Adaptation of the community to the impact of drought on water availability in Bloemfontein, Free State Province, South Africa

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Declaration

I Majang Irene Mokgadi declare that the subject matter of experimental work entitled '**Adaptation of the community to the impact of drought on water availability in Bloemfontein, Free State Province'** was conducted at the Central University of Technology, Free State under the supervision of Dr Leana Esterhuizen.

I have used only the literature and other information sources that are cited in the work and listed in the bibliography at the end of this work. No part of this thesis has been submitted for any research degree or diploma to any other University/Institute.

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Majang Irene Mokgadi

2021

I certify that the above statement is correct

………………………………………

Dr Leana Esterhuizen

Acknowledgments

I would like to give God almighty the glory for seeing me through my studies and for providing me with all the strength as well as the wisdom to complete them.

I want to acknowledge my husband (Keoagile) and daughter (Ogorogile) for their continued support, encouragement, and understanding throughout my studies.

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Abstract

Background:

Drought is considered to be a life-threatening natural disaster that results in many uncertainties. Drought has been occurring globally in the past decades due to climate change. The reduction of the availability of water in the impacted regions is one of the features of drought. Many cities in South Africa lack drought impact adaptation plans to deal with the increased water demand. Therefore, it is important to conduct drought monitoring models for adaptation in cities that lack the capacity. The study aims to determine the impacts of the recent droughts on the availability of water and the adaptation of the community toward water restrictions.

To achieve this aim, five objectives were devised; namely: (i) To determine the impact of drought on the Bloemfontein area by assessing the annual meteorological data, rainfall levels as well as dam levels of Bloemfontein from 2016 to 2018, (ii) To assess the household water use behaviour of the Bloemfontein community members after the implementation of water restrictions, (iii) To evaluate the annual data on water use in Bloemfontein from 2016 to 2018, and (iv) To review the Disaster Risk Management Plan that is currently in place in the Mangaung Metropolitan Municipality governing the Bloemfontein area.

Methodology:

The study aimed to determine the impact of drought on citizens' lives, if and how they adapted to the consequences of drought, and whether the governing body's planning adequately provides for strategies to prevent/counter the impact of drought. Meteorological data (temperatures and rainfall) and data on dam levels were collected electronically for the years 2016 to 2018 – the period under study. Monthly water use data for that period in time also were collected electronically from the municipality concerned. Multiple-choice questions and close-ended questions were used in a questionnaire survey to gather data on community members' perceptions, actions, and behaviour during the drought. Quantitative data were analysed statistically, and qualitative data (close-ended questions) were categorised into themes, and which were then quantified for comparisons.

Results:

The study established that the average annual maximum temperatures of 2016, 2017, and 2018 were 26,4°C, 26,5°C, and 26,4°C were higher than the normal 23°C annual maximum

temperatures due to the impact of drought during the study period. The results also showed that the annual rainfall for the years 2016 at 451 mm, 2017 at 500,8 mm, and 2018 at 478 mm was less than the normal annual rainfall of 500-600 mm for the study area, which was indicative of a period of drought. The lack of awareness by the community members could have been one of the reasons why participants did not use more water-saving strategies continually to reduce their water use despite the implementation of the water restrictions. The study finally demonstrates that the Disaster Risk Management Plan of the study area is being implemented continuously as areas that are experiencing disasters including drought are identified and measures such as the implementation of general water restrictions, to ensure continuous water provision, and thus reducing the risk of disaster for the community members

Conclusions:

The study concluded that the temperatures, rainfall, and dam water levels of the Bloemfontein city have been impacted by drought during the study period. The study also established that the community of Bloemfontein needs to use more strategies to use water sparingly during the drought periods. The study has lastly shown that the implementation of the Disaster Risk Management Plan in Bloemfontein has been put in place and it is effective.

Keywords: drought, water use, drought impacts, adaptation to drought.

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Abbreviations

ANOVA- Analysis of variance

CC- Centre City

COP - Conference of Parties

CSIR- Council for Scientific Institution Research

CUT, FS- Central University of Technology, Free State

DEA – Department of Environmental Affairs

DWS- Department of Water and Sanitation

DWAF - Department of Water and Forestry

GDP- Gross Domestic Product

IDP- Integrated Development Plan

IPCC – Intergovernmental Panel on Climate Change

ISS- Institute for Security Studies

MMM- Mangaung Metropolitan Municipality

NDWS- National Department of Water and Sanitation

NDVI - Normalised Difference Vegetative Index

SASSA- South Africa Social Security Agency

SAWS- South African Weather Services

SPEI- Standardised Precipitation-Evapotranspiration Index

SPI- Standardized Precipitation Index

StatsSA- Statistics South Africa

UNFCCC - United Nations Framework Convention on Climate Change

WRC- Water Research Commission

Chapter 1

Introduction

1.1 INTRODUCTION

Extreme weather conditions such as droughts and the task of drinking water providers to provide safe and clean drinking water can be challenging (Dolnicar, Hurlimann; and Grün; 2012). This is because such water suppliers experience reduced water volumes during drought or even water supply depletion (Shiferaw *et al.*, 2014, Himayoun and Roshni, 2019). The demands from the consumers for water supply also have increased in recent years. The quantity of water is affected by weather resulting in floods which then influence human health in communities (Miyan, 2015).

The changes in climate variability, such as weather extremes resulting in drought, affect the environment which supplies us with water. When communities avoid measures to ensure effective care for their environment, satisfying water needs will become a challenge. The impacts of drought on water availability have been anticipated to increase during this century, which means the current health threats such as heat-related illnesses will increase which may result in some communities becoming extinct (Austin *et al.*, 2019).

In 2015, the countries within the United Nations Framework Convention on Climate Change (UNFCCC) agreed at the Conference of Parties (COP) 21 that was held in Paris, to combat the impacts of climate change, such as drought, from the year 2020 by dealing with finance, greenhouse-emissions moderation, and adaptation (Climate Change Report, 2016 and England *et al.*, 2018). Projections have been made about the distribution and variation in the frequency of droughts in different regions worldwide to enable governments and other parties concerned to curb the negative impacts of climate change (Reshmidevi *et al.*, 2018). Those who are concerned with the well-being of citizens can plan and prepare in good time to take measures to prevent drought disasters, the economy and health of the citizens can be taken care of better.

Since the awareness of droughts as a result of climate change has increased, research into droughts and water availability has also shown an upsurge over the past ten years (Reshmidevi *et al.*, 2018). These studies are aimed at improving the knowledge base of the community members to better inform their actions and decisions regarding water use and preservation (Aguiar *et al.*, 2018). Regional changes in dry-season water availability over recent decades have shown to be highly impacted by the recent climate change events (IPCC, 2013).

To strengthen the ability of a country to combat the impact of projected drought, capacity building should be enhanced (Haida *et al.*, 2019). The community members should be educated and trained on water-saving measures (Lutz *et al.*, 2014). Bottom-up approaches encourage people to become change agents by reducing their water footprints significantly and thus to be capable of adapting to the impacts of climate change such as drought (Haida *et al.*, 2019). This, in turn, ensures an approach that is participative and needs continuous evaluation.

Adapting to drought incidences may result in impacts that are positive to human health such as reduced heat-related illness such as Hypertension and water-washed diseases such as Trachoma due to adequate water supply management (Dolnicar, Hurlimann and Grün, 2012). The poverty experienced by humans can also be reduced when adaptation to drought impacts on water resources is enhanced (Ahmadalipour and Moradkhani, 2018). Human lives will be preserved as drought impacts on water availability are being mitigated (Haile and Tang, 2019).

According to the National Climate Change Adaptation Strategy of the Republic of South Africa, a water strategy is required to assist in creating operative governance and legislative procedures to incorporate climate change in development planning (DEA, 2017). Thus, The Department of Environmental Affairs is also in the process of developing a Climate Change Act which must still be passed through Parliament and has also introduced the Climate Change Bill to present a solid legal obligation for climate laws (DEA, 2019). Below, Figure 1.1, shows how water supply is divided and distributed in the different sectors in South Africa according to their needs or demands.

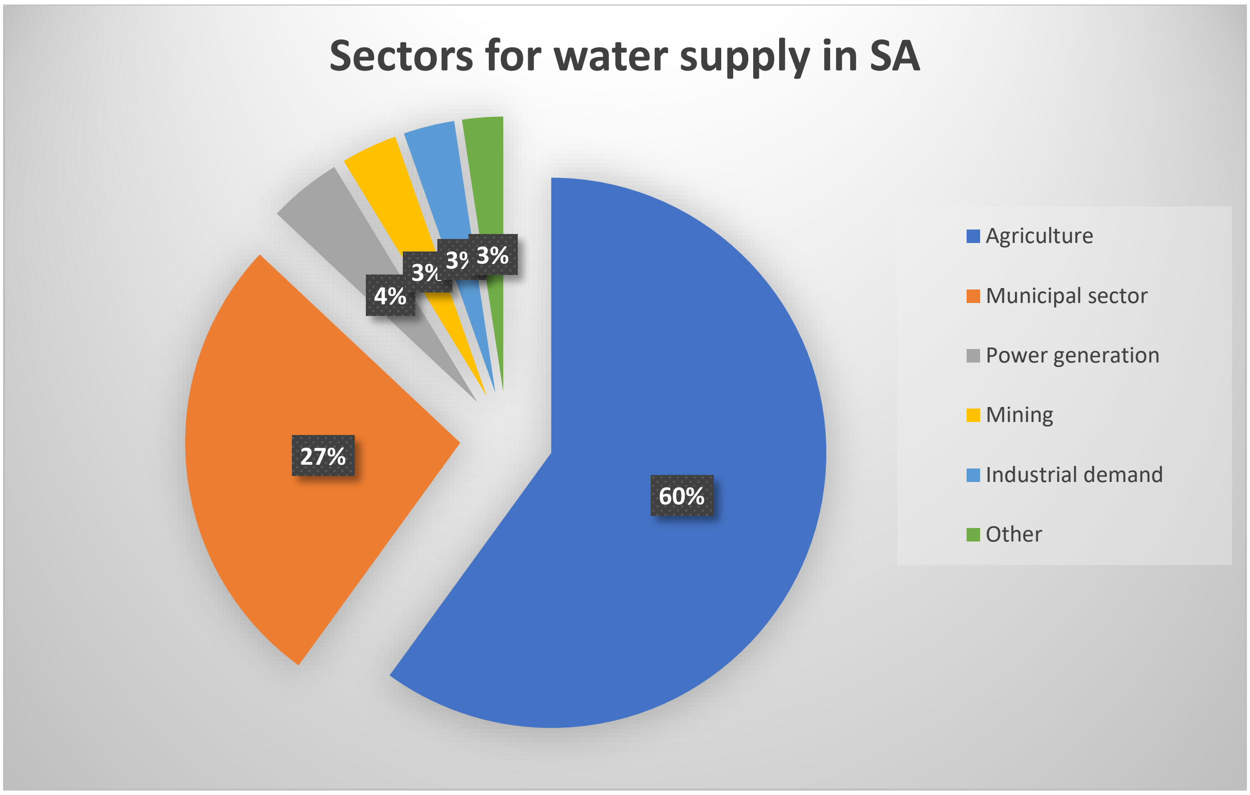

Figure 1.1: Water supply distribution in South Africa (WRC,2018).

The Mangaung Municipality in the Free State, South Africa, therefore, has developed mitigation strategies to determine the impact of drought as a result of climate change on water resources and the management thereof. The Mangaung Metropolitan Municipality appointed NM Envirotech Solution (Pty) Ltd to conduct a research project on climate change adaptation and mitigation in the community. This was a collective effort with significant contributions from many organisations and individuals. Strategy workshops were conducted and valuable input to processes was provided.

The study analysed the adaptation of the Bloemfontein community to the impact of drought on water availability following the implementation of the water restrictions. To this end, the study investigated how the community of Bloemfontein was responding to using water sparingly as embedded in the Municipality's Disaster Risk Management Plan.

1.2 RESEARCH PROBLEM

Drought is seen as a big limitation that is having an impact on the livelihoods of more than 2 billion people around the world who stay in dry areas (Solh and Ginkel, 2014).

The drought impacts include the ecosystems globally but may differ from region to region (Miyan, 2015). Thus, countries in Africa are being faced with an urgent need to reduce their vulnerability to climate changes (Shiferaw *et al.*, 2014). Drought is described as a temporary reduction in water availability below the usual quantities (Lund *et al.*, 2018). According to Muller and Cross (2014), epidemics, malnutrition due to food insecurity, and displacement of communities may result from drought.

Drought has been shown to be an environmental concern, with many challenges for development. Climate change is also a major global challenge of the 21st century and needs collective action. Authors, Kiem and Austin (2013), stressed the need for a robust adaptation to the impacts of drought. At all government levels, more preparedness to respond and mitigation to drought is globally recognized as a need (Dilling *et al.*, 2019).

Drought and a massive El Nino occurrence during 2015 and 2016 severely affected South Africa (Baudoin *et al.*, 2017). This was declared the worst drought in more than two decades (Baudoin *et al.*, 2017). The drought resulted in a decrease in water availability and water harvest or crops. Water restrictions were then implemented in many cities around South Africa. Community members in the local areas, as well as the national economy, are affected by the impact of drought. Increased unemployment due to pressures mounting on the system of the agro-economics of the nation is one of the consequences of droughts.

Because of its predicted low vulnerability and low adaptive capacity, the African continent has been identified as the most vulnerable continent to climate change impacts (Kusangaya *et al.*, 2014). The water resources have been seen to be the most affected by the impacts of drought. Important goals for cities should be how to increase service or maintain water efficiency as well as to control risk management regarding water resources (Jeong and Park, 2020). The uncertainty of climate change impacts, knowledge of the individuals, and the lack of finances for resources can badly affect the health adaptation of the public (Austin *et al.*, 2019).

With the frequent drought events experienced over the past three decades, its impacts cannot go unnoticed. The government has a very important role to play in the development of measures to counter this impact and the implementation thereof.

Therefore, this study investigates the response of the Bloemfontein community to using water sparingly following the implementation of water restrictions by the Mangaung Metropolitan Municipality. This study strived to inform future drought adaptation strategies and also to contribute to the general knowledge regarding the effects of water restrictions.

1.3 SIGNIFICANCE OF THE STUDY

Over the years, various regions in the world have experienced drought. It is considered an extremely rare event that has significant impacts on humans and ecosystems (Botai et al, 2016). Drought has become the subject of many studies because of its impact on society at large (Haile and Tang, 2019).

Severe drought has a significant impact on the water availability and growth of various organisms. Although the effects of drought have been studied, more research is needed on how to adapt to drought (Kiem and Austin, 2013). Local and global communities, human lives, and ecosystems functioning around the world are impacted by drought (Himayoun and Roshni, 2019).

The event of drought can unfortunately not be significantly predicted thus the preparation for and adaptation to drought needs to be in place. The success of sustaining water sources of cities internationally has always depended on active adaptation (Lund *et al.*, 2018). To facilitate the implementation of mitigation and adaptation measures for climate change, annual water availability and resources information must be obtained and evaluated (Faramarzi *et al.*, 2013).
South Africa has been experiencing droughts frequently over the past years due to it being located in the southern African region (Baudoin *et al,* 2017). Drought was viewed as the most relevant hazard in South Africa (Walz *et al.*, 2018). Thus, in South Africa it must be a high priority is to understand disaster risk to apply proactive risk management and risk reduction.

In 2015 the Mangaung Metropolitan Municipality announced the implementation of water restrictions to secure a continuous supply of water as set out in Government Gazette No. 39679 of 2016 and prescribed by the National Department of Water and Sanitation (NDWS) (Mangaung, 2015).

1.4 RESEARCH AIM, QUESTIONS, and OBJECTIVES

1.4.1 Research aim

This study aimed to determine the impacts of the recent droughts on the availability of water and the adaptation of the Bloemfontein community toward water restrictions.

1.4.2 Research questions

Following the purpose of the research outlined in this study, the following research questions are presented:

1.4.2.1 Is the Bloemfontein community adapting to the implementation of water restrictions by using water sparingly?

1.4.2.2 Is the Municipality's Disaster Risk Management Plan being effectively implemented in Bloemfontein city?

1.4.3 Research objectives

To answer the research questions and achieve the aim of the study, the research was designed to attain the following objectives:

- To determine the impact of drought on the Bloemfontein area by assessing the annual meteorological data, and rainfall levels, as well as dam levels of Bloemfontein from 2016 to 2018,
- To assess the household water, use behaviour of the Bloemfontein community members after the implementation of water restrictions,
- To evaluate the annual data on water usage in Bloemfontein from 2016 to 2018,
- To evaluate the implementation of the Disaster Risk Management Plan that is currently in place in the Mangaung Metropolitan Municipality governing the Bloemfontein area.

1.5 SCOPE AND LIMITATIONS OF THE STUDY

The discipline and science of drought are intense and affect many areas of the environment. To reduce the scope of the study, the focus would be on the impact of drought on water availability in the city of Bloemfontein and the adaptation thereof of the households in the community to the effects of drought. This was to limit the scope of the study without intentionally discrediting the significance of other drought impacts.

Many of the other impacts of drought are briefly discussed in the study report. However, the different drought impacts fall under various thematic areas. Thus, the study looked into the impact of drought on the availability of water. Considering that the city of Bloemfontein has been declared a drought-stricken area during the 2015/2016 hydrological year, ensured the availability of relevant literature from a spectrum that is diverse.

The study collected meteorological data on daily maximum and minimum temperatures, as well as the daily rainfall levels. These were obtained electronically from the South African Weather Services (SAWS) for the years 2016 to 2018 for validation of the study. Data on monthly dam levels were collected electronically from the Department of Water and Sanitation Free State, Bloemfontein for the years 2016 to 2018.

Data on monthly water use also were collected electronically from the Mangaung Metropolitan Municipality-Water division for the years 2016 to 2018 for the validation of the study. In addition, a survey was conducted among respondents who were purposively selected. Due to financial and time constraints, the number of respondents was limited which may have an impact on the generalization of the results. The evaluation of the Mangaung Metropolitan Municipality Disaster Risk Management Plan mostly included its key objectives and measures taken, which resulted in excluding the Municipal strategies that would have enriched the study.

1.6 DISSERTATION LAY-OUT

1.6.1 Chapter 1: Introduction

In this chapter, a clear and concise explanation of the problem of drought is provided, after which the significance of the study and the aims, the research questions, the objectives of the study, and the scope and limitations of the study are described followed by the lay-out of the dissertation which is sketched to provide an overview of the study.

1.6.2 Chapter 2: Literature review

In this chapter, a theoretical in-depth view of the drought experienced would be presented, including its history and background. The different types of droughts that occur worldwide are described. Furthermore, the chapter is devoted to an explanation of the impact of drought brought on by climate change on the water resources, the environment, and the economies of various countries, as well as continents. The chapter then also focuses on the different drought management strategies introduced and implemented utilizing various strategies, as well as adaptation models used to combat drought worldwide. Water use during water restrictions was assessed by studying the behaviour/ actions/ beliefs of the community members in water-wise cities.

1.6.3 Chapter 3: Methodology

In this chapter, a description of the methods that were used to conduct the study is given. The focus, therefore, is on the study area and the extensive study design. Using a quantitative approach, meteorological data were collected to obtain information on daily weather conditions, maximum and minimum temperatures in the Bloemfontein area, annual rainfall levels, and water levels of the Rustfontein, Welbedacht, and Knellpoort dams in the Bloemfontein area. Questionnaires were used to interview Mangaung community members on their knowledge about drought impacts and water-use behaviour.

Water-use data of the Bloemfontein community members for the years 2016 to 2018 were gathered to determine the level of water use, and finally, the current adaptation plans to droughts by reviewing the Disaster Risk Management Plan of the Mangaung Metropolitan Municipality. The data obtained were used to evaluate the water availability, as well as the community's perceptions of drought, and to determine if there were any changes in water availability during the past three-year cycle, that is, from 2016 to 2018, and to compare the dam levels to the meteorological data. Lastly, the water-use data were compared to the data on the available water to determine if the Bloemfontein residents adhered to the restrictions and if water was used sparingly.

1.6.4 Chapter 4: Data Results

This chapter offers a summary of findings on the impact of the drought experienced, the daily maximum and minimum temperature levels in the city, daily maximum rainfall levels in the city, and the net capacity of the dam levels supplying water to the city. These findings are based on data that were obtained over the three years, 2016, 2017, and 2018. The collected data were processed and analysed in various combinations for accuracy. An assessment of the daily water use behaviour was conducted based on the data obtained from the local municipality since the start of the implementation of water restrictions due to the drought and infrequent rains experienced, that is, from 2016 to 2018.

