Flood risk adaptation measures on the wastewater system

A comparison between the Netherlands, Germany and the United States

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Abstract

This research deals with flood risk adaptation measures on the wastewater system. The objective of this research is to make a comparison with foreign examples. In order to do that, it is investigated what knowledge is available of flooding of the wastewater system, what actions have been taken to prevent flooding of the wastewater system and which of these actions can be implemented in the Netherlands.

Climate change increases the flood risk and with that the flood vulnerability in the Netherlands. To decrease the flood vulnerability, climate change adaptation measures can be used. Comparing flood risk adaptation measures in different cases is done with the use of a matrix for comparison, which is based on barriers to climate change adaptation. The matrix for comparison addresses the physical, economic, political and ideological context in which adaptation measures are taken in each case. Four cases of flooded wastewater systems have been analyzed in two different countries; Saxony (2010) and Germany (2013), both in Germany, and New Orleans (2005) and St. Louis (2015), both in the United States.

The matrix for comparison was completed for all three countries (the Netherlands, Germany and the United States). Several interesting adaptation measures were found among the cases. After a comparison between these cases and the Netherlands based on the matrix, four types of adaptation measures were found that are of interest for the Netherlands; experiences from the past, cooperation, focus on the recovery phase and communication.

1. Introduction

In this chapter, the background of the research is first explained in the light of the Delta Programme and critical infrastructure. The issue that this thesis addresses, flood risk adaptation on the wastewater system, can be derived from a scientific background and from a policy background. The scientific background of the issue is explained in detail in the theoretical framework of this thesis; the policy background serves as an introduction. It should be mentioned, however, that considered from both backgrounds the wastewater system is a niche that requires more attention. After the policy background, the problem definition and research questions are defined. Then in the research design, the three main steps that this research follows are elaborated further. In the Reading Guide, the outline of this thesis is explained.

1.1 Policy background

Flood damage due to extreme precipitation has been a topic of discussion for urban water managers in the Netherlands in recent years. Especially flooded basements, shops and houses as a result of limited capacity of the wastewater system are frequently in the news, especially in summer. The spatial spreading of these events seems random. Due to the considerably damage, the attention from media and the frequency with which this occurs, preventing flood damage due to extreme precipitation is relevant (Deltares, 2012).

The general issue of this thesis, flood risk adaptation on critical infrastructure, originates from the issue of climate change. As climate change is imposing an increased flood risk on the Netherlands, which is explained in the theoretic framework, the need for a response grows. In this case that would be a solution for the Netherlands to increase the level of water safety in the country. One possibility is climate change adaptation, which covers flood risk adaptation as one if its components. In order to explain this phenomenon as it is seen in current policies, the Delta Programme should be addressed.

In 2015, the Dutch government presented a new version of the Delta Programme to protect the Netherlands against flooding and at the same time keep freshwater resources available. The Delta Programme is a cooperation between the national government, provinces, municipalities, water boards and the private sector in the Netherlands. It attempts to provide the next generations in the Netherlands with fresh water and protect the country against high water (Deltaprogramma 2015). The Delta Programme consists of five 'Delta Decisions' (Deltabeslissingen) that all revolve around increasing the 'robustness and resilience' of the country against climate change and extreme weather events. One of these Delta Decisions is the Delta Decision Spatial Adaptation.

In the 'Delta Decision Spatial Adaption' (Deltabeslissing Ruimtelijke Adaptatie), the water management in the Netherlands is addressed. The decision deals with the effects of climate change in the Netherlands and how to adapt the Dutch water management to those effects. This led to a separate programme on Spatial Adaptation, which covers the ambitions and plans of the Delta Decision. The key goal of the Programme Spatial Adaptation is to adapt and strengthen vital and vulnerable functions. Vital and vulnerable functions are functions that require special attention during floods as they are either crucial for disaster management or can cause severe damage to people, environment or economy (Deltaprogramma 2015). There are eight groups of vital and vulnerable functions, as can be seen in Table 1. From now on, vital and vulnerable functions will be addressed as critical infrastructure in this research. This is a more common scientific term, where vital and vulnerable is a policy term, which is why critical infrastructure is preferred here.

Function	
Drinking water	Healthcare
Energy Sector	Telecom / IT Sector
Wastewater	Pumping stations / Locks
Road Transport	Chemical Sector

Table 1: Vital and vulnerable functions

This study will focus on one part of critical infrastructure; the wastewater system. The Dashboard for vital and weak functions, which is a guideline for policy makers when dealing with critical infrastructure, defines the wastewater function as consisting of three sectors; the wastewater system, wastewater treatment plants and sewerage. For each sector of the wastewater system the possible threats in case of a flood are defined (Ministerie van Infrastructuur en Milieu, 2014).

For instance, the wastewater system might pollute the water in the surrounding environment in case of a flood. It is highly dependent on the availability of energy, telecom and IT. However, up until now there is limited knowledge on the effects of a flood on the wastewater system. Wastewater treatment plants could overflow in case of a flood. If that happens, the wastewater can get mixed with clean water, for example drinking water, surface water or groundwater. During a flood, dirt or waste can get into the tubes and clog them. Wastewater treatment plants are very chain-dependent. Sewerage is vulnerable to floods; it depends on the type of system (combined or separated) how vulnerable the sewerage is. Like treatment plants, the sewerage system is also very chain-dependent. The possible effects of a flooding of the wastewater system will be described in more detail later on in this research.

It is a goal of the Delta Programme to create a common policy for flood protection measures on critical infrastructure. The Delta Programme suggests that this will go through three phases; knowledge, policy and implementation. Each phase has specific goals and expected deadlines. The knowledge phase aims to describe the vulnerability and chain-dependency of the wastewater system (Deltaprogramma 2015). In other words, it aims to identify to which extent a flood affects the wastewater system and what influence other types of critical infrastructure such as energy or drinking water have on this. This research is part of the knowledge phase for the wastewater system. The conclusions of this research will serve as a reference to recommend flood risk adaptation measures on the wastewater system in the Netherlands.

1.2 Problem definition

As mentioned before, this research deals with flood risk adaptation measures on the wastewater system. All adaptation measures should deal with public health, nuisance reduction, environment, sustainability and convenience for the citizens. In addition, research on flood risk adaptation measures should contain possible adaptation measures before, during and after a flood (Deltaprogramma 2015). Key goal of this research is to provide opportunities for the wastewater chain to adapt to an increased flood risk. Part of this research will be carried out by looking into foreign examples. Due to the relatively small amount of floods that have occurred in the Netherlands in recent years, little is known about the effects that a possible flooding will have on the wastewater system. Other countries have had more floods in recent years; these countries have had their wastewater system flooded and thus have more experience with the effects that a flooded wastewater system brings.

Therefore, *the objective of this research is to make a comparison with foreign examples of flooding of the wastewater system.* This research aims to find out what knowledge is available on flooding of wastewater systems, what actions have been taken abroad to prevent flooding of the wastewater system and to which extent these actions can be of value to the situation in the Netherlands. These three steps form the main frame of the research. The main research question is: *What flood risk adaptation measures that are taken on the wastewater system in foreign countries can be implemented in the Netherlands?* The foreign countries that are mentioned here are countries that experienced flooding of the wastewater system in the past.

1.3 Theoretical approach

Key concept in this thesis addresses ***flood vulnerability***, one of the effects of climate change (which can be explained by Huitema et al., 2011). In order to discuss flood vulnerability a definition of flood vulnerability will be designed (based on Brooks, 2003 and Adger, 2006). Then the relation between flood vulnerability and ***critical infrastructure,*** in our case the wastewater system, will be explained (based on Dircke et al., 2012 and Barbosa et al., 2012). Dircke et al. (2012) and Barbosa et al. (2012) define the negative effects that increased flood vulnerability can have on the wastewater system. They do not describe ways to reduce the flood vulnerability, however. This is where a scientific niche appears; measures to reduce the flood vulnerability of critical infrastructure.

To describe these measures, the two components of flood vulnerability (flood risk and flood impact) are explained. Measures to reduce flood risk are categorized as flood risk mitigation; measures to reduce flood impact are categorized as ***flood risk adaptation*** (based on Fischer et al., 2007). A focus will be set on adaptation measures and in specific to barriers to these adaptation measures. The reason for this is that the goal of this research is to make a comparison with foreign examples of flooding of the wastewater system. To make this comparison, the limitations of such a comparison will have to be analyzed; the ***barriers to flood risk adaptation***. This analysis is made based on a matrix, developed with the use of the barriers described in *Challenging barriers in the governance of climate change adaptation* by Biesbroek (2014).

1. 4 Research design

The researcher has worked as an intern at the Ministry of Infrastructure and the Environment from January 2016 until December 2016 to contribute to the knowledge phase of flood risk adaptation measures on the wastewater system that is mentioned before. More about this internship is explained in the methodology.

This thesis has three main points of interest, as described before, which all three follow in a logical order. These three points of interest serve as the frame for this research; it is both the sequence of steps that need to be taken to gain the required knowledge as well as the line that the narrative follows while explaining the research in this thesis. Each point of interest is formulated as a research question.

The first point of interest is to *figure out what knowledge is available about the effects of a flood on the wastewater system.* The related research question is: what happens to the wastewater system during a flood? This question has multiple components. In order to understand the effects, first a basic description of the wastewater system in the Netherlands is necessary. This can act as a frame of reference while comparing foreign examples to the Netherlands. Second is that for each individual case the effects that the flooding had on the wastewater system will have to be described in their own setting.

The second point of interest is to find out *what measures have been taken abroad to prevent flooding of the wastewater system.* The research question is: what flood risk adaptation measures have been taken in foreign countries? This includes actions in all three stages of a flooding; before, during and after the flooding. Actions can be examples of infrastructure planning but do not necessarily have to be tangible. Changes in the social awareness or policymaking can also be examples of actions that have been taken.

The final point of interest is to see *to which extent these measures can be of value to the situation in the Netherlands.* For this part, each foreign example will be considered for policy transfer with the help of a framework, based on comparative research literature. The research question is: how can flood risk adaptation measures that have been taken in foreign countries be implemented in the Netherlands? If actions taken abroad are suitable for the Dutch system according to these standards, the actions can be suggested in the overall research for the Delta Decision.

1. 5 Reading guide

This thesis follows the sequence of the three steps mentioned in the previous section; what knowledge is available on the effects of a flood on the wastewater system, what measures have been taken abroad to prevent flood of the wastewater system and to which extent can these actions be implemented in the Netherlands. If these three steps are followed, ultimately the overall research question can be answered; *which flood risk adaptation measures that are taken on the wastewater system in foreign countries can be implemented in the Netherlands?*

In the second chapter, a general description of the wastewater system is given. This mostly serves as an introduction to the wastewater system, so that readers who have no background in wastewater systems can learn the basics that are required to read this thesis.

In the third chapter, the theoretical framework is explained. It starts off with the effects of a flood on the wastewater system, after which the concept of climate change is addressed to define what the effects of climate change on flood risk are. Then the balance between flood risk, flood impact and flood vulnerability is explained. Based on the flood impact, the concept of climate change adaptation is described. Comparing climate change adaptation measures between various cases can be done using barriers to climate change adaptation; this is explained next. Based on these barriers, a matrix for comparison is designed which is then used to compare climate change adaptation measures between various countries.

The fourth chapter, methodology, provides information on the concept of a case study as well as the type of case study that is used in this research. After that, the concept of lesson drawing is used to explain how the cases used in this research were selected. Then, the methods for data gathering are explained; focus groups, interviews, document analysis and participatory observation. A short description is given of how the collected data is analyzed.

In the three following chapters, each country of analysis (the Netherlands, Germany and the United States) is described based on the matrix for comparison. For the chapters on Germany and the United States a case description of the flood events and an overview of interesting adaptation measures are given first before discussing the results based on the matrix. The chapter on the Netherlands only discusses the results based on the matrix.

In the final chapter, first an empirical reflection is made. Then a comparison is made among the three countries, based on the completed matrix for each case. With the use of this comparison and the adaptation measures from the previous chapters, conclusions are drawn on which measures might possibly be implemented in the Netherlands. The methodology is also discussed and reflected upon in this chapter and recommendations for further research are made.

2. The wastewater system

The first step in this research is finding out what knowledge is available on the effects that a flood has on the wastewater system. In order to understand these effects, first a basic description of the wastewater system in the Netherlands is necessary. This can act as a frame of reference while comparing foreign examples of wastewater systems to the Netherlands. In this chapter, the basic of the sewer system will be explained first, and then the difference in sewer systems and in the end the functioning of a wastewater treatment plant will be explained. All information in this chapter is provided by Stichting RIONED (2013) and Deltares (2012) (unless cited otherwise) and written with the advice of Hans van der Eem.

An increased flood risk brings multiple threats for society. Wastewater systems that are not adapted to floods can cause threats to public safety and health. Public safety is threatened by possible floods that can cause damage to property or to individuals. Besides damage to property or individuals, also the public health is at risk when the wastewater system floods. Flooding of the sewer system in a city could possibly cause health hazards (Stichting RIONED, 2013). The wastewater system can be divided in three parts; wastewater treatment plants, pumping stations and tubes (or sewers). Flooding has different effects on each part, with different threats coming from their particular failures.

2.1 The urban water system

In order to understand the wastewater system in the Netherlands, first a general overview of the urban water system is required. Figure 1 shows how water flows between various components of the urban water system. A distinction can be made between two types of water; water that is purified before it returns to the water system (which is colored red in figure 1) and water that is not purified before it returns to the water system (which is colored green in figure 1). This does, however, not mean that the non-purified water is actually clean, or that the water that is purified actually needs to be purified. The distinction is just made for the division between water that is purified and water that is not.

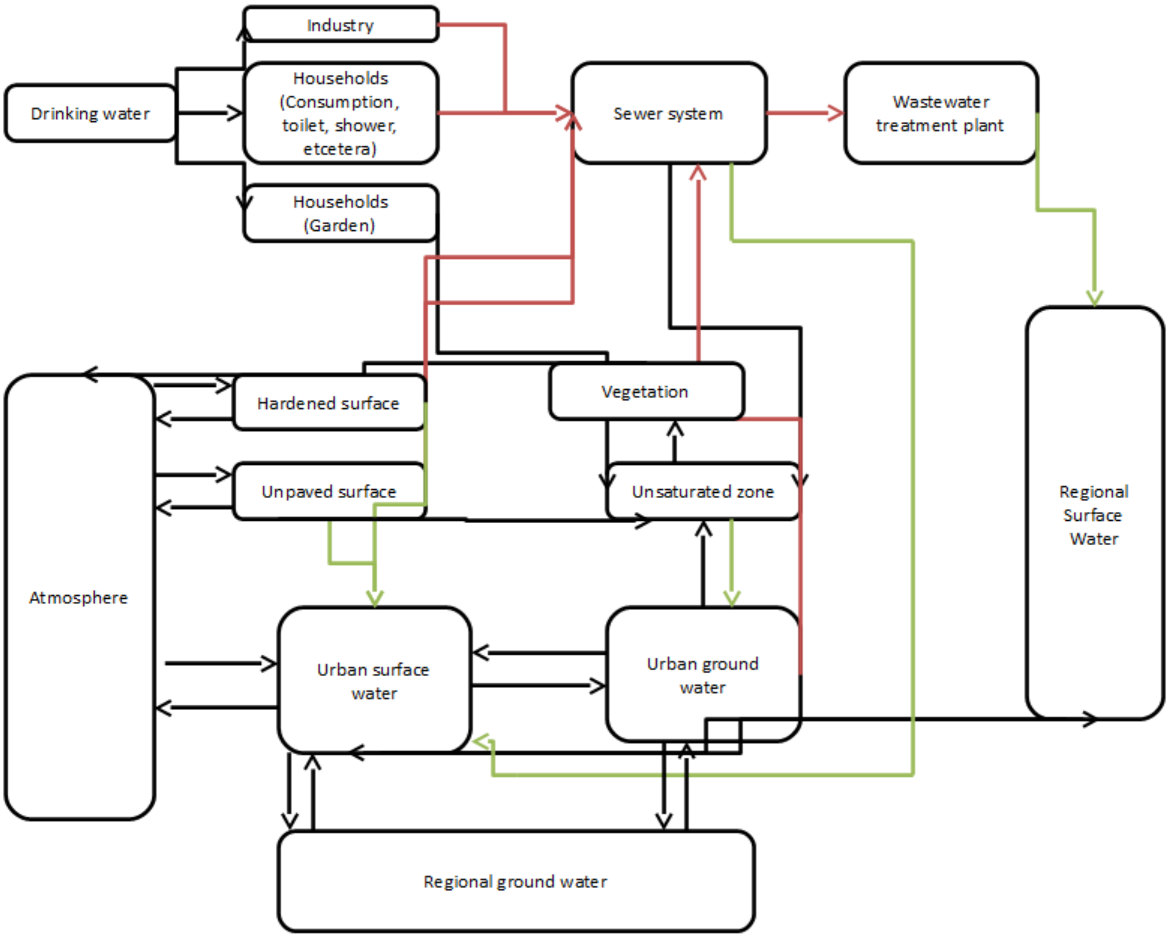

Figure 1: A schematic overview of the wastewater system

The first category (purified water; red in figure 1) covers the discharge of the industry and households towards the sewer system, the runoff of hardened and unpaved surfaces towards the sewer system, the leakage of urban groundwater into the sewer system as well as the discharge from the sewer system towards the wastewater treatment plant. The second category (non-purified water; green in figure 1) covers the runoff from hardened and unpaved surfaces into urban surface water, drainage of the unsaturated zone into urban groundwater, overflow from the sewer system into the urban surface water as well as the discharge from the wastewater treatment plant into the regional surface water. The different treatment for each category is explained later on in this chapter, after the basic components of the wastewater system are explained.

2.2 The wastewater system

Figure 2 shows the wastewater system on a household level. The wastewater system consists of tubes, wells**,** pumping stations and locks. Tubes transport the water, wells connect the tubes and serve as entrances for cleaning or maintenance and locks provide an entrance for surface runoff to enter the tubes that run under streets. Pumping stations pump water away, for example towards the wastewater treatment plant or towards the surface water. When the system is full and the pumping stations do not have the capacity to get rid of the incoming water, the system is provided with storm water discharges to serve as emergency discharge points. Storm water discharges are only used in emergencies, as the water that discharges through them is not purified before it is discharged unto surface water. A storm water discharge can be provided with a settling tank to increase the quality of the discharged water; within a settling tank, heavy particles such as debris and contaminants settle into sludge, discharging the cleaner water unto the surface water. Sludge can be removed from the settling tanks in drier periods afterwards.

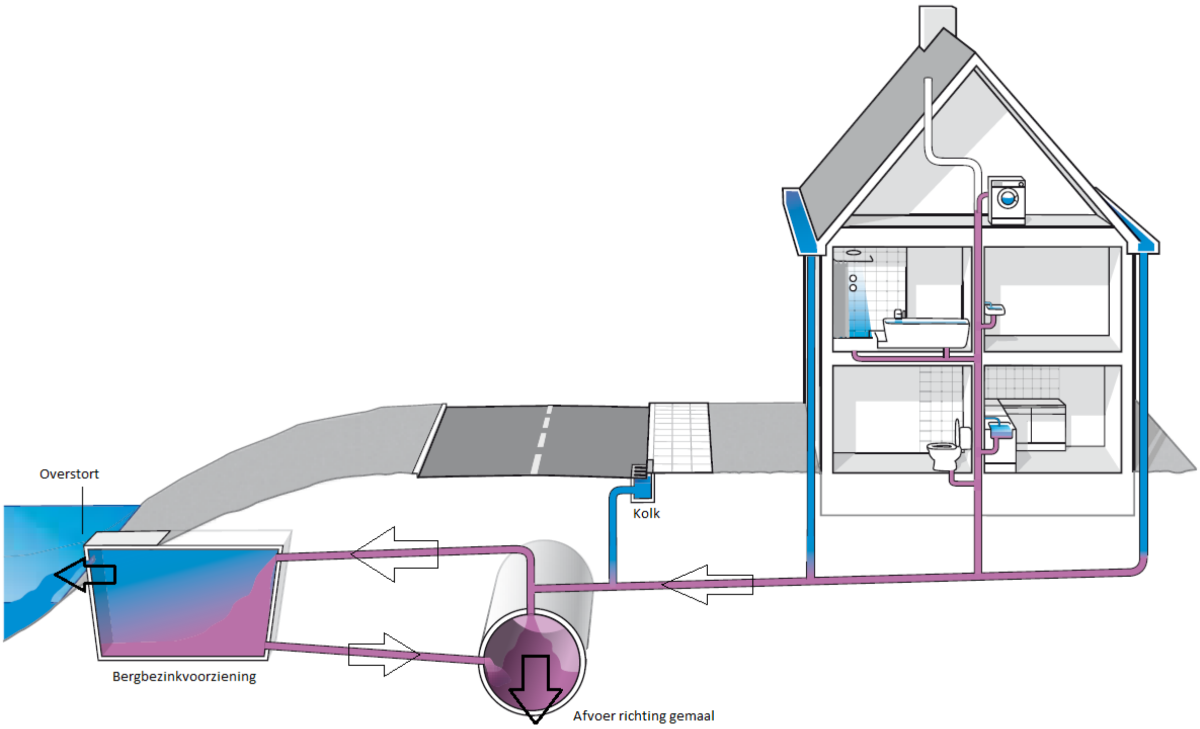

Figure 2: The wastewater system on a household level (adapted after RIONED, 2013); in this figure we can see a storm water discharge (overstort), a settling tank (bergebezinkvoorziening), a tube (afvoer) and a lock (kolk).

In the Netherlands, three different types of sewer systems can be distinguished; slope systems, mechanical systems and IBA (individual treatment of wastewater; in Dutch IBA, individuele behandeling afvalwater). Slope systems can be separated into mixed, separated and improved separated systems. In a mixed system rainwater and wastewater from households and industry end up in one tube, which is purified at a wastewater treatment plant (this can be seen in figure 2). In a separated system, only wastewater is discharged towards the wastewater treatment plant; rainwater ends up in a separated tube which discharges directly unto surface water (see figures 3, 4 and 5). An improved separated system does the same, except for the fact that rainwater is measured before it is discharged unto surface water. If the quality of the rainwater is too low to be discharged unto surface water, it can be redirected to the wastewater treatment plant to be purified (see figure 6). This can be the case when, for example after a dry period, the surface is contaminated and thus contaminates the runoff water; this is called the first flush.

