Master Thesis

Integration of Flood and Drought Management in Zwolle towards improving Climate Resilience

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Abstract

The Netherlands is typically known as a country vulnerable to flooding. However, recent events and studies show that the country is also becoming increasingly prone to drought. Therefore, scientific and practical knowledge on the management of flood and drought risks is essential to adapt to climate change and become climate resilience. This thesis examines how the management of flood and drought in Zwolle, as one of the adaptation frontrunners in The Netherlands, by applying a general framework of disaster risk management. Furthermore, the integration among the authorities in Zwolle and its surrounding areas are investigated to enhance flood and drought management towards making Zwolle a climate resilience city by 2050. This study was guided by a qualitative research using semi-structured interviews and document reviews to create evidence on the type of data used, the disaster risk management framework, and the integration on flood and drought management. From this study, I found that the data used for flood and drought management involve community participation too, and some others are obtained through organised research. The framework used by the authorities to manage flood and drought risks is varied. Not only are safety approaches released by the central government adopted, but they also use abundant types of tools and models. In terms of integration, the water authority plays a major role, since it has broad responsibilities in water management, covering both flood and drought management, whereas the municipality is mostly in charge of planning related to infrastructures that can contribute to flood and drought management.

Acknowledgements

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List of Abbreviations and Acronyms

DHV	Ingenieursbureau Dwars, Heederik en Verhey
DMPs	Drought Management Plans
DRM	Disaster Risk Management
EO	Earth Observation
GDPR	General Data Protection Regulation
GGD	Gemeentelijke Gezondheidsdienst
GHG	Green House Gas
GIS	Geographic Information System
HIS-SSM	The Damage and Casualties tool of the High-Water Information System in The Netherlands
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
KNMI	Koninklijk Nederlands Meteorologisch Instituut
MIPWA	Methodiekontwikkeling voor Interactieve Planvorming ten behoeve van Waterbeheer
NBC	National Broadcasting Company
RRV	Reliability, resilience, and vulnerability
SOBEK	a modelling suite for flood forecasting, optimization of drainage systems, control of irrigation systems, sewer overflow design, river morphology, salt intrusion and surface water quality
SPEI	Standardized Precipitation Evaporation Index
SPI	Standardized Precipitation Index
STOWA	Stichting Toegepast Onderzoek Waterbeheer
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WDO Delta	Waterschap Drents Overijsselse Delta

1. Introduction

1.1. Empirical background

Over the last two decades, two of the most destructive impacts of climate crisis – floods and droughts, have affected 3 billion people, with astonishing costs in human adversity and financial loss (World Bank, 2021). Floods and droughts happen in all countries, including developed countries such as the Netherlands. The government of the Netherlands has been setting out plans to protect the country from flooding, reduce the impact from extreme weather events, and secure freshwater supplies (Delta Programme, 2022).

The number of urban floods have been increasing due to climate change, land use, population growth, and infrastructure deterioration (Casiano Flores et al., 2021). Furthermore, causes of floods are complex, and involve precipitation as well as physical and hydrological characteristics of a catchment area (Morin & Yakir, 2014). On the other hand, drought, a natural disaster caused by lack of precipitation, is described in several categories based on the hydrological cycle or other abnormality in water supply failures (Pedro-Monzonís et al., 2015; Qiu et al., 2023. Both flood and drought are influenced by the hydrological cycle. Therefore, their management should be integrated towards climate resilience. The disaster risk management (DRM) cycle offers this management approach, through four operational phases: mitigation, preparation, response, and recovery (Alexander, 2002; Bosher et al., 2021).The management of flood risk involves hazard, exposed aspects, vulnerability, and capacity, in terms of coping and being adaptive as a system (Birkmann et al., 2013; Rana et al., 2021; Rana & Routray, 2018; Schanze, 2006), which are contained in the DRM cycle. Drought risk also contains several aspects in the DRM cycle, such as drought hazard, drought exposure, and drought vulnerability (Carrão et al., 2018).

In this research, I focus on flood and drought, whereas any discourses about heatwaves, sea level rise, and other climate issues are not elaborated for the sake of focus. Regarding the stakeholders' perspectives, I only analyse climate resilience from the perspective of governmental authorities. In the Netherlands, the main governmental organisations responsible for water management and climate adaptation are the national government (Ministry of Infrastructure and Water Management, and Rijkswaterstaat), regional water authorities, provinces, and municipalities (Jong & Brink, 2017). These organisations have different types of roles and obligations. According to the Constitution of the Netherlands "*the powers of provinces and municipalities to regulate and administer their own internal affairs shall be delegated to their administrative organs*" (Kingdom of the Netherlands, 2019). The "powers" mentioned in the constitution for municipalities cover urban planning, traffic and transport, education, welfare and social affairs, etc. On the other hand, the regional water authorities are responsible for regulating water levels, wastewater treatment, dike management, water-related nature management, and monitoring of water quality (Rijksoverheid, 2021).

Zwolle, the capital city of Overijssel Province of the Netherlands, is a frontrunner in climate action. This research is conducted as part of the project of Delta Futures Lab, a thematic group with 4TU Centre for Resilience Engineering, and in collaboration with several educational institutions; TU Delft, Wageningen University & Research, TU Eindhoven, and University of Twente, also supported by Municipality of Zwolle (Gemeente Zwolle) and Waterschap Drents Overijsselse Delta (WDO Delta). I conducted preparatory interviews with representatives from WDO Delta in February 2023, and the Municipality of Zwolle in March 2023. From those interviews, I obtained background information regarding flood and drought in Zwolle and its surrounding regions.

1.2. Research problem

Floods and droughts occur within the hydrological cycle, the measures and plans for managing risks mostly focus only on floods or on droughts (Ward et al., 2020). Therefore, empirical knowledge is needed on the interlinkages between the management of flood and drought, and the degree of integration among the management processes.

According to a representative of Municipality of Zwolle from the interview conducted in March 2023, the adaptation strategy which is related with water issues or water system in Zwolle, is integrated between the city and surrounding rural areas because it is considered as a cross-boundary object. From this statement, I notice how the connectivity of urban-rural in Zwolle and its surrounding region on integrating management of flood and drought in basic of "cross-border object" which is water system. Therefore, it is essential to not only focus with the city but also pay attention to the surrounding rural areas as well.

Furthermore, there are several knowledge gaps and challenges to embody the integration between flood and drought risk management, such as a holistic approach to address synergies and trade-offs of hazards and measures, how Anthropocene influences hazard, exposure, and vulnerability, understanding of monitoring and observation data, and collaboration across multiple scientific disciplines and practices (Ward et al., 2020).

1.3. Research objective

The objectives of this research are threefold. First, I aim to improve the conceptual understanding about the integration between flood and drought management, especially with data and information used by each institution who are involved in the management. Second, I explain the coherence between flood and drought resilience in Zwolle with DRM cycle, by reviewing involved indicators from various dimensions with the principle of DRM cycle. Thirdly, I assess the degree of integration between flood and drought management among governmental institutions by seeing the shared tasks of related authorities.

1.4. Research questions

To achieve the research objectives, I formulated the main question as follows:

> *How can flood and drought management be integrated to improve climate resilience in the city of Zwolle and the surroundings?*

The main question is elaborated through the following sub-questions:

1. *How do governmental authorities use flood and drought data to improve climate resilience in Zwolle and surrounding regions?* This is an exploratory question since I will find the answer through data analysis in form of interviews with the stakeholders. By knowing how they use the data, I will gain an understanding on these data influence climate resilience improvement in Zwolle and its surroundings.
2. *How is the assessment of flood and drought resilience applied in Zwolle and surrounding regions with respect to the principles of DRM cycle?* This explanatory type of question includes the explanation on how flood and drought resilience applied in Zwolle compare with principles of DRM cycle. The answer to this question is expected could give an insight on principle that is used to improve climate resilience in Zwolle and its surroundings.
3. *What is the degree of integration between local and regional governmental authorities in flood and drought management based on phases of DRM cycle?* The last sub-question is an evaluative one since I am going to assess the integration level between flood and drought management among different authorities. The information about this integration will help to understand the cross-institution management pattern used to improve climate resilience in Zwolle and its surroundings.

2. Conceptual Framework

In this chapter, I define and elaborate on the concepts that are related to my thesis research. I starts with a definition of climate change and climate resilience, as well as flood and drought resilience. Then I provide a detailed explanation about disaster risk management cycle, and end with the description of criteria and indicators used to monitor resilience. These concepts are attentively arranged to form a coherent conceptual framework for the thesis.

2.1. Climate change

Climate change is defined as "*a change in the state of the climate that can be identified (e.g., by using statistical test) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer*" (IPCC., 2012). Furthermore, UNFCCC describes it as a change of climate which impacts human activities directly or indirectly, and it influences the atmosphere's composition and it is observed for a period of time (UNFCCC, n.d.). Major impacts of climate change include more frequent and intense climate extremes, i.e., floods, droughts and heatwaves, as well as sea level rise.

Climate change is happening all over the world, which requires taking action, so that its harmful impacts can be decreased. The actions that can be done to reduce the impacts can be in the form of adaptation and mitigation. For measures in adaptation, scholars have conducted studies to define a concept for long term climate change adaptation and water security on the urban scale. These measures cover water supply, water demand, emergency water management and planning, management and organisations, operation and maintenance, and urban land use planning and management (Ray Biswas et al., 2022). The detail of each measure is depicted in the figure below.

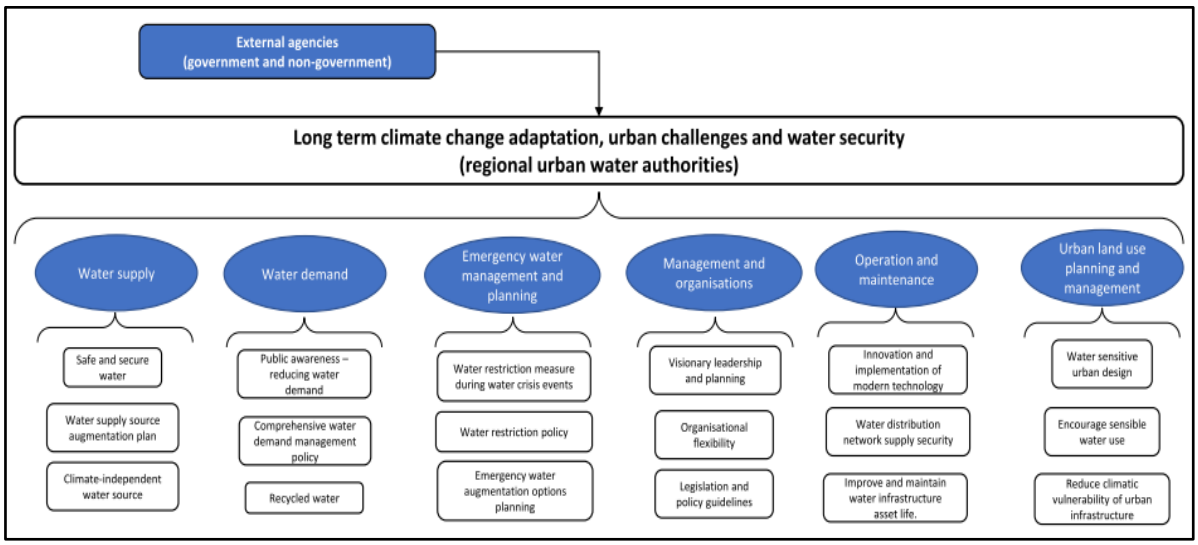

Figure 2.1. Concept of long-term adaptation for climate change and water security
Source: Ray Biswas et al., 2022

On the other hand, mitigation is more of an effort to reduce any activities that may cause greenhouse gas (GHG) emissions (UN Water, 2020). In terms of water, efforts could be made by reducing water consumption, implementing rainwater harvesting systems to conserve water, and improving the efficiency of water use in industrial and agricultural sectors.

In the Netherlands, the projections toward flood protection in terms of climate actions are dominated by river widening and dyke improvement, according to National Delta Programme

2021. For drought prevention, the projections are embodied in form of 202 measures from the regional scale of measures to the main water system in general in the 'Freshwater supply' project (National Delta Programme 2021). In general, the vision of the Netherlands towards climate resilient nation that also covers flood and drought resilience is emphasized in detail 'Climate Agreement' where there are commitments regarding built environment, mobility, industry, and electricity (Ministerie van Economische Zaken en Klimaat, 2019).

2.2. Climate resilience

The definition of resilience differs among study fields (Zhou et al., 2010). Resilience is usually defined as a system's capability to cope with sudden disturbance and the ability to get back to its normal condition (Leichenko, 2011). Others defined it as the ability of ecosystem to "endure" towards shocks or changes, but this endurance does not have to mean that the system should steady still (Holling, 1973; Meerow & Stults, 2016). Furthermore, the discussion regarding resilience involves five main dimensions; social, economic, institutional, infrastructural, and environmental (Assarkhaniki et al., 2020).

According to International Energy Agency (IEA), climate resilience is the ability to foresee, ingest, accommodate, and recover from detrimental impacts of climate (IEA, 2021). Specifically for flood, flood resilience depends on the capability to immediately recover from a flood calamity (Gilbert, 2010; Kuang & Liao, 2020; Lhomme et al., 2013). In addition, there are several types of floods: flash floods (sudden and massive floods due to high intensity of rainfall), coastal floods (flooded coast by the sea water due to wind-push generated by the storm), urban floods (mostly caused by inappropriate drainage system in urban area), fluvial floods (floods caused by the overflow of rivers), and pluvial floods (floods due to inadequate water catchment in the area when high precipitation occurs). On the other hand, a precise definition of drought resilience or drought adaptation is difficult to find. Only in one paper, drought adaptation is described as a combination of private (individual behaviours) or public (government-driven) measures (van Duinen et al., 2015). However, referring from the definition of resilience in general, drought resilience could be described as the capability to withstand from water deficiency and recover back to the initial condition.

Urban resilience is the ability of urban system with its socio-ecological and socio-technical networks beyond period and spatial scales to recover from shocks, to justify with changing conditions, and change the systems that restrain present or upcoming adaptive capacity (Meerow et al., 2016). In relation to urban resilience, Zwolle is currently challenged by floods which are caused by extreme rains and droughts along the dry periods in recent years (Casiano Flores et al., 2023).

2.3. Disaster risk management cycle

The disaster risk management cycle is a well-known approach to understanding and manage disaster events and their impacts (Ahmad Basri et al., 2022; Rana et al., 2021). Alexander (2002) describes four stages of the DRM cycle that take place before, during, and after the disaster: preparation, response, recovery and mitigation, as can be seen in Figure 2.2. Each stage of the cycle has their own period to be executed, from days to years (Tay et al., 2022). Moreover, the use of those four stages of disaster risk management cycle is also implemented by the European Union as their disaster risk management policy (Albris et al., 2020; European Commission, n.d.) that is why this framework is considered as suitable tool to assess flood and risk management in Zwolle, and its integration across different authorities in terms of management and policy.

Specifically for flood, flood risk has been visualised as phenomena caused by complex and dynamic interactions in natural and human systems (Herath & Wijesekera, 2020). The

application of DRM cycle in flood management and components per dimension can be seen on the Table 2.1. In that table, there are several measures that can be taken for flood risk management categorised specifically to each phase in DRM cycle.