1.6.5 Chapter 5: Discussion

In this chapter, the findings are interpreted, and the statistical processes conducted in the study are discussed. The focus of the findings is on whether the measures introduced have been adhered to or ignored by the community members living in the study area, to ensure continuous water supply to comply with the regulations as contained in the Government Gazette No. 37421 of March 2014 of the National Department of Water and Sanitation (NDWS).

1.6.6 Chapter 6: Recommendations and conclusion

In this chapter, possible limitations of the study were identified, reflecting on the course the study took and its findings, and recommendations are made based on the findings of the study. A summary of all the findings with further recommendations concludes this thesis.

1.7 CONCLUSION

The impact of drought on water availability is resulting in poor human health in many communities. South Africa has implemented water restrictions as a measure to control water use to prevent water shortages during drought. This study will help to guide future drought adaptation measures as well as general information about the consequences of water restrictions. The study focused on the impact of drought on water availability in the city of Bloemfontein and the adaptation thereof of the households in the community to the effects of drought to limit the study scope.

Chapter 2

Literature Review

2.1 INTRODUCTION

Drought has been known to cause severe water shortages. According to Mera (2018), when the precipitation in all seasons is below the long-term or normal average, drought occurs. Over the past 30 years droughts frequently have occurred all over the world (Solh and Ginkel, 2014). Drought can be defined as a long or extended period with unusually low rainfall, or the prolonged lack or absence of rain which affects the living and growing conditions of human, animal, and plant life (Shah, Bharadiya and Manekar, 2015).

The timescale of drought is determined by the time interval from the start of a period of water scarcity and the impact on the assets of the environment (Botai *et al*, 2016). Haile and Tang (2019) explicated that most continents have experienced frequent droughts lately. Moreover, Solh and Van Ginkel (2014) alluded to it as a climactic event that cannot be prevented. This natural disaster starts unobserved and develops slowly with impacts that are not immediately observed, but which impair properties and lives seriously (Muller and Cross, 2014; Miyan, 2015).

A study by Botai (2016) asserted that droughts have been linked to many epidemics such as malnutrition due to food shortages and a high risk of communicable diseases from lack of water supply. Global information shows that drought is a prevailing and routine feature of the Australian climate (Kiem and Austin, 2013). Furthermore, South Asian regions are known to be prone to regular droughts (Miyan, 2015). Droughts have several features; one notable feature is the reduction of water availability over an area in a particular region (Muller and Cross, 2014). Considering the number of people found to be affected, drought is ranked high among all-natural disasters as a damaging and costly climate extreme due to its spatial extent (Ahmadalipour and Moradkhani, 2018; and Dilling *et al.*, 2019). In addition, more than half of the deaths in the world that are related to natural hazards are caused by drought events (Dilling *et al.*, 2019). It can be concluded that droughts are challenging societies and the environment in the whole world (Haile and Tang, 2019).

The primary challenge in many developing nations is the issue of sustainable development. Water scarcity management requires intelligent systems to have a meaningful impact. The migration and global population dynamics in urban centres threaten the sustainability of urban water supplies in the face of droughts (Dilling *et al.*, 2019). One of the devastating effects of droughts, according to Olmstead (2014), is that it has a long-term impact on the availability of water resources in many regions globally.

2.2 THE INFLUENCE OF CLIMATIC VARIATION ON DROUGHTS

The impact of climatic variation experienced worldwide manifests in occurrences of severe droughts with pro-longed changes in precipitation and temperature. In France, climate change has an impact on the important ecosystem services that are being supplied by the mountain social-ecological systems (Lavorel *et al.*, 2019). However, this has resulted in an extensive increase in the adaptation of planning for and research into the impacts of climate change (Aguiar *et al.*, 2018).

Climate change has affected the water sector significantly (IPCC, 2013). In Africa, it was shown that in terms of the anticipated impacts of climate change, the wet areas experience fewer uncertainties than the dry areas (Faramarzi *et al.*, 2013). This indicated that regions' climate change scenarios projected the same direction of changes in water resources, increasing the occurrences of drought and their duration in the future. Drainage will be reduced by 17% by the year 2050 when the average rainfall of sub-Saharan Africa decreases by 10% (Misra, 2014). It was found that community management of water systems use is also influenced by seasons, causing them to receive less support during natural disasters and thus rendering them unable to carry out maintenance on as well as operation of the systems (Kelly *et al.*, 2018). South Africa has to face the reality that it is prone to droughts as it is located in the southern African region (Baudoin *et al.*, 2017).

In low-income areas, adapting to climate change is a multi-faceted challenge, as factors such as a lack of impact models, climate data, and sufficient financing to support adaptation hamper efforts (Adenle *et al.*, 2017 and Shezi *et al.*, 2019). Therefore, institutionally designed propositions that have been adjusted are important when facilitating the learning process of dealing with uncertainties related to climate change impacts (Huntjens *et al.*, 2012). An example is that for low-cost household water treatment to be effective, larger tanks with a large roof size are recommended for use during seasons most affected by water insecurity and savings (Kisakye and Bruggen, 2018). It is also suggested that the engagement of community members should take place regularly during water committee training (Kelly *et al.*, 2018).

2.3 WATER SCARCITY

Water demands for regular use have exceeded the amount of available fresh water in Cyprus and many other places (Papadaskalopoulou *et al.*, 2015). It has also been proven that even though the adaptation measures have been enhanced to assist in combating climate change effects on water resources as well as the availability of water, globally general vulnerability is still high when droughts are experienced globally. It has been demonstrated that even though there is an increase in the adaptation measures to assist in combating climate change effects on the availability of water, the overall vulnerability is still high as the demands in certain areas are still not met during drought seasons (Papadaskalopoulou *et al.*, 2015 and Thomas *et al.*, 2019).

An evaluation of two drought-stricken areas in India revealed that there was a massive reduction in the groundwater boost and runoff share (Reshmidevi *et al.*, 2018), resulting in water stress being aggravated. In the USA (Mansur and Olmstead, 2012) investigated the implications of typical drought policies on the welfare of communities, where local governments mandated 'command-and-control approaches such as prohibiting certain water uses, such as outdoor watering. Their findings suggest that prevailing restrictions are aimed at water uses that the majority of households, themselves, are willing to do without. However, they also found that restricting water use has major financial implications, primarily due to household diversity, especially when it has to do with willingness and ability to pay for scarce water.

South Africa does not have enough fresh water resources to meet its population's demands (DEA, 2017). It is seen as the 30^{th} water-scarce country globally (DEA, 2012). Through operational water resources planning such as equal water allocation for beneficial use and active service delivery, the country greatly aims at restoring its water resources with support from society and a tangible economy regardless of the challenges (DEA, 2012).

This, however, could not be realized, mostly due to a failing economy and the total collapse of services. For issues concerning resource quality and pollution, social development and service quality, as well as water security, South Africa needs to adopt a smart and advanced approach to water management to be able to deal with these challenges. Approaches must focus mainly on prioritizing active use and demand management, re-use, and protecting the water resources for sustainable management (DWS, 2019).

For the water sector to be able to address these water challenges, technology development is needed. This technology should be appropriate to the economic, cultural, and environment, as well as technical innovation that is greatly stimulated. However, the focus should be on rural areas with low-income backgrounds because this is where a great deal of funding is used for operational services (WRC, 2018). The management of the Department of Water and Forestry (DWF) held a conference with engineering, institutional and social consultants to discuss the sustainability and appropriate technologies of water services delivery (DWS, 2016). At this conference, the importance of technology was discussed, and it was emphasized that technology should be easily comprehensible and physically manageable and within the ability of the people who are responsible for the maintenance and operation of water treatment plants.

Furthermore, it was suggested that the equipment and spare parts of the new technology should be easily available in South Africa and the level at which services are to be delivered should be desirable and culturally suitable for the end-users. Lastly, it was discussed that the appropriate technology should not be a low-cost option (DWS, 2012).

Water institutions such as the Department of Water and Sanitation (DWS) and the Water Research Commission (WRC) are responsible for running awareness campaigns, so that water users and the water institutions can be knowledgeable on water-related climate change issues to be able to handle them. Stakeholders should also be consulted by the Department of Water Affairs about suitable strategies for climate change response. Poor communities have difficulty coping with the strategies, thus there is a need to build on them to be able to reduce their vulnerability and encourage resilience (DWS, 2013).

With the assistance of an ongoing Consumers Education and Awareness Programme in public meetings, school awareness programmes, and coverage in the media, communities are adapting to water restrictions. Assessments, however, are still required to enable governing bodies to determine and remedy the impacts of drought.

2.4 TYPES OF DROUGHTS

Droughts can be classified into different types from many viewpoints. The indicators of drought are needed to distinguish the changing nature of a certain drought type (Haile and Tang, 2019). Meteorological drought is defined as a condition where the annual rainfall over an area is less than the normal rainfall for a prolonged period, that is, a month, season, or year (Diasso and Abiodun, 2018). Meteorological drought occurs first, and it leads to the occurrence of other types of drought (Himayoun and Roshni, 2019).

Meteorological drought characteristics have been identified by the use of various developed indices in the past decade (Zuo *et al.*, 2019). Lack of precipitation and how factors such as temperature and wind influence the amount of moisture decide meteorological drought. It is expressed in terms of a region's average conditions (Diasso and Abiodun, 2018; Himayoun and Roshni, 2019; Wickham *et al.*, 2019; Zhang *et al.*, 2019). Since precipitation varies greatly from region to region, meteorological drought is region-specific. The result of high evaporation rates caused by the hot temperatures leads to meteorological drought (Spinoni *et al.*, 2019). A variety of studies on drought types needs to be conducted as shown in Table 2.1.

Table 2.1. Summary of drought types and description

Drought Type	Description	References
Meteorological	Meteorological drought is determined by lack of precipitation and how conditions such as temperature and wind affect the amount of moisture. It is expressed concerning the average conditions for a region. Meteorological drought is region-specific since precipitation is highly variable from region to region.	(Diasso and Abiodun, 2018; Bae *et al.*, 2019; Himayoun and Roshni, 2019; Thomas *et al.*, 2019; Wickham *et al.*, 2019; Zhang *et al.*, 2019)
Agricultural	This type of drought links the characteristics of meteorological drought to agriculture or landscapes. Agricultural drought focuses on precipitation shortages, evaporative demand, and soil moisture deficits. This type of drought is also dependent upon plant type, stage growth, and soil properties.	(Miyan, 2015; Wan *et al.*, 2018; Wickham *et al.*, 2019)
Hydrological	Hydrological drought is associated with the effects of rain and snow shortfalls on streamflow, reservoir and lake levels, and groundwater. Because it takes longer for precipitation deficiencies to show up in other components of the hydrological system, this type of drought can be out of phase with other types of drought.	(Bae *et al.*, 2019; Forootan *et al.*, 2019; Wickham *et al.*, 2019)
Socio-economic	Socio-economic drought includes the impact of drought on the economy related to supply and demand. While people typically think of agricultural loss, drought can also affect hydroelectric energy generation, ethanol production, and numerous other items. In addition, drought impacts tourism, public health, infrastructure, and many other components of society.	(Wan *et al.*, 2018; Haile and Tang, 2019; Wickham *et al.*, 2019; Salvador *et al.*, 2020)
Ecological	This type of drought results from prolonged and widespread deficits in naturally available water supplies that create multiple stresses across ecosystems. Also, this type of drought emphasizes the link between people and nature in the context of drought. It captures the environmental consequences of drought and its feedback into natural and human systems.	(Wang *et al.*, 2017; Wang and Yuan, 2018; Sankaran, 2019; Wickham *et al.*, 2019)

Agricultural drought is a weather condition that mostly affects food production, and is the result of inadequate rainfall (Miyan, 2015 and Wickham *et al.*, 2019). A drought of one to six months may result in agricultural impacts. This type of drought has environmental effects, such as insufficient soil moisture for crops, which are detrimental for the agricultural sector. It impacts hay and nursery production and may cause damage to athletic and other sports fields, parks, and lawns. It may ensue in new patterns of diseases and pests, livestock loss, and a lack of planting material and seeds (Zuo *et al.*, 2019). The characteristics of meteorological drought are linked to agriculture or landscapes in this form of drought. Drought in agriculture is defined by a lack of precipitation, evaporative demand, and soil moisture deficits. The plant type, stage of development, and soil properties all play a role in this type of drought (Miyan, 2015; Wickham *et al.*, 2019). Different techniques are used for measuring the effects of droughts on vegetation, of which the most common is quantifying vegetative drought using a Normalised Difference Vegetative Index (NDVI) (Haile and Tang, 2019).

Some researchers have noted the limited studies on hydrological droughts in East Africa (Haile and Tang, 2019). Hydrological drought refers to a drought linked to the effects of or resulting from periods of precipitation shortage on water supply. The impact of rain and snow shortages on streamflow, river and lake levels, and groundwater are all linked to hydrological drought. This form of drought can be out of step with other forms of drought because precipitation shortages take longer to show up in other components of the hydrological system (Bae *et al.*; 2019; Wickham *et al.,* 2019). Typically, a drought of a 12 to 24-month period applies to hydrological impacts (Bae *et al.*, 2019). One of its features is a decrease in groundwater levels and flow streams that are very low resulting from low evapotranspiration in the absence of rainfall (Miyan, 2015). In addition, it also causes severe hydrological unevenness in the affected area.

Socio-economic droughts are the result of precipitation conditions having a negative effect on available supplies, and resulting in industry and suppliers not being able to meet the demands for goods (Wan *et al.*, 2018). A drought that lasts for one to two years has socioeconomic impacts (Haile and Tang, 2019), for example, commercial shipping can be halted when basin water levels are lowered due to the drought experienced. The effect of drought on the economy in terms of supply and demand is referred to as socioeconomic drought. Although most people think of drought as affecting agriculture, it can also affect hydroelectric energy generation, ethanol production, and a variety of other activities (Wickham *et al.*, 2019). Drought also has an effect on tourism, public health, infrastructure, and a variety of other aspects of society (Haile and Tang, 2019; Wickham *et al.*, 2019). However, the main cause of socioeconomic instabilities in African countries is drought resulting in food insecurity situations. Miyan (2015) emphasizes that the monitoring and diagnosis of drought and its effects are important because drought's relation with food and nutrient security is intimate.

Ecological droughts are caused by long-term and widespread shortages of naturally available water, putting several habitats under stress. In addition, in the sense of drought, this form of drought emphasizes the connection between people and nature (Wang *et al.*, 2017 and Wickham *et al.*, 2019). It captured the effects of drought on the ecosystem as well as the feedback it has on natural and human systems.

During the 2015/2016 hydrological year, the South African government declared the Free State Province a drought disaster area (Botai; 2016; Dlamini, Zwane and Phadul, 2016). The immediate consequence of drought and the ensuing lack of rain and soaring temperatures is a reduction in crop production, due to inadequate and poorly distributed rainfall. Additionally, livestock production is impacted due to low rainfall, which causes poor pasture growth and may also lead to a decline in fodder supplies from crop residues. Droughts have serious developmental, environmental, economic, and social consequences, irrespective of the types of drought (Miyan, 2015).

2.5 IMPACT OF DROUGHT ON WATER RESOURCES

Water resources are the centre of the anticipated climate change impacts within the matrix of climate change (Kusangaya *et al.*, 2014). Water is a substance that can be found in a solid, liquid, and gas state. It is composed of hydrogen and oxygen chemical elements. However, the chemical and physical properties of water are more complex. Ensuring human health risks of climate change are the result of the decrease and quality of the supply of safe drinking water which is becoming a global problem (Boholm and Prutzer, 2017).

The usefulness of water as a solvent is important to all living organisms. Water is one of the most essential and plentiful compounds in the world. Moreover, water has been given less attention even though the number of studies on urban metabolism such as water uses analyses has increased (Jeong and Park, 2020). At room temperature, water is an odourless and tasteless liquid but an absolute necessity for all forms of life. Water affordability is of vital importance, and ensuring household water security is an achievement strived for globally (Stoler *et al.*, 2019). Water has a blue colour at a red wavelength resulting from the light absorbed, even though it appears to be colourless in small quantities.

The supply of water is affected by high temperatures and droughts. The importance of water cannot be overstated. Water has played a religious role for a long time in history because of its prominence. Biologically, aqueous solutions such as digestive juices and blood are essential to human health. Furthermore, water is vital for recreation, habitat, and transportation for both animals and plants because it maintains as a liquid on the earth's surface (Boholm and Prutzer, 2017). Dolnicar, Hurlimann and Grün (2012), anticipated that the reliability of water supplies will decrease because of the reduced rainfall.

On the surface of the earth, water is found mostly in the ocean, with seawater having dissolved salts in large quantities. The rest is found in glaciers, ice caps, rivers, groundwater, and freshwater lakes. Although water is essential for living creatures and vegetation, outbreaks of waterborne diseases and risks are reported increasingly. The chemical and physical properties of water are very complicated, even though its molecules are quite common in structure (H_20). Water has a boiling point of 100^0 C and a melting point of 0^0 C which is much higher than those of analogous compounds (Boholm and Prutzer, 2017). The recycling and purification of water have become increasingly crucial as the earth's population continues to grow and the need for water increases. Optimal use and internal recycling have become important goals for cities regarding their water efficiency and water resources (Jeong and Park, 2020). Water is a most important resource, and the authorities have to

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continually watch out for water wastage as this will result in water shortages. The shortage of water is closely related to the occurrence of droughts. The frequent occurrence of droughts has led to water scarcity that affects the level of groundwater severely (Thomas *et al.*, 2019).

Understanding drought conditions help deal with future drought episodes more successfully. Water resources have been badly damaged by frequent drought events that have not been quantified and assessed, and which therefore are not fully comprehended or misunderstood (Sankaran, 2019). The impact of drought on water resources mostly is a serious deterioration of water quality (Haile and Tang, 2019). The results of drought on water supply are that tailwater consumers end up having insufficient water and/or bad-tasting and oftentimes unhealthy water due to the increase of aquatic plants, leading to higher degrees of treatment being required, as well as interruptions in the water supply to non-essential users (Martins *et al.*, 2019).

For the effective and environmentally sustainable management of water supplies by municipalities, the conservation of water resources is an essential and critical service requirement (Dolnicar, Hurlimann and Grün, 2012). The aquatic systems such as lakes, ponds, rivers, streams, springs, bogs, and wetlands have also been impacted largely by drought (Haile and Tang, 2019). This has resulted in the loss of habitat in many of these water bodies. By hampering the aquatic biota, drought affects both flowing and standing water. The reduction of streamflow in general results due to drought occurrences. It is thus important to monitor and manage lakes, rivers, and dam resources to detect early drought warnings.

Figure 2.1 shows the number of published studies conducted from the year 2016 to 2020 on the Impact of drought on water availability. In 2016 around 178 articles on the consequences of drought on water availability were published, and in 2019, 254 similar studies were reported in articles that were published. This shows the amount of research invested globally in the impact of droughts over the years.

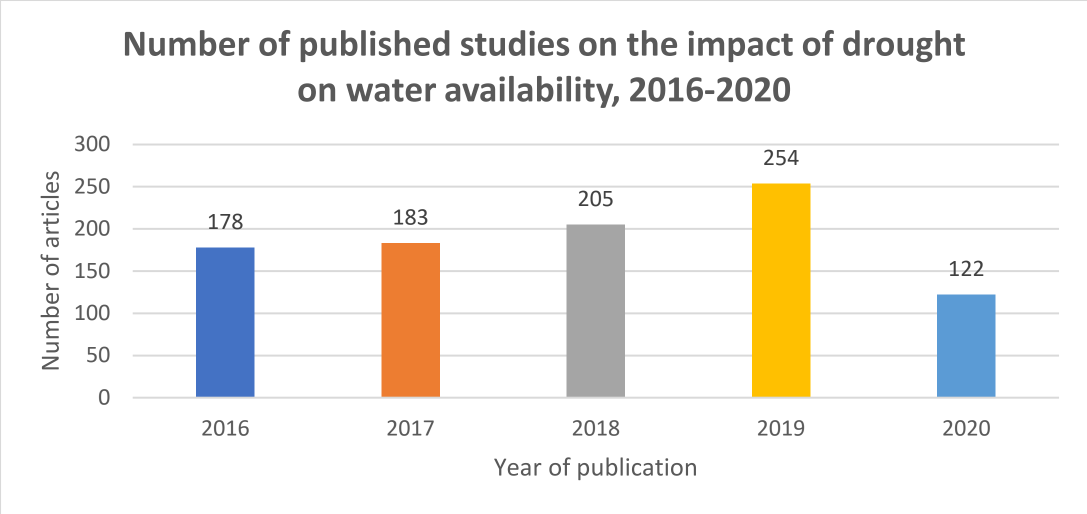

Figure 2.1: Number of published Studies on the impact of drought on water availability between 2016 and 2020.

