Community Adaptation and Mitigation of Storm and Flood Risk: The Influence of Knowledge and Community Perceptions in the Case Study of Ekurhuleni

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Abstract

The role of local level governance and participation in managing climate disasters is gaining precedence in global and local (South African), discourse. In recent years, floods have caused major disasters in urban centres around the world. A lack of disaster preparedness in developing countries has resulted in much damage in urban environments. Such damage will have long-term repercussions for governance, communities and the natural environment. Heavy rainfall events are projected to become more intense and frequent due to climate change, and many recently affected areas may consequently face increased risk of flooding in future. A range of factors influences the ability to manage disasters through all phases of preparation, response and recovery at the local level. The objective of this research is to investigate the extent to which a range of factors interacts to either enhance or limit resilience to flood disasters at the local scale. This is explored through triangulating the results of three investigations into both physical and social factors of understanding and managing flood disasters. The case study of flooding in Ekurhuleni Metropolitan Municipality (EMM) in South Africa, with specific focus on the Atlasville suburb, provides the basis of the research. The research uses a multidisciplinary approach to examine disaster management, which includes perceptions and non-technical information in addition to statistical analysis. Flooding in the EMM is used as a case study to investigate how a multiple-perspective understanding of rainfall and flood events can help communities and municipalities better plan for and manage disaster events. This research argues that in order to understand the nuances of flood disasters, a combination of different sets of knowledge is necessary, as each set of knowledge plays an important part to inform how flood risks can be managed.

Dedication

To Luel, the love of my life

~

"...a cord of three strands is not easily broken"

Preface

Parts of Chapter 5 have been published as follows:

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>
> This chapter draws on this publication, however the work presented in the chapter is my own (with co-authored).

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Glossary of Terms

ACF	Atlasville Community Forum
ANOVA	Analysis of Variance
ARIMA	Auto Regressive Integrated Moving Average
BAR	Basic Assessment Report
BEN	Benoni Country Club weather station
BOK1	Boksburg, East Rand weather station
BOK2	Boksburg, Brandweer weather station
DELM	Delmas weather station
DIR	Disaster Incident Report
DMA	Disaster Management Act
DROP	Disaster Resilience of Place
DRR	Disaster Risk Reduction
EMM	Ekurhuleni Metropolitan Municipality
H_A	Alternative Hypothesis
H_O	Null Hypothesis
ICLEI	International Council for Local Environmental Initiatives
NDMC	National Disaster Management Centre
NDMF	National Disaster Management Framework
NIGE	Nigel, Brandweer weather station
ORT	OR Tambo Airport weather station (airport data includes previous airport names)
PULP	Geduld Pulp Factory weather station
SAWS	South African Weather Service
SD	Standard Deviation
SPR1	Springs weather station
SPR2	Springs, Olympia Park weather station

1 Contextualising Urban Flood Disasters

"How, at the levels of community, polity, space and time, will scientists' impersonal knowledge of the climate be synchronized with the mundane rhythms of lived lives and the specificities of human experience?" (Jasanoff, 2010, p238).

1.1 Research Context

In recent years, there has been a slow shift towards the role of the local level implications of global phenomena such as climate change in urban governance. Organisations and forums have been established to encourage research and knowledge sharing within and between cities in South Africa and elsewhere in the world (e.g. International Council for Local Environmental Initiatives (ICLEI), Ecocity Summit, South African Local Government Association (SALGA)). Building resilience[1], which is a key component of sustainability, has become the focus for many cities across the world (e.g. Carmin *et al.*, 2009; Cities Alliance, 2009). Currently, and in the future, natural disasters and the impacts of climate change, pose the greatest challenges for governance and resilience of urban residents and structures (O'Brien and Leichenko, 2000; Williams and Jacobs, 2011). Cities are at the intersection of many factors that compound and result in potentially high risk and vulnerability to disasters. Global and local trends of rapid urbanisation with a lag in infrastructural development has resulted in many people settling in marginal and vulnerable areas within cities (e.g. flood plains) (Vogel, 1996; Easterlings *et al.*, 2000; O'Brien and Leichenko, 2000; Gallopin, 2006; Satterthwaite *et al.*, 2007; Cutter *et al.*, 2008; Douglas *et al.*, 2008; Price and Vojinovic, 2008).

Since the start of democracy in South Africa, all levels of government have been faced with the challenge of providing infrastructure and basic services to those previously excluded. The progress in bridging this gap has been slow, particularly because of rapid urbanisation in many cities around the country. Furthermore, the focus on building new infrastructure has limited the resources available for maintenance in areas with existing infrastructure. Consequently, large numbers of people from a range of income groups are vulnerable to the impacts of climate disasters.

In light of the intersection between rapid urbanisation, poor infrastructure and service delivery, it is not surprising that disasters in the developing world tend to result in greater numbers of fatalities and affected people than disasters in the developed world (Kates, 2000; El-Masri and Tipple, 2002; Seneviratne *et al.*, 2010). Where vulnerable communities and vulnerable areas intersect, relatively small events translate into disasters that cause major damage to households and communities (Kasperson *et al.*, 1988; Satterthwaite *et al.*, 2007; Douglas *et al.*, 2008; Cities Alliance, 2009). This phenomenon is apparent in many urban areas where people have settled in flood plains and areas without formal drainage.

[1] Resilience is defined in this research as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (Walker *et al.*, 2004, p1)

Global circulation models reveal a likely overall increase in the intensity of the global hydrological cycle due to the increased energy from global warming (Fauchereau *et al.*, 2003). These changes are expected to be most notable as extreme rainfall events are projected to become more intense and frequent (Mason *et al.*, 1999; Bates *et al.*, 2008, Engelbrecht *et al.*, 2012). Despite the growing consensus regarding global and regional climate projections, there remains uncertainty as to how these projections will affect local areas and communities. It is likely, however, that many recently affected areas and communities may face more heavy rainfall and flooding in future. In the context of this information, the approach to minimising disaster risk is biased towards dealing with the physical risk. Disaster risk reduction (DRR) measures have focused on understanding and responding to the physical aspects of disasters, which can be limited, particularly because of the uncertainty of climate projections. Furthermore, disasters occur within and are influenced by social and political contexts, and cannot be accounted for by a physical perspective alone. Understanding the whole context of disasters enhances the possibility of effective DRR.

Perceptions of storm and flood risk play an important role in how people engage with current events and future risk (Dow *et al.,* 2007; IPCC, 2009). Risk and vulnerability to disaster events are perceived differently among individuals and different sectors of society, because the impacts of these events are not homogenous across urban areas or within communities (Cutter, 1996, O'Brien *et al.,* 2004). Harvatt *et al.* (2011) argue that the experience of a disaster influences the individual perception of future risk, which in turn influences responses. Engaging with community vulnerability and perceptions of extreme climate events across different areas and communities is essential if risk to these events is to be effectively addressed. Although it is well understood that lower income communities have low coping capacities and are thus more vulnerable to risk (Bulkeley, 2001; ISDR, 2004; Gallopin, 2006; Douglas *et al.,* 2008; Bates *et al.*, 2009), the complexities of building resilience in a developing context are comparatively unexplored. Daily challenges influence the capacity of individuals and municipalities to cope with extreme events, and it is within the individual and day-to-day context that adaptation is most likely to be effective (Janjua, 2010, Jasanoff, 2010). These complexities and challenges are articulated through the range of perceptions of risk in and across society. Understanding the complexity and challenges related to community vulnerability and perceptions thereof, is an important precursor to building effective structures and behaviours to reduce vulnerability and build resilience to these risks (Vogel *et al.*, 2007).

Communities that have a low level of resilience to disasters may be able to build resilience through effective DRR decision-making that is rooted in experience- and perception-based knowledge. Communities can be empowered through acknowledging that their experience and social networks are valuable components of building locally specific solutions to disaster risk. Yamamura (2010) draws attention to the importance of communities using relevant information and knowledge of disasters to help protect them from future disasters, particularly through building social networks and structures to help them prepare for and cope with disasters (Harvatt *et al.,* 2011).

In addition to community vulnerability, a lack of disaster preparedness in the developing world has resulted in much damage in urban environments. Such damage will have long-term repercussions for governance, communities and the natural environment. In light of this, disaster governance needs to ensure a reduction of risk and increase in resilience to disasters. Urban governance underpins the ability to manage disasters, through all phases of preparation, response and recovery. Disaster management in South Africa is guided by the Disaster Management Act (DMA) No. 57 of 2002, which provides the policy requirements and stipulations for disaster management at all levels of government. However, the implementation of this act has been limited, particularly at the local municipal level. The challenge of ensuring effective disaster management at the local scale is not restricted to South Africa. In recent years, this challenge has sparked a burgeoning debate on DRR around the world, and many cities have worked on upgrading disaster response plans to build resilience to climate events in cities, particularly in light of predicted outcomes of climate change. Much of the focus of these debates is from a developed perspective (e.g. Ligeti *et al.*, 2007; Shaw and Theobald, 2010). There is a great need for such research to be focused in developing regions and address the complex interactions between natural, social and political spheres related to disaster management at the local level. Understanding political and community contexts, and how they interact can reveal the direct and underlying causes of flood risk, which are necessary for developing effective DRR strategies. It is important to acknowledge that political and community contexts are strongly influenced by local context and history.

An improved understanding of the complexities of context and history, however, does not automatically increase resilience to natural disasters (Vogel *et al.*, 2007). Other factors also play an important part in local government responses, such as the underlying power distributions and competing interests and priorities (e.g. poverty reduction and job creation vs. DRR) (Koch *et al.*, 2007). In order to understand these complexities and influence how disasters and disaster risk are managed, combined knowledge of the hazard and people's experience and perceptions is required (Renn et al., 1992; O'Brien and Leichenko, 2003; Koch et al. 2007; Adger et al., 2009; Jasanoff, 2010; Harvatt et al., 2011). Integrating perceptions into policy is not widely applied, particularly not in a developing context. This study explores the limits and opportunities for such integration through a case study of a middle-income community in South Africa that has suffered flood disasters in the recent past. This research investigates both social and physical aspects of flood disasters, as each component addresses the limits of the other investigations.

1.2 Local context

Flood disasters in EMM have been identified by the municipality as a key problem, which affects a large proportion of residents from a range of socio-economic areas. EMM spans a wide spatial region, which has undergone rapid urban development during the past two decades (EMM, 2009). The topographic characteristics of the area in which EMM lies, facilitates wetland development and increases the likelihood of water build-up and subsequent flooding. The risk of flash floods is further exacerbated by sudden onset, intense thunderstorms, which are characteristic of the area. Pluvial flooding[2] has been identified as a key area that needs to be addressed, as flood disasters at the local level in EMM place a great burden on residents and EMM, with the effectiveness of DRR having been limited. Many of the flood disasters in EMM occur in informal areas with limited or no formal drainage. However in the past decade Atlasville, a middle-income area established in the 1970s, has experienced numerous flood disasters. Studies of disasters in developing countries tend to focus on the low-income communities as they are at the greatest risk. This case study, however, highlights risk and vulnerability to floods within a socio-economic group that is typically not thought to be at great risk of such disasters. This research investigates the different components of DRR within Atlasville in EMM, a middle-income area within an urban developing context.

[2] Flooding caused by rainfall

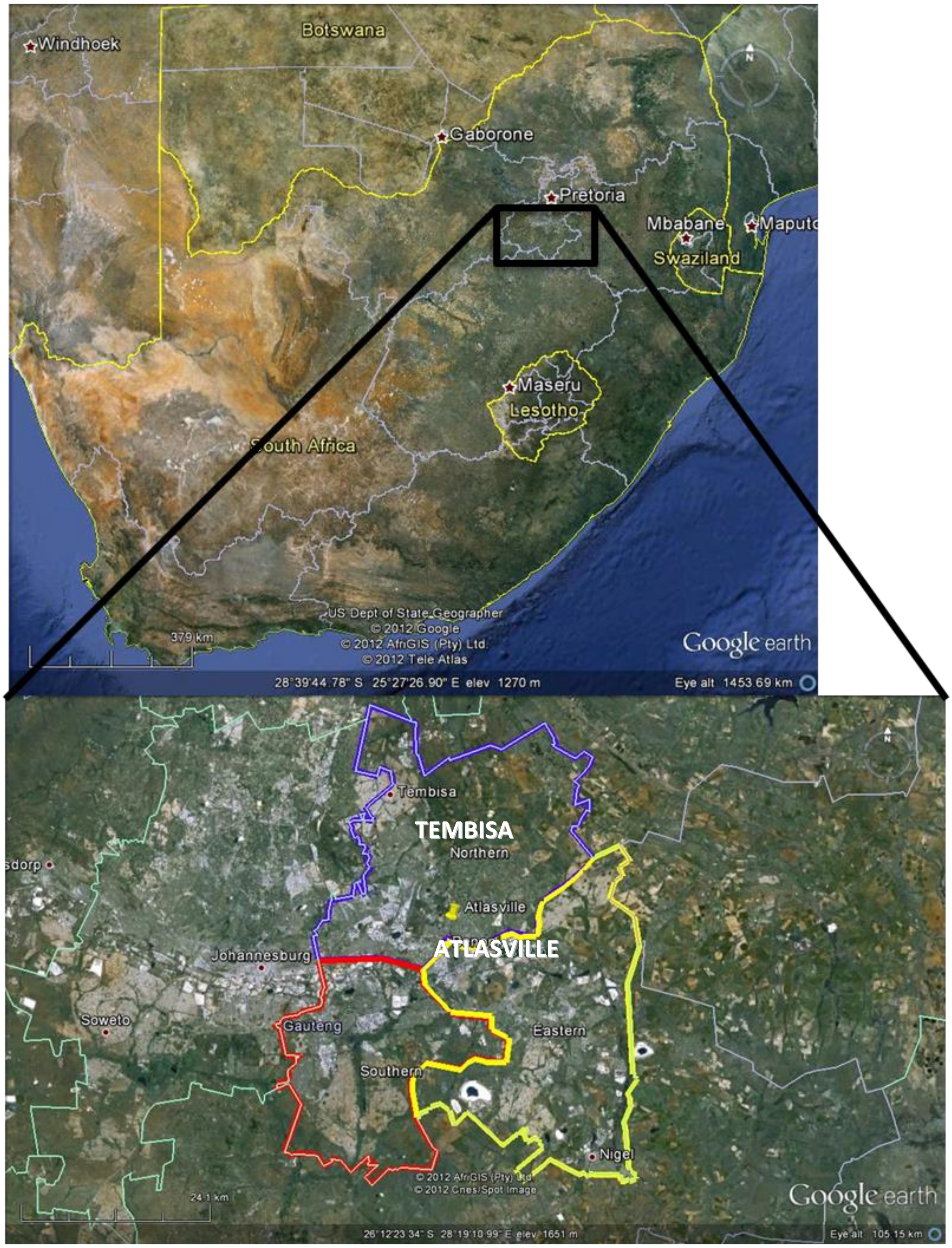

Figure 1.1: Location of Ekurhuleni in South Africa including the three regional areas, and Atlasville in the Northern Section (Google Earth).

1.3 Research Overview

In light of the overall flood problem in EMM, and specifically Atlasville, this project explores some of the different components that influence effective disaster management at the local level in EMM. The objective of this research is to investigate the extent to which a range of factors interacts to either enhance or limit resilience to flood disasters at the local scale. The factors examined are defined through the following research questions:

1. What is the physical context and status quo of disasters in the EMM;
2. How does the policy context influence perceptions and implementation of disaster management at the local municipal scale;
3. How do different stakeholders engage with disasters?

Kates (1985) posits that it is important not only to investigate the impacts of climate, and society, individually, but also to understand their interaction. This MSc research project is designed around gaining understanding of both physical and social factors relating to flood disasters, and to gain a deeper understanding of what types of knowledge influence how communities manage disasters. EMM is one such example where in the past few years, storms and floods have affected a range of communities that have responded in different ways to these events. The first research question is addressed through statistical and quantitative analyses of rainfall and disaster incident data for EMM. The second research question is addressed through analysis of policy and report documents, and interviews with municipal managers. The final research question is addressed through analysis of community experience and perceptions, which are extracted from interviews and public participation documents. The results of these investigations are subsequently triangulated to address the main objective of the research.

The concepts of vulnerability and resilience are necessary in order to understand and manage disasters. Vulnerability describes how internal and external factors within a system intersect and create the potential for damage to the system in the event of a hazard (Messner and Meyer, 2006; Cutter *et al.*, 2008). Resilience describes the way in which a system absorbs a disturbance (such as a disaster) and evolves in response to the disturbance, in a way that maintains the fundamental characteristics of the system. Many models exist exploring the interaction between these concepts. Cutter *et al.*'s (2008) Disaster Resilience of Place (DROP) model is used as a lens through which DRR is framed in this research, because it uses an integrated approach to the way vulnerability and resilience interact in the context of a disaster.

An integrated approach to DRR provides the opportunity for the barriers or limitations of one approach to be addressed by another. This is particularly relevant for the case study of flooding in Atlasville, EMM where a focus on either the physical or social context in isolation is insufficient to explain the context of flood disasters. This study investigates the extent to which knowledge, the political environment and risk perceptions influence disaster management from an integrated perspective. This framework not only defines different aspects of the research, but it also binds the physical and social investigations into a unified study. This approach aims to examine DRR from a system perspective, rather than the components of DRR in isolation. This enables the analysis of the interaction between the different components (e.g. physical, social and political), and the opportunity for knowledge to be co-produced through combining the different components.

In the context of this research, an investigation of storm and flood events is more comprehensive if social perceptions and responses to these events are included, because each approach is limited in its ability to explain the whole context of DRR. DRR strategies are designed in response to the existing knowledge of the disaster. Effective DRR strategies address disasters from an integrated systems perspective, and thus this research explores the whole context of disasters, and does not focus on just one component. In order to conduct such an investigation, a multidisciplinary approach is necessary. This research explores the need for forms of knowledge that take into account complexity, to guide decision-making about building resilience to disasters in developing countries. An overview of the dissertation in the forthcoming chapters is outlined.

The chapter hereafter is dedicated to the literature investigation, which investigates the theoretical context of DRR at the local scale. The theoretical framework links the range of components of DRR, with vulnerability and resilience at the centre of the investigation. The review is further dedicated to understanding a range of knowledge types related to DRR, including the physical context of rainfall and floods, the community context of local knowledge and perceptions, and the management context of DRR. The literature review chapter is followed by the design and methods chapter, which identifies the range of datasets and the methodology that is used to conduct each investigation of the research. Chapters 4, 5 and 6 are the results from the respective investigations into the physical, political and community contexts of flood disasters in EMM. These results are integrated and discussed to enhance the understanding of floods and DRR at the local level in South Africa.

2 Developing a Multidisciplinary Conceptual Framework

"A comprehensive theory is needed that is capable of integrating the technical analysis of risk and the cultural, social, and individual response structures that shape the public experience of risk" (Kasperson *et al.,* 1988, p113)

2.1 Introduction

Currently, and in the future, natural disasters and the impacts of climate change pose the greatest challenge for urban governance and safety of urban residents (O'Brien and Leichenko, 2000; Williams and Jacobs, 2011). In recent decades, there has been an increase in the number of reported disasters around the world (Bournay, 2005; Seneviratne *et al.*, 2010; Harvatt *et al.*, 2011). There has also been a global trend of urbanisation and, increasingly, development is taking place and people are living in marginal and vulnerable areas within cities (e.g. flood plains), particularly in the developing world (Vogel, 1996; O'Brien and Leichenko, 2000; Easterlings *et al.*, 2000; Gallopin, 2006; Cutter *et al.*, 2008; Douglas *et al.*, 2008; Price and Vojinovic, 2008). Effective DRR is vital to ensure the safety and sustainability of cities, particularly in light of climate change and rapid urban development. Urban flood DRR is positioned at the intersection between physical and social spheres. This research assesses a range of knowledges that are needed to understand the whole context of flood disasters at the municipal level in developing countries. This chapter forms a review of relevant literature from the three focus areas; namely the physical, political and community contexts of disaster risk and management. This review further provides the framework for the research methodology and analysis.

This research aims to investigate how knowledge[3] and perceptions can be amalgamated into an integrated understanding of disaster risk and how this can enhance the management thereof. The investigation is constructed around the concepts of vulnerability and resilience in a middle-income community in a developing context. The review asserts that information of different factors, including physical, social and political factors, influence vulnerability to disasters, and the ability to cope and adapt to them in the future. These concepts are explored through the lens of pluvial flood disasters at the municipal level in South Africa. The first three sections of the theoretical framework are dedicated to understanding different types of knowledge related DRR. These sections include the physical context of rainfall and floods, the community context of local knowledge and perceptions, and the management context of DRR. The conceptual framework of DRR, based on Cutter *et al.*'s (2008) Disaster Risk of Place (DROP) model, is developed to link the vulnerability and resilience components of disasters to response and management thereof.

[3] Knowledge is defined in this context as information regarding disaster events that is obtained through scientific investigation or indigenous knowledge bases regarding these events.

2.2 Physical Context of Rainfall and Flooding

Rainfall and flood events have recently caused great damage to infrastructure, lives and livelihoods across the world. In order to plan for and manage the associated risks, it is important to understand trends in frequency and intensity of these events (Bates *et al.* 2008). Highlighting past and projected rainfall trends that may potentially exacerbate flood risk in a local area is conducted through investigating the physical context (Ligeti *et al.*, 2007). Understanding past flood events and the rainfall characteristics that have been associated with past floods, may provide insight into the scale and potential of future events (Williams *et al.*, 2007). Past trends are important in providing an idea of the general rainfall patterns that can be expected from year to year, as well as what constitutes an extreme event for a specific area (Dyson, 2009). Examining these physical components can also highlight flood hotspots and allow municipal decision-makers prioritise areas and impacts (Ligeti *et al.*, 2007). Investigating and establishing robust information about current rainfall variability and trends is identified by Bates *et al.* (2008) as the first step in adapting to and managing future events.

2.2.1 Historical and observed rainfall

Convective thunderstorms bring the majority of precipitation to the Highveld[4] region of South Africa (Tyson and Preston-Whyte, 2000). Dyson (2009) conducted an investigation of daily rainfall in Gauteng, to gain a better understanding of rainfall variability in the area. Dyson (2009) identified that in Gauteng, January is the month with the highest average rainfall, and also identified January as the month with the greatest frequency of days with heavy and very heavy rainfall (daily rainfall exceeds 15mm and 25mm respectively). Further studies in South Africa have indicated that there has been an increase in intensity and frequency of heavy rainfall events and an increase in dry periods in the last 50-100 years (Kruger, 2006; New *et al.,* 2006; Douglas *et al.,* 2008; Fatti and Vogel, 2011). Findings from a study of EMM indicate that the number of thunderstorms per season[5] decreased between 1960 and 2009, while the average rainfall per storm increased (Fatti and Vogel, 2011). Accurate climate baselines for local regions reduce the uncertainty of climate projection models, and they allow disaster management strategies to be tailored to specific contexts. Reliable, long-term rainfall data and analyses, which are necessary for accurate climate projections, are not always available, particularly in developing countries, such as those in Africa (Easterlings *et al.,* 2000; Christensen *et al.,* 2007). Despite this uncertainty, climate projections are nonetheless useful for the inclusion in long-term development and management strategies. The greatest impact of a changing climate is likely to be experienced through an increase in extreme events (Fauchereau *et al.,* 2003).

2.2.2 Extreme rainfall and Climate Change

An extreme event[6] can be defined according to the rareness of the climatic event vis-à-vis the statistical distribution for the area, or by the impact that it has on infrastructure and society (Easterling *et al.,* 2000; IPCC, 2007). Figure 2.1 shows that according to this distribution, most rain days will comprise light rainfall, fewer medium rainfall and only a very small proportion of heavy rainfall days (Climate Change Science Program [CCS]), 2008; Fatti and Vogel, 2011). The rainfall distribution depends on historical analyses of rainfall events for a specific region, and is variable across temporal and spatial scales (Knight, 2011). Extreme rainfall events are defined as those events

[4] The Highveld region is situated in South Africa's central interior, in which the Gauteng province is located

[5] The rainfall season in the Highveld extends from October to March.

[6] Extreme events are defined in this study in terms of the physical hazard, (storm and rainfall events).

where their intensity[7] exceeds the 90th or 95th percentiles of heavy rainfall events (Easterlings *et al.,* 2000; Kruger, 2006; New *et al.,* 2006; IPCC, 2007; CCSP, 2008; Dyson, 2009). Because rainfall distribution differs across regions, threshold intensities above which extreme rainfall events are classified, vary (Easterlings *et al.* 2000; IPCC, 2007).

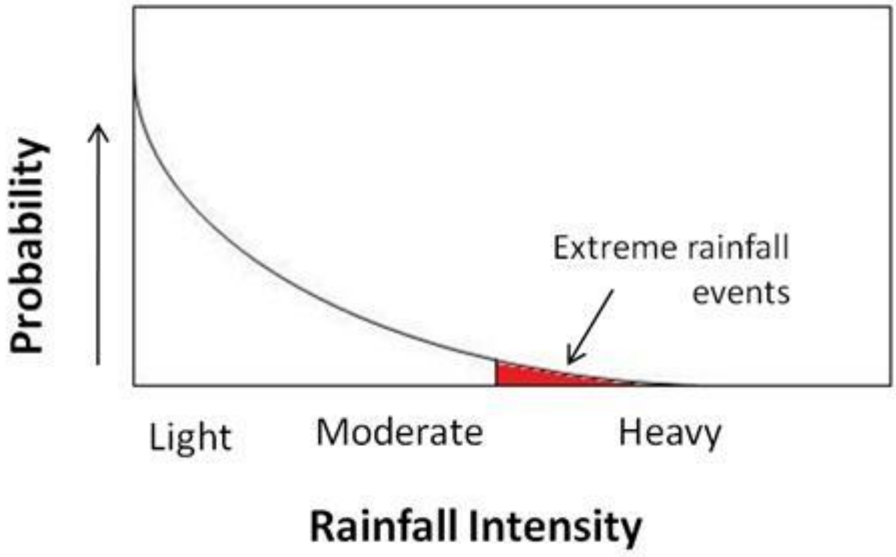

Figure 2.1: Schematic of daily rainfall distribution (Fatti and Vogel, 2011, after CCSP, 2008)

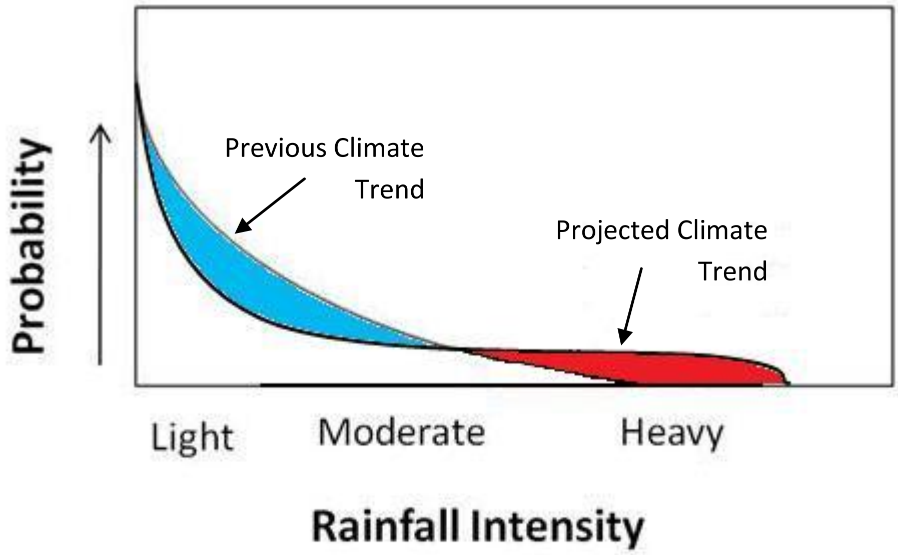

Figure 2.2: Schematic of likely climate change impact on daily rainfall distribution (CCSP, 2008)

There is, however, relatively high confidence in climate change projections that suggest that the hydrological cycle will become more volatile, with increased frequency of extreme rainfall events and droughts in different parts of the world (Fauchereau *et al.*, 2003; Huq *et al.*, 2003; Williams *et al.*, 2007; Bates *et al.*, 2008; Moser and Satterthwaite, 2008; Williams *et al.*, 2010). Figure 2.2 depicts the projected change in daily rainfall distribution considering climate change. The graph shows a decrease in days with light rain, and an increase in the number of days with heavy rain. The total

[7] Intensity is defined in this research as the amount of rain produced in one day

number of rainfall days is likely to decrease, thus leaving longer dry spells between rainfall events, and consequently the average intensity of rainfall events is likely to increase as the same amount of rain falls within a fewer number of rainfall events.

A recent study has shown that southern Africa is likely to show a trend of increased extreme rainfall events, particularly in the convective rainfall regions of the country (Engelbrecht *et al.*, 2012). Although there is increasing consensus regarding these likely changes, there remains great uncertainty regarding the implication of these projections on local regions. The paucity of downscaled climate change projections over Africa (Engelbrecht *et al.*, 2009), combined with the lack of baseline data, makes it difficult to further studies on the potential implications of floods and their associated impacts on society.

Climate forecasts and projections have come under criticism, particularly in developing contexts, due to the limited usefulness of their current form (e.g. Archer, 2003; Blench, 1999; Jasanoff, 2010; Roberts, 2010; Vogel *et al.,* 2007). The criticisms can be broken down to issues of scale and relevance. Climate change projections are highly complex and lose a great deal of meaning when they are simplified in order to make them applicable for local communities or managers (Blench, 1999). The scale of these projections is generally too coarse to give relevant information for local areas, and require detailed downscaling. Tailoring climate and flood information to specific contexts and users requires an understanding of how these risks are perceived by communities. This challenge arises, partly because of patchy weather stations and records. The paucity of data limits the ability to understand the rainfall distribution across municipal areas and, in turn, to draw conclusions about past and future floods.

2.2.3 Urban flooding

Urban flooding occurs where runoff exceeds the capacity of a drainage system to remove the water from an urban area. This research focuses on pluvial (rainfall related) flooding in urban areas. Some of the worst impacts recorded are from intense rainfall events that cause flash floods, which are very difficult to predict accurately, and consequently warn against (Dyson, 2009). Urban flooding occurs from both riverine and ponding sources. Riverine flooding occurs mainly from heavy rainfall events, where water does not infiltrate into the ground and instead, flows across surfaces in channelized flows. These torrents of water often flow very quickly through urban areas, being obstructed and directed by infrastructure and buildings and can cause much damage to infrastructure, people and vehicles (Moser and Satterthwaite, 2008). Ponding, on the other hand, results from stationary water due to saturated underground areas or blockages in stormwater systems for example, which prevent water from draining away and instead cause water to seep in from below and flood urban areas (Douglas *et al.*, 2008).

In areas where one or more of these contributing factors are present, these and the adjacent areas are more prone to flooding than other areas (Adger *et al.*, 2003, Dodman *et al.*, 2010; Douglas *et al.*, 2008). The type and scale of risk to storms and floods are variable across spatial and social scales. The Highveld in South Africa, for example, receives convective storms that can result in flash floods, whereas areas that receive frontal rain are more likely to experience a slow onset of floods. Thus, the relationship between rainfall amount or intensity and the scale of the flood is not necessarily proportional. With an increase in frequency of heavy rainfall events, as revealed in historical trend analyses and climate change projections (Bates *et al.*, 2008; Fauchereau *et al.*, 2003; Williams *et al.*, 2007), there is, nonetheless, likely to be a coupled increase in urban flooding events.

Although rainfall is the primary driver, there are many other factors that can influence the extent of urban flooding (Douglas *et al.*, 2008). Flooding disasters are exacerbated by increased density of settlements, impenetrable surfaces (such as roads, pavements, concrete surfaces etc.), blocked drains and poor waste management (Douglas *et al.*, 2008). These factors are often concentrated in urban areas. In light of this and other studies, merely a good understanding of climate forecasts and projections is insufficient in building resilience to natural disasters such as floods (Cohen *et al.*, 1998; Fatti and Vogel, 2011).

Understanding the causes of and managing urban flooding risk, is highly complex in some urban areas in developing countries, where development has occurred rapidly, and informal settlements have been built in high-risk areas (El-Masri and Tipple, 2002; Douglas *et al.*, 2008). These areas often have little to no planned drainage systems, which can lead to runoff flowing through houses and can thus cause extensive damage to property, and harm to people and livelihoods (Douglas *et al.*, 2008). In many cases, where formal drainage systems are in place, the maintenance thereof is insufficient, which reduces the effectiveness of drainage. In cases where rainfall patterns have shifted (e.g. increased rainfall per event due to a changing climate), the system design may no longer have sufficient capacity to deal with the flood load (Denault *et al.*, 2006, Douglas *et al.*, 2008). The disaster that resulted from recent flooding in Bangkok, Thailand, has been blamed, not on the unusually heavy rainfall, but poor management of the environment and urban areas (www.nytimes.com, 14 October 2011). It follows that a good understanding of climate forecasts and projections is insufficient in building resilience to natural disasters such as floods (Fatti and Vogel, 2011). An understanding of municipal and social contexts is necessary in managing the direct and underlying sensitivity to flood risk. Nevertheless, Adger (1996, p47) posits that an "...understanding of present climate variability on society will reduce the ultimate impacts of climate change on individuals and society".

The literature draws strong linkages between vulnerability to disasters and poverty, particularly in developing countries (Bulkeley, 2001; El-Masri and Tipple, 2002; ISDR, 2004; Gallopin, 2006; Bates *et al.,* 2008; Douglas *et al.,* 2008). The impacts of floods are rooted in development issues, but are not restricted to low income, unplanned areas. Where vulnerable communities and vulnerable areas intersect, relatively small floods translate into disasters that cause major damage to households and communities (Kasperson *et al.*, 1988; Satterthwaite *et al.*, 2007; Douglas *et al.*, 2008; Cities Alliance, 2009). The physical context of flood disasters is a vital component of understanding disaster risk, and a strong focus of this research is placed on this component. Nonetheless, this research argues that in addition to the physical hazard, complex interactions between civil society and local government, which are rooted in context and the history of past disasters, also play an important role (Hajer, 1995). An understanding of municipal and social contexts is necessary for effectively managing the direct and underlying causes of flood risk. The following section examines the political context of DRR.

2.3 Political Context of Disaster Risk Reduction

The day-to-day effects of storms and floods are borne by local communities and municipalities. It is the municipality's role to reduce these impacts, through disaster management designed for local contexts (Roberts, 2008). Local governments are responsible for providing disaster management in the form of development and disaster response strategies (Shaw and Theobald, 2010). It is vital to plan for both reducing the risk of future events and enhancing the recovery after such events. Both proactive and reactive responses are necessary in ensuring that communities and infrastructure can survive and thrive despite intense storm and flood events. Reactive responses are necessary to deal with storm and flood impacts as they arise. These can include rebuilding damaged infrastructure, evacuation as well as actions on individual and household scales. Planned mitigation is necessary to minimise the risk and intensity of future disasters, and can include early warning systems and community-led strategies. Effective DRR strategies are embedded in broader municipal infrastructure and services.

Many sites of rapid urban development are in areas that lack necessary infrastructure, resulting in higher disaster risk. In areas, where infrastructure development is desperately needed, but there is limited budget for this purpose, municipal officials have to prioritise the type of development that takes place (Lempert and Kalra, 2011). The lack of sufficient budget often prevents effective long-term strategies and plans (e.g. maintenance of existing and planned infrastructure) that should be put in place to ensure risk of future disaster events (Lempert and Kalra, 2011). In the Philippines, like many other developing countries, management of climate disasters is limited to disaster response, and there is limited to no strategic planning to mitigate such events or to build structures that encourage recovery of livelihoods, infrastructure and the local environment (Dodman *et al.,* 2010).

A full commitment to DRR includes providing opportunities for decision-makers and managers to support and encourage DRR approaches. This is accomplished through allocating appropriate budget and resources, and the space for creativity and innovation (Janjua, 2010). Creating an environment in the municipality that encourages the incorporation of adaptation into policy (particularly with respect to climate change) has proven to be dependent on a 'champion', who drives this vision and can encourage effective governance (Janjua, 2010; Roberts, 2008).

2.3.1 Governance

Governance is the concept that describes the systems of governing through ''authoritatively allocating resources and exercising control and co-ordination'' (Rhodes, 1996 in Bulkeley, 2005, p877). Bulkeley (2005) extends this description by including the need for a combination of state and non-state actors to fulfil different roles. In other words, different stakeholders take responsibility for roles where they have capacity and authority to do so. Governance is thus likely to vary across spatial and temporal scales. Botha *et al.* (2011) posit that local municipalities act as the bridge between government, policy, and society, as governance at the local level, builds linkages between management of municipalities and the day-to-day experiences and lives of those living in those areas. Good governance not only engages with society, but also ensures that there is synergy between local, provincial and national scale interventions (Bulkeley *et al.*, 2010). If there is cooperation across all these levels, limited resources can be directed most effectively, particularly in disaster situations. When resources are limited it is important to see where people's priorities lie in order to understand where the most effective actions can be directed.

Urban communities, in affected areas, are at the centre of the immediate impacts of and responses to storm and flood events (Adger *et al.,* 2009). Community vulnerability to climate events, such as floods is negatively affected by poor governance. In recent years, water resource management has tried to address this link through shifting from top-down management, which used technical information and predictions, to a governance approach that acknowledges the importance of engaging with society and other stakeholders (Pahl-Wostl *et al.*, 2008). Effective disaster management requires “an integrated, multi-sectoral, multi-disciplinary approach” (RSA, 2003, p6). There is a tension in South African disaster management legislation between addressing the range of different contexts and risk profiles across the country, and the need for a uniform approach to disaster management.

Effective governance relies on context specific information and tailors strategies to these contexts. Through combining different types of information, such as infrastructure requirements and management and social support structures in flood risk areas, management strategies can be devised to help prevent floods from becoming social disasters (Moser and Satterthwaite, 2008). Not only are ineffective strategies wasteful of limited resources, but strategies that do not take this variation across society and communities into account are likely to fail (IPCC, 2009). Combining scientific information with local knowledge and perceptions, may be the most effective way of reducing vulnerability to disaster events across all parts of society (Mercer *et al.,* 2009; Lempert and Kalra, 2011). In order to implement adaptation policies and strategies effectively, good governance and public participation is necessary (Janjua, 2010).

“When disasters occur or are threatening to occur, the initial response to the event comes from those directly affected by it” (RSA, 2005, p19), however, individual responses to storm and flood risk are often less understood and known than larger community- or government-led responses. Coordination within communities is important so that individual actions do not exacerbate or create greater risk for them or their neighbours (Moser and Satterthwaite, 2008). Pelling (2003) discusses the potential for civil society groups to provide alternative capacity for socially and politically excluded communities and individuals to reduce vulnerability to disasters. Relationships and trust develop over time through face-to-face communication between individuals, and facilitate social capital development that can be tapped into during or post disasters (Dietz *et al.*, 2003). Adaptation to risk in developing contexts, where government capacity is limited, can be initiated at a community level, and works from a ‘bottom-up’ approach (Ziervogel and Parnell, 2012). This relies on effective governance, which provides an enabling environment for community adaptation (Anderson *et al.* 2008).

2.3.2 Justice in Disaster Risk Reduction

Disaster risks are experienced differentially across society and communities in ways that are both related and unrelated to the spread of physical risk. The nuances of different situations are often lost when disasters are approached from a broad, city or community level perspective. Management that does not take the variation across society and communities into account is likely to fail to some extent (IPCC, 2009). The consequences of disaster events "can differ for different members of the same community as when some individuals or groups perceive an opportunity with change, and others perceive a loss, thereby changing community dynamics and complicating decisions about how to adapt and the apportionment of costs of adaptation" (McCarthy *et al.*, cited in O’Brien and Leichenko, 2003, p98).

The processes of environmental policy-making and disaster management are uneven where knowledge, values, power and perspectives vary dramatically across stakeholder groups (Gibbs and

Jonas, 2000; Dietz *et al.*, 2003). Middle and upper income groups generally have more influence over decisions than lower income groups, particularly those in illegal and informal settlements. As a result, these higher income groups are given more government attention (Douglas *et al.,* 2008). This means that the most vulnerable people and communities are not sufficiently supported by local governments. By excluding the perceptions and priorities of low-income groups, these communities are undermined and the risks that they face are unlikely to be minimised through municipal action (Burgess, 1999). The urban poor seldom have much of a voice or influence and are thus less able to ensure that their needs and priorities are considered in planning or adaptation (Douglas *et al.*, 2008). In developing contexts, middle-income groups often face increased disaster risk due to poor governance and municipal management. Understanding how middle-income communities make their voices heard in such situations may help guide how lower income groups can make themselves heard and build adaptive capacity to disaster risk. Understanding middle-income struggles in disaster situations can provide a baseline to contrast and construct the vulnerability that low-income groups are faced with in the face of disasters, and the different capacity and resource bases that the groups draw from.