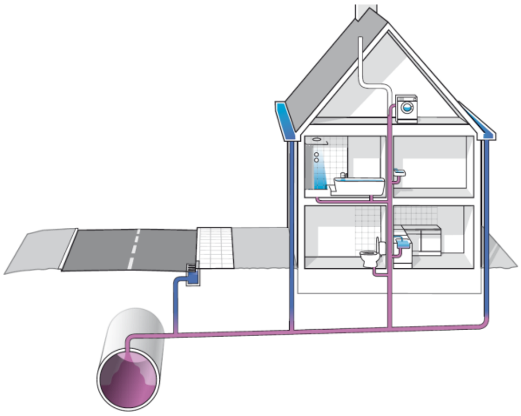

Figure 3: Mixed wastewater system (adapted after RIONED, 2013); in the following figures wastewater is depicted in purple and precipitation water in blue

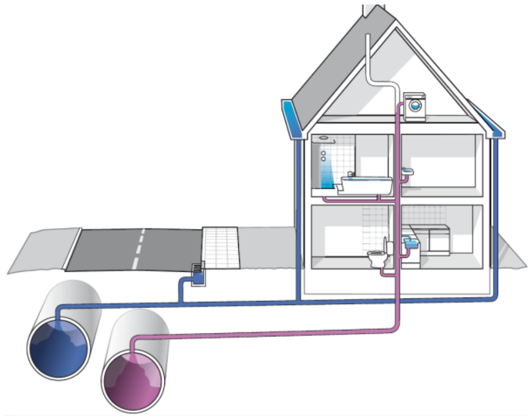

Figure 4: Separated wastewater system (adapted after RIONED, 2013)

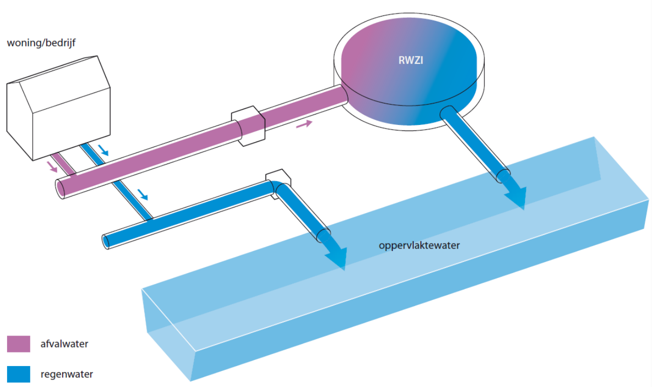

Figure 5: Separated wastewater system (adapted after RIONED, 2013); the blue square represents surface water (oppervlaktewater)

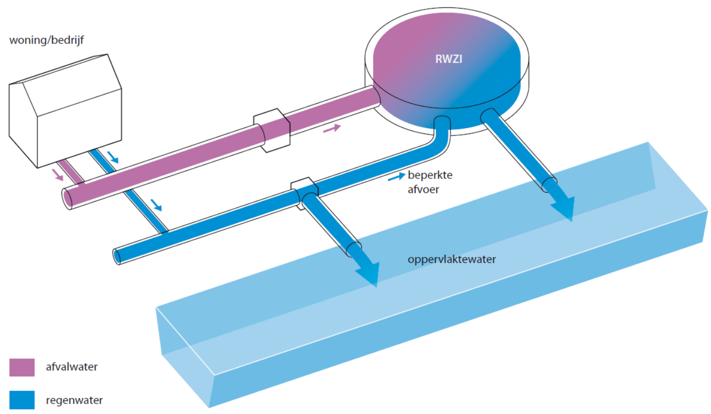

Figure 6: Improved separated wastewater system (adapted after RIONED, 2013)

When great distances between households have to be bridged, it can be cheaper to use a mechanical sewer system, which works with pressure. A mechanical sewer system pumps wastewater through tubes from wells. Rainwater is not allowed to end up in this system and is therefore discharged separately.

When the distance from a household to the general sewer system is too great, IBA is used. IBA, the individual treatment of wastewater, works like a small wastewater treatment plant and discharges purified water unto the surface water (see figure 7). How a wastewater treatment plant works is described later on in this chapter.

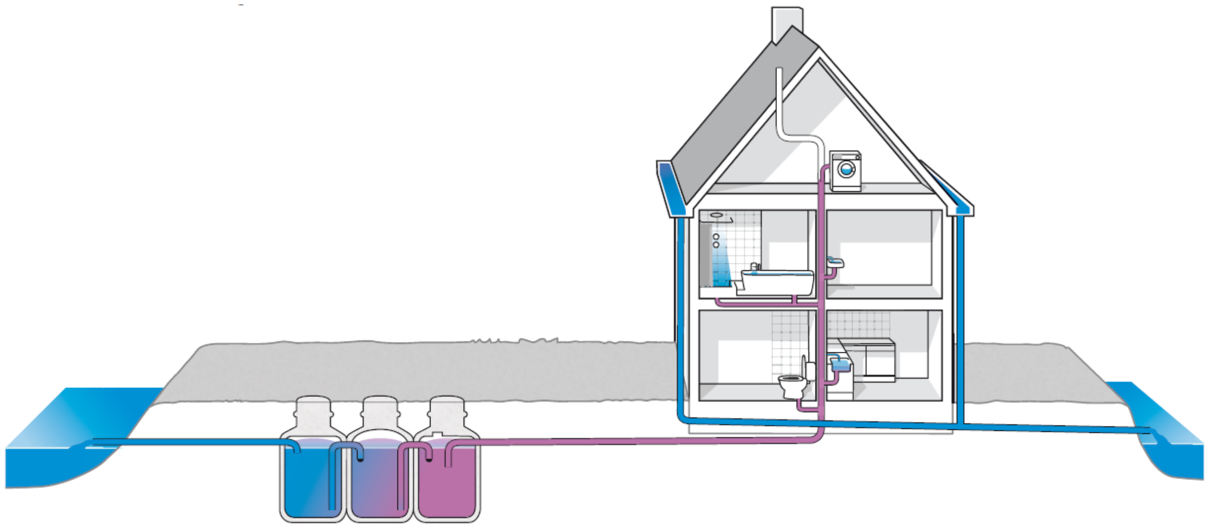

Figure 7: Individuele behandeling afvalwater (IBA) (adapted after RIONED, 2013)

2.3 Purified water

Discharge from industry and households into the sewer system – As mentioned before, wastewater from industry and households is transported to the wastewater treatment plant through tubes, wells and pumping stations. This includes process water from industry (which is sometimes already purified before), 'grey' wastewater from sinks, showers and washing machines and 'black' wastewater from toilets.

Runoff from the surface into the sewer system – When the quality of rainwater is good enough, it can be discharged unto the surface water without purification. In other cases, for example with a first flush, the rainwater needs to be purified. This is the case with a separated or an improved separated system, or through specific treatment of the surface runoff before it is discharged unto surface water.

Leakage of urban groundwater into the sewer system – In situations where the groundwater level is too close to the surface, drainage tubes can be installed to discharge groundwater into surface water. In these cases, leaking tubes cause clean groundwater to enter the sewer system, where it is purified even though that is not necessary for groundwater, which is economically inefficient.

Discharge from the sewer system to the wastewater treatment plant – All the water that is transported through the sewer system that is not discharged earlier, ends up at the wastewater treatment plant. Here it is purified; the purification process is described later on in this chapter.

2.4 Non-purified water

Surface (hardened and unpaved) runoff to urban surface water – As mentioned, if the quality of rainwater is good enough, it can be discharged directly unto surface water. This is the case with separated and improved separated systems.

Drainage of the unsaturated zone to urban groundwater – This includes all the water that is absorbed, through the ground, in the groundwater. This can be infiltration through unpaved surface, irrigation water but also leakage of the sewer system itself.

Emergency discharge of the sewer system unto urban surface water – as mentioned before, storm water discharges are emergency measurements that are only used in case of extremely high discharge (for example during extreme rain events). The discharged water is non-purified, but also highly diluted wastewater that is discharged unto surface water.

Discharge (effluent) from the wastewater treatment plant to the regional surface water – The purified water is discharged unto surface water, where it becomes part of the water cycle again. The quality of the discharged water is measured according to specific standard to guarantee good water quality at the discharge point.

2.5 Wastewater treatment plant

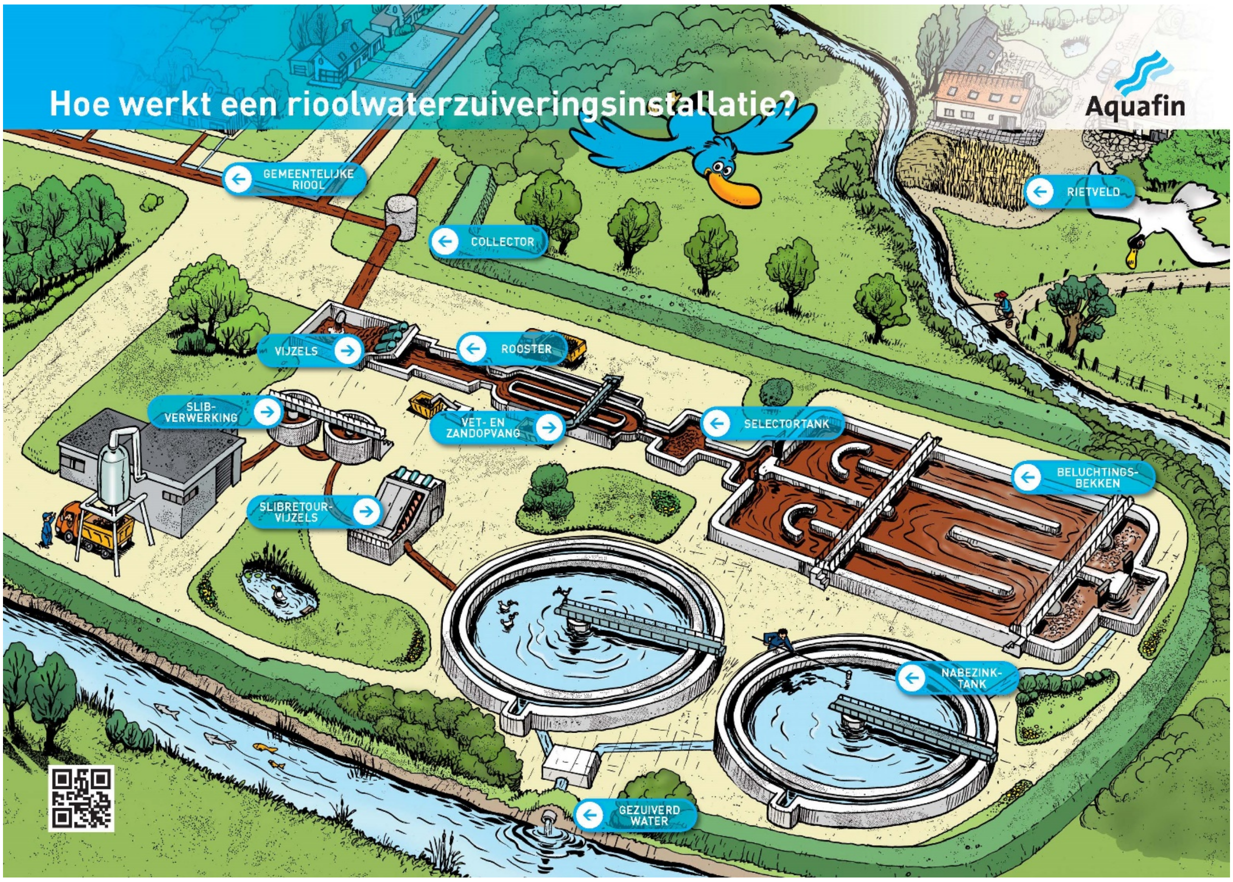

Figure 8: Wastewater treatment plant (Hans van der Eem, 2016); the various steps of treatment are explain in the text

A wastewater treatment plant consists of several elements (some of the more compact treatment plants combine multiple elements), which are depicted in figure 8; first a collection point, where wastewater enters the wastewater treatment plant. Then a roster that filters out large parts of debris and a pump to raise the wastewater to a higher level so it can run through the rest of the plant using gravity. Then the pre-settling tanks let fine, heavy particles settle and separate light particles. This, together with the large debris filter, is called mechanical treatment. After the mechanical treatment come the treatment tanks, where wastewater is purified through biological or chemical processes. This is called the biological treatment. Finally, the water enters settling tanks, to separate the sludge that is created in the biological treatment from the purified water.

Throughout the process contaminants are removed and organic material (sludge) is created. The sludge that is created is treated in a sludge treatment installation. It can be used to produce energy, for example through sludge fermentation. There is always sludge left that cannot be further processed; this sludge is dewatered and transported to a waste treatment plant. Here it can further degraded into useful organic components, for example phosphate or nitrogen.

2.6 Flooding of the wastewater system

Now that a general description of the wastewater system is provided, it is time to answer the first research question; what happens to the wastewater system during a flood? In other words: what is the relation between flood vulnerability and critical infrastructure, in this case the wastewater system? This chapter deals with that question from a scientific perspective, where practical examples will be given in the results.

A flood can have two possible causes; an extended period of precipitation that causes rivers to flood (*river flooding)* or a heavy storm that causes a dike breach (*coastal flooding)*. A river flooding is a flood caused by precipitation, which is in some literature called pluvial flooding. In the Netherlands, both river flooding and coastal flooding are unlikely to occur due to our high protection standards. A more realistic threat comes from a combination of both; a storm that occurs during an extended period of precipitation (Riedstra, 2016). In the case of river flooding, the event can be predicted. When a city next to a river floods it is very likely that another city downstream that same river will flood later on. This is called 'ribbon thinking' (lintdenken) and can be of great value while taking preparations against a flooding (Riedstra, 2016). A third possibility, another form of pluvial flooding, is that during a period of intense precipitation the volume of the incoming water is too large for the sewer system to process. In that case, the street serves as a buffer zone, where the incoming water can stay until it is transported towards surface water, groundwater or into the sewer system. In situations like these, the event is called water nuisance rather than flooding. Water on the streets is troublesome but acceptable. Some exceptions should be made; when the water causes material damage, when the water block major traffic routes or when the water flows out of sewers unto the streets, measurements should be taken (Stichting RIONED, 2016). However, as experts on the wastewater system consider water on the streets nuisance rather than flooding, decided is to not take up this type of events into this research. This decision is based upon a discussion that took place in the first workshop, which can be found in the appendix.

The possible damage that a flooding imposes on the wastewater system can be divided in three event; failure of the wastewater treatment plant, failure of pumping stations and clogging of tubes. Most wastewater treatment plants should be shut down the moment water enters the facility. The reason for this is that most wastewater treatment plants are dependent on electricity and to reduce further damage all electronic installations are turned off (Bosch, 2016). When a wastewater treatment plant fails, water purification is no longer possible, but sanitation is. This means that people are still able to flush the toilet, but that wastewater is no longer purified before it reaches the surface water, which means that surface water can be polluted. In the case that pumping stations fail, the discharge of wastewater from households is no longer possible and thus sanitation is no longer possible. The tipping point for the availability of sanitation thus lies with the functioning of pumping stations. When tubes get clogged, discharge of wastewater is also no longer possible; the clogging of tubes also depends on the availability of pumping stations (Workshop faalmechanismen en maatregelen afvalwaterketen Genemuiden, 2015). Practical examples of what assets have been damaged during each case can be found in the results.

2.7 Recovery phase

Whenever a wastewater system floods, the recovery of the system can be carried out by following specific steps, which are not all necessary if not every part of the system suffered damage. Whenever the recovery phase of a wastewater system is mentioned, the steps that are described in table 2 are mentioned. The steps for the recovery of a wastewater system is based on an old model from the World Health Organization, adapted after discussions with the experts that took part in the workshops. . To quickly run through the model; the first step is to make sure that the area is accessible; it can no longer be flooded. Then, for safety reasons, the stability of structures needs to be guaranteed before entering. An inventory of damage needs to be made so that priorities for recovery can be defined. Before the recovery process can continue, debris needs to be removed from the area. If wastewater has been discharged, the area needs to be disinfected for health reasons. When that has been done, a schedule for recovery can be drawn, based on the priorities that have been defined earlier. After that, it is a matter of restoring power so that electronic equipment can run. When the power is back, all other assets can be restarted.

Accessibility of the area
Stability of structures
Inventory of damage and priorities
Cleaning up debris, desinfecting the area
Drawing schedule for recovery
Start electric circuit or back-up electricity
Open up tubes and settling tanks
Activate sludge dispension
Start mechanical treatment
Clean treament tanks
Start chemical treatment
Back to automatic processes

Table 2: Recovery phase of a wastewater treatment plant

Now that a general description of the wastewater system has been provided and the expected effects of a flood on the wastewater system have been described, the relation between flood vulnerability and the wastewater system can be explained. This will be done in the next chapter.

3. Theoretical framework

The relation between flood vulnerability and the wastewater system, the critical infrastructure that this research addresses, has been described. Now, as is explain in the theoretical approach, the measures to reduce the flood vulnerability of the wastewater system should be identified.

To do this, first the concept of climate change has to be discussed to define what the effects of climate change flood risk are. Then the relation between flood risk, flood impact and flood vulnerability is explained. Based on the flood impact, the concept of climate change adaptation can then be described. The goal of this research is to compare flood risk adaptation measures between various cases and for this barriers to climate change adaptation are used. Based on these barriers a matrix for comparison will be designed which can be used to compare climate change adaptation measures between various countries.

3.1 Climate change and flood vulnerability

Chapter 2 explained the relation between flood vulnerability and critical infrastructure, in this case the wastewater system. In order to define flood vulnerability, climate change should be addressed first. Climate change refers to any change in climate over time, caused by natural variability or by human activity (Parry, 2007). As this research deals with adapting to the effects of climate change rather than with the sources of climate change, decided is to stick to this definition, which means that where climate change is written, it consists of both climate change caused by natural variability and human activity. Huitema et al. (2011) state that climate change has impacts on nature, industry and society. Not all causes and impacts of climate change will be discussed in this thesis; the main effects will be addressed to explain the relation between climate change and flood vulnerability.

The main effects that climate change will have in Northwest Europe is an increase in temperature, a decrease in summer precipitation but an increase in extreme weather events and an increase in winter precipitation (Huitema et al, 2011). The most important impact of those changes is that flood *vulnerability* will increase, both inland flood vulnerability and coastal flood vulnerability (Scott, 2013). The inland flood vulnerability is increased by an increased frequency of extreme precipitation events, causing surface, fluvial and groundwater flooding. Coastal flood vulnerability is increased by sea level rise and an increase in storm surges in coastal locations (Scott, 2013). It is important to first define what vulnerability exactly is.

Vulnerability can be described as the degree to which a system is susceptible to and unable to cope with an issue (Parry, 2007). Kelly & Adger (2000) define climate change vulnerability as the extent to which climate change may damage or harm a system, depending on both the sensitivity of a system as well as the ability of a system to adapt to new conditions. In the case of climate change, vulnerability is a function of the character, magnitude and rate of climate change to which a system is exposed combined with the sensitivity and adaptive capacity of that system (Parry, 2007). Sensitivity is the degree to which a system will respond to climate change, which means that vulnerability depends on the potential climate change effects and the adaptive response of a system (Kelly & Adger, 2000). Adaptive capacity of a system is the ability to accommodate environmental hazards or policy change and the amount of variability with which a system can cope (Adger, 2006).

Brooks (2003) explains that vulnerability in climate change can also be defined as a product of the probability that a hazard can occur (risk) and the potential damage caused to a system (impact). In this equation, the first part (character, magnitude and rate of climate change) defines the risk imposed on a system; the second part (sensitivity and adaptive capacity of a system) defines the possible impact on a system.

$$Vulnerability = Risk\ X\ Impact$$

When this formula is applied to floods, it can be stated that flood vulnerability is the flood risk times the impact of a flood. Adger (2006) defined hazard vulnerability (in this case a flood is the hazard) as the probability times the impact of the disaster. Risk refers to the potential for negative effects on public safety, public health, economic assets, social assets, cultural assets and infrastructure (IPCC, 2016). Flood risk thus represents the potential for negative effects; in other words, flood risk is the probability that a flood will occur.

The hazard impact, in our case flood impact, is based on the sensitivity of a system. The sensitivity of a system is based on the degree to which a system is modified or affected by a hazard (Adger, 2006).

An increased flood risk brings multiple threats for society, especially in urban areas. Human activities in urban areas generate waste and pollutants that can be washed out to water bodies during extreme weather events. Therefore, drainage systems are necessary to ensure the functionality and safety of urban areas and to guarantee public health (Barbosa et al., 2012). Wastewater systems that are not adapted to floods, for example these drainage systems, can cause threats to public safety and health. Possible floods that can cause damage to property or to individuals threaten public safety.

Climate change and increased flood risk due to climate change is a relevant topic in scientific literature at the moment. As the intensity and frequency of precipitation and extreme precipitation events increases, there is a risk that the wastewater system may not be able to treat and drain the surplus water (Dircke et al., 2012). During a flood, especially in urban areas, this would mean that there are discharges from two sources; sewer overflows and storm water runoff (Burton & Pitt, 2002). Both these sources increase the flood risk.

Besides damage to property or individuals, also the public and environmental health is at risk when the wastewater system floods. Flooding of the sewer system in a city could possibly cause health hazards. Waste and pollutants, transported by storm water can result in both quantity and quality problems. Quantity problems indicate an overload of water that the wastewater system cannot process. Quality problems indicate possible polluted water. Both affect public health and the environmental quality (Barbosa et al., 2012). However, reducing the impact of flood risk and thus reducing the vulnerability can compensate for all the threats that flood vulnerability imposes on society.

3.2 Flood risk adaptation versus flood risk mitigation

Reducing the impact of a flood (and thus the flood vulnerability) can be seen as a response to an increased flood risk due to climate change. Responses to the effects of climate change can be divided in two types; mitigation to climate change and adaptation to climate change (Fischer et al, 2007). In order to discuss the possible responses to increased flood risk caused by climate change, first the response to climate change should be addressed.

Mitigation is about reducing the chance that an event will occur. In the context of climate change, mitigation attempts to limit global climate change by reducing emissions of greenhouse gases or increasing their sinks (Fischer et al, 2007). In other words; climate change mitigation focuses on reducing the risk of climate change. As this research focuses on the effects of climate change rather than the causes, climate change mitigation is not focused on. However, the difference between mitigation and adaptation in general need to be explained in this chapter.

Adaptation deals with minimization of the disturbing effects of an event. Parry (2007) defined adaptation as the adjustment in systems in response to the effects of climate change, which moderates harms or exploits beneficial opportunities. Termeer et al. (2013) describe that adaptation involves both infrastructural adjustments as well as broader processes of societal change. Fischer et al. (2007) state that climate change adaptation targets the vulnerability of the system. This can be seen as the most essential difference between mitigation and adaptation; mitigation focuses on reducing the risk of climate change, adaptation focuses on both the risk and the impact to reduce the vulnerability.

