MASTER THESIS

Management of (climate) uncertainties in urban development projects

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Summary

The municipality of Zwolle is looking to develop new residential areas within the city as a result of major housing shortages in the Netherlands. However, due to the position of Zwolle in the IJssel-Vecht Delta, a portion of the city lies within the unembanked space. This includes existing and planned residential areas. It is important to be aware of the uncertainties that come with project development in the unembanked space. Uncertainty related to climate change and social developments, related to technical feasibility of project designs, but also uncertainty prevalent between stakeholders of the to be developed residential areas.

So far, research in uncertainty management mainly focussed on policy-making on a higher governmental level ((inter)national), but not on the more practical local level. In this research, it is researched what uncertainties practitioners – participating in the project – experience during the project development process of residential areas in the unembanked space, during what phase in the development process they first become aware of the uncertainties, and ultimately, how they deal with the experienced uncertainties. The purpose of this research is to find out how practitioners deal with uncertainties as they encounter them in projects. The question asked is: What (climate) uncertainties arise in urban development projects in the unembanked area and how are the uncertainties dealt with in practise?

Two case projects have been examined to answer this question. The uncertainties practitioners experience have been derived from document analysis and through semi-structured interviews with participants of both projects. The data resulting from this was compared to literature about uncertainty management in water management. This literature distinguishes between three separate uncertainty types, and proposes adequate measures to deal with a given type of uncertainty. The three types of uncertainty are related to the nature in which they present themselves, which are: 1) a lack of knowledge, 2) unpredictability of a system or phenomenon, or 3) uncertainty originating from many possible interpretations of a situation.

The study shows that practitioners collectively experience a wide range of uncertainty within projects. But at the individual level practitioners often times experience one uncertainty type over the others. 23 different uncertainty themes were derived from the uncertain situations that were described either in project documents or by participants that were interviewed. The most important one is uncertainty related to getting parties on the same page and talking about the same things. Other notable themes included: 1) climate induced future water level increase, 2) integration of the project into the river landscape, and 3) whether one should want to build in the unembanked space.

Practitioners are very aware of the differences in nature between the uncertainties they experienced during the project. This is also reflected by the methods they applied to deal with the uncertainties they had experienced. Most of the time, practitioners adequately dealt with the uncertainties they experienced. Doing more research (knowledge), worst-case scenario planning (unpredictability), and dialogical learning (interpretations) were the most used methods for each type of uncertainty respectively.

However, the methods to deal with a given uncertainty differed between projects, and in some instances also between individual practitioners in the same project. Because of these discrepancies between practitioners, in this research it is heavily advised to start with documenting uncertainties, and acknowledging their presence and effects in the projects. It is proposed to actively involve uncertainty management into the project development process by applying uncertainty management in a similar fashion to risk management, where uncertainties of different types are inventoried and methods to adequately deal with them are decided upon based on the type of uncertainty experienced.

Samenvatting

De gemeente Zwolle zoekt naar nieuwe woongebieden binnen de stad vanwege het grote woningtekort in Nederland. Door de ligging van Zwolle in de IJssel-Vechtdelta ligt een deel van de stad echter buiten de bedijkte ruimte. Dit omvat bestaande en geplande woongebieden. Het is belangrijk om bewust te zijn van de onzekerheden die gepaard gaan met projectontwikkeling in de onbeschermde ruimte. Onzekerheid met betrekking tot klimaatverandering en maatschappelijke ontwikkelingen, met betrekking tot technische haalbaarheid van projectontwerpen, maar ook onzekerheid tussen stakeholders van de te ontwikkelen woonwijken.

Onderzoek naar onzekerheidsmanagement richtte zich tot nu toe vooral op beleidsvorming op een hoger bestuurlijk ((inter)nationaal) niveau, maar niet op het meer praktische lokale niveau. In dit onderzoek wordt onderzocht welke onzekerheden praktijkbeoefenaars – participerend in het project – ervaren tijdens het projectontwikkelingsproces van woongebieden in de onbedijkte ruimte, in welke fase van het ontwikkelproces zij zich voor het eerst bewust worden van de onzekerheden, en uiteindelijk hoe zij omgaan met de ervaren onzekerheden. Het doel van dit onderzoek is na te gaan hoe praktijkmensen omgaan met onzekerheden zoals zij die in projecten tegenkomen. Daarbij wordt de vraag gesteld: Welke (klimaat)onzekerheden doen zich voor bij stedenbouwkundige projecten in het buitendijkse gebied en hoe wordt er in de praktijk met de onzekerheden omgegaan?

Om deze vraag te beantwoorden zijn twee casus projecten onderzocht. De onzekerheden die praktijkbeoefenaars ervaren zijn ontleend aan documentanalyse en door middel van semi-gestructureerde interviews met deelnemers aan beide projecten. De gegevens die hieruit voortkwamen zijn vergeleken met de literatuur over onzekerheidsmanagement in het water management domein. In deze literatuur wordt onderscheid gemaakt tussen drie afzonderlijke typen onzekerheid en worden adequate maatregelen voorgesteld om met een bepaald type onzekerheid om te gaan. De drie soorten onzekerheid houden verband met de aard waarin ze zich voordoen, te weten: 1) een gebrek aan kennis, 2) onvoorspelbaarheid van een systeem of fenomeen, of 3) onzekerheid die voortkomt uit vele mogelijke interpretaties van een situatie.

Uit het onderzoek blijkt dat de project deelnemers als collectief een breed scala aan onzekerheden ervaren binnen projecten. Maar op individueel niveau ervaren beoefenaars vaak een type onzekerheid boven een andere. 23 verschillende onzekerheidsthema's werden afgeleid uit de onzekere situaties die werden beschreven in projectdocumenten of door geïnterviewde deelnemers. De belangrijkste is onzekerheid met betrekking tot het op één lijn krijgen van partijen en het over dezelfde dingen praten. Andere opvallende thema's waren: 1) klimaat verandering gedreven toekomstige waterpeilstijging, 2) integratie van het project in het rivierlandschap, en 3) of men in de onbedijkte ruimte zou moeten willen bouwen.

Beoefenaars zijn zich zeer bewust van de verschillen in aard tussen de onzekerheden die ze tijdens het project hebben ervaren. Dit blijkt ook uit de methoden die zij hebben toegepast om met de ervaren onzekerheden om te gaan. Meestal gingen beoefenaars adequaat om met de onzekerheden die ze ervoeren. Meer onderzoek doen (kennis), worst case scenario planning (onvoorspelbaarheid) en dialogisch leren (interpretaties) waren respectievelijk de meest gebruikte methoden voor elk type onzekerheid.

De methoden om met een bepaalde onzekerheid om te gaan, verschilden echter tussen projecten en in sommige gevallen ook tussen individuele beoefenaars van hetzelfde project. Vanwege deze discrepanties tussen praktijkbeoefenaars wordt het in dit onderzoek sterk aangeraden om te beginnen met het documenteren van onzekerheden en het erkennen van hun aanwezigheid en effecten in de projecten. Voorgesteld wordt om onzekerheidsmanagement actief te betrekken bij het projectontwikkelingsproces door onzekerheidsmanagement toe te passen op een vergelijkbare manier als risicomanagement, waarbij onzekerheden van verschillende typen worden geïnventariseerd en methoden worden gekozen om er adequaat mee om te gaan op basis van het type ervaren onzekerheid.

Table of Contents

List of Figures

List of Tables

1. Introduction

1.1: Zwolle; Housing, Water & Uncertainty

An ongoing and ever growing problem in The Netherlands for the past years are the housing shortages. In 2021 shortages were estimated to be around 279,000 dwellings (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, n.d.; Correspondent, 2022). This is especially prevalent in urban areas (read: cities). There are a variety of causes for the housing shortages. On the one hand the cities appeal to people as cities can offer education, jobs, recreational opportunities, events, creativity, and the presence of other people, which is especially attracting for highly educated young people (Nijskens et al., 2019). On the other hand, the housing supply is lagging behind the ever growing demand. The supply of new properties is only increasing slowly since land suitable for residential development is scarce due to administrative building restrictions, the increasing 'not in my backyard' mentality of people (Nijskens et al., 2019), and increased prices for raw materials and scarcity of (skilled) personnel within the construction industry (Obbink, 2021; Cobouw, 2022). On top of that, fuelled by low interest rates, residential properties have become an increasingly popular investment good for both domestic and foreign investors (Nijskens et al., 2019; Trouw, 2022). All these factors combined result in affordability problems for the average citizen to buy their own property.

The city of Zwolle also faces a boom in housing prices. Average sales prices in Zwolle have increased by ~66% in the period between 2015-2021 (from €218,349 up to €363,081) (CBS Statline, n.d.). The demand for affordable dwellings is growing, especially for people looking to buy their first home. However, the city does not have an abundance of space available to facilitate for this demand. A policy called 'the ladder for sustainable urban development' (Dutch: de Ladder voor Duurzame Verstedelijking) restricts the municipality to focus on exploration of urban development within the existing urban boundaries before turning to green or open areas outside of the city (Ministerie van Infrastructuur en Milieu, 2017). The region of Zwolle is also assigned to be one of the NOVI regions. These are selected regions throughout the Netherlands which act as innovation testing grounds for issues in the living environment prevalent in the Netherlands as a whole. For Zwolle this means that extra attention is paid to adaptation of the built environment to climate change in order to ensure the liveability in the region in the future (Regio Zwolle, 2021). Because of the two policies mentioned, the municipality turns their attention to underutilized properties and areas within the city to redevelop into residential areas where special attention is paid to climate adaptation. However, what is special about these redevelopment areas in Zwolle is that some of them are located in the unembanked space.

Redeveloping underutilized areas into residential areas in the unembanked space raises, among other, the question whether water safety can be guaranteed for these residential redevelopment projects under the imminent climate change. Especially since the recent flooding in parts of Belgium, Germany and Limburg are still fresh on people's mind (de Bruijn, 2021). Recent analyses show that Zwolle and the surrounding area are just as vulnerable to flooding as the area struck by the flooding in Limburg in 2021 (Deltares, 2022).

Historically, Zwolle is not unfamiliar with building in the unembanked space. The city – like many urban areas within the Netherlands – is located near one of the big rivers flowing through the country. The city lies in the IJssel-Vecht delta, where multiple rivers and channels come together (Figure 1). The canals that run through the city are influenced by water coming from different directions where the Vecht, Sallandse Weteringen and the IJsselmeer form the most important influences (Dolman et al., 2019). Some parts of the city – most notably the city centre – are not protected by embankments or other water defence structures/mechanisms, which means that the city is relatively vulnerable to changes in the water system, be it as a result of climate change or human interventions both upstream and downstream of Zwolle (Dolman et al., 2019; STOWA, 2020). An extensive analysis of the water system in and around Zwolle can be found in Appendix A: Water System in and around Zwolle.

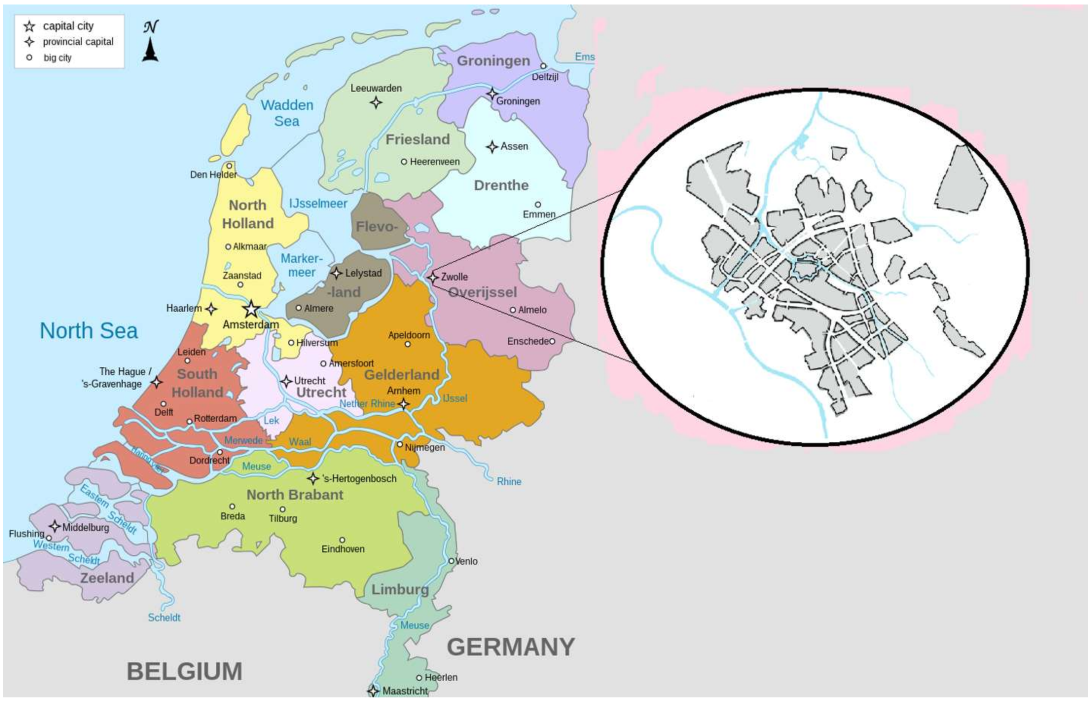

Figure 1: Location of Zwolle in the Netherlands. (Adapted from Alphathon (2010) and buro MA.AN (2017))

When designing urban development projects in unembanked areas, it is important to be aware of the areas' vulnerability to future climate change. One has to deal with uncertainties regarding future climate development such as future water levels and changes to rainfall, but also social developments such as economical or population developments (Pahl-Wostl, 2007). Determining how to deal with uncertainties (such as, future water level, future economic development, effects of projects on nature etc.) in projects where highly uncertain phenomena are involved is often times not an easy task. Some uncertainties can be diminished through analyses of the system and its behaviour during certain scenarios (Walker et al., 2003). However, some important uncertainties that determine normative principles – to which a project has to conform to – cannot always be fully diminished.

1.2: State of the art

There are many different approaches one can take to manage uncertainty in projects. For example, one could apply adaptive planning (Kwakkel et al., 2010; Rauws, 2017), or evaluate a real options analysis (Morano et al., 2011). However, uncertainty management is a relatively underexposed topic within the urban (re)development literature. From the scarce literature that is available, some focus solely on socio-economic uncertainty (Morano et al., 2011) or multi-actor uncertainty (Lami & Todella, 2019), while others approach uncertainty from a complexity theory point of view (Rauws, 2017). While these are all valid approaches to uncertainty, each method only focusses on a select source of uncertainty. None explore the wider spectrum of different natures of uncertainty and its many sources.

Urban (re)development literature seems to be lacking behind other literature in terms of uncertainty management. Because of this underdevelopment, other literature domains were consulted to take inspiration from. Literature with more developed uncertainty management research include the aviation sector (Kwakkel et al., 2010) or water management and safety literature (Pahl-Wostl, 2007; Kwadijk et al., 2010). The latter of which is a suiting literature domain for this research because it has a very relevant interface with this research. The interface being the specific focus on urban development projects unprotected by embankments or other water defence structures. Water management and safety literature is advanced to the point where it has adopted uncertainty theory (Walker et al., 2003 & Kwakkel et al., 2010) and expanded upon it in the context of the expertise (Brugnach et al., 2008; van den Hoek, 2014; Warmink et al., 2017; Dewulf & Biesbroek, 2018). Because of the combination of extensive and refined literature available in the water management and safety domain, and the relevance of water management to this research, it was chosen to predominantly adhere uncertainty management from a water management and safety literature perspective in this research.

1.3: Problem description

Following from literature on uncertainty management in the water management and safety domain, public policy makers tend to prefer determinism and certainty during the decision-making process in projects. They tend to aspire elimination of uncertainties (Bradshaw & Borchers, 2000; Warmink et al., 2017). In other words, optimal solution policy-making. Policy makers often resort to doing more research to the uncertain phenomenon experienced, which may not be adequate depending on the type of uncertainty being encountered (Walker et al., 2003; Warmink et al., 2017). Not all uncertainties lend themselves for this preference. Some uncertainties cannot be quantified or modelled in such way that it is possible to know exactly what is going to happen, how fast it is going to happen and what the consequences are. Walker et al. (2013) and van der Sluijs (2006) further stress this point, describing that gaining more knowledge, information or better data (doing more research) does not always lead to more certainty. On the contrary, it can lead to discovery of new uncertainties as a result of deeper understanding of the uncertain system or phenomenon (Walker et al., 2003). This is what makes optimal solution policy-making inherently flawed.

It is currently unknown what uncertainties practitioners – rather than policy makers on the policy level – experience on the project level during urban development projects in unembanked areas, if practitioners experience differences between types of uncertainty, in which phase in the project a given uncertainty shows itself, and how they decide to cope or deal with different types of uncertainty they might experience. Not knowing how to effectively deal with an uncertain phenomenon can lead to indecisiveness or anxiety towards the given uncertainty. The result of this can be that projects are severely delayed, that stakeholders retract from the project resulting in insufficient funds, or complete termination of the project (van den Hoek, 2014). Termination of urban development projects as a result of the uncertainties would be detrimental during a time of high pressure on the availability of (new) dwellings in the urban built environment.

1.4: Research objective

The research focusses itself on what (types of) uncertainties arise in urban development projects, when in the development process they first present themselves, as well as how uncertainty is dealt with by practitioners within the boundaries of a project. To do this, uncertainties that practitioners experience and consequently, what methods they apply to deal with them are analysed. In doing so, the research attempts to form a bridge between propositions by (water management and safety) literature and its applicability for practitioners in real-life situations. The main research question is as follows:

What (climate) uncertainties arise in urban development projects in the unembanked area and how are the uncertainties dealt with in practise?

To support the main research question, a number of sub-questions have been set up to address the different activities that are needed to be done. Collectively the sub-questions need to be able to answer the main research question. The sub-questions are formulated as follows:

1. What (types of) uncertainties do project participants experience during an urban project development process and during what project phase do these first arise?
2. In practise, how do project participants deal with the experienced uncertainty?
3. How do the experienced uncertainties and methods to deal with uncertainty by practitioners relate to literature's propositions?

1.5: Research scope

The purpose of this research is to find out how practitioners deal with uncertainties as they encounter them in projects, but also to identify situations where practitioners could benefit from strategies proposed by literature to deal with these uncertainties more adequately in future projects. There are many different theories about uncertainty (management) and subsequent extensions/expansions of these theories available in literature. To keep the research manageable and avoid sidetracking as much as possible, it was decided to adopt one approach on uncertainty theory and uncertainty management (explained in the theoretical framework) and use this as a baseline theory – or a starting point – for this research. This also improves the comprehensibility for interviewees in terms of what type data is sought after, and increases accessibility of the report for readers of the study.

The research focusses on urban development projects in which the municipality of Zwolle is or was participating in. Two projects are chosen to function as cases for this research. Both are within the city boundaries of Zwolle. This means that the research is geographically bound by the municipal management area of the municipality of Zwolle. However, the research is not bound by the municipality of Zwolle – as an organisation – in terms of data collection. The research aims to develop a complete view on experienced uncertainties by practitioners by gathering data from all involved parties in the assessed case projects, both public and private. Furthermore, the research is delimited in terms of the time available for conducting the master's thesis. The results (and the quality) are therefore bound to the time available to obtain and analyze data. The data were obtained between July and October 2022.

1.6: Report outline

The report is structured in six chapters. Figure 2 shows a visual representation of the outline of the report. The second chapter will cover the theoretical concepts that constitute the theoretical framework used in this research. Chapter three will focus on thoroughly explaining the research methods and the process of operationalizing the theoretical concepts of the data collection and data analysis. The findings and results of the case research will be covered in the fourth chapter. In chapter five the research methods and results will be discussed and put in context relative to other research. Lastly, conclusions and recommendations are located in chapter six.

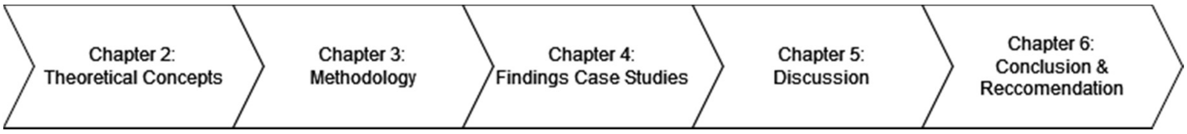

Figure 2: Report outline

2. Theoretical concepts

2.1: Defining Uncertainty

Uncertainty is a vital component in this research, but what does it mean exactly? In the literature, there is no single definition of what uncertainty means or what it encompasses exactly (Appendix B: Authors' definitions of uncertainty). Some authors simply refer to uncertainty as the lack of knowledge or information (Willows et al., 2003; Winch, 2010; Morgado et al., 2014). Other authors imply that the nature of uncertainty is rather deterministic and mathematically quantifiable. Walker et al. (2003) defined uncertainty as: '*any departure from the unachievable ideal of complete determinism'*. In a follow-up article this definition is expanded upon by the following explanation: "*Take event Y, If probability(Y) ≠ 0 or 1, then Y is uncertain"* (Walker et al., 2013, p. 2). Willows et al. (2003) and Krupnick et al. (2006) adopt a similar approach towards uncertainty being quantifiable, using terms like 'imprecise knowledge', 'probabilistically determined' and 'parameter uncertainty'.

A characterisation of uncertainty that is increasingly adopted in (climate & water management) literature is that uncertainty consists of two components. These are incomplete knowledge and inherent variability of a (modelled) system. This suggests that uncertainty envelops more than just a knowledge gap in itself. In some instances uncertainty cannot be fully eliminated due to the variability (or unpredictability) of the uncertain phenomenon (Walker et al., 2003; Krupnick, 2006; Brugnach et al., 2008; van den Hoek, 2014; Warmink et al., 2017; Dewulf & Biesbroek, 2018). In addition to these two components of uncertainty, van der Sluijs (2006) argues that uncertainty has both a quantitative and a qualitative aspect. It always involves a subjective judgement and interpretation from involved actors about a given uncertainty.

Brugnach et al. (2008), Warmink et al. (2017), and Dewulf & Biesbroek (2018) expand on this by acknowledging social processes that underlie decision making processes and project development under uncertainty. They explain that there are multiple valid ways in which problems and solutions can be framed in multi-actor decision settings, dependent on actors' believes, values and interpretation of the real world (framing/frame of mind). Here, framing – or a frame of mind – by a person refers to the construction and representation of the interpretations of the world around them (Lewicki et al., 2003). In projects this expresses itself by different ways of understanding a given problem, its boundaries and who/what to focus the attention upon on the one hand, and on the other, possible differences in interpretation on information and its meaning regarding a given problem (Brugnach et al., 2008; Brugnach et al., 2011). These factors can heavily influence the direction a project will take (Lewicki et al., 2003).

For this research, the definition and characterisation of uncertainty by Brugnach et al. (2008) has been adopted. In their research, they address uncertainty from a multi-actor decision making process perspective which is fitting for research related to urban (re)development project management. The definition of uncertainty is as follows:

> *"Uncertainty refers to the situation in which there is not a unique and complete understanding of the system to be managed." – Brugnach et al. (2008, p4)*

Following from this definition, a distinction is made between three different types of uncertainty: incomplete knowledge, unpredictability and multiple knowledge frames. The three types of uncertainty are named after the nature that underlies them, which is epistemic, ontological and ambiguity respectively. A definition of each given type of uncertainty along with and an example in the context of the research is shown in Table 1.

The distinction between the three types of uncertainty seems to be most suitable to capture the intrinsic nature of uncertainty in urban (re)development project processes. Urban (re)development projects – especially those in the unembanked area – often include a wide range of stakeholders with diverse visions, backgrounds, experiences, believes and values. These different frames can lead to ambiguity between stakeholders that coexists alongside the uncertainties related to lack of knowledge or unpredictability/variability of an uncertain phenomenon. As of now, the theory and characterisation of uncertainty by Brugnach et al. (2008) has been applied in research to investigate the uncertainties arising in large scale building with nature flood projection projects (van den Hoek, 2014). Following the outcomes, it is safe to assume that this characterisation of uncertainty is suitable for research on uncertainty within multi-actor decision-making processes like projects. This means that it is also suitable for this research on uncertainties arising in urban (re)development projects in the unembanked area.

Table 1: Definition of the uncertainty types used in this research and examples of each type of uncertainty

Name	Definition	Uncertainty example
Epistemic Uncertainty	Uncertainty related to incomplete or imperfect knowledge (Walker et al., 2003; Brugnach et al., 2008)	How can you integrate the project into the unembanked area? What should you take into account?
Ontological Uncertainty	Uncertainty due to inherent variability or unpredictability in behaviour of a system or phenomenon (Walker et al., 2003; Brugnach et al., 2008)	How will climate changes affect normative water levels and discharge regimes in the river?
Ambiguity	Uncertainty originating from many possible interpretations of a situation (different knowledge frames) (Brugnach et al., 2008)	Should you want to build in the unembanked area?

2.2: Dealing/coping with uncertainty

Following from the definition of three different types of uncertainty, it is only logical to touch upon adequate methods to deal or cope with each respective type of uncertainty. After all, once a given uncertain phenomenon is identified as being either epistemic, ontological or ambiguous in nature, participants of a project probably want to manage the uncertain phenomenon by dealing with it in an adequate manner. At first, it might seem intuitive to try to increase or refine knowledge about the uncertain topic in order to diminish the uncertainty by, for example, doing research or taking more accurate measurements (Termeer & van den Brink, 2013; Warmink et al., 2017). However in the case of ontological uncertainty, this might not yield the desired results (Pahl-Wostl, 2007; Brugnach et al., 2008; Walker et al., 2013;). For example, one could try to increase their ability to predict the outcome of a 6-sided dice by doing research and collecting data on previous outcomes of dice rolls. However, the added knowledge of previous outcomes will not help to more accurately predict the very next roll (provided the dice is fair).

In this respect, it is important to understand that there are different methods to adequately deal with a given type of uncertainty, be it ontological, epistemic or ambiguous (Brugnach et al., 2008, Brugnach et al., 2011; Dewulf & Biesbroek, 2018). There is no universal method to adequately deal with all three types of uncertainty (Walker et al., 2003; Zandvoort et al., 2017). For this research, scientific literature is used to identify adequate methods to deal with each uncertainty type. An overview of adequate methods per uncertainty type is shown in Table 2. This list is by no means extensive enough to claim that it includes all possible ways to adequately deal with uncertainty. However, it does propose a reasonable amount of methods to serve as a baseline for this research.

Table 2: Methods to deal with different uncertainty types with literature sources

Epistemic Uncertainty	
Method	Source
Assessment/Evaluation by experts	Brugnach et al., 2008; Dewulf & Biesbroek, 2018.
Research by experts	Brugnach et al., 2008; van den Hoek, 2014; Warmink et al., 2017; Zandvoort et al., 2017; Dewulf & Biesbroek, 2018.
Experimenting with different designs	Kwadijk et al., 2010; Zandvoort et al., 2017.
Doing research (increasing joint knowledge)	Kwadijk et al., 2010; Warmink et al., 2017; Zandvoort et al., 2017; Dewulf & Biesbroek, 2018.
Implication of knowledge gaps research	Brugnach et al., 2008; Dewulf & Biesbroek, 2018.
Developing confidence intervals	Brugnach et al., 2008; Warmink et al., 2017.
Taking more accurate measurements	Kwadijk et al., 2010; Warmink et al., 2017; Zandvoort et al., 2017.
Expert opinion	Brugnach et al., 2008.
Ontological Uncertainty	
Method	Source
Scenario planning	Pahl-Wostl, 2007; Kwadijk et al., 2010; Kwakkel et al., 2010; Ministery of Infrastructure and Environment & Ministery of Economic Affairs, Agriculture and Innovation, 2011.
Worst-case scenario planning (enduring uncertain phenomenon)	Pahl-Wostl, 2007; Brugnach et al., 2008; Kwadijk et al., 2010; Walker et al., 2013.
Incorporating flexibility (adaptability)	Kwakkel et al., 2010; Ministery of Infrastructure and Environment & Ministery of Economic Affairs, Agriculture and Innovation, 2011; Scholtes & De Neufville, 2011; Haasnoot et al., 2012; Walker et al., 2013; Zandvoort et al., 2017; Dewulf & Biesbroek, 2018.
Accepting uncertainty and deal with consequences as they occur	Brugnach et al., 2008; Warmink et al., 2017.
Taking measures usable within the timespan of an event	Brugnach et al., 2008.
Improvisation	Brugnach et al., 2008; Termeer & van den Brink, 2013.
Developing robust solutions usable for a multitude of scenarios	Pahl-Wostl, 2007; Brugnach et al., 2008; Kwakkel et al., 2010; Scholtes & De Neufville, 2011; Walker et al., 2013; Dewulf & Biesbroek, 2018.
Ambiguity	
Method	Source
Persuasive communication	Brugnach et al., 2008; van den Hoek, 2014; Dewulf & Biesbroek, 2018.
Dialogical learning	Brugnach et al., 2008; van den Hoek, 2014; Zandvoort et al., 2017; Dewulf & Biesbroek, 2018.
Negotiation approach	Brugnach et al., 2011; van den Hoek, 2014; Dewulf & Biesbroek, 2018.
Rational problem solving	Brugnach et al., 2011.
Imposing frame onto others	Brugnach et al., 2011; Dewulf & Biesbroek, 2018.
Accept different knowledge frames	van den Hoek, 2014; Zandvoort et al., 2017.

While most methods – such as doing research – explain themselves, some might be more complicated and need some explanation. This includes methods to deal with ontological uncertainty such as scenario planning, worst-case scenario planning, and incorporating flexibility, but also methods to deal with ambiguity. This includes methods like dialogical learning and rational problem solving. Only the methods – which might need explanation – most relevant for this research will be explained in this section. However, an extensive list that includes descriptions and examples of all methods presented in Table 2 can be found in Appendix C: Methods to deal with uncertainty.

Scenario planning involves developing or applying a number of plausible scenarios for the future and projecting those scenarios onto the project (Kwakkel et al., 2010). Scenarios show predictions of plausible future realities, both positive and negative (for the project) (Kwadijk et al., 2010). Scenario planning can help project actors assess potential future conditions the project might have to deal with during its lifespan. Scenarios can be made for a variety of uncertain future developments. For example, scenarios can take the form of predictions of future maximum water levels (Kwadijk et al., 2010), population growth/shrink, or temperatures.

Worst-case scenario planning is when one applies scenario planning and chooses to deal with the unpredictability of future conditions by making sure the project is able to withstand or deal with the most negative plausible (and known) scenario (Pahl-Wostl, 2007, Kwadijk et al., 2010). An example would be using different plausible scenarios for future maximum water levels and aiming to build an embankment capable of dealing with the most negative future scenario. The scenario with the highest maximum future water levels in this case. Then designing the embankment so that it is strong and high enough to resist those water levels, making sure the embankment is capable to withstand all plausible (known) scenarios for future water levels during its lifespan.