Understanding and tapping into the current capacity of individuals and communities to cope with and respond to the impacts of climate events can empower people and communities (Bohle *et al.,* 1994). Individual and community "decisions are fundamentally influenced by the underlying distributions of power" (Koch *et al.*, 2007, p1329). The perception of one's own power or lack thereof, influences the fervour with which one argues, or the speed to which one backs down. Communities and individuals who understand their rights and the responsibility of the local authority are more likely to demand service and responses from the municipality, as well as to take responsibility for their situations. It is important for communities to be empowered through efforts such as education, improving available evacuation options and emergency action and encouraging participation in pre-emptive action (e.g. clearing drains of litter) (Douglas *et al.*, 2008). Hajer (2003) discusses the impact that citizens who become empowered through political protest can have in the political sphere. Different groups and communities are likely to engage in such protest in different ways, and understanding how each group gains influence, can guide how disempowered groups can make themselves heard. The following section investigates the role of community based knowledge and perceptions on disaster response.

2.4 Community Context of Knowledge and Perceptions of Disaster Risk

Effective DRR of climate disasters enables city inhabitants to be resilient in the face of these events. DRR includes pre-emptive and responsive actions (IPCC, 2007), which depend heavily on how people understand and anticipate the impacts of these events (Adger *et al.*, 2009). Mitigation and preparation efforts tend to be most effective when drawn from community perceptions and priorities (Victoria, 2003; RSA, 2005). The impacts of disasters are experienced on a local and community level and depend not only on the hazard, but also on individual social contexts (Renn *et al.*, 1992; Victoria, 2003), which are not homogenous across or within communities (Adger *et al.*, 2003; Pelling, 2003; Victoria, 2003; O'Brien *et al.*, 2004). In order to understand what shapes management of disaster events, it is important to recognise how vulnerability and risk to these events is distributed across society, as well as how these events are perceived. Individual contexts inform how people frame issues, their beliefs and the way they understand and describe the world, which in turn determines how they act and react to things (Kitchin and Tate, 2000).

Because "DRR is a community-driven process" (RSA, 2005, p18), understanding the perceptions held by individuals and different communities is a vital precursor to building effective structures and behaviours to reduce vulnerability and build resilience to these risks (Vogel *et al.*, 2007). Perceptions are defined here as the way in which individuals and communities understand flood risk, and they are born out of knowledge and experiences of these events (Dow *et al.* 2007). Beck (2006) posits that there are three possible responses to risk, namely denial, apathy and transformation. Individual perceptions of disasters, and their resulting responses can similarly be categorised into such categories. Renn *et al.* (1992, p137) posit that "events pertaining to hazards interact with psychological, social, institutional, and cultural processes in ways that can either heighten or attenuate individual and social perceptions of risk and shape risk behaviour". This suggests that people's responses to disaster risk are shaped by their individual experiences, knowledge and perceptions of this risk, and thus are not homogenous across or within communities (Mol, 2000; Messner and Meyer, 2006; Dow *et al.,* 2007; Adger *et al.*, 2009; Dodman *et al.*, 2010; Harvatt *et al.*, 2011; Fatti and Patel, 2012).

For example, a community that has recently been affected by a flood is more likely to take preventative action against future flooding, than a community that has never experienced a flood (Dodman *et al.*, 2010; Harvatt *et al.*, 2011; Yamamura, 2010). Beck (2006, p338) describes this as the "involuntary enlightenment" of a previously unknown risk, which may result in a proactive response to future risk. As a result, anticipatory adaptation efforts at a community level, tend to be most effective when they are based on the community's perceptions and priorities, as community members can take ownership and responsibility for these actions (Victoria, 2003). Allocating resources to reduce future risk is unlikely if the immediate risk to survival is high (Moser and Satterthwaite, 2008). Unless addressing risks is seen as a priority in communities' day-to-day lives, it is unlikely that action will be taken to avert these risks (Adger *et al.,* 2009). Mercer *et al.* (2009) reflect on the dynamic nature of local knowledge and management of disasters. As experience and knowledge grow and change, so do management of disasters and risk.

Local knowledge is defined in this research as knowledge gained by local communities through channels such as experience, community practices, institutions and information passed down from generations, to name but a few (Mercer *et al.*, 2009). Individual experiences are nuanced by history, social structures, and political environmental and spatial contexts (Jasanoff, 2010). Generalisations and averages often hide the range of vulnerability and resilience within one community. These nuances can only be discovered through in-depth investigation into individual and community experiences and perceptions. Local knowledge is fast becoming accepted as vital for reducing vulnerability to disasters (Mercer *et al.*, 2009), as it is locally specific. Harvatt *et al.* (2011) emphasise the importance of informal knowledge sharing through social networks. Exchanging first-hand experience and knowledge, is one of the most effective tools in social learning, which is in turn strongly links to the increased probability for communities to mitigate and prepare for disasters (Cutter *et al.*, 2008; Harvatt *et al.*, 2011). In a participatory study in Papua New Guinea, a lack of knowledge and loss of indigenous knowledge[8] were identified by communities, as factors that increased vulnerability to disaster events (Mercer *et al.*, 2009). The community's ability to combine

[8] Indigenous knowledge is defined in this research as local knowledge that has been passed on from generation to generation.

scientific knowledge with indigenous knowledge and perceptions, allowed them to minimise the risk of disasters effectively (Mercer *et al.*, 2009).

The task of obtaining and using local knowledge and perceptions is, however, onerous (Mercer *et al.*, 2009) and a report published in 2011 suggests that municipalities in South Africa have limited communication and involvement with public interest organisations and communities on issues related to disaster management (Botha *et al.*, 2011). The participatory vulnerability analysis conducted by Action Aid (Douglas *et al.*, 2008) provides an example of how community participation can be conducted in areas that have experienced floods. Focus groups were led through a range of questions regarding floods and community responses. It was found that many individuals felt that their knowledge and input was seldom considered in flood alleviation (Douglas *et al.*, 2008). Dodman *et al.* (2010) comment on the importance of municipalities and communities working together in building effective disaster response strategies. Such synergies also enhance the communication between levels of governance, which are particularly absent in most low income urban communities (Bulkeley *et al.*, 2010; Dodman *et al.*, 2010).

Disasters are not evenly distributed and different communities have different sources of resilience, such as insurance or social capital (Adger *et al.*, 2003; Neumayer and Plümper, 2007; Berke *et al.*, 2008). Hajer (2003) identifies the potential for citizens to become politically active through public protest, and in turn create change in their local community or municipality. Through acknowledging the different sources of resilience and adaptive capacity in communities, be they latent or active, adaptations can be tailored to the capacity available in different communities (Pelling and High, 2005). Recognising diversity across different communities is particularly important in realising how resilience is achieved or is not achieved across different communities, and where different types of social capacity lie. Identifying vulnerability to flood disasters relies on combining the physical characteristics of storm and flood events, with the way communities engage with these events. Understanding this vulnerability can play an important role in managing disaster risk.

2.5 Conceptual Framework of Disaster Risk Reduction

In order to understand and influence how local government and residents respond to specific disasters and disaster risk, combined knowledge of the hazard, people's experience and perceptions is required (Renn *et al.*, 1992; O'Brien and Leichenko, 2003; Koch *et al.* 2007; Adger *et al.,* 2009; Jasanoff, 2010; Harvatt *et al.,* 2011). Integrating scientific information with local knowledge and perceptions, may be the most effective way of reducing vulnerability and building resilience to disaster events (Mercer *et al.,* 2009; Lempert and Kalra, 2011).

The concepts of vulnerability and resilience, which frame this research, are contested in the literature. Nonetheless, they play important roles in DRR at local and community scales. In the context of DRR, which have been explored through different forms of knowledge and perceptions, vulnerability and resilience are discussed and linked through Cutter *et al.*'s (2008) DROP model. Although many models exist to explain the interaction between vulnerability, resilience and disaster management (e.g. Bohle *et al*., 1994; Cutter, 1996; Folke, 2006; Seneviratne *et al*., 2010), the DROP model integrates these components to be relevant for disasters at a local community level.

Vulnerability is a contested concept in both definition and application (Bohle *et al.*, 1994; Adger, 1996; Cutter, 1996; Huq *et al.*, 2003; Pelling, 2003; O'Brien *et al.*, 2004; Gallopin, 2006; Janssen *et* *al.*, 2006; Dow *et al.*, 2007; Janssen, 2007). It is rooted in both social and physical contexts and is perceived differently across and within communities and sectors (Pelling, 2003). Vulnerability is defined here as the characteristics of a system that create the potential for a disaster to cause damage to that system (Messner and Meyer, 2006; Cutter *et al.*, 2008). These characteristics are a combination of external and internal factors; namely exposure, sensitivity and coping capacity (Figure 2.3) (Bohle *et al.,* 1994; Cutter, 1996; O'Brien *et al.*, 2004; Luers, 2005; Messner and Meyer, 2006; IPCC, 2007; Cutter *et al.*, 2008; IPCC, 2009). Exposure is characterised by an external hazard, such as a flood (Bohle *et al.*, 1994; Cutter, 1996). The past and future trends in distribution, magnitude, frequency and intensity of an event give an indication of the exposure to that event. Sensitivity is a combination of external and internal factors. The external factors include, but are not limited to, location and robustness of infrastructure. The internal factors include individual features such as age, gender, income levels and health. Coping capacity comprises the ability of people or a system to respond to an event or disaster (Bohle *et al.*, 1994) and consists of both individual and community strategies such as insurance, early warning systems and community support structures.

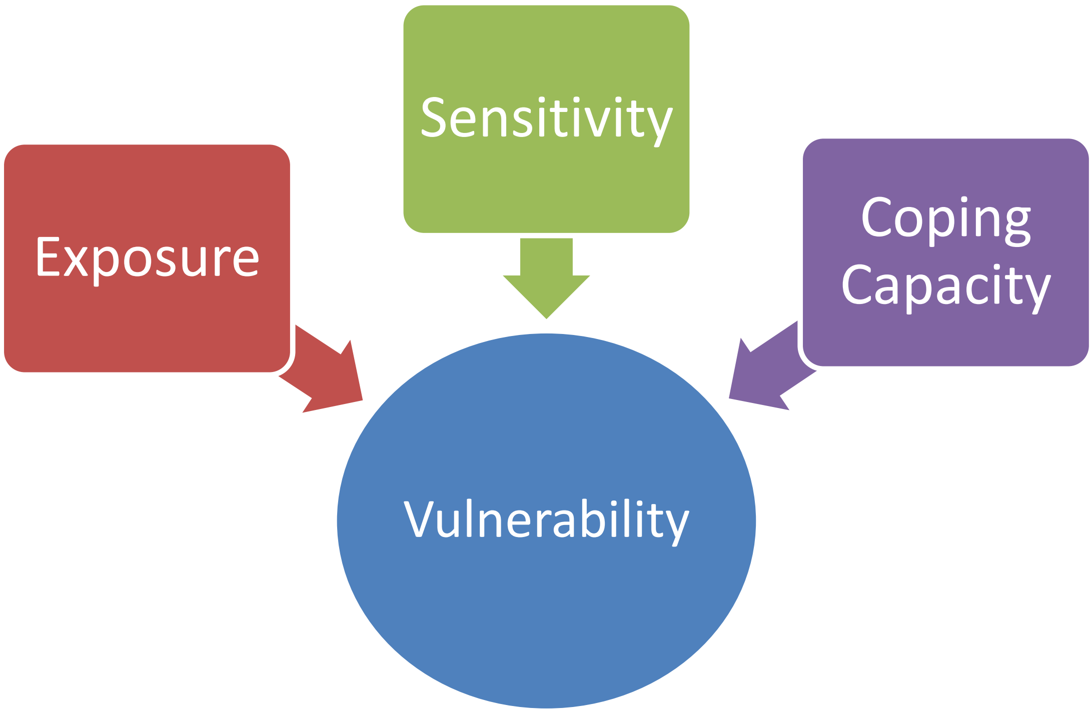

Figure 2.3: Visual depiction of the components of vulnerability

Although each of the factors of vulnerability has been described here in isolation, they influence and affect each other in ways that are not always identified or easy to describe (O'Brien *et al.*, 2004). Most of the debate around vulnerability arises from its complex construction in language and the struggle for the concept to encompass all the relevant factors and influences, but, at the same time, not lose value through being overly generic (Jasanoff, 2010). The way in which vulnerability is understood influences concepts of resilience.

There is broad agreement that in general, resilience is "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (Walker *et al.*, 2004, p1). Building resilience is, however, not just the ability to absorb the impacts of a disaster and return to the status quo before the event, but the ability to adapt and become less vulnerable in the future (Folke, 2006; Shaw and Theobald, 2010; Manyena *et al.*, 2011). Manyena *et al.* (2011) explore the idea of resilience being the ability to bounce forward and positively transform the fundamental structure of a system after a disturbance. Manyena *et al.* (2011) further argue that the resulting changes (e.g. physical, social and psychological changes) that affect social, economic and the environmental systems are more important than the disaster impacts themselves. Understanding how different stakeholders manage disasters can be more illuminating of potential disaster management strategies than understanding the disaster or disturbance (Manyena *et al.*, 2011). Resilience thus cannot be understood without a context and it is important to understand what or who is resilient, when are they resilient, and what they are resilient to, as these are not constant. Pelling (2003) and Folke (2006) assert that resilience is a proactive response towards risk. This suggests that there is an element of anticipation of a risk, which motivates a response, and in turn increases the ability of a system to recover in the event of a disaster. Understanding what drives changes in a system can help inform where strengths or weaknesses are and where adaptive capacity can be developed or used to improve disaster management A focus on resilience in governance thus means working towards proactive responses to anticipated risk, which enables society to prepare for disasters to mitigate the impacts, cope with a disaster and adapt to the resulting post-disaster state. Building resilience has become a key priority for many urban areas around the world, particularly in light of recent disasters caused by floods and the projected risks associated with climate changes (IPCC, 2007; Carmin *et al.*, 2009; Cities Alliance, 2009). Central to resilience and DRR are the concepts of adaptation and adaptive capacity.

Adaptation is the process by which changes are coped with and responded to (Gallopin, 2006). Adaptive capacity is the ability of a community to adapt, and the process of learning, which is one way that resilience can be developed. Pelling and High (2005) investigate adaptive capacity through the lens of social capital, and argue that "the multi-layered and multi-faceted social ties of everyday social interaction may be a community's best resource in maintaining a capacity to change collective direction" (Pelling and High, 2005, p317). The ability to respond and adapt to disaster events depends on the resources that are available and accessible to those affected (Bohle *et al.*, 1994; Adger *et al.*, 2003; Huq *et al.*, 2003; Dow *et al.*, 2007).

The DROP model (Figure 2.4) by Cutter et al. (2008), is used to frame the disaster management context of this study. This model describes the relationship between vulnerability and resilience to natural hazards, at a community level. The antecedent physical, socio-economic and political conditions provide a point of departure for the model. These combine with hazard characteristics, and are amplified or reduced by community coping responses, to produce the disaster impacts. The extent to which these exceed the community's capacity to absorb the impacts and learn to adapt, influences how effectively the community will recover. Social learning and recovery are identified as instrumental factors in determining and influencing the antecedent conditions in the subsequent disaster event (Cutter *et al.*, 2008). Messner and Meyer (2006) identify the influence that preceding disaster events have on the vulnerability of a system to a subsequent flood disaster. Risk perception is identified as an important factor that encompasses social learning and the way communities manage future disaster risk to enhance disaster resilience (Kasperson *et al.*, 1988; Messner and Meyer, 2006; Cutter *et al.*, 2008; Adger *et al.*, 2009; Dodman *et al.*, 2010; Botha *et al.*, 2011).

The DROP model facilitates the use of multiple knowledges through integrating the concepts of vulnerability, adaptive capacity and resilience. The feedback loops identify the cyclical nature of resilience, and the concept that experience of previous disasters influence the way future disasters are responded to (Harvatt *et al.*, 2011). This model is appropriate for this case study, not only in its ability to incorporate the range of contexts and their influence on DRR, but also the model's appropriateness at the local scale. The model dissects the whole process of DRR and identifies how different components influence and interact with each other, which facilitates the ability to identify barriers and opportunities for resilience that is context specific. This integrated approach of the DROP model that includes a wide range of factors suggests the need for a multidisciplinary approach to DRR.

2.6 Multidisciplinary Research

Resilience and disaster management in the past has had a strongly technical approach, which focused on understanding and responding to the natural hazard (Huq *et al.*, 2003; Ligeti *et al.*, 2007; Cities Alliance, 2009). Although this approach is necessary for effective DRR, it neglects the influence that social and governance systems have on the disasters themselves and the management thereof. In many research fields such as this, no single approach or technique can sufficiently explain or fulfil the requirements of the research (Lemos and Morehouse, 2005), and there is a need to include contributions from a range of disciplines that span across the social and natural sciences (Harris *et al.*, 2012).

In a study that aims to investigate both social and physical aspects of disasters, it is necessary for a multidisciplinary approach to be used, in order to enable the co-production of knowledge, which acknowledges different information and perspectives and to reveal different aspects of the same phenomenon (Bryman, 2007; Cartwright *et al.*, 2012). The co-production of knowledge is becoming a sought after attribute in research, particularly that which is used to inform policy (Lemos and Morehouse, 2005). However, a major difficulty in combining the two is that scientific quantitative research aims to be completely detached from the subjects whereas qualitative research aims to engage with the subjects, in a meaningful way (Latour, 1998).

Botha *et al.* (2011) discuss two schools of thought regarding disasters and disaster risk; namely constructivism and objectivism. Objectivism can be associated with natural science approaches, where a disaster or risk can be calculated through quantitative techniques such as mathematical formulae, and statistical and actuarial models. The constructivist school of thought can be paired more with the social science approaches, where disasters are seen as a social construction. This approach requires a qualitative investigation into understanding people's perspectives and attitudes towards the risk, as well as an assessment of the interacting social factors and stakeholders (Botha *et al.*, 2011).

The way research frames disasters directly influences the way those disasters are responded to and managed. Similarly, the way in which relevant stakeholders frame disaster risk (e.g. related to climate change or poor infrastructure), will influence the strategies that are developed. It is thus important that multidisciplinary research be conducted so that disaster risk is framed from a integrated perspective, and the limitations of individual perspectives are addressed through other perspectives. It is important to combine community knowledge and perceptions with scientific knowledge, if vulnerability to disaster events is to be reduced (Mercer *et al.*, 2009). Through identifying strengths and barriers of the different components of disasters and DRR, it is possible to find an integrated approach to DRR.

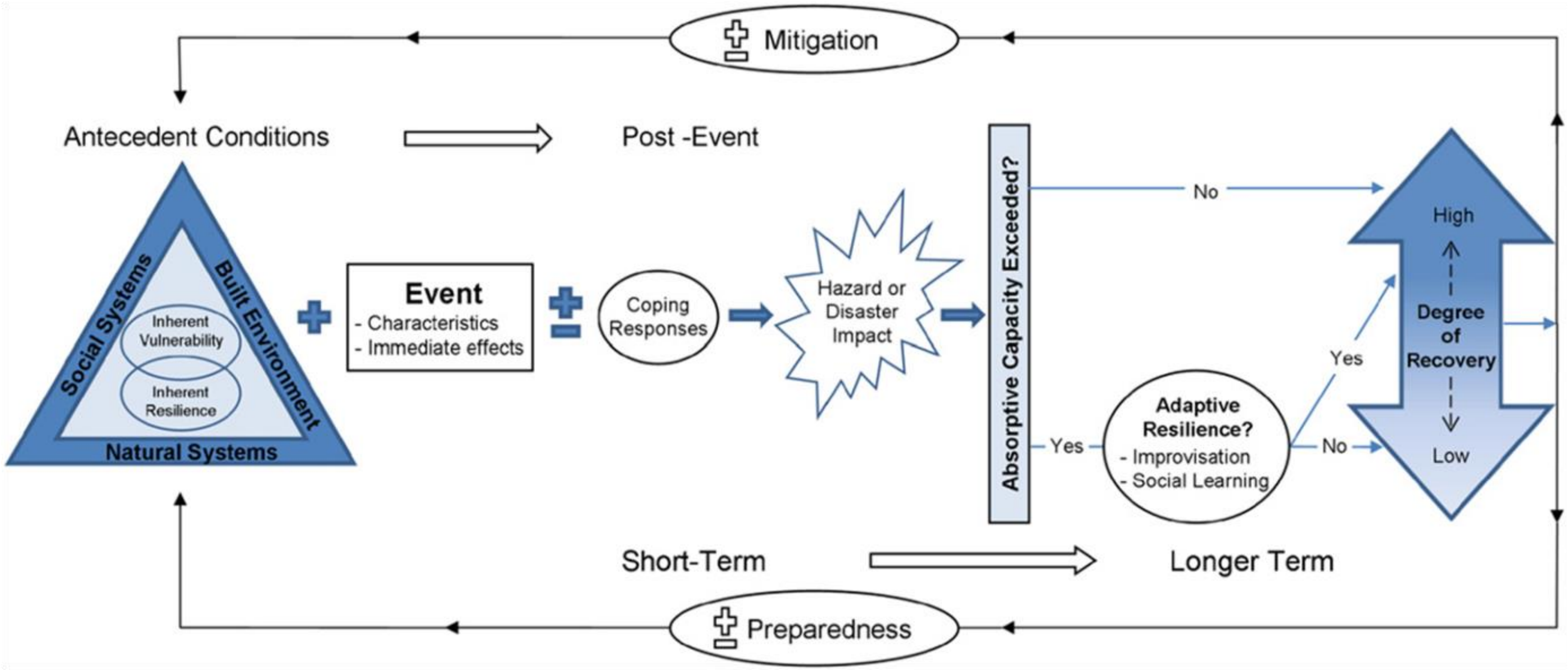

Figure 2.4: Cutter *et al.*'s (2008) Disaster Resilience of Place (DROP) model (p602).

2.7 Conclusion

In order to ensure effective municipal responses to flood risk, a good understanding of the risks to both physical and social environments is required. The impacts of climate events span across both physical and social boundaries. In the case of storm and flood events, the physical characteristics of these events and their spatial distribution are vital in understanding where the most flood prone areas are. Similarly, understanding how communities engage with these events is important so that vulnerable communities and areas can be identified. Community and individual responses, although very important, are not sufficient in dealing with all factors contributing to vulnerability and risk to rainfall and flood events. There is a need for household and community scale adaptations that focus on securing individuals and community, as well as for broad scale disaster management, infrastructure development and warning systems, which work towards ensuring the security of whole communities.

In this chapter, the literature related to DRR at the local and community level has been investigated, with specific reference to flood disasters. The review identified the need for all aspects of DRR to be considered as interrelated components of one system, and not viewed in isolation. Cutter *et al.*'s (2008) DROP model is used as a framework to link the different components. The review investigated how external exposure and internal sensitivity influence the ability to manage disasters at the local level. Physical rainfall and flood information is important for understanding the nature of the disaster hazard, and understanding the social and political contexts provides information on how knowledge and perceptions influence how disasters are experienced and managed. Understanding the local context of these issues is important if the risks associated with climate events are to be minimised. The justice issues associated with low income and vulnerable groups need to be considered when responses are planned and implemented, from both community and government perspectives. This is, however, difficult as a result of the limited understanding of the implications of differential risk due to storm and flood events and the intricacies of how the characteristics of these events affect different people and communities. The following chapter comprises the design and method for this research, which has been guided by the literature presented here. The research design acknowledges and addresses the gaps within and challenges of effective DRR at the local and community scale, and these challenges are explored through the case study of rainfall and flood events in the EMM.

3 Constructing the Multidisciplinary Research Approach

"…no matter how many theoretical approaches, data sets, or analyses are part of a research project, it will never answer a research question in all its complexity" (Bergman, 2011, p274)

3.1 Introduction

The previous chapter reviewed the relevant literature from the three focus areas of this project, namely the physical, municipal and community contexts of disaster risk and management. The review explored some of the gaps revealed in the literature regarding disaster management at the local level, where flood disasters pose a great risk for residents and municipalities in South Africa. In order for communities to be resilient to disaster events, actions need to be taken to reduce the risk and improve coping capacity of local residents. The South African DMA of 2002 provides a guide for how disasters are to be managed in the country. Despite it being a progressive and comprehensive policy document, there has been a lack of implementation of the requirements of this policy through the different levels of government (Botha *et al.*, 2009). This chapter identifies how the problem of poor disaster management at a local level in South Africa is investigated through a case study of flooding in EMM.

This chapter outlines the structure of the project, including how the different investigations are conducted, their data management and how the individual investigations are integrated together. The project design, including objectives and research questions, provides the framework of the project. This is followed by a brief background of EMM, the study area, to provide further justification for the appropriateness of the case study. Data collection and management are important aspects of this study, because of the range of data that are considered. These are described before going into the details of the physical, political and community investigations. The chapter concludes with a description of how the individual investigations are integrated together.

3.2 Design

The objective of this study is to investigate the extent to which a range of factors interact to either enhance or limit resilience to flood disasters at the local scale. This objective is divided into three parts, the first of which includes a physical analysis and the following two comprise the social investigations. The factors that are assessed include understanding the physical drivers of floods (in this case rainfall), the formal management of flood disasters and the experiences and perspectives of those affected by the floods. In order to understand how each of these factors interact, it is first necessary to gain an understanding of each factor in isolation. How these are investigated is formalised through the following questions:

1. What is the rainfall context and status quo of flood disasters?
2. How does the policy context influence perceptions and implementation of disaster management on the local municipal scale?

3. How do communities engage with flood disasters?

These questions are investigated through a case study of pluvial floods in EMM, specifically in the suburb of Atlasville, and deal with different aspects of DRR. Rainfall, being the major driver of pluvial floods, forms the core of the physical analysis and investigates the hazard event. Rainfall is however not the only physical factor that influences flooding, and factors such as densification and changes in land use can substantially alter surface hydrology and in turn affect flood risk. Investigating these factors falls outside the scope of this short Masters research, but would be a valuable focus for further research. The physical rainfall and flood analysis investigates three hypotheses, namely:

1.1. There is spatial variability in rainfall patterns across EMM.
1.2. There are temporal trends in recent rainfall data in EMM.
1.3. There is a correlation between rainfall and flood incidence in EMM.

These hypotheses set the scene for the hazard event that triggers flood disasters. The second investigation, which focuses on the second research question, investigates how such disasters are formally managed by the municipality. The analysis of political context is structured around testing the following hypotheses:

2.1. The DMA does not create an enabling environment for policy to be translated into effective disaster management at the local level.
2.2. Factors not directly related to flood disasters and risk influence DRR efforts in EMM.

The final analysis investigates the experience and perceptions of flood disasters by community members who have been affected by floods in the past. The focus of this investigation is to understand how Atlasville residents engage with flood disasters, where the following hypotheses form the basis of the investigation:

3.1. Community experiences and perceptions influence their approach to DRR.
3.2. Adaptive capacity and resilience at the community level can be developed through non-technical knowledge and informal structures.

Physical and social investigations are typically conducted separately, despite their interaction in fields such as disaster risk. The main objective of the research is achieved through a multidisciplinary research approach that allows for a more integrated understanding and potential management of disaster risk. Cutter *et al.*'s (2008) DROP model is used as the lens through which the different studies are investigated, and how they interact. This model describes the relationship between vulnerability and resilience to natural hazards, at a community level, which is applicable to this research, with the focus on the EMM. The following section describes the case study area, followed by the methodological details of each investigation.

3.3 The Case of Flooding in Ekurhuleni Metropolitan Municipality

EMM is situated in Gauteng Province, South Africa. It was established in 2002, with the amalgamation of 9 smaller municipalities (Figure 1.1). It is an industrial and commercial centre in South Africa, and is home to approximately 2.7 million people, who live in a range of informal and formal areas (EMM, 2009). EMM is situated on the Highveld, which experiences sudden onsets and intense thunderstorms (EMM, 2004). The municipal area is relatively flat (particularly the southern region) and contains many wetlands. There are seven major river catchments in EMM, all of which have their source within the municipality along a major watershed (Figure 3.3).

In the flat southern parts of the municipality, water collects in depressions, where water drains away very slowly. The impact of this flooding is exacerbated by informal settlements positioned in these depressions. In addition to these areas, both formal and informal houses have been built on or near wetlands and floodplains. Low-income informal and higher-income formal areas have been severely affected by storms and floods since 2006 (VC Management Services, 2010; www.eyewitnessnews.co.za, 26 January 2010; www.esbcon6.com, 26 January 2011; www.iol.co.za, 27 January 2011).

In the 1970's, housing was required for the growing number of employees of aviation companies. Atlasville, an area just east of Johannesburg's major airport, was allocated for this development. This area was originally a wetland that was drained by the Atlas Spruit[9] and was canalised to make space for the development. The wetland around the Atlas Spruit was filled in with building rubble and currently contains mainly alien grass species. The channel of the Atlas Spruit is inundated with reeds (VCMS, 2010). Over the following few decades, the residential area became more and more densely populated, and today it is a middle-income suburb, which houses a few hundred people.

Residential and industrial developments have increased runoff in the municipality, which has added to the load on the stormwater infrastructure and at times exceeds the infrastructural capacity. In addition to this, some recent developments have been built in such a way, that water is channelled into bottlenecks and results in flooding (Manager *J*). One such example of this is the suburb of Atlasville.

Since 2006, there has been periodic flooding along the eastern banks of the Atlas Spruit. During each flood, water inundated the spruit, the adjacent open park space and the nearby roads and houses, causing major property damage. Figure 3.1 delineates one of the areas in Atlasville, which has been worst affected by flooding since 2006. Water in some properties reached waist-height, and caused many people to leave their homes for a number of months while renovations and repairs were undertaken. In order to understand the drivers of these floods and the management thereof, this research investigates a number of different sets of data, which are described in the following section.

3.4 Data Collection and Management

The collection and management of data in this project is important, due to the range of data that are used in the three individual investigations. The datasets, and the investigations that they contribute to, are depicted in Figure 3.2. The first investigation comprises the physical context of rainfall and floods in EMM. Daily rainfall data were obtained through the South African Weather Service (SAWS), for all weather stations in Gauteng for the period between 1977 and 2011. Flood data were obtained from the Disaster Management Department of EMM for the period between 2009 and 2012, which is the whole period in which these events have been monitored and reported. The political context comprises the second investigation. This investigation triangulates three sets of data including the South African DMA (2002), a report by SALGA investigating the implementation of the DMA at the

[9] Spruit is an Afrikaans name for a small stream or river

local level in South Africa, and responses from interviews conducted with twelve EMM managers. The final investigation of the project examines the community context of flood disaster. The primary perspectives were obtained from the public participation section of a Basic Assessment Report (BAR) for a project designed to deal with flood issues in Atlasville. Ten interviews were conducted with flood-affected residents in Atlasville to supplement the perspectives extracted from the BAR. The methodologies for each of these investigations are described in more detail in the following sections.

Figure 3.1: Highlighted area indicates worst flooded houses in Atlasville (2006 and 2010) adjacent to the Atlas Spruit (Google Earth).

The physical context of flood disasters is a fundamentally important component in understanding DRR as a whole, and thus unsurprising there is a bias towards this component in the literature. Likewise, this investigation is biased towards the physical context of flooding in EMM, in line with the researcher's strengths. Nevertheless, there is increasing evidence that the physical components of disasters are not sufficient in providing comprehensive understanding of disasters. The political and community contexts augment the outcomes of the physical context investigation to facilitate an integrated approach to DRR. This research focuses on the interaction between these different components, which is relatively unexplored.

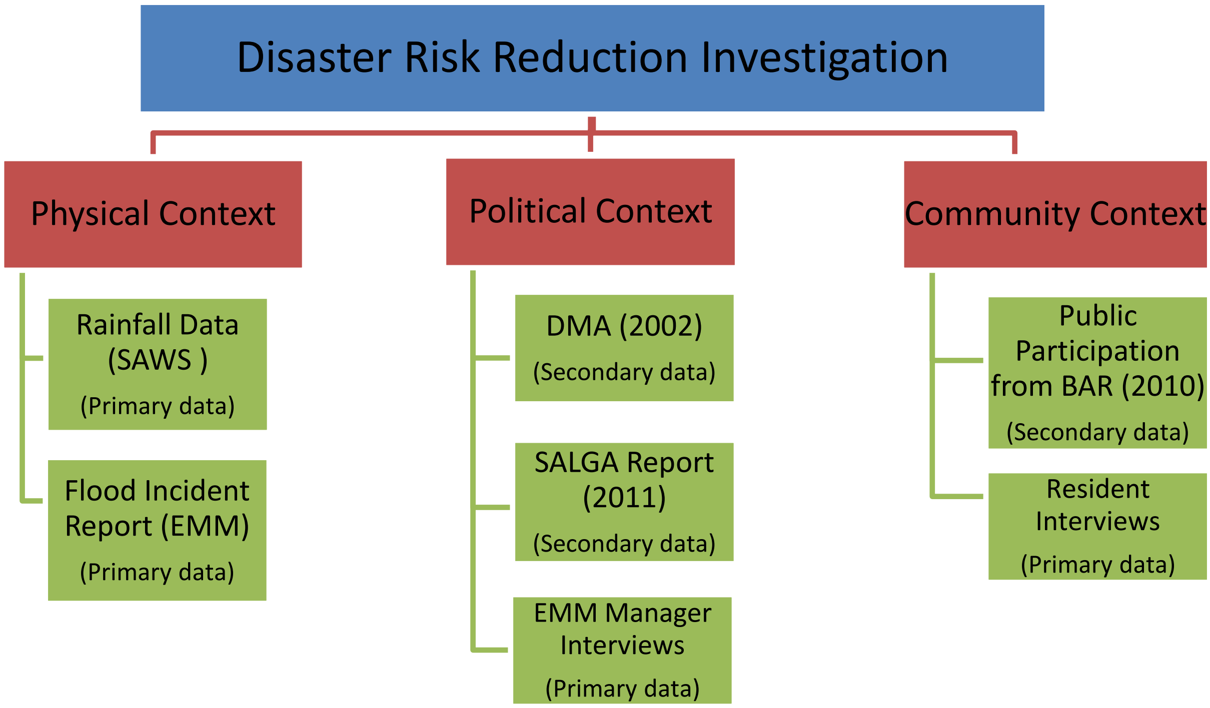

Figure 3.2: Management of datasets in the three investigations

3.5 Physical Context

The physical investigation assesses pluvial flooding in EMM to answer the first of the three research questions (Section 3.2). Understanding rainfall distribution within EMM is the first step towards understanding the occurrence of pluvial flooding in the area. The first and second hypotheses assess the spatial and temporal rainfall distribution respectively, with rainfall data from EMM. The final hypothesis within the physical investigation tests whether a correlation exists between past rainfall to flood occurrence in EMM. The first and second hypotheses are tested through statistical analysis of EMM rainfall data, which were obtained from the SAWS. The third hypothesis is tested through comparing SAWS daily rainfall data to disaster incident reports (DIRs) obtained from EMM. The details of these analyses including data collection, methodologies and limitations are discussed in the following sections.

3.5.1 Rainfall Analysis

EMM is situated on a local watershed (see Figure 3.3), thus floods occurring in the municipality result directly from rain falling within the municipal boundary, and thus understanding rainfall characteristics within the municipality is essential. Convective thunderstorms, which characterise rainfall in this area, can be intense and have unpredictable routes. The first hypothesis tests whether these expected characteristics are observed in EMM, resulting in spatial variation in rainfall distribution. Recent research has identified that climate change is likely to affect convective and extreme rainfall trends in South Africa (Engelbrecht *et al.*, 2012). Since extreme rainfall events are likely to influence flood occurrence, the second hypothesis tests whether there are any temporal trends in rainfall distribution within EMM.

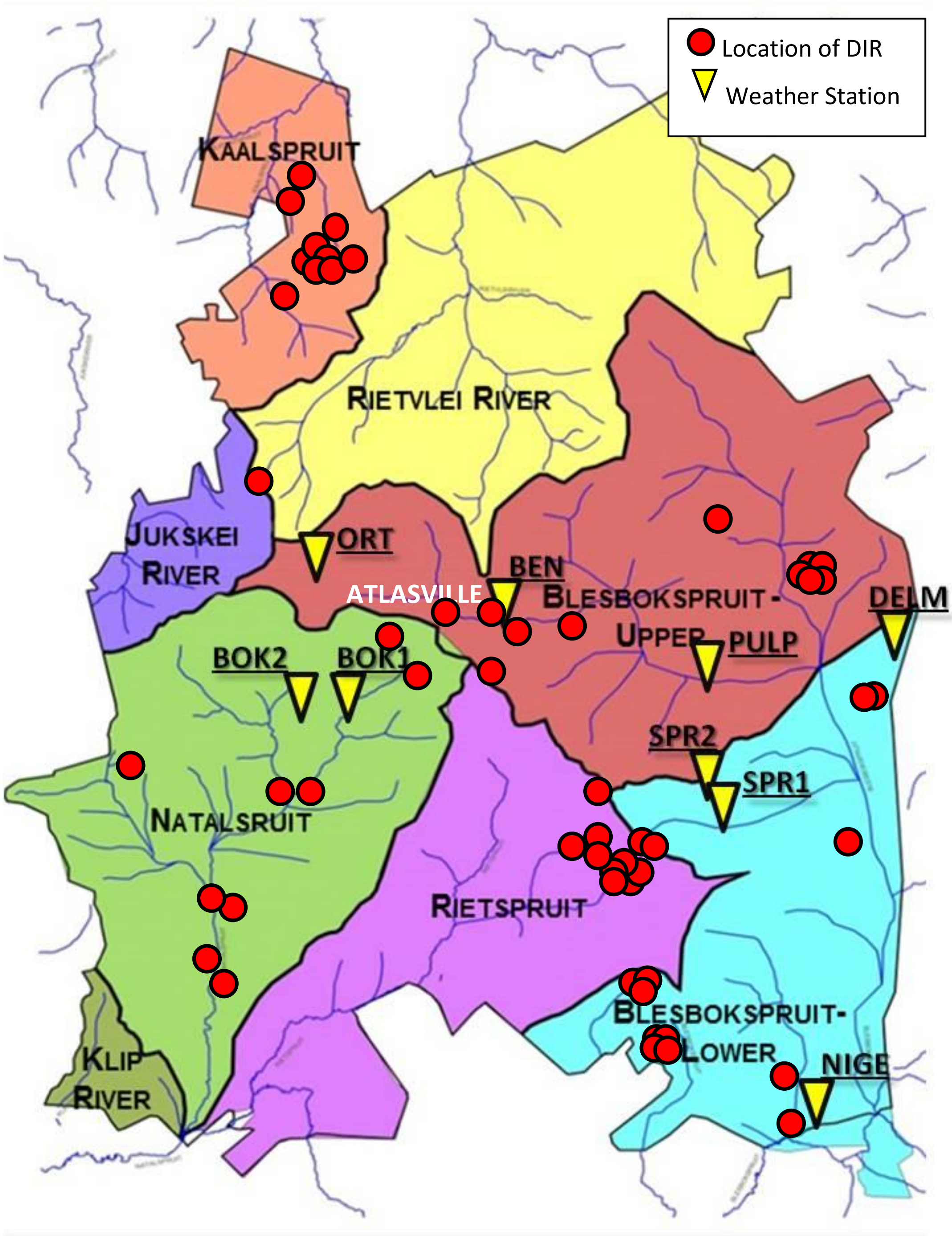

Figure 3.3: The division of the seven river catchments with the position within Ekurhuleni Metropolitan Municipality of weather stations and flood disaster incident reports (adapted from EMM, 2006)

3.5.1.1 Data Collection

Rainfall and storm analyses can be performed using either remotely sensed data or observed data. Remotely sensed data, such as radar or satellite data, provide insight into detailed storm characteristics such as rainfall intensity, storm depth, which can be used to track storm paths. Although these data can be very useful, remotely sensed data provide more information than that required for the current masters project, and are highly time and computer intensive. For this investigation, observed rainfall data are preferred because they provide an indication of rainfall measured within the Municipality, and such rainfall is a primary contributor to pluvial floods.

Remotely sensed data contain superfluous information for this investigation, whereas observed data contain only the required data.

Daily rainfall data from 9 stations around EMM from 1978-2011 were obtained from the SAWS, via Dr Liesl Dyson. Daily data are captured at 08h00 (South African Standard Time) and represent the total rainfall accumulated during the previous 24 hours (Dyson, 2009). The stations include Benoni Country Club weather station (BEN), Boksburg, East Rand weather station (BOK1), Boksburg Brandweer weather station (BOK2), Delmas weather station (DELM), Nigel, Brandweer weather station (NIGE), O.R. Tambo International Airport weather station (ORT) (airport data include previous airport names), Geduld Pulp Factory weather station (PULP), Springs weather station (SPR1), and Springs Olympia Park weather station (SPR2). The positions of these stations around the municipality are presented in Figure 3.3. Because the analysis is focused on rainfall trends, and EMM is in a summer rainfall area, which typically extends from October to March, only these months are investigated.