2.6 IMPACT OF DROUGHT ON THE ENVIRONMENT

Environment refers to the land, water, or air on or in which humans live. It is described as the collective of surroundings of conditions or things that can influence an individual's life. It also can be the complex of biotic, physical, and chemical factors like soil and living things that affect an ecological community. More than other natural hazards, the impact of drought can be experienced across great geographic areas (Wickham *et al.*, 2019). Drought affects the environment and society, as humans, animals, and plants are dependent on water to survive.

Furthermore, drought also reduces groundwater levels and freshwater availability, which may have long-lasting effects on the environment (Diasso and Abiodun, 2018). Such effects are profoundly felt in some regions in Africa, like in South Africa, where habitats are greatly damaged and food supplies are derogated, which at times may be irreversible or, on the more positive side, at other times only may be temporary (Baudoin *et al.*, 2017).

Drought has a significantly negative impact on human safety and health. It can result in many living organisms experiencing great incidences of heat strokes and death (Sankaran, 2019). Where there are severe water shortages, conflicts may arise amongst communities competing for water resources. Drought even causes some of the living organisms to have fewer recreational activities like swimming and fishing.

A great increase in wildlife risk can also be provided by drought conditions. Due to the lack of precipitation, an increase of diseases and insect infestations occurs, and trees and plants wither and die because of drought, and eventually, this results in them becoming fuel for wildfires (Bae *et al.*, 2019). The longer the drought conditions continue, the more intense the wildfires become resulting in habitats, crops, and neighbourhoods being destroyed severely.

Droughts often do not have the same dramatic effects and immediate visuals displayed. The severity of the impact of the drought will differ depending on its location, duration, and the time of year at which it occurs. Shah *et al*. (2015) proclaimed that drought has a significant impact on social, environmental, economic, agricultural, and hydrological systems. Miyan (2015) asserts that drought can cause moisture deficits with serious effects on humans, animals, and vegetation over a large area. Spinoni *et al*., (2019)'s study found that ineffective and inefficiently executed land management practices result in irreversible soil and land degradation.

2.7 ECONOMIC IMPACTS OF DROUGHT

The economy is the state of a region or a country about the supply of money and rendering, and consumption of services and goods. It can also be referred to as the proper, effective, and efficient management of resources (Ahmadalipour and Moradkhani, 2018). A poor economy has long-lasting effects on any nation. The impact of drought in South Africa during 2015-2016 has resulted in a great reduction in the harvesting of crops (Baudoin *et al.*, 2017). The economy can hardly afford the movement of these services and goods into many different entities and companies which sell and buy them. Martins *et al,,* (2019) report that the repercussions of a drought on a reservoir in Brazil resulted in severe socio-economic strain in the community due to the implications on surface water change and turbidity.

The main purpose of the economy is to control the production and distribution of goods to satisfy the needs of households, such as food and water that are important to sustain human life. The national and local economy of South Africa, however, has been seriously affected by droughts over recent years (Baudoin *et al.*, 2017). The economy of South Africa, as well as the global economy, needs to be informed and responsible managers are expected to see to the needs of the communities for whom they are responsible. The issue is not merely money, but rather being informed and having the knowledge and will to make a difference, although money is a facilitator to obtain access to the resources that are available (Ahmadalipour and Moradkhani, 2018).

An active economy is viewed as a growing activity in areas such as impact investment, social entrepreneurship, and sustainable development. In the southern African region, food insecurity is being affected by higher prices on the market (Baudoin *et al.*, 2017). An active economy is a humane model of capitalism that mainly looks at tackling development challenges globally, including increasing inequality, as well as escalating poverty. A balanced inflation rate indicates the presence of a healthy economy. As a result, the GDP (gross domestic product) growth of many African countries has decreased due to the frequent drought conditions (Shiferaw *et al.*, 2014)

A good economy needs the government and communities to collaborate with investors and businesses to warrant sufficient housing, proper healthcare, and adequate jobs. The impact of drought as a result of climate change will reduce international trade patterns in South Africa (Calzadilla, Zhu and Rehdanz, 2014). A good economy prospers on wide inclusion and dynamism. The essential aspects of a healthy economic life include creativity, entrepreneurism, and innovation. To understand drought, we need to understand the impacts of drought. The economic impacts of drought manifest differently and may be direct or indirect (Shiferaw *et al.*, 2014). Droughts can cause the suspension of economic activities such as farming, ensuing in weakening finances (Haile and Tang, 2019). In economic terms, the impacts of drought are difficult to measure.

Table 2.2 below depicts a summary of the direct and indirect effects of drought on human beings. Not only do humans experience financial loss, but some of the effects can be psychological.

Table 2.2: Summary of the direct and indirect impact of drought on human health

Direct and indirect effects of drought on human health	References
Food insecurity (Undernutrition/malnutrition)	(Watts *et al.*, 2017; Parida *et al.*, 2018; Cooper *et al.*, 2019; Salvador *et al.*, 2020)
Contaminated water sources and ensuing diseases	(Bell *et al.*, 2018; Salvador *et al.*, 2020)
Vector-borne disease risk	(Brown, Medlock and Murray, 2014; Alpino, de Sena and de Freitas, 2016; Bell *et al.*, 2018)
Contaminated atmospheric air (increased particulate matter)	(Bell *et al.*, 2018; Salvador *et al.*, 2020)
Forest fires affecting agricultural production and animal feeding	(Bell *et al.*, 2018; Salvador *et al.*, 2020)
Low hydropower outputs	(Salvador *et al.*, 2020)
Mental health of food producers	(Parida *et al.*, 2018)

2.8 ADAPTATION STRATEGIES IMPLEMENTED TO COMBAT DROUGHT IMPACT

The Millennium Drought emphasized the importance of strong drought adaptation strategies (Kiem and Austin, 2013). Adaptation strategies and the numerous government policies that have been implemented have proven to be unsuccessful in the past due to anthropogenic climate change given the estimates for increased drought risk across many parts of Australia (Kiem and Austin, 2013). South Africa has the National Disaster Management Act of 2002 that is world-leading improved legislation over the past decades (Baudoin *et al.*, 2017).

Due to the limited availability of water concerning the demands, water management in the Mangaung region is challenging. The dependable supply and access to sufficient water have been identified as one of the most important activities in the city by the Integrated Development Plan (IDP) (DWS, 2013). Water conservation can be estimated to reach about 20% of the total water use as indicated by the Water Reconciliation Strategy Study for the Large Bulk Water Supply systems.

Uncertainties about the causes and effects of drought require enhanced strategies for adapting to drought. Shah *et al*., (2015) stated that it is important to have detailed information about the impacts of drought before planning how to respond to drought and how to mitigate the negative impact. Such information will assist the decision-makers to better recognize and lessen vulnerability to drought. The timely diagnosis of drought is also essential for the utilization of drought projections using climate modelling facilities for the stakeholders, decision-makers, and planners of relevant authorities (Masinde, 2014 and Masinde, Mwagha and Tadesse, 2018).

Having an accurate rainfall forecast is important for the prediction and analysis of drought (Masinde, 2014; Masinde *et al.*, 2018; and Haile and Tang, 2019). Moreover, to decrease the health impacts associated with drought, all relevant levels of government should learn to adapt and plan to face the challenges of climate change (Austin *et al.*, 2019).

South Arica has a drought forum in place that regulates actions concerning agricultural drought and other developmental dimensions impacted by drought

(Baudoin *et al.*, 2017). As a result of climate changes, countries worldwide have begun to set up national drought strategies that include the development of comprehensive drought monitoring systems that are capable of providing early warnings of the onset of a drought, can pre-determine drought severity and spatial extent, and convey the information to decision-makers timely (Masinde *et al.,*2018*)*. Such information can be used for water reconciliation strategies and to reduce or avoid the imminent negative impacts of drought.

The governments and a wide range of stakeholder's consistent, determined, cohesive efforts in the disaster risk management reform are reflected in the proclamation of the Disaster Management Act, 2002 on January 2003 (Disaster Management Act, 2002). Each province in South Africa has an established disaster management centre regulated by the district municipalities. All state organs are required to under the Act to develop, implement and review the Disaster Risk Management plan to ensure comprehensive planning by identifying the vulnerabilities that are common in the communities within the province (Disaster Management Act, 2002).

2.9 CONCLUSION

The literature on drought and adaption can assist many countries and cities in planning for droughts and dealing with their impacts on water provision thoroughly. In Africa, great improvement has occurred regarding drought prediction and water reconciliation research over the past decades. South Africa has key departments, strategies, and plans in place that should be mobilized more efficiently and plans and strategies should be implemented effectively. Another challenge faced is a lack of funding for these adaptive activities in many regions of the country. Useful knowledge also must be shared with communities, for example, information on water conservation activities. Thus, there are still many challenges in mitigating the impacts of drought in societies effectively.

Chapter 3

Methodology

3.1 INTRODUCTION

The following objectives were attained to achieve the aim of the study:

- To determine the impact of drought on the Bloemfontein area by assessing the annual meteorological data, and rainfall levels, as well as dam levels of Bloemfontein from 2016 to 2018,
- To assess the household water, use behaviour of the Bloemfontein community members after the implementation of water restrictions,
- To evaluate the annual data on water usage in Bloemfontein from 2016 to 2018,
- To evaluate the implementation of the Disaster Risk Management Plan that is currently in place in the Mangaung Metropolitan Municipality governing the Bloemfontein area.

The approach to research is discussed in this chapter by explaining the methodology that was used to execute the research project. In this chapter, the research design, the study area, topography and climate, sampling and sample selection, data collection methods, data analysis, and data control are explained. The research limitations, data reliability, and validation, and ethical considerations are also discussed in detail.

This chapter explains various methodologies that were used in gathering data and analysis which are relevant to the research. The methodologies will include areas such as the location of the study, research design, sampling and sample size, types of data, data collection method and its management.

The study aimed at evaluating the adaptation behaviour of community members on the impact of the recent drought on water availability in the area. The limitations of this study are that it relied on samples from a limited geographical region and a small sample size.

3.2. RESEARCH DESIGN

The research design refers to the plan or a blueprint according to which one intends to conduct research (Babbie and Mouton, 2008).

For this study, a quantitative research design was used. The quantitative approach was utilized to gather quantitative data from the participants concerning water use behaviour in the city of Bloemfontein. Quantitative research can be defined as the systematic or structured study of a phenomenon by collecting quantifiable data and using statistical, mathematical, or computational data analysis techniques, rendering findings that can be depicted in a numerical form (Question Pro, n,d).

3.3 STUDY AREA AND POPULATION

Bloemfontein is situated in the Free State Province and is also known as "The City of Roses", which emphasizes its dynamic character in the tourism sector. The province has the proximity of about 129 825 km^2, which makes the Free State the third biggest province with regard to land area (Botai *et al.*, 2016). It is bordered by six other provinces, namely Gauteng, Eastern Cape, Northwest, Kwazulu-Natal, Mpumalanga, and Northern Cape, as well as the neighbouring country of Lesotho.

The city of Bloemfontein is governed by the Mangaung Metropolitan Municipality which falls under the category A municipalities as it has major authority over its surrounding towns (Mangaung, 2019). The main economic sectors in this study area are the finance sector, which is growing due to the construction activities and very active estate developments, and the government sector which has also grown due to an increase in government programs.

Small businesses play a major role in the economy of Mangaung by creating employment, output growth, and income generation. There are approximately 230 000 households in Mangaung Metropolitan Municipality with 720 000 water users receiving water from the Bloemfontein water supply system as shown in Figure 3.2 (WaterAfrica, 2017). The demand for water has increased due to extensive commercial activities and a growing population (Mangaung, 2019).

Figure 3.1 represents the Elevation Map of Bloemfontein, South Africa. It shows the range of elevation in varying colours. Elevation data from NASA'S 90m resolution STRM were used to generate the map. The map provides an image of the contour and topography of Bloemfontein displayed at varying zoom levels.

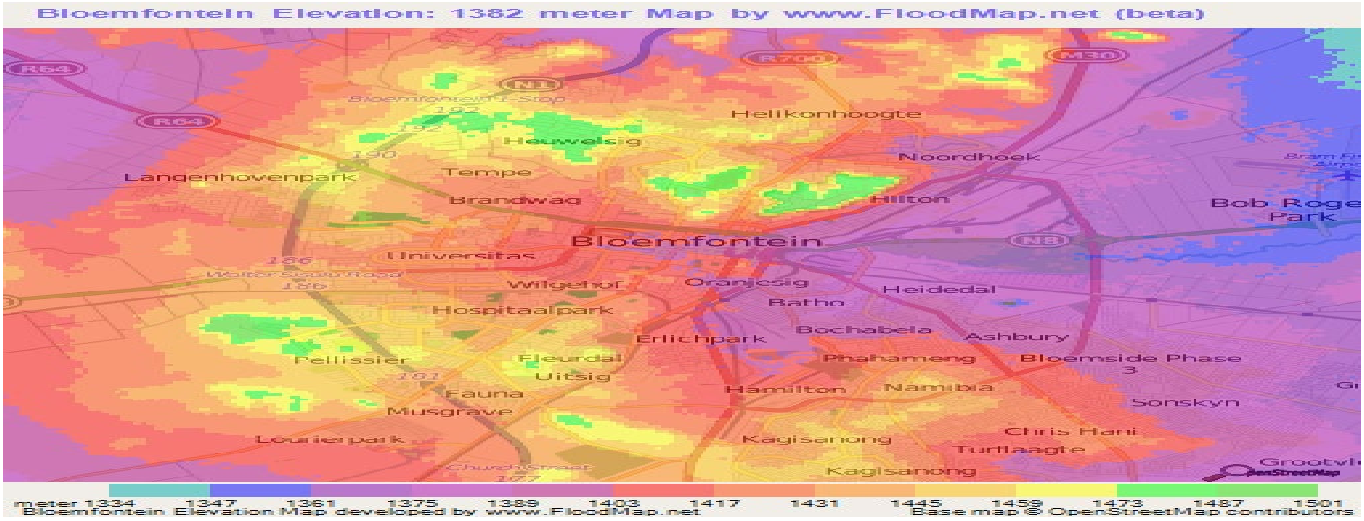

Figure 3.1: Bloemfontein, South Africa: Elevation Map (FloodMap, 2018).

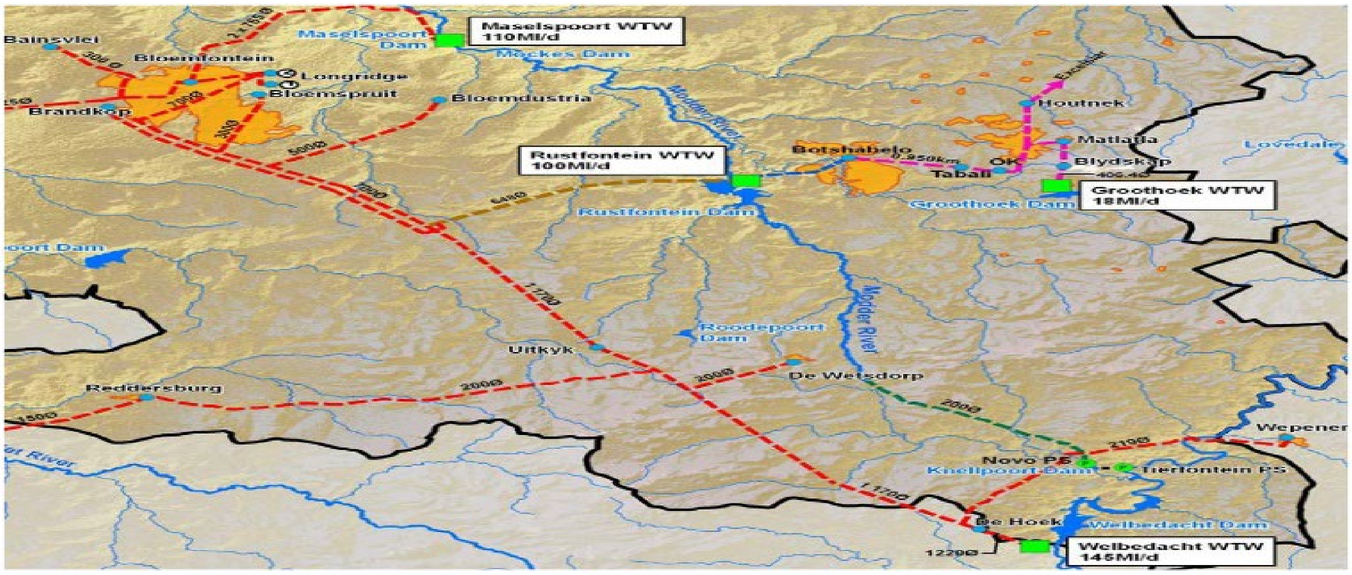

Figure 3.2: Greater Bloemfontein Water Supply System (DWA, 2019).

Bloemfontein has hot summer days and cooler, dry winters with frost resulting in a semi-arid climate. With a summer average low of 15° C and an average high of 30° C, the hottest day of the year has been recorded in January (Weatherspark, 2020). The hot season, has a duration of about five months from November to March, with an average daily temperature of above 27.2° C. In winter, Bloemfontein has an average low temperature of -2° C and a high of 16° C, with the coldest day having been recorded in July (Weatherspark, 2020). The cold season is from May to August, with an average daily high temperature below 18° C. Snowfall in Bloemfontein is rare, but in 2006 it snowed in the city, with snowfalls occurring again at the Bram Fisher Airport in 2007 (Mangaung, 2019).

Bloemfontein City is surrounded by a large number of suburbs. Furthermore, the city comprises some industrial areas, as well as a number of smallholdings in the close vicinity of the city. To collect information, questionnaires were distributed by hand in 37 suburbs in Bloemfontein.

In table 3.1 below the suburbs concerned are listed, as well as the number of questionnaires distributed per suburb using a purposeful sampling method.

Table 3.1: Number of questionnaires distributed per suburb

Keys: **Frequency** = number of questionnaires distributed per suburb
Percent = percentage of questionnaires distributed per suburb
Cumulative Frequency = total number of questionnaires distributed of the previous and current suburb
Cumulative percent = total percentage of questionnaires distributed of the previous and current suburb

List of Bloemfontein areas				
Suburb	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
	24	11.94	24	11.94
Batho	1	0.50	25	12.44
Bays Water	1	0.50	26	12.94
Bergman	1	0.50	27	13.43
Bloemside	3	1.49	30	14.93
Botshabelo	56	27.86	86	42.79
Dan Pienaar	3	1.49	89	44.28
Dinaweng	2	1.00	91	45.27

List of Bloemfontein areas				
Suburb	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Downtown	1	0.50	92	45.77
Fauna	1	0.50	93	46.27
Fichardt Park	12	5.97	105	52.24
Gardenia Park	1	0.50	106	52.74
Generaal De Wet	2	1.00	108	53.73
Grassland 3	1	0.50	109	54.23
Heidedal	10	4.98	119	59.20
Hewelsig	1	0.50	120	59.70
J.B Mafora	1	0.50	121	60.20
Langenhoven Park	20	9.95	141	70.15
Lourier Park	1	0.50	142	70.65
Mothshabi	1	0.50	143	71.14
Namibia	1	0.50	144	71.64
Noordhoek	5	2.49	149	74.13
Phahameng	1	0.50	150	74.63
Pellissier	3	1.49	153	76.12
Pentagon	1	0.50	154	76.62
Phase 2	1	0.50	155	77.11
Phase 3	1	0.50	156	77.61
Phase 4	2	1.00	158	78.61
Phase 5	1	0.50	159	79.10
Phase 6	2	1.00	161	80.10
Phelindaba	1	0.50	162	80.60
Pine Heaven	1	0.50	163	81.09
Rocklands	14	6.97	177	88.06
Showgate Centre	2	1.00	179	89.05
Universitas	2	1.00	181	90.05

List of Bloemfontein areas				
Suburb	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Vista Park	5	2.49	186	92.54
Westdene	2	1.00	188	93.53
Willows	13	6.47	201	100.00

3.3.1. Topography and climate

Bloemfontein is situated in central South Africa on the southern end of the highveld at a rise of 1,400 meters (4,600 ft), surrounding the semi-region of the Karoo (Mangaung, 2012). The area is generally flat with some hills and the overall vegetation comprises grasslands. The topography only has some variations within two miles of the Bloemfontein CBD (Central Business District) with areas covered by 30% artificial surfaces, while the remainder comprises 22% cropland and 66% grassland within 50 miles from the CBD (Weatherspark, 2020).