Incorporating flexibility a method where one applies scenario planning and tries to deal with unpredictable future by developing measures or designs that are adaptable as new or more accurate information becomes available in the future with regards to the unpredictable future (new or refined scenarios/knowledge) (Pahl-Wostl, 2007, Haasnoot et al., 2012, Walker et al, 2013). Using the same example about designing an embankment as before, one still uses plausible scenarios for future maximum water levels. However, instead of designing the embankment solely around the scenario with the highest future water levels, one decides to design the embankment to resist a more middle of the road scenario – with lower future water levels – but does not disregard the worst-case scenario. This can be done by designing the embankment in such way that it can be adapted to potentially resist the worst-case scenario in the future when new or refined information might suggest it is needed.

Dialogical learning is a method to deal with ambiguity where dialogue and mutual learning between actors in the project is used to handle frame (frame of mind) differences. In this method, actors engage in an interactive communicative process with the goal to create a joint problem definition or perception that all actors can accept (Brugnach et al., 2011). The thought behind this method is that people can develop a mutual understanding of one another and understand the rationale behind their point of view and problem perception (frame) through dialogue (Brugnach et al., 2011; Dewulf & Biesbroek, 2018). A potential application of dialogical learning is a role playing game. This is a game where actors play the role of another actor. The goal is for actors to gain understanding of where other actors are coming from and to reflect others' perspectives (frames) onto their own (Brugnach et al., 2011).

Rational problem solving is used to produce one clear frame towards a problem or situation while disregarding other possible frames. The frame that gets chosen is often a result of a substantiation of scientific evidence and factual information given by scientists or experts on the matter (Brugnach et al., 2011; van den Hoek, 2014). For example, a scientist explains through use of hydrological models and precipitation statistics that there is a need for a new or expanded fresh water reservoir because current supply of fresh water outweighs the demand. The problem is framed as a resource problem (availability of fresh water), backed up by scientific data. The goal is to convince other people that this is the 'real' problem. Meanwhile other possibly valid problem frames, such as overconsumption rather than availability, are disregarded.

Within the methods to adequately deal with epistemic or ontological uncertainty, there are three points of attention one should be aware of. Otherwise it could seem like the methods show redundancies or replications between one another. However for the sake of this research, separating some methods and adding more distinct or specific characteristics allows for a more complete overview on how uncertainty is being dealt with by project participants. The three points of attention are:

1) One way of dealing with epistemic uncertainty is to do research. In this study, doing research is split into research being executed by the individual project actor (person/organisation) and research being executed by an (external) expert. The reason for this is that during project development, expert knowledge or research is commonly consulted to fill knowledge gaps within the project coalition (Berggren et al., 2001).

2) In this research a distinction has been made between the kind of activity experts perform whenever they are consulted during the project (Table 2). 'Assessment/Evaluation by experts' differs from 'research by experts' in that the topic is not researched. No new or refined information is being gathered. Rather, expert knowledge is being applied to check whether a design is feasible or in line with national regulatory policy for example. 'Expert opinion' is when the expert is simply asked to vent their opinion on a certain topic or design based on their knowledge.

3) From literature that mentions methods to deal with ontological uncertainty (Pahl-Wostl, 2007; Brugnach et al., 2008; Kwakkel et al., 2010; Ministery of Infrastructure and Environment & Ministery of Economic Affairs, Agriculture and Innovation, 2011; Scholtes & De Neufville, 2011; Haasnoot et al., 2012; Walker et al., 2013; Warmink et al., 2017; Dewulf & Biesbroek, 2018; Zandvoort et al., 2017), it is evident that scenario planning forms the basis for the other methods mentioned to deal with the ontological uncertainty and is therefore embedded in the other methods listed. However, for this study it is reasonable to include it separately since one of the project cases is still in a development stage. It is plausible that the project coalition has carried out scenario planning or analysis, but has yet to decide on what method to apply in the design of the project (physical object). Additionally, it could be evident from project documentation or an interview that scenario planning has been applied, but not what dealing method consequently got chosen.

2.3: Projects as a problem solving cycle

When trying to address uncertainties in different phases of a project it is important to define how the research will look at the nature of project development processes and phases it goes through. There are a number of different ways one could look at how projects are developed.

A common approach to describe the phases a project goes through is to describe it as a linear process chart. Generally, authors agree that a project would start with an initiative or an inception of an idea (El-sokhn & Othman, 2014; Khodir & Dine, 2018; South et al., 2018). However after this, the phases of project development process charts often start to diverge. Some mention a design phase following from the initiative (El-sokhn & Othman, 2014; Khodir & Dine, 2018), another places a procurement phase in between the initiative and the design phase (South et al., 2018). Some even completely ignore the pre-construction phases and start with a bidding phase (Renuka et al., 2014). However, what most of these linear project phasing process charts have in common is that they have a clear beginning and an end. After the project is handover, the project is finished. From these process charts, it seems that they mostly represent project phasing from a classic contractor's point of view: a project starts as soon as there is a design to be bid on. However judging from the findings of van den Hoek (2014), most uncertainty has already arisen before and during the design phase. It would be illogical for a client to start construction when they are not yet sure how uncertainties are going to be dealt with in the final design or during construction of the project. Also, in the face of climate change, it seems more important than ever to monitor the performance of the project after its delivery and adapt or modify it whenever this may be needed (Huitema et al., 2009; van Buuren et al., 2013). From this, one could argue that a project should look more like a circular diagram where the exploitation/monitoring phase can yield motives to cycle into a new project initiative to adapt or revise the finished project.

Alternatively, one could step away from the traditional project process charts and turn to a more general problem solving method to describe the phases a project goes through. Van Aken et al. (2007) propose a problem solving cycle in organisations that follows a pretty straight forward cycle of problem definition → analysis → plan of action → intervention → evaluation. Although these are all steps that are done within a project development process, it does not fully cover the project development process in its entirety. This cycle seems to be bound by an assumption that after an analysis of the problem, an optimal plan can be formulated to perform an action/intervention that is the best solution to the problem. It is highly unlikely to perform an optimal solution in urban development projects. This cycle misses components that address developing solution/design alternatives and appraisal of proposed alternatives. These are components that are customary in engineering projects and are parts of the cycle where decisions have to be made under uncertainties. In other words, where uncertainties could arise or be recognized.

A different approach to the project development cycle was adopted in the Thames Estuary 2100 project (TE2100), where stakeholder involvement/participation was central in their project development approach. In this approach, a four-phase approach was used to define and develop the plans for the project. In the first phase the scope and strategy for the project were developed after which – in stage two – studies were done and conceptual options were made. Both stage three and four consisted of refinement of the conceptual options through consultation of stakeholders. Their feedback would be used for the refinement of the plans and, at the same time, the plans would gain more depth through each iteration, increasing the depth of the plans for each consultation. In the end, this led to a definitive plan (McFadden et al., 2009). The development cycle used in the TE2100 project seems more applicable than the problem solving cycle proposed by van Aken et al. (2007) in the sense that this model does not assume the perfect plan to a problem exists. Instead, they opted for stakeholder participation to give feedback on the plans and refine the plans to become more fit for purpose across multiple iterations. However, this four-phase method seems to lack a distinction between developing options and choosing which options would be viable alternatives to develop further. This may be done implicitly during the stakeholder consultant meetings but is not an explicit part of this model.

For this research, the activities that take place in project development processes are defined by the problem solving cycle proposed by Kolkman et al. (2005, p321), which is shown in Figure 3. It was chosen to follow their circle because – contrary to the more classic contractor focussed line charts – it encompasses the process of developing an initiative into a definitive design in more detail whilst still including construction preparation and execution. Additionally, it is more focused on the phases of (construction) project development than a general problem solving cycle such as presented by van Aken et al. (2007). Decisions about uncertainties are made throughout various stages of the cycle which is why a detailed cycle explicitly mentioning every progressive step within project development is useful in this research. The problem solving cycle seems to include most of the points where uncertainties can be identified or recognized through either a decision making node, or through nodes that include exploration of possible effects of options (see solution space generation and alternative analysis). Although this problem solving cycle does not explicitly include stakeholder inclusion, it does not seem farfetched to assume that important stakeholders will be included during some, if not most of the important decision-making nodes. This makes explicit inclusion of stakeholder participation (and the results thereof) as a phase in the project in the way it was done by McFadden et al. (2009) unnecessary.

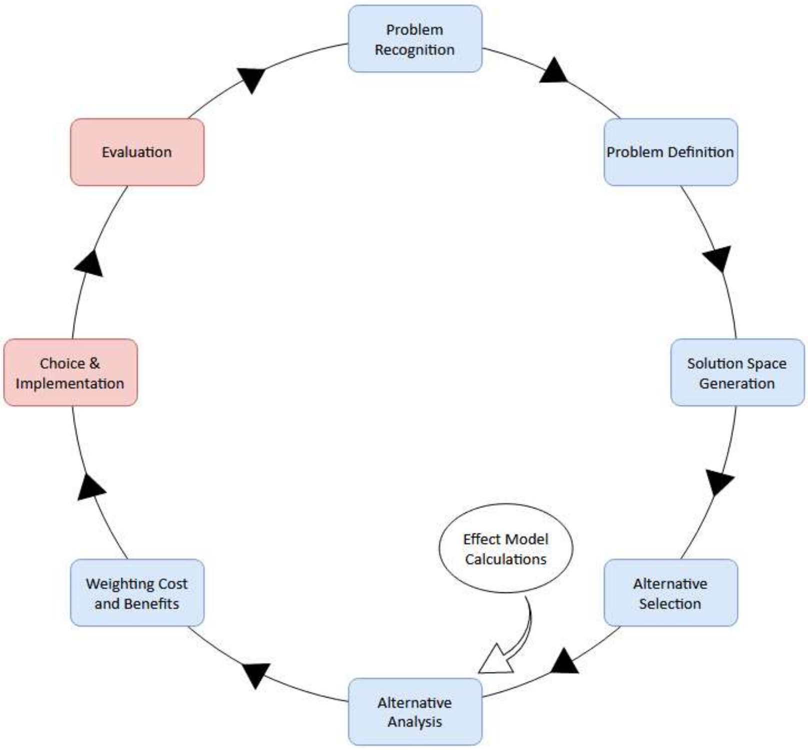

Figure 3: Phases in the project cycle

2.4: Synthesis

This section will consist of a short synthesis of what was presented in the past three sub-chapters, summarizing the literature and theoretical concepts applied in this research.

In this research, uncertainty is defined as the situation in which there is not a unique and complete understanding of the system to be managed. (Brugnach et al., 2008, p.4) and is broken down into three separate types of uncertainty. These are:

> **1)** Epistemic uncertainty. Uncertainty related to incomplete or imperfect knowledge (Walker et al., 2003; Brugnach et al., 2008);
>
> **2)** Ontological uncertainty. Uncertainty related to inherent variability or unpredictability in behaviour of a system of phenomenon (Walker et al., 2003; Brugnach et al., 2008);
>
> **3)** Ambiguity. Uncertainty originating from many possible interpretations of a situation (different knowledge frames) (Brugnach et al., 2008).

Since there is no universal method to adequately deal with all three types of uncertainty (Walker et al., 2003; Zandvoort et al., 2017; Dewulf & Biesbroek, 2018), scientific literature has been consulted to identify adequate methods to deal with uncertainty. In total, 21 unique methods to adequately deal with uncertainty of different types were identified. These are presented in Table 2 and thoroughly explained in Appendix C: Methods to deal with uncertainty. The methods to deal with each type of uncertainty found in literature function as a base-line for the possible methods used by practitioners. Descriptions by practitioners or in documents about how uncertainty was being dealt with during the project will be linked to the identified methods. However, when a method described by practitioners or in documents does not fit any of the methods found in literature but was adequate to deal with their uncertainty, new methods can be added and linked to one uncertainty type as a method to deal with that type of uncertainty.

To pinpoint at what time – or during what project activities – in the project development process practitioners first identify the uncertainties they experience, it is important to define the phases a project goes through throughout the development process. In this research, the phases a project development process goes through is defined by the problem solving cycle proposed by Kolkman et al. (2005, p321) (Figure 3). In this cycle it is assumed that a project will go through eight different phases before returning to the first phase again. The first being problem recognition. This version of a problem solving cycle has been chosen because it is more tailored towards (construction) project development than a more general problem solving cycle is. Additionally, the simplicity of the cycle (and its phases) makes it easier for practitioners to relate an activity in which an uncertainty arose to a given project phase even if they would be less acquainted with project development phasing.

3. Methodology

3.1: Approach

In order to uncover the uncertainties practitioners face during different phases of the project and how they deal with them, two project cases in which the municipality of Zwolle participated in have been chosen. A case study approach was chosen because it allows to capture uncertainty as it arises in a specific setting the investigation is focussed on (Leedy & Ormrod, 2015). In this research, the setting is urban development projects influenced by water safety/management. A case also gives a narrative or a framework for practitioners to refer to when thinking of uncertainty they experience. This makes it easier to pinpoint uncertainties that are specific to urban development projects. Two case projects were chosen because it allows to assess whether the experienced uncertainties and methods of dealing with uncertainty differ from project to project (Leedy & Ormrod, 2015) depending on variables as project location, calendar year of development, and involved actors.

Criteria of the case projects were that (1) the municipality was a key participant or the party driving the project, (2) water safety/management should be a relevant topic in the cases, (3) uncertainties must be able to be unravelled in these projects, meaning documentation has to be sufficient and the projects should not be too far in the past for practitioners to remember what uncertainties they encountered. (4) The case(s) has to be at least halfway into the assessed project phases of the research, and lastly (5) the case(s) has to have multiple different parties participating in the project development. At least four or more. Through meetings with the municipality the suitability for different projects was addressed. In the end, the projects that were deemed most suited for this research were projects Zware Water Zone and Kraanbolwerk (Municipality of Zwolle, Personal communication, n.d.). What both projects have in common is that they are both urban redevelopment projects in the unembanked area in the city, and thus unprotected to flooding by embankments or other water defence structures. The difference is that Zwarte Water Zone is currently in a development stage (destination/land-use plan), whereas Kraanbolwerk has been finished in 2019 and officially delivered in 2022 (Stijkel, 2022). Figure 4 and Table 3 show the geographical location of the both projects within the city of Zwolle along with general information about each project. A more extensive introduction to each case project is located in 4. Research findings.

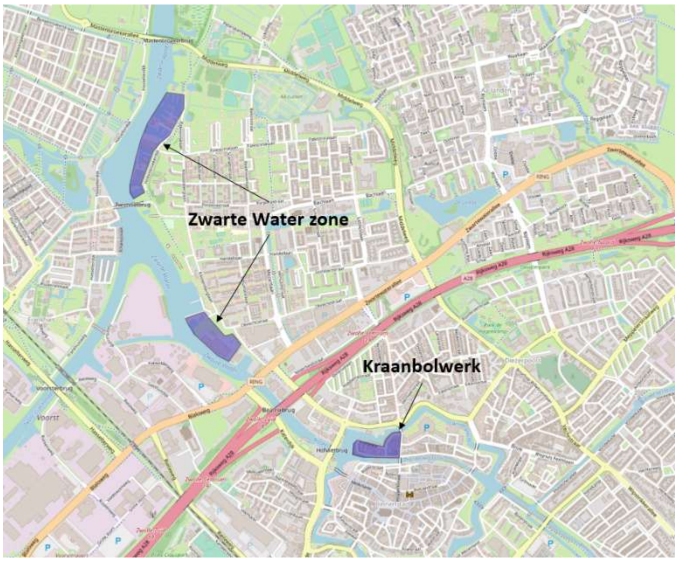

Figure 4: Case projects' location in Zwolle

Table 3: General information case projects

Project name:	Kraanbolwerk	Zwarte Water Zone
Project type	Urban Redevelopment (unembanked)	Urban Redevelopment (unembanked)
Project location:	City Centre (former industrial area)	Near Holtenbroek (industrial area + floodplain/marinas)
Project duration:	2011 - 2022	2018 - now
Initiator(s):	Project developer & Municipality of Zwolle	Project developer & Municipality of Zwolle
Other oganisations involved:	Province of Overijssel; Water Authority.	Project developer (different to initiator); Province of Overijssel; Rijkswaterstaat (Department of Waterways and Public Works); Urban planning and architectural consultancy; Water Authority; Water safety and management consultancy.
(expected) dwellings realized:	110 apartments, 48 ground-level homes	280 (mix of apartments, ground-level homes and floating homes)

Data were collected through a combination of document analysis and semi-structured interviews. The documents used in the document analysis were collected through both publicly available sources (example: municipal council documents or publications by the project developer), and (internal) documents received from project participants (example: work documents, design sessions). In total, 15 relevant documents were analysed for Kraanbolwerk (7) and Zwarte Water Zone (8).

With the interviews it was strived to interview at least one project participant from each individual organisation (both public and private) involved in the project development process for each case project. For case project Zwarte Water Zone, interviews were held with project participants from all but one involved organisation, being the Province of Overijssel. For Kraanbolwerk, project participants from all participating organisations were interviewed. The relevant interviewees were identified through the network of the municipality of Zwolle and by asking the interviewees whether there were additional project participants that would be valuable candidates. The interviews were held in Dutch and took between 1 - 1.5 hours. Every interview was recorded and transcribed to ensure not data was true to the answers the interviewee gave and that no data got lost during the data collection period. In total, 15 interviews were held. Nine interviews with 11 different project participants were held for case project Zwarte Water Zone. The remaining six interviews were held for case project Kraanbolwerk with six different project participants. Included in Appendix D: Documents and interviewees are the document names and their respective code for this research along with the interview participants, their (coded) organisation, and the type of organisation they work in.

During this research, two approaches – one for document analysis and the other for interviews – have been developed in order to be able to operationalize ‘measuring’ uncertainty present within the case projects. These methods were developed based on definitions and propositions presented in the theoretical framework of this research, similar research within the uncertainty literature relevant to this research, and through consultation with other researchers within the uncertainty management field. The process and results of the operationalization is found in 3.2: Document analysis and 3.3: Interview protocol for the document analysis and interviews respectively.

To analyse the data, a combination of deductive and inductive approaches have been used. After the data were collected, patterns within the data were identified through thematic code book analysis (Braun et al., 2019). This allowed to quantify, among other things, different themes or situations interviewees would mention when talking about a given uncertainty. The coding structure was refined throughout process of data analysis in an iterative manner. During data analysis, findings that fell outside of the (initial) boundaries of the research (research questions + theoretical framework) were intentionally left out of the coding structure and added as separate findings. 3.4: Data analysis covers the data analysis and the process of developing this coding structure in more detail. Figure 5 shows a visual representation of the research approach.

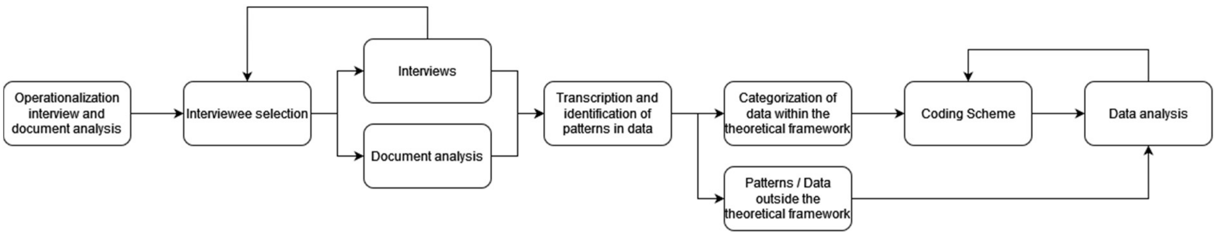

Figure 5: Research approach

3.2: Document analysis protocol

The goal of the document analysis was to identify possible uncertainties within the project process ahead of the interviews. This makes it possible to ask more specific questions during the interview. It also helps to form a broad overview of the uncertainties the project participants have all more or less agreed on to being present during the project as a whole. The documents – especially documents destined for the municipal council – had the tendency to try to avoid the term uncertainty or similar terms since the goal of those documents is to convince people of the benefits of the project. The avoidance of these terms proved to make it difficult to both identify exactly what uncertainties were present during the project and pinpoint where in the process an uncertainty arose during the project. Therefore, for the document analysis it was opted to serve more as an exploration of the uncertainties (that could be) present in the two case projects rather than an in-depth data source.

Operationalization of document analysis

To be able to practically analyse the project documents the theoretical framework needs to be operationalized to identify uncertainties present (mentioned) in the project documents. Van den Hoek (2014) made an operationalization on a similar research topic for the identification of uncertainty in document analyses. The operationalization consists of keywords and topics that would signal the presence of an uncertainty. The research by van den Hoek has multiple interfaces with this research, the most notable being the adoption of the definition and conceptualization of uncertainty, and the different types of uncertainty proposed by Brugnach et al. (2008). Given this interface, the operationalization van den Hoek (2014) has done is fitting to use as a starting point for the operationalization of document analysis in this research. Relevant indicators for this research were slightly modified in the sense that some indicators are left out due to relevancy to this research.

Additionally, examples were added to further elaborate on what each indicator means. The adapted operationalization of indicators of uncertainty are shown in Table 4.

Table 4: Indicators of uncertainty. Adapted from van den Hoek (2014, p. 33)

Indicators of uncertainty	Example
Instances of uncertainty and risk being mentioned explicitly.	It is uncertain that … is going to happen.
Statements or assumptions, estimates or scenarios with a probability of occurrence.	There is a 60% chance that during normative water levels the embankment will show signs of failure mechanisms.
Instances where scenarios/predictions with a certain likelihood – or an idea thereof – are mentioned.	It is more likely that the embankments will show signs of failure mechanisms during normative water levels than not.
Instances where scenarios/predictions are proposed or mentioned.	It could be that in the future we need to strengthen the embankment to avoid failure mechanisms from showing during normative water levels.
Acknowledgement of a lack of knowledge which cannot be decreased (within the project boundaries).	We cannot predict what failure mechanisms embankments will show during normative water levels.
Acknowledgement of a lack of knowledge but where additional knowledge (research or more reliable data) can be acquired.	The failure mechanisms the embankment will show under normative water levels are currently unknown but can be studied in small-scale practical experiments.
Framing differences between parties involved in the project.	When expert A says the embankment is at risk of failure for piping while expert B claims there is no evidence of that therefore claiming embankment is perfectly fine.
Prioritization/priority differences between parties or stakeholders in the project.	Project member A is primarily concerned about water safety for an embankment while project member B is primarily concerned about swallows' nesting being disrupted.
Statements about ignorance on a topic.	Nobody had an idea what the embankment will do during normative water levels.

3.3: Interview protocol

To discover how project participants experience uncertainties within the two case projects (ZWZ, KBW), interviews are done to understand/uncover what uncertainties project participants experience. It is not only important to uncover what uncertainties are experienced by practitioners, but also how these uncertainties are perceived (Ontological/Epistemic/Ambiguous) and dealt with within the case projects.

Defining the desired data (topics) of the interview

To give guidance on what the interview should cover to yield the desired results, a number of variables are formulated to help shape the interview. These variables are related to the uncertainties practitioners experience, where in the project they first recognized the uncertainty, and how they subsequently deal with them. A total of nine different variables have been identified. The interview variables are included in Appendix E: Interview variables, goals and questions. Defining variables that need to be addressed in the interview to retrieve the desired information relevant to the research helps guide the researcher to formulate questions able to reliably gain the information needed for the research.

Complementary to the interview variables a number of goals have been set. By the end of the interview the goals need to be able to be answered. Where the interview variables describe only the data needed based on the theoretical framework to answer the research question, the interview goals are more practical in nature and also cover things that are not directly related to the theoretical framework of the research, such as the organisation the interviewee is active in and what their role in the project is/was. The goals ensure that during the interview one can check whether the interview is yielding the desired results and adjust if this is not the case. The interview goals are also included in Appendix E: Interview variables, goals and questions.

Content of the interview

Based on the goals and variables, the interview is structured in three parts. Each part contains a topic related to uncertainty management as described by the theoretical framework in this research. The first part of the interview serves as a way to identify who the interviewed person is, what roll they fulfil (in the project), during what phases of the project they were involved, and the intensity of their involvement. These questions are intentionally very straightforward and easy. This is done to let the interviewee ease into the conversation and become comfortable being interviewed (van Thiel, 2014). The second part of the interview focusses more on the theoretical aspects of the research. In this part the interviewee is asked what uncertainties they have encountered during their participation in the project and how they would typify this uncertainty. During this part, the interviewee is also asked during what phase in the problem-solving cycle this uncertainty arose. In part three of the interview, the interviewee is asked what method or strategy is used to deal with the experienced uncertainty during the project, whether they think this method was effective/adequate, and if not, what method they think would be more adequate. The goal of these questions is to be able to identify how practitioners deal with a given type of uncertainty, whether the methods or strategies are corresponding with adequate methods proposed by literature, and to possibly identify differences between interviewees' preferred way dealing with a given uncertainty (adequately or inadequately). The translated interview questions along with their relation to the interview variables and goals are included in Appendix E: Interview variables, goals and questions.

Operationalization of theoretical concepts

To be able to 1) accurately pinpoint the perceived type of uncertainty the interviewee experienced and 2) to identify how a method or strategy to deal with a given uncertainty relates to the adequacy for the perceived type of uncertainty, the theoretical concepts need to be operationalized for the interview. The operationalization of the types of uncertainty experienced by the interviewee (Table 5) is done by 1) redefining the theoretical concepts as a work definition that is easily understood by interviewees, 2) defining when a mentioned uncertainty can be characterized as one of the three types of uncertainty addressed in this research, and 3) by defining a number of key-words that insinuate the presence of a certain type of uncertainty. The key-words are based on the properties of different types of uncertainty described by literature and jointly formulated in collaboration with other researchers. The key-words were actively expanded upon during the data gathering process by adding words used by interviewees themselves.

To identify whether proposed methods of dealing with uncertainty by the interviewee are adequate for the type of uncertainty they experience, the methods of dealing with uncertainty also need to be operationalized. In a similar way to the operationalization of the identification of the type of uncertainty experienced by the interviewee, a work definition is made along with descriptions of methods adequate for dealing with each type of uncertainty based on the theoretical framework. Additionally, a number of concrete methods have been added which are a product of the literature study on what uncertainties arise during urban development (in unembanked areas) and what strategies are proposed to adequately deal with them (Table 6).

Table 5: Operationalisation of the identification of different types of uncertainty

Theoretical concept	Definition	Operationalisation	(Dutch) Key-words
Epistemic uncertainty	Uncertainty related to incomplete or imperfect knowledge (Walker et al., 2003; Brugnach et al., 2008)	When the interviewee relates the uncertain phenomenon to lack or incompleteness of knowledge/data/data accuracy	- Gebrek aan kennis; - meer kennis nodig; - onderzoek zou onzekerheid verminderen; - gebrek aan informatie; - kennis/data is onbetrouwbaar; - informatie is niet volledig; - betere metingen nodig.
Ontological uncertainty	Uncertainty due to inherent variability or unpredictability in behaviour of a system or phenomenon (Walker et al., 2003; Brugnach et al., 2008)	When the interviewee deems the uncertain phenomenon as irreducible due to inherent variability, unpredictability or randomness.	- Variabiliteit; - onvoorspelbaarheid; - verandert altijd; - willekeurigheid; - ontkomt niet aan de onzekerheid.
Ambiguity	Uncertainty originating from many possible interpretations of a situation (different knowledge frames) (Brugnach et al., 2008)	When the interviewee describes an uncertain phenomenon where people had contradictive interpretations, prioritization or views on a certain matter which resulted in uncertainty between participants involved in the project.	- Perspectief; - mening; - andere visie; - tegenstrijdig; - interpretatie; - kijken vanuit een andere discipline; - perceptie; - houding; - andere verwachting.

Table 6: Operationalisation of adequate methods to deal with a given type of uncertainty

Theoretical concept	Definition	Operationalisation	(Dutch) Key-words/methods
Dealing with epistemic uncertainty	Strategies or methods to deal with uncertainty related to incomplete or imperfect knowledge or data.	When the interviewee mentions strategies or measures which require gathering data and/or doing research where results would reduce the uncertainty	- Experimenten; - onderzoek doen; - extern onderzoek; - meer kennis vergaren; - nauwkeurigere metingen/gegevens verzamelen; - beoordeling door experts; - de implicaties van het gebrek aan kennis onderzoeken; - Het maken van een 'confidence interval' van de onzekerheid.
Dealing with ontological uncertainty	Strategies or methods to deal with uncertainty due to inherent variability or unpredictability in behaviour of a system.	When the methods proposed by the interviewee are related to accepting the uncertainty as it is and deal with the uncertainty through other means than gather more/deeper knowledge.	- Onzekerheid accepteren en omgaan met de gevolgen van de onzekerheid in plaats van de onzekerheid beperken (zoals schadebeheersing tijdens/na een overstroming i.p.v. voorkomen van de overstroming); - aanpassingsvermogen incorporeren (flexibiliteit); - het onzekere fenomeen doorstaan (worst-case scenario plannen); - ontwikkelen van diversiteit in de maatregelen om deze voor een breed scala van scenario's bruikbaar te maken; - realiseren van maatregelen welke binnen de tijdsspan van een gebeurtenis van waarde kunnen zijn (b.v. een stormvloedkering) - improvisatie. Pas wat gaan doen wanneer het onzekere fenomeen zich daadwerkelijk voor doet.
Dealing with ambiguity	Strategies or methods to deal with uncertainty originating from many possible interpretations of a situation (different knowledge frames)	When the interviewee mentions efforts made to align visions or create mutual understandings of the matter between participating parties, to develop an accepted frame within the project team or to negotiate what to focus on first / what data to use.	- Frame samenhang tussen betrokken partijen; - acceptatie van frame-verschillen; - standpunt/perceptie van een persoon aannemen; - gezamenlijk een standpunt of perceptie van een situatie ontwikkelen; - onderhandelen over waarop gefocust moet worden; - Dialoog over betrokken partijen hun perceptie/interpretatie op een zekere materie.

Points of attention in the interview protocol

Ahead of the interviews it was expected that practitioners predominantly experience epistemic and ontological uncertainties due to practitioners' general focus on technical uncertainties (example: required design height of a project to guarantee safety for flooding at some chance interval) and their preference for 'solving' uncertainties by doing more research or gathering more information (Koppenjan & Klijn, 2004; Hommes et al., 2009; Warmink et al., 2017). Because of this, special attention is payed to uncovering ambiguities as it was expected that these are less focussed on or less actively recognized by practitioners in the work field. A specific question in part two of the interview is asked to trigger interviewees to actively start thinking of ambiguities that were present within the project.

The term 'uncertainty' is intentionally avoided in the interview questions in order to allow more freedom to interviewees to freely share their experiences (Roberts, 2020). The main reason for this is that previous researchers experienced that interviewees often respond rather avoidant to the presence of uncertainties within a given (project) process by stating that there are or were no uncertainties (van den Hoek, personal communication, 2022). However, – when one formulated the questions differently – replacing the term uncertainty with a similar term – like 'bottlenecks', 'Points of discussion', or 'knowledge gaps' – that insinuates uncertainty without explicitly mentioning the term, would trigger people to more openly discuss the uncertainties they had faced in during the process and how they handled those situations (van den Hoek, personal communication, 2022).