3.5.1.2 Methodology of Statistical Techniques

The statistical analysis of rainfall data from EMM is undertaken using SAS Enterprise Guide, MS Excel and R. A descriptive analysis of the data precedes the detailed quantitative statistical analyses. The hypotheses are tested according to the appropriate statistical tests and significance levels. The first hypothesis is tested using ANOVA and Multiple comparison tests, and the second hypothesis is tested with Time series analysis.

3.5.1.2.1 Descriptive Analysis

The first step of any statistical analysis is a descriptive analysis of each dataset in order to understand the spread of the data within each sample. In each area, daily rainfall data (including extreme events at 90th, 95th and 99th percentiles of daily rainfall) are analysed according to descriptive techniques (mean, variance, standard deviation (SD), range) (Galpin and Krommenhoek, 2011).

3.5.1.2.2 ANOVA and Multiple Comparison Tests

In order to test whether there is a difference between several independent samples an ANOVA test is required. If such differences exist, then a multiple comparison test determines *where* they lie (Galpin and Krommenhoek, 2011). The ANOVA test assesses whether there is a significant difference in the variability between the means of the treatment groups and within them (Galpin and Krommenhoek, 2011). The stations with the longest common period were the major basis of comparison. This period ran from the 1980/1981 season to the 2003/2004 season (excluding the 1999/2000 owing to missing data), and the stations included BOK1, BOK2, BEN, PULP, SPR1, DELM and ORT. The rainfall patterns that were analysed include number of rainfall days, average rainfall and maximum rainfall. A second analysis was conducted for the period where all stations had a common period. This period spanned from 1998/1999 season to 2003/2004 season (excluding 1999/2000 where there were missing data). Each analysis had the null (H_o) and alternative (H_A) hypothesis as follows:

$H_0 : \mu_{BEN} = \mu_{BOK1} = \mu_{BOK2} = \mu_{DELM} = \mu_{NIGE} = \mu_{PULP} = \mu_{SPR1} = \mu_{SPR2}$

H_A: there is a difference between at least 2 of the groups (μ_i)

The ANOVA test makes a number of assumptions about the underlying data. These assumptions include that the data for each level are independent random samples, which are normally distributed around the mean. The assumption of homoscedasticity exists, in that the error variance is the same for all groups involved in the comparison. It is thus important to test the homogeneity of variance, which is performed through the Levene's Test for Homogeneity of Variance.

H_0: variances for all groups are equal

H_A: variances for groups are not equal

If variances between the groups are sufficiently different, then the data may need to be transformed as this makes the error variances between the groups more similar. The analysis of residuals is also important, as they need to be normally distributed. These can be analysed through assessing the fit diagnostics.

3.5.1.2.3 Time Series Analysis

Time series methods are used to reveal possible trends over time, and the analyses are compared across the different sites. The ORT dataset was selected for this analysis, as it is the most complete of all the sets for the available period. The first step in this analysis is to determine if there is a serial correlation between seasons. If this correlation exists, a time series model can be applied to the data. If, however, this correlation does not exist in the data, the time series analysis is not appropriate.

3.5.1.3 Limitations

There is a non-random distribution of stations across the region, which means that they are not necessarily representative of the whole region (Figure 3.3). Four of the seven catchments in EMM do not have weather stations within the catchment area, which limits the ability of the investigation to assess rainfall distribution, and related flooding in these areas. This investigation addresses this limitation by using the ORT station as it is the most complete station and thus provides the best possible basis for the physical analysis. The specific suburb of Atlasville is downstream of the ORT station in the Blesbokspruit Upper catchment, which makes it an ideal station for the specific investigation related to this case study. Because the weather station selection is not random, the analysis here cannot be used to make broader generalisations about weather patterns outside the municipality. This is, however, not an issue because the focus of this research is limited to the municipality.

There are some data capturing errors in the dataset and because these are secondary data, it is difficult to ensure accuracy for the entire dataset. Because the focus of this investigation is to assess the general distribution across the municipality over a long period of time, and not of a specific event, minor errors in the data would not have a dramatic effect on the conclusions. The data were checked for obvious outliers, but none was found that could not be explained[10]. Within the data, are included days where weather stations were not operational, which results in non-reports, and brings inaccuracies into the analysis. As far as possible, these gaps in the data are avoided through selecting uninterrupted sections of data; however it is not possible to completely avoid this risk when

[10] Many outliers are attributed to the heavy rainfall associated with intense events such as tropical cyclones, and cut off lows.

analysing these data. In the descriptive analysis, the issue of missing data is addressed. To overcome some of the limitations of the data and the study design, the study tries to limit the analyses of data where there are many missing values. In most cases, repeat tests are conducted to ensure the validity of the tests. In cases where missing values may skew data, comment is made about this and the results from these tests are not strongly regarded for the remainder of the research.

3.5.2 EMM Flood Incidence and Rainfall comparison

Assessing the link between rainfall and flooding in the municipality is a fundamental part of understanding the physical context of flood risk in EMM. The third hypothesis tests the correlation between observed rainfall and flood incidence across the municipality. Assessing the flood incidence in EMM forms a link between the quantitative statistical analysis and the qualitative social perspective analysis. A report was obtained from the EMM Disaster Management Department, which details a comprehensive list of the disasters that the department addressed between September 2009 and January 2012. Flood disaster incidents are extracted from this report detailing the date, extent of damage (including people affected) and intervention, and any other relevant comments. These occurrences are then visually compared to the rainfall data (from the statistical analysis) to assess any links between rainfall and flood events through this period.

The flood incident analysis is further compared with the perspectives from local residents and municipal managers. This section attempts to understand the link (or lack thereof) between perceptions and responses to flood disasters. In order to conduct this next step of the analysis, qualitative research methods are also necessary.

3.5.2.1 Limitations

The DIRs obtained from EMM extend over a very short period, which limits the ability to conduct meaningful statistical analyses on the data, and the associated rainfall data for that period. Consequently, only limited assessment of the correlation between the two data sets is possible. As the DIRs database is developed in the Municipality, long-term trends can be assessed and compared to the extensive rainfall data. The different periods of the two data sets in the physical analysis provide the opportunity to focus on specific periods where disasters occurred within the context of the rainfall dataset.

An additional limitation of the DIRs is that the purpose of these records is not for research, but in adherence to policy requirements and auditing purposes. Thus, the details required for a comprehensive investigation into disaster incidence, which links catchment specific rainfall to actual flooding downstream, is not currently possible. The DIRs were obtained from the disaster management department and do not include the disasters addressed by other department, and although it is the most comprehensive record of disasters in the municipality, it is likely that some incidents have been excluded. The data do however provide an indication of the flooding extent within EMM, which can be compared to the general rainfall within the area.

3.6 Social Contexts

The social investigations in this research are designed to address the second and third research questions, which assess how the policy context influences perceptions and the implementation of disaster management at the local municipal scale, and how communities engage with flood disasters, respectively. This research explores these questions separately through testing relevant hypotheses with qualitative techniques.

Qualitative research often comprises a number of data types (e.g. interviews, document analysis, questionnaires), which are used to reveal a broad perspective of the research topic or context (Creswell, 2009). The qualitative investigation in this research consists of multiple forms of data, including interviews, policy documents and environmental analysis reports. All of these are used to gain an insight into the management of rainfall and flood disasters. The intention of using more than one form of data is to ensure that a broad insight into the context of flood disasters can be gained, however this requires that the various data can be linked through analysis. The ability to draw connections across very different kinds of data depends on the method of analysis. It is of particular importance in multidisciplinary research that all parts of the investigation are integrated, and that their insights are mutually illuminating. A thematic approach to the qualitative investigation has thus been selected, because this approach allows comparisons and links to be drawn across the data types with relative ease.

A thematic approach involves the identification of themes, sub-themes and patterns in the data that can be tracked and compared within and across the different forms of data (Aronson, 1994). This approach is more appropriate for this study than a discourse analysis for example. Although a discourse analysis would be a good way to investigate the policy documents and disaster reports, it would be insufficient for analysing the interviews, particularly those that required a translator, where the intricacies of language are lost. Further research on Disaster Management in South Africa would benefit from a discourse analysis of the policies. However, for the purpose of this research, the thematic approach is preferred.

The social context investigation is divided into two broad categories comprising an analysis of the DMA, and an analysis into social perceptions of disaster risk and management within Ekurhuleni. The primary purpose of the investigation into social perspectives is to determine how perceptions and the social environment affect DRR. The social component of this investigation comprises political and community context analyses. The interaction between the political and community contexts is important as the perspectives and responses of the municipal managers and community members influence each other. This study investigates the extent to which the political and community contexts interact to either enhance or limit resilience to flood disasters at the local scale.

3.6.1 Political Context

The political context of disaster management and floods in EMM is investigated through answering the second research question by testing two hypotheses. The first hypothesis posits that the DMA does not create an enabling environment for policy to be translated into effective disaster management at the local level. The second hypothesis suggests that factors not directly related to flood disasters and risk influence DRR efforts in EMM. These hypotheses are investigated through an analysis of the DMA (2002), a report by SALGA (2011) and interviews with EMM managers.

The DMA (2002) is used in this research as the standard of disaster management that should be in place in South African municipalities. This document provides standards and procedures required by government for disaster management, and it is thus important to understand their strengths and weaknesses. The policy analysis is restricted to the DMA because all other disaster management policies (such as the National, Provincial and Municipal Disaster Management Frameworks) must comply with the stipulations of the DMA, and thus it is superfluous to analyse the other documents in as much detail. A descriptive analysis of the DMA provides the context for disaster management in South Africa. This is followed by a thematic analysis of its content, to identify themes and patterns, which are later compared and contrasted with other sections of the investigation. The motivation for using a thematic method is similar to that described for the qualitative investigation in the entire research project. The investigation conducted by SALGA to investigate the status quo of disaster management in South African municipalities, is analysed in a similar way (although less in depth) to that of the policy documents, namely with a descriptive analysis, followed by a thematic analysis. Twelve semi-structured interviews were conducted with Ekurhuleni municipal managers from the strategic to operations levels (See Appendix I for the questionnaire that formed the starting point of these interviews). In each interview, managers were asked to discuss the major issues that exist, how these are being addressed or planned to be addressed, and what limitations they encounter. The interviews with municipal managers are assessed similarly to those with local residents, through considering their knowledge, perceptions and actions. The themes and patterns identified in this section are used in Chapter 7, where the three investigations are integrated together.

3.6.2 Community Context

The investigation into the local community context addresses the third question of how communities engage with flood disasters. This question is investigated through testing two hypotheses. The first hypothesis asserts that community experiences and perceptions influence their approach to DRR, whilst the second hypothesis claims that adaptive capacity and resilience at the community level can be developed through non-technical knowledge and informal structures. These are tested using two datasets, which provide community perceptions in the short and long terms after flood disasters.

Community perceptions, during a flood disaster in 2010, were extracted from the public participation section of a Basic Assessment[11] Report (BAR) for a project designed to deal with flood issues in Atlasville. These were supplemented by ten interviews with flood-affected residents, two years after the public participation was conducted. The approach used in this section is framed around postmodernism where there is an acknowledgement of differences in perceptions across society and that no one perspective is either wrong or right (Kitchin and Tate, 2000). This phase of the research aims to show that universal truths (as used in modernist approaches) are not relevant in understanding and responding to risk to extreme events across society. This is done through testing if perceptions and disaster management are homogenous across and within communities. This investigation, similar to that in ethnography, acknowledges “the subjective nature of the observation” (Kitchin and Tate, 2000, p222).

Perspectives were obtained from the BAR and from interviews, instead of conducting ethnographic research, because of the challenges of accessing flood-affected areas and predicting flood occurrence. In addition, post-disaster interviews allow people to describe their experiences, assess how they reacted and give details of their perspectives and any plans for possible future floods.

[11] A Basic Assessment is similar to an Environmental Impact Assessment, however is required for small-scale activities and does not involve as stringent assessment of the impacts. Public participation is mandatory for both EIA and BA reports

Engaging with people in the midst of a disaster is likely to be challenging as their focus is on their immediate situation and their experiences are heightened due to the intensity of their current situation. The social perspectives obtained from the BAR and from interviews are investigated through a thematic analysis, which forms the political context analysis in Chapter 5.

Contact with Atlasville residents was established through the Atlasville Community Forum (ACF), a community based organisation. This included the minutes from a meeting of interested and affected parties (held on 24 February 2010, at Summerfield Primary school, where 63 people attended), 5 letters in response to the aforementioned meeting, and 75 emails and faxes from residents (VCMS, 2010). Two years later, in February 2012, ten interviews were undertaken with residents, who had been affected by floods in the past. The interviewees were systematically selected from within the affected area (Figure 3.1) to obtain a representative sample of flood victims in Atlasville. This sample represents 20% of the affected households in the area. Perspectives were obtained from residents who had lived in the area for a range of time from three years to over thirty years. The majority of interviews (eight of the ten), however, were with male residents.

A formal questionnaire with a combination of closed- and open-ended questions was used to interview residents (Appendix II). Closed-ended questions provide opportunity to compare responses between residents and conduct quantitative analyses of the responses. Open-ended questions are important as they allow individual stories and perspectives to emerge and potentially reveal factors that had not been expected by the researcher. This questionnaire focused on residents' experiences of floods and perceptions of future risk, including their experiences and expectations of the municipality's management of floods and disaster risk.

Interviews with residents from different socio-economic backgrounds (i.e. Tembisa a low-income area, and Atlasville, a middle-income area), were planned in the proposal stage of the project. Both areas have been badly affected by recent storms and floods, and are high on the municipality's priority list. They are also hotspots identified by a recent analysis of EMM's vulnerability to flash floods (Akoon, unpublished). Similar to interviews conducted by Action Aid (Douglas *et al.*, 2008), the social and cultural contexts of the different communities were considered and taken into account before interviews were conducted. The same questions were posed to all community interviewees. The area within the suburb that was affected by floods includes four streets where two to three people were interviewed per street. This sample selection method was chosen to ensure some randomness in the sample. The initial three interviews were conducted with residents, contacted through the ACF, whilst the remaining seven were undertaken by going from door-to-door. Two interviews were conducted in Tembisa with residents who had been affected by floods. A manager from the local Tembisa Stormwater depot identified the flood prone areas and assisted as translator.

Subsequent to the two pilot interviews in Tembisa, the guide and translator became unavailable. The responses from the two interviews were nonetheless included in the community context investigation (Chapter 6). These insights provide an indication of possible differences and similarities between the different areas. Research into flood disasters in informal and low-income areas in Cape Town, is currently being conducted (Ziervogel and Smit, 2009). Such research in middle-income communities is, however, virtually unexplored in the South African context, and developing context as a whole. The potential differences between different socio-economic areas and communities would be a valuable direction for further research.

3.6.2.1 Ethical Considerations

It is important that individuals who are vulnerable to rainfall and flood events are included in the study and thus ethical considerations were taken into account when interacting with local residents. The vulnerability mentioned here relates specifically to people during flood disasters. People were not interviewed during these times, which ensured that the interview process did not place anyone at further risk from floods, nor create an expectation that their being interviewed would be rewarded in a way that would help them deal with floods. People were free to choose if they were or were not willing to be interviewed, and they signed a consent form before the interview was conducted. The study ensures complete confidentiality and anonymity for all respondents. The questionnaire was designed in a way that did not place risk or stress on any of the individuals interviewed. A translator was used in Tembisa to ensure that there are no misunderstandings due to language differences. This was not necessary in Atlasville, as all residents spoke English. Approval from the ethics committee at the University of the Witwatersrand was obtained before any interviews were conducted.

3.7 Integrating Investigations

The final component in this research project addresses the major objective of the research, which is to investigate the extent to which a range of factors interacts to either enhance or limit resilience to flood disasters at the local scale. This requires the three investigations related to the physical, political and community contexts of disasters and DRR to be combined, and in so doing enhance the understanding of floods and DRR at the local level in South Africa. This component triangulates the three multidisciplinary investigations to assess how they can be mutually illuminating with regard to all aspects of DRR. A true multidisciplinary approach requires an integration of the different investigations, and not just placing them alongside each other in a research report. As with the political and community investigations, a thematic approach is used in this research to bring all separate investigations together. The DROP model, by Cutter *et al.* (2008), is used as a lens through which to frame the disaster management context of this study.

Themes and results that are revealed through each investigation are compared and contrasted across the three investigations. This process is used to extract new themes and information that are revealed through looking at the whole context of flood disasters. The insights gained through the integration of different investigations are used to assess what the implications of differential risk and perceptions of risk are for informing disaster management decision-making and strategies, particularly in the context of the DMA. Factors (e.g. scientific studies, knowledge bases and individual perceptions) that influence disaster management are identified to assess the effectiveness of the DMA in facilitating local disaster management.

The focus of this research project on one municipality allows the context of disasters and DRR to be investigated in detail, which may not have been possible if a greater number of municipalities had been investigated. However, the themes and core findings of this research can be useful for contexts outside of EMM in the challenge of managing disasters effectively in South African municipalities. This research design outlines an investigation that is not common and thus has the potential to provide insight into how a multidisciplinary approach can offer a highly integrated understanding and management of flood risk.

This chapter has outlined the structure of this research, identifying the research objective, research questions and related hypotheses. The data, methodologies and limitations describe how these are addressed through integrating three investigations of physical, political and community contexts of DRR at the local level in South Africa. The subsequent chapters present the results of these investigations, as well as their integration. The physical context investigation is the first of these investigations and is presented in the following chapter.

4 Physical Context

"Urban areas always present some risk of flooding when rainfall occurs"
(Satterthwaite *et al.,* 2007, p17)

4.1 Introduction

Flood disasters in EMM are used as a case study against which the research hypotheses and questions are tested. The focus of this chapter is to understand the physical context of flood disasters as a crucial component of flood DRR. Two aspects of the DROP model (Cutter *et al.*, 2008) that are investigated in this analysis include understanding the disaster 'event' and the 'inherent vulnerability' with respect to the natural environment. Rainfall being the main driver of pluvial floods forms the basis of the investigation, which is supplemented with an analysis of floods in EMM. This investigation addresses the first research question, which asks: What is the rainfall context and status quo of flood disasters? This investigation contributes to addressing the broader objective of investigating the extent to which different factors interact to either enhance or limit resilience to flood disasters at the local scale through understanding the physical drivers of flood disasters. The case study of rainfall and floods in EMM is the specific focus of this investigation. The research question is explored through three hypotheses:

1. There is spatial variability in rainfall patterns across EMM.
2. There are temporal trends in recent rainfall data in EMM.
3. There is a correlation between rainfall and flood incidence in EMM.

The physical context analysis is divided into two components, including understanding rainfall as an important driver of pluvial floods, and the floods themselves. The first of which addresses the first two hypotheses using statistical techniques, and the second component probes the third hypothesis through comparing daily rainfall data with flood incident reports.

The results of the rainfall investigation are divided into a number of different sections. A descriptive analysis is conducted, followed by a comparative investigation between different weather stations around the Municipality, and the final investigation assesses rainfall at the OR Tambo Airport station (ORT) over the available period (i.e. 1977-2011). This is followed by an assessment of flood disaster incidence in EMM. Daily rainfall from ORT and flood incidence are examined together to determine if any potential connections exist between rainfall and flood disasters in EMM. These investigations require two sets of data, namely rainfall data from the SAWS and DIRs from the EMM Disaster Management Department (described in more detail in Section 3.4). To assist in understanding the statistical components of this investigation, the following section explains some of the statistical terminology and techniques that are used.

4.2 Background of Statistical Techniques

Understanding statistical techniques and the analysis thereof relies on understanding the terminology that is used to describe them. This section has been taken largely from the 'Course notes for Statistical Research Design and Analysis' compiled by Galpin and Krommenhoek (2011).

This background section does not attempt to provide a comprehensive explanation of the concepts, as it is not part of the research scope.

A great deal of statistical tests and techniques are based on the idea of a normal distribution, which is more commonly referred to as the 'bell curve', because of its bell-like shape (Figure 4.1). A histogram graph is used to present the data visually and plots the data points such that the proportion of data points at the range of values is depicted. The data in a normal distribution is evenly distributed on either side of the mean (μ). The Standard Deviation (SD) provides a measure of how the data are spread around μ. A normal distribution implies that about 68% of the data fall within one SD of μ, and 95% fall within ±2 SDs of μ. A Box and Whisker plot provides a summary plot for the dataset (Figure 4.2). These plots divide the data into three sections: a rectangle with two lines extending from either side of the outermost vertical lines. The leftmost vertical line represents the point below which 25% of the data lie, and correspondingly for the rightmost vertical line. The box between the left and right vertical lines is referred to as the interquartile range. The vertical line in the centre indicates the μ. If there are data points that extend further than one and a half times the interquartile range from either the left or right-most vertical lines, these points are outliers and are represented by a separate point.

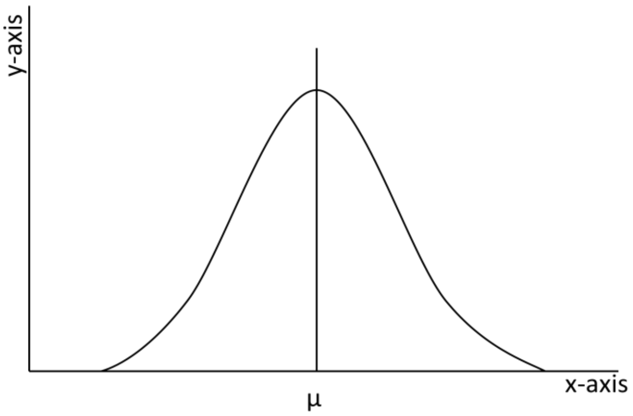

Figure 4.1: Representation of a Normal Distribution

In some instances the data are not normally distributed, and instead are asymmetrical around μ. If the majority of the data sits closer to (further from) the y-axis, the distribution is skewed to the right (left)[12]. In such situations, it is necessary to transform the data so that it is normally distributed (e.g. with log-transformation) (Galpin and Krommenhoek, 2011). A descriptive analysis is used to represent the data before conducting any statistical tests or models. These provide an indication of the distribution and spread of data within the dataset.

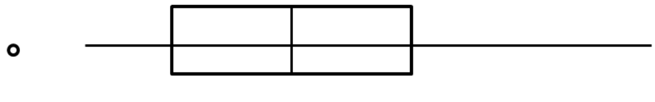

Figure 4.2: Box and Whisker Plot

[12] Skewness to the right indicates that the data is right-tailed, i.e. the distribution spreads out further to the right (larger values) than to the left, and correspondingly for left-tailed distributions.

These concepts are important when interpreting statistical tests and models, through confidence intervals. Confidence intervals provide a range within which μ falls. Statistical analyses test whether μ falls within the 95% confidence level, which indicates a 95% certainty that the μ falls within the tested range. This is primarily used when testing hypotheses. In statistical analyses, a null hypothesis (H_o) and an alternative hypothesis (H_A) are set up and tested with the use of confidence intervals. Statistical analyses test against H_o. If the μ of the test lies outside the 95% confidence interval, the H_o is rejected at the 5% level, and the H_A is accepted in its place (Galpin and Krommenhoek, 2011).

In this investigation, data from different sites are compared using the ANOVA Test. This test is appropriate when testing hypotheses between more than 2 groups. In essence, ANOVA tests assess the difference in μ of each group. The test assumptions include that each group of data is independent of the other groups, the error term is normally distributed, and error variance is equal for all groups (Homoscedastic). Fit diagnostics test whether or not the data fit these assumptions, the results of which can be found in Appendix III). The two-way ANOVA tests for a difference between two factors (i.e. in this study it tests for differences between stations over a period of seasons; and between seasons across the stations). If the ANOVA test finds a difference between the factors, a multiple comparison test is conducted to identify where the difference lies. This can be done with a number of tests, including the Scheffee, Bonferoni and Tukey tests. The Tukey test is chosen for this investigation, as it is the least conservative of the three (i.e. there is a high chance of detecting a difference in mean between the groups).

Time series analyses assess whether the dataset shows evidence of patterns or trends over time in order to forecast or understand the underlying mechanism generating the series, based on the data. A number of models can be used to assess data over time. Models that assume there is no trend in the data include Auto Regressive (AR) and Moving Average (AR) models. These can be combined to form the Auto Regressive Moving Average (ARMA) model. For data where a trend is assumed to exist in the data, the Autoregressive integrated moving average (ARIMA) and Seasonal ARIMA (SARIMA) can be used. In this investigation, the ARIMA model is used to assess trends in average rainfall at OR Tambo International Airport weather station for the period 1977-2011. The ARIMA model assumptions include that there is a trend in the data, the data points vary around the μ value, variance is constant (otherwise the data must be transformed), and that there is no evidence of strong seasonality. The ARIMA model assesses a number of factors, which can indicate whether the appropriate model stipulations have been chosen in accordance with the data. This includes the autocorrelation function (ACF) which assesses the correlation between consecutive observations in the dataset, and the partial autocorrelation function (PACF) assessed the correlation between non-consecutive observations. The ACF and PACF provide indicator variables of whether there is a temporal trend in the dataset or not (Galpin and Krommenhoek, 2011).

A Regression model is the final analysis that is used in the temporal rainfall data investigation. Similar to the time-series analysis, the regression analyses assess whether there is a trend in the data. However, the regression analysis assumes that the points are not correlated, but instead completely independent of adjacent data points (Galpin and Krommenhoek, 2011). The following section comprises the statistical analysis of rainfall data from EMM, using the techniques described in this section.

4.3 Rainfall Analysis

Daily rainfall data from the SAWS are the basis of this investigation, and these data are used to assess rainfall variation between stations and seasons. This analysis explores the spatial and temporal distribution of rainfall in EMM, to enhance understanding of the drivers of pluvial flooding, through testing the first two hypotheses in the physical context investigation. These investigations are conducted through investigating average daily rainfall, maximum daily rainfall and seasonal rain day totals, and these characteristics are compared across the municipality and over time. The analyses include only days where rainfall was recorded, and excludes those where no rain fell. The rainfall comparison across the municipality addresses the first hypothesis. This investigation seeks to ascertain whether rainfall characteristics are comparable across the municipality, or whether some areas receive higher rainfall, and thus increasing the risk of flooding in those areas. The second hypothesis is tested through examining whether there has been a statistically significant trend in rainfall over time. This gives a potential indication of whether or not rainfall trends have increased the risk of pluvial flooding over time. A descriptive analysis of the rainfall data at each station is conducted, followed by these spatial and temporal analyses.

4.3.1 Rainfall Distribution

The descriptive analysis of the data includes a histogram of the entire dataset from each station, including days are no rain was recorded (Figure 4.3, Figure 4.4 and Figure 4.5). It is clear that the data at all stations are highly skewed to the right. This is mainly due to the large number of days where no rain falls (value of 0). This distribution is consistent with usual daily rainfall distribution, which is skewed to the right (CCSP, 2008; Fatti and Vogel, 2011).

The distribution of data at each station is compared in Table 4.1. These statistics, and all further investigations, include only rain-days. The data are presented for each station, under a number of headings, where rainfall is measured in millimetres. The daily rainfall observed, is averaged across all the available data to provide an indication of the average rainfall observed in a 24hour period at each station (‘Ave rain/day (mm)’). The average daily rainfall ranges from 7.58-14.93mm. ORT has the second lowest average daily rainfall, which may be due to changes in cloud characteristics because of the increased pollution from aircrafts (Mather, 1991).

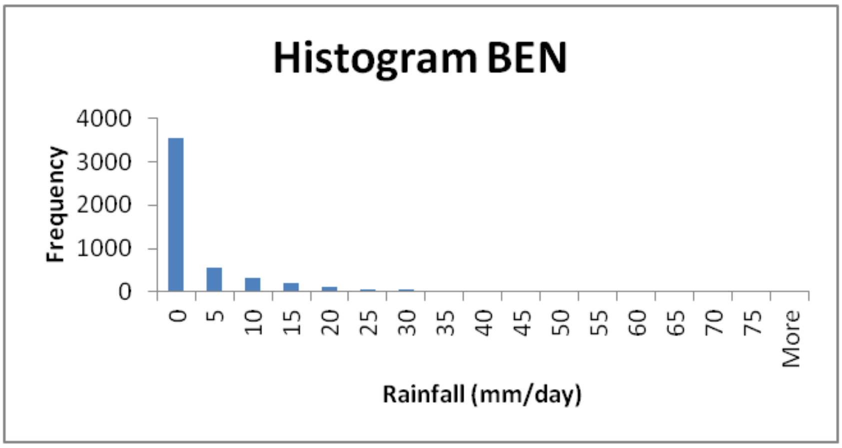

Figure 4.3: Histograms of rainfall (mm/day) for 1 of the 9 weather stations in EMM (1977-2011)

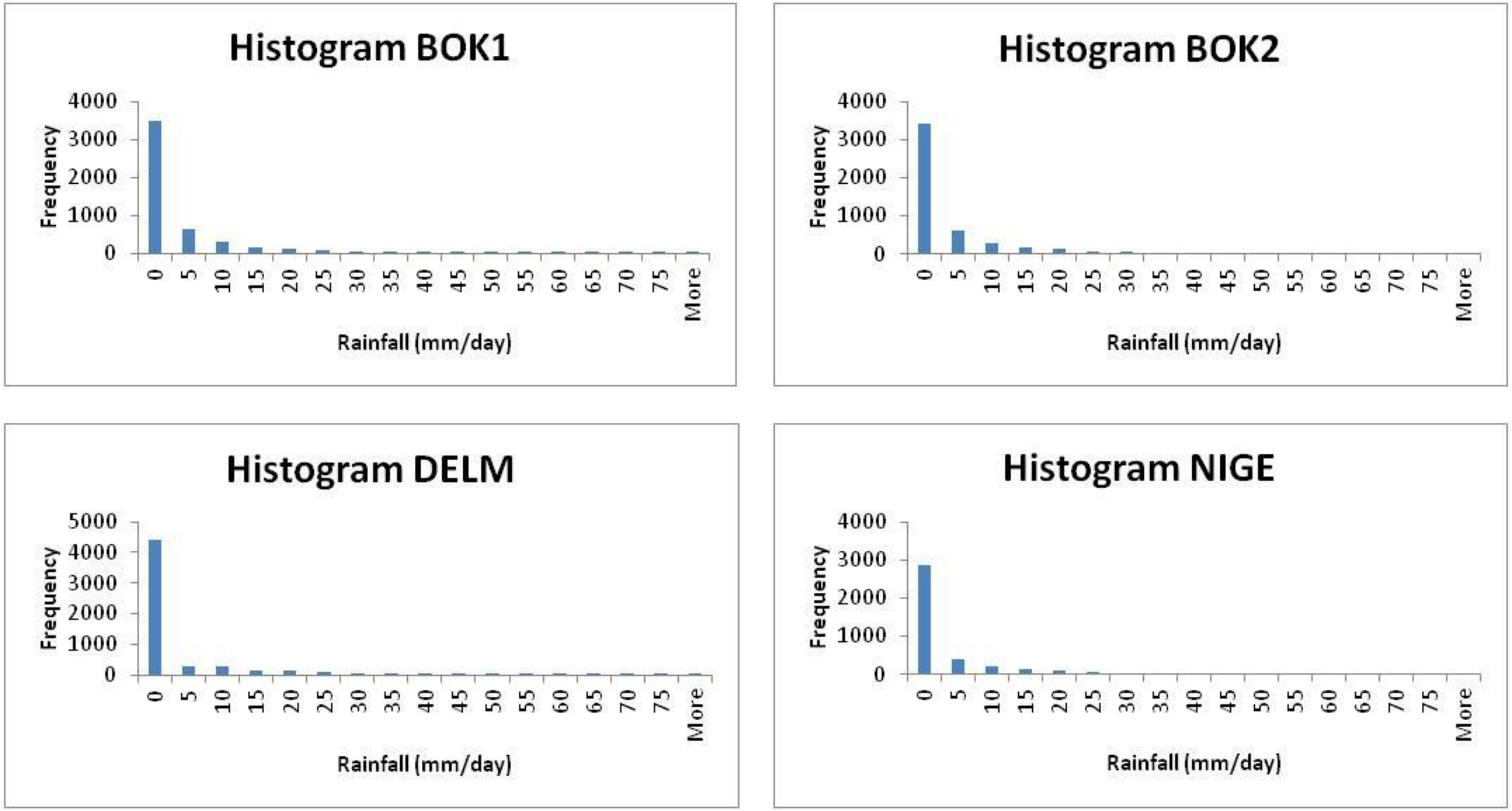

Figure 4.4: Histograms of rainfall (mm/day) for 4 of the 9 weather stations in EMM (1977-2011)

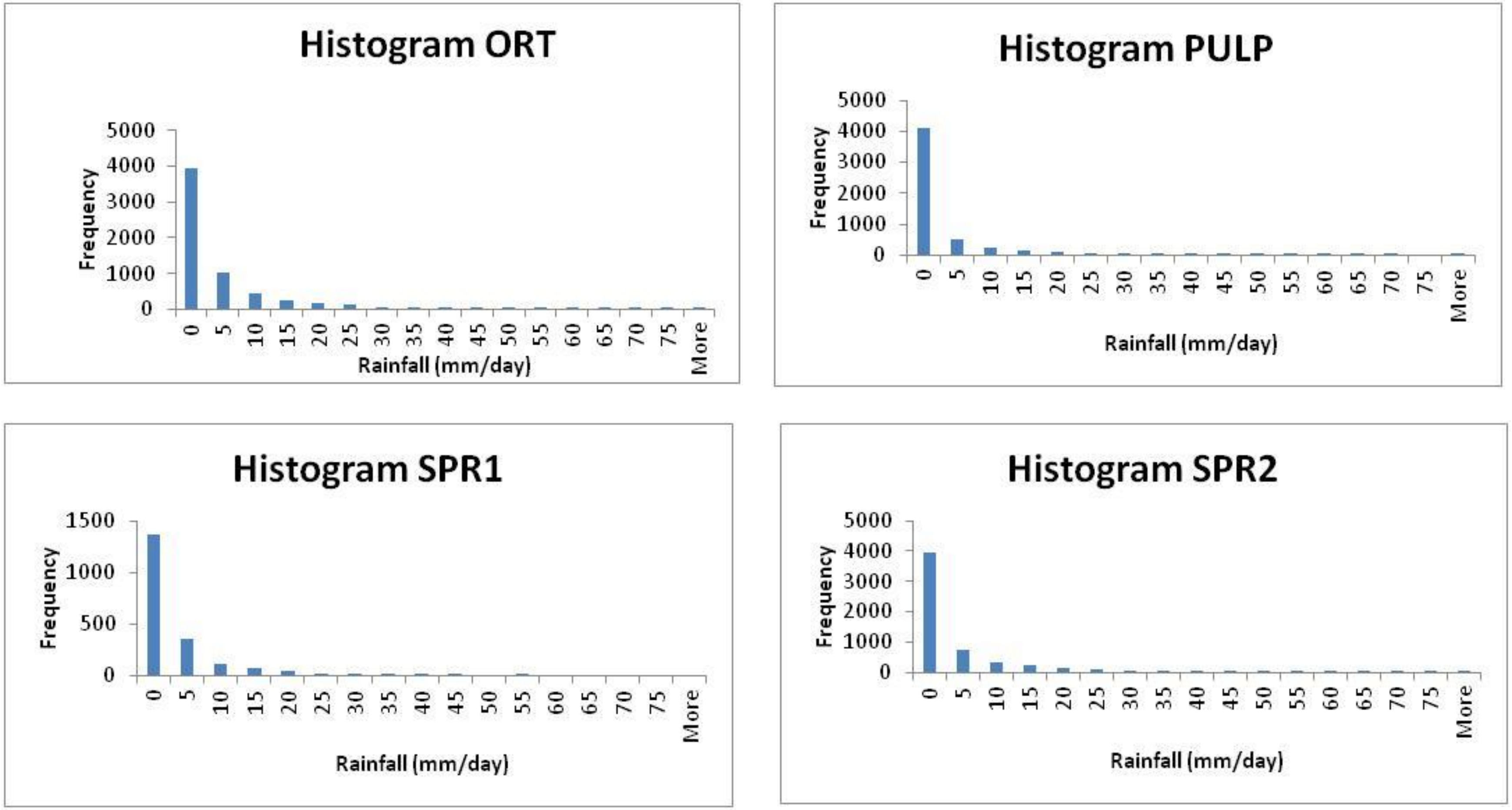

Figure 4.5: Histograms of rainfall (mm/day) for 4 of the 9 weather stations in EMM (1977-2011)

The second column provides the average number of days in one season (October to March) when rainfall is recorded. This is averaged across all the seasons of available data. The standard deviation (SD) is calculated for the full set of daily rainfall observations from each station. SD is highest for BOK1 at 10.11 and lowest for SPR1 at 5.88. This low SD may be owing to the relatively low maximum rainfall observed at the SPR1 station (53mm) which is 32mm less than any of the maximum values at any of the other stations. The maximum value refers to the highest observation within full range of daily rainfall per station. The number of data points that are available for each station, and the number of missing data points are presented as 'N' and 'N miss' respectively. The number of days (and possible data points per station) in the period is 6165. ORT has the most complete dataset for the period, with only four missing values. SPR1 has the least complete dataset with 32% of the data points present.

The 90th, 95th and 99th percentiles are calculated from all observed daily rainfall data and refer to the cut off points above which 10%, 5% and 1% of the data fall, respectively. These are important for understanding the heavy rainfall thresholds for each station. Percentiles are further used in hydrology analyses when determining flood events and flood lines. In each of these percentiles, SPR1 is below the other stations' values, because of the low maximum and mean rainfall observed at this station. This is likely because of missing data in the high rainfall months. ORT has the greatest 90th percentile cut-off at 13mm, but for 95th and 99th percentiles, NIGE has the highest thresholds at 22mm and 48mm respectively.

Table 4.1: Summary table for descriptive analysis of daily rainfall across stations in EMM (1977-2011)

Station	Ave Rain days/ season	Ave rain/day (mm)	SD (mm)	Max (mm)	Ave Tot Rain/ Season (mm)	N	N Miss	Observed Period	90th	95th	99th
BOK1	54	11.71	10.11	200	633	4 955	1 210	1977-2005	11.0	19.0	45.0
BOK2	52	11.00	8.46	112	570	4 830	1 335	1977-2005	10.5	19.0	41.0
BEN	50	11.70	8.55	125	584	4 999	1 166	1977-2006	12.0	20.0	42.0
PULP	35	12.17	8.28	114	428	5 316	849	1977-2011	9.0	18.0	43.0
SPR1	53	7.58	5.88	53	400	2 001	4 164	1998-2011	8.0	15.0	28.0
SPR2	54	11.82	9.05	85	651	5 657	508	1977-2008	12.0	22.0	45.0
NIGE	47	13.61	9.72	106	638	3 906	2 259	1990-2011	12.0	22.0	48.0
DELM	33	14.93	8.90	220	500	5 513	652	1977-2011	10.0	20.0	42.0
ORT	65	10.01	8.32	110	653	6 161	4	1977-2011	13.0	21.0	41.0

Table 4.2 shows the combined data across all the stations per season (October – March), and gives an idea of rainfall characteristics in EMM. For each characteristic, the average, SD and maximum are calculated from the data calculated per season (i.e. not directly from the averages presented in Table 4.1). The average rain per day is 12.11mm with the maximum season average across the whole data set of 41.12mm. This very high total comes from BOK1 station where during that season there were only 40 rain days, 14 of which exceeded the 99th percentile of 45mm within one day. The

number of rain days in EMM per season is 49 days, with a maximum of 83, which was observed at the ORT station in the 1986/1987 season. This was due to an intense low pressure system over Botswana that was responsible for intense and extended rainfall through the Gauteng region (Dyson, 2009). The average total rainfall per season is 558mm, which is roughly 150mm per year less than the Gauteng average (Dyson, 2009). The BOK1 station recorded the highest rainfall in one season of 1 686mm in the 2001/2002 season. The highest maximum observed throughout the period is 220mm in a day, at DELM in October 1995. This resulted from a deep low pressure system over Namibia, which brought moisture from the Indian Ocean and subsequent rainfall to Ekurhuleni (Dyson, 2009).

Table 4.2: Summary table of rainfall data across all stations in EMM for the rainfall season (1977-2011)

Across all Stations	Ave	SD	Max
Average Rain (mm/rain day)	12.11	4.10	41.12
Rain days (count/season)	49	17.11	83
Rainfall Total (mm/season)	558	233.22	1 686.00
Max rainfall (mm/rain day)	56.39	25.27	220.00

The data described thus far are depicted in graph form to provide a visual representation of the spread of data across all the weather stations per season. Figure 4.6 shows the average daily rainfall for the stations in EMM calculated per season. This graph shows DELM to have average rainfall values that are in general higher than the rest of the stations, which is reflected in the highest average rainfall per day across all stations (Table 4.1). The outlier in 2001/2002 at BOK1, which is discussed above is clearly an outlier. The values for SPR1 are generally lower than the rest, which is reflected in this station having the lowest average daily rainfall across the stations.

