Towards developing a prediction model for managing river flood disasters in the SADC-region

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DECLARATION

I, Tichaona Muzuwa, hereby declare that: "Towards developing a prediction model for managing river flood disasters in the SADC-region" is my own work, that all sources used or quoted have been indicated and acknowledged by means of complete references and that this thesis was not previously submitted by me or any other person for degree purposes at this or any other university.

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Signature Date

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ABSTRACT

In the Southern African Development Community (SADC)-region, and elsewhere internationally, statistically floods are considered to affect more people, animals, the environment and cause more economic losses than any other hazard. According to the core values as expressed in Disaster Risk Management actions and studies there is need to be guided by beliefs that all possible steps should be taken to alleviate human suffering arising out of calamity and that those affected have a right to life with dignity and assistance. Within this context floods have to be mitigated through the use of both structural and non-structural measures.

As such, this thesis is aimed towards developing a prediction model for managing flood disasters in the SADC-region specifically the Southern sub-region. The main research objective was to identify which aspects or dimensions could be included in a flood prediction model to improve the functionality and efficiency of reducing river flood risks in the SADC-region. To achieve the objective, both theoretical and empirical scopes of research applied in the study. As far as the theoretical dimensions are concerned a conceptual, historical and contextual survey on the current and past management of river flood disasters in the SADC-region were conducted. Literature regarding flood prediction research, the use of flood prediction models worldwide and how some of the prediction methods and research may serve as possible instruments to deal with the management of river floods in the SADC-region were also scrutinized for focus and guidance. Some models as identified include scientific and indigenous ways of predicting river floods that are discussed and exposed in the study.

To utilise, assess and in many ways complement the theoretical dimension of the study, a process of empirical research followed, though mostly through a qualitative method approach that involved data collecting from disaster experts and community leaders through recorded interviews. These were afterwards transcribed into written text. Community members were also identified from four SADC-countries and questionnaires used to gain information on their experiences of flood disasters, their expectations, how well they have managed and their opinions on how flood disasters should be managed. The rationale for the selection of these particular countries was mainly due to that they constitute much flooding in the region as indicated by statistics in some sections in chapters that follow.

Findings in the study, amongst others, revealed that flood disasters are continuing unabated in the SADC-region. The need therefore is to devise other flood prediction methods or improve on the current flood mitigation methods. As observed, the SADC-region is also making frantic efforts to mitigate flood effects but the methods currently used require improvement to be more effective. Also past scientific methods regards flood mitigation seems to be failing to efficiently and practically control flood disasters. Effectively combining scientific and indigenous knowledge methods of river flood predictions appears to be a better way to progress towards predicting floods, especially at local levels. Therefore literature on specifically indigenous knowledge application with regards to flood prediction in the SADC-region that were analysed, were utilised in consideration of existing scientific methods to develop a "Regional river flood prediction model". Further to that, there must be coordinated flood prediction institutions from a village or ward level up to national level. It was found that the model will not work successfully in isolation but will also have to be supported by other factors like flood legislation, political will, efficient governance, a support of knowledgeable institutions, sufficient infrastructure settings and community participation.

KEY WORDS

Disaster, Risk, Risk reduction, Prediction, Mitigation, River Floods, indigenous knowledge, Southern African Development Community (SADC)-region, Southern Africa, flood prediction models, Zambia, Zimbabwe, Botswana, South Africa.

ACRONYMS

ANN	**-**	Artificial Neural Network.
CBOs	**-**	Community Based Organization.
CCA	**-**	Climate Change Adaptation.
CDC	**-**	Centre for Disease Control.
CoGTA	**-**	Cooperative Governance and Traditional Affairs.
CPU	**-**	Civil Protection Unit.
DDF	**-**	District Development Fund.
DDMC	**-**	District Disaster Management Coordinators.
DMAF	**-**	Disaster Management Advisory Forums.
DMMU	**-**	Disaster Management and Mitigation Unit.
DMS	**-**	Department of Meteorological Services.
DRM	**-**	Disaster Risk Management.
DWA	**-**	Department of Water Affairs.
DWAF	**-**	Department of Water Affairs and Forestry.
EMA	**-**	Environmental Management Act.
EMA	**-**	Environmental Management Agency.
ENSO	**-**	El Nino Southern Oscillation.
EU	**-**	Europan Union.
FFI	**-**	Flood Forecasting Initiative.

FFRWS	**-**	Flood Forecasting Warning and Response System.
GFAS	**-**	Global Flood Alert System.
GFDS	**-**	Global Flood Detection System.
GFFMS	**-**	Galway Flow Forecasting and Modelling System.
GIS	**-**	Geographical Information Systems.
GPM	**-**	Global Precipitation Measurement.
GRACE	**-**	Gravity Recovery and Climate Experiment.
HFA	**-**	Hyogo Framework of Action.
HYCOS	**-**	Hydrological Cycle Observing System.
IDP	**-**	Integrated Development Plans.
IFRC	**-**	International Federation of the Red Cross.
IKS	**-**	Indigenous Knowledge Systems.
ITCZ	**-**	Inter-Tropical Convergence Zone.
KMD	**-**	Kenya Meteorological Department.
KMS	**-**	Kenya Meteorological Service.
NAC	**-**	National Aids Council.
NASA	**-**	National Aeronautics and Space Administration.
NCCC	**-**	National Climate Change Committee.
NCDM	**-**	National Committee on Disaster Management.
NDMO	**-**	National Disaster Management Office.

NDMTC	**-**	National Disaster Management Technical Committee.
NDRF	**-**	National Disaster Relief Fund.
NEMA	**-**	National Environmental Management Act.
NGOs	**-**	Non-governmental Organizations.
NOIKS	**-**	National Office on Indigenous Knowledge Systems.
NRF	**-**	National Research Foundation.
NRZ	**-**	National Railways of Zimbabwe.
RDA	**-**	Road Development Agency.
RFFA	**-**	Regional Flood Frequency Analysis.
SADC	**-**	Southern African Development Community.
SAWS	**-**	South African Weather Service.
SKS	**-**	Scientific Knowledge Systems
UN	**-**	United Nations.
WFP	**-**	World Food Programme.
WMO	**-**	World Meteorological Organization.
ZESA	**-**	Zimbabwe Electricity Supply Authority.
ZINWA	**-**	Zimbabwe National Water Authority.
ZRCS	**-**	Zimbabwe Red Cross Society.
ZVAC	**-**	Zambia Vulnerability Assessment Committee.

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CHAPTER ONE: OVERVIEW OF THE STUDY

1.1 Introduction

Trends in natural disasters the world over show that river flood disasters are the most recurrent and pose major impediments to the achievement of human security and sustainable socio-economic development (UNESCO, 2009:1). This can be witnessed in the most common disasters caused by the Indian Ocean tsunami in 2004, Hurricane Katrina in 2005, Cyclone Sidr in 2007, Cyclone Nargis in 2008, (UNESCO, 2009:1) and Hurricane Sandy in 2012 (Shreve & Kelman, 2014), Typhoon Haiyan in 2013 and in the Southern African Development Community (SADC) region floods affected countries like Zimbabwe and South Africa in 2013 (Kron, 2015:35). Accordingly, global changes in climate are increasing the risk of river floods in the SADC-region (SADC 2004:19). The SADC-region, as shown in Figure 1.1: A simplified map showing countries that form part of the SADC by 2016. comprises 15 countries, namely Angola, Botswana, Democratic Republic of Congo, Lesotho, Malawi, Seychelles, South Africa, Swaziland, Madagascar, Mauritius, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe (Abrahams *et al*., 2010:21).

