# Cloudburst emergency planning in urban areas

Increasing the resilience and limiting the vulnerability of urban areas by developing a theoretical framework for cloudburst emergency planning and by giving recommendations for cloudburst emergency planning in urban areas


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**Summary:**

Due to climate change, cloudbursts happen more often. This might put our cities at risk. Increasing the resilience and limiting the vulnerability of cities can limit the effects of these events.

In this report, it is studied which aspects in relation to information, knowledge, organization and collaboration are important for good cloudburst emergency planning, starting from the following research question:

*How to plan for cloudburst emergency situations to increase resilience and reduce vulnerability in a specific urban context?*

Together with a literature review, a case study analysis is conducted to explore cloudburst management practices in Amsterdam and Rotterdam.

As a result, a theoretical framework for cloudburst emergency planning is developed and recommendations are given for cloudburst emergency planning in urban areas.

## Preface

This problem based learning master thesis is written in the fourth semester of the Master Programme Sustainable Cities, in the Department of Development and Planning at the Aalborg University Copenhagen. This master thesis counts for 30 ECTS and has been carried out in the period from the 1st of February to the 2nd of June 2016. This research was conducted in combination with an internship at the headquarter of Waternet in Amsterdam. Chiara Farné Fratini as supervisor from the Aalborg University and Eljakim Koopman as supervisor from Waternet gave advice and help along the whole semester.

The main objective of this research is to develop a theoretical framework for cloudburst emergency planning and give recommendations to urban areas around the world about the different elements that are important in cloudburst emergency planning. With my work, I hope to show the academic world the importance of the different identified elements of cloudburst emergency planning and help cities around the world to prepare better for upcoming cloudbursts and to limit the negative effects of these events by increasing the resilience and reducing the vulnerability of cities around the world in relation to cloudbursts.

Reference style

The references and bibliography have been arranged in accordance with the APA reference style. The bibliography has been arranged in alphabetic order.

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Amsterdam, June 2016

Jody de Graaf

## Executive Summary

Cloudburst happen more often due to climate change. And because of high percentages of paved surfaces and because urban sewage systems are not designed to process this amount of extreme precipitation, cities are specifically vulnerable. At the same time, other shifts and changes take place, like citizen participation, changing patterns of governance, digitalization of the society, urbanization and increasing concentration of economic activities in urban areas.

The main objective of this research is to develop a theoretical framework for cloudburst emergency planning and give recommendations to urban areas around the world about the different elements that are important in cloudburst emergency planning. With my work, I hope to show the academic world the importance of the different identified elements of cloudburst emergency planning and help cities around the world to prepare better for upcoming cloudbursts and to limit the negative effects of these events by increasing the resilience and reducing the vulnerability of cities around the world in relation to cloudbursts.

This is a grounded theory research, based on case studies: the cloudburst emergency management in the cities of Amsterdam and Rotterdam. This is done by conducting interviews, studying documents, doing observations and organizing a workshop. Furthermore, the theoretical framework for cloudburst emergency planning is advanced on the base of a literature review on resilience and vulnerability and the outcomes of the empirical investigation.

The framework consists of four phases: preparedness, event, response and recovery. The main characteristic of cloudburst emergency planning is resilience, which consists of four elements: information and knowledge, organization, collaboration and learning and application of new knowledge. The aspects of information and knowledge are: awareness, expectations, geography of the city, perspective for action, real-time information, resourcefulness and adaptation. In relation to organization, the actors that should be involved are rainwater management, local government, emergency services, weather forecast, knowledge institutes, utility companies, public transport and citizens. The other aspects of organization are: willingness to act, balance prepared and overprepared, clear roles within organization, coping capacity, resourcefulness and efficiency and responsiveness. The aspects of collaboration are: tasks and responsibilities, coordination and information sharing.

The following recommendations are given for cloudburst emergency planning in an urban context, based on the theoretical framework and the empirical investigation:

- Make sure that information, organization, collaboration and learning are incorporated in the different phases
- Involve all necessary actors, make sure they are aware of the risk and consequences of heavy precipitation and are willing to act
- Know the tasks, roles, responsibilities and have perspective for action
- Know the physical and social geography of the city and have real-time information
- Find a balance between being prepared and being overprepared
- Coordinate actions and share information among actors and evaluate afterwards

Keywords: cloudburst emergency planning, heavy precipitation, resilience, vulnerability, theoretical framework, urban areas, Amsterdam, Rotterdam.

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# 1. Introduction

The main aim of this research is to advance a theoretical framework for cloudburst emergency planning[1] that I started developing during my internship at the Municipality of Rotterdam in the fall semester 2015 (De Graaf, 2016). This framework aims at providing guidance to plan for cloudburst emergency planning in urban areas. With this purpose, the concepts of resilience[2] and vulnerability[3] have been used in the process of developing the framework because they are central to the academic debates on sustainable water management and disaster management (Miller *et al.*, 2010). Inspired by a literature review on resilience and vulnerability, the central elements whose investigation would improve the quality of the framework were identified. Therefore, this study focuses on the elements 'information and knowledge', 'organization' and 'collaboration', because these were found to be the most influential in tackling vulnerability and enhancing urban resilience. By focusing on these elements before, during and after a cloudburst event[4], the negative effect on urban areas can be mitigated. Because the concepts of resilience and vulnerability emerge from different academic communities, they have not often been combined in previous research. But according to Miller *et al.* (2010), they can be linked successfully and complement each other.

Therefore, the following research question is developed:

> *How to plan for cloudburst emergency situations to increase resilience and reduce vulnerability in a specific urban context?*

The following sub questions are created to help answer this question:

1. *Which information and knowledge is necessary for developing an effective plan to handle vulnerability and increase urban resilience, how can this information be obtained and how can this information be accessed?*
2. *Who should be involved in developing and implementing the plan? What are the challenges for organizing collaboration among the relevant actors?*

The topic of research is briefly introduced in this chapter. First, the context of the report is introduced. This is broken down in three parts: global trends, urban areas and cloudbursts and the Netherlands, Amsterdam and Rotterdam. Second, the theoretical framework for cloudburst emergency planning is presented. Third, the academic and societal relevance are defined. To conclude, the research design is given and then, the report's structure is presented.

## 1.1 Context

### 1.1.1 Global trends

Today, scholars are largely agreeing that several ecological and social shifts and changes are taking place. Not only is the earth's climate changing, increased digitalization[5] of the society, participation of citizens[6], changing patterns of governance, urbanization and the increasing concentration of economic activities in urban areas are other trends that are taking place at this moment (Bingham, Nabatchi, & O'Leary, 2005; Castells, 2012; Jha, Block & Ramond, 2012; Sassen, 2011). Some say the society has changed to an information society (Webster, 2014) or that this is a time of transition (Habermas, Cronin, & Pensky, 2006).

All of these trends are influencing flood risk management (Jha *et al.*, 2012). Some can be used to improve it, for example, the participation and commitment of citizens and the increasing digitalization and information orientation of the society can be employed to generate data and information about flooding and other water related problems (Wehn, Rusca, Evers, & Lanfranchi, 2015; White, Kingston, & Barker, 2010). Through the use of smartphones, social media and internet, it becomes more and more easier to use citizens as a source of information of these problems (RIONED, 2015a; Wehn *et al.*, 2015). Therefore, it is important to also consider their role in water management and emergency planning so the functioning of these governmental tasks can be improved.

### 1.1.2 Urban areas and cloudbursts

In relation to cloudbursts, cities are vulnerable places (Bulkeley, 2013). This vulnerability is even exaggerating. While cloudbursts and other types of extreme precipitation are occurring more often due to climate change, the percentage of paved surfaces and the density of cities are increasing (see figure 1.1). This limits rainwater infiltration and therefore increases the chances on disruption and damage (see figure 1.2) (Jha *et al.*, 2012). The amount of flooding and damage is mainly influenced by the type of city district, density, the quality of the sewer system and the presence of green and water (PBL, 2011). There are also other characteristics that make cities vulnerable. Certain infrastructural systems, like underground transportation systems and tunnels, are vulnerable to flooding. Also, some other infrastructural systems rely on, are situated close to and/or are linked to each other, so problems in one system can negatively influence other systems and can potentially have high impacts in the socio-economic field (Bulkeley, 2013; EEA, 2012; Jha *et al.*, 2012). In addition to that, the location of critical infrastructure[7] and vulnerable objects[8], like important highways and hospitals, is often mainly planned on political and economic factors and by the choice for their location, flooding has not been considered (White, 2008).

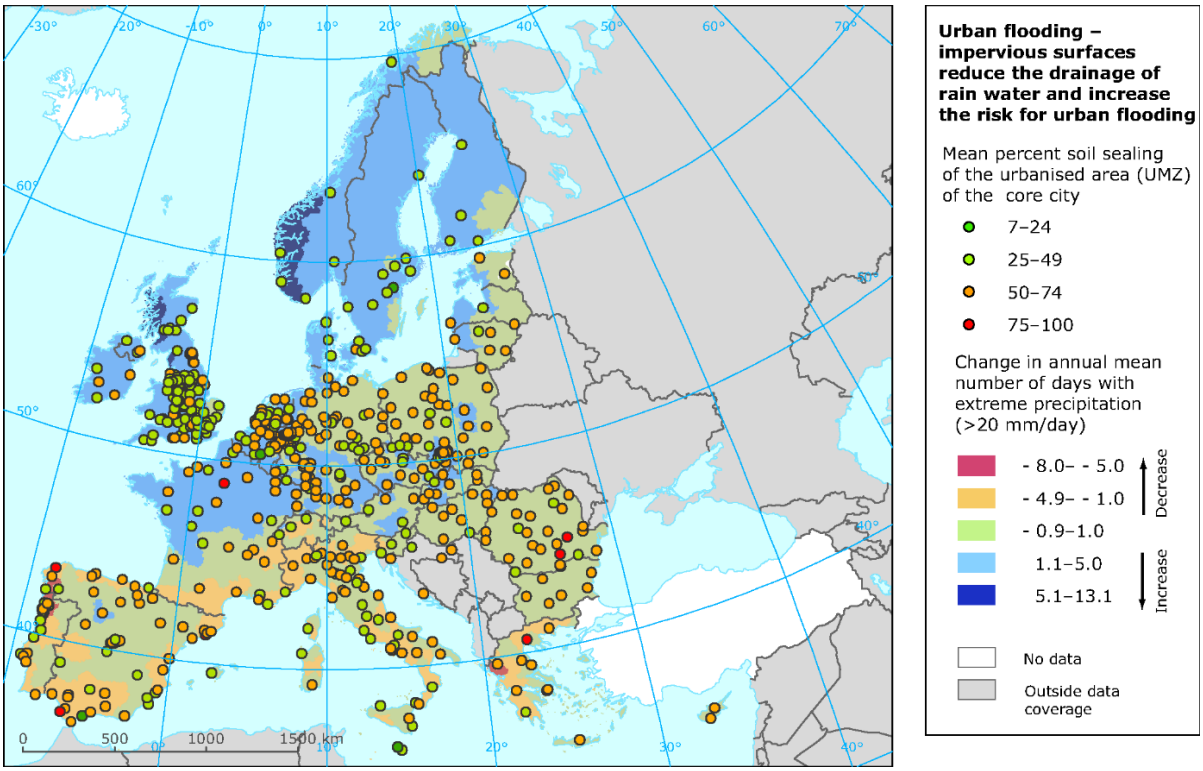


**Figure 1.1: Risk of urban flooding in Europe. Source: EEA, 2012.**

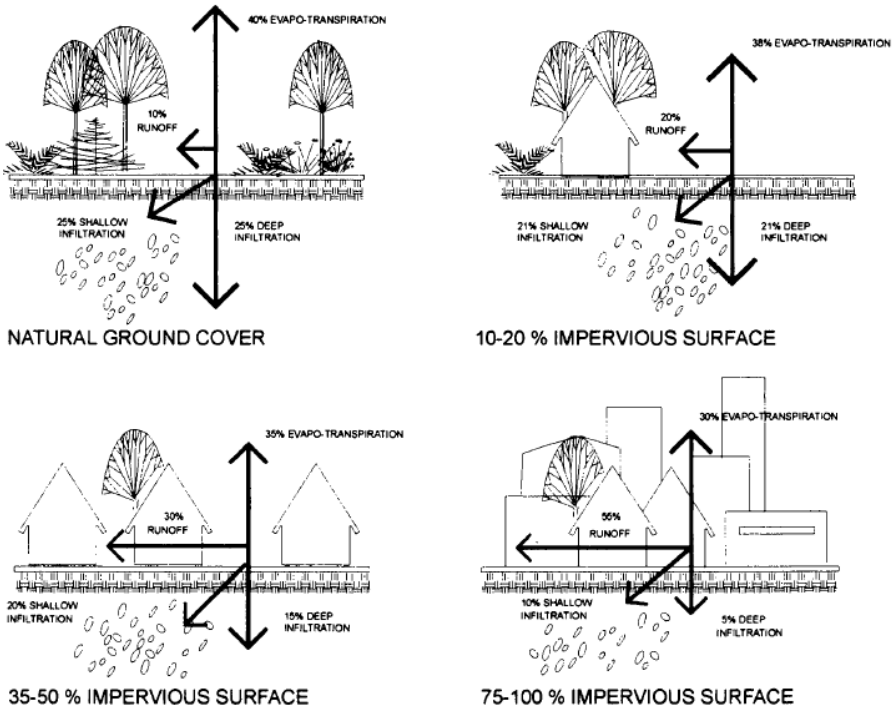


**Figure 1.2: Percentage of paved surfaces and rainwater infiltration. Source: Arnold & Gibbons, 1996.**

Especially in cities in developing countries, cloudbursts can have large consequences. In these cities, a proper drainage system is not present, drains are sometimes removed for road construction and/or the drains are poorly maintained and often clocked with waste (Satterthwaite, Huq, Pelling, Reid & Lankao, 2007). Examples of cities in developing countries that are vulnerable for cloudbursts are Lagos (Nigeria), Buenos Aires (Argentina) and Bamenda (Cameroon) (Satterthwaite *et al*., 2007). The main problem caused by cloudbursts in these cities is localized flooding caused by inadequate drainage (Douglas *et al.*, 2008).

The design and function of urban sewer systems in the developed world is good, but they do not have the capacity to cope with the extreme rainfall from cloudbursts. Although heavy downpour normally only causes rather small flooding with limited consequences, like disruption of traffic and annoyance for pedestrians through pools on sidewalk and crosswalks, extreme precipitation can cause large damage with higher costs (Ten Veldhuis & Clemens, 2010). Cloudbursts that happened around the world, for example in Copenhagen in 2011 and in Amsterdam in 2014, increase awareness in other cities that climate change adaptation[9] is very important, but also that it will not be fast enough to make sure that a city can deal with a cloudburst without problems and negative effects. For example, the City of London identifies surface water flooding caused by heavy precipitation as the most likely type of flooding (City of London Corporation, 2014). Cloudburst emergency plans are necessary so it is clear what to do in this type of situations and to limit their negative effects. In other words: to be able to deal with residual risk (Jha *et al.*, 2012). A plan can help to organize the response and limit the consequences (IPCC, 2014; Jha *et al.*, 2012). Preparedness[10] for cloudbursts can limit the consequences, contribute to organize the response and can help to assemble all the necessary and relevant information to limit the effects of future events (Perry & Lindell, 2003). Until now, the only cities with a cloudburst emergency plan are Amsterdam and Copenhagen. Extreme weather events can cause a window of opportunity for improved

organization for future events of this type (Næss, Bang, Eriksen, & Vevatne, 2005; Van den Berg & Coenen, 2012; White, 2013). Apparently, this is the case in these cities.

Changes in flood risk are driven by changes in climate, territory and socio-economic related systems (Kundzewicz & Schellnhuber, 2004). The impacts and likelihood of urban rainwater flooding and developments that influence it, positively or negatively, are summarized in figure 1.3. This information in this figure is based on Bingham *et al.* (2005), EEA (2012), Jha *et al.* (2012), KNMI (n.d. a) and White *et al.* (2010).

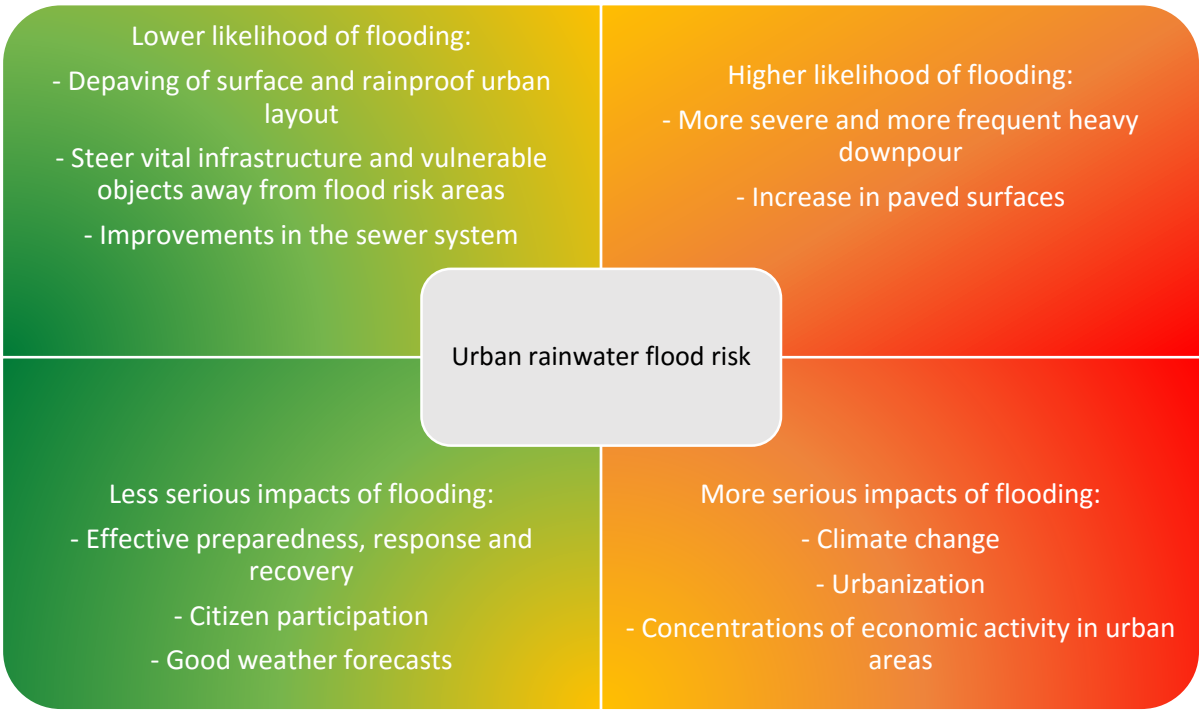


**Figure 1.3: Impacts and likelihood of urban rainwater flooding (own figure).**

### 1.1.3 The Netherlands, Amsterdam and Rotterdam

*Climate change*

It is estimated that in the future, it will rain more often and also harder in the Netherlands. The Royal Netherlands Meteorological Institute (KNMI)[11] indicates in its research that the rainfall intensity will increase approximately 14 per cent in the Netherlands with every degree the temperature in Celsius increases (Lenderink, Mok, Lee, & Van Oldenborgh, 2011). The manifestation of extreme weather will thus also increase. It is expected that in the summer season, the chances on heavy downpour events with an intensity of at least 20 millimeters per hour will increase but the number of days on which it rains will decrease (KNMI, n.d. a).

Also, extreme precipitation occurs more often somewhere in a city than on a set location in that city. How larger the size of the city, how higher the chances are on heavy downpour (Overeem, 2014). On average in the Netherlands, a cloudburst happens once in ten years at a certain spot (KNMI, n.d. b).

In the Netherlands, the standard definition of a cloudburst is at least 25 millimeters of rainfall within an hour or when it rains ten millimeters or more in five minutes, set by the Royal Netherlands Meteorological Institute (KNMI, n.d. b).

The number of days on which it rained 50 millimeters or more at measuring stations of the Royal Netherlands Meteorological Institute has been increasing. These events happen mainly during the summer months (see figure 1.4) (KNMI, n.d. b). An increase in heavy downpour events can have considerable consequences in the Netherlands. The chances on flooding and other problems related to rainwater will increase (RIONED, 2015b).

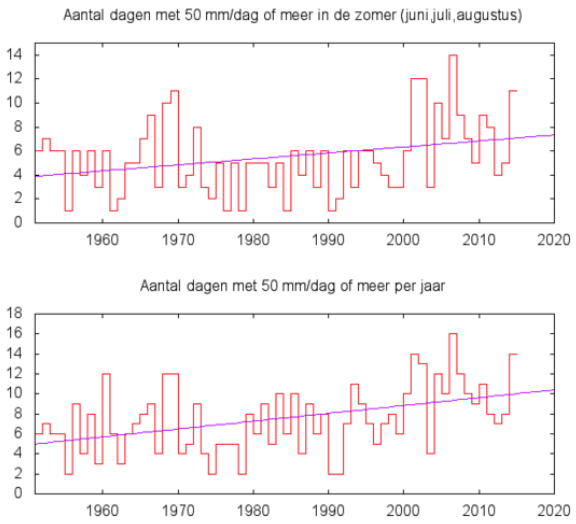


**Figure 1.4: Total of days per year on which ≤ 50 millimeter rainfall was measured at the measuring stations of the Royal Netherlands Meteorological Institute in the Netherlands. On top: during the summer (months June, July and August). Below: throughout the year.**
**Source: KNMI, n.d. c.**

*Multilevel safety*

The Netherlands has a strong tradition of water management and flood prevention. In the past, these professions were mainly focused on sea- and river flooding and on prevention (Vis, Klijn, de Bruijn, & van Buuren, 2003). Therefore, the attention for emergency organization and disaster management[12] in relation to flooding is under developed in comparison to these other concepts. The government implemented a new concept, multilevel safety, to change the focus of attention.

Multilevel safety is a concept for water safety and flood risk management, introduced by the national government of the Netherlands (Oranjewoud & HKV Lijn in Water, 2011). The concept consists of three levels, which are: prevention, spatial planning and -organization and emergency management (see figure 1.5) (Rijksoverheid, 2009). Combinations of actions on these three different layers can limit the effects of flooding (Oranjewoud & HKV Lijn in Water, 2011). The concept of multilevel safety can help to increase water safety when measures in the first layer are not possible or will take a long time (Oranjewoud & HKV Lijn in Water, 2011). The second and third layer can be used to manage residual risk (Ministerie van Verkeer en Waterstaat, 2008).

**Figure 1.5: Multilevel safety. Level 1: prevention; level 2: sustainable spatial planning and -organization; and level 3: emergency management.**
**Source: Oranjewoud & HKV Lijn in Water, 2011.**

The third layer is focused on limiting the consequences of residual risk (Ministerie van Verkeer en Waterstaat, 2008). Research concluded that taking some rather inexpensive emergency management measures in level three can increase resilience, reduce the amount of damage and be a useful addition to the measures taken on the other levels (Oranjewoud & HKV Lijn in Water, 2011). Being well prepared is important for effective management during an emergency event, which can limit damage and victims (Ministerie van Verkeer en Waterstaat, 2008). Because risk is central in this concept, it is

possible to choose measures that fit to the local characteristics (Oranjewoud & HKV Lijn in Water, 2011). An institutional barrier for the implementation of the concept is that the actors mainly focus on the prevention part and therefore, the other aspects like preparedness, response and recovery receive very limited attention (Van der Most, H., de Wit, S., Broekhans, B., & Roos, W., 2010 in: Raad voor de leefomgeving en infrastructuur, 2011). Cloudburst emergency management focuses on the third layer, which is the layer that is often neglected, especially in cities (Wamsler, 2014).


**Figure 1.6: Location of Amsterdam and Rotterdam in the Netherlands. Map made with google maps.**

The Municipality of Amsterdam and the water authority[13] Amstel, Gooi and Vecht are both using the concept. AGV thinks it is important to translate the concept of multilevel safety to specific projects to become future proof (Waterschap Amstel, Gooi en Vecht, 2015) and the Municipality is using it in the process of location choices for vulnerable objects (Municipality of Amsterdam, 2011).

*Amsterdam*

Amsterdam is the biggest city and the capital of the Netherlands, with 833,625 inhabitants (CBS, 2016). It is located in the western, lower parts of the country (see figure 1.6).

The city is famous for its canals in the historical city center (Municipality of Amsterdam, 2011). Originally, the city was quite compact, but expanded greatly after the 1860s because of large population growth due to high economic activity in the harbors (see figure 1.7) (Programma Amsterdam Waterbestendig, 2010).

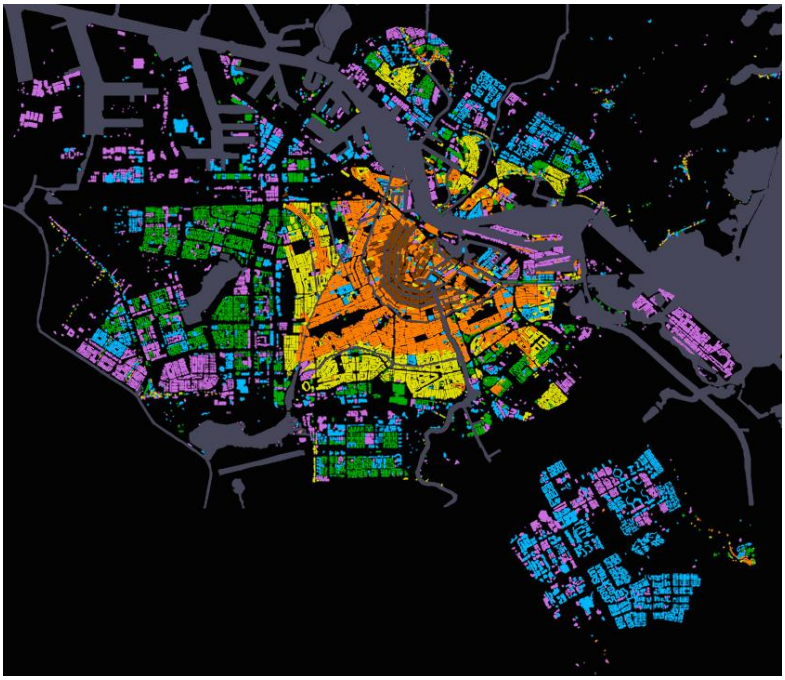

**Figure 1.7: Map building age Amsterdam. Brown: before 1860; orange: 1860-1919; yellow: 1920-1945; green: 1946-1965; blue: 1966-1990; and purple: after 1990.**
**Source: http://maps.amsterdam.nl/bouwjaar/?LANG=en**

In the past, a lot of the land has been filled with sand and therefore, most of the residential areas are located around NAP[14] (see figure 1.8). The filling was necessary, because the soil in Amsterdam was peat, which is very soft and moist (Municipality of Amsterdam, 2012). In relation to flood risk, the filling with sand has also been beneficial. Because most parts of the city are now located above

the surface water levels, rainwater can flow directly from the neighborhoods in the surface water, without having to be pumped. Also, more rainwater can infiltrate in sand than in peat.

The city faces the challenge to realize 70,000 more houses within the city boundaries in 2040 (Municipality of Amsterdam, 2011; Programma Amsterdam Waterbestendig, 2010). Therefore, the density of the city will increase, which in combination with increased extreme precipitation due to climate change causes a challenge to make the city rainproof and limit damage (Waternet, 2015a).

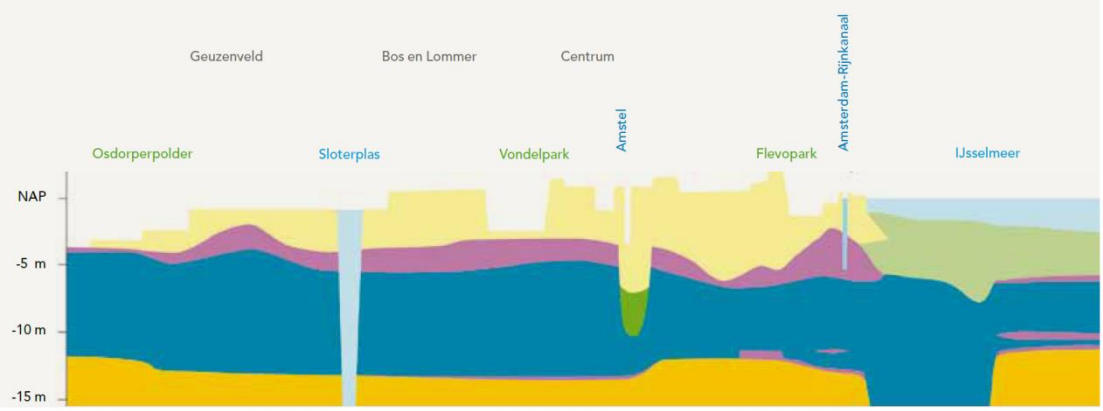


**Figure 1.8: Soil composition Amsterdam. Yellow: fill sand; light green: South Sea clay; purple: peat; green: Amstel clay; blue: mudflat sediment; orange: Pleistocene sand deposits; and light blue: water. Source: Municipality of Amsterdam, 2012.**

*Organization water management in Amsterdam*


**Figure 1.9: Borders of the Municipality of Amsterdam and the different water authorities in the region. Black line: Municipal boundary; blue: Hoogheemraadschap Amstel, Gooi en Vecht; red: Hoogheemraadschap Hollands Noorderkwartier; green: Hoogheemraadschap van Rijnland (own figure).**

Amsterdam is located on the catchment areas of three water authorities: water authority Amstel, Gooi and Vecht (AGV), Hoogheemraadschap van Rijnland (HHvR) and Hollands Noorderkwartier (HHNK). HHNK only manages the regional waters in the northern, more rural part of Amsterdam. HHvR has only two small areas in Amsterdam (a part of a lake and of an industrial area) for which it is responsible. The rest of the regional waters are managed by AGV (Programma Amsterdam Waterbestendig, 2010) (see figure 1.9).

The Municipality of Amsterdam and the water authority Amstel, Gooi and Vecht (AGV) both have their executive function in the field of water management combined in the water cycle company Waternet[15] (Waternet, 2015a). In Amsterdam, this company is responsible for drinking water, wastewater and surface water, but in the end, the Municipality and the water authority still have the responsibility for the tasks executed by Waternet (Programma Amsterdam Waterbestendig, 2010; Waterschap Amstel, Gooi en Vecht, 2015). By combining these water management tasks in one organization, all aspects can be taken care off in coherence (Waternet, 2015a). It is the first organization in the Netherlands where this is done (Waternet, 2015a). Both the water authorities and the Municipality, as well as Waternet, are public authorities. The organization of the public space, in relation to rainwater, is still part of the Municipality of Amsterdam.

*Vision and ambition for Amsterdam*

The Municipality has the ambition that in 2020, the city can cope with a cloudburst with an intensity of 60 mm per hour, without damage to houses and vital infrastructure. 20 mm will be processed by the sewer system and 40 mm will be temporarily retained and stored in both public and private space (Waternet, 2015a). The vision for 2040 is that extreme precipitation is not causing damage or nuisance and that the citizens of Amsterdam do not take good water management for granted (Waternet, 2015a). The 'acceptable level' of damage and nuisance is set by the Municipality (Waternet, 2015a). Amsterdam Rainproof informs citizens and makes them aware that they also play a role in the management of rainwater. Both public and private space is used to prevent flooding by extreme precipitation (Waternet, 2015a). Therefore, these ambitions are a responsibility of all citizens of Amsterdam (Waternet, 2015a).

The water authority Amstel, Gooi and Vecht has the ambition to cooperate more with the Municipality and the Safety Region[16] in disaster management (Waterschap Amstel, Gooi en Vecht, 2015). The water authority also wants to work together with knowledge institutes, other governmental bodies and private companies on innovations and involve citizens and local businesses in solving water related problems (Waterschap Amstel, Gooi en Vecht, 2015).

*Sewer system in Amsterdam*

The biggest part of the sewer system in Amsterdam is a separated system, around 75 per cent (see figure 1.10). The combined system is mainly located in the older parts of the city (see figures 1.11 & 1.12). Since 1923, the collection of sewage water and rainwater is separated (Waternet 2015a). Excess rainwater is transported through the combined sewer system to a wastewater treatment plant or through the separated system to surface water or infiltration facilities (Waternet, 2015a). Because infiltration of rainwater in the ground is difficult because of the composition of the soil, surface water is often used to store the water (Waterschap Amstel, Gooi en Vecht, 2009).