Total rainfall per season for each of the stations is depicted in Figure 4.7. The seasonal variability seems to follow a roughly similar pattern across the stations until approximately 1999, after which the data across stations are more distributed and do not have as clear a pattern. There is one outlier in the period, observed at BOK1 in the 2001/2002 season, which is identified in Table 4.2 as the maximum total seasonal rainfall, and discussed previously.

Figure 4.8 provides a visual representation of maximum rainfall per season for each of the stations. The fluctuations obvious between seasons is indicative of the intrinsic variability of maximum rainfall values. The graph clearly shows the outliers of DELM in 1995/1996 season and BOK1 in 2001/2002 as discussed above. Figure 4.9 depicts the number of rain days observed per season across the different stations. The graph shows quite wide variability, which suggests that there may be spatial variability with respect to the number of rain days observed within EMM. The following section presents the findings of statistical analysis of the three characteristics of rainfall as presented in the descriptive analysis to assess the spatial distribution of rainfall in EMM.

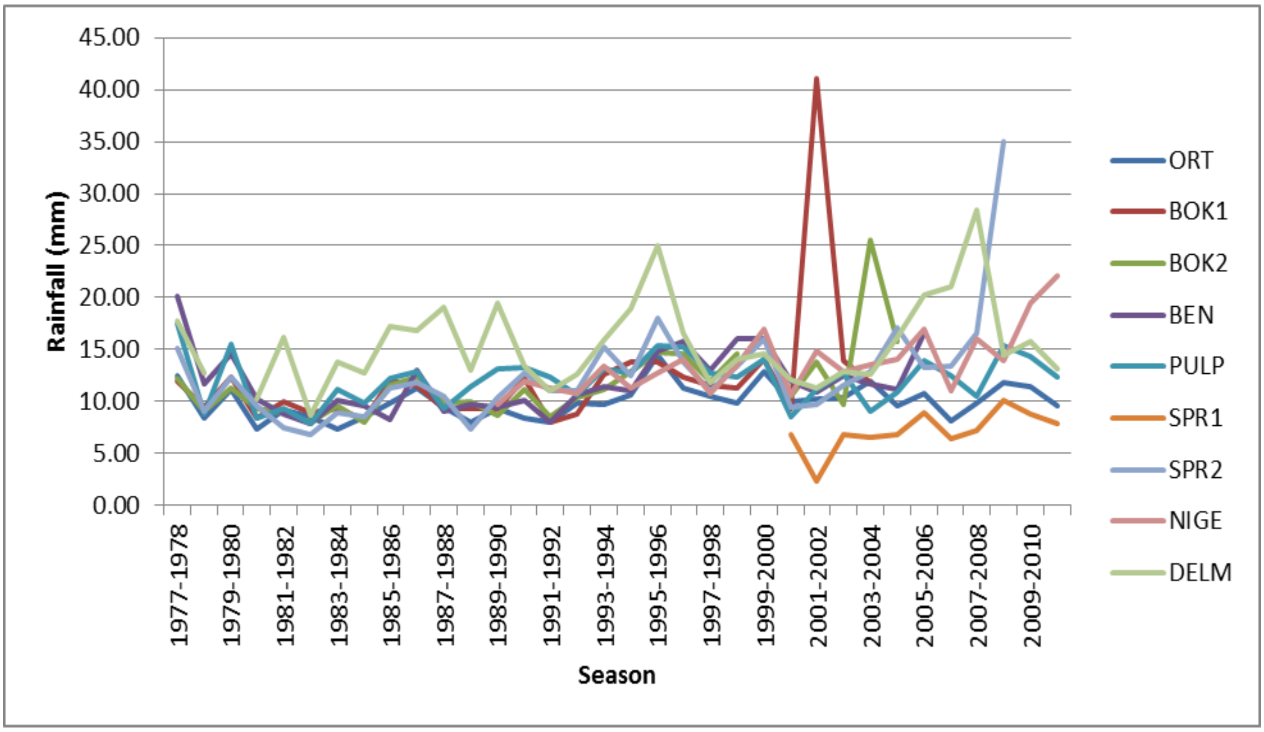

Figure 4.6: Average daily rainfall (mm) for all stations in EMM (1977-2011)

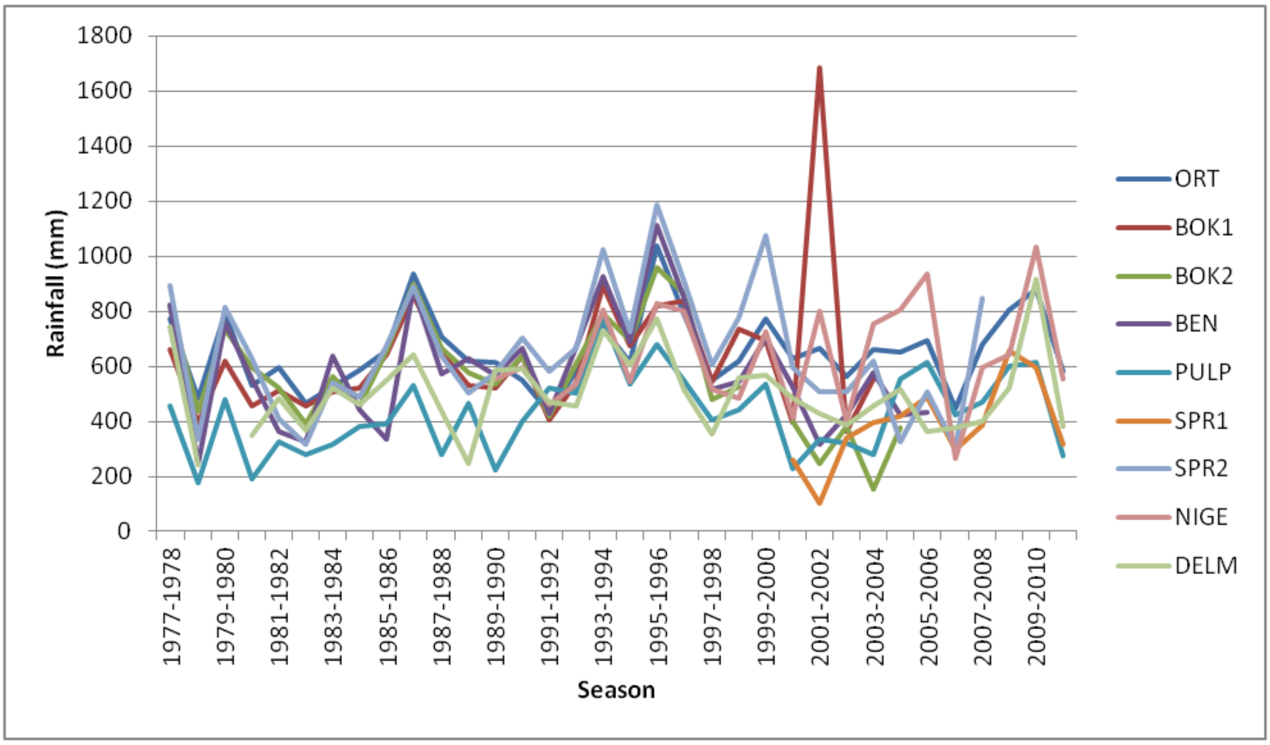

Figure 4.7: Total rainfall per season for all stations in EMM (1977-2011)

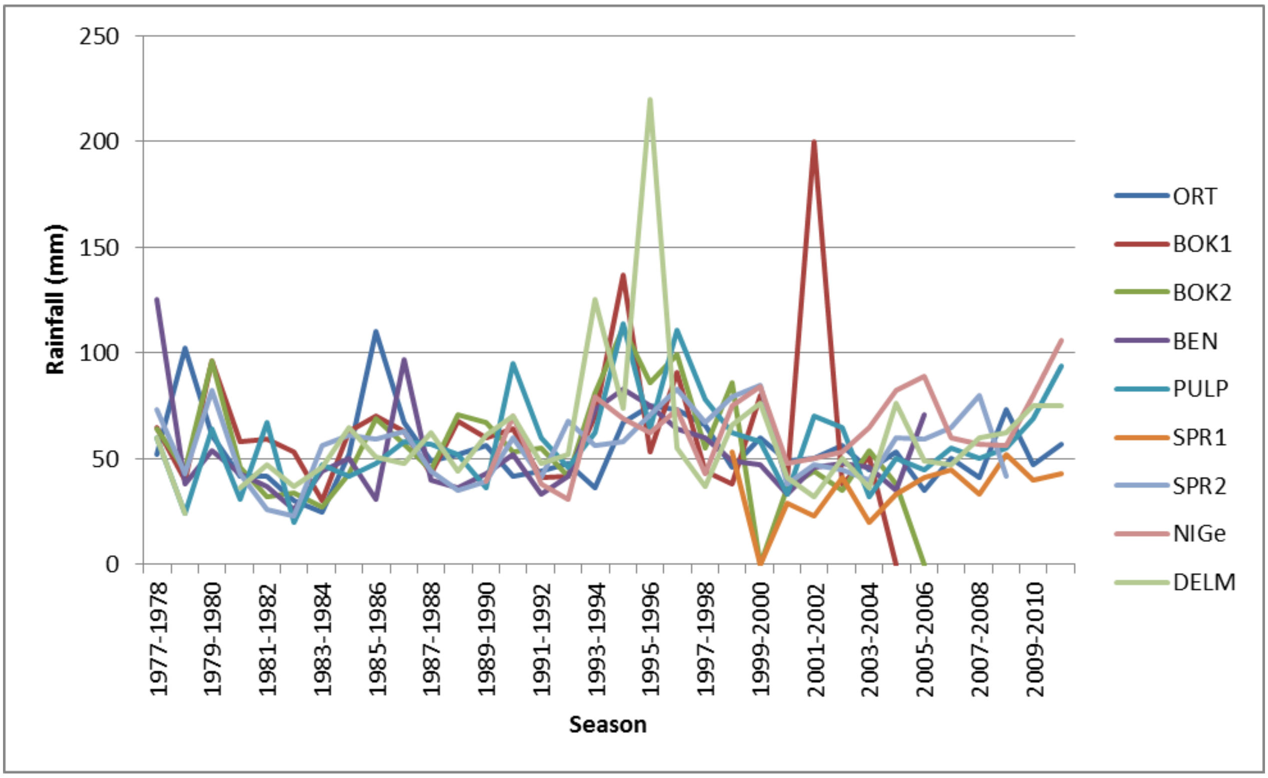

Figure 4.8: Maximum daily rainfall per season for all stations in EMM (1977-2011)

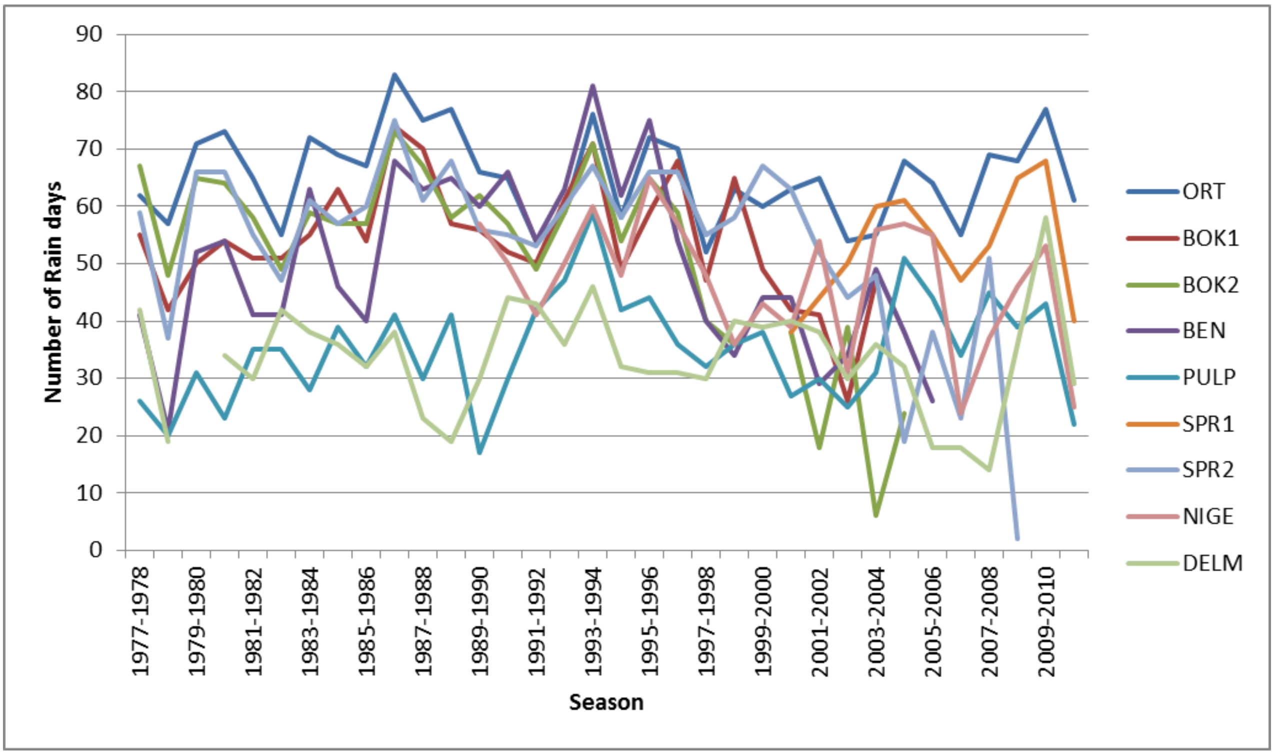

Figure 4.9: Number of rain days per season for all stations in EMM (1977-2011)

4.3.2 Spatial Comparison of Rainfall Distribution

Following from the descriptive analysis of rainfall in EMM, this section assesses if there are significant differences between rainfall distributions of stations in different areas of EMM. This analysis specifically tests the first hypothesis, which states that there is spatial variation in rainfall patterns across EMM. This is conducted using a two-way ANOVA test (respective fit diagnostics can be found in Appendix III), and if this test identifies that a significant difference exists, a multiple comparison test is conducted to show where the difference lies. The tests are done using daily average and maximum rainfall, and the number of rainfall days per season. The ANOVA test assesses if there are significant differences between both stations and seasons. The focus of this aspect of the investigation is on spatial distribution through the comparison between stations, and thus the multiple comparison tests are only conducted for differences between stations, not seasons. Temporal rainfall distribution is addressed in section 4.3.3.

4.3.2.1 Average Daily Rainfall

The average rainfall refers to daily rainfall averaged across a season[13], and then compared between stations and seasons. Initially, a longer period with seven stations is tested for significant differences, and then the shorter period, which includes all nine stations, is tested. Both two-way and one-way ANOVA tests are used to compare the stations. To ensure that the data hold to the ANOVA test assumptions, fit diagnostics are analysed.

4.3.2.1.1 Seven Station Analysis

The fit diagnostics show that the residuals are fan-shaped, indicating the data are skewed to the right, and need to be log-transformed (using natural log) before conducting the ANOVA test. The spread of data are depicted in the box and whisker plot in Figure 4.10. Most of the data fall between 1- 5mm (0 - 2 in the log-transformed data). There is an outlier for the BOK1 Station of 9.47mm (non-transformed). This outlier is due to a number of heavy rain days in the summer season of 2001/2002. In this season, there are a number of days where 24h-rainfall measured up to 200mm. It is possible that this was due to a very large storm, which would constitute as an extreme rainfall event, or a calibration or data input error. These large values are the reason for the very skewed distribution (to the right) for BOK1. The outliers observed in BOK2 and DELM at the lower end of the scale, are due to some missing data during peak rainfall months, which results in the average being lower than it otherwise would be.

The results of the two-way ANOVA test are shown in Table 4.3. The comparison between seasons has an extremely small p-value of 5.99E-18, thus the null hypothesis is rejected and it is concluded that there is a highly significant difference between the average rainfall observed from season to season. The comparison between stations also has an extremely small p-value (2.54E-07), thus the null hypothesis is rejected and it can be concluded that there is a highly significant difference between the average rainfall observed from station to station. In order to test where the difference lies, multiple-comparison tests are conducted, and their results are detailed in Table 4.4.

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[13] All references to 'average daily rainfall' refers to average rainfall for rain days only

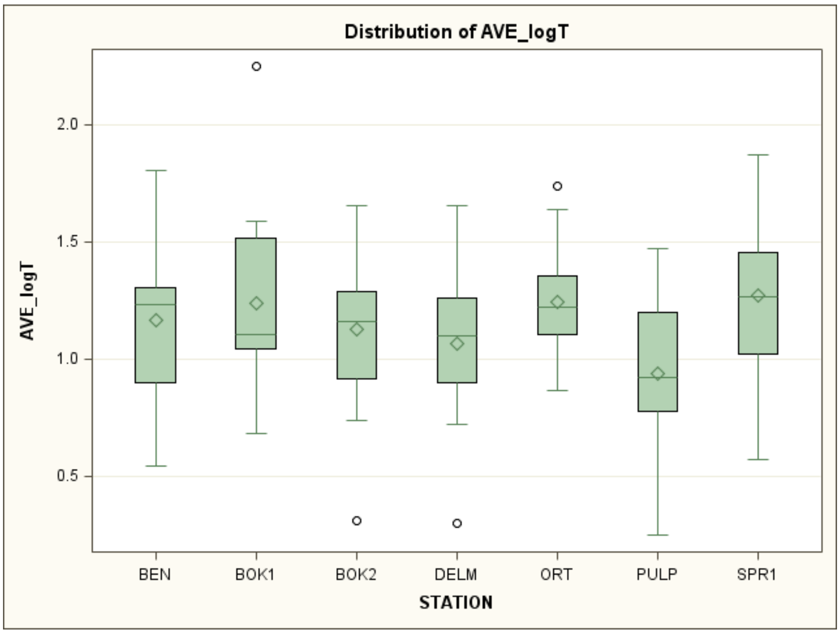

Figure 4.10: Box & Whisker plot for log-transformed average daily rainfall per season (7 Stations, 1989-2004)

Table 4.3: Two-way ANOVA for log-transformed average daily rainfall per season (7 station, 1989-2004)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	8.28	22	0.38	9.45	5.99E-18	1.62
Stations	1.90	6	0.32	7.94	2.54E-07	2.17
Error	5.26	132	0.04			

Table 4.4: Multiple comparison ANOVA test for log-transformed average rainfall per season (7 Station, 1989-2004)

STATION	**Mean**	**Tukey Grouping**	
SPR1	1.27		A
ORT	1.24		A
BOK1	1.23		A
BEN	1.16	B	A
BOK2	1.13	B	A
DELM	1.06	B	A
PULP	0.94	B	

All three multiple comparison tests, show that the stations can be divided into two groups. The test indicates that there is a significant difference between SPR1 and PULP, ORT and PULP, and BOK1 and PULP. The strongest difference is identified between SPR1 and PULP. These two stations are positioned in relatively close proximity to each other despite this difference in daily rainfall averages. That ORT and BOK1 are grouped together may be partially attributed to their proximity.

4.3.2.1.2 Nine Station Analysis

The comparison between all the stations could only be conducted over a few years, and thus the test is not as strong and the results need to be viewed with more caution than the seven station tests. Levene's test for homogeneity gives a p-value of 0.09 and 0.16 for the average rainfall and the log transform of these data respectively. Since p>0.05 in both cases, the null hypothesis of this test fails to be rejected, which means that different samples are be assumed to be Homoscedastic.

The fit diagnostics show that the data are skewed to the right, so the dataset is log-transformed data thus fulfilling the assumptions of the ANOVA test. The Box and Whisker plot of these data is shown in Figure 4.11. The outlier in BOK1 is visible in this data set as it is in the seven-station analysis. The ORT range is relatively small, with one outlier in the 2000/2001 season. Because the period of this data set is so small, this outlier shows more than it would in the context of the remaining available data for that station, where it is not an outlier in that context.

The two-way ANOVA tested on the log-transformed average rainfall data (Table 4.5), gives a non-significant p-value (p=0.051) for the seasonal comparison, thus the null hypothesis fails to be rejected, and there is no significant difference between the average rainfall observed between these seasons. Analysing the station comparison, the p-value is smaller than 0.05 (p=0.01). This means we can reject the null hypothesis, and conclude that there is a significant difference between the average rainfall between the stations. The multiple comparison ANOVA test is conducted and finds that the difference in stations lies between BOK1 and SPR1 (Table 4.6).

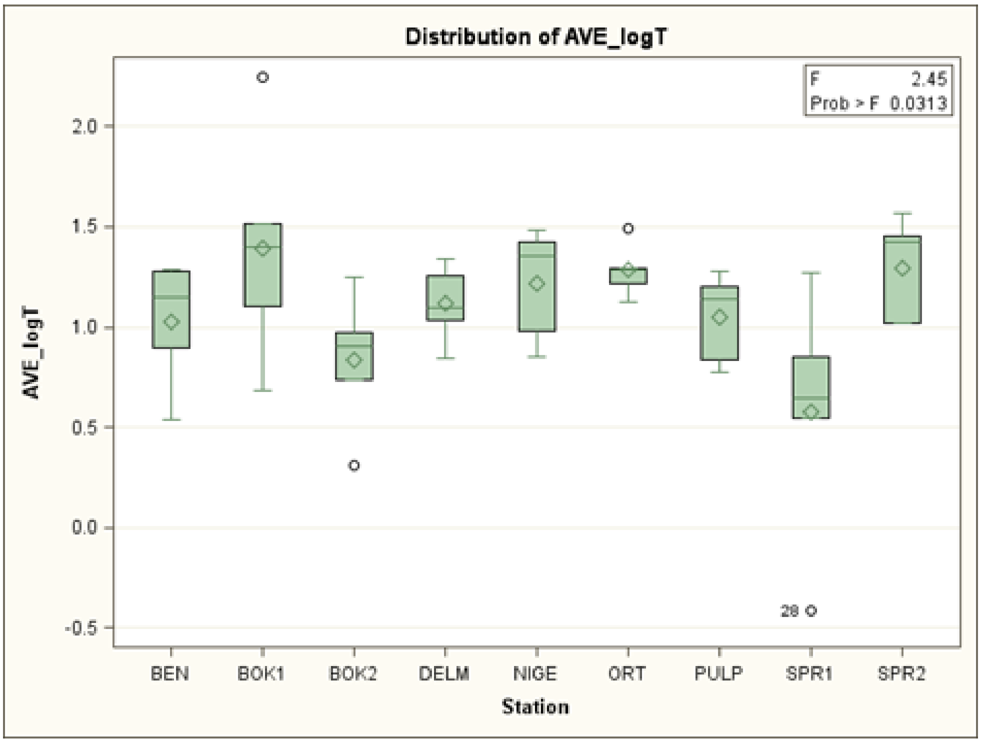

Figure 4.11: Box and Whisker Plot for log-transformed average rainfall per season (9 Stations, 1998-2004)

The ANOVA test for the seven-station analysis finds a highly significant difference between both seasons and stations, however the nine-station analysis found no significance between the seasons and a weak significance between the stations. This is due to the limited amount of data in the nine-station analysis that is not as likely to detect differences that are clearer over a longer period. The results of the multiple comparison tests did not correspond for average rainfall, likely for a similar reason.

Table 4.5: Two-way ANOVA for log-transformed average rainfall per season (9 station, 1998-2004)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	1.19	4	0.30	2.65	0.051	2.67
Stations	2.60	8	0.32	2.90	0.01	2.24
Error	3.58	32	0.11			

Table 4.6: Multiple comparison ANOVA test for log-transformed average rainfall per season (9 Station, 1998-2004)

STATION	Mean	Tukey Grouping	
BOK1	4.61		A
SPR2	3.76	B	A
ORT	3.64	B	A
NIGE	3.49	B	A
DELM	3.10	B	A
PULP	2.91	B	A
BEN	2.90	B	A
BOK2	2.41	B	A
SPR1	2.04	B	

4.3.2.2 Maximum daily rainfall

Maximum rainfall in this analysis is the highest single day rainfall total within one season. These data are compared across stations and seasons, similarly to the average daily rainfall analysis. The analysis of maximum rainfall in a 24-hour period gives an indication of the spatial distribution of the extreme rainfall events across the different stations. The details of this analysis are discussed below, where again the longer period with 7 stations is tested, followed by the shorter period including all 9 stations.

4.3.2.2.1 Seven Station Analysis

The fit diagnostics for the seven-station analysis of maximum daily rainfall show that the residuals are fan-shaped, indicating that the data are skewed to the right and need to be log transformed before comparing them across the stations. The log-transformed residuals fit the ANOVA test assumption of normally distributed data more closely. Levene's test for homogeneity, gives the maximum and log-transformed rainfall data p-values of 0.44 and 0.86 respectively. Since the p-value is not significant in both cases, the null hypothesis fails to be rejected, which means that the different samples are Homoscedastic.

The spread of the log-transformed data is depicted in the box and whisker plot in Figure 4.12. Most of the data across the stations fall between 3.5 and 4.5. There are outliers for the DELM and ORT Stations of 220 and 200 respectively (from non-transformed data). These outliers are likely to be due to an extreme rainfall event. Although days with that much rain are very rare, they do occur. On both of these occasions, there was heavy rainfall (although to a lesser extent) noted at the other stations, which indicates that a large storm went through the area. The maximum rainfall observed across the stations seems relatively comparable.

The two-way ANOVA test, in Table 4.7, analyses the differences between seasons and stations. The seasonal comparison is highly significant (p=1.48E-09), so the null hypothesis is rejected, indicating that there is a highly significant difference between the maximum rainfall observed from season to season. This result is not surprising as there is natural variability in rainfall between seasons, which is most evident in maximum daily rainfall figures. The comparison of maximum rainfall from season to season is explored more in the temporal rainfall distribution analysis. The station comparison is not significant (p=0.27), and thus the null hypothesis fails to be rejected, indicating that there is no significant difference between the maximum rainfall observed across stations. Because there is no significant difference in the maximum rainfall between stations, no multiple comparison test is conducted.

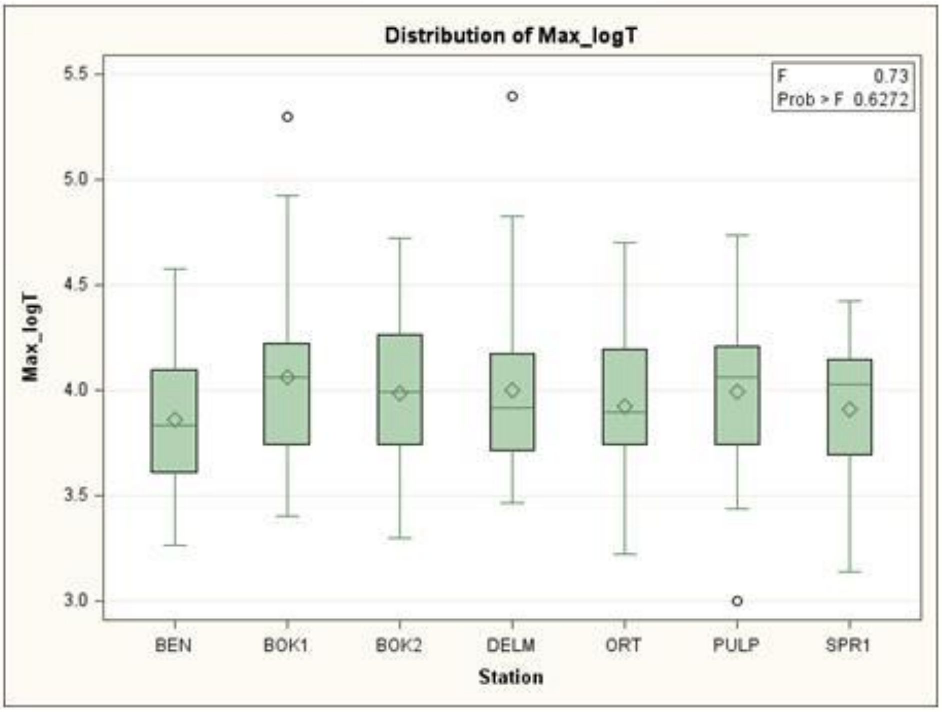

Figure 4.12: Box and Whisker plot for log-transformed maximum rainfall per season (7 Stations, 1989-2004)

Table 4.7: Two-way ANOVA for log transformed Maximum Rainfall (7 station, 1989-2004)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	9.97	22	0.45	5.04	1.48E-09	1.62
Stations	0.69	6	0.12	1.283	0.27	2.17
Error	11.86	132	0.90			

4.3.2.2.2 Nine Station Analysis

Similar to the seven-station analysis, the fit diagnostics indicate residuals are skewed to the right and fan-shaped. The log-transformed data rectifies these problems. Levene's test for homogeneity for the average rainfall and log transform data, gives a p value of 0.10 and 0.08 respectively. Since p is not significant in both cases, the null hypothesis of this test fails to be rejected, which indicates that the the different samples can be assumed to be Homoscedastic.

The comparative distribution of maximum rainfall (after log transformation) between the stations is shown in Figure 4.13. SPR1 displays the lowest distribution with its mean and mode below 3.5, compared to the other stations where their means and modes all sit around the 4.0 mark.

The two-way ANOVA test on the log-transformed maximum rainfall data is shown in Table 4.8, where p-value for the season comparison is greater than 0.05 (p=0.18). Thus, the null hypothesis fails to be rejected, and there is no significant difference between the maximum rainfall observed between these seasons. Analysing the station comparison, the p-value is >0.05 (p=0.09). This means the null hypothesis fails to be rejected, and conclude that there is no significant difference between the maximum rainfall between these stations, and thus a multiple comparison test is not necessary.

Neither the seven- nor nine-station analyses identified significant differences between the stations for the maximum daily rainfall observed in a season. Similar to the average daily rainfall analysis, the seven-station analysis detected a highly significant difference between seasons, where no significant difference is detected in the nine-station analysis. These results are likely because maxima are intrinsically variable and thus it is much less likely to detect significant differences between stations, but very likely to detect significant differences between seasons.

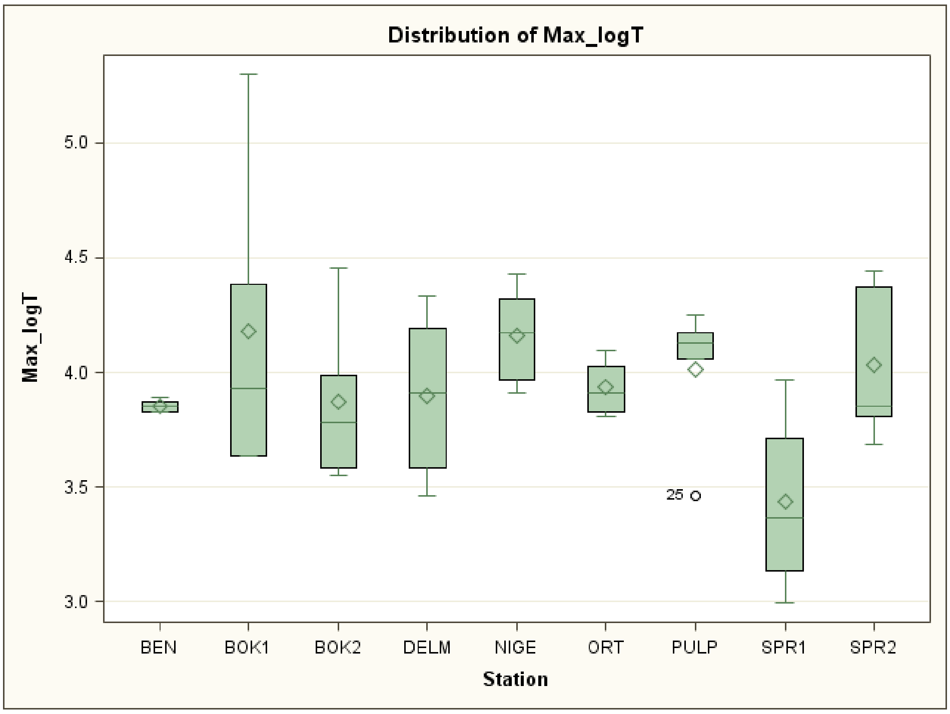

Figure 4.13: Box and Whisker plot for log-transformed maximum rainfall per season (9 Stations, 1998-2004)

Table 4.8: Two-way ANOVA for log-transformed maximum rainfall per season (9 station, 1998-2004).

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	0.83	4	0.21	1.67	0.18	2.67
Stations	1.93	8	0.24	1.93	0.09	2.24
Error	4.00	32	0.13			

4.3.2.3 Number of Rain Days

The number of rain days refers to the count of days within a season where rainfall was recorded. The number of rain days observed per season is compared across stations and seasons, where again the longer period with seven stations is tested followed by the shorter period including all nine stations. A two-way ANOVA test is used to compare the stations, and if a significant difference is found between stations, a multiple comparison test is used to identify where the difference lies.

4.3.2.3.1 Seven Station Analysis

In Figure 4.14, the distribution of the number of rain days across the stations is compared. The two-way ANOVA test (Table 4.9) analyses the differences between rainfall seasons and stations. The seasonal comparison has a highly significant p-value (p=1.35E-11), so the null hypothesis is rejected, indicating that there is a highly significant difference between the number of rain days observed between seasons. The station comparison also has a very small p-value (p=7.69E-27), thus the null hypothesis is rejected, and it can be concluded that there is a highly significant difference between the number of rain days per season across the stations. The data range between 30 and 80 rain days per season (October to March). ORT has an outlier of 103 days in the six-month season. BOK2 has the lowest outlier of six days. This value could have resulted from poor data capturing, rather than a very dry season.

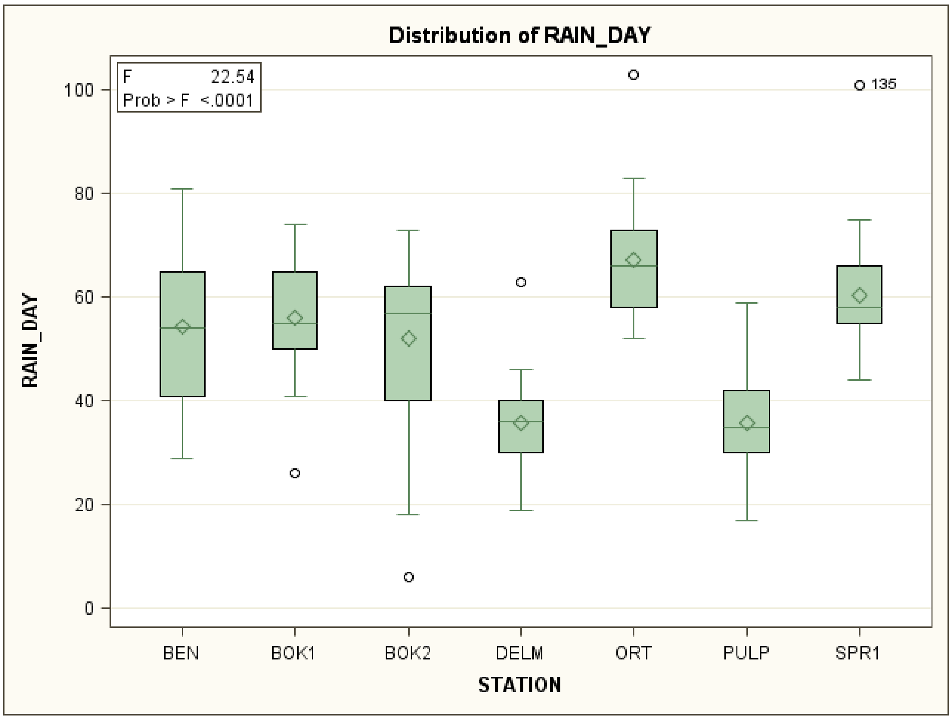

Figure 4.14: Box and Whisker plot for rain days per season (7 Stations, 1989-2004)

The fit diagnostics shows that the residuals are not fan-shaped, and the data are normally distributed, thus the data can be compared across the stations without using a log-transformation. Levene's test for homogeneity, gives p > 0.05 (p=0.30) for the number of rain days, thus the null hypothesis fails to be rejected, which indicates that the different samples can be assumed Homoscedastic.

The multiple comparison test (Table 4.10) reveals that the stations can be divided into three groups with respect to the rainfall days. The test groups PULP and DELM together and are significantly different from all the other stations; SPR1, BOK1, BEN and BOK2 are grouped together; and ORT is grouped with SPR1 and is significantly different from all the other stations. The clustering of these groups seems to correspond quite well with their spatial distribution (Figure 3.3), except for SPR1.

Table 4.9: Two-way ANOVA for rain days per season (7 station, 1989-2004)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	11145.09	22.00	506.60	6.02	1.35E-11	1.62
Stations	19540.00	6.00	3256.67	38.70	7.69E-27	2.17
Error	11109.43	132.00	84.16			

Table 4.10: Multiple comparison ANOVA test for rain days per season (7 Station, 1989-2004)

STATION	**Mean**	**Tukey Grouping**	
ORT	67.30		A
SPR1	60.39	B	A
BOK1	55.96	B	
BEN	54.35	B	
BOK2	51.96	B	
PULP	35.87		C
DELM	35.74		C

4.3.2.3.2 Nine Station Analysis

In Figure 4.15, the distribution of the number of rain days across the stations is compared. The distribution is relatively symmetrical. ORT has an outlier, as observed in the 7-station analysis. The low outlier in BOK2 is again consistent with that observed in the 7-station analysis. The two-way ANOVA for rain days (Table 4.11) has a p-value=0.27 for the season comparison, which is not significant, thus the null hypothesis fails to be rejected, indicating that there is no significant difference between the number of rain days observed between seasons. In the station comparison, the p-value is very small (p=4.17E-05), thus the null hypothesis is rejected, indicating that there is a highly significant difference between the numbers of rain days observed across the stations, and a multiple comparison test is conducted (Table 4.12).

The multiple comparison test identified four test groups within the set of stations. ORT has the highest mean and is significantly different from BEN, DELM, PULP and BOK2. BOK2 is significantly different from SPR1 and SPR2, and PULP is significantly different from SPR2.

As with the previous two investigations, the rain day investigation again detect the conflict between the seven- and nine-station analyses with respect to seasonal comparison, where a significant difference between seasons is detected in the seven-station analysis and not in the nine-station analysis. The limited number of seasons that are compared in the nine-station analysis is the likely explanation for this discrepancy.

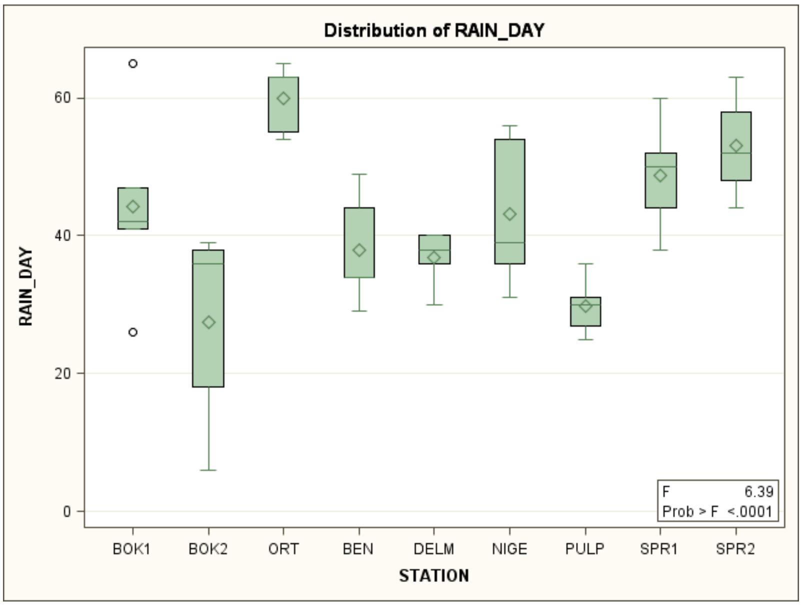

Figure 4.15: Box and Whisker plot for rain days per season (9 Stations, 1998-2004)

Table 4.11: Two-way ANOVA for rain days per season (9 station, 1998-2004)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	460.31	4.00	115.08	1.36	0.27	2.67
Stations	4507.11	8.00	563.39	6.64	4.17E-05	2.24
Error	2714.89	32.00	84.84			

Table 4.12: Multiple comparison ANOVA test for rain days per season (9 Station, 1998-2004)

STATION	**Mean**	**Tukey Grouping**			
ORT	60.00			A	
SPR2	53.00	B		A	
SPR1	48.80	B		A	C
BOK1	44.20	B	D	A	C
NIGE	43.20	B	D	A	C
BEN	38.00	B	D		C
DELM	36.80	B	D		C
PULP	29.80		D		C
BOK2	27.40		D		

The hypothesis that there are spatial differences in rainfall distribution in EMM is found to be true with respect to average daily rainfall and number of rain days per season. However, there was no statistical difference found in maximum daily rainfall between stations. In a number of the two-way ANOVA tests, significant differences were found not only between stations, but also between seasons. The following investigation assesses the temporal distribution of rainfall between 1977 and 2010.