River floods are influenced by a number of climate system characteristics, such as the intensity, duration and amount of precipitation and temperature patterns (Kundzewicz *et al.,* 2014:2). They are also impelled by drainage basin conditions (water levels in rivers and soil character) as well as status (permeability, soil moisture, content and vertical distribution), the rate of urbanization and the presence of dikes, dams and reservoirs (Bates *et al*., 2008:37). Member states therefore need to devote more time and attention to forecasting floods and risk mitigation through developing and implementing efficient and effective strategies.

In Chapter One, a research motivation for the study is exposed. A representation on the past and present status of river flood disasters in the SADC-region forms the key focus. The intention is to deliberate on research in literature from the distant past up to existing times to explain the reasoning behind having identified a shortcoming in the views on flood prediction and flood prediction models. Improving the functionality and efficiency of reducing river flood risks in the SADC-region is the key focus of this research. This is eventually done by means of a newly developed and introduced "Regional river flood prediction model".

To follow is a general orientation and background of the SADC-region in relation to its composition, purpose, flood disaster situation, management and some models used in flood forecasting all over the world. Discussing the problem statement is deliberated on using systematic, theoretical and empirical exploratory methods. By conversing the problem statement, the intention is to explore and set the scene for the study, after which the research questions and objectives are outlined. The content is presented through logically sequenced chapters to further clarify the order of the research. Discussions in Chapter One thus serve as a vehicle for the attainment of the research outcomes which are structured towards the development of a prediction model for managing river flood disasters in the SADC-region**.**

A hypothesis, research methodology, coupled with limitations and delimitations of the study as well as the importance of the study are broadly viewed. Provision has been made for some ethical considerations which are also outlined. A provisional chapter outline is also concisely outlined to guide the reader through the rest of the chapter discussions.

1.2 Orientation

This study focuses on research working towards the development of a prediction model for managing flood disasters in the Southern African Development Community (SADC)-region specifically the southern sub region. The mission of the SADC is to promote sustainable and equitable economic growth and socio-economic development through efficient productive systems, deeper cooperation and integration, good governance and durable peace and security, so that the region can emerge as a competitive and effective player in international relations and the world economy (Fisher & Ngoma, 2005:2).

The SADC-region has 15 major trans-boundary river basins, that is, water courses shared by two or more countries. They include the Congo River basin, the Zambezi

River basin which crosses eight SADC-states and the Umbelusi River basin in Mozambique and Swaziland (SADC-regional Water Policy, 2005:v). The Zambezi

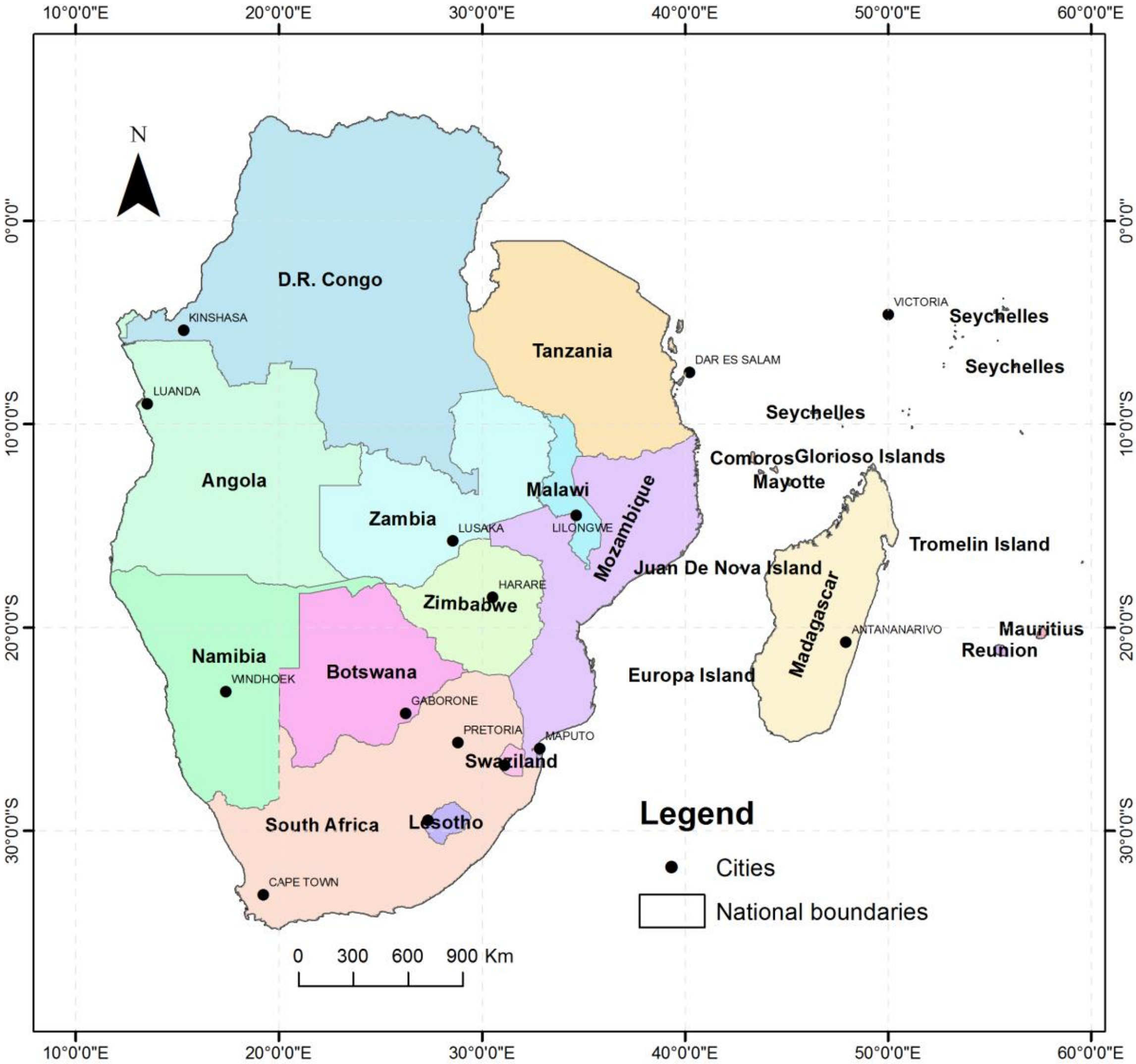

Figure 1.1: A simplified map showing countries that form part of the SADC by 2016.

Source: Authors depiction, January 2016.

River is the fourth largest river basin in Africa and also the largest river basin in the SADC-region. Its basin area extends through Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe (SADC, 2008:2).

River floods are said to be among the most common natural hazards on Earth. Over one billion people are at risk and thousands of people die in floods every year (Reilly, 2009:01). Reasons for this include climate change, deforestation, improper land use planning, inadequate structural and non-structural flood measures (Carmo vaz, 2000:15; Tingsanchali, 2012:25; Chisola, 2012:15). Increased frequency of floods is perceived to be resulting from global warming due to climate change (Wilby & Keenan, 2012:348; Braman *et al.*, 2013:144; Glantz, 2002:17). The incidence of flooding is projected to rise as the effects of global warming speed up the water cycle, causing more extreme storms, rainfall and flooding (Reilly, 2009:1).