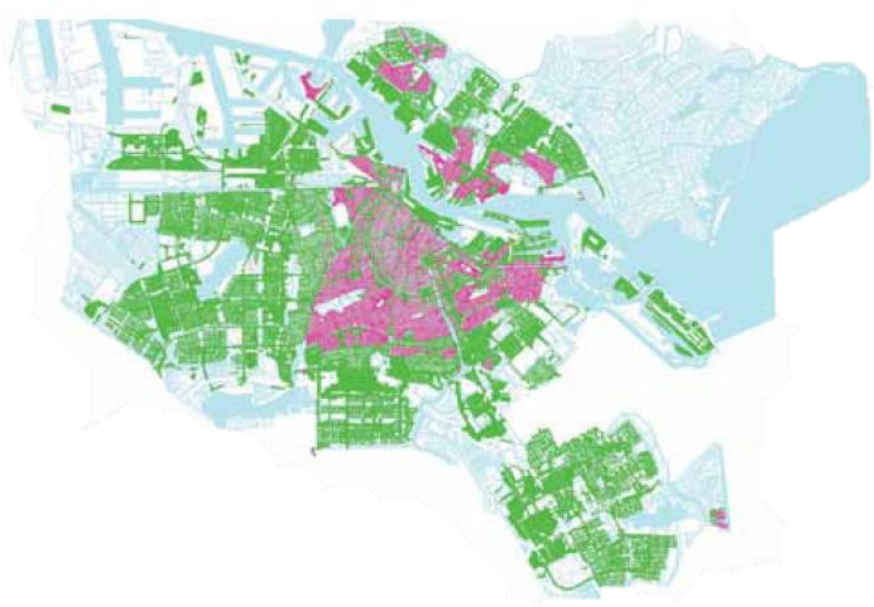

**Figure 1.10: Sewer system in Amsterdam. Purple: combined system; green: separated system. Source: Programma Amsterdam Waterbestendig, 2010.**

The plot owner is in principle responsible for processing rainwater on his own property (Waternet, 2015a), which is defined by the law (Waterwet, 2009). Subsequently, the municipality takes care that the plot owner can discharge the rainwater which he cannot process himself (Waterschap Amstel, Gooi en Vecht, 2009). Therefore, when new houses are built or existing houses are

remodeled, it needs to be possible to store 10 to 20 millimeters rain on plot level (Programma Amsterdam Waterbestendig, 2010).

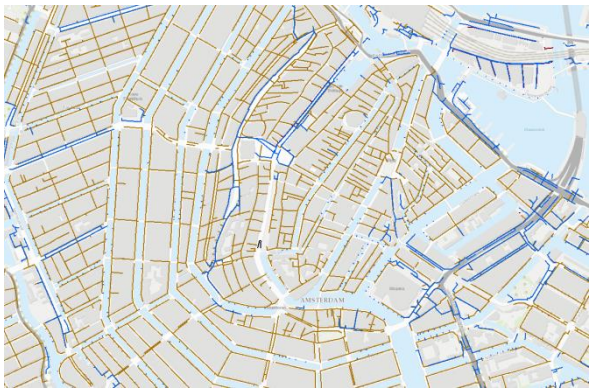

**Figure 1.11: Sewer system city center Amsterdam. Brown: combined system; blue: rainwater system (own map).**

**Figure 1.12: Sewer system city area "Bijlmer" in Amsterdam. Blue: rainwater system; red: sewage system (own map).**

The sewer system in Amsterdam is designed for heavy downpour with an intensity of 20 millimeters per hour, which has a return period of 2 years[I] (Programma Amsterdam Waterbestendig, 2010). The sewer system is thus not designed to cope with cloudbursts and other types of extreme precipitation. Another problem is that the functioning of the sewer system is influenced by the compacting of the soil (Waternet, 2015a). The capacity of the sewer system is rather high but limited. Therefore, not all the rainwater can be processed via the sewer system in extreme situations. In these situations, surface water is important in preventing and limiting problems due to heavy downpour (see figure 1.13).

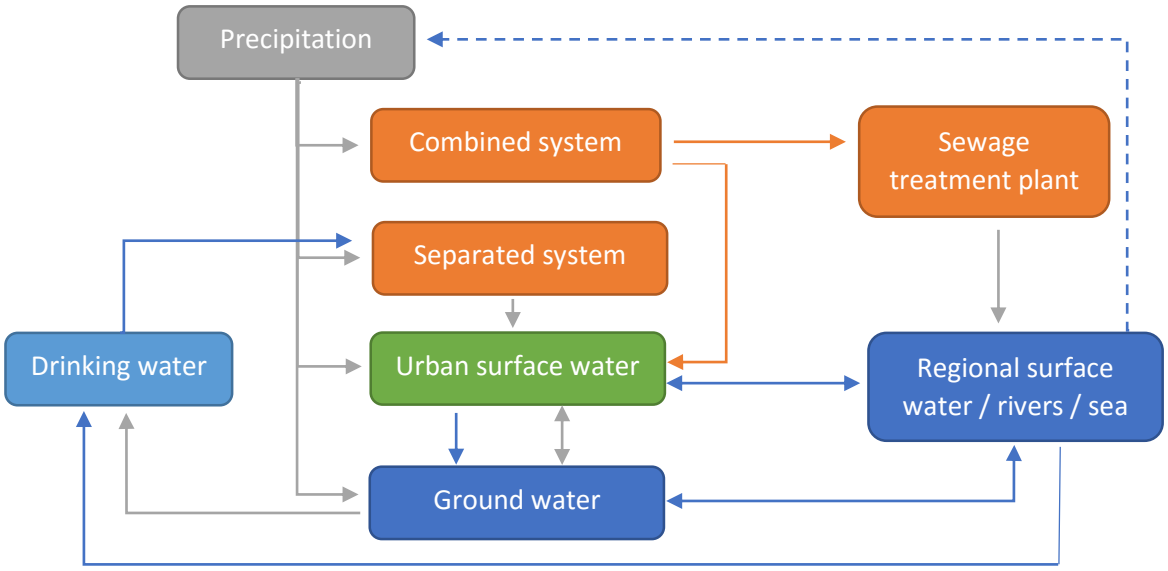


**Figure 1.13: Water cycle Amsterdam. Based on: Waternet, 2015a.**

[I] The heavy downpour with a return period of 2 years is a standardized rainfall event that is presented in the 'Guideline sewer system (Leidraad Riolering)' (RIONED, 2004) and is used by municipalities in the Netherlands as a standard to test the functioning and capacity of sewer systems. Return periods are specific for each climatologic area (Jha *et al.*, 2012). However, the rainfall in this standard rainfall event is almost the same as the Danish return period of 10 years that is used for designing sewer systems (see Bentzen (2014), Københavns Brandvæsen (2012) and RIONED (2004). See RIONED (2004) for more information on this standard.

Water on the streets is to a certain level acceptable, as long as it is not causing dangerous situations or damage (Programma Amsterdam Waterbestendig, 2010; Waternet, 2015a). Also, the Municipality of Amsterdam is making changes to make it possible to store rainwater in public spaces (Waternet, 2015a). In some areas of Amsterdam, the standstill principle is used. This means that rainwater is primary retained on plot level or stored in a network of waterways (Programma Amsterdam Waterbestendig, 2010).

The use of return periods to express the severity of rainfall events might give a slightly wrong impression. This return period is based on data of historical rainfall events and is therefore not taking dynamics like climate change into account (White, 2013).

The cloudburst that happened on 28 July 2014 in Amsterdam showed that the city is vulnerable for extreme precipitation (Waternet, 2015a). Even in areas where the sewer system is not combined, problems occurred. In some parts of the city, the extreme precipitation caused flooding. In the parts with a separate sewage system, this was mainly caused by the urban lay-out at ground level (i.e. the design of the street) and compacting and settling of the soil (Waternet, 2015a).

The Municipality of Amsterdam initiated the program Amsterdam Rainproof[17], which works on limiting the effects of extreme precipitation and making the city more rainwater proof by working together with citizens, businesses and research institutes (Waternet, 2015a). The focus is on smart and small-scale actions, which also make the city more attractive and a better place to live in (Waternet, 2015a). Citizens are also encouraged to report flooding and other problems related to heavy downpour, so more insight can be developed on the weak spots in the city (Waternet, 2015a). This program was already in action when the cloudburst occurred, but is accelerated afterwards (Waternet, 2015a).

*Rotterdam*

Rotterdam is the second biggest city of the Netherlands with 629,606 inhabitants (CBS, 2016). The city is also located in the western, lower parts of the country, in the delta of the rivers Meuse and Rhine (see figure 1.6). For the next decades, this city is also facing the challenge to accommodate a growing population within the municipal boundaries (Municipality of Rotterdam, 2013a). Large parts of the city are located in polders behind dikes. Only the harbors and some residential areas are located in outer-dike areas (see figures 1.14 and 1.15). Rainwater causes primarily problems in the inner-dike areas, because the soil level can be as low as around 6 meters below sea level. The soil level in the outer-dike areas is often around 3 meters above sea level and the rainwater that falls there goes directly to the river. The biggest part of the sewage system in Rotterdam is a

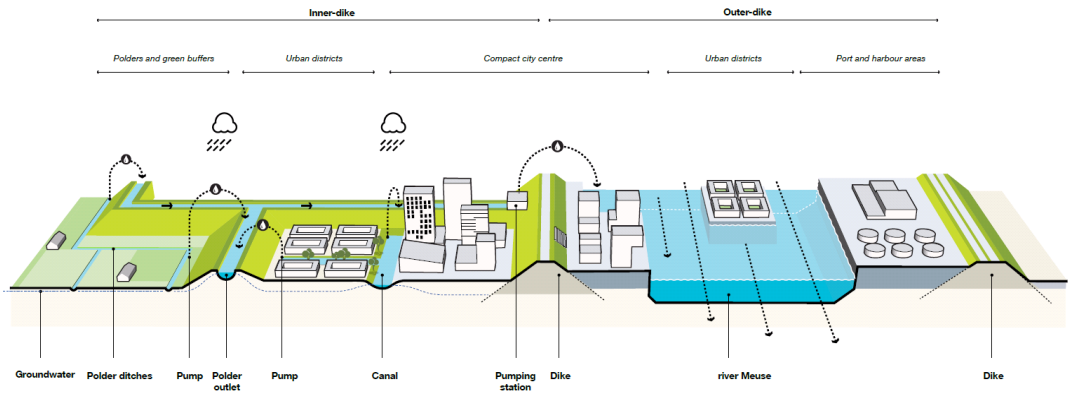


**Figure 1.14: Water system of Rotterdam. Source: Municipality of Rotterdam, 2013b.**

combined system, which is designed to cope with the same intensities as the sewage system in Amsterdam (Municipality of Rotterdam, n.d.). Like Amsterdam, Rotterdam is also located on three different catchment areas, but the situation is more complex here (see figure 1.16). A more elaborate introduction on rainwater management in Rotterdam can be found in De Graaf (2016).

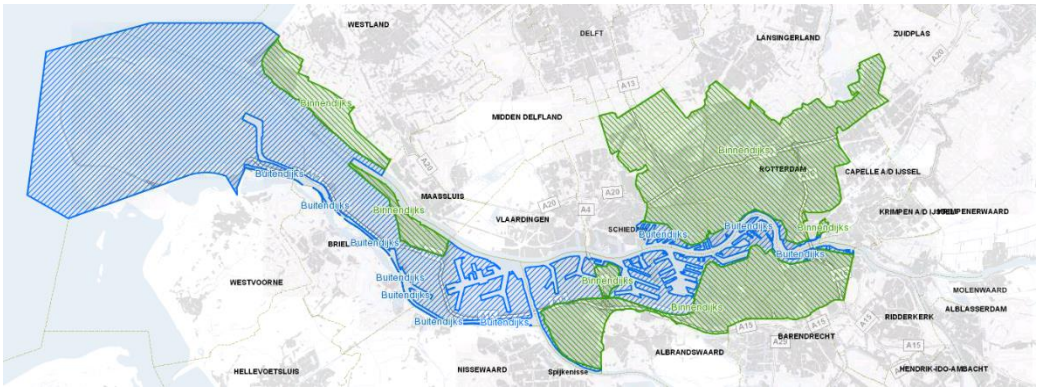


**Figure 1.15: Inner- and outer-dike areas within the municipal borders of Rotterdam (own figure) Green: inner-dike areas and blue: outer-dike areas.**

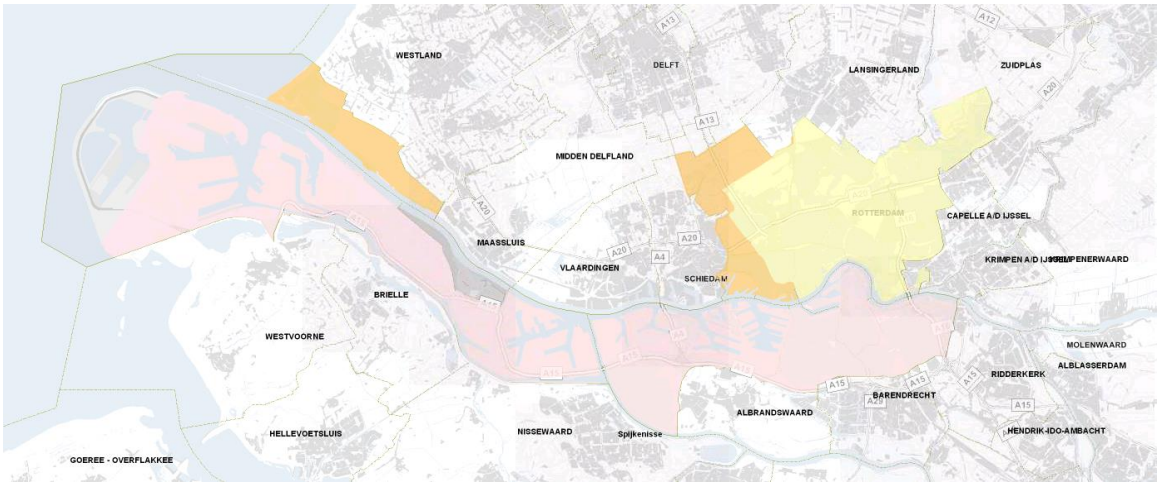


**Figure 1.16: Districts of the three different water authorities within the municipal borders of Rotterdam. Orange: Hoogheemraadschap of Delfland, yellow: Hoogheemraadschap of Schieland and the Krimpenerwaard and pink: Waterschap Hollandse Delta (own figure).**

## 1.2 Cloudburst emergency planning framework

On a previous research on cloudburst emergency planning, I developed a theoretical framework. The reason for designing a framework myself was that, after extensive literature review, I concluded that there were no theoretical frameworks on resilience and vulnerability that fit to cloudburst emergency planning in cities. The framework was developed on the base of an empirical investigation of cloudburst emergency planning in the city of Rotterdam and a literature review on resilience and preparedness.

Four phases can be distinguished in cloudburst emergency planning: preparedness, event, response and recovery (see figure 1.17). Actions in all these phases are necessary to limit the effects of cloudbursts. Resilience characterizes cloudburst emergency planning and the elements information & knowledge, organization, cooperation, communication, participation and learning & application of knowledge are necessary to reach resilience. All phases should have these elements in them and should be ready for use when a cloudburst hits the city.

*"Mitigation and non-structural measures tend to be potentially more efficient and long term more sustainable solutions to water-related problems and should be enhanced, in particularly to reduce the vulnerability of human beings and goods exposed to flood risk"* (WDEU, 2003, pp. 5). Therefore, this frameworks focusses on non-structural measures. But when structural measures are missing, the focus should be on implementing these first (Grey & Sadoff, 2006). For a more detailed description of the framework, its phases and its elements, see De Graaf (2016).

In this study, I decided to focus on the elements 'information & knowledge', 'organization' and 'collaboration' as, in De Graaf (2016), these were identified as the central elements to reduce vulnerability and increase resilience in a 'non-structural' manner. The concept of 'collaboration' is introduced in this study to include all the processes characterizing the elements of 'cooperation', 'communication' and 'participation'. The element of 'learning & application of new knowledge' will not be included in this study as it would require the introduction of additional literature and the use of an additional set of fieldwork approaches. This will hopefully be investigated in further studies.

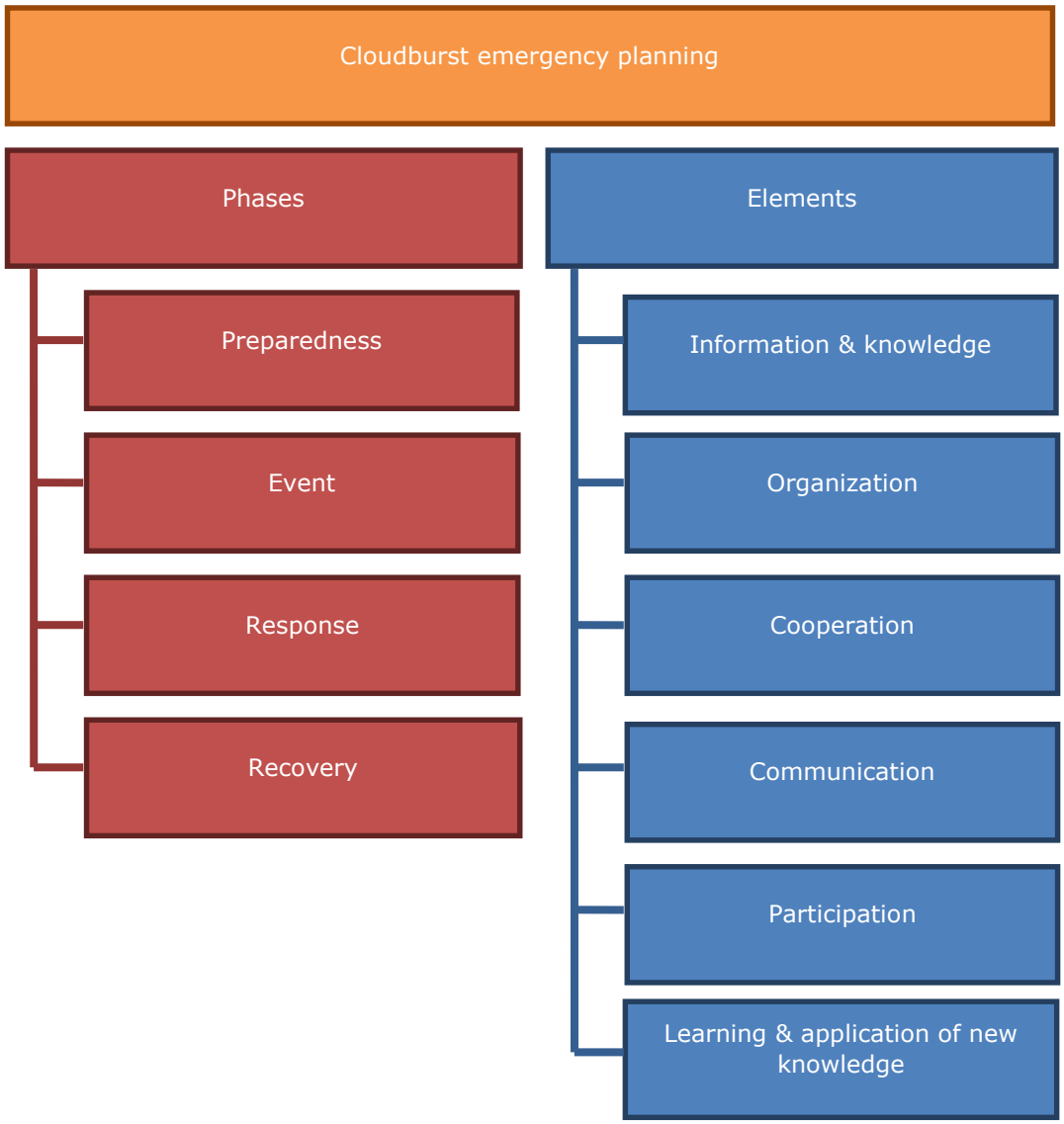


**Figure 1.17: Cloudburst emergency planning framework (De Graaf, 2016).**

### 1.3 Academic and societal relevance

The last decades, a substantial amount of research has been conducted in relation to climate change adaptation in cities. When this has been investigated in relation to cloudbursts, these researchers mainly focus on the increased manifestations of extreme precipitation events or on physical measures, for example alteration of the sewer system, that can reduce their negative effects (e.g. Kessler, 2011; Plate, 2002; White *et al.*, 2010; Zimmerman & Faris, 2011). The use of cloudburst emergency management to limit these effects, decrease the vulnerability and increase the resilience of cities is hardly researched. Nonetheless, the fields of vulnerability, resilience, preparedness and disaster management in relation to cities have been researched (e.g. Bulkeley, 2013; Godschalk, 2003; Solecki, Leichenko, & O'Brien, 2011; Wamsler, 2009; Wamsler, 2014; Wamsler, Brink, & Rivera, 2013). When these studies were conducted in relation to water management, the researchers focused mainly on flash floods or seawater- or river flooding (e.g. Kron, 2005; Montz & Gruntfest, 2002).

Therefore, a knowledge gap exists of the contribution of cloudburst emergency planning to climate change adaptation. This is why this research wants to show the academic world the importance of the different identified elements of cloudburst emergency planning to limit the vulnerability of cities and the effects of climate change, with a special focus on information & knowledge, organization and collaboration.

The societal relevance of this research is to help cities around the world to prepare better for upcoming cloudbursts and to limit the negative effects of these events for the citizens and businesses by investigating the elements of information & knowledge, organization and collaboration of cloudburst emergency planning in more detail.

This research is conducted as part of the master programme "Sustainable Cities" of the Aalborg University Copenhagen. The education in this master programme is mainly focused on improving the sustainability of the following five systems: buildings, energy, transportation, waste and water. Also, the synergies between these systems are highlighted. This research fits in this master programme, because it is not only focused on water management, but also keeps an eye on how cloudbursts can affect the other systems and vice versa.

### 1.4 Research design

On the base of the research question and –objective, the following research model is designed to structure the work done within this project (see figure 1.18). The analysis and results are based on and positioned in related literature, so steps can be made to further understand cloudburst emergency planning (Stern, 2007).

On the base of a literature review on cloudburst emergency planning, resilience and vulnerability of cities, a literature review of studies describing the effects of rainwater flooding in different contexts and of practices of emergency planning and a description of cloudburst emergency management practices in Rotterdam in relation to resilience and vulnerability, the cloudburst emergency management practices in Amsterdam are investigated. Then, the results from this investigation are compared with the results from Rotterdam and other cases found in the literature. This will lead to insights on the elements information & knowledge, organization and collaboration in cloudburst

emergency management. This will be used to advance the framework for cloudburst emergency planning and give recommendations for cloudburst emergency planning in urban areas.

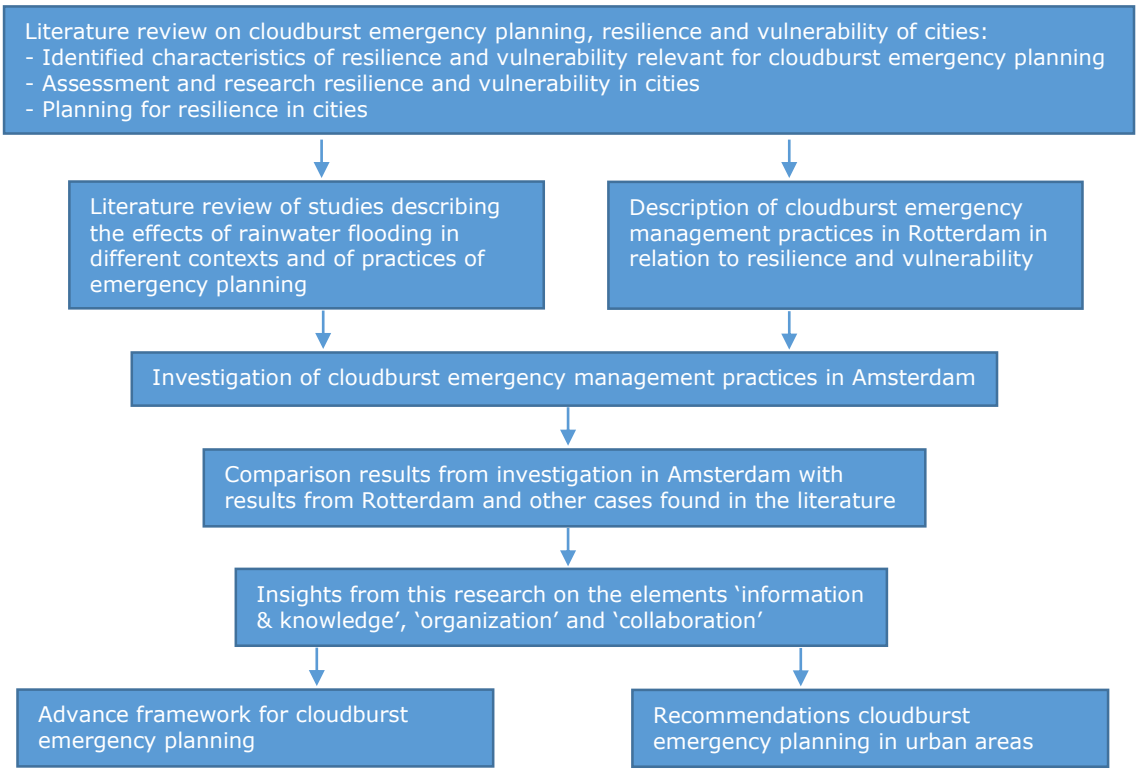


**Figure 1.18: Research model (own figure)**

### 1.5 Structure of report

The first chapter has introduced the problems related to cloudburst resilience and framed the topic of this research. In chapter two, the used methodology is explained. A literature review on the resilience and vulnerability of cities and cases of the effects of rainwater flooding and practices of emergency management is conducted in the third chapter. Chapter four consists of a summary of the results from the fieldwork research on cloudburst emergency planning in Amsterdam and Rotterdam. An advanced version of the theoretical framework for cloudburst emergency planning, recommendations for cloudburst emergency planning in an urban context and reflections on the research are given in chapter five. In chapter six, the research is concluded by answering the research question and by giving recommendations for further research.

**Notes**

1. Cloudburst emergency planning is the process required to build preparedness and resilience of a city to minimize the effects of a cloudburst event.
2. Resilience is *"the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions"* (UNISDR, 2009, pp. 24).
3. Vulnerability is the (degree of) susceptibility to risk, harm and damage.
4. Cloudbursts are a type of extreme precipitation in which a substantial amount of rain falls within a limited time frame. Sewer systems in most countries are not built to cope with these excessive

amounts of rain and therefore, large scale storm water flooding is likely to occur. In the Netherlands, the standard definition of a cloudburst, defined by the Royal Netherlands Meteorological Institute, is: at least 25 millimeters of rainfall within an hour and/or ten millimeters or more in five minutes (KNMI, n.d. b).

**5.** Digitalization is the increase in the use of digital technology. Especially in social life and digital communication, this trend is visible. In this research, the digitalization of the society and of organizations are of special interest.

**6.** Participation is the engagement of citizens in governance by taking part in tasks of or sharing relevant information with public authorities.

**7.** Critical infrastructure is infrastructures that can cause social disruption when they are not available. The failure of one element can have cascading effects on other elements of the same infrastructural network and/or elements of other networks of vital infrastructure.

**8.** Vulnerable objects are buildings in which a lot of persons can be or where persons can be that are not able to rescue themselves (patients, disabled people, elderly and small children), located in flood prone areas.

**9.** Climate change adaptation is the process of taking measures to limit the impacts of and vulnerability in relation to current and future climate change.

**10.** Preparedness is *"the readiness of a political jurisdiction to react constructively to threats from the environment in a way that minimizes the negative consequences of impact for the health and safety of individuals and the integrity and functioning of physical structures and systems"* (Perry & Lindell, 2003, pp. 338).

**11.** The Royal Netherlands Meteorological Institute (KNMI) is the national institute of the Netherlands for meteorology and seismology, but is also an independent, authoritative and international recognized reference institute. The KNMI is part of the Ministry of Infrastructure and Environment (IenM).

**12.** Disaster management is the organization, planning and management of all aspects of disasters to limit their impact.

**13.** A water authority is in the Netherlands a Public authority that is responsible for the management of the water system and the treatment of waste water.

**14.** The Amsterdam Ordnance Datum (NAP) is the national reference level of the Netherlands for land height. Zero NAP is approximately the same as sea level.

**15.** Waternet is a water cycle company that is taking care of the executive functions of the Municipality of Amsterdam and the water authority Amstel, Gooi and Vecht (AGV) in the field of water management.

**16.** A safety region is a district in the Netherlands in which the cooperation between different public authorities on the field of safety is organized. In total, there are 25 safety regions in the Netherlands.

**17.** Amsterdam Rainproof is a program in the city of Amsterdam, initiated by the Municipality, that works on limiting the effects of extreme precipitation by working together with citizens, (local) businesses and research institutes.

## 2. Methodology

The following methodological approach was designed in order to make sure that the results of this research are credible and can be used in further research. The research strategy is presented first and after that, information is given on the research design and material used for this research.

### 2.1 Research strategy

This research was conducted as part of a 3.5 months full-time internship at the Asset management water cycle (Assetmanagement waterketen) Department of Waternet, the organization that is responsible for the water management tasks of the water authority AGV (Amstel, Gooi and Vecht) and the Municipality of Amsterdam. The internship started at the 15th of February and ended on the 31th of May. The motivation for carrying out this research is that I wanted to continue the research on cloudburst emergency planning that I did during an internship at the Water Department of the Municipality of Rotterdam, as part of the 3rd semester of the master education in "Sustainable Cities" of the Aalborg University in Copenhagen (see De Graaf, 2016). After finishing that research, I searched for an organization in another city in the Netherlands that is interested in research on this topic. Waternet was enthusiastic about this opportunity and offered me an internship position at their headquarter in Amsterdam. During the internship, the daily activities and affairs on the cluster Wastewater (Afvalwater) were observed, which helped to get familiar with the context of cloudburst emergency management in Amsterdam. During the internship, I worked fulltime on developing the research presented here.

While working on cloudburst emergency planning in Rotterdam, I realized that it would be interesting to also investigate the cloudburst emergency management in other cities. The city of Amsterdam is an interesting case, because steps have already been taken on the field of cloudburst emergency planning. A cloudburst occurred on the 28th of July 2014 in this city, which made the stakeholders in cloudburst emergency management aware of the risks that these events bring for the city. A cloudburst emergency plan has already been developed in 2015, but this has not been implemented yet. This made Amsterdam a perfect case to advance the theoretical framework for cloudburst emergency planning, developed during the internship in Rotterdam. In this research, the institutional context of rainwater management in the city of Amsterdam is examined. The rainwater management in Rotterdam is also further researched, to be able to compare the rainwater management in the two cities with each other. I decided to use the results of both investigations to elaborate the developed theoretical framework for cloudburst emergency planning further on the elements of information & knowledge, organization and collaboration. These elements seem to be of the highest importance for effective cloudburst emergency planning. Therefore, the choice is made to give these elements priority over the other elements, because due to time constraints, it was not possible to focus on all the elements. All the phases (preparedness, event, response and recovery) will be incorporated in this process.

A qualitative research strategy was chosen to get the best results. Because this study is a pioneering research in cloudburst emergency planning and no other theoretical frameworks have been developed on these fields other than the one I developed myself, this seemed to be the best way to obtain the information necessary for the research (Creswell, 2013).

The research can be described as a grounded theory research, based on case studies. In this research, I try to not only describe the situation, but also generate a theoretical framework for the process of cloudburst emergency planning, which is, according to Creswell (2013), the definition of grounded theory research. It is a systematic way of analyzing data, which results in a theoretical framework (Charmaz & Belgrave, 2012). The theoretical framework for cloudburst emergency planning will give a general explanation of the important elements and phases of the process. The theoretical framework is verified and further developed on the base of data collected by talking with a number of experts and persons that are involved with cloudburst emergency management in the field. Case studies have the advantage that they can be used to test perspectives directly regarding the object of study (Flyvbjerg, 2006). The grounded theory is based on a multisite, collective case study: the investigation of cloudburst emergency management in the cities of Amsterdam and Rotterdam (Cresswell, 2013). Both cities can be seen as fieldwork locations to investigate cases of cloudburst emergency management (Flyvbjerg, 2006; Czarniawska, 2014). These cities were chosen because I wanted to conduct my research in the Netherlands, which is my home country, and these cities are probably the only cities which are doing something in relation to cloudburst emergency planning. Amsterdam is already taking action on cloudburst emergency planning and Rotterdam wants to develop a cloudburst emergency plan while a cloudburst has not occurred in the city yet. In all other cases in which a cloudburst emergency plan is developed, it was after a cloudburst happened in the specific city. In this research, the rainwater management in the city of Rotterdam is only described shortly, because it has already been described more in detail in earlier research conducted by me (De Graaf, 2016).