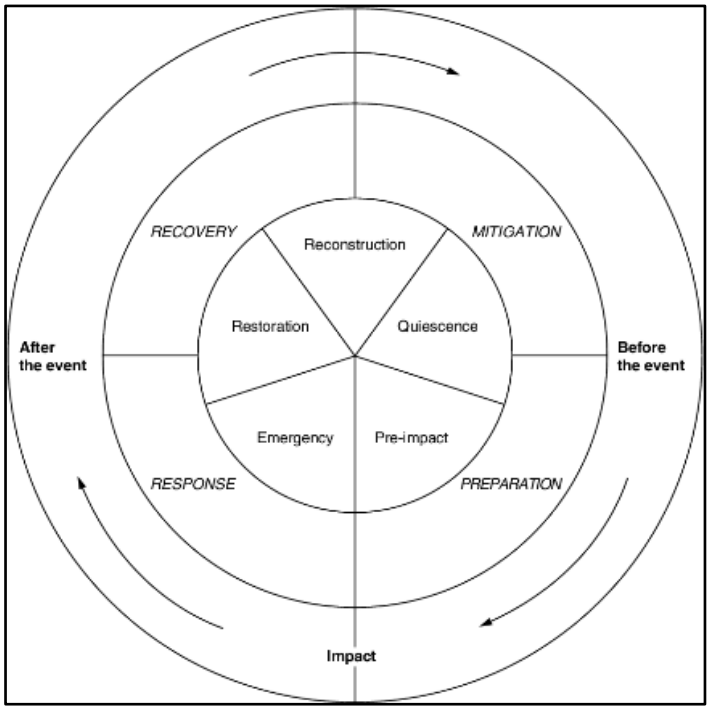

Figure 2.2. Disaster risk management cycle
Source: Alexander (2002)

Table 2.1. Flood risk management based on DRM cycle (Rana et al., 2021)

Phase on DRM cycle	**Dimension**	**Measures**
Preparation	Institutional	- Financial resources
		- Technical experts' availability
		- Early warning system
	Community	- Knowledge in flood risk / risk perception
		- Community preparedness plans
Response	Institutional	- Social media elaboration on risk
		- Community trust
		- Integrated contingency plan
		- Roles and responsibilities during emergency
	Community	- Evacuation scheme
		- Evacuation route
		- Relief camps availability
Recovery	NGOs	- Trust by government institutions
		- Financial checks by government institutions
	Institutions	- Methods for damage assessment
		- Relocation ad resettlement protocols
		- Trust in local institutions
	Communities	- Social capital on urban settings
Mitigation	Structural	- Construction of embankment
		- Cleaning of drainage/canals
	Non-structural	- Control on buildings
		- Embankment condition
		- Clarity on boundaries of jurisdictions and responsibilities

Drought risk management can be in form of engineering measures (pumping system, water project, etc.) and non-engineering measures (laws and regulations) (Liu et al., 2021). The application of DRM cycle in drought management and measures taken are shown in Table 2.2.

Table 2.2. Drought risk management based on DRM cycle (Primadita et al., 2021).

DRM cycle phase	Measures
Preparation	- Water shortage' real-time monitoring in every water infrastructures - Monitoring on groundwater level - Hotspot monitoring identification with terrestrial imagery or sensory - Forest area management to reduce forest-fire during dry season - Encourage cropping plants that suit dry conditions - Provision on water pump assistance
Response	- Weather modification technology - Groundwater usage when water from river is insufficient
Recovery	- Stabilisation on prices and amount of yields - Supports on clean water - Supports on energy deficits - Conservation on catchments areas
Mitigation	- Early-warning system from meteorological forecast - Mapping on drought risks, exposure, hazard, and vulnerability - Develop training program on severe drought events

2.4. Criteria and indicators for resilience assessment

There are several ways of using indicators or criteria to assess flood and drought resilience.

2.4.1. Flood indicators

De Bruijn (2004) explained indicators for flood risk management in environmental dimension, such as monitoring amplitude, graduality, and recovery rate. The assessment can also be done through social indicators, such as community participation, social support, shared information, etc. (Khalili et al., 2015). Furthermore, there are indicators that focus on safety and broader water-related problems, which include awareness, strategies, more space for rivers, spatial planning, knowledge, responsibilities, investments, and international co-operation (van Stokkom et al., 2005; Van Stokkom & Witter, 2008). Table 2.3 shows the indicators for flood risk management that I found in previous studies, grouped into each resilience dimension.

Table 2.3. Flood indicators and resilience dimensions

Dimension	Indicator	References
Social	Community participation, social support, shared information, awareness, knowledge	Khalili et al. (2015), van Stokkom et al. (2005), Van Stokkom & Witter (2008)
Economic	Investment	van Stokkom et al. (2005), Van Stokkom & Witter (2008)
Institutional	Strategies, spatial planning, responsibilities, international co-operation	van Stokkom et al. (2005), Van Stokkom & Witter (2008)
Infrastructural	More space for rivers	van Stokkom et al. (2005) Van Stokkom & Witter (2008)
Environmental	Amplitude, graduality, recovery rate	De Bruijn (2004)

2.4.2. Drought indicators

Commonly-used drought indicators are in form of reliability, resilience, and vulnerability (RRV) indicators (Hazbavi et al., 2018). The RRV indicators have a range (e.g., 0.53 ± 0.21), which is obtained by conducting a series of calculations for each indicator (Hashimoto et al., 1982; Hazbavi et al., 2018; Kjeldsen & Rosbjerg, 2004).

Drought indicators can also be in form of indicators by using Standardized Precipitation Index (SPI) and Standardized Precipitation Evaporation Index (SPEI) (Bachmair et al., 2016). Both indices are expressed in form of a scale (e.g., +1.5 to -2). Furthermore, a study using SPI to categorize drought had ever done in Germany and the Netherlands by observing more than 2,000 groundwater wells among those countries (Kumar et al., 2016). The example of SPI and SPEI values can be seen in Figure 2.3.

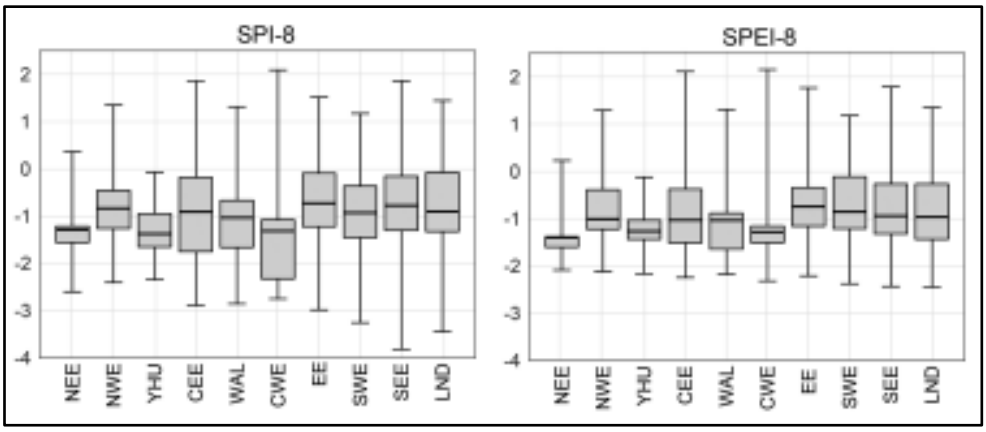

Figure 2.3. Example of SPI and SPEI values
Source: Bachmair et al., 2016

In the Netherlands, there are five relevant indicators for drought risk management (Mens et al., 2021): 1) Intensity and severity of soil moisture deficiency; 2) Average levels of groundwater during summer; 3) Intensity, duration, and level of saltwater intrusion; 4) Intensity and level of water shortage from main rivers, lakes, and canals; 5) Frequency and duration of low water depths along the main waterways which could impact inland shipping. In Table 2.4, I summarise the indicators for drought risk management that I found in scientific papers, and group them into resilience dimensions.

Table 2.4. Drought indicators and resilience dimensions

Resilience dimension	Indicator	Reference
Social	Resilience, vulnerability	Hazbavi et al. (2018)
Economic	Livelihood dependency on agriculture	Meza et, al. (2019)
Institutional	Reliability	Hazbavi et al. (2018)
Infrastructural	Population without access to clean water, poor water quality, total capacity of dam	Meza, et al. (2019)
Environmental	SPI, SPEI, soil moisture, groundwater level, saltwater intrusion, level of rivers, lakes, and canals, level of water depths in waterways	Bachmair et al. (2016); Mens et al. (2021)

2.4.3. Integration of flood and drought management

To have a better understanding on disaster risk reduction measures and strategies between flood and drought, it is essential to consider the interaction between those phenomena, because in

practice, those measures and strategies usually focus on either flood or drought (Ward et al., 2020).

Particularly for flood management, the government of the Netherlands has a multi-layer safety approach, which enables cross-sectoral collaboration of authorities to work on each phase in DRM cycle that is implemented on the layers as described by Bosoni et al. (2021). They created a table of policy integration to show the corelation between multiple institutions with their roles of each layer in multiple-layer safety approach. Figure 2.4 shows the interaction between each institution with every layer of the multi-layer safety approach for flood risk management.

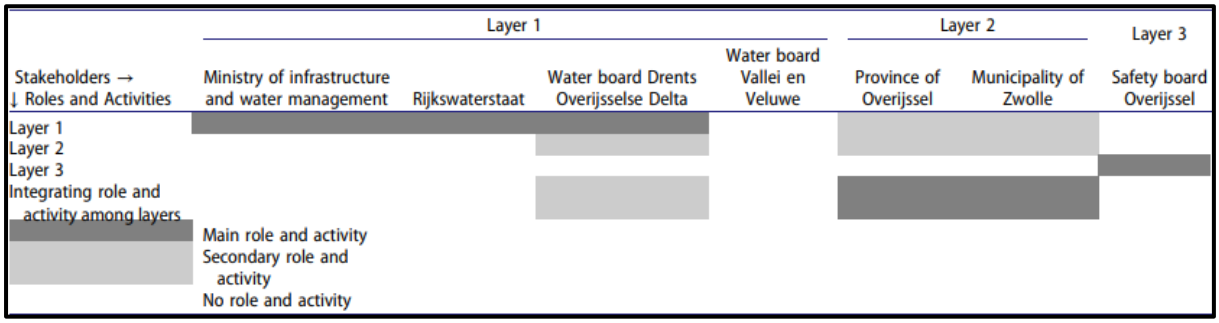

Figure 2.4. Policy integration among authorities in multiple-layer safety approach
Source: Bosoni et al., 2021

Layer 1 focuses on flood prevention, and in the DRM cycle it is considered as the preparation phase. Layer 2 is more into spatial planning which is related with preparation and mitigation in DRM cycle. The last layer is about disaster management that closely similar with response phase in DRM cycle (Alexander, 2002; Bosoni et al., 2021).

For drought management, on the other hand, I could not find any specific reference about its corelation with DRM cycle. It was also difficult for me to find a comprehensive program of drought management in the Netherlands to further connect it with the phases of DRM cycle.

2.5. Cross-sectoral policy integration

In this research, the term ‘integration’ refers to policy integration where multiple sectors are involved in a joint policy, or when there is more than one element of policies that are mutually integrated (Baulenas & Sotirov, 2020). Flood and drought management in Zwolle involve several institutions from administrative government (municipality, provincial), technical government (water authority, safety region), and inter-sectoral government (work region), where there are cross-policies in the form of shared activities among them. Therefore, examining the policy integration in this study is relevant to understand flood and drought management in Zwolle and its surrounding regions, especially given the connection with disaster risk management, an inherently cross-sectoral issue.

3. Research Methodology

3.1. Overall methodology

Since this research is more in collecting data by conducting document reviews and interviews with stakeholders, and not requiring any technical calculations, this type of research is best to be identified as qualitative research. The collected data was further analysed based on the requirements contained in research questions, such as comparing and assessing.

3.2. Case selection

I selected the city of Zwolle and the surrounding rural areas due to sever reasons. The first reason is due to my interest on seeing Zwolle city in the Netherlands which is having a firmed plan towards climate resilience improvement, and having a unique geographical profile since it is located between the IJssel and Vecht rivers also makes this zone a suitable area for researching in flood and drought resilience. On the other hand, my involvement on Delta Futures Lab project which is located in Zwolle becomes the additional reason.

3.3. Data collection

Data required for this research study are in form of primary and secondary data. The primary data is collected through interviews with several stakeholders: WDO Delta, Municipality of Zwolle, and provincial government of Overijssel. I conducted two preparatory interviews with representatives from WDO Delta and Municipality of Zwolle in February and March 2023, respectively. Further interviews then conducted continuously in June and July 2023 in the period of data collection of this research.

Table 3.1. Interview respondents

Code	Organisation	Date of interview
1	WDO Delta	Feb ‘23
2	WDO Delta	Feb ‘23
3	Gemeente Zwolle	Mar ‘23
4	Gemeente Zwolle	Jun ‘23
5	WDO Delta	Jun ‘23
6	Provincie Overijssel	Jun ‘23
7	Climate resilience expert	Jun ‘23
8	Veiligheidsregio IJsselland	Jul ‘23
9	RIVUS	Jul ‘23

The interviews were in the form of semi-structured interviews, a common method in data collection for qualitative research (Kallio et al., 2016). This type of interview is selected since it is suitable for addressing complex research questions in social-behavioural subjects (Adeoye-Olatunde & Olenik, 2021), where there is a list of questions related with objective data or information, and some of the questions listed are developed according to the answers from the respondents. The interview questions are also adjusted based on the expertise of each respondent, so respondents can receive different types of questions. All the interviews were recorded under the consent from the respondents and next the recordings are transcribed into text using software.

Table 3.2. Research questions and data sources

Research question	Type of data needed	Data sources
How is flood and drought data used by the governmental authorities to improve climate resilience in Zwolle and surrounding regions?	- Data regarding flood and drought events that is used for flood and drought management - Process that authorities conduct to take decisions on improving flood and drought resilience by using the flood and drought data	- Interviews with WDO Delta and the municipality of Zwolle - KNMI - Helpdesk Water - Waterschap Aa En Maas - Gemeente Zwolle website - Klimaatadaptatieve Delta
How is the assessment of flood and drought resilience applied in Zwolle and surrounding regions with respect to the principles of Disaster Risk Management Cycle?	- DRM cycle principles - Principles applied in Zwolle to manage disaster risk for flood and drought - Criteria and indicators of social, economic, institutional, infrastructural, and environmental dimensions used to assess flood and drought	- Interviews with WDO Delta, Gemeente, Zwolle, province of Overijssel, Veiligheidsregio IJsselland, and climate resilience expert - Previous scientific studies on DRM cycle
What is the degree of integration between local and regional governments in flood and drought management to improve climate resilience?	- Information on whether and how local and regional governmental organisations and networks collaborate in their activities for flood and drought management	- Interviews with WDO Delta, Gemeente Zwolle, Province of Overijssel, Veiligheidsregio IJsselland, RIVUS and climate resilience expert

The secondary data are collected from grey literature sources, such as websites, reports, brochures from the governmental authorities. Most of the authorised websites which are originally published in Dutch could automatically translated into an English on the browser, while information in form of brochures is mostly written in Dutch, so it has to be translated first.

I used the Scopus database to search for scientific articles, which has a wide coverage of social knowledge (Özerol et al., 2018). In addition, I used several keywords, like 'flood management', 'drought management', 'flood resilience', 'drought indicators', 'indicator dimensions', 'policy integration', etc. For each keyword, I found many articles, but I sorted it based on 'relevance' and I prioritised to select the articles that conducted or applied in the Netherlands. The function of scientific articles for this study are not using them as a data source, but as references regarding previous studies that relate with this research topic. For the literature sources that also provide data which are relevant for the Zwolle case and its surrounding areas, I use it for secondary source of data as well.

3.4. Data analysis

I used software for processing and analysing data from interviews. First, I did the data processing by transcribing the recorded interviews with Amberscript, the transcript obtained from the software then reviewed to remove words which are not related with the discussion and to make the transcription text more concise. After the transcription text was ready, I coded by categorising per topic based on the keywords of the research questions, such as 'disaster risk management', 'community participation', 'integration, etc. using the Atlas.ti software. Then I categorised the coded data according to the topics that are related to each sub-question. question. Below I describe the data analysis method for each sub-question.

1. *How is flood and drought data used by the governmental authorities to improve climate resilience in Zwolle and surrounding regions?*

To identify the types of data gathered and used by WDO Delta, Municipality of Zwolle, and provincial government of Overijssel, before, when, and after the flood or drought occurred in Zwolle and in surrounding rural areas. These types of data are in form of all component indicators (e.g., community participation, spatial planning, access to clean water, groundwater level, etc.) contained in resilience dimensions; social, economic, institutional, infrastructural, and environmental. The analysis is in form of finding out how those data influence the decision making of each authority to take measures on improving resilience on flood and drought.