A build-up of greenhouse gases resulting in changes in the atmosphere, hydrosphere and biosphere has been observed (Watson *et al.*, 1997:1; Wisner *et al.*, 2003:83). These changes have the effect of increasing the intensity and frequency of climate hazards and increase areas affected by them (Kuhle, 2003:443; Wisner *et al.*, 2003:83). Climate change provoked by global warming is predicted to increase the number and intensity of storms and cyclones, causing more river flooding in some areas, including the SADC-region (Manfred *et al*., 2003:166; Liverman, 1989:28-9; ESPON, 2013:6).

Southern Africa experiences drought and hydro-meteorological hazards which are the main causes of mortality and economic losses (Mulugeta *et al.*, 2007:4; Dilley *et al*., 2005:35). The rainfall season in most Southern African countries stretches from October to March (Chaguta, 2008:01). Flooding in Angola, for example, then affects rivers in Namibia and the Zambezi River in Zimbabwe and Zambia. Floods in northern Zambia also affect the Zambezi River in Zimbabwe and Mozambique. Rains from the Angolan Highlands flood the Okavango Delta in Botswana (Magole *et al.*, 2009:4). The Botswana floods are mainly caused by heavy rains in the country as well as flooding in the neighbouring countries (UNDP, 2012:15) during the rainy season from October to March (UNDP, 2012:10). It is also of value to note that rains falling in southeast Angola cause flooding in the downstream Caprivi area, affecting Namibia and Botswana (Botswana water account report, 2006:11). The Caprivi Strip is a narrow peninsula in Namibia that stretches east-west along the Zambezi River between Zambia and Botswana (Alexander & Hagen, 2010:71; Chase, 2007:78).

Climatic variability is a major problem for southern Africa, especially against the background that the majority of the communities are rural, rely on substance farming and dependent on a rain-fed agriculture. Significant proportions of farmland have been destroyed in the past through river flooding (Gwimbi, 2007:155). People lose lives, homes, roads, railway lines, electricity, water supply, sewage disposal systems and energy supply are damaged (Schneidergruber *et al*., 2004:8). According to Chaguta, (2008:1), flooding in parts of the region has claimed lives and destroyed property and infrastructure. Chaguta (2008:1) goes further to state that the La Nina or El Niňo effect is occasionally inducing rainfall in southern Africa. This phenomenon is characterised by a cooling of the temperature of the sea surface in the equatorial Pacific and has significant impacts on rainfall patterns in southern Africa and across the world. This impact has caused cyclones that affect SADC-countries like Mozambique, Madagascar, Zimbabwe and South Africa (Davis, 2011:9).

Even though low rainfall has been predicted during the 2015-2016 rain season, floods are still being expected in the SADC-region (OCHA, 2015:8) The region experiences normal to above normal rainfall, hand in hand with occasional cyclones across the region (Davis, 2011:9). There is a need for flood prediction, monitoring and alertness to the possibility of river floods. People in river flood risk areas need to be prepared for such eventualities. Effective disaster risk management rests on risk reduction (Lavell *et al.,* 2012:27; UNISDR Africa, 2012:8), of which river flood prediction appears to be a good starting point. A river flood prediction method that suits the southern African region is a need that has to be crafted and which may help in predicting floods in good time.

To undertake the research on developing a prediction model for managing river flood disasters in the SADC-region, four countries of the Region have been selected, namely South Africa, Zimbabwe, Zambia and Botswana. This is due to the fact that the Zambezi River Basin floods affect Zimbabwe, Zambia and Botswana (Zambezi Watercourse Commission, 2012:3). The Limpopo River also floods South Africa, Botswana and Zimbabwe (WMO, 2012:2; Spaliviero *et al.*, 2014:2027). These countries are border neighbours and carrying out a study on them would not only offer convenience to the researcher in terms of cost, time and distance to be covered, but the outcome of the research can also be easily made relevant to the rest of the SADC-countries, as these four countries represent about 26% of the 15 SADC-countries.

Disaster management and related professionals generally are in agreement that an increased focus on defining proactive approaches to disasters is urgently needed (ALNAP 2008:4; Lao People's Democratic Republic (PDR), 2014:v). In 2005, national representatives attending the World Conference on Disaster Risk Reduction in Hyogo, Japan, adopted a framework for action intended to build the disaster resilience of nations and communities. Among other recommendations the *"Hyogo Framework of Action (HFA)*" urged a paradigm shift towards a much greater focus on Disaster Risk Reduction (Hyogo Framework, 2005:2). The framework was well received and adopted by countries that implemented various DRR activities (Djalante *et al*., 2012:781). Among specific gaps in current disaster management approaches, specifically mentioned in the Framework, are risk identification, assessment, monitoring and early warning, along with the reduction of underlying risk factors and preparedness for effective response and recovery (Wilby & Keenan, 2012:349; Hyogo Framework, 2005:2).

However, the Hyogo Framework of Action (HFA) 2005-15 has been succeeded by the Sendai Framework for disaster risk reduction 2015 to 2030 which was adopted on 18 March 2015 in Sendai Japan. The framework continues with the work under the HFA, still with a strong emphasis on disaster risk reduction as opposed to disaster management (UNISDR, 2015:5). The Sendai framework has seven global targets which include the reduction of disaster risk as an expected outcome, preventing new risk, reducing existing risk and strengthening resilience. Set out are also guiding principles where states have primary responsibility to prevent and reduce disaster risk through engaging and the participation of all communities, State institutions and other stakeholders (UNISDR, 2015:5). Although not directly mentioned in the Frameworks, the element of disaster prediction is a very important precursor in disaster reduction activities. This is the subject of this study, which explored and attempted to develop a method towards flood prediction for specifically the SADC-region.

It is perceived that structural works in developed countries, intended to control floods, have failed to prevent them (Krysanova *et al.*, 2008:3; Manuta *et al.*, 2005:2; Clement, 2001). This has resulted in a paradigm to allow rivers to run freely and unconstrained by earthworks, embankments and concrete walls (Benjamin, 2008:49). What this means is that rivers should be allowed to flow freely in valleys and in the process restore flood plains (Benjamin, 2008:49). If this approach were to be adopted, flood prediction and the development of a regional river flood prediction model will be very important. From this paradigm and trends of discussions there appears to be a growing sense that flood disasters are caused by people and not water (Benjamin, 2008:49; Penning-Rowsell *et al.*, 2006:325). There is an increase to flood risk due to intensive and unplanned human settlements in flood prone areas (Di Baldassarre *et al.*, 2010:1). People tend to settle close to water, where the land is fertile, for transportation, industrial and agricultural needs (Fang, 2008:11). This means that people are staying and working in disaster prone areas which may be avoidable.

1.2.1 Prediction models used in and outside the SADC-region

The SADC-region uses some flood models. In Southern Africa several models are used for visualizing and monitoring floods. A few of the most prominent models are discussed like the SERVIR-Africa remote system (Macharia, 2010:1). Zambia, Zimbabwe, Botswana and South Africa are using the Regional Flood Frequency Analysis (RFFA) which uses the combination of the L-moments and the index-flood method (Haile, 2011:2). Jury and Lucio (2004:141) did research on the Mozambique floods of 2000 and developed a statistical model to enable the prediction of flood risk some months in advance.