Mitigation traditionally received greater attention than adaptation, both from scientists and policy-makers; the main reason for this is that mitigation is a solution for all systems, where adaptation only works for specific systems (Fischer et al., 2007). Another essential difference between climate change mitigation and climate change adaptation is the scale of effect; climate change mitigation has an effect on a global scale, where climate change mitigation has an effect on a local scale (Fischer et al., 2007).

Despite the traditional preference for climate change mitigation, the call for climate change adaptation is getting stronger. The 4th IPCC assessment report from 2007 can be seen as a breaking point on the recognition of climate change and its effects as a problem for flood risk (Termeer et al., 2012). The report led to an increase in recognition of the need for society to adapt to the impacts of climate change rather than mitigate climate change itself (Termeer et al., 2012). This shifting increase in the need for society to adapt rather than mitigate is called a *paradigm shift*. As emissions are already affecting climate conditions right now and will continue to do so in the near future, combined with the knowledge that emission reduction takes at least several decades to become apparent, action is needed on a shorter lead time (Fischer et al., 2007). Termeer et al. (2012) define climate change adaptation as consisting of three components; the development of infrastructure, the establishment of societal change and an increase in adaptive capacity. Up until 2012, the focus in Europe has mainly been on the development of infrastructure; a recommendation was given by Termeer et al. (2012) to invest more in the establishment of societal change and the increase in adaptive capacity.

Societal change is about getting public support for climate change adaptation. An example of the societal change can be explained with the paradigm shift in water management from mitigation to adaptation. In the beginning of this century, in Germany climate change adaptation was seen less frequently in policy making than climate change mitigation. Adapting to climate change was considered surrender to global warming and the focus of policies should be on the mitigation of climate change rather than climate change adaptation (Huitema et al., 2011). Adaptive capacity is defined by Gallopín (2006) as a system's ability to deal with exposure or risk. Adaptive capacity in climate change then becomes the ability of a system to adjust to the effects of climate change, moderate potential damages and take advantage of opportunities.

To make things clear at this point; when climate change adaptation measures are mentioned, measures that reduce the impact of climate change are meant. When flood risk adaptation measures are mentioned, measures that reduce the impact of a flood are meant. Reducing the chance that a flood occurs is called flood risk mitigation and that is not the main interest of this research. Both flood risk mitigation and flood risk adaptation are parts of climate change adaptation, which is why climate change adaptation science (Termeer et al., 2012 and Huitema et al., 2011) is used to draw up a framework for comparison.

Now that the concepts of climate change, flood vulnerability and climate change adaptation have been explained, it is time to focus on the comparison. A ground for comparison is required in order to make a comparison of climate change adaptation on the wastewater system in different countries. This is found in barriers to climate change adaptation.

3.3 Barriers to adaptation

Comparing adaptation measures among several countries can be done by focusing on the limitations that adaptation measures have to deal with; the barriers. Barriers are increasingly used to describe obstacles for the implementation of climate change adaptation measures (Eisenack et al., 2014) The more similar the barriers are in two cases, the more likely similar measures are to be successful when policy transfer is used from one case to the other. This is explained in the following pages. One important thing that should be mentioned is that the framework used for the comparison is based on climate change adaptation, where the actual comparison made is based on flood risk adaptation. This means that a shift will be made within this chapter; from the theoretical perspective climate change adaptation is described, but the matrix will be designed based on flood risk adaptation. Flood risk adaptation is a part of climate change adaptation, as increased flood risk is an effect of climate change; the matrix for comparison will thus focus on specific parts of climate change adaptation theory.

Climate change adaptation is highly context-specific. It depends on climatic, environmental, social and political conditions in the targeted area (Fischer et al., 2007). Thus, in order to compare countries, this context should be defined and the conditions in the targeted area described. To describe these conditions, the defining context, it is necessary to define the barriers to climate change adaptation so that these can be compared later on.
Examples from policy practice show that adaptation is not free from barriers (Biesbroek et al., 2013). Barriers to adaptation can generally be defined as obstacles that impede adaptation (Eisenack et al., 2014). What a barrier exactly is depends on the goal of adaptation; in general is a barrier an action that raises questions on the efficacy and legitimacy of climate change adaptation (Biesbroek et al., 2013). When the concept of barriers is applied to flood risk adaptation, barriers can be defined as obstacles that challenge the efficacy and legitimacy of flood risk adaptation and thus impede flood risk adaptation.

Barriers are also relevant in comparative research and policy transfer theories. Comparative case methods aim to explain variation in how barriers in different contexts are addressed and understood (Biesbroek et al., 2010). In other words; the type of barriers and their presence in the various countries in case studies can define the similarities and differences between countries. Williams et al. (2014) stated that the bigger the similarities between countries are, the more successful policy transfer can be. This is based on the assumption made by Rose (1991) that the same problems exist in different countries and that policymakers in cities, regional governments and nations can learn from the way their counterparts in other countries respond to these problems.

Williams et al. (2014) also state that problems can occur when policy transfer occurs between different economic, political and ideological contexts. How these contexts can cause issues for policy transfer depends on the barriers that are allocated in each context. These economic, political and ideological contexts are the boundaries that define our cases, in combination with the physical context as cases that are not prone to flood risk are of no interest for this research. If cases are not prone to flood risk at all, there is no flood risk adaptation necessary and thus there is no base for comparison. Each of these contexts can be analyzed and compared individually, based on the barriers that each context contains. First, an overview of barriers to climate change adaptation can be established. After that, barriers can be divided to then define each context in the matrix for comparison. Biesbroek (2014) arranges barriers into seven clusters; conflicting timescales; substantive, strategic and institutional uncertainty; institutional crowdedness and institutional voids; fragmentation; lack of awareness and communication; motives and willingness to act; resources.

Biesbroek et al. (2010) analyzed the national adaptation strategies of various European countries. All countries deal with water resource management in their national adaptation strategies. This is why the barriers that Biesbroek et al. (2013) define are of interest for this research. Swart et al. (2009) state that there are significant institutional differences in political priority, availability of resources, scales of research programs, institutions and organizations in place and external pressure on the national adaptation strategies. Biesbroek et al. (2010) adds to this that it has become clear that especially in the UK, the Netherlands and Germany adaptation ranks high on the political agenda. Motivational and facilitating factors are in place and large budgets are available for regional and local vulnerability and adaptation research (Biesbroek et al., 2010).

Biesbroek et al. (2011) state, based on a questionnaire among various scientists, policymakers and actors involved in climate change adaptation, that conflicting timescales is the most important barrier to climate change adaptation in the Netherlands. Biesbroek (2014) mentions that conflicting timescales are the lengths of long-term planning in strategic policy documents (20-30 years) versus the lengths in which climate change impacts are measured (100 years or more). This difference makes it difficult to mainstream adaptation in new and existing policies and practices (Biesbroek, 2014). The key issue here is the flexibility of policies; this will be explained later on.

Other important barriers are conflicting interests, lack of financial resources, unclear division of tasks and responsibilities, uncertain social costs and future benefits as well as fragmentation within and between scales of governance. Bauer et al. (2011) describe four main challenges to climate change adaptation, which also can be seen as barriers; cross-sector governance, cross-level governance, uncertainty of future effects of climate change and the range of non-state actors. Each of these challenges can be put in the physical, economic, political or ideological context that have been described by Williams et al. (2014), to define the factors for the matrix for comparison, which is shown in the following pages.

3.4 Matrix for comparison

Based on the definition described above, this matrix has been created to compare flood risk adaptation between various cases. The matrix will be used to answer the third research question; to which extent can flood risk adaptation measures in foreign countries be implemented in the Netherlands? The matrix consists of four different contexts that each contain various phenomenon, based on clusters of barriers as described by Biesbroek (2014). Each cluster of barriers, in one case two clusters, is translated into a phenomenon that can be researched and analyzed for each case. First an overview of the matrix is given, and then each phenomenon is briefly described in the following pages.

Context	Cluster of barriers	Phenomenon
Physical context	No floods possible	Flood risk
	System essentially different	Wastewater system
Economic context	Lack of resources	Financial resources
	Uncertain future benefits	Relevance of protection
Political context	Unclear division of tasks and responsibilities / Conflicting interests	Responsibility
	Uncertain social costs	Public opinion
	Conflicting Timescales	Current policies and timescales
Ideological context	Institutional voids	Trend in policies

Table 3: Matrix for comparison

3.4.1 Physical context

The physical context was added by the author with the specific goal of comparing settings. As every wastewater system is essentially different when talking about physical matters such as assets, geological setting and flood projections, it is not relevant to compare physical adaptation measures. General physical adaptation measures cannot be drawn, as the implementation of those will have different effects on each installation. However, in order to compare systems it is still important to make a definition of the physical context of the system to validate the comparison. To achieve this, the author created two more clusters of barriers that are not based on Biesbroek (2014).

An example of this was experienced during the workshop; a misunderstanding between two participants occurred, as one of the participants had a wastewater system with a gradient that also could discharge wastewater without power, whereas the other participant had a horizontal system that required electric pumps to transport wastewater. To prevent misunderstandings like these, the physical setting of each case should be described.

Flood risk – Barriers of no floods possible (own barrier)

For effective climate change adaptation, a specific climatic and environmental context is necessary (Fischer et al., 2007). We are looking into a context where flood risk is high, or at least where the wastewater system is prone to flooding. This does not only mean that a certain flood risk is defined, but it is also relevant how this flood risk was defined, what standards were used and who defined this flood risk.

Wastewater system – Barriers of system essentially different (own barrier)

Not all wastewater systems are similar; this has been explained in chapter 2 about the wastewater system. In order to make a comparison between countries, the wastewater systems need to be similar to some extent. In order to make this comparison, a short description of the system is therefore necessary; is it separated or mixed, does it work with pumping stations or under a gradient, what is the degree of connectivity? Basic information on the sewer system is required to make a comparison between adaptation measures as some measures have different effects on different systems.

3.4.2 Economic context

Financial resources – Barriers of lack of resources

A lack of resources or the inaccessibility of resources can be a barrier to climate change adaptation. These resources include human resources (like employees), financial resources, information resources (such as research and availability of data), physical resources (technological measures) and natural resources (availability of land) (Biesbroek, 2014).
Financial resources in particular need to be allocated and defined for climate change adaptation measures and thus for flood risk adaptation measures. It is relevant to describe per case how adaptation measures are financed or organized. In order to do so, funds should be investigated; are there funds available for measures, are measures financed otherwise? How is the availability of employees and knowledge arranged?

Relevance of protection – Barriers of uncertain future benefits

Climate change adaptation involves unprecedented methodological challenges because of the uncertainty and complexity of the hazards (Fischer et al., 2007). In most cases, it is unknown whether the effects of climate change will have a disastrous impact on systems or a rather small impact. It is important to take in consideration what is being protected and what the costs will be in the future to keep protecting.
This can be researched by defining how the flood risk adaptation in a specific case is organized. Are measures area-based, focusing on protecting an entire area, or more sector-based, focusing on specific targets in an area? When the approach is area-based, some targets in a low-priority area might encounter barriers while taking adaptation measures. On the other hand, when the approach is sector-based, some targets may struggle to take measures, as they do not belong to the appropriate sector and thus encounter barriers.

3.4.3 Political context

Responsibility (based on two clusters of barriers)

1– Barriers of unclear division of tasks and responsibilities, causing fragmentation within and between scales of governance

Bauer et al. (2011) define cross-level governance as a possible barrier for climate change adaptation. Adaptation policies on a national scale are used to frame climate change adaptation within the overall water management. On a national scale, climate change adaptation policies often deal with safety (Termeer et al, 2012). A good example of this is the Delta Programme in the Netherlands, which is explained in chapter 1. The national Delta Programme has water safety as a starting point, but splits climate change adaptation into various themes like flood protection, freshwater management, urban water management, etcetera. Each theme is then elaborated into regional climate change adaptation policies and projects. The problem with this distinction is that it limits the possibilities for trans boundary cooperation, due to the fragmented climate change adaptation policies (Termeer et al, 2012).

Within a country, however, this fragmentation can be of great value. An example of this can be seen in Germany, as described in Huitema et al. (2011). The National Adaptation Strategy in Germany serves as a coherent climate change strategy on a national level, which initiates and coordinates action on a regional or even a local level. This way, the National Adaptation Strategy serves as a guideline that can be implemented according to context on lower levels of governance. It should be mentioned that some coastal states in Germany have their own policies regarding climate change adaptation against coastal flooding, which is not integrated in the National Adaptation Strategy (Huitema et al, 2011).

2– Barriers of conflicting interests

Bauer et al. (2011) define that cross-sector governance is a barrier to overcome for climate change adaptation. Climate change adaptation requires close collaboration between scientists, practitioners, decision-makers and other stakeholders (Fischer et al., 2007). Therefore, it is important to define clearly who is responsible for climate change adaptation to prevent conflicting interests and improve cooperation. Climate change adaptation is a multi-level and a multi-sector issue, which might make fragmentation issues even more severe (Biesbroek, 2014).

Public opinion – Barriers of uncertain social costs

Climate change adaptation deals with the effects of climate change at the end, rather than trying to prevent climate change from occurring. This does not help to increase the popularity of adaptation (Fischer et al., 2007). In order to clear the ground for climate change adaptation, the public opinion on adaptation needs to be positive; this can lead to an increase in bottom-up decision making. This is also relevant to increase autonomous adaptation measures, which are important as adaptation measures are most effective on a local scale (Fischer et al., 2007). What factors lead to adaptive behavior? An effective motive for adaptive behavior is the occurrence of an extreme event (Biesbroek, 2014).

Current policies – Barriers of conflicting timescales

Conflicting timescales have been defined by Biesbroek (2014) as the most important barrier for climate change adaptation in the Netherlands. Conflicting timescales can be seen in the difference between the long-term planning found in strategic policy documents, 20 to 30 years, and the long-term impacts of climate change, 100 years or more. To compare cases, the current climate change adaptation policies in other countries should be taken in consideration, with a focus on the timescales they run. Conflicting timescales make it difficult to integrate adaptation in policies and practices (Biesbroek, 2014). When timescales are conflicting, policies need to be able to adapt to the long-term impacts of climate change. The relevant factor to define this is the flexibility of policies. The more flexible policies are, the more they can adapt over time and the better they can respond to changes in climate projections over time.

3.4.4 Ideological context

Flood risk mitigation or adaptation – Barriers of institutional voids

The paradigm shift from mitigation to adaptation is described in the theoretical framework. Key to this paradigm shift is societal change; the example is given of the change in policies in Germany from mitigation to adaptation (Huitema et al., 2011). The current trend in policies should be defined for each case; do the policies deal with mitigation or rather with adaptation? An institutional void occurs when institutions lack to enable, facilitate or stimulate climate change adaptation. It can trouble communication between actors. An institutional void is connected to a lack of shared understanding on adaptation, a lack of sense of urgency as well as a lack of instruments (Biesbroek, 2014).
This is to some extent similar to 'Public opinion', with the one relevant difference that the ideological context is dealing with governmental authorities rather than private authorities. To which extent is climate change adaptation integrated in the policy makers' behavior?

Now that each phenomenon has been described, based on a cluster of barriers as defined by Biesbroek (2014) or by the author, a framework for comparison is designed. The next step now is to gather the required data to complete the matrix for comparison.

3.5 Conclusion

The matrix for comparison can be completed by gathering data in various ways. In order to define flood risk, literature research can be done and policy documents can be analyzed to see what flood risk projections are used. Professionals can be asked to see how these flood risk projections are defined. Knowledge on the wastewater system can be found in policy documents and through interviews with professionals. The allocation and organization of resources as well as the relevance of protection can be found in literature, policy documents and through interviews with experts. Responsibility should be found in policy documents, to see what authorities have responsibilities to take adaptation measures and to define the role of private actors. To find information on the public opinion on flood risk adaptation among private actors, interviews with professionals are necessary. To compare long-term policies on climate change in each country and the flexibility of these policies, policy documents need to be analyzed as well as interviews with experts. The transgression from flood risk mitigation to flood risk adaptation in policies in the various countries can be defined through policy documents and interviews.
All these data collection methods are defined in the following chapter, methodology.

4. Methodology

In this chapter, the research design will be elaborated. First, the concept of a case study will be explained as well as the type of case study that is used in this research. After that, the concept of lesson drawing is used to explain how the cases used in this research were selected. Then, the methods for data gathering are explained; focus groups, interviews, document analysis and participatory observation. After that, the data analysis method is explained.

4.1 Case study methodology

The main goal of this research is to compare the Dutch flood risk adaptation on the wastewater system with the flood risk adaptation in foreign countries. In the last twenty years, the Netherlands has not had any major floods. A flooding of an entire wastewater system, including the entire area of wastewater collection, has not occurred. The little experience that the Netherlands has with events of flooding of the wastewater system is the reason that the Ministry of Infrastructure and the Environment decided study foreign cases, which was the catalyst for this research. The idea is that the experience that other countries have with events of flooding of the wastewater system can be a valuable lesson to the Netherlands as well. In order to compare those countries to the Netherlands, with the ultimate goal to draw lessons from these measures and eventually implement those in the Netherlands, a matrix for comparison was designed in the theoretic framework. Now, the research design should be elaborated to address case selection and data gathering methods.

Scientific research can be separated into experimental and non-experimental research. It is impossible to manipulate political or urban systems in an experimental fashion (Peters, 1998), therefore social scientists use comparison as a substitute for the experimental method. Non-experimental research can be separated into statistical research, comparative research and case studies (Peters, 1998). In order to define what type of non-experimental research fits this research best, the research goals have to be defined. As mentioned before, the main goal of this research is to compare the Dutch setting with foreign cases. In order to make this comparison, the matrix for comparison that was developed in the theoretic framework should be completed for each case. In order to make this comparison and draw conclusions out of it, a research design is needed. Yin (1994) describes research design as an action plan to answer a set of questions and draw conclusions out of these. Baxter & Jack (2008) define seven different types of case study designs; explanatory, exploratory, descriptive, multiple-case, intrinsic, instrumental and collective. Yin (1994) divided case study designs in categories types (see table 4); single-cased versus multiple-cased designs and holistic versus embedded designs.

	Single-Case Design	Multiple-Case Design
Holistic (single unit of analysis)	Type 1	Type 3
Embedded (multiple units of analysis)	Type 2	Type 4

Table 4: Categories types of case study design (based on Yin, 1994)

In order to choose between single-case and multiple-case designs, one first needs to decide what the case study is used for. Single case studies are used when the case represents the critical case in testing a well-formulated theory, when the case represents an extreme or unique case or when a phenomenon previously inaccessible to scientific investigation is described (Yin, 1994).
Multiple-case designs are considered more compelling and therefore more robust. Multiple-case studies can be used when the same results are predicted for each of the cases. The cases should serve in a manner similar to multiple experiments, with similar results or contrasting results predicted explicitly at the outset of the investigation (Yin, 1994).
The description of the multiple-case study that Yin gives fits best to what this research wants to achieve: *"Multiple-case studies enable the researcher to explore differences with and between cases. The goal is to replicate findings across cases. Because comparisons will be drawn, it is imperative that the cases are chosen carefully so that the researcher can predict similar results across cases, or predict contrasting results based on a theory."* (Yin, 2003).
The replication design does not necessarily mean that each case study needs to be either holistic or embedded; the individual cases within a multiple-case study may be either. Decided is to approach this research as a case study with multiple cases.

Now that the type of non-experimental research that fits this research best (multiple-case) has been defined, the amount of cases necessary has to be defined. Non-experimental research can be separated into statistical research, comparative research and case studies (Peters, 1998).
This division within non-experimental research is made based upon the number of cases. For one case study, only one case is necessary. For a comparative research or multiple-case study, two or a few cases are necessary. For statistical research, many cases are required (Peters, 1998). When many cases have been analyzed, statistical models can be used to analyze data. However, it is not intended to use statistical analysis on the cases seen. This is due to the fact that, as explained, every wastewater system has a different physical context. It would not make sense to make generalizations in this. Considering the fact that we are dealing with both case studies and comparative research, multiple cases are required but not too many (as statistical research is not required).

It has been explained why cases should be used and how many cases are required. The next step in the methodology is to now choose specific cases. In order to justify the choice of cases, the case first has to be constructed (Peters, 1998). The researcher has to create a research design first, that answers the questions 'what do I use?' and 'why do I use it?' The next part of this chapter will explain how the selected cases were chosen.

4.2 Case selection for lesson drawing

The first criterion in selecting a case should always be to maximize what we can learn (Stake, 1995). In order to maximize the learning process, cases should be picked that lead us to understandings. The learning process that we are trying to achieve in this research is to learn from policies in other countries. In order to do that, a jump needs to be made towards theories on comparative research.

Rose (1988) states that every country considers their problems unique. However, when confronted with a common problem, policy makers can learn from other policy makers that have dealt with the problem before elsewhere. This is called comparative research. In the case of the flooding of wastewater systems in the Netherlands, this is a fairly new problem. Policy makers in foreign countries that have dealt with flooding of the wastewater systems before can possibly be a source of inspiration for Dutch policy makers. In order to see to which extent this source of inspiration can also be implemented in the Netherlands, the possibility for policy transfer has to be analyzed.

Policy transfer can be useful in various cases. Dolowitz & Marsh (1996) make a distinction between coercive transfer and voluntary transfer, in which a voluntary transfer is optimal and has the highest chance of success. As we are not dealing with a coercive transfer here it can be considered a voluntary transfer. Rose (1991) suggests that in order to achieve an effective policy transfer the researcher first has to justify the choice of cases on theoretical grounds. The three main reasons for policy transfer according to Rose (1988) are the need to keep cities or regions resilient and sustainable, coercive transfer and failure of the current policies. The need to keep cities or regions resilient and sustainable is the case in this research. It is no matter of coercive transfer; there is no international pressure or other form of obligation to change policies. Neither is the current policy failing; however, the relatively small amount of floods has led to a lack of knowledge in the Netherlands. What will the possible effects of a flooding be? In order to keep the flood protection system up-to-date, to keep it resilient and sustainable, more knowledge is required.

Dolowitz & Marsh (2000) state that there are three possible reasons for failure of policy transfer. The first reason is when the transfer is applied with a lack of available knowledge on policies or institutions that are involved in the transfer. When too little is known about the institutional setting of the transfer, this is referred to as an *uninformed transfer*.

The second possibility is that the appropriate amount of knowledge is available, but crucial elements of the policy have been left out. In this case we speak of an *incomplete transfer*.