A time plan (see Appendix E) was developed in which three milestones were set in collaboration with the supervisors in order to obtain feedbacks and organize the work. This time plan was communicated with both the university and Waternet, so both organizations knew what to expect. The first month of the project was used to do focus the research, do background reading and write the introduction and methodology chapters. In the second month, the main part of the theoretical chapter was written and the collection and analysis of the research material was started. The remaining of the data collection and the analysis of it took place in the third month of the research. The fourth month was used to write the final chapters of the academic report, which were analysis, results, discussion and conclusion, and to review the other parts of the work on the base of what I discovered in the field.

### 2.2 Reflections on the research design practice

According to Charmaz and Belgrave (2012), the best source of information for grounded theory research is interviews. Creswell (2013) also identifies interviews as the main form of data collection for grounded theory research, next to documents and observations. Therefore, these types of data collection are also used, to supplement the information gathered by the main source of information: interviews (see figure 2.1). Stern (2007) also describes qualitative materials as the most suitable for grounded theory research (i.e. interviews). The researcher gets more control over the material by using these methods (Charmaz & Belgrave, 2012). The use of multiple sources of data helps to develop an in-depth understanding and a holistic picture (Creswell, 2013). This comparison of sources and methods increases the credibility and depth of the research and helps to

obtain an integral and holistic view (Creswell, 2013; Verschuren & Doorewaard, 2007). Data triangulation is also obtained by interviewing respondents with different professional backgrounds and perspectives on the issue (Beitin, 2012).

Semi-structured interviews were conducted with colleagues of Waternet, Amsterdam Rainproof, the Safety Region Amsterdam-Amstelland, the fire brigade Amsterdam-Amstelland and the GVB (see table 2.1). The representatives were selected on their roles and the potentiality of their knowledge and experience in rainwater management, which would help to develop and improve the theoretical framework and to comply with the aims of the research (Beitin, 2012; Stern, 2007). A balance needed to be found in collecting enough data for offsetting misleading information and for the theory development, but not too much which could limit the analysis (Charmaz & Belgrave, 2012; Stern, 2007). The interview guides that are used at these interviews consisted primarily of open, information-seeking questions, so called Wh-questions (Wang & Yan, 2012), and were based on the research question and -aim (Beitin, 2012) and information needed to elaborate the theoretical framework. When new areas of interest emerged, the interview guides for future interviews were altered (Charmaz & Belgrave, 2012). Because the literature review and the interviews were conducted at the same time, they influenced each other. Different questions were sometimes asked after new insights emerged from the literature, other articles were read and/or parts of interviews or articles started to make more sense. The literature also influenced the methodology and coding, because it gave inspiration for which actors to talk with and which codes to use. The interviews were recorded, transcribed, coded, categorized and analyzed in a thematic way (Czarniawska, 2014). One interview was not recorded, in according to the wishes of the respondent. During the research, notes were written in a journal to foster the development of theoretical insights (Stern, 2007). All interviews were conducted in Dutch, because this is the professional working language of the respondents and therefore they can express themselves the best in this language.

The snowball method (Biernacki & Waldorf, 1981) was used to find interesting respondents. At the end of each interview, the respondent was asked about other potentially interesting persons who could be interesting for me to talk with.

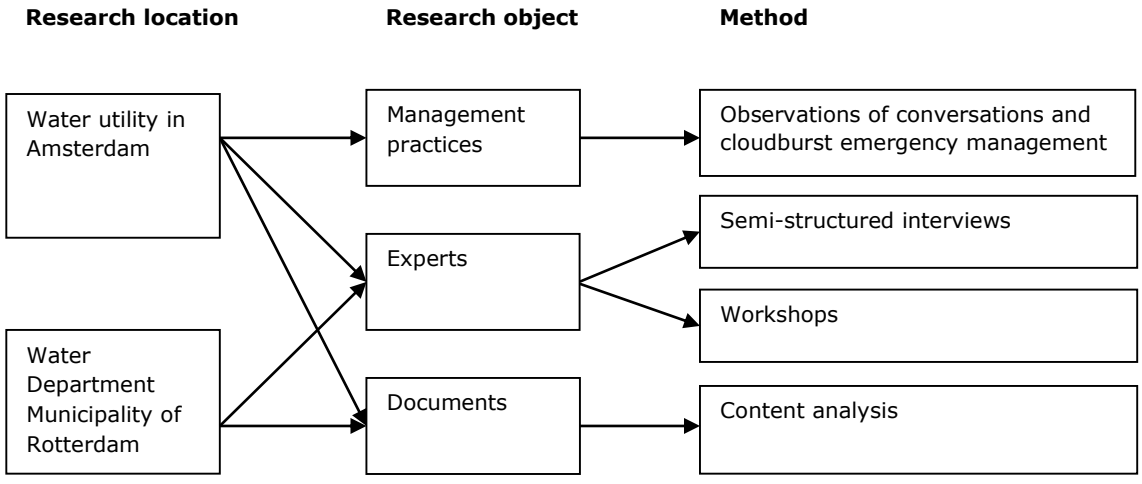


**Figure 2.1: Model of research design (own figure)**

**Table 2.1: List of respondents**

| Date | Name | Function | Organization |
|---|---|---|---|
| 10 March 2016 | Jeroen Kluck | Researcher and teacher | Tauw bv & Hogeschool van Amsterdam (HvA) |
| 14 March 2016 | Koen Tromp | Employee hydraulic analyses | Waternet (cluster Wastewater; Asset management water cycle department) |
| 14 March 2016 | Eljakim Koopman | Policy advisor | Waternet (cluster Wastewater; Asset management water cycle department) |
| 18 March 2016 | Bas de Nijs<br>&<br>Joyce Dankelman | Control specialist<br><br>Control specialist | Waternet (cluster Wastewater; Water treatment management department)<br>Waternet (cluster Wastewater; Water treatment management department) |
| 21 March 2016 | Louis van Parera | Program manager ("business as usual") & duty officer (emergency organization) | Waternet (cluster Wastewater; Sewer department) |
| 21 March 2016 | Lot Locher | Program strategy and product development | Amsterdam Rainproof |
| 23 March 2016 | Paul Juten | Crisis coordinator waste water | Waternet (cluster Wastewater; Water treatment management department) |
| 23 March 2016 | Rob Mom | Safety officer | Fire brigade Amsterdam-Amstelland |
| 23 March 2016 | Marianne Daling | Crisis coordinator surface water | Waternet (cluster Water system; Policy, Assets and Nautical management department) |
| 23 March 2016 | Jojanneke Dirksen | Policy advisor | Waternet (cluster Wastewater; Asset management water cycle department) |
| 25 March 2016 | Jos Ketelaars | Crisis coordinator | Waternet (cluster Board and Management assistance; Board and Management assistance department) |
| 25 March 2016 | Daniël Goedbloed | Program manager | Amsterdam Rainproof |
| 30 March 2016 | Nico Beumer | Asset manager ("business as usual") & coordinator scenario's (emergency organization) | Waternet (cluster Wastewater; Asset management water cycle department) |
| 30 March 2016 | Ad Voss (personal communication) | Tram manager | GVB |
| 1 April 2016 | Teun Timmermans | Advisor crisis management | Safety Region Amsterdam-Amstelland |

Next to semi-structured interviews, a workshop was organized in which important elements of cloudburst emergency management and -planning were discussed. The workshop was a get together of persons involved in the process of rainwater management in the cities of Amsterdam and Rotterdam. The attenders were either employed at the Water Department of the Municipality of Rotterdam, Waternet or Rainproof. The purpose of this workshop was to exchange experiences between the two cities, to help each other with barriers that emerged and brainstorm about how cloudburst emergency planning can be improved by identifying what important aspects are. A description of the workshop can be found in appendix A.

**Table 2.2: List of participants in workshop**

| Name | Function | Organization |
|---|---|---|
| *Amsterdam* | | |
| Anja Kleijburg | Coordinator crisis management | Waternet (cluster Water system; Policy, Assets and Nautical management department) |
| Bas de Nijs | Control specialist | Waternet (cluster Wastewater; Water treatment management department) |

| | | |
|---|---|---|
| Eljakim Koopman | Policy advisor | Waternet (cluster Wastewater; Asset management water cycle department) |
| Frank Tibben | Trainee of National Water Traineeship | Waternet (cluster Wastewater; Asset management water cycle department) |
| Jojanneke Dirksen | Policy advisor | Waternet (cluster Wastewater; Asset management water cycle department) |
| Louis van Parera | Program manager ("business as usual") & duty officer (emergency organization) | Waternet (cluster Wastewater; Sewer department) |
| Nico Beumer | Asset manager ("business as usual") & coordinator scenario's (emergency organization) | Waternet (cluster Wastewater; Asset management water cycle department) |
| Paul Juten | Crisis coordinator waste water | Waternet (cluster Wastewater; Water treatment management department) |
| Peter Wassenaar | Head of the Asset management water cycle Department | Waternet (cluster Wastewater; Asset management water cycle department) |
| Daniël Goedbloed | Program manager | Amsterdam Rainproof |
| Jody de Graaf (Organization) | Intern/researcher | Waternet (cluster Wastewater; Asset management water cycle department) |
| *Rotterdam* | | |
| Annemarij de Groot | Policy advisor water | Municipality of Rotterdam (cluster Stadsbeheer; Water department) |
| Bas de Wildt | Policy advisor water | Municipality of Rotterdam (cluster Stadsbeheer; Water department) |
| Elijan Bes | Policy advisor water | Municipality of Rotterdam (cluster Stadsbeheer; Water department) |
| Jerôme Schepers | Operational manager | Municipality of Rotterdam (cluster Stadsbeheer; Water department) |
| Johan Verlinde | Assetmanager water | Municipality of Rotterdam (cluster Stadsbeheer; Water department) |
| Jorg Pieneman | Policy advisor water | Municipality of Rotterdam (cluster Stadsbeheer; Water department) |
| Michel Bunt | Policy advisor water | Municipality of Rotterdam (cluster Stadsbeheer; afdeling Water) |
| John Jacobs (Host) | Policy advisor water | Municipality of Rotterdam (cluster Stadsbeheer; Water department) |
| Raisa Salomon (Assistent) | Student | Hogeschool van Rotterdam (Student Watermanagement) |

In addition to that, the planning process for cloudburst emergency management was observed by observing meetings and the emergency organization of Waternet. These situations are relevant because they give an insight on which frames are used for rainwater management and emergency organization and what the opportunities and pitfalls are in relation to that. A journal in which notes of observations were written was kept.

Documents were also studied to understand the organizational structure of rainwater management in Amsterdam and its context (see table 2.3). To understand the context of rainwater management and flooding on the national level, the documents listed in table 2.4 were studied.

**Table 2.3: Overview documents studied to understand the organization structure of rainwater management in Amsterdam and its context**

| Title (English) | Original title (Dutch) | Author(s) | Content |
|---|---|---|---|
| Analysis cloudburst 28 July 2014 | Analyse wolkbreuk 28 juli 2014 | Dirksen & Koopman, 2015 | Analysis of the cloudburst that occurred on the 28th of July 2014, the problems it caused and the effectiveness of the response organization. |
| Communication strategy flooding | Communicatiestrategie wateroverlast | Waternet, 2015b | Communication strategy about how, when and with which message citizens |

| | | | |
|---|---|---|---|
| | | | are informed in relation to cloudburst by Waternet. |
| Emergency management plan waste water | Calamiteiten bestrijdingsplan AW | Juten, 2015 | This document contains the emergency management plan of the Waste water Department. |
| Crisis management plan Waternet & Water authority Amstel, Gooi and Vecht | Crisisbeheersingsplan Waternet & Hoogheemraadschap Amstel, Gooi en Vecht | Waternet, n.d. | In this document, the emergency management organization of Waternet is elaborated. |
| Water management plan 2016-2021: aware of water and robust to water | Waterbeheerplan 2016-2021: Waterbewust en waterrobuust | Waterschap Amstel, Gooi en Vecht, 2015 | Plan in which the strategy, policy and goals of the water authority Amstel, Gooi and Vecht for the coming years are given. |
| Amsterdam Waterproof | Amsterdam Waterbestendig | Programma Amsterdam Waterbestendig, 2010 | Publication that gives insight in how the city of Amsterdam developed, how the water system in the city works and gives information on which challenges the city will face in relation to water. |
| Municipal Sewage plan Amsterdam 2016-2021 | Gemeentelijk Rioleringsplan Amsterdam 2016-2021 | Waternet, 2015a | In this plan, the Municipality of Amsterdam tells how it will comply with the responsibilities given to them through the Water Act in the coming years and justifies the way it is going to do that. |
| Guidebook Rainwater | Handboek Hemelwater | Waterschap Amstel, Gooi en Vecht, 2009 | Report in which the water authority Amstel, Gooi and Vecht shares its vision, strategy and knowledge on rainwater and how to deal with it. |
| Vision Amsterdam 2040: Economic strong and sustainable | Structuurvisie Amsterdam 2040: Economisch sterk en duurzaam | Municipality of Amsterdam, 2011 | Vision from the Municipality of Amsterdam on how the city will be in 2040 and with which policies this can become reality. |

**Table 2.4: Overview documents studied to understand the context of rainwater management and flooding on the national level.**

| Title (English) | Original title (Dutch) | Author(s) | Content |
|---|---|---|---|
| Summary report pilot areas Multilevel safety | Syntheserapport Gebiedspilots Meerlaagseveiligheid | Oranjewoud & HKV Lijn in Water, 2011 | Report in which the experiences from the pilots on multilevel safety in several areas, in which the possibilities of the concept are explored, are combined. |
| A moving delta. Building blocks for a climate proof development of the Netherlands | Een delta in beweging. Bouwstenen voor een klimaatbestendige ontwikkeling van Nederland | PBL, 2011 | Report in which possible solution strategies for how the Netherlands can become climate proof are analyzed and elaborated. Attention is given to choices that need to be made. |
| Time for water safety: Strategy for flood risk management | Tijd voor waterveiligheid: Strategie voor overstromings-risicobeheersing | Raad voor de leefomgeving en infrastructuur, 2011 | Report in which advice is given on how the policy on water safety should be changed so it fits to the current situation. |
| Water safety 21st century. Summary document | Waterveiligheid 21e eeuw. Synthesedocument | Ministerie van Verkeer en Waterstaat, 2008 | Document of the national government of the Netherlands that elaborates their viewpoint and policy in relation to water safety. |
| National Waterplan 2009-2015 | Nationaal Waterplan 2009-2015 | Rijksoverheid, 2009 | Report of the national government of the Netherlands in which it elaborates on its point of view in relation to water and the strategies and policies that it will use to make sure that the country is as safe as possible in relation to flooding. |

## 3. Resilience and vulnerability in relation to cloudbursts in urban areas

A literature review on two theoretical concepts is conducted in the following sub-sections. First, the characteristics of resilience, the assessment of this concept in cities and how resilience can be reached are discussed. Second, the characteristics of vulnerability and how this concept can be researched and assessed in urban areas are examined. Effects of pluvial flooding on urban areas are incorporated in this sub section, to show the possible consequences of flooding. Third, a number of case studies on the effects of pluvial flooding and practices of emergency planning are reviewed. Also, the relation between resilience, vulnerability and urban sustainability is discussed. To conclude, the application of the literature in this project is presented.

This literature review is selectively conducted, because of time constrains. Only the main publications on the characteristics of resilience and vulnerability, the assessment and research of these two concepts in urban areas and how cities can become more resilient through planning are included. Selection criteria are that vulnerability and resilience have to be linked with cities/urban areas, disaster management and/or flooding. The publications are selected by searching in Google Scholar, ScienceDirect and the library of the Aalborg University Copenhagen, reading these publications and articles and look at the publications cited. Articles published in the last months of 2015 and the first months of 2016 received special attention, because these articles could not have been included in the literature review conducted in the previous research (see De Graaf, 2016). Some of the material used in that report is also included in this report, but modified to fit the focus of this report.

### 3.1 Resilience

Resilience is *"the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions"* (UNISDR, 2009, pp. 24). In relation to cloudburst emergency planning, resilience is important because it can give directive in how the impacts of cloudbursts on urban areas can be limited. The literature review on resilience will be used to have an understanding of what makes cities resilient and how this can be assessed and increased. This information will be used to understand how actors could plan for cloudburst emergency situations, in advancing the theoretical framework and to give recommendations for cloudburst emergency planning in urban areas. An elaborate review on the concept of resilience was already conducted in my previous research (De Graaf, 2016) and is therefore not included in this review.

All publications in the following paragraphs point at different aspects of resilience, how it can be assessed and increased. The identified aspects will be used to assess the resilience of cloudburst emergency management processes in Amsterdam and Rotterdam and how this can be improved.

#### 3.1.1 Characteristics

> *"In the context of flood management, resilience can be defined as the capacity of a system, community or society, potentially exposed to hazards, to adapt by resisting or changing, in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase this capacity for learning from*

*past disasters for better future protection and to improve risk reduction measures. This can simply be restated as: resilience is equal to resisting, recovering, reflection and responding"* (Djordjević, Butler, Gourbesville, Mark & Pasche, 2011, pp. 864).

Leichenko (2011) points out that the characteristics of resilience can differ, depending on which perspective is used to study the resilience of urban areas (e.g. ecology, disaster management, economy or policy/governance) because each of these fields focus on different elements of urban areas.

Several authors tried to identify the characteristics of resilience in relation to urban areas, urban hazard mitigation, climate change adaptation, systems and spatial planning (e.g. Albers & Deppisch, 2013; Béné, Godfrey Wood, Newsham & Davies, 2012; Godschalk, 2003; Kallaos, Mainguy & Wyckmans, 2014; Leichenko, 2011; Lu & Stead, 2013; Satterthwaite *et al.*, 2007; The Rockefeller Foundation, 2014; Tyler & Moench, 2012; Wardekker, de Jong, Knoop & van der Sluijs, 2010). These authors were chosen because they made an attempt to identify resilience in relation to fields that relate to cloudburst emergency planning. In table 3.1 at the end of this chapter, the input from these publications is summarized and categorized.

### 3.1.2 Resilience in cities

Having insights on how to assess the resilience of urban areas is important. By knowing that it is not only possible to 'measure' the resilience of a city, but information is also obtained on how the resilience can be improved.

In their research, Lu and Stead (2013) assessed the resilience of Rotterdam by using the following indicators: monitoring current situation; forecast; predicting patterns and trends; assessment of risks; evaluation; prioritization; setting standards; scenarios; proposing of actions; collaboration; communication of findings; innovation; and public awareness.

Wamsler (2014) states that resilience of cities, in relation to disasters, can be assessed by looking at the reduction of location-specific vulnerability, hazards and response and recovery deficiencies by stakeholders and the degree of mainstreaming measures at the institutional level.

Bozza, Asprone and Manfredi (2015) developed a framework that can be used to assess the disaster resilience of cities, in a human perspective. The framework consists of a set of indicators to measure the functionality of urban networks, environmental sustainability and citizens' happiness, taking economic and social background conditions into consideration. The framework is looking at the same time at the single structure level, the infrastructure system level and the urban level. At the end, looking at the difference between the values of the indicators before and after the occurrence of an extreme event can show the resilience of an urban area.

The framework developed by Restemeyer, Woltjer and van den Brink (2015) can be used to assess the resilience of cities in relation to flooding. Restemeyer *et al.* (2015) see robustness, transformability and adaptability as the key characteristics of resilience. Robustness can be assessed by looking at technical and spatial measures; public responsibility; collaboration between water managers and spatial planners; and expert knowledge. For transformability, it is important to raise awareness and communicate about risks with both public and private stakeholders; mutual

trust between private and public stakeholders; and to establish learning organizations and interdisciplinary networks. Adaptability can be assessed by urban planning and building regulations (e.g. discourage the location of vital infrastructure in flood prone areas); warning schemes; shared responsibility; strong collaboration between all stakeholders; making use of both expert and local knowledge; awareness of citizens that they need to invest in measures themselves; and political support for an approach that is not only focused on resistance, but also takes the possibility of flooding into consideration. Context, content and process factors in relation to these three characteristics are all important to make cities resilient to flooding.

### 3.1.3 Planning for resilience in cities

Godschalk (2003) pinpoints at several ways through which a city can increase its resilience. These are: vulnerability reduction; networked communications; hazard mitigation capability and commitment; using equity standards; mitigate the impacts of business interruption; and assist the vulnerable.

Zevenbergen, Veerbeek, Gersonius and van Herk (2008) identify several transitions that should be made to increase flood resilience. These are: use of long-time horizon; alignment of process and content with context; both bottom-up and top-down planning; vulnerability reduction; solutions for the whole system; strategic alternatives; being aware of uncertainties of changes in systems; and having capacity and resources to adapt to unpredictability.

According to Collier *et al.* (2009), researchers and practitioners need to cooperate more, so the concerns and questions of the people on the ground are included in research. Further, it is important that the approaches for resilience are participatory, help to understand the system and assess risks. Knowledge networks; social learning; 'communities of practice'; effective communication; collaboration; and flexibility are important to increase resilience.

Djordjević *et al*. (2011) identify three elements through which the flood resilience of cities can be increased. The first possibility is through urban planning policies which guide the urban landscape. The second chance is an information system that gives real-time information about urban flooding. This system can limit damage, because it increases the warning time and emergency plans can be implemented better. It is important to know beforehand per actor which information is important. The third option is a holistic and comprehensive vision, which promotes changes in behavior, policies and technology.

Surjan, Sharma and Shaw (2011) determine three sectors in which interventions can be done to increase resilience: institutional synergies, spatial planning and community interface. They also discuss several aspects that are important for the resilience of cities: proper urban functions management; participation, rules and regulation on physical growth; good governance; city planning; building bylaws; and quality of infrastructural systems.

Desouza and Flanery (2013) state that planning for resilience in cities can be difficult, because it is an abstract term. They indicate that it is important to evaluate the vulnerable elements, understand the key procedures, interactions and processes of the organization of these elements and establish the capacity through which the structuring of elements and the interactions between

these elements to achieve resilience. The complexity of urban areas can be reduced by looking at the components and the interactions. To be able to plan for resilience, it is important to identify to what the city should be resilient. It is also important to keep in mind that urban areas constantly change. In planning for resilience, special attention should be given to the three dimensions that are important: temporal, spatial and evolutionary, and to the interactions between agents and between objects.

The resilience of cities can be influences in three different ways (Desouza & Flanery, 2013). The first option is through planning: creating flexible plans and let citizens participate more in the planning process. The second possibility is through design: create objects that are adaptable. The third and last chance is through managing: managing should be agile and vigor so that challenges can be addressed and opportunities can be used.

Cartalis (2014) identifies that the following aspects are important for making cities more resilient: understand and assess the risks; clear roles and responsibilities; budget; early-warning; urban and spatial planning; building regulations; robust infrastructure; training; education; and response and recovery plans. Barriers for resilience planning are: weak governance; limited coordination between stakeholders; favoring short-term planning; and lack of services.

Vale (2014) points at the importance of even resilience, because uneven resilience can limit the functioning of cities in the political, economic or social spheres. It is important in planning for resilience to keep an eye on for who the city is made resilient and against what. Resilience in at least the following three domains is important to recover from disasters: economy, built environment and emotional revitalization of individuals. A barrier in planning for resilience is that elected officials often focus on the medium- and short-term, while it is important for resilience planning to focus on the long-term.

### 3.2 Vulnerability

Vulnerability is *"the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard"* (UNISDR, 2009, pp. 30). Different perspectives can be used in relation to this concept. The most common are: physical, economic, social and environmental aspects and factors (UNISDR, 2009). In relation to cloudburst emergency planning, vulnerability is important because it can give directive in how the negative effects, impacts and damage caused by cloudbursts in urban areas can be limited. The literature review on vulnerability will be used to have an understanding of what makes cities vulnerable, how this can be assessed and what the effects of rainwater flooding can be. This information will be used to understand how actors could plan for cloudburst emergency situations, in advancing the theoretical framework and to give recommendations for cloudburst emergency planning in urban areas.

All publications in the following paragraphs point at different aspects of vulnerability, how it can be assessed and what effects of pluvial flooding are on urban areas. The identified aspects will be used to assess the vulnerability of cloudburst emergency management processes in Amsterdam and Rotterdam and how this can be decreased.

### 3.2.1 Characteristics

Quarantelli (1977) states that post-disaster and pre-disaster problems are closely related. Often, disaster planning is focused on being prepared for the last disaster that occurred, not the next to come. Planning ahead intelligently can limit vulnerability. The general problems and demands in relation to disasters, such as communication, resources, coordination and continues assessment of the situation, can be organized beforehand. It is not possible to prepare for specific problems and demands in advance; these need to be solved when the disaster occurs. Problems that arise are often also present in normal times, but in emergency situations, the urgency to act is much higher and therefore, the problems stand out more.

Officials should be aware of the fact that an emergency plan needs to be convenient for the citizens (Quarantelli, 1977). Otherwise, it will not limit vulnerability. Also, emergency planning is a continuous process and is not finished when a plan is produced. Everyone needs to be aware that plans cannot prevent cloudbursts to happen, but can alter what will happen.

Lavell (1996, in: Field *et al.*, 2010) defined redundancy in systems, coordination and characteristics of flood prone areas as elements that can influence the vulnerability of cities in relation to climate change. Hauger, Mouchel and Mikkelsen (2006) point at physical elements and planning as vulnerabilities in relation to pluvial flooding. Messner & Volker (2006) identify flood characteristics, coping capacity, preparedness, risk perception and physical elements as characteristics of vulnerability. According to Sato (2006), vulnerability is influenced by dynamics of the population at risk; the confidence that the government will provide safety; accumulation of buildings in flood prone areas; and changes in local structures.

Satterthwaite *et al.* (2007) define dynamics of the population at risk; community resources; physical elements; extent and quality of public services; development context; exposure to flooding; concentration of physical capital; possibility of cascading effects; reliance on larger systems (e.g. electricity and food); economic, social, environmental and political influences; preparedness; access to information; and willingness to act as characteristics of vulnerability.

Balica, Douben and Wright (2009) see flood vulnerability as the susceptibility to exposure, limited by the resilience to floods. Four types of components can influence vulnerability: physical, economic, social and environmental components. Indicators for the physical component are flood characteristics and topography. Economic factors are indicators for the economic component. Indicators for the social component are: urban planning; dynamics of the population at risk; awareness; communication penetration rate; early-warning; and emergency services. Physical elements are indicators for the environmental component.

Jha *et al.* (2012) identify several factors that influence the vulnerability of urban areas for flooding. These are: preparedness; awareness and willingness to act; early-warning; physical elements; organization; planning and governance; economic factors; flood characteristics; and resilience. According to Jha *et al.* (2012), it is important to understand the vulnerability mechanisms and find a balance between structural and non-structural measures to design an appropriate flood management plan.

Vulnerability is influenced by the potential impacts and the response capacity (Swart *et al.*, 2012). The first is divided in exposure and sensitivity, while the latter consists of coping capacity and adaptive capacity. Climate change, human drivers (e.g. urbanization) and hydrological and morphological drivers together influence exposure, while economic assets within the city (e.g. buildings), population and external services (e.g. electricity, water, telephone network) together influence sensitivity. Action, awareness and ability influence both the coping and adaptive capacity, while willingness to adapt only influences the latter. All of this can be influenced by mitigation and adaptation policies.

Stone *et al.* (2013) identify several indicators for urban vulnerability in relation to flooding, which mainly relate to: dynamics of the population and areas at risk; physical elements; critical infrastructure; governance; awareness; and information and communication.

Field *et al.* (2013) indicate population growth, rapid urban development, financial pressures, socioeconomic inequalities and failing governance as drivers for vulnerability. Response and recover capacity can lower vulnerability. Characteristics of these types of capacity are planning and governance; economic factors; dynamics of the population at risk; and early-warning.

According to Wamsler *et al.* (2013), susceptibility, response and recovery are all part of vulnerability. Indicators for vulnerability are: built environment; cascading effects; population density; physical capital; economic diversification; health; natural resources; social cohesion; and the existence of peace and equity.

Vulnerability can be seen in two ways. The first is oriented on the society and its coping capacity. The second is more technical oriented, focuses on how places function and comes from natural sciences (White, 2013). White (2013) describes vulnerability mainly as the result of development paths in the past. He suggests that in the future, vulnerability is primarily influenced by which decisions are made and which measures are implemented.

According to White (2013), elements that influence the vulnerability are: dynamics of the population at risk; planning and governance; the ability to change behavior; economic factors; emergency response; and critical infrastructure and vulnerable objects. Pappenberger *et al.* (2015) identify flood characteristics, uncertainty, forecast, absence of data, response and cooperation as indicators of vulnerability. Sherly, Karmakar, Parthasarathy, Chan & Rau (2015) divide vulnerability of urban areas to disasters in four themes: socioeconomic, critical facilities, infrastructure and social vulnerability.

Solecki *et al.* (2015) define the following characteristics of urban vulnerability: physical elements; changes in financial, physical, natural, social and human capital; accumulation of physical capital in flood prone areas; and economic factors. Solecki *et al.* (2015) conclude in their research that although there has been quite some research conducted in the field of urban vulnerability, there is no consensus on what the variables of urban vulnerability are.

Yang, Scheffran, Qin and You (2015) define exposure, sensitivity and adaptive capacity as elements that influence the vulnerability of a city. Indicators that they used in their research are: physical elements; dynamics of the population at risk; and economic factors.

### 3.2.2 Vulnerability in cities

Turner *et al.* (2003) point at several elements that are important when doing a vulnerability analysis. It is essential to incorporate multiple stresses and their effects; cascading effects; interconnections; effects on different scales; sensitivity; and coping, response and recovery capacity. Although it is desirable to look at the system in totality, this is often not possible. Nevertheless, researchers should not forget that vulnerability is part of a coupled, multifaceted system that is operating at several spatial scales. While conduction a vulnerability analysis, it should not be assumed that all parts of the system and rather similar systems have the same vulnerability. Every part and every system has its own characteristics and vulnerabilities.

The assessment of vulnerability in cities needs to have both a quantitative and a qualitative approach to cover all dimensions (Field *et al.*, 2013). The variables that need to be measured are: physical, economic, environmental, social and cultural.

Sherly *et al.* (2015) designed a framework which can be used to make an assessment of the vulnerability of an urban area in relation to disasters. They point at the fact that the goal of vulnerability assessment is not to give a quantitative level of damage, but to identify the vulnerability of places and population groups. Relevant themes and indicators of vulnerability are identified so, at the end of the assessment, GIS maps of vulnerability of the urban areas can be made. The adaptive capacity of the urban area is also included in the assessment, because it can limit the vulnerability of urban areas.

### 3.2.3 Showcasing vulnerability: effects of pluvial flooding on urban areas

Rose (2004) states that, in the past, property damage has had the most attention, although the damage caused by direct and indirect disruption of businesses can also be a considerable amount. This is because it takes a quite long period for the business flow to recovery completely.

It is important to analyze flood events and look at past experiences to determine what might happen in the future (Kron, 2005). The damage caused by flooding is nowadays quite high, because people have a lot of possessions. These possessions also have higher values, are vulnerable to flooding and often located in the lower parts of buildings.

Floods can have consequences on all kinds of fields (Messner & Volker, 2006). Not only humans, their belongings and their health are affected, industrial production, public infrastructure, strength of the economy, ecological systems and cultural heritage can also be damaged.

For businesses, flooding can have consequences on three different levels (Swart *et al.*, 2012). First, flooding can cause physical damage to buildings and their interiors. Secondly, the company loses production, because it cannot operate as long as water is in the building and the damage is not restored. As last, the loss of production in one company can have negative effects on the productivity of other companies in the supply chain.

The effects of flooding depend, among others, on how long critical infrastructure is disrupted (public life is quite significant disturbed through failing critical infrastructure), cascading impacts; and the role of the city on different spatial scales (global, continental, national and regional) (Swart *et al.*, 2012).

According to Rose (2013), *"the quantification of economic losses from natural and manmade hazards is necessary to gauge individual and community vulnerability, evaluate the worthiness of mitigation, determine the appropriate level of disaster assistance, improve recovery decisions, and inform insurers of their potential liability"* (Rose, 2013, pp. 13).

Different categories can be distinguished in the effects of flooding, e.g. direct effects, indirect effects, business interruption and property damage. He highlights that the spatial context, public policy and resilience of businesses and consumers affect hazard impacts. He also points at the importance of the estimation of the effects of flooding to reduce these negative impacts through mitigation (Rose, 2013).