Several flood prediction methods, which are concisely introduced further on, have been developed and are being used in a number of developed countries. These methods have some procedural and technical linkages to the ones used in the SADC-region. However, disaster prediction methods that are specifically crafted for the SADC-region, must also be further developed and enhanced. This is due to limitations, uncertainties and errors in flood prediction by some of the methods (Akbari *et al.*, 2012:73) which surface more clearly in the chapters to come. Apart from the contribution by researchers in academia, authorities (by means of professionals in their sevice) too have developed various prediction models.

SERVIR-Africa Remote System

Flooding in Southern Africa has a serious effect on socio-economic structures, infrastructure including loss of human life, livelihoods and displacement (Macharia, 2010:4). To enhance flood prediction activities, Southern Africa is using the SERVIR-Africa remote system. The SERVIR-Africa is a regional visualization and monitoring system for predicting floods (Macharia, 2010:1). Its focus is to have an integrated platform for data acquisition, sharing, use and service discovery (Thiemig, 2011:66). The process involves identification of both flood potential and flood area using remote sensed data and predictive models and field data based for the analysis of socio-economic and ecological conditions (Macharia, 2010:1). It's now possible to mitigate flood effects through flood prediction, using satellite rainfall analysis using time and space resolutions. The prediction requires indication of the timing (when), geographical area (where), water level and velocity as key variables. These indicators are monitored through satellite and ground observations (Macharia, 2010:6). This process of using remote sensed data is ideal for the flood prediction model developed in this study. Therefore, remote sensing was included as a way of gathering data for flood prediction (see Figure 8.1 in Chapter Eight).

Related to this model are other models used internationally like the, the Global Flood Detection System (FDS), a real-time flood management system that has been run by the National Aeronautics and Space Administration (NASA) since 2006. The system implements real-time based rainfall data along with topography, land cover and soil property data into the Natural Resources Conservation Service Curve Number model (Thiemig *et al.,* 2011:67). This model is simple, stable, easy to understand and apply and accounts for most of the runoff (Mishra *et al.,* 2012:1157). It uses real-time rainfall data in relation to soil type, land use, hydrologic condition, moisture condition, topographic, land cover and soil property data that is numerical and might be easy to get or collect (Mishra *et al*., 2012:1157).

Also linked to the SERVIR-Africa remote system are Gregoire and Kohl (1986:287) who developed a river flood prediction model in which space techniques can measure and collect data on the ground using data-collecting platforms and telecommunication techniques. The model also gives a dynamic description of ground surface characters on the river catchment areas, like vegetation cover, free surface water areas and swamps. The model helps in monitoring natural indicators of both rainfall and river water through remote sensing techniques. Overally the method integrates data transmission and remote sensing for river flood prediction.

Earth observation satellites are also used the world over and are related to the SERVIR-Africa remote system. Jeyaseelan (2004:291-2) states that space technology makes contributions to the management of flood disasters. The technology uses earth observation satellites that provide comprehensive coverage of large areas, both in real time and frequent intervals. Satellites continuously monitor atmospheric and surface parameters related to floods. Advances in remote sensing technology and geographical information systems also help in real-time monitoring.

Generally linked to the SERVIR-Africa remote system are advances in technology thats is giving rise to modern models in the field of applied hydrology by expanding the capabilities of data acquisition and analysis. There is remote sensing through the use of radar technologies, powerful computers that receive and handle data in a timely manner and software such as Geographical Information Systems (G.I.S) that link information with location. These modern tools maximize the benefits to be gained from forecasting under severe weather conditions (Fang, 2008:15). These modern methods among many may also be usable in the SADC-region, as they use modern technology like remote sensing and G.I.S. that aggregate all the sources of information and produce disaster risk maps (Głosińska & Lechowski, 2013:120). Other advantages of GIS include low or no acquisition and mapping costs, and the ability to map over large and inaccessible regions (Ireland *et al.*, 2015:3373). The use of technologies was critical in the development of the flood prediction in this study (see Figure 8.1 in Chapter Eight).

<u>Regional Flood Frequency Analysis (RFFA)</u>

Southern Africa, including countries like Zambia, Zimbabwe, Botswana and South Africa, is using the Regional Flood Frequency Analysis (RFFA) which uses the combination of the L-moments and the index-flood method (Haile, 2011:2). The RFFA model is based on recorded observations from sites in a similar region and then a single form distribution is fitted to the pooled data. Flood frequency analysis estimates the magnitude of a flood. The approach is based on hydrologists trying to formalize people's experiences and ideas on how often floods of a given size occur at given places. This formalization involves establishing a network of gauging stations and then the recording of information. RFFA is practiced in a joint use of on-site and regional data. This method assumes that flood events at several sites in a region might have similar statistical characteristics. Part of this method was also included in the flood prediction model designed in this study. The important part would be that of setting on-site gauging stations at community level in areas that have a risk of river floods. Information obtained at these levels would then be used for flood predictions, specifically in affected areas (see Figure 8.1 in Chapter Eight).

There is also an international model known as the Flood forecasting system based on grid technologies, which is related to the Regional Flood Frequency Analysis (RFFA) discussed in this section. Hluchy *et al*. (2004:51) conducted a research on a prototype of flood forecasting system based on grid technologies. The research involved modelling and simulation of floods with the intention of making flood forecasts. Simulations involved intensive computing activities, using high performance computing along large areas along rivers. The use of high performance computers reduced the computational time of flood simulations. In the study, meteorological and hydrological simulations were integrated for accurate flood forecast.

The use of integrated hydrological and meteorological data or information is very critical in flood prediction, as the information can complement each other. The involvement of hydrologists and meteorologists has to be coordinated in such a way that, when the data they collect which is related to floods is integrated, it is expected that the produced flood forecast is efficient and effective. The flood prediction developed also emphasises that the two groups of professionals work together by collecting, sharing and having an integrated product that predicts river floods.

Statistical flood prediction models in Mozambique

Jury and Lucio (2004) conducted a research on the Mozambique floods of 2000 that were due to torrential rains influenced by cyclone Eline in February 2000. Even though Mozambique is not part of the studied countries, it is part of the study area, namely the SADC-region and therefore, flood prediction in that country motivates an interest in developing a flood prediction model for the SADC. The study made use of monthly and daily rainfall and information from global weather models to provide a background on the flood scenario. Rainfall data was collected from various data bases focusing on the summer season, December to March, when tropical cyclone flooding is prevalent. The analysis was done over a period of many years. The study by Jury and Lucio (2004) concluded that the El Nino Southern Oscillation (ENSO) phase and seasonal rainfall can be predicted reliably at more than three months lead time with statistical models and at less than three months lead time with numerical models. The value of this research is that it has been an indicator for the possibility of predicting floods in time to avoid flood disasters, provided that victims have faith in the predictions and early warning systems. What can be learned from this study is that flood prediction can be done using both statistical and numerical models. More so, that data was being collected from December to March, the same period that most of the countries in the SADC-region in general and the studied countries in particular also receive their rains.

The model by Jury and Lucio (2004) is related to other international models like the Unit Hydrograph Model created by Szöllösi-Nagy (2009:30). The model forecast looks at the identification of the expected occurrence of a specified hydrological event with respect to its actual time of occurrence, its quantitative measure and its reliability as conditioned by available past and present information. As the lead time of the forecast increases, so does the level of uncertainty. The longer the lead time, the less reliable the forecasts (Jayawardena, 2014:269).