3.4: Data analysis

After collecting the data through both documents analysis and interviews, the next step was to process the qualitative data into something that is analysable. This was especially important for the interview data since it mostly consisted of descriptions of uncertain situations, not the underlying uncertainty. It did not yet have concrete, analysable names or themes (example: climate induced water level rise). Qualitative descriptions of uncertainty in documents and interviews can be quite chaotic. To structure all individual descriptions into more analysable data a thematic codebook analysis was used to iteratively develop a codebook from the data. A thematic codebook approach is a method to capture patterns or themes within qualitative data (Braun et al., 2019). This approach allows to more or less categorize the data and form a clear coding structure to deductively reveal patterns within the data. This made it possible to include the elements of the theoretical framework (typification of uncertainty and how to deal with uncertainty) in the analysis (Braun et al., 2019).

The first version of the coding structure was developed by familiarization of the data and through written notes on patterns between interviews throughout the interview transcription process. This led to an inductive identification of a number of more general uncertainty themes through the descriptions given by the interviewees. The uncertainty themes were direct input for the coding structure and used as tags. Each tag was linked to one of the three uncertainty types defined in the theoretical framework. Parallel to the identification of the uncertainty themes, another coding structure was made to enable coding of the methods used to deal with the uncertainties mentioned by interviewees. The (adequate) methods to deal with uncertainty – proposed in the theoretical framework – formed the base line for this coding structure. The base line was expanded upon by adding new methods described by the interviewees. In order for a method to be added, the new method had to be fully independent. This means that it does not rely on other already defined methods to deal with the uncertainty type. An in-depth example of both a dependent and an independent method is given in 4. Research findings. During data analysis, both coding structures were expanded or restructured as more unique tags were identified through an iterative data analysis process.

The coding structure was then applied to the interview transcriptions. Segments of data were structured using Microsoft Excel and assigned a tag (either an uncertainty theme or dealing method). The project phase (from the project problem solving cycle) in which a given uncertainty was first recognized was also noted down. Because of the structured question order in the interviews, it was possible to easily identify from the transcriptions which method of dealing with uncertainty was linked to what specific described uncertain topic or theme. Bringing together the uncertainty themes and the corresponding methods used to deal with them allows for a number of data patterns to reveal themselves. Among other, this includes 1) identification of preferences towards dealing with a given uncertainty type or theme, 2) whether the used method corresponds to (one of) the adequate methods to deal with the given type of uncertainty that is experienced according to literature, or 3) the categorization of a number of individual uncertainty themes into more overarching uncertainty categories. An example of what one code looks like (uncertainty theme + project phase + dealing method) is shown in Table 7.

Table 7: Coding structure

Uncertainty Theme	Desc. Interviewee	Phase	Interviewee perceived Type	Lit. Type	Method dealt in proj.	Desc. how dealt with
Climate induced future water level increase (sea level rise, river discharge, precipitation)	We weten niet wat zeespiegelstijging gaat doen. (P.3)	Problem Recognition	Ontologic	Ontologic	Scenario Planning	Er zijn constant kennis leemtes en die zijn er nog steeds en We hebben een manier gevonden om daarmee om te gaan In de zin van hè programma van eisen (P.3)

Uncertainty themes

As explained, descriptions of uncertainty by interviewees were used to develop more general themes. All themes together form the codebook and applied is in the data analysis. All individual instances of an uncertainty mentioned by the interviewees are linked to one theme. The thematic codebook approach has led to the identification of 23 unique uncertainty themes being present in the two researched cases. Some uncertainty themes are specific to only one of the two researched cases. As a result of this, the uncertainty themes that are not applicable for a given case project are not shown in the presented data for that case. Table 8 shows per defined uncertainty theme what type of uncertainty it is assigned to and whether the theme is case specific or present in both cases. In case of the former, the case project that the theme is concerned with is shown. Appendix F: Description of the uncertainty themes includes an explanation for each identified theme and what it encompasses.

In the results, instances of uncertainty found in documents are also linked to these themes where possible. However, instances of uncertainty found in documents are not included in the tables that display data such as how often one uncertainty theme is mentioned or how they are dealt with. Instead, it will be mentioned – again, where possible – in the text. The reason for this is that most instances of uncertainty in documents either do not describe the method used to deal with the uncertainty, where in the process this uncertainty arose, or the documents only consistently mention one uncertainty theme and avoid mentioning the presence of others. Adding these to the interview data would cloud the overall quality due to the incompleteness of the document data compared to the interview data. Therefore, it was deemed unfitting to use the document analysis data in the same way as the interview data.

Table 8: Defined uncertainty themes per uncertainty type

Epistemic uncertainty themes	Case project present
Consequences of submersible parking garage	Zwarte Water Zone
Condition quay walls	Kraanbolwerk
Construction of services (electr., water, etc.)	Zwarte Water Zone
Integration project into river landscape	Both
Magnitude of soil pollution and effect in project	Kraanbolwerk
Parties required to be involved and when	Zwarte Water Zone
Policy interrelations	Zwarte Water Zone
Projects' effect on hydraulic characteristics	Both
Testing/Advising as organisation	Zwarte Water Zone
Ontological uncertainty themes	Case project present
Changes in policy/policital composition	Zwarte Water Zone
Changing view on water safety in future	Both
Climate induced future water level increase	Both
Future discharge distributions	Both
Government induced future water level increase	Both
Inter-organisational testing (design/policy)	Zwarte Water Zone
Uncertain market function	Both
Ambiguity themes	Case project present
Acceptance thresholds (internal)	Zwarte Water Zone
Actors' neglectance or ignorance to uncertainties	Both
Competent authority in the project	Both
Parties on the same page & talking about the same things	Both
Responsibility & ownership (risk and €)	Both
Should you want to build in the unembanked area?	Both
Working & testing integrally	Both

Uncertainty categories

In addition to the uncertainty themes, four overarching categories were identified through similarities between the defined uncertainty themes. The similarities being the context of how the described uncertainties manifest themselves in the project. It was found that there were overarching uncertainty categories where the defined uncertainty themes stem from. Four separate categories were defined based on similar characteristics between uncertainty themes. The four uncertainty categories can be used to capture the identified uncertainty themes. Throughout the data analysis process, it became clear that the defined uncertainty themes – used to concretise and analyse the qualitative descriptions of experienced uncertainties by the interviewees – showed similarities between each other. The next sections will cover the context of the uncertainties that make up each category.

Long-Term Development Uncertainty

This category predominantly consists of uncertainties that are not bound to the project. Instead the uncertainty is often a result of long-term developments on both the generally accepted view on matters – such as building embankments to ensure water safety – and gradual changes to a system over time, on the social-governmental and climate level. They express a non-linear and somewhat chaotic behaviour (Brugnach et al., 2008). Uncertainties placed in this category are issues where project participants cannot accurately predict or research how a phenomenon will manifest itself in the future, or where project participants cannot exert a direct influence upon the uncertain phenomenon. Ontological uncertainties are dominant in this category, and are supplemented by an occasional ambiguity related to perception of the ontological uncertainties. Uncertainties in this category often transcend the boundaries of the project. Hence uncertainties placed in this category seem to be underlying causes of for uncertainties placed in other categories.

Technical Uncertainty

The technical uncertainty category consists of uncertainties related to knowledge about the technical requirements, feasibility, or construction methods needed to construct the intended project design. To construct the project one needs to know (or learn) what to conform to, what requirements need to be fulfilled to acquire the necessary permits and what methods are most suited to construct the project. Because the category mostly consists of uncertainty related to (a lack of) knowledge, this category predominantly consists of epistemic uncertainty themes. However, there is one exception made in this category due to case project specifics where an uncertainty manifests itself as ontological despite it usually (and should be) manifesting itself as epistemic uncertainty.

Institutional Uncertainty

This uncertainty category covers a number of uncertainties related to the need for actors with different institutional backgrounds to participate in the project. The category consists of uncertainties that arise due to the lack of knowledge surrounding applicable policies from different sectoral authorities, and consequently, differences in perception of problems, objectives, interests, and/or frame of knowledge because of project participants being part of different – mostly public – organisations with different sectoral authority. The objectives of each organisation are often guaranteed through their policies. First, knowledge has to be gained about what policies from different sectoral authorities are applicable for the project and where these policies clash or overlap in the project. However, after that, it is still uncertain how these clashing or overlapping policies should interact with each other and be handled in the project. The process of dealing with the uncertainties surrounding the interaction of clashing and overlapping policies is subject to ambiguities in the form of differences in interpretations, values, considerations, interests and frame(s) of knowledge between project participants. The combination of lack of knowledge and ambiguities leads to inclusion of both ambiguity and epistemic uncertainty being present in this category.

Assessment Uncertainty

Uncertainties belonging to this category revolt around the questions: 1) How do we test/assess (aspects of) the project to policies, ambitions and/or demands as an organisation? and 2) When do we – as an organisation – think something is sufficient or do we accept it? This category specifically focusses on assessment uncertainties within a given participating organisation. Understanding how to assess whether aspects of the project conform to a given policy is something that can be examined and learnt. However, the assessment of conformity to ambitions or demands – usually imposed at the beginning of a project – sometimes needs to be re-evaluated during the project development process due to unexpected situations or to decrease complexity. As one interviewee put it: "…do you settle for a 7 out of 10 or only for a 10 out of 10?" (Z-007). Uncertainty about where you should draw the line is subject to interpretation, feasibility perception and (public) interests. This leads to uncertainties placed in this category to be typified as either ambiguity or epistemic uncertainties.

One could argue that this category should be fused with the category institutional uncertainty as both include ambiguity and epistemic uncertainty related to multi-actor decision making processes. However, this category is deemed a separate category to the institutional uncertainty category because the uncertainties manifest themselves in different decision-making arenas. Uncertainties placed in the institutional uncertainty category are ambiguities and epistemic uncertainties manifesting themselves in the arena between participating organisations involved in the project. ambiguities and epistemic uncertainties belonging to the assessment uncertainty category are subject to the arena within a given participating organisation. Figure 6 shows a visual representation of the different arenas.

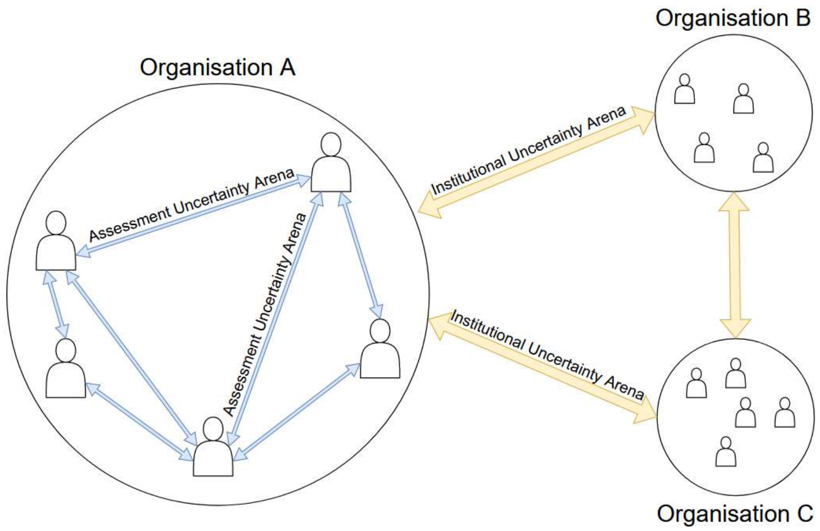

Figure 6: Assessment Uncertainty Arena vs Institutional Uncertainty Arena

Following the definition of the four uncertainty categories, each defined uncertainty theme – identified through the process of developing the thematic codebook – was categorized under one of the four categories. An uncertainty theme cannot be assigned to multiple categories. Figure 7 shows a (coded) uncertainty theme categorized under one of the four uncertainty categories and the distribution of the uncertainty themes assigned to each category. The four uncertainty categories are displayed at the top of the table, the uncertainty themes assigned to one of these four categories are placed underneath them.

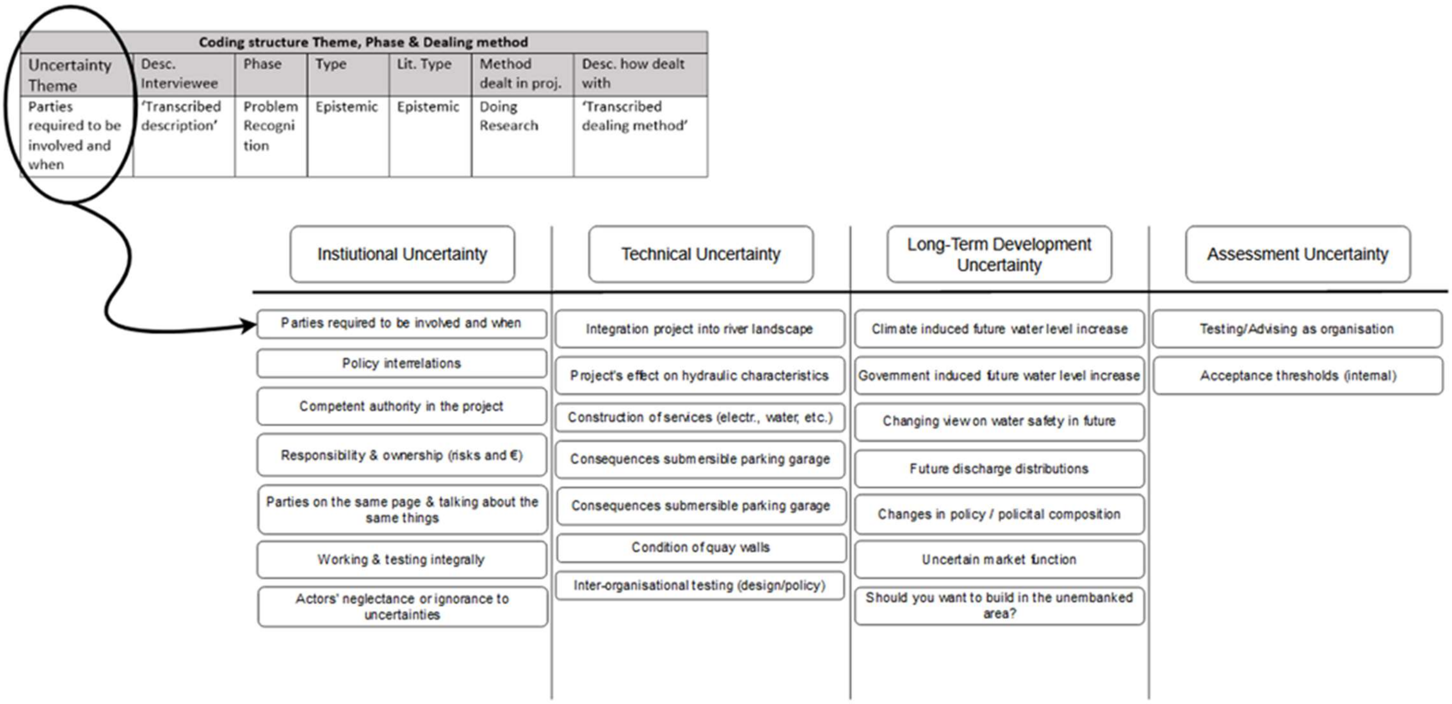

Figure 7: Categorization of uncertainty themes

4. Research findings

The results of both document and interview data analysis will be covered in this chapter. The case results for Kraanbolwerk will be presented in 4.1: Results case project: Kraanbolwerk, followed by the case results of Zwarte Water Zone in 4.2: Results case project: Zwarte Water Zone. In 4.3: Cross-case analysis, the similarities and differences between the results of both case projects will be highlighted in a cross-case analysis.

4.1: Results case project: Kraanbolwerk

In this sub-chapter the results of the document and interview analysis in the Kraanbolwerk project will be explained. The section starts with an introduction which includes background information of the case project. After that, the results of the case study will be presented. The results consist of 1) what uncertainties were found, 2) what project phase the first presented themselves or were first acknowledged, 3) How the uncertainties are dealt with, and 4) a new way to deal with uncertainty found in this case study. Throughout this sub-chapter the most mentioned uncertainty themes will be highlighted and methods to deal with them explained, along with special cases that stood out from the other results.

Introduction project Kraanbolwerk

The residential area of Kraanbolwerk is a project that has been delivered in July of 2022, after eight years of construction (Stijkel, 2022). Kraanbolwerk is located on the northern island (Dutch: Noordereiland) within the city centre of Zwolle. Originally, the area was occupied by factories and warehouses which used to be part of protected cityscape (Gemeente Zwolle, 2011). However, a change in the zoning/land-use plan (Dutch: bestemmingsplan) and the leave of lacquer factory Schaepman in 2011 led to the opportunity to redesign the industrial area in the city centre into a residential area. According to the urban plans of the municipality of Zwolle, the Kraanbolwerk would become home to roughly 110 apartments with different sizes and price ranges. The apartment complexes are largely located directly along the city canals and have a variety in height, ranging from four to eight stories high (Gemeente Zwolle, 2011). Additionally, 48 ground-level homes were to be built in the inner parts of the area not directly facing the city canals (Gemeente Zwolle, 2011). To allow for inhabitants of Kraanbolwerk to park their car, a semi-underground collective (car) parking lot has been constructed underneath almost the entirety of the area that Kraanbolwerk entails. All residential buildings are built on top of this semi-underground parking lot.

The location of Kraanbolwerk inside the city centre along the canals meant that that the area was/is unembanked and therefore vulnerable to flooding (STOWA, 2020). The municipality wanted the homes to stay habitable during high water situations. To do this, the municipality decided that the residential area had to become a terraced landscape (Figure 8) where the current quay levels would be maintained and the houses and apartments would be built on higher ground to ensure habitability during high water periods (soil surface level: 2.60 – 3.20m +NAP). The semi-underground parking lot helped reach this goal, adding 1.20 – 1.35m to the ground-level height underneath the to be built residential houses and apartment complexes. An added benefit to the semi-underground parking lot was that this meant that less soil had to be remediated, as the decades of industrial activities in the area had contaminated the soil in the area significantly (Gemeente Zwolle, 2011). An overview of the completed Kraanbolwerk within the city is shown in Figure 9.

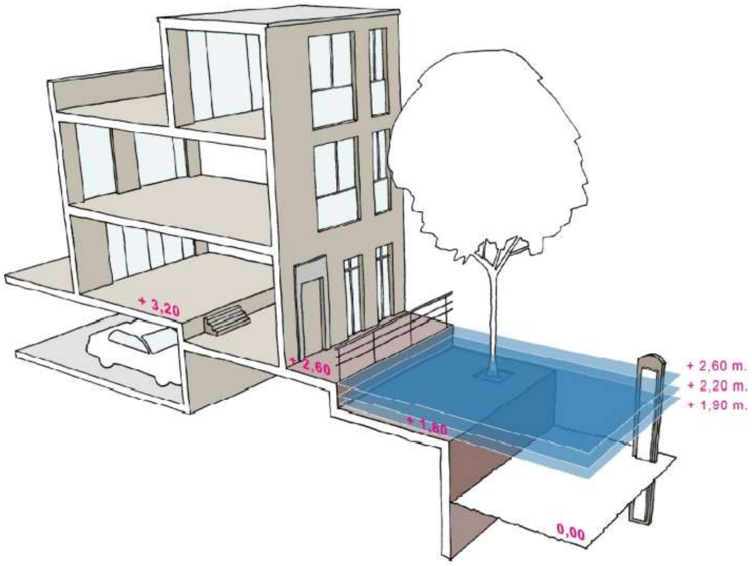

Figure 8: Terraced landscape Kraanbolwerk (Helpdesk Water, n.d.)

Figure 9: Overview finished project Kraanbolwerk (VanWonen, n.d.)

Uncertainties within the project development process

Document analysis was performed first to gain insight in the possible uncertainties present during the development of Kraanbolwerk. The document analysis gives a decent overview of uncertainties being present in the Kraanbolwerk project. The documents show the presence of all three types of uncertainty being experienced during the project development process. The data results from the interviews confirm that this is the case. In total, 46 different uncertainties were mentioned by the interviewees. The distribution of the types of uncertainty (epistemic/ontological/ambiguous) are rather evenly spread across the experienced uncertainties mentioned by the interviewees. Table 9 shows how many times each uncertainty theme was mentioned by the interviewees, their respective uncertainty type, and what percentage they make up within the totality of the results.

Table 9: Mentioned uncertainties by interviewees for project Kraanbolwerk

Category	Uncertainty Theme	Unc. Type	Total # Mentioned	% of total
Institutional uncertainty	Parties on the same page & talking about the same things	Ambiguity	7	15.22%
	Responsibility & ownership (risks and €)	Ambiguity	5	10.87%
	Working & testing integrally	Ambiguity	5	10.87%
	Competent authority in the project	Ambiguity	1	2.17%
	Actors' neglectance or ignorance to uncertainties	Ambiguity	1	2.17%
Technical uncertainty	Integration project into river landscape	Epistemic	4	8.70%
	Magnitude of soil pollution and effect in project	Epistemic	4	8.70%
	Condition of quay walls	Epistemic	3	6.52%
	Project's effect on hydraulic characteristics	Epistemic	1	2.17%
Long-term development uncertainty	Climate induced future water level increase	Ontologic	6	13.04%
	Government induced future water level increase	Ontologic	5	10.87%
	Uncertain market function	Ontologic	2	4.35%
	Should you want to build in the unembanked area?	Ambiguity	1	2.17%
	Future discharge distributions	Ontologic	1	2.17%

Ambiguities in Kraanbolwerk

The data shows that the uncertainties mentioned by the interviewees comprise for over 60% of only five different uncertainty themes, predominantly ambiguities. As briefly mentioned before, the biggest theme being about getting on the same page. In the case of this theme, there were numerous different ways an uncertainty allocated to this theme was explained by interviewees. It includes among others: 1) the decision-making of what services/functions are allowed to flood during high water periods (K-001; K-005; D004), 2) the ability of other participants to empathize with the climate adaptation theme and make it their own (K-001), 3) how to re-involve inhabitants and other stakeholders and keep them involved with the project in a positive manner (K-003), and 4) how to keep participants committed to the project and start building despite the numerous uncertainties (K-001; D003). Additionally, a number of (potential) risks to the project are described in risk tables in D004. These risks are accompanied by causes and consequences. Sometimes, defined risks in these risk analysis tables match nearly one-to-one with a defined uncertainty theme (independently defined from this table). For example, in these tables the following risk is mentioned:

"Collaboration with other IJVD-partners does not work or too slow" – D004 (translation from Dutch)

it matches very well with the theme about whether it is possible to get involved parties on the same page with each other and whether each party is on the same knowledge frame.

The theme 'working & testing integrally', showed different situations as well. The most notable being that the public parties focused more on carrying out a 'good' process of the project, whereas private participants allocated most of the uncertainties in this theme to monetary discussions. Public participants for example, mentioned the differences in preferred working methods between the municipality and developer (K-003). As a result, it led to ambiguities related to what working method to adhere. On the other hand, a private participant mentioned that the ambiguities surrounding how to work together were mainly related to participants being concerned with ensuring that risks – and therefore financial consequences – do not get allocated to them (K-004). But what all the interviewees' described ambiguities in this theme have in common is that they were always ambiguities between developer and municipality, never between other parties that were involved.

The ambiguities related to responsibility and ownership of (parts of) the project – and therefore ownership of the risks – were mainly a result of technical uncertainties related to the soil pollution and the condition of the quay walls (K-002; K-004). For example, measurements were taken to identify the condition of the quay walls before deconstruction of the existing buildings. However, during the deconstruction process it turned out that the quay walls were in a worse condition than initially researched, and had to be replaced (K-002; K-003; K-004). This would be a source of ambiguities between municipality and developer as neither party knew who the owner of this problem was. Is it the developer that is building at the location, or is it the municipality who is partial owner (together with the Water Authority) of the quay wall (K-002; K-004)? K-003 made a point that the ambiguities regarding ownership of parts of the project were extra complicated in this project, especially ownership of everything below ground level. Due to the heavy soil pollution at the project location, the costs of remediation were so high that the business case for a developer would not be profitable. In order to make sure that the project would not strand, the municipality bought the land, which made them partial owners of the project. They also could not give the land to the developer since that would mean they would have gotten state support.

Ontological uncertainties in Kraanbolwerk

Two uncertainty themes that all interviewees said they had experienced were climate and government induced water level increase. This was also reflected in the documents (D001; D003; D005; D006). In these documents it was described that the somewhat newly discovered uncertainty regarding future water levels posed a risk to the project. The interviewees' descriptions were all virtually the same. All mentioned that during the project development process they would struggle with what height the ground levels should be at to account for climate change and what scenario should be chosen? This was further fuelled by plans to increase the water levels in the IJsselmeer to account for longer periods of drought in summer, which would also affect the water levels in Zwolle. As one of the interviewees said in regards to government induced water level increase:

"…at the time (of the project development), raising the level of the IJsselmeer was being discussed, and that discussion at one point went something like this. Yes, that's all fine and well, because when you think of the IJsselmeer you just think of a fresh water basin, but not that has an effect on the city centre of Zwolle. However, it is outside the embankments!" – K-002 (translation from Dutch)

An important note is that prior to the IJsselmeer water levels being discussed, nobody in the project actually realized that areas such as the city centre – where Kraanbolwerk is located – were actually unembanked and that increased water levels in the IJsselmeer also had consequences to water levels in Zwolle (K-001; K-003). This government induced water level uncertainty was accompanied by the term or idea of climate change becoming more and more influential or accepted to be a real thing (K-001). Especially in projects like Kraanbolwerk, where a new neighborhood was being developed in a now understood unembanked area of the city.

Where in project cycle did uncertainties first present themselves?

During the interviews, interviewees would be asked during what phase (of the project-cycle) in the project an experienced uncertainty first arose or when they first acknowledged it as being an uncertainty. Table 10 shows the project phases in which a given uncertainty first presented itself of was first acknowledged. The uncertainties mentioned by interviewees seemed to be predominantly arisen during the problem recognition and the solution space generation phases. For some uncertainties it is unknown during which phase of the project an experienced uncertainty first arose. These are labelled as 'Unk' in Table 10. The reason for this was either due to a lack of time during the interview or the interviewee having a hard time applying the definition of the project as a problem solving cycle approach to the goal of the question.

One interviewee (K-004) made the point that uncertainties continually arose and disappeared throughout the process. For instance, it would appear during the problem recognition, be absent during the problem definition and solution space generation, but would reappear during the alternative selection. To account for this vision of uncertainties arising and disappearing during the project development process, a separate column has been made which includes the uncertainties that were found to pop in and out of view during the entirety of the project development process. This column is called 'All'.

Two uncertainty themes particularly standing out in the table are the climate and government induced water level increase. They mainly started arising after the initial stages of the project were finished. This appears to be the case because around the solution space generation phase of the project, Commissie Veerman (n.d.) published a report which – for this case project specifically – put climate change and the need for adaptation to the consequences on the map definitively (K-001; K-002; K-003; K-004; K-005; K-006). K-001 and K-004 even mentioned that during the development of Kraanbolwerk, the term climate change was pretty much non-existent until the report by stating:

"You couldn't even write it (the term climate change) down, I'm serious. And if you did, you were not taken seriously at all!" – K-001 (translation from Dutch)

"Climate adaptation? We did not know that word. No, but what I mean is, in the Netherlands, not just me, but in the Netherlands as a whole, we just were not aware of it at the time." – K-004 (translation from Dutch)

After the report by Commissie Veerman (n.d.) was published, it seemed that all participants understood the need for adaptation to prepare for possible higher water levels than previously accounted for (K-001; K-002; K-003, K-004).

Table 10: Phases where uncertainties were first recognized in Kraanbolwerk. Phases where no uncertainty arose are excluded in the table. (Alternative selection, weighing costs & benefits, and evaluation)

Category	Uncertainty Theme	Unc. Type	Prob. Rec.	Prob. Def.	Sol. Sp. gen.	Alt. An.	Cho. & Imp.	Unk.	All
Institutional uncertainty	Competent authority in the project	Ambiguity		**1**					
	Responsibility & ownership (risks and €)	Ambiguity	**1**					**1**	**3**
	Parties on the same page & talking about the same things	Ambiguity	**1**	**1**	**3**	**2**			
	Working & testing integrally	Ambiguity	**1**	**1**					**3**
	Actors' neglectance or ignorance to uncertainties	Ambiguity			**1**				
Technical uncertainty	Integration project into river landscape	Epistemic	**1**	**1**	**1**				**1**
	Project's effect on hydraulic characteristics	Epistemic							**1**
	Magnitude of soil pollution and effect in project	Epistemic		**1**	**1**		**1**		**1**
	Condition of quay walls	Epistemic			**2**				**1**
Long-term development uncertainty	Climate induced future water level increase	Ontologic	**1**		**4**				**1**
	Government induced future water level increase	Ontologic	**2**		**2**	**1**			
	Should you want to build in the unembanked area?	Ambiguity							**1**
	Future discharge distributions	Ontologic			**1**				
	Uncertain market function	Ontologic	**1**			**1**			
# Uncertainties per category per phase									
# Institutional uncertainty per phase			3	3	5	2	0	1	7
# Technical uncertainty per phase			1	2	4	0	1	0	3
# Long-term development uncertainty per phase			4	0	6	2	0	0	2
Total # uncertainties in each phase			8	5	15	4	1	1	12

Dealing with uncertainty

The last thing that was researched are the methods of dealing with the experienced uncertainties. The methods used to deal with the found uncertainties experienced in the project are shown in Table 11. Some of the interviewees described a combination of two methods that were used to deal with one uncertainty in the project. In order to show in which themes this was the case, two columns have been added that display the total times an uncertainty theme was described (same as in Table 9) along with the total number of methods that were mentioned. Never were there more than two methods mentioned to deal with one uncertainty. In some instances it was either not possible to derive a method or strategy used to deal with an uncertainty, or it was mentioned that the uncertainty was not (yet) dealt with. If this were the case, the dealing method was labelled as UNK (unknown) and NDW (not dealt with) respectively.

Dealing with ontological uncertainty

The propositions made in the documents corresponded with the methods used to deal with the uncertainties according to the interviewees. From the data, almost all interviewees agreed that a combination of scenario planning and designing the project around enduring the uncertain phenomenon (worst-case scenario planning) was applied to deal with the uncertain future water levels (K-001; K-002; K-003; K-005; D001; D002). K-005, D001, and D002 specifically mentioned that the method of enduring the uncertain phenomenon was applied across multiple projects. The IJVD (IJssel-Vecht Delta) jointly developed an uniform minimum required design height (2.60 m+NAP) for all projects in and around the city centre. The IJVD is a steering group that consisted of practitioners from the Province of Overijssel, Municipality of Zwolle, and the Water Authority Groot-Salland (now Drents-Overijsselse Delta). According to K-005, this worked great at the time since it was a very straightforward requirement. Because of that, it would prevent ambiguities between the sectoral authorities regarding how to deal with the water level uncertainty, how to manage working together, and what to conform to in these projects. This is also reflected in the data; no interviewee mentioned the existence of ambiguities between IJVD-partners during the project.