Bloemfontein has hot summer days and cooler, dry winters with frost resulting in a semi-arid climate. With a summer average low of 15° C and an average high of 30° C, the hottest day of the year has been recorded in January (Weatherspark, 2020). The hot season, has a duration of about five months from November to March, with an average daily temperature of above 27.2° C. In winter, Bloemfontein has an average low temperature of -2° C and a high of 16° C, with the coldest day having been recorded in July (Weatherspark, 2020). The cold season is from May to August, with an average daily high temperature below 18° C. Snowfall in Bloemfontein is rare, but in 2006 it snowed in the city, with snowfalls occurring again at the Bram Fisher Airport in 2007 (Mangaung, 2019).

Bloemfontein City is surrounded by a large number of suburbs. Furthermore, the city comprises some industrial areas, as well as a number of smallholdings in the close vicinity of the city.

The following is the list of Bloemfontein areas:

- Batho
- Bays Water
- Bergman
- Bloemside
- Bochabela
- Dan Pienaar
- Dinaweng
- Downtown
- Fauna
- Fichardt Park
- Gardenia Park
- Generaal De Wet
- Grassland 3
- Heidedal
- Hewelsig
- J.B Mafora
- Langenhoven Park
- Lourier Park
- Motshabi
- Namibia
- Noordhoek
- Phahameng
- Pellissier
- Pentagon
- Phase 2
- Phase 3

- Phase 4
- Phase 5
- Phase 6
- Phelindaba
- Pine Heaven
- Rocklands
- Showgate Centre
- Universitas
- Vista Park
- Westdene
- Willows

These areas listed above represent the urban and non-urban areas in the city of Bloemfontein which many of the participants reside in. These areas were selected by purposeful sampling to represent the population of the city of Bloemfontein due to limited resources of the study.

3.3.2 Sampling and sample selection

The research was conducted to gain insight into the household water-use behaviour in different households. The respondents were from all sorts of backgrounds, some were from suburbs associated with high-income homeowners to SASSA allowance dependants. The suburbs concerned are listed, as well as the number of questionnaires distributed per suburb using a purposeful sampling method.

Through these survey questionnaires administered at a household level, data were collected from willing participants. Several volunteering students from the Central University of Technology, Free State (CUT, FS) Environmental Health Department were deployed to walk from door to door in selected streets in the selected suburbs, handing over the questionnaires with the questions to be answered to the adult residents they found at home and asking them to complete the questionnaires.

The **inclusion criteria** for the implementation of the questionnaires were that participants had to be adults of eighteen years and older, they had to be found at home, they were the homeowners, or a member of the households that proved to be having sufficient information on and insight in the household's water-use behaviours, for example, what the household's primary source of water was, and whether water saving methods were implemented in the household, and what the household members' feelings were about water restrictions.

The **exclusion criteria** entailed those persons such as employees, for example, the gardeners and domestic workers, were not interviewed, because they were not full-time members of households responsible for the water usage at the specific homes and who were not residing in the home for more than 12 months.

3.3.3 Field workers training

Field workers were trained Environmental Health students studying at the CUT, FS. The training took place at the Central University of Technology, Free State campus on 2nd of December 2018 and was presented by Dr. Leana Esterhuizen, Lecturer in Environmental Health. The fieldworkers received training on how to conduct household surveys such as approaching the participants, completing the questionnaires, and post-field work analysis exercises such as data sorting and capturing.

3.4 DATA COLLECTION

3.4.1 Data collection instruments

The following instruments were used in collecting data questionnaire:

- A4 copy paper
- Printers
- Paper ink
- Clip boards
- Staplers
- Black pens
- Paper clips
- Highlighters

The degree to which the measurement instrument has consistent and stable results is referred to as reliability (Norman, 2003). Thus, if the results of the questionnaire survey can be shown to be consistent, with the use of the same research methodology, we can conclude that the data collected were reliable. However, Moharaj (2017) found that reliability is more interested in the confidence that the researcher shows in the data collected. There are many different known types of reliability.

Table 3.2: Data Sources

P = Primary; S = Secondary

Institution	P or S data	Data Type	Contacts
South African Weather Services	Secondary data	Minimum, Maximum Temperatures and Rainfall levels for 2016, 2017 and 2018	**Moitheri Ramatsa** <Moitheri.Ramatsa@weathersa.co.za>
Department of Water and Sanitation	Secondary data	Dam levels for 2016, 2017 and 2018	**Jojozi Amanda Avela** <JojoziA@dws.gov.za>
Household water use study	Secondary data	Questionnaires completed during 2018	Nikki Funke <NFunke@csir.co.za>
Mangaung Metropolitan Municipality: Water Division	Primary data	Water use data for 2016, 2017 and 2018	Ikaelelo I.P. Likhi <Ikaelelo.Likhi@mangaung.co.za>
The Disaster Risk Management Plan	Secondary data	Disaster Risk Management Plan 2018 downloaded from the Mangaung Metro Municipality website	http://www.mangaung.co.za/wp-content/uploads/2019/05/16-Council-59.1-IDP-2019-2020-ANNEXURE-M-Disaster-Management-Plan.pdf

3.4.2 Questionnaire

In this study, two data collection strategies were used, namely document analysis and a survey questionnaire. Meteorological data for daily maximum and minimum temperatures, as well as the daily rainfall levels, were collected electronically from the South African Weather Services for the years 2016 to 2018. Monthly dam levels were collected electronically from the Department of Water Affairs, Free State, Bloemfontein for the years 2016 to 2018. Furthermore, monthly water-use data also were collected electronically from the Mangaung Metropolitan Municipality Water division - also for the years 2016 to 2018. The Disaster Risk Management Plan document was downloaded from the Mangaung Metropolitan Municipality.

The primary data were collected through a structured survey and respondents were asked the same set of questions throughout the interview sessions. The researcher reckoned that a quantitative approach and design would serve the purpose of the study best, as the researcher planned to quantify the data and to generalize the results to the relevant population; data collection would be done in a structured way and data would be analysed statistically.

The questionnaire compiled by the CSIR (see Appendix 3) was adopted and used to collect the data from participants in the study and is divided into different sections. The first section is control information, followed by the water-saving practices, and then the water-use perceptions, perceived household water use, water sources, water restrictions and regulations, and lastly the actual household water use, and situational factors. Due to limited project duration and financial resources, a total of two hundred and one questionnaires were distributed and 196 were completed in full. The questionnaires consisted of 14 questions.

Informed consent letters (see Appendix 1) were handed to the participants together with the questionnaires. These information letters carried the researcher's study name and contact details, the CSIR's logo with company name, and the reasons for the interview. The participants were put at ease by the consent letter, as an undertaking was given that participating in the study would not cause them discomfort or harm, their responses would be dealt with anonymously and confidentially, and that the research would be beneficial to them and the broader community (McNeill, 1990).

Only a small number of questions compiled by the CSIR researcher were taken up in the questionnaire to ensure that participants did not become bored, to get more carefully thought through responses, and to facilitate a high response rate. The questions were arranged from general to specific, and from easy to difficult (Hofstee, 2006). Participants were once again assured of confidentiality. The questionnaires were also compiled in a way that rendered them easy to analyse and turn the findings into numerical (quantitative) results (Hofstee, 2006). The questionnaire survey, however, did not allow for interaction with the respondents, nor was it possible to investigate participants' deviation from the set format (Hofstee, 2006).

Multiple-choice questions and closed-ended questions were used in the questionnaire. Multiple-choice, closed questions were included as they provided an opportunity to decrease the time the participants needed to complete the questionnaires, and thus also decreased the time utilized to analyse the completed questionnaires (Mouton, 2006). Closed-and-open-ended questions were also utilized to allow the participants to answer in their own words, and to express themselves clearly; thereby giving them a sense of control (Hofstee, 2006).

3.4.3 Document analysis

The first data collection strategy was document analysis. To assess the annual meteorological data, rainfall levels and the dam levels a time series of daily precipitation, maximum and minimum temperatures, and daily rainfall levels from one weather station were obtained electronically from the South African Weather Service of the city Bloemfontein for the period 2016 to 2018 as shown in Table 3.4.

The monthly average of the maximum and minimum temperatures for the years 2016 to 2018 was measured using the weather radar system at the South African Weather Service, and the data were collected electronically from the service provider by the researcher. The data on monthly average rainfall levels, also for the years 2016 to 2018, was measured using the rain gauge network of the South African Weather Service and also were submitted electronically to the researcher by the service provider.

The data on the average monthly water levels of the Rustfontein, Welbedacht, and Knellpoort Dams respectively, for the years 2016 to 2018 were measured using the flow-gauging weirs of the Department of Water and Sanitation, Bloemfontein Office, and were electronically collected from the Department by the researcher.

The monthly average water usage of Bloemfontein City for the years 2016 to 2018 was measured using the Swift database software product that shows water-meter readings for customer billing by the Mangaung Metropolitan Municipality and the data were collected electronically from the municipality by the researcher.

Table 3.3: Summary of meteorological data collected

Climate Station Number	Station	Year
0261307A4	Bloemfontein	2016
0261307A4	Bloemfontein	2017
0261307A4	Bloemfontein	2018

The dam levels of the Rustfontein, Welbedacht, and Knellpoort Dams, for the period 2016 to 2018 were also electronically obtained from the Department of Water Affairs, Bloemfontein Free State as shown in Table 3.4 below.

Table 3.4 Water levels of the Rustfontein, Welbedacht, and Knellpoort dams collected.

Dam Site	Name	Year
C5ROO3	Rustfontein	2016
		2017
		2018
D2ROO4	Welbedacht	2016
		2017
		2018
D2ROO6	Knellpoort	2016
		2017
		2018

Water-use data of Bloemfontein, for the period 2016 to 2018 were also electronically obtained from Mangaung Metropolitan Municipality – Water Division, Bloemfontein Free State as shown in Table 3.5 below.

Table 3.5 Water use data collected of the Bloemfontein city, Free State.

Area	*Year*
Bloemfontein	2016
Bloemfontein	2017
Bloemfontein	2018

3.4.4 Data Collection

To assess the household water-use behaviour of the Bloemfontein community members after the implementation of water restrictions, a survey questionnaire was used. The questionnaire compiled by the CSIR (see Appendix 3) was adopted and used to collect the data from participants in the study and is divided into different sections. Some of the questions in the original questionnaire were omitted for relevancy. For the purpose of the study, the researcher and volunteers distributed 201 questionnaires to the participants.

3.5 DATA ANALYSIS

Data were captured electronically in Microsoft Excel. The analysis was done by a statistician using SAS Version 9.2. Descriptive statistics, namely frequencies and percentages were calculated for categorical data, and means and standard deviations or median and percentiles were calculated for numerical data. The Shapiro-Wilk test was used to determine if numerical data followed a normal distribution. To compare monthly, yearly meteorological, and dam level data analytical statistics, namely analysis of variance (ANOVA) was used to investigate significant mean differences. A significance level (α) of 0.05 was used in this study.

3.6 DATA CONTROL

The data was collected by students from the Department of Environmental Health and captured on Microsoft Excel on a computer by the researcher. The collected data were stored safely in a folder on a password-protected computer and will be kept there for five years. Only the researcher and the supervisor had and will have access to the folder. All the hard copy questionnaires containing data collected are stored in a locked cupboard at the researcher's and supervisor's offices and will remain there for five years after completion of the study. All the information on the questionnaires and data captured on the computer will then be double deleted.

3.7 DATA VALIDITY

Validity refers to the extent to which a measuring instrument measures that which it is intended to measure. The data collected for this study were obtained electronically from the different section managers in the South African Weather Services, Department of Water and Sanitation, Mangaung Metropolitan Municipality – Water Division, and the Council for Scientific Industrial Research (CSIR) respectively, to ensure the validity and reliability of this study.

3.8 ETHICAL CONSIDERATIONS

It is important for researchers to comply with specific ethical rules governing scientific studies. Respondents and others involved should be sufficiently provided with information on the research to enable them to decide whether or not to participate. An ethical clearance letter was obtained from the CSIR research ethics committee prior to commencing with the study (Clearance Letter 240/2017). Written permission was also obtained from the Mangaung Metro Municipality to conduct the study. In addition to this, participants were fully informed about the purpose of the study and what would be expected from them.

They were requested to complete the consent forms before participating in the study. The participants were informed that should they wish to withdraw from the study at any time they could do so. The confidentiality of the information and the anonymity of participants was guaranteed. To ensure their safety and set the minds of participants at rest, the students acting as data collectors had to identify themselves and approach only those prospective participants who had been informed of the study beforehand.

On completion of the research, a copy of the study report would be submitted to the Mangaung Municipality for reference purposes. The outcome of the research will hopefully assist the municipality in improving water supply services and to better understand the Bloemfontein community's needs and attitudes to matters concerning water supply.

3.9 CONCLUSION

In this chapter the research methodology and study design used were explained as well as the background course the study took. Data were collected and analysed using qualitative and quantitative research methods, which proved to be the best way to achieve the research aim and objectives. The figures depicted the study area to give a clear image of the water sources under investigation. Sample size and study population were explained, and data reliability and validation were discussed to demonstrate that the study satisfied the criteria for scientific studies. The ethical clearance letter was submitted to the Council for Scientific Industrial Research (CSIR) ethics committee and approval was granted.

Chapter 4

RESULTS

4.1 INTRODUCTION

In this chapter, the research results that were obtained with the use of the methodology discussed in the previous chapter are reported. The data collected during the study have been analysed to address the objectives of this study, which were to determine the impact of drought on the Bloemfontein area by (i) assessing the annual meteorological data, rainfall levels, and dam levels of the Bloemfontein area for the period between 2016 to 2018; (ii) to assessing the household water use behaviour of the Bloemfontein community members after the implementation of water restrictions, and (iii) to assessing the annual data of water-use in Bloemfontein from 2016 to 2018.

The analysis and interpretation of the data were performed in three phases. The first phase, dealing with the results of average monthly minimum and maximum rainfall, and dam water levels for the years 2016 to 2018, rendered quantitative data. During the second phase the results of the questionnaire survey, conducted in December 2018, were analysed and interpreted. Thus, a mixed-methods approach was used in this study. These findings provided important quantitative data. The third phase, dealing with the results of the water-use data of Bloemfontein for the years 2016 to 2018, rendered quantitative data.

Throughout the study, the researcher sought to assess the adaptation of the Mangaung community to the effects of a serious drought and how they adapted to using water sparingly.

4.2 METEOROLOGICAL DATA

In this section, the temperatures data, rainfall, and dam levels are provided in graphs and tables and discussed. The methods of analysis of the data have been described fully in Chapter 3 (see section 3.5).

4.2.1 Average temperature levels

Temperatures were high at the beginning of the year 2016 with an average of up to 34 °C recorded in December (see Figure 4.1 below). July was the month with the lowest average temperature, namely 0.9° C.

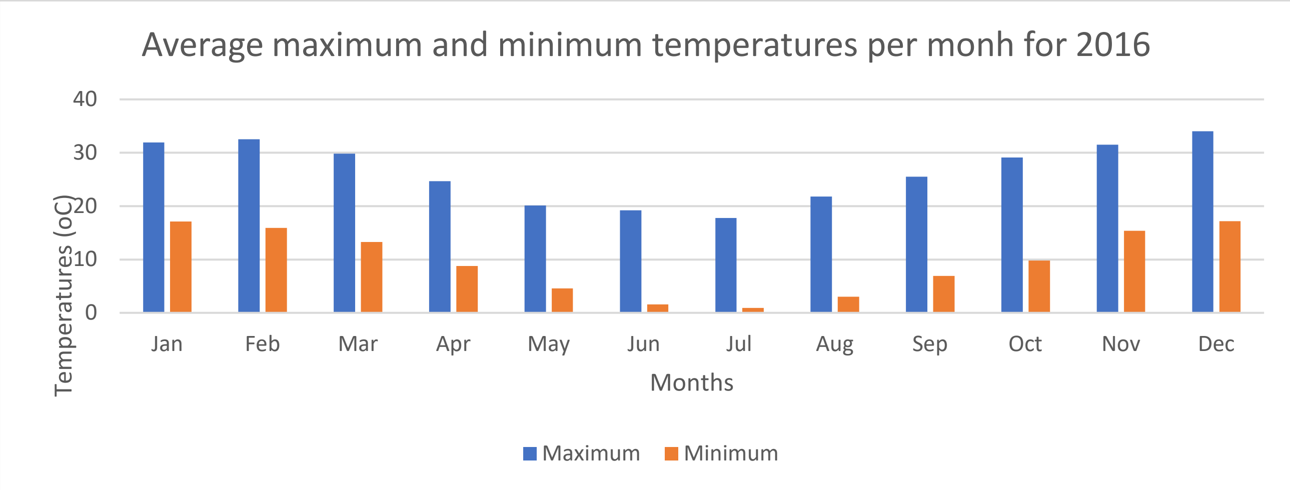

Figure 4.1: Average maximum and minimum temperatures per month for 2016.

During 2017 the highest monthly average temperature of 32.1 °C was recorded in December, and the lowest monthly average temperature ranging between 0.8° C and 0.6° C was recorded in June and July (see Figure 4.2 below).

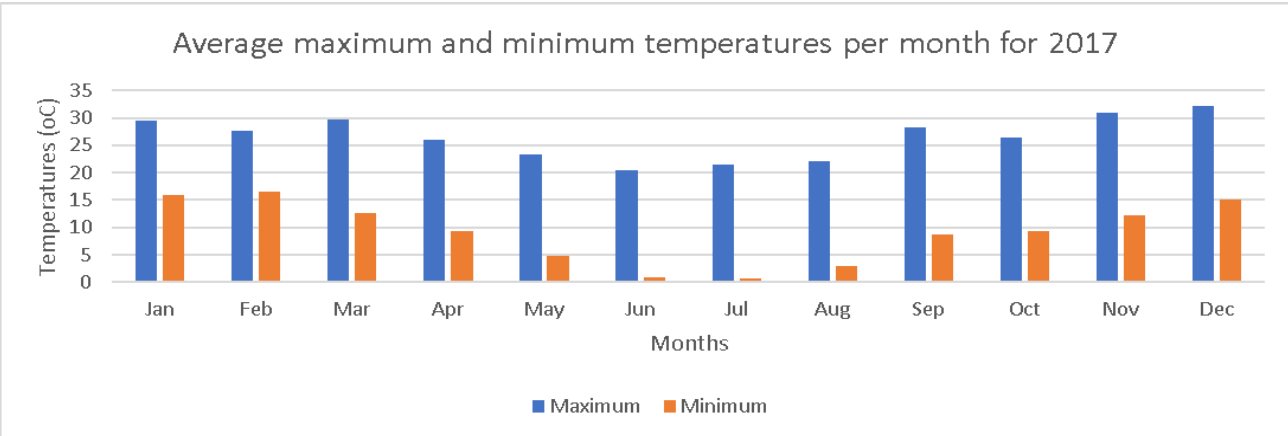

Figure 4.2: Average maximum and minimum temperatures per month for 2017

As in the previous two years, the hottest month was recorded in December with an average monthly temperature of 34.5 °C (see Figure 4.3 below), and the coldest months were recorded with an average monthly temperature ranging between 0.3°C and 0.4°C in June and July for the year 2018.