The last possibility is when enough knowledge is present and the whole policy is transferred, but due to some unforeseen or unaddressed differences, the policy is not suitable for the receiving country. In this case we speak of an *inappropriate transfer* (Dolowitz & Marsh, 2000). This is connected to the idea of Rose (1991) that the choice of cases has to be justified on theoretical grounds first. When there are essential differences between countries, policy transfer might not work. This can be solved with the use of communication; the higher the level of communication between donor country and receiving country, the higher the chance of a successful policy transfer (Dolowitz & Marsh, 2000). To this we can add the fact that cases should be picked that are easy to get to and hospitable to inquiry and preferably have actors that are willing to inform you and comment on draft materials (Stake, 1995).

When these qualifications are combined, it means that we are looking for cases on which enough knowledge is available and that are also either essentially similar to the Netherlands or at least have a high level of communication with the Netherlands. This means that the cases have to have some form of communication with the Netherlands, either through contact persons, cooperating in projects or information exchange programs. On top of that, they should be cases that are able and willing to cooperate with the researcher.

With these requirements (enough available knowledge, to some extent similar to the Netherlands, level of communication, willing to cooperate), the selection of cases was done. As the researcher was involved in an internship in the field, many experts were seen through the organized workshops. An overview of the experts that participated in the workshops and the organizations they represented can be found in the appendix. The first case, the flooding of the Neisse River in Germany in 2010, was found while discussing these requirements with an expert from RIONED. The flooding of the Meramec River in St. Louis (US) was recommended by an expert from the Ministry of Infrastructure and the Environment. The case of hurricane Katrina in New Orleans was discussed with experts from the RIVM (Rijksinstituut voor Volksgezondheid en Milieu; State Institute for Health and Environment), initially for the interest in health hazards due to exposure to wastewater, but during the workshop the whole flooding of the wastewater system was included. The floods in Germany in 2013, which affected many cities throughout the country, were recommended by experts from Rijkswaterstaat as several examples of flooded wastewater systems could be seen there. Several other cases were discussed, but those cases did not meet the requirements of available knowledge, level of communication or extent of similarity, so it was decided to stick with these four cases. This has partly to do with the fact that literature on these events is often only available in the native language, which limited the possible research countries to English, Dutch or German-speaking countries. Possible interview partners could be addressed in either English or German, which increased the willingness to cooperate.

Two cases involved small floods in which wastewater treatment plants had flooded (St. Louis and Saxony), two cases involved major floods that affected bigger regions, including the wastewater system (New Orleans and Germany). All four cases are listed in table 5.

Location	Body of water	Affected cities	Year
Saxony (Germany)	Neisse	Zittau, Hirschfelde	2010
Germany	Saale, Elbe, Danube, Inn, Rhine	Many	2013
New Orleans (USA)	Mississippi	New Orleans	2005
St. Louis (USA)	Meramec	St. Louis	2015/2016

Table 5: Selected cases

Interesting about these cases is that four cases are located in two countries. This means that we are essentially dealing with a multiple-case study with four cases, if we would take each event as a case, but with two cases if we would consider each country as a case. As our matrix for comparison (that is explained in the theoretical framework) often deals with issues on a national level, it is decided to take both Germany and the United States as cases. The individual examples of flood events can then be used to describe the cases.

All four flooding events are described in detail in chapters 6 and 7. However, before those chapters are addressed, it should be explained how data was gathered on each of the cases. This will be explained in the following pages.

4.3 Methods

4.3.1 Focus groups

Key to the research is the data gathering method *focus groups*; in cooperation with the Ministry of Infrastructure and the Environment, the researcher organized workshops with experts from the wastewater management field. A short summary of each workshop is included in the appendix of this research. In the appendix, each workshop is described with the location, date and participants. The topics that were discussed have then been elaborated, based on the section of the workshop. Throughout the workshops three themes were followed. In the first workshop it was attempted to figure out what exactly happens when a wastewater system floods, the second workshop addressed two scenarios (one where the wastewater system fails but there is still discharge and one where both the wastewater system and the discharge area flood) and the third workshop focused on possible adaptation measures. Within these workshops, several cases were discussed based on presentations done by the researcher. More about this is explained on the next pages.

Three workshops have been organized, in which participants of various institutes take place. Overviews of these workshops can be found in the appendix. First, the theory behind organizing focus groups will be addressed and then the focus groups that took place will be described.
A focus group is a form of a group interview that capitalizes on communication between research participants in order to generate data (Kitzinger, 1995). Rather than asking questions to a group of people, focus groups use group interaction as a method and encourage participants to talk to one another. Focus groups are particularly useful for exploring the knowledge and experience of participants (Kitzinger, 1995). The group dynamics can help participants to generate their own questions, taking the research in new directions. This possibility for interaction between participants as well as interpersonal communications such as body language is what makes focus groups a unique data collection technique. A disadvantage of using focus groups is that the group discussion may silence participants or lead the discussion in one particular direction, leaving relevant information out (Kitzinger, 1995).

Most researchers aim for homogeneity within the focus group in order to capitalize on people's shared experiences; it can be an advantage, however, to bring together a diverse group (people with different backgrounds or professions) to maximize exploration of different perspectives (Kitzinger, 1995). As this suits the research goal, decided was to bring together a diverse group. We chose for people with various professional backgrounds (policy making, wastewater treatment, public health, drinking water, flood risk) as well as various scales of interest (from the national government to local authorities as well as both public and private organizations).
Sessions should be relaxed, with a comfortable setting and refreshments; sitting in a circle will help to establish the right atmosphere. The researcher may take a back seat at first, allowing the discussion to go on while observation, but can adopt a more interventionist style later on; urging debate to continue beyond the stage where it might end or introducing a new topic when the discussion gets stuck (Kitzinger, 1995).

Analyzing focus groups works the same way as analyzing any other qualitative self-report data. It is important to pay attention to minority opinions and examples that do not fit within the researchers' overall theory. The only unique feature of using focus group data is that group dynamic and sessions analysis should take advantage of the interaction between participants. Coding the script using special categories for certain types of narratives is recommended (mostly the type of interaction, such as “question” or “deferring the opinion of the other”) (Kitzinger, 1995).

Participants represented the Ministry of Infrastructure and Environment, Rijkswaterstaat, the municipalities of Dordrecht, Venlo and Tholen, the water boards Noorderzijlvest and Limburg, Stichting RIONED, RIVM (national institute for public health and the environment), Evides (a drinking water company) and Waternet (a water company). The sessions were organized in a circle to stimulate discussion. During the sessions, various professionals presented, after which the content of the presentations was discussed. The researcher also held multiple presentations, during the first and the third workshop, presenting two of the cases that are analyzed in the research. Each workshop was recorded and summarized afterwards. The overall results of the workshop are presented in a report, which will be showed to the participants before presenting it to the Ministry.

4.3.2 Interviews

Besides the focus groups, *interviews* have been carried out with people involved in climate change adaptation, both on a practical level as well as on a policy level. Interviews were held with actors in the Netherlands, Germany and the United States. The interviews were done with the idea to eventually complete the matrix for comparison for each case, based on the acquired information. Several interviews have been conducted throughout the research. Some actors have been interviewed to talk about climate change adaptation on a practical level, others on a more abstract level, for example climate change adaptation governance. Below can be seen a table of the people that have been interviewed and what organization they represent.

Two principal uses of case study research are to obtain the descriptions and interpretations of others. Different people have different viewpoints on cases (Stake, 1995). Key to the research is to obtain various interpretations of cases by others. Part of this is experienced during the focus groups, but interviews can be of great added value. Qualitative researchers should discover and portray multiple views of the case; the interview is a road to multiple realities (Stake, 1995).
Interviews are essential sources of case study information. An interview should be interpreted through the eyes of the interviewed and can provide important insights into a situation (Yin, 1994).

Name	**Organization**	**Date**
Hugo Gastkemper	Stichting RIONED (NL)	5 July 2016
Ronald van Dokkum	Rijkswaterstaat (NL)	15 September 2016
Meinte de Hoogh	Ministry of Infrastructure and the Environment (NL)	10 November 2016
Peter Wassenaar & Saskia Holthuijsen	Waternet (NL)	31 October 2016
Henryk Predki	Metropol Region Northwest Germany (DE)	26 October 2016
Thomas Klenke	COMCOAST / FRAMES (DE)	28 October 2016
Lance LeComb	St. Louis Metropolitan Sewer District (USA)	March – June 2016 (by email)

Table 6: Interviews

The information gathered through interviews is used to describe the cases, but most of all used in the chapter results to give an accurate interpretation of the matrix for comparison for each case. In the text will be referred to the interviews as the organization rather than the person interviewed. This means that the interview with Hugo Gastkemper will be referred to as the interview with RIONED, the interview with Ronald van Dokkum as the interview with Rijkswaterstaat, the interview with Meinte de Hoogh as the interview with the ministry, the interview with Peter Wassenaar and Saskia Holthuijsen as the interview with Waternet, the interview with Henryk Predki as the interview with Metropolregion Nordwest, the interview with Thomas Klenke as the interview with FRAMES and the interview with Lance LeComb as the interview with SLMSD.

4.3.3 Document analysis

As an addition to these interviews, *policy documents* have been analyzed. Policy documents were an addition to the interviews to complete the matrix for comparison in each case. Several documents on climate change adaptation, wastewater management and trans boundary cooperation have been collected throughout the research to serve as references. A detailed overview of which documents were analyzed can be found on the next pages.

Documentation is relevant to every case study topic. Documentation can take many forms and should be part of the data collection plan (Yin, 1994). Gathering data by studying documents is essentially similar to observing or interviewing. The researcher should keep his mind organized and still be open for unexpected clues (Stake, 1995).
In this research, a wide variety of documents have been studied. The list of documents studied can be found below. Documents have mostly been used to describe the cases but also to serve as references to give an interpretation of the matrix for comparison. Especially on the political context in the matrix for comparison, policy documents were needed to fill in questions.

Netherlands

-Amsterdam Waterbestendig (Waternet, 2010)

-Assset Management voor afvalwatertransportleidingen (Waterbedrijf Limburg, 2015)

-Benchmark 2013 (Stichting RIONED, 2013)

-Gezondheidsrisico's Stedelijk Waterbeheer (RIVM, 2016)

-Het Draait Om Water: Watercyclusplan 2010-2015 (Waternet, 2010)

-Leven met water: strategie waterveiligheid en klimaatbestendigheid in de Ijssel-Vechtdelta (INFRAM, assigned by the province of Overijssel, 2015)

-Schades door watertekorten en -overschotten in stedelijk gebied (Deltares, 2012)

-Towards Water Robus Critical Infrastructure (Various authors assigend by the Ministry of Infrastructure and the Environment, 2015)

-Waterbeheerplan 2016-2021: Waterbewust en waterrobuust (Waterschap Amstel Gooi en Vecht – WS AGV, 2016)

-Waterbestendige Westpoort: Pilotstudie vitaal en kwetsbare functies in de haven van Amsterdam (MUST in cooperation with Witteveen + Bos, assigned by the Ministry of Infrastructure and the Environment, 2013)

Germany

-Benchmark 2013 (Stichting RIONED, 2013)

-Gezondheidsrisico's Stedelijk Waterbeheer (RIVM, 2016)

-Interkommunale Koordinierungsstelle Klimaanpassung: Leitfaden zur Starkregenvorsorge (Metropolregion Nordwest, 2016)

-Klimaatadaptatiestrategie voor het internationaal Rijndistrict (ICBR, 2015)

-Korrespondenz Abwasser – Abfall: KA International Special Edition (DWA, 2015)

-Sewer Systems Wastewater Management: KA International Special Edition (DWA, 2016)

-Towards Water Robus Critical Infrastructure (Various authors assigend by the Ministry of Infrastructure and the Environment, 2015)

-Under the Focus of Statistics: Sewerage and Stormwater Treatment in Germany (H. Brombach and J. Dettmar, assigned by DWA, 2016)

-Wasserhaushaltzgesetz (Bundesministeriums der Justiz und für Verbraucherschutz, 2009)

United States

-Climate Change and the Resilience of New Orleans: the Adaptation of Deltaic Urban Form (Carbonell, A. & Meffert, D.J., commissioned by the World Bank, 2009)

-First Aid for a Flooded Septic System: small community wastewater issues explain to the public (Pipeline, published by the National Environmental Services Center assigned by the US Environmental Protection Agency, 2006)

-Hurricane-Damaged Drinking Water and Wastewater Facilities: Impacts, Needs and Response (Copeland, C. assigned by Congress, 2006)

-The President's Climate Action Plan (Executive Office of the President, 2013)

-Towards Water Robus Critical Infrastructure (Various authors assigend by the Ministry of Infrastructure and the Environment, 2015)

-Water in de openbare ruimte heeft risico's voor de gezondheid (De Man, H. assigned by Stowa and RIONED, 2014)

4.3.4 Participatory observation

Finally, as the writer of this thesis is involved in the research through an internship, *participatory observation* has been used as a method to collect data as well. This is slightly different from the other methods of data gathering; rather than gathering information, participatory observation is relevant for the way data is interpreted. More information on the internship and data interpretation can be found later on in this chapter.

Direct observation can be useful in providing information about the topic being studied, but participatory observation can add an extra dimension to case study research. Various roles of participatory observation provide various opportunities; for example the ability to gain access to events or groups that are otherwise inaccessible or the ability to get a viewpoint from someone inside the case study (Yin, 1994). But the most important ability of participatory observation is the possibility to manipulate minor events, like meetings (Yin, 1994). Especially during the focus groups the double role of participant and observer is useful in this situation.

During the internship at the Ministry of Infrastructure and the Environment in Den Haag from January to December 2016, the researcher has worked on the general project on flood risk adaptation on the wastewater system in the Netherlands. This included the organization, conduction and briefing of the workshops as most important task. After the workshops, the researcher contributed to the general report on flood risk adaptation to the wastewater system.
Besides the workshops, the researcher also took part in other activities. The researcher visited several meetings on wider topics, like water quality, water cycle management and ground quality. Examples of this are the meetings of ‘Stuurgroep DRAB’ and management meetings at the Ministry. Two wastewater treatment plants were visited, in Tollebeek and in Utrecht, to discuss adaptation on a practical level. Several congresses and conferences on the wastewater system, climate change adaptation and flood risk adaptation were attended. Examples of this are RIONEDdag 2016 in Utrecht, Werkconferentie Ijssel-Vecht Delta in Zwolle and Deltaconferentie Klimaatadaptatie in Den Haag. Besides the general meetings, the researcher also participated in the 'Werkgroep VenK' (taskforce for vital and vulnerable infrastructure). In meetings with this taskforce, the chain dependency of vital and vulnerable infrastructure was discussed, as well as the progress of the project on flood risk adaptation of the wastewater system. Here, the researcher contributed to the overall report on vital and vulnerable infrastructure. There were also other activities that the researcher participated in, that are not relevant to this research and therefore not addressed specifically.

Stake (1995) wrote that during observation, a qualitative case study researcher should keep a good record of events to provide a relatively incontestable description for analysis and reporting. Yin (1994) mentioned several problems that can occur during participatory observation. First, the personal viewpoint of the participant can get in conflict with the neutral viewpoint of the observer role, especially when the participant is supporting a group or organization. Second, the participant role may require too much attention relative to the observer role. Especially during the workshops this might be a problem, when the researcher is doing presentations and needs to observe the workshops simultaneously. Information gathered through participatory observation mostly serves as a way to interpret data. Especially the information gathered through focus groups can be interpreted better when the researcher has been present at the focus groups. The role of observer is in this case more valuable for data collection than the role of participant.

4.4 Data analysis

Each type of data was analyzed in a different way. This paragraph will briefly describe the method of analysis for each type of data.

The *workshops* (or focus groups) were recorded while they were conducted. Besides that, the researcher and the other two organizers of the workshop took notes. After the workshop, the researcher listened to the recorded audio while he wrote a summary of the workshop. This summary was sent to the other workshop organizers, who included their own comments in the text. The summary of each workshop can be found in the appendix.

To analyze the data found in the workshops, each topic or item that was discussed in the workshop was analyzed to see whether this item fitted to a description that was necessary to complete the matrix; the matrix was used as a coding scheme. If this was the case, the item was described under the appropriate header in the chapter results.

The *interviews* were also recorded while they were conducted. Unlike the workshops, the interviews were fully transcribed. The transcripts of the interviews can be found in the appendix.

To analyze the interviews, the researcher worked through the transcripts from the beginning to the end. The coding scheme used was based on the categories of the matrix. When items were discussed that seemed of interest to complete the matrix, a short summary of the item was written in the results chapter. While writing the results chapter, the researcher could then use these summaries to elaborate on the text.

For the *document analysis and participatory observation*, the researcher had a notebook that served as a journal and as a database. Whenever the researcher came across relevant information, whether it was through reading policy documents, literature or while discussing topics in meetings or conferences, it was noted in this notebook with a reference to what meeting or document it was based on. This notebook served as a key database while writing the results chapter.

After all this data had been analyzed, the results chapter was written. However, as the chapter had become rather large, decided was to split up the results chapter in three separate chapters; the Netherlands, Germany and the United States. The chapter on the Netherlands then starts off with the completed matrix and includes only the results. The chapters on Germany and the United States first describe the events of the analyzed cases, before the results are discussed based on the completed matrix.

5. The Netherlands

Each chapter on a specific case (The Netherlands, Germany and the United States) provides a completed version of the matrix. The chapters on Germany and the United States will start with a case description of the flood events. As the Netherlands does not have examples of recent flooding of the wastewater system, this chapter starts with the matrix.

Physical context	Flood risk	Increasing temperature, rising sea level and an increase in extreme precipitation events lead to an increasing flood risk
	Wastewater system	High degree of connectedness, approximately 30% separated systems, large wastewater treatment plants
Economic context	Financial resources	Adaptation measures are to be integrated in existing investments to reduce costs
	Relevance of protection	Area-based approach of protection; country is divided in safety regions with different levels of protection
Political context	Responsibility	Adaptation measures are taken by regional authorities (water boards, municipalities); safety region takes over during a crisis
	Public opinion	Water nuisance is relevant, but little measures against flooding are taken on private lands
	Current policies and timescales	Keeping multiple scenarios open with frequently adjustable policies; timescale of the Delta Programme set for 2050
Ideological context	Trend in policies	Adaptation has shifted from a Delta Decision to a Delta Programme, completing the shift from science to policy

Table 7: Matrix for the Netherlands

5.1 Matrix

As mentioned before, the Netherlands is the country in which the suitable adaptation measures should be implemented. International cooperation is seen as a possibility for employing, raising knowledge and thinking out of the box to find innovative solutions for water issues (Waterschap AGV, 2016). In order to make a comparison to see whether implementation of foreign flood risk adaptation measures could be successful, however, the matrix for comparison should also be completed for the Netherlands, so that each factor can be compared individually.

5.1.1 Physical context: flood risk

It is difficult to give an accurate prediction for climate change in areas as small as the Netherlands. For Western Europe it can be said that fluvial patterns will change due to climate change, but it is hard to predict exactly to which extent (KNMI, 2006). Various climate scenarios have been made for different amounts of impact. All scenarios have the following characteristics in common; an increase in temperature, resulting in warmer winters and summers; more precipitation in winter, with an increase in precipitation intensity; more extreme showers in summer, but less days of rain; an increase in intensity; an increasing sea level.

For 2050, a temperature rise between 1 and 2 degrees Celsius can be predicted (ICBR, 2015). The trend in increasing intensity of precipitation is depicted in figure 9. As can be seen, various points in the Netherlands show a significant increase in intense rainfall events. The increase in precipitation events causes higher peak discharges (INFRAM, 2015), which increases the pressure on the wastewater system. It is stated by Dircke et al. (2012) that due to the intensity and frequency of extreme rainfall events in the future, there is a risk that the current sewage system may not be able to treat and drain the surplus water. An increase in precipitation requires the wastewater system to increase the capacity. This means that not only the local system needs a higher capacity but also the communal wastewater system and the regional water system (as discussed in the interview with RIONED). Besides the increase in precipitation events, the increasing urbanization rate in certain parts of the Netherlands causes an increasing pressure on the wastewater system (Waternet, 2010). It should be kept in mind that the amount of water that can be discharged across the border into the great rivers in the Netherlands is limited, as these rivers will flood in Germany at a certain level before they do in the Netherlands. In other words; the more measures are taken in Germany, the higher the flood risk in the Netherlands due to the increased discharge from Germany to the Netherlands (as discussed in the first workshop).

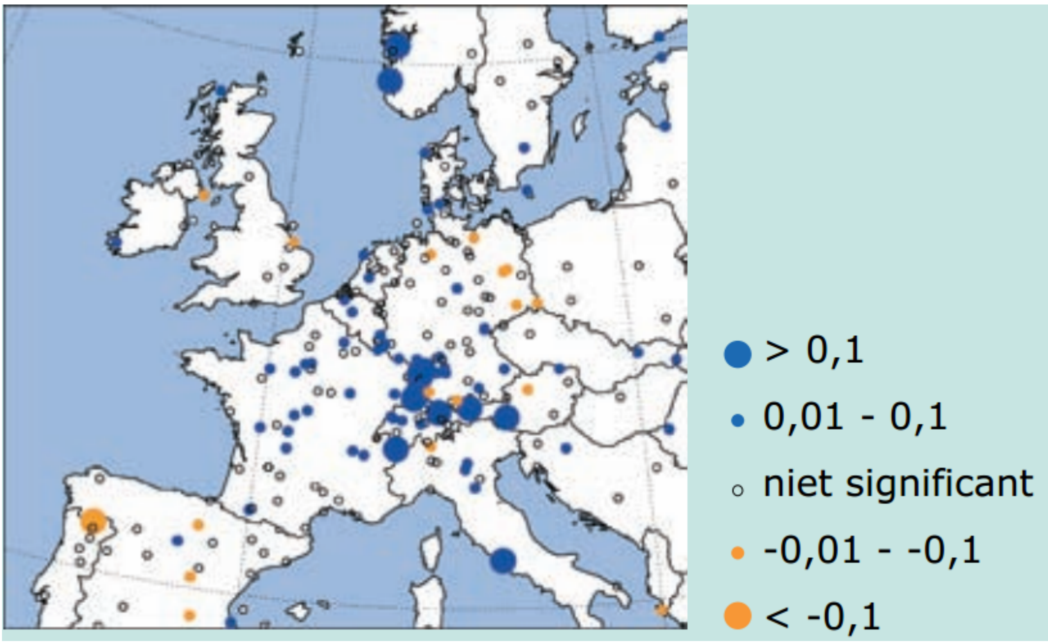

Figure 9: Trend in increases in precipitation intensity in Western Europe (KNMI, 2006)

When the wastewater system floods, it is likely that the transport and purification of wastewater can no longer continue and that wastewater will be discharged unto surface water. Besides that, the fast recovery of the wastewater system after a flood is an important issue (INFRAM, 2015). The effects that a flood will have on the wastewater system, varies heavily with each location. Therefore, physical measures on the wastewater systems are not of interest for this research. Examples of physical measures on the wastewater system can serve as inspiration, however, and have been included in the general report from the Ministry. In this research they are not addressed as possible interesting measures. A limitation of the capacity of a wastewater treatment does not necessarily have to cause social disruption, as long as the water in the streets is held within acceptable limits (as discussed in the first workshop). This means that water in the streets is considered water nuisance rather than flooding and this research deals with flood risk adaptation, not with water nuisance adaptation.