2. *How is the assessment of flood and drought resilience applied in Zwolle and surrounding regions with respect to the principles of Disaster Risk Management Cycle?*

This research question aims to compare between answers from sub-question 1 with the basic principle of disaster risk management cycle. In addition, I ask about detail criteria and indicator for risk management of flood and drought through interviews with all authorities to enrich data that are going to be compared with the principles of Disaster Risk Management Cycle from the literature.

3. *What is the degree of integration between local and regional governments in flood and drought management to improve climate resilience?*

Finally, through this research question I assess the extent to which one authority's flood and drought management is integrated with other authority's management. If there is integration, I also explain how the integration form looks like. This assessment process could be reviewed by using answers that I obtain from sub-question 2 with additional questions on interviews that specifically ask about the existence of integration on flood and drought management in one authority with the management in other authorities.

3.5. Ethical considerations

It has been explained before that this study will conduct interviews with several stakeholders. Therefore, it is essential to consider ethical values towards interview respondents. Since the interviews are in form of semi-structured interviews with typical of open-ended questions, the interview are mostly recorded. Besides applying general data protection regulation (GDPR) guideline, I also asked them to fill consent form as form of their approval for being interviewed and recorded. The faculty of Behavioural Management and Social Sciences (BMS) obliges every student who conduct interview or survey for research or thesis to submit the proposal for ethical assessment. Thereby, the research could only be started if the student has sent the proposal to BMS Ethics Committee and gain approval from them. The chart of personal data use according to GDPR is attached on Appendix A.

4. Results

Findings are elaborated per sub-question in this chapter. I begin with the flood and drought data used by Gemeente Zwolle and WDO Delta, proceeded with a comparison between applications of flood and drought resilience in Zwolle and DRM principles, and finished with the assessment of integration between the municipality of Zwolle and WDO Delta regarding flood and drought management.

4.1. Flood and drought data used by governmental authorities

In this research, data and information used for flood and drought management are divided into three major categories. The first type is in the form of community participation and sharing information among the citizens. This type of data mainly uses websites provided by the government as the platform. The second one is for monitoring and evaluation, which it is mostly conducted by the authorities in the form of modelling software and programs. The last type of data is based on results from research about climate resilience, specifically related to flood and drought. Besides those major types of data, other data used by the authorities for flood and drought management in Zwolle and its surrounding areas are in the form of weather forecasts. For example, the prediction of heavy rainfall in the upcoming period, or if the upcoming period is predicted to be dry. Moreover, Python software is also used for certain analyses (Respondent 2), application of drones for experiments in monitoring the extent of floodings, and using data from satellite for certain measurements like evaporation and soil moisture content. All gathered data is used by authorities to manage flood and drought. For example, report from community in revising risks maps to mitigate flood and drought impacts, results from monitoring and evaluation that are used by the water authority as input to the municipality for spatial planning, etc.

4.1.1. Community participation and sharing information in flood and drought data creation

The municipality of Zwolle provides 'MijnWijk', an online platform for the citizens so that they can share their ideas towards improvement of the neighbourhood. "*The platform performs like a bottom-up initiative, where the citizens act like 'the boss'. If people have initiative or opinion regarding [a] climate-resilience project, they can submit it in a platform called MijnWijk*" (Respondent 3). First things that citizens can see from the homepage are ideas from inhabitants in form of community's activities, plans on facilities, and news regarding livelihood which related with environmental impacts in the neighbourhood. In addition, people can also view others' ideas and join the conversation to discuss the ideas with others. On MijnWijk, there is no specific action that classified for flood and drought. All ideas and initiatives from citizens are merely in general form of actions to improve climate resilience in Zwolle, such as 'Greening waste and street', 'Building façade gardens', 'Green meeting jetty', etc. The overview of MijnWijk can be seen in Appendix B.

The municipality also informs citizens regarding government's actions towards climate adaptation and energy transition through their website 'Dit doet de Gemeente' (Gemeente Zwolle, n.d.a). Additionally, several contents from Zwolle adaptation strategy and green-blue network are shown in separate menus, where each menu contains concerns about the content, and their projects or plans towards this content. Specifically, there are three menus that specifically discussed about climate, flood, and drought: Zwolle adaptation strategy, Green-blue network, and Climate change.

In ‘Zwolle adaptation strategy’, there are explanations about collaboration forms, criteria about sensitive areas, climate opportunity map, and reminder to all inhabitants to pay attention to their own lands’ measures. On the menu of ‘Green-blue network’, most content merely describes the benefits of greenery, and offers advice about tile removal from private properties. Contents in the section on ‘Climate change’ are presented in four points. Two of those points focuses on flood, one on drought, and the last one on heat. Some efforts by the government to tackle floods are mentioned, for instance infrastructures, dike reinforcement, and a map showing areas vulnerable to flood based on the conducted stress test. For the drought section, I could only find some measures mentioned, for example ‘active groundwater level management’, ‘cooling water regulations’, but no comprehensive description. Apart from receiving information, citizens can contribute to improve their environment by removing tiles in their private residences, which enables rainwater to infiltrate to the underground optimally (Dit doe de Gemeente Zwolle).

The residents of Zwolle can participate in updating vulnerability maps regarding floods. On the Zwolse Klimaatatlas website (Gemeente Zwolle, n.d.b), there is a link for citizens to make a report if they experience floods in their surrounding area. The area reported by the citizens is then added to the map to update the data. Moreover, residents use this platform to report the heat stress that they experienced (Respondent 4). The inhabitants can also contribute to maintaining the performance of dikes, which is essential for flood protection. As stated by a respondent from WDO Delta “*If someone spotted a rat or beaver making holes into the dike, then we have to make an emergency inspection to see if that is the case, and we have to take measures to prevent damage on the dike.*” (Respondent 2).

4.1.2. Monitoring and evaluation of data for drought and flood management

The respondent from the water authority explained about tools and data that they use for flood and drought management, model simulation, data record, equipment usage in some monitoring points up to satellite surveillance (Respondent 1). These tools and data play an essential role as it provides city planning, administration of land, and risk management (Casiano Flores & Crompvoets, 2020; Wu, et al., 2012).

Groundwater profile and monitoring

Groundwater profiling is one of the most essential indicators for drought management in the Netherlands. Most water usage for agriculture in Netherlands are withdrawn from groundwater, whereas groundwater plays an essential role in keeping the stability of land from land subsidence and to prevent sea water intrusion especially in coastal areas. Therefore, to keep the groundwater level stays in predetermined standard, the authorities monitor it through the depth of groundwater level. This measurement is done by monitoring the depth between the existence of groundwater beneath the ground with ground surface. In addition, this measurement profile can be accessed online in several monitoring spots spread all over the Overijssel Delta through their official website which is affiliated with ArcGIS Waterbeeld (Respondent 1).

Other data used for monitoring drought risk are also in the form of SPI and SPEI. These indicators are monitored online in 1,080 spots over the jurisdiction of WDO Delta, and it is monitored together with the provincial government and Vitens, the drinking water company (Respondent 2) through Droogteportaal (Informatiehuis Water, n.d.). The overview of SPI and SPEI monitoring website can be seen in Appendix C.

Surface water monitoring

Surface water levels are monitored for keeping the groundwater level in a proper regulated standard, which is achieved by controlling input and output water into the system. In rainy season or wet periods, the groundwater level is high, and if the ground contains too much water, it will not be fit for agricultural use. In that case, water from surface water system is discharged by pumping it out, “*when lowering the surface water levels, you can drain the [groundwater]*”

(Respondent 2). During dry periods, the groundwater level drops, and the water authority pumps water into the system to maintain the groundwater level. The monitoring of surface water level is conducted continuously especially during the dry period, because the use of groundwater for irrigation depletes groundwater quickly; the pump then works continuously to charge the water into the water system. However, if the water surface level gets too low, then pumping water into the system will not be feasible. Consequently, the water authority should take measures to overcome this situation, such as forbidding farmers to irrigate their crops (Respondent 2).

4.1.3. Research and development in flood and drought management

Besides contributions from people, applying methods and sophisticated tools, the sustainability of flood and drought management in Zwolle and its surrounding regions should be maintained by conducting collaborative research and development for both flood and drought. Results from such research and development can be also used for decision-making in urban planning.

Stress test

Stress test is a method to identify the potential of natural hazards in certain areas, which is initiated by the Delta Plan on Spatial Adaptation Commission. According to the plan (Kennisportaal Klimaatadaptatie, n.d.), a stress test aims to predict the possibilities of an area towards heat, drought, urban flooding, and waterlogging. This test is urged to be conducted every six years for every province, municipalities, and regional water authorities. The procedure to carry out stress test is standardized and guided by instructions, such as background information related to climate vulnerabilities, directions on how to map the vulnerabilities by using public basic information and advice on the usage of the stress test results. Moreover, the stress test is based on modelling or simulation by using existing data, and not conducted by taking samples of environmental elements, such as dirt, water, and air. The team of the stress test is simulating the model of some environmental scenarios that might happen in Zwolle and predict the possible impacts (Respondent 4). However, some points on the website of Kennisportaal Klimaatadaptatie are about subjects not meant by the stress test. For example, "*The stress test sets no mandatory standards*" and "*The stress test does not result in a list of suitable adaptation measures*". In response to the question on how the government institutions use the outcome of stress test, Respondent 4 states that they it to adapt spatial planning to climate change, especially for new projects in housing and infrastructure. The results of the stress test can be accessed on the website of Delta Plan on Spatial Adaptation 2018 (Voorbelden, n.d.), as shown in Appendix D.

STOWA (Stichting Toegepast Onderzoek Waterbeheer)

As indicated by its name, STOWA is a foundation for applied research in water management. This organisation consists of members from groundwater and surface water managers from water authorities in the Netherlands, whose main focus covers water systems, water defence, wastewater systems, and water chain. (Respondent 2). The focussed research on STOWA is not categorised specifically into flood and drought fields. However, I still could find some specific published documents regarding floods by opening the menu of 'Deltafacts' such as 'Spatial development and on flood defence', 'Floods directive', and 'Reduce flood risks by compartmentalisation dikes'. For drought, I could only find 'Drought determines function'. The overview of those findings is depicted in Appendix E. Specifically for Zwolle, I see a report about action perspectives toward water-robust Zwolle within the Salland waterways (STOWA, n.d.).

4.2. Comparison of flood and drought resilience applications with DRM cycle principles

Several flood and drought risk management approaches are applied to improve climate resilience in Zwolle and surrounding regions. Based on the interviews I conducted with respondents from municipality Zwolle and WDO Delta, I found more information regarding risk management by WDO Delta. The following methods and framework are specifically divided into five-layer approach to flood prevention, groundwater models, surface water and damage, and response action towards flood and drought by regional safety region, and will be compared with DRM cycle respectively.

4.2.1. The application of flood and drought disaster risk management in Zwolle

Five-layer approach to flood prevention

After the severe flooding in Limburg in 2021, the Ministry of Infrastructure and Water Management released an advise for flood and high-water prevention which was released in December 2022 (Ministerie van Infrastrutuur en Waterstaat, n.d.). This advice aims to improve the former approach of flood safety from three to five layers. Previously, the multi-layer approach of safety consisted of 1) 'prevention', which relies on technical and engineering measures, i.e., dikes, 2) 'mitigation', which focuses on spatial planning, and 3) 'crisis management', which is related to the evacuation scheme.

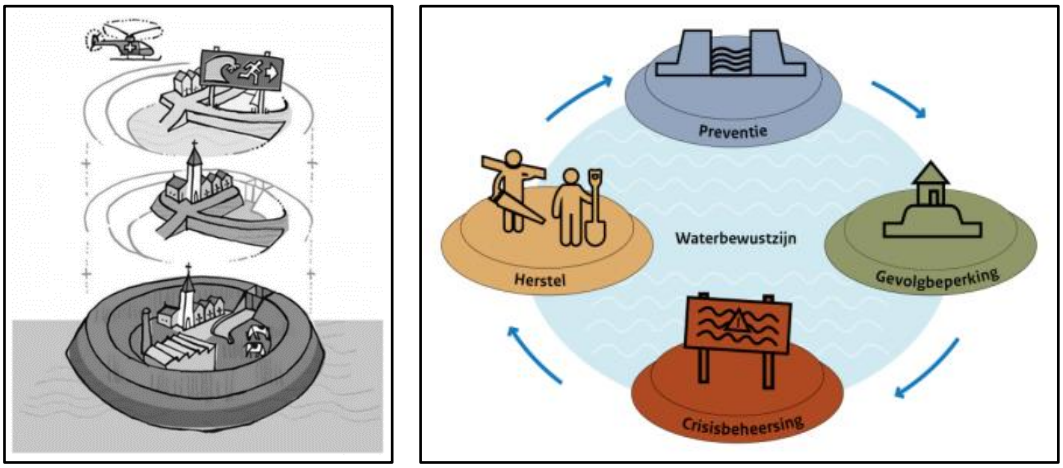

Figure 4.1. Multi-layer of flood safety approach from 3 (left) to 5 (right) layers
Source: Bosoni et al., 2021 (left)
Final Advice on Policy Table for Flooding and High Water (right)

As seen in the above figure, in the new safety approach, there are two additional layers: 'recovery' and 'water awareness'. These layers are derived from the theme of the final advice 'prevention is not possible, but preparation is', where it urges all societal components from governments, citizens, and companies to be prepared for extreme precipitation, which is expected to become more frequent and intense in the future. Table 4.1 compares each aspect in the five-layer flood safety approach with the four phases of the DRM cycle.

Table 4.1. Comparison between the 5-layer flood safety approach and DRM cycle

5-layer flood safety approach	**Phases of the DRM cycle**			
	Preparation	**Response**	**Recovery**	**Mitigation**
Prevention	✓			
Mitigation				✓
Crisis management		✓		
Recovery			✓	
Water awareness	✓			

The ‘prevention’ layer contains all technical and engineering measures to prevent flood, such as enhanced dikes, so the efforts in this stage correspond to the ‘preparation’ phase of the DRM cycle. On the next layer, ‘layer mitigation’ covers spatial planning to build city order from housing, infrastructures, and facilities, all built to reduce the impact that might be caused if and when flood happens. Therefore, this layer is closely related with the ‘mitigation’ phase of the DRM cycle. Next, the action form as a reaction of inevitable flood is depicted in ‘crisis management’ where the authorities start to enforce emergency situation such as evacuation scheme for all citizens, which corresponds to the ‘response’ phase of the DRM cycle. The ‘recovery’ layer in the flood safety approach is obviously in-line with the ‘recovery’ phase in DRM cycle. Lastly, ‘water awareness’ is considered as ‘preparation’ in DRM cycle due to citizen’s understanding of flood complications, so by being aware of it, they can contribute to take action regarding the risk of flood.

In Zwolle, the five-layer approach is essential, since this delta region is vulnerable to floods. The first layer is about the dikes that protect the city and surrounding regions. The dikes are one of the responsibilities of the water authority: The provision of dikes is included in the function of ‘water safety’ from the water authority. The next layer is ‘mitigation’ which is related with spatial planning conducted by the municipality. The water authority can also give advice for the spatial planning especially if it is related with water infrastructures. The layer of ‘crisis management’ deals with emergency actions like evacuation scheme and things to do or not to do during the flood happened, which is under the authority of Veiligheidsregio, and it is also considering input from the water authority, “*As a water authority, we supply them with advice. What's the likelihood that the dike will break, what is going to happen if the dike break? Which area would be flooded? How fast is the water coming into certain areas? How high is the water coming*?” (Respondent 2). For the next layer of the approach, I could not find a firm answer because, based on the statements that I received from the respondents, they suggested having a look at how the handling of flood recovery in Limburg was in 2021. Here I sense that there is still no fixed procedure on how to overcome the aftermath of the flood if it happens in Zwolle and surrounding regions. The last layer is ‘water awareness’ which is widely disseminated in every government’s program that is related with water. It is promoted in the municipality’s official website, on the website of Delta Plan on Spatial Adaptation, and on other institutions’ publications. This ‘water awareness’ layer is becoming the responsibility of every organisation and all the citizens from various layers of society.