Dealing with ambiguities

Despite efforts to prevent ambiguities on how to manage working and testing integrally between IJVD partners, this theme was still mentioned quite often. However, all the mentioned ambiguities can be allocated to managing working together between municipality and developer. As stated in the section about uncertainties in the project, public participants mentioned differences in preferred working methods between the municipality and developer were experienced. This is one of the ambiguities in which dialogical learning between developer and municipality was applied (K-003). D003 also highlighted the need for dialogical learning to deal with uncertainty about working and testing together, stating:

"…integrating developments therefore means connecting experiences. This integration starts with the awareness of other experiences, knowledge and role holders. From a developed consciousness it is then possible to act". – D003 (translation from Dutch)

The other instance of application of dialogical learning involved a combination of dialogical learning and a negotiation approach to deal with an ambiguity around a difference in approach to costs and risks. No one wanted to pay the bills (K-004). Because of these differences, the project suffered additional costs (K-004). Dialogical learning was first applied to understand where both parties were coming from, what their roles are, and what their issues were (K-004). After that, the negotiation approach was used. K-004 gave a good description of how this worked:

"For instance, if with both parties had an issue that has a financial theme, then you have a negotiation. But suppose one does not want the hassle of something and the other does not want the costs. Then you could say okay, if I take over your hassle and charge you for it, then maybe you will not mind that bill since you got rid of your hassle" – K-004 (translation from Dutch)

Table 11: Methods used to deal with uncertainty in Kraanbolwerk

Category	Uncertainty Theme	Unc. Type	Methods Epistemic						Methods Ontological				Methods Ambiguity							Other		Sum of	Total #
			A/EE	RE	DR	IKGR	DCI	TMAM	WCSP	SP	IF	BIIDM	PC	DL	NA	RPS	ADKF	EUS	IFOO	UNK	NDW	methods used	Uncertainties
Institutional uncertainty	Competent authority in the project	Ambiguity																	**1**			1	1
	Responsibility & ownership (risks and €)	Ambiguity												**3**	**3**					**1**		7	5
	Parties on the same page & talking about the same things	Ambiguity											**2**	**2**	**1**	**1**		**1**				7	7
	Working & testing integrally	Ambiguity											**1**	**3**	**1**		**1**			**1**		7	5
	Actors' neglectance or ignorance to uncertainties	Ambiguity												**1**					**1**			2	1
Technical uncertainty	Integration project into river landscape	Epistemic		**2**	**2**																	4	3
	Project's effect on hydraulic characteristics	Epistemic			**1**																	1	1
	Magnitude of soil pollution and effect in project	Epistemic	**1**		**1**	**1**		**2**														5	4
	Condition of quay walls	Epistemic					**1**	**1**												**1**		3	3
Long-term development uncertainty	Climate induced future water level increase	Ontologic							**5**	**5**										**1**		11	6
	Government induced future water level increase	Ontologic							**4**	**3**		**1**										8	5
	Should you want to build in the unembanked area?	Ambiguity												**1**	**1**							2	1
	Future discharge distributions	Ontologic																			**1**	1	1
	Uncertain market function	Ontologic									**1**									**1**		2	2
Sum of each method used		N/A	1	2	4	1	1	3	9	8	1	1	3	10	6	1	1	1	2	5	1		

Legend dealing methods

A/EE:	Assessment/Evaluation by experts	WCSP:	Worst-case scenario planning (endure uncertain phenomenon)	NA:	Negotiation approach
RE:	Research by experts	SP:	Scenario planning	RPS:	Rational problem solving
DR:	Doing research	IF:	Incorporating flexibility (adaptability)	ADKF:	Accept differetn knowledge frames
IKGR:	Implication of knowledge gaps research	BIIDM:	Being informed and interferring with decision-making*	EUS:	eliminating uncertainty source*
DCI:	Developing confidence intervals	PC:	Persuasive communication	IFOO:	Imposing your frame onto others
TMAM:	Taking more accurate measurements	DL:	Dialogical learning	*:	New methods found in interviews

The methods to deal with uncertainties belonging to the theme related to getting all involved parties on the same page has a particular spread between the methods used. Never was a combination of methods mentioned in order to deal with ambiguities in this theme. The chosen methods are mainly dependent the described situation in which the ambiguities took place. K-001 and K-003 described two instances where persuasive communication was used. In the case of K-001, it was about the acceptance of climate change (and changes to water levels) being a real issue that should be accounted for in the project. Acceptance was achieved by avoiding the term climate change, instead only describing the consequences in order to convince other parties of the importance of future climate changes to Kraanbolwerk. K-003 described that an alderman of the municipality applied persuasive communication to get stakeholders – such as local residents – to agree that the project was of general public value. He achieved this by dubbing Kraanbolwerk a 'monument to the future and a living room for the city' (K-003). To ensure that Kraanbolwerk would become a living room for the city, dialogical learning between local residents (and other stakeholders) and the project team was applied to develop a joint vision on what Kraanbolwerk should look like. This was done to deal with dissatisfaction of stakeholders – who were not directly involved in the project – in regards to previous preliminary designs (K-003). By giving them "a podium to shine with their ideas (regarding design and living with water)" (K-001), the municipality was able to re-involve the public in a positive manner and generate added value to the project (K-003).

An instance of intentionally avoiding dialogical learning and instead dealing with ambiguity through rational problem solving was when discussing what services or functions should be constructed at what height. For instance, it would be more acceptable for a pedestrian path to flood at a higher frequency compared to if the houses would flood (K-001). To assess this, rational problem solving in the form of model calculations the water authority had performed were used to determine what the accepted return times for different functions should be. It was done in this way because there was no other way to get a grip on this matter without delving too much into the grey areas of individuals' thoughts on the matter (K-001). So in this instance, a conscious decision was made to not apply a method like dialogical learning or persuasive communication since it was deemed not to yield a beneficial result.

Dealing with epistemic uncertainty

A set of uncertainties that interviewees deemed very impactful on the project were the epistemic uncertainties related to soil pollution and the condition of the quay walls (K-002; K-003; K-004; K-005). K-002 explained that pre-construction, extensive research and measurements were taken to capture the extent of these uncertainties. However for the soil pollution in particular, they found that taking more accurate measures to the point where you would have fully eliminated the uncertainty was impossible due to buildings (to be demolished) standing on top of the polluted soil (K-002). In the end, the soil pollution was still underestimated and the soil turned out to be more polluted than thought (K-002; K-003). It is unclear whether this was related to the buildings hindering the measurements and research.

New methods to deal with uncertainty

During the interviews, one interviewee (K-001) described a method to deal with the uncertainty of government induced water level increase that had an somewhat extraordinary and new approach. When Commissie Veerman published their report and subsequently announced the Delta Programme, multiple (public) organisations operating in the IJssel-Vecht Delta realized that the proposition of increasing the water levels in the IJsselmeer by 1.5 meters would affect the water levels in Zwolle and other cities located near the Zwarte Water and IJssel. The organisations ended up influencing the decision-making of the water levels in the IJsselmeer. As K-001 put it:

"In fact, we sought dialogue with the Delta Programme. We influenced them and vice versa. With Kraanbolwerk we have been able to display the vulnerable position of the Zwolle region to changes in the IJsselmeer water levels." – K-001 (translation from Dutch)

The organisations operating in the IJssel-Vecht Delta, instead of trying to deal with the ontologic nature of uncertain decision making by using methods such as scenario planning or incorporating flexibility (as proposed by the theoretical framework), brought knowledge to the source of their ontological uncertainty, being the Delta Programme's intended IJsselmeer water level increase. The knowledge of the impact of the water level increase to the Zwolle region was apparently/seemed unknown for the Delta Programme (K-001). So by dealing with another party's epistemic uncertainty, the organisations in the IJssel-Vecht Delta were capable of reducing their ontological uncertainty.

During non-formal conversations, it turned out that this interference and being involved in decision-making processes in higher governmental layers is consistently being used ever since this project. It was deemed to be a separate method to deal with ontological uncertainty surrounding decision-making one normally does not have an influence on. The method for interfering with decision-making on a higher governmental level was named 'being informed and interfering with decision-making' and added to the list of adequate methods to deal with ontological uncertainty. A separate method was made which is just called 'being informed', and specifically targets dealing with uncertainty by staying up-to-date or monitoring processes outside of one's influence to be able to anticipate changes or developments. This is different because when one has the opportunity to interfere with a decision-making process, they do have (some) influence on the process.

4.2: Results case project: Zwarte Water Zone

In this sub-chapter the results of the document and interview analysis in the Zwarte Water Zone project will be explained. The section starts with an introduction which includes background information of the case project. After that, the results of the case study will be presented. The results consist of 1) what uncertainties were found, 2) what project phase the first presented themselves or were first acknowledged, 3) how the uncertainties are dealt with, 4) new methods to deal with uncertainties found in this case study, and 5) the role of trust in uncertainty management. Throughout this sub-chapter the most mentioned uncertainty themes will be highlighted and methods to deal with them explained, along with special cases that stood out from the other results.

Introduction project Zwarte Water Zone

The project Zwarte Water zone consists of two project locations that are in development currently. Project location 'Tiferto & Botermanhaven / Stadskade' is the smaller southern area of project Zwarte Water zone depicted in Figure 4. The Stadskade is an unembanked area of the city and lies near an important infrastructural junction in Zwolle. Currently the area is home to a number of industrial facilities: (1) shipyard Leenman (which recently turned into an indoor ski centre), (2) a wholesale in fertilizers called Triferto B.V. (now largely moved to a city nearby), (3) a small harbour called Botermanhaven that is owned by the municipality of Zwolle which currently houses a (yacht) furniture manufacturer, and (4) a parking lot used by the nearby school Deltion College (Steenbergen, 2019; BEMOG & BPD, 2021). The area lies within a noise zone (Dutch: geluidszone) regarding traffic noise by the nearby road, highway and industrial activities in the nearby area Voorst. Therefore, the area is unfit for noise sensitive functions like (permanent) residential housing (Gemeente Zwolle et al., 2018).

The area lies near an important infrastructural junction. It is deemed advantageous to change the function of the area into a more accessible and attractive area for tourists, cultural activities, ateliers, sports and other recreational activities. In the project area Stadskade, the municipality of Zwolle –

along with other parties – aims to overhaul the current industrial area and turn the area into a space where – in the current urban plan – leisure, hospitality business (hotel/bars), creative and cultural businesses/activities will thrive. In the current design, the area will be redesigned to have catering facilities, a hotel and small workshops and business offices. An exception to this is that the indoor ski centre in the old shipyard of Leenman will be maintained (Gemeente Zwolle et al., 2018; BEMOG & BPD, 2021). Additionally, the marina for the recreational boat club ‘Zwolsch Watersportcentrum’ will be added to this area. The marina are currently located in the northern project area. The marina will be moved to this area in order to make space for residential housing in the northern project area.

The flood protection structure near the project location – embankment ring 53 – does not comply with the current assessment tools the water authorities use. As a result, the water authority aims to increase the embankment height by approximately 0.70m. This means its width will also increase. Sheet piles will be constructed inside to embankment to increase stability to failure mechanism and to allow for trees being planted near the embankment without it affecting its strength negatively (Tauw et al., n.d.). An impression of what the southern project area Stadskade will look like is shown in Figure 10.

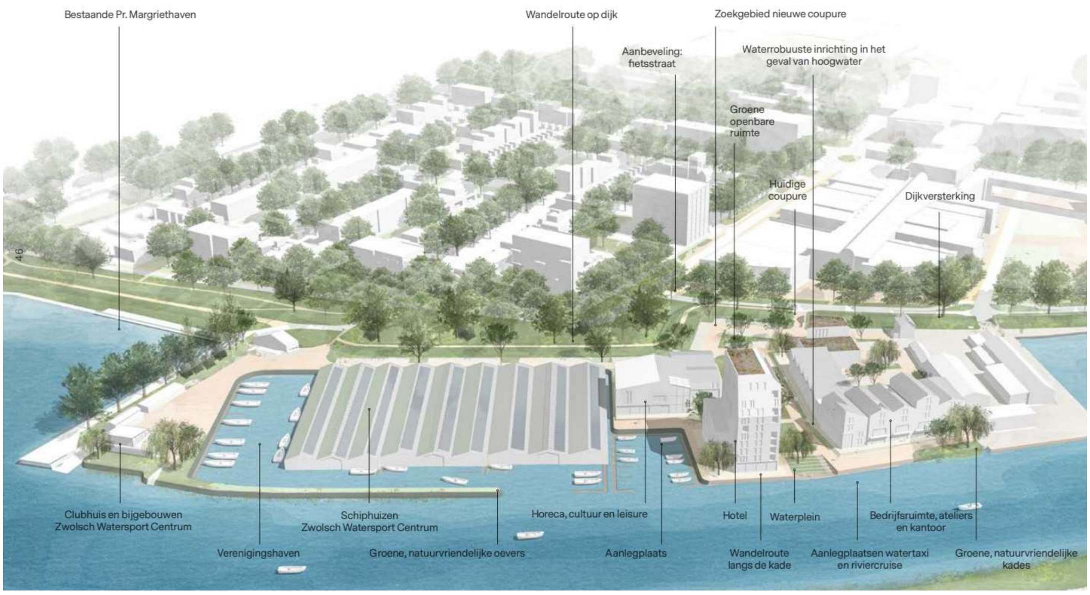

Figure 10: Impression design project area Stadskade (BEMOG & PMD, 2021, p.46-47)

The second project area in the reconstruction project Zwarte Water Zone called ‘Jachthavens’ is located to the north of project location Stadskades (Northern location in Figure 4). This area is intended to be redesigned into a residential area with recreational value for its future inhabitants and the surrounding residential areas. In this project location roughly 280 dwellings will be built with different sizes and price ranges. The area will be designed with green and blue infrastructure in mind and will be habitable during normal and high water level scenarios (return period: ~1:10.000). This will take a prominent role in the design of the residential area (Gemeente Zwolle et al., 2018; BEMOG & PMD, 2021). Cars will be mostly prohibited within the residential area and an underground parking lot will be built for inhabitants to park their car in.

Currently, this area houses two marinas owned by ‘Jachthaven de Hanze Zwolle’ and ‘Zwolsch Watersportcentrum’, a former shipyard for reparation of small yachts (terminated), a canoe club and some residential houses spread around the marinas that also lie inside the project area. In the current redesign plans the marina owned by Zwolsch Watersportcentrum will be moved to project location Stadskade as a result of the intended plans to redesign that part of the marinas into a residential area. The residential houses present in the current situation will be maintained.

For the reconstruction of project area Jachthavens it is divided into three project sections: Dijkzicht, de Hanze and Recreatiehaven. The section Recreatiehaven roughly encompasses the area owned by Jachthaven de Hanze Zwolle where some minor adjustments to the current situation will be made in the form addition of (floating) houses with a mooring area for a boat/yacht (BEMOG & PMD, 2021).

Project section Dijkzicht will be transformed into a residential area with recreational value for people in and around project location Jachthavens. Housing will be located close to the embankment that is – like location Stadskade – also located right next to the project area. This allows for recreational opportunities near the Zwarte Water river. Walking routes will run through the residential area and near the Zwarte Water river to create recreational value inside the green and blue infrastructure within project section Dijkzicht. The residencies in this section will consist of stacked apartment complexes with different sizes in a cascaded style with terraces that allow for biodiversity and rainfall interception (Gemeente Zwolle et al., 2018; BEMOG & PMD, 2021).

Project section de Hanze will also be transformed into a residential area which partially consists of ground-level (floating) houses in addition to stacked apartments (less floors than section Dijkzicht). These will be located further away from the embankment. The walking routes from project section Dijkzicht are extended into this project section, connecting both sections to each other. Some houses in this section come with a mooring area for a boat/yacht (BEMOG & PMD, 2021). This is the section with a relatively higher price range. Project section de Hanze will also be the location where the underground parking lot will be constructed. There are ambitions for the parking lot to be floodable for the purpose of water storage in times of high water levels but that is yet to be decided definitively. A map of the project section is shown in Figure 11.

The water authorities plan to enhance the embankment that borders this project location – part of embankment ring 53 – also. The embankment will be increased in both height and width (precise measurements are unknown) and two screens will be constructed both the water side (side of the new residential area) and on the land-side mainly to increase the strength of the embankment against the failure mechanism piping (Tauw et al., n.d.).

Figure 11: Map overview design impression project area Jachthavens (BEMOG & PMD, 2021, p.62-63)

Uncertainties within the project development process

Based on the document analysis, it would seem that there are barely any uncertainties present in the Zwarte Water Zone project apart from uncertain future water levels and an occasional technical uncertainty. However, the interviews show that this is in fact not the case. In total, 80 different uncertainties were mentioned by the interviewees. Table 12 shows how many times each uncertainty theme was mentioned by the interviewees, their respective uncertainty type, and what percentage they make up within the totality of the results. What immediately stands out is that there are six uncertainty themes that contribute to over 50% of the total uncertainties found. The six most frequently mentioned uncertainty themes were spread across most interviewees relatively equally. None of the interviewees mentioned three or more of one uncertainty theme. The most dominant theme throughout the interviews is the uncertainty about project participants being on the same page and being able to agree with each other in combination with whether there are differences in interpretation of certain decisions, designs, or information ('Is it possible to get everyone on the same page and are we talking about the same things (the same knowledge frame)?').

Table 12: Mentioned uncertainties by interviewees for project Zwarte Water Zone

Category	Uncertainty Theme	Unc. Type	Total # Mentioned	% of total
Institutional uncertainty	Parties on the same page & talking about the same things	Ambiguity	11	13.75%
	Working & testing integrally	Ambiguity	4	5.00%
	Actors' neglectance or ignorance to uncertainties	Ambiguity	3	3.75%
	Competent authority in the project	Ambiguity	3	3.75%
	Parties required to be involved and when	Epistemic	3	3.75%
	Responsibility & ownership (risks and €)	Ambiguity	3	3.75%
	Policy interrelations	Epistemic	1	1.25%
Technical uncertainty	Integration project into river landscape	Epistemic	8	10.00%
	Consequences submersible parking garage	Epistemic	5	6.25%
	Construction of services (electr., water, etc.)	Epistemic	2	2.50%
	Inter-organisational testing (design/policy)	Ontologic	2	2.50%
	Project's effect on hydraulic characteristics	Epistemic	1	1.25%
Long-term development uncertainty	Should you want to build in the unembanked area?	Ambiguity	8	10.00%
	Changes in policy/policital composition	Ontologic	7	8.75%
	Climate induced future water level increase	Ontologic	6	7.50%
	Changing view on water safety in future	Ontologic	3	3.75%
	Government induced future water level increase	Ontologic	3	3.75%
	Uncertain market function	Ontologic	2	2.50%
	Future discharge distributions	Ontologic	1	1.25%
Assessment uncertainty	Acceptance thresholds (internal)	Ambiguity	3	3.75%
	Testing/Advising as organisation	Epistemic	1	1.25%

Ambiguities in Zwarte Water Zone

Although almost all interviewees mentioned at least one uncertainty allocated to this theme, it was not always linked to a particular situation they had been in. Rather, it was more of an observation they had made throughout the project development process as a whole. They would describe – often without explicitly naming a situation in which it had occurred – that they felt like it was hard to get everyone on the same page in the project (or agree with each other), and expressed that mutual understanding between participating party's perceptions or stances on a certain matter in the project had been difficult to attain (Z-001; Z-003; Z-005; Z-006; Z-007; Z-009).

One interviewee simply mentioned that with more participants, more (unique) perceptions will be present that lead to ambiguity (Z-003). Others explained that everyone has a different frame of mind that is constructed through their expertise, education, the function they are fulfilling in the project, and the organisation they are representing (Z-005; Z-006; Z-007). These different frames lead to different approaches or stances towards the project, and ambiguity on what principles or possible solutions to adhere in the project (Z-005; Z-007). Z-007 explained that the effects different frame of minds have on the project are not limited to participants within the project team, it also plays a role between local residents and the project team. Z-007 goes on to explain that this ambiguity cannot be ignored as it can pose a serious risk to the development of the project.

There were instances where a concrete situation was mentioned. For instance, the view on feasibility (non-technical) of integrating the parking garage of Zwarte Water Zone with the Stadsdijken project (Z-001; Z-002; Z-009). Interviewees did not go into further detail on this situation, likely because at the time of the research the uncertainty had already been resolved. Another situation was given by Z-001 and Z-007. They mentioned an ambiguity about what units of measurement to use when calculating the possible water retention capacity in the development area. The retention capacity was calculated in square meters rather than cubic meters, which led to a string of other uncertainties (Z-007). Lastly, Z-006 described ambiguity between participants regarding what data to use. They described a situation about a traffic research carried out by the developer, where the municipality thought it was insufficient. So the municipality carried out their own research. The risk of this is that slight differences in interpretation between the traffic researches might lead to even more ambiguity regarding the 'correct' data (Z-006).

The second most mentioned uncertainty is 'should you want to build in the unembanked area?', also an ambiguity. Here, the interviewees agreed that this ambiguity was partially between project participants, but mostly between the project team and local residents. Local residents would express their concerns about water safety and risks involved with living in the unembanked space, deeming it too dangerous or unwise (Z-001; Z-002; Z-004; Z-006; Z-009). The discussion about whether it was responsible to build in the unembanked space was further fuelled by recent flooding in Limburg (Z-009). Some argued that the source of this ambiguity was due to a lack of knowledge/expertise about how to build responsibly in the unembanked space by both local residents and project participants (at the start of the project) (Z-001; Z-002; Z-004; Z-009). Sometimes this would be followed up by expressing that local residents only brought up the water safety aspect to substantiate their underlying motive (Z-004; Z-009). They felt like the discussion between local residents and the project team mainly had to do with local residents not wanting the project to come into being for their own reasons. For example, because it would potentially harm their view over the water. Based on the review of a document containing over 200 questions by local residents and other stakeholders about the project, it seems plausible. Out of all the questions asked, only one was tailored towards water safety (D102).

One interviewee specifically mentioned their concern about water safety, not just for inhabitants of Zwarte Water Zone, but also for the areas surrounding it (Z-008). Asking themselves the question whether construction of the Zwarte Water Zone does not lead to lock-ins to the water system in the future:

"…that building in the unembanked space could be vulnerable. Not only for the Zwarte Water Zone itself, but also in the long term for the flood defences. Perhaps there is actually a question of water safety: Is there enough space for the water (in the future) or do we lock the system this way?" – Z-008 (translation from Dutch)

They go on to explain that this concern is a hard case to make because no real laws and regulations currently exist about how one can/should build responsibly in the unembanked space to avoid problems in the future. For example, potential future lock-ins (Z-008).

Ontological uncertainty in Zwarte Water Zone

Perhaps the most obvious uncertainty being experienced in the project are the uncertain future water levels. A little more than half of the interviewees mentioned the presence of ontological uncertainty related to climate induced future water level increase (Z-001; Z-005; Z-006; Z-008; Z-009), and was widely mentioned throughout the documents (D101; D103; D104; D106; D108). When describing uncertainty allocated to this theme most interviewees described it up in the same way as the documents did. They explained that the uncertain future water levels were particularly important in this project because they have to make decisions about design the project with today's knowledge and model calculations, while keeping in mind that it is subject to change during or after construction of the project (Z-001; Z-005; Z-006; Z-008; Z-009). Some mention what this practically means for the project. In the end, it boils down to the consideration of how much (water level) change are you willing take into account, where do you stop (Z-006; Z-009)?

While uncertain future water levels might be the most obvious ontological uncertainty, changes in policies or political composition affecting the project is the most mentioned. However, four out of the seven uncertainties allocated to this theme were mentioned by only one interviewee (Z-004).

What is remarkable is that the interviewees that did not mention experiencing uncertainty around future water levels were the main contributors to the policy and political composition theme (Z-002; Z-004; Z-007; Z-008). Both Z-002 and Z-004 mention an event at the start of the project where a policy related to building in the floodplain (Dutch: Beleidslijn Grote Rivieren) was changed, which enabled the project to be eligible for the required permits. They follow up that because of this event, they found that the longer the project stays in a development stage, the more opportunities for policy changes will present themselves. Z-004 and Z-007 explicitly mention possible changes in composition of the municipal council (coalitions) as a driver to policy change because the project was not unanimously accepted. Z-007 explained the consequences quite clearly:

"…that (projects such as Zwarte Water Zone) are really quite long development processes that also have a good chance of being confronted with new coalitions in provincial or municipal coalitions. …(If a new coalition is formed), then there will be a coalition agreement with additional ambitions compared to those we had a month before. And the new coalition would also like you to incorporate that into your current projects, which are already underway. That is also possible provincially, of course." – Z-007 (translation from Dutch)

While the above is mainly about consequences of change in composition of sectoral authorities' council, Z-008 focused more on long-term project transcending reciprocal influence of policy changes between sectoral authorities involved in the project. They mention that it seems to become more and more important to develop integral policy between sectoral authorities. The uncertainty revolts around that we do not know, as "BV Netherlands", how we want to integrally account for uncertainties – such as climate change – yet (Z-008). In other words, what the integral policies should look like and how much time it will take to get there.

Epistemic uncertainty in Zwarte Water Zone

An uncertainty theme that turned out to include a multitude of different uncertain instances (or situations) was about the knowledge of requirements and points of attention related to integration of the project into the river landscape. It ranges from 1) knowledge about policies and regulation of different sectoral authorities (Z-004), 2) under what circumstances it would be possible to integrate project Zwarte Water Zone with strengthening of the adjacent embankment from a technical point of view, and gaining knowledge about what to take into account when combining the dynamic between water safety and spatial visions (Z-003; Z-008), to 3) the technical feasibility of ambitions into the project. Most notably, reaching +10% water retention capacity compared to the current capacity (Z-005; Z-007), 4) what functions can we fit where into the project. Such as residing, leisure, and recreation (Z-001), but also things like required design heights of some functions – like escape routes or electric transformers – to keep them functional during a flood (Z-005), and 5) uncertainties related to embankment stability, soil quality, nautical management, and spatial planning during and after the construction of the project (D103).

Z-006 described a more overarching, project transcendent problem related to the applicability of global/regional climate models – and the outcomes – on the local level like a project. Because global/regional climate models have a relatively low resolution, they are not always accurate or representative for local conditions. The knowledge gap lies in how to apply or translate national assessment criteria (policy) – based on the global/regional climate models – to a local level like a project. Z-006 states that this makes it hard to know what you should or should not take into account when designing the project (Z-006).

Where in project cycle did uncertainties first present themselves?

Table 13 shows the project phases in which a given uncertainty first presented itself or was first acknowledged. Uncertainties were mentioned to have arose in nearly all phases of the project except for the evaluation phase. For some uncertainties it is unknown during which phase of the project an experienced uncertainty first arose. These are labelled as 'Unk' in Table 13. The reason for this was either due to a lack of time during the interview or the interviewee having a hard time applying the definition of the project as a problem solving cycle approach to the goal of the question.

From the data it can be concluded that most uncertainties experienced during the project present themselves relatively early according to the interviewees. 45 out of 80 experienced uncertainties were first acknowledged in the first three phases of the project circle (problem recognition, problem definition, and solution space generation). Most interviewees explain that uncertainties belonging to the category 'long-term development uncertainty' present themselves almost immediately when the project starts. In most interviews, the interviewees seemed under the impression that these uncertainties were just commonplace, that everyone is aware of them. Statements include: *"Yes, I think so, because that has a bit to do with that gut feeling, does it not? We know that something is going on there."* (Z-008) (translated from Dutch) And *"Yes, in Zwolle this is always (acknowledged) at the start"* (Z-005) (translated from Dutch). This was especially the case for uncertainties related to (climate or government induced) future water level increase and policy changes that (can) affect the project.

Uncertainties belonging to the technical uncertainty and institutional uncertainty category are somewhat evenly spread across the project development process. For example, the uncertainties belonging to the 'how can/do you integrate the project into the river' theme seem to arise early in the process, whilst the other more project specific technical uncertainty themes arise from the solution space generation and onward when more information becomes available or more knowledge is being gathered.

An important note should be made about ambiguities and their distribution across the different project phases. The data shows that ambiguities arise or are being acknowledged throughout the entire project process. Z-006 gave an explanation to why this might be the case:

"So if the project still has a certain abstraction, you appear to understand the word(s) in the same way, but you also have no more means to express it (your point of view/frame) differently. So in that sense, you settle for that uncertainty and feeling that you understand each other." – Z-006 (translation from Dutch)

This suggests that ambiguities could be present as early as the problem recognition. However, due to the level of abstraction in the early phases they are not acknowledged yet. Z-006 then goes on to explain that these ambiguities present themselves more and more once the level of abstraction goes down and the project design becomes more concrete. Then it becomes clear – by other means than just words – what the differences between perceptions or frames of other participants were. You can now see the outcome, instead of just reading about it.

Table 13: Phases where uncertainties were first recognized in Zwarte Water Zone. Phases where no uncertainty arose are excluded in the table (Evaluation).

Category	Uncertainty Theme	Unc. Type	Prob. Rec.	Prob. Def.	Sol. Sp. gen.	Alt. Select.	Alt. An.	Weigh. C&B	Cho. & Imp.	Eval.	Unk.	All
Institutional uncertainty	Parties required to be involved and when	Epistemic	1		2							
	Policy interrelations	Epistemic		1								
	Competent authority in the project	Ambiguity			1	1					1	
	Responsibility & ownership (risks and €)	Ambiguity		1	1							1
	Parties on the same page & talking about the same things	Ambiguity	2	2	1	1	1		1		3	
	Working & testing integrally	Ambiguity		1		1	2					
	Actors' neglectance or ignorance to uncertainties	Ambiguity			2		1					
Technical uncertainty	Integration project into river landscape	Epistemic	2	3	1			1			1	
	Project's effect on hydraulic characteristics	Epistemic			1							
	Construction of services (electr., water, etc.)	Epistemic						1			1	
	Inter-organisational testing (design/policy)	Ontologic			1		1					
	Consequences submersible parking garage	Epistemic			1	2	1				1	
Long-term development uncertainty	Climate induced future water level increase	Ontologic	3	1							2	
	Government induced future water level increase	Ontologic	3									
	Should you want to build in the unembanked area?	Ambiguity	1	2	2	1	1				1	
	Changing view on water safety in future	Ontologic	2						1			
	Future discharge distributions	Ontologic									1	
	Uncertain market function	Ontologic	1					1				
	Changes in policy / policital composition	Ontologic	5					1			1	
Assessment uncertainty	Testing/Advising as organisation	Epistemic		1								
	Acceptance thresholds (internal)	Ambiguity					1	1			1	
# Uncertainties per category per phase												
# Institutional uncertainty per phase			3	5	7	3	4	0	1	0	4	1
# Technical uncertainty per phase			2	3	4	2	2	2	0	0	3	0
# Long-term development uncertainty per phase			15	3	2	1	1	2	1	0	5	0
# Assessment uncertainty per phase			0	1	0	0	1	1	0	0	1	0
Total # uncertainties in per phase			20	12	13	6	8	5	2	0	13	1

Dealing with uncertainty

The methods used to deal with the found uncertainties experienced in the project are shown in Table 14. The table shows methods used that did not correspond to the type of uncertainty experienced with a grey outline. The adequate methods that were applied to deal with a corresponding uncertainty type (according to the theoretical framework)are uncoloured. Some of the interviewees described a combination of two methods that were used to deal with one uncertainty in the project. In order to show in which themes this was the case, two columns have been added that display the total times an uncertainty theme was described (same as in Table 12) along with the total number of methods that were mentioned. Never were there more than two methods mentioned to deal with one uncertainty. In some instances it was either not possible to derive a method or strategy used to deal with an uncertainty, or it was mentioned that the uncertainty was not (yet) dealt with. If this were the case, the dealing method was labelled as UNK (unknown) and NDW (not dealt with) respectively.