Davies (2015) analyzed the social costs of flooding. Flooding is not beneficial, although the GDP often rebounds after the flood and may even rise temporarily to a higher level, but this is caused by the influx of resources for repair and reconstruction. Increased population and development have increased the damage of flooding. The benefits of effective preparedness, response and recovery should also be understood and analyzed, in addition to flood costs analysis, to get a complete picture of the flood-related projects and policy measures (Davies, 2015).

Costs of flooding can be divided in *ex ante* and *ex post* costs (Davies, 2015). Four types of *ex post* costs can be considered: capital damage, net output losses, non-pecuniary costs and relief and cleanup costs. Examples of net output losses are temporary unemployment and effects of displacement of work. Lost leisure and home production, volunteer labor and value reduction of housing services for owner-occupiers are examples of non-pecuniary costs. As Davies points out, *"establishing the costs of flooding requires a comparison of what happens with flooding compared with what* would *have happened in a non-flood counterfactual*" (Davies, 2015, pp. 6). Another aspect to take into consideration is that *"higher income areas and victims tend to be more vocal and visible, and partly for that reason may get more attention in relief and cleanup, as well as in reconstruction activities*" (Davies, 2015, pp. 13).

Davies (2015) indicates that the private sector is more vulnerable than the public sector, because the effects for the last can be limited because it is engaged in emergency planning and disaster management. During the flood, businesses and industries are interrupted and during response and recovery, the production will be started again gradually. Vital infrastructure, also known as lifelines, play an important role in the impacts of floods. Geography can influence the vulnerability of these infrastructures.

Hammond, Chen, Djordjević, Butler and Mark (2015) conducted a literature review on the impact assessment of urban flooding. They classified the following damage criteria: direct tangible damage; indirect tangible damage and business interruption; infrastructural damage; and intangible damage. Direct tangible damage is caused by physical objects that come in contact with water. Econometric models can also be used to assess the damage of flooding. The most prominent intangible damage is health effects (mental health and physical health). At the end of their review, they concluded that there is a lot of literature on direct tangible damage, although critical infrastructure is often neglected. Information on wider economic impacts (indirect tangible

damage), infrastructural damage and health effects of flooding is limited and needs to be researched more.

### 3.3 Case studies

In this sub section, the focus is on publications which describe and discuss examples of the effects of flooding and how these can be assessed and examples of practices of emergency planning in relation to flooding.

#### 3.3.1 Assessment effects pluvial flooding

Price and Vojinovic (2008) divide flood damage in tangible and intangible damage. The first can be further divided in direct and indirect damage. Tangible direct flood damage is often estimated by using the flood depth, flood duration and land use characteristics.

Meyer *et al.* (2013) have a slightly different approach. They use the following five categories to divide the costs of flooding: *"1. direct costs, 2. business interruption costs, 3. indirect costs, 4. intangible costs, and 5. risk mitigation costs"* (Meyer *et al.*, 2013, pp. 1353).

Stone *et al*. (2013) identify several variables and impacts that give insight on local scale effects of urban pluvial flooding in the Netherlands (see figure 3.1). Because of the duration and scale of the event, pluvial flooding is seen as a local problem in the Netherlands. Material damage can be caused when urban assets are flooded. Casualties due to pluvial flooding are very rare in the Netherlands, but accidents and illnesses caused by polluted water can happen. Also, roads can become inaccessible for emergency services, which can prevent that people get help on time. Production losses can be caused by traffic jams, flooding of roads, buildings, electricity substations and communication failure. This can also have effects downstream or upstream the production chain. Four emergency services are involved with urban pluvial flooding, each with their own specific tasks. Although pluvial flooding in the Netherlands has often a short duration time, it can temporarily disrupt daily life.

Carrera, Standardi, Bosello and Mysiak (2015) conducted an analysis of the costs of the Po river flood in 2000. They state that the costs of disasters are often undervalued, because often only direct impacts are considered in the estimation of the damage. Indirect damages are thus excluded, but in the modern world in which national economies depend on each other, indirect damages need to be considered to assess the full damage of flooding. Therefore, Carrera *et al.* (2015) included both direct and indirect losses in their analysis. Direct losses can cause indirect losses in other parts of the supply chain. Elements that were considered when calculating indirect losses are duration of impacts and percentage of labor and economic sectors affected. The direct impact on the economy is calculated by using land-use type, damage and flooded area.

The results of their research indicated that the biggest share of damage was in industrial/commercial areas and urban discontinuous areas. The total damage was between 3.9 and 10.3 billion euros, of which 0.6 to 2.5 billion euro is indirect damage. The indirect losses in the Po river area are partially compensated, because non-affected areas in the country gained economically from the flood (Carrera *et al.*, 2015).

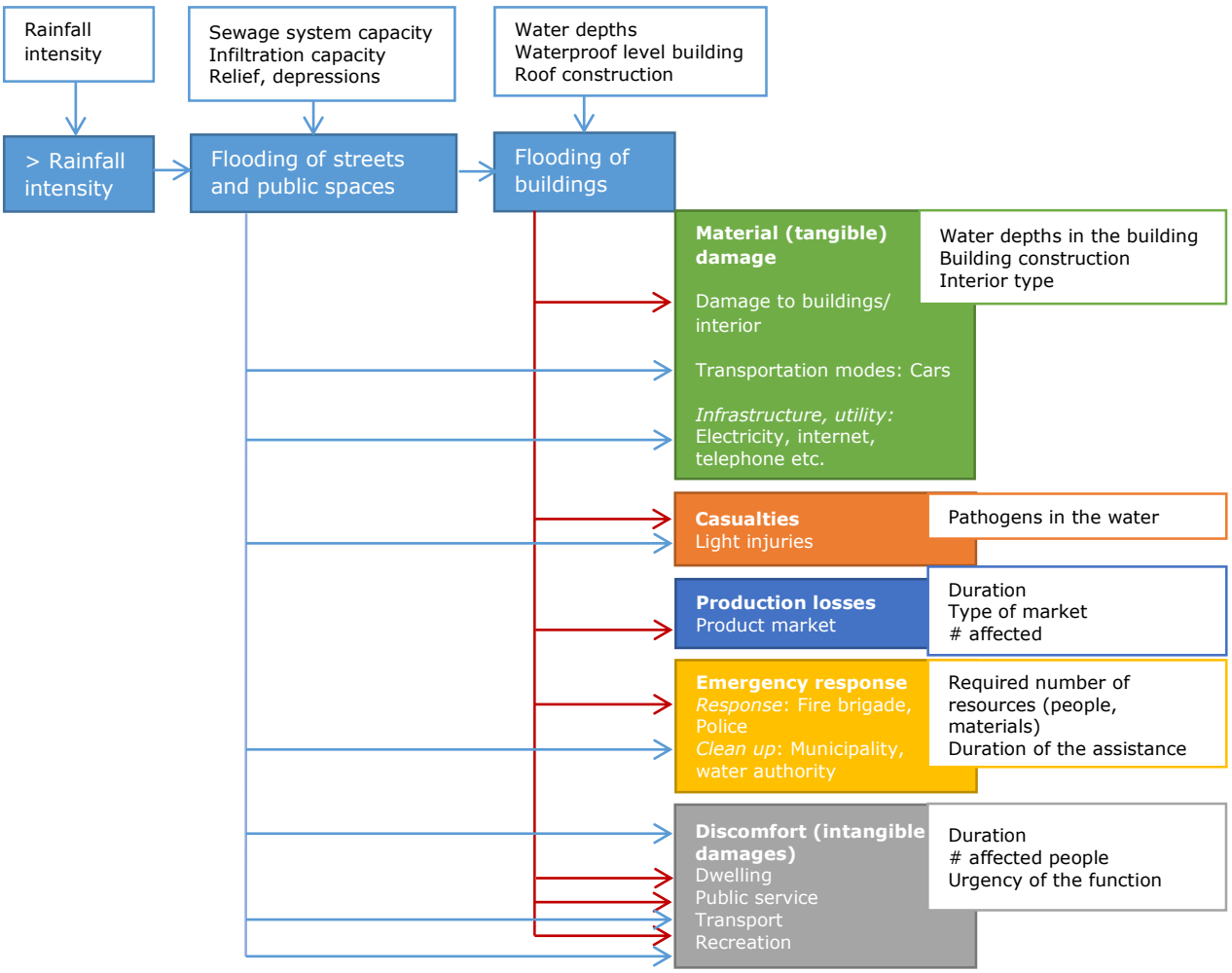


**Figure 3.1: Overview of variables and impacts of urban pluvial flooding in the Netherlands. Based on: Stone *et al.*, 2013.**

Haddad and Teixera (2015) investigated the economic impact and financial losses of floods in the city of São Paulo, Brazil, by using a Spatial Computable General Equilibrium (SCGE) model. Due to concentration of economic activities and people in São Paulo, the economic losses caused by flooding have increased substantially in the past decades (Haddad & Teixera, 2015). The main driver for economic losses in relation to flooding is that the temporarily shutting down of businesses and the disruption of infrastructure hamper potential economic growth. On the other side, reconstruction and additional maintenance can activate investments. The extend of both the direct and indirect effects of flooding depend on at which hour it occurs (Haddad & Teixera, 2015).

Households, businesses, industries, infrastructures and private and public services are affected by urban floods (Haddad & Teixera, 2015). In addition to financial losses, they can also affect housing prices, transportation infrastructure, health, time-loss in education and work and buildings and other property. Urban floods do not only affect the city. They can have wide effects, like reducing citizens' welfare and the international competitiveness of the city, and can even have consequences on the national level. The economic effects spread out through business and income linkages. Like as they say: *"one needs to consider interactions both inside and outside an urban system to assess the consequences of apparently local phenomena"* (Haddad & Teixera, 2015, pp. 112).

Kluck, Geisler and Janmaat (2016) calculated and tried to give an impression of the damage caused by a cloudburst with an intensity of 60 mm per hour in Amsterdam. This research was done by Tauw bv, on behalf of Amsterdam Rainproof. Kluck *et al.* (2016) made the damage clear, so the costs of measurements to limit flooding can be justified. During their research, they experienced that there was no good method to measure damage caused by a cloudburst in an urban area. They made their own method and used flood modelling software to model the cloudburst. They used the results of 3Di simulation to assess the depth of water on streets and only assessed damage for water that enters buildings on street level and not via roofs or leaking pipes. They made a distinction between direct, indirect and societal damage, e.g. loss of image and cultural value of objects. To assess the costs, they first made an overview of the possible damage and selected the relevant and quantitative ones. Secondly, they estimated the damage per object and after that, they estimated the damage for the city in total. Because it was for the moment not possible to incorporate all indirect damage, only the indirect damage in relation to buildings is included in this research. The total damage for the city is estimated with a certain range, but due to confidentiality, these numbers could not be presented here. Almost all damage is caused by direct and indirect damage of buildings, plus additional damage that could not be quantified.

#### 3.3.2 Practices of emergency planning

Price & Vojinovic (2008) state in their case study on urban flood disaster management that information, knowledge and effective communication are very important for disaster management. Technical information and data need to be presented in such a way that it is understandable for everyone who needs to use it. All appropriate means need to be provided. Modelling can be used to understand possible consequences and to inform stakeholders. Other technology can also be used. The increased use of cellphones can be used for new possibilities in flood disaster management, e.g. early-warning and providing information. Beforehand, agreements need to be made on warning levels and action plans. For a successful plan, it is important that all affected stakeholders are involved in designing it. This can give the planners access to local knowledge and improve the plan. In the response and recovery phases, stakeholders can provide useful information about the consequences of the disaster.

Yang *et al.* (2015) suggest the following improvements for emergency planning in relation to flooding: increase the transparency and sharing of information to make sure that plans fit to the local context and to increase the use of online social media, because people share a lot of potential useful information for emergency response via this communication channel.

### 3.4 Resilience and vulnerability in relation to urban sustainability

Resilience and vulnerability are two concepts that complement each other. Vulnerability gives understanding on which negative effects may occur and which historical, economic, political, social and cultural processes increase the risks of these effects, while resilience gives insight on how these negative effects can be mitigated (Joakim, Mortsch & Oulahen, 2015). Understanding vulnerability is necessary to adapt appropriately to extreme precipitation events (Field *et al.*, 2013).

Long-term urban sustainability can not only be accomplished by climate change adaptation. Combining climate change adaptation and disaster risk reduction is necessary to reach this goal (Wilbanks and Kates, 2010). For this, it is important to focus on time dimensions and to consider how decisions that are made today affect the resilience and vulnerability on the long-term (Rose, 2013).

### 3.5 Application of the literature

It is important to understand resilience, vulnerability and the impacts of flooding to make urban areas cloudburst resilient[1]. The knowledge obtained by doing the literature review is combined and will be used when analyzing the practices of cloudburst emergency management in the cities of Amsterdam and Rotterdam, when advancing the framework for cloudburst emergency planning and when giving recommendations for cloudburst emergency planning in urban areas. In the tables 3.1 and 3.2, an overview is given of the outcomes of the literature review. The terms authors listed are grouped and combined by identifying some more general aspects. This is done because a lot of different terms are used by the others, which often have a lot in common. The categorization of the aspects is based on which aspects are important for increasing resilience and limiting the vulnerability and impacts of flooding in urban areas.

The literature and aspects also have informed my grounded theory analysis, especially in the process of developing codes and categories. In chapter 5, the identified aspects of resilience and vulnerability, together with the outcomes of the analysis of the fieldwork, will be used to advance the theoretical framework for cloudburst emergency planning. Although the way resilience and vulnerability relate to information and knowledge, organization and collaboration might not be something very obvious, in this research there is an important relation. To increase the resilience and decrease the vulnerability of urban areas in relation to cloudburst, measures can be taken on different fields. Because this research is focusing on cloudburst emergency planning, these are often not infrastructural measures, but more in relation to information, organization, collaboration and learning. Understanding what important aspects are of resilience and vulnerability can help to identify which aspects are important in relation to information and knowledge, organization and collaboration to limit the negative effects of cloudbursts on urban areas.

**Table 3.1: Aspects of resilience**

| Aspects | Sources |
|---|---|
| Accepting change and uncertainty | Béné *et al.* (2012); Desouza & Flanery (2013); Zevenbergen *et al.* (2008). |
| Adaptability | Albers & Deppisch (2013); Godschalk (2003); Kallaos *et al.* (2014); Restemeyer *et al.* (2015). |
| Collaboration/ cooperation | Béné *et al.* (2012); Cartalis (2014); Collier *et al.* (2009); Godschalk (2003); Restemeyer *et al.* (2015); Surjan *et al.* (2011). |
| Diversity | Albers & Deppisch (2013); Béné *et al.* (2012); Godschalk (2003); Kallaos *et al.* (2014); Leichenko (2011); Tyler & Moench (2012). |
| Flexibility | Albers & Deppisch (2013); Béné *et al.* (2012); Bozza *et al.* (2015); Collier *et al.* (2009); Kallaos *et al.* (2014); Leichenko (2011); The Rockefeller Foundation (2014); Tyler & Moench (2012). |
| Interdependency | Albers & Deppisch (2013); Béné *et al.* (2012); Godschalk (2003); Kallaos *et al.* (2014). |
| Knowledge, experience and learning | Béné *et al.* (2012); Collier *et al.* (2009); Djordjević *et al.* (2011); Kallaos *et al.* (2014); Leichenko (2011); Lu & Stead (2013); Restemeyer *et al.* (2015); Satterthwaite *et al.* (2007); The Rockefeller Foundation (2014). |
| Participation | Béné *et al.* (2012); Collier *et al.* (2009); Desouza & Flanery (2013); Lu & Stead (2013); |

| | |
|---|---|
| | Surjan *et al.* (2011); The Rockefeller Foundation (2014). |
| Planning and governance | Albers & Deppisch (2013); Cartalis (2014); Desouza & Flanery (2013); Djordjević *et al.* (2011); Leichenko (2011); Lu & Stead (2013); Restemeyer *et al.* (2015); Satterthwaite *et al.* (2007); Surjan *et al.* (2011); The Rockefeller Foundation (2014); Tyler & Moench (2012); Wardekker *et al.* (2010). |
| Preparedness and foresight | Albers & Deppisch (2013); Béné *et al.* (2012); Bozza *et al.* (2015); Wardekker *et al.* (2010). |
| Redundancy and modularity[2] | Albers & Deppisch (2013); Bozza *et al.* (2015); Godschalk (2003); Kallaos *et al.* (2014); The Rockefeller Foundation (2014); Tyler & Moench (2012); Wardekker *et al.* (2010). |
| Resourcefulness and efficiency | Bozza *et al.* (2015); Godschalk (2003); Kallaos *et al.* (2014); Satterthwaite *et al.* (2007); The Rockefeller Foundation (2014); Tyler & Moench (2012); Wardekker *et al.* (2010); Zevenbergen *et al.* (2008). |
| Responsiveness | Kallaos *et al.* (2014); Tyler & Moench (2012). |
| Risk assessment and reduction | Cartalis (2014); Collier *et al.* (2009); Djordjević *et al.* (2011); Lu & Stead (2013); Satterthwaite *et al.* (2007). |
| Robustness | Bozza *et al.* (2015); Kallaos *et al.* (2014); Restemeyer *et al.* (2015); The Rockefeller Foundation (2014). |
| Safe failure | Kallaos *et al.* (2014); Tyler & Moench (2012). |
| Strength | Albers & Deppisch (2013); Bozza *et al.* (2015); Godschalk (2003); Wardekker *et al.* (2010). |

**Table 3.2 Aspects of vulnerability**

| **Aspects** | **Sources** |
|---|---|
| Accumulation of physical capital in flood prone areas | Balica *et al.* (2009); Lavell (1996, in: Field *et al.*, 2010); Sato (2006); Satterthwaite *et al.* (2007); Sherly *et al.* (2015); Solecki *et al.* (2015); Stone *et al.* (2013); Swart *et al.* (2012); Wamsler *et al.* (2013). |
| Awareness and willingness to act | Balica *et al.* (2009); Jha *et al.* (2012); Messner & Meyer (2006); Satterthwaite *et al.* (2007); Stone *et al.* (2013); Swart *et al.* (2012). |
| Coordination, cooperation and organization | Lavell (1996, in: Field *et al.*, 2010); Pappenberger *et al.* (2015); Quarantelli (1977). |
| Coping capacity | Messner & Meyer (2006); Swart *et al.* (2012); Turner *et al.* (2003). |
| Critical infrastructure and possibility of cascading effects | Satterthwaite *et al.* (2007); Sherly *et al.* (2015); Stone *et al.* (2013); Swart *et al.* (2012); Turner *et al.* (2003); Wamsler *et al.* (2013). |
| Dynamics of population at risk | Balica *et al.* (2009); Field *et al.* (2010); Sato (2006); Sherly *et al.* (2015); Stone *et al.* (2013); Swart *et al.* (2012); Wamsler *et al.* (2013); White (2013); Yang *et al.* (2015). |
| Early-warning | Balica *et al.* (2009); Field *et al.* (2010); Jha *et al.* (2012); Stone *et al.* (2013). |
| Economic factors | Balica *et al.* (2009); Field *et al.* (2010); Solecki *et al.* (2015); Stone *et al.* (2013); Wamsler *et al.* (2013); White (2013); Yang *et al.* (2015). |
| Emergency response | Field *et al.* (2010); Pappenberger *et al.* (2015); Swart *et al.* (2012); Turner *et al.* (2003); Wamsler *et al.* (2013); White (2013). |
| Exposure to flooding | Satterthwaite *et al.* (2007); Swart *et al.* (2012). |
| Flood characteristics | Balica *et al.* (2009); Jha *et al.* (2012); Messner & Meyer (2006); Pappenberger *et al.* (2015); Swart *et al.* (2012). |
| Information and communication | Balica *et al.* (2009); Pappenberger *et al.* (2015); Quarantelli (1977); Satterthwaite *et al.* (2007). |
| Physical elements (quality, damage susceptibility, etc.) | Balica *et al.* (2009); Hauger *et al.* (2006); Jha *et al.* (2012); Messner & Meyer (2006); Satterthwaite *et al.* (2007); Solecki *et al.* (2015); Stone *et al.* (2013); Swart *et al.* (2012); Turner *et al.* (2003); Wamsler *et al.* (2013); White (2013); Yang *et al.* (2015). |
| Planning and governance | Balica *et al.* (2009); Field *et al.* (2010); Hauger *et al.* (2006); Lavell (1996, in: Field *et al.*, 2010); Sato (2006); Stone *et al.* (2013); White (2013). |
| Preparedness | Jha *et al.* (2012); Messner & Meyer (2006); Quarantelli (1977); Satterthwaite *et al.* (2007). |
| Resources | Jha *et al.* (2012); Quarantelli (1977); Satterthwaite *et al.* (2007); Solecki *et al.* (2015); Turner *et al.* (2003); White (2013). |

**Notes**

1. *"A cloudburst resilient city is a city that processes and deals with the rainwater efficiently and relatively fast when exposed to cloudbursts, while the disruption of daily life practices in the city is minimized. The city is well prepared for the cloudburst to minimize negative effects and knows how to use its resources to be able to respond and recover quickly. The preparation limits the occurrence of problems and the problems that do occur are resolved rapidly so they cannot cause much disturbance. The cloudburst resilient city is also able to learn from previous events, from other cities and from information provided by knowledge institutions to improve its cloudburst management and rainwater system"* (De Graaf, 2016, pp. 8).
2. Redundancy is that there is space capacity and buffering so it is possible to manage flow disruption or extreme pressure and demand. Modularity is that there are multiple ways and options to meet a demand.

## 4. Cloudburst emergency planning in Amsterdam and Rotterdam

In this chapter, practices of cloudburst emergency planning in Amsterdam and Rotterdam are described. In both cities, these practices have been described using the cloudburst emergency planning framework as analytical lens. The organization of cloudburst emergency planning in Amsterdam, the collaboration between the actors and the aspects in relation to information and knowledge are examined, after which the cloudburst emergency planning in Amsterdam is discussed in relation to resilience and vulnerability. Second, the same is done for Rotterdam. Third, the differences between cloudburst emergency planning in these two cities are given. To conclude, a short overview of the results is presented.

### 4.1 Cloudburst emergency planning in Amsterdam

#### 4.1.1 Organization

In figure 4.1, the actors involved in cloudburst emergency planning in Amsterdam and their relations with each other are presented visually.


**Figure 4.1: Actors cloudburst emergency planning in Amsterdam (own figure).**
**(See appendix B for a full page version)**

*Waternet*

Waternet is a water cycle company which was founded ten years ago by combining the executive functions of the water authority Amstel, Gooi and Vecht and the "Water Department" of the Municipality of Amsterdam (Waternet, 2015a). The company is responsible for surface water, drinking water and waste water. The service areas of these tasks overlap, but the Municipality of Amsterdam is the only location where these three different services are provided by Waternet.

The company consist of several different departments, but here, only the most relevant ones in relation to cloudburst emergency planning will be presented.

After the cloudburst of 28th July 2014, two policy advisors from the Strategy development team of the Waste water department made an analysis of what happened and what could be improved (Dirksen & Koopman, 2015). Normally, this is something that should be done by the emergency organization of Waternet, but because it was unclear who was responsible for the analysis and because the roles and tasks of specific functions are not clear in the organization and people are more or less free to do what they consider relevant, these two policy advisors started doing it (Dirksen, interview, 23 March 2016; Koopman, interview, 14 March 2016).

> *"So what you notice is that the Waternet organization is very flexible: when you are the person that wants to do something and you are good at it, than you do so. We all have an official function, but that has in general little to do with the work you are doing. Which I find sometimes annoying, because nobody is responsible for anything."* (Dirksen, interview, 23 March 2016)(own translation)[1]

After finishing the analysis, it was recommended that an emergency plan should be made in relation to extreme precipitation and the board agreed to do so. This was done improperly by the person that was made responsible for it. The results of his work were very limited and therefore, the same two policy advisors that conducted the analysis started to make a set-up for it (Koopman, interview, 14 March 2016). At this moment, the emergency organization of Waternet is busy implementing the plan and trying to implement some of the recommendations done in this emergency plan and to develop it more in detail.

Each sector of Waternet (drinking water, surface water and waste water) has its own emergency coordinator, which is responsible for making emergency plans for their departments and to make sure that all necessary information is available (Ketelaars, interview, 25 March 2016). These sectorial emergency coordinators are steered by an emergency coordinator that is responsible for the whole organization (Ketelaars, interview, 25 March 2016). But the role of these emergency coordinators is very limited during an emergency situation. Only when some information is missing, they will come in action (Juten, interview, 23 March 2016). The people that do come in action are the duty officers. Most of these duty officers have a 'business-as-usual' function and another function in an emergency situation. Once every few weeks, these duty officers have seven days duty, from Monday morning seven o'clock to the next Monday morning at seven o'clock (Beumer, interview, 30 March 2016). When an incident or emergency situations happens during their duty, they come in action (Ketelaars, interview, 25 March 2016; van Parera, interview, 21 March 2016). But otherwise, they only perform their 'normal' tasks.

By using network-enabled capability[2], the accessibility and sharing of information within the organization that is useful in emergency situations is ensured (Waterschap Amstel, Gooi en Vecht, 2015). *"Before we had the network-enabled capability, we were often talking endlessly in practice situations and in real emergency situations about: what is exactly happening?"* (Ketelaars, interview, 25 March 2016)(own translation).[3] Waternet uses LCMS-W[4] as the tool to make network-enabled capability possible (Ketelaars, interview, 25 March 2016).

*Municipality of Amsterdam*

The Municipality of Amsterdam is divided in four clusters and seven city districts. The clusters are responsible for designing municipal policies on the city scale, while the districts are mainly

responsible for the execution of these policies and making them fit to that local area (Municipality of Amsterdam, n.d.). It is important to inform the districts properly, to prevent that they do not know what is going on. *"So you need to keep them up-to-date about: what is happening and what you are doing"* (Ketelaars, interview, 25 March 2016)(own translation).[5]

The Traffic & public space department (V&OR)[6] is an actor in cloudburst emergency planning, because they are involved in the temporary road closures in the Municipality. This could be done as part of preparedness, that tunnels or other lower located parts of the city that regularly flood and can cause dangerous situations are closed beforehand. But they can also be involved during and after the cloudburst, to close parts of roads that are dangerous for the public due to flooding. Until now, there is not much cooperation between Waternet and this department of the Municipality.

*Safety Region Amsterdam-Amstelland*

In the Safety Region Amsterdam-Amstelland, the fire brigade, police, GHOR[7], different municipalities and the National Public Prosecutions Department cooperate to protect the people in the area from risk and disasters (Timmermans, interview, 1 April 2016). The Safety Region Amsterdam-Amstelland consists of five strong 'pillars' (the different actors) which each need to have their houses in order and the Security Office of the Safety Region functions as a linking pin between these 'pillars' (Timmermans, interview, 1 April 2016). The structure and organization of the Safety Region is very clear and is practiced regularly (Timmermans, interview, 1 April 2016).

The Safety region only comes in action in relation to a cloudburst when the public order and public safety are endangered. It is not likely that a cloudburst can cause this on its own, but this can be the case when cascading effects cause a black-out, for example (Timmermans, interview, 1 April 2016). But the actors included in the Safety Region can of course also act on their own.

The added value of the Safety Region is primarily the coordination of actions from these different actors and that they combine their efforts and knowledge to bring the situation back to normal as good and as fast as possible. *"In case you want to do these kind of things, or you see that a hospital might flood, that you need to make decision: how am I going to prioritize my efforts?"* (Timmermans, interview, 1 April 2016)(own translation).[8] The Security Office sometimes needs to intermediate when the actors want to do different things (Timmermans, interview, 1 April 2016). Only when an emergency situation is classified as a GRIP-situation[9], the Safety Region gets involved. In addition to the five standard partners, the Safety Region can ask other actors to join the meetings, for example Waternet, Liander and/or Dutch Railways (NS), to provide information, to help to make scenarios of what can happen and to help to make prioritizations (Timmermans, interview, 1 April 2016).

*Fire brigade*

The fire brigade is during and after heavy precipitation primarily busy with responding on emergency situations and other reports, mainly in relation to flooded basements (Mom, interview, 23 March 2016). During an emergency situation, "*[a] different protocol is used in the control center and then they try to isolate the urgent reports from the less urgent reports"* (Mom, interview, 23 March 2016)(own translation).[10] A queue of reports will start to exist, *"[b]ut that is only based on*

*which information the operator receives and after that he tries to make a separation between where we immediately need to respond to and what can wait a little longer"* (Mom, interview, 23 March 2016)(own translation).[11] The fire brigade has also a role in some of the possible cascading effects (blackouts, gas grid failure, etc.) (Mom, interview, 23 March 2016). In relation to flooding, the fire brigade seems to be primarily focusing on flooding due to dike breaks (Mom, interview, 23 March 2016).

*Amsterdam Rainproof*

Amsterdam Rainproof is a network and knowledge platform, initiated by Waternet, which has as purpose to make the stakeholders in the city more aware of the problems that heavy precipitation can cause and to make Amsterdam more rainproof in the future (Goedbloed, interview, 25 March 2016). Although that Amsterdam Rainproof is more focusing on long-term transitions and making the public and private space more climate proof, it can also play a role in cloudburst situations. Amsterdam Rainproof already designed a webpage that will go online shortly before, during or after a cloudburst and which gives guidance to citizens in relation to what they can do. It gives information about which problem to report to which organization and asks people to make pictures of flooding and damage and to send it to them (Locher, interview, 21 March 2016). Because Amsterdam Rainproof is more or less an independent vehicle of Waternet (Goedbloed, interview, 25 March 2016), Waternet can use this information to supplement the information they receive through reports, which makes it easier to assess where the most problems are and which of them are most urgent. Amsterdam Rainproof is also keeping an eye on the social media in relation to extreme precipitation, flooding and other problems in relation to that and occasionally writes, together with Waternet, the evaluations of heavy precipitations events and reports to the alderman about what happened (Locher, interview, 21 March 2016). According to the cloudburst emergency plan, this should be taken over by the actor who is really responsible for this: Waternet (Dirksen & Koopman, 2015).

*Weather forecast*

The KNMI and MeteoGroup are weather forecast organizations that are used by the different actors in cloudburst emergency planning in Amsterdam to obtain information about rainfall. Waternet has a contract with MeteoGroup to provide meteorological information to them. This information is nowadays used to take preparation measures in the surface water system, but will in the future also be used as a trigger to start the cloudburst emergency management in the organization.

*Utility companies*

Flooding can hamper the provision of utility services. Liander manages the energy network in the province of North-Holland, in which Amsterdam is located. Several providers are responsible for the telecommunication services. The network of KPN is used by the emergency services for their communication. Waternet provides drinking water to Amsterdam. There has been some contact between Liander and Rainproof on the vulnerability of parts of the energy network to flooding (Locher, interview, 21 March 2016). Some years ago, the fire brigade came in contact with KPN during an incident in which the communication system which is used by the emergency services to

communicate could not been used because a cable was damaged during an excavation (Mom, interview, 23 March 2016).

*Public transport companies*

Stations and other parts of the public transport network can be very vulnerable locations in relation to cloudbursts. Especially in rather flat countries like the Netherlands, tunnels and through passes are often used in public transport networks and/or for other mobility modes so they intervene as little as possible with each other.

> *"Stations are often a risk point. […] There is often a low tunnel or low entrance [and] pedestrian tunnels as underpass. Those can be dangerous. You should keep those locations in mind. There are often different altitudes at which things happen."* (Kluck, interview, 10 March 2016)(own translation)[12]

Until now, the public transport companies in Amsterdam have not been involved in cloudburst emergency planning, but they do come in contact with flooding. A road tunnel close to the train station Amsterdam Amstel, which is also used by the light rail, is flooded quite regularly when it rains heavily (Dirksen, interview, 23 March 2016). This is problematic, because light rail can cope with some puddles, but more than ten centimeter water or puddles as long as hundred meters can cause damage to the vehicles and the network (Voss, personal communication, 30 March 2016). Also, one of the train stations in Amsterdam, Amsterdam-Zuid, gets regularly flooded, because the main part of the station is located underground and there are different surface water levels at each side of the tunnel, so rainwater starts to flow through the tunnel to the lower surface water level (Dankelman, interview, 18 March 2016).