Models for groundwater, surface water and damage

While multi-layer safety approach is specifically for flood risk management, it was explained that the water authority uses several kinds of other tools for each flood and drought risk management. “*We use a lot of tools for droughts. We for example, have groundwater models, and for floodings we have surface water models which we can use to check if our water system still meets the standards which we want to accommodate. We also have damage models so we can also make a kind of protection*” (Respondent 2). For drought risk management, they apply ‘Methodiekontwikkeling voor Interactieve Planvorming ten behoeve van Waterbeheer’ (MIPWA), a hydrological instrument for groundwater modelling or simulation, developed by a consortium of several regional water authorities, provincial governments, and private companies. The software uses data from land use, soil data, precipitation and evaporation data from KNMI, and data about groundwater abstraction for drinking water. Those data then are simulated to profile groundwater in the designated area (MIPWA, 2022).

For flood risk management, the water authority uses several software for flood modelling, such as SOBEK and 3Di. SOBEK is not only for flood modelling, but also for other simulations such as drainage system optimization, sewer overflow design, profiling river morphology, and many others. The simulated model can be represented as one-dimensional (1D) and two-

dimensional (2D) (Deltares, n.d.). For 3Di, the simulation starts with model building in a GIS format; then the software runs a simulation of the built model, and analysing the simulated result in cloud or personal computer (Lisa, 2022). The example of simulations by SOBEK and 3Di can be further seen in Figure 4.2.

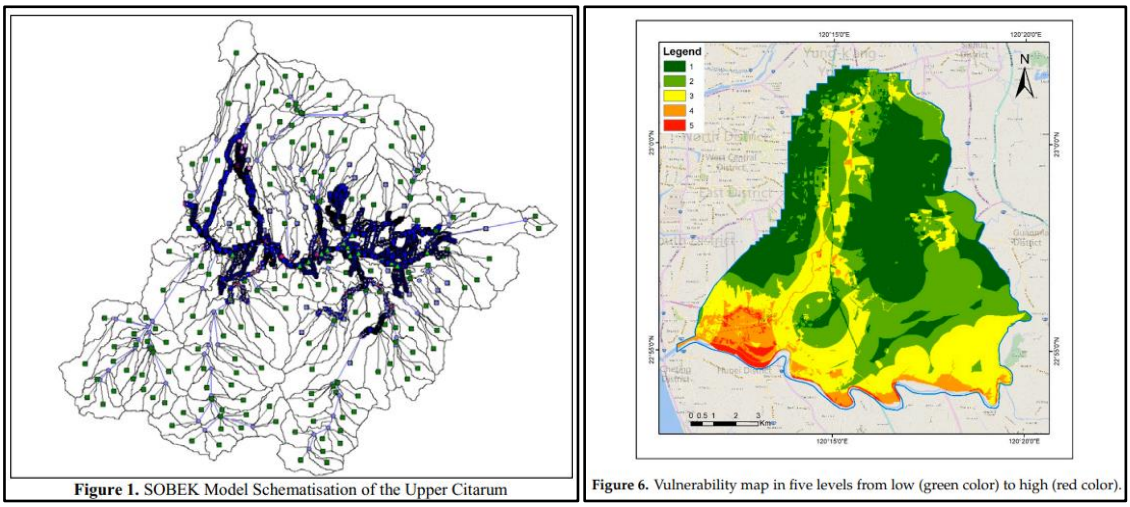

Figure 4.2. Figure example of SOBEK (left) and 3Di (right)
Source: Fauzi et al., 2020 (left),Afifi et al., 2019 (right)

In addition, the water authority applies other tools to simulate the possible damage separately from tools for flood and drought models simulations. Respondent 2 mentioned that they use 'Waterschadeschatter', a damage model developed by STOWA. Waterschadeschatter is like a water damage estimator which simulation can be requested by inputting some categories step by step on its web. They also use HIS-SSM, a standard method in the Netherlands to estimate flood damage by combining data of building and land-use in different types of spatial scales, and artificial curves of damage (de Moel & Aerts, 2011). The last one is Waterwijzer, a software related with, among others, drought and agriculture. The depictions of Waterschadeschatter, HIS-SSM, and Waterwijzer can be seen on Appendix F.

The abovementioned software and programmes can be applied in both of 'preparation' and 'mitigation' phases. "*It can be both* (preparation and mitigation), *but then it has to be used also like as a diagnostic way more*," (Respondent 7). Furthermore, those software and programmes are used by the water authority to simulate the situations that might happen in the future based on existing data. Therefore, I conclude that the application of these tools is in-line with the 'preparation' phase of the DRM cycle. The results of the modelling by these tools are also used as considerations for spatial panning that aim to reduce the impact of flood and drought' risks, and this is in accordance with the 'mitigation' phase.

Response action towards flood and drought by regional safety board

As part of IJssel region, general security management in Zwolle and its surrounding areas is handled by the regional safety region of IJsselland (Veiligheidsregio IJsselland). The regional safety region usually consisted of and located together with health centre or Gemeentelijke Gezondheidsdienst (GGD) and firefighter station (Brandweer). The role of Veiligheidsregio is more in 'response' phase in DRM cycle, since the services provided by this authority are mostly to overcome happening issues like fire, flood, health emergency, and many others (Veiliheidsregio IJsselland, 2023).

Regarding flood management, the regional safety region arranges an evacuation route when a severe flood occurs. For evacuation, the safety region accepts a command from the mayor of

the municipality within the discussion with crisis organisation, Furthermore, the crisis organisation is a temporary team formed when a disaster happens, it consisted of fire department, police, emergency service, and representative from the municipality. For the evacuation route, people would be directed to the area where the utilities are well provided and also safe from the flood impact, and no such a kind of prioritisation in terms of specific sectors like healthcare facilities, power plants, industrial areas, or any other sector "*Our focus is the continuity of the society, because our priority is to save people's lives and animals, that is our priority. Because that's by law.*" (Respondent 8).

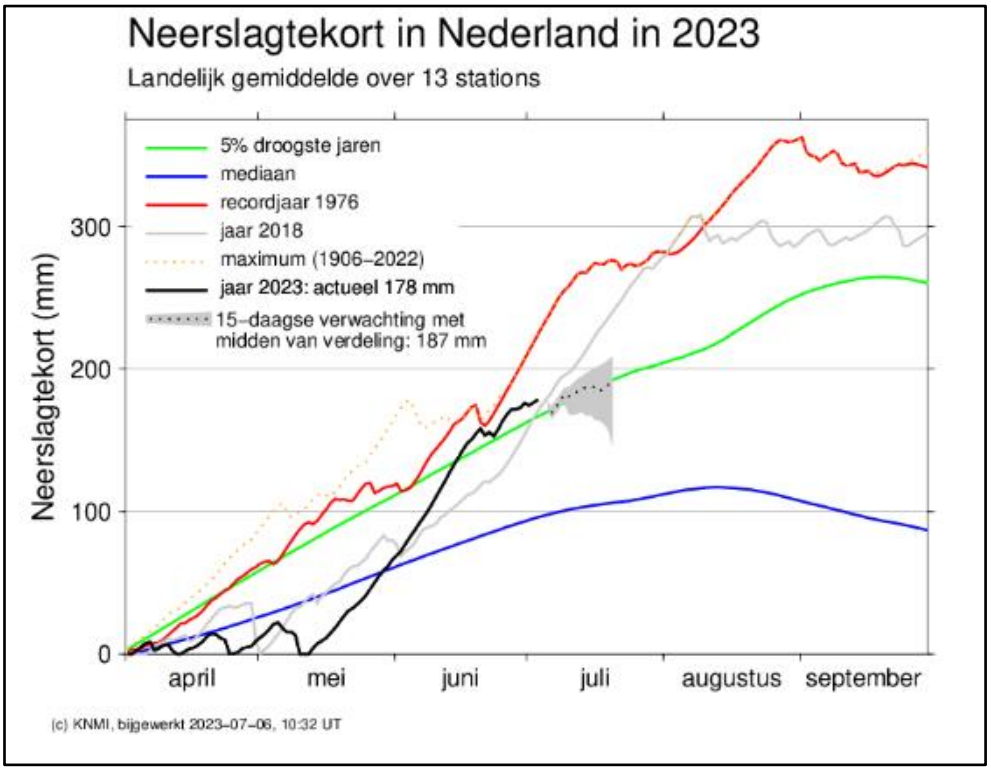

Figure 4.3. Precipitation deficit in 'drought monitor' from KNMI
Source: Online Waterberichtgeving, n.d.

For drought management, the Veiligheidsregio monitors the critical drought event through 'drought monitor' from KNMI's website. The figure above depicts the precipitation deficit as a measurement of drought. The black line shows the actual condition, when there is indication about period of 'crisis management'. If this situation keeps going to be worse, there is a possibility for the authorities to take measures towards industries, and perhaps farmers (Respondent 8). Furthermore, the Veiligheidsregio also deals with the aftermath of decision-making. For example, anticipating the mass protest due to groundwater prohibition during drought period, "*A few years ago, it was also in the drought period, and they (farmers) were blocking industries roads. We facilitated a conversation between some mayors, some representatives from the government, and some farmers groups, and try to sit them together and facilitate the conversation, and maybe hopefully they come together and giving another outcome than only protesting.*" (Respondent 8).

4.2.2. Flood and drought management criteria in Zwolle

In chapter 2, I reviewed the indicators used for flood and drought management and categorised them into five different dimensions: social, economic & financial, institutional, infrastructure, and environmental. In this section, I present my findings on each of those dimensions and elaborate on them with respect to DRM cycle and the involved stakeholders.

Most of the indicators in the ***social dimension*** are related to the preparation phase, and it applies generally to both flood and drought management. In addition, the indicator of 'social support' is categorised as response phase in DRM cycle due to the activity of report from community if there is a puddle that already concerned as disturbance. People can report it through the Zwolse Klimaatatlas (Gemeente Zwolle, n.d.b.) and help the authority renew the vulnerability map of flood. The indicator of 'vulnerability' is also categorised as response phase in this dimension because this indicator related with health risk, especially elderly who are more vulnerable to heat stress and drought. Therefore, the Veiligheidsregio provides things to do and to be avoided when dealing with drought and a hotline number for emergency.

For the indicators of the ***economic dimension***, the relevant DRM phases are diverse, especially for indicators 'fundings' and 'investment'. These indicators are related to spatial planning, infrastructure maintenance and development, which cover preparation and mitigation phases. In addition, 'livelihood dependency on agriculture' indicates the portion of people in Zwolle who have an occupation in the agricultural sector. This sector is related to drought as it would be the front-line sector that is impacted by drought.

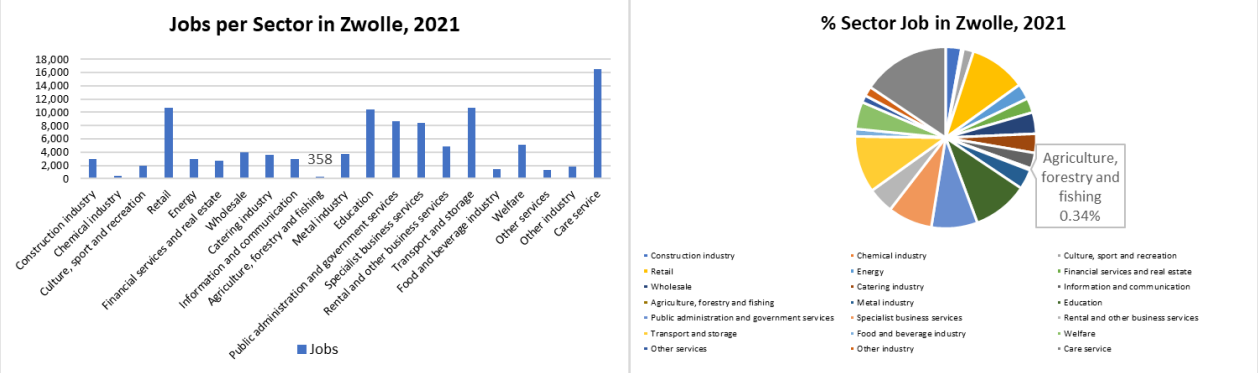

Figure 4.4. Number (left) and percentage (right) of sectoral occupation in Zwolle in 2021
Source: Labour Market In Zicht, n.d.

Figure 4.4. shows the portion of jobs per sector in Zwolle for the year 2021, the most recent data that accessible about occupation profile. The portion of agricultural sector is published together with forestry and fishing. However, from this data, I can conclude that the indicator of 'livelihood dependency on agriculture' does not have much impact since the agricultural sector has the lowest portion of occupation. On the other hand, the indicator of 'increasing crop yields' is relevant for the water authority. They conduct trainings for farmers to help them increase their crop yields or improve water retention during dry periods (Respondent 2).

Indicators in ***institutional dimension*** have complete phases of DRM cycle; both preparation and mitigation phases are applied in 'national and international cooperation' and 'spatial planning'. The water authority is actively involved in almost all indicators, especially for the cooperation and the prohibition of groundwater use. In addition, the water authority helps other institutions, giving advice for spatial planning with the municipality, and providing information regarding the prediction of flood impact for Veiligheidsregio to prepare an evacuation route scheme when severe flood occurs. On the other hand, the provincial government has the main role on legal term like regulating the groundwater use.

The following table represents indicators for flood and drought management in detail based on respective dimensions of social, economic, institutional, infrastructure, and environment. All indicators are specified into types of flood and/or drought management, and also provided with information of responsible authorities for each indicator. As can be seen, the indicators between flood and drought are nearly equal in number, and WDO Delta turns out to be the most responsible authority in indicators for flood and drought management.

Table 4.2. Application of indicators for flood and drought management

Dimensions	Indicators	DRM Cycle Phase	Flood	Drought	Gemeente Zwolle	WDO Delta	Provincie Overijssel	Veiligheidsregio IJsselland
Social	Knowledge & awareness	Preparation	✓	✓	✓			✓
	Community participation	Preparation	✓	✓	✓			
	Social support	Response	✓	✓	✓			
	Shared information	Preparation	✓	✓	✓			✓
	Vulnerability (health risk)	Response	✓	✓				✓
	Community resilience	Preparation	✓	✓	✓			
Economic	Fundings	Preparation, Mitigation	✓	✓			✓	
	Investment	Preparation, Mitigation	✓	✓			✓	
	Livelihood dependency on agriculture	Mitigation		✓	✓		✓	
	Increasing crop yields	Response		✓		✓		
Institutional	National & international cooperation	Preparation, Mitigation	✓	✓		✓		
	Spatial planning	Preparation, Mitigation	✓	✓	✓	✓		
	Groundwater usage regulation	Mitigation		✓			✓	
	Evacuation scheme due to severe flood	Response	✓			✓		✓
	Groundwater usage prohibition	Response		✓		✓		
	Recovery assessment after flood/drought	Recovery	✓	✓				
Infrastructure	Dikes management	Preparation	✓			✓		
	Water pump operation	Response		✓		✓		
	Sewage maintenance	Preparation	✓		✓	✓		
	Blue-Green Infrastructure	Preparation, Mitigation	✓	✓	✓			
	Groundwater level instrument	Preparation, Mitigation		✓		✓		
Environment	Flood inundation	Response	✓			✓		
	Graduality (water discharge vs damage)	Response	✓			✓		
	Recovery rate	Recovery	✓					
	Soil moisture, saltwater intrusion, water system level	Preparation, Mitigation	✓	✓	✓	✓		
	SPI & SPEI	Preparation, Mitigation		✓		✓		

The majority of indicators in ***infrastructure dimension*** are part of water authority's responsibility. It is indeed so due to infrastructural issues that mainly relate with technical aspects that are part of water authority's expertise, such as dikes, water system, and groundwater profile. However, both the water authority and municipality are responsible for the indicator 'sewage maintenance'. The indicator 'blue-green infrastructure' is related to spatial planning and city landscape, and therefore it becomes the main responsibility of the municipality, although the water authority can also give advice on it, especially in relation to water facilities, such as the sewage system and 'space for water'. This new strategy in Zwolle regarding spatial planning is called 'sponge city' (Respondent 7).