Table 14: Methods used to deal with uncertainty in Zwarte Water Zone. Methods that do not fit with the type of uncertainty are marked in grey.

Category	Uncertainty Theme	Unc. Type	Methods Epistemic				Methods Ontological						Methods Ambiguity								Other		Sum of	Total #
			A/EE	RE	EDD	DR	WCSP	SP	IF	AUDC	BIIDM	BI	PC	DL	NA	RPS	ADKF	EUS	IFOO	IOP	UNK	NDW	methods used	uncertainties
Institutional uncertainty	Parties required to be involved and when	Epistemic		**2**																	**1**		3	3
	Policy interrelations	Epistemic																				**1**	1	1
	Competent authority in the project	Ambiguity								**1**				**1**	**1**								3	3
	Responsibility & ownership (risks and €)	Ambiguity											**1**		**1**			**1**					3	3
	Parties on the same page & talking about the same things	Ambiguity			**1**									**4**		**1**		**2**	**1**	**1**		**2**	12	11
	Working & testing integrally	Ambiguity				**1**								**2**	**1**						**1**		5	4
	Actors' neglectance or ignorance to uncertainties	Ambiguity												**1**				**1**			**1**		3	3
Technical uncertainty	Integration project into river landscape	Epistemic	**1**	**2**	**2**	**2**										**1**						**1**	9	8
	Project's effect on hydraulic characteristics	Epistemic		**1**																			1	1
	Construction of services (electr., water, etc.)	Epistemic		**1**		**1**																	2	2
	Inter-organisational testing (design/policy)	Ontologic																				**2**	2	2
	Consequences submersible parking garage	Epistemic	**1**			**2**															**2**		5	5
Long-term development uncertainty	Climate induced future water level increase	Ontologic				**1**	**1**	**2**	**2**	**1**												**1**	8	6
	Government induced future water level increase	Ontologic						**1**	**1**		**1**												3	3
	Should you want to build in the unembanked area?	Ambiguity											**2**	**3**		**2**	**1**		**1**		**1**	**1**	11	8
	Changing view on water safety in future	Ontologic							**1**	**2**												**1**	4	3
	Future discharge distributions	Ontologic								**1**													1	1
	Uncertain market function	Ontologic						**2**	**2**														4	2
	Changes in policy / policital composition	Ontologic								**1**		**3**		**1**							**1**	**2**	8	7
Assessment uncertainty	Testing/Advising as organisation	Epistemic			**1**																		1	1
	Acceptance thresholds (internal)	Ambiguity											**2**			**2**							4	3
Sum of each method used		N/A	2	6	4	8	1	5	6	6	1	3	5	12	3	6	1	4	2	1	7	10		

Legend dealing methods

A/EE:	Assessment/Evaluation by experts	AUDC:	Accepting uncertainty and deal with consequences as they occu	ADKF:	Accept different knowledge frames
RE:	Research by experts	BIIDM:	Being informed and interferring with decision-making*	EUS:	Eliminating uncertainty source*
EDD:	Experimenting with different designs	BI:	Being informed*	IFOO:	Imposing your frame onto others*
DR:	Doing research	PC:	Persuasive communication	IOP:	Introduce other perspectives*
WCSP:	Worst-case scenario planning (endure un	DL:	Dialogical learning	*:	New methods found in interviews
SP:	Scenario planning	NA:	Negotiation approach		
IF:	Incorporating flexibility (adaptability)	RPS:	Rational problem solving		

Dealing with ontological uncertainty

To deal with ontological uncertainties related to climate induced water level increase, the municipality – together with a consultancy – used scenario analysis/planning to develop a functional program of requirements (Z-001; Z-005; Z-009). The document includes requirements for the developer with regard to building in the unembanked space through the use of scenario analysis (scenario planning) (D101). Z-005 mentioned that they think that everything one can account for within the boundaries of the project is put in this program of requirements. However, they also recognized that there are so many facets to future water level uncertainty that it is hard to fully capture in project specific requirements, especially with an eye to the future. A total of five requirements are listed in this document and consist of the following (D101):

1. No unacceptable damages may occur to dwellings, vital infrastructure and parked cars during high water situations;
2. Developer must be able to demonstrate in their design that – possibly with minor changes to the design in the future – the project can withstand extreme water levels of 3.5m +NAP (upper bound scenario) without damages to vital infrastructure;
3. For the purpose of climate robust design, the municipality wants that the current water retention capacity of the project area is at least maintained. However, the aim is to increase retention capacity by 10%;
4. For future residents and other users there needs to be an evacuation route available to leave the area, and a way for emergency services to reach the area in times of high water situations;
5. During development, realisation and delivery the developer has to clearly communicate about the position of the project in the unembanked space, the associated risks to flooding, and the own responsibility for residents/users regarding water defence.

Z-001 explained that they arrived at the requirement of being able to withstand extreme water levels of 3.5m +NAP – with or without minor design changes – by assuming an extreme climate scenario and adding another meter onto the water level associated with that scenario. Along with the functional program of requirements, interviewees mentioned they had expressed to the developer that the requirements did not necessarily mean that the project had to be built on a big mound (Dutch: terp). Instead, they advised to think about incorporating adaptability into the design to allow for flexibility to deal with future climate developments, both positive and negative (Z-008; Z-009). In the end, it was chosen to deal with uncertain water levels by designing to endure the worst-case scenario (worst-case scenario planning) for the area that has dwellings on top of the soil. Preliminary designs show that the ground level the dwellings will be built on is located at 4.20m +NAP (D108), which is 0.7 meters higher than the requirement stated in the program of requirements (D101). An exception to this are the floating homes (D108). During informal conversations with some of the interviewees, it seemed that this ground level was still relevant and unchanged since the publication of this document.

Dealing with ambiguities

With regard to dealing with ambiguity related to whether you should want to build in the unembanked space, interviewees had very different experiences on how this ambiguity was dealt with. Part of this has to do with what audience they were targeting. One stated that they applied persuasive communication through substantiation of scientific evidence in order to convince (mainly) the municipal council that building in the unembanked space can be done safe and responsibly (Z-001; Z-009). In order get local residents to agree that water safety can be accounted for in the project, interviewees said to have used a combination of dialogical learning combined either persuasive communication (Z-004) or accepting different knowledge frames and moving on (Z-008).

Since the question whether you should want to build in the unembanked space was largely sparked by local residents living near the project, it was important to get them on the same page with the project team about the project (theme: parties on the same page & talking about the same things). Z-007 said that to get the local residents to be open towards the project team's perception on the project, they had to include them in the project and let their voices also be heard. To do this, a combination of dialogical learning and rational problem solving was applied. Intensive stakeholder participation was used to the point where local residents had influence on the process and (project) product (dialogical learning) (Z-007). Z-007 explained that they actively looked into how they could serve the needs or wishes of these people, but if it was not feasible or they could not tailor the project to their needs, the project team would explain why and substantiate the decision by data they had gathered (rational problem solving). Through the combination of these two methods, Z-007 argued that the local residents became far more receptive to the project as they organised more participation events.

There were not just ambiguities about getting on the same page between project team and local residents, but also within the project team. To create a joint knowledge frame between project participants, dialogical learning was applied. Z-005 explained that the method consisted of laying all perceptions of participants out on the table to understand from what point-of-view (frame) every participant was looking at – or where they were coming from with regards to – the project. Once that was clear, they jointly worked on a solution (design of the project) that would fit with the different frames (Z-005). Z-006 had a similar take to the same effect on how to create a joint knowledge frame. However they described it a little differently and more concise:

"The only way to get to a joint knowledge frame is to communicate with each other rather than communicating to each other. Not just sending but also listening." – Z-006 (translation from Dutch)

However, dialogical learning was not always the preferred method to deal with all ambiguities. The ambiguity between some participants about what units of measurement to use to calculate the retention capacity was quickly resolved by imposing one frame onto the others. Just stating that it has to be done in cubic meters and nothing else (Z-001). A rather unique situation was presented by Z-003. They explained that experimenting with different designs – normally a method used to deal with epistemic uncertainty – was applied to deal with different perceptions or frames of mind between participants about the integration of Zwarte Water Zone with the Stadsdijken project (non-technical). By showing different integrated designs, an attempt was made to get participants on the same page and more receptive to the integration when seeing the added benefits to the environmental quality as a result of integration of the two project (Z-003). However, this method proved to be ineffective to get parties on the same page (or frame) as the exploration of integrating the two projects was discontinued.

The data shows that dialogical learning is by far the most applied method to deal with ambiguities in the project development process. Most interviewees mentioned a form of dialogical learning to deal with various ambiguities they experienced during the project development process (Z-004; Z-005; Z-006; Z-007; Z-008; Z-009). Additionally, dialogical learning is the most popular method to pair with another. The use of a combination of dialogical learning with another method to deal with ambiguity is the main reason for having more dealing methods than experienced uncertainties in the data. Based on the interviews, a wide variety of other methods to deal with ambiguities were used to pair with dialogical learning (Z-004; Z-005; Z-007; Z-008). For example, Z-004 and Z-008 proposed that they had used dialogical learning in combination with persuasive communication (Z-004) or accepting different knowledge frames (Z-008) to deal with ambiguity about whether you should want to build in the unembanked space. However, when facing ambiguity about working and testing together (integrally), Z-005 mentioned that they paired dialogical learning together with a negotiation approach to deal with the ambiguity.

From this data, a majority of interviewed project participants show a preference towards applying dialogical learning to deal with ambiguity. The wide spread openness to the application of dialogical learning by project participants is very positive since the effectivity of dialogical learning very much depends on the willingness of people to participate in the process of creating a joint knowledge frame (Brugnach et al., 2010). However, on one occasion an interviewee stressed that dialogical learning was not the answer to every ambiguity. Z-006 found that dialogical learning did not have a positive effect in regards to dealing with the uncertainty theme related to getting parties on the same page. They stated in the interview that when one would try to deal with this ambiguity through a workshop with a fictional case it was possible to come to agreements, seemingly lowering the ambiguities. However, as soon as it is about a real-life situation again, the project participants would pull back into their original frame of mind, thereby deeming a workshop ineffective.

Dealing with epistemic uncertainty

As shortly explained in the section about the uncertainties present in the project, the most dominant epistemic uncertainty theme ‘integration project into river landscape’ had quite a lot of different situations where knowledge gaps were attached to. Z-004 mentioned that at first there was an absence of knowledge about what policies and regulations were in place – and by what organisations – that say something about building in the floodplain. This information was needed in order to assess whether Zwarte Water Zone was a promising initiative. To gain the desired knowledge, a company was hired to research this for the project team (research by experts). The company looked into policies by – and spoke with – different sectoral authorities about building (a residential area) in a floodplain (Rijkswaterstaat, Province of Overijssel, water authority Drents Overijsselse Delta) (D103; Z-004). The method was deemed quite effective as after that it was clear what policy requirements they had to conform to in order to be able to go through with the project (Z-004).

A few interviewees described uncertainties (allocated to how to integrate the project into the river as a lack of knowledge) about design principles and possible layout of the project areas in Zwarte Water Zone (Z-001; Z-003; Z-005). Despite not mentioning the same specific uncertain situation, Z-001 and Z-003 explained that they applied experimenting with different designs to lower their knowledge gap about the specific design of a part of the project and the technical integration of the project into the embankment respectively. Z-001 explained that in addition to experimenting with different designs, both the municipality and developer brought in an external party to understand what was and was not possible in terms of design for water safety. Z-005 mentioned that they applied rational problem solving – normally a method to deal with ambiguity – in order to deal with uncertainty around deciding the required height of critical infrastructure in the project to ensure safety in the unembanked space. Critical infrastructure in this case are functions that need to stay functional during high water situations such as electric transformers or evacuation routes (Z-005).

Lastly, ambitions were set to increase the water retention capacity of the project location by 10% compared to the current situation. Both Z-005 and Z-007 mentioned that this ambition resulted in a lack of knowledge about whether it was possible to reach in the project, and if it was, how to process this into the project location. Initially, research was done by a project participant to know whether the +10% retention capacity was feasible (Z-001; Z-005; Z-007). However, Z-001 and Z-007 pointed out that this calculation was ‘wrong’ as a result of an ambiguity about what units of measurement to use when calculating the possible water retention capacity (m^2 instead of m^3). After this became apparent, an external organisation was consulted to do the calculations. However, they came to the conclusion that +10% retention capacity was only possible if the parking garage could be used for retention (Z-007). This consequently sparked the inception of another uncertainty: Consequences submersible parking garage. As Z-007 pointed out in the interview:

"Well, then you already have the next uncertainty: What does that mean (floodable parking garage) if it is filled with electric cars in the future? Then too you see that a lack of knowledge about that … is missing. That, again, raises risks and questions." – Z-007 (translation from Dutch)

Z-007 was not alone in their experience. This uncertainty was widely recognized by other project participants as well (Z-001; Z-004; Z-006; Z-008). The interviewees were very much in agreement with each other that it should be dealt with by doing research followed by an assessment by experts.

Uncertainties not (yet) dealt with

In a project that is still in development, there are uncertainties that have been dealt with, that are in the process of being dealt with, or are not (yet) dealt with. There are two uncertainty themes mentioned that until the time of this research have not yet been dealt with or in the process of being dealt with despite them arising fairly early in the project development process (project phase). These are 'how do policies relate to each other' (Z-003) and 'how do other organisations test' (Z-004; Z-007). The latter in particular was described as a major uncertainty, potentially leading to project termination if other (public) organisations do not approve of certain aspects of the project (Z-007). While Z-007 highlights the ontological uncertainty towards other organisation's acceptance threshold, Z-004 describes that for some aspects of the project, they do not know how a public organisation will test at all because the particular organisation does not specify what their requirements are. In the interview they told that:

"they will just need to make a design and send it to the particular organisation and then they will say whether it is okay." – Z-004 (translation from Dutch)

In contrast to the instances where interviewees found that a given uncertainty was not yet dealt with but were sure it would be later on, there were also uncertainties where no method or strategy was pursued to try to deal with it. This was particularly the case for ontological uncertainties such as climate induced water level increase, changing views on water safety, and policy changes or changes in political composition that affect the project. In the case of the latter two, it was mentioned that changes to some policies could virtually happen overnight without forewarn (Z-004), while changes to views on water safety is a gradual process (Z-005). The seemingly very sudden or gradual nature made the interviewees think the uncertainty cannot be influenced.

Timing of dealing with uncertainty

During the interviews, interviewees mentioned (Z-004; Z-007; Z-008) that some things that are uncertain at some point in the process become less uncertain as the project development progresses, and that an uncertain phenomenon does not always have to be dealt with as soon as it shows itself. The term used by both interviewees to describe this process is 'working from coarse to fine' in the project development process. Some uncertain phenomena will intentionally be left uncertain – meaning little to no efforts will be made to decrease the uncertainty – until the project progresses. According to the interviewees this is done because 1) as the project progresses, more concrete information about the project (design) will become available, which in turn can reduce the previously ignored uncertainty (increased knowledge -> less uncertainty) and 2) trying to solve/deal with a given uncertainty too early in the process might lead to unnecessary complexity early on in the project. A concrete example of this was given by Z-008 who said the uncertainty became apparent in the problem definition. However, it will be dealt with in the alternative selection and analysis since more information will be available by that time:

"… so there were building plans in which construction and excavation work would take place very close to the embankments. Normally we start from the current situation (embankment measurements) and then we look at what impact the work of Zwarte Water Zone will have on that situation. Only, we already know that the current situation will be different in a few years, because then we will have carried out embankment reinforcement. But we don't know exactly what (it will look like) yet. … Then you will try, because you are not quite sure yet, to make as many alternatives as possible that can be used in various possible scenarios for the embankment reinforcement (zoning). But for now we say that we accept that uncertainty and we expect to be able to resolve later." – Z-008 (translation from Dutch)

By describing waiting – or pushing the uncertainty forward – as an effective method to deal with (some) uncertainty, one could argue that it should be added to the other new methods to deal with uncertainty found in this research. The other methods that were added as new methods were methods to deal an uncertainty by itself. The new methods such as 'Being informed and interfering with decision-making' were included as a new method because they were deemed adequately methods deal with a given uncertainty as a standalone method. No previously known complementary method was needed for this new method to deal with an uncertainty adequately. This is not the case for waiting. Whenever waiting was mentioned, it was coupled with a previously known method to eventually use when it was 'time to start dealing with the uncertainty'. In the example of Z-008, the complementary method was experimenting with different designs given a number of possible scenarios. Based on the interviews it seems that this method is only viable, or rather, used by interviewees for uncertainties with an epistemic nature.

New methods to deal with uncertainty

While some ontological uncertainties related to policy changes or changes in political composition cannot be influenced according to the interviewees, there are a few instances where new methods (unknown prior to this research) were applied to deal with uncertainties in this theme. For example, Z-001 explained that they apply the same method of being informed and interfering with decision-making to deal with government induced water level increase after it was first used during Kraanbolwerk (and presumably other parallel projects). Participants from both public and private organisations mentioned they apply the method of being informed (without interfering) to deal with uncertainty in policy changes affecting the project (Z-002; Z-004). Z-004 specifically mention that to accomplish this, they maintain a close network with advisors who alert them when something is changing that could affect them.

Sometimes, ambiguities were being dealt with in a rather unique way by just eliminating the uncertainty source. This might seem odd, and certainly this cannot be applied to every uncertainty. However, in the context in which this method was used it might make more sense. The context being the potential integration of the project Zwarte Water Zone with the project Stadsdijken to integrate the parking garage into the to be strengthened embankment. From the data it seems that it was possible from a technical point of view. However, institutional uncertainties related to overlap and collision of policy led to ambiguities. So much so that it was decided to split the projects and treat them as separate projects (Z-001; Z-002; Z-008; Z-009), effectively eliminating the uncertainty source: possibility to integrate both projects.

Lastly, another new found method was proposed by Z-006. In this method, one makes use of introducing other perspectives to deal with ambiguities between project participants. Judging from their description of this method, this is a tool to allow someone to break free from one's original frame of mind, becoming more open to certain ideas. This is different from dialogical learning in that one actively pursues gaining even more perspectives into the project matter to take inspiration, rather than trying to understand and come to understanding of the already involved parties in the project. In their own words:

"…but (someone) that really thinks differently. And, as Henk Oving always says, I mean, you just have to bring performers and artists to bring new perspectives" – Z-006 (translation from Dutch)

The role of trust in uncertainty management

During the interview sessions, some interviewees described a lack of trust between participating parties to be an uncertainty. The appearance of a lack of trust seems to only be consciously experienced in the project Zwarte Water Zone, not in Kraanbolwerk. Some interviewees named it in the literal sense, others described a situation where it could be evident that there might be a lack of trust, with descriptions such as:

"…that is my analysis of the (development) process, the mutual trust between participants, and that I think it was lacking in a lot of things." – Z-006 (translation from Dutch)

"…there just was no will to work together!" – Z-003 (translation from Dutch)

Although trust might not be an uncertainty in itself – hence it is not included as an uncertainty theme – it could be a manifestation of an underlying uncertainty. All interviewees for project Zwarte Water Zone mentioned an uncertainty about the possibility to integrate the underground parking garage of Zwarte Water Zone with the project Stadsdijken (parking garage integrated in the embankment). Based on the interviews, the project participants generally had the impression that the integration of projects would be mutually beneficial. Integration of the projects would yield efficient use of space and added value for the liveability in the Zwarte Water Zone (and possibly execution costs). However, the process of getting to integration had a lot of obstacles. The causes for these obstacles often had to do with the presence of uncertainties belonging to the institutional uncertainty category which mostly consists of uncertainties related to the interface between and overlap in (public) organisations' sectoral authority and policies within the project.

There are strong demarcations in sectoral authority between participating (public) organisations in the project (and in the Netherlands in general). However, it is impossible to execute the project if the (public) organisations strictly stay within their own policy frameworks and responsibilities. The willingness to handle the interfering or overlapping policies more 'fluidly' is essential to lower the sectoral policy demarcations and execute the project. In other words: lower, deal or solve the institutional uncertainties. However, the willingness to lower the demarcation seems to be missing amongst some participants of the project, hindering the creation and growth of trust in the process. Interviewees give different reasons for this:

"…and then I already had to conclude that we do not actually want this integration. It is way too scary." – Z-006 (translation from Dutch)

"If it starts to become complex, the first instinct is to go back to the sectorality (authoritarian policy frameworks). But a project such as Zwarte Water Zone is too complex and diverse to only advise from your own sector." – Z-005 (translation from Dutch)

It was not possible to identify whether the interactions between participants in the past or their mutually perceived reputation played a role in the creation or growth of mutual trust between parties. This is due to the cross-sectional nature of the research and the data collection not being focussed on mutual trust.

4.3: Cross-case analysis

In this sub-chapter, the results of the two case studies are compared to one another. The notable similarities and differences between experienced uncertainties, where in the project cycle uncertainties first presented themselves, and how uncertainties are dealt with.

Uncertainties within the project development process

There were similarities between the two project cases in terms of uncertainties interviewees had experienced. For example, in both cases the themes ‘parties on the same page & talking about the same things’, ‘climate induced future water level change’, and ‘integration project into river landscape’ (Table 15) were consistently mentioned by interviewees in both case projects. However, in case of the first theme, there was a slight difference in how one would arrive at this uncertainty. When interviewees in the Zwarte Water Zone case would mention ambiguity in regards to conflicting point-of-views (frames), about half of the time they would not necessarily give a situation in which they had found getting people on the same page was hard because of some frame difference. Instead, they would give more of an observation they had made throughout the project development process as a whole. But in Kraanbolwerk there seemed to always be a concrete situation in which they had experienced conflicting frames leading to disagreement, be it that these situations were very divergent.

Table 15 Mentioned uncertainties by interviewees for project Zwarte Water Zone & Kraanbolwerk

			Zwarte Water Zone		Kraanbolwerk	
Category	Uncertainty Theme	Unc. Type	Total # Mentioned	% of total	Total # Mentioned	% of total
Institutional uncertainty	Parties required to be involved and when	Epistemic	3	3.75%	N/A	N/A
	Policy interrelations	Epistemic	1	1.25%	N/A	N/A
	Competent authority in the project	Ambiguity	3	3.75%	1	2.17%
	Responsibility & Ownership (risks and €)	Ambiguity	3	3.75%	5	10.87%
	Parties on the same page & talking about the same things	Ambiguity	11	13.75%	7	15.22%
	Working & testing integrally	Ambiguity	4	5.00%	5	10.87%
	Actors' neglectance or ignorance to uncertainties	Ambiguity	3	3.75%	1	2.17%
Technical uncertainty	Integration project into river landscape	Epistemic	8	10.00%	4	8.70%
	Project's effect on hydraulic characteristics	Epistemic	1	1.25%	1	2.17%
	Construction of services (electr., water, etc.)	Epistemic	2	2.50%	N/A	N/A
	Inter-organisational testing (design/policy)	Ontologic	2	2.50%	N/A	N/A
	Consequences submersible parking garage	Epistemic	5	6.25%	N/A	N/A
	Magnitude of soil pollution and effect in project	Epistemic	N/A	N/A	4	8.70%
	Condition of quay walls	Epistemic	N/A	N/A	3	6.52%
Long-term development uncertainty	Climate induced future water level increase	Ontologic	6	7.50%	6	13.04%
	Government induced future water level increase	Ontologic	3	3.75%	5	10.87%
	Should you want to build in the unembanked area?	Ambiguity	8	10.00%	1	2.17%
	Changing view on water safety in future	Ontologic	3	3.75%	N/A	N/A
	Future discharge distributions	Ontologic	1	1.25%	1	2.17%
	Uncertain market function	Ontologic	2	2.50%	2	4.35%
	Changes in policy / policital composition	Ontologic	7	8.75%	N/A	N/A
Assessment uncertainty	Testing/Advising as organisation	Epistemic	3	3.75%	N/A	N/A
	Acceptance thresholds (internal)	Ambiguity	1	1.25%	N/A	N/A

However, a noticeable difference between both case projects – not just ambiguities about getting on the same page – was between who the ambiguous situations took place. Where in Kraanbolwerk interviewees mostly described ambiguous situations to be between the municipality and developer. For Zwarte Water Zone it is mostly between sectoral authorities (Water Authority / Municipality / Rijkswaterstaat / Province). It seems that coordination between sectoral authorities was, and is, the biggest driver of ambiguity between project participants in the Zwarte Water Zone. More coordination between sectoral authorities is needed for Zwarte Water Zone compared to Kraanbolwerk. The main reason is the geographical location of the Zwarte Water Zone project. It is located right next to the embankment owned by the Water Authority on the one side, and a waterway (Zwarte Water) owned by Rijkswaterstaat on the other. The plans to integrate the parking garage into the embankment did not help to lesser the need for coordination. The need for coordination, along with the initial abstractness of the project (design), are a prime ingredient for ambiguities to arise is when there is need for a lot of coordination between different parties (with different goals). This is something that was not present in the Kraanbolwerk case since the Water Authority and Rijkswaterstaat did not really have anything to approve in that project because it was not located inside their sectoral jurisdiction (Dutch: sectorale bevoegdheid).

In case of ontological uncertainty related to the climate induced future water levels theme, interviewees from both case projects were very consistent in their descriptions. Pretty much all who had mentioned uncertain water levels described the same two uncertain phenomena: 1) a lingering uncertainty throughout the entire project process about future water levels, and 2) that one can choose to design at a certain height now based on current climate models, but that these models are subject to change due to new/updated knowledge becoming available, resulting in – among other things – other water level (return period) predictions.

What was particularly remarkable about the experienced ontological uncertainties between projects is that almost all interviewees in the Kraanbolwerk case mentioned they had experienced uncertainty related to government induced future water level increase. Only one mentioned to experience it in the Zwarte Water Zone case. It should be noted that the person who mentioned it in the Zwarte Water Zone case was acquainted with what happened during development of Kraanbolwerk, so this might have had an influence on why they experience the uncertainty and the other interviewees do not. In part, this can be explained due to the method to deal with the uncertainty that was developed and applied by the IJVD during Kraanbolwerk. Being informed and interfering with decision-making is not some project specific method, it is project transcending. Because it is project transcending, it is likely being dealt with in the background of all projects rather than on the individual project basis. Because of this, practitioners do not experience the uncertainty as much on the project level in Zwarte Water Zone.

Contrary to the government induced water levels, practitioners of the Zwarte Water Zone project pretty much all mentioned the ambiguity around people questioning whether you should want to build in the unembanked zone. This is an ambiguity that was – apart from one interviewee mentioning it – non-existent during development of Kraanbolwerk. From the data it seems that the during Kraanbowlerk the local residents were more focussed on making sure Kraanbolwerk would fit in the cityscape rather than questioning the safety to flooding like in Zwarte Water Zone, which seems logical since the location Kraanbolwerk was built at has existed for many years prior to it becoming a residential area. Another possible explanation might be the absence of general knowledge about climate change during the development of Kraanbolwerk, and the fact that the project development had already passed the first phases of the project cycle (problem recognition → alternative selection). Since Kraanbolwerk, general knowledge about climate change has rapidly developed and could now be considered commonplace knowledge. Hence why building in the unembanked space is a much more contested (public) topic in the Zwarte Water Zone.

Where in project cycle did uncertainties first present themselves?

The first notable differences between the case projects is the development regarding the adoption of climate change (and uncertainties resulting from it) as commonplace knowledge. Uncertainty regarding future water level increase started arising or being acknowledged relatively late in the project development cycle for Kraanbolwerk. The acknowledgement was mainly sparked by the report of Commissie Veerman (n.d.) during the solution space generation phase of the project. But in the current time, people have gone so far in adopting and acknowledging climate uncertainties that interviewees for Zwarte Water Zone were almost confused when the question would be asked during what phase the climate uncertainties would first present themselves. So much so, that they used terms like:

"Yes, in Zwolle this is always (acknowledged) at the start." (Z-005) (translation from Dutch).

When one would specifically look at the tables showing where in the project development process a given uncertainty theme arose or was first recognized (Table 10 and Table 13), it stands out that ambiguities arise during nearly all phases of the project. This indicates that ambiguities arise during the entirety of the project, unlike with ontological uncertainties, that are condensed to just one or two phases of the project. K-004 gave some explanation for it by stating that ambiguities continuously 'pop in and out of sight'. Ambiguities can be resolved at one point in time, only to become relevant again later on in the project. A different reason was given by Z-006, – also stressed in 4.2: Results case project: Zwarte Water Zone – that abstraction of the project at the early stages is a feeding ground for ambiguities to arise as there are no other means to describe what your point-of-view or perception is other than in words.

Dealing with uncertainty

From the results of both cases independently, it seems that the methods to deal with uncertainty applied or developed during project Kraanbolwerk, are still applied during Zwarte Water Zone. For instance, the emphasis on dialogical learning is by far the most used method to deal with ambiguities in both projects. The focus on getting to know each participant's point of view (or frame) from their expertise, experience, or project role seems to be important in the researched projects. Or as K-001 and K-003 put it:

"By really creating something for community through sessions and giving people a platform. Yes, really giving a stage. That was really the strategy. So to let People shine with that story and their part of it." - K-001 (translation from Dutch)

"and how do you deal with that? I think it's very much about also involving your intuition and your feeling and your emotion and the narrative of being able to come up with a story where people say, oh, I want that." - K-003 (translation from Dutch)

From these quotes it is evident that the interviewees perceive that the application of dialogical learning leads to more support among the different stakeholders towards the project. The consistent application of the method between the two case projects indicates that participants find the results of applying this method to be positive. On top of that, in the time between both projects, methods to deal with ambiguities have been more developed or better understood by the project practitioners in terms of what does and what does not work. In the case of Kraanbolwerk, interviewees were more descriptive when talking about dialogical learning as they mention key words such as openness to other perceptions, opening dialogue about people's perceptions about a certain matter, or allowing stakeholders to bring their ideas. But in the case of Zwarte Water Zone, interviewees sometimes almost gave the exact definition of dialogical learning when describing how they dealt with an ambiguity. The best example of this is given by Z-005:

"…but as a collective, you know. Get those perspectives on the table so, from what point of view are you coming from, and work together to jointly form those kinds of requirements just works very well." – Z-005 (translation from Dutch)

Another similarity between both projects is that in both cases the project was designed to be able to endure the uncertain event (worst-case scenario planning) even though the data from Zwarte Water Zone do not suggest that at first glance. Interviewees for Kraanbolwerk would explain that they took inspiration from Hafencity in Hamburg and designed Kraanbolwerk. They performed scenario analysis to gain knowledge on recurrence times of certain water levels. Following this, they added more height to the ground level of the buildings to make sure they could endure even extraordinary high water levels outside of model predictions. However, when interviewees from Zwarte Water Zone were asked how they dealt with the ontological uncertainties about future water leves, most replied that they had used scenario planning to develop the requirements that were written down in the functional program of requirements, sometimes adding that they were trying to create an adaptive design (incorporating flexibility).