The Dutch Railways (NS)[13] provides the train traffic and the GVB[14] takes care of bus, light rail and metro traffic in the Municipality of Amsterdam. The GVB seems to be slightly aware of the possible risks and problems that heavy precipitation can cause for them, but is at the moment not taking any measures in relation to that (Voss, personal communication, 30 March 2016). It seems that the organization is willing to come in contact with other actors involved in cloudburst emergency planning in Amsterdam to explore the role they can play and to share information about when rainwater and flooding can influence their daily operations (Voss, personal communication, 30 March 2016). Amsterdam Rainproof has been in contact with the GVB to ask for information about when rainfall and flooding causes problems for the busses, light rail and metro (Locher, interview, 21 March 2016).

*Citizens*

The role of the citizens in cloudburst emergency planning has until now been quite limited. Up to this day, citizens were only involved because they made reports of problems. Waternet and Amsterdam Rainproof are investigating how citizens can have a bigger role in this type of emergency planning. They want to actively ask the citizens to take pictures of problems and to make more reports, because the information about what is really happening in the city when cloudbursts occur is limited and far from complete. *"I think that primarily citizens and those kind of actors, are the people that should send information, via twitter, in various ways. And that is the information that we need to collect"* (Koopman, interview, 14 March 2016)(own translation).[15] Also,

they want to give citizens more information about what they can do themselves in relation to cloudburst, so damage and nuisance is limited as much as possible (Tromp, interview, 14 March 2016). *"Citizens can make reports and know what they can do themselves. You should give them information about the actions they can take"* (Koopman, interview, 14 March 2016)(own translation).[16]

4.1.2 Collaboration among actors

Several actors point at the importance of good collaboration between the different organizations. For example, the fire brigade says: *"The most important is that the actors know how they can cooperate and know from each other what their processes are and which questions can be asked. That should be the big gain"* (Mom, interview, 23 March 2016)(own translation).[17] And: *"The only thing that really helps is that you already know the other actors beforehand. That you know from each other what each other's tasks and responsibilities are"* (Mom, interview, 23 March 2016)(own translation).[18] It seems to be important to have contact with other actors, for example by informing them about what is happening and what you are doing, so they can prepare and take measures (Ketelaars, interview, 25 March 2016; de Nijs, interview, 18 March 2016).

> *"You are in a certain format, 'tunnel vision' and when you […] talk with a foreigner, for example, you can suddenly have very different ideas […]. And that is how you get out of that deadlock situation. And that is in my opinion very important."* (Juten, interview, 23 March 2016)(own translation)[19]

Actors should cooperate together and make agreements (Juten, interview, 23 March 2016; Kluck, interview, 10 March 2016) because proper cooperation can limit the barriers between different actors. *"But the thing that is important is: how you cooperate together. And when your cooperation is organized well, then it should not be such a big deal that you are part of different organizations"* (Goedbloed, interview, 25 March 2016)(own translation).[20]

There are several topics on which the different actors should cooperate. It is important to know from each other's systems what the critical factors are. *"[W]hat are the important moments? […] Or when does your story completely change? Tipping points"* (Timmermans, interview, 1 April 2016)(own translation).[21] But also what the opinion is of the local authority about how much the sewer system should be able to handle (Ketelaars, interview, 25 March 2016).

Also, you should coordinate where each actor is focusing on. *"You really must preselect: what are you going to focus on, what are we going to focus on and what is it we can solve together"* (de Nijs, interview, 18 March 2016)(own translation).[22] Decisions should be coordinated with other actors and they should be informed about decisions if necessary (Ketelaars, interview, 25 March 2016). Further, agreements should be made beforehand on which problems and areas have the most priority and all actors should be aware of the effects of possible cascading effects (Mom, interview, 23 March 2016; van Parera, interview, 21 March 2016).

The fire brigade is already cooperating with the other emergency services. They are deciding together what the situation is (what is going on, how many people are in danger and what are the scenarios), which information they need and what they are going to do and what the role of each actor is in that (Mom, interview, 23 March 2016). But they would like to have this cooperation also

with the other actors that are involved during a cloudburst emergency situation. It is important *"that you clearly know, together: this is what is happening, these are the consequences, what are we going to do?"* (Mom, interview, 23 March 2016)(own translation).[23]

The cooperation between the actors is nowadays not as good as it could have been. At the moment, the cooperation is rather limited (de Nijs, interview, 18 March 2016). The emergency management organization is now quite differentiated in Amsterdam and more cooperation between these actors is needed (de Nijs, interview, 18 March 2016). Another problems is that the organizations have different responsibilities and this sometimes influences the cooperation. For example, in relation to educating, training and practicing together, difficulties can occur. *"When we look specifically at water, we always want to go faster and do more than the [Safety] region can. Because they have to take the risks into account"* (Ketelaars, interview, 25 March 2016)(own translation).[24]

There is also limited cooperation on information, but this is important because the combination of data from different actors can produce information (Koopman, interview, 14 March 2016). For example:

> *"There is a lot of information, but a lot of the information is located outside Waternet. For example, the functions of buildings, the vital infrastructure, you can trace them, but that is not a map we can have and use within Waternet with a single click of a button."* (Koopman, interview, 14 March 2016)(own translation)[25]

Beforehand, it is important to share the output of modeling situations and analyses and information about bottlenecks with other actors, to inform them about what can happen and to increase awareness (Goedbloed, interview, 25 March 2016; Locher, interview, 21 March 2016; de Nijs, interview, 18 March 2016). Also, simulations, analyses and scenarios can be made together with other actors (Kluck, interview, 10 March 2016; Locher, interview, 21 March 2016). It is important to know beforehand where the vulnerable locations and vital infrastructure are and what the consequences of failures in one system can be on other systems (Locher, 21 March, 2016; de Nijs & Dankelman, interview, 18 March 2016).

Shortly before a cloudburst, actors should be informed about what can happen, what their responsibilities are and know what they should do or should not do (Kluck, interview, 10 March 2016; Koopman, interview, 14 March 2016; Tromp, interview, 14 March 2016).

During and after a cloudburst, it is important to share information to get a clear picture of what is happening and to check if everything is going okay (Daling, interview, 21 March 2016). The actors should make clear together how long the situation will last, what the consequences are and which cascading effects can happen (Mom, interview, 23 March 2016). The actors should not be reluctant to use experts when they can help and give advice (Ketelaars, interview, 25 March 2016). Also, the use of equipment and manpower can be coordinated among the different actors (van Parera, interview, 21 March 2016). In the Safety Region, some steps are already made in relation to this. The actors need to bring the information that is necessary to the meeting, so a picture can be made of what is happening, how severe it is and which response measures need to be taken (Timmermans, interview, 1 April 2016).

Also, reports could be exchanged between the actors. Nowadays, the information in reports is limited, so the actors should include the information that other actors need when they are registering the reports (Tromp, interview, 14 March 2016). The sharing of information about reports between the different actors is important, because it makes it possible to assess where the bottlenecks are and where they should focus their energy on (van Parera, interview, 21 March 2016).

4.1.3 Information and knowledge

*"When everyone sticks to it, then you know for sure that you have the right information during this type of emergency situation"* (Tromp, interview, 14 March 2016)(own translation).[26] The above statement from Koen Tromp highlights the importance of information provision and especially of the right information.

The first knowledge aspect, is that people need to be aware of the risk of flooding. In the last years, the attention for this has been growing in the fire brigade (Mom, interview, 23 March 2016). "*The awareness that a flood is more than a bunch of water you need to get rid of*" (Mom, interview, 23 March 2016)(own translation).[27] Also, there has to be awareness among the employees about when an incident is sever enough to start the emergency organization (Ketelaars, interview, 25 March 2016). The employees should be aware that it is sometimes better to prepare or respond unnecessarily, than to wait too long.

Furthermore, it should be clear who should do what. *"I think that the most important aspect is that the roles are clear when you start acting in an emergency situation"* (Tromp, interview, 14 March 2016)(own translation).[28] Roles should be clear, people should know what their role is, how everything works and who to involve (Beumer, interview, 30 March 2016; Dirksen, interview, 23 March 2016). This can be done by informing and educating employees on what their roles are and what they need to do (Juten, interview, 23 March 2016). But it is also important to know the roles of all the organizations and all the people that are involved with such an emergency situation (Tromp, interview, 14 March 2016). It should be clear what each actor is going to do, what their tasks and responsibilities are, how their organizations work and which questions they can expect from others (Mom, interview, 23 March 2016).

Moreover, knowing what to do is also very important (Locher, interview, 21 March 2016). People should have an idea where to focus on, who to contact and which information, knowledge and tools they need (Dirksen, interview, 23 March 2016; Juten, interview, 23 March 2016; Kluck, interview, 10 March 2016; de Nijs, interview, 18 March 2016). *"Most of all, it is a plan that you can activate the right people, as quickly as possible. That you know how to find each other"* (Dankelman, interview, 18 March 2016)(own translation).[29] In relation to that, information about the weather forecast is very important (Beumer, interview, 30 March 2016; Ketelaars, interview, 25 March 2016; de Nijs, interview, 18 March 2016; Tromp, interview, 14 March 2016).

But it is also important to know what you cannot do at that moment. An example is that you need to identify which bottlenecks can be solved, because a lot of them are unsolvable at that moment (Beumer, interview, 30 March 2016). Another example is: *"[y]ou cannot do anything, in technical sense. That is another problem that I experience: the higher management and a part of the*

*colleagues does not understand that that is the case"* (van Parera, interview, 21 March 2016)(own translation).[30]

Moreover, knowledge about the city is important as well. It should be known where the bottlenecks, objects that cause problems and vulnerable areas are (Beumer, interview, 30 March 2016; Dirksen, interview, 23 March 2016; Juten, interview, 23 March 2016; de Nijs, interview, 18 March 2016). These locations can be visualized on a map and be coded in relation to priority (de Nijs & Dankelman, interview, 18 March 2016). But is also important to have information on what makes these areas vulnerable, what the sensitivity of each area is in relation to heavy precipitation and what the effects will be when specific parts of the system fail (de Nijs, interview, 18 March 2016; Tromp, interview, 14 March 2016). Now, when this knowledge is available, it is often limited to knowledge about the district where people come in contact with in their work. *"So when you are having duty shift, but something is happening in a different district that yours, you have little knowledge and skills in that district. How do you get that streamlined and easily accessible?"* (Juten, interview, 23 March 2016)(own translation).[31]

It is also important to have up-to-date information about the exact location of all parts of the sewage system and of the spare parts, know the current state of the system and know where vital infrastructure is located in the city, but also the vital infrastructure and vulnerable locations within buildings (Juten, interview, 23 March 2016; Ketelaars, interview, 25 March 2016; Kluck, interview, 10 March 2016; Koopman, interview, 14 March 2016).

In like manner, it is good to know about maintenance, construction and buildings projects that are going on in the city. *"Sometimes it happens that you find out that construction is going on somewhere and it would have been useful if you would have known that."* (Daling, interview, 23 March 2016)(own translation).[32] Therefore, an up-to-date map of the city and real-time information on the maintenance of the sewage system and on projects going on in the city that can cause extra damage or hinder is useful (Kluck, interview, 10 March 2016; Koopman, interview, 14 March 2016).

For easy access, all this information can be combined in one tool, for example an information collection device like LCMS or a GIS-system. In this way, it is possible to have fast information provision to get a clear picture of what is going on (Ketelaars, interview, 25 March 2016). Also, all the information needs to be accessible for the persons who need it, so fast response is possible (Juten, interview, 23 March 2016). Smaller incidents can also be included in such a system, so that if it escalades, all information is direct available (Ketelaars, interview, 25 March 2016).

> *"What I think you could use is a GIS-system in which you can see: what is happening? In which you can combine layers with information: what did I expected to happen with heavy precipitation? Where is my electricity net? Where are the traffic elements? Where are the vital objects?"* (Kluck, interview, 10 March 2016)(own translation)[33]

This tool can also be used to evaluate afterwards on what has happened. Therefore, it is important to keep track of what is exactly happening, register what is done and collect feedback (Kluck, interview, 10 March, 2016; Koopman, interview, 14 March 2016; Tromp, interview, 14 March 2016). *"You always need to get feedback about what really happened when you are trying to keep*

*control over an emergency situation"* (Tromp, interview, 14 March 2016)(own translation).[34] The information about what happened can also be used as input for analyses (Locher, interview, 21 March 2016).

To know what to do, it is important to have an overview of what can happen (Kluck, interview, 19 March 2016). Scenarios can be made beforehand to give an indication of what happens when the rain falls, what the consequences are, where damage can occur and which measures can be taken to limit damage and nuisance (Ketelaars, interview, 25 March 2016; Kluck, interview, 10 March 2016; Mom, interview, 23 March 2016; Tromp, interview, 14 March 2016). These scenarios can be used to look at the vulnerable locations, vital infrastructure, vulnerable locations that are important for the accessibility of areas and what you need to do in relation to these objects (Kluck, interview, 10 March 2016; Mom, interview, 23 March 2016; Tromp, interview, 14 March 2016). The scenarios can be based on the information that the different actors bring and together, important tipping point can be identified (Timmermans, interview, 1 April 2016). At Waternet, some scenarios are currently being developed.

The scenarios can give an indication on where the actors are preparing for, how much manpower should be ready and where to focus on (Ketelaars, interview, 25 March 2016; de Nijs, interview, 18 March 2016). The scenarios cannot only be made beforehand, but can also be made on the base of real-time information (Tromp, interview, 14 March 2016). At most actors, enough information is available, so the scenarios only need to be made (Tromp, interview, 14 March 2016).

> *"That is the big difference. It is good to make a distinction between [flooding due to heavy downpour and flooding from rivers or sea]. And that is why these flood analyses of cloudbursts are relevant. Those indicate where flooding will occur. And not flooding through a dike burst or polders that flood. That is a totally different story."* (Kluck, interview, 10 March 2016)(own translation)[35]

The effect of flooding is often way bigger than people initially think (Mom, interview, 23 March 2016). Therefore, simulations can be used to get more information about what can happen, where you can expect problems, where bottlenecks are and what their causes are (Goedbloed, interview, 25 March 2016; de Nijs, interview, 18 March 2016; van Parera, interview, 21 March 2016).

> *"What I think you need is: an indication of what can happen during very heavy precipitation. Just where the flooding will be. You could indicate where most damage will be. When you do an estimation of the damage from flooding and say: these are the vulnerable objects. When you know that, you already know quite a lot. I think you should look at locations where it can go wrong when it gets blocked. That is what you should know."* (Kluck, interview, 10 March 2016)(own translation)[36]

The outputs of the simulations can be used for doing analyses and as information (Goedbloed, interview, 25 March 2016; Koopman, interview, 14 March 2016). *"That you know what can happen and that you assess: is this acceptable to happen or not?"* (Kluck, interview, 10 March 2016) (own translation).[37] For example, the simulation can be used to assess how to get rid of the water in a fast and effective way, to check the effect of certain measures, compare it with maps of vital infrastructure and to make decisions in relation to prioritization (Kluck, interview, 10 March 2016; de Nijs, interview, 18 March 2016). In figure 4.2, an example is given of a simulation and analysis.

Knowing what is happening is also crucial (Beumer, interview, 30 March 2016; Ketelaars, interview, 25 March 2016; Kluck, interview, 10 March 2016). This information should also be shared, so everyone knows what is going on (Ketelaars, interview, 25 March 2016; Tromp, interview, 14 March 2016). It is especially important to keep an eye on the weather forecast, the vulnerable areas and functioning of the system (Beumer, interview, 30 March 2016; de Nijs, interview, 18 March 2016; van Parera, interview, 21 March 2016). *"Keeping track and following the incident could be done better. And when you know exactly where the precipitation is concentrated, you can focus your energy on that area"* (van Parera, interview, 21 March 2016)(own translation).[38] This information can be used to assess if the measures that are identified beforehand are really necessary (Ketelaars, interview, 25 March 2016).

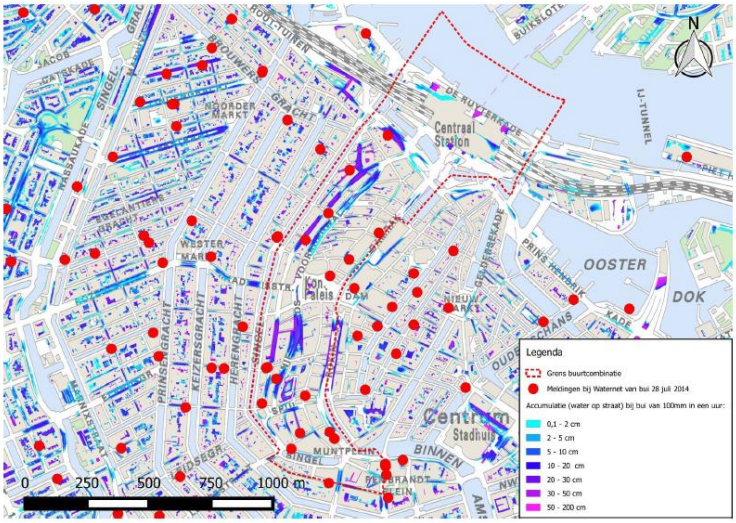


**Figure 4.2: Cloudburst simulation in the city center of Amsterdam, combined with the database of reports of 28 July 2014. Source: Amsterdam Rainproof, 2015.**

The focus should be on dangerous situations and public safety (Dirksen, interview, 23 March 2016; Kluck, interview, 10 March 2016; Koopman, interview, 14 March 2016; de Nijs, interview, 18 March 2016; van Parera, interview, 21 March 2016; Timmermans, interview, 1 April 2016; Tromp, interview, 14 March 2016).

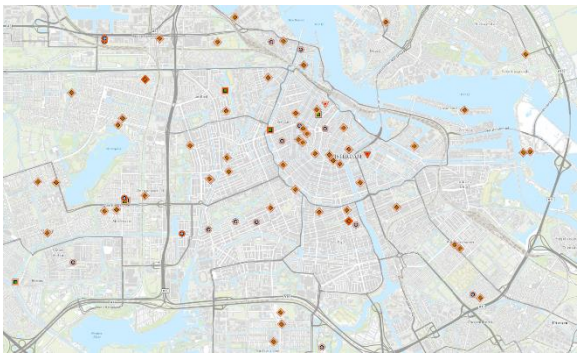

**Figure 4.3: Example reports geo-located on a map (own figure).**

It is also important to identify the bottlenecks and problems (Ketelaars, interview, 25 March 2016; van Parera, interview, 21 March 2016). This can be done by collecting reports and by geo-located them on maps (Dirksen, interview, 23 March 2016; de Nijs, interview, 18 March 2016) (see figure 4.3). This is important for effective response, prioritization and to see if they are spatially concentrated (van Parera, interview, 21 March 2016). At the moment, this is not always going as smooth as could be.

> *"And that you know the location of the problem and not of the person who reports it. When someone sees a pool of water on his way from work to home, you want to have the location of that pool and not his home address."* (Dankelman, interview, 18 March 2016)(own translation)[39]

In addition to the right location, it is also important to register what the problems are, the causes of them, the activities done to resolve them and that not more organizations then necessary are working on solving the issue (Daling, interview, 23 March 2016; Dirksen, interview, 23 March 2016).

To make the response and recovery most effectively, it is important to be able the steer manpower effectively (van Parera, interview, 21 March 2016). Therefore, it would be good to know at any given time where the manpower and materials are and to have good communication between people inside and outside (Beumer, interview, 30 March 2016; Dirksen, interview, 23 March 2016; de Nijs & Dankelman, interview, 18 March 2016). Also, it should be possible to compare reports with previous identified bottlenecks and to give direct instruction and steering to manpower in the field (Dirksen, interview, 23 March 2016; de Nijs, interview, 18 March 2016).

> *"[T]hat you know where the people are and that when you receive a call about another location, that you can say: that one is nearest, and this report has a higher priority than that other report, so go there instead."* (Dankelman, interview, 18 March 2016)(own translation)[40]

4.1.4 Resilience in cloudburst emergency planning in Amsterdam

*"Risk is probability multiplied effect. You can do very little in relation to the probability. Flooding will occur when it is raining heavily. But the risks, the effects, that is something you do have influence on"* (Dirksen, interview, 23 March 2016)(own translation).[41] As the quote from Jojanneke Dirksen illustrates, it is important to lower the effects of flooding to lower the risk. The resilience and vulnerability of the city are important in relation to the risks of flooding.

> *"Well, […] I think the vulnerability has to do with the position that people hold to become resilient again. To be able to cope with it. So it does not always have to be that the water is not 'touching' the house. That the building is not affected, that it is not causing nuisance, but that people know how they should respond to it, which makes you less vulnerable."* (Locher, 21 March 2016)(own translation)[42]

The system needs to stay intact and function properly during extreme precipitation. *"When you get a report about a broken main pressure pipeline during such an emergency situation, then it is a totally different story"* (van Parera, interview, 21 March 2016)(own translation).[43] The chance on a combination of different emergency situations at the same time should be prevented as much as possible. *"But when the system needs to handle maximum stress, there is a greater risk that something will fail"* (van Parera, interview, 21 March 2016)(own translation).[44] Therefore, it is important that the system is in good condition. *"I am getting the impression that some managers think they can overcome the shortcomings in the system with a cloudburst emergency plan. But that is of course not the case"* (van Parera, interview, 21 March 2016)(own translation).[45] It is also important to know if everything is still functioning and how fast it can be repaired if not (Kluck, interview, 10 March 2016).

In relation to information and knowledge, resilience can be increased by learning from passed events and adapt.

> *"I think that there will not be a lot less problems during the cloudburst. There is very little you can do about that. I think that the most important thing is that you learn a lot from the cloudburst and will take measures and start actions in the years afterward to make improvements."* (Dirksen, interview, 23 March 2016)[46]

Afterwards, there should be assessed what happened, what the causes of the problems were, what the experiences are of all actors, what can be learned from it and if it is necessary to make changes (Beumer, interview, 30 March 2016; Ketelaars, interview, 25 March 2016; Tromp,

interview, 14 March 2016). It is important that these evaluations have some kind of spin-off and measures are taken afterwards, in anticipation of the next event (Dirksen, interview, 23 March 2016). It is also important to learn from other cities and develop and share knowledge with other cities (Beumer, interview, 30 March 2016; Juten, interview, 23 March 2016).

Regarding organization, it is important to find a balance between preparation, practice and being unnecessarily prepared. Because cloudbursts and flooding are not a routine situation, education and practice are important to get to know the possible situation and the other actors (Koopman, interview, 14 March 2016; Mom, interview, 23 March 2016). But it is always difficult to find the balance between taking preparations and taking them unnecessarily. For example, in relation to convene a meeting of the emergency team and going to a higher level of emergency organization.

> *"When is it unnecessary? You never know. And then I think: put them together for a while and let them think. You can then say: we have a clear picture of the situation. When [the cloudburst] falls, then we know the vulnerable locations. […] Will it fall or not. But then you are always better prepared than what is nowadays the case."* (Ketelaars, interview, 25 March 2016)(own translation)[47]

Being able to cope with unusual situations, coincidence and surprise in the organization is also very important in relation to the resilience of Amsterdam. *"There is still a big chance that things will go differently than you had expected, for some kind of reason that you could not have foreseen"* (Kluck, interview, 10 March 2016)(own translation).[48] So the actors need to be prepared, but also should always be able to improvise (Koopman, interview, 14 March 2016; Mom, interview, 23 March 2016). Also, it should be able to act effectively, even when improvisation is necessary because not all the parts and steps of a cloudburst emergency plan are ready to use (Dirksen, interview, 23 March 2016).

There are two important factors in relation to collaboration that increase the resilience in cloudburst emergency planning in Amsterdam. The first is that Amsterdam Rainproof is functioning as a bridge builder between the different actors. This makes that all actors start to be aware of the risk and consequences of heavy precipitation and in the future, this network can be used to bring different actors together and improve the collaboration between them. Second, most actors have already some kind of emergency plan in which some general scenarios are outlined. *"It helps that you have identified an overall strategy on some topics beforehand. And the aim of it"* (Mom, interview, 23 March 2016)(own translation).[49]

#### 4.1.5 Vulnerability in cloudburst emergency planning in Amsterdam

> *"That's why I say: you do your best to organize the measures through which you have influence [on the situation]. And it is a little subjective, but in my opinion, is that the part that you can influence very little in comparison to the vulnerability of a city and the actual situation."* (van Parera, interview, 21 March 2016)(own translation)[50]

As Louis van Parera points out, it can be difficult to see the ways in which the vulnerability of a city in relation to cloudbursts can be limited. By investigating the situation in Amsterdam, quite some issues in which improvement is possible are identified.

In relation to information and knowledge, the most important matters are in relation to the gathering, accuracy and sharing of information. It is always difficult to get a clear picture of what is happening in the city and where the problems are (Beumer, interview, 30 March 2016; Dirksen, interview, 23 March 2016). *"You want to have installed a lot of cameras everywhere and that you can just look anywhere what is going on"* (Beumer, interview, 30 March 2016)(own translation).[51]

The legal situation in relation to information, possible sensitive information and sharing of it, is also influencing the vulnerability. *"On the one hand, as Waternet, you can have a lot of information about vulnerable areas, which we also have. But on the other side, you cannot just throw it in the public domain"* (Tromp, interview, 14 March 2016)(own translation).[52] Also:

> *"[…] it should not be personal-related information, because they are not allowed to report about that. Because that is another big problem. You are not allowed to share it with others, precisely because they are phone calls, the information is on home address level, on the household level. That is a very big problem."* (Locher, interview, 21 March 2016)(own translation)[53]

Another problem regarding the sharing of information is that each actor has a different way of data collection, categorization and reporting (Locher, interview, 21 March 2016). Also, Waternet and the emergency organizations like the Safety Region and the fire brigade work in a different LCMS environment, and therefore it is not possible to share information directly in emergency situations (Mom, interview, 23 March 2016; Timmermans, interview, 1 April 2016). Besides that, some information is registered in other systems. For example, all the reports that people make at the fire brigade are recorded and registered in a different system than LCMS. The feedback from the people in the field on these reports is also included in that system. But this system is not part of LCMS and therefore, even apart of the legal question, is not accessible for Waternet (Mom, interview, 23 March 2016).

Other problems in relation to information are the limited predictability of rainfall, the difficulty to reach everyone, awareness of the risks of cascading effects and being able to provide information and to give steering to activities at the same time (Ketelaars, interview, 25 March 2016; Kluck, interview, 10 March 2016). Further, it can be challenging to get all the information from the reports, report them in a clear way, find the real cause and prioritize them (Dirksen, interview, 23 March 2016; de Nijs, interview, 18 March 2016). Besides, some information is missing or not correct. *"It is quite well registered on pipe level, but the interface with the public space, like the gullies, that is missing"* (Koopman, interview, 14 March 2016)(own translation).[54] Another example is that most actors at the moment have no information about vulnerable objects and vital infrastructure of other actors, which they can use in scenarios (Beumer, interview, 30 April 2016). Also, there is a high reliance on the ICT-infrastructure for information. *"Because there can also be a blackout. So you should always be able to rely on hard copies"* (Juten, interview, 23 March 2016)(own translation).[55]

Moreover, some people think that you cannot do anything when a cloudburst happens, while there is almost always something that can be done (Beumer, interview, 30 March 2016).

> *"If there are bottlenecks that you can resolve. You cannot resolve everything, but there is always something you can do. There are people quite high in the emergency organization who say: But you do*

> *nothing about it, so we are not doing anything. But that is a little too easy. I think that there is always something you can do."* (Beumer, interview, 30 March 2016)(own translation)[56]

Regarding organization, the importance for Waternet to have a good reputation can be a vulnerability. Waternet seems to be extremely sensitive for complaints and is sometimes taking measures that have not much result, just to show the public that they are doing something and to give a good impression (Beumer, interview, 30 March 2016; Kluck, interview, 10 March 2016; de Nijs, interview, 18 March 2016). *"So reputation is also very important, that it stays clean. Because we want to be a good service provider. And also have that reputation. So the quicker we can act to resolve problems, the better"* (Juten, interview, 23 March 2016)(own translation).[57] This is not only visible in the way Waternet responds to reports and problems, but also in communication.

> *"Unfortunately, we did not do it last time. Waternet really took a defensive role: the sewage system could not handle it, such as shame, we do what we can. But in my opinion, it would be good if the director, together with the Communication Department, had said: the city has functioned very good, because we only have this much reports and we have seen that streets and squares were flooded and that is how it should be."* (van Parera, interview, 21 March 2016)(own translation)[58]

Also, a lot of actors are unaware of their responsibilities and see Waternet as responsible for flooding and other problems in relation to heavy precipitation (Goedbloed, interview, 25 March 2016). Waternet is a water cycle company and therefore, all knowledge on water management is combined there. This is very beneficial for the water cycle, but less good for the public space. Everyone sees Waternet as responsible, but Waternet is technically only responsible for the pipe, not even for the gullies. So then the problem starts of who is responsible for the rainwater (Locher, interview, 21 March 2016).

In addition to that, there is the classic discussion of where does the role of the public authorities stop and the responsibility of the people themselves start (Mom, interview, 23 March 2016). Nowadays, there is no clarity and knowledge about responsibilities. Not in the private sector, nor in between the different sectors of the Municipality (Locher, interview, 21 March 2016). There also seems to be limited awareness of the consequences of heavy precipitation. The output of modeling situations and analysis can be shared with other actors to show what can happen and thereby to increase awareness (de Nijs, interview, 18 March 2016).

This problem is also present within the organization of Waternet. People have clear function titles, but their role and responsibilities are unclear and often people decide themselves what they should do within their function (Dirksen, interview, 23 March 2016). *"And that it is written down on paper and that is it shared or that it is checked that all responsibilities are covered"* (Dirksen, interview, 23 March 2016)(own translation).[59] Therefore, it is now not possible to call someone on and people often do not dare to take responsibility and to make decisions, because they do not see it as part of their function (Dirksen, interview, 23 March 2016). Also, not everyone is doing their tasks as proper as it should be done or do not see the importance of it (Koopman, interview, 14 March 2016). In addition to that, there is also limited awareness of the importance of proper maintenance (Dirksen, interview, 23 March 2016).

Within the organization of Waternet, there is also limited cooperation between different departments. *"And unfortunately […], even though we merged almost ten years ago, we are still sitting on different islands in relation to some things"* (Juten, interview, 23 March 2016)(own translation).[60] Waternet is a water cycle company and more or less a combination of the Water Department of the Municipality of Amsterdam and the water authority Amstel, Gooi and Vecht, but here *"there is also a distance between the 'water authority' part and the 'sewage system' part. Those are simply internal departments"* (Goedbloed, interview, 25 March 2016)(own translation).[61]

*"But still, when you do not properly organize when you are reacting on reports or not, or when to prioritize them, then I think you do not decrease your vulnerability and response time"* (Tromp, interview, 14 March 2016)(own translation).[62] It should be clear what to do in a cloudburst emergency situation. Unfortunately, the scenario of heavy precipitation is currently not included in the emergency plans of Waternet, the fire brigade and the Safety Region (Beumer, interview, 30 March 2016; Mom, interview, 23 March 2016; Timmermans, interview, 1 April 2016). Also, you need to *"[…] make different plans for different actors. In relation to what they can do, which 'language' they speak and what they can understand"* (Locher, interview, 21 March 2016)(own translation).[63] Further, the plan should also fit to the current situation. *"There is still a large gap between what we wrote down as an ideal plan and where I think reality is ready for"* (Dirksen, interview, 23 March 2016)(own translation).[64] Besides that, the organization should also have enough capacity to collect all reports.

> *"Now we have the telephone lines that are open. And that is a beautiful natural hopper. Because you will not receive more phone calls than the telephone team can handle. But you will probably also miss a lot of dangerous situations."* (Dirksen, interview, 23 March 2016)(own translation)[65]

In relation to cooperation, there is limited interaction and sharing on information and problems (Dirksen, interview, 23 March 2016; van Parera, interview, 21 March 2016). Although the importance of cooperation seems to get a foothold. *"There are some things we have learned from the 28th of July: we have our own area, which we can manage properly. But sometimes we depend on others"* (Daling, interview, 23 March 2016)(own translation).[66]

### 4.2 Cloudburst emergency planning in Rotterdam

This sub-section is primarily based on the fieldwork that I conducted in relation to the previous research on cloudburst emergency management in Rotterdam and on some of the outputs of the workshop. A more elaborate description of the results and analysis of that fieldwork can be read in De Graaf (2016).

#### 4.2.1 Organization

Cloudburst emergency planning is in Rotterdam slightly different organized than in Amsterdam (see figure 4.4). Here, the executive tasks of the water authority and the Municipality in relation to rainwater management are still at those organizations. Also, Rotterdam is located in the catchment areas of three different water authorities. Another important difference is that there is not a knowledge platform like Amsterdam Rainproof active in Rotterdam. In addition to that, utility companies have until now not been included in cloudburst emergency planning. The last important

difference is that the Safety Region Rotterdam-Rijnmond consists of seven actors, while the Safety Region Amsterdam-Amstelland consists of five actors. In Rotterdam, the Port of Rotterdam Authority and DCMR environmental services are also part of the Safety Region, which makes sense considering that Rotterdam is one of the biggest ports in the world with quite some chemical activities.