4.3.3 Assessment of Temporal Rainfall Distribution

The temporal analysis of rainfall distribution tests the second hypothesis, which states that there are temporal trends in recent rainfall data in EMM. In order to conduct this analysis the most complete dataset is needed for the entire period. The ORT station is thus used for this analysis as it has the most complete set of data of the available stations, for the longest period. The first step in testing a temporal trend is to conduct an autocorrelation analysis. This assesses whether there are any autocorrelations between consecutive seasons. If the autocorrelation analysis shows positive results that a correlation exists within the period, then a regression analysis is conducted to investigate details of the existing correlation.

The average daily rainfall per season at ORT is presented in Figure 4.16. There is no obvious visual trend in the data for the period. Throughout the period, average daily rainfall lies between 7mm to 13mm. There is one outlier recorded in the 1995/1996, which is due to a particularly wet season, as described in section 4.3.1. The maximum daily rainfall recorded per season at ORT is presented in Figure 4.17. Once more, there is no obvious visual trend in the data for the period. There are two notable outliers in 1978/1979 and 1985/1986 seasons. Although the 1978/1979 season was particularly dry, on 22 December 1978 102mm of rain was recorded. The 1985/1986 outlier was due to a heavy rainfall event in October 1985. Besides these outliers, the maximum daily rainfall ranges between 30mm and 75mm per season. The number of rain days per season is graphed in Figure 4.18 for the period 1977-2010. The number of rain days ranges between 50 and 80 per season. This is only exceeded in the 1985/1986 season, the details of which have already been discussed.

The results of the autocorrelation for average daily rainfall, maximum daily rainfall and number of rain days, per season from 1977-2010, are presented in Table 4.13. In the autocorrelation calculations for each of the characteristics, the p-value is greater than 0.05, and thus it can be concluded that there is no autocorrelation for lag1 correlations. This indicates that there is no statistical annual trend in any of the rainfall characteristics observed at ORT station.

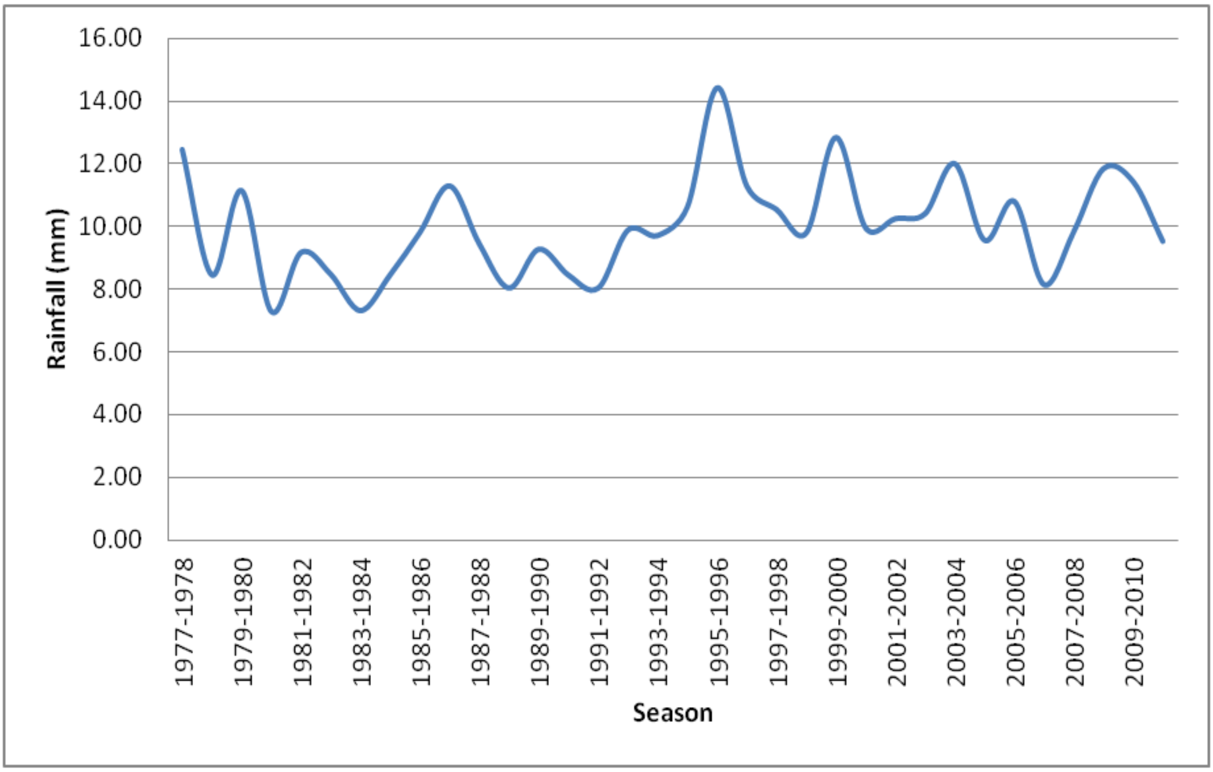

Figure 4.16: ORT Average Daily Rainfall (mm) for the period 1977-2010

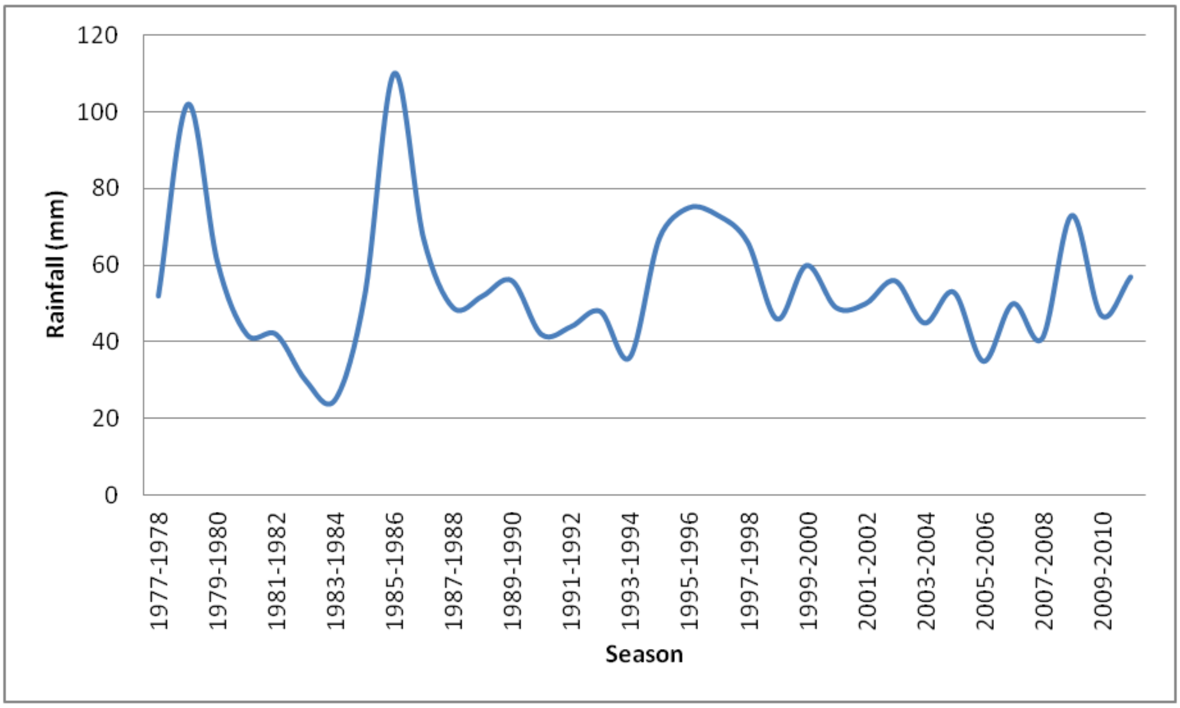

Figure 4.17: ORT Maximum Daily Rainfall per season (mm) for the period 1977-2010

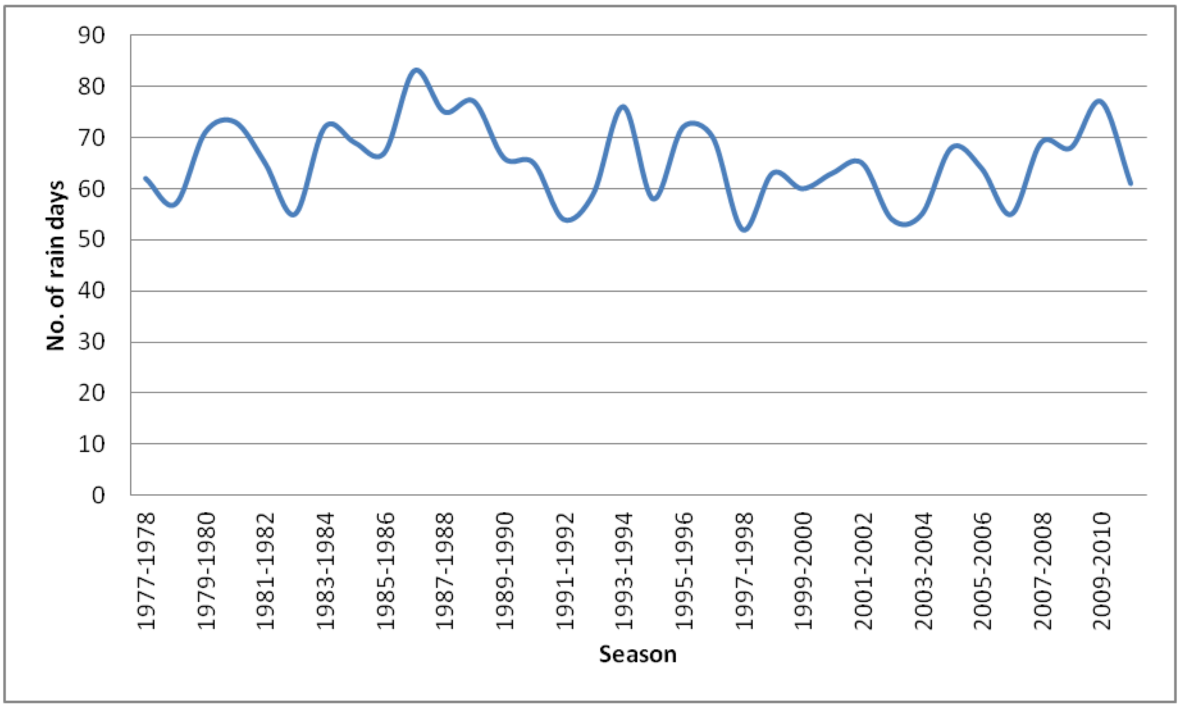

Figure 4.18: ORT Number of rain days per season for the period 1977-2010

Table 4.13: Autocorrelation results for rainfall characteristics at ORT for lag1 correlation (1977-2010)

Rainfall Characteristic	p-value	Autocorrelation
Average daily rainfall/season	0.21	None
Max daily rainfall/season	0.23	None
No. Rain days/season	0.13	None

4.3.3.1 Regression Analysis

Figure 4.16 shows the distribution of daily rainfall (excluding non-rain days) averaged over each season at ORT between 1977-2010. There does not seem to be any significant change in distribution over time. A linear regression model is fitted to the data, and it gives a non-significant p-value (0.306), thus the null hypothesis fails to be rejected indicating that there is no statistical trend in the data. This supports the findings of the Time Series Analysis.

The rainfall analysis presented in this chapter, identifies that average daily rainfall and the number of rain days are not homogenous across the municipality. Although the seven-station ANOVA tests identify that there are significant differences between seasons, there is no temporal trend and thus these differences are likely as a result of climate variability. Extreme rainfall events in urban areas are often linked with flood disasters. The following section aims to see if there is a connection between rainfall and flood events in EMM.

4.3.4 Summary of Rainfall Analysis

The significant results of the two-way ANOVA tests are presented in Table 4.14. In the cases where significant differences were found between stations, multiple comparison tests were conducted. The results of these tests are summarised in Table 4.15. In each of the average rainfall and rain day analyses, ORT is identified as being significantly different from at least one other station. This is important for this investigation because the ORT station is located upstream in the catchment of the case study area of Atlasville. The number of rain days per season received at ORT has the highest mean of all the stations, and is significantly different from the majority of other stations (in the seven-station analysis). The PULP station is also identified as significantly different from other stations in each of the analyses. These findings highlight that rainfall is not homogenous across the municipality. This likely influences the ability to anticipate rainfall accurately, and in turn warn of potential floods across the municipality.

Table 4.14: Summary of Significant differences identified in the two-way ANOVA tests

Average Rainfall	
	***Significant difference between*:**
Seven Station	Seasons & Stations
Nine Station	Stations
Maximum Rainfall	
	***Significant difference between*:**
Seven Station	Seasons
Nine Station	-
Number of Rain Days	
	***Significant difference between*:**
Seven Station	Seasons & Stations
Nine Station	Stations

The results of all the seven-station analyses show a clear difference in rainfall observed between seasons, however this difference is not detected in the nine-station analyses. Since a difference is detected between seasons through the seven-station analysis, which considers a greater number of seasons, it is important to identify whether these differences are due to a temporal trend or whether the differences can be explained through climate variability. The same finding is made for the maximum daily rainfall as well as for the number of rainfall days. The following section investigates the temporal distribution of rainfall in EMM over the period 1977-2010.

Table 4.15: Summary of Significantly Different Groups Identified in the Multiple Comparison Test

Average Rainfall			
Seven Station	ORT; SPR1; BOK1	→	PULP
Rain Days			
Seven Station	ORT	→	BOK1; BEN; BOK2; PULP; DELM
	PULP; DELM	→	SPR1; BOK1; BEN; BOK2
Nine Station	ORT	→	BEN; DELM; PULP; BOK2
	BOK2	→	SPR2; SPR1
	PULP	→	SPR2

The second rainfall analysis into the temporal distribution assessed whether there is a trend in rainfall characteristics over the period of available data. For each of the characteristics, it was found that there is no autocorrelation within the data in the period. It can thus be concluded that the second hypothesis does not hold, and there is no trend in temporal distribution in EMM.

4.4 Flood disaster Incident

The DIRs were obtained from the EMM department of Disaster Management. Data are collected per disaster to which the department responds, and the following details are recorded: date and time of incident, type of incident, structural damage, fatalities, injuries, people affected, intervention, and provincial intervention. The dataset is small relative to the rainfall datasets in the previous analyses, as disaster events have been recorded in EMM only since September 2009. The dataset is too small to obtain useful confidence intervals for a statistical analysis. The dataset is nonetheless useful in analysing and understanding the rain and flood related disasters within the available period. This comparison is mainly conducted for illustrative purposes.

Rainfall and flood related disasters are extracted from the DIR list and analysed in conjunction with the rainfall dataset. Between October 2009 and January 2012, 50 flood disasters are recorded. Many of these reports relate to the same event, but relate to different areas in the Municipality. The number of reports provides an indication of how widespread the disasters are, rather than the intensity. Figure 4.19 shows the distribution of disaster reports for the period.

The disaster reports tend to fall within the rainfall season. Disasters are most evident in December and January, which are the peak rainfall months (Dyson, 2009). Between October 2009 and February 2012, two disasters relating to sinkholes were reported, affecting over 300 people. Underground caves were potentially weakened through excessive rain and result in collapse and sinkhole development.

There are two clusters of disaster occurrences in the data, namely in the beginning of 2010 and at the end of 2010. The number of disaster reports within one day is the highest within these two clusters. These sections in the data are selected and combined with the recorded rainfall data[14] for the period.

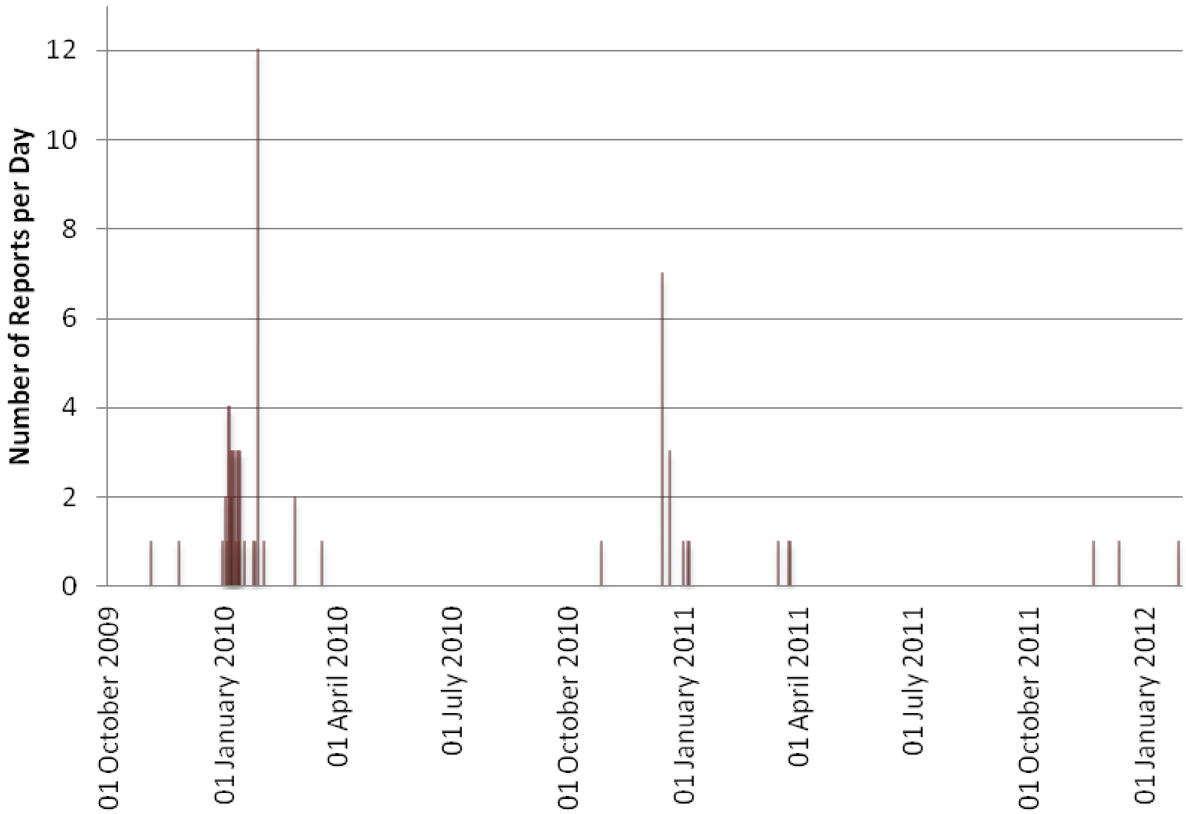

Figure 4.19: EMM Rainfall and Flood Disaster Reports (Oct 2009- Jan 2012)

Figure 4.20 shows the period from 25 December 2009 to 7 February 2010. Within this period, a total of 365mm of rain fell and there were 50 disasters reported. In the descriptive analysis (Section 4.3.1) of rainfall data in EMM, rainfall of above 21mm in a day is within the top 5% of rainfall events (95th percentile). For the period depicted in Figure 4.20, there are five occasions where this threshold is surpassed, and two occasions where the 99th percentile threshold (41mm) is surpassed. The first disaster during the period is reported just after the second rainfall event that exceeded the 95th percentile. The highest daily rainfall total for the 2009/2010 season (47mm) is on 25 January 2010. Although there is only one disaster report for this day, the two reported fatalities during the period occurred on this day, in the Pomolong informal settlement in Tembisa. There is a 5 day gap between this peak rainfall event and the day with the highest disaster reports, during which time it continued to rain, albeit less intensely. This supports the literature, which suggests that the worst damage may not be caused by the most intense rainfall events (Douglas *et al.*, 2008). However, the cumulative effect of heavy rainfall within a relatively short period may account for the peak in DIRs towards the end of the period. There were no reports of injuries or fatalities in Atlasville for this period.

[14] Rainfall data from ORT was used as it is the most comprehensive dataset, and maximum rainfall was not found to be significantly different between stations in the municipality.

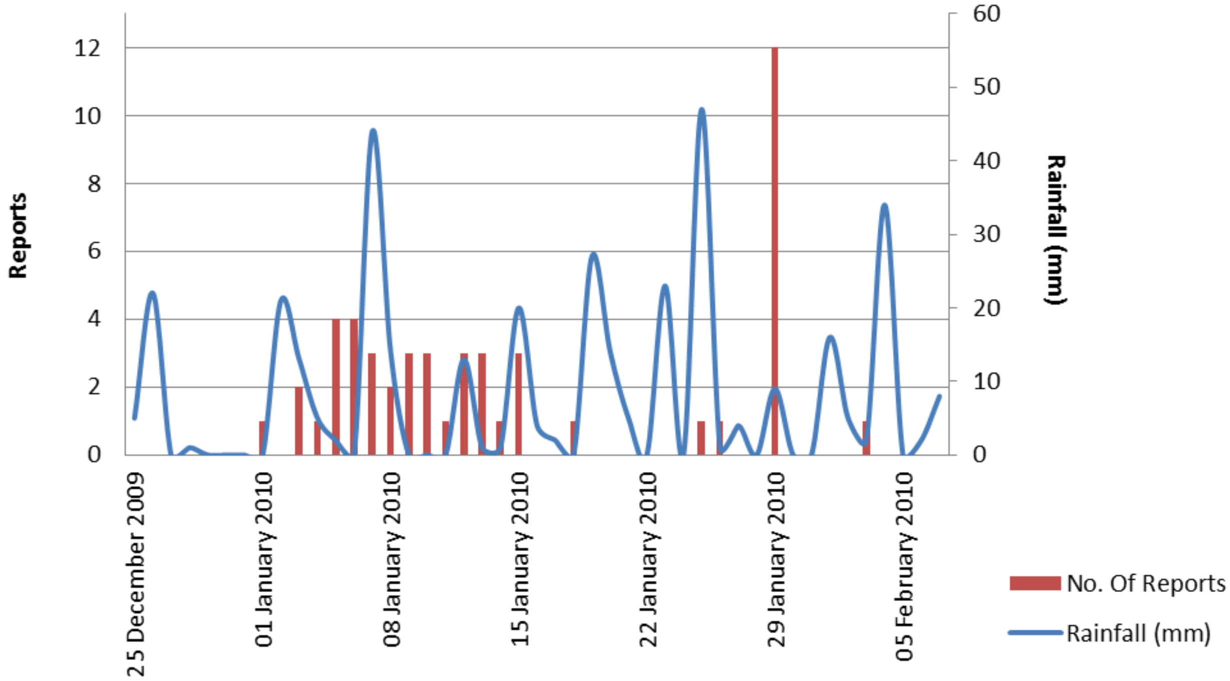

Figure 4.20: Visual Representation of Rainfall at ORT and the Flood Disaster Incident Reports in Ekurhuleni (25 Dec 2009 - 7 Feb 2010)

Figure 4.21 shows the rainfall and disaster reports between 7 December 2010 and 11 January 2011. Within this period, a total of 286mm of rain fell and 13 disasters were responded to in EMM. There are four days where rainfall exceeded the 95th percentile threshold and two days where the 99th percentile is exceeded. The first seven disasters are reported in the wake of a major rainfall event with three consecutive days of heavy rainfall, where 20mm, 57mm and 21mm of rain fell on consecutive days. The second set of flood disasters occurred after minor rainfall is observed at ORT. Towards the end of the period, two disasters were reported, subsequent to two days of very heavy rainfall (where the 99th percentile thresholds were exceeded). This may be accounted for by a mismatch in catchments between rainfall observed and flood incidence. The accumulation of rainfall may have contributed to increased risk through the period, leading to saturated ground areas, which are likely to result in flooding from relatively small amounts of rainfall (e.g. 29 January 2010). Throughout the period, the DIRs recorded extensive damage to houses, properties, and many[15] people were affected, this too may have been due to the accumulation of flood stress over an extended period of weeks.

Although the disaster report data are not as extensive as the rainfall data, comparing the incidence of rainfall events and flood disasters provides insight into the relationships between these phenomena in EMM. The two periods assessed in this analysis found that there seems to be a correlation between extreme rainfall events and flood disasters. Extensive flood disasters across EMM seem to be associated with periods of intense rainfall, and not just once off events.

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[15] The report does not specify numbers, merely states “many” people were affected.

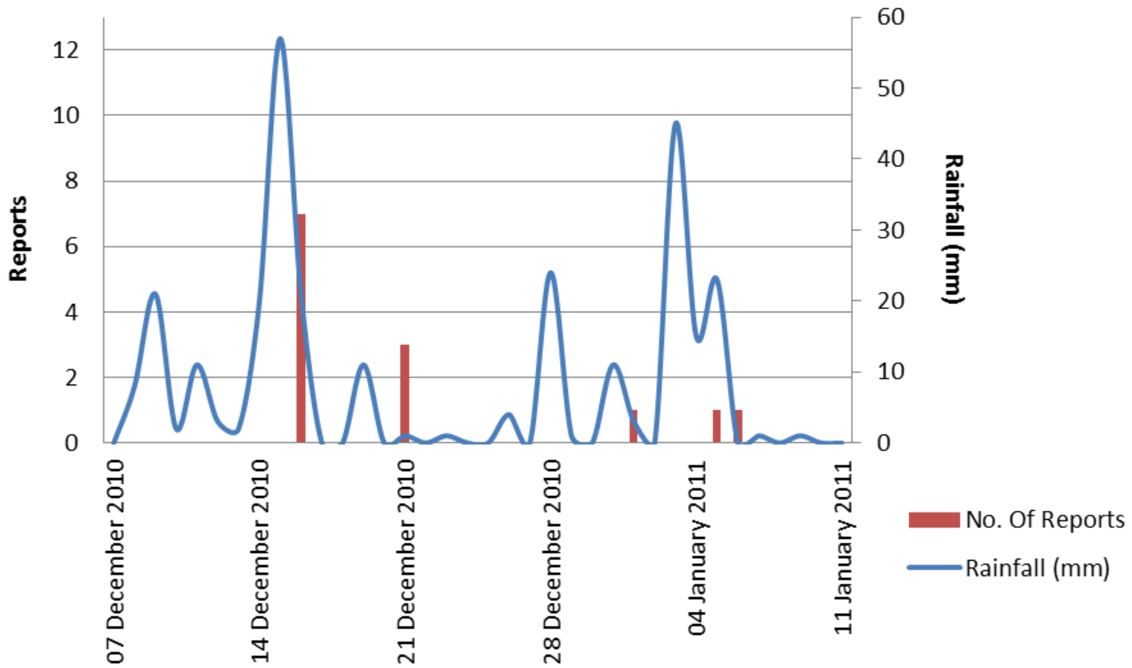

Figure 4.21: Visual Representation of Rainfall at ORT and the Disaster Incident Reports in Ekurhuleni (7 Dec 2010 - 11 Jan 2011)

4.5 Summary of Results

The rainfall investigation finds that significant differences are identified between rainfall patterns across different stations. Some of these differences may influence runoff and flood patterns in EMM, however further investigation is necessary to corroborate the findings. There were significant differences between some stations around EMM, particularly for average rainfall and number of rain days per season. This indicates that there is spatial variability across EMM, some of which can be accounted for by distance between weather stations. One of the major limitations of this comparative analysis is the distribution of weather stations across EMM. The stations used in this study are clustered in the central parts of the municipality. There are large gaps in rainfall data, particularly obvious in Tembisa, where some of the worst flooding occurs. In addition to this, the weather data from the existing stations is sometimes incomplete and contains data capturing errors. The patchiness of the data limits the ability to gain a comprehensive understanding of rainfall distribution across the municipality, and the connection between rainfall and flood events. This in turn impedes the ability to manage flood disasters effectively, and assess the potential impacts of climate change on rainfall and flooding across the municipality.

Consistent with climate projections for the area, the study found no trend over time of average daily rainfall in EMM (Engelbrecht *et al.*, 2012). Although the two-way ANOVA found significant differences in maximum rainfall per season, the temporal analysis indicates that there has been no statistical trend over time. The difference found between seasons is thus accounted for by the intrinsic climate variability. Climate projections for the Highveld region suggest that extreme rainfall events are likely to become more frequent (Easterling *et al.,* 2000; Fauchereau *et al.,* 2003; IPCC, 2007; Williams *et al.*, 2007; Bates *et al.*, 2008; Engelbrecht *et al.*, 2012) ; however neither average daily rainfall, nor maximum daily rainfall in EMM shows this trend.

Although some of the greatest flood events in the EMM DIR are associated with extreme rainfall events, not every extreme rainfall event results in a flood disaster. It is likely that the accumulated rainfall through the period caused the ground to become saturated, which in turn increases runoff when it rains, and is more likely to result in floods. Within the period included in disaster reports, many more rainfall events exceeded the 95^{th} and 99^{th} percentile thresholds than there are flood reports. In addition to this, flood disasters also occurred on days with much less rainfall than the extreme event thresholds. This supports the literature, which states that vulnerability to floods is not solely dependent on extreme rainfall events (Douglas *et al.*, 2008), and the duration of the wet spell is an important contributor to flood risk.

4.6 Conclusion

This chapter comprises a physical analysis of rainfall and flood events in EMM, the first of three investigations, which contribute to understanding the rainfall context and status quo of flood disasters in EMM. The first investigation confirmed the hypothesis that there is spatial variability in rainfall patterns across the municipality, with respect to average rainfall and number of rain days per season. However, the hypothesis was rejected with respect to maximum rainfall. The second hypothesis which tested for temporal trends in rainfall data for EMM found that although there were statistically significant differences between seasons, there was no trend found in the data for any of the rainfall characteristics. The final hypothesis that tested the correlation between rainfall and flood incidence in EMM, was confirmed through the limited data available for flood disaster incidence, that flood disasters are clustered during periods of heavy rainfall. This correlation is however not completely consistent, because not every heavy rainfall event results in flooding, and not every flood results from a heavy rainfall event.

The results of the physical investigation suggest that the flood disasters in EMM that residents and municipal managers claim to have shifted over time cannot be accounted for by increasing rainfall intensity (Easterling *et al.,* 2000; Fauchereau *et al.,* 2003; IPCC, 2007). Variability in rainfall characteristics across small areas makes accurate predictions difficult, and consequently difficult to warn against (Dyson, 2009). The DIR and rainfall investigation suggests that periods of extreme rainfall can be associated with widespread flooding in EMM, including Atlasville. The outcomes of this chapter reveal that the physical analysis alone is not sufficient in explaining why flood disasters have increased in Atlasville, and that there must be other factors that are contributing to flood risk (Douglas *et al.*, 2008). A more nuanced investigation into this connection may help the municipality and affected communities to anticipate and prepare for future floods. The following chapter assesses how the municipal context of disaster management, including relevant policy and implementation, affects disaster risk and management.

5 Political Context

"The most important sphere for the effective implementation of disaster risk management is local government" (Botha *et al.,* 2011, p24).

5.1 Introduction

The previous chapter analyses the physical context of disaster management and identifies the patterns and possible climate drivers of floods in EMM. The investigation highlights that although some significant spatial differences in average daily rainfall and number of rain days across the municipality are identified, the temporal investigation found no trend over time, and thus is not sufficient to attribute the change in flood risk, which has been identified in EMM and specifically Atlasville to changes in rainfall patterns. The investigation further highlights the link between heavy rainfall and flood disasters, which is supported by the literature. However, no significant differences are found in maximum daily rainfall, which again suggests that other factors, besides rainfall are contributing to this increased risk. Understanding the context of past rainfall and flood events can assist planning for future events. For example, the potential correlation found between extreme rainfall events and flood disasters may help anticipate and prepare for future floods, because the DIR analysis finds that flood disasters are associated with periods of heavy rainfall. However, although floods tend to be associated with high rainfall amounts, the rainfall data and DIRs comparison highlighted that the occurrence of high rainfall does not necessarily result in flooding. This suggests that the physical investigation is limited in explaining and anticipating the drivers of flood disasters, and that there may be factors related to managing and preventing disasters, which are contributing to disaster risk.

Governance practices and policy documents influence government implementation of, and approaches to, disaster management. These documents guide municipal processes and are the primary bases for assessing municipal managers and keeping them accountable. The focus of this chapter is to address the second research question which aims to understand how the policy context influences perceptions and implementation of disaster management at the local municipal scale. This question is interrogated through testing the following two hypotheses:

1. The DMA does not create an enabling environment for policy to be translated into effective disaster management at the local level.
2. Factors not directly related to flood disasters and risk influence DRR efforts in EMM.

This component of the research fits into the DROP model (Cutter *et al.*, 2008) by addressing how the social, natural and built environments are governed, how the immediate effects of disasters are managed and coped with, and the longer term management that addresses recovery, mitigation and preparedness.

This investigation uses three sets of data to assess the political context of disaster management at the local government scale. The sets of data include the South African DMA, No. 57 of 2002, which provides the policy requirements and stipulations for disaster management. The second set of data is a SALGA research report, outlining the "status quo of disaster management within the local sphere of Government" (Botha *et al.*, 2011, p10), which assesses how effectively the DMA has been implemented in municipalities throughout South Africa. The final set is made up of the interview responses of EMM managers, which provides information regarding how the people in charge of implementing this Act have found this process.

Each data set is first described and thereafter a thematic analysis is undertaken. The themes that are used for the analysis are extracted from the DMA as recurring and cross-cutting ideas that influence how disasters are managed and engaged with. The themes that are identified across the different data sets are used to triangulate the three sets and assess whether the findings support each other or not (Figure 5.1). This allows limitations to be identified in the political context, extending from the policy document to its implementation. Cooperative governance is a fundamental principle of South Africa's governance structures and is the first theme of this analysis. The policy encourages a highly proactive approach to disasters through focussing on prevention and mitigation of disasters. This approach is in line with international best practice for disaster management, and serves as the second theme of this analysis. The third theme is knowledge, which forms a key theme in the dissertation as a whole, because of the role that knowledge and information have in influencing decisions about disaster management. Vulnerability and adaptive capacity are also important factors that influence disaster management, and thus comprise the final theme of this analysis.

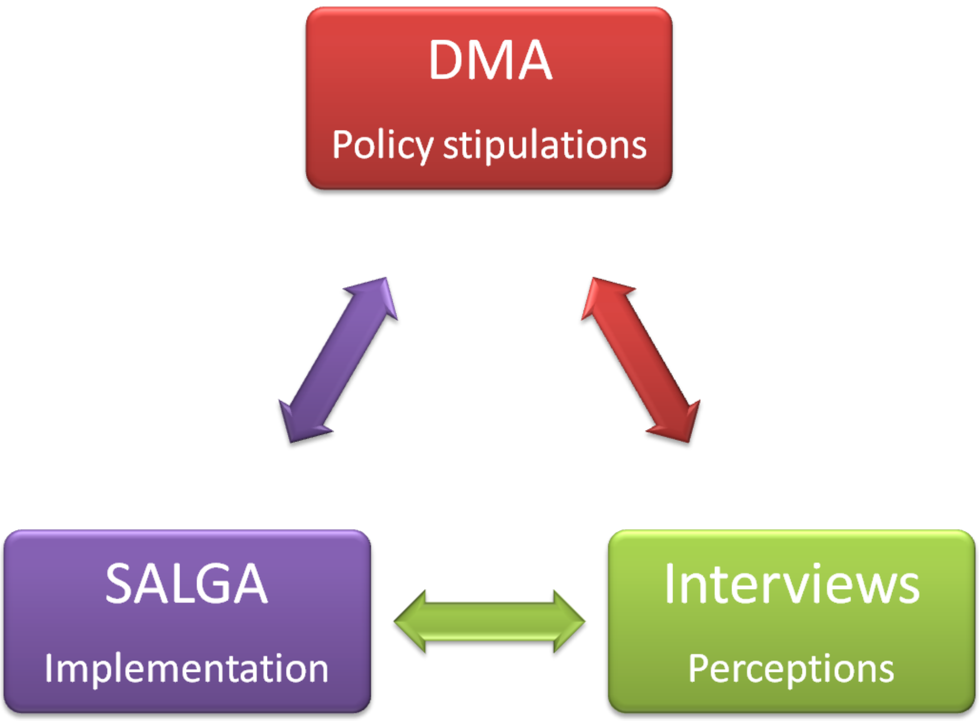

Figure 5.1: Triangulation of the three sets of data in the policy analysis

This chapter argues that although the policy documents themselves are highly regarded, implementation is not solely dependent on the document. The poor implementation of the DMA suggests that it does not create an enabling environment for managers and decision-makers to translate the policy into action at the local level.

5.2 Data Description

The political context of DRR in EMM is assessed through three datasets including the South African DMA (2002), a report by SALGA on the implementation of the DMA at the municipal level, and twelve interviews with a range of municipal managers from EMM. Each of these pieces of data is described in more detail in the following subsections. These are followed by an analysis of these datasets in combination.

5.2.1 South African Disaster Management Act

The DMA forms the basis of the policy context of this research. This document outlines the way in which disaster management is approached and conducted at all scales of governing in South Africa. It states the relationship between the scales of government, which ensures the structures guiding cooperative governance are set out. The local government sphere is nested within the provincial structures, which in turn are nested in national governing structures. Because of the aforementioned structure, although research focus is on the local scale, understanding the national and provincial scales is important as they have an influence at local level. The approach of the DMA is predominantly 'top-down' and creates a strong hierarchical structure. This structure has the potential to limit or obstruct grassroots or local scale initiatives from influencing higher levels of government.

South African disaster management legislation is nonetheless viewed as some of the most progressive in the world, as the focus lies in prevention, mitigation and preparation, and not purely response and recovery (Botha *et al.*, 2011). Although in theory, South Africa's legislation is highly progressive, its major shortfall is its lack of implementation, and thus is rendered ineffective. This suggests that the policy does not sufficiently enable local government to put the policy into effect. The DMA, No. 57 of 2002 provides the foundation for disaster management in South Africa. The description includes the underlying principles and general procedures as stipulated by the Act, but does not go through every requirement or stipulation.

The central focus of the DMA is to provide for:

> *"an integrated and coordinated disaster management policy that focuses on prevention and reducing the risk of disaster and mitigating the severity of disasters, emergency preparedness, rapid and effective response to disasters and post disaster recovery; the establishment of national, provincial and municipal disaster management centres; disaster management volunteers; and matters incidental thereto" (RSA, 2002, p2)*

These concepts are used as the basis for the structure of the DMA, and consequently the envisioned implementation of the Act. The effectiveness of the policy lies in the ability for these concepts to be implemented, and thus have an important role in guiding this analysis. The approach of the DMA illuminated through the definitions of two key concepts that are used throughout the policy; namely 'disaster' and 'disaster management'.

The DMA describes a **disaster** as:

> *"a progressive or sudden, widespread or localised, natural or human-caused occurrence, which causes or threatens to cause death, injury or disease; damage to property infrastructure or the environment; or disruption of the life of a community; and is of a magnitude that exceeds the ability of those affected by the disaster to cope with its effects using only their own resources" (RSA, 2002, p6)*

This definition is the primary starting point for the Act and it is intrinsically linked to the way in which disasters management is framed in the DMA. Disasters can be divided into three linked ideas that need to be addressed in disaster management. These include:

1. Hazard
2. Impact, or potential impact
3. Coping ability

Disaster management needs to deal with each of these aspects of a disaster, such as is described in the DMA definition of **disaster management** as**:**

> *"a continuous and integrated multi-sectoral, multidisciplinary process of planning and implementation of measures aimed at preventing or reducing the risk of disasters; mitigating the severity or consequences of disasters; emergency preparedness; a rapid and effective response to disasters; and post disaster recovery and rehabilitation" (RSA, 2002, p6)*

This definition identifies each of the three aspects of disasters, namely hazard, impact and coping ability. In addition it identifies the prescribed approach towards disaster management in South Africa in dealing with disasters proactively to reduce impact, responding rapidly and effectively, and facilitating recovery and rehabilitation. Similar to other South African policy documents (such as the Constitution), the DMA draws on principles of cooperative and integrated governance, and promotes communication and collaboration between all stakeholders involved in disaster management, at all scales.

The DMA is structured broadly into disaster management requirements for each of national, provincial and local scales of government. The policy prescribes how the following structures and actions should be organised and managed:

- intergovernmental structures and policy frameworks;
- funding post disaster recovery and rehabilitation; and
- disaster management volunteers.

Figure 5.2 depicts the structural layout stipulated in the DMA, which is discussed in the following sections. This depiction highlights the subtle distinction between the relationship between the disaster management centres and the disaster management frameworks at different levels. The requirements of the national disaster management centre (NDMC) are stipulated in the DMA and subsequently elaborated in the Disaster Management Framework (DMF). In contrast, the provincial and local disaster management centres are required to establish a disaster management framework, which is relevant to their specific context and within the stipulations of the structures at higher levels of the hierarchical structure.