Climate change also has an impact on the chances that a coastal flooding occurs. Long time perspectives on the Dutch coast predict severe pressures in the future. The estimates of mean sea level rise in the North Sea for the next 100 years are 20 centimeters in the most optimistic scenario, 50 centimeters in a realistic scenario and 100 centimeters in the worst case scenario (Grootjans, 2016).

Another effect of climate change that can have negative impact on the wastewater system is an increase in droughts. During drought the amount of surface water is reduce, which means that the wastewater system can discharge less effluent onto the surface to maintain the same dilution levels (as discussed in the interview with Rijkswaterstaat). However, as this thesis focuses on the increase in flood risk this is not further addressed in the results.

Flood risk projections can be made in various ways in the Netherlands. The LIWO (Landelijk Informatiesysteem Water en Overstromingen – National Information system for Water and Floods) provides an online risk analysis tool that can be used on any location and in any scenario. Every possible dike breach in the Netherlands can be simulated to see which area might flood. On a national level, there are various flood scenarios available for the Delta Programme. On a more local level, the water boards have access to more detailed flood scenarios that can provide more specific information than the LIWO can (as discussed in the first workshop).

5.1.2 Physical context: wastewater system

The Dutch wastewater system is the responsibility of the water boards. There are no private companies that are responsible for the operation of the wastewater system, although several water boards outsource the work to private enterprises in a public-private partnership (as discussed in the interview with the ministry).

The general specifications of a wastewater system have been described in chapter 2. In the Netherlands, 99,7% of the households is connected to the wastewater system, of which more than 95% is connected to a slope system, 4% to a mechanical system and 0,3% to an IBA. Of the 95% households that use slope system, 68% is a mixed sewer system and 27% a separated system.

The Dutch wastewater system has an average lifespan of 60 years, but can vary between 30 and 100 years depending on the location (Stichting RIONED, 2013). The largest part of the Dutch wastewater system has been established during the start of the law for polluted surface waters (Wet Verontreiniging Oppervlaktewateren), in the 1970s and 1980s. Over the next years, the maintenance of the wastewater system (especially the tubes) will require more attention due to the increasing age and the increase of infrastructure below the surface (Waterbedrijf Limburg, 2015).

It can be said that on average the wastewater treatment plants in the Netherlands are larger and more complex than treatment plants in Germany or in the United States. An overview of all wastewater treatment plants of the Netherlands can be seen in the appendix, projected against the current flood risk map that is used in the Delta Programme. It should be mentioned that this flood risk map does not include scenarios of extreme precipitation (as discussed in the first workshop).

5.1.3 Economic context: financial resources

The total cost for all wastewater systems in the Netherlands was 1,45 billion euros in 2012 and rise with an average of 3% per year (Stichting RIONED, 2013). These costs are financed through the wastewater tax (zuiveringsheffing). Municipalities with an old wastewater system, a high building density or 'bad ground' (in Dutch: slechte bodem) have higher average maintenance costs. The costs to renew the wastewater system are not included in the wastewater tax. In addition, big budget cuts on the wastewater system are a potential threat to the quality of the wastewater system in the Netherlands (Stichting RIONED, 2013). In critical situations, especially when water nuisance becomes too much of a problem, municipalities can choose to increase the water tax. In most municipalities, the wastewater tax covers the expenses on adapting the wastewater system to increased precipitation (as discussed in the interview with RIONED). However, flood adaptation measures are not included in this. It is possible to build in a stimulant in the wastewater tax, where those that take adaptation measures to reduce the discharge onto the wastewater system get to pay a lower wastewater tax. This is starting in big municipalities like Rotterdam or Amsterdam, but not in small municipalities, possibly due to a lack of resources (as discussed in the interview with the ministry).

Besides this stimulant in the water tax, there is a stimulation fund for climate change adaptation measures, but that is mostly focused on research. It is still a point of discussion whether direct funding is necessary while taking climate change adaptation measures. Up until now, the idea is that climate change adaptation measures should be integrated into spatial measures. When you are (re-) developing a neighborhood, adaptation measures can often be integrated without extra expenses (as discussed in the interview with the ministry). An example of this is was seen during the researchers' visit to the wastewater treatment plant in Utrecht. On this site, the wastewater treatment plant is renovated. During the renovation was chosen to relocate the servers and electronic equipment from the ground floor to the first floor to prevent is from flooding. This measure did not bring any extra costs to the renovation. Research has been done on this, and as long as the effects of climate change impose no actual threat, it is effective when climate change adaptation measures are integrated into other policies (as discussed in the interview with the ministry).

An even more important barrier on financial resources, regarding to the ministry, is to coordinate investments. Many authorities have budgets, but a strong cooperation is needed to also invest those budgets together in measures. All government agencies as well as private parties need to be willing to invest part of their budget in an integrated program (as discussed in the interview with the ministry). This is often not the case, either because these integrated programs do not exist or because the willingness to invest is lacking. What makes this even more complicated is the regulation on spending budgets. For example Waternet works with wastewater taxes, water board taxes and drinking water taxes. However, if they want to do an integrated project, it is not possible to use one of these funds but it has to be a combination of all. That means that investing in projects becomes much more complicated, to a point where sometimes projects can not go through for this reason (as discussed in the interview with Waternet). A possible solution for this might be to make a collective tax system that can be used for integrated projects, but politically this is complicated (as discussed in the interview with the ministry).

5.1.4 Economic context: relevance of protection

On the matter of flood protection, the Netherlands has been divided into different areas that all have their own levels of flood protection. The level of protection depends on the possible impact a flood can have in that area, for example how many people there are living (as discussed in the interview with the ministry). Flood risk is dealt with in Netherlands with an area-based approach. A spatial planning approach is used to reduce flood risk; policies are made based upon entire areas rather than specific targets in that area. The idea is that the economic prosperity of an area is the result of the safety and the livability of a region; if that is taken care of, economic prosperity can follow (as discussed in the interview with Waternet).

It is difficult to decide what level of protection is necessary for a specific region. For example Westpoort, the harbor area west of Amsterdam; there are no civilians living in this area, there are no hospitals and no prisons. The small amount of people that require help during a flood would suggest that this region is no priority for climate change adaptation measures. However, the harbor area does include several vital and vulnerable functions that are essential for the city of Amsterdam to function. Westpoort includes a power plant, the distribution center for power from the national grid to the city, the largest share of wastewater treatment installations in the city as well as several companies that work with dangerous materials. On a larger scale, the harbor provides the national Dutch airport with kerosene and is the largest harbor worldwide for gasoline and cacao trades (MUST, 2013). This puts the area in a different spotlight, making it a relevant area to protect against flooding.

In general it can be said that it is important to not overprotect while take climate change adaptation measures (as discussed in the first workshop). Large investments are being made in flood protection along coasts and rivers, which already reduces the flood risk of wastewater systems. Relevant is also that different regions require different measures; especially the difference between urban water systems and rural water systems should be kept in mind (as discussed in the first workshop).

5.1.5 Political context: responsibility

Besides a national government, provinces and municipalities, the Netherlands has a fourth level of governance; regional water boards. A water board is a democratic board, elected by society. In order to make decisions about water in society, a water board cooperates with the state, provinces, municipalities and landowners (Waterschap AGV, 2016). The wastewater system is responsibility of the water boards. That means that the transport and purification of urban wastewater is responsibility of the local water board. To guarantee the quality of the discharge water, water boards work in planning periods for maintenance, renovation and optimization (Waterschap AGV, 2016). However, a well-functioning wastewater system requires clear guidance from the municipality. A municipality needs to cooperate with companies and other governmental institutions to get a clear overview of what needs to be done and how this can be achieved. Good commissioning can be a challenge over the coming year, especially in the light of the decreasing amount and the ageing of employees (Stichting RIONED, 2013).

Water safety, on the other hand, is a responsibility of various governmental authorities at various levels. The national government and water boards are responsible for primary flood defenses. The province is responsible for defining levels of regional flood defenses, which are then implemented by water boards. Provinces, municipalities, companies and civilians are included in the process to see if other issues can be integrated (INFRAM, 2015). For the wastewater system it is relevant that the regional water system (which is a responsibility of the water boards) has enough capacity for the discharged water from the wastewater system. If the wastewater system cannot discharge onto the regional water system, it does not function (as discussed in the interview with RIONED). In case of an emergency the evacuation strategy is responsibility of a safety region. A safety region is a board that consists of members of various governmental institutions that organize safety measures and crisis management in an assigned area. Province, municipalities and water boards communicate to the public to increase awareness of water safety. The safety region facilitates that communication through knowledge and publication materials (INFRAM, 2015). When a regional flood is about to occur, the flood is no longer responsibility of the water board but then becomes responsibility of the safety region. The safety region is better prepared for emergency scenarios and can take action quickly. As experienced in Garmerwolde, firefighters managed to take emergency measures to prevent serious damage (as discussed in the second workshop). It can be complicated to define when this responsibility shifts from the water board to the safety region; during a real crisis this is clear, but before that it depends on which measures have to be taken (as discussed in the interview with the ministry).

On the matter of responsibility for climate change adaptation, the fragmentation of responsible parties makes is hard to integrate data (as discussed in the first workshop). Unlike the wastewater system, water safety or evacuation issues, climate change adaptation is not the responsibility of one governmental authority. Climate change adaptation is a topic that can be and should be initialized at different levels of governance (INFRAM, 2015). The fact that no authority has the ultimate responsibility, and therefore no green light to make investments, makes is complicated to take action. If nobody feels responsible, nobody is willing to take responsibility (as discussed in the interview with Waternet).

In the Ijssel-Vecht delta, for example, the province of Overijssel decided to take the initiative and start a cooperation with the water board Groot Salland, the safety region Ijsselland and the municipalities of Zwolle, Kampen and Zwartewaterland. The goal of this cooperation was to start an integral climate change adaptation process in which organizations, enterprises and civilians take part. The Ijssel-Vecht delta region serves as a pilot program for multilayer safety in the Delta Programme (INFRAM, 2015). The multilayer safety concept is a three-layered approach to reducing flood vulnerability; the first layer is flood protection, the second layer is reducing flood impacts by adapting the spatial layout and the third layer is enhancing the emergency response (Van Herk et al., 2014). In the Westpoort area, local climate change adaptation measures have to be initiated by local authorities, harbor authorities and cooperating private enterprises. The flood risk awareness among enterprises is necessary to invoke small, simple measures to be taken. When these small measures are integrated in bigger renovations, the costs can be kept low. When there is an investment in the area, it should be investigated whether there are possibilities to integrate climate change adaptation measures in this investment (MUST, 2016).

In general it can be concluded that all levels of governance need to work on climate change adaptation. The national government can steer a bit with laws, but the actual measures need to be organized by regional governments like water boards and municipalities, as they design the living environment (as discussed in the interview with the ministry). In order to increase the carrying capacity of climate change adaptation measures, communication with relevant actors as well as the public is essential. Various possibilities to represent the interests of actors exist; participation in an observation organization, founding project groups and joint projects to increase cooperation between actors, information exchange between actors and communication methods like brochures or websites (ICBR, 2015).

5.1.6 Political context: public opinion

The awareness of climate change among civilians and companies is an important base while trying to implement climate change adaptation policies. Civilians and companies can have an important share in the struggle against an increased flood risk, by reducing the discharge from private areas onto public areas (INFRAM, 2015). On the matter of flood risk, there is a high carrying capacity for flood mitigation measures among civilians. Dikes and other visible measures are commonly accepted. For flood adaptation measures, however, there is much less carrying capacity. The topic has only been addressed in recent years through the multilayer safety concept, so in some policy areas and in research areas it is a current topic, although then we are mostly talking about water nuisance measures. The possible advantages for an area can increase the carrying capacity for measures, but the real need is not there yet (as discussed in the interview with the ministry).

The average Dutch person has a low preparedness to take up climate change adaptation measures on private grounds. Only a small amount of people plans their private grounds in a way to reduce the pressure on the wastewater system during periods of heavy precipitation (Stichting RIONED, 2013). On the other hand, the interest in water nuisance due to precipitation has increased, probably due to the fact that the heaviest extreme precipitation events in the history of the Netherlands have occurred in the last decade. The public acceptance of water nuisance due to precipitation seems to have increased (Stichting RIONED, 2013).

Many wastewater system operators deal with climate change adaptation, but to a limited extent. The amount of precipitation is a current issue, because that is defining for the way the wastewater system functions. The effect of increased flood risk, however, is not taken into account by most wastewater system operators (as discussed in the interview with the ministry). The changes in precipitation due to climate change are taken into consideration by wastewater system operators in a way that more water can be stored in systems and on the streets (as discussed in the interview with RIONED). An important issue is the lack of knowledge on flood risk of the wastewater system. The majority of wastewater system operators have no insight in the possibilities of failure of the wastewater system. This lack of knowledge due to institutional problems is a big weakness of the wastewater system (as discussed in the second workshop). The average Dutch civilian has a high appreciation of the functioning and the quality of the wastewater system and give the wastewater system an average grade of 8 (Stichting RIONED, 2013). This might make it complicated to show the needs for renovation and investments.

Climate change adaptation on private grounds is the responsibility of private entities. Provinces and municipalities can make demands to project developers, for example how to plan areas spatially to reduce the surface runoff and increase the permeability (INFRAM, 2015). It is expected that private companies pay attention to the developments in climate change adaptation, to get ready when decision need to be made that can influence their management or turnover (as discussed in the interview with the ministry). Much research has been done on the effects of increased precipitation on the wastewater system. Thanks to this knowledge, private landowners are taking up adaptation measures on their own terrain to reduce the discharge unto the sewer system (as discussed in the interview with RIONED). This is still mainly focused on precipitation events and water nuisance and less on increased flood risk, though.

Municipalities and water boards discuss flood risk with private companies, especially if they provide important functions for a region. Recommendations are given to implement adaptation measures, although these are not legally binding. Companies are most likely to take up measures when they have experience problems with water nuisance or flooding in the past. However, it should be mentioned that commercial companies would only invest in measures if there were a commercial validity in the investment, which is a different driver than for other actors that take up climate change adaptation measures (as discussed in the interview with Waternet).

5.1.7 Political context: current policies and timescales

First the national adaptation strategy. Up until 2010 the Dutch policies on climate change adaptation were primarily focused on flood prevention. In 2013, it was stressed that Dutch citizens should also know what to do in case of a flooding event. An effort was made to focus policies on making critical infrastructure water robust, as is explained in the introduction. These policies are then assigned to other public authorities or private authorities for the implementation (Ministry of Infrastructure and the Environment, 2015). The Delta Programme has a set goal of 2050; by then, the Netherlands has to be protected against the impacts of climate change. This goal is set with the idea that the policy can be adapted along the way, but also has a goal to work towards to. However, it should be kept in mind that this does not work if the whole period is filled in with set goals; the time period should be filled in as the process continues (as discussed in the interview with Rijkswaterstaat).

To move towards more local climate adaptation policies; many municipalities are anticipating extreme precipitation events with local climate change adaptation measures (as discussed in the first workshop). On a local level climate change adaptation measures are taken, especially as a response to flood experiences. However, when no damage is done, there can be lack of evaluation. In Garmerwolde no further climate change adaptation measures are made to the wastewater system, due to a lack of evaluation. Looking back on successful protection measures can provide valuable lessons as well (as discussed in the second workshop). All municipalities in the Netherlands get to deal with water nuisance due to precipitation. With the exception of one, all municipalities also take action to reduce the nuisance due to extreme precipitation events. Many of these actions deal with the reduction of discharge onto the wastewater system (as discussed in the interview with RIONED).

Then the policies specifically for the wastewater system. Since 1993, the municipal wastewater plan (Gemeentelijk Rioleringsplan, GRP) is the policy document in which municipalities shape their asset management of the wastewater system. On average, municipalities make a new GRP every five years (Stichting RIONED, 2013). The GRP is not the only plan that is renewed every five years; every governmental period (period in which a new board is chosen of the authority), plans are evaluated and if necessary adapted. Due to the high depreciation period of wastewater infrastructure, it is necessary to draw pathways of investments for the future years. If a new wastewater treatment plant is built for a large amount of money, it will stand there for at least 40 years and it can not be removed after five years, so these kind of investments need to be taken in consideration (as discussed in the interview with Waternet). Infrastructure like the wastewater system has to meet certain standards, which are adjusted over time. In the past, investments in infrastructure to meet those standards has mostly been based on the price, continuity and quality of the investment. Through the years, other factors also become more relevant: sustainability, safety and image of the investor (Waterbedrijf Limburg, 2015).

Overall, at a national level, various ministries cooperate to integrate climate change adaptation policies. On a state level, this cooperation will be less and on a municipal level, the focus is mainly on visible climate adaptation measures or water nuisance. Integrated policies are mostly seen on a national scale, but before integrated design of the living environment can be seen on a local scale, a transition is needed. The Delta Programme Spatial Adaptation can help to establish this transition. Municipalities have the possibility to stimulate either civilians or companies to take climate change adaptation measures (as discussed in the interview with the ministry).

On the matter of flexibility of policies, one possibility to increase the flexibility of a policy is to build in an adaptive strategy. That means that periodically it is checked whether a policy still suits the current situation or if it needs to be adapted. This makes it complicated for decision makers, however, to agree on a plan as it is a lot less clear what you actually agree on. Another possibility is to take measures that leave space for additional measures, or oversizing. Another relevant issue is to pay attention to the depreciation period of infrastructure and relate policies to that; this is also effective to reduce the costs of measures (as discussed in the interview with the ministry). Besides the depreciation period making it unwanted to adapt some infrastructure, other infrastructure can not be adapted at all. A good example of this can be seen in the inner city of Amsterdam, which has a mixed sewer system. In the ideal case, this would be replaced with a separated system, but the inner city of Amsterdam is too narrow to replace the sewer system with a separated system (as discussed in the interview with Waternet).

One thing that should be kept in mind while making policies on climate change is that no scenario is the right one. Often, multiple projections of climate change and multiple flood scenarios are available. In the ideal case, a plan is designed for each possible flood scenario, so that policies can be adapted to the most realistic in the future. A barrier when dealing with the wastewater system is that investments are often done for extended periods of time, as wastewater infrastructure is durable and cannot be changed frequently (as discussed in the interview with the ministry). Besides that, ideas and visions also change over time. What policymakers decided on 20 years ago is seen as old now, but might be back in practice 30 years later. Making the decision with the knowledge that we currently have does not mean that these decision are right (as discussed in the interview with Waternet).

5.1.8 Ideological context: trend in policies

Up until now, climate change adaptation has been part of the general Delta Programme, as a Delta Decision. The general Delta Programme is focused on flood protection and prevention. In 2017, a special Delta Programme will be made especially for climate change adaptation, which focuses more on spatial adaptation, social adaptation and public health. This is the result of an ongoing development in climate change adaptation. In the past, climate change has mostly been relevant at a scientific level. Over time, it is moving from the scientific level towards a policy level, which is resulting now in a separate Delta Programme for climate change adaptation (as discussed in the interview with the ministry). The Dutch water management has a tradition of planning ahead and trying to anticipate on future changes. Often space is given to adaptation measures that are not necessary yet, but might become needed later (as discussed in the interview with RIONED).

With the increase of acceptance of water nuisance due to precipitation, the amount of measures taken by municipalities against this also has increased. In practice, municipalities take action (sometimes in cooperation with water boards) in areas where water nuisance gets problematic, to reduce pressure on the wastewater system (Stichting RIONED, 2013). However, when we divide the general climate adaptation measures into flood risk mitigation and flood risk adaptation, most authorities as well as private entities still focus on flood risk mitigation. Private companies generally feel safe behind dikes and assume that the government will take care of the quality of flood defense. The fact that a big flood can also occur through the regional system and not from the sea is often unknown. Many private companies do not have an evacuation plan for floods and do not see it as comparable to other disasters like a fire or terrorism (MUST, 2013).

6. Germany

6.1 Saxony, 2010

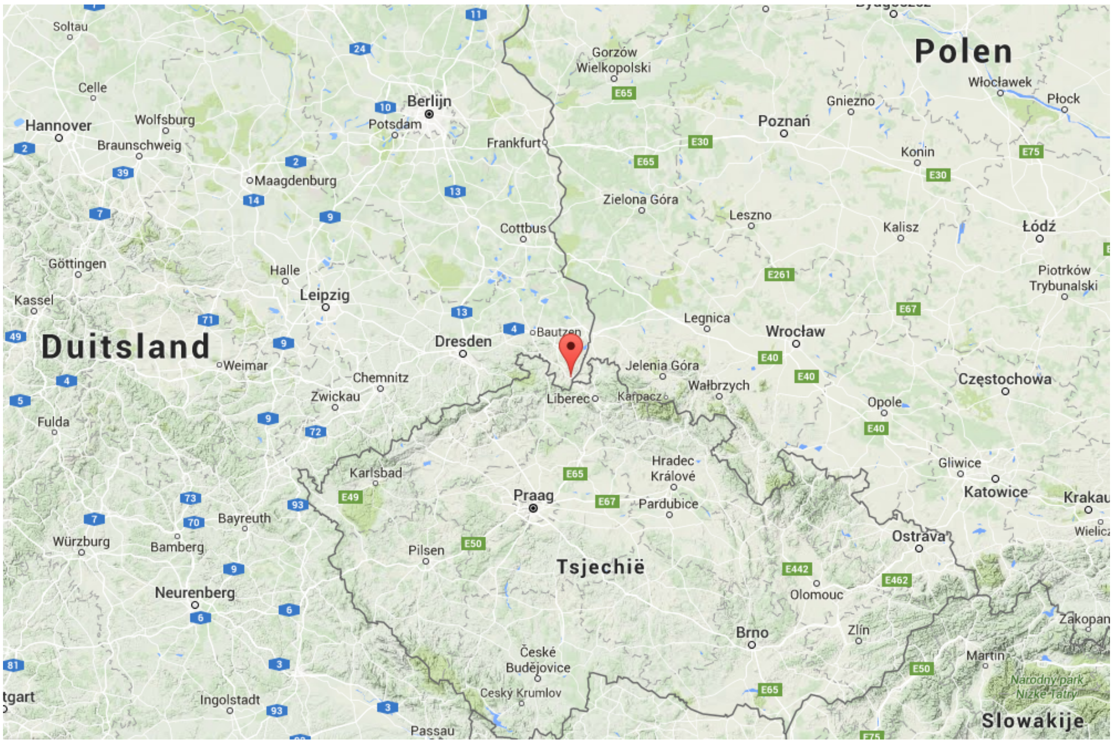

Figure 10: Location of Zittau and Hirschfelde

On the seventh of August 2010, two wastewater treatment plants located in Zittau and Hirschfelde (Saxony, see map above), had to be shut down because there was more inflow than the treatment plants could process. Extreme precipitation in combination with high water levels caused local floods. The water level of the local river Neisse rises with four meters in a timespan of three hours. The wastewater treatment plant in Zittau was the first one to flood; the dike protecting the plant was strong enough, but the water got around it and got to the treatment plant anyway. As soon as the water levels at the treatment plant reached one meter, the power at the installation was turned off and the employees evacuated. In Hirschfelde, the employees attempted to pump the water out but due to a lack of capacity they had to stop their efforts and turn the power off. Eventually the water level at Zittau reached 2,5 meters (see figure 11), in Hirschfelde six meters. An emergency zone of 500 meters was created around both treatment plants; in this zone people were not allowed unless they were equipped with the appropriate protective suits.