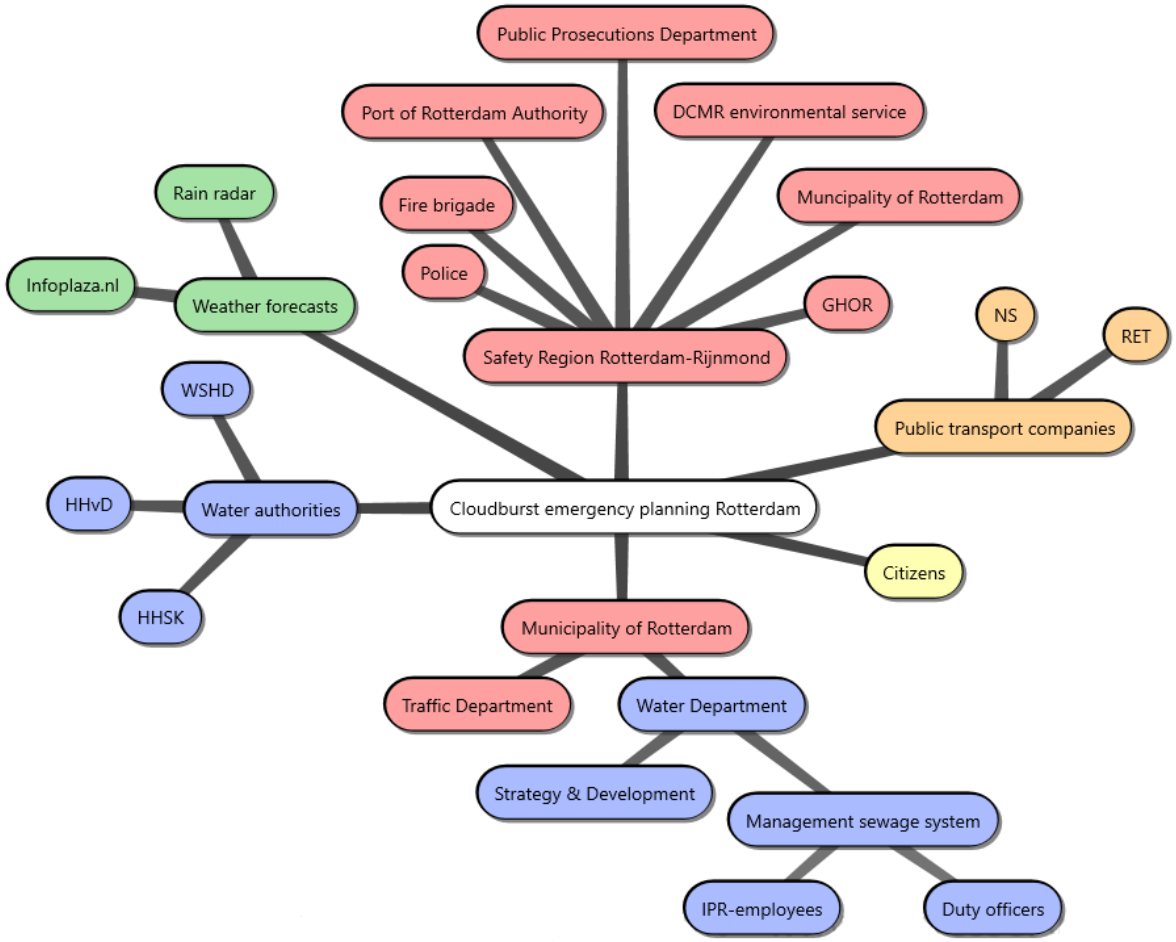


**Figure 4.4: Actors cloudburst emergency planning in Rotterdam (own figure). (See appendix C for a full page version)**

### 4.2.2 Collaboration among actors

At this moment, there is little cooperation among the different actors in relation to emergency measures. Especially the information exchange, interaction and collaboration can be improved. Several actors have their own strategy and protocol, which they will use if necessary. It would be useful if the actors have information on the protocols and strategies of each other, so they know what others are doing. Primarily, information on reports should be shared and certain decisions should be made collectively.

### 4.2.3 Information and knowledge

The Water Department keeps an eye on the weather forecast and radar images. Since October 2015, the Municipality has its own radar installed in the city, which is used in combination with national radars to assess the situation. Also, the Water Department has technology to constantly

have insight on what is happening in the sewage system. In the Central Process and Control room Water (CPRW)[67], the employees can access this information and steer the system

It should be possible to retrieve more information from reports and collect information on where in the city flooding sometimes already occurs. One way this could be done is by visualizing reports on a map and combine this map with other information in GIS-software to conduct analyses. Also, it should be known which equipment and materials are available and where it is located.

Nowadays, there is limited awareness on the risks and consequences of heavy downpour and the risk of cascading effects. Awareness can be created by using modeling software to simulate flooding and give an indication of what might happen. To be able to do this correctly, the actors should have an overview of vulnerable objects and vital infrastructure in the city, so they know where to focus on.

#### 4.2.4 Resilience in cloudburst emergency planning in Rotterdam

In relation to information and knowledge, the resilience of Rotterdam is increased because of several reason. First, the Municipality of Rotterdam has a Central Process- and Control room Water, in which they have fully and continuously insight in what is happening in the sewage system and have the possibility to steer all the different pumps. Second, the Water Department of the Municipality can use the output of a rain radar in the city, which is more precise than the rain radars used by the KNMI. Therefore, this radar provides more detailed information about where the rain is falling in Rotterdam. A third aspect is that at the Municipality of Rotterdam, problems can be reported by phone and via internet, so citizens have more ways to report problems and the Municipality has more possibility to collect as much reports as possible. Regarding collaboration, the resilience of Rotterdam benefits from the rather good contact and cooperation that the Water Department has with other departments of the Municipality, which is primarily in projects.

#### 4.2.5 Vulnerability in cloudburst emergency planning in Rotterdam

In relation to information and knowledge, one of the main matters is the reports. Not only the information form the reports is often very limited, there is no up-to-date map of reports in relation to flooding, it is not possible to evaluate the urgency of reports on a systematic way and reports made at the Municipality are not directly communicated to the Water Department.

Also, there is limited information on locations where flooding nowadays already sometimes occurs and where bottlenecks, vulnerable objects and vital infrastructure are in relation to flooding. In addition to that, there is limited up-to-date information on the exact location, condition, function and maintenance history of all the parts of the sewage- and rainwater systems. Further, the range of the rain radar is only 40 kilometers, so the information from it needs to be combined with other radars to be able to see heavy precipitation approaching.

Besides, there is little awareness among the different actors of the possible consequences of a cloudburst and the necessity to have a cloudburst emergency plan. Also, there is no recognition of the risks of a blackout during or shortly after a cloudburst. Plus, heavy precipitation events are nowadays not systematic evaluated. Only the functioning of the system is now included, but collaboration and the provision and sharing of information are aspects that should also be included.

Regarding organization, the main issues are that different actors are responsible for rainwater management in Rotterdam, that sometimes roles and responsibilities are unclear and that the Water Department is not directly part of the emergency organization of the Municipality. Also, there are no communication strategies about when to inform others. However, there is a communication strategy with instructions which messages should be send to citizens, but this strategy is not used nowadays and is also not tuned with the communication of other actors.

In relation to collaboration, the vulnerability of Rotterdam is increased for several reasons. The collaboration, information exchange and interaction between the actors can be improved. For example, there is no interaction between the actors on reports. The cooperation is more difficult, because there are three different water authorities for the Municipality to cooperate with. Additionally, there has been no contact with the public transport companies about the risk and the consequences of flooding due to heavy precipitation. Further, citizens are limited informed about heavy precipitation, what they can do themselves and that they should report problems. Also, the Safety Region Rotterdam-Rijnmond is very limited aware of the risks and consequences of flooding.

### 4.3 Differences between cloudburst emergency planning in Amsterdam and Rotterdam

*"So, there really is a big difference. Combined, separated. Polder and outlet area. And river and canal, so to say. And water cycle [company] and just Municipality."* (Goedbloed, interview, 25 March 2016)(own translation).[68] This statement of Daniël Goedbloed shortly summarizes some of the main differences in relation to resilience and vulnerability between Amsterdam and Rotterdam.

The first three differences he mentions have to do with the urgency of climate change adaptation. This is higher in Rotterdam than in Amsterdam (Goedbloed, interview, 25 March 2016). Rotterdam is mainly located in polders, below sea level and build on a weak soil. Amsterdam is mainly build at or slightly above sea level and the soil was strengthened by filling it with sand (Goedbloed, interview, 25 March 2016).

> *"So Rotterdam, except for the harbor and outer dike areas, is located under sea-level. So every drop of rain that falls, within the dikes, needs to be pumped out again. Which means that all the rainwater that is too much to dispose, which happens quite fast, you need to store temporarily in the city."* (Goedbloed, interview, 25 March 2016)(own translation)[69]

There is also a difference in the amount of surface water (Goedbloed, interview, 25 March 2016). Rotterdam has only limited surface water. There are only a few canals in the city center, while Amsterdam has lots of surface water and is famous for its canals.

This links to another difference, which is that the Water Department from the Municipality in Rotterdam has full-time insight in what is happening in the sewage system (Goedbloed, interview, 25 March 2016). The reason for this is that there is more necessity of having continuous insight in the system in Rotterdam than in Amsterdam (Goedbloed, interview, 25 March 2016).

> *"Imagine that it is raining very hard. The overflow pumps, that is partially going automatic, but also partially not. So they need to be able to look at the system and see where the water is and where less water is and then they are taking measures. For that, you need knowledgeable people. But when it is raining very hard here, a very big part [of the sewage system] is separated, so the rainwater is just finding its way. It is not going to a pump."* (Goedbloed, interview, 25 March 2016)(own translation)[70]

The fourth difference he mentions is about the organization of the water management in the two cities.

> *"The difference in how it is organized here is very clear. In Rotterdam, water management is part of 'Stadsbeheer', which is part of the Municipality, and therefore must communicate directly with colleagues of other departments. So, their connections are shorter; here the connections are longer. But here is greater knowledge, at Waternet."* (Goedbloed, interview, 25 March 2016)(own translation)[71]

Some people think that by making one company responsible for all phases of the water cycle, in which the tasks of the Water Department of a Municipality and of the water authority are combined, is perfect, but this is not the case.

> *As if you can solve the problem of the distance between organizations by combining them as one. That is not true. There is a distance. And this distance from the water authority is a bit bigger in Rotterdam; there, they are not direct colleagues."* (Goedbloed, interview, 25 March 2016)(own translation)[72]

Another difference between the two cities is that the Safety Region Amsterdam-Amstelland seems to be more aware of the risk and the consequences of flooding than the Safety Region Rotterdam-Rijnmond. Also, a strong bridge building platform or actor like Amsterdam Rainproof is not active on the field of cloudburst emergency planning in Rotterdam, although Water Sensitive Rotterdam, a 'movement' initiated by the Water Department of the Municipality, is gaining firmer foothold. Further, the Municipality of Rotterdam has the rain radar and has thereby access to accurate information about precipitation, while the actors in Amsterdam have to rely on the national rain radars. The last difference is that the Waternet can use LCMS as a tool to collect and combine information and make it accessible for everyone who needs it. The Water Department of the Municipality of Rotterdam is not having a tool like that.

### 4.4 Summary results and analysis

In tables 4.1, the important aspects in relation to information and knowledge, organization and collaboration in cloudburst emergency planning in Amsterdam are summarized. In table 4.2, the same is done for cloudburst emergency planning in Rotterdam. Thereafter, elements that influence the resilience and vulnerability of Amsterdam and Rotterdam in relation to cloudburst emergency planning on the before mentioned three fields are outlined (see table 4.3).

**Table 4.1: Important aspects of cloudburst emergency planning in Amsterdam in relation to organization, collaboration and information and knowledge.**

| Fields | Aspects |
|---|---|
| **Organization** | Actors: Waternet (rainwater management); Municipality of Amsterdam (local authority); Safety Region Amsterdam-Amstelland and fire brigade (emergency services); Amsterdam Rainproof (knowledge institute); KNMI and MeteoGroup (weather forecast); Liander, Waternet and KPN (utility companies); NS and GVB (public transport companies); Citizens |
| **Collaboration** | Know the other actors and their responsibilities, tasks and processes |
| | Coordinate where each actor is focusing on and make agreements |
| | Aware of what can happen and the effects of possible cascading effects |
| | Share information on bottlenecks and output of simulations and analyses and/or make simulations, analyses and scenarios together |
| | Combine data from different actors to create information |
| | Share information on what is important for your organization (tipping points, vulnerable objects, vital infrastructure) |
| | Decide together what the situation is and which information is needed from other actors |
| | Coordinate use of manpower and equipment |

| | |
|---|---|
| | Know where to focus on together and how efforts can be combined |
| | Inform each other on what you are doing and about decisions |
| | Share information on reports |
| **Information and knowledge** | Awareness for the risk of flooding and the consequences of it |
| | Aware of the importance of preparedness |
| | Clear roles, responsibilities and tasks and know them of each other |
| | Know what to do and what you cannot do |
| | Weather forecast |
| | Know the city (bottlenecks, vulnerable areas, vital infrastructure, priority of objects, sensitivity of areas, location all parts system, current state system, effects of failure of parts system) |
| | Up-to-date information on maintenance, construction and building projects going on |
| | Tool to collect, combine and share information |
| | Know what can happen (scenarios, simulations) and assess and analyze that |
| | Know what is happening |
| | Know what happened |
| | Focus on dangerous situations and public safety |
| | Geo-locate problems and reports on maps (effective response, prioritization, possible spatial concentration) |
| | Know the problem, cause and resolve activities |
| | Steer manpower effectively |
| | Good communication between people inside and outside |

**Table 4.2: Important aspects of cloudburst emergency planning in Rotterdam in relation to organization, collaboration and information and knowledge (based on De Graaf, 2016).**

| Fields | Aspects |
|---|---|
| **Organization** | Actors: water authorities and Water Department Municipality of Rotterdam (rainwater management); Municipality of Rotterdam (local authority); Safety Region Rotterdam-Rijnmond and fire brigade (emergency services); Infoplaza.nl and rain radar (weather forecast); NS and RET (public transport companies); Citizens |
| **Collaboration** | Coordination among actors |
| | Inform other actors |
| | Interaction, cooperation and information exchange among actors |
| | Exchange reports and make decisions together |
| **Information and knowledge** | Weather forecasts and information on actual rainfall |
| | Know what is going on in the system |
| | Know what happened and which measures were taken |
| | Know where the problems are |
| | Develop scenarios for generic procedures |
| | Have insight in the unused capacities of the actors |
| | Have information on where problems already occur |
| | Possible to assess the priority of problems |
| | Overview of vulnerable objects and vital infrastructure in the city |
| | Know the weak spots |
| | Use modelling software to have an idea of what can happen |
| | Visualize reports on maps and conduct analyses with these maps in GIS-software |
| | Get all the information you need from reports |
| | Being aware of the risk  cloudbursts and cascading effects |
| | Have up-to-date information on all parts of the sewage system |

**Table 4.3: Identified aspects that influence the resilience and vulnerability of Amsterdam and Rotterdam in relation to cloudburst emergency planning.**

| | | |
|---|---|---|
| **Amsterdam** | | |
| **Resilience** | Information and knowledge | System needs to stay intact |
| | | Learning from events, from other cities and adapt |
| | Organization | Balance between preparation, practice and being unnecessarily prepared |
| | | Being able to cope with unusual situations, coincidence and surprise (balance between preparation and improvisation) |
| | Collaboration | Build bridges between organizations (increased awareness and improve cooperation) |
| | | Emergency plan with general scenarios |
| **Vulnerability** | Information and knowledge | Gathering, accuracy and sharing of information |
| | | Difficult to get a picture of what is going on |
| | | Legal situation limits sharing of information |
| | | Each actor different way of data collection, categorization and reporting and uses other systems |
| | | Limited predictability precipitation |
| | | Limited awareness risk cascading effects |
| | | Difficult to reach everyone |
| | | Provide information and steer activities at the same time |
| | | Reports: get all information, report clearly, find the cause and prioritize |
| | | Missing or incorrect information |
| | | No information about vulnerable objects and vital infrastructure of other actors |
| | | High reliance on ICT-infrastructure |
| | | Some people think you cannot do anything |
| | Organization | Importance good reputation |
| | | Actors unaware of responsibilities |
| | | Limited awareness consequences heavy precipitation and importance proper maintenance among actors |
| | | Roles, responsibilities and tasks of people sometimes unclear within organizations |
| | | Limited cooperation between departments of the same organization |
| | | Scenario heavy precipitation missing in emergency plans |
| | | Enough capacity to collect all reports |
| | Collaboration | Limited interaction and sharing on information and problems |
| **Rotterdam** | | |
| **Resilience** | Information and knowledge | Continuous insight sewage system and steering possibility |
| | | Accurate and detailed information on precipitation |
| | | Multiple ways citizens can report problems |
| | Collaboration | Good contact between departments of the Municipality |
| **Vulnerability** | Information and knowledge | Limited information from, no up-to-date map of reports, not possible the evaluate the urgency systematically and reports made at the Municipality are not directly communicated to the Water Department |
| | | Limited information on the location of existing problems, bottlenecks, vulnerable location and vital infrastructure |
| | | Limited up-to-date information sewage- and rainwater systems |
| | | Range rain radar limited |
| | | Limited awareness among different actors of possible consequences heavy precipitation and necessity cloudburst emergency plan |
| | | Limited evaluation |
| | Organization | Different actors responsible for rainwater management |
| | | Sometimes roles and responsibilities unclear |
| | | Water Department not directly part of emergency organization Municipality |
| | | No or not used communication strategies |
| | Collaboration | No interaction between actors on reports |
| | | Three different water authorities to cooperate with |
| | | Public transport companies not included |
| | | Citizens are limited informed |
| | | Safety Region very limited aware of risks and consequences flooding |

**Notes**

**1.** *"Dus wat je merkt: de waternet organisatie is heel erg flexibel in: als jij nou eenmaal degene bent die dat wil doen en die dat goed kan, dan doe je dat. We hebben allemaal wel een officiële functie, maar dat heeft over het algemeen weinig te maken met het werk dat je doet. Wat ik ook wel eens irritant vind, omdat je dan nergens verantwoordelijk voor bent."* (Dirksen, interview, 23 March 2016)

**2.** Network-enabled capability is a working method through which information is shared, so during an emergency, decisions can be made based on an up-to-date and consistent image of the emergency situation.

**3.** *"Tot we dat netcentrisch werken hadden, zaten we in oefeningen, ook bij echte incidenten, vaak ellenlang te bepraten, te bespreken van: wat is er nou precies aan de hand?"* (Ketelaars, interview, 25 March 2016)

**4.** LCMS is the National Crisis Management System ('Landelijk Crisis Management Systeem'), which is a protected environment in which information can be shared between emergency organizations in emergency situations, crises and planned events. LCMS-W is the LCMS version for the water authorities.

**5.** *"Dus je moet ze in ieder geval op de hoogte houden van: wat gebeurd er en wat je aan het doen bent."* (Ketelaars, interview, 25 March 2016)

**6.** V&OR is in Dutch the abbreviation for 'Verkeer en Openbare Ruimte'.

**7.** GHOR is the Health Aid Organization in the Region that is responsible for the organization, and coordination of the medical aid during emergency situations and consist of ambulance services, hospitals, pediatricians and some other healthcare organizations.

**8.** *"Stel dat je toch dat soort dingen wilt gaan doen, of je ziet dat er een ziekenhuis onder water gaat lopen, dan moet je daar beslissingen nemen: hoe ga je je inzet prioriteren?"* (Timmermans, interview, 1 April 2016)

**9.** GRIP is the coordinated regional emergency organization procedure and is used to decide how the coordination between emergency services is. There are six levels: 1 to 5 and GRIP RIJK, from a local incident to national emergency organization.

**10.** *"Dan gaat er op de meldkamer een apart protocol draaien en dan proberen ze echt de spoedeisende klussen te isoleren van de wat minder spoedeisende klussen."* (Mom, interview, 23 March 2016)

**11.** *"Maar dat is echt op basis van welke informatie krijgt de centralist binnen en die probeert een scheiding te maken tussen waar we echt naar te moeten en wat even kan wachten."* (Mom, interview, 23 March 2016)

**12.** *"En stations zijn wel vaak een risicopunt. Die treinen zijn niet allemaal echt hoog genoeg… Er komt vaak een lage tunnel of een lage ingang, voetgangerstunnels onder de treinen door. Die zijn allemaal risicovol. Die moeten echt wel bekeken worden. Daar zijn vaak meerdere hoogtes waar dingen op gebeuren."* (Kluck, interview, 10 March 2016)

**13.** The Dutch Railways (NS) is the train company that provides the train traffic on the main railway net of the Netherlands.

**14.** The GVB is the Municipal Transport Company, which is responsible for bus, light rail and metro traffic in the Municipality of Amsterdam.

**15.** *"Ik denk voornamelijk dat burgers en dat soort dingen, dat zijn de mensen die de informatie de wereld in moeten schieten, via twitter, op allerlei manieren. En dat is dan de informatie die wij dan*

*weer moeten verzamelen."* (Koopman, interview, 14 March 2016)

**16.** *"Burgers kunnen meldingen doen en zelf weten wat ze moeten doen. Je zou ze een handelingsperspectief kunnen bieden."* (Koopman, interview, 14 March 2016)

**17.** *"Het belangrijkste is dat de partijen elkaar weten te vinden en van elkaar weten wat hun processen zijn en welke vragen er op tafel kunnen komen. Dat zou de grote winstpakker moeten zijn."* (Mom, interview, 23 March 2016)

**18.** *"Het enige wat hier goed bij helpt is dat je elkaar van te voren al weet te vinden. Dat je van elkaar weet wat ieders taken en verantwoordelijkheden zijn"* (Mom, interview, 23 March 2016)

**19.** *"Jij zit ook in een bepaald stramien, een koker te kijken en als jij, omdat je met een buitenlander spreek bij wijze van spreken, kan je ineens hele andere ideeën hebben […]. En dan kom je uit die impasse terecht. En dat vind ik heel belangrijk."* (Juten, interview, 23 March 2016)

**20.** *"Maar het gaat er maar om: hoe ga je met elkaar samenwerken. En als je die samenwerking goed georganiseerd hebt, dan zou het niet zoveel uit moeten maken dat je in verschillende organisaties zit."* (Goedbloed, interview, 25 March 2016)

**21.** *"[W]at zijn nou de belangrijke momenten? […] Of wanneer verandert je hele verhaal? Van die kantelpunten."* (Timmermans, interview, 1 April 2016)

**22.** *"Je moet echt gaan voorsorteren: waar gaan jullie je vooral op richten, waar gaan vooral wij op richten en wat kunnen we juist samen nog heel goed oplossen."* (de Nijs, interview, 18 March 2016)

**23.** *"[D]an als je met elkaar duidelijk hebt: dit is er aan de hand, dit zijn de consequenties, wat gaan we dan doen?"* (Mom, interview, 23 March 2016)

**24.** *"Alleen, wij zijn specifiek gericht op water, dus wij willen altijd sneller en meer dan wat de [Veiligheids]regio kan. Omdat die met veel meer risico's rekening moet houden."* (Ketelaars, interview, 25 March 2016)

**25.** *"Er is heel veel informatie, maar heel veel informatie ligt ook buiten waternet. Bijvoorbeeld de functies van gebouwen, de vitale infrastructuur, die kan je wel herleiden, maar dat is niet een kaart die gebruikt wordt binnen waternet die met 1 druk op de knop daar is."* (Koopman, interview, 14 March 2016)

**26.** *"Als iedereen zich daaraan houdt, dan weet je zeker dat je de juiste informatie hebt tijdens zo'n calamiteit."* (Tromp, interview, 14 March 2016)

**27.** *"Het besef van: een overstroming is meer dan een hoop water dat je daarna weer weg moet zien te krijgen."* (Mom, interview, 23 March 2016)

**28.** *"Ik denk dat het allerbelangrijkste is dat je, als je zo'n calamiteit ingaat, dat je de rollen duidelijk hebt."* (Tromp, interview, 14 March 2016)

**29.** *"Het is vooral een plannetje dat je zo snel mogelijk de juiste mensen in actie kan zetten. Dat je elkaar weet te vinden."* (Dankelman, interview, 18 March 2016)

**30.** *"Want in technisch/inhoudelijke zin, kan je niks doen. Dat is dan een ander probleem dat ik ervaar: het hogere management en een deel van de collega's begrijpt niet dat dat zo is."* (van Parera, interview, 21 March 2016)

**31.** *"Dus als jij op een gegeven moment wachtdienst hebt, maar het gebeurd in een andere sector die niet van jou is, heb je heel weinig kennis en vaardigheden in dat gebied. Hoe krijg je dat gestroomlijnd en makkelijk zichtbaar?"* (Juten, interview, 23 March 2016)

**32.** *"Soms is het wel dat je ertegen aanloopt dat ze ergens aan het werk zijn en dat het handig was dat je dat geweten had."* (Daling, interview, 23 March 2016)

**33.** *"En wat ik denk dat je eigenlijk zou kunnen gebruiken is een GIS-systeem waarin je ziet: wat*

*gebeurt er? Waarin je verschillende lagen aan kunt zetten met wat had ik gedacht dat er zou gebeuren met een extreme bui? Waar ligt mijn elektriciteitsnet? Waar liggen verkeers dingen? Wat zijn de vitale dingen?"* (Kluck, interview, 10 March 2016)

**34.** *"Als je regie probeert te houden over een calamiteit moet je uiteindelijk ook terug kunnen krijgen wat er nou daadwerkelijk gebeurd is."* (Tromp, interview, 14 March 2016)

**35.** *"Dat is het hele verschil. Dat is wel goed om daar onderscheid tussen [overstroming door hevige neerslag en overstroming door rivieren of zee] te maken. En daarom zijn die wateroverlast analyses van wolkbreuken relevant. Die zeggen zoveel water komt daar. En niet zomaar een verhaal van dijkdoorbraak of polders die vollopen. Dat is een heel ander verhaal."* (Kluck, interview, 10 March 2016)

**36.** *"Maar ik denk wat je nodig hebt: een inschatting wat er gebeurt bij een hele extreme bui. Gewoon van: waar staat heel veel water. Een inschatting van waar vindt grote schade plaats, zou je kunnen doen. Dus als je een waterschadeschatting doet en zegt, dat zijn dus kwetsbare panden, dat is eigenlijk… Als je dat weet, dan ben je een heel eind. Ik denk dat je zou moeten kijken van zijn er plekken waar het heel erg misloopt als het geblokkeerd raakt. Dat zou je moeten weten."* (Kluck, interview, 10 March 2016)

**37.** *Van dat je weet wat er zou kunnen gebeuren en dat je bedenkt: vind ik dat oké of vind ik dat niet oké?"* (Kluck, interview, 10 March 2016)

**38.** *"Het volgen van het incident zou beter kunnen. En als je precies weet waar het zwaartepunt van zo'n bui ligt, kan je daar ook je energie op richten."* (van Parera, interview, 21 March 2016)

**39.** *"En dat je ook de locatie weet van de overlast en niet van de beller. Als iemand onderweg van zijn werk naar huis een plas tegenkomt, dat je dan de locatie van die plas hebt en niet zijn woonadres."* (Dankelman, interview, 18 March 2016)

**40.** *"[D]at je wel weet waar de mensen zijn en als je nog gebeld wordt voor een andere plek, dat je dan kan zeggen: die is het dichtste bij, deze heeft meer prioriteit dan daar, dus kom maar hier heen."* (Dankelman, interview, 18 March 2016)

**41.** *"Je hebt het risico=kans x gevolg. De kans, daar ga je weinig aan doen. Als het heel hard hoost, dat water zal er wel staan. Maar de risico's, de gevolgen, daar kan je wel van alles aan doen."* (Dirksen, interview, 23 March 2016)

**42.** *"Nou, […] volgens mij heeft kwetsbaarheid te maken […] met de positie die de persoon in neemt om weer resilient te zijn. Om daar tegen te kunnen. Dus het hoeft niet altijd zo te zijn dat het water echt het huis niet raakt. Dat het pand niet raakt, dat het de overlast niet geeft, maar dat men wel weet hoe men daar op moet reageren, waardoor je minder kwetsbaar wordt."* (Locher, interview, 21 March 2016)

**43.** *"Als je een melding krijgt van een gesprongen hoofdpersleiding tijdens zo'n incident, dan wordt het natuurlijk een heel ander verhaal."* (van Parera, interview, 21 March 2016)

**44.** *"Maar ja, als het systeem maximaal belast wordt, is er natuurlijk ook een groter risico dat er iets kapot gaat."* (van Parera, interview, 21 March 2016)

**45.** *"Ik krijg de indruk dat sommige managers met zo'n protocol hoosbuien de tekortkomingen in de infrastructuur kunnen ondervangen. Maar dat is natuurlijk niet zo."* (van Parera, interview, 21 March 2016)

**46.** *"Dus ik denk dat het niet zozeer tijdens de hoosbui dat nou de overlast veel minder wordt. Dan kan je eigenlijk ook vrij weinig doen. Ik denk dat het voornamelijk erin zit dat je heel veel leert van de hoosbui en in de jaren die daarop volgen dus de acties uitrolt om het beter te maken."* (Dirksen, interview, 23 March 2016)

**47.** *"Wanneer is het onnodig? Dat weet je dus niet. En dan denk ik: zet ze maar even bij elkaar, laat ze maar even denken. Dan kan je altijd nog zeggen: we hebben de situatie in beeld. Als die valt, dan weten we waar de kwetsbare plekken zitten. […] Valt ie dan of valt ie niet. Maar dan ben je er beter op voorbereid dan nu vaak het geval is."* (Ketelaars, interview, 25 March 2016)

**48.** *"En zelfs grote kans dat het dan toch om een andere reden die je dan niet hebt kunnen voorzien toch weer anders loopt."* (Kluck, interview, 10 March 2016)

**49.** *"Dan helpt het dat je van te voren op hoofdlijnen wat onderwerpen al hebt benoemd. En het doel ervan."* (Mom, interview, 23 March 2016)

**50.** *"Daarom zeg ik: je doet je best om datgene waar je invloed op hebt zo goed mogelijk organisatorisch te ondervangen. En dan is het een beetje subjectief, maar mijn mening is dat het gene waar je invloed op hebt, is relatief klein als je het afzet tegen de kwetsbaarheid van zo'n hele stad en de feitelijke situatie."* (van Parera, interview, 21 March 2016)

**51.** *"Eigenlijk zou je gewoon willen dat je een hoop camera's hebt hangen, overal, en dat je overal gewoon kunt kijken hoe het in elkaar steekt."* (Beumer, interview, 30 March 2016)

**52.** *"Aan de ene kant kan je heel veel informatie hebben, als waternet zijnde, over kwetsbare gebieden, en dat hebben we principe ook wel. Maar aan de andere kant, doe je dat ook niet zomaar in het publiek gooien."* (Tromp, interview, 14 March 2016)

**53.** *"Met het feit dat het natuurlijk geen persoonsgebonden informatie is waardoor ze niet mogen rapporteren. Want dat is het andere grote probleem, natuurlijk. Juist doordat het telefoontjes zijn, is het op adres niveau, is het op huishoudniveau, mag het eigenlijk niet aan anderen openbaar gemaakt worden. Daar heb je een heel groot probleem mee."* (Locher, interview, 21 March 2016)

**54.** *"Op leidingniveau is dat op zich wel goed geregistreerd, maar de interface met de openbare ruimte, zoals de kolken bijvoorbeeld, dat is er dan weer net niet."* (Koopman, interview, 14 March 2016)

**55.** *"Want de stroom kan ook uitvallen. Dan moet je dus kunnen terugvallen op eigen hard copies."* (Juten, interview, 23 March 2016)

**56.** *"Of er knelpunten zijn die je op kunt lossen. Je kunt vast niet alles oplossen, maar je kunt vast wel wat doen. Er zijn mensen die hoog in de wachtdienst zitten die zeggen: Maar daar kan je niks aan doen dus dan doen we niks meer. Dat is iets te makkelijk. Je kunt altijd dingen doen, denk ik."* (Beumer, interview, 30 March 2016)