The use of the Unit Hydrograph Model was also described by Dooge (1959:242) who stated that the model assumes that a river catchment acts on an input of effective precipitation in a linear and time-invariant manner to produce an output of direct storm runoff. In another observation, Dooge (1973:6) stated that the main purpose of the Unit Hydrograph Model is its use to predict the direct runoff due to any excess precipitation event which has not been used in the estimation of the unit hydrograph. This model is relevant to this study and the development of the SADC flood prediction model as it is designed to measure and predict the effects of any excess rain water. It is this excess runoff which mostly causes floods in the SADC-region and the studied countries. The idea of using statistical and numerical models was also considered or form part of the flood prediction model developed in Chapter Eight of this study. The flood prediction developed in this study also uses information on access rainfall to help predict river floods (see Figure 8.1 under scientific knowledge processing).

The flood forecasting initiative (FFI) is another major flood-forecasting initiative operated under the World Meteorological Organization (WMO) related to Statistical flood prediction models in Mozambique. It is a global network that was launched in 2003 and incorporates 58 countries and over 300 participants from national meteorological and hydrological services. The project analyses the strengths and weaknesses of the current flood forecasting systems in the member states. The network further endeavours to improve the flood forecasting and warning. This is done by improving the capacity of meteorological and hydrological services through joint and timely delivery of accurate flood predictions for decision-makers and communities. Although not yet in the SADC-region, the FFI has projects in the Nile River Basin and in Ghana. The project is identifying technical and administrative flood prediction challenges and is offering solutions (Thiemig, 2011:65-66).

Flood forecasting is a critical, very effective and relatively inexpensive non-structural flood control measure (Rao *et al.,* 2011:31). Flood forecast models have one thing in common, namely that all have been or are still being used in river flood prediction. Flood prediction models provide information to stakeholders (Masinde, 2012:2). Evaluation of real time forecasting methods shows that river routing models are more accurate than rainfall runoff models and rainfall runoff forecasts are more certain than rainfall forecasts (Benn *et al*., 2011:30). This indicates that some of the models are better than the others, therefore choosing the better methods like river routing would be helpful in predicting river floods in the SADC-region (Benn *et al*., 2011:30). Flood forecasting systems are also essential in the warning process (Werner & Van Dijk, 2005:1). The benefits of a relationship between indigenous knowledge and scientific knowledge forecasting systems can be accelerated, using ICTs in the flood prediction models (Masinde, 2012:1).

A major weaknesses of the existing international prediction methods is that they emphasize on macro and international level information (Masinde, 2012:1).

According to Moore *et al*. (2006:104) there is a need to develop models that forecast a location where there is a risk of flood damage. The use of mobile phones to disseminate location-based warnings to individuals who are threatened in an area needs some exploration (Davidson, 2011:28). The neutral network model which uses rainfall and water level information is capable of predicting accurately only within specific time limits, which makes it a challenge (Campolo *et al*., 1999:1191). Even if carefully calibrated, forecasting models are naturally uncertain (Benn *et al*., 2011:30). There are also problems of model configuration and calibration which requires improvement (Moore *et al.*, 2006:104). More flood prediction models need to be developed and calibrated by experts and configured into a system capable of running them efficiently (Benn *et al.,* 2011:30). The methods of gathering and analysing hydrologic data being used are traditional and the extensive field observations and calculations involved are time consuming. However, with the development of remote sensing and computer analysis techniques, it is hoped that traditional techniques will be improved with new methods of acquiring quantitative and qualitative flood hazard information (Rao *et al.,* 2011:31).

Forecasts must be satisfactorily accurate for communities to have confidence and respond when warned (WMO, 2013:7). Inaccurate forecasts compromise their credibility, leading to non-response (WMO, 2013:7). Chowdhury (2006:716) identified shortcomings in short-range flood forecasting and information dissemination which included lack of feedback from end-users and dissemination networks that were outdated. It is therefore important to note that information is power (Masinde, 2012:2). Ensuring access to localised and tailor made information on impending river floods by the local communities is one way of empowering them to mitigate flood effects (Masinde, 2012:2). Suitable community education programmes have to be created that assist in interpreting flood warning products (Davidson, 2011:28).

The uniqueness of the river floods problem in the SADC-region is found in the inadequacy and ineffectiveness of the region‘s preparedness to floods (Masinde, 2012:2). According to Masinde (2012:1) the main form of forecasts in the SADC-region is seasonal climate forecasts that are difficult to discern meaning at the local level. Forecasts also change from time to time, which can be confusing to the end user (Benn *et al*., 2011:30). Although suitable for the purpose, hydrological and hydraulic models used to predict river floods in the region are inflexible to change. There is an increasing need to develop flood forecasting systems that use data and models that are flexible to change (Werner & Van Dijk, 2005:1). Since the SADC-region holds a number of river catchment areas, hydrological modelling in large river catchments has complex challenges in collecting and handling of spatial and non-spatial data, such as rainfall and gauge-discharge data (Rao *et al.*, 2011:31). Existing flood forecasting systems are mostly developed for upstream catchment areas, whilst there are no sound forecasting systems for downstream catchment (Kar *et al.*, 2010:880). Better communication with upstream dam managers seems to be a necessity to notice any significant or excessive discharges on time (Manhique *et al.*, 2015:680).

Revisiting flood forecasting models go hand in hand with changing community needs. Communication systems in the most remote communities must be upgraded for timely communication of warnings (Davidson, 2011:28). Utilisation of disseminated information is loaded with challenges emanating from its unreliability and difficult interpretative nature, making it irrelevant at the local level (Masinde, 2012:2). Traditional media, such as radio, television and the internet have to be complemented by newer media, such as Facebook and Twitter (Davidson, 2011:28). Furthermore, the design and implementation of flood communication strategies normally ignore the affected communities who host crucial indigenous knowledge on flood prediction, their environment and indigenous coping mechanisms (Masinde, 2012:2). It is being realized that SK and IK complement each other (Masinde, 2012:3), therefore there are renewed effort towards promoting IKS and harnessing it with SKS (Mercer *et al*., 2010:216).

In reviewing these flood prediction models, some elements could be benchmarked and utilised in developing a comprehensive river flood prediction mechanism useful for disaster risk management for the SADC. As already being highlighted under each of them, some use basic information related to topographic features, soil type and land cover. Some emphasize on the need of effective data sharing and coordination and use numerical values. Moreso in other models the uses of technology like satellites, remote sensing and G.I.S. are applied. With enough finance, some of the technologies may be acquired and used to enhance river flood prediction. At the same time, the models expose a research gap in that none of them integrates the use of indigenous knowledge with scientifically gained knowledge, which seems to be a critical factor in enhancing river flood prediction in the SADC-region.

What is brought to people’s attention by the research is that there is increased focus on flood management in Africa. This shows a positive move, as there will be potential to significantly improved flood prediction in the region. That will only be if there is information on the work being undertaken by different stakeholders. Flood prediction will also succeed when there is effective and efficient coordination of work being done, knowledge and data sharing. Unfortunately, one drawback cited in this study, was a lack of coordination of research and implementation efforts, as there are many different institutions focusing on flood management. In the flood prediction developed in this study, the element of coordinating activities and stakeholders was identified as critical (see Figure 8.1 under coordination in Chapter Eight).

1.3 Problem statement

Before the advent of advanced technology for flood prediction and early warning systems, local communities worldwide used and predicted floods using indigenous methods passed on for generations (ISDR, 2008:iii). Indigenous knowledge is a body of knowledge acquired through experience by local people over time and passed down through generations (Mapara, 2009:140; Ocholla & Onyancha, 2005:247). When Africa was colonized, ”IKS started disappearing due to cultural repression, misrepresentations, misinterpretations and devaluation” (Shizha, 2013:3). Colonization transformed Africa's indigenous knowledge systems into their detriment (Jenjekwa, 2016:188). SKS criticized IKS as unscientific, untried and untested for education and social development (Shizha, 2013:4). Colonization made the IKS “alienated, irrelevant and constantly subverted by the new system” (Jenjekwa, 2016:188).