The functional program of requirements reflects this vision as it is specifically mentioned that the project has to be able to withstand water levels of 3.5m +NAP with minor changes to the design. This insinuates that the current design does not have to be able to withstand 3.5m +NAP, but it does need to be upgradable through minor adjustments in case the worst scenario does become reality. However, from the preliminary designs it is evident that this adaptive/flexible design philosophy was not adhered to. The preliminary designs show an additional 0.7m margin on top of the required 3.5m +NAP, – which already included a 0.75m margin to current 1/10.000 recurrence times to account for the upper boundary scenario of climate change – which indicates that the chosen strategy is to endure the uncertain phenomenon, instead of adopting a flexible design to allow for adaption as the direction climate change is taking becomes more apparent or known.

Lastly, there seems to be a key difference between the dealing methods used in both project development processes to deal with epistemic uncertainty. During Zwarte Water Zone, most knowledge gaps were filled by letting experts do research, or by doing research on an uncertain topic themselves. Not a single time a method such as taking more accurate measures, or developing confidence intervals was mentioned. In project Kraanbolwerk, these methods were used to deal with the uncertainties of the condition of the project location. Perhaps these methods will be used in later stages of the project when the final design for the Zwarte Water Zone will be completed and new uncertainties arise about the conditions of the project location. Uncertainties with a more concrete technical/logistical nature than the relatively high abstraction level uncertainties still present in the Zwarte Water Zone project today.

5. Discussion

This section puts the findings of the research in perspective. Notable events or situations during the process of the research related to the findings will be highlighted and reflected upon. This chapter will focus on how the research fits in existing literature, reflection on the process of data collection and the results, and the limitations of this research.

Desire to diminish uncertainty

At the start of this research, it was mentioned that policy makers tend to lean towards determinism and certainty. In this pursuit they often resort to just seeking more (accurate) knowledge to diminish the uncertain phenomenon without looking into the nature of the uncertainty they are faced with (Walker et al., 2003; Warmink et al., 2017). However, practitioners participating in the projects did not reflect this statement at all. During the interviews for this research it particularly stood out that the practitioners working on the projects have a fairly good sense on what methods are and are not effective. The vast majority of descriptions interviewees gave in regards to how they dealt or are dealing with the uncertainty they had encountered lined up very well with one or two adequate methods defined in the theoretical framework. Only in the Zwarte Water Zone case did mismatches between uncertainty type and dealing method occur.

However, what was rather confusing is that sometimes multiple interviewees would describe the same uncertain situation but then – between each other – propose different methods on how the uncertainty was dealt with in the project. These differences were actively tried to highlight in the results. Perhaps the most clear example of this was the situation where the safety of building in the unembanked space was questioned by people from outside the project team (such as local residents) in the Zwarte Water Zone project. Some mentioned they had applied dialogical learning in combination with persuasive communication, while another mentioned that they applied a combination of rational problem solving and persuasive communication instead. One would think that a strategy to deal with the uncertainty would be collectively decided upon by the participants, and that the collectively decided 'best method' to deal with it would be propagated to the outside. It is unclear whether people actually used different methods between one another during the project, but surely they have different perspective on how they went about things to deal with this uncertainty.

New methods

Throughout the results a number of new methods were identified that were previously unknown in literature. Table 16 shows the four new found uncertainties that practitioners put forth when explaining how they dealt with or would have dealt with uncertainties during the project. It would seem that these methods for dealing with uncertainty are rather specific to projects and less to policy making unlike the methods defined in the theoretical framework. The first two methods shown in Table 16 are 'being informed' and 'being informed and interfering with decision-making'. The first is a rather reactive approach to anticipate changes, whereas the latter takes a more proactive approach. It is important to note that in order to interfere with decision-making, one has to have at least some influence or say in the decision-making process. For example, by bringing specific knowledge to the table, or by being the ones to carry out the decisions on a practical level. Hence why private parties likely do not have opportunity to interfere with decision-making as the governmental layer the decision-making takes place gets higher. A possible explanation for the absence of a similar method in literature such as by Brugnach et al. (2008) or Dewulf & Biesbroek (2018) is that in their papers it seems they emphasis is laid on policy making in the upper governmental layers, such as national or international. At the higher layers, uncertainty about policy changes or decisions are less relevant since they are the ones to decide. The decisions and policy making in these upper governmental layers affect both governmental bodies in a lower layer and private parties like the people involved in the project cases of this research.

Eliminating uncertainty source looks like a final tool to deal with uncertainty when knowledge cannot be sufficiently increased or when ambiguities between project participants cannot be solved or relieved. A project always has some kind of schedule and needs to progress. One cannot endlessly try to resolve ambiguities between participants if the project is coming to full stagnation because of it. Therefore, it could be beneficial to just cut the source of the uncertainty out of the project. This is somewhat contradictory to policy making (for example, on the national level) where participants are mostly elected to represent a chosen party and have to come to an agreement between each other in order to go through with a policy. It seems rather unlikely for one to just cut out parts of a policy in order to move on to implementing it, as some participant(s) in the process likely has interest in the part being cut. There simply would be no ambiguity within the process otherwise. This fundamental difference in the time-decision spectrum is maybe why this method is not applied to policy making.

Lastly, introducing other perspectives likely has its place in both project management and policy-making. Introducing some dissentient person's take on a given problem (from outside the project team or policy-making field) can help in both cases as it aims to relieve ambiguity or disagreement between participating parties. However, for this to be effective or successful, participants need a high degree of social skills and willingness to participate in a constructive dialogue. Same as with dialogical learning.

Table 16: New methods to deal with different types of uncertainty

Method	Uncertainty type	Description
Being informed	Ontological uncertainty	Staying up to date with decision-making in a (governmental) body one has limited or no influence on in order to timely anticipate decisions – such as changes to policy – as they are being made.
Being informed and interfering with decision-making	Ontological uncertainty	Staying up to date and influencing the decision-making by actively participating/interfering in the decision-making process of a (governmental) body one has limited influence on to influence or steer decision making – such as changes to policy – as it is happening.
Eliminating the uncertainty source	Epistemic uncertainty / Ambiguity	Deciding not to build, construct or design certain ideas into the project because sufficient knowledge cannot be gathered within the available time, or because it leads to such complex ambiguity between participants that it cannot be resolved or dealt with in the available time.
Introduce new/other perspectives	Ambiguity	Allow people with certain (different) disciplines to present their perspective on the project/design to promote breaking free from an engraved frame of mind and to become open to other, new, or innovative ideas.

Research through design

Sometimes during, but mostly after the interviews, interviewees affiliated to the municipality frequently mentioned making use of what they called 'research through design' in developing their projects. It boils down to performing research through developing different designs. They explained that they apply this method to get a better picture of what has to be done and how (lowering epistemic uncertainty), but also to get to know other participants' standpoints/point-of-views on the matter as different preliminary designs are being made. From their descriptions of what this entails, it seems that the research through design method is a combination of experimenting with different designs, rational problem solving, and dialogical learning.

Based on the answers given by the interviewees, the municipality's version of research through design is most in line with the 'advocacy/participatory' research by design strategy proposed by Lenzholzer et al. (2013) because it is most in line with the three clustered methods to deal with uncertainty that were captured in the research by design of the municipality. In this type of research by design, a more social approach is chosen towards knowledge generation. Joint knowledge is generated through design loops that function as a way to shed light on people's perceptions and ideas (Lenzholzer et al., 2013). In this method, dialogical learning is stimulated through the iterative process of experimenting with different designs.

Although it is definitely a good strategy to apply in a situation like Zwarte Water Zone, where sectoral authorities have – what looks like – conflicting perceptions on a problem or situation regularly, this strategy would not always work as effectively. As seen in the results of both Zwarte Water Zone and Kraanbolwerk, a plethora of different methods are used to deal with a given uncertainty theme depending on the situation. It is important not to lose sight of other methods to deal with uncertainty when applying a cluster method such as research through design. Another method might be more adequate.

Cascading effect

In this research, the uncertainties experienced by practitioners were very much approached as separate, independent entities. However, in practise uncertainties are often interrelated to each other. From the data and the uncertain situations described by interviewees it is quite clear that these interrelations between uncertainties are very much present in urban development projects in the unembanked space. Van den Hoek et al. (2014) studied the interrelations of uncertainties in building with nature projects. In their research, it is explained that the uncertainties found in the research are subject to a cascading effect, where one uncertainty can lead to a cascade of other uncertainties. However, it stood out that in the results presented by van den Hoek et al. (2014) all cascades of uncertainty eventually led to an ambiguity as its end-point. In this research, it was found that it is not always the case. It is proposed that the cascades of uncertainty do not necessarily have to include an ambiguity as an end-point. The next two paragraphs will explain a situation where the end-point of the uncertainty is not an ambiguity (from the eyes of a project team member). Figure 12 shows a visual representation of the situation.

The cascades of uncertainties are related to the Zwarte Water Zone project. At first, it was unknown whether it was possible to increase the retention capacity by 10% at the project location (epistemic). After calculations, the uncertainty was dealt with and they came to the conclusion that +10% retention capacity was feasible. However, later on in the project it turned out that the wrong units of measurement were used to calculate the retention capacity and were therefore incorrect because the calculator thought it was supposed to be in m^2 (Ambiguity). Using the correct units of measurements they came to the conclusion that it was possible to realize the 10% retention capacity, but only if the subsurface parking garage would become floodable. Designing the parking garage to be floodable comes with consequences to the design and questions. For example:

- What needs to be changed in the design to safely flood the parking garage when needed (epistemic)?;
- What is the effect of evacuating all the parked cars to a neighbourhood next to the project area (epistemic)?;
- What happens if people are on vacation and the car is not evacuated (epistemic)?;
- Who is responsible for cleaning and repairs after a flooding (perception/ambiguous)?

After this knowledge is gathered, it becomes a matter of finding out whether one can deal with the consequences (either monetary or technically) and whether they want to deal with the consequences (perception/ambiguity). As the decision of actually making the parking garage floodable comes with a lot of complexity (and likely costs), organisations are reassessing how important they find reaching +10%. Is it a hard requirement, or do we also accept +8% as it will lower the complexity of the project significantly (perception/ambiguity)? If the project team decides to accept a lower retention capacity increase, it needs to get accepted by the municipal and provincial council who are still under the assumption +10% is being achieved. This adds uncertainty to how they are going to react and assess this matter the matter at hand (ontological), also keeping in mind the recent changes to the composition of the provincial council.

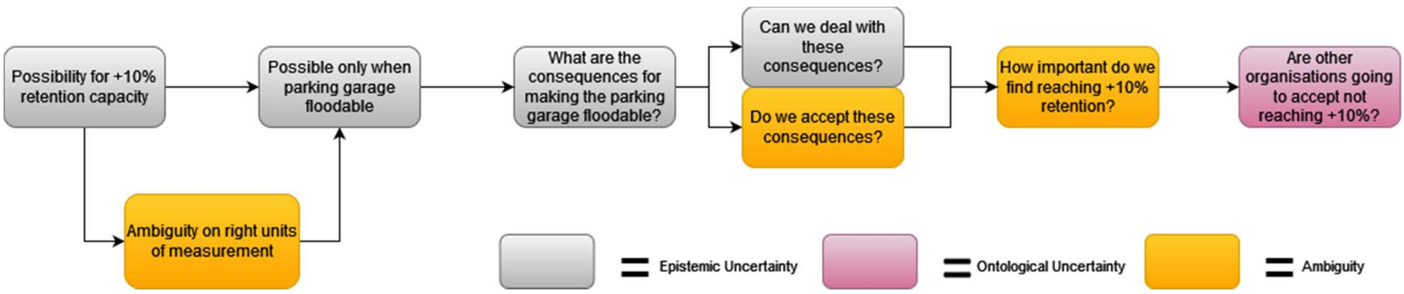

Figure 12: Cascades of uncertainty in Zwarte Water Zone project

Similarities between institutional uncertainty category and literature

The categories were initially made to order the different experienced uncertainties. The goal was to order the uncertainties by origin to gain to make it easier to analyse the data. At first there were only three categories: long-term development uncertainty, uncertainty related to technical feasibility, and uncertainties related to conflicting or overlapping policy fields. As more themes were identified, a distinction between uncertainties originating from conflicting or overlapping policy fields in a network of organisations and uncertainty originating from working together inside one organisation. Because of a lack of a good definition other than 'conflicting and overlapping policy fields', the book 'managing uncertainties in networks' by Koppenjan & Klijn (2004) was consulted. In their book they describe an object of uncertainty that perfectly captured the uncertainties that originate from conflicting or overlapping policy fields, and was therefore adopted in this research. They call this institutional uncertainty (Koppenjan & Klijn, 2004). Rather accidentally, it was found that the paper by Dewulf & Biesbroek (2018) had combined the objects of uncertainty by Koppenjan & Klijn (2004) with the uncertainty types by Brugnach et al. (2008). In the paper, Dewulf & Biesbroek (2018) linked all three types of uncertainty to the three objects of uncertainty presented by Koppenjan & Klijn (2004). Surprisingly their definition of what epistemic uncertainty and ambiguity present in the institutional uncertainty category would look like fits perfectly with the uncertainties that were present in the category made in this research.

Trust in uncertainty management

As mentioned in the research findings, trust between project participants was mentioned by some interviewees as an uncertainty they had experienced in the Zwarte Water Zone case project. Initially, there was no real link between uncertainty management and trust. It seemed like an uncertainty source, rather than in uncertainty itself. For trust to become relevant or necessary there must be uncertainty about either the behaviour of other (project) participants in future situations and/or benefits/advantages concerning how a problem should or will be resolved (Gambetta, 1988). In other words, an ambiguity. If cooperation within a (project) network is intensive and uncertainty is high, trust becomes an important factor. Trust between participants of a project can enhance the knowledge exchange between participants and encourages learning and innovation (Koppenjan & Klijn, 2004). Koppenjan & Klijn (2004) describe four factors – mentioned in literature – that influence the emergence and growth of trust between actors in a network. These are:

- Interactions in the past: more interaction and social contacts between actors improves the growth of trust;
- Reputation of a given actor: Past experience and other people's experience/opinion about the professionalism of another actor improves the development of trust;
- Expectation of future benefits: The Knowledge of actors that continued interaction between each other will be mutually beneficial, which makes for a favourable condition to develop trust between actors;
- The nature of binding network rules: Network rules can have an effect on the creation and growth of trust. Rules that result in strong domain demarcations (such as the established sectoral authority) are not conductive to creation and growth of trust.

Judging from the data and conversation with the interviewees, the nature of binding network rules seems to be the bottle neck leading potentially leading to the experience of a lack of trust experienced by some interviewees in the Zwarte Water Zone project. Interviewees mentioned that the willingness to lower the demarcation seems to be missing in some participants of the project, hindering the creation and growth of trust in the process. Specific situations of uncertainty described by interviewees could not be linked to trust directly because the interviewees were not asked about the origin of the uncertainty, the only times the origin of an uncertainty would be discussed is if an interviewee would bring this up themselves.

Desired methods of dealing with future water level uncertainty

From the data we can see that the most used method of dealing with uncertain water levels (for example) is worst-case scenario planning. However, judging from the interviews, in the time between projects Kraanbolwerk and Zwarte Water Zone it looks like the municipality and other public organisations have become increasingly open to other methods to deal with ontological uncertainties related to water levels. This is quite evident from the interviews. Interviewees would frequently stress the need for adaptive and flexible designs looking at the uncertain future. In D101 it is specified that the project (Zwarte Water Zone) has to be able to withstand a water level of 3.5m +NAP in the future. However, they do not state how to achieve this. This leaves room to, for example, build for adaptability (flexibility), where one could repurpose (parts of) the project in case the upper boundary scenario (the 3.5m +NAP) would become reality. Another method could be to make use of the method 'taking measures usable within the timespan of an event'. This could be applied by for example constructing rabbets (Dutch: sponningen) into the buildings where one would be able to slide stop logs or flashboards into to prevent flooding of the buildings during high water situations between 3.20 – 3.50m +NAP for example. That way it is not necessary to use currently, but it would be usable in case the upper boundary scenarios would occur in the future.

But somewhere in the development process it was decided to still apply the more traditional method of enduring the uncertain phenomenon despite the opportunity to apply another. The buildings are going to be built on quite a high ground level (artificially raised) of 4.20 m +NAP (D108). From a maintenance point of view this seems rather logical. Project participants do not want to have the uncertainty that they have to revisit the project to do more work on it down the line if they can prevent it right now. However, in doing so comes the risk of over dimensioning – and therefore overinvesting – if the upper boundary scenario would end up not becoming reality. It seems to be somewhat of a pick your poison situation. Either you accept the risk of over dimensioning, or accept the risk of having to revisit the project down the line. However, if the municipality would have acted as more of a project owner instead of project tester/assessor, it probably would have been easier to implement the adaptive or flexible design philosophy that was seemingly advocated for in the functional program of requirements.

Ownership of the project and preventing uncertainty

One interviewee did mention that a lot of uncertainty would have been avoided (not dealt with!) had the municipality been set as the owner of the project for Zwarte Water Zone. In the interview they explained that if they were able to start over – or do a project in the same setting – they would set the municipality as the owner of the project in regards to building and developing in the unembanked space and everything that is related to it. The reason they would do this is to avoid uncertainty related to ambitions such as circularity and climate adaptation, because then the municipality would have more grip on the project and could set the frameworks (Dutch: kaders). They go on to say that the municipality – right now – has a testing role in regards to the design and that they can say things about the design, but if they do you move into the grey areas rather quickly (ambiguity).

Judging from the interviews and experienced uncertainties by the interviewees, it would seem like setting the municipality as project owner would have avoided some key uncertainties within the project. It would – to some extent – prevent uncertainties related to ambitions such as the +10% water retention capacity – and all uncertainty themes that can be linked to it – from occurring. Moreover, it would also give the municipality a grip to make sure their 'preferred' way to deal with uncertain water levels gets used. Like highlighted in the section about dealing with ontological uncertainties, it seems like the people that were involved with the making of the functional program of requirements tried to steer towards an adaptable design. Setting the municipality as the owner would allow to actively steer towards developing an adaptive (adaptable/flexible) design. Perhaps it would have also smoothened the collaboration with and avoid uncertainties between other sectoral authorities since the municipality has closer connections to them, a view of their interests, and knows the power relations in the playing field well compared to a developer.

Data composition: interviewees' uncertainty experience

When looking at the data, the interviewees gave a well balanced view of the projects. Collectively, they seemed to experience each type of uncertainty rather evenly. In neither of the case projects was there an uncertainty type that had been mentioned significantly more often than the others. However, it is worth noting that each interviewee had their own take on uncertainty and the direction they wanted to take in the interview. One would focus more on epistemic uncertainty, highlighting technical feasibility, unknown conditions of certain assets, and how they did measures and research to deal with it. The other would focus more on the project process and the ambiguities that arose during the project and give different reasons to why they think these ambiguities arise in the first place. Some would even go beyond the scope of three types of uncertainty and, for example, introduce trust as their central theme to which they connected all uncertainties to. The variety in views between project participants was very insightful and made each interview feel unique, but also highlights how every participant has their own perspective on the project and uncertainties. It confirms the propositions by Brugnach et al. (2008) regarding possible differences in the way a problem is understood and the meaning that is given to it. Participant A could see a problem or an uncertainty of a given type, while participant B might not even recognize it, let alone deem it important.

The differences in uncertainty perception between project participants is particularly highlighted by instances where an interviewee would mention an uncertain situation, but when asked to typify the uncertainty they would state that the situation was not uncertain (Z-004; Z-006; Z-007). Whenever this was the case, they usually followed-up that it was not uncertain because “it is just something we have to discuss” (Z-004; Z-007). In most cases, the situations that were later deemed uncertain were ambiguities. Perhaps the most confusing instance of this was that one interviewee expressed that they do not know what requirements their design has to conform to in order to be accepted. That they just have to send in a design to see whether or not it is accepted (Z-004). However, when asked what type of uncertainty they perceived it as, they said that it was not uncertain since they just need to make a design. Other interviewees that mentioned similar situations described this as a major uncertainty in the project (Z-005; Z-007; Z-008).

Recognition of uncertainties in the project between interviewees

During the interviews, whenever an uncertain situation or topic would be mentioned by the interviewee, they were asked to typify the uncertainty as either epistemic, ontological or ambiguous. There were two reasons for this. The first was to see whether the interviewees’ perception of the uncertainty type corresponded with the theoretical framework. The second reason was – in the case of perception not aligning with the theoretical framework – to be able to assess whether the method they described to deal with the uncertainty was adequate for the type they perceived or what the theoretical framework would suggest. Initially, this was thought to be the most difficult question because interviewees had to link their experiences with some literature they only had been introduced to right before the interview. This ended up not being an issue at all. Typification of uncertainty came rather intuitively. The interviewees were very aware of the differences in nature between the uncertainties they experienced during the project. Almost all of the mentioned uncertainties by interviewees were typified in correspondence to the theoretical framework.

The effect of sectoral jurisdiction between organisation on the ambiguities in the project

Unrelated to the identification of uncertainties, but rather remarkable was that quite a few interviewees in the Zwarte Water Zone case, particularly from public organisations, mentioned that ambiguities in the project are not always a result of participants not understanding other participants’ view on a certain matter or conflicting perceptions on data and its significance. In these cases they suggested that ambiguity arises purely due to the fact that participants represent different organisations and therefore have some sectoral interest to defend, mostly between sectoral authorities. What they meant by this is that the ambiguity arises not necessarily through differences between peoples own frame of mind or their risk perception, but through the frame that one has to carry out on behalf of the organisation they are representing. This would suggest that there is not actually an ambiguity present between the project participants, but rather some sort of conflict of interest. While the interests of the organisation someone is representing unquestionably plays a role in the arising of ambiguities in the project, it seems very unlikely that ambiguities in the project are solely be attributed to acting from one’s organisation interest while ignoring their own frame of mind. Most interviewees have an advisory or project management role but in different disciplinary backgrounds. Each role requires specific knowledge, expertise and experience about the matter you are advising in. With the diversity in expertise, education, and experiences coming together to develop a project comes ambiguity. It is hard to think that one could fully 'turn-off' their own frame of mind to solely act out of their organisation's 'imposed frame' to defend certain interests.

Applicability of the problem-solving cycle on a project.

In order to make pinpointing the point in time where interviewees first identified the uncertainties they experience, the problem-solving circle was used. The problem solving cycle gives a rather general and accessible representation to the steps that are gone through in a project without excluding progressive steps within project development. The absence of specific technical terms in the cycle was deemed to be of value for data collection with people of different disciplines. It would allow interviewees to more easily relate the uncertainties to the process. However, it seems that in some instances using the problem solving cycle for this purpose turned out to be too general. Several interviewees pointed out that they thought the circle was a reoccurring process within the project. They would explain that the problem solving circle was either not very applicable to characterize the project, or they would explain that for every problem or uncertainty they encounter in the project, this circle would be gone through in its entirety to solve or deal with it. Figure 13 shows a visual representation of the latter.

As a result, the results about indicating where in the project process uncertainties had first arisen was a hit or miss situation. Either the interviewees were very comfortable with this circle, or they were quite disconnected with the take of describing projects as a problem solving cycle. Fortunately, complete disconnection to the cycle only happened on a few occasions. However, this disconnection is part of the reason for the unknowns to appear in both data sets regarding the identification of where in the process uncertainties first arose. The other part of the unknowns consisted of situations where interviewees mentioned that they themselves did not know where an uncertainty first popped up.

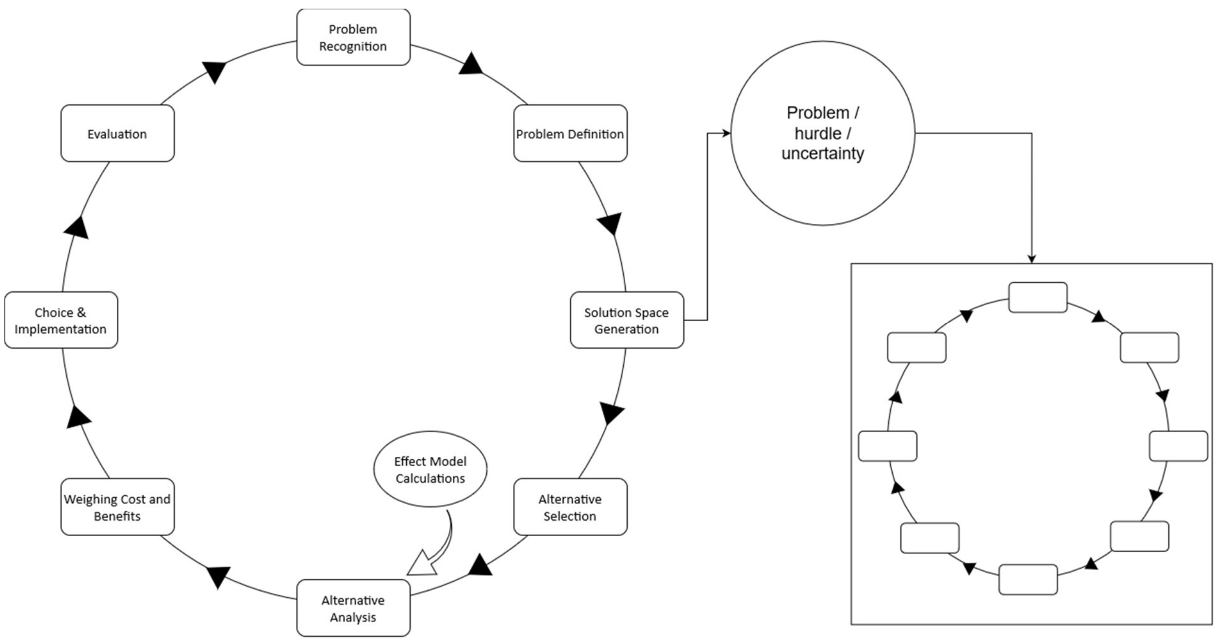

Figure 13: Impression of the problem solving cycle being applied on each uncertainty individually

Alternative methods and preventing uncertainty

Towards the end of the interviews, the interviewees were asked whether they thought another method to deal with their experienced uncertainty would have been more adequate than the method that was used (in the project). The main goal of this question was to see whether interviewees were aware of the use of inadequate methods to deal with a given type of uncertainty by the project team if this were the case. However, this situation almost never occurred due to the very good sense of interviewees on adequate measures to deal with uncertainties in relation to the theoretical framework. Often times interviewees would say that they would not know if there is a better method or that they are not actively trying to find 'better methods' during projects. If a method they applied works, its fine, so no extra thought would be going into developing a better method. But if it does not work, then a better method has to be formulated and applied.

Limitations to this research

Internal validity of the results

The validity of this research is somewhat difficult to fully guarantee since gained data was gathered and interpreted by an individual – in this case the researcher – who can interpret data differently than other researchers might. The research is susceptible to possible personal biases by the researcher. It is unlikely that one can remain fully objective and turn off their own frame of mind when dealing with – and analysing – qualitative data such as interview outcomes (Leedy & Ormrod, 2015). Therefore, it is important to show reflexivity as a researcher and critically evaluate whether possible biases could research process and research outcomes (Johnson, 1997).

Three different strategies were used to counteract personal biases a much as possible in this research. The first strategy is related to what Leedy & Ormrod (2015) describe as thick description. A style of reporting where situations are described in great detail so that readers can also draw conclusions from the data themselves. Second, the research will adopt a respondent validation from the interviewee's that participate in the study. This is done to verify whether the transcribed statements by interviewees were in line with what they meant at the time. The third measure is that of triangulation through common themes that appear in the data following the interviews with project participants, within one case and between the two cases. When more interviewees experienced the same problem or situation and they would seem to be in agreement regarding the experience, it is more likely to have a truth underlying the statements of the interviewees rather than it being a construct that is experienced on the level of an individual (Leedy & Ormrod, 2015; Johnson, 1997).

Thematic codebook analysis

The thematic codebook analysis, and the resulting themes made the somewhat chaotic data would become analysable and presentable. For example, one can easily recognize that the methods applied to deal with different uncertainty types during the projects were adequate and in line with literature's propositions most of the time. But using codebook analysis in the way it was done in this research does have some flaws. Sometimes, multiple uncertain situations (with the same context and uncertainty type) are captured in the same uncertainty theme. This is particularly the case for themes related to ambiguity. Perhaps the best example is of this is the theme 'is it possible to get all parties on the same page with each other and are we talking about the same things?'. It might be that one given situation – mentioned by three interviewees – was dealt with by using dialogical learning, while another situation – mentioned by two interviewees – was dealt with by using rational problem solving. So it shows up in the data as dialogical learning being used to deal with three instances of a given theme, while rational problem solving was used to deal with two. This makes it hard to differentiate between specific situations. This was another reason (other than to counteract biases) why it was chosen to highlight the different situations within a given uncertainty theme in much detail in the text through thick description. Especially for the bigger themes as they included a larger amount of different situations. The exception to multiple situations being mentioned for one uncertainty theme are most of the case specific themes.

Although assigning different uncertain situations to the same uncertainty theme comes with its flaws, I would argue that making a separate theme for every single unique situation would not have led to a better data set or better results, as the list of themes would probably have doubled at least. It would not have led to a more clear data set and it would make the research even more complicated (and long) than it is now. One would have to deal with a lot of individual situations, which does not really help understand what uncertainties arise in projects and how to deal with them in the grand scheme of things. It would lose the value and applicability for future projects or research. It feels like using the somewhat general contexts for the themes works better for this purpose.

Reliance on interview data for the results

Because of the lack of project development process documents available for this research (especially ones like progress meeting documents or design-sessions), the research relied very heavily on the data that was gathered through the interviews. It was not that there were no documents available, it was mostly that the available documents mostly consisted of the formal documents presented to the world outside the project team, which usually purposefully does not mention most uncertainties surrounding the project – apart from the very obvious flooding risks involved with building in the unembanked space – because the goal of these documents is to promote enthusiasm of the reader for the project. Not to scare them off by telling what could go wrong or what the potential risks and uncertainties are.

In the case of ZWZ the documents consisted almost in its entirety of these formal documents. This means that the results of the research are almost fully dependent on what interviewees found to be uncertain but also what the interviewees were willing to share. A lot more uncertainties might be present which cannot be uncovered. As a result, you go into the interviews rather blind. you had little to no idea of what uncertainties you can expect. This means that the interview questions were quite open ended because you really did not know what to expect. During the first few interviews in each case project it was very hard/impossible to ask targeted questions about some uncertainties. After like 3-4 interviews this became easier since you'd get some level of knowledge of what uncertainties were generally experienced. But this makes it so the first 4 interviews are essentially lower in quality because of the lack of knowledge of the uncertainties that were generally accepted to be existent (which could be evident by the documents were they available/made). For additional research in on a similar topic as this research, it would be highly recommended to choose case projects that have more documents available. Especially documentation of non-formal documents would be very beneficial. What I mean by that is documentation of design sessions, meetings, and reasoning behind decisions.