Blue-Green design principle	Spatial scale	Who?
1. Sufficient urban "sponges" for detaining (using), retaining or delaying rainwater.	Buildings, streets and neighbourhoods.	Municipality of Zwolle together with its residents and actors.
2. Blue-green city network on which "sponges" can drain excess water and in which discharge and storage takes place.	Neighbourhoods, districts and city.	Municipality of Zwolle together with water authority of WDODelta.
3. Emergency valves for the blue-green network and overflow areas where water can temporarily go in extreme situations.	City, region and delta.	City of Zwolle together with water authority of WDODelta, province of Overijssel and neighbouring municipalities.

Figure 4.5. Principles of blue-green Infrastructure in Zwolle and involved stakeholders
Source: Royal Haskoning DHV, n.d.

Most indicators in the **environmental dimension** are specific for flood or drought management except the indicator of 'soil moisture, saltwater intrusion, water system level'. The indicators of 'flood inundation' and 'graduality' are related to flood (Respondent 2). For the indicator of 'soil moisture, saltwater intrusion, water system level', it is applied generally for flood and drought, and the monitoring of this indicator is conducted by the water authority and sometimes with the municipality. While the indicator of 'SPI & SPEI' is specifically for drought, and it is regularly monitored by the water authority through online platform.

4.3. Integration of flood and drought management among authorities

After defining the types of data and the coherence with the DRM cycle, I analyse the integration of governmental authorities involved in flood and drought management in Zwolle and its surrounding regions. The integration will be depicted in form of relation between each phase in DRM cycle, authorities, and its relevance with flood and/or drought, while the description will be described per institution. The overview of authorities' integration based on DRM cycle phases, with detailed activities and the correlation with flood and drought, can be seen in Appendix G.

Starting with Gemeente Zwolle, I identify the activities that are the municipality's main tasks: awareness raising, public participation, spatial planning, stress test, sewage system maintenance, and monitoring the soil moisture, groundwater level and water system level. Although they are in charge for those tasks, the majority of the tasks are conducted together with the water authority and almost all the shared tasks are also part of water authority's main responsibilities as well, such as sewage system maintenance, and monitoring on soil moisture, groundwater level, water system level.

The municipality and the water authority play major roles in flood and drought management in Zwolle and surrounding areas. Furthermore, besides some main tasks mentioned previously,

the municipality also has some other duties like checking on groundwater monitoring equipment, involve in climate adaptation research on flood and drought, although they are just slightly responsible.

WDO Delta is responsible for both water management in Zwolle city and surrounding areas, and for the development and management of dikes as the first layer of multiple-layer approach for flood management. Regarding drought management, they are responsible for the operation of water pumps to keep the groundwater level stay in predetermined standard. In addition, the water authority has shared tasks with the municipality such as, give suggestion for spatial planning, sewage management, etc. The overview of sewage management is as follows: "*Sewerage system in Netherlands is divided into several systems. If it is connected to the house, then it's a responsibility of house owner. When it goes to the street it is a responsibility of the municipality. And when it goes to wastewater treatment plant, it is a responsibility of the water authority. And then it flows back to the river, which is the part of service water again, and then the water drinking supply that you get; that's the responsibility of Vitens. So that's how the cycle works basically, and our responsibility is to maintain our tasks well.*" (Respondent 4). There is an effective cooperation between the water authority and the municipality, especially in sewage system as one of main water infrastructures in water management.

In terms of water management, the provincial government is not in charge of sewage management (Respondent 6), while it is responsible for groundwater policy, waterways and recreational use of water (Respondent 7). However, this responsibility on water matters is mostly independent and not related with other institutions. Additionally, the connection between provincial government with water authority is like a horizontal relation where the provincial government really counts on the water authority since there are a lot of expert in water authority, "*I think that we are now getting to more on a like equal level with them* (the water authority) *and they have more experts, I think that's a good thing and we have a good collaboration with them*," (Respondent 6). On the other hand, the relation between provincial government with municipality is seen more like a vertical connection. Most of the projects from municipality has to be assessed and approved by the provincial government, "*Sometimes it's a bit difficult because we want to work with them* (the municipality) *on an equal level, but we also have to assess all their plans in the areas*," (Respondent 6). Moreover, the provincial government also acts as a budget provider for plans in the municipality, so it is like more emphasizing the hierarchical level of the provincial government above the municipality.

Besides being legally connected in horizontal and vertical relations, governmental authorities in Zwolle also participate in regional work programme called Delta Plan on Spatial Adaptation (Klimaat Adaptatie Nederland, n.d.). There are 45 working regions (werkregios) in the Netherlands established to make Netherlands climate-proof and water-robust by 2050 (Klimaat Adaptatie Nederland, n.d.). The working region in Zwolle and its surrounding areas is called RIVUS. This program focusses on wastewater chain, which is embodied into five different themes: public health, climate resilience, environmental impact, reliability, and the recovery of energy and raw materials (RIVUS, n.d.). Regarding flood and drought management, RIVUS helps the authorities in Zwolle to conduct the stress test that can help for preparation and mitigation towards floods and droughts in the future. The result of the stress test are communicated with related parties to make decisions on the assessment of climate risk impact, whether the risks should be addressed or accepted, follow up actions toward addressed risks, and to establish agreements if needed (Respondent 9).

RIVUS involves eight municipalities: Dalfsen, Deventer, Kampen, Olst-Wijhe, Raalte, Staphorst, Zwartewaterland, and Zwolle, with Overijssel province and WDO Delta complimenting this work region. The example of recent collaboration is socialisation about soil

and water control (Water en Bodem Sturend) from the Ministry of Infrastructure and Water Management, which is related with flood and drought prevention. Within the work region, they learn to understand this policy, what it means for the municipalities, how to apply it, etc. Other projects on flood include creating more space for water by removing tiles from house gardens to prevent the rainwater flowing directly to wastewater system, and managing subsidies for these projects.

The form of collaboration is mostly in form of regular meetings. The meetings are varied from meeting among all staff members from municipalities and provincial government, up to the managerial meetings, which is less frequent. In addition, the meeting agendas mostly focus on the work progress, make sure that the work fits the budget that was being agreed upon.

Specifically for drought, the province of Overijssel has a recent research programme on increasing need for recreational water in the region: "*So, it becomes hotter. People want to go outside, they want shade, they want water, they want cooling down. So, we have more swimming, more shipping, more boats, … what can we collectively see, what are the trends there, are there any issues, does it have an effect on water quality?*" (Respondent 9). Drought also impacts GHG emissions; that is why the province takes this issue seriously: "*Where the water is lower, [it] means we have more CO_2 that leaves the soil. So, that's […] an issue because we have to reduce our CO_2 footprint.*" (Respondent 9).

5. Discussion

This thesis has three objectives: 1) to improve the understanding about types of data used for flood and drought management, 2) to compare the application of flood and drought risk management in Zwolle and its surrounding region with the principle of DRM cycle, and 3) to assess the integration of flood and drought management in Zwolle and its surrounding region among institutions. Findings regarding the objectives are described in Chapter 4, and discussed in this chapter, with reflections from previous studies.

5.1. The availability of data for flood and drought management

I divided the types of data based on the form and how to obtain them, and not categorising them into flood vs. drought data. As far as I could observe, the availability of data between data of flood and data of drought is imbalanced, since more data was available for flood than for drought. In addition, the existence of drought cases is merely connected within the EU Water Framework Directive briefly, without mandatory actions (Blauhut et al., 2022; Hervás-Gámez & Delgado-Ramos, 2019). This might be one of the reasons of the gap between data availability for flood vs. drought. Moreover, flood is considered as a main concern in the Netherlands, since it is highly vulnerable to flood. The first form of data used by the authorities is community participation. In Zwolle, the community participation is embodied in form of digital platform provided by the government: 'MijnWijk' and 'Dit doet de Gemeente'. In MijnWijk, the contents are mostly about citizens' activities, which are related with improving the neighbourhood like adding greeneries, creating eco-friendly space for public gathering. I found no specific content dedicated to flood and drought. However, those activities aim to enhance environmental performance through activities that citizens are able to do, and eventually can contribute to flood and drought prevention. While MijnWijk presents a summary and reflections on what people do for the neighbourhood, Dit doet de Gemeente, on the other hand, is more like a summary of information from the municipality about programs conducted by the government which are related with actions towards climate change and sustainability. Furthermore, from these two different platforms, I found a gap between the availability of data provided and actions conducted between flood and drought as explained in previous chapter. From this community participation type of data, I can conclude that the action that done by the inhabitants are still not directly contribute for each flood and drought preventions. In addition, the information provided by the municipality is found still imbalanced between projects for flood management and actions for drought management.

Monitoring and evaluation of data is mostly conducted by the water authority in form of groundwater profiling, monitoring parameters in the field, and analytical calculations. One of examples is data records, which is also obtained by monitoring using satellite and further used for calculating the main indicators to monitor drought. For this type of data in monitoring and evaluation, I found that it is technically more used for drought management. However, satellite technology such as Earth Observation (EO) can support flood management, and if it is combined with GIS, it can contribute to a high-resolution flood mapping and be useful for vulnerability assessment at the phase of prevention (Bach et al., 2004). Furthermore, authorities in Zwolle are capable to utilise technology for gaining more information for flood management.

Research and development can also contribute to creating data and information for flood and drought management. However, this form of information is not widely applied for specific regions in the Netherlands. STOWA has designated research projects for flood and drought in associated with climate adaptation programme, which are still national projects, and not

implemented in specific regions, like Zwolle. On the other hand, the stress test is more specific into regions, since it is conducted per area.

5.2. Methods used for flood and drought risks management

Frameworks to manage flood and drought risks include the multi-layer safety approach by the Ministry of Infrastructure and Water Management, and the tools used by the authorities. In Zwolle, the flood risk management there is based on the multi-layer safety approach from the ministry, where now there are additional of two layers that covers recovery which is one of the stage in DRM cycle. I can see that most of the efforts done by the authorities to prevent flood not only in Zwolle, but also in whole area in the Netherland are relying on the first two-phases of DRM cycle: prevention and mitigation. Ultimately for prevention, the government spends a lot in enhancing dikes and planned to allocate 750 million euros to strengthen Afsluitdijk (NBCnews, 2007). In terms of mitigation, the government established many research institutions for spatial planning and development, which aimed to create better urban planning to deal with climate change, and so for the flood and drought preventions. Some respondents mentioned that 'sponge city', an approach used to improve evapotranspiration, infiltration, and stormwater catchment in urban areas (Casiano Flores et al., 2023; Zevenbergen et al., 2018), is being implemented and developed in Zwolle, particularly to preserve excess water during rainy season and prevent floods, while during dry period, the preserved water can be used to prevent shortage. In addition, the safety region supports flood risk management in phase of 'response', where the safety region has already arranged plans to overcome severe flood. However, when it comes to 'recovery', most respondents could not give appropriate answers for steps or actions to be taken for flood recovery if it happened in Zwolle. They would give reference to try to look at Limburg case and ask me to find out the recovery scheme there. Based on this result, I conclude that in terms of recovery phase for flood risk management, the authorities of Zwolle still need improvement.

5.3. Interactions between authorities in flood and drought management

In terms of collaboration, I found that there is nothing specific between the interaction for flood management and for drought management in Zwolle. Since both flood and drought are related with water management, the water authority plays a major role in both. From most of the DRM phases, the water authority is in charge to maintain the dikes (prevention), simulate or modelling the area for spatial planning (mitigation), controlling water pump station and regulate groundwater usage (action). However, the water authority is also coordinating with other institutions for these tasks, for example, discussing spatial planning with municipality, planning evacuation with safety region, and sometimes collaborating with provincial governments to discuss about policy and regulations, especially about groundwater usage. While dikes management is closely related with flood prevention, the management of groundwater usage is closely related with drought management. In Zwolle, the provincial government is also in charge for groundwater policy for a broader use like recreational function, water ways, etc., and its management is connected with surface water level monitoring. This finding is in-line with a previous study that states any interest of groundwater levels should be balanced with surface water level management, since groundwater level management becomes water authority's responsibility and various interests attached within the water authority (Hellegers & Van Ierland, 2003). Besides collaboration as a form of interaction, I also found a coordination in form of hierarchical interactions, like the connection between

the municipality of Zwolle and provincial government of Overijssel. It is a common form of interaction since they are at different governance levels.

On the other hand, the existence of the work region adds more interaction among institutions on flood and drought management. At first, I thought that the role of work region would overlap with the job desks from related institutions since the members of the work region are from various institutions like water authority, municipality, and provincial government. But the interviews revealed that this work region is useful to establish a better coordination between institutions, for example when the central government released a regulation about water and soil control (Water en bodem sturend), the dissemination about this regulation is found easier within the work region. However, since the existence of RIVUS is still considered as new, it is not prominently involved in flood and drought management, although they work in climate adaptation.

5.4. Complications between results with the sub-questions

Regarding the first sub-question about data used for flood and drought management, most of the results I found were about climate change and sustainability, especially for data type of community participation and research. For example, regarding the community's activities towards environmental enhancement, I found no evidence on specific actions that can contribute to reduce flood or drought. In addition, most research is in the form of national pilot projects, so those are not appropriate enough to be applied in certain regions, especially Zwolle.

For the comparison between flood and drought management with DRM cycle, I was able to compare the methodology of risk management that used by the authorities for flood. Every stage in safety-layer approach is clearly aligned with the phases of the DRM cycle. However, regarding the frameworks used for drought management, most of them are in the form of modelling by using software and programs. I was expecting that they would use a particular framework, like what I found in flood risk management method. Previous studies, such as (Urquijo-Reguera et al. (2022), mention Drought Management Plans (DMPs) as a proactive risk-based management tool for drought, including components like drought hazard characterisation, drought vulnerability, and drought measures and management, as depicted in Appendix H. Instead of finding such frameworks as DMPs, the feedback that I received from respondents was more into tools that they use for drought management, like MIPWA, SOBEK, and 3Di.

Lastly, for integration assessment of authorities for flood and drought management in Zwolle, I wasn't able to achieve any specific findings, but there was a slight contradictive information that I received from different organisations about particular tasks. The respondent from water authority mentioned that together with the safety region they control the groundwater usage by inhabitants, especially farmers, when they had to prohibit groundwater extraction as a response to drought. In contrast, after I had the interview with the safety region, the respondent stated that it was merely the task of water authority. Furthermore, the respondent from the safety region confirmed that what they do in terms of response activity is handling the aftermath caused by groundwater extracting prohibition, such as protest actions from community or farmers, etc.

6. Conclusion

This chapter presents the conclusion from my research in finding answers for the main question: *How can flood and drought management be integrated to improve climate resilience in the city of Zwolle and the surroundings?* through answers to the three sub-questions. The following paragraphs summarize the answers, followed with a reflection on methodological limitations and directions for future research.

Data used by the authorities for flood and drought management in Zwolle and its surrounding areas are in form of community participation, monitoring and evaluation, as well as research and development. The inhabitants participate in improving the environmental quality in their neighbourhood by submitting their ideas and suggestions through an online platform provided by the government. However, these actions initiated by the community are not specified into categories of flood and drought, although they may contribute to flood and drought prevention in their areas. On the other hand, data for monitoring and evaluation are more in technical form and mostly collected and used by the water authority, for instance in monitoring groundwater and surface water. Research and development involve broader institutions, since it is a form of collaboration. In this study, I found the stress test and the research institutions like STOWA as prominent examples of research and development form of data, while stress test is obliged to be conducted by the Delta Plan on Spatial Adaptation Commission, STOWA's research is more into a national project supported by the government. However, the information provided by research and development mentioned are found not specialised for flood or drought management.

Management of flood and drought risks in Zwolle and surrounding regions in general comply with the phases in DRM cycle. The government implements the new form of multi-layer safety approach for flood risk management, which also covers the phase of 'recovery'. However, in the region of Zwolle and its surroundings, no concrete 'recovery' actions were found to overcome the situation if severe flood occurred in this area. For drought risk management, the respondents refer more to technical tools used for modelling groundwater, surface water, and damage simulation, rather than structured management, such as DMPs. Additionally, I applied several indicators to evaluate the performance of flood and drought management risks in Zwolle like social, economic, institutional, infrastructure, and environmental indicators. I found that the municipality and the water authority are dominantly in charge in most of the indicators for both flood and drought risk management, and most of the criteria applied are in form of 'preparation' and 'mitigation' phases according to DRM cycle.