After gaining independence and faced by insistent technological and socio-economic problems, African countries now have a new thrust towards solving its problems based on the concept of “home grown solutions” (Jenjekwa, 2016:189). However Indigenous Knowledge is not yet that commonly used by communities, scientists, practitioners and policymakers (Hiwasaki, 2014:15). Even though local knowledge is still used on its own, integrating it with science may result in effective flood risk reduction (Hiwasaki, 2014:15). According to Mercer, (2009:214) a growing body of literature is now emphasizing the importance of integrating IKS and practice into development projects since the 1970s. In the 1980s, some forms of IKS came to being and were commonly accepted by scientists in agriculture, pharmacology, water Engineering and many other disciplines (Alexander, et al., 2011:477). Some communities in countries in the SADC-region use IKS for forecasting floods (Speranza, et al., 2010:297; Soropa, et al., 2015:1067). According to Mapara, (2009:140), generations of indigenous people have developed traditional ways of weather forecasting that help them predict the weather (Mapara, 2009:140). Communities rely on Indigenous Knowledge to predict weather through observation and monitoring the behaviour of animals, birds, plants and insects (Kijazi et al., 2013:275) and even through daily observation of river levels (Dekens, 2007:3). Such resilience by communities raises the question why science usually ignores (even though contentious) the indigenous knowledge of such populations, preferring to focus and use technocratic and scientific solutions to manage floods denying the historical and social dimensions of flood risk reduction (Mercer et al., 2007:251).Therefore the important role, that local knowledge and practices can play, in reducing flood risk must be seriously considered. The integration of Indigenous knowledge and western based knowledge creates flood mitigation solutions that are culturally acceptable to the society in stress (Puffer, 1995:1). Interaction between IK and SK can create an atmosphere for dialogue between local populations and flood risk professionals. This will help in designing flood mitigation projects that reflect people's aspirations and actively involve them. (Nyong et al., 2007:795). The value of indigenous knowledge, if integrated with modern knowledge systems, is that, it can help to alleviate poverty (Mwaura, 2008:9).

There are repeated instances of flooding that are putting various challenges on governments, as they keep on responding to the same people in the same affected areas each time. In South Africa, flood disasters annually occur in various parts of the country. Zambia suffers from flood disasters especially along the Zambezi River (Zambezi Water Commission, 2012:4). Namibia had disaster floods in the Caprivi strip in 2008 and Zimbabwe has had the same fate on several occasions, especially in the Muzarabani area (Gwimbi, 2007:73), while in Botswana's Okavango river basin seasonal flooding occurs from late August to October each year (Wolski *et al.,* 2006:2). These disasters seem to have the same pattern, whereby people continue staying in flood risk areas even after a catastrophic flood has occurred. Apart from river floods, the countries also suffer from flash floods (Chagutah, 2008).

There has been a great deal of resource wastage by governments and private relief agencies in disaster response (Wisner *et al.,* 2003). This means that there is a gap in disaster risk reduction measures being taken by governments in SADC-countries. There are many institutional river flood forecasting initiatives ongoing in Africa, but information about them is not easily accessible (Thiemig and Roo, 2010). Efforts were made in this research to get all the relevant information on such initiatives in Africa. This was one of the focuses of this study as it is presently a shortcoming. There is also urgency for improvement in the dissemination of existing river flood forecasts to the end user and the public (Thiemig and Roo, 2010). This implies that dissemination of information has been poor and therefore the need for improvement on this. Although all the flood research and models cited in this chapter have various constituences that may have been adopted and bench marked in the model developed in this study, the most important shortcoming in flood prediction models and research, is that none of them integrates the use of indigenous knowledge with scientifically gained knowledge, which seems to be a critical factor in enhancing river flood prediction in the SADC-region.

In a comprehensive disaster risk management scenario, that integrates IKS and SKS, river flood disaster problems would be dealt with once and for all without recurrence. Establishing a viable river flood prediction system for communities at risk is clearly required. A river flood forecast system must provide sufficient lead time for communities to respond. Increasing lead time increases the potential to lower the level of damages and loss of life. Forecasts must be sufficiently accurate to promote confidence so that communities will respond when warned. If forecasts are inaccurate, then the credibility of the programme will be questioned and no response actions will occur.

The main problem to be grappled within this study was that there seem to be no sufficient scientific knowledge cum IKS integrated river flood prediction models in the management of flood disasters in the SADC-region. The development of a revised or combined river flood prediction model from existing models, and inclusive of Indigenous Knowledge Systems for the SADC-region *per se* might serves as a pro-active point of departure to efficiently consider, record, manage and eventually reduce the effects of river flood disasters.

1.4 Research questions

Based on the aim of the study, which is to develop a flood prediction model that integrates both IKS and SKS to efficiently and effectively predict river floods in the SADC-region specifically the southern sub region, the main research question under discussion is:

Which IKS considerations and existing dimensions of scientific knowledge should be included in a flood prediction model to improve the functionality and efficiency of river flood predictions in the SADC-region, to reduce river flood risks?

Sub-questions that derive from the main research question are**:**

- What is the past and present status of river flood disasters in the SADC-region?
- What have the governments of the four SADC-countries under discussion (Zambia, Zimbabwe, Botswana, South Africa) done so far to mitigate the effects of river flood disasters occurring in the region?
- Have any specific prediction models as dimensions of knowledge been used in the SADC-region to help in river flood disaster risk reduction, and how can they serve as possible flood management instruments?
- To what extent has past research provided guidance in river flood prediction possibilities?
- What is the relevance of considering Indigenous Knowledge Systems (IKS) in river flood prediction possibilities?
- Are there any possibilities of working towards developing a river flood prediction model to serve as a feasible procedure in managing river flood risks?

1.5 Research objectives

From the research questions as outlined, the main research objective is to identify which IKS considerations and existing dimensions of knowledge should be included in a flood prediction model to improve the functionality and efficiency of river flood predictions in the SADC-region, to reduce river flood risks?

Sub-objectives that derive from the main research objective are:

- To investigate the past and present status of river flood disasters in the SADC-region.
- To find out what the governments of the countries under discussion (Zambia, Zimbabwe, Botswana, South Africa) have done to mitigate the effects of river flood disasters occurring in the SADC-region.
- To identify any specific prediction models as dimensions of knowledge been used in the SADC-region to help in river flood disaster risk reduction, and how can they serve as possible flood management instruments?
- To determine the extent to which research has provided guidance in river flood prediction possibilities.
- To investigate the relevance of considering Indigenous Knowledge Systems (IKS) in river flood prediction possibilities.
- To identify possibilities of working towards the development of a prediction model that could serve as a feasible procedure in managing river flood risks.

1.6 Central theoretical statement

The SADC-region lacks sufficient integrated, IKS-inclusive procedures and models for efficiently managing river flood prediction (Tshimanga & Hughes, 2014:1174). A boast of past prediction models, still frequently in use, could serve as a basis to work towards the development of a common prediction model in managing flood disaster risks in the SADC-region.

1.7 Methodology

The research methodology used comprised both a literature review and an empirical study.