Municipality of Zwolle as a point of departure

As the research was done at and partially for the municipality of Zwolle, they were a point of departure for the data collection. The first interviewees were identified through the network of the municipality. Also, more interviews were held with people from the municipality than for example with developers or the water authority. Had the research been carried out at another organisation, it might have made a difference in the results as it would likely also have led to a slight different composition who would have been interviewed. Although the emphasis on a certain uncertainty type was not one-to-one traceable to the function they fulfil in the project, every interviewee seemed to put more emphasis on one or two uncertainty type(s) over the other. Because of that, a different interviewee selection could potentially lead to other uncertainties – or uncertainty types – becoming more dominant than in this research. So if for example the research was carried out a developer, it might have resulted in somewhat different results since the developer would have likely had a larger representation in the data set of this research compared to the municipality.

6. Conclusion & recommendation

In this last chapter, the most important findings of the research are summarised. Also, recommendations for future research and practical recommendations are provided.

6.1 Conclusion

In this research, a case study approach was applied answer the question: *What (climate) uncertainties arise in urban development projects in the unembanked area and how are the uncertainties dealt with in practise?* Water management related uncertainty management was used as a theoretical background. Two projects functioned as cases for this research: Kraanbolwerk and Zwarte Water Zone.

The research shows that practitioners face a wide range of uncertainty throughout the project development process. More or less balanced in terms of uncertainty types with a slight preference to ambiguities. However, on the individual level it shows that some practitioners are more sensitive to one uncertainty type than others. Furthermore, practitioners in this research are very aware of the type(s) of uncertainty they are facing (ontological/epistemic/ambiguous) and quite proficient at pinpointing which one is which. In total, 23 unique uncertainty themes were identified through the gathered data from both case projects. The most important theme is uncertainty related to getting parties on the same page and talking about the same things (ambiguous), followed by climate induced future water level increase (ontologic), integration of the project into the river landscape (epistemic), and whether one should want to build in the unembanked space (ambiguous).

With regard to when uncertainties arise, practitioners generally agreed that uncertainties of a given theme arise (or are being acknowledged) within the same two or three – often subsequent – phases. Most uncertainties are acknowledged in the earlier stages of the project during the problem recognition, problem definition, and solution space generation. An exception to this is the arising of ambiguities throughout the process. Judging from the data, uncertainties with an ambiguous nature can arise during all phases of the project development cycle. Interviewees explained this is due to the inherent abstractness of the project during the earlier phases of the project, and because uncertainties 'pop in and out of view' throughout the development process.

In terms of dealing with the experienced uncertainties, most practitioners leaned towards doing more research as their main way to deal with epistemic uncertainty. To deal with ontological uncertainties, both cases differed in the methods they had applied in the project. Part of this is due to the fact that participants in the Zwarte Water Zone project experienced a wider variety of ontological uncertainties compared to Kraanbolwerk. However, participants of the Zwarte Water Zone project do not always agree with each other about what dealing methods were applied in the project. Especially when talking about uncertainty related to future water levels. This was not the case for Kraanbolwerk. In the Zwarte Water Zone project, it was tried to apply other methods than worst-case scenario planning to deal with ontological uncertainty, which was the prime method mentioned in Kraanbolwerk. As for ambiguities, both cases showed that practitioners prefer dialogical learning. It was consistently mentioned throughout both cases. Practitioners from both case projects also regularly mentioned they had used dialogical learning in combination with another (adequate) method to deal with ambiguities. The methods used in combination with dialogical learning include: negotiation approach; rational problem solving; persuasive communication; accepting different knowledge frames and moving on; imposing your frame onto others.

6.2 Recommendation for future research

The identified themes give a good overview of the landscape of uncertainties that were present in both case projects, but is by no means perfect nor complete. Future research could focus on expanding or refining the uncertainty themes by linking them to the objects of uncertainty (Koppenjan & Klijn, 2004) present in networks. Refining the uncertainty themes would increase the applicability of the uncertainty themes for research on a particular case project.

Alternatively, one could focus on the differences in preferred dealing methods between individuals in a project. From this research, it is clear that the preferred way to deal with a given uncertainty differs from person to person. However, it is unclear how these differences affect the project development process. Also, each adequate method to dealing with a given uncertainty type is considered equal in this research. However, it might be that one method to deal with an ambiguity might be more suitable than another depending on the situation. It could be beneficial to conduct research on finding out what parameters or conditions drive each individual to apply a certain method, or when it is best to apply one method over the other.

Lastly, this research could be expanded upon by analysing the influence of mutual trust between project participants on (effective) uncertainty management. This could take the form of developing a framework to measure the degree of trust between two or more actors. Possibly, it can be linked back to the uncertainty management themes and categories in such way that one gains insight into what methods practitioners prefer to apply given a certain degree of mutual trust.

6.3 Practical recommendations

The research results emphasizes that uncertainties are very much encapsulated in individuals, and that they are not always spoken out between one another as there were barely any uncertainties that were universally mentioned by all participants. This holds even more so for the methods to deal with the experienced uncertainties. Focussing more on uncertainties present within a project or between participants could prove to be beneficial for the development goals. Participants of this research sometimes described different uncertainty types within one given situation.

Uncertainty management could be an activity, similar to risk management, where uncertainties of different types are inventoried and methods to deal are assigned to them. One could start by doing this for just their own organisation. Usually there are multiple participants – with different backgrounds – from the same organisation involved in one project who experience different uncertainties through their perceptions or point of view on the project. They could use the 23 themes identified in this research as a starting point to identify and document uncertainties and decide on a method to deal with them. It could even be expanded upon by looking further than just individual uncertainties, also taking into account the interrelations of the experienced uncertainties by the participants of the project.

By laying the uncertainties different project participants experience on the table, it is encouraged to jointly think about how to deal with them in an adequate manner. It is recommended to actively communicate about the uncertainties each participant experiences and how these should be dealt with during the project. Active communication about uncertainties is particularly useful for uncertainties that are epistemic or ontological in nature as it could prevent participants from applying different methods independently to deal with the same uncertainty. This strategy might be less effective for the identification of ambiguities between project participants, because ambiguities often unconsciously arise through peoples frame of mind based on their expertise, background, and past experiences, rather than just through seeing different problems or risks. Between participants of the same organisation it might be less easier to get ambiguities on the table compared to between organisations. Certain parties might intentionally not reveal their frame of mind from a strategic point of view (De Bruijn et al., 2018).

Identifying ambiguities requires some sensibility of practitioners towards situations in which conflicting or mismatching perceptions could be present. If one observes an ambiguity to be the present within the project, it is important to understand between who (what participants) the ambiguity lies and whether the ambiguity has impact on the development process. If it does not have impact, one can choose to accept the ambiguity and move on. If it does have impact, it is recommended to discuss this openly with the participants whom it concerns. From that conversation, one might be able to choose an 'optimal' method to deal with the ambiguity. If both parties seem not interested in participating in dialogical learning, a better method might be to apply rational problem solving instead. In the end, the best method to deal with ambiguity very much depends on the situation and between who the ambiguity arises. Dialogical learning would be effective when participants are open to others' point of view to a certain matter (Brugnach et al., 2011). Rational problem solving is effective when one participant is an expert – and has data or evidence backing their perception – in the subject the ambiguity is about. Persuasive communication is useful when one has a good motivation behind their rationale they can communicate well to other participants. A negotiation approach is useful when neither party wants to relate to the other's (problem) perception, but both want to gain something (Brugnach et al., 2011). Imposing your frame onto another is effective if one of the participants has some power over the other (Zandvoort et al., 2018), but might lead to potential distrust as a result of the nature of binding network rules (Koppenjan & Klijn, 2004).

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Appendices

Appendix A: Water System in and around Zwolle

The city of Zwolle inseparably connected to water and the management thereof. The city is located in the east of the Netherlands inside the IJssel-Vecht Delta. The IJssel, Vecht and the Sallandse Weteringen are rivers and channels that either flow through or past the city and exert an influence on the water levels within the city's canals. Additionally, the historic city centre is not protected by embankments like the rest of the city. It lies outside of the embankment system protecting the rest of the city, meaning it is more vulnerable for flooding as a result of rising water levels in the canals within the city (STOWA, 2020). Dolman et al. (2019) describe that Zwolle has to deal with water coming from five different directions: (1) north-western storm on the IJsselmeer, (2) rainfall in the city, (3) rivers (Vecht and IJssel), (4) channels from Salland (Sallandse Weteringen) and (5) ground water flows from Salland and Veluwe (Figure 14). This chapter will explain the working of the water systems responsible for the water that flows past, through and towards Zwolle. Additionally, the effects of these water systems on the city in times of storms and high discharges will be explained.

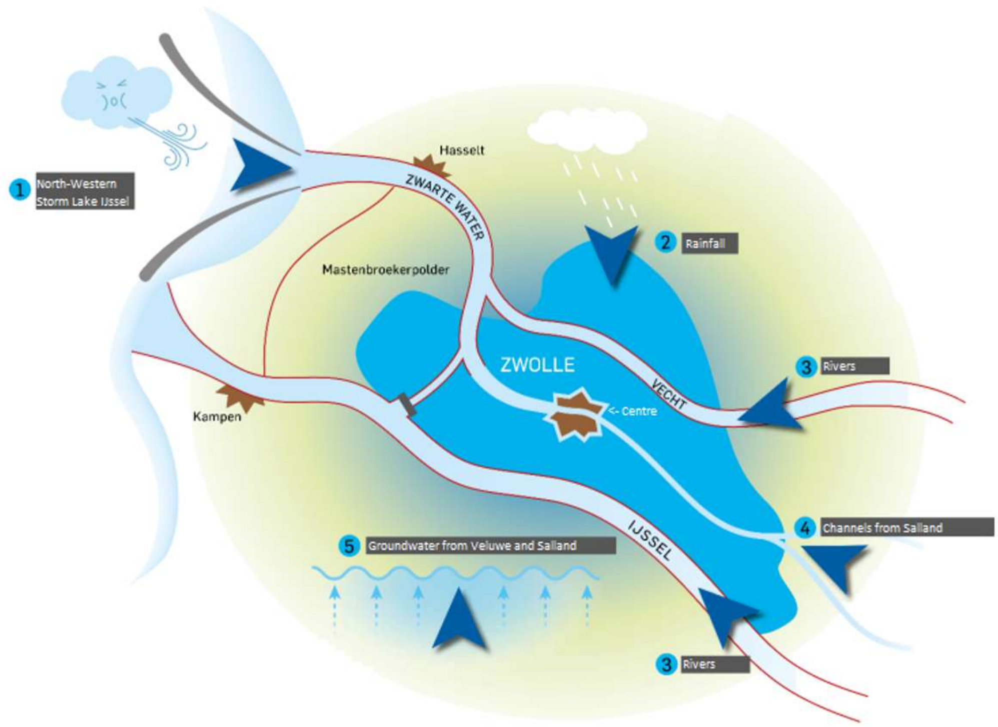

Figure 14: Water directions towards Zwolle (Adapted from Dolman et al. (2019))

Thrust of Water from the IJsselmeer (during north-western storm)

The IJsselmeer serves as a fresh water reserve for the Netherlands for drinking water, flushing of salt water in polders and for agriculture. The complete IJssel-Vecht delta discharges into the IJsselmeer. Therefore, the water levels in Zwolle are also directly related to and affected by the water levels at the IJsselmeer through an open connection of the Zwarte Water and Zwarte Meer to the IJsselmeer (INFRAM, 2018; Dolman et al., 2019).

Under normal circumstances the water flows from Zwolle to the Zwarte Water northwards and ultimately discharges into the IJsselmeer. In the event of a north-western storm at the IJsselmeer, the water in the IJsselmeer will be thrusted towards the eastern side of the IJsselmeer and into the Zwarte Meer and Zwarte Water towards Zwolle. To counteract this phenomenon, an inflatable storm surge barrier at Ramspol has been designed to stop the water from flowing into the Zwarte Meer in times of north-western storms (van Goor, 2010). However, the barrier can only be closed for a limited amount of time because water from the Zwarte Water will not be able to discharge onto the IJsselmeer when the storm surge barrier is closed, meaning the flow profiles will fill itself behind the storm surge barrier. The reverse flow of water from the IJsselmeer is currently not normative for the water defences in the Zwarte Water and in and around Zwolle but it will sometimes cause activation of inundation areas downstream in the Zwarte Water. During normative situations the water levels in the Zwarte Water and in Zwolle are predominantly determined by discharges from the river Vecht (INFRAM, 2018). This is a direct result of the construction of the Ramspol storm surge barrier (HKV, 1996). However, a new phenomenon can occur when the storm surge barrier at Ramspol is closed. Because of the closing of the storm surge barrier, water from the Zwarte Water can no longer discharge onto the IJsselmeer, resulting in rising water levels in the Zwarte Water. A western storm can thrust the water building behind the Ramspol storm surge barrier back towards the Zwarte Water (HKV, 1996), much like a north-western storm does on the IJsselmeer. The significance of this is, however, not addressed.

While the extreme weather events corresponding to the thrusting mechanism are accounted for in the current situation, the average water levels of the IJsselmeer might change in the upcoming years. Because of increasing annual fluctuations in discharge in the river Rhine (thus IJssel) and sea level rise in the Wadden Sea making it harder to sluice water from the IJsselmeer into the Wadden Sea, it is likely that in the future the water levels in the IJsselmeer will increase and fluctuate more, matching the discharge regime of the river IJssel more closely (MNP, 2005). Additionally, it is not unlikely that future average maintained water levels will be increased in order to deal with increased chances and duration of dry spells in summers in the future as a result of climate change. Rijkswaterstaat (2009), who is the owner and is responsible for the maintenance of the IJsselmeer, already shows interest in more natural fluctuations and general water level increase in the IJsselmeer.

An increase in normal water levels in the IJsselmeer will enhance the thrusting effect as a result of north-western storms in the future. Additionally, the discharge potential of upstream rivers in the IJssel-Vecht delta will be permanently decreased as a result. Water levels in these rivers will increase as a result of slower flow speeds, meaning that discharging rainwater from the inland will become harder (Dolman et al., 2019). Research by Deltares (2010) concludes that when the normal water levels in the IJsselmeer will be increased to between +0.2m NAP and +0.6m NAP (current maintained level: -0.2m NAP), embankments along the IJssel would need to be strengthened to compensate for this loss of discharge potential. Embankments along the Zwarte Water do not need to be strengthened. Since Zwolle, again, has a direct connection to the IJsselmeer and the Zwarte Water, the (ground) water levels in the city will also be influenced by the effects of permanent water level rise in the IJsselmeer.

Rainfall (and lack thereof) in the city

In the past half century, extreme rainfall events have become more frequent in the world. So much so that it is beyond the natural climate variability (IPCC, 2022). As a result of imminent climate change, scientists expect that in the future the intensity of the rainfall events as well as the frequency of extreme rainfall events will increase continuously as air temperature in increases in the world (Martel et al., 2021). Global Climate Models (GCM) projections seem to have a rather consistent prediction regarding the amount of change in rainfall. The models show roughly a 7% change in heavy rainfall for each degree Celsius temperature rise (~7%/^{o}C) for countries at mid-latitudes (Fischer et al., 2014). However, one should be cautious with applying a 7%/^{o}C rate at small scales, such as regions, cities or point locations, because global climate models do not offer great predictions at smaller scales due to grid sizes in these models usually being in the scale of 110 km resolution (Martel et al., 2021). Increased rainfall intensity can lead to flooding problems in urban areas due to (1) the relatively high degree of impenetrable soil (brick, buildings, concrete etc.), (2) sewage systems not being designed to cope with more intensive rainfall events and (3) absence of areas for controlled water storage in times of need.

Additionally, because of climate change longer periods of drought will become more frequent. Research by Burt et al. (2015) shows that, in eastern England, the amount of rainfall days per year have steadily declined over the past century, but that the rainfall intensity and total annual rainfall has increased. While the total annual rainfall will increase, the rainfall events will be shorter and have higher intensities than they do now, resulting in longer periods of drought in between rainfall events. Both droughts and increased intensive rainfall events can have adverse effects on cities. Longer periods of drought can lead to a number of issues in cities: (1) ground water level declination, resulting in degradation of foundation of homes and issues with waterborne objects such as (house)boats; (2) Trees are unable to access enough water to sustain themselves, resulting in branches breaking and falling; (3) decrease in quality of (drinking) water, resulting in both lower surface water quality and lower drink water availability (Gemeente Zwolle, n.d.).

To address the vulnerability to rainfall events and droughts, the municipality of Zwolle has done a stress test. A rainfall event equal to 150mm in two hours (~1:1000) has been projected onto Zwolle to analyse the effects of high intensity rainfall on the city (Gemeente Zwolle, n.d.). Additionally, the distribution of temperatures within the city during a warm day has been addressed to show which parts of the city are vulnerable for heat stresses. Figure 15 shows impactful locations where water will flow into buildings as a result of the rainfall event. One may assume that most low-lying public areas such as parks, playgrounds and roads will be flooded as well, these are left out of the figure to preserve clarity in the image. During intense rainfall the water that falls onto the city likely cannot be discharged onto the canals of Zwolle, the IJssel nor the Zwarte Water because those water systems will likely already be dealing with high discharges as a result of rainfall from upstream of the area (Dolman et al., 2019). This means that Zwolle needs to be able to hold the rainwater inside the city until the water system is less heavily loaded with rainwater from the upstream areas.

Figure 15 shows locations with increased heat stress compared to other parts of the city are shown. Unsurprisingly, the areas where buildings would face flooding outside of the city centre are also the areas with low ground levels (OVH SAS, n.d.). Rainwater that falls in areas that have a higher ground level will naturally flow towards these low-lying areas which is largely the cause for the flooding of buildings (A. van Rooijen, personal communication, April 4, 2022).

An interesting fact about the heat stress distribution is that currently it shows that the north-western part of Zwolle suffers quite heavily from heat stress on a warm day. The reason for this is that this part of Zwolle is rather new so vegetation has not had enough time to properly grow yet. No quantitative stress tests regarding the effect of droughts on the city have been conducted as of yet because this does not seem to be a challenge to Zwolle currently, since ground water levels are mostly equal to the water levels in canals in the city centre (Dolman et al., 2019).

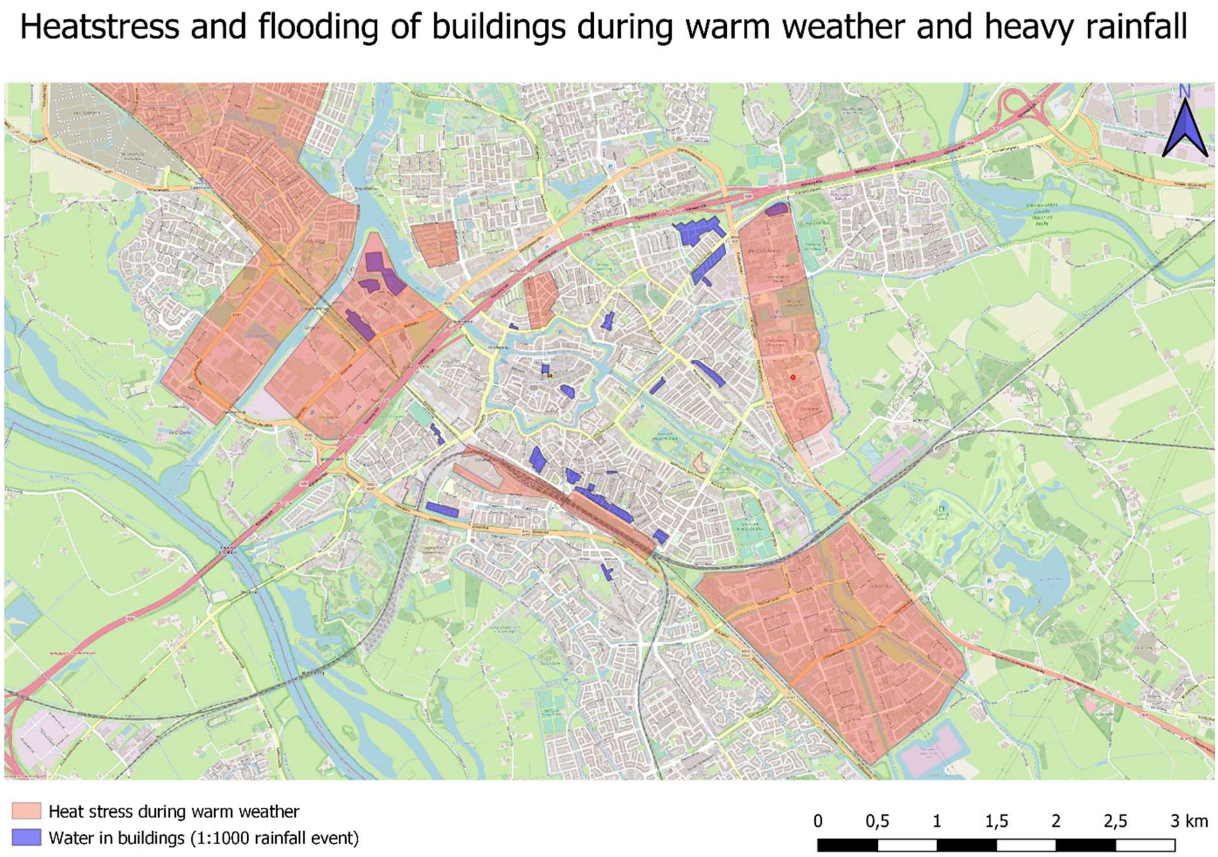

Figure 15: Heat stress and flooding of buildings during warm weather and heavy rainfall (adapted from Gemeente Zwolle, n.d.)

River IJssel

The river IJssel is a lowland river, starting around the city of Arnhem flowing to the north of the country to eventually discharge onto the IJsselmeer. The IJssel lies within a vale between the Sallandse Heuvelrug and the Veluwe. It is a free flowing river, meaning that it is not controlled by weirs. This means that the water levels can get quite low in times of drought (Eshuis et al., 2021). The IJssel is part of the numerous Rhine river branches. Under normal circumstances the IJssel receives around 1/9th of the discharge volume the Rhine carries into the Netherlands (Ministerie van Infrastructuur en Waterstaat, 2022). The IJssel is responsible for 70% of the transportation of fresh water towards the IJsselmeer (van Riel, 2020). Downstream from Zwolle the water levels in the IJssel are mainly influenced by the water levels in the IJsselmeer (Eshuis et al., 2021).

In times of high water periods in the Rhine, the IJssel will receive a bigger fraction of the discharge volume. During high water periods the IJssel will receive 15.4% of the total discharge volume of the Rhine. In the highest current discharge scenario for the Rhine (16,000 m^3/s) the IJssel will have a discharge of roughly 2461 m^3/s (Brandsma, 2016).

The city of Zwolle is adjacent to the IJssel but, unlike the Sallandse weteringen and the river Vecht, the river does not have a direct connection to the city. Zwolle is protected from high water periods by primary embankments that run along the river’s trajectory. These are part of the embankment ring 53 and are designed on a recurrence time of 1:10,000 years. These embankments have a low recurrence of failure since failure leads to large flooding of Zwolle. Roughly two to five meters of water. Inside these embankments 3 locks are located. The Spooldersluis makes shipping possible between the IJssel and the city centre as well as the Zwarte Water. The other two locks are part of the Katerveersluis-complex. However, these no longer have the function of lock. Nowadays, they function as a sluice to drain city water towards the IJssel through the pumping stations installed in the lock doors.

Thrust from the IJsselmeer has an influence on the discharge and water levels in the IJssel. This influences the water levels in the IJssel upstream at Zwolle as well. This effect reaches up to Wijhe (Eshuis et al., 2021). In the future, it is likely that the water levels in the IJsselmeer will rise as a result of complexities regarding sluicing onto the Wadden Sea due to sea level rise and the increased need for fresh water buffers in dryer summers (Rijkswaterstaat, 2009). Additionally, due to climate change average winter and summer discharges in the Rhine are likely to change. It is expected that winter discharges in the Rhine will increase between 13-30% and drought projections (in summer) will lead to decrease in discharge of 5-40% (van Pelt & Swart, 2011). The IJssel will likely follow this trend, if not be more extreme. Because certain water levels have to be maintained in the Waal and Neder-Rijn (other Rhine branches) in order to facilitate shipping, it is not unlikely that during dry spells the IJssel will receive less water. Conversely, in winter it is likely that more water will flow through the IJssel due to both increased natural run-off but also to create fresh water buffers in the IJsselmeer to be prepared for dry spells in summer. The increased fluctuations in water levels in the IJssel will affect water levels in the IJsselmeer and might affect Zwolle in the future mainly through affecting groundwater levels in the city. However, the extend of this has not been quantified yet.

River Vecht

The Vecht is a river that springs in Germany and flows through the north-eastern provinces of the Netherlands where eventually it discharges onto the Zwarte Water. The river is responsible for drainage of rainwater in large parts of Overijssel and parts of Drenthe and Germany (INFRAM, 2018). The river Vecht is a rain fed river. Discharges of the Vecht in the Netherlands can fluctuate between 2 – 550 m^3/s (Vreeze, 2018), where 550 m^3/s is equal to a 1:1000 year recurrence time (INFRAM, 2018; Deltares, 2022). These big fluctuations of discharges are a result of precipitation deficits in summer, surpluses in winter and a system of weirs and locks, placed inside the river to maintain steady water levels in the river and allow ships to navigate upstream. The most important function of the weirs is to maintain a high water level in summer. In winter the water levels in the Vecht are reduced by ~30 – 40 cm to allow drainage of agricultural land in the catchment area (Kramer, 2004; Waterschap Vechtstromen, 2017).

In the Netherlands the Vecht flows through the management area of two different water authorities. Water authority Vechtstromen is responsible for the Vecht from the border with Germany to just downstream of Ommen (Varsen), where the Regge joins the Vecht. From there, the Vecht continues to flow inside the management area of water authority Drents Overijsselse Delta until the end of the river, where it discharges onto the Zwarte Water slightly downstream of Zwolle. These water authorities are responsible for maintenance of the weirs and embankments in and along the Vecht in their respected management area. Inside the management area of water authority Vechtstromen regional embankments cover both sides of the Vecht. Designed on a discharge recurrence time of 1:200. Additionally, two water retention areas (Noord Meene & Zuid Meene) are located near Hardenberg which are designed to relieve pressure off of the embankments during peak discharges. In the management area of water authority Drents Overijsselse Delta embankments are defined differently. In the management area of Drents Overijsselse Delta the embankments are considered primary embankments instead of regional embankments. The southern embankment (embankment ring 53) has a higher protection level than the northern embankment (embankment ring 9). The recurrence times of both embankments are 1:10.000 and 1:1000 years respectively.

The Vecht is responsible for most of the water that flows through the Zwarte Water towards the IJsselmeer. In times of a high water situation the discharges in the Vecht are the dominant factor determining the water levels in the Zwarte Water and upstream towards Zwolle (INFRAM, 2018; HKV, 1996). High water situations at the river Vecht and in the Sallandse Weteringen have a high probability to occur simultaneously (A. van Rooijen, personal communication, April 4, 2022). If both happen at the same time, water levels inside the Zwarte Water will rise significantly. This leads to loss of discharge potential upstream, resulting in increased water levels in Zwolle and the Sallandse Weteringen. Section 2.4 covers the consequences of this event in more detail. According to INFRAM (2018) a north-western storm as described in 2.1 does have a significant influence on the water levels inside the Zwarte Water and Zwolle as long as the Vecht discharges less than 450 m^3/s onto the Zwarte Water (1:200 recurrence). At 450 m^3/s the Vecht becomes the dominant driver of water level increase in the Zwarte Water and Zwolle. HKV (1996) supports this statement. However, they state that the discharges of the Vecht have been dominant only since the construction of the storm surge barrier at Ramspol. This means that normative high water situations in Zwolle are predominantly caused by high discharges of the river Vecht and upstream channels, the Sallandse Weteringen.

Sallandse Weteringen (Channels from Salland)

The Overijsselse Kanaal, Nieuwe Wetering and Soestwetering together form the water system known as the Channels of Salland (Dutch: Sallandse Weteringen). The catchment area of these channels is roughly 50.000 ha (van Goor, 2010). Figure 16 gives an overview of the catchment area and the embankments along parts of the channels. The channels act as a way to transport excess water from the low-lying areas within the catchment northward to the IJsselmeer during times of a precipitation surplus in the catchment. On the way to the IJsselmeer the water passes through the city centre of Zwolle and the Zwarte Water (WDOD (Salland), 2022). During the growing season water from the IJssel, Vecht or Twente Kanalen is let into the area in order to maintain ground water and surface water levels in the area (WDOD, 2022).

Along parts of the channels and along the canals in Zwolle embankments are situated which act as water defence for the low-lying parts of the catchment area and the area around the city centre of Zwolle when the channels are faced with high discharges due to prolonged precipitation. All embankments in this part of the system are located inside the management area of water authority Drents Overijsselse Delta. The embankments are qualified as regional embankments. These regional water defences are designed on a 1:200 year chance to fail based on the current assessment tools (Dutch: beoordelingsinstrumentarium) (STOWA, 2020). The accepted recurrence times are lower as the embankments along the IJssel because of the lower impact flooding of the Sallandse Weteringen in the surroundings. Important to note is that the city centre is not protected by these embankments and is, therefore, unprotected by embankments (Figure 16). During prolonged precipitation the embankments come under pressure because it has to deal with increased discharge from the run-off water of the catchment, increasing the water levels. Additionally, the regional embankments are affected by possible water level rise in the Zwarte Water as a result of high discharges in the Vecht. It is quite likely that high discharges within the Sallandse Weteringen go hand in hand with high discharges in the Vecht and vice versa.

In times of a high water situation, the water system of the Sallandse Weteringen cannot be seen as a separate water system. The discharge potential in the Sallandse Weteringen is heavily affected by the water levels in the Zwarte Water. In case of high discharge on the river Vecht and/or a north-western storm on the IJsselmeer, the water levels in the Zwarte Water will rise. As a result of the water level rise in the Zwarte Water the discharge potential in the areas upstream will decrease. This means that the Sallandse Weteringen and the canals in Zwolle cannot discharge the rainwater from the catchment at maximum potential, resulting in increased water levels. This can be especially problematic in the city centre of Zwolle since it is not protected by embankments.

The regional embankments are safe in the current normative precipitation situation for the Sallandse Weteringen catchment and until now, the water levels in the Sallandse Weteringen and the canals of Zwolle have remained within the limits of the systems' capacity whenever a combination of scenarios has occurred. However, (partly) as a result of climate change, more intense precipitation events and prolonged wet periods will become more likely, mainly in winter (IPCC, 2022). This makes a combination of water level increase scenarios, such as high discharge on the Sallandse Weteringen in combination with high discharge on the Vecht more likely to occur (STOWA, 2020) and will likely lead to higher peak discharges along with higher occurrence frequencies of these discharges in the Vecht and the Sallandse Weteringen. Research by INFRAM (2018) concluded that when the current normative precipitation occurs in combination with high water levels in the Zwarte Water (due to 1:200 discharge in the Vecht river), it will already lead to overtopping of the regional water defences upstream, affecting the hinterland, including Zwolle.