The collaboration on flood and drought management in Zwolle and surrounding regions is involving several institutions from administrative authorities like municipality and provincial government, and also technical authorities like the water authority and safety region. The integration among them is mostly in form of sharing tasks like conducting stress test, sewage maintenance, monitoring water and soil indicators which are done by the municipality and the water authority. Other form of integration also conducted by giving suggestion in form to enhance the management performance like collaboration between the municipality and the water authority in spatial planning, and between the water authority and the safety region in arranging standard operational procedure for evacuation if severe flood happened. However, when it comes to policy, each institution has their own territory as part of their main responsibilities, such as the policy of groundwater use and water use for broader purposes, e.g.,

recreation, waterways, which are regulated by the provincial government, or the policy of prohibition on groundwater use to prevent drought, which is the responsibility of the water authority. Furthermore, it requires more than one institution's involvement to implement those policies, such as the municipality who is directly in-touch with the community, and the safety region who can support direct and technical operations, such as evacuation, emergency facilities in hospitals, etc. Moreover, besides those forms of collaboration mentioned, the organisations also collaborate in the work region, through the RIVUS.

Despite the rich empirical evidence it created, this study has some limitations in terms of technical aspects and study materials. Although the study was part of the Delta Futures Lab project, the time for data collection was quite limited, and while there were potential respondents that could be involved, some of them were difficult to be contacted and could not respond quickly. Additionally, since the study topic is considered as essential in the Netherlands, some of the sources were in Dutch, which even the respondents struggled to explain in English. In terms of research materials, I found that one of my study subjects, which is related with DRM cycle and integration of flood and data management, was slightly difficult to understand for some respondents. However, before and during the interviews, I tried to provide explanation about the subject, which helped them to eventually understand it. Hence, the data that I obtained which is related with management risk of disaster in both flood and drought have room for improvement. Additionally, I found that data and information regarding several regions around Zwolle city is not sufficient enough to support the impacts or connections between flood and drought management in Zwolle and the surrounding regions. Results showed that several activities are done not only by the Zwolle city itself but also in cooperation with other areas, for instance the maintenance of cross-area facilities, like pump station, water ways, etc. Dedicated interviews or other forms of data collection could have been conducted in these connected regions or municipalities around Zwolle.

Based on the results and findings I obtained from this study, I propose three future research directions. First, the connection between Zwolle and surrounding regions can be improved by specifically identifying more regions surrounding Zwolle which are significantly impacting the implementation of flood and drought management in Zwolle. This future research direction can be further elaborated in topic of urban-rural nexus in terms of flood and drought management. Second, the risk management of disaster for both flood and drought can be modified by using another framework besides DRM cycle. Although the framework of DRM cycle is widely used for risk management of disaster, the implementation of risk management for flood and drought in the Netherlands, especially in Zwolle, could possibly having a better review by applying different form of method. Lastly, a national-level organisation, such as Rijkswaterstaat, can be involved in such studies to give more insight and wider perspective about the complexity of flood and drought management, especially for Zwolle, which is located in a delta area and being part of national projects through Delta Plan on Spatial Adaptation.

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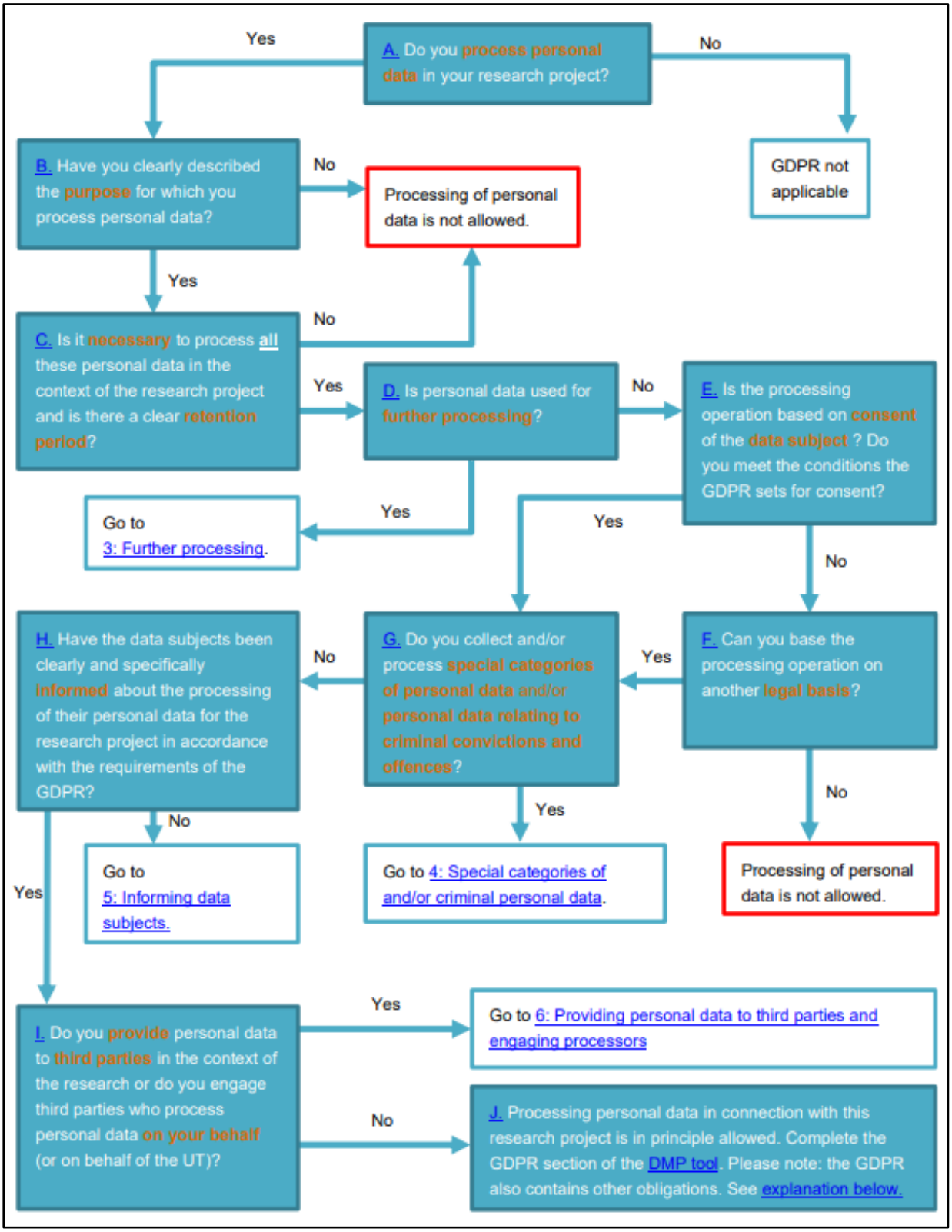
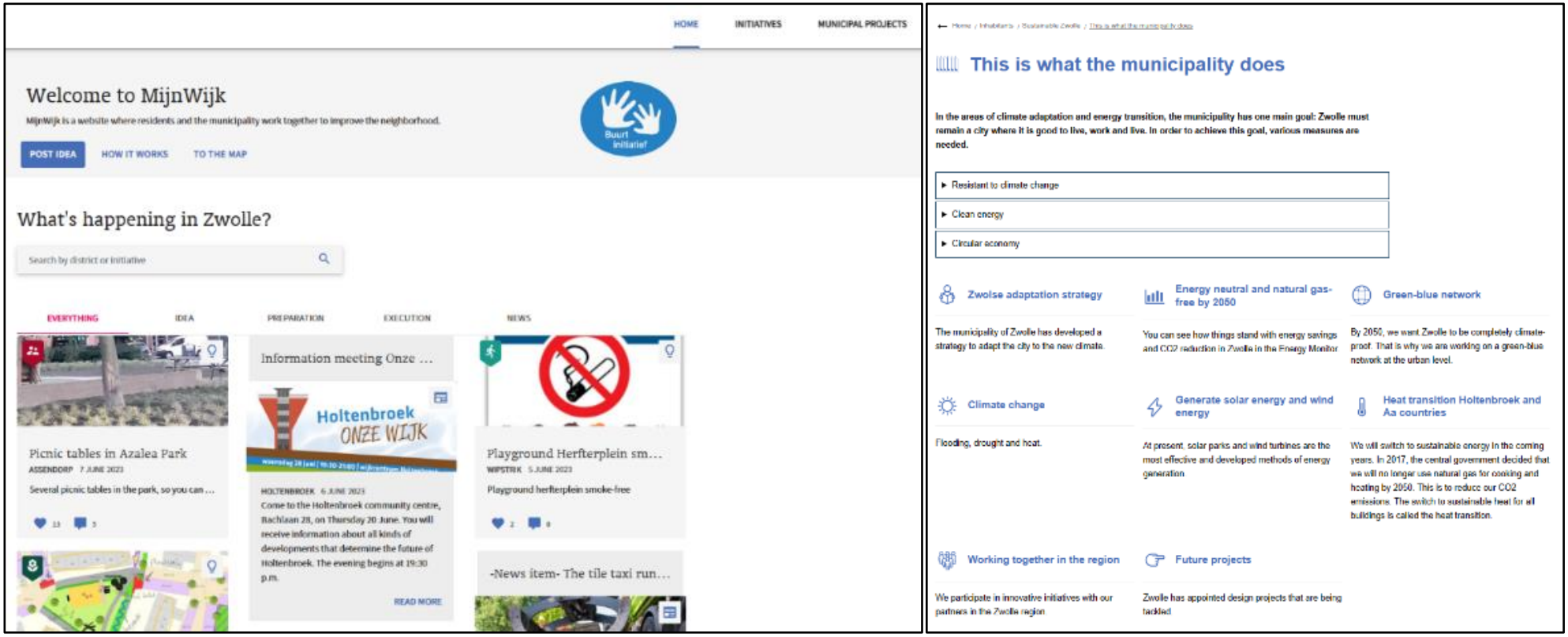
Appendix A – Flow Chart for Personal Data Use according to GDPR by BMS DataLab

The chart below explains the process of GDPR application in BMS Faculty, University of Twente from the beginning of process personal data identification through several sequences until it is stated 'applicable'.



Appendix B – Homepage of MijnWijk and Dit Doet De Gemeente

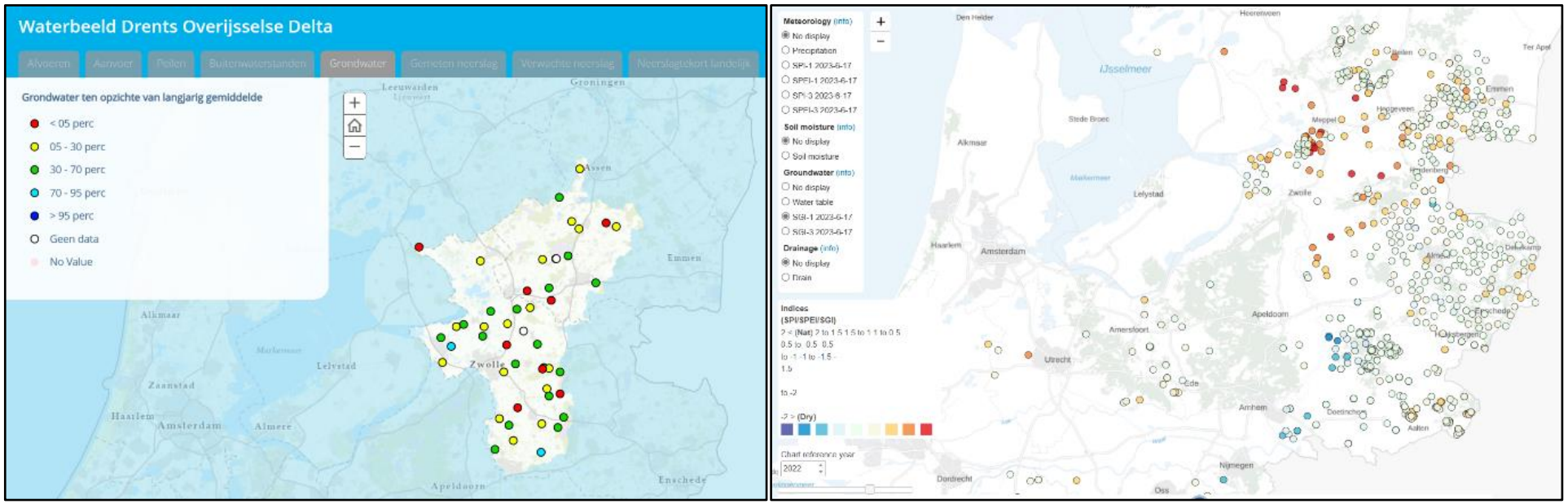
Homepage of MijnWijk (left) and Dit doet de Gemeente (right)



Source: MijnWijk (https://mijnwijk.zwolle.nl) (left), Gemeente Zwolle (n.d.a) (right)

Appendix C – Monitoring of Groundwater Level, SPI, and SPEI

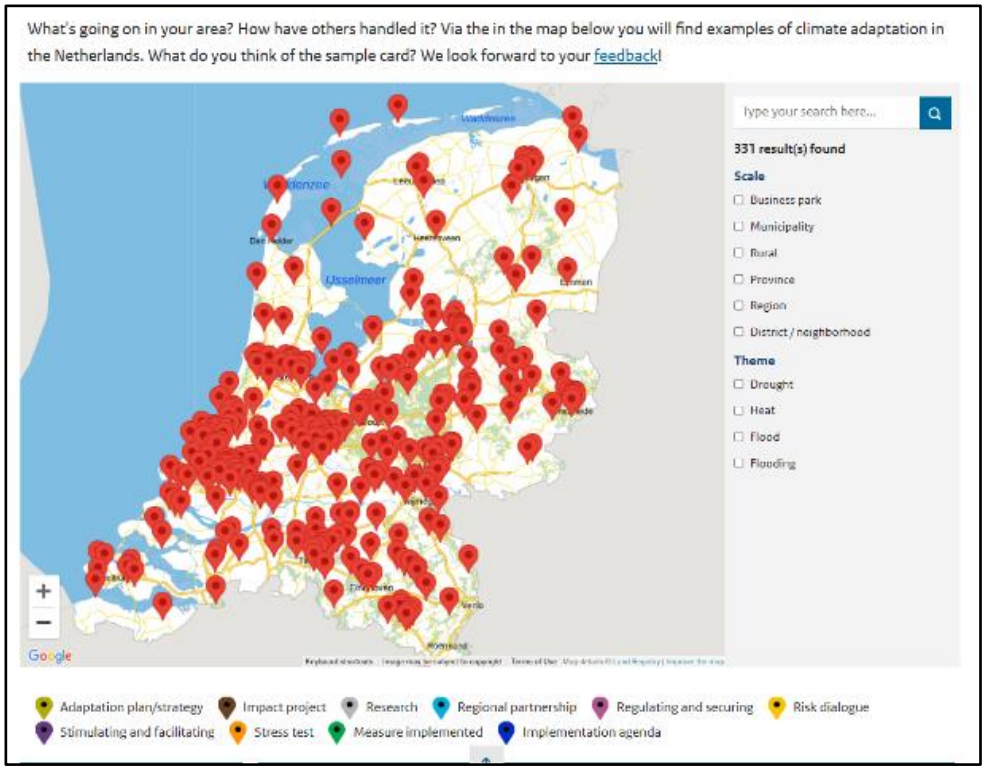
Online monitoring of groundwater level (left), SPI and SPEI (right)

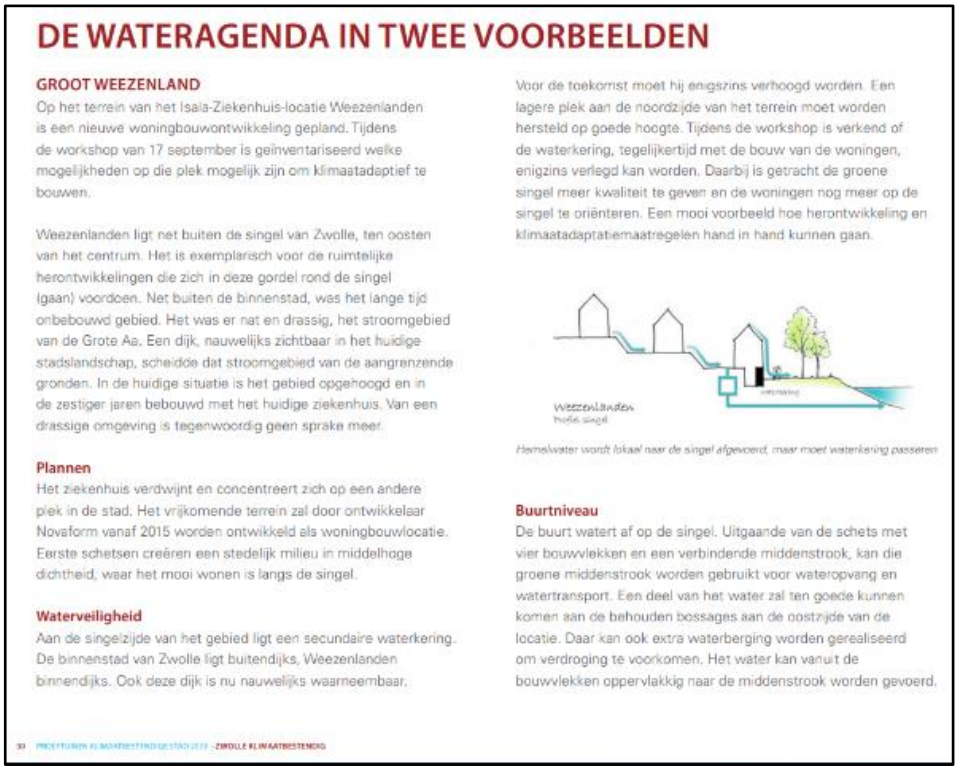


Source: Waterbeeld Drents Overijsselse Delta (arcgis.com) (left), Droogteportaal (right)

Appendix D – Stress Test

Locations of stress test (left) and example of stress test report in Zwolle (right)




DE WATERAGENDA IN TWEE VOORBEELDEN

GROOT WEEZENLAND

Op het terrein van het Isala-Ziekenhuis-locatie Weezenlanden is een nieuwe woningbouwontwikkeling gepland. Tijdens de workshop van 17 september is geïnventariseerd welke mogelijkheden op die plek mogelijk zijn om klimaatadaptief te bouwen.