1.7.1 Literature Review

During the study theoretical and empirical literature, such as books, journals, the Internet and other records on disaster risk reduction and river flood prediction models were reviewed, looking at both scientific and indigenous knowledge methods. Also included was a conceptual, contextual and historical survey on the presence and management of river flood disasters in the SADC-region specifically the southern sub region. River flood prediction theories were studied to develop a representative impression of how they have been used in Africa and elsewhere in the world, and to see if those from the developed countries have been used in Africa, in particular in the SADC.

Furthermore, literature on research done on the prediction of river flood disasters (successful and less successful) was reviewed. Some appear to believe that river floods can be predicted in the short, medium and long term, whilst others strongly question this possibility. Also important to review were river flood prediction models from other continents or areas. Problems with these models were identified and noted, as adopting such models might mean inheriting the problems. Though the theoretical approach towards eventually creating a model may appear ambitious, it is of value to build new thinking on a strong foundation of past efforts and knowledge. While the researcher acknowledges that it could not be possible to review all relevant data worldwide, it had been anticipated that the assembling and analysing of as much research in this field as possible would provide a representative and solid guide for developing a river flood prediction model that is efficient and effective for the SADC-region.

Amongst others, the following databases were consulted:

- THORPEX Interactive Grand Global Ensemble Database.
- Project spitfire – towards grid web service databases.
- Network Security Services (NSS) Database.
- Advanced Hydraulic Prediction Service.
- Environment Agency Database.
- Flood forecast in Cross grid project.
- Lots of water in flood forecast update.

- Complex Emergency Database.
- The International Disaster Database: Centre for Research Epidemiology of disasters.

Secondary sources (such as records) were examined at the four National Disaster Management Centres of Zambia, Zimbabwe, Botswana and South Africa.

1.7.2 Study population and sample

A population is a complete set of cases or group members from which a sample is taken (Saunders *et al.*, 2009:212). The SADC-region is made up of 15 countries. Four SADC-countries, namely Zambia, Zimbabwe, Botswana and South Africa were selected from the regional group from the southern sub region. The chosen countries have a high prevalence of river flood disasters and moreover are neighbouring countries, which made travelling and collection of data relatively easy and achievable. Within the four studied countries, four National Disaster Managers were selected for structured interviews. However, in this group, there were additional respondents like climatologists/meteorologists and other private disaster management practitioners who were also interviewed during the data collection exercise. The number rose to eight respondents. All these respondents were selected as they are the most pivotal when it comes to disaster risk management issues in each country.

Another sample of eighty (80) community members, that is, 20 community members in each of the four countries under study were also targeted for data collection, using questionnaires. These community members were the group of people who were affected by the recurrence of river flood disasters from the year 2000 to 2013, within the selected studied countries. Further to that, there was also another group of 40 targeted people in the selected studied communities. The group was composed of government or private organisation community workers, or community leaders who worked and stayed in communities that experience floods. Data was collected from the group using interviews.

All the study groups in this research were accessible and assumed available for the research (Berg, 2001:29). The whole sample(s) was/were considered on the ground that respondents were either victims of recurring flood disasters or that they were employed to manage disasters. The data collected was assumed to be very credible. Responses were recorded on information related to their past and present experiences in flood river disasters.

1.7.3 Empirical study

In this section the various methods and activities used in collecting data in this study were explored.

1.7.3.1 Research design

The study used the descriptive survey design. Descriptive research is the process of describing the characteristics of any selected phenomenon (Bellis, 2003:436). The purpose of survey designs is to produce an accurate or real or factual representation of persons, events or situations (Saunders *et al.,* 2009:590). This study focused on "which" and "what" questions, making it mostly a descriptive study. This is reflected as indicated by the research questions of this study cited in section 6.2.1. Chapter Six. Guiding the study was the assumption that the study population and sample had historical experiences on floods and their management. Failure to have such historical experiences would render the data they gave invalid for this study. These experiences and the proposals made by experts and victims helped the researcher in crafting or developing a river flood model in Chapter Eight (see Figure 8.1 in Chapter Eight) that took into consideration the experiences, concerns and proposed ideas of those who are affected by and managing disasters. This created a sense of cooperation and ownership in the development of the river flood prediction model. Involving stakeholders will enhance the efficient and effective implementation of the model. The victims' and managers' experience and thoughts might also bring out other issues that could be areas for further research.

Disaster practitioners were asked about the status of river flood disasters, prediction models being used, what governments have done to help, any possibilities to serve as alternatives and suggestions for prediction models. Victims of river floods were asked about their experiences of flood disasters, their expectations, how well they have managed and their opinions on how flood disasters should be managed.

Although victims were not necessarily qualified to provide substantial information in efficiently addressing the problem of food river disasters, they were included in the research because victims are the first respondents to floods and they have their local ways of managing them.

The researcher also collected data from other community members who were professionals, community leaders/workers but were not part of a formal questionnaire process. All the selected interviewees were recorded as anecdotal information regarding their past and present experiences in river flood disasters. This data was critically utilised before being added to the formal data as part of the process to be community inclusive in the research process and findings.

1.7.3.2 Sampling

Sampling is defined as the collection of data from a sub-group than all possible cases or elements (Saunders *et al.,* 2009:210). A non-probability sampling approach was used in this study. According to Saunders *et al.,* (2009:213), non-probability sampling is the selection of elements using sampling techniques in which the probability of each case being selected from a population is not known. The methods of non-probability sampling that were used are convenience and purposive (see Section 6.5.1 and 6.5.2 in Chapter Six).

1.7.3.3 Data collection procedure

Data was collected from sample populations through structured questionnaires and structured interviews. This was done through interviews (see Appendix A and Chapter Six) with eight Professional Disaster Risk Experts in each of the selected countries, namely Zambia, Zimbabwe, Botswana and South Africa. This group comprised of national disaster managers, climatologists and meteorologists from national centres of the four SADC-states understudy. The researcher, with the support of research assistants, also visited one river flood disaster declared area in each country, namely Chanyanya in Zambia, Tokwe-Mukosi in Zimbabwe, Satau in Botswana and Tonga in South Africa. In these areas data was gathered using the questionnaires (see Appendix C) completed by 80 community members and also through interviews (Appendix B) with 40 civil servants and private relief or social workers who were based in the communities under study. In total, data was collected from a sample of 128 people, as indicated in Table 1.1: The study's respondents by country and group.

Table 1.1: The study's respondents by country and group

Country	**Interviews** Disaster Risk Experts	**Questionnaires** Community Members	**Interviews** Community Leaders/Workers	**TOTAL**
Zambia	3	20	10	**33**
Zimbabwe	2	20	10	**32**
Botswana	1	20	10	**31**
South Africa	2	20	10	**32**
TOTAL	**8**	**80**	**40**	**128**

Source: Authors depiction, January 2016

Involving communities affected by floods in this study was meant to eliminate a possible biased perception if information from only National Disaster Management Centre managers was considered. Collecting data from communities as victims of floods was another angle from which the research could benefit and was critical to arrive at more inclusive conclusions and recommendations. The everyday activities and experience of inhabitants as well as community leaders in flood disaster areas were required to obtain a more comprehensive view on flood risks and show how flood prediction models needed to consider and/or be inclusive of human experience and knowledge.