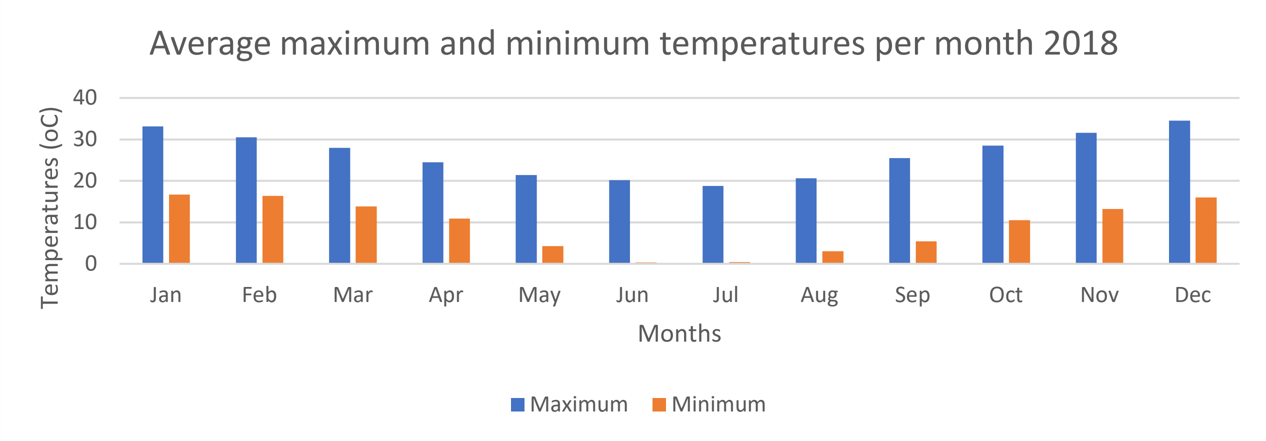

Figure 4.3: Average maximum and minimum temperatures per month for 2018

4.2.2 Monthly rainfall levels for 2016, 2017, and 2018

The average rainfall was high during the summer months of the year 2016, at 83.8 mm in November; in February 2017 it was 202.4 mm, and it was 116.2 mm in March, with a lack of rain between June and September for the year 2018 as shown in Figure 4.4.

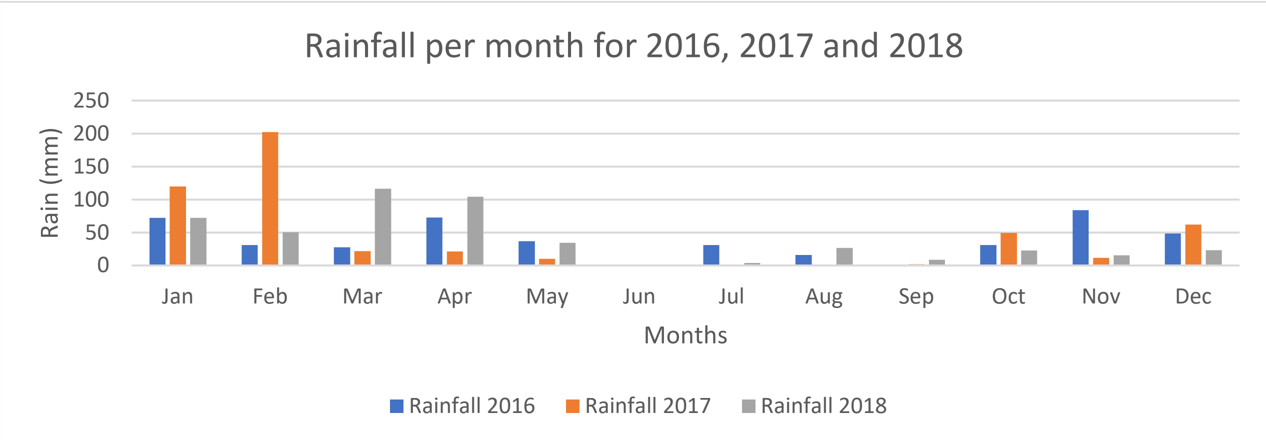

Figure 4.4: Rainfall per month for 2016, 2017 and 2018

Summaries of the minimum and maximum temperatures and the rainfall measured during 2016, 2017, and 2018 respectively are given in Table 4.1, 4.2, and 4.3 below resulting from the Shapiro-Wilk test which showed that the numerical data followed a normal distribution.

The average maximum temperature for 2016 of 32.83 °C during 2016 was higher than the average maximum temperatures of 2017 and 2018.

Table 4.1: Summary of temperatures and rainfall in Bloemfontein during 2016

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
Max Temp	91	32.83	3.73	2987.20	21.40	41.40
Min Temp	91	16.74	2.16	1523.00	9.80	22.80
Daily Rainfall	29	5.23	6.17	151.60	0.20	26.00

The average minimum temperature of 2017 of 15.89 °C is the lowest compared to 2016 and 2018 average minimum temperatures.

Table 4.2: Summary of temperatures and rainfall in Bloemfontein during 2017

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
Max Temp	90	29.82	3.92	2684.20	19.40	36.30
Min Temp	90	15.89	1.99	1430.20	10.80	20.10
Daily Rainfall	39	9.85	9.95	384.00	0.20	37.20

The average daily rainfall of 2018 was the lowest compared to 2016 and 2017 with a sum of 145.80 recorded.

Table 4.3: Summary of temperatures and rainfall in Bloemfontein during 2018

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
Max Temp	90	32.77	3.31	2949.30	25.60	38.60
min temp	90	16.37	2.49	1473.20	9.40	21.20
Daily Rainfall	24	6.08	9.18	145.80	0.20	41.20

4.2.3 Average Water levels of dams for 2016 to 2018

Figure 4.5 indicates the average annual water levels of the dams in litres (L) for the year 2016. The Rustfontein Dam had the lowest annual average water level of 21%, while the Welbedacht dam had the highest annual average water level of 98% for the 2016 year.

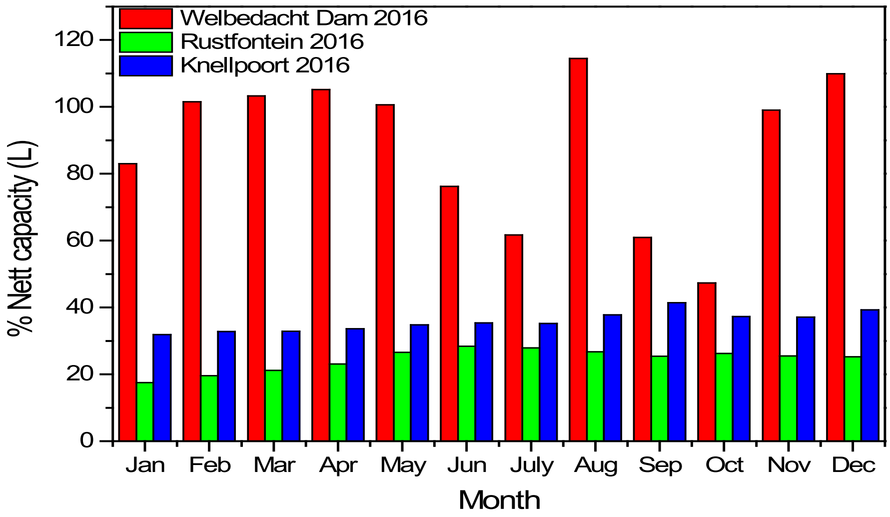

Figure 4.5 Monthly dam levels per month for 2016

Water dam levels for Bloemfontein during 2017 are depicted in Figure 4.6 above. These data have a bearing on the Rustfontein with 21% minimum and 45% maximum, Welbedacht with 21.5% minimum and 62.2% maximum and Knellpoort with 35% minimum and 44.5% maximum, the levels of which are displayed per month.

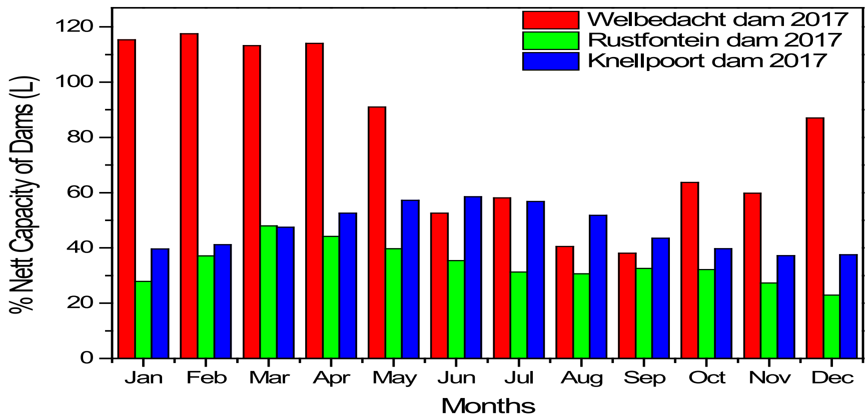

Figure 4.6: Monthly dam levels per month for 2017

Figure 4.7 indicates the average annual water levels of the dams in litres (L) for the year 2018. The dam levels showed an increase during this year.

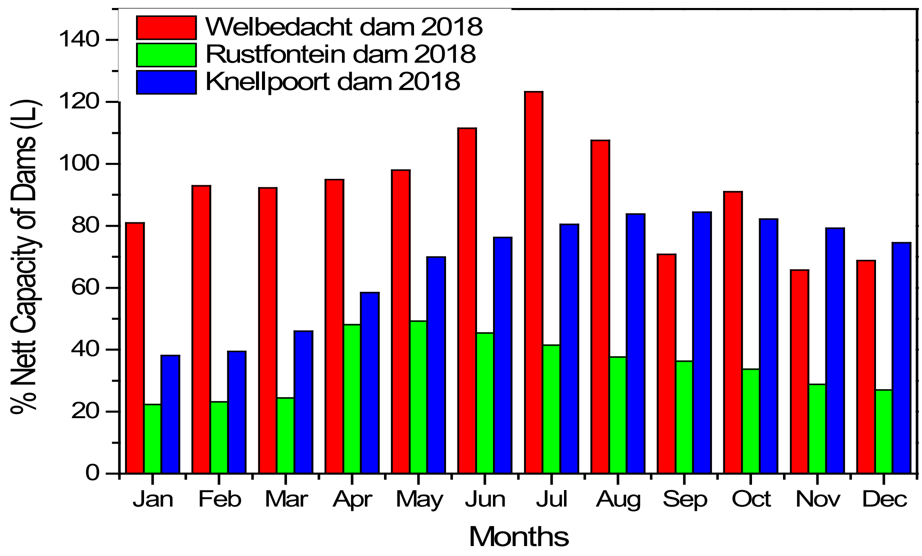

Figure 4.7: Monthly dam levels per month for 2018

Table 4.4 below indicates the significant differences between the Rustfontein Dam water levels for the years 2016 to 2018 To compare monthly, seasonal, or yearly meteorological or dam level data analytical statistics, namely analysis of variance (ANOVA) was used to investigate significant mean differences.

Table 4.4: Significant differences in the Rustfontein Dam water levels – 2016-2018

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Among	2	2879.277382	1439.638691	71.4972	<.0001
Within	267	5376.201735	20.135587		
Average scores were used for ties.					

Table 4.5 below indicates the significant differences in the Knellpoort Dam water levels for the years 2016 to 2018.

Table 4.5: Significant differences in the Knellpoort Dam water levels - 2016 to 2018

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Among	2	12786.700342	6393.350171	62.1556	<.0001
Within	267	27463.725014	102.860393		
Average scores were used for ties.					

Table 4.6 below indicates the significant differences in the Welbedacht Dam water levels for the years 2016 to 2018.

Table 4.6: Differences in the Welbedacht Dam water levels – 2016-2018

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Among	2	31301.517545	15650.75877	42.6258	<.0001
Within	267	98033.430439	367.16641		
Average scores were used for ties.					

4.3 QUESTIONNAIRE DATA

A total of 201 questionnaires were distributed, 196 (97%) questionnaires were completed. Only five questionnaires were partially completed as a result they were excluded in data analysis.

The majority, 83 (42.29%), of the participants were males which may be due to the females and those who identify as 'other' running household errands during the day (see Table 4.7).

Table 4.7: Gender distribution

Gender				
	Male	Female	Other	Total
Number of respondents	83	70	43	196
% per gender group	42,29	35,32	22,39	100

As can be seen in the table 4.8 below, Black people, 114 (58.21%) formed a major part of the participants, while 'Colored' respondents were the least represented with only 1 (0.5%) respondent (Table 4.8).

Table 4.8: Racial distribution

	Race					
	Black	White	Coloured	Indian	Race Not Specified	Total
Number of respondents	114	5	1	30	46	196
% per race	58,21	2,49	0,5	15,52	23,38	100

Table 4.9 elucidates that 50 (25.52%) respondents' educational levels were a grade 12 level qualification and only 3 (1,56%) had no schooling at all (Table 4.9).

Table 4.9: Educational levels of participants

	Educational Level										
	No response	**Grade 3**	**Grade 7**	**Grade 10**	**Grade 12**	**Under-graduate**	**TVET\ College**	**Post-graduate degree**	**No schooling**	**Don't know**	**Total**
Number of respondents	24	3	3	9	50	36	19	46	3	3	196
Percentage	11,98	1,56	1,56	4,69	25,52	18,23	9,9	23,44	1,56	1,56	100

92 (47%) of the participants responded that they had started practicing water-saving behaviours, but almost one-third had not been doing anything or had not made an effort to save water in their households (Figure 4.8).

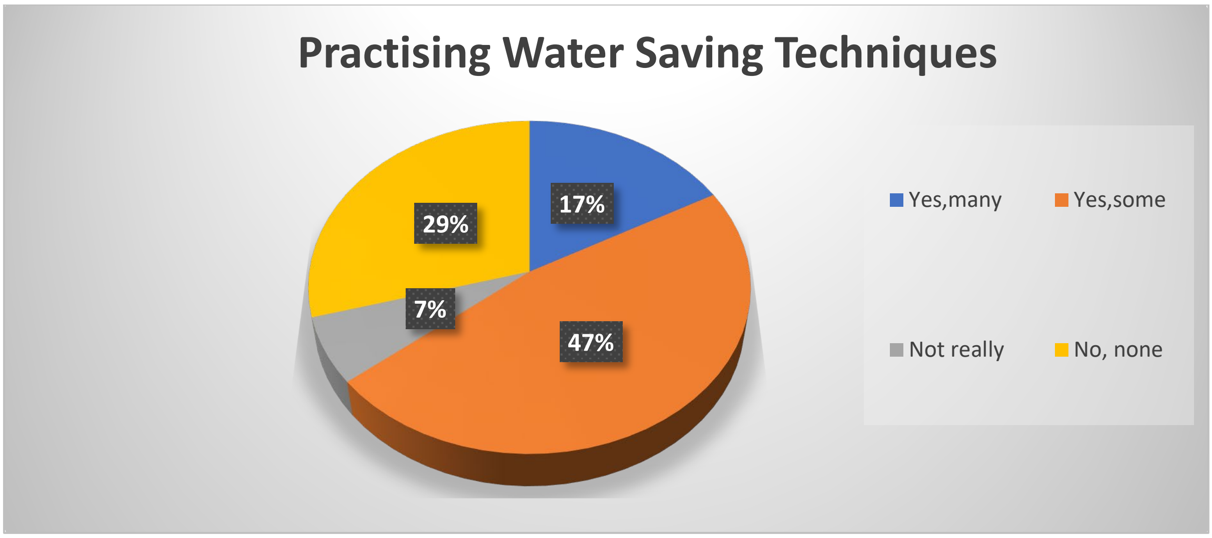

Figure 4.8: Responses (%) of the participants regarding their water-saving practices

When asked what they did to save water, 82 (42.6%) of the participants indicated that they used recycled water in their households as the main method, while others made use of the tips seen in the media to save water (Figure 4.9). Only 25 (13.3%) participants did not respond or admitted that they did nothing to use water more sparingly.

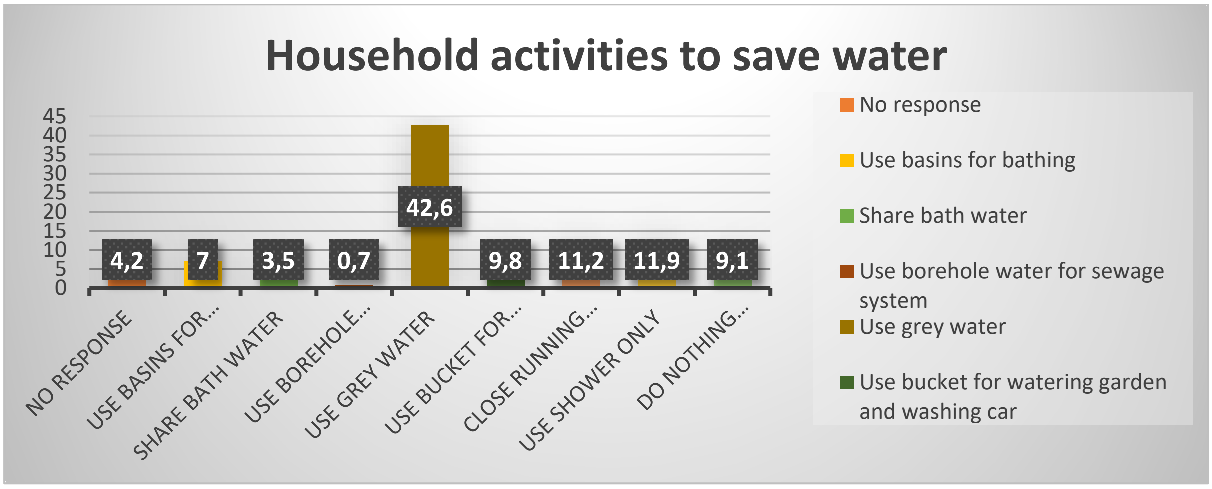

Figure 4.9: Responses (%) about household activities aimed at using water sparingly

The highest percentage of the participants, 62 (32%), indicated that they had been using water sparingly for about a decade or longer, while the second-highest percentage indicated that they only had started more recently, about less than two to five years ago. (see Figure 4.10).

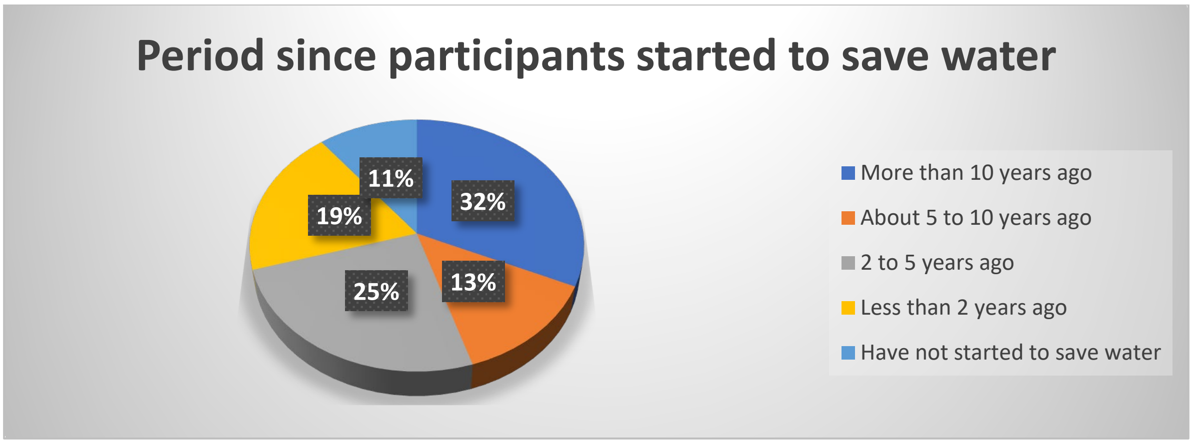

Figure 4.10: Pie chart indicating percentages of participants and periods they had been saving water

The main trigger to save water by the participants was based on their knowledge about the water crisis and for others it was triggered by the high municipal water bills (see Figure 4.11).