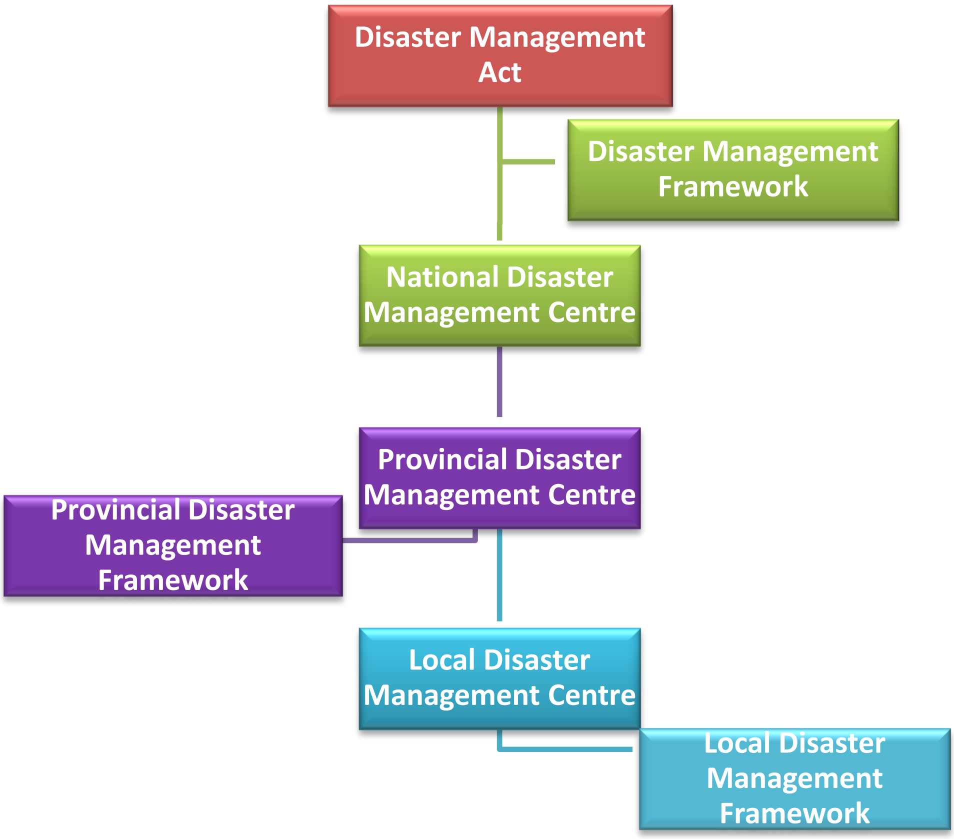

Figure 5.2: Depiction of the structural hierarchy stipulated by the DMA (2002)

5.2.1.1 National Disaster Management Framework

The DMA requires the development of a national disaster management framework (NDMF), which is in line with the DMA, and provides details on the interpretation and implementation of the Act, and which is applicable for the whole of South Africa. The intention of the NDMF is to provide clarity and interpretation of the DMA to enhance its implementation. Although the framework addresses disaster management in its entirety, the emphasis is placed on preventing and mitigating potential disasters, and reducing vulnerability to disasters. The framework is designed to:

- facilitates cooperation, coordination and participation of relevant stakeholders;
- encourage disaster management capacity-building and research;
- develop a comprehensive information system, which considers indigenous knowledge; and
- provide a framework for funding disaster management.

The DMA also stipulates that each province and municipality must "establish and implement a framework for disaster management in the province [municipality] aimed at ensuring an integrated and uniform approach to disaster management in the province [its area]" (DMA, 2002, p30 [p42]), and consistent with the Act and the National Framework. This is important because the Act acknowledges that in different contexts, the details of disaster management may vary, despite the need to adhere with the principles of the Framework and Act. There is a delicate balance between ensuring that each scale of government is based on the same principles and structures, without restricting the ability to tailor disaster management to their specific context. These processes, prescribed by the DMA and elaborated by the NDMF, are managed by the disaster management centres.

5.2.1.2 Disaster Management Centres

The disaster management centres are designed to coordinate disaster management structures and efforts within their jurisdiction and to coordinate with centres at different levels of management. These centres are designed to "promote an integrated and coordinated system of disaster management" (DMA, 2002, p16). These centres must incorporate comprehensive management of disasters including reduction, mitigation and preparedness, response, and recovery and rehabilitation. They are required to support both formal and informal initiatives that assist in achieving the objectives of the DMA.

The NDMC is charged with establishing communication links and maintaining a directory of institutional role-players, including all spheres of government, civil society, private sector, experts in disaster management and other local and international organisations involved in disaster management. The NDMC must monitor the different capacity each stakeholder has in assisting with disaster management.

The NDMC is designed to oversee all disaster management in the country, and is responsible for ensuring that the provincial and municipal centres are in alignment with the DMA. The NDMC is responsible for disaster management in the event of a national disaster, and it must liaise and coordinate with the provincial and municipal disaster management centres. The provincial centres are in turn required to align themselves with the NDMC, and the municipal centres are to be aligned with the provincial and national centres. The municipal disaster management centre is required to assist the provincial and national disaster centres in their duties as stipulated by the DMA, including in the event of a national or provincial disaster. The provincial centre is required to assist in the event of a national disaster, and if they are able to, they are to assist with municipal disasters. There is a potential tension in this design of the NDMC in the case of flood disasters. Flooding tends to be localised, even when there is widespread heavy rainfall, there will typically only be pockets of flooding. Local municipal centres may be limited in their ability to respond effectively to localised flooding if the national centre has the power to dictate how these events are managed.

Although the disaster management centres are designed to encourage and participate in cooperative governance, the structure is very hierarchical. The local centres need to adhere to the structures set out by both national and provincial centres, which may restrict their ability to organise disaster management in a way that is tailored to their specific context. This type of centralised management system has the potential for the local level to shift responsibility to higher levels. In addition to this, the local level tends to have limited resources and capacity for local level obligations. In the event of a national or provincial disaster, these limited resources are required to assist management. Such a disaster puts additional pressure on local centres and shifts the focus away from local disaster management. In contrast to this, the national and provincial centres are only required to assist with disasters at lower levels where possible.

The requirements of provincial and municipal disaster management are highly comparable and are as a result of the cooperative and integrated basis of the DMA. The NDMF (2005) states that the primary aim of the provincial disaster management centre is to provide support for the NDMC. It is also required to provide municipal disaster centres with assistance where possible. Similarly, the municipal disaster management centres provide support to the provincial and national centres.

Provincial and municipal disaster management is subject to the authority of the national DMA, framework and centre. Municipal disaster management must adhere and be aligned to the relevant provincial structures. Provincial and municipal bodies are required to coordinate and establish structures to share expertise and resources to assist in disaster management on provincial and municipal scales. Partnerships and cooperation is required between provinces; between provinces and municipalities; and between municipalities, where mutual assistance agreements must be established.

Each municipality's Integrated Development Plan (IDP) must adhere to the requirements of the DMA. Municipal disaster management plans are required to prepare a disaster management plan "according to the circumstances prevailing in the area" (DMA, 2002, p52). This ensures that the local context is taken into account in local disaster management, which should permit local municipalities to address locally specific risks and impacts.

The DMA stipulates that in each centre, a detailed process of gathering, compiling and distributing disaster information is necessary. They are required to produce reports on the state of disaster management including plans, strategies, implementation and assessments of how effectively the centres are functioning. The disaster management centres are required to fulfil a very diverse range of activities. This is in part due to the obligations from different centres that they have to adhere to, in accordance with the DMA. This places great pressure on these centres, particularly at the local level, to ensure that they have sufficient capacity and resources to fulfil activities effectively, and integrate these activities in a way that creates a unified approach to disaster management.

5.2.1.3 Prevention and Mitigation

The DMA places special emphasis on prevention and mitigation of disasters, rather than response and recovery. This is to be done, at all levels of government, through:

- Assessing the types and levels of risk
- Identifying communities and people that are vulnerable to disasters and the associated impacts
- Building community coping capacity and reducing their potential risks
- Monitoring potential risks and communicating these to the relevant stakeholders.
- Designing and implementing disaster response strategies, which are integrated into development plans
- Promoting and encouraging initiatives and behaviour that reduce or avoid risk
- Managing high-risk developments
- Identifying and addressing areas of weakness in the capacity to deal with disasters and implementing strategies

5.2.1.4 Disaster occurrence and response

In terms of responding to disasters, the DMA calls for "a rapid and effective response" (RSA, 2002, p6) from the relevant level of government. This requires immediate classification of the disaster to the appropriate level of government, and an assessment on the magnitude and intensity of the disaster, or potential disaster. The assessment and classification of the disaster must be done immediately, and with the advice and consultation of the disaster management centres. If a disaster is not declared a provincial or national disaster, it is automatically classified as a local disaster. Classifications aim to allocate the primary responsibility to the relevant level of government. This does not preclude assistance from any other level. Disasters are allocated to different levels according to the following criteria:

A **Local Disaster** is declared if the disaster is restricted to a single municipality, and if that municipality is able to cope with the disaster effectively.

A **Provincial Disaster** is declared if the disaster spans across more than one municipality in the province, if a single municipality is unable to cope with the disaster, or the disaster occurs in a cross-boundary municipality, and the province is able to cope with the disaster effectively.

A **National Disaster** is declared if the disaster spans across more than one province, or if the province is unable to cope with the disaster effectively.

In the event of a disaster, the primary responsibility remains with the relevant sphere of government, unless they do not have the capacity to deal with the disaster effectively, then the responsibility shifts to the next level of government. All spheres of government can assist other levels in disaster recovery, if they have the ability and capacity.

In the event of a disaster, in any of the spheres of government, relevant resources and personnel must be released to respond to the disaster. Response strategies must be implemented. If necessary, people in the disaster-affected area should be evacuated to a temporary shelter, traffic and movement of people and goods should be monitored and restricted, temporary communication lines should be maintained, and information regarding the disaster and disaster recovery should be disseminated. Action must be taken to ensure the protection and preservation of life, and to ensure that the disaster situation does not escalate further.

National, provincial and municipal disaster response resources and capacity are organised by the NDMC and incorporated into the disaster management information system. Emergency response details must also be obtained for neighbouring states and international relief agencies. The NDMC is responsible for allocating responsibility for emergency response, and creating contingencies and strategies, to be used in the event of a disaster. Particulars of all disasters must be recorded and reported in the disaster management centres' annual reports (including magnitude and severity of the disasters, and their effects).

5.2.1.5 Post-disaster recovery and rehabilitation

In terms of funding recovery and rehabilitation after disaster events, the DMA places the responsibility of state infrastructure repair or replacement on the department that is responsible for maintenance thereof. The allocation of additional funding for disaster recovery takes into account the extent to which prevention and mitigation strategies have been initiated and implemented. Additional funds cannot be allocated if municipal, provincial or local funds have been exhausted. The DMA does not stipulate that recovery and rehabilitation projects be monitored or reported on in the annual reports for any of the three levels of government.

5.2.1.6 Volunteers

A unit of volunteers can be established in a municipality to assist in the event of a disaster. A municipality may call upon volunteers in a disaster to help deal with a disaster. The DMA does not prevent people from managing disasters in an appropriate and reasonable manner until the municipality takes control of the situation.

5.2.1.7 Phase-in period

The DMA makes provision for a phase in period, within which time the different levels of government are to work towards compliance with the DMA. This period cannot exceed two years, but may vary between different levels of government.

Following this description of the DMA, the second set of data, the SALGA research report is described.

5.2.2 SALGA Research Report

In 2011, the South African Local Government Association (SALGA) initiated an analysis of South African disaster management policies and their effectiveness and implementation (Botha *et al.,* 2011). SALGA, the legislative representative of local government in South Africa, is responsible for bridging the gap between policy and implementation on a local government level. This report was prompted by the poor implementation of the DMA, despite its provisioned phase-in period. Local implementation of the DMA is essential for the implementation of the DMA as a whole. This analysis was designed to assess the state of disaster management in South Africa. This report analyses disaster risk management in South Africa from national, provincial and local government perspectives, with the focus on municipalities.

Nearly a decade after the DMA came into effect, Botha *et al.* (2011), on behalf of SALGA, conducted research into the implementation of the DMA through all spheres of government, focusing on the local sphere. A variety of interviews was conducted with government managers to gain insight into the institutional status quo of disaster management in South Africa. The report was divided into the following broad sections of analysis:

- Institutional arrangements
- Implementation of legal frameworks
- Division of roles and responsibilities
- Financial commitments at municipal level
- Multi-stakeholder engagement
- Local challenges to disaster management

The results of these subsections are not described in detail because of the overlap with the thematic analysis themes. However, general findings not included in the thematic analysis are described henceforth. The report strongly emphasises that the most effective disaster management is performed on a local government scale. However, at the municipal scale there is relatively poor implementation of the structures stipulated in the DMA. It suggested that this might be due to an inadequate understanding of the legislation, rather than the legislation not being adequate. This has resulted in municipal managers and departments not being able to fulfil the DMA’s requirements effectively, and people not being trained adequately for their positions.

The report further identifies that there is weak adherence to procedures set out in the DMA, and thus municipalities are not functioning properly with regard to disaster management. This is also reflected in the findings regarding budget allocation and provision for disaster management. In some municipalities, no budget is allocated towards disaster management, which indicates that disaster management is not a high priority for such municipalities. Within municipalities where budget is allocated for disaster management, there is a general perception that the budget is insufficient and tends to be restricted to the disaster management department.

The report synthesises the findings of the interviews into a section dedicated to the challenges municipalities face with regard to disaster management. These are divided into financial challenges, and the lack of equipment, skills, political will, government involvement, community participation and communication strategies. The lack of political will is identified in the report as a major barrier to all aspects of disaster management, and thus the final set of data, municipal manager perspectives, follows logically hereafter.

5.2.3 Municipal Perspectives

Municipal strategies concerning stormwater management for EMM are managed across three major jurisdictions of the municipality, namely the southern, northern and eastern regions (Figure 1.1). These strategies are implemented on a smaller scale for operations and maintenance. Municipal managers at each of the three hierarchical levels (overall strategic, regional strategic and operations levels) were interviewed. Although EMM has a comprehensive set of policies and frameworks regarding disaster management at the municipal scale, there is limited reference to flooding and specific management plans to deal with flood disasters in the municipality.

Municipal perspectives were obtained from a range of Ekurhuleni municipal managers, from the strategic to operations levels. Managers were contacted initially through the Strategic Planning Forum, which consists of all the department heads. A snowballing technique was then used to obtain contact details for the relevant municipal managers. Twelve semi-structured interviews were conducted and in each interview, managers were asked to discuss the major flood-related issues that exist under their jurisdiction, how these are being, or plan to be, addressed, and what limitations they encounter. The managers, not involved directly with floods, were asked to discuss the EMM context regarding management and governance issues.

5.3 Thematic Analysis

The major themes that are tracked through each dataset are identified as important cross-cutting ideas, extracted from the guiding principles of the policy and the definitions of a disaster and disaster management (DMA, 2002). Although the wording of the themes used here has been altered from the DMA, the principles remain intact. These themes are mirrored in the SALGA report, and the responses from municipal managers link well into these categories as well. The analysis comprises of four themes, namely cooperative governance, pro-active approach, knowledge, and vulnerability and adaptive capacity. Each of these themes is important in gaining an understanding of how different components of the DROP model (Cutter *et al.*, 2008) are linked with respect to disaster management and the political context. In some instances information and perspectives don't fit obviously within one of the sections, however they have been inserted where they link most closely. This facilitates the ability to compare across the different context specific analyses.

5.3.1 Cooperative governance

The principles of cooperative governance, as stipulated in the constitution, are contained in the guiding principles of the DMA, which state that the DMA provides for "an integrated and coordinated disaster management policy" (RSA, 2002, p2). The NDMF expands on this in the statement:

> "The DMA gives explicit priority to the application of the principle of cooperative governance for the purpose of disaster risk management and emphasises the involvement of all stakeholders in strengthening the capabilities of national, provincial and municipal organs of state to reduce the likelihood and severity of disasters." (RSA, 2005, p4).

The DMA's definition of 'disaster management' draws strongly from principles of cooperative governance through "*integrated*, *multi-sectoral, multi-disciplinary"* management of disasters (RSA, 2002, p6). The DMA acknowledges that the strengths and capacity from different stakeholders is necessary to ensure that prevention, mitigation, response and recovery from disasters are undertaken effectively. The SALGA report supports this in highlighting that "the integrated approach towards disaster risk management on local government level cannot be overemphasised" (Botha *et al.*, 2011, p24). Emphasis is placed on local government in implementing the DMA since this level of government deals with operational activities and is likely to be the first level to respond to a disaster. The report also acknowledges that local government must encourage and foster effective disaster management at the community level. Local disaster management is not isolated, but fits within national and provincial structures.

The NDMC provides procedures and plans to be implemented across South Africa as a whole. It is also designed to liaise and coordinate disaster management across all spheres of government, and ensure that each level of disaster management is performing adequately. This structure is designed to ensure good governance through creating a synergy between local, provincial and national scale interventions (Bulkeley *et al.*, 2010). The provincial centres are responsible for taking the national plan, and preparing a plan for the whole province, whilst the municipal centres within that province are responsible for using the provincial plan to create a specific disaster management plan for the municipality. This process outlined by the DMA ensures consistency and uniformity across all levels of disaster management in South Africa. However, the SALGA report identified that these structures are not in place as slightly less than half of municipalities have a disaster management centre; 40% reported that no centre was set up and 6% claim that they did not know if there was one. Metropolitan municipalities reported that their disaster centres were performing well, to very well; yet this was not the case with district or local municipalities. Structures that encourage interdepartmental communication in municipalities have not been established or do not work effectively.

The DMA states that coordination and good communication links between different stakeholders is essential for the range of components of disaster management to be integrated, and result in a uniform management process. Communication networks allow stakeholders to consult one another, and give advice and recommendations on matters relating to disaster management. The NDMF aims to provide an environment that emphasises cooperation between international, national and local stakeholders. Government structures should support partnerships and coordination between stakeholders, particularly on multi-disciplinary and cross-functional issues, and create a joint standard for procedures and practices. Cooperative governance ensures that disaster management includes and involves all stakeholders, but also that all components of disasters and disaster information are included. However, the SALGA report notes that at a local level, there has been limited coordination and allocation of responsibility for disaster management, which limits the effectiveness of the DMA. Difficulties of ensuring public participation in disaster management, and particularly with risk reduction, have further limited the DMA's effectiveness. Anderson *et al.* (2008) posit that effective governance provides an enabling environment for community adaptation.

The SALGA report states that there is a strong need for more cooperation as the report reveals that at the municipal level there is a low level of coordination between departments to work in a unified way. Comment was specifically made that departments do not cooperate with each other on issues of disaster management, and information sharing is very limited. Including people from different departments could however, be an asset as each department adds additional perspective to the situation, and thus integration across different sectors should be encouraged.

The municipal managers supported the SALGA report findings that the communication and coordination between departments in local municipalities is limited if at all present. An example was given by one of the managers on EIA processes, which has revealed a disconnection between the departments in EMM. EIAs can take a number of months to finalise and pass through the system. In a flood emergency, this is too long to wait before action is taken by disaster management teams. This has led to frustration between departments, as they seem to work against each other in their attempt to fulfil their duties. Manager *H* commented that the lack of communication and collaboration between departments could lead to and has led to further delays and frustration.

A further concern was raised regarding EIAs and the general strategic management of the municipality. The municipal council is responsible for ensuring that the cumulative impact of different developments is considered, based on environmental and flood-related concerns. Manager *G* raised concerns that decisions passed by council are strongly influenced by political factors, rather than environmental and disaster-related factors. The concerns raised here are indicative of the lack of cooperative governance in the municipality, both between departments, and between the strategic and departmental levels. Manager *J* however, highlighted that their department had been able to work effectively with most department with respect to disaster management. This indicates that although interdepartmental coordination is limited, it is not altogether absent in EMM. Although the DMA acknowledges that interdepartmental coordination is necessary, structures are not set out to ensure that this takes place. This has resulted in an environment that is not as conducive to integration and coordination.

Cooperative governance structures described in the DMA extend into obtaining and disseminating information on disasters and disaster management. This information includes monitoring and reporting disaster incidence, as well as climate predictions and warning. Disaster management centres may advise and consult with other centres and stakeholders on disaster management issues, and encourage an enabling environment for research and knowledge sharing across all the relevant groups. This centre liaises and coordinates between the different levels and ensures effective communication links are in place. The NDMC is charged with ensuring there is alignment between the municipal, provincial and national frameworks and disaster management procedures. Disaster management principles and procedures, as stipulated by the DMA must be included in Municipal IDPs.

Cooperative governance is particularly important in situations where cross-boundary disasters occur. Communication links must, however, be established before disasters to make coordinated disaster responses rapid and effective, and ensure they are uniform across the entire affected area. This is facilitated through liaisons and coordination between disaster management centres between and across all levels. The interviews revealed that political complications arise from the mismatch between drainage basins and municipal areas. A few catchments, for example, flow between EMM and the City of Johannesburg. Although the catchments are similar and processes in the separate areas generally affect the same watercourses, there is apparently little effective communication between these municipalities in this regard, despite the catchments affecting each other.

The DMA provides an option for provincial and municipal centres to establish a disaster management advisory forum. This structure can encourage and ensure cooperative governance, because it provides a platform where a wide range of stakeholders can consult with each other and coordinate disaster management efforts. Despite the great potential value of these advisory forums in ensuring cooperative governance, they are an option, rather than requirement of the DMA.

Botha *et al.* (2011) posit that a lack of clear guidelines for the interpretation of the DMA at a local government scale has resulted in misinterpretation. It is also argued that the local interpretation and implementation of the DMA is crucial for its effectiveness as a whole. A major problem identified is the lack of understanding of roles and responsibilities at the local level for disaster management. Disaster management is often viewed as an optional extra for municipal management, which results in poor implementation and integration of disaster management into municipal management processes. Manager *G* revealed that they have experienced challenges in marrying the requirements from different national legislation, namely DMA and the National Environmental Management Act (NEMA) (RSA, 1998). The implementation of NEMA in disaster situations sometimes restricts the emergency services from doing what they need to do to reduce the impact of disasters.

Botha *et al.* (2011) suggest that the lack of clear guidelines and the misinterpretation of disaster management policy have undermined the structures envisioned by the DMA. There is a tension between the need for a dedicated disaster management section of government at all levels, and the need for disaster management to be integrated into all aspects of governing. A strategic planning forum was established in EMM to encourage coordination between departments and provide opportunities for different departments to comment on projects and approaches of other departments. One area where this is evident is in the leadership of the disaster management centre. Seventy-five percent of municipalities reported that a head had either (a) not been appointed or (b) also held another position in the municipality. This demonstrates the lack of commitment and emphasis on disaster risk management in municipalities. The head of disaster risk management should encourage the incorporation of disaster risk planning into each department, rather than establish a new department to organise all components of disaster management. The report emphasises that this position should encourage and facilitate communication and coordination between departments within the municipality. Many departments feel that responsibility for disaster management should be restricted to the disaster management departments.

As highlighted earlier in the chapter, the hierarchical structure of the disaster management centres can put extra pressure on the local managers, particularly in disaster situations. Manager *H* highlighted that in a disaster situation, there is pressure from councillors and senior level managers to sort problems out in the timeline that suit the higher levels of government, and which are not dependent on the technical and on-the-ground perspectives. According to Manager *B*, "there is political interference", which makes it difficult for managers to do their job in the way that they see fit, and instead they have to comply with external pressure, which can sometimes have severe consequences and possibly affect the efficiency and effectiveness of disaster responses. EMM managers felt that the people who understand the context of the local situation are not given the freedom to deal with disasters when they arise.

Decisions relating to disaster management are often "fundamentally influenced by the underlying distribution of power within and between institutions" (Koch *et al.*, 2007, p1329). This is evident in the example regarding disaster situations, as outlined in the previous paragraph. Managers in EMM also identified this issue relating to budgeting and capital expenditure. In some cases where infrastructure grants are allocated to local municipality, the amount of money is often influenced by the political context and does not necessarily relate well to the actual need on the ground. Manager *B* commented that when budget is allocated, those responsible for budget allocation "want visible infrastructure...it is political". This has resulted in a situation in Tembisa[16] where roads were built (visible), but due to limited budget, the stormwater infrastructure (invisible) was not prioritised. This is illustrated in Figure 5.3, where a road, with kerb inlets, was constructed without connection to a stormwater line. The kerb inlets give the illusion that infrastructure is in place where it is not. It is important to note that in some instances the lack of such infrastructure can be attributed to a contractor not completing a job as stipulated by the municipality (Manager *C*).

In addition to this, some of the managers commented that decisions about developments were often made at a political level and sometimes do not take environmental concerns into account. In some cases this means that developments take place in areas where they should not. This has caused many issues in areas such as Atlasville, where houses built along the Spruit are at risk of flooding from small rainfall events, if all drainage lines are not effectively maintained. Such situations cause maintenance and upkeep of these areas to be very difficult and costly. In some cases, it causes the residents to be vulnerable to flooding or other disasters.

The EMM environmental department has identified the EIA process as an area of frustration and has actively tried to assist other departments in better planning and incorporating EIAs and related policy requirements (Manager *G*). This ensures that in an emergency, a strategy is already devised which guides disaster management while considering the environment. The environmental department's attempt to work together seems isolated in the municipality. Despite some challenges between the local managers and those at strategic and provincial levels, managers noted that cooperation between some departments has improved in the recent past. Some departments identified that misunderstandings and frustration had developed between some of the departments due to limited understanding of the different departmental responsibilities. Some of these departments have taken the initiative to work with other departments, thereby assisting them to

[16] Tembisa is an area in the Ekurhuleni Metropolitan Municipality that is comprised partly of informal settlements, where there is a severe lack of basic services and a high susceptiblity to flood events.

understand and streamline processes and requirements. This is one of very few examples where a proactive approach has been taken to improve cooperative governance and integration.

Figure 5.3: Kerb inlet not connected to a stormwater drainage line in Tembisa

5.3.2 Proactive approach

Although this theme is not restricted to prevention and mitigation of disaster, the focus on a proactive approach is apparent from the beginning of the DMA. This approach also extends to emergency preparation, which may not minimize or halt the disaster, but aims to improve the ability of affected stakeholders to cope in the event of a disaster. In some instances in the DMA, the proactive approach is evident in the recovery process, where lessons learned from previous disasters help plan and cope with subsequent disasters.

Prevention is described as the "measures aimed at stopping a disaster from occurring or preventing an occurrence from becoming a disaster" (RSA, 2002, p8), and mitigation is defined as those "measures aimed at reducing the impact or effect of a disaster" (RSA, 2002, p8). This theme tracks any action or "measure" taken pre-emptively to lessen the impact and enhance resilience to disasters. The emphasis on prevention and mitigation is relevant for every level of government and is included in the objectives of each disaster management framework and centre.

The proactive approach towards disasters and disaster management is acknowledged internationally and locally as the best way of managing disasters, and this is reflected in the DMA. However, the SALGA report and the EMM managers identify that this approach does not guide how municipalities in South Africa are functioning. In a management context where "everything is reactive" (Manager *A*), it is not possible to adhere to disaster management and environmental policies which are fundamentally proactive. Adherence relies on effective planning and implementation, which are not being undertaken in EMM. Managers do not feel they have the capacity to adhere to these policies.

The NDMC is charged with developing disaster management plans and strategies, which guide, support and assist disaster preparation. These plans are important in providing a consistent approach for all spheres of government, for preparation, prevention and mitigation, coordinating, and assisting with all measures that aim to enhance the ability to deal with disasters effectively. The DMA is meant to create an enabling environment for other centres to focus, plan and prepare in a proactive way. The evidence shows that this environment has not been created, which weakens the ability to manage disasters and “has the potential not only to put the lives of citizens at risk but also to undermine the roots of development particularly within already vulnerable communities” (Botha *et al.*, 2011, p53).

Botha *et al.* (2011, p24) blame the lack of proactive disaster management on “the lack of awareness, resources and political will” of municipal managers. There is a sense that budget allocated to disaster management is directed mainly to disaster response units and less towards prevention and mitigation of disasters. This may be attributed to the type of information and knowledge about disasters that is available. Identifying and anticipating drivers of disasters is highly complicated, whereas dealing with the consequences of a disaster are much easier to identify. In many of the municipalities, operational departments do not budget for disaster risk management at all, which indicates that a proactive approach to disaster management is not prioritised at all, as stipulated by the DMA. The report revealed that most people appointed into disaster management roles come from the emergency service background. This supports the finding that disaster management is mainly reactive, as that is the training and perspective from which disaster management staff are skilled in.

The DMA emphasises that proactive measures to disaster management require appropriate allocation of state funds. This particular area seems to be a major challenge in EMM, because funding for disaster management is allocated to the Disaster Management Department and does not seem to be transferred to other departments to support maintenance and proactive disaster mitigation and adaptations. Managers stated that their activities are severely constrained by the financial operational budget and capacity to plan to be more proactive. Stormwater drains, for example, are usually cleared before the summer rains start, and from there onwards, they are cleared when required. Most of the operations and maintenance that is required to ensure that systems work well are not done. Many of the managers complained about not having the budget that would allow them to monitor and maintain the systems in a way that would allow them to identify problems before they occur. Moser and Satterthwaite (2008) suggest that allocating resources to reduce future risk is unlikely if the immediate risks and challenges are high.

For a range of reasons discussed here, there seem to be great challenges in implementing a proactive approach to management at the local level, and particularly disaster management. Resilience is argued in the literature to be based on a proactive approach towards disaster risk (Pelling, 2003; Folke 2006), and thus it can be argued that the resilience in local municipalities in South Africa is low. The SALGA report identified that poor understanding and awareness is a major reason for a reactive approach. Information and knowledge of disasters and disaster management are key parts of being able to focus on effective prevention and mitigation measures.

5.3.3 Knowledge

One of the key themes that is identified and tracked through the framework is that of knowledge and types of information. Knowledge guides decisions about strategies and plans, as well as the way in which disasters are managed. Principles of cooperative governance are evident in this theme. The DMA charges disaster management centres with storing and disseminating information concerning disasters and their management. It further requires that research into all aspects of disasters be encouraged and promoted. Identifying vulnerability and adaptive capacity plays an important role in effective disaster management. Identifying, monitoring and addressing underlying risk factors and capacity weaknesses are important in building resilience to disasters. This information can be used to anticipate, mitigate and prepare for disasters.

A directory of stakeholders, relating to disaster management, must be developed and maintained. Communication links must be established with these stakeholders to ensure that information can be shared and disseminated between and to relevant stakeholders. The NDMC can use information to give advice and make recommendations on disaster management. The SALGA report identified that there is limited communication and coordination with non-state actors who are working in the field of disaster management. This means that the experiences and information that these stakeholders have are not transferred to the municipality. This also limits the ability to coproduce knowledge, which according to Lemos and Morehouse (2005) is becoming a sought after attribute in research, particularly that which is used to inform policy.

The DMA states that disaster related information must be freely available to everyone, and dissemination to vulnerable communities is prioritised. It is particularly important, in the event of a disaster, that those most vulnerable and at risk to the disaster are given relevant information to assist with dealing with disasters. Good communication links are necessary between the different levels of government, particularly in the event of a disaster. The DMA requires that information be used to build capacity and educate communities about disaster risk and management. Manager *J* discussed some of the communication initiatives that the department of disaster management had undertaken to increase disaster related communication and awareness in the Municipality. This positive move towards implementing the above stipulation is undermined by the communication only being broadcast in English, because of possible translation errors. This means that many people who are highly at risk, cannot access warnings because of language barriers.

The DMA requires that a record of disasters, including their magnitude, severity and impacts, be kept by the relevant disaster management centre and reported on in their annual report. The directory of disasters, disaster impacts, their management and recommendations are very useful in assessing how future disaster can be managed. The EMM managers identified that they have been able to document disasters since 2009. A challenge that has occurred in this process is that some councillors have been unwilling to share information regarding disaster response. According to the DMA, this should not be a problem as Disaster management centres may request information that they deem necessary, to aid disaster management and planning thereof. These centres are required to consider the advice and recommendations that are obtained from other disaster management centres.

The SALGA report emphasises the need to incorporate climate change and adaptation information into disaster management planning, because of the potential for the impacts of climate change to reduce understanding of weather events, and increase the likelihood of disasters. This needs to be incorporated not only into disaster management plans, but also into IDPs. The managers felt that this is important, but they were unsure how climate change would affect their area of management, or what they could do to address these potential issues. Knowledge and understanding of the disaster management legislation is important for municipalities to implement these correctly and effectively. The SALGA report revealed that a large proportion of staff does not have such adequate knowledge. Adger *et al.* (2009) highlight that decisions and responses to future climate events depend heavily on how people understand and anticipate the impacts of these events. If managers do not understand the disaster context effectively, they are unlikely to make informed decisions. In addition to this, the EMM managers identified that institutional memory and knowledge is being lost. Knowledge and experience are not passed down through the municipality from people who have worked there for a long time or who have been involved in particular projects. Although the DMA requires good data management and documentation, EMM managers commented that they do not have the capacity to document things properly.

The DMA asserts that government policies and legislation are primary pieces of information to be included in guiding disaster management and planning. The inclusion of different types of information, including indigenous knowledge, is also recognised as being valuable in building a comprehensive information base. This supports the literature, which posits that local knowledge is fast becoming accepted as essential for reducing vulnerability to disasters (Mercer *et al.*, 2009). However, the DMA does not provide details on how this information should be obtained or integrated into planning. This increases the likelihood that context specific disaster management will not occur as no one strategy can be effective for all situations (Kaklauskas *et al.*, 2009).

One of the main objectives of this research is to use a number of different types of knowledge to enhance the understanding of disasters. Statistics and DIRs provide the primary source of information that guides disaster responses. The physical investigation of this research identified that this approach alone is insufficient in explaining and anticipating all the drivers of flood disasters. Recently, the approach towards water resource management has shifted from top-down management, using technical information and predictions, to a governance approach that acknowledges the importance of engaging with society and other stakeholders (Pahl-Wostl *et al.*, 2008). This shift towards using a range of information to inform disaster management is not evident in the DMA; instead the focus of information and knowledge in the DMA is on data management and dissemination. This is indicative of the perception towards different types of information and knowledge. The approach towards multidisciplinary and integrated disaster management and research is clearly not being engaged with, and the technocratic approach is prioritised. This means that important information and perspectives are likely to be left out of the decision-making process. This is particularly concerning in areas where risk and vulnerability to disasters is high. Vulnerability and adaptive capacity are fundamental pieces of information needed for effective disaster management, and thus form the final theme of this analysis.

5.3.4 Vulnerability and adaptive capacity

Identifying vulnerability is an important step in determining where disaster prevention and mitigation, and recovery efforts should be focussed, and is a key aspect of a proactive approach. Vulnerability is first mentioned in the DMA in its definition as "the degree to which an individual, a household, a community or an area may be adversely affected by a disaster" (RSA, 2002, p10). This definition does not acknowledge that vulnerability is rooted in both social and physical contexts and is perceived differently across and within communities and sectors (Pelling, 2003).

The identification of adaptive capacity allows strategies and disaster management plans to be tailored to feasible actions in the relevant area or community. Adaptive capacity is not mentioned in so many words in the DMA, but the concept of adaptation and the relevant capacity to deal with disasters certainly is included. The disaster management centres in all spheres of government are charged with increasing community and household capacity to “minimise the risk and impact of disasters that may occur” (RSA, 2002, p22, 34 & 48), through disseminating relevant information and giving advice and guidance to vulnerable communities. The language challenge in early warnings, as aforementioned, limits the ability of communities to prepare for and protect themselves from imminent disasters. The SALGA report argues that disaster risk in South Africa is strongly associated with poverty and the scars of inequality left after apartheid. Bohle *et al.* (2004) argue that capacity to respond to disasters is a question of empowerment. Some of the lowest income groups are some of the most vulnerable to disasters as often they are situated in the most disaster prone areas, and they seldom have the capacity (financial and other) to prevent or avoid disasters (Gallopin, 2006; Douglas *et al.*, 2008;Botha *et al.*, 2011). If these communities are unable to access early warnings, they become further disempowered during a flood event. In addition to this, these groups tend to have a small voice in society and thus are unlikely to get the attention from government that they need (Douglas *et al*, 2008).

The DMA states that an important part of building adaptive capacity within communities and municipalities is ensuring that volunteers are trained and available to assist with disaster management. The DMA allows the public to provide alternative capacity, to formal structures and plans, through taking reasonable steps to prepare for and deal with disasters. This supports the potential that Pelling (2003) identifies for civil society groups to provide alternative capacity where the municipality has limited capacity. The DMA encourages municipalities to support such efforts and encourage communities to take responsibility for disaster management in their area. This approach does not seem to have been adopted at the municipal level, as the concepts that reoccurred in the interviews related to internal challenges in the municipality. Internal challenges and limited capacity are in many cases linked to budgetary challenges.

Although the DMA states that appropriate budget and capacity is to be allocated to disaster management, both the SALGA report and the interviews identified that budgets, staff and resources were the greatest capacity limitations. The SALGA report identified that disaster management centres have limited resources and equipment, which in turn limits the capacity to deal with and mitigate disasters. The report identified that there are issues with no budgeting for disaster response and rehabilitation. This means that disaster reduction measures are not implemented, and are thus vulnerability to disasters is not minimised, and in some instances can worsen in the wake of a disaster. The report also revealed that there is an absense of people with the correct skills, but it was identified that there is no sufficient budget to improve this problem and obtain the skilled people that they require. The vast majority of municipalities do not have volunteer units as suggested in the DMA. This limits the ability to foster good cooperation and coordination between municipalities and communities.

Budgetary constraints are identified by the operational managers as major limiting factors to their effectiveness in managing the stormwater system. The annual budget for the area is allocated to maintenance, disaster response and infrastructure development and "there is not enough money" to manage all of these areas as is required (Manager *A*). In 2002, when EMM was established and a number of areas were combined under one management, the budgets were not increased proportionately to the new area of management. In addition to this, budgets tend to be cut from year to year, instead of increasing annually. Manager *F* commented that the budgets submitted to the council are not considered as strongly as the respective department's historical budget allocation and use. Manager *A* reported, however, that his annual budget had been cut each year by up to 10%, despite the fact that his budget was already only sufficient for seven months per annum, and that he could "use the annual budget in two months" (Manager *A*, 2011). As a result, problems are dealt with as they arise, based on urgency, and are not identified and dealt with proactively. Operations managers do not trust that the council responsible for budget allocation would provide sufficient budgets for years to come. Consequently there is an underlying feeling of disempowerment in dealing with the floods effectively.

The SALGA report highlights that only 21% of disaster management centres reported to have sufficient staff to implement requirements of the centres. Of the current staff in these centres, very few have received professional training and there is a great lack of capacity in disaster management skills. The provincial centres confirmed this through the unanimous feeling that municipalities do not have sufficient disaster management skills or staff to perform their duties "associated with disaster risk reduction particularly in regard to activities with regard to prevention and mitigation" (Botha *et al.*, 2011, p56). In many cases "disaster risk management centres function with very low numbers of staff which could ultimately impede their abilities to carry out their duties" (Botha *et al.*, 2011, p38). There seems to be a great lack in human capacity from too few staff, to inadequately trained staff and the limited number of volunteers (Botha *et al.*, 2011). These deficiencies are sometimes more easily identified by external people and organisations.

A number of the managers made strong reference to the social capacity that they lack in their departments. There are issues between labour unions and the municipality, such that neither of these stakeholders is happy, and thus the municipality is unable to fill critical vacancies. The inability to gain new employees means that as staff leave, they cannot be replaced and the pressure and load on the remaining people becomes heavier. As a result, many of the departments are losing people because they are not able to progress or see job growth potential, as vacancies are not being filled and there is a lack of training people to ensure skills turnover.

In line with the focus of the DMA, the concepts of vulnerability and adaptive capacity are most prevalent in sections relating to reducing the risk of future disasters, and fostering risk-avoidance behaviour across all stakeholders. Each disaster management centre is required to identify, monitor and record vulnerable communities within their jurisdiction. The DMA calls for capacity weaknesses to be identified and addressed, and the capacity of vulnerable communities to be increased to minimise the risk, and increase the ability to cope with a disaster. Another proactive stipulation is for developments with a high risk of disaster to be monitored and managed appropriately. The DMA calls for stakeholders to work together and assist vulnerable or disaster stricken areas where they have capacity to do so. As both the SALGA report and the interviews identified, the institutional capacity weaknesses limit the ability for weaknesses directly related to disaster risk to be identified and addressed.

According to the stormwater managers, the most effective way to allocate budget is according to the Municipality's stormwater assets (e.g. kerb inlets, size and length of pipes), because "the main issue is maintenance" (Manager *B*). Managers *A*, *B* and *D,* however, indicated that the EMM does not have complete and updated stormwater infrastructure plans. In addition to this, the Municipality lacks a municipal-wide storm and flood monitoring plan to track and evaluate the damages and cost of storms and floods. Manager *E*, at the strategic level, commented that without this information, actions to mitigate stormwater and flood issues can only be ad hoc and therefore they respond only to the most urgent problems. In such cases, "the guy who complains gets a bit of help" (Manager *A*), and the areas where they receive many complaints tend to be those where they direct their minimal resources.