After two days, the water levels had dropped enough to enter the wastewater treatment plant at Zittau. Hirschfelde could be entered a day later. With the help of technicians and water experts from the cities of Dresden and Aue-Schwarzenberg, the water could be pumped out, after which the recovery process could start. The recovery process of a wastewater treatment plant is described in detail in chapter 2. By the twentieth of august, both treatment plants were running again, although only mechanical treatment was possible at the time. It took three more weeks before chemical treatment was possible again in Zittau and four weeks until Hirschfelde had chemical treatment again. It is mentioned in the article by Kuba (2010) that the support and cooperation with other cities was most relevant to speed up the recovery process. The experience that local operators had with floods also helped to reduce damage.

Figure 11: The flooded treatment plant in Zittau (Kuba, 2011)

6.2 Germany, 2013

Throughout Germany, several incidents of flooding and nuisance on the wastewater system were reported during the summer flooding of 2013.

Figure 12: Treatment plant in Soßmar (Fischer, 2013)

Figure 13: Control room of the treatment plant in Soßmar (Fischer, 2013)

The first example of water nuisance was seen in Lower Saxony, in the area Hildesheim / Braunschweig / Harz. A combination of heavy precipitation over an extended period of time caused the Bruchgaben, usually a small stream, to grow to large proportions. In Soßmar, south of Hannover, the water gathered at a local wastewater treatment plant and reached the edges of the settling tanks (see figure 12). The control room (with the electronic equipment) could be protected in time by placing sand bags around the entrances (see figure 13).

The wastewater treatment plant in Söhlde-Steinbrück (southeast of Hannover) is located at the Fuhse. Just like the Bruchgaben, the Fuhse grew to large proportions due to extreme rainfall. With the installation of emergency pumps, the local firefighters could prevent the settling tanks from flooding by pumping the excess water away.

Figure 14: Flood in Dresden (Fischer, 2013)

Figure 15: A pumping station protected by sand bags in Dömitz (Fischer, 2013)

Figure 16: Flood in Meißen (Fischer, 2013)

Figure 17: Inflatable dike in Dresden (Fischer, 2013)

The second example of water nuisance can be found along the Elbe. In Dömitz (Mecklenburg-Vorpommern) the Elbe reached the highest water level since 1888. Due to the high water level, safety measures had to be taken to protect pumping stations. In figure 15 can be seen how a pumping station is protected against flooding with sand bags.

Besides nuisance, flooding also occurred along the Elbe. Dresden already had experienced flooding of the wastewater system in 2002; local flooding then caused the wastewater treatment plant to be out of service for two weeks. In 2013, the city flooded again, as can be seen in figure 14.

After the 2002 flood, adaptation measures were taken in Dresden, resulting in a high water defense program. Part of this program was an inflatable dike, which can be seen on figure 17. The measures taken helped to protect the wastewater system from flooding.

In Meißen, located further downstream along the Elbe, the local wastewater treatment plant did flood (as can be seen in figure 16). As river floods can be predicted up to two days before, which is explained in chapter 2.6, measures could be taken in time. Two days before the flood, employees of the treatment plant started evacuating the building, removing vulnerable engines from the installation and shutting down the power. When the water was gone, the engines were reinstalled and the installation was up and running within a week.

Also in Bavaria extreme precipitation caused the water levels to rise, which resulted in multiple flooded wastewater systems. Especially the south and east of Bavaria, where the Donau flows, was struck heavily. In Passau, a city with much flooding experience, water levels were reached that had never been seen before. The local wastewater treatment plant could be protected against the water with an emergency dike made with bags of sand (see figure 18). Several pumping stations did flood; in order to recover them quickly, the city of Munich and some private companies assisted the local authorities with manpower and expertise.

Figure 18: Emergency dike (Fischer, 2013)

A flood can not always be predicted accurately; in Saxony multiple wastewater system suffered damage. In Frankenberg the river Zschopau flooded earlier than expect; the flood caused a dike to break, resulting in the flooding of the local wastewater treatment plant. In Crimmitschau, the wastewater treatment plant had never dealt with flood risk before. As the possibility of a flood had never been considered at the site, there were no measures taken and the flood caused severe damage; pumps and blowers had been completely destroyed and needed to be replaced. In Zwickau, adaptation measures had been taken to protect the wastewater treatment plant from flooding. The mechanical part of the installation had been protected with an aluminium wall that can be drawn if necessary.

At the wastewater treatment plant in Neumarkt-St.Veit, the water level was so high that the water reached the windows of the control room and managed to flow in. The local operator managed to switch off the power in time and firefighters started pumping the water out immediately. When all the water was pumped out, the electronic equipment was dried with hot air, which made it possible that within two days the wastewater treatment plant was operational again.

Figure 19: Settling tanks are high enough to endure a flood in Tittmoning (Fischer, 2013)

Firefighters managed to protect multiple wastewater systems. In Bad Reichenhall and Freilassing, the placement of emergency dikes and pumping was enough to protect installations. Other treatment plants did flood, for example in Tittmoning and Hartkirchen, but over there the water did not manage to do damage to the installations (see figure 19).

6.3 Adaptation measures

Adaptation measures seen in Germany that can be of interest for the Netherlands are using ***experiences from past events, communication to the public*** and ***cooperation between authorities***, as seen during the flooding of the Neisse in 2010 and the flooding in Germany in 2013. The ***recovery time*** of flooded wastewater treatment plants was relatively low in Germany, of which we can learn valuable lessons. The use of ***physical measures*** like dikes or bypasses is of less interest, as each wastewater system is different and it depends on the physical setting which measures can be useful (as discussed in the first workshop).

The use of experiences from the past has been relevant to reduce damage during a flooding and to reduce the recovery time. Especially knowledge of the area can help to come up with simple measures that can be highly effective. This does not mean that this knowledge has to be present at the current location; also experiences from other professionals can be useful. This can be seen during the floods in Germany in 2013, where operators from cities that did not flood but that had flooded in the past used their experience to help out in 'newly flooded' cities.

The communication to the public proved especially relevant in Saxony in 2010. Most people are unaware of the threat to public health that a flooded wastewater treatment plant brings (as discussed in the workshop). During a flood event, people need to be warned about the health risks when they are exposed to untreated wastewater, and should be recommended to prevent contact. In Saxony, safe zones were established around the treatment plants to prevent people from getting in touch with the untreated wastewater.

The cooperation between authorities is especially useful when neighboring authorities did not suffer damage from flooding and can support flooded sites with materials or personnel. This is another measure where knowledge of the area can prove valuable. If a neighboring treatment plant has relevant experience with flooding, there is a high chance that this authority can provide help to a treatment plant in an emergency scenario. It is not a requirement, however; also authorities from further away can be of useful help, especially if they can provide resources (as was seen in Germany in 2013).

Sending in a small group of experts to get the treatment plant running again, as seen in Germany, can reduce the recovery time of a wastewater treatment plant. In order to do so it is necessary that drinking water and power are available on site, as well as emergency sanitation provisions. If the discharge of wastewater is not possible, it is not safe for people to return to a flooded area.

6.4 Matrix

Physical context	Flood risk	Increasing temperature and an increase in extreme precipitation events lead to an increasing flood risk
	Wastewater system	High degree of connectedness, approximately 25% separated systems, small wastewater treatment plants on average but some large important plants
Economic context	Financial resources	Adaptation measures can be funded through two federal schemes; mostly focused on strategy design and research; both public and private actors can apply for funds
	Relevance of protection	Sector-based approach of protection, with an economic perspective
Political context	Responsibility	By law municipalities are responsible for protection of the wastewater system and thus for adaptation measures; many private operators so communication is important
	Public opinion	Mitigation of floods is widely accepted, adaptation to floods less accepted; little action on private lands
	Current policies and timescales	Focused on current climate change expectations, but little flexibility; timescale of the DAS Klimawandel set for 2100
Ideological context	Trend in policies	Policies focus on flood mitigation, flood adaptation is starting but not seen much

Table 8: Matrix for Germany

6.4.1 Physical context: flood risk

Climate change affects Germany to a much similar extent as the Netherlands; an increase in temperature, an increase in intensity and frequency of extreme weather events and a decrease of overall precipitation. For 2050, a predicted temperature rise between 1 and 2 degrees Celsius can be predicted; this counts for the entirety of Western Europe. This increase in air temperature also causes an increase in water temperature. Besides an increase in temperature, climate change also affects the water cycle (ICBR, 2015).

Climate change affects the water cycle in Germany; extreme precipitation events increase in intensity and frequency (DWA, 2016). An empirical analysis by the DWD (Deutsche Wetter Dienst or German Weather Service) shows that in the light of ongoing climate change, it is likely that an increase of extreme precipitation events will occur in the future in Germany. Other climate models also show an increase in extreme precipitation events (Metropolregion Nordwest, 2016). These extreme precipitation events can best be seen in summer. For regular precipitation events, an increase in precipitation in winter causing a higher discharge is visible as well as a decrease of precipitation in summer, causing a lower discharge (ICBR, 2015).

Municipalities can define their local flood risk in three different ways; a basic risk analysis based on available information in the municipality, a topographical risk analysis based on GIS data or a hydraulic analysis through flood simulation. A basic analysis costs less time and resources, but will also provide less information than the other two options. Which of these options is used to define flood risk depends on the goal of the analysis, the characteristics of the municipality and the available resources (Metropolregion Nordwest, 2016).

6.4.2 Physical context: wastewater system

In Germany, state-assigned authorities must deal with the wastewater produced. Municipalities and water associations with a special legal status usually perform the task of wastewater disposal (DWA, 2016). In Germany, more than 95% of the households is connected to the wastewater system (Stichting RIONED, 2013). This number, however, varies highly by state; it can be seen in figure 20 that the states of former East Germany have a lower connection rate than the states of former West Germany. These differences will continue to balance out in the future, however.
The federal average of combined sewer systems is 71,2%. Separate sewer systems dominate in rural areas, newer suburbs and development areas of cities (DWA, 2016).

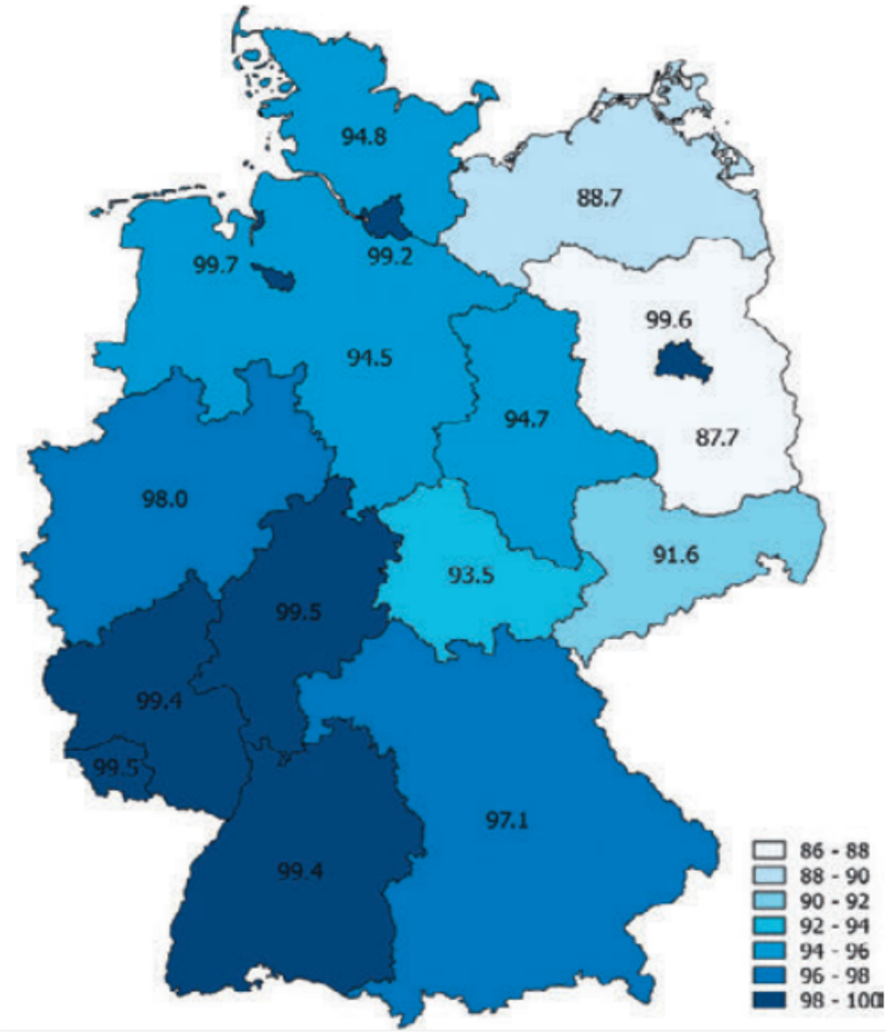

Figure 20: Connection rate to the wastewater system in Germany (DWA, 2016)

The number of wastewater treatment in Germany plants reached a maximum of 10.312 in 1998 and then started dropping to 9.632 in 2013. The wastewater from 97% of all inhabitants is treated in these wastewater treatment plants. Out of the 9.632 wastewater treatment plants in Germany, only 4% have a size greater than 100.000 P.E. (population equivalent) but these plants represent 52% of the total installed capacity (DWA, 2016). The quality of wastewater treatment plants in Germany has been improved over the last year. An effect of this can be seen with an increased water quality of the Rhine at the border with the Netherlands (RIVM, 2016). It is, however, still necessary for some installations in all size ranges to be brought up to present technical standards (DWA, 2016). Most wastewater system have been privatized in the past and are no longer the property of municipalities. A division should be made in small, local companies with roots in the region and bigger, international companies (as discussed in the interview with FRAMES).

6.4.3 Economic context: financial resources

The federal government has two funding schemes for climate adaptation, both made available by the Ministry of Environment and Construction. The first one, which is called ‘Programm zu Forderung Anpassung Klima’, is available for municipalities and is focused on non-technical measures; it is used to get people together and to create new forms of cooperation between municipalities. It is also possible that private companies apply for this fund, albeit only for non-technical measures. This funding can be used to develop a strategy for climate adaptation in order to analyze the risk and opportunities that climate change brings for your municipality or company. The second funding scheme, called ‘Nationale Klimaschutz Initiative', is used to fund integrated mitigation strategies. Public infrastructure operators can apply for this funding; part of the program is meant for climate change adaptation measures (as discussed in the interview with Metropolregion Nordwest). Besides the national funds, states also invest in adaptation. On the matter of flood protection for example, the states invest more for flood protection in the hinterland where the federal states invests more for coastal protection. The local communities also have a financial input; the financing of adaptation measures is a complicated balance between government authorities and there is no specific balance for it (as discussed in the interview with FRAMES). Some states do offer funding to support action on a regional or local level. By funding 'lighthouse projects', projects that can serve as an inspiration to the region so other authorities can copy this example; they hope to increase the amount of climate adaptation measures. This is varying per state and rather limited (as discussed in the interview with Metropolregion Nordwest).

The financing of climate change adaptation measures can be difficult in Germany, due to the fact that the national government has funds available, but the states are responsible for the implementation of measures. This causes tension between the states and the national government, resulting in slower implementation of measures. The problem is that climate change adaptation measures are often integrated projects that cross the areas of responsibility. Authorities do not want to pay for measures that are not their responsibility (as discussed in the interview with Rijkswaterstaat). A big issue with the funding of climate change adaptation is that there are no funds available to actually construct something, only to develop strategies. Municipalities are responsible for the wastewater system and receiving funding from the states to finance this, but they do not receive funds for climate change adaptation measures. Without funding, many municipalities choose to not take up adaptation measures (as discussed in the interview with Metropolregion Nordwest).

6.4.4 Economic context: relevance of protection

Flood risk adaptation policies in Germany are carried out on with a sector-based approach rather than an area-based approach. The federal state, the Ministry of Education and Research, launched a research project called NordWest 2050. The idea of this research project was to develop and test new strategies and ideas to respond to climate change. This project was focused on securing the economy by focusing on economic clusters and adapting those to climate change. The goal was to secure the economic value of the region by protecting it against the effects of climate change and see if chances appear to profit economically from climate change. Economic sectors still focus mainly on flood mitigation, which slows down the development of climate change adaptation measures. An example of this can be seen in flood prone areas; rather than preventing construction here or recommending companies to take climate change adaptation measures, stronger dikes are constructed instead (as discussed in the interview with Metropolregion Nordwest).

For the river Rhine, an instrument was designed to define flood risk levels based on protection goals. The first level there is the amount of casualties, the second level the economic value of an area, the third level cultural heritage and the fourth level is ecological value. Based on this flood scenario's were made that show the most relevant industrial areas that needed protection (as discussed in the interview with Rijkswaterstaat). This is a good example of this sector-based approach.

6.4.5 Political context: responsibility

In Germany there is a national climate change adaptation strategy (more about this later), but each state also has their own climate adaptation strategy. The Water Framework Directive, for example, is organized at EU level, which means that it also applies to the Netherlands. In Germany the Water Framework Directive is the responsibility of the national government but is implemented by each state individually. This can make situations complicated; it can be unclear which agency is responsible for what, especially to outsiders. Each river has its own 'flussgebietsgemeinschaft'; a regional water authority, comparable to the Dutch water boards. Besides the individual climate adaptation strategies, all states have a representative in the LAWA (LandesArbeitsgruppe Wasser und Abfall – national taskforce water and waste). The LAWA meets to discuss the implementation of measures and discusses mutual agreements between states (as discussed in the interview with Rijkswaterstaat). It should be mentioned that states in Germany are not always comparable to provinces in the Netherlands.
This is partly because of the size (some states are the size of the Netherlands), but also because of the federal structure of the German governance system. States in Germany have much more responsibility and power than a province in the Netherlands. In the Netherlands it is easier to organize on a national scale. Coordination from a national level is therefore usually on a strategic level in Germany (as discussed in the interview with Rijkswaterstaat)..

Each state is individually responsible for the protection of inhabitants by ensuring the functioning of critical infrastructure within their borders. Implementation of measures is then carried out on a local level, where local authorities develop climate change adaptation measures and emergency plans. However, as the majority of critical infrastructure is privatized in Germany, the joint responsibility is carried by government agencies and the national industry. This makes close cooperation between private and public actors highly relevant (Ministry of Infrastructure and the Environment, 2015). The division between small, locally embedded companies and large international companies is relevant here. Local companies are often embedded in the decision-making network, which makes the implementation of measures easier. Large, international companies often work more from a business perspective and stick to economically profitable solutions (as discussed in the interview with FRAMES).

In the WHG (Wasserhaushaltzgesetz, the German law on the protection and use of surface water and groundwater) it is written that everyone who can possibly be hit by a flooding is obliged to take measures against the possible damaging effects of a flooding, up to a point where this is possible and reasonable. Measures in this case mean to reduce possible damage from floods to people, property or the environment. Municipalities and treatment plant operators are obliged to protect the capacity of public wastewater treatment plants against damage. This essentially means that this obligation covers the protection of a wastewater treatment plant against flooding (Bundesministeriums der Justiz und für Verbraucherschutz, 2009). In general, flood protection strategies are responsibilities of the states. The strategies are filled in with schemes drawn up by local authorities, municipalities. The municipalities are responsible for the implementation of measures (as discussed in the interview with FRAMES).

However, it would not be reasonable to consider flood protection measures as the responsibility of municipalities. For economic and technical reasons, local water systems are not always able to deal with the effects of climate change. Therefore, climate change adaptation measures should be the responsibility of many organizations. Also planners, politicians and other decision makers, land owners, civilians and emergency services have responsibilities when it comes to a proper functioning flood protection system (Metropolregion Nordwest, 2016). As an addition, for flood protection there are also water boards, supralocal organizations. Water boards can apply for national funding to draw up schemes for flood protection, with the help of the states. The states executes the plans the water boards make and then the water boards are responsible for the maintenance of the constructed measures (as discussed in the interview with FRAMES).
In order to increase the carrying capacity of climate change adaptation measures, communication with relevant actors as well as the public is essential. Various possibilities to represent the interests of actors exist; participation in an observation organization, founding project groups and joint projects to increase cooperation between actors, information exchange between actors and communication methods like brochures or websites (ICBR, 2015).

6.4.6 Political context: public opinion

The German water management focuses on flood mitigation. The majority of practitioners and citizens trust that the states will provide flood protection by constructing dikes. During the discussion on climate change, however, people start questioning these solutions and get more critical towards flood mitigation. This is partly caused by insurance issues; whenever damage is caused, the insurance company has an option to terminate the contract. People that have experienced floods lose their insurance sometimes, which makes them more interested in taking adaptation measures themselves or push local politicians to take flood adaptation measures (as discussed in the interview with FRAMES).

It is essential to the effectiveness of climate change adaptation that communities are aware of the possibility that a flood occurs. This way, it can be communicated what can happen and what can be done about it. This makes the decision-making process around climate change adaptation measures faster and more effective (Metropolregion Nordwest, 2016). Acceptance of climate change adaptation measures can be created in various ways. One way is to implement measures on public buildings to increase the visibility and knowledge about measures. The most effective way, however, is to inform people and companies individually about flood risk and what they can do (Metropolregion Nordwest, 2016).
Not in all cases communication on flood risk is necessary; especially in the east of Germany, people have suffered the effects of floods frequently in recent years. People can get the feeling that nothing is happening, despite that fact that the government is taking measures (as discussed in the interview with Rijkswaterstaat). In those cases, information on climate change adaptation strategies should be provided to help private actors adapt to an increased flood risk.