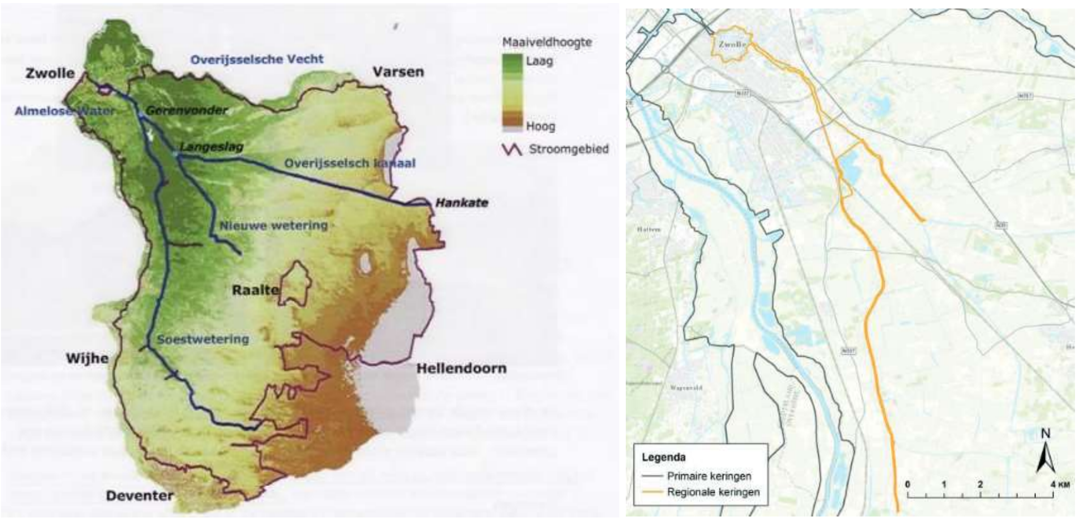

Figure 16: (left) Catchment area channels/streams flowing towards Zwolle (van Goor, 2010) and (right) regional water defences in Salland and Zwolle in orange (STOWA, 2020)

Ground Water Flows

Parts of the precipitation that falls in Salland and the Veluwe are transported through ground water flows towards Zwolle. Groundwater levels in Zwolle are usually close the water levels inside the canals (Dolman et al., 2019). However, the ground water levels are influenced by the river IJssel. If the IJssel has increased water levels, it increases ground water levels inside the city (INFRAM, 2018). In theory this could lead to seepage in the city. Buildings and houses located at the north-western areas of Zwolle (closer to the Zwarte Water) will possibly see consequences to increased groundwater levels. Houses could become somewhat humid which affects human health (A. van Rooijen, personal communication, April 4, 2022). Conversely, in theory the Sallandse Weteringen, and thus the canals in Zwolle, can dry out as a result of long dry spells or low water levels in the Zwarte Water and IJsselmeer (A. van Rooijen, personal communication, April 4, 2022). Such event would negatively affect the ground water levels in the city, exposing foundations of buildings to degradation processes.

As of now, none of these events happened in such magnitude that it caused issues in Zwolle. However, due to possible changes in normal maintained water levels in the IJssel and IJsselmeer which is explored by the Department of Waterways and Public Works (Rijkswaterstaat, 2009), and changes in precipitation and discharge patterns as a result of climate change, ground water level fluctuations could impose problems such as described above in the future.

Appendix B: Authors' definitions of uncertainty

Table 17: Definitions of uncertainty in literature

Author	Title Book/Paper	Definition
Brugnach et al. (2008)	Toward a Relational Concept of Uncertainty: about Knowing Too Little, Knowing Too Differently, and Accepting Not to Know	"Uncertainty refers to the situation in which there is not a unique and complete understanding of the system to be managed." (P. 4)
Dewulf & Biesbroek (2018)	Nine lives of uncertainty in decision-making: strategies for dealing with uncertainty in environmental governance	"we distinguish the nature of uncertainty into three types. The main reasons for distinguishing between ontological uncertainty, epistemic uncertainty and ambiguity are that they (a) pertain to different phenomena, (b) imply a different scale for assessing their degree and (c) require different types of strategies." (P. 444)
Janssen et al. (2010)	The effect of modelling expert knowledge and uncertainty on multicriteria decision making: a river management case study	"It (uncertainty) should not merely be regarded a statistical uncertainty in input, parameters and output of the model. Rather, it comprises information about the simplifications made during the translation of a natural (socio-economical, etc.) system into a (in this case software) model." (P. 230)
Krupnick et al. (2006)	Not A Sure Thing: Making Regulatory Choices Under Uncertainty	"We agree with the principal distinction between variability and lack of knowledge, which can be broken down into three further broad categories, leaving us with four primary "types" of uncertainty: variability, parameter uncertainty, model uncertainty, and decision uncertainty." (P. 11)
Morgado et al. (2014)	The Impact of Stress in Decision Making in the Context of Uncertainty	""Uncertainty" refers to this lack of knowledge concerning the outcomes of a specific choice." (P. 839)
Perminova et al. (2007)	Defining uncertainty in projects – a new perspective	"a context for risks as events having a negative impact on the project's outcomes, or opportunities, as events that have beneficial impact on project performance." (p. 76)
Van der Sluijs (2006)	Uncertainty, assumptions, and value commitments in the knowledge base of complex environmental problems	"Uncertainty is more than statistical error or inexactness of numbers: it is increasingly understood as a multi-dimensional concept involving quantitative and qualitative dimensions. Uncertainty can manifest itself at different locations in risk assessments. In problems that are characterized by high systems uncertainties, knowledge gaps, and high decision stakes, unquantifiable dimensions of uncertainty may

		well dominate the quantifiable dimensions.” (p. 70)
Walker et al. (2003)	Defining Uncertainty	“any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system.” (P. 5)
Warmink et al. (2017)	Coping with Uncertainty in River Management: Challenges and Ways Forward	“we conceive uncertainties in river management as related to deficits of knowledge (possibly epistemic or ontological in nature) and to the ambiguity resulting from the presence of multiple, and valid, ways of framing problems and solutions.” (P. 4589)
Willows et al. (2003)	Climate adaptation: Risk, uncertainty and decision-making	“Uncertainty exists where there is a lack of knowledge concerning outcomes. Uncertainty may result from an imprecise knowledge of the risk, i.e. where the probabilities and magnitude of either the hazards and/or their associated consequences are uncertain. Even when there is a precise knowledge of these components there is still uncertainty because outcomes are determined probabilistically.” (P. 43)
Winch, (2010)	Managing Construction Projects	“The fundamental problem in the management of information is uncertainty; in other words, the lack of all the information required to take a decision at a given time.” (p. 7)

Appendix C: Methods to deal with uncertainty

Methods to deal with epistemic uncertainty

Assessment/evaluation by experts
Asking or contracting experts to evaluate or check a project product(s). For example: a design is finished and experts are consulted to assess whether this design is feasible or in line with regulations.

Research by experts
Asking or contracting experts to perform research in a certain topic in the project. For example: it is unclear what policies are in place at the project location. Experts are consulted to determine what policies are in place at the project location and what principles the project must conform to in order to be eligible for the required permits. This is different than assessment/evaluation by experts in the sense that here experts have to conduct research to enhance information rather than checking something and giving feedback based on their already existing knowledge.

Experimenting with different designs
Identifying the trade-off between objectives within a project by designing different solutions for a project in order to assess the benefits and drawbacks of a certain solution (Zandvoort et al., 2018). An example would be to develop multiple designs for an embankment, one that is high enough to resist the worst-case scenario (modelled), and another that is adaptable to resist the worst-case scenario if needed in the future. The first gives the security that the project ensures safety for every possible scenario (known at the time) for a certain period of time after it is finished (no regret option). However, it has higher initial costs to build, takes up more space, could be overdimensioned, and could have a negative impact on the local environment/ecology. The second design has less initial costs, takes up less space, and has less impact on local environment/ecology. However, it has drawbacks such as the need for periodic monitoring after the project is finished to check whether the embankment still holds up to current conditions, and if it does not, one must return to the project in the future to enhance the embankment when the worst-case scenario comes into being, which could lead to additional costs on the long-term.

Doing research (increasing joint knowledge)
Research or information exchange performed by one or more project actors involved in the project themselves without consultation of external experts. This includes knowledge generation or information sharing between the actors but also coordinated sessions like joint fact finding and knowledge co-creation (Dewulf & Biesbroek, 2018).

Implication of knowledge gaps research
Assessment of how a lack of knowledge affects the problem description or problem understanding of a situation in a project. A strategy where evaluation and quantification is used to assess the effects of the uncertainty at hand (Brugnach et al., 2008). An example can be found in risk management practises, where potential negative situations (risks) and their subsequent effects on the project are evaluated and quantified, usually in monetary costs or delays. Think of a lack of knowledge regarding the extent or severity of soil pollution at the project location and the effects to the project (process) if it is worse than expected.

Developing confidence intervals
Performing a range estimation of the effects that certain variables have on the system or project. This could take the form of a sensitivity analysis (Brugnach et al., 2008), where the behaviour of a system under different (project induced) conditions can be analysed.

Taking more accurate measurements
A method where uncertainty is lowered through the use of experiments or tests. This method can be used to either gather new information (knowledge) or to gather more precise and reliable information (data) about a phenomenon or an element of the project. Examples include 1) testing the structural condition of quay walls in a harbour or 2) measuring the average flow rate of a river at a given location with a sensor that has increased accuracy compared to previous sensors or measuring methods.

Expert Opinion
Asking an expert to give their opinion about a certain (part of the) project based on their experience or knowledge. This can be based on their past experiences with similar situations, to test the waters about reception of the project, or because the expert plays an important role later on in the project development process.

Methods to deal with ontological uncertainty

Scenario planning
Developing or making use of a multitude of plausible future scenarios based on past trends, time series, and/or identified theories about underlying mechanisms in a system (Kwakkel et al., 2010). Perhaps the most obvious example of this is modelling of climate scenarios, where a multitude of scenarios are developed based on different assumptions of future development and underlying mechanisms in the world. The results are different scenarios – or estimates – showing possible effects of climate change, ranging from moderately low change to extreme changes. These scenarios show things like future water levels (Kwadijk et al., 2010), average temperatures, and changes to precipitation intensity and frequency (Pahl-Wostl, 2007) in the future per scenario.

Worst-case scenario planning (enduring uncertain phenomenon)
A method to deal with unpredictability by taking measures to resist the worst (known) possible scenario or risk. In water management literature also referred to as prediction and control (Pahl-Wostl, 2007). An example would be using plausible future scenarios for maximum water levels and aiming to build an embankment that can withstand the worst plausible scenario. In other words, an embankment that is strong and high enough to resist the scenario with the highest possible future water level (at some return period). This would make the embankment able to endure all plausible (known) scenarios during its lifespan.

Incorporating flexibility (adaptability)
This method involves trying to deal with unpredictability by taking measures (or developing policies) that are adaptable as new or more accurate information becomes available in the future regarding the unpredictable situation (Pahl-Wostl, 2007, Haasnoot et al., 2012, Walker et al, 2013). For example, a hospital could account for potential decline in patients in the future by designing the building in such way that (parts of) the building can easily be converted into apartments. Alternatively, when one designs an embankment using a number of future climate scenarios, one can choose not to use the scenario with the highest potential water level (worst-case). Instead, they decide to design the embankment to resist a more middle of the road scenario while not disregarding the worst-case scenario. This can be done by designing the embankment in such way that it can be adapted to potentially resist the worst-case scenario in the future when new or refined information might suggest it is needed.

Accepting uncertainty and deal with consequences as they occur
Dealing with an unpredictable phenomenon by dealing with the consequences of the phenomenon rather than the phenomenon itself (Brugnach et al., 2008). This could take the form of financial damage control in cases of damage to assets as a result of a flood, but could also be developing an evacuation plan for a given scenario, instead of developing physical measures.

Taking measures usable within the timespan of an event
This method consists of developing a temporary measure that is capable of dealing with an event during the time window it unfolds (Brugnach et al., 2008). Example of this include 1) a storm surge barrier that can be closed in the event of extreme water levels or 2) constructing rabbets for stop logs at the front door of houses or other buildings to keep them safe in the event of a high water in the streets (as a result of heavy precipitation or extreme water levels).

Improvisation
Making decisions about how to deal with an unpredictable phenomenon on the fly while it is happening. An instance of this can be found during the 1953 flood disaster in the Netherlands, where a mayor ordered two fishermen to barricade a hole in the embankment by sinking their ships at the hole in order to close it and block water from flowing into the inland (Termeer & van den Brink, 2013).

Developing robust solutions usable for a multitude of scenarios
Dealing with unpredictability through designing solutions that are effective under a multitude of environmental variation. In a water management case, a multi-functional landscape with restored floodplanes could be used for recreation during normal situations, but parts of the landscape function as temporal flooding zones in the event of a flood (Pahl-Wostl, 2007) or as water storage during drought(s).

Methods to deal with ambiguity

Persuasive communication
This method involves convincing others of the meaningfulness or importance of their frame of reference. The goal of this strategy is that other people will adopt the frame of reference after it is presented and communicated to them (Brugnach et al., 2011). Examples include awareness raising campaigns in media, communicating some kind of message to invoke concern towards an issue, and/or lobbying to influence 'powerful' people's behaviour towards the topic in favour of the frame that is presented.

Dialogical learning
In this method, dialogue and mutual learning is used to handle frame differences. It engages actors in an interactive communicative process to create a joint problem definition or perception that all involved actors can accept. The thought behind this method is that people can develop a mutual understanding of one another and understand the rationale behind their point of view and problem perception (frame) through dialogue (Brugnach et al., 2011; Dewulf & Biesbroek, 2018). Participants need a high degree of social skills and willingness to participate in a constructive dialogue. Participation of as many actors as possible is vital to creating a joint frame or problem definition all parties can accept (Brugnach et al., 2011). An example of dialogical learning includes 1) facilitation, where a neutral person – the facilitator – assists two or more actors to work together more effectively. The role of this facilitator is just to facilitate the group process and to improve communication between the actors, not to make decisions (Brugnach et al., 2011). Another example is 2) role playing games. This is a game where actors play the role of another actor. The goal is for

actors to gain understanding of where other actors are coming from and to reflect others' perspectives (frames) onto their own (Brugnach et al., 2011). These interventions can provide opportunity to explore others' frames and add of new elements to one's own frame of mind. The success of dialogical learning is hindered by distrust between actors, conflictive personalities, the exertion of power games, and stereotyping (Brugnach et al., 2011).

Negotiation approach
A method that strives to reach (an) agreement through negotiations despite the presence of frame differences between actors. The preferred outcome of this method is a settlement of a fair deal through calculative involvement of actors (Brugnach et al., 2011). In this kind of method actors engage in information exchange sessions and position themselves strategically. The fundamental difference between the negotiation approach compared to the dialogical approach is that actors take a strategic position that is not necessarily communicated to other actors. Ambiguity is not directly addressed when using this method since participating actors mostly retain their original frame. However, it does address ambiguity indirectly because the agreement – following from the negotiation process – has to make sense from the point of view (frame) of each actor (Brugnach et al., 2011).

Rational problem solving
The aim of this method is to produce one clear frame and disregard all other possible frames. The chosen frame to adhere to is often a result of substantiation of scientific evidence and factual information (Brugnach et al., 2011; van den Hoek, 2014). Project actors are essentially taught by an expert what the relevant or 'correct' frame is. It does not actively support the creation of co-ownership nor a shared sense of responsibility between project actors. The risk is that each expert initiates their own research to support their problem perception (frame) whilst disproving others' (Brugnach et al., 2011). For example, a scientist explains through use of hydrological models and precipitation statistics that there is a need for a new or expanded fresh water reservoir because current supply of fresh water outweighs the demand. The problem is framed as a resource problem (availability of fresh water), backed up by scientific data. The goal is to convince other people that this is the 'real' problem while disregarding other possibly valid problem frames such as water shortage due to overconsumption rather than availability.

Imposing frame onto others
This method involves imposing a particular frame through power strategies. This method is often used by more powerful actors within a project process in order to streamline the process and give direction to the project. This situation or strategy is most often seen when different actors or parties have a history together where they have had confrontations with each other and/or a lack of collaboration. This strategy can eventually lead to a negotiation strategy (Brugnach et al., 2011).

Accept different knowledge frames
In this method there is no strategy or approach to try generating a joint problem definition nor an effort to get all actors on the same page with one another regarding a situation of problem (on the same frame). Instead, different – sometimes incompatible – frames of mind of participating actors are accepted and the project is continued. This method is only viable when different knowledge frames or differences in risk perception, such as severity of climate change and its long-term effects, does not negatively affect realizing adequate spatial interventions nor lead to notable stagnation in the project development process (Zandvoort et al., 2018).

Appendix D: Documents and interviewees

Table 18: Documents used for both case studies

Kraanbolwerk	
Document ID	Document name
D001	Notitie Ontwerpwaterstanden stuurgroep 25-3-2013
D002	Voorstel stuurgroep 10 juli 13
D003	(Bijlage) A deel 1: Binnenstad Deltaproof Zwolle
D004	(Bijlage) B deel 2: Investeringsagenda deltaproof binnenstad Zwolle
D005	F-Bijlage D: Kraanbolwerk in woelig water
D006	Stedenbouwkundig plan Kraanbolwerk
D007	Collegevoorstel aanpassing grondexploitatie Kraanbolwerk
Zwarte Water Zone	
Document ID	Document name
D101	Functioneel programma van Eisen buitendijks bouwen
D102	Participatiejournaal 2017-heden
D103	Vergunbaarheid Waterwet
D104	Rijkswaterstaat - Schriftelijke inbreng tbv informatieronde Zwartewaterzone
D105	Cauberg Huygen - Wet Natuurbescherming
D106	Beantwoording openstaande vragen uit debatronde Zwarte Waterzone 8 november 2021
D107	NatuurPlatformZwolle - Schriftelijke reactie SOP ZwarteWaterzone
D108	Stedenbouwkundig ontwikkelplan zwarte waterzone

Table 19: Interviewees and their backgrounds for each case study

Kraanbolwerk		
Interviewee ID	Organisation ID	Public/Private
K-001	O-01	Public
K-002	O-01	Public
K-003	O-01	Public
K-004	O-02	Private
K-005	O-03	Public
K-006	O-04	Public
Zwarte Water Zone		
Interviewee ID	Organisation ID	Public/Private
Z-001 (2 persons)	O-01	Public
Z-002	O-05	Public
Z-003	O-01	Public
Z-004 (2 persons)	O-06 & O-07	Private
Z-005	O-01	Public
Z-006	O-08	Private
Z-007	O-01	Public
Z-008	O-09	Public
Z-009	O-10	Private

Appendix E: Interview variables, goals and questions

Table 20: Variables interview protocol

Interview Variables	
1	The uncertainties experienced (# and 'what')
2	Phase(s) where uncertainty(s) are encountered (Problem Solving Cycle-location)
3	Type of uncertainties being experienced (Epi/Onto/Ambi)
4	Perceived effective method to deal with (a) uncertainty (perceived most effective practise)
5	Does the perceived effective way match with the type of uncertainty experienced?
6	Solution space for dealing with the uncertainty (what was there to choose from within the project boundaries)
7	Fittingness of the chosen strategy for the type of uncertainty
8	Ambiguity within the project coalition (different prioritization/interpretation/consensus etc)
9	Dealing with ambiguity within the project coalition

Table 21: Interview goals as input for the interview protocol

Interview goals per part	
Part 1	
1.1	Get to know the interviewee's function in the organisation/firm which they are a part of.
1.2	Gain insight in the interviewee's role/part in the project.
1.3	Get to know how long they were involved in the project.
1.4	Get to know how intensively they participated in the project.
1.5	Assess in which parts of the problem-solving cycle the interviewee was involved in the project.
Part 2	
2.1	Gain insight in what uncertainties are experienced by the interviewee during the project's process.
2.2	Uncover how the interviewee would describe the type of each uncertainty (Ontological/Epistemic/Ambiguous).
2.3	Get to know where in the process (problem-solving cycle) each uncertainty was recognized.
2.4	Uncover whether there were ambiguities present between project participants (regarding the type of uncertainty faced, how to deal with it, differences in stance on the uncertainty)
Part 3	
3.1	Gain insight into the solution space (options) to deal with each uncertainty that was experienced.
3.2	Get to know how the experienced uncertainties were dealt with by the project participants.
3.3	Gain insight in the perceived effectiveness of the chosen method/strategy to deal with each uncertainty.
3.4	Get to know whether actions were taken to resolve ambiguity between project participants.
3.5	Get to know what the interviewee's preferred way of dealing with each experienced uncertainty would have been.
3.6	Uncover whether the methods used to manage uncertainties match with the uncertainty type being experienced.

Table 22: Interview protocol

Interview Questions (and variables)			
(Main) Question	**Sub Question(s)/Probe(s)**	**Variables probe / Variables question**	**Goal no.**
Interview Part 1			
How long have you been active in the current organisation/firm?	- What function do you fulfil in the organisation or firm?	None / None	1.1.
What function did you fulfil in the project?	- In what phases of the project were you active? - How intense were you involved in the project during that time? What was your input?	None / none	1.2; 1.3; 1.4; 1.5.
Interview Part 2			
In the project process, were there moments where it was hard to make decisions due to knowledge gaps, vagueness, points of discussion or uncertainties in the project?	- Were there more of these instances?	1 / 1	2.1.
Where in the project process was this Knowledge gap, point of discussion or uncertainty first identified?	None	2	2.3.
How would you categorize or typify the knowledge gap, vagueness, point of discussion or uncertainty? Was it a lack of knowledge or accurate data or because of lack of agreement/consensus?	- What is the core or origin of the uncertainty? - Was the uncertainty due to a lack of knowledge and/or reliable information? If so, would research or experiments help to decrease the uncertainty? - Would you describe or typify the uncertain phenomenon as an unpredictability? If so, would more research and/or experiments help to decrease the uncertainty (in the timespan of the project, not 100 years ahead). - Is the uncertainty related to differences in interpretation, prioritization, stances on data, or opinion which leads to lack of agreement on how to act?	3 / 3	2.2.

Did you have the feeling that other people had a different perspective on the vagueness, knowledge gap or uncertainty? Did they have another perception of the situation?	- If Yes: Could you explain what the different perspectives were and how did it compare to yours? - If No: Was everyone on the same page on how to deal with the situation/uncertainty?	8 8	2.4.
	Interview Part 3		
What was the method or strategy used to deal/cope with the knowledge cap, vagueness, point of discussion or uncertainty within the project? How was it dealt with?	- Were there alternative options to deal with this phenomenon? Why were they not chosen or deemed less adequate? • Why do you think this method or strategy was not chosen? • Were there methods that were not chosen, Or were there (some) methods that were deemed unfeasible within the project's boundaries? - In case of an Ambiguity: In your experience, were there any activities or meetings that had the goal of reaching a consensus and getting everyone on the same page regarding the uncertain phenomenon? • How successful were these activities? Was this beneficial for the project process?	6; 9 7	3.1; 3.2; 3.3; 3.4; 3.6.
Did you think that the chosen method to deal with the uncertainty, knowledge gap, vagueness or point of discussion was adequate?	- If Yes: Would this method be suitable to apply universally in similar projects, or is the method of dealing with uncertainties unique for every project? • Is this also dependent on project team composition? - If No: Why was the method inadequate? What was missing or what could have been done different to make it adequate?	7 4; 7	3.3.
What is in your opinion the best method to deal with situations when this knowledge gap, uncertainty, vagueness or point of discussion arises?	- Why is this the most adequate method? - Would there be more methods that would also be adequate?	4; 5; 6 4; 5; 6; 9	3.1; 3.5; 3.6.

Appendix F: Description of the uncertainty themes

Themes related to epistemic uncertainty

Parties required to be involved and when (Who should be involved and when?)
Knowledge regarding who or what organisation should be involved at what stages of a project development process to make sure the project goes through from a policy or strategic standpoint.

Policy interrelations (How do policies relate to each other?)
Knowledge gap about how two or more policies from different sectoral authorities interact with one another in a project.

Integration project into river landscape (How can/do you integrate the project into the river? What should you take into account?)
Situations allocated to this uncertainty theme are situations where there is a lack of knowledge about what is and what is not possible to do in the design of the project. This includes having a lack of knowledge in: 1) Technical and financial feasibilities. What can we do in this area from a technical and financial standpoint?; 2) Laws and regulation about what is needed to get permits; 3) Demands/requirements (by a given sectoral authority) on technical aspects of the design; 4) What technical functions should be fit where into the project. For example, how to fit a safe evacuation route into the project, or at what height electric transformers should be constructed; 5) how to incorporate ambitions for the project into the design. For example reaching additional water retention capacity with the development of the project.

Project's effect on hydraulic characteristics (What are the hydraulic consequences of building the project (Morphological, discharge capacity))?
Uncertainty related to a lack of knowledge about how hydraulic properties of the area will change as a result of building the project. For example: morphological changes to the current-carrying water stream, or maximum discharge capacity in times of high water situations.

Construction of services (electr., water, etc.) (How are certain services constructed?)
Knowledge gap related to how services such as 1) how electricity and sewage are constructed through the embankment, 2) what to do with the sludge that is being dredged from the marina basin, or 3) measures related to traffic.

Consequences submersible parking garage (What are the consequences for making the parking garage floodable (effect, limitations, pros/cons)?)
Uncertainty related to the consequences to design or implications for other aspects of the project as a result of allowing the parking garage to flood during high water situations. This includes: 1) constructive redesign, 2) the effect (retention capacity), 3) how do we account for cars parked in the garage during flooding?, 4) where are you going to construct a lose pipe for future charging stations for electric cars?, 5) how can you make sure that all key infrasture stays available when the parking garage floods?, and 6) how we integrate the electric transformers or electric outputs into the project?

Magnitude of soil pollution and effect in project (What is the magnitude of soil pollution and are the consequences of remediation to project?)
Uncertainty related to a lack of knowledge about the extent of soil pollution in the subsurface soil underneath the project location, but also the things to take into account when carrying out soil remediation at the location. This includes knowledge 1) about the partial vacuum (how much water will come to the surface), and 2) knowledge about what other pollutions you might attract as a result of extracting water from the soil.

Condition of quay walls (What is the condition of the quay walls?)
Lack of knowledge about the constructive condition of quay walls at the project’s location.

Testing/Advising as organisation (How do we test/advise as organisation? What are our principles?)
Lack of knowledge surrounding what requirements to put on aspect of the project, or how do we advise to build/design parts of the project. An example from the research is: new regulations and zoning as a result from reinforcement of the nearby embankment in the near future. Where are you allowed to do what and where are you not allowed to do some things? How do we advise now, despite not yet knowing the exact zoning of the new embankment.

Themes related to ontological uncertainty

Inter-organisational testing (design/policy) (How do other organisations test/assess?)
Uncertainty related to an unpredictability towards how other organisations are going to test or assess parts of the project design. For example: it is unknown whether a given sectoral authority is going to agree on acceptance of <10% retention capacity, because of circumstances that happened during the project.

Climate induced future water level increase (sea level rise, river discharge, precipitation)
Uncertainty related to the inherent unpredictability of climate change and its effects in the future. This includes uncertain future water levels during high water situations and changes to river discharges as a result of changes to precipitation regimes upstream induced by climate change

Government induced future water level increase
Changes to water levels at the project location as a result of human interventions in the water system up or down stream of the project. An example is decision-making about increasing normal water levels in the IJsselmeer.

Changing view on water safety in future (Will our view on water safety change in the future (view on dikes etc.)?)
How will we apply water safety measures in the future and do we account for this in the project? For example: 1) We might stray away from the ideology of building higher embankments and applying a different method to deal with water safety, or 2) How do we want to deal with our dikes In the future? Does the project possibly limit this vision?

Future discharge distributions (What will the future discharge distribution in the system look like?)
Uncertainty regarding the future discharge distributions and how much the project can/will contribute to relieving high water levels by applying water retention (effectivity of retention on the water levels downstream).

Changes in policy / policital composition (Policy changes affecting the project and changes to political composition in (public) organisations)
Uncertainty about unpredictable policy changes possibly affecting the project, or changes to political compositions in organisations resulting in new requirements or ideas around the project. An example is the introduction of the 'omgevingswet'.

Uncertain market function (building costs, housing market, mortgage interest, etc.)
Ontological uncertainty related to the unpredictability of future economic conditions within the timespan of the project.

Themes related to ambiguity

Competent authority in the project (Who is the authority having jurisdiction in the project?)
Ambiguity originating from the absence of a clearly defined authority who has jurisdiction in the unembanked space. An example from the research: Then you will continue to ask, who will be the authority that has jurisdiction for us? Is that Rijkswaterstaat, the province or is that the municipality?

That's another point, for example. We still don't have a very good answer to that. Who has the final verdict?

Responsibility & Ownership (risks and €) (Who is responsible for or the owner of a given part of the project?)
Ambiguities resulting from unclear ownership of parts of the project. This includes: 1) discussion about who should pay for what during the project or in case of setbacks during construction that can be allocated assets owned by a given party. But also 2) the future owner of (parts) of the project after the project is finished, such as who the owner of the wall (and therefore responsibly for maintenance) of the parking garage if it were to be constructed into the embankment.

Parties on the same page & talking about the same things (Is it possible to get involved parties on the same page with each other and are we talking about the same things (The same knowledge frame)?)
Ambiguity that originates from participants or stakeholders having different perceptions or ideas on a given problem or matter. Perhaps the most general theme encompassing of a lot of different ambiguous situations during the case projects. Examples include but are not limited to: 1) What data or research are we going to adhere to? Do we agree with (or trust) research or conclusions by a given research or should we get another party to do it? , 2) If the parking garage floods twice in one year, despite the 1/10.000 recurrence time, and all 500 cars are evacuated to the nearby neighbourhood twice. Resulting in massive stagnations in the neighbourhood. Is evacuating the then the right decision?, 3) can we get on the same page about integrating project Stadsdijken with the Zwarte water zone? And what are the perspectives of each participant regarding the integration?, or 4) not being on the same knowledge frame about how to calculate retention capacity.

Working & testing integrally (How do you manage working and testing (conformity to policy) integrally?)
Ambiguity related to the a situation where multiple policy fields – or interests – collide or do not agree with each other and it is unclear what to adhere. An example from the research: 1) Nobody as a definitive say about the unembanked space. However, everyone (sectoral authorities) has to put their stamp of approval on it. Or 2) difference in working methods and interests (between municipality and developer). How do you work together and what interests do you have?

Actors' neglectance or ignorance to uncertainties (Are some parties neglecting some uncertainties or points of attention (because they don't see them?)?)
Ambiguities resulting from participants not seeing or accepting uncertainties that other participants experience. Example: One party fails to acknowledge or understand the importance of involving different sectoral authorities within the project because they do not see the dependence on approval from these parties for the construction of the project.

Should you want to build in the unembanked area?
Ambiguity between project participants and between other stakeholders whether you should want to build in the unembanked area. This includes questioning the future water safety for residents of a residential area in the unembanked area

Acceptance thresholds (internal)(When is something sufficient or do we accept (7/10 okay or only 10/10?)?)
Ambiguity related to requirements and the acceptance threshold by practitioners of the same organisation. Example: Do we want to accept <10% retention capacity increase in the project area to avoid a subsequent uncertainty (or complexity) about the consequences of making the parking garage floodable?