In the event of a disaster, the primary focus is the preservation of life and assistance of disaster stricken or threatened areas and communities. Disaster response actions include providing relief to affected communities and areas, assisting and protecting the public and property. The DMA requires that disaster recovery and rehabilitation efforts work to reduce the future risk of a similar disaster and in so doing, reduce vulnerability. Adaptive capacity required to deal with disasters from a municipal perspective ranges from on-going maintenance and service provision, to preparation and response. As identified in the SALGA report, the lack of government capacity to ensure that these are all undertaken, has played a part in the poor implementation of the DMA at a local level.

5.4 Conclusion

This chapter explores the South African policy context for disaster management to identify how perceptions and implementation of disaster management are affected by this context at the local scale. The DMA is the primary legislation that prescribes how disaster management should be conducted in the country. This policy document is analysed through a thematic approach, using four themes; namely 'Cooperative governance', 'Proactive approach', 'Knowledge', and 'Vulnerability and Adaptive capacity'. The SALGA report and the interviews with managers are used to enhance the analysis of the DMA. The analysis identifies that the DMA has been poorly implemented. This is partially attributed to a lack of political will, insufficient budget and weak cooperative governance within and between government spheres. Janjua (2010) discusses that implementation of adaptation plans requires good governance and public participation. Some of the responses from municipal managers suggested that communities have a role to play in disaster management. Where there is limited capacity in the municipality, communities can take responsibility for this where they are able. Due to a lack of cooperative governance and institutional limitations, the implementation of the DMA has proved to be very limited. The investigation confirms the hypothesis that the DMA does not provide an enabling environment for effective DRR at the local level. However the limited implementation of this policy is to some extent a result of governance structures that are specific to the municipality, and the limited extent to which departments are prepared to coordinate. Through the identification of challenges and limitations in the policy context of DRR, this analysis found that there are factors not related to flood disasters that affect the ability to manage them effectively, thus the second hypothesis is found to hold true. The SALGA report also identifies that there is a range of constraints to effective DRR that are not related to technical knowledge or information of disasters and risk. This highlights the need to incorporate perceptions and non-technical knowledge into DRR. The following chapter examines the usefulness of this type of information through the perspectives of residents from Atlasville.

6 Community Context

"The community is at the coalface of disaster risk management" (RSA, 2008, p18).

6.1 Introduction

This chapter comprises the third and final results section of this research, and investigates community perspectives towards floods through an assessment of how individuals have experienced and perceive floods, and the management thereof. This investigation identifies that there are factors that influence flood risk, which are influenced by perceptions and non-technical knowledge. This investigation addresses the third research question, which interrogates how communities engage with flood disasters. This component contributes to addressing the broad research objective through assessing community experiences and perspectives. The research question is answered through testing two hypotheses:

1. Community experiences and perceptions influence their approach to DRR.
2. Adaptive capacity and resilience at the community level can be developed through non-technical knowledge and informal structures.

Community perceptions and experiences of DRR feed into many components of Cutter *et al*. (2008)'s DROP model, including the antecedent social systems, coping responses, adaptive capacity, degree of recovery, and preparedness and mitigation. In addition, this investigation highlights how the political context has influenced flood management in Atlasville, and how this management has been perceived by the people who were affected.

The focus of this chapter is on understanding the community context of knowledge and perceptions of flood disasters, as it is a crucial part in understanding disaster management as a whole. This chapter uncovers how different stakeholders experience and perceive flood disasters. Community risk perceptions were obtained through two methods, to account for the change over time, specifically during and after disaster events. This study assesses two types of data (primary and secondary) to obtain a comprehensive understanding of perceptions in this context.

The social perspectives obtained from the BAR and interviews are investigated through a thematic analysis, similar to the political context analysis in Chapter 5. This analysis reveals the change of perspectives over time, as well as the range of experiences and perceptions across the affected area. The results from two interviews conducted in Tembisa are used to compare resident experiences and responses across different areas in the Municipality. Due to limitations in conducting interviews in Tembisa (details in Chapter 3), this comparison aims to identify possible differences and indications of where further research is required, so as to make better conclusions on the difference between the different socio-economic areas.

6.2 Case study background

Since 2006, there has been periodic flooding along the eastern banks of the Atlas Spruit. Flooding in 2006 and 2010 were the two worst floods in the area in the residents' memory (over 30 years), when water inundated the Spruit, the adjacent open park space and the nearby roads and houses.

Flooding caused major damage to property and disrupted the lives of the affected residents. Water in some properties reached waist-height, and caused many people to leave their homes for a number of months while renovations and repairs were undertaken. These floods resulted from medium to high rainfall events, but not from exceptional downpours. These rainfall events occurred after previous rains had saturated the ground. However, the Atlasville residents do not attribute the floods they experienced to heavy rainfall events alone. The interviews[17] conducted with residents are examined through a thematic analysis using the four themes that were identified for the political context analysis. This analysis reveals the social experiences and perceptions of flood disasters both during and after these events.

6.3 Thematic analysis

To ensure that the political and social context analyses are comparable, the major themes used in the analysis of the policy context, are also used in this analysis, namely: cooperative governance, pro-active, approach knowledge, and vulnerability and adaptive capacity. This analysis draws out residents' attitudes and perceptions within each of the themes. Although in some instances, perspectives and information did not fit exactly into the themes, but they are included into those to which they relate most closely so that the different context analyses are more easily linked.

6.3.1 Cooperative governance

Governance at the local level builds linkages between management of municipalities and the day-to-day experiences and lives of those living in such areas. For this reason, the relationship between the municipality and the community is important. In the interviews, residents of the Atlasville community made a number of references to their interaction with and understanding of, the municipality. Overall, residents believe that the municipality is the stakeholder that should be responsible for reducing flood risk and repairing flood damage. Figure 6.1 shows the breakdown of Resident Responses concerning who should be responsible for flood recovery and mitigation in the area. The majority (7 out of 10) said that it is the sole responsibility of the municipality; one respondent said that it was up to the individual affected, and the remaining residents responded that flood management should be a combined effort between the municipality and individuals. The participants from Tembisa reported that it was solely the municipality's responsibility to deal with their flood risk.

Poor maintenance and monitoring of the stormwater system and Atlas Spruit, was identified as one of the main causes of flooding. This seems to be a relatively new problem. During the 2010 floods, Resident *P*, who has lived in the area since 1982, noted a progression of decreasing service delivery over time. In the 1980s and 1990's, when the municipality maintained the area sufficiently, floodwater did not cause issues in people's houses. He noted, however, "since the amalgamation of the municipalities, this maintenance has become non-existent". In 2010, he and many other residents agreed with Resident *Q*'s observation that the flooding "problem is getting worse" and that flooding occurs more often and from smaller rainfall events". Residents identified the lack of maintenance of the Spruit, as a source for concern, and many residents' perceptions of future risk are strongly tied to their observation of this pattern. These concerns were mirrored in the

[17] The identities of residents and managers are protected in accordance with the ethical stipulations of the study

interviews, which found that people's perceptions regarding whether they would experience floods in the future was strongly linked to the maintenance and upgrade of stormwater systems in the area.

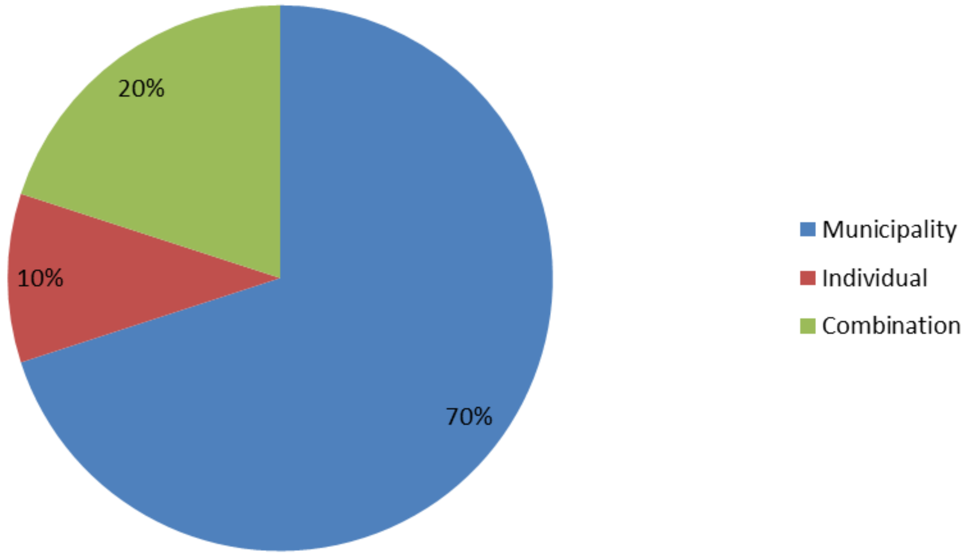

Figure 6.1: Residents' opinion on who should be responsible for flood recovery and mitigation (n=10)

In 2010, many residents believed that EMM had not used their rates effectively to serve the community in reducing the flood risks. They felt frustrated that the money had been wasted on short-term solutions. Although they acknowledged that EMM has a very limited budget, they felt that the lack of adequate planning is more expensive in the long term and does not solve the problems that they have experienced. Members of the community were frustrated with the Municipality's lack of service delivery and poor communication. Resident *N* said that she had complained about the maintenance issues "for seven months without results". The perceived absence of results by the municipality has led to a lack of trust that the municipality is committed to ensuring the community's constitutional right to a safe environment. This sentiment was supported by Resident *M*:

> *"...do you really and honestly think the [municipality] cares about us? They care only as long as we pay rates and taxes. That's it." (*Resident *M,* 2010*)*

As mentioned previously, a number of the residents had become so disillusioned by the flood management in 2010, that they suggested that a rates boycott should be initiated. This would involve the residents' rates being paid to a ratepayers association, which would ensure "that their rates and taxes are being effectively applied to the good maintenance and servicing of their residential stands and the surrounding lands" (Resident *L*). The residents felt that this initiative would empower them to take control of the situation and that "[they], all together, can manage this water resource for [them]selves. Then [they] do not have to rely on the [municipality]." (Resident *M*, 2010).

The community was concerned that if they left the municipality to address the situation, that it would deteriorate over time and they could become more and more vulnerable to flooding. This suggests that local residents' risk perceptions are influenced by historical relationships of distrust with local government. However, by the time the interviews had been conducted, the ratepayers association had not been established, and the Municipality had taken measures to reduce the flood risk in the area, including clearing vegetation from the Spruit and upgrading a stormwater culvert. Residents *H* and *V* both commented that people in the community are much less angry now than they were immediately after the floods. Across most of the interviews, this was evident, and the animosity and desire to fight against the municipality seems to have decreased since the BAR. However, Resident *B* observed that he did not believe that the municipality would have taken the steps that they did, had the residents not put pressure on them to find a solution to their flood risk. Residents acknowledged that the pressure that they, as a community, had placed on the municipality had led to action being taken to improve their situation. Nevertheless, there was a lingering distrust of the municipality, and a feeling that the municipality "turn[s] a blind eye" (Resident *F*) to issues in their area.

All residents in both the Atlasville and Tembisa communities believed that the municipalities knew about the flood problems in their area, even if they believed the municipality is not acting on this knowledge. Figure 6.2 shows the breakdown of whether Atlasville residents report problems to the municipality. Seventy percent of the respondents do report to either the municipality or the ACF. Twenty percent revealed that they previously tried to report problems, but became frustrated that the telephones were never answered, and have subsequently stopped reporting problems. Both residents from Tembisa report to the municipality and identified things that the municipality had undertaken to reduce their flood risk (e.g. clearing reeds from waterways). However they both had suggestions regarding things that the municipality still needed to do to minimise their risk.

Residents in Atlasville did not acknowledge that they were empowered through their capacity to identify problems to the municipality, which were subsequently addressed. Acknowledging the value of their capacity and their responsibility to keep the municipality accountable to fixing their problems, may empower them to play an active role in cooperative governance, instead of fostering the distrust they feel towards the municipality. In the Atlasville community's perspective, resilience to flood events is unlikely to develop from actions taken by the municipality. The history of poor management has created distrust between the community and the municipality. The disconnection between the municipality and the community limits co-operative governance, which Anderson *et al.* (2008) posit provides an enabling environment for community engagement and adaptation. Without support from the municipality, the community's capacity has the potential to work against municipal structures instead of with them. This is supported by Dodman *et al.* (2010, p5) who state that "an important component of any community's response is negotiating the support of local government to the long term development priorities identified by local residents".

6.3.2 Proactive approach

A proactive approach to disaster management is the most effective way to minimise and prepare for disaster risk. The Atlasville residents identified that the municipality has not minimised their flood risk at either a long- or a short-term. The long-term downfall is that the municipality allowed houses to be built within a flood zone; and in the short-term, general maintenance of the area has been identified as a major contributor to the flooding.

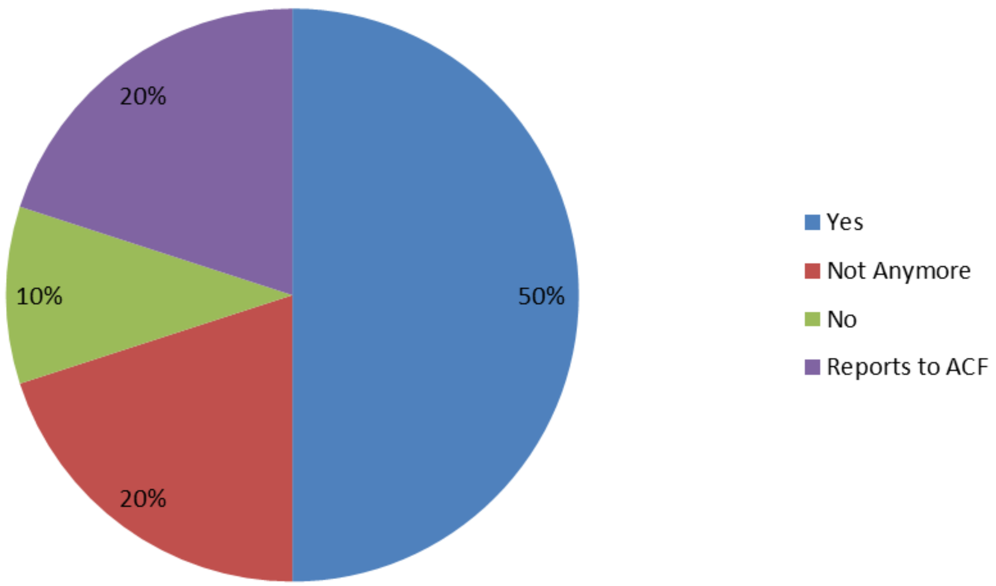

Figure 6.2: Residents responses on whether they report problems to the Municipality (n=10)

Resident *K* believed that "the [municipality] must take responsibility" for flooding of houses that are within the 50 year flood zone. Resident *L* agreed with this sentiment and commented that because the Municipality "proclaimed the land as suitable for residential development... [it is] their responsibility to ensure that such suitability continues". Generally, residents felt that if the municipality did not take on this responsibility, then it was not ensuring the safety of the community through effectively planning development and infrastructure. In situations, such as this, where houses are established in a flood-prone area, effective monitoring and maintenance of the stormwater system is crucial to minimise flood risk. However, Resident *M* noted that there seemed to be "no continuous commitment from the municipality to undertake repairs and maintenance on a regular basis". He further commented that the municipality had addressed the flooding problems with "short-term, cheap and quick-fix solutions" (e.g. Reed removal, Figure 6.3). It was observed that "ongoing maintenance...will alleviate much of the problem" and that unless effective monitoring, maintenance and repair were planned and budgeted for, all responses would only be short-term solutions.

An issue that is linked to EMM's poor provision of flood solutions, is the seeming lack of attention that the local authorities focus on budgeting and planning appropriately to ensure that flooding does not reoccur in this area. Resident *C* felt that "[EMM] needs to find money for Atlasville now and for the bigger picture later", which is in contrast with the policy approach. The community did not trust that the local authorities would take the necessary actions to protect this community from flood risk, yet they called for immediate and decisive action in this regard. Although the community felt that a comprehensive solution needed to be found and implemented by the municipality, Resident *O* stressed that "some help is better than none at all". Some of the residents were frustrated that the Municipality had not done enough in response to the flooding, and they threatened to obtain court orders to ensure that they could undertake effective measures.

Residents perceived that the Municipality has a history of creating reactionary and short-term flooding solutions. Resident *N* felt that the Municipality "runs from one crisis to the next without planning any proper effective intervention". The community did not expect reactionary management to solve their flooding problems in the long-term. A concern was raised that some of the Municipality's actions would in fact cause more damage in the long-term (e.g. digging out reeds and soil from the canal will lead to erosion and further damage) (Figure 6.3). Resident *A* noted that there is a focus on the small issues, such as removing reeds during a flood, but the underlying problem of allowing further development, which exacerbates flood risk, is ignored. Resident *M* went so far as to question the ability of the municipality to monitor and enforce environmental legislation, as required by national policy. The National Environmental Management Act (NEMA) requires both Environmental Impact Assessment and Strategic Environmental Assessments to be considered in any proposed development (RSA, 1998). Residents identified that weak implementation of this legislation resulted in new developments causing or exacerbating environmental degradation and disaster risk. Frustration at EMM's inability to deal with this problem has resulted in the community taking their own action towards finding and creating a sustainable flood management option; namely the upgrade of the Atlas Spruit stormwater management system.

Figure 6.3: Debris remaining after the Municipality removed reeds and soil from the Atlas Spruit (February 2010)

Residents identified actions that they had taken to minimise the flood risk in their property, including measures to assist them in the event of a flood. Three of the residents mentioned that they always have sandbags and bricks ready in case of flooding. Resident *V* pre-empted the floods in 2010 and placed his furniture on bricks a month before the flood occurred in 2010. Tembisa residents had similarly taken measures to reduce their flood risk, such as building walls to channel water away from their houses. It has become increasingly evident that "people in the community are taking responsibility for making sure the area is maintained" (Resident *B*). Although the DMA makes provision for government to support community DRR initiatives, there seems to be limited evidence of this being implemented or encouraged at the local level.

6.3.3 Knowledge

The interview responses revealed not only people's knowledge regarding floods, but also the means by which people use to obtain this knowledge. Knowledge guides decisions about strategies and plans, as well as the way in which disasters are managed. The interviews revealed that none of the residents had prior experience or knowledge of floods in Atlasville before 2006. This does not imply that small floods had never occurred in the area, but that people and houses were not affected by the flooding and thus residents did not retain memory of such events. In discussing his shock during the first flood event, resident *V* stated that "people don't understand if they haven't experienced it". This relationship between the lack of expectation of the floods and the ability to prepare and to cope with it, confirms a trend found in the literature (Mol, 2000; Messner and Meyer, 2006; Adger *et al.*, 2009; Harvatt *et al.*, 2011).

All the residents noted that there are no early warning systems in place to warn of possible floods. However, residents *A, D* and *J* stated that warning wouldn't necessarily be helpful because "there's nothing you can do" (Resident *A*). Although residents do not receive official warnings from the municipality, many residents commented that they are on alert when it rains, particularly at night. However, residents *B* and *C* noted that they have found specific indicators that warn them that their property and house may be flooded. These indicators tend to be the level of water in the street outside a resident's house, or water build-up at particular sections of a road. Resident *B* uses these indicators to prepare for floods by lifting furniture and electrical equipment. Residents commented that subsequent to these disasters, they have become more proactive about looking for information, such as what has caused the floods and indicators that will help minimise the impact or warn them of future floods.

A number of the residents noted that prior to these floods, communication networks within the community did not exist, be it related to floods or less formal communication. Subsequent to this event, neighbours began to share experiences and knowledge of floods and flood management. The ACF was established by members of the community to increase public participation from Atlasville residents and to provide a platform from which issues relating to the suburb could be dealt with in a unified and effective way. The recent flooding issue revealed the need for a forum where the community could communicate and share experiences and knowledge. The ACF provided a platform for residents to share their knowledge and experience, and to obtain expert advice and opinions regarding the cause of the floods. Through this forum, internet and mobile phone communication groups were established to enable effective communication between the residents in the area. Informal information sharing, and "improvements in communications, risk awareness, and preparedness" (Cutter *et al.*, 2008, p603) through social networks, have proved to be an important way that Atlasville has increased its social resilience (Harvatt *et al.*, 2011). This community's frustration with the Municipal responses ignited a desire to become active in the political sphere, to ensure that their risks and concerns were taken seriously. This confirms Hajer's (2003) conjecture that where policy has not been effective, public protest can trigger political change through the day-to-day issues at a local community level.

Informal knowledge sharing is one of the main ways that residents get information and warning about floods. A number of residents revealed that during periods where there is rain for a number of consecutive days, they speak to each other to assess how things are going on their properties. The Community Forum website and social networking websites (e.g. Twitter©) are used for residents to alert each other to flooding and other risks in the area. A number of the residents identified that a BBM (Blackberry Messenger) group had been created to further increase communication in the area.

Responses from residents in Tembisa revealed that, like residents in Atlasville, they receive no warning of floods from the municipality. Similar to residents in Atlasville, one of the Tembisa residents commented that early warning of potential floods is not necessarily helpful, because they feel that there is little they can do in the immediate lead up to a flood. This is indicative of their limited set of options and resources available to cope and mitigate flood impacts. However, unlike Atlasville, the residents in Tembisa had not established a formal social network to enhance information and knowledge sharing. This limits the Tembisa residents from creating a unified voice with which to create a political voice in the community, which further disempowers these residents (Hajer, 2003).

6.3.4 Vulnerability and adaptive capacity

One of the primary concerns raised in both the BAR and the interviews was why the area had become vulnerable to floods, where previously this was not an issue. Residents *M, N, A* and *P* noted that the shift in flood occurrence might be in part due to the increase in development and hard surfaces in the surrounding areas, which are likely to have increased surface runoff. Many of the residents and municipal managers referred to a recent development upstream from the flooded area that is likely to have affected flood risk. This factor and changing rainfall patterns were suggested as possible reasons for the flooding. There was, however, no consensus between residents about the cause of the change in flood occurrence. Across both sets of data, it is clear that residents feel a tangible sense of fear every time it rains, that they will be flooded.

> *"Every time we see a cloud in the sky, we wonder if history will repeat itself. I had only just overcome the anxiety attached to the first flood when the second one hit. I echo someone's thoughts from last night - We don't really mind what plan gets implemented, but please, please, please do it quickly." (*Resident *R*, 2010*).*

A number of the residents noted that the floods have caused them psychological damage, and they become anxious and struggle to sleep when it rains at night. Many residents feel helpless during a flood. Resident *F* said that during a flood, "there is no one that can help" and that the only thing that helps is to "pray that the rain stops". However, not all residents feel helpless or anxious because of the floods. Resident *H* was confident that he and his family "are resilient", and their ability to restore their life quickly back to the way things were before the floods, is the best thing that helps them to cope. Residents identified that family and friends tend to provide the initial support in flood events, and the neighbours really "pulled together" (Resident *E*). Every resident said that they knew people, or had friends in the area, and most (60%) of the residents said that their neighbours helped them to cope with their flood problems. This reveals that relationships and social capital play an important part in enabling residents to cope with the floods. The Tembisa residents also commented that they knew people in the area and that their friends and family were the most important things that allowed them to cope with the immediate effects of floods.

All the Atlasville interviewees identified that they have insurance (even if this is limited to home insurance), and they claimed from their insurer for flood damage. This supports Resident *E*'s perception that "you can't do without it". Some residents revealed, however, that their insurer only compensated them for the first flood and refused to pay for damage resulting from the second flood. One resident said that his insurer would not pay out for the damage from the second flood because it was caused by municipal negligence and thus it was the municipality's responsibility to compensate for damages. The history of flooding and their fear for more damaging floods in the future has made them concerned that their insurance companies will stop covering their claims, thus contributing to feelings of insecurity and helplessness. Neither of the residents from Tembisa had insurance, and they commented that the floods had expensive financial consequences to them.

The financial consequences of the floods, have had a wider influence than the community and many interviewees identified that property prices in the area had dropped since the floods. Nevertheless, people commented that many of the worst affected people have sold their houses and left the area, because the fear of future floods outweighed selling their house below value. It was found that three of the ten residents interviewed would be willing to move from the area because of the floods. Two of the three respondents who said that they would be willing to move, said that they are unable to because they have been unable to sell their house, because of the negative perception that the area has a high flood risk. One of the Tembisa residents, despite experiencing floods annually, said that this only occurred once a year and was not worth moving for.

Due to the community's level of concern about the flooding, they have ensured that they apply continuous pressure on EMM to take note of their problems through the ACF. In 2011, the municipality upgraded a section of the stormwater piping through the area. Although this helped to reduce some of the resident's anxiety regarding potential floods, they remain sceptical about the required maintenance continuing in future. EMM's history of inadequate stormwater management lingers in the community's memory. Figure 6.4 shows the breakdown of responses whether people believe they will be affected by floods again. Just less than half of the residents believe that floods would continue in the area, in the future, because of a range of reasons including climate change and continued infrastructural development in EMM. The majority (five out of six) of respondents, who said they hoped or did not believe that they would experience floods in the future, attributed this to the new stormwater culvert that had been upgraded. This was echoed in residents' comments that "the new drainage line has helped a lot" (Resident *V*) because "2012 is the first year since 2006 that there were no floods" (Resident *J*).

The 2010 flood resulted in a situation where instead of participating and supporting the municipality, members of the Atlasville community suggested a boycott against municipal structures by setting up a ratepayers' association[18]. The community would direct their municipal rates towards

[18] A ratepayers' association is an organisation formed by a group of people from a specific geographical area, such as a suburb, with the intention of creating a unified political platform for the respective area. Any person in the area would be free to join the association.

this association, instead of the municipality, for it to take responsibility for maintaining the suburb and ensure that the community receives the services that it requires. This action can be seen as a protest against poor municipal service delivery. Over the past few years in South Africa, there have been many violent protests as communities, such as that of Atlasville, have lost patience with municipalities for not providing the services that they are, by law, required to provide. However, the Atlasville community is different from most disenchanted communities, which are typically low-income areas with very poor service and infrastructure in place. This community is a middle-income group that, instead of protesting with public marches, threaten protest action through withdrawal of their rates and taxes. This suggestion, had however, not been implemented by the time the interviews were conducted. Nevertheless, the threat reveals the deeper power relations at play between the community and the municipality. Due to the recent history of poor service delivery, this community did not have faith that the municipality would provide what the law requires them to, and so they use what they see as their advantage - their rates and taxes - to try and force the municipality to take action in this area. This action would undermine governance structures that should be in place and available for the community within the municipal area. This highlights the potential for social capital to have negative impacts for cooperation with the municipality, and supports Pelling and High (2005, p310) identifying the danger of uncritically viewing social capital as a 'social good'. Social capital, however, was also expressed in a positive way, where individuals supported their neighbours, both emotionally and financially, to help each other cope with the impacts of floods.

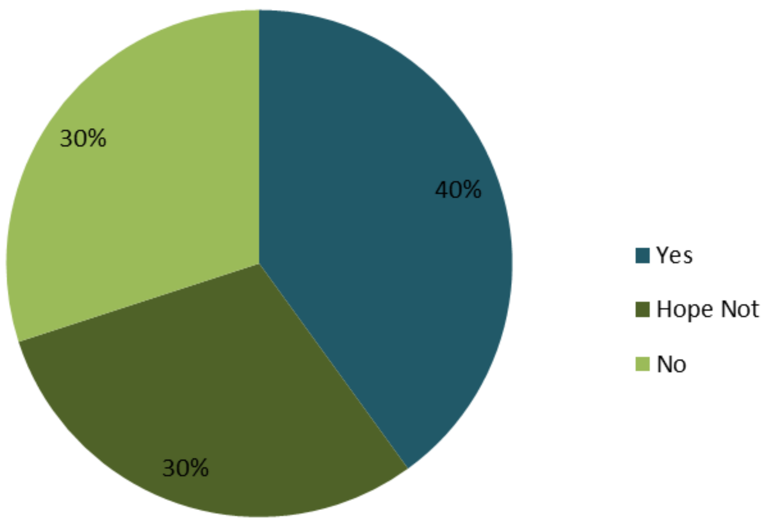

Figure 6.4: Residents' perceptions on whether they will experience floods in the future (n=10)

Despite the negative impacts of a potential ratepayers' association, the community showed a level of adaptive capacity through identifying a weakness in the system and creating alternative ways to strengthen this weakness. The community was able to unite and pool resources and share ideas, in an attempt to sort out the flooding problem, through clearing, maintaining and repairing the drainage channels, which they were not confident the municipality was going to be able to repair. Resident *F* revealed that a few residents had provided financial support for a family who was not insured and was unable to afford the post flood repairs. This adaptive capacity that the community demonstrated, supports the premise that capacity is not always found in typical forms, such as insurance (Pelling and High, 2005). The local government is unable to be as flexible, due to the formal structures within which it has to work, which limits its capacity to deal with this problem. This also highlights an underlying belief that people trust their community that they are familiar with, rather than the municipality for information and support (Harvatt *et al.*, 2011).

6.4 Conclusions

This chapter investigates the social context of floods. Primary and secondary data are used to gain insight into how communities in Ekurhuleni have been affected by floods and their perceptions towards future floods and their management. Atlasville residents raise questions about who is responsible for flooding. They also comment on the effectiveness of basic service provision and the changes that they have observed regarding the floods and the stormwater management in the area. The BAR reveals a strong sense of dissatisfaction with EMM and it is clear that there was little trust that EMM would reduce the community's flood risk in future. However, the interviews reveal that this frustration and distrust has decreased over time. This is mainly because the municipality now conducts regular cleaning and maintenance of the Atlas Spruit, and a new culvert has been installed to increase the stormwater drainage capacity in the area.

Overall, this chapter argues that residents have the capacity to take responsibility for some of the flood management and to keep the municipality accountable for maintaining their area. The community organisation provides a potentially powerful tool for the residents to enhance their resilience to flood risk, which is within the stipulations of the DMA (2002). The investigation highlights that the Atlasville community enhanced their adaptive capacity through creating a social support structure. Through collective action, and pooling experiences and resources they were able to put pressure on local government to deal with their flood problem. The responses from Atlasville residents support the suggestions made by Pelling and High (2005, p317); namely in that "the multi-layered and multi-faceted social ties of everyday social interaction may be a community's best resource in maintaining a capacity to change collective direction". The chapter reveals how different types of knowledge and capacity can build resilience to floods through social cohesion, independent of a formal policy framework. The following chapter investigates how combining the three investigations in this research (Chapters 4,5 and 6) provides a better understanding of floods and their management, rather than by examining each investigation in isolation.

7 Discussion and Conclusion

"...events pertaining to hazards interact with psychological, social, institutional, and cultural processes in ways that can either heighten or attenuate individual and social perceptions of risk and shape risk behaviour" (Renn *et al.,* 1992, p137).

7.1 Introduction

This research has thus far developed information on flood disasters and the management thereof from a range of perspectives, obtained through three investigations. The previous three chapters present the results of these investigations into the different components of DRR, namely the physical, political and community contexts in developing countries. The literature for DRR in developing countries focuses on low-income and informal areas, but the challenges related to the developing context can also result in middle-income areas becoming vulnerable. Atlasville in EMM is one such example, which forms the case study for this research. The physical context investigation (Chapter 4) assessed the status quo of rainfall and flood disasters in EMM. This investigation reveals that heavy rainfall and flood disasters potentially are closely correlated, however there is no statistical evidence to support that rainfall has increased in intensity through the period. This highlights that there must be other factors that have led to an increase in perceived flood risk in EMM. Chapter 5 investigates whether these factors are related to the political context of DRR, through an assessment of the policy requirements, implementation and challenges of disaster management at the municipal level. This investigation identifies some institutional and DRR policy-related factors that may have attributed to the increased risk. A number of additional factors unrelated to the technical management of flood disasters, however are identified. These additional factors are examined through the community context investigation (Chapter 6), which assesses residents' knowledge and perceptions towards disasters and management thereof. The knowledge that each investigation highlights addresses some of the weaknesses of the other investigations. This chapter integrates the three investigations to enhance the understanding of floods and DRR at the local level in South Africa.

Figure 7.1 depicts a simple illustration of the three components of the research and the way in which they interact in the context of DRR. In this chapter, these components are triangulated to assess how they can be mutually illuminating with regard to all aspects of DRR. This is facilitated by the use of the DROP model (Cutter et al., 2008), which is depicted (Figure 2.4) and discussed henceforth.

A summary of the three investigations is provided to identify each of the key findings and limitations. This is followed by the composite investigation of DRR of flooding in EMM. This is divided into three sections, which encompass the pre- and post-disaster, and future disaster contexts. These contexts include the drivers of flood disasters, absorptive and adaptive capacity, and mitigation and preparation for future disasters. The implications for DRR at the local level in the developing world are discussed through the insights gained from the three previous sections.

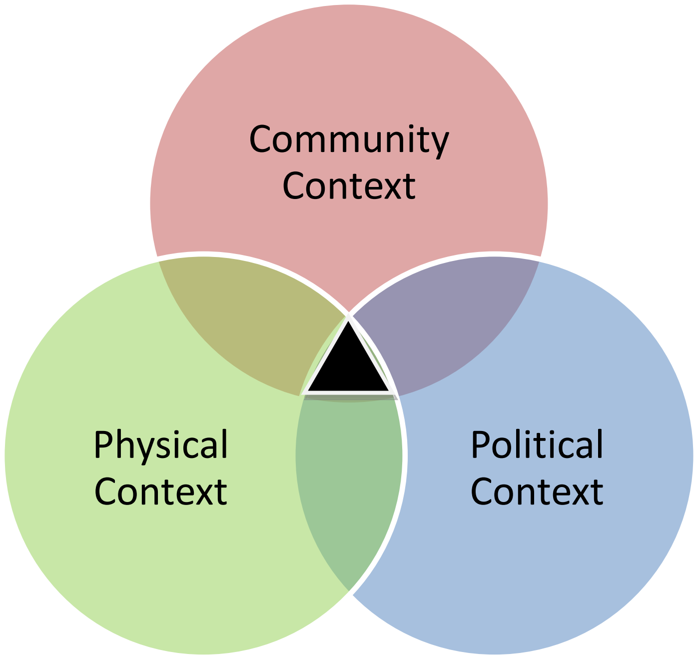

Figure 7.1: The intersection of the three interacting spheres of disaster risk reduction

7.2 Summary of Results

The results of each investigation provide important information on DRR in the case of flood disasters in EMM. Each of the investigations from Chapters 4, 5 and 6 reveals factors that influence DRR. Some of the limitations from in the various investigations are addressed by the other investigations. A summary of the key findings of each investigation is provided below to aid the discussion on the interaction between the three investigated spheres.

7.2.1 Physical Context of Rainfall and Flooding

The physical context investigation comprised a statistical analysis of rainfall and an investigation of flood disasters in EMM. Daily rainfall data sets from SAWS and flood incident reports from EMM were used for the purpose of this investigation. The main results, and the challenges and limitations of this investigation are outlined.

7.2.1.1 Core results

The rainfall analysis identifies that average rainfall and the number of rainfall days varied spatially, with maximum rainfall showing no significant variation spatially. The analysis identifies no statistical trend in average daily rainfall, maximum daily rainfall and number of rain days per season at ORT over the period. The perceived change in flood risk in Atlasville can thus not be attributed to changes in rainfall distribution. The flood disaster analysis found that the greatest concentration of flood disasters occur in the month of January. The available data show the disasters are clustered during periods of extended periods of extreme rainfall, where the greatest number of DIRs occurred subsequent to the highest rainfall peak in the assessed periods. The findings, however, suggest that periods of extreme rainfall are associated with widespread flooding in EMM. This investigation indicates that heavy rainfall events are likely to be the major driver of flood risk in Atlasville, but rainfall trends have not intensified over the period of investigation, which means that there must be additional factors that are contributing to observed changes in flood risk. These are potentially attributable to factors such as land use changes, upstream urbanisation, which fall into the jurisdiction of municipal management of disasters, and thus the subsequent investigation examines the political context of DRR.

7.2.2 Political Context of Disaster Risk Reduction

The political context investigation makes use of three sets of data to assess the political context of disaster management at the local government scale. These include the South African DMA (2002), a SALGA research report (2011), which details the implementation of the DMA at the local level in South Africa, and interview responses from EMM managers. A thematic analysis is used to triangulate the three sets of data.

7.2.2.1 Core results

The datasets analysed through a thematic approach, use four themes including 'Cooperative governance', 'Proactive approach', 'Knowledge', and 'Vulnerability and Adaptive capacity'. The core results of this investigation comprise the range of factors that limit the implementation of the DMA. Although principles of cooperative governance and proactive approach to management are emphasised in the DMA and other national documents, there is weak adherence to these principles at the local municipal level. In addition, the approach towards multidisciplinary and integrated disaster management through knowledge and research is clearly not being engaged with, and the technocratic approach is prioritised. This means that important information and local residents' perspectives are likely to be left out of the decision-making process.

Although the DMA states that appropriate budget and capacity is to be allocated to disaster management, both the SALGA report and the interviews identified that budget, staff and lack of resources were the greatest capacity limitations. These limitations not only decrease the adaptive capacity of municipal management, but also entrench vulnerability to disasters due to poorly serviced areas and unaddressed risk. Some of the responses from municipal managers suggested that communities have a role to play in disaster management. Where there is limited capacity in the municipality, communities can take responsibility for this where they are able, which the Atlasville community was able to do.

7.2.3 Community Context of Knowledge and Perceptions of Disaster Risk

The community context investigation assesses residents' knowledge and perceptions of flood disasters, which are obtained from the public participation section of the BAR, and interviews with residents in Atlasville. The main results, and the challenges and limitations of this investigation are outlined.

7.2.3.1 Core results

Atlasville residents raised questions about who was responsible for flooding, on the effectiveness of municipal service provision and the inconsistency of maintenance that they have observed regarding the flood risk in the area. The BAR revealed a strong sense of dissatisfaction with the Municipality and it is clear that there was little trust that the Municipality would reduce the community's flood risk in the future. The interviews over time, however, revealed that this frustration and distrust had decreased through time, which was a result of the Municipality now conducting regular cleaning and maintenance of the Atlas Spruit, and the installation of a new culvert to increase the stormwater drainage capacity in the area.

Overall, this investigation found that Atlasville residents have the capacity to take responsibility for some of the flood management, and to keep the municipality accountable for maintaining their area. The community organisation provides a potentially powerful tool for the residents to enhance their resilience to flood risk. Through collective action, and pooling experiences and resources, residents were able to put pressure on local government to deal with their flood problem.

7.2.3.2 Challenges and Limitations

The investigation identified a number of challenges in obtaining and extracting resident perceptions on floods and flood management, the most significant of which was that of conducting interviews from a representative sample of EMM residents who had been affected by floods. In Atlasville, this was due to people not being at home or coming to their gates. In addition, the majority of interviewees were male. The primary challenge in Tembisa was related to language barriers. Two interviews were conducted with a municipal manager as translator, however it was not only possible for any further interviews. This means that the perceptions and knowledge of a large group of people has had to be excluded from the research.

7.3 Understanding the Context of DRR of Flood in EMM

The context of DRR is made up of a number of components. Cutter *et al.*'s (2008) DROP model (Figure 2.4) is used in this section of the investigation to integrate the three separate investigations. The context of DRR is divided into three components, using this model. The first component groups the factors and drivers that combine and influence the disaster impact. The second component comprises the absorptive and adaptive capacity of affected systems in the wake of a disaster. These factors influence the degree to which recovery from the disaster can occur. The final component is made up of preparation for and mitigation of future disasters. The three investigations in this research provide the platform from which each of the components of DRR are discussed with respect to flood disasters in EMM.

7.3.1 Drivers of Flood Disasters

According to Cutter *et al.*'s (2008) DROP model, there are a number of factors that contribute to a disaster, including the antecedent conditions of social, built and natural systems, the event characteristics and effects, and immediate coping responses. Each of these components are assessed through the three investigations related to the case of flood disasters in EMM. Douglas *et al.* (2008) assert that although the primary driver of pluvial floods is rainfall, many other factors can influence the extent of such disasters.

The DIRs highlight that most flood disasters are concentrated in the month of January, which receives the highest rainfall (Dyson, 2009). This suggests that there is a strong link between high rainfall and flood incident. This is confirmed in the investigation of the 2010 and 2011 floods, which demonstrate that floods are clustered in a period of heavy rainfall. These periods of high flood incidence not only receive high rainfall but also consisted of many consecutive days of rainfall. Residents identified that this type of rainfall saturates the ground causing increased runoff and ponding (Douglas *et al.*, 2009). The topography of most of EMM is relatively flat and contains wetlands, limiting the ability of water to drain from the area and increasing flood risk. This is exacerbated by the sudden onset, and intense thunderstorms characteristic of the area. These physical attributes combined, leave the municipality at a high risk of flooding.