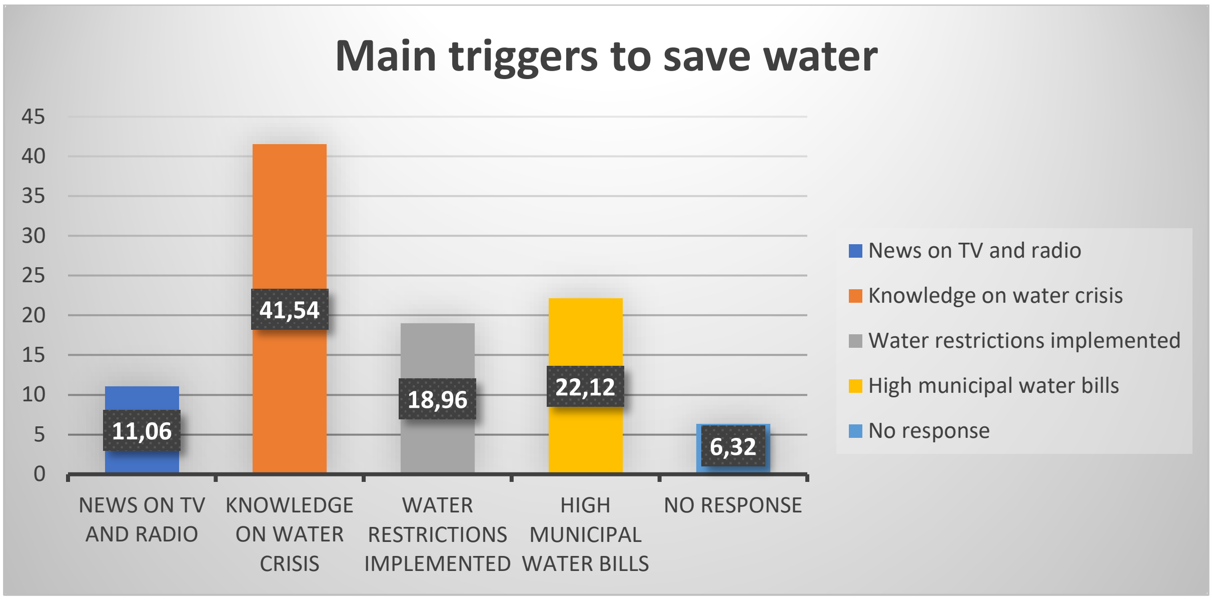

Figure 4.11: Percentages of participants' responses about their main triggers to save water

The general water restrictions (23.39%) seemed to be the most effective measure implemented to control the water use of many of the participants as did the assistance to implement water-sensitive design measures (20.55%) by the municipality (see Figure 4.12).

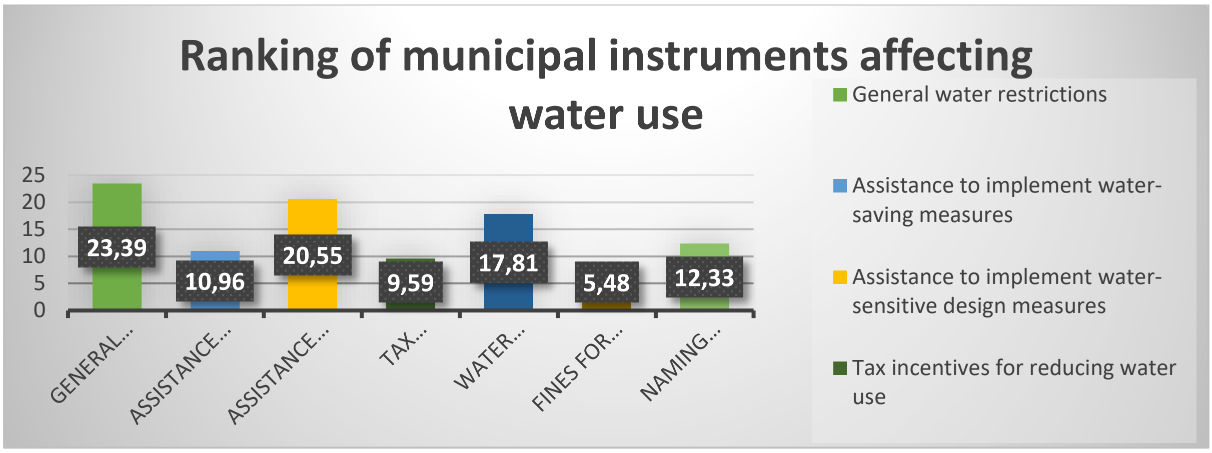

Figure 4.12: Percentages of the participants' responses in ranking municipal instruments affecting water use

Most of the participants,81 (41.54%), seemed to have adhered to the general water restrictions, for example, by not washing their cars to save water, whereas 13.85% indicated that they still washed their cars at least once a week (see Figure 4.13). It must be noted here that 36 (18.46%) of the participants did not respond to this question.

Figure 4.13: Participants' responses (%) about how often they washed their cars

The study was conducted on participants staying in urban households, thus, for the majority of them, municipal water (96.26%) was their main source of water, while less than 4% used a natural or another source of water (Figure 4.14).

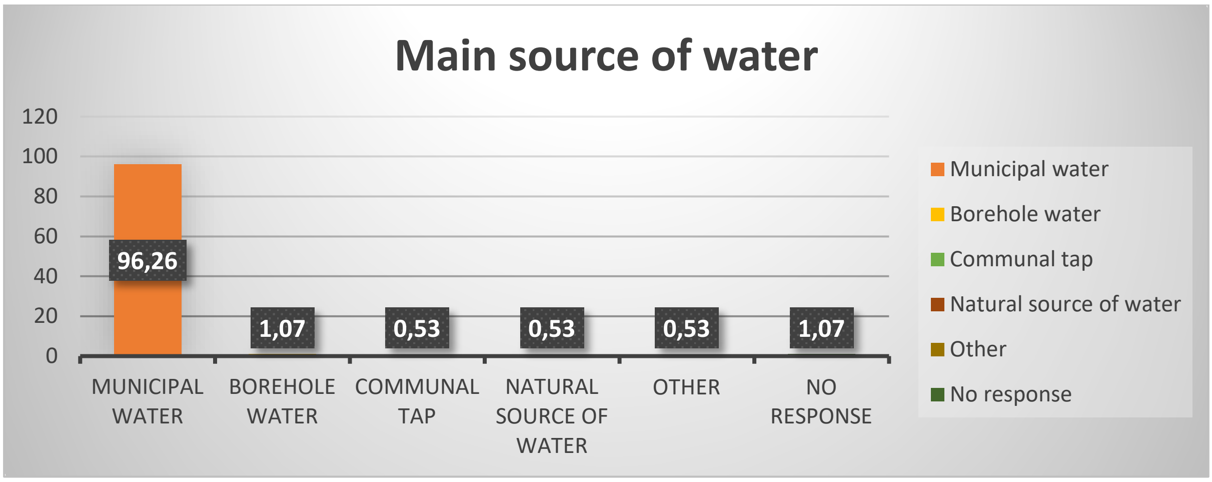

Figure 4.14: Percentages of participants according to their main source of water

Only 26% of the participants indicated that they were experiencing the water restrictions in their households, while others (46%) said they were unsure of the water restrictions instituted in the area (Figure 4.15).

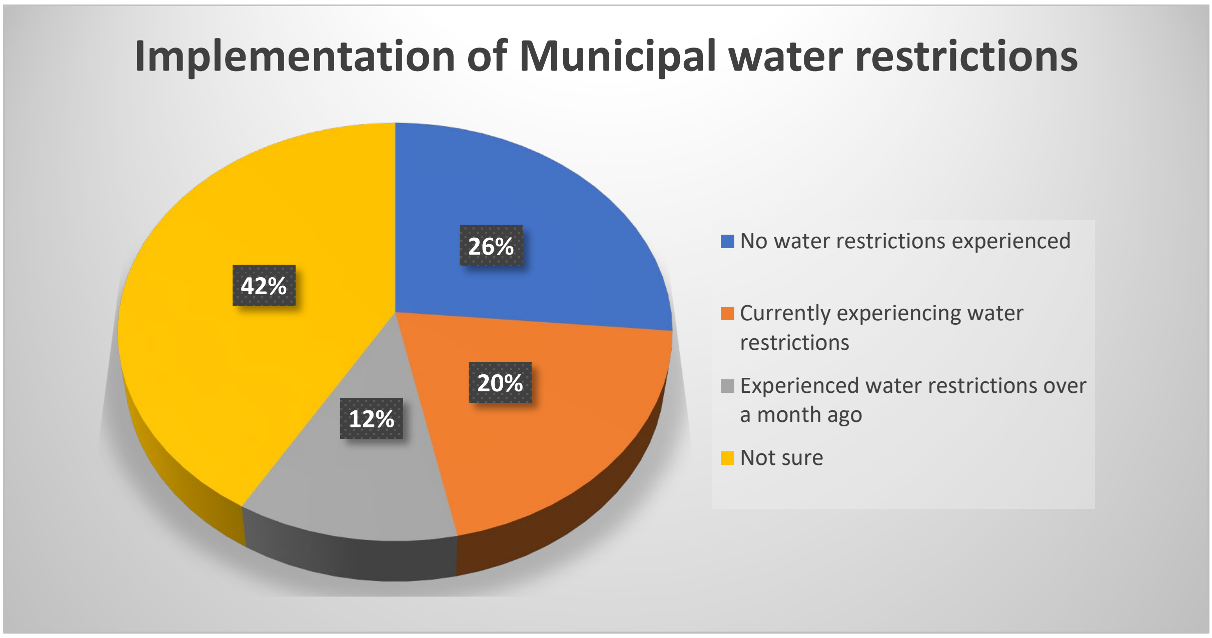

Figure 4.15: Percentages of participants experiencing municipal water restrictions

The participants mostly lived in freestanding houses, thus they had full control of and accountability for water use in their households (Figure 4.16).

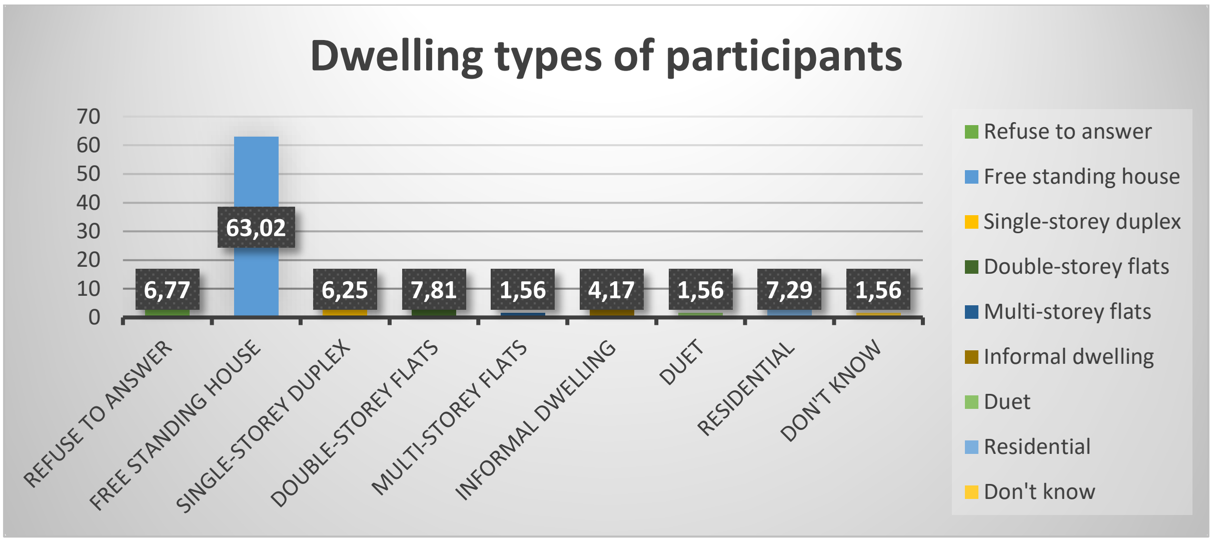

Figure 4.16: Dwelling types of participants (%)

The participants were unsure about how to respond to this item – almost half, 93 (47.92%) did not respond or responded that they did not know. Among those who did respond the majority believed that they as individuals came first before society, and this greatly affected their water use behaviour. A few participants (5.73%) responded that society should rule their water affairs, and even fewer were of the opinion that no government (4.17) was needed to implement water regulations (Figure 4.17).

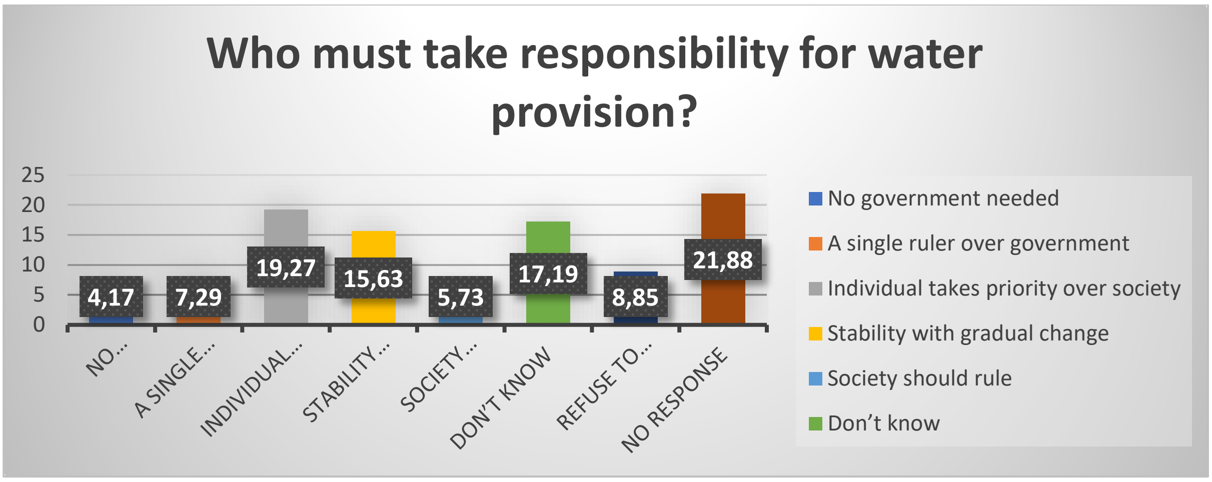

Figure 4.17: Percentages of participant responses regarding who should be responsible for water provision rulings.

The majority of the participants had a type D meter installed in their households (Figure 4.18).

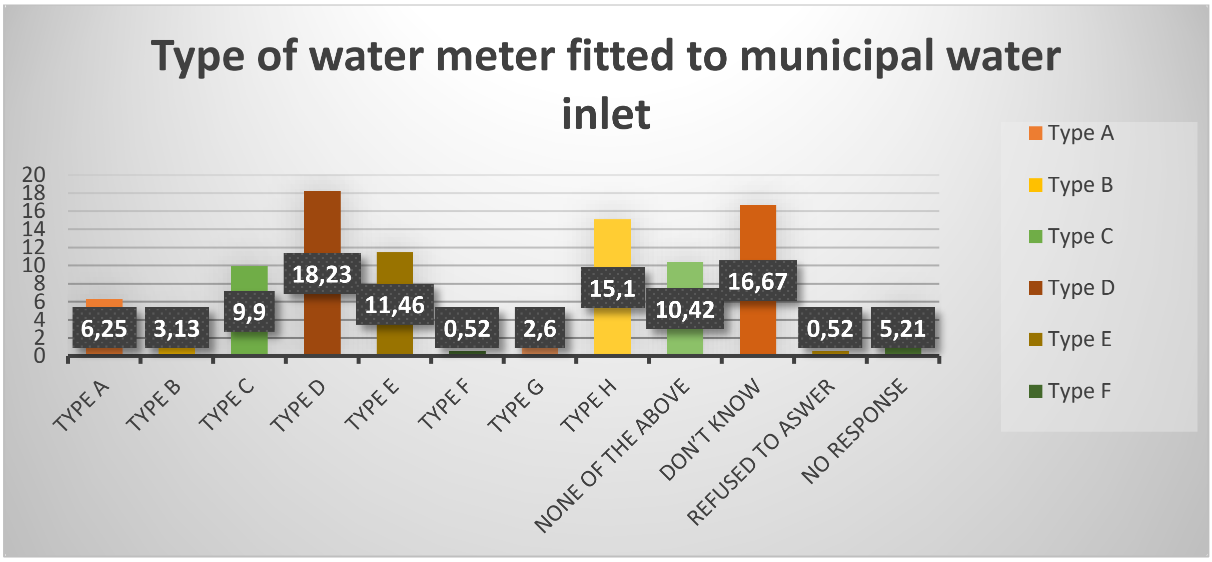

Figure 4.18: Percentages of the participants according to the type of meter fitted to their municipal water inlet

4.4 WATER-USE DATA

Findings of the processed and analysed data about the water use in the study area are provided in Tables and Figures.

During June of 2017 and 2018, water use in the city was very high, while the lowest water use in one month was recorded in July 2018, as depicted in Table 4.10. The water uses as recorded by the municipality for the years 2016 to 2018 are provided per month in Table 4.10.

Table 4.10 Actual water consumption data from 2016 to 2018 for Bloemfontein

Month	Year 2016 (million m³/month)	Year 2017 (million m³/month)	Year 2018 (million m³/month)
January	6,40	5,94	7,02
February	5,50	6,07	5,42
March	5,96	5,99	5,60
April	No data	6,17	5,57
May	5,56	5,63	5,57
June	5,60	8,40	8,83

July	5,31	3,85	3,03
August	5,42	6,15	6,39
September	5,71	6,40	6,55
October	5,72	5,96	6,17
November	5,42	6,60	6,71
December	5,61	6,04	5,99
Total	**62,21**	**73,2**	**72,85**

During the year 2016, the municipality did not succeed in including or persuading the community members to comply with the water use target. With no data recorded during April, the month of October was the only month in which the consumption did not exceed the targeted consumption (Figure 4.19).

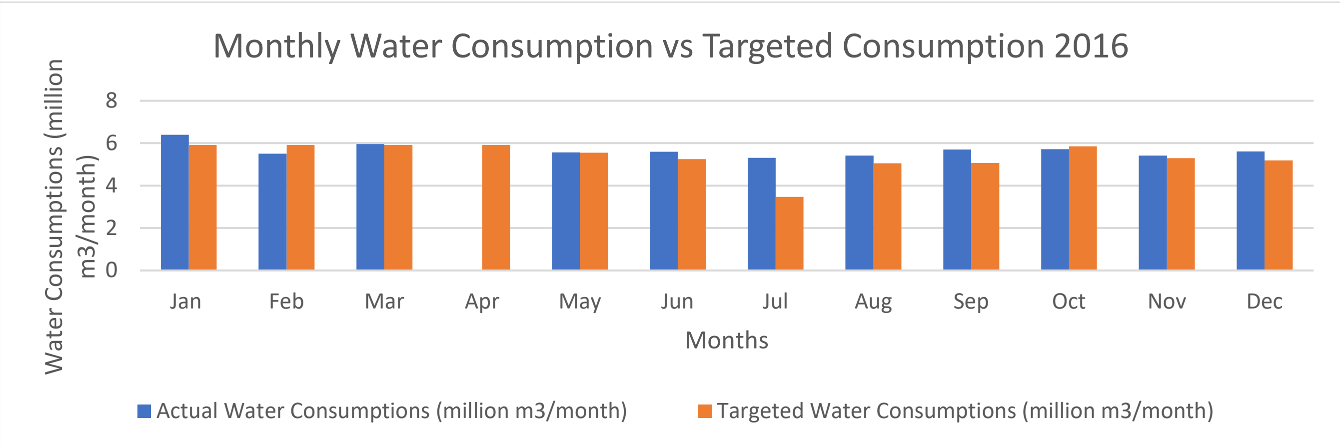

Figure 4.19: Monthly water consumption versus Targeted consumption in 2016

In 2017, the consumption of water was below the target in May (6 million³), July (5.86 million³), and October (6.1 million³), equalled the target in March and December, and for the remaining months exceeded the target, with the most excessive water-use in June (8.1 million³) (Figure 4.20).

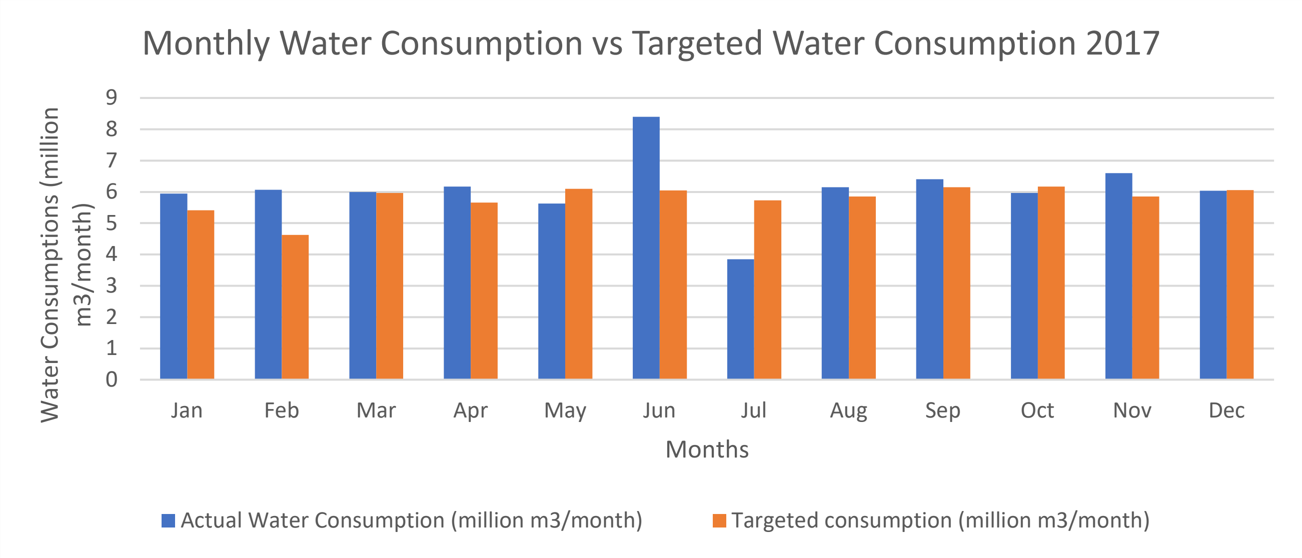

Figure 4.20: Monthly water consumption versus targeted consumption in 2017

For the year 2018, the highest monthly water consumption was in June (8.8 million³), and the lowest was in July (3 million³), while no data was recorded in April. Consumption again exceeded the targeted water use such as in January (7 million³), February (5.4 million³), and November (6.7 million³) (Figure 4.21).

