, this research only covered SLR development, yet other long term developments that now might be overlooked when focussing on the near-future, are also recommended to be explored and identified.

These long term perspectives therefore contribute by creating novel insights for informed decision making. This confirms the observation done in existing literature that embracing longer-term perspectives allows for a more thorough grasp of uncertainty and empowers individuals and organizations to more effectively foresee and navigate future circumstances.

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