Weezenlanden ligt net buiten de singel van Zwolle, ten oosten van het centrum. Het is exemplarisch voor de ruimtelijke herontwikkelingen die zich in deze gordel rond de singel (gaan) voordoen. Net buiten de binnenstad, was het lange tijd onbebouwd gebied. Het was er nat en drassig, het stroomgebied van de Grote Aa. Een dijk, nauwelijks zichtbaar in het huidige stadslandschap, scheidde dat stroomgebied van de aangrenzende gronden. In de huidige situatie is het gebied opgehoogd en in de zestiger jaren bebouwd met het huidige ziekenhuis. Van een drassige omgeving is tegenwoordig geen sprake meer.

Plannen

Het ziekenhuis verdwijnt en concentreert zich op een andere plek in de stad. Het vrijkomende terrein zal door ontwikkelaar Novaform vanaf 2015 worden ontwikkeld als woningbouwlocatie. Eerste schetsen creëren een stedelijk milieu in middelhoge dichtheid, waar het mooi wonen is langs de singel.

Waterveiligheid

Aan de singelzijde van het gebied ligt een secundaire waterkering. De binnenstad van Zwolle ligt buitendijks, Weezenlanden binnendijks. Ook deze dijk is nu nauwelijks waarneembaar.

Voor de toekomst moet hij enigszins verhoogd worden. Een lagere plek aan de noordzijde van het terrein moet worden hersteld op goede hoogte. Tijdens de workshop is verkend of de waterkering, tegelijkertijd met de bouw van de woningen, enigszins verlegd kan worden. Daarbij is getracht de groene singel meer kwaliteit te geven en de woningen nog meer op de singel te oriënteren. Een mooi voorbeeld hoe herontwikkeling en klimaatadaptatiemaatregelen hand in hand kunnen gaan.

Hemelwater wordt lokaal naar de singel afgevoerd, maar moet waterkering passeren

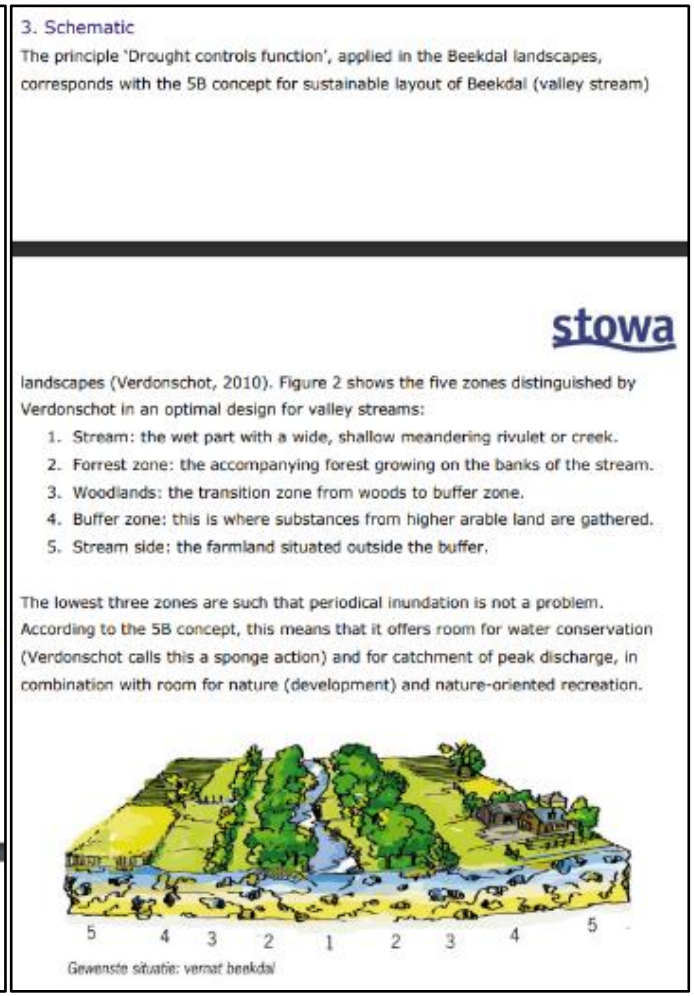
Buurtniveau

De buurt watert af op de singel. Uitgaande van de schets met vier bouwvlekken en een verbindende middenstrook, kan die groene middenstrook worden gebruikt voor wateropvang en watertransport. Een deel van het water zal ten goede kunnen komen aan de behouden bossages aan de oostzijde van de locatie. Daar kan ook extra waterberging worden gerealiseerd om verdroging te voorkomen. Het water kan vanuit de bouwvlekken oppervlakkig naar de middenstrook worden gevoerd.

Source: Kennisportaal Klimaatadaptatie (n.d.)

Appendix E – STOWA Publications on Flood and Drought

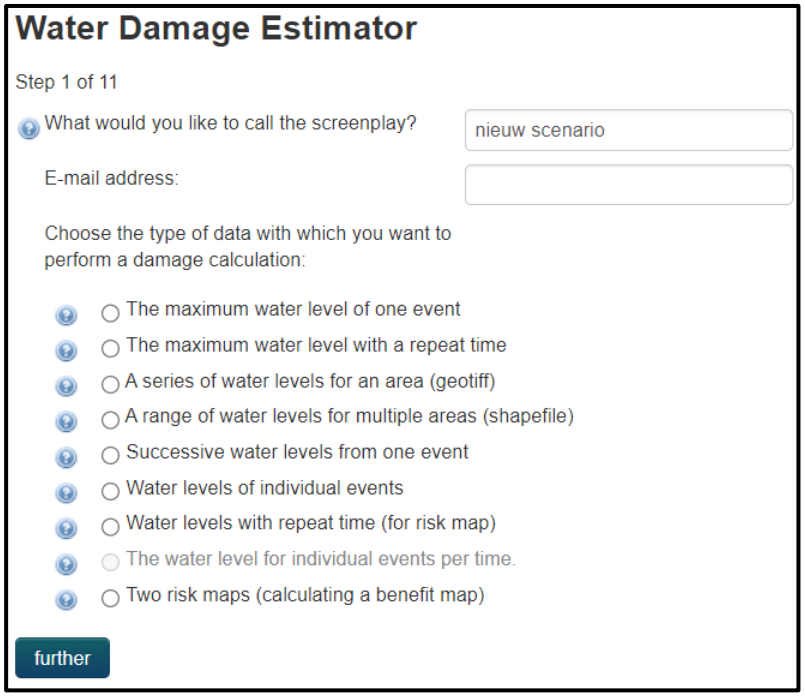
Publication related to flood (left) and drought (right)

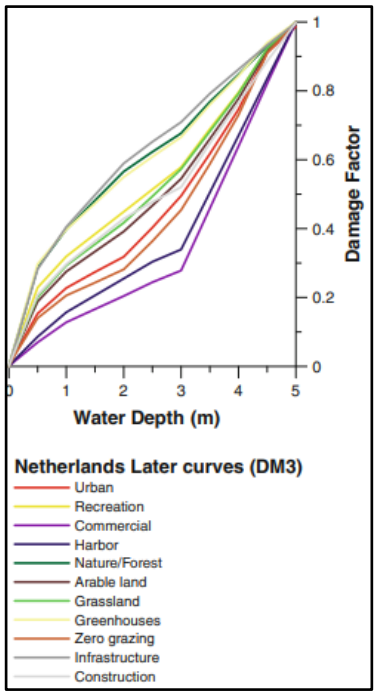


Source: Stichting Toegepast Onderzoek Waterbeheer (n.d.)

Appendix F – Waterschadeschatter, HIS-SSM, and Waterwijzer

Waterschadeschatter (left), examples of HIS-SSM model (middle) and Waterwijzer (right)





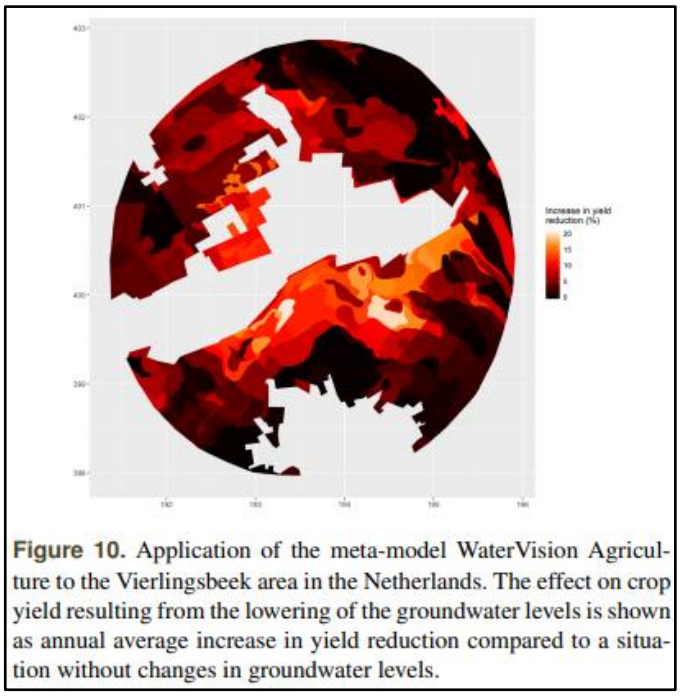


Figure 10. Application of the meta-model WaterVision Agriculture to the Vierlingsbeek area in the Netherlands. The effect on crop yield resulting from the lowering of the groundwater levels is shown as annual average increase in yield reduction compared to a situation without changes in groundwater levels.

Source: Waterschadeschatter, n.d. (left), de Moel & Aerts, 2011 (middle), Hack-Ten Broeke et al., 2016 (right)

Appendix G – Integration of activities, DRM cycle, and authorised organisations

DRM Cycle Phase	Activities	Organisation				Flood	Drought	Relevant quotes from interviews
		Municipality of Zwolle	WDO Delta	Overijssel Province	Veiligheidsregio IJsselland			
Preparation	Dikes maintenance and development		++			✓		"*Our national government has a program called the HWBP (Hoogwaterbeschermingsprogramma). It is a High-Water Protection Program, because as a water authority we are responsible for the dikes that are strong and high enough.*" (Respondent 2)
	Awareness socialisation	++	++			✓	✓	"*I think there's a growth in awareness, the initiatives that they have and some other neighbourhood initiatives, they're growing bigger*," (Respondent 4) "*If people have initiative or opinion regarding climate-resilience project, they can submit it in a platform called MijnWijk, … and probably could also schedule a meeting between the citizen and the representative of the municipality to discuss the idea.*" (Respondent 3)
	People's initiatives gathering	++				✓	✓	"*The municipality also have another way of participation like organising a big event to promote their project to the citizen and persuade the citizen to cooperate with the municipality to execute the project, and also asking their opinion directly*." (Respondent 3)
	Models' simulation		++			✓	✓	"*We use a lot of tools, … for example, we have groundwater models, and for floodings we have surface water models which we can use to check if our water system still meets the standards which we want to accommodate. We*

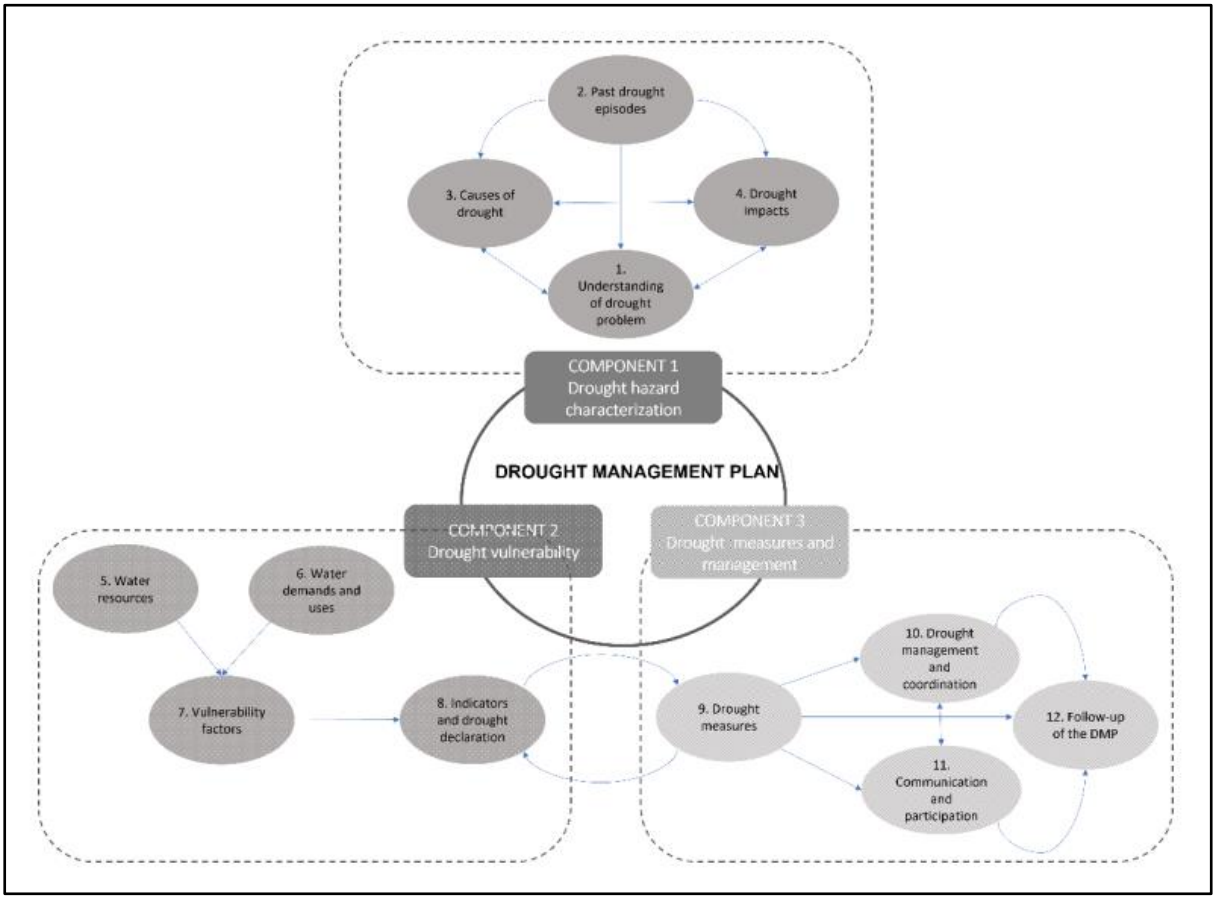
DRM Cycle Phase	Activities	Organisation				Flood	Drought	Relevant quotes from interviews
		Municipality of Zwolle	WDO Delta	Overijssel Province	Veiligheidsregio IJsselland			
								also have damage models so we can also make a kind of protection." (Respondent 2)
Preparation	Stress test	++	++			✓	✓	"*There is a stress-test conducted by the municipality to measure whether the area is adaptive or resilient enough towards the flood or drought case, the municipality uses this result to arrange adaptation strategy.*" (Respondent 3) "*The models that we simulate relate with the stress test that conducted by the municipality.*" (Respondent 2)
	Sewage system maintenance	++	++			✓		"*When it goes to the street, it is a responsibility of the municipality, and then it goes to wastewater treatment plant it is a responsibility of the water authority,*" (Respondent 4) "*There is an interaction between the sewer system which transport the wastewater and cleaning the water in our wastewater treatment plants. The wastewater treatment plants are controlled by the water authority, and the sewer system is mostly a responsibility of the municipalities. So, we work together with the municipalities to optimize that system.*" (Respondent 2)
	Monitoring on soil moisture, groundwater level, water system level	++	++			✓	✓	"*We do that* (the monitoring) *together with the water authority,*" (Respondent 3) "*Water level in the surface water system, and if the water level is below the standard level, water authority will take measures.*" (Respondent 1)
	Checking on groundwater monitoring equipment	+	++				✓	"*As a water authority, we conduct them in hundreds of locations,*" (Respondent 2)