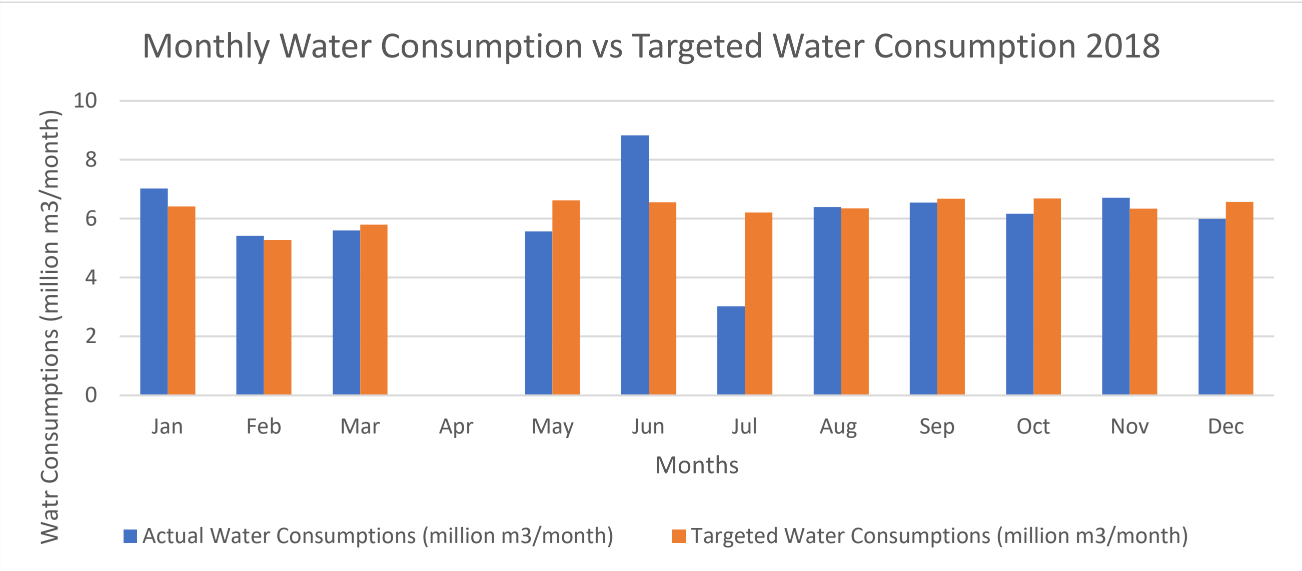

Figure 4.21: Monthly water consumption versus targeted consumption in 2018

The municipality lodged a water-saving campaign during 2018, as it had experienced serious water losses over the previous two years. Table 4.11 provides a summary of the water losses per month for the years 2016 to 2018.

From the data in Table 4.11, the conclusion can be drawn that the water-saving campaign of the municipality bore fruit, as the water losses seem to have decreased in 2018. A matter of concern, however, is that the municipality as the provider had no data available on water losses available during some months.

Table 4.11: Data on Water losses/savings data from 2016 to 2018 for Bloemfontein

Key: (-) indicate a loss

No (-) indicate a saving

Month	Losses/Savings Year 2016 (million m3/month)	Losses/Savings Year 2017 (million m3/month)	Losses/ Savings Year 2018 (million m3/month)
January	No data	-0,35	-0,60
February	0,41	-1,43	-0,14
March	-0,05	-0,03	0,20
April	No data	-0,51	No data
May	-0,01	0,47	1,04
June	-0,35	-2,35	-2,27
July	-1,84	1,88	3,18
August	-0,37	-0,30	-0,05
September	-0,64	-0,25	0,13
October	0,13	O,21	0,52
November	-0,13	-0,75	-0,37
December	-0,42	0,02	0,58
TOTAL	**-3,27**	**-3,57**	**2,22**

4.5 EVALUATION OF THE IMPLEMENTATION OF DISASTER RISK MANAGEMENT PLAN MEASURES

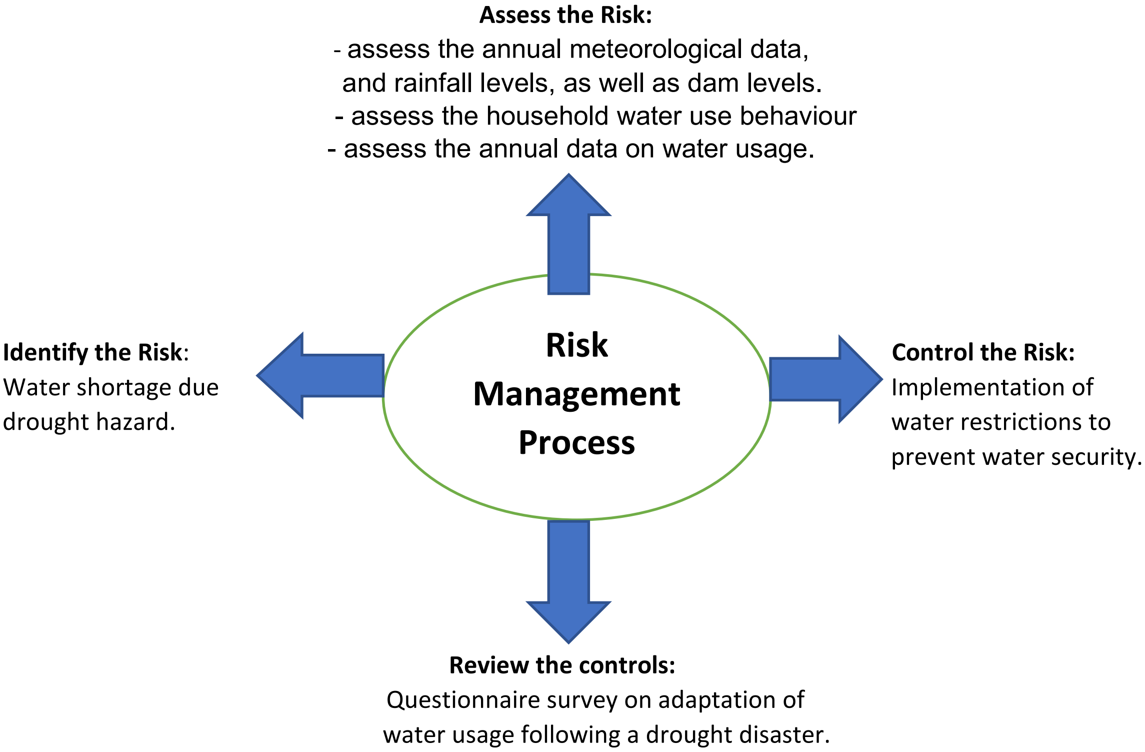

Figure 4.22: Risk management process as stipulated in the Disaster Risk Management Plan of Mangaung Metropolitan Municipality.

The Disaster Risk Management Plan was implemented as areas that were experiencing hazards such as drought were identified, and measures taken were the implementation of general water restrictions to help prevent water insecurity and alleviate the impact of drought on water availability.

The average annual maximum and average annual minimum temperatures showed to have increased over the three years of the study as follows: the yearly average maximum temperatures for 2016, 2017, and 2018 were 26,4°C, 26,5°C, and 26,4°C respectively and the average minimum temperatures in 2016 was 9,5°C, in 2017 it was 9,0°C, and in 2018 it was 9,2 °C. This increases of the temperatures compared to previous years showed that there was a drought impact in the city of Bloemfontein during the study period.

The results of the annual dam water levels showed the following: average annual water levels was 24% for 2016, 34,1% for 2017, and 34% for 2018 for the Rustfontein

Dam; average annual water level was 10% for 2016, 22% for 2017, and 27% for 2018 for the Welbedacht Dam and average annual water levels was 35,7% for 2016, 46,9% for 2017, and 67,7% for 2018 respectively for the Knellpoort Dam, thus the increases indicated that the implementation of the water restrictions by the municipality were effective to prevent water insecurity in the area.

However, the questionnaire survey with the participants' responses in the indicated that the Mangaung Metropolitan Municipality Disaster Risk Management Plan's aim to establish communication mechanisms externally was not properly addressed as many of them were unaware of the water restrictions implemented in the area.

4.6 CONCLUSION

The data provided in this chapter will be applied to determine the effects of a serious drought on community members, and whether they would be able to adapt to using water sparingly. Quantitative data on temperatures, rainfall, and dam levels were collected through an analysis of documents received from the Mangaung Municipality, and quantitative data comprising demographics, the use of water, and ideas on saving water were obtained from a questionnaire survey conducted among community members.

The findings provided above will be used to determine whether the objectives of the study have been attained, and to achieve the aim of the study, namely, to determine the impact of the recent droughts on the availability of water and the adaptation of the community toward water restrictions.

Chapter 5

Discussion

5.1 Introduction

This chapter outlines the discussion of the main findings of the data analysis elucidated in the previous chapter. The literature is also used to establish links with the outcomes of the research study where applicable. The study seeks to assess the adaptation of the Mangaung community to the drought effects and how participants adapt to using water sparingly.

The objectives of the study were to determine the impact of drought on the Bloemfontein area by (i) assessing the annual meteorological data, rainfall levels, and the dam levels in Bloemfontein during the period from 2016 to 2018; (ii) assessing the household water use behaviour of the Bloemfontein community members after the implementation of water restrictions; (iii) assessing the annual data of water-use in Bloemfontein during the period from 2016 to 2018 and (iv) To evaluate the implementation of the Disaster Risk Management Plan that is currently in place in the Mangaung Metropolitan Municipality governing the Bloemfontein area.

Rainfall in South Africa is characterized by unequal distribution and accessibility, leading to unsustainable water use. The Regional Climate Change Model shows that there has been a decrease in rainfall in some regions of the country (Kahinda *et al*.,2010). Rainfall in the Free State area marked an east-west gradient of at least 1000 mm annually. From this portion 700 mm was from the eastern part whereas 300 mm originated from the western part (DWAF, 2003). However, there has been insufficient rainfall which is attributed to the impact of droughts in Mangaung (Mangaung, 2019). Moreover, the average annual rainfall of 407 mm mostly occurred in summer (DWAF, 2003).

Mangaung receives 79 million m3/a total bulk water and about 37% of the total bulk water is lost due to water leakages, old water pipes, and illegal water usage (Reconciliation Strategy for Greater Bloemfontein, 2012). During the year 2015, the

South African government declared the Free State province a drought disaster area for the 2015/2016 hydrological year (Botai et al,2016).

Thus, due to the drought episodes and infrequent rains, water resources were unable to meet the population demands hence the city's Municipality had to implement water restrictions to limit and control water use. The Mangaung Metropolitan Municipality decided to implement water restrictions to secure a continuous supply of water according to Government Gazette No. 37421 of 2014 by the National Department of Water and Sanitation (Mangaung, 2019).

5.1.1 Biographical data

The findings of the data analysis are discussed according to the objectives of the study. To start the biographical results, depicted in Table 4.7 are provided as background. Table 4.7 shows that there were more males (n=83) than females (n=70) participants that completed the questionnaire during the survey. This may be due to the females running household errands during the day. Table 4.8 indicates that the majority of the participants were black people (n=114). According to Stats SA's survey, the vastest majority of the South African population is Black African at 80.7%, with 83.3% black Africans in Bloemfontein (Statistics South Africa, 2019). Some of the participants who took part in the study were matriculants and had a good knowledge of water scarcity matters.

5.2 Analysis of results

5.2.1 Objective 1: To determine the impact of drought on the Bloemfontein area

Figures 4.1, 4.2, and 4.3 depict the average yearly maximum and minimum temperatures in degrees Celsius (°C) for the Bloemfontein city per month. The average maximum temperatures for the years 2016, 2017, and 2018 were 26,4°C, 26,5°C, and 26,4°C respectively. It was found that high crop water needs result from high temperatures (Calzadilla, Zhu and Rehdanz, 2014). While the Water Research Commission has shown that South Africa has specific challenges regarding regional temperature trends because of a lack of well-maintained and accurate records of climate change observations (WRC,2018).

Research has established that the temperatures on earth can be impacted by the inconsistent energy levels that the sun radiates as shown in historic data (Lavorel *et al.*, 2019). There has also been a significant increase in the maximum temperatures for all the seasons in South Africa since the year 2010 (Botai *et al.*, 2016). Figures 4.1, 4.2 and 4.3 indicated that the average yearly minimum temperatures in degrees Celsius (°C) for Bloemfontein city for the years 2016 was 9,5°C, in 2017 it was 9,0°C, and in 2018 it was 9,2 °C. This may be because the central interior shows a cooling trend of the minimum temperatures during the winter months (WRC, 2018). It was also found that the minimum temperatures are becoming higher much quicker than the maximum temperatures (Kusangaya *et al.*, 2014). Statistically, there is no significant difference between the temperatures during the study period.

Bloemfontein city normally experiences an average annual maximum temperature of 23°C and an average annual minimum temperature of 8°C annually (Gandure, Walker and Botha, 2013). Therefore, according to the results of this study for the three years (2016-2018), the average annual maximum and average annual minimum temperatures were higher than normal. Thus, the increase of the temperature in the study period established that there was a drought impact in the Bloemfontein area due to an increase in temperatures.

Figures 4.4 indicate the average yearly rainfall in millimetres (mm) per month for Bloemfontein city for the years 2016 at 451 mm, 2017 at 500,8 mm, and 2018 at 478 mm. The South African Weather Service found that during May 2017, a cut-off low affected the country which was followed by a powerful cold front (SAWS,2017). This resulted in heavy rain and flooding, gale-force winds, and disruptive snow along the south and west coasts of the country.

The Water Research Commission's 2018 report stated that the rainfall of January and February provided some relief from the 2014 - 2016 drought, even though the renewable water sources of South Africa still were being overburdened (WRC;2018). The rainfall then showed a decrease in some months while June saw no rainfall at all in Bloemfontein these three years. The normal rainfall levels for Bloemfontein city for previous years were 500-600 mm (Gandure, Walker and Botha, 2013). Thus, it was shown that low rainfall defines a drought period (Shah, Bharadiya and Manekar, 2015).

Temperature changes result in changes in rainfall patterns, this may be because during the autumn months the rain days and rainfall figures had shown significant decreases, ensuing in a shorter wet season (Kusangaya *et al.*, 2014). Evidence has shown that the Southern Free State had extreme rainfall increases by 2010 but with some parts of the province experiencing prolonged dry spells as reported by (Botai *et al*.,2016).

The rainfall levels in Bloemfontein city are normally between 500-600 mm annually (Gandure, Walker and Botha, 2013). For the study period, the results show that the annual rainfall was less than the normal annual rainfall for the Bloemfontein area during 2016, 2017, and 2018. The low rainfall thus is indicative of a period of drought.

In Figures 4.5, 4.6, and 4.7 the average dam levels in terms of the volume of each dam in liters (L) are indicated for the Rustfontein, Welbedacht, and Knellpoort dams for the years 2016 to 2018. It should be noted that the Welbedacht dam has a greater capacity than the other dams and the Rustfontein Dam has the lowest capacity of all the dams. The Rustfontein Dam's average annual water levels were at 24% for 2016, 34,1% for 2017, and 34% for 2018. The Welbedacht Dam's average annual water level was 10% for 2016, 22% for 2017, and 27% for 2018. While the Knellpoort Dam's average annual water levels were 35,7% for 2016, 46,9% for 2017, and 67,7% for 2018 respectively.

The months of June and July showed low dam water levels because of less rainfall in winter. While Tables 4.4, 4.5, and 4.6 indicate the significant difference for the Rustfontein, Welbedacht, and Knellpoort dams from the years 2016 to 2018. The capacity for all the three dams over the study period was studied and presented a p-value of <0.0001, meaning there was a significant difference in the water level in the dams during the study period.

The Institute for Security Studies (2018) reported that the low level of rainfall recorded during the year 2015 had an impact on the dam levels of South Africa, reducing them from 93% to 48% during November 2016 and further stated that the dam levels started to pick up in early 2017 but declined in 2018 (ISS;2018).

As a result of the implemented water restrictions by the municipality of Bloemfontein, the average annual dam water levels increased in 2018 for the Rustfontein, Welbedacht, and Knellpoort dams supplying water to the city. Thus, it appears that community members have responded to the effects of drought by conserving water so that dam water levels can sustain available water for the community.

5.2.2 Objective 2: Household water use behaviour of the Bloemfontein community members

Most of the participants, namely 64% (n=98), who completed the survey said they practised some techniques to help save water in their households as shown in Figure 4.8. This might be an indication that the Bloemfontein community members were adhering to the municipal laws and regulations demanding households and industries to use water sparingly. The WHO recommends each person utilize a minimum of 50 L of water per day (Visser *et al.*, 2021). The use of greywater appeared to be a common water-saving technique used among 43% (n=64) of the participants, which indicated that was how they endeavoured to bring down their water use (see Figure 4.9). Globally the conservation of water resources has become an increasingly important matter which is widely researched (Dolnicar, Hurlimann and Grün, 2012; Olabanji *et al.* 2020). The challenge of water scarcity in cities was brought to our attention by the city of Cape Town's water problem (Visser *et al.*, 2021).

About 32% (n=49) of the participants had already started to save water about a decade ago, with the main reason for saving water being knowing about the national water crisis. Over four billion people worldwide are suffering from severe freshwater shortages, and this figure is predicted to climb (Visser *et al.*, 2021). While the other majority's reasons were due to the high municipal bills that they were receiving and had to pay, and others merely did so to comply with the water restrictions implemented and in response to the calls made on the news on tv and radio as shown in Figures 4.10 and 4.11. This demonstrates that at least some of the Bloemfontein community members had known about the impacts of drought on water availability even before the city was declared a drought disaster area in 2015 and had already started to use water sparingly.

Figure 4.12 indicates that implementation of water restrictions by the Municipality as a municipal instrument to decrease water usage had a major impact on how 23% (n=35) of the participants used water. This shows that only a few of the Bloemfontein community members regarded the impact of having water shortages as a crisis. It was also found that water usage records before and after the implementation of water restrictions were compared to identify the decrease in water use (Survis and Root, 2012; Olabanji *et al.* 2020).

In Figure 4.13 it was shown that 42% (n=64) of the participants who completed the questionnaire indicated that they had washed their cars by using a bucket as a water-saving measure as indicated in Figure 4.9. Other water-saving measures were also used such as sharing bathwater, using basins to bath, and closing running taps. These Bloemfontein community members were upholding the water use restrictions as instructed by the municipality to ensure the continuous supply of water in the area. This finding is in agreement with Dolnica *et al.* (2012)'s study which shows that it has become increasingly important to conserve water resources globally.

Only a few of the participants 2% (n=3) did not make use of the municipal water supply but used other water sources other than the municipal water supplied such as borehole water, communal taps, and natural sources of water including surface water and rainwater (see Figure 4.14). These residents may be part of the Bloemfontein community who settled in restricted areas in the city and therefore did not have municipal water connections. The majority of the Bloemfontein community, however, uses the municipal water supply system that is monitored regularly. This means that the municipality can regulate water use in the area much more effectively. Such regulation of water usage is extremely important. The reason is that natural hazards, such as drought, extremely high temperatures, and a decrease in rainfall were found to have an impact on water availability (Boholm and Prutzer, 2017) and it was established that water supplies may take weeks, months, or even years to recover, following a drought period (Wickham *et al.*, 2019).