In addition to factors related to the climate and terrain, urban structural factors also increase flood risk. There has been rapid densification in EMM for a number of years, including the development of Atlasville. Atlasville was built in a drained wetland area, and houses were constructed within the 50-year flood zone (VCMS, 2010). Industrial and residential developments in the municipality have resulted in hard surfaces across large portions of the municipality. Atlasville residents identified that developments upstream of the suburb cause increased runoff, which floods Atlasville as it flows to the Atlas Spruit. This could explain why floods have increased, however, this trend does not explain the sudden onset of flooding. The interviews revealed that none of the residents had prior experience or knowledge of floods in Atlasville before 2006. Many residents placed the blame and responsibility for the floods on the municipality. The residents identified that the municipality permitted development without addressing the additional runoff. Furthermore, residents identified that inadequate maintenance of the Atlas Spruit prevented water from draining away from the flooded area (e.g. overgrown reeds, litter and silt in the waterways).

The issues identified by the residents were echoed by many of the municipal managers. Operations managers identified that limited financial and staff capacity prevent ongoing monitoring and maintenance of areas in the municipality. Botha *et al.* (2011, 24), however, extend this and blame the lack of proactive disaster management on “the lack of awareness, resources and political will”. Residents identified a shift in the area’s management since the amalgamation of the municipality in 2002. The managers highlighted that at that time, the areas of jurisdiction shifted dramatically, however, without associated budget and staffing adjustments. In addition, managers identified that institutional memory and knowledge has been lost. This may account for why the ongoing maintenance of the Atlas Spruit did not continue after the amalgamation.

Since the Atlasville floods in 2010, the municipality has started maintaining the Atlas Spruit and has upgraded one of the stormwater culverts. Overall, the residents perceive that their flood risk has decreased dramatically and many believe that they will not experience floods again as a result. However, this perception is too simplistic as floods result from a composite set of factors. The changes in average daily rainfall combined with the projection of more frequent extreme rainfall events (Engelbrecht *et al.*, 2012), suggest that the rainfall events may increase the event characteristics that are associated with floods. In addition to these, factors of absorptive and adaptive capacity, and mitigation and preparation, will influence the likelihood and extent of disaster impact in future.

7.3.2 Absorptive and Adaptive Capacity

The second component of the DROP model is the absorptive and adaptive capacity of a system in the wake of a disaster. The absorptive capacity of the system relates to how well the system can cope with the impacts from a disaster, or in other words, how well the system absorbs these impacts (Cutter *et al.*, 2008). Adaptive capacity relates to the ability of the system to improvise and encourage social learning in order to adapt to changes. Cutter *et al.* (2008) describe social learning as the process of building social cohesion and initiating collective action. This component is discussed through the interaction between the three investigations.

Although adaptive capacity is more strongly tied to social factors, floods can be absorbed to an extent by the natural environment. Rainfall can be absorbed into the ground, which reduces the amount of runoff, and in turn the likelihood of flooding. Wetlands provide important natural water filtration and purification systems, and have been identified by the municipality as key protection areas (EMM, 2004; Manager *G*, 2012). The ability of these systems to absorb water, which should minimise the flood impact, is limited because residential areas and infrastructure have been built within their natural flood zone. As a result, the flood risk is increased through the retention of water. The flood investigation, and resident responses highlighted that in periods of rainfall across a number of consecutive days, the risk of flooding is high due to saturated ground. In such cases, the absorptive and adaptive capacity of social systems becomes particularly important. The amount of rainfall through such periods is not necessarily a useful indicator to guide disaster response strategies.

The political investigation identified that the conditions for cooperative governance in EMM are weak, which implies a poor likelihood that municipal structures will encourage social cohesion within and between the managers and residents in the municipality. A key driver of this is limited capacity in the municipality, which results in managers feeling that they are not able to encourage and facilitate anything beyond their immediate responsibilities. The political and community investigations highlighted that the municipality has not fostered an environment that encourages community participation within governance structures.

The Atlasville community identified this weakness in the municipality and took initiative to establish structures and social networks to assist their recovery from flood disasters. These structures provide a unified collective voice for the suburb through which they are able to place pressure on the municipality to address their concerns and problems. The community's ability to place pressure on the municipality and gain attention from municipal decision-makers highlights the point that Douglas *et al*. (2008) make that middle-income groups are better able to raise the profile of their concerns than lower income groups.

This highlights the adaptive capacity of Atlasville residents through building social cohesion, which resulted in political change with respect to flood issues in the suburb (Hajer, 2003). These changes and reorganisation of the social structure and dynamics are examples such as Manyena *et al.* (2011) discuss as being more important than the physical disaster impact. The community's capacity to respond to flood risk is identified in the literature (Pelling, 2003) and in the political investigation (RSA, 2003) as important to bridge the gap of limited capacity in municipal government. Pelling and High (2005, p310), however, emphasise the danger of uncritically viewing social capital as a 'social good'. Communication and cooperation between the municipality and social groups is an important safety mechanism to ensure that community capital provides a positive influence in managing disasters. This is supported by Dodman *et al.* (2010, p5) who state that "an important component of any community's response is negotiating the support of local government to the long term development priorities identified by local residents".

The local government has limited ability to be flexible and improvise, due to the formal structures and procedures required, particularly in the context of a disaster. The limited proactive approach of the municipality, identified by managers and in the SALGA report, further limits absorptive and adaptive capacities. In the Atlasville community's perspective, resilience to flood events is unlikely to develop from actions taken by the municipality. The history of poor management has created distrust between the community and the municipality. However, there is a mismatch between the perceptions of the municipal managers and that of the community regarding responsibilities and responses to flood risks. The community believes that the municipality does not prioritise the flooding issue and has not taken the required decisive and urgent action to reduce the risk; whereas municipal managers believe they are doing all they can with the capacity they have. This suggests that the policy framework is not enabling or supportive for DRR at the local level.

Another aspect of social learning is the use of different forms of knowledge to enhance absorptive and adaptive capacity, and the knowledge gained from the processes of absorption and adaptation. The Atlasville community revealed through the interviews that they had a good understanding of different drivers of the floods in their area. This knowledge was gained through communicating between other members of the community, hiring hydrology experts to examine the technical aspects, and individual experience of the floods. In addition to these sets of knowledge, the community gained an understanding of how to engage with the municipality in an effective way. The combination of these knowledge sets enabled the community and individuals to direct their actions toward appropriate responses to flooding. This knowledge gain from immediate flood management also enhances the long-term mitigation of, and preparation for, future floods.

7.3.3 Mitigation and Preparation

The final component of DRR encompasses the proactive mitigation of and preparation for future disasters, which emerge from the experience and response to past disasters. The literature suggests that a proactive approach to future disasters is most likely in communities and areas where disasters have occurred in the past (Dodman *et al.*, 2010; Harvatt *et al.*, 2011; Yamamura, 2010). Manyena *et al.* (2011) argue that the resulting changes that affect society, economics and the environment are more important than the impacts themselves. The impact that these changes have on future flood preparation in EMM are discussed below.

Prevention and mitigation of disaster risk, as required in the DMA, rely heavily on disaster predictions and understanding of the status quo, before a disaster occurs. The physical investigation of this research provides some insight into understanding the past disasters, which may be useful in anticipating and reducing the impact of future disasters. Combining the temporal analysis of daily rainfall and potential impacts of climate change, EMM is likely to experience an increase in extreme rainfall events. This increase has the potential to affect the frequency of flooding if the other drivers of flood disasters are not addressed.

The political analysis revealed however that local municipalities in South Africa, including EMM, face great challenges to implementing a proactive approach to disasters. The SALGA report identified that poor understanding and awareness is a major reason for a reactive approach. The patchy rainfall and flood data, which was highlighted in the physical context analysis, suggests that an inadequate understanding and awareness of disaster risk is likely to continue in EMM, particularly in low-income and informal areas. This in turn makes mitigating and preparing for future floods in these areas nearly impossible from a municipal management perspective. The EMM managers, however, are not unaware of this challenge, but their ability to respond is limited by capacity constraints and prioritising their resources elsewhere.

Reactive management was identified as a limiting factor in building resilience to flood disasters by both residents and managers. In particular, the tension highlighted by Moser and Satterthwaite (2008) between short-term flood response and long-term prevention and mitigation actions, was noted by the residents. Municipalities, such as EMM, which manage reactively and have the capacity to respond only when there is an urgent need or disaster, create no space for resilience to future floods to be built (Pelling, 2003). This problem is deeply rooted in other factors in the municipality, such as budget and capacity constraints. All of these factors limit the ability for municipal managers to fulfil various legal and policy requirements.

Municipal managers in Ekurhuleni felt limited by requirements of different environmental and disaster policies. Instead of these policies empowering municipal managers with the tools of effective management of the environment and flood risk, the current policies and limited capacity of the local municipality help to create a situation where the managers feel disempowered and frustrated that they are unable to manage such disasters effectively. The inability of the municipal managers to fulfil their responsibilities is indicative of deeper problems within governance structures in South Africa. There is weak co-operative governance and a disconnection between strategic planning and the ability to implement plans on the ground, as well as a further lack of co-operation between departments within the municipality.

Although EMM responds to disasters reactively, the Atlasville residents identified that through pressuring the municipality, the stormwater drainage through their area has been improved and ongoing maintenance of the Atlas Spruit is being conducted. The establishment of the ACF and their commitment to ensuring that the municipality be held accountable to mitigating flood risk in the area, highlight the social change that has occurred in the community, which in the long-term is likely to reduce and potentially mitigate future flood risk in the area. In addition to this, a number of residents identified adjustments that they have built and put in place to warn against or decrease the impact of future floods.

The intention of the three preceding sections was to use the various investigations in this research to enhance the understanding of flood management in EMM. Cutter *et al.*'s (2008) DROP model proved to be a valuable lens through which DRR can be framed at the local scale to include a range of types of information. This model provides a framework for integrating the outcomes of each of the individual investigations and providing an enhanced understanding the whole context of DRR. This model provides an effective model for local scale management of disasters, which enhances the ability to incorporate various information and types of knowledge in framing DRR. The following section extracts the implications of this research, as a whole, on DRR at the local level in developing countries.

7.4 Implications for Disaster Risk Reduction at the Local Scale in the Developing World

Understanding the causes and management of urban flooding risk is highly complex in urban areas in developing countries where development has occurred rapidly, and informal settlements have been built in high-risk areas (El-Masri and Tipple, 2002; Douglas *et al.*, 2008). Some of the limitations and challenges identified through this research are the key factors that need to be considered for DRR in EMM, and throughout South Africa.

This research identifies the constraints of municipal structures and governance and the implications on disaster risk at a local level. One of the first steps towards building resilience to floods is through strengthening local municipality capacity for cooperative governance, both within municipalities and between municipalities and all other stakeholders. Shaw and Theobald (2010, p10) posit that "risk management is still no substitute for great leadership and a culture of teamwork and trust which can respond effectively to the unexpected". All municipal departments need to recognise that the effectiveness of their department has an impact on disasters, and DRR should not be limited to the Disaster Management departments. Capacity weaknesses need to be identified and addressed in all aspects of DRR. This research highlighted that it is important to assess multiple sources of knowledge to identify the range of challenges to DRR at the local level. In addition to this, it is necessary to identify and promote alternative sources of capacity, and encourage residents and community organisations to assist their municipality in reducing their immediate and long-term flood risk.

The results of this research highlight that within the developing context, poor planning and capacity limitations can result in increased vulnerability for middle-income communities. This increased vulnerability can lead to community mistrust of local government, as is revealed in Atlasville. Disenchanted middle-income communities have the potential to act in opposition to the municipality if they believe their interests are not being prioritised by the municipality. Addressing flood risk and building resilience effectively, relies on acknowledging local experiences, capacity and history. DRR strategies that do not consider factors such as these, are likely to be rejected by local residents and be ineffective in building resilience to future disasters. This has the potential to entrench further community feelings of mistrust and frustration towards the municipality.

The literature strongly identifies that the urban low-income groups are those most vulnerable to disasters. Because of this intersection, there is a need to find synergies between effective disaster responses and poverty reduction strategies (Kasperson *et al.*, 1988; Satterthwaite *et al.*, 2007; Douglas *et al.,* 2008; Moser and Satterthwaite, 2008). The physical analysis of rainfall identified that the rainfall distribution across the municipality is not homogenous, but because there is a lack of data in the major informal and low-income areas, the implications for these areas cannot be investigated. Patchy information limits the ability of mitigation and preparation efforts to be guided by understanding some of the drivers of flood disasters. This research provides a baseline of flood risk for a middle-income group that can be compared to low-income groups that face similar physical risks, but may not have access to the same resources and are thus more vulnerable.

The risk of disasters and limited effectiveness of disaster management in low-income and informal areas of South Africa raise questions of inequality. The research identified that harnessing and unifying community capacity can strengthen the political voice of the community, and compel the municipality to take their concerns seriously. Some of the methods that the Atlasville community use to build networks (internet or cell phone applications) are not viable in lower income areas. Although building these networks is not dependent on these tools, they simplify the process. Such examples highlight further that residents in low income and informal areas, who tend to have high flood risk, are further disadvantaged due to a range of other factors. Factors such as the lack of rainfall data, poor governance, limited capacity and a weak voice, compound the limited capacity to adapt, prepare and mitigate future disasters.

The institutional and governance challenges identified in this research support those found in research in Cape Town, which focused on flooding in informal settlement areas (Ziervogel and Smit, 2009). Ziervogel and Smit (2009) highlighted the need to enhance the capacity of all stakeholders to manage flood risk. The limited interviews from Tembisa highlighted that research similar to that being conducted by the 'Flooding in Cape Town under Climate Risk' group, needs to be extended to EMM and other municipalities in South Africa. This will enhance the understanding of the nuances of flooding in informal and low income areas. Comparing the differences between different socio-economic areas, such as between Atlasville and Tembisa, may in turn develop local municipalities' ability to provide effective DRR.

7.5 Conclusion

The objective of this research is to investigate the extent to which a range of factors interact to either enhance or limit resilience to flood disasters at the local scale. This was investigated through understanding the rainfall and flood context, the policy context at the local municipal scale, and the community context of flood disasters in EMM. The physical context analysis found that although there is statistical variation in rainfall distribution from a spatial perspective, there was no trend found in temporal distribution. From the limited DIR data available, a correlation seems to exist between extreme rainfall events and flooding in EMM. The policy analysis found that although the DMA identifies a good approach to DRR, some of the structures entrench hierarchical structures which limit effective cooperative governance. It was found that a range of factors, which were not directly associated with flood disasters limit the implementation of the DMA. The community component of the investigation found communities' perceptions of flood risk and DRR are indeed affected by their experience and past interaction with their community and municipal management. The Atlasville community showed that their adaptive capacity developed over time through social networks and interaction, and creating a unified voice to heighten awareness of their flood problems.

Through identifying how each of these individual investigations fit into Cutter *et al*. (2008)'s DROP model, the separate investigations were brought together to highlight different aspects of DRR. This facilitated integration of the different contexts of flood disasters in order to highlight how each of these brings different aspects of DRR to light. The multidisciplinary approach used in this research is fundamental to the ability to assess how different factors interact to either enhance or limit resilience to floods.

The results of this study show that in order to understand the nuances of flood disasters, a combination of different sets of knowledge is necessary, the weaknesses of one analysis being addressed by the other analyses. The finding that heavy rainfall events are associated with flood disasters, does not adequately account for the perceived increased flood risk in Atlasville, because no statistical trend in average daily rainfall is found. Factors related to the government management of floods are identified, in the political analysis, as limiting the effectiveness of DRR at the local level. Some stipulations of the DMA are identified as limiting municipalities' abilities to deal with local scale disasters, such as floods. Patchy knowledge and limited capacity for proactive DRR, are highlighted as critical factors entrenching disaster risk. This analysis further identifies factors, which are not related to limitations of political and institutional frameworks that influence disaster risk. These factors are investigated through the community context analysis. The results of this investigation highlight the potential for social capital to empower communities and provide additional capacity for communities to build resilience and reduce flood risk.

The case study of Atlasville shows that each set of knowledge (i.e. physical, political and community) plays an important part in informing how flood risks can be managed. This case study echoes Manyena *et al.*'s (2011) assertion that the resulting changes subsequent to a disaster and understanding how different stakeholders manage disasters are more important than the impacts themselves. The relationship between these stakeholders influences the resilience of communities and the potential impact of future floods. The lack of trust between the community and the municipality means that the resources and capacity that each group has are not shared. Much of the global literature regarding resilience speaks to technical solutions (e.g. Huq *et al.*, 2003; Ligeti *et al.*, 2007; Cities Alliance, 2009) and although these include local knowledge, what this case study has shown, is that in the developing world merely including this knowledge is not sufficient. History and local stories of mistrust have profound influences on the way and extent to which local perspectives can influence actions to build resilience.

In framing this research, the argument is made that in order to manage flood risk in urban areas, it is necessary to understand the physical hazard, the related institutional governance structures and the perceptions of those faced with managing flood disasters. The focus on multiple sources of knowledge in this research aims to enhance understanding of the limits and the potential of effective DRR. The results of this study suggest that the way the community and the local municipality responds to flood risk, and how these groups interact, are key factors in understanding the effectiveness of flood management. History and local stories of mistrust have profound influences on the way and extent to which local perspectives can influence actions to build resilience.

Inadequate multilevel governance structures, however, limit the ability to build resilience through integrating strategic and operations requirements. Poor governance, not only limits the ability to build resilience, but can also contribute to reducing resilience through creating more frustration. The context of poor DRR and limited capacity, which result in reactive management, fosters mistrust of local government by communities, and leaves municipal managers with a feeling of powerlessness in building long-term resilience to future flood disasters. Rigid institutional procedures and inadequate communication limit the adaptive capacity of flood management. Because municipal budget and resources are so limited, municipalities need to harness social capacity outside of government, such as have been identified in Atlasville.

This research has identified that governance structures and practices play an important role in the implementation of policy. This research highlights the need for policy to take account of the effect of current challenges and constraints to implementation at the local level. It is necessary for decision makers to understand the institutional challenges such as human capital constraints that prevent effective implementation of policy. In addition, local municipalities need to foster an environment where coordination and communication between departments is encouraged. Finally local municipalities should try to encourage local communities to take responsibility for looking after their area through active citizenship and positive engagement with municipal structures. Effective local level DRR relies on understanding all aspects of disaster risk. Adopting a multidisciplinary approach at the local scale, is identified in this research as a necessary tool for understanding the whole context of disasters in developing countries and consequently influencing DRR strategies.

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Appendix I

Municipal Manager Questionnaire

1. Vulnerability to flood events

1.1. Have there ever been flooding in 'AREA'?

1.1.1. When?____

1.1.2. Where? ____

1.2. How often do you think floods affect this area?____________________________________

1.3. How are people affected by the flooding?____

1.4. Can you tell me what happens when a flood occurs? _________________________________

____

1.5. What type of problems would your department expect to experience in the event of a flood?

____

2. Knowledge bases

2.1. Do people hear /get warned about floods in this area before they happen?

____

2.1.1. If so, how do they hear about them?

____

2.2. Does the local municipality tell them about possible flooding?

____

3. Resources

3.1. What resources do you have to help you plan and cope for an emergency?

____

3.2. Do you feel you have sufficient resources to adequately plan for and cope with emergencies? ____

3.3. Do people do anything to lower the chance of being affected by floods in the future?

____

3.3.1. If so, how?

____

3.4. What helps people to cope with a flood?

____

3.4.1. Whom do they ask for help you in a flood situation?

____

3.4.2. Do people call EMS/police?____

3.4.3. Who do people contact first to help them?

____

____

3.5. What do people need to help them cope with a flood (what is the best way of flood prevention)? ____

____

3.5.1. How do you think they can get these things?

____

4. Perceptions and Responses

4.1. Do you think there will be floods in the future?

____

4.1.1. Why?

____

4.2. Does the risk of future floods concern you? If so, how?

____

4.3. In an emergency, what are your greatest priorities?

____

4.4. What are the worst effects of floods (financial, social, failing to meet legal requirements)?

____

4.5. Are there times when people feel most scared of being affected by floods?

____

4.5.1. When/Where/Why?

____

____

4.6. What do you think causes the floods; is it just a lot of rain or are there other things that cause floods?

____

4.7. What do you think makes one flood worse than another does?

____

4.8. Who do you think is worst affected when a flood occurs?

____

4.9. Who or what do you think should be responsible for fixing flood damage?

____

4.10. Who or what do you think should be responsible for reducing flood risk?

____

4.11. Would you ever move/change jobs/use different route to avoid the risk of floods?

____

4.12. Has anyone else in the community done anything to make themselves less vulnerable to floods in the future?

____

4.12.1. What allowed them to do this?

____

5. Role of the municipality

5.1. Do people tell the municipality of damaged roads/pavements/drains?

____

5.2. Do you think that the municipality knows about residents problems?

____

5.3. Do you feel that residents' experiences/concerns/priorities are taken in to consideration in the strategic planning process?

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NOTES

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Appendix II

Local Resident Questionnaire

1. Context

1.1. What do you do (e.g. live/work/pass through) in Atlasville?___________________________

1.2. How long have you been in Atlasville?____

1.3. How much time do you spend here? (per day/week/month) __________________________

1.4. Do you know the people living in the area? ____

2. Vulnerability to flood events

2.1. Have you ever seen flooding in Atlasville?____

2.1.1. When?____

2.1.2. Where? ____

2.2. How often do you think floods affect this area?_____________________________________

2.3. Have you ever been affected by flooding in this area? ________________________________

2.3.1. How were you affected by the flooding?____

2.4. Can you tell me what happens when a flood occurs? ________________________________

____

____

3. Knowledge bases

3.1. Did you hear about floods in this area before you saw one here?

____

3.1.1. If so, from who and what did they tell you

____

3.2. Do you get warned about possible floods before they happen?

____

3.2.1. If so, how?

____

3.3. Does the local municipality tell you about possible flooding?

____

4. Resources

4.1. Have you or your household done anything to lower the chance of being affected by floods in the future?

____

4.1.1. If so, how?

____

4.2. What helps you to cope with a flood?

____

4.2.1. Whom do you ask to help you when a flood happens?

____

____

4.2.2. Do your neighbours help at all - how?

____

4.2.3. Do you call EMS/police? ____

4.2.4. Who do you contact first to help you?

____

____

4.3. What do you need to help you cope with a flood(what is the best way of flood prevention)?

____

____

4.3.1. How do you think you can get these things?

____

4.4. Do you have insurance?

____

5. Perceptions and Responses

5.1. If you have been affected by floods, do you think you will be affected by floods again?

____

5.1.1. Why?

____

5.2. What are your greatest priorities in the event of a flood?

____

5.3. Are there times when you feel most scared of being affected by floods?

____

5.3.1. When/Where/Why?

____

____

5.4. What do you think causes the floods; is it just a lot of rain or are there other things that cause floods?

____

5.5. What do you think makes one flood worse than another does?

____

5.6. Who do you think is worst affected when a flood occurs?

____

5.7. Who or what do you think should be responsible for fixing flood damage?

____

5.8. Who or what do you think should be responsible for reducing flood risk?

____

5.9. Would you ever move/change jobs/use different route to avoid the risk of floods?

____

5.10. Has anyone else in the community done anything to make themselves less vulnerable to floods in the future?

____

5.10.1. What allowed them to do this?

____

6. Role of the municipality

6.1. Do you tell the municipality of damaged roads/pavements/drains?

____

6.2. Do you think that the municipality knows about your problems?

____

6.2.1. What are they doing/should they be doing about your flood problems?

____

6.2.2. What are they doing/should they be doing about the community's flood problems?

____

NOTES

____

____

____

Appendix III

Detailed Statistical Methodology and Investigation

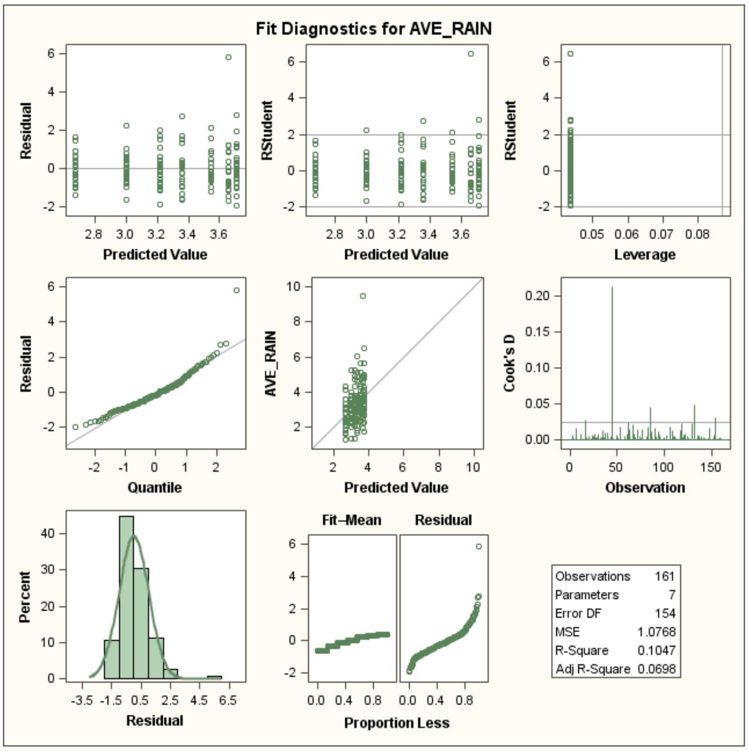

Figure 0.1: Goodness of Fit test for Average Rainfall (7 Stations, 1989-2004)

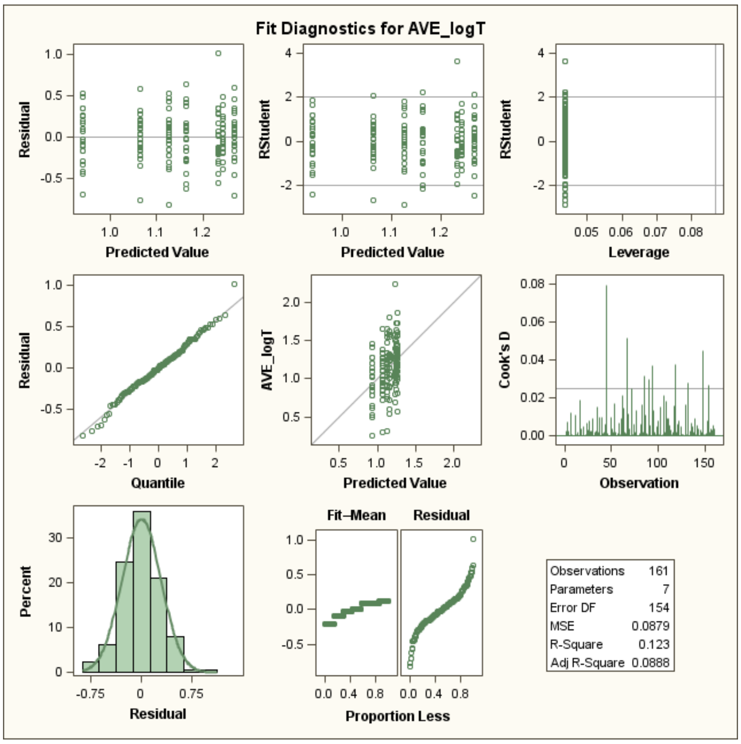

Figure 0.2: Goodness of Fit test for Log transformed Average Rainfall (7 Stations, 1989-2004)

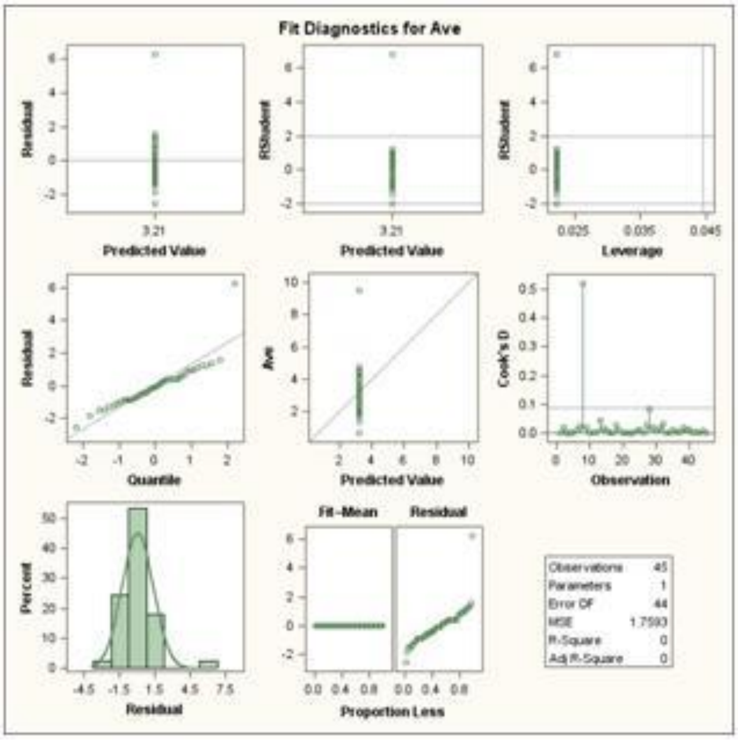

Figure 0.3: Goodness of Fit test for Average Rainfall (9 stations, 1998-2004)

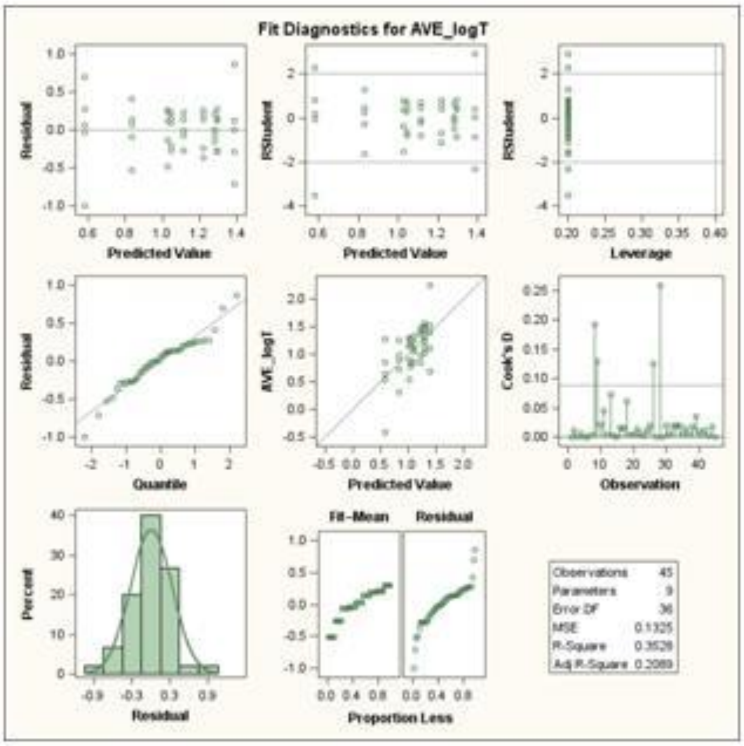

Figure 0.4: Goodness of Fit test for Log Transformed Average Rainfall (9 stations, 1998-2004)

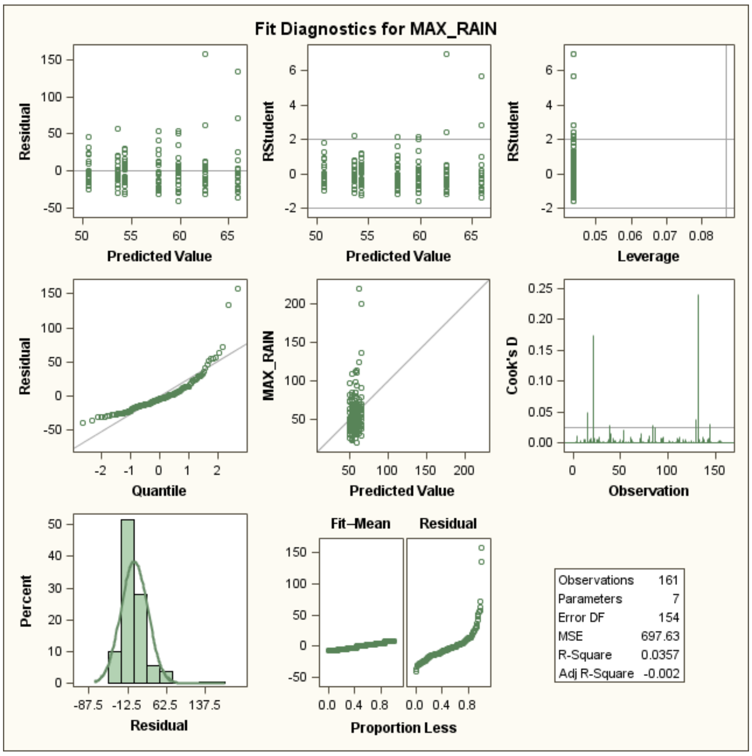

Figure 0.5: Goodness of Fit test for Maximum Rainfall (7 Stations, 1989-2004)

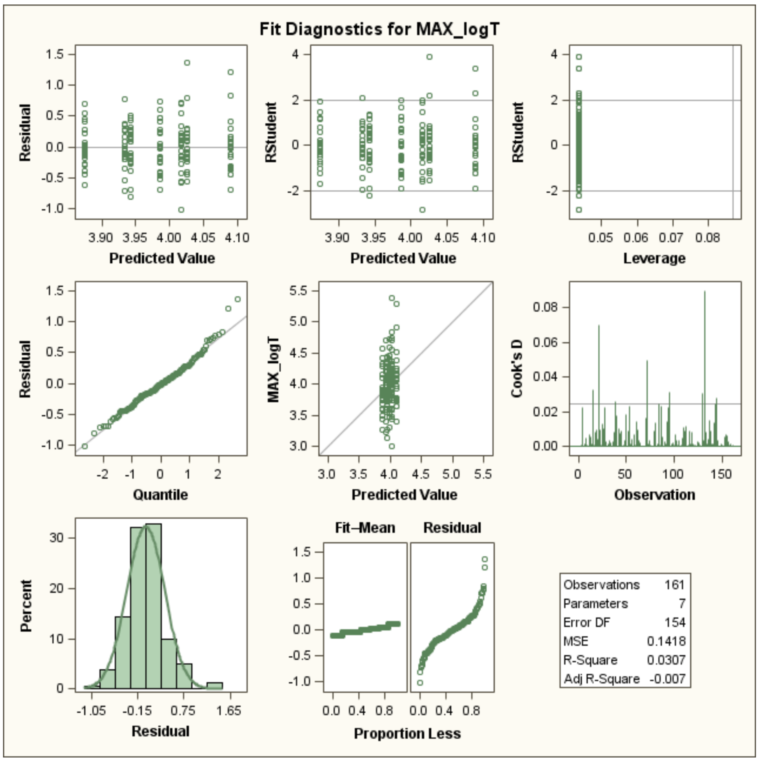

Figure 0.6: Goodness of Fit test for Log transformed Maximum Rainfall (7 Stations, 1989-2004)

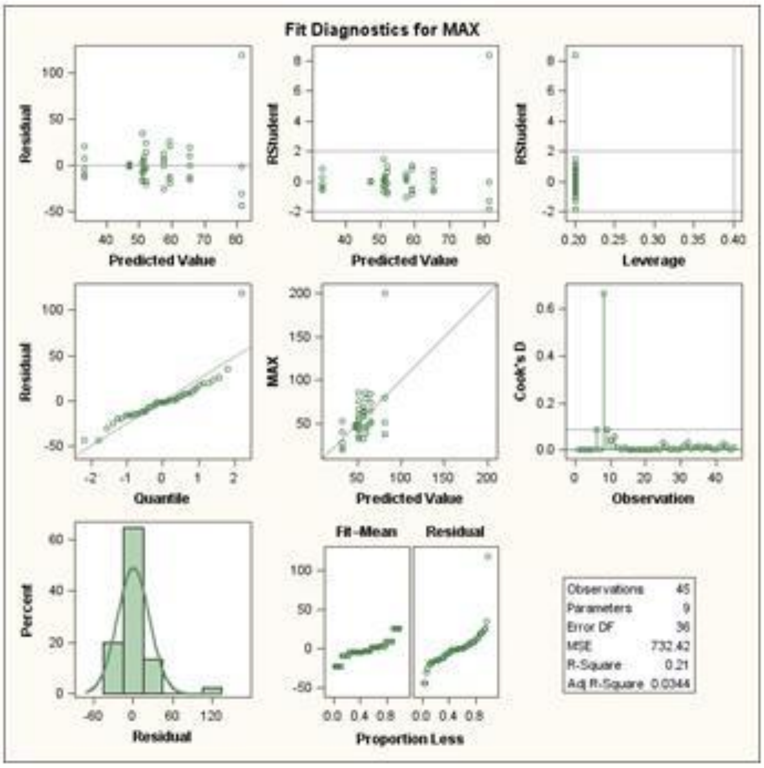

Figure 0.7: Goodness of Fit test for Maximum Rainfall (9 Stations, 1998-2004)

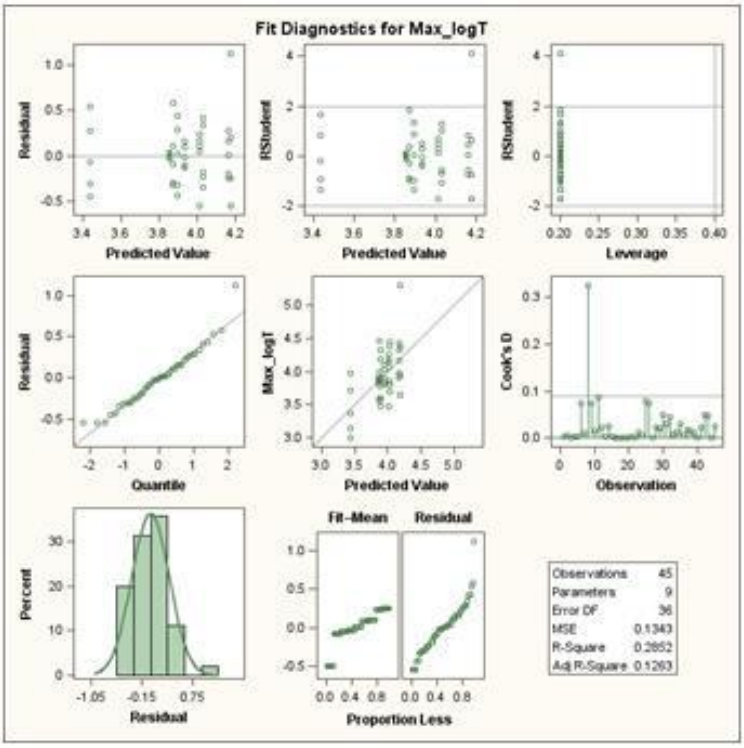

Figure 0.8: Goodness of Fit test for Log transformed Maximum Rainfall (9 Stations, 1998-2004)

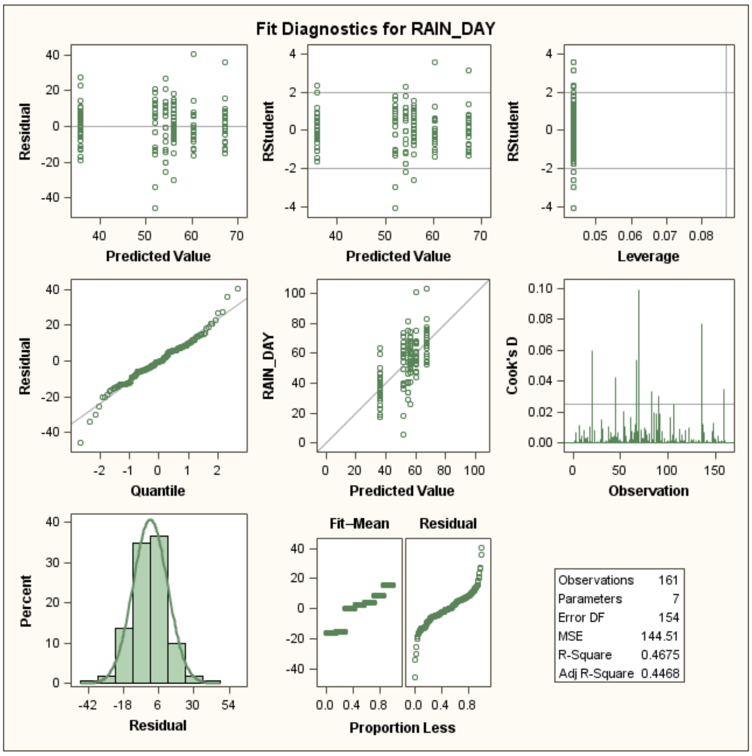

Figure 0.9: Goodness of Fit test for Rain Day (7 Stations, 1989-2004)