6.4.7 Political context: current policies and timescales

Germany has a national climate adaptation strategy from 2008, which addresses all possible effects of climate change. At a minister's conference in 2007 in Bonn, climate change adaptation was addressed in policies (as discussed in the interview with Rijkswaterstaat). Climate change adaptation was connected to river management plans, and the Rhine among other rivers needed to integrate climate change adaptation in its river management plan. The focus was heavily on research; modeling discharge and temperature change.

At the Rhine, this modeling was more difficult than in the rest of Germany due to a mix of Dutch and German data. This eventually led to a general climate change adaptation strategy on the river Rhine. This climate change adaptation strategy mostly deals with water quality and less with flood protection (as discussed in the interview with Rijkswaterstaat). Besides the national climate adaptation strategy, the federal government also developed the Nordwest 2050, focusing more on economic sectors rather than regions. For this program, climate projections for the next 50 and 100 years were used, which led an overview of suggestions what could be done to adapt the region to climate change, albeit on a scientific level without political support. For the InKoKa project, the Metropolregion Nordwest developed an overview of possible climate adaptation measures in the region and municipalities are then free to choose whether they use these recommendations or not (as discussed in the interview with Metropolregion Nordwest).

Germany has established a system called KRITIS (KRITische InfraStrukturen) for the identification of protection measures on all critical infrastructure. The KRITIS system provides guidance for local communities for risk analysis, taking climate change adaptation measures or implementing local crisis management. For the implementation of measures, there is the UP KRITIS system, which is a public-private cooperation between the private owners of infrastructure and the authorities responsible for them. There is a law on the protection of critical infrastructure, which is the framework for the cooperation between the state and the states. This mainly focuses on the state as a counselor for the states that carry responsibilities (Ministry of Infrastructure and the Environment, 2015).

In general it can be said that in Germany it is more common to choose a strategy and stick to it, while in the Netherlands strategies are more often evaluated and adapted as the process goes on (as discussed in the interview with Rijkswaterstaat). The tendency in Germany is to have a fixed goal with a development plan that is decided upon, to base plans on numbers. The fact that these numbers can change in the future does not match with these fairly rigid plans (as discussed in the interview with FRAMES). One reason for this is that without any projections, legally it is very hard to take measures; it is problematic that projections are based on experiences from the past and are said to be no longer accurate due to climate change. An example of this can be seen in the state of Lower Saxony, where the state is responsible for coastal and river flood protection. A coastal defense plan was developed for 2080, in which it is decided there to increase the height of dikes by 80 centimeters, with a possibility to add another 50 centimeters later. Municipalities often do not attempt to look into the future at all but rather deal with ongoing problems, due to a lack of resources (as discussed in the interview with Metropolregion Nordwest).

6.4.8 Ideological context: trend in policies

Dikes and other forms of flood risk mitigation are prioritized in Germany. There is an extensive system of qualifications for dikes, although the authorities struggle to get enough space for retention areas. In general the German water management is more reactive than proactive, especially when compared to the Dutch management (as discussed in the interview with RIONED). Especially in Germany, environmental and water management technologies are well developed. Many professional organizations have a high expertise in technical solutions. The DWA (German Union for Water, Wastewater and Waste; in German Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall) is working in international standardization bodies, which can be useful for operators and suppliers of technical equipment (DWA, 2016). The general mindset is that technical measures are enough to protect the country against flooding, especially with the possibility to reinforce dikes in the future. Spatial adaptation measures and risk management are not much discussed in municipalities and states, these measures are are at the moment mostly discussed at a scientific level (as discussed in the interview with Metropolregion Nordwest).

This focus on flood risk mitigation can be seen in the following example. In Lower Saxony, a strategy for spatial flood risk adaptation on the coastal system was developed (COMCOAST). Initially the state responded positive, but eventually when the state agency for coastal protection decided to discredit the COMCOAST strategy and choose for flood risk mitigation measures instead (as discussed in the interview with FRAMES).

Another example can be read in the InKoKa (Inter-communal Coordinating Body Climate Change; in German Interkommunale Koordinierungsstelle Klima-anpassung). The InKoKa project from the Metropolregion can be seen as a strategy for the region. In the InKoKa, an overview is drawn of various climate change adaptation measures in the region. At this moment, there is only one municipality in the area with a climate change adaptation strategy. The topic of extreme precipitation events is an actual topic in the area due to experiences from the past, but other climate change adaptation measures are a fairly new phenomenon. Most of the municipalities are still heavily focused on climate change mitigation, so the goal is that the InKoKa can raise awareness of possible climate change adaptation measures in the region (as discussed in the interview with Metropolregion Nordwest).

7. United States

7.1 New Orleans, 2005

Figure 21: Location of New Orleans

On August 29, 2005, hurricane Katrina hit New Orleans (Louisiana, see map above). Katrina was a category 4 hurricane, which caused heavy wind and rain in New Orleans. The wind and rain caused multiple levee breaches in New Orleans, resulting in the flooding of approximately 80% of the city and the nearby parishes. On September 21, 2005, hurricane Rita hit New Orleans, flooding parts of the city that had been pumped dry after the hurricane Katrina flooding. After that, on October 11, 2005, the whole city of New Orleans had been pumped dry (Anderson et al., 2007).

The biggest wastewater treatment plant of New Orleans, the East Bank Plant, was flooded. During the hurricane the East Bank Plant stayed up and running for as long as possible, despite evacuations. When the levee breached, up to six meters of water flooded the plant (Anderson et al., 2007). During the hurricane the plant could still process the incoming rain, but the floodwater was too much; the electric pumps had to be turned off the employees had to be evacuated (Sewage & Water Board of New Orleans, 2016) An emergency team of four people was the sent to the treatment plant. This emergency team, equipped with food and clothes, had the task to assess the damages and see what had to be done to get the plant up and running again. (Sewage & Water Board of New Orleans, 2015)

During the time when the East Bank Plant was out of service, untreated sewage was deposited unto the surface water, causing unsanitary conditions. In general the contamination levels did not reach dangerous levels. *'The levels of fecal coliform bacteria exceeded health screening values but are expected to naturally decrease over time'.* This has to do with the fact that bacteria die when the sediment that contains them dries out. Especially in the 750 refugee centers, host to more than 200.000 refugees, many people got infected with for example noro virus (Centers for Disease Control and Prevention, 2005). When the treatment plant was up and running again, the pumping capacity of the plant could be used to dewater the city. When the city originally flooded, it was expected that it would take 90 days until the water was gone, but with the help of the plant this could be heavily reduced (Sewage & Water Board of New Orleans, 2016)

The smaller wastewater treatment plant, the West Bank Plant, did not flood but only suffered wind damage. As the levees did not breach in the part of the city where the West Bank Plant is located, it remained free from floodwater. The plant had enough capacity to process the excess precipitation water (Sewage & Water Board of New Orleans, 2016). Over all of Louisiana, 50% of wastewater treatment plants and 20% of the total wastewater system was destroyed (FEMA, 2005).

The recovery process after hurricane Katrina was coordinated through the National Response Plan (NRP). Four governmental agencies were involved through the NRP;the Federal Emergency Management Agency (FEMA), the Environmental Protection Agency (EPA), the US Army Corps of Engineers (USACE) and the US Department of Agriculture (USDA) (Copeland, 2005). The EPA mandated primary and secondary wastewater treatment within 60 days .The FEMA granted the financial resources for the recovery process. In order to receive emergency funds, the SWB had to make clear what they needed to get the plant up and running. The USACE supported the SWB with experience and knowledge (Sewage & Water Board of New Orleans, 2015). Veolia Water North America took account for 42 million dollar worth of recoveries on the East Bank Plant. In order to get the wastewater treatment plants running as fast as possible, a quick assessment of workforce, facilities and equipment was done. Within a month, the plant was dewatered and could resume service. Within a matter of sixty days, chemical treatment was possible again at the plant. This fast recovery was partly due to Veolia's industrial expertise and their ability to draw resources and manpower from around the country.. (Sewage & Water Board of New Orleans, 2016)

After the recovery phase, the USACE made recommendations to the SWB to make the facilities stormproof. Investments were made in new back-up generators, new pumping stations to increase the capacity even more, a power plant and turbines to guarantee their own power source as well as investments in pipes and purification (Sewage & Water Board of New Orleans, 2015). During the flooding it became clear that experience is highly valuable in an emergency situation. If people know what they can do and what they have to do, the recovery process is speeded up. In this particular case it led to the fact that the city could be pumped dry faster. The FEMA funding was also essential on this part. Before the hurricane, maintenance on the treatment plant was carried out on a day-to-day base. After the hurricane and the flooding, the maintenance has moved towards a long-term vision, with projects aiming to reach goals in the future rather than keeping to the current status quo (Sewage & Water Board of New Orleans, 2015).

7.2 St. Louis, 2015

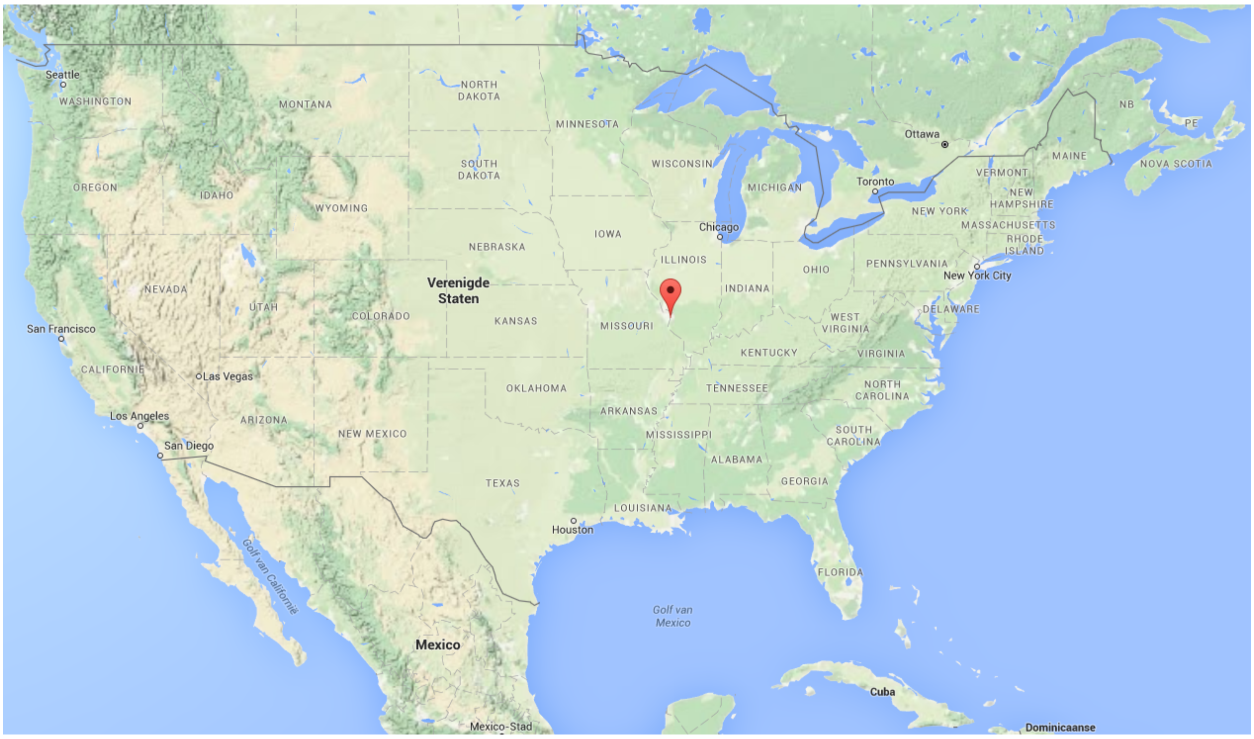

Figure 22: Location of St. Louis

St. Louis (Missouri, see map above) flooded on December 30, 2015. This overview is written based on information provided by Lance LeComb (SLMSD). From the 26th to the 30th of December 2015, St. Louis had to deal with extreme precipitation. By the 30th of December, the water level of the Meramec River that flows through St. Louis had risen by seven meters. At that point, the St. Louis Sewage & Water Board decided to evacuate all employees from the local wastewater treatment plants. As St. Louis has a relatively high gradient with wastewater treatment plants at the lowest points, discharge of wastewater was still possible, although treatment was no longer done and untreated wastewater was discharged into the Meramec river.

St. Louis has three wastewater treatment plants; Grand Glaize, Fenton and Missouri River. The Grand Glaize plant has a relatively low level of protection (a 1/100 dike), whereas the Fenton and Missouri River plants have a higher level of protection (a 1/500 dike). As mentioned in chapter 2.6, river floods can be predicted multiple days before the actual flood.

In the case of St. Louis, it was predicted that the Grand Glaize plant would flood due to the low level of protection, but that the protection level at the Fenton and Missouri River plants was high enough to prevent it from flooding. This is why at the Grand Glaize plant, protection measures were taken; the treatment process was stopped, the vital points of the installation were protected with emergency dikes (see figures 23 and 24) and the employees were evacuated. Because of these protection measures, serious damage was prevented and the plant was fully functioning again within three weeks (mechanical and chemical treatment.

Figures 23 and 24: Grand Glaize Treatment Plant during the flood (SLMSD, 2016)

At the Missouri River plant the 1/500 protection dike was strong enough to keep the water out; the capacity of the pumping station had to be increased to process all the incoming water, but no damage was done. At the Fenton plant, the 1/500 protection dike broke (for unknown reasons), causing two meters of water to enter the treatment plant grounds (see figure 25). As no further protection measures were taken, severe damage was done to the installation. Mechanical treatment was not possible for almost a month after the flooding and the restoration of chemical treatment facilities took multiple months.

Figure 25: Fenton Treatment Plant during the flood (SLMSD, 2016)

7.3 Adaptation measures

Adaptation measures seen in the United States that can be of interest for the Netherlands are a clear ***communication structure*** as well as ***cross-training***, as seen during the flooding of the Meramec in 2015 (as discussed in the first workshop). It is important to disconnect knowledge on wastewater systems from specific employees. Being dependent on knowledge that is only available from specific employees can be catastrophic, for example when those employees are not present or can not be reached. By ***making the system replaceable,*** the recovery time can be reduced heavily. If information is written down and shared, more people can get this knowledge, which leads to a quicker response time and a faster recovery face (as discussed in the third workshop). Last but not least, the ***response to flood risk*** can make a large difference.

A clear communication structure is essential in the recovery phase. During a flooding event, communication procedures can be different from normal (for example due to lack of phones, no connection or inaccessible terrain), which makes it more relevant to have a plan before. Making the public aware of what is going on is essential in preventing health hazards. In St. Louis, this was carried out properly, as people were recommended to stay away from river water that contained untreated wastewater. In New Orleans, many people fell ill after being exposed to untreated wastewater.

Cross training is the concept that all employees on a wastewater system have a basic knowledge on how the wastewater system works. This means that during a flood event, all the employees that are present at the installation can react faster and make better decisions. This was seen especially in St. Louis, where the damage to treatment plants could be reduced with fast acting thanks to cross training.

Making a system replaceable can be done in two ways; making the technical installation replaceable or making the employees replaceable. The technical installation can be made replaceable by using parts that are easily accessible or available at different locations. This was seen in New Orleans, where Veolia managed to replace the pumps of the treatment plant within a matter of days, as they had similar pumps at different treatment plants. Also the replacement of employees can be made easier by writing down information and making sure that anyone who is on-site can access the required information to act against flooding. (SOURCE?)

The response to flood risk and quick acting makes a large difference in damage suffered. In St. Louis, the relatively low level of protection at the Grand Glaize treatment plant caused the operators to take emergency flood protection measures (shutdown of the plant, removal of items and construction of a sand bag wall), whereas the Fenton plant was not protected because it was assumed that the dike would be strong enough. After a dike breach, severe damage was caused at the Fenton plant whereas the Grand Glaize plant suffered less damage.

7.4 Matrix

Physical context	Flood risk	Large differences within the country; in the north more precipitation, in the south less precipitation but more extreme storms and sea level rise; in the whole country an increase in extreme precipitation events
	Wastewater system	St. Louis: separated gravitational system, New Orleans: gravitational system with electric pumping stations; large wastewater treatment plants
Economic context	Financial resources	Private operator is responsible for the flood protection on treatment plant and finances adaptation measures
	Relevance of protection	Sector-based approach of protection, with an economic perspective
Political context	Responsibility	Private operators of treatment plants responsible for adaptation measures; water safety in general responsibility of the state, federal government only acts during crisis
	Public opinion	Experience teaches private actors how to deal with flooding of the wastewater system; more focused on the recovery phase than preventing damage
	Current policies and timescales	Federal state adapts infrastructure to climate change based on current climate change projections, investments made in climate change science; Presidential Climate Action Plan has no defined timescale
Ideological context	Trend in policies	‘ Dutch system’ is recommended but not carried out; policies focus on relocating people rather than protecting them

Table 9: Matrix for the United States

7.4.1 Physical context: Flood Risk

It is expected that temperature in the US will rise by 1.5-5 degrees Celsius by the end of this century, depending on future emissions. The north of the country will experience more precipitation, where the south of the country will experience more droughts. The total precipitation will increase with approximately 7% and the frequency and intensity of extreme precipitation events will increase, resulting in a higher flood risk. Another threatening effect is the increase in strength and frequency of big storms (Ministry of Infrastructure and the Environment, 2015).

A sea level rise is expected, especially in the Gulf of Mexico and the Atlantic coast, which is another possible increasing factor for flood risk. The EPA (Environmental Protection Agency) recommends home owners to always be aware of flood hazards, but also mentions that especially people that live in low-lying areas, near water or downstream from a dam (Pipeline, 2006).

7.4.2 Physical context: Wastewater system

The United States is a large country and it would not be of added value to generalize the wastewater system. Instead, chosen was to describe the wastewater system in both case sites (St. Louis and New Orleans). It should be mentioned that throughout the United States wastewater treatment plants are generally operated by private companies.

The city of St. Louis has a predominantly gravitational wastewater system, with a few pumping stations, especially near the wastewater plants. The wastewater system is a separated system, where wastewater and storm water collection systems are separate and do not mix by design, although the system does have inflow and infiltration issues. The city has three wastewater treatment plants; Fenton, Grand Glaize and Missouri River. The Fenton and Missouri River plants are protected by a 1/500 dike, the Grand Glaize plant by a 1/100 dike (as discussed in the interview with SLMSD).

The city of New Orleans has a gravitational wastewater collection system with 2333 kilometers of tubes and 82 electric pumping stations, making it the second largest drainage system in the world (Sewage & Water Board of New Orleans, 2015). The city has two wastewater treatment plants. The East Bank Plant is by far the most important treatment plant in the city, with a capacity of 122 MGD (mega gallon per day), which is the equivalent of 18930 m3 per hour. The West Bank Plant is much smaller, with a capacity of 20 MGD, the equivalent of 3155 m3 per hour. Both wastewater treatment plants are operated under public-private partnerships between Veolia Water North America (the private party) and the Sewage & Water Board of New Orleans (the public party) (Anderson et al., 2007).

7.4.3 Economic context: financial resources

All around the United States, wastewater utilities face significant investment needs to meet the requirements from the Clean Water Act. An estimate by the EPA expects that over the next twenty years more than 460 billion dollars is needed, which is unlikely to be provisioned by the federal government. Congress has authorized a number of programs to assists local communities in wastewater treatment problems, some financed through grants, some through loans (Copeland, 2006). This does not include additional costs, like damaged structures due to emergencies or climate change adaptation measures.

Various programs exists that can provide emergency assistance to the wastewater system. During an emergency, affected communities can rely on federal assistance as well as traditional infrastructure programs administered by the EPA. The Senate has passed a bill to streamline the delivery of funds for the repair of damaged sewage treatment and drinking water plants through existing EPA programs (Copeland, 2006). However, the possibility to fund climate change adaptation measures still is unclear.

The US economy is very large and has both the financial as well as operation resources to adapt to climate change (Ministry of Infrastructure and the Environment, 2015). One financial mechanism that can be used to finance climate change adaptation measures is the State Conservation and Mitigation Trust Fund, which allows states to acquire fee ownership or surface rights to high-risk lands. This means that private landowners pay a fee to contribute to governmental climate change adaptation projects (Carbonell & Meffert, 2009).

7.4.4 Economic context: Relevance of protection

Besides community-based measures, which are explained under 'Current policies and timescales', measures are also taken in attempt to protect the economy and natural resources. Vulnerabilities of key sectors are identified, resilience in the health sector is promoted as well as insurance leadership for climate safety. Measures are taken to conserve land and water resources and to maintain agricultural sustainability (Executive office of the President, 2013). This shows that the climate change adaptation policy in the United States has a clear sector-based approach.

7.4.5 Political context: Responsibility

Besides a federal state, states and municipalities like in the Netherlands and in Germany, the US has an extra layer of governance between the states and municipalities called counties. Local democracy and decentralization are important in the United States. The states are the main body to govern and control local authorities, the federal states operates on a more strategic level (Ministry of Infrastructure and the Environment, 2015). The states or local authorities are also responsible for flood protection in the United States, on a regional level. Flood protection on site is the responsibility of private operators of wastewater systems.

In case of an emergency, the responsibility shifts from a local to a national level, and the FEMA (Federal Emergency Management Agency) becomes responsible for emergency plans. The National Response Plan, a framework to coordinate emergency response activities from the federal government to other levels of governance, authorizes the EPA and USACE to conduct assessments of water infrastructure system. The EPA and USACE assist state and local authorities with the evaluation of damages, the operating status and the assessment of needs (Copeland, 2006).

As wastewater systems are operated by private enterprises, climate change adaptation measures are limited to the wastewater system itself. In the case of St. Louis, all wastewater treatment plants have either been built in 500-year floodplains or have a dike protecting them. Other climate change adaptation measures are responsibility of either the State of Missouri, the county of St. Louis or local municipalities (as discussed in the interview with SLMSD).

7.4.6 Political context: Public opinion

The EPA attempts to create public awareness on the topic of flooding wastewater systems. In Pipeline (2006) it is written that national events such as the flooding devastation brought about by Hurricane Katrina in the southern US have prompted many to consider how they can protect their wastewater system. Here it is also mentioned that the less water is sent to the system, the better off the system will be, and recommendations are given how to reduce the discharge onto the wastewater system.