Less than half of the participants 30% (n=46) seemed to have been affected by municipal water restrictions, while 42% (n=64) of the participants were unaware of the municipal water restrictions as shown in Figure 4.15. Perhaps this lack of awareness could have been one of the reasons why participants did not limit their water use despite the restrictions. Dolnica *et al.* (2012) and Olabanji *et al.* (2020) suggested that water restrictions should be viewed as a solution that can be used for the short term. However, a study by Survis and Root (2012) investigated the reaction of the public to the implemented water restrictions in recent years and found them to be effective in conserving water. More studies need to be conducted on water restrictions as a mechanism to help combat serious water shortages.

5.2.3 Objective 3: To assess the annual data of water use in Bloemfontein from 2016 to 2018

In 2016 the water consumption recorded in the Bloemfontein area was 62,21 million m^3, while it was 73,2 million m^3 for 2017, and 72,85 million m^3 for 2018 respectively, as shown in Table 4.11. In the year 2016, less water was used because of the introduction of water restrictions by the municipality. The Bloemfontein community had started to use water sparingly as per the municipal instructions. During the year 2017 year, there was a huge increase of 0,92% (10,99 million m^3/month) in water used by the Bloemfontein community. In 2018 the water use was reduced again by 0,03% due to the measures implemented by the municipality such as placing more than a thousand posters all over the city for water conservation awareness and by increasing water tariffs (Report, 2018).

The water consumption of the Bloemfontein community exceeded the targeted water consumption for most of the years 2016, 2017, and 2018 years per month, as shown in Figures 4.19, 4.20, 4.21. However, there was a 23% saving in water consumed between 2016 and 2017 (Report, 2017). This may be the result of the Bloemfontein community members experiencing water cuts and receiving instructions from the municipality to use water sparingly.

It is also indicated that during 2018, the actual water consumption and the targeted water consumption differed profoundly, as the targeted water consumption was exceeded for the greater part of the year (see Figure 4.21). The Bloemfontein community members might have ignored or neglected to apply water-saving practices to keep water consumption low. No actual water consumption data were reported for April 2016 and no targeted water consumption was reported for April 2018. This might have been due to some disruptions as the municipality entered a new financial year, although this disruption surely should not have affected peoples' practices and behaviour in terms of water use.

Losses of water were experienced in Bloemfontein during the years 2016 and 2017, while in 2018 the city recorded water savings as shown in Table 4.9. These losses might have been due to the multitude of water of the pipe leaks and bursts pipes not being reported, or when reported, not being attended to and fixed (Report, 2018). There were no water losses and/or savings captured for January and April of 2016 as well as for April 2018. Even though these disruptions did not affect the operations and services of the municipality, no water target data were captured in April 2016 shown in Table 4.10.

Therefore, according to the results of the study, for the three years under investigation, the total annual water consumption, with 20% water restrictions for 2016, was below the targeted water consumption of 63 million m^3/annum. This may be ascribed to the Bloemfontein community members adhering to the municipal laws and regulations aimed at using water sparingly, as well as the strict implementation of the said water restrictions. The total annual water consumption, with 30% water restrictions for 2017, was also higher than the targeted water consumption of 61,3 million m^3/annum, while the total annual water consumption with 15% water restrictions for 2018, was lower than the target of 79 million m^3/annum set. It may be assumed that this was the result of the community members no longer adhering to the municipal laws and regulations for water restrictions and not applying water-saving techniques regularly.

Thus, the decrease in the water consumption from 2017 to 2018 during the study period, established that there was an improvement in the Bloemfontein community member's behaviour and that they adapted to drought impacts in the area.

5.2.4 Objective 4: To evaluate the implementation of the disaster risk management plan that is currently in place in the Mangaung Metropolitan Municipality governing the Bloemfontein area.

The Mangaung Metropolitan Municipality's 2017 Disaster Risk Management Plan was first developed on 1 April 2017 as per the Guidelines of Development and Structure of a Disaster Risk Management Plan (Disaster Management Act, 2002). This was to be implemented by the Head of the Disaster Risk Management Centre to be reviewed and updated by the Municipal Council annually. The plan is mainly meant for the Municipality to learn, initiate and exercise the principles outlined to promote and sustain a secure and robust environment for the community members in the area (Mangaung Metropolitan Municipality Disaster Risk Management Plan,2018).

The plan was devised to comply with Section 53 of the Disaster Management Act of 2002, which states that all Municipalities must have a Disaster Risk Management Plan in place (Disaster Management Act, 2002). The Mangaung Metropolitan Municipality Disaster Risk Management Plan was aimed at creating a disaster management framework for municipal actions to be in line with and comply with the demands of the Disaster Management Act of 2002. The Disaster Management Act of 2002 entails an integrated and coordinated disaster management policy, focusing on the prevention of and/or reduction of the risk disasters, mitigating the severity of disasters, ensuring preparedness for emergencies, and providing for rapid and effective response to disasters and post-disaster recovery (Disaster Management Act, 2002).

Objectives of the Mangaung Metropolitan Municipality Disaster Risk Management Plan are to anticipate the disasters that might occur within the area of the Council, identify communities that are at risk of disaster within the area of the Council, and identify measures that can be taken to decrease the vulnerability of disaster-prone areas are some of within the municipal boundaries. According to the plan, it is the vision of the Mangaung Metropolitan Municipality Disaster Risk Management Plan to practice the disaster risk management principles to ensure a safe and resilient environment for its residents. Furthermore, the municipality undertook to establish and maintain an all-inclusive integrated and effective disaster risk management programme for the Mangaung Metropolitan Municipal area to ensure effective and speedy response in the case of disasters and emergencies to the benefit of all communities (Mangaung Metropolitan Municipality Disaster Risk Management Plan, 2018).

This study provides proof that the Disaster Risk Management Plan is being implemented continuously as areas that are experiencing disasters including drought are identified and measures are taken in response, such as the implementation of general water restrictions to ensure continuous water provision, and thus reducing the risk of disaster for the community members (Mangaung Metropolitan Municipality Disaster Risk Management Plan, 2018). The participants' responses in the questionnaires survey indicated that the Mangaung Metropolitan Municipality Disaster Risk Management Plan's aim to establish communication mechanisms externally was not properly addressed as many of them were unaware of the water restrictions implemented in the area.

The emergency plans and procedures have been established as set out in the plan for the event of a disaster such as a drought, where water use is regularly monitored. The study thus establishes that The Mangaung Metropolitan Municipality Disaster Risk Management Plan is being implemented effectively in the Bloemfontein area (Mangaung Metropolitan Municipality Disaster Risk Management Plan, 2018).
In the final chapter of this research study, recommendations based on the findings of the study will be brought to the reader.

5.3 Conclusion

The community members have responded to the impacts of drought by conserving water so that dam water levels can be maintained for the community's use. They were also abiding by municipal laws and regulations requiring households and businesses to save water. In the Bloemfontein area, the Mangaung Metropolitan Municipality Disaster Risk Management Plan is being implemented efficiently.

Chapter 6

Recommendations and Conclusion

6.1 INTRODUCTION

In this final chapter of the research report, recommendations that ensued from the findings of the research are elucidated. It is trusted that these recommendations will make a contribution to alleviating the difficulties a drought brings to citizens and the local government. Droughts have an impact on the livelihoods of billions of people around the world who live in arid and drought-stricken areas (Solh and Ginkel, 2014). Countries in Africa, especially, are compelled to reduce their vulnerability to climate changes in the light of threatening scarcities of food. Therefore, the municipality and communities in the study area might carefully consider these recommendations for the future management of drought.

6.2 OBJECTIVE ACHIEVEMENTS:

To determine the impact of drought in the area, the study found that the maximum and minimum temperatures increased, the rainfall levels decreased but the dam water levels increased and sustained the community with the implementation of the water restrictions for the year 2016.

The household water uses of the community members in the area showed that perhaps due to the lack of awareness, some did not limit their water use during 2018. By assessing the annual water use data from 2016 to 2018, the study found that there was an improvement over the years in water use as the community members adapted to using water sparingly.

By analysing the area's Disaster Risk Management Plan, the study established that the plan is being successfully implemented as areas that are experiencing disasters including drought are identified and measures are taken in response, such as the implementation of general water restrictions to ensure continuous water provision, and thus reducing the risk of disaster for the community members

The study then concluded that the Bloemfontein community was adapting to the implementation of water restrictions by using water sparingly as the annual dam water levels increased and annual water use data levels decreased over the study period.

6.3 RECOMMENDATIONS

Founded on the findings of the research the following recommendations are made: - The Bloemfontein Metropolitan Municipality is recommended to:

- Adopt clear response strategies and policies to avoid adverse drought outcomes on the economy.
- Stimulate community-led adaptative initiatives through large-scale adaptation and recognition of the local impacts of climate change.
- Preparedness for a disaster requires planning and budgeting, currently, the Mangaung Municipality is under administration, and this must be addressed.
- Maintain drought management plans that support the building of economic and social security on national, regional, and local levels; and
- Refurbish meteorological departments by revising mission statements with regards to climate change, training, and agriculture.
- Conduct community awareness campaigns more regularly.
- Updated records of climate conditions and change observations should be archived.

Globally the conservation of water resources has become an increasingly important matter which is widely researched; therefore, the municipality should research and follow best practices to combat negative outcomes of drought in similar areas. The first step in this direction would be to ensure that well-maintained and accurate records of climate conditions and change observations are kept. The Mangaung Metropolitan Municipality must ensure that national directives are obliged and that the Disaster Risk-Management Plan is being implemented effectively in the Bloemfontein area.

As for the citizens and community of Bloemfontein, the recommendation is made to ensure that they are kept informed of the essentiality of using water sources sparingly. Actual water consumption data must be available, and community members should endeavour to report water pipe leaks and burst pipes immediately. To this end, the community must be made aware of the urgency to respond to the calls made on them

– on television, radio, and other means – to participate in the global fight for the conservation of water sources.

6.4 CONCLUSION

An extensive literature survey on drought and adaption can assist many countries and cities in terms of planning for drought events and dealing with its impacts on water availability. Great improvements in drought prediction capabilities have been observed over the past few decades in Africa. Across sub-Saharan Africa, varying degrees of effectiveness in terms of climate risk management is experienced. An African research network programme that involves researchers, meteorologists (with their respective departments), farmers, and local communities should be encouraged to participate in data collection.

South Africa has key contact departments, strategies, and plans that are in place and should be mobilized more efficiently. However, there is a lack of funding for these adaptative activities in many regions of the country. Useful knowledge, such as knowledge of water conservation activities, could also be shared with communities. Thus, further research should be conducted on drought prediction to mitigate its impact on societies.

In conclusion, a call should be made on schools, colleges, universities, and other institutions to take up the challenge to become involved in water conservation efforts to safeguard communities from the consequences of drought. The youth of South Africa is our future, but there will be no future if there is no water available for use.

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Appendices

Appendix 1: Consent form

Date: December 2018

Re: Consent to participate in a research project

Study title: Adaptation of the community to the impact of drought on water availability in Bloemfontein, Free State Province, South Africa.

I ________________________________ am knowledgeable on the study, I know the importance of the study.

I have been granted an opportunity to complete the questions about the study and have answered to my satisfaction.

I consent that my participation in this study is voluntary and that I may refuse to answer at any time, moreover my answers will be confidential and will not be used with my identity.

Thank you for your participation.

_____________________ _____________________

Signature of Participant Date

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CSIR Project: Towards more effective instruments for demand side management of water in South Africa: A focus on urban household water use

Duration: April 2017 – March 2020

Project communication to stakeholders

Who are we?

The **CSIR** (Council for Scientific and Industrial Research) is one of South Africa's science councils. Our main campus is in Pretoria and we also have other offices across the country. The CSIR receives money from various institutions, companies and Parliament to conduct research. **The vision of the CSIR is to create a better future for all South Africans through science.**

What is this project about?

The project is to advance our understanding of household water use and water wise behaviour in six major South African metropolitan areas by, comparing actual household water use with perceived water use in different dwelling types (houses, flats, informal settlements) and, for a variety of indoor and outdoor activities. The metropolitan municipalities are: City of Cape Town, City of Joburg, City of Tshwane, Ekurhuleni, eThekwini, and Mangaung. The project team will, furthermore, collate individual perceptions on the most effective water-wise behaviour as well as the main drivers influencing household water use behavioural change. Additionally, the project will also identify past or existing water-wise/public awareness/save water/demand management interventions implemented by a range of institutions and assess their impact in changing water use behaviour, or not, over a three-year period.

In the first year of the project, the project team will do a research screening and scoping of household water consumption per metropolitan municipality. We will follow this with phase two in year 2 (2018/19) with our data collection endeavours including a household survey in all the metropolitan municipalities, interviews with national and local government officials, and conduct our first or preliminary data analysis. In this year, we will cross-validate the data through focus groups and stakeholder workshops. Through these activities, we will be able to co-create solutions towards more permanent water demand management measures at metropolitan level. During the final two phases, we will conduct further data processing and analysis and develop an integrated model of household water use and probable solutions in curbing excessive use.

How can stakeholders benefit from this research?

We hope that we can help our stakeholders and residents to better understand household water use at local government level and the measures they could take to curb excessive household water use by designing more informed policies and more nuanced household water use practices. We also hope to contribute to strengthening existing efforts to curb excessive household water use and overcome water demand management-related challenges in the project's case study areas by working closely together with the stakeholders we will be engaging.

What will happen to the information you give us?

All information gathered during this research will be confidential and used only for research purposes. We will not share it with anyone else and it will be stored in a way that protects your identity. Results from the study will be reported as group data and will not identify you in any way.

How can you contact us?

Please direct any project specific questions to Dr Inga Jacobs-Mata (project leader).
Email address: ijacobsmata@csir.co.za
Phone number: 012 841 4134

Towards more effective instruments for demand side management of water in South Africa: A focus on urban household water use
Council for Scientific and Industrial Research
University of Pretoria

SURVEY

Control information	
Team number:	**Interview number:**
Interviewer names:	
Suburb:	**Municipality:**
Sex of person interviewed (please circle): M/F/Other/Unsure	**Race of person interviewed (please circle): Black/White/Coloured/Indian/Other**

Date			Result	Results code	Time Beg	Time End
DD	MM	YYYY		1. Complete		
				2. Partial		
				3. Refused		
				4. No one currently at home/residents temporarily absent		
				5. Uninhabited house		

The highest level of education obtained. Tick one option only.	
Completed junior primary school (Gr 3)	
Completed senior primary school (Gr 7)	
Completed Gr 10	
Completed high school (Gr 12)	
Completed undergraduate degree	
Completed TVET and/or other college	
Completed postgraduate degree	
No schooling	
Don't know	
Refuse to answer	

SECTION 1 – WATER SAVING PRACTICES

1. Does your household implement any water saving techniques (i.e. try to save water)? Tick only one option.

☐ Yes, many ☐ Yes, some
☐ Not really ☐ No, none

2. What does your household do to save water?

3. When did you start to save water? Tick only one option.

☐ More than 10 years ago ☐ About 5 to 10 years ago
☐ 2 to 5 years ago ☐ Less than 2 years ago
☐ We have not really started to save water, yet

4. What was the main trigger to start saving water in your household?

SECTION 2: WATER USE PERCEPTIONS

5. Please rank the following municipal instruments from 1 (being most effective) to 7 (being least effective) that would cause your household to reduce future municipal water use:	**Ranking out of 7**
General water restrictions	
Assistance to implement water-saving measures (e.g., constant flow regulators, smart metering, water-saving shower heads, etc.)	
Assistance to implement water-sensitive design measures (e.g., water harvesting, grey-water recycling, permeable paving, etc.)	
Tax incentives for reducing or limiting water use	
Water rate increases (simply increasing the cost of water to meet demand)	
Fines for increasing use or using water above a certain quantity	
Naming and shaming of our neighbourhood for increasing use or using water above a certain quantity	
Not applicable	

SECTION 3: PERCEIVED HOUSEHOLD WATER USE (PAST, PRESENT AND FUTURE)

6. How often do you wash your car or have your car washed? Tick only one option.

☐ Never ☐ Weekly
☐ Every fortnight (2 weeks) ☐ Once a month
☐ Every second month ☐ Twice a year

SECTION 4: WATER SOURCES

7. What is your main source of water for the following (tick only one per column):	**Other in-house domestic uses e.g. bathing, washing dishes and laundry?**	**Outdoor purposes e.g. for a swimming pool, ponds and fountains, gardening and washing cars?**	**Irrigation purposes i.e. a system to water your plants outside.**

Municipal water (metered water with indoor taps and/or taps on the property)			
Borehole water			
Communal tap			
Natural source of water (e.g., rainwater, river/stream, fountain or dam)			
Other (Please specify……………………………….)			

SECTION 5: WATER RESTRICTIONS AND REGULATIONS

8. When was the last time your municipality implemented municipal water restrictions in your neighbourhood? Tick only one option.

☐ There have never been municipal water restrictions in my neighbourhood, or at least none in the last 12 months

☐ Municipal water restrictions are currently in place in my neighbourhood!

☐ The last time was more-or-less…………………………………. [month and year]

☐ Not sure

9. How did you primarily hear/find out about the last time your municipality implemented municipal water restrictions in your neighbourhood? Tick all applicable boxes and circle the one that was the most effective in creating awareness/conveying the message to you.	**Tick all applicable boxes**
Municipal - printed bill/pamphlet/notice	
Municipal - email message	
Municipal – website	
Management agency/body corporate/residents' association - printed pamphlet/notice	
Management agency/body corporate/residents' association - email message	
Management agency/body corporate/residents' association - website	
Printed newspaper	
Online newspaper	
Radio	
Television	
Social media (e.g., Facebook, Twitter, WhatsApp group, etc.)	
Word-of-mouth (e.g., talking to family, friends, or neighbours, etc.)	
Other (Please specify……………………………….)	
Don't know	

10. How would you primarily prefer to hear/find out about future municipal water restrictions in your neighbourhood? Tick all applicable boxes.	**Tick all applicable boxes**
Municipal - printed bill/pamphlet/notice	
Municipal - email message	
Municipal – website	

Management agency/body corporate/residents' association - printed pamphlet/notice	
Management agency/body corporate/residents' association - email message	
Management agency/body corporate/residents' association - website	
Printed newspaper	
Online newspaper	
Radio	
Television	
Social media (e.g., Facebook, Twitter, WhatsApp group, etc.)	
Word-of-mouth (e.g., talking to family, friends, or neighbours, etc.)	
Other (Please specify………………………………)	
Don't know	
Not applicable – I/we usually ignore municipal water restrictions	

Thank you for answering all these questions to help us understand the situation in your household. There are a few more last things to clarify.

SECTION 6: ACTUAL HOUSEHOLD WATER USE

11. How do you think **your water** bill compares to other households similar to your household in your area?

☐ Much lower ☐ Lower ☐ Similar ☐ Higher ☐ Much higher

☐Don't know ☐Refuse to answer

SECTION 7: SITUATIONAL FACTORS

12. What is your dwelling type (tick one option only)?	
Free standing house (on a separate stand or yard)	
Single-storey duplex	
Double-storey flats/housing complexes	
Multi-storey flats (more than 3 floors)	
Informal dwelling /shack	
Duet	
Residential (other) Please specify:……………………………………	
Don't know	
Refuse to answer	

13. Which of the following descriptions best resonates with the way you think society should be organised? Tick the most dominant belief you have.	
The best government is absolutely no government. Everything about governments is repressive and therefore must be abolished entirely.	
A single ruler should have control over every aspect of the government and of the people's lives. Everything should be carefully structured, including society. The law must be obeyed.	

The individual takes priority over society. Individuals have the right to make choices for themselves. No person is morally or politically superior to others. Hierarchies are rejected.	
Stability is a precious thing, and change must be made gradually in order to preserve it. Excessive freedom is bad, lets people ignore societal responsibilities and overlook social customs.	
Human beings are social by nature, and society should respect this. Individualism is poisonous. Society, not individuals, should own the property. The government plans the economy; there is no free market.	
Don't know	
Refused to answer	

14. What type of water meter is fitted to your municipal water inlet? – show image card with number to each picture and tick the most appropriate option.	
A	
B	
C	
D	
E	
F	
G	
H	
N - None of the above	
Don't know	
Refused to answer	

THANK YOU FOR PARTICIPATING IN THIS SURVEY!