**57.** *"Dus ook de naam is heel belangrijk, dat die gezuiverd blijft. Want wij willen graag een goede dienstverlener zijn. En zo ook bekend staan. Dus hoe sneller we kunnen acteren om het op te lossen, des te beter het is."* (Juten, interview, 23 March 2016)

**58.** *"De vorige keer vond ik dat jammer. Waternet nam heel erg een defensieve rol aan, van: oh god, het rioolstelsel kon het niet aan, en oh god wat erg, we doen wat we kunnen. Maar ik had het wel leuk gevonden als onze directeur, samen met onze communicatieafdeling had gezegd: de stad heeft uitstekend gefunctioneerd want we hebben maar zoveel klachten en we hebben allerlei straten en pleinen vol zien lopen en zo hoort het ook."* (van Parera, interview, 21 March 2016)

**59.** *"En dat het ooit op papier gezet wordt en dat het gedeeld wordt of dat gekeken wordt of er ergens verantwoordelijkheden buiten de boot vallen of niet."* (Dirksen, interview, 23 March 2016)

**60.** *"En helaas […], al zijn we nu bijna 10 jaar gefuseerd, we zitten bij sommige plekken nog behoorlijk op eilandjes."* (Juten, interview, 23 March 2016)

**61.** *"er is hier ook een afstand tussen het waterschapsgedeelte en het rioleringsgedeelte. Dat zijn gewoon interne afdelingen."* (Goedbloed, interview, 25 March 2016)

**62.** *"Maar nog steeds, als je dan niet goed organiseert wanneer je wel op meldingen af gaat en*

*wanneer niet of wanneer je dat dan prioriteert enzo, dan denk ik niet dat je daar je kwetsbaarheid en responsetijd daarmee verbeterd."* (Tromp, interview, 14 March 2016)

**63.** *"[…]voor verschillende actoren maak je dan verschillende soorten plannen. Om naar aanleiding van wat ze kunnen doen en naar aanleiding van wat voor 'taal' ze hebben en wat ze kunnen begrijpen."* (Locher, interview, 21 March 2016)

**64.** *"Er zit nog wel een heel gat tussen wat wij opgeschreven hebben als ideaal stappenplan en waar ik denk dat de werkelijkheid klaar voor is."* (Dirksen, interview, 23 March 2016)

**65.** *"Nu hebben we de telefoonlijnen die open staan. En dat is een hele mooie natuurlijke trechter. Want je krijgt niet meer telefoontjes dan dat jouw telefoonteam aankan. Maar daardoor mis je waarschijnlijk heel veel wel gevaarlijke situaties."* (Dirksen, interview, 23 March 2016)

**66.** *"Dus dat zijn nog wel dingen waar we naar aanleiding van 28 juli geleerd hebben van: we hebben ons eigen gebied, dat hebben we redelijk op orde. Maar soms zijn we ook afhankelijk van anderen."* (Daling, interview, 23 March 2016)

**67.** In Dutch, CPRW is the abbreviation for 'Centrale Proces- en Regelkamer Water'.

**68.** *"Dus daar zit wel echt het grote verschil. Gescheiden, gemengd. Polder en boezem gebied. En rivier en kanaal, zal ik het noemen. En watercyclus en gewoon gemeente."* (Goedbloed, interview, 25 March 2016)

**69.** *"Dus Rotterdam, behalve de haven en de buitendijkse gebieden, ligt alles onder zeeniveau. Dus elke druppel regenwater die valt, binnen de dijk, moet er weer uitgepompt worden. Dus dat betekent dat al je regenwater, als het meer is dan je kunt afvoeren, wat al heel snel is, dat je dat tijdelijk een plek moet geven in de stad."* (Goedbloed, interview, 25 March 2016)

**70.** *"Stel nou dat het heel erg hard regent. Die bemaling overstorten, dat gaat deels automatisch, maar ook deels niet. Dus ze moeten gewoon naar dat systeem kijken en zien waar er meer water is en waar minder water is en daar doen ze dan acties. Daar heb je gewoon mensen nodig die verstand van zaken hebben. Terwijl als het hier hard regent, een heel groot gedeelte is gescheiden, dus dat regenwater loopt gewoon weg. Dus dat gaat niet naar een pomp."* (Goedbloed, interview, 25 March 2016)

**71.** *"Hier zit het verschil 'm heel duidelijk in hoe het georganiseerd is. In Rotterdam zit watermanagement gewoon bij stadsbeheer, dat zit in de gemeente, en die moet rechtstreeks communiceren met zijn collega's bij de andere diensten. Dus daar zijn die lijnen wat korter; hier zijn die lijnen wat langer. Maar hier is wel de kennis groter, bij Waternet."* (Goedbloed, interview, 25 March 2016)

**72.** *"Alsof het door het onder 1 noemer te brengen die afstand er helemaal niet is. Dat is niet waar. Daar zit wel degelijk nog een afstand in. En in Rotterdam is die afstand weer wat groter met het waterschap; dat zijn natuurlijk geen rechtstreekse collega's."* (Goedbloed, interview, 25 March 2016)

## 5. Discussing cloudburst emergency planning in urban areas

In this chapter, the outputs of the research and the research itself are discussed. First, the framework for cloudburst emergency planning is discussed in relation to the elements 'information and knowledge', 'organization' and 'collaboration'. Second, recommendations are given for cloudburst emergency planning in an urban context. After that, the research is reflected.

### 5.1 Framework for cloudburst emergency planning

The theoretical framework for cloudburst emergency planning is advanced on the base of the literature review on the characteristics of resilience and vulnerability in chapter 3 and the outcomes of the results and analysis of the results of the fieldwork in chapter 4. Categories were identified through which the elements could be subdivided. In the following subdivisions, the elaboration of the framework on the elements 'information and knowledge', 'organization' and 'collaboration' will be discussed first, followed by a full presentation of the advanced theoretical framework.

#### 5.1.1 Information & knowledge

The aspects that are important for proper information and knowledge in all phases of cloudburst emergency planning are outlined in figure 5.1 and presented below. Awareness of the risk of flooding, the consequences of heavy precipitation and flooding, the risks of cascading effects, the importance of preparedness and the necessity of having a cloudburst emergency plan is important to have all relevant actors willing to cooperate and to make sure that all people that are involved in cloudburst emergency planning fulfill their tasks properly.


**Figure 5.1: Framework information & knowledge (own figure).**

Having an idea of what can happen is really necessary for proper preparedness, but also for effective response and recovery. Scenarios and simulations can give an impression of what might happen. The outputs of these scenarios and simulations can be assessed and analyzed, which can provide useful information about the causes of problems and the effects of taking certain measures.

Knowing the physical and social geography of an urban area is very essential in relation to having an idea about what can happen, which measures can be taken as preparedness and how the response should be prioritized. It is important to know where the bottlenecks, vulnerable areas and vital infrastructure are located, the sensitivity of each area for heavy precipitation, which areas might flood, the dynamics of the population at risk and the susceptibility of physical elements. It is also relevant to know the exact location of all parts of the sewage system, the state of the system and the effects of failure of parts of the system. Another aspect that can improve cloudburst emergency planning is up-to-date information on maintenance, construction and building projects going on in the urban area.

It is vital to have a perspective for action and to know what should be done and what is not possible or should not be done. Also, there is always something that can be done and the focus should be on dangerous situations and public safety.

For taking effective measures in all phases of cloudburst emergency planning and to limited the damage and nuisance as much as possible, it is crucial to have real-time information on what is happening. Accurate and detailed information on the weather forecast, precipitation and characteristics of the flood is important to know the weather conditions and how long the situation might last. Continuous insight in the sewage system and steering possibilities can also limit the damage. Collecting all reports, all information that is needed about the problems, finding the cause, geo-locate them on maps, make prioritizations and keeping track of the resolve activities undertaken is primarily important for an effective response and for the evaluation afterwards. A tool to collect, combine and share information between people and actors can improve the communication between people inside and outside and can make it easier to assess the situation.

Resourcefulness is mainly important in relation to the effectiveness of the response. Not only the system needs to stay intact, it should also be possible to prioritize, steer manpower effectively and provide information and steer activities at the same time. Also, actors should be aware that they should not only rely on ICT-infrastructure, because of the risk of a black-out.

Knowing what happened, evaluate, learn from events and other cities and know if it is necessary to adapt also plays a role in information and knowledge.

5.1.2 Organization

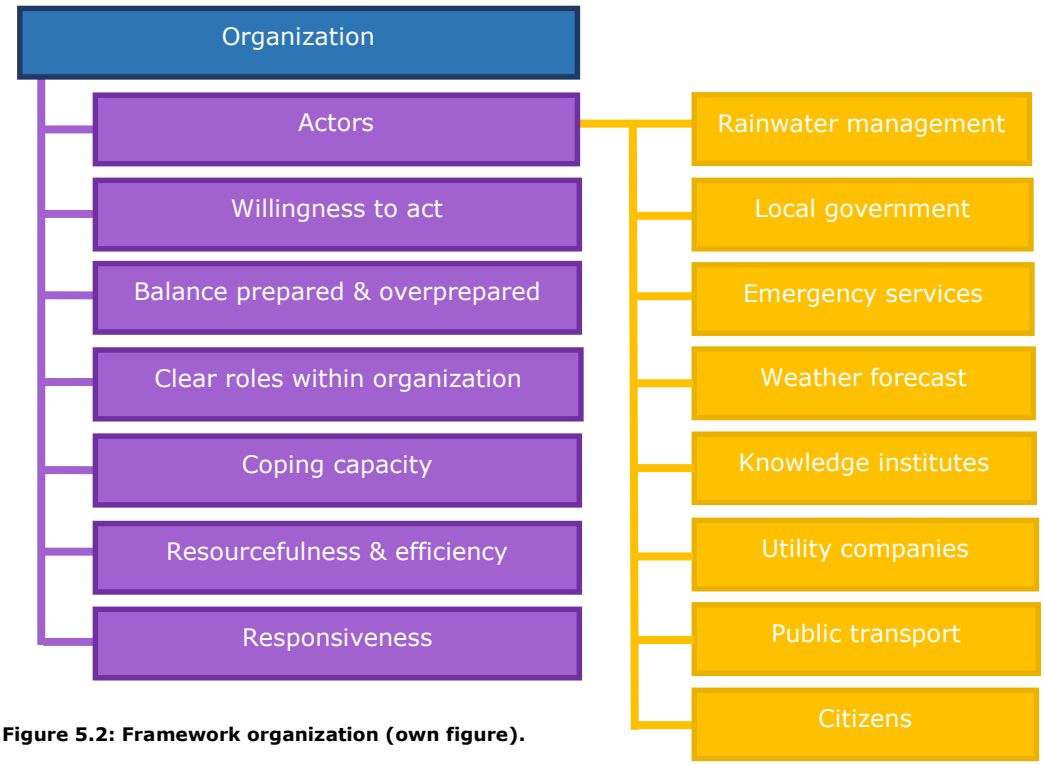


**Figure 5.2: Framework organization (own figure).**

In figure 5.2, the aspects that are relevant for good organization in all phases of cloudburst emergency planning are outlined and these are further described below.

The actors that need to be involved in cloudburst emergency planning in a specific city are the organizations that are responsible for rainwater management, the local government, emergency services, weather forecast organizations, knowledge institutes, utility companies, public transport companies and citizens (see figure 5.3). This are the actors that should be involved. When actors do not exist or have a different role in some urban areas, they can be excluded. Also other actors can participate when they do have a role in cloudburst emergency planning in a city, but are not included in this blueprint.

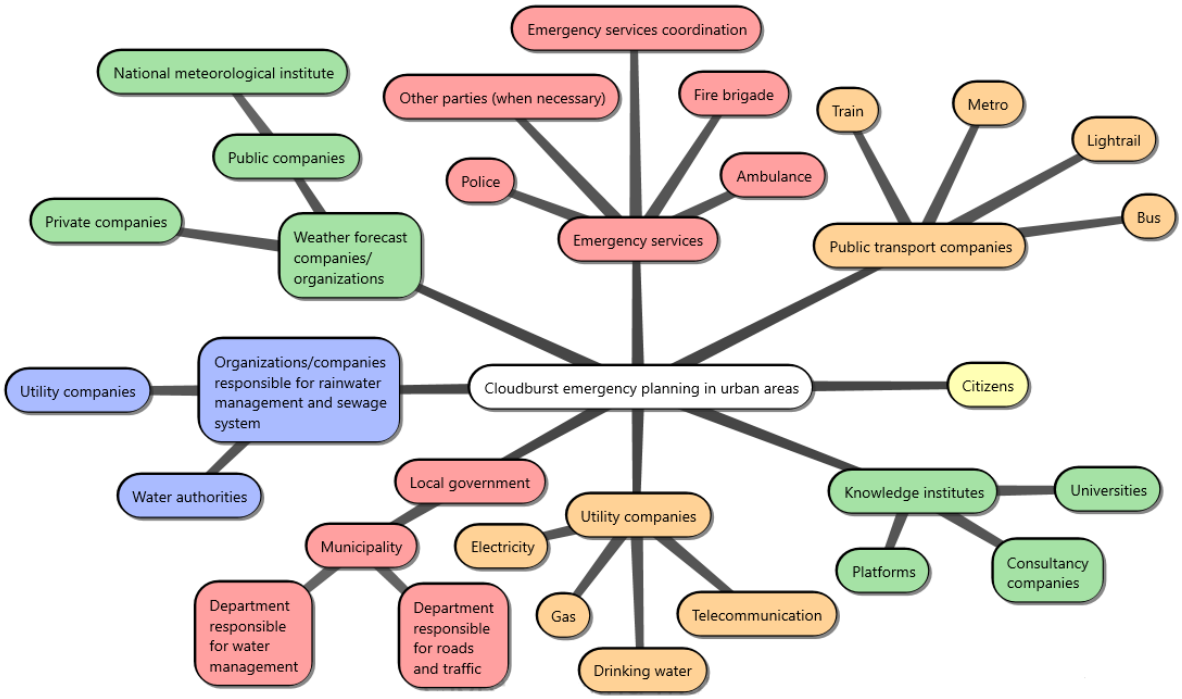


**Figure 5.3: Blueprint actors cloudburst emergency planning in urban areas (own figure). (See appendix D for a full page version)**

Organizations and/or companies that are responsible for rainwater management and the sewage system are often utility companies or water authorities. These need to be included because they are responsible for what is happening 'under the ground' and in the surface water.

The local government is a city is usually the Municipality. Often, only two departments need to be involved: the department that is responsible for water management and the department that is responsible for roads and traffic. The first needs to be included because it often also has some responsibilities in relation to rainwater management and the sewage system. The roads and traffic department is important for the temporarily closure of roads that are flooded.

The emergency services that need to be included are the fire brigade, police and ambulance. Emergency service coordination should be included to coordinate the actions of the different emergency services when this is presented and other parties can be asked to participate if necessary.

Weather forecast companies and/or organizations have a rather essential role in cloudburst emergency planning, because they provide information on precipitation, on the changes of extreme

precipitation and can provide early-warning. These companies and organizations can be either public or private.

Knowledge institutes like platforms, universities and consultancy companies can play an important role in developing and providing information about what can happen, the effectiveness of possible measures and by building bridges between the different actors.

Utility companies that are responsible for the provision of electricity, gas, drinking water and telecommunication should be part of cloudburst emergency planning, because parts of their network can fail due to flooding, which can hamper the response and recovery and can increase damage and nuisance.

Public transport companies that are responsible for train, metro, light rail and bus can be part of cloudburst emergency planning, because parts of their infrastructure are often risk points. But they should only be included when this is really the case. *"When a bus station is located on top of a dike and all the rain flows down from it and nobody has problems, except for the fact that you are getting wet, you do not have to bother anyone"* (Kluck, interview, 10 March 2016)(own translation).[1]

Citizens can play a rather important role in cloudburst emergency planning, because they can limit the damage and nuisance by taking measures themselves and by providing information on what is happening and where the problems are.

Actors need to be willing to act and be aware of the possible consequences of heavy precipitation, the importance of proper maintenance and of their responsibilities. Also, it is important to find a balance between being prepared and being overprepared. There needs to be preparation and the situation needs to be practices, but the preparation should be 'unnecessarily' too often or too strict. In addition to that, the roles, responsibilities and tasks of people need to be clear within the organizations, so people know what others should be doing, know who to contact for certain information and can call someone on. Further, the coping capacity of the organization needs to be large enough to be able to cope with unusual situations, coincidence and surprise. Therefore, there needs to be a balance between preparation and improvisation, so the organization is still flexible. Resourcefulness and efficiency is also influential. There needs to be good collaboration between departments of the same organization, offering citizens multiple ways to report problems and to have enough capacity to collect all reports to ensure this. Responsiveness is also meaningful. By having the scenario of heavy precipitation prepared and included in an emergency plan and have communication strategies ready, the response can be done quick and efficient.

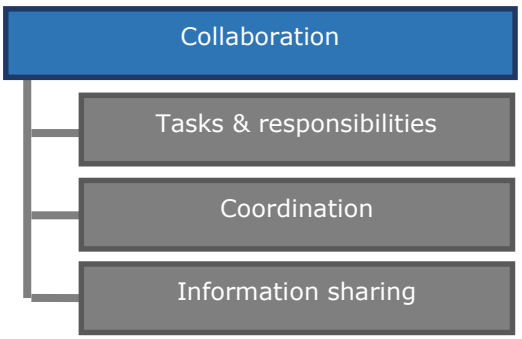


**Figure 5.4: Framework collaboration (own figure).**

5.1.3 Collaboration

The aspects that are important for proper collaboration in all phases of cloudburst emergency planning are outlined in figure 5.4 and presented below.

It is important that tasks and responsibilities of each actor are clear and that all actors are familiar with the other actors, their responsibilities, tasks and processes.

Coordination between the actors is crucial to limit the negative consequences of cloudbursts. The actors should coordinate where each actor is focusing on, know where to focus on together, know how efforts can be combined, make agreements, decide together what the situation is, decide which information they need, coordinate the use of manpower and equipment and inform each other on what they are doing and which decisions are made. In addition to that, bridges need to be built between organization, so the awareness of the consequences of heavy precipitation and the collaboration are improved.

The sharing of information is also very meaningful. Beforehand, information on bottlenecks and the output of simulations and analyses can be shared and/or these simulations, analyses and scenarios can be made together, so other actors are aware of what can happen and what the effect of possible cascading effects is. By making scenarios together, information is created by combining data from different actors. Another important aspects is the sharing of information on what is important for a specific actor, for example vulnerable objects, vital infrastructure and tipping points. The sharing of information on reports and the informing of other actors about what is happening and what they can do is necessary as well.

### 5.1.4 Total framework

During this research, the theoretical framework I develop in a previous research on cloudburst emergency planning in Rotterdam was developed further (see De Graaf, 2016). After comparing the framework with the results and analysis of this research, my interpretation is that the framework also fits to cloudburst emergency planning in Amsterdam and only needs to be changed by merging the elements 'cooperation', 'communication' and 'participation' in the concept of 'collaboration', to include all the processes characterizing these elements. I experienced that the different elements of resilience in relation to cloudburst emergency planning are less clear categories than I expected beforehand. A lot of the different aspects could be placed in several categories. Therefore, some interconnection exists between the elements. The aspects are placed in connection with the element to which they relate the most. In figure 5.5, the elaborations of the elements 'information and knowledge', 'organization' and 'collaboration' that were introduced above are included in the framework.

Four phases can be distinguished in cloudburst emergency planning: preparedness, event, response and recovery. In the preparedness phase, weather forecasts are followed and proactive measures are undertaken. During the event, response actions are started and the situation is monitored. Flooding and other problems are solved coordinated, effective, quick and prioritized. In the recovery phase, the event and the cloudburst emergency planning process are evaluated and the emergency planning is adapted if necessary.

Resilience is the main characteristic of cloudburst emergency planning. The elements that are important for this are: information and knowledge; organization; collaboration; and learning and application of new knowledge. These elements play roles in all the different phases.

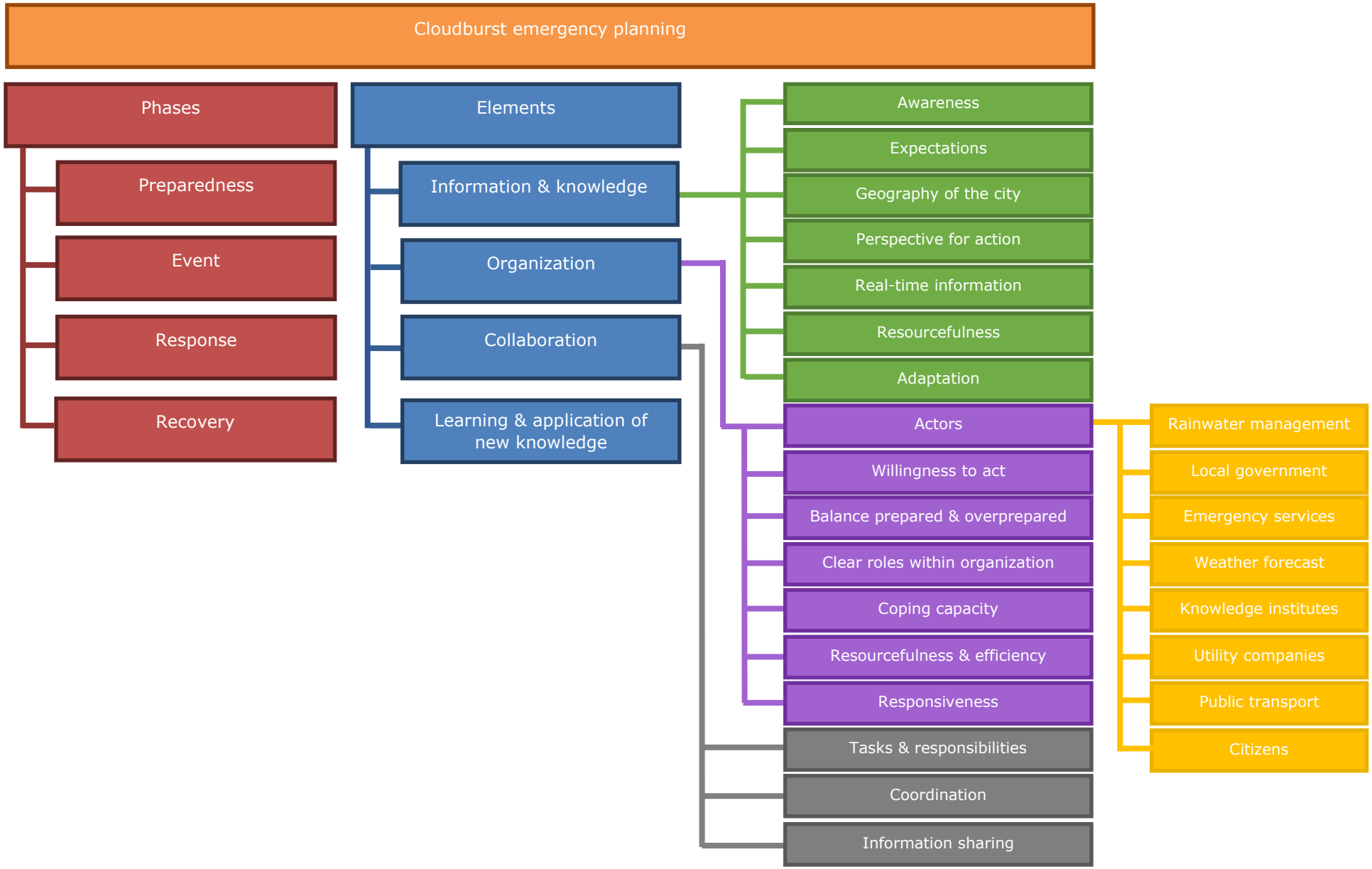


**Figure 5.5: Cloudburst emergency planning framework (own figure). Left: phases; middle: elements; and right: aspects.**

Information and knowledge is relevant for effective measures. Actors should be aware of the risks, have expectations on what might happen, know the physical and social geography of the city, have a perspective for action, have real-time information on what is happening, use resources effectively and know what happened and learn from it.

In relation to organization, it is important that the right actors are involved in the right way and that they are willing to take actions. The actors that need to be involved are: the actors responsible for rainwater management, the local government, emergency services, weather forecast organizations, knowledge institutes, utility companies, public transport companies and citizens. There should be a balance between being prepared and being overprepared, so events are not ignored but also the occasions of being unnecessarily prepared are limited. The roles within the organizations are clear and the organizations have enough flexibility to be able to cope with coincidence and surprise. The processing of reports should be done efficiently and all actors should have enough resources to deal with the potential high number of reports. Plans need to be ready beforehand, so the response can be done effectively.

For good collaboration, it is necessary that the actors know theirs and each other's responsibilities. The actors need to coordinate their actions so the situation is resolved efficiently and damage and nuisance is limited. By sharing of information, the actors know exactly what can happen, what is happening and what is important for each actor. An integral evaluation afterwards is important to learn lessons from what happened, but lessons can also be learned from developing new knowledge and from other cities.

### 5.2 Recommendations for cloudburst emergency planning in an urban context

On the base of the above theoretical framework, the following recommendations are given for cloudburst emergency planning in an urban context. Each recommendation is illustrated with an example of a vulnerability in cloudburst emergency planning in Amsterdam and an action through which this can be decreased.

#### 5.2.1 Make sure that information, organization, collaboration and learning are incorporated in the different phases

It is important that the elements 'information and knowledge', 'organization', 'collaboration' and 'learning and application of new knowledge' are embodied in the different phases of cloudburst emergency planning, which are preparedness, event, response and recovery.

Practical example Amsterdam: the collaboration between the actors is in all phases is rather limited. Action: beforehand, information on what can happen and on which measures are taken can be shared between the actors. During and after the event, information can be shared on problems and reports.

#### 5.2.2 Involve all necessary actors, make sure they are aware of the risk and consequences of heavy precipitation and are willing to act

All actors that have a role in cloudburst emergency planning in a specific urban context need to be involved. These are in general the rainwater management organizations, local government,

emergency services, weather forecast companies, knowledge institutes, utility companies, public transport companies and citizens, but also other actors that play a role can be included. All actors need to be aware of the risks in relation to heavy precipitation, the consequences of it and should be willing to take actions.

Practical example Amsterdam: the local public transport organization GVB is not involved in cloudburst emergency planning and is not aware of the risk and consequences of cloudbursts, but does suffer from the effects of cloudbursts. Action: cooperate more with actors as the GVB, make them aware of what can happen and collect information on when flooding causes problems for them. This can be done by using digital technology used to visualize possible scenarios. Amsterdam Rainproof is already working hard on making actors aware of the risks and consequences of heavy precipitation and should continue doing this.

5.2.3 Know the tasks, roles, responsibilities and have a perspective for action

All people and actors should know what the tasks, responsibilities and roles of themselves and each other are and what they should do before, during and after a cloudburst. This improves the efficiency of the measures and makes the response faster and better. Due to changing patterns of governance and increasing participation of citizens, these might have changed during the past years.

Practical example Amsterdam: other actors are often not aware of the responsibilities they have and often see Waternet as responsible for the effects of cloudburst. Action: make the other actors aware of their role and responsibilities in cloudburst emergency planning. Amsterdam Rainproof is already taking actions on getting the different responsibilities clear and informing other actors about their roles. This should be continued.

5.2.4 Know physical and social geography of the city and have real-time information

Having real-time information on what is happening in the city and knowing the exact location of all parts of the sewer system, where maintenance, construction and building projects are going on, which areas are vital and/or vulnerable and what can happen and which measures can be taken is very beneficial in preparing and knowing what to do and where to focus on. Urbanization and increasing concentration of economic activities in urban areas keep influencing and changing cities continuously.

Practical example Amsterdam: nowadays, different actors are unaware of where maintenance, construction and building projects are going on in the city that can influence cloudburst emergency planning negatively. Action: make an up-to-date database in which all involved actors register these kind of projects that can potentially limit preparedness, response and recovery and/or can cause extra damage and nuisance.

5.2.5 Find a balance between being prepared and being overprepared

It is important that there is a balance in cloudburst emergency planning, so that the planning gives guidance, but also leaves room for improvisation. The plan should not be a strict protocol which should be followed step-by-step, but should provide direction to manage the situation most

effectively and efficiently and to prevent that panic takes over the control in a situation where experts should take the lead. Also, the actors should have enough coping capacity to deal with coincidence and surprise.

Practical example Amsterdam: in the cloudburst emergency plan that is recently developed, the development of certain products is identified as beneficial for the organization. However, these products are not available yet and the people should be able to deal with this and find other ways to collect information where they can base their decisions on. Action: inform people in emergency organization of actors and make them aware that a certain amount of improvisation is requested and necessary.

5.2.6 Coordinate actions and share information among actors and evaluate afterwards

Actors should coordinate where each actor is focusing on and inform each other on activities and decisions. Also they should know where to focus on together, how the efforts of different actors can be combined and coordinate the use of manpower and equipment effectively. In addition to that, they should inform each other on what can happen by sharing the output of simulations and analyses, inform each other on bottlenecks, vulnerable objects and vital infrastructure in relation to their own systems and areas and share information on what is happening, reports and tipping points.

Practical example Amsterdam: when a cloudburst causes a GRIP-situation, the actions of different actors are coordinated by the Safety Region. But the chances that this will happen, are not very high. Therefore, the coordination and sharing of information between actors should also take place when the Safety Region is not involved. Action: coordinate with all actors who is going to take which measures where and how efforts can be combined. Also, provide information on vulnerable objects and vital infrastructure in own systems and areas to other actors. Amsterdam Rainproof is currently working on collecting information from different actors on this and should proceed with it.

### 5.3 Reflection on the research

The main objective of this research is to advance the theoretical framework for cloudburst emergency planning that I developed in a previous research (De Graaf, 2016) and use this framework to give recommendations to urban areas around the world about the different elements that are important in cloudburst emergency planning. A special focus is on the elements 'information and knowledge', 'organization' and 'collaboration', because these seem to be the most influential obtaining the goal of good cloudburst emergency planning. By improving these elements in the preparation, event, response and recovery phases of cloudburst emergency management, the negative effects, like flooding and other types of problems can be limited. In this way, this research can help to increase the resilience and reduce the vulnerability of the cities around the world in relation to cloudbursts.

This research has two limitations. The literature review was conducted selectively, due to time constraints. Only the main publications on the characteristics of resilience and vulnerability, the assessment and research of these two concepts in urban areas and how cities can become more resilient through planning are included. Selection criteria are that vulnerability and resilience have

to be linked with cities/urban areas, disaster management and/or flooding. More literature could have been included in the review when more time was available.

Another limitation is that citizens are not interviewed about their experiences with cloudburst emergency planning and what their role could be in it. Also, utility companies, large businesses and the company responsible for train traffic (NS) could have been included. This research is already quite elaborate. The fire brigade, Safety Region, GVB and Amsterdam Rainproof were included in this research and due to time constrains, it was not possible to also include the other actors more in the research. And there was a lot to do more. It would have been nice to see how cloudburst emergency planning is in other cities in the world, but because I preferred to stay in my home country and Dutch is my native language, this research was conducted in the Netherlands.

**Notes**

**1.** *"Als blijkt dat je je busstation bovenop een dijk hebt gelegd en alle regen loopt er vanaf en niemand heeft er last van, behalve dat je nat wordt, dan hoef je daar niemand over lastig te vallen."* (Kluck, interview, 10 March 2016)

## 6. Conclusion

Due to climate change, cloudbursts happen more often. At the same time, other changes like urbanization, increased concentration of economic activity in urban areas, digitalization, citizen participation and changing patterns of governance are taking place. Also, there is currently a discussion on if physical measures are enough to deal with floods or measures also need to be taken on other fields.

The main objective of this research was to advance a theoretical framework for cloudburst emergency planning and give recommendations to urban areas around the world about the different elements that are important in cloudburst emergency planning, so advice can be given on how to increase the resilience and reduce the vulnerability of the cities around the world in relation to cloudbursts. This is more or less a continuing of the Dutch perspective on living with flooding, which is developed on their long term experience in flood management because they live in a strongly flood prone area. The following research question and sub questions were formulated to achieve this objective:

> *How to plan for cloudburst emergency situations to increase resilience and reduce vulnerability in a specific urban context?*
>
> - *Which information and knowledge is necessary for developing an effective plan to handle vulnerability and increase urban resilience, how can this information be obtained and how can this information be accessed?*
> - *Who should be involved in developing and implementing the plan? What are the challenges for organizing collaboration among the relevant actors?*

By investigating the cloudburst emergency planning practices in Amsterdam and Rotterdam, it can be concluded that it is important that cloudburst emergency planning encompasses all the different phases, which are preparedness, event, response and recovery. Different elements need to be included in these phases: information and knowledge; organization; collaboration; and learning and application of new knowledge.