7.4.7 Political context: Current policies and timescales

The President's Climate Action Plan from 2013 consists of three pillars; cutting carbon pollution through stronger regulations, preparing the countries' infrastructure for the impacts of climate change and leading international efforts to combat global climate change (Executive office of the President, 2013). Especially the second pillar is of interest, as this is dealing directly with climate change adaptation measures. The Climate Action Plan has various tools to prepare the US infrastructure for the impacts of climate change. Economy-based measures have been explained under 'Relevance of Protection', but community-based measures are also included. First, federal agencies will be directed to identify and remove barriers for climate-resilient investments through agency grants and technical assistance.

Second, the president established a short-term task force of state, local and tribal officials to advice the federal government so that communities can be supported well while taking measures. Third, the National Institute of Standards and Technology creates a resilience framework, providing guidelines for climate change adaptation measures on infrastructure (Executive office of the President, 2013). These measures are all focused on protecting communities against climate change.

Current policies are framed upon current flood risk projections. Protection levels are based on flood risks as they are projected at this moment, but not how they might change over time due to climate change. Clear goals are set and little space is left for incremental change. To prepare for the future, investments in climate change science are made. A public-private research partnership was funded to increase understanding of climate change impacts, scientific information will be translated into practical knowledge for decision makers, a climate data initiative is launched and a toolkit for climate resilience is developed (Executive office of the President, 2013).

7.4.8 Ideological context: Trend in policies

From public comments, high priority was given to adopting the 'Dutch system' of water management in New Orleans, to hold more water in the city with canals and retention ponds. However, a low priority was placed on a comprehensive water management system or to use parks and vacant land for water storage, which seems contradictive. However, the storm water runoff can be reduced with community engagement, creating community support for these adaptation measures (Carbonell & Meffert, 2009).

It is suggested that there has been a paradigm shift in thinking about flood management; from flood control to integrated water resource management. This shift was made from a focus on structural measures to non-structural measures (in other words; from dikes to laws and regulations). Part of this is that the planning of cities should discourage settlement in vulnerable areas and relocate people to safe areas (Carbonell & Meffert, 2009). This means, however, that this paradigm shift indicates that areas are not protected better against flooding but rather that the inhabitants are relocated to safer areas.

8. Discussion and conclusion

8.1 Introduction

In this chapter, first the three research questions that are part of each step of the research will be answered. After that, a comparison is made between all cases to answer the main research question; *which flood risk adaptation measures that are taken on the wastewater system in foreign countries can be implemented in the Netherlands?* Based on this comparison, a conclusion is drawn to answer the main research question. At the end of the chapter, there will be reflected on the methodology of this research and recommendations for further research are given.

8.2 Empirical reflection

What happens to the wastewater system during a flood?

What happens to the wastewater system during a flood has been described in the chapter wastewater system. The possible effects can be divided in three categories; failure of the wastewater treatment plant, failure of pumping stations and clogging of tubes. Various of the assets described in the chapter on the wastewater system can get damaged with different effects, but for the general overview this is the most important distinction that should be made. It has been explained that when a wastewater treatment plant no longer functions but pumping stations do, discharge of wastewater is still possible, which means that sanitation is also possible. If pumping stations no longer function or tubes get clogged, discharge of wastewater is no longer possible, which means that the users of the wastewater system require alternative sanitation.

Several examples have been seen where the first situation occurred; discharge of wastewater was still possible, but there was no purification because the treatment plant did not function. This has been seen in St. Louis and in Saxony. In those cases, untreated wastewater was discharged unto surface water and a warning message was carried out to inhabitants in the area to prevent them from exposure to this wastewater. It gets more complicated when pumping stations no longer function and inhabitants of an area are exposed to wastewater, which happened in New Orleans; public health can be endangered and alternative sanitation needs to be arranged in order for people to enter the flooded area.

In practice, it is visible that the difference as mentioned in literature (is it possible to discharge wastewater or not?) is essentially the tipping point whether a damaged wastewater system becomes a threat to society or not. With functioning pumping stations and tubes but no treatment plant, the wastewater system is a threat to the environment but not directly to public health. This means that the key vulnerability of the wastewater system, the critical infrastructure in this case, lies with the functionality of pumping stations and tubes (from a perspective of public health and safety, at least).

What flood risk adaptation measures have been taken in foreign countries?

Various adaptation measures have been seen during the case studies. In Germany experiences from past events, communication to the public and cooperation between authorities are types of adaptation measures that are of interest for this research. The focus on reducing the recovery time of flooded wastewater system is another type of measure that is seen in Germany. In the United States relevant adaptation measures are a clear communication structure, cross-training, making the system replaceable and responding to flood risk.

The use of physical measures like dikes or bypasses is of less interest, as each wastewater system is different and it depends on the physical setting which measures can be useful. The intention of this research was not to provide wastewater systems with physical adaptation measures or to make an overview of physical measures that are possible. The goal of this research was to make a comparison with foreign examples of flooding of the wastewater system, to ultimately answer the main research question; *what flood risk adaptation measures that are taken on the wastewater system in foreign countries can be implemented in the Netherlands?*

How can flood risk adaptation measures that have been taken in foreign countries be implemented in the Netherlands?

Flooding of wastewater system in the Netherlands is a fairly new problem. As explained before, adaptation measures that have been taken in foreign countries can possibly be a source of inspiration for Dutch policy makers. In order to see to which extent adaptation measures can be implemented in the Netherlands, the possibility for policy transfer has been analyzed.

In the methodology, it was explained that this is an example of a voluntary transfer (according to the types described by Dolowitz & Marsh, 1996). There are three possible reasons for failure of policy transfer. The first reason is when the transfer is applied with a lack of available knowledge on policies or institutions that are involved in the transfer (uninformed transfer).
The second possibility is that the appropriate amount of knowledge is available, but crucial elements of the policy have been left out (incomplete transfer).
The last possibility is when enough knowledge is present and the whole policy is transferred, but due to some unforeseen or unaddressed differences, the policy is not suitable for the receiving country (inappropriate transfer) (Dolowitz & Marsh, 2000).
When there are essential differences between countries, policy transfer might not work (Rose, 1991). The higher the level of communication between donor country and receiving country, the higher the chance of a successful policy transfer (Dolowitz & Marsh, 2000). Based on this, a comparison is made between the Netherlands, Germany and the United States; how likely is it that the adaptation measures mentioned in the second research question can be implemented successfully in the Netherlands? This comparison is made in the next chapter.

8.3 Comparison

8.3.1 Physical context

Physical context: Netherlands	Flood risk	Increasing temperature, rising sea level and an increase in extreme precipitation events lead to an increasing flood risk
	Wastewater system	High degree of connectedness, approximately 30% separated systems, large wastewater treatment plants
Physical context: Germany	Flood risk	Increasing temperature and an increase in extreme precipitation events lead to an increasing flood risk
	Wastewater system	High degree of connectedness, approximately 25% separated systems, small wastewater treatment plants on average but some large important plants
Physical context: United States	Flood risk	Large differences within the country; in the north more precipitation, in the south less precipitation but more extreme storms and sea level rise; in the whole country an increase in extreme precipitation events
	Wastewater system	St. Louis: separated gravitational system, New Orleans: gravitational system with electric pumping stations; large wastewater treatment plants

Table 10: Physical context compared

Physical context: Flood risk

The increasing flood risk due to climate change in the Netherlands and Germany is fairly similar; an increase in temperature, an increase in extreme precipitation events and sea level rise. In the United States, the north of the country will also receive more precipitation, where the south of the country will endure more droughts. The frequency of extreme weather events (extreme precipitation, storms) increases everywhere. The south of the US also has a rising sea level.

Physical context: Wastewater system

The biggest difference between the countries can be seen in the amount of separated wastewater systems; in Germany and the Netherlands around 25-30% of the wastewater system is separated, where in St. Louis the whole wastewater system is separated. Another difference is the size of the wastewater treatment plants; in Germany there are many small, low-capacity plants where in the Netherlands and especially in the United States it is more common to have big, high-capacity plants. One last important difference is the fact that in the Netherlands water boards operate wastewater treatment plants, where in Germany and the United States most plants are privatized. Especially in Germany this is done in a tight cooperation with authorities, however.

8.3.2 Economic context

Economic context: Netherlands	Financial resources	Adaptation measures are to be integrated in existing investments to reduce costs
	Relevance of protection	Area-based approach of protection; country is divided in safety regions with different levels of protection
Economic context: Germany	Financial resources	Adaptation measures can be funded through two federal schemes; mostly focused on strategy design and research; both public and private actors can apply for funds
	Relevance of protection	Sector-based approach of protection, with an economic perspective
Economic context: United States	Financial resources	Private operator is responsible for the flood protection on treatment plant and finances adaptation measures
	Relevance of protection	Sector-based approach of protection, with an economic perspective

Table 11: Economic context compared

Economic context: Financial resources

In all three cases, different ways of financing climate change adaptation measures have been seen. In the Netherlands, authorities attempt to integrate adaptation measures with existing investments; attention is paid to the depreciation period to keep costs as low as possible. Germany has federal funds to which authorities but also private companies can apply; these funds can be used to develop a climate adaptation strategy. However, no funds are available for physical measures. In the United States, private operators of treatment plants have to finance adaptation measures themselves.

Economic context: level of protection

The approach for flood protection in the Netherlands seems unique compared to the other cases. The Netherlands has an area-based approach of flood protection; areas are protected at a certain level, which is depending on what is in that area. As opposed to this, in Germany and the United States, flood protection strategies are sector-based. Sectors of high economic value are targeted for protection rather than creating a ground for economic prosperity through a safe area.

8.3.3 Political context

Political context: Netherlands	Responsibility	Adaptation measures are taken by regional authorities (water boards, municipalities); safety region takes over during a crisis
	Public opinion	Water nuisance is relevant, but little measures against flooding are taken on private lands
	Current policies and timescales	Keeping multiple scenarios open with frequently adjustable policies; timescale of the Delta Programme set for 2050
Political context: Germany	Responsibility	By law municipalities are responsible for protection of the wastewater system and thus for adaptation measures; many private operators so communication is important
	Public opinion	Mitigation of floods is widely accepted, adaptation to floods less accepted; little action on private lands
	Current policies and timescales	Focused on current climate change expectations, but little flexibility; timescale of the DAS Klimawandel set for 2100
Political context: United States	Responsibility	Private operators of treatment plants responsible for adaptation measures; water safety in general responsibility of the state, federal government only acts during crisis
	Public opinion	Experience teaches private actors how to deal with flooding of the wastewater system; more focused on the recovery phase than preventing damage
	Current policies and timescales	Federal state adapts infrastructure to climate change based on current climate change projections, investments made in climate change science; Presidential Climate Action Plan has no defined timescale

Table 12: Political context compared

Political context: Responsibility

The division of responsibilities is done quite similar in all cases, although small differences can be noticed. In the Netherlands, local authorities (water boards and municipalities) are responsible for the implementation of adaptation measures. In case of an emergency, the safety regions or the national government take over, until the worst crisis has passed and local authorities become responsible again. In Germany this is fairly similar, with the difference that most treatment plants are operated by private companies that have to be part of the decision making process. In the United States, the responsibility of adaptation measures at the wastewater system is for the private companies that operate the system, although just like in the Netherlands and Germany the national government is responsible during an emergency situation.

Political context: Public opinion

On private grounds, in all cases there is still space for improvement. Private companies and civilians in the Netherlands are taking action against water nuisance due to extreme precipitation. However, an increasing flood risk is not an actual topic on private terrain. The mindset in Germany amongst private companies and civilians is still heavily in favor of the government being responsible for flood protection. In the United States some signs can be seen of flood adaptation on private grounds, although this is mostly as a response to past flooding events.

Political context: Current policies and timescales

Large differences can be seen in the flexibility within climate change adaptation strategies among cases. The Netherlands has the Delta Programme, which attempts to make the country resilient to flooding by 2050. This programme is fairly flexible with the possibility to adjust policies along the way as climate change scenarios change. Germany has climate adaptation strategies on a national level as well as on state levels. Adaptation strategies in Germany have more fixed values; a scenario is chosen to define the level of protection that needs to be reached at a certain time, with a pathway of how to get there. The United States have a Climate Action Plan, which is based on current levels of flood risk and does not provide much flexibility for plans, although investments are made in climate science.

8.3.4 Ideological context

Ideological context: Netherlands	Trend in policies	Adaptation has shifted from a Delta Decision to a Delta Programme, completing the shift from science to policy
Ideological context: Germany	Trend in policies	Policies focus on flood mitigation, flood adaptation is starting but not seen much
Ideological context: United States	Trend in policies	‘ Dutch system’ is recommended but not carried out; policies focus on relocating people rather than protecting them

Table 13: Ideological context compared

Ideological context: Policy trend

Trends in policy vary heavily between the cases. In the Netherlands, climate adaptation has made the shift from science to policies, which can be seen with the establishment of the Delta Programme Spatial Adaptation. In Germany, the first municipalities start taking adaptation measures, but in general the focus is still heavily on flood mitigation. In the United States the 'Dutch System' of water management is recommended, but barely visible in policies. Rather than adapting regions to flooding, it is recommended to not build in flood prone areas anymore.

8.4 Conclusion and action perspective for the Netherlands

As mentioned in the chapter results, several adaptation measures that were seen in the United States and Germany are of interest for this research. In Germany, interesting measures were the use of experiences from the past, the communication to the public, the cooperation between authorities and the recovery time reduction. In the United States, interesting measures were a clear communication structure, cross training, making a system replaceable and the response to flood risk. We can combine these measures into four larger themes; experiences from the past, cooperation, focus on the recovery phase and communication. The reason for this is that some of the adaptation measures that were initially addressed individually have the same goal. Experiences from the past were seen in Germany. Cooperation was seen in Germany (between authorities) and in the United States (with private companies). The focus on the recovery phase was seen in both cases, although different strategies were used in each case. The communication issue was also seen in both cases. Each adaptation measure is explained further in this section.

Experiences from the past – As seen in Germany in 2013 and Saxony in 2010, experiences from the past can help to prevent damage to the wastewater system during a flood. In Germany this experience was seen when during a flood municipalities received help from nearby municipalities that had experienced flooding before. Especially the area-specific knowledge that operators have is valuable and should be cherished.

To make a comparison with the Netherlands; both in the Netherlands and in Germany, the local authorities (water boards and municipalities) are responsible for adaptation measures. In Germany, authorities seek advice at other authorities that experienced floods during crisis situations; when this is also done before a flood happens, damage can be prevented. Especially experts from the region can provide useful measures, as they are more likely to have knowledge of the area.

However, not only the knowledge that other authorities have is relevant. Also the knowledge that operators have of their own region and of the floods that happened in the past can help to prevent damage and decrease recovery times. This might be even more effective in the Netherlands than in Germany, as flood protection is carried out with an area-based approach in the Netherlands, as opposed to the sector-based approach in Germany. Area knowledge, especially on flood protection, can be even more relevant in the light of this approach.

Cooperation – Not only with other authorities but also with private companies. In Germany, authorities help each other during emergencies. In New Orleans we have seen a good example where the private operator of a wastewater treatment plant managed to get the treatment plant up and running in a short time, thanks to the availability of resources. Although this might be different in the Netherlands as governmental authorities operate treatment plants, it is definitely of interest to get private companies involved in crisis management. What resources do they have available, how can they be of help during a flood in the Netherlands?

In the Netherlands it might probably be even more interesting to look for cooperation with other authorities that have not experienced flooding during an event. Is there a possibility to exchange resources or employees in a crisis situation? When water boards are in touch and know what they can expect from each other during crisis times, emergency measures can be taken more effectively. This fits well in the idea that costs for adaptation measures are kept low in the Netherlands. By cooperating between various authorities, and maybe even with private companies, expenses can be reduced.

Focus on the recovery phase – A working wastewater system is essential for the return of people. This was successfully established in New Orleans, where the wastewater system could be used to drain water out of the area and guarantee a rather fast return of people. Shortening the recovery phase can be done by making the system replaceable, both parts as well as employees. This might be complicated in the Netherlands; large wastewater treatment plants are technically more complicated and thus less likely to be easily replaceable, whereas small treatment plants can be restored easier.

The specific knowledge that employees have about the treatment plant where they work needs to be available to possible emergency employees. Cross training also brings a valuable solution for this, as employees can act quicker and more effective during emergencies or during the recovery phase. A problem with measures like this (training employees) is that in the Netherlands there is no funding for measures like this. In Germany, adaptation strategies can receive funding from the federal state and in the United States private companies do this out of economic interest, but in the Netherlands this might be harder.

A possible reason for the fact that adaptation measures in the analyzed cases are more focused on the recovery phase than in the Netherlands, is that the concept of climate adaptation is more integrated in the Dutch water management than in the analyzed cases. This might sounds controversial at first; in Germany and in the United States flood risk mitigation policies are more popular than flood risk adaptation policies. However, if a flood occurs, the damage to infrastructure in Germany or in the United States will be more severe as it is not adapted to flooding. That is a reason why the focus is on the recovery phase rather than preventing damage.

Communication – Keep people up-to-date of what is going on. In St. Louis and in Saxony, people were warned in time about the health hazards that the discharge of untreated wastewater unto the surface water imposes on the population. In New Orleans, various cases have been seen where people got ill due to exposure to untreated wastewater during the flooding. The public opinion on flood adaptation in the Netherlands is developing fast, people are getting aware of the possibilities of a flood risk. Making them aware of the risks that exposure to untreated wastewater brings, should be easier than in Germany or the United States. In the Netherlands the public acceptance of a possible flooding is increasing, whereas in the other cases a flood is still not seen as a possibility.

8.5 Methodological reflection

8.5.1 Single case versus multi case

There are several aspects of the methodology that are of interest while reflecting on the research. In the beginning of the methodology, the difference between single case studies and multiple case studies has been explained. At this point, it was described that this research is a multiple case study. However, as described by Yin (1994), single case studies are used when a phenomenon previously inaccessible to scientific investigation is described. As mentioned before, flood risk adaptation on the wastewater system is a scientific niche and is a fairly new topic on policymaking as well. It would appear that a single case study would have been appropriate in this case.

On one hand, this is the case; if the research would have been carried out based on a single case, more in-depth information could have been provided. More practical knowledge of the effects of a flood on the wastewater system could have been described if one case would have been analyzed in-depth rather than four cases on a general level. On the other hand, however, by analyzing multiple cases, more information could be found in order to compare. One of the goals of multiple case studies is to replicate findings across cases (Yin, 2003) and this is exactly what suits the research objective of this research; to make a comparison with foreign examples of flooding of the wastewater system. The use of information from multiple sources forms a more solid base for comparison and thus the decision to use multiple cases is acceptable. In addition to that, it should be mentioned that wastewater system are depending on the physical context in which they are set; by focusing on one specific case, this physical context can not be rationalized as well as while using multiple cases. To give an example of this; the use of inflatable dikes that was seen during the floods in Germany in 2013 might seem like a suitable solution in this case, but would have been no reasonable solution in St. Louis due to the physical setting.

8.5.2 Case selection

Cases were selected with the goal to maximize what we can learn (based on Stake, 1995). Maximizing what we can learn however does not automatically imply that the case should be ideal for policy transfers. The explanation of how cases were found refers to the fact that cases could be selected if enough knowledge was available, if there was a certain level of communication and willingness to communicate. These are the requirements for a successful policy transfer and not the requirements for a maximization of learning.

However, what should be mentioned is that this is a comparative research and therefore these requirements apply. Maybe other cases could have been found that had more information available on the effects of a flood on the wastewater system. If this information could not be applied to the situation in the Netherlands, this information would have been of no value. This means that the cases can still be considered as valuable for learning, especially the cases in Germany that had information available on them. With extra information the matrix could have been completed more in detail for the United States, if more interviews were held, though.

8.5.3 Methods of data collection

Focus groups have shown to be an effective way to gain information in a short time. The fact that multiple experts discuss a topic simultaneously could give the researcher an impartial view of that topic. Questions that the researcher would normally address in interviews could now be discussed in the workshops, saving time and providing answers with a solid foundation. It should be mentioned, however, that according to Kitzinger (1995) focus groups can be used to analyze interaction between participants. Due to the fact that the researcher was participating rather than observing during the workshops, the interaction between participants has not been analyzed in detail. The workshops have thus served more as a source of information than a way to analyze information.

Yin (1994) mentioned that the personal viewpoint of the participant could get in conflict with the neutral viewpoint of the observer role while working a case study. Information gathered through participatory observation mostly serves as a way to interpret data rather than gathering the data itself. The idea of providing sanitation to people and the role of the wastewater system in this as a main focus is something that was stressed heavily throughout the workshops and might have influenced the researcher while he was participating in the workshops. However, as both literature and practical examples agree on this point it provides a valuable answer to the first research question.

The interviews and document analysis proved to be the most valuable source of information in order to complete the matrix. Especially the political and economic context could not have been completed without the input from the gathered data. Participatory observation, which was mostly the internship the researcher did, also contributed to this but in a different way. Through participatory observation sources could be accessed; policy documents, interview partners and also the focus groups. The researcher, however, has been more participant than observer, especially during the workshops. The extra value of interpreting relations between actors that can come from participatory observation is not noticeable in most parts of the research. The question is if this extra value is relevant; it could be useful to interpret the ideological context of each case, but that was also possible based on information sources. .

8.6 Recommendations for further research

Three recommendations can be made for further research on flood risk adaptation on the wastewater system. First of all, as explained, flood risk adaptation is only a part of climate change adaptation. With the use of the knowledge that is available on climate change adaptation, a framework has been drawn for comparison, in the shape of the matrix. Based on this framework, multiple comparisons could be made, not only on flood risk adaptation on the wastewater system, but also flood risk adaptation on other types of infrastructure. When talking specifically about the wastewater system, also other effects of climate change can be addressed using the same methodology. Climate change has multiple impacts, not only an increase in flood risk but also an increase in for example extended periods of drought. The effects that droughts have on the wastewater system and the adaptation measures taken against this could also be compared with the use of a matrix.

Second, more cases could be analyzed. Throughout the research, several other cases appeared that might have been of interest for the research; mentioned are floods that affected the wastewater system in Denmark. If an international database would be available, or more water management contact organizations could be addressed, other cases might be found as well. Analyzing more cases with the use of this matrix can be done relatively easy and provide a broader range of measures for implementation. Besides that, other cases of flooded wastewater system might appear in the upcoming years. Documentation of these events can be relevant to implement more measures in the future.

Last, as mentioned before, a single case study could provide further researchers with more in depth knowledge of flood events on the wastewater system. In order to compare measures for implementation, this is maybe less relevant. However, from a policy perspective, a pilot project or detailed event description can be of great value. The researcher visited the wastewater treatment plant in Utrecht, where flood risk adaptation measures are integrated in the design of a new treatment plant that currently is being built. An analysis of the measures taken there, the costs and effectiveness of these measures can be a source of inspiration for other wastewater systems.

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