DRM Cycle Phase	Activities	Organisation				Flood	Drought	Relevant quotes from interviews
		Municipality of Zwolle	WDO Delta	Overijssel Province	Veiligheidsregio IJsselland			
	SPI and SPEI monitoring	+	++				✓	"*We do have a website which can calculate them, … you can see that the SPI and the indicators that you mentioned, you can access them here*" (Respondent 2)
	Assessing spatial plans from municipality	+		++		✓	✓	"*We also have to assess all their plans in the areas, … like they want to make a new business park or a more living area in their municipality.*" (Respondent 6)
	Budget provision for spatial plans	+		++		✓	✓	"*We have own budgets to also fund projects from municipalities and Waterschappen, to fund local projects,*" (Respondent 6)
Mitigation	Spatial planning	++	+			✓	✓	"*The municipality sets the rules for spatial planning area, … We have some policies regarding infrastructure, mobility, green-blue infrastructure, … it is legally binding, that's part of Omgevingsvisie Zwolle*" (Respondent 4) "*The municipality has to indicate the instrument, which is called Watertoets, it means that the water authorities are given the possibility to give an advice and the municipality, or the spatial planners have to take that advice into account.*" (Respondent 2)
Response	Emergency scheme due to severe flood		+		++	✓		"*We have to know where to evacuate people, for example, not only where they can have dry feet, but also where they can have the care they needed.*" (Respondent 8) "*As a water authority we supply them with advice. What's the likelihood that the dike will break, but also what is going to be happened if the dike break? Which area would be flooded? How fast is the water coming into certain*

DRM Cycle Phase	Activities	Organisation				Flood	Drought	Relevant quotes from interviews
		Municipality of Zwolle	WDO Delta	Overijssel Province	Veiligheidsregio IJsselland			
								areas? How high is the water coming?" (Respondent 2) "*There is also Veiligheidsregio IJsselland, they are responsible for extreme disaster in Zwolle like severe flood,*" (Respondent 4)
	Monitoring prohibition on groundwater usage		++		+		✓	"*We facilitated a conversation between some mayors, some representatives from the government, and some farmers groups, and try to sit them together and facilitate the conversation*" (Respondent 8) "*So, we have people in the field that can check if people are using water for functions that are not allowed anymore*" (Respondent 5)
	Operating water pump		++				✓	"*We are responsible for the maintenance of the watercourses and pumping stations*," (Respondent 2)
Preparation & Mitigation	Climate adaptation research on flood and drought	+	++			✓	✓	"*We the water authorities have a kind of organization which is called STOWA, and that's a kind of institution that coordinates all the research which are done on behalf of the water authorities.*" (Respondent 2) "*We do take part of some research,*" (Respondent 4)
	Collaboration with international bodies		++			✓	✓	"*The water authorities are more active. They are more like giving out information or helping foreign countries with their water management,*" (Respondent 6)

++ = Main responsibility
+ = Slight involvement

Appendix H – Framework of DMPs



Source: Urquijo-Reguera et al., 2022

Appendix I – Interview Guide

Interviewee :
Date of the interview :
Interviewer :

Introduction

- Greeting and knowing the expertise background of the interviewee.
- Introducing myself, my educational institutional where I from and what I study.
- Introducing my research topic in general.
- Reconfirming consent to record the interview based on the consent form that had been shared previously.
- Informing that during the interview the interviewee may ask for a break, refuse to answer the question, and clarify the statement/answer.
- Asking if the interviewee has questions before the interview start.

Start of recording

- Asking questions based on interviewee's profile on Appendix J, give the attention to the answers, and reconfirm the answers or statements from the interviewee if necessary.

End of interview

- Asking if the interviewee had any questions before the interview ended.
- Offering to have the transcript of the interview, if yes, ask if they only want to have it or also want to check and clarify it.

Appendix J – Interview Questions

Municipality of Zwolle

1. What is your perspective as a person who works in official government (municipality) on how do people in Zwolle see flood and drought in general?
2. What people especially do when flood and drought happened nearby them? What become their primary concern regarding flood and drought?
3. Is there any change in patterns of this awareness in the recent years?
4. What are the funding sources to support those programs towards improving climate resilience in Zwolle?
5. Is there any categorization for projects funding, like funding for research, funding for enhancement for flood and drought prevention infrastructures? If there's any, could you mention and explain an example?
6. Is there any funding specifically for flood-related projects and drought-related projects? If there is such funding, could you explain with an example?
7. How many people in Zwolle and its surrounding rural areas have a job in the agricultural sector? In which areas are they concentrated the most? What are the common crops that are cultivated in those areas?
8. Is the municipality of Zwolle in charge of stabilizing those commodities' prices? If it is, what would be the role and what measures would be taken? Are those measures conducted cooperatively with other governmental institutions, or the municipality of Zwolle is fully authorized to take measures? If it is not part of municipality of Zwolle's authority, which organization has the authority? If there is cooperation with other institutions, how do such cooperative actions look like?
9. Specifically related with agriculture, does the municipality have efforts to increase the yield for farmers' crops? If it does, what are the efforts you take?
10. How do you cooperate with national or international agencies to improve climate adaptation strategies and spatial planning in Zwolle? How do you engage with those entities/agencies? What would be the form of the cooperation? Do you think that this cooperation effective?
11. Do you use any particular method or tool for risk management? For example, disaster risk management (DRM) cycle. Or do you use any other framework?
12. In terms of evacuation system during emergency situation (like flood), as part of 'response' phase in DRM cycle, is the municipality in charge of determining evacuation scheme and route in case of a severe flood? If so, do you also manage it with other institutions? If so, how does the coordination among stakeholders look like?
13. After a flood or drought occurs, does the municipality in charge of assessing the damage caused, for example like total financial lost, number of casualties, severity of damaged buildings? What would be the method used to conduct this assessment?
14. What are the roles of municipality in making future plans for housing, public infrastructure/facilities, and special infrastructures and/or space for water? What are the considerations to be taken when making those plans? Which specific data or information do you use as part of the considerations?
15. Besides the implementation of Blue-green Infrastructure (BGI), are there any other approaches to improve climate resilience in Zwolle?
16. For cross-boundary infrastructure like water ways, pumping stations, etc., what is the role of municipality in managing them? How is the coordination between the

institutions? Could you please mention all other facilities related with flood and drought controls which have broad function for more than one region?
17. In terms of preventive actions, do the municipality take measures in form of direct monitoring for example soil moisture, groundwater level, saltwater intrusion, level of rivers, lakes, and canals, level of water depths in waterways?
18. Are there measurements in the form of data analysis and calculation? For example, Standardized Precipitation Index, Standardized Precipitation Evapotranspiration Index, Reliability Resilience and Vulnerability?
19. Are there any other measurements that haven't been mentioned in the questions that are also implemented to prevent flood and drought in Zwolle and surrounding areas?
20. What does the stress test methodology look like? Is it conducted by installing tools or equipment in a certain area, or taking samples of environmental elements like water, dirt, air?
21. Is the implementation of stress test conducted separately for each case of flood and drought? How are the procedures of stress test for flood and stress test for drought?
22. There were points mentioned on the website stating that "The stress test sets no mandatory standards", and "The stress test does not result in a list of suitable adaptation measures". So how does the government institution use the outcome from this stress test in order to improve climate resilience?

Water Authority WDO Delta

1. As we know the government has many programs towards improving climate resilience. So, what are the funding sources to support those programs?
2. Is there any funding which is specifically for flood-related projects and drought-related projects? If there is such funding, could you explain an example?
3. Is there any categorization for projects funding, for example like research funding, enhancement for flood and drought prevention infrastructures? If there's any, could you mention and explain an example?
4. Which efforts do your organization make to help farmers increase the yield for their crops?
5. Is the water authority in charge of the operation and maintenance of water infrastructures (like dikes, waterways, levees), and controlling the operation of water pumps to store and drain the water? Could you please explain me how the detail roles like? Is it also collaborated with other institutions? How would be the collaborations look like?
6. In some cases, the maintenance of water infrastructures is taken outside the determined schedule. What are the measures taken about the maintenance of the water infrastructures (dikes, waterways, levees) outside the regular schedule plan (if there's any)?
7. How do you cooperate with national or international agencies to improve climate adaptation strategies and spatial planning in Zwolle? Is this cooperation effective?
8. For flood and drought risk management, do you use any particular method or tool for risk management? For example, disaster risk management cycle (DRMC). Or do you use any other framework?
9. Is the water authority in charge of determining evacuation scheme and route in case of a severe flood? Is it also coordinated with other institutions? How does the coordination among the stakeholders look like?

10. I was told that groundwater regulation is used as drought response measure. What are the other possible measures? Are there any other additional measures taken? If not, why only rely on groundwater regulation?
11. I was also told that there was a certain limit where farmers could withdraw groundwater up to this limit without permit from water authority. What is exactly that limit? Who decide that limit? What considerations were taken to come up with that limit?
12. Is there any effort like weather modification to trigger rain to overcome drought? If there is, does the water authority in charge in deciding it and who is in charge in executing it?
13. After a flood or drought occurs, does the water authority in charge of assessing the damage caused, for example total financial lost, number of casualties, severity of damaged buildings? What are the methods conducted to do this assessment? Is it also coordinated with other institutions?
14. Besides municipality, does the water authority also have authority to get involve in future plans for housing, public infrastructure/facilities, and special infrastructures and/or space for water in Zwolle and surrounding regions? What are the considerations to be taken when making those plans? Which specific data or information do you use as part of the considerations (new data from monitoring, scientific studies, etc.)?
15. Sometimes the cause of water scarcity is not drought. Are the issues like lack of access to clean water, and insufficient water quality becoming issues in Zwolle and surrounding areas?
16. For cross-boundary infrastructure like water ways, pumping stations, etc., what is the role of water authority in managing them? How is the coordination and tasks dividing between the institutions? Could you please mention all other facilities related with flood and drought controls which have broad function for more than one region?
17. According to a scientific paper, there is a set of flood indicators which covers amplitude of reaction (flood inundation), graduality on the increase of reaction due to severe flood waves (relation between water discharge vs damage caused), and recovery rate. Does the water authority apply this set of indicators when the flood occurred in Zwolle and surrounding areas?
18. In terms of preventive actions, does the water authority take measures in direct monitoring, for example soil moisture, groundwater level, saltwater intrusion, level of rivers, lakes, and canals, level of water depths in waterways? How often? Is it also conducted with other institutions? If yes, how would be the coordination look like?
19. Besides direct monitoring, are there measurements in the form of data analysis and calculation? for example SPI, SPEI, RRV?
20. Are there any other measurements that haven't been mentioned in the questions that are also implemented to prevent flood and drought in Zwolle and surrounding areas?

Province of Overijssel

1. Could you give me a general insight about what are the institutions involved in managing climate resilience improvement, especially towards flood and drought, in the province of Overijssel? Is there also private sector? Such as private consultant, contractor, etc.?
2. As for the provincial government, what do you think of the role of provincial government for flood and drought management in Zwolle and its surrounding region?

Do you consider that the provincial government plays an important and major role? Or do you think that the provincial government just support in some minor aspects?
3. Could you provide me an information about what would be the real action conducted by the provincial government for flood and drought management in Zwolle and its surrounding region? To conduct those actions, do you use any data and information as a consideration or to be taken into account? If yes, could you mention what data or information you use, and how you use it?
4. How does the coordination like between provincial government and other institutions like municipalities, Veiligheidsregio, in order to manage flood and drought in Zwolle and its surrounding regions?
5. Besides coordinating with municipalities and water authorities, do you also cooperate with other legal institutions?
6. Does the provincial government also collaborate with foreign or international entities for these flood and drought management? Specifically in Zwolle?
7. how do you think about the current integration form among the institutions for flood and drought management?

Safety Region IJsselland

1. Do you manage the disaster risk caused by flood and disaster risk caused by drought separately, or just combine those disaster risks in the same management framework?
2. What framework or method you use to manage flood disaster risk and drought disaster risk?
3. Do you also apply the principle of Disaster Risk Management (DRM) cycle (preparedness, action, recovery, mitigation) in both flood and drought management?
4. Could you provide me the detail procedures on how you determine evacuation scheme if there is severe flood happens, and detail procedures on how you overcome extreme drought?
5. What are the considerations that you take into account for determining the procedures as an action to overcome severe flood and drought? Do you use any specific data or information to be considered as well?
6. When the drought period comes, the water authority sometimes will announce the prohibition to use groundwater. Are you also involved in monitoring if there are still farmers who use groundwater? If you found there's any, what will you do?
7. Are there any measurements that you take regarding response related with drought?
8. Do you also collaborate with other institutions for these emergency responses? If yes, what are the institutions? How the collaboration forms look like?
9. Besides with governmental institutions, do you collaborate with other stakeholders like private sector, international entities, etc.? If yes, what are the stakeholders? How the collaboration forms look like?

RIVUS

1. Could you explain me how RIVUS can be transformed from wastewater treatment into work region?
2. Could you explain me about your program, specifically for flood and drought management?
3. How would the collaborations look like? Are there any regular meetings? Or any other form of activities?

Climate Resilience Expert

1. How would you think about the lack of activities in 'recovery' phase? Perhaps they miss this 'recovery' thing? Or they really don't have any specific activities to be categorised as 'recovery'?
2. Could you give me ideas about the 'recovery' activities for drought management?
3. How important do you think the application of models in flood and drought risk management? Do you think that the government use these models as the primary tools? Or maybe you have different opinion on other tools that used by the government, and what will be the primary tool one?
4. Do you think that this modelling is more into 'preparation' phase or 'mitigation' phase? Or can be both?
5. From the current integration of authorities in Zwolle, do you think that this form of integration has been giving optimum results in both flood and drought management in Zwolle and surrounding areas? Do you notice a lack of this form of integration?
6. How do you think about the possibility of upgrading current integration among authorities in Zwolle to improve their performance on flood and drought management? For example, adding more power/authority to regulate or to generate policy, or involving more stakeholders for certain tasks,
7. Do you think the existence of work region can help to improve the implementation of flood and drought management?