Actors should be aware of the risks, have expectations on what might happen, know physical and social geography of the city, have a perspective for action, have real-time information on what is happening, use resources effectively and know what happened and learn from it. This information can be obtained by combining the knowledge of the different actors and developing the missing information by doing observations and by making simulations and scenarios. The information can be accessed and combined in an information sharing tool, for example LCMS.

Also, it is important that the right actors are involved and that they are willing to take actions. The actors that need to be involved are: the actors responsible for rainwater management; the local government; emergency services; weather forecast organizations; knowledge institutes; utility companies; public transport companies; and citizens. There should be a balance between being prepared and being overprepared, so events are not ignored but also the occasions of being unnecessarily prepared are limited. This is also important for the efficiency. The roles within the organizations are clear and the organizations have enough flexibility to be able to cope with

coincidence and surprise. The processing of reports should be done efficiently and all actors should have enough resources to deal with the potential high number of reports. Plans need to be ready beforehand, so the response can be done effectively.

For good collaboration, it is necessary that the actors know theirs and others responsibilities. The actors need to coordinate their actions so the situation is resolved efficiently and damage and nuisance is limited. By sharing of information, the actors know exactly what can happen, what is happening and what is important for each actor. The challenges for organizing collaboration among the relevant actors are that they are often not aware of their role and responsibilities and of the risks and consequences of heavy downpour. The collaboration is also hampered by some more practical issues, like different registration systems and the law which influences the sharing of information. An integral evaluation afterwards is important to learn lessons from what happened, but lessons can also be learned from developing new knowledge and from other cities.

This research has contributed to understanding how to increase the resilience and reduce the vulnerability of urban areas in relation to cloudbursts by focusing on emergency planning and to foster the collaboration between actors. It is better to invest in organizational practices and solutions than in structural measures, so it is possible to deal with extreme events which cannot be taken into account in the design of the system. Some interesting aspects have been highlighted which can further the current discussion on the use and importance of non-physical measures in flood management. More research could actually further this by doing research in other cities to test and advance this framework for cloudburst emergency planning and to understand what are important elements and aspects in relation to this type of emergency planning. Also, the element of 'learning and application of new knowledge' should be studied further, because it is an important element of the framework but was not studied in this research due to time constraints. It seems that the framework for cloudburst emergency planning can be best applied on urban areas in developed countries, with advanced rainwater management systems. But it would be interesting to investigate the relevance of the framework in less developed countries. The organizational part is even more important when the structure of the system is missing. Further research can also be done on the roles of citizens, businesses, utility companies and public transport companies, implementation strategies for cloudburst emergency planning in an urban area and establishing collaboration between the different actors.

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## Appendix A: Description workshop

On the 18th of April from 14:30 to 16:30, a workshop was organized to give employees of Waternet in Amsterdam and the Water Department of the Municipality of Rotterdam, who come in contact with heavy precipitation in their work, the possibility to meet each other and to share experiences and knowledge. The location of the workshop was 'De Rotterdam', one of the buildings in which the Municipality of Rotterdam has their offices. This location was chosen, because the Water Department is located in this building and therefore also the CPRW (Central Process- and Control room Water)[1]. A visit to this control room was part of the workshop. The room which was used this afternoon is located at the 40th floor, the top floor of the building, which is always a very inspiring location because of the magnificent views over the city of Rotterdam.

The participants of the workshop were selected in relation to their function and role in the organizations, the tasks and activities they conduct and their affinity with the topic. This resulted in a group of around 20 participants who all were interested in the topic and had something to bring to the table, but also were involved with it and viewed it from different perspectives (see table A1). John Jacobs of the Water Department of the Municipality of Rotterdam was asked to host the workshop, to connect the different elements of the day by a short talk and to steer the discussions. Raisa Salomon took care of taking pictures and the materials (pens, paper and post-its). This enabled that I could fully focus on the interaction between the participants and the results of the workshop in relation to my research.

**Table A1: List of participants in workshop**

| Name | Function | Organization |
|---|---|---|
| *Amsterdam* | | |
| Anja Kleijburg | Coordinator crisis management | Waternet (cluster Water system; Policy, Assets and Nautical management department) |
| Bas de Nijs | Control specialist | Waternet (cluster Wastewater; Water treatment management department) |
| Eljakim Koopman | Policy advisor | Waternet (cluster Wastewater; Asset management water cycle department) |
| Frank Tibben | Trainee of National Water Traineeship | Waternet (cluster Wastewater; Asset management water cycle department) |
| Jojanneke Dirksen | Policy advisor | Waternet (cluster Wastewater; Asset management water cycle department) |
| Louis van Parera | Program manager ("business as usual") & duty officer (emergency organization) | Waternet (cluster Wastewater; Sewer department) |
| Nico Beumer | Asset manager ("business as usual") & coordinator scenario's (emergency organization) | Waternet (cluster Wastewater; Asset management water cycle department) |
| Paul Juten | Crisis coordinator waste water | Waternet (cluster Wastewater; Water treatment management department) |
| Peter Wassenaar | Head of the Asset management water cycle Department | Waternet (cluster Wastewater; Asset management water cycle department) |
| Daniël Goedbloed | Program manager | Amsterdam Rainproof |
| Jody de Graaf (Organization) | Intern/researcher | Waternet (cluster Wastewater; Asset management water cycle department) |
| *Rotterdam* | | |
| Annemarij de Groot | Policy advisor water | Municipality of Rotterdam (cluster Stadsbeheer; Water department) |
| Bas de Wildt | Policy advisor water | Municipality of Rotterdam (cluster Stadsbeheer; Water department) |

| | | |
|---|---|---|
| Elijan Bes | Policy advisor water | Municipality of Rotterdam (cluster Stadsbeheer; Water department) |
| Jerôme Schepers | Operational manager | Municipality of Rotterdam (cluster Stadsbeheer; Water department) |
| Johan Verlinde | Assetmanager water | Municipality of Rotterdam (cluster Stadsbeheer; Water department) |
| Jorg Pieneman | Policy advisor water | Municipality of Rotterdam (cluster Stadsbeheer; Water department) |
| Michel Bunt | Policy advisor water | Municipality of Rotterdam (cluster Stadsbeheer; afdeling Water) |
| John Jacobs (Host) | Policy advisor water | Municipality of Rotterdam (cluster Stadsbeheer; Water department) |
| Raisa Salomon (Assistent) | Student | Hogeschool van Rotterdam (Student Watermanagement) |

The workshop started with coffee, tea and some biscuits, which helped to get the participants in the 'right', slightly informal, mood and setting. After that, the 'official' program started (see table A2). John Jacobs introduced the purpose of the afternoon, which for most participants was to meet their colleagues that are working in another city and to share experiences. For me, the purpose was to collect data, which I could use for my research. The intention of the first part of the workshop was to meet the desires of all participants. First, Johan Verlinde showed a short movie about the rain radar, which is used to detect rainfall in and around the city of Rotterdam and can be used to improve the steering of the sewage system (see figure A1). After that, questions were asked about the radar, what its capabilities are and if/how the information is and will be used. The second presentation was from Eljakim Koopman about the analysis he and Jojanneke Dirksen conducted on the cloudburst of 28 July 2014 in Amsterdam, the outputs of this analysis and how these are going to be implemented (see figure A2). A lot of questions were asked afterwards, which showed the interest of the colleagues from Rotterdam. Thereafter, the participants went to the 16th floor to

**Figure A1: Johan Verlinde showing short movie about rain radar (own picture).**

**Figure A2: Eljakim Koopman presenting the analysis of the cloudburst of 28 July 2014 in Amsterdam (own picture).**

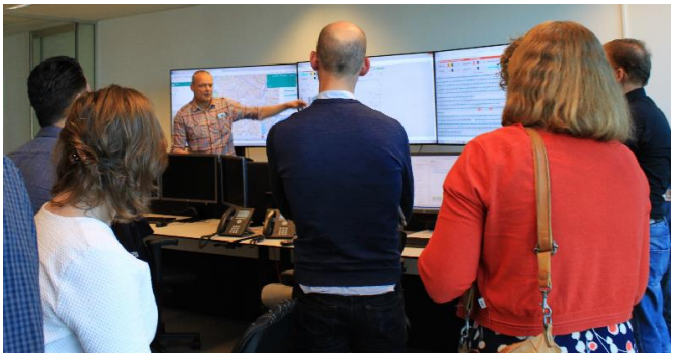


**Figure A3: Visit to the Central Process- and Control room Water (CPRW) with explanation of Jerôme Schepers (own picture).**

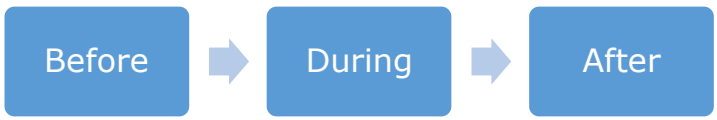
visit the Central Process- and Control room Water (CPRW) and got an explanation of Jerôme Schepers of the function of it and its role in dealing with heavy precipitation (see figure A3). In Rotterdam, the Water Department continuously has insight in what is happening in the sewage system and can steer all the different pumps from one location. This is not the case in Amsterdam and therefore, the participants from this city showed a lot of interest.

**Table A2: Program of workshop**

| **Time** | |
|---|---|
| **14:30** | Short introduction of the purpose of the workshop and short introduction of each participant |
| **14:40** | Exchange experiences and examples of how and what is happening now. Short presentations about the rain radar in Rotterdam by Johan Verlinde and the analysis and the outputs of it of the cloudburst of 28 July 2014 in Amsterdam by Eljakim Koopman and time for questions. |
| **15:10** | Visiting the CPRW (Central Process- and Control room Water) and explanation of the function of the room by Jerôme Schepers. |
| **15:40** | Brainstorm on areas of concern in relation to information, organization and cooperation before, during and after heavy precipitation. |
| **16:15** | Feedback first results and consultation about continuing the exchange of knowledge between Amsterdam and Rotterdam in relation to water management |
| **16:30** | End |

Following, the participants returned to the 40$^{th}$ floor, where I gave a short instruction about the next part of the workshop. In the invitation, a document was included with a scheme that would be used in the workshop and participants were asked to look at it beforehand. In the scheme, questions are asked in relation to actors, the sewage system, information, organization, communication and problems/barriers (see table A3). Four identical copies were put on the wall across the room and I asked the participants to distribute themselves over the different copies with a mix of participants from Amsterdam and Rotterdam at each copy and to fill in the scheme using post-its and pens with their ideas, opinions and experiences (see figures A4, A6 and A9).

**Table A3: Scheme "What to do before, during and after heavy precipitation?"**




| | | | |
|---|---|---|---|
| **Actors** | | | |
| - Involve which actors? | | | |
| - Why? | | | |
| **System** | | | |
| - What are you going to do? | | | |
| - What are critical objects and locations? | | | |
| **Information** | | | |
| - What do you want to know? | | | |
| - What do you need? | | | |
| - How can you get this information and how can you make it accessible for everyone who needs it? | | | |
| **Organization** | | | |
| - Who is doing what? | | | |
| - When are you going to do what? (which triggers?) | | | |
| - Who should do what? | | | |

| | | | |
|---|---|---|---|
| **Communication** | | | |
| - When are you going to send which message to which actors? | | | |
| **Problems/barriers** | | | |
| - Which problems/barriers do you experience? | | | |
| - Which problems/barriers can and/or do you expect to experience? | | | |
| - How could you prevent and/or resolve these problems/barriers? | | | |

When the participants had started to write down their ideas, I walked through the room to give some more instructions and to observe what happened. The participants should have the change to write down their own ideas, opinions and experiences, which was often done first. After that, participants at each copy started to discuss their ideas with each other and tried to identify more important elements, which was exactly what my intention was. A powerpoint presentation was running during the introduction of the workshop and the brainstorm part with some inspiring pictures of the effects of heavy precipitation around the world. During their work, I wrote down some interesting inputs. I used these in the feedback part of the workshop to ask participants to clarify what they meant and to talk about some ideas that I perceived as interesting and rather 'new' insights. The input that I used here was the post-it with a question mark at "Organization: who is doing what?" from Paul Juten, the post-it about (reversed) triage from Frank Tibben and the post-its from Nico Beumer and Jojanneke Dirksen, who were in different groups, on having information on projects that are happening in the city that can influence the cloudburst emergency management. The last part of the workshop was a short discussion about the idea of continuing this type of knowledge sharing on water management topics between the two organizations and cities. The response was very positive and people thought it would be very interesting to have meetings twice a year about a certain topic. An important point made was that the participants of those meetings should be relevant for the topic to get the best results, so the participants should not necessarily be the same as in this workshop.

**Figure A4: Group one: Jerôme, Johan, Jojanneke and Peter (own picture).**

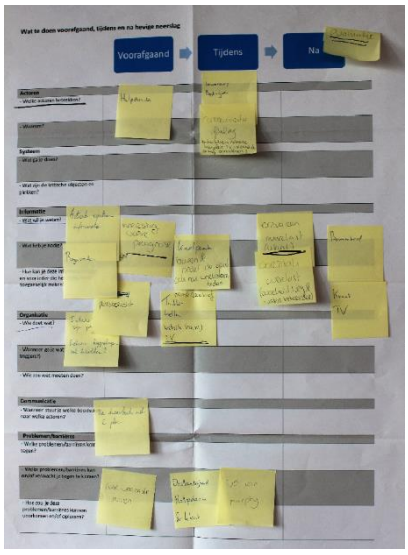



**Figure A5: Output group one (own picture).**

Afterwards, the schemes with outputs (see figures A5, A7, A8 and A10) were collected and analyzed in the days after the workshop (see table A4). Photographs were taken to be able to check the original location of the post-its in cause some would fall off.

**Figure A6: Group two (left): Annemarij, Frank, Louis and Michel & group three (right): Anja, Eljakim, Jorg and Paul (own picture).**

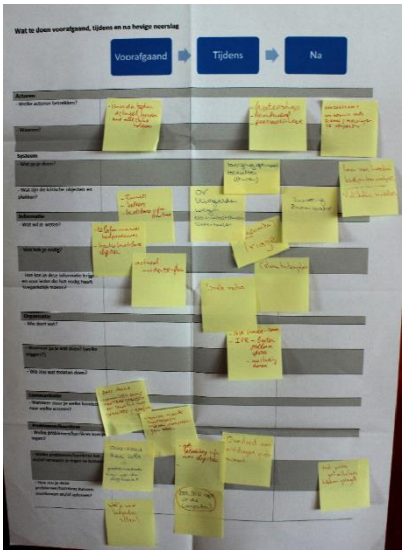



**Figure A7: Output group two (own picture).**

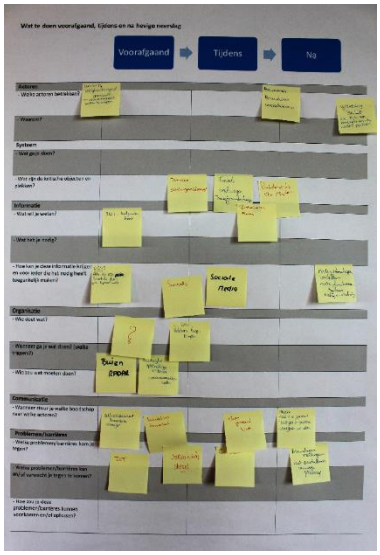



**Figure A8: Output group three (own picture).**

**Figure A9: Group four: Bas, Bas, Daniël, Elijan and Nico (own picture).**

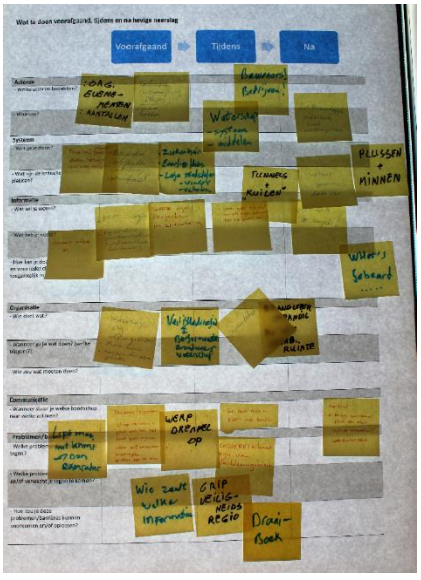
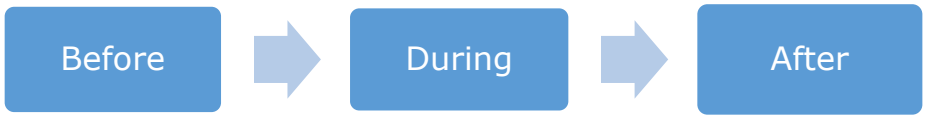



**Figure A10: Output group four (own picture).**

**Table A4: Input participants combined in scheme "What to do before, during and after heavy precipitation". Blue = group 1; green = group 2; red = group 3; and purple = group 4.**



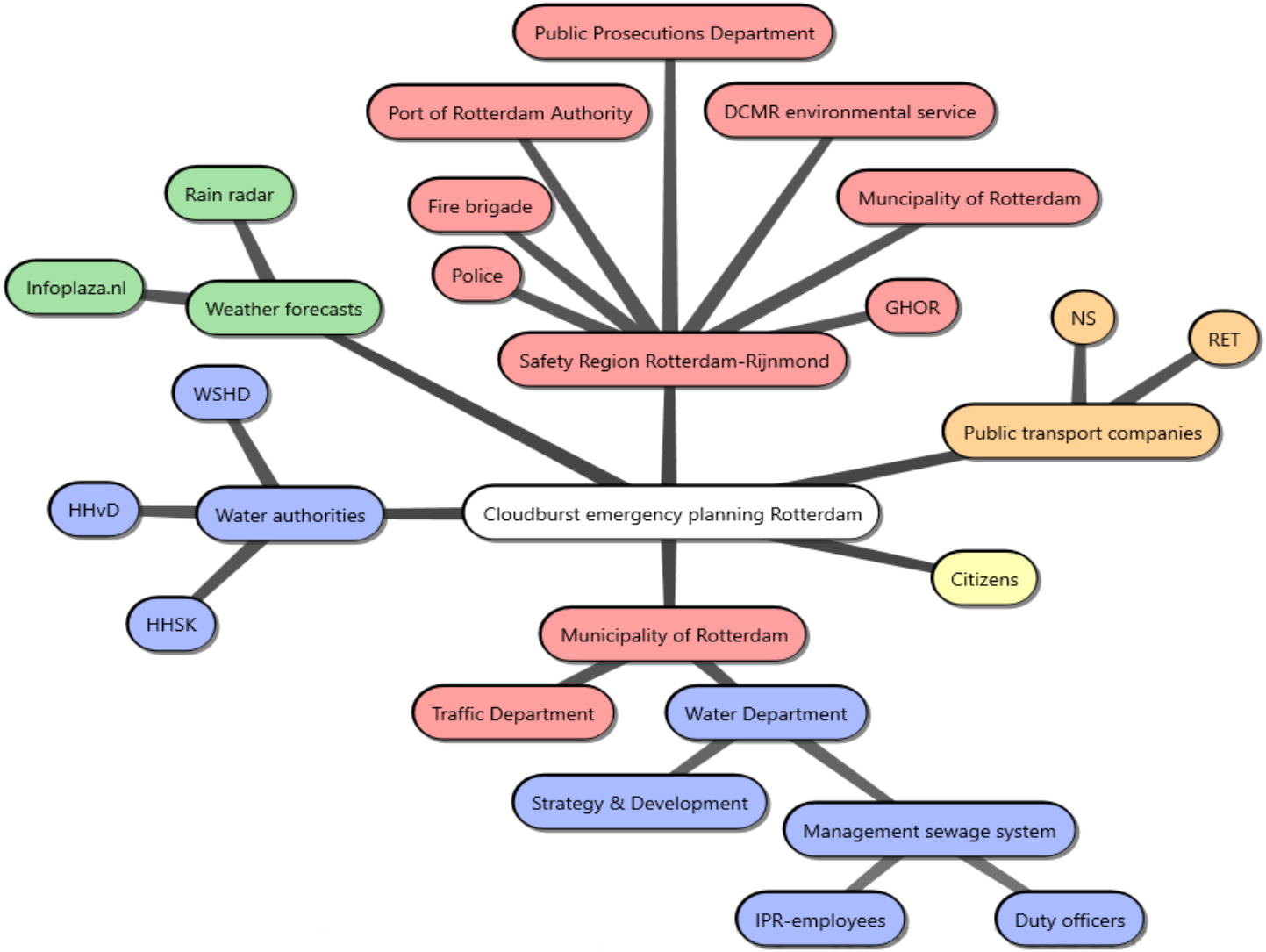

| | | | Evaluation |
|---|---|---|---|
| **Actors** | | | |
| - Involve which actors? | Emergency services<br>Keeping the emergency plan up-to-date with all actors<br>Safety Region (fire brigade, police) and Municipality to have the responsibilities clear<br>Organization events (numbers); districts (executing organization maintenance) (communication, gullies) | Citizens, businesses; communication department; involve external canals (TV, internet etc.) Active approach?<br>Water authority, fire brigade, press officer<br>Citizens, fire brigade, insurance companies<br>Water authority: system, materials; Citizens, businesses | Water authority, fire brigade, press officer; insurance companies, to gather information about damage/reports<br>Citizens, fire brigade, insurance companies; also resolve problems that are reported at other actors<br>Water authorities. Interaction sewage system water system |
| - Why? | | | |
| **System** | | | |
| - What are you going to do? | Preventive cleaning of gullies and possibly also sewage pipe in known vulnerable areas; special objects, water storage facilities operational | Optimal use of the water storage facilities (control) | Learn from the cloudburst. Analysis of bottlenecks. Validation models<br>Pros and cons; clean up rubbish, dead fish |
| - What are critical objects and locations? | Tunnels, basements, vulnerable infrastructure | Public transport, airports, roads, electricity cabinets, hospitals<br>Tunnels, highways (basins); tunnels, highways, transformer stations; hospitals, museums; manhole covers<br>Hospitals, energy hubs, lower parts of the city (shops, schools); tunnels + 'holes' | Treatment, bathing water<br>Manhole covers |
| **Information** | | | |
| - What do you want to know? | Real-time information system; forecast rainfall; bottlenecks on and underground, also in relation to maintenance or construction activities<br>Phone numbers emergency services; location vulnerable objects<br>3Di bottlenecks map<br>Millimeters rain, special circumstances (maintenance, construction, events); where is maintenance/ construction going? | Real-time information system; bottlenecks on and underground, also in relation to maintenance or construction activities; experience of nuisance (costumer); cause of problems (public authorities, road & water management)<br>(Reversed) triage<br>Where are the problems?<br>How much rain falls where?<br>Are all pumps working? | Real-time information system; experience of nuisance (costumer); cause of problems (public authorities, road & water management)<br>(Reversed) triage<br>Overflows on canals?; What happened? |
| - What do you | Rain radar | Rain radar | Rain radar |

| | | | |
|---|---|---|---|
| need? | Up-to-date emergency plan<br>Scenario analysis 3Di | Emergency plan | Emergency plan |
| - How can you get this information and how can you make it accessible for everyone who needs it? | Press release; twitter, phone calls, website (nu.nl), tv. Pro & reactive<br>LCMS (also in case of a potential phase 1); socials | Twitter, phone calls, website (nu.nl), tv. Pro & reactive<br>'Fast' media<br>LCMS; socials; social media | Letter to citizens; newspaper, tv<br>LCMS; tell colleagues of water authority about functioning system (water ↔ sewage system) |
| **Organization** | | | |
| - Who is doing what? | Agreements are made with the organization. Also involve external actors?<br>?<br>Executive organization, repair service, control room, account holders districts; Safety region ↔ mayor, fire brigade, water authority | Agreements are made with the organization. Also involve external actors?<br>Water Department: communication. IPR: solve problems outside and steer third parties<br>Fire brigade: drain basements<br>Safety region ↔ mayor, fire brigade, water authority; emergency management; fire brigade inside building, Waternet public space | Agreements are made with the organization. Also involve external actors?<br>Fire brigade: drain basements<br>Fire brigade inside building, Waternet public space |
| - When are you going to do what? (which triggers?) | Weather radar; clear scaling-up criteria and responsibilities | | |
| - Who should do what? | | | |
| **Communication** | | | |
| - When are you going to send which message to which actors? | See road map with communication plan<br>Press/media: communicate knowledge vulnerable areas to residents/road users/businesses; people can take measures<br>Stimulate self-reliance of citizens; Give information what they can do<br>Residents/owners: Warning, there is a high chance on extreme downpour. Take preventive measures yourself (barrier for door); raise the doorstep | See road map with communication plan<br>What is happening where<br>Go home and install your barrier | See road map with communication plan<br>Media: what happened, what is done, what are we going to do.<br>Afterwards: raise doorstep, install a barrier. Go to rainproof.nl/ watersensitive010.nl |
| **Problems/barriers** | | | |
| - Which problems/barriers do you experience? | Too much information = problems can be perceived as less urgent; poor information about objects<br>ICT; design system<br>Use information from the KNMI, then use rain radar | Poor information about objects; too much reports at the peak<br>Design system; capacity<br>Inaccessibility of problem area | Reports made at the fire brigade are not available due to privacy |
| - Which problems/barriers can and/or do you expect to experience? | That the rain does not fall<br>Who is sending which information | Expertise helpdesk and costumer; Murphy's law<br>GRIP Safety Region | Expertise helpdesk and costumer<br>Not having set the right priorities |
| - How could you prevent and/or resolve these problems/barriers? | Do you know where the bottlenecks are?; have a good basis (objects) | Have a good basis (objects)<br>Road map | Road map |

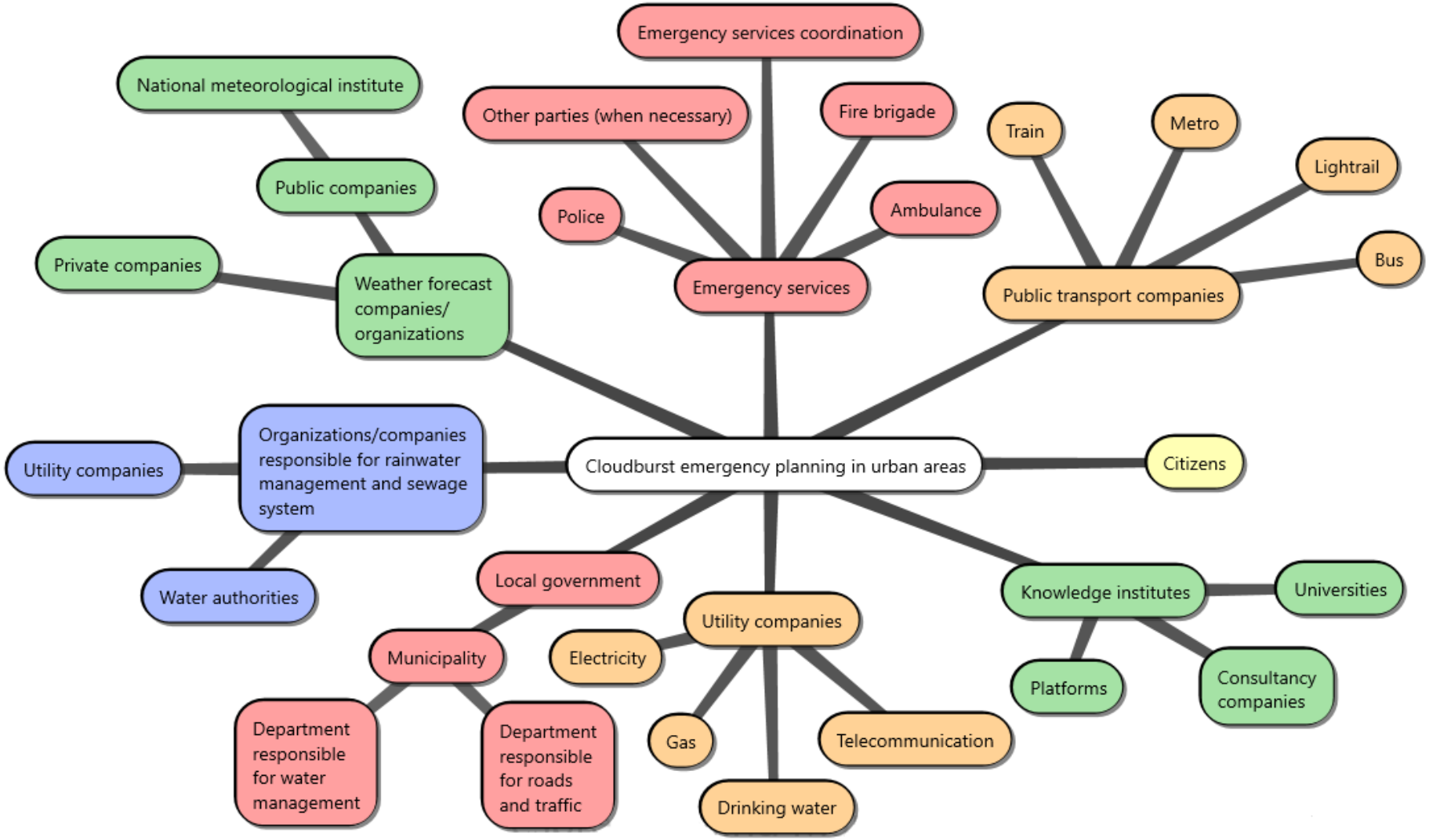
In my opinion, the workshop was very successful in improving the contacts between the water managers of Amsterdam and Rotterdam and sharing information about what they do before, during and after heavy precipitation. The outcomes for my research were a little disappointing, because not a lot of new information and insights were brought up by the participants. But when taking into consideration that I interviewed almost every participant in relation to my previous research on cloudburst emergency management in Rotterdam and/or my current research, the provided inputs should not have been very surprising. The consistency of the information obtained by the interviews and the workshops also provides insights on the credibility of it. Another factor that could have influenced the outcomes of the workshop is that the preparation of the participants was less than expected. A lot of them had not looked at and thought about the scheme beforehand because of lack of time or they were not aware of it, although it was clearly asked in the invitation of the workshop.

**Appendix B: Actors cloudburst emergency planning in Amsterdam**

**Appendix C: Actors cloudburst emergency planning in Rotterdam**



**Appendix D: Blueprint actors cloudburst emergency planning in urban areas**



**Appendix E: Time plan**

| | Week 5 (01-02/05-02) | Week 6 (08-02/12-02) | Week 7 (15-02/19-02) | Week 8 (22-02/26-02) | Week 9 (29-02/04-03) | Week 10 (07-03/11-03) | Week 11 (14-03/18-03) | Week 12 (21-03/25-03) | Week 13 (28-03/01-04) | Week 14 (04-04/08-04) | Week 15 (11-04/15-04) | Week 16 (18-04/22-04) | Week 17 (25-04/29-04) | Week 18 (02-05/06-05) | Week 19 (09-05/13-05) | Week 20 (16-05/20-05) | Week 21 (23-05/27-05) | Week 22 (30-05/02-06) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Orientation | X | X | | | | | | | | | | | | | | | | |
| Background reading | X | X | X | | | | | | | | | | | | | | | |
| Writing introduction | | | X | X | | | | | | | | | | | | | | |
| Writing theoretical chapter | | | | X | X | X | X | X | | | | | | | | | | |
| Preparations collection research material (interview guides etc.) | | | | X | X | | | | | | | | | | | | | |
| Collection research material | | | | | X | X | X | X | X | X | X | X | X | | | | | |
| Analysis research material | | | | | | X | X | X | X | X | X | X | X | | | | | |
| Writing methodology | | X | X | | | | | | | | | | | X | | | | |
| Writing analysis | | | | | | | | | | | | X | X | X | | | | |
| Writing results | | | | | | | | | | | | | X | X | | | | |
| Writing discussion | | | | | | | | | | | | | | X | X | | | |
| Writing conclusion | | | | | | | | | | | | | | X | X | | | |
| Writing abstract & preface | | | | | | | | | | | | | | | | X | X | |
| Finishing touch | | | | | | | | | | | | | | | | X | X | X |
| Hand-in | | | | | | | | | | | | | | | | | | X |

Milestones

Milestone 1: 25-03 First 3 chapters academic report finished (introduction, theory and methodology)

Milestone 2: 13-05 Draft version academic report finished

Milestone 3: 01-06 Academic report finished

After every 2 weeks (12-02, 26-02, 11-03, 25-03, 08-04, 22-04, 06-05 & 20-05), I send an update to Chiara about my progress and send draft versions of chapters.