The research instruments were crafted so as to answer the research questions and address the research objectives. The questions were scientifically developed to secure scientific information but short and simple enough to understand. Both open- and closed-ended questions were used. Closed-ended questions were used to elicit views where it was felt that there was a limited set of possible responses. Open-ended questions were included to solicit the opinion of respondents where the range of possible responses could not be ascertained. This afforded respondents the opportunity to express their opinions. The research objectives given above had a number of questions addressing each of them (see Section 6.9 in Chapter Six).

1.7.3.4 Data analysis

Raw data was collected using structured recorded interviews and questionnaires. The data in questionnaires was in textual form and recorded interviews in voice form. Voice data was transcribed into textual form by a professional transcriber. The textual data from the transcriptions, field notes and questionnaires were cleaned and then stored in a folder in the researcher's computer. This was done to keep track of the data after collection. This also ensured access, use, systematic analysis and documentation of the data. Further to that, it would make it possible to verify the same study through replication, if there was any need (Berg, 2001:35) (see Section 6.12.2 of Chapter Six). Data analysis consisted of three concurrent processes of data reduction, data display, conclusions and verification (see Section 6.12.3 of Chapter Six).

1.8 Limitations of the study

The data collection exercise also had its limitations. It was not easy to quickly access the respondents because of processes the researcher had to go through to get authority to collect data. Some heads of sections were even afraid or hesitant to give such authority despite the fact that the student had a letter (see Appendix E) from the North-West University, stating that the researcher was a student who was doing research as part of his studies. This problem was faced both at national and community level. With patience the researcher succeed after following the required procedures.

In the communities, there were also cases where some participants saw themselves less knowledgeable and afraid to take part. They were left out even if they had very useful information as this exercise was solely voluntary. Some had a perception that the exercise was for purposes of food aid and other relief items. Once more, these participants did not volunteer to take part after realising that there was no food to gain. However, capable and information rich participants were identified through the help of the local leadership.

Another limitation in the communities was language barrier and accessibility. The researcher could not speak the local languages. As such, it was not easy to get reliable impressions of the respondents. Nevertheless, the problem was averted by engaging interpreters to assist making the study more costly. Transport was also a challenge as it was very limited to and from some of the villages. Despite the above limitations, the researcher is confident that the study generated data which made a valuable and significant contribution to disaster risk management in general and flood prediction in particular.

1.9 Delimitations

The study focused on four SADC-countries, namely Zambia, Zimbabwe, Botswana and South Africa. These four are connected with two or more boundaries and suffer from serious river floods. Information gathering was limited to National Disaster Management Centres, one specific area in each country that has had recurrence of serious river flood disasters. The study only focused on flood disasters in the studied countries, between 2000 and 2013. During that period a number of floods with serious impacts in terms of loss of life, damage to property and infrastructure and the environment had occurred in these countries. The period had justifiable data/information that could be considered in evaluating flood effects and management and in coming up with a flood prediction model for the region.

1.10 Significance of the study

Various specific stakeholders should find value in the study, such as:

1.10.1 Disaster managers

The outcome of the study should add value to the body of knowledge in the field of Disaster Risk Reduction. Effective prediction of river flood disasters will help in preventing or reducing loss of life and damage of the environment and structures.

1.10.2 Government

Disaster response is an expensive exercise compared to disaster risk reduction (Murtaza *et al.*, 2013:24; Miller, 2014:9), especially if one responds to river flood disasters every time they occur. The study helped government and other interested parties to reduce spending on responding to river flood disasters through flood risk reduction measures. Money saved and time spent on responding to disasters could be put to other good uses.

1.10.3 Communities

Communities are the victims of river flood disasters. They are also the first responders to flood situations. This study is informative on how communities can be involved in assisting to reduce the flood risk they face. They will need to adopt some of the recommendations in the study and use the flood prediction model that was developed with their input and suggestions. The study also encourages the use of Indigenous Knowledge Systems(IKS), which is deeply rooted within different communities, but seems to be easily ignored as of less value (Ruheza & Kilugwe, 2012:166).

1.10.4 Scientific community

The outcome of this study will make an important contribution of knowledge to the scientific community. A revised and refreshed angle of looking towards effective flood prediction in communities, inclusive of workable parts of available global flood prediction models and visible in the SADC-region, as well as integration of IKS considered in one model, could serve as a refreshed way forward of improving flood prediction.

1.10.5 SADC-countries

It is anticipated that the recommendations of the study will be applicable to most of the SADC-countries, and/or any other developing country that may experience similar river flood problems.

1.10.6 General

This study is inspired to enlighten and encourage SADC-countries to seriously recognise the usefulness of predicting river flood disasters. The implementation aspect is very important. The researcher has a vision of a future in which water-related disasters like river floods are predicted and effectively mitigated so that they do not impact negatively on the people's quality of life and the environment.

1.11 Ethical considerations

The intended research process was cleared by the Ethical Committee of the faculty of arts at the North-West University, Potchefstroom and an ethics number, NWU-00131-12-S0, was issued for this study. The researcher made use of four gate keepers. These are managers of the national disaster management centres of the four SADC-states under study. A letter seeking to carry out this study was sent to each of the selected countries (see Appendix E attached). In the studied communities Chanyanya, Tokwe-Mukosi, Satau and Tonga, authority to enter and gather data was also sought from various people and officials who included District Administrators, headmen and councillors.

As in any other field, researchers are bound by rules and regulations in the name of ethics. It was important that the researcher honoured the following ethical considerations in relation to this study (see Section 6.10 in Chapter Six). Failure might ruin the essence of the research project. The data is usually collected from third parties. It is these third parties that are critical and must be treated with due respect and humanity. If respondents are alienated, no data or information will be extracted, which can jeopardize the research endeavours. According to Leedy and Ormrod (2001), the following ethical considerations were paramount and strictly followed in this study, as reflected in sections 1.11.1 to 1.11.4.

1.11.1 Informed consent

- Research participants were told of the nature of the study to be conducted and were given the choice of participating or not.
- They were told that, if they agree to participate, they had the right to withdraw from the study at any time. Participation in the study was voluntary.
- All the respondents were asked to sign a consent letter for their participation (see Appendix D attached).

1.11.2 Right to privacy

- The study respected participants' right to privacy as no names were and will not be disclosed.

- The research report (oral or written) was not presented in such a way that others became aware of how a particular participant responded.

1.11.3 Honesty and integrity with professional colleagues

- Findings were reported in a complete and honest way, without misrepresenting what had been done, or intentionally misleading others as to the nature of findings.
- No data was fabricated to support a particular conclusion, no matter how noble it was.
- Appropriate credit was given where it was due. Any use of another person's idea or words was acknowledged. The above requirements are accentuated in:

  (people.uwec.edu/piercech/researchmethods/planning/ethicalissuesin-research.htm as accessed on 14/07/12)

- There will be a constructive effort made to inform professionals on the outcome of the research through workshops, conferences and journal articles. However, this is work in progress.

1.11.4 Community report back and acknowledgement

- Efforts were made to report back results of the study to the communities that had been involved in the data collection exercise. Their participation is also acknowledged in the study through a letter to their community leaders.
- The members of community and any respondent could at any point in time pull out of the research and that that would be respected.
- Data that was collected through interviews and questionnaires is stored by the researcher, the study leader and NWU authorities for five years.

1.12 Chapter outline

The study comprises of nine logically linked chapters influenced by the problem statement, and read in conjunction with the major research problem and articulated in the research questions and objectives. A research motivation on the past and present status of river flood disasters in the SADC-region is provided in Chapter

One. Highlighted in the chapter is the general orientation and background of the SADC-region in relation to flood disasters, management and models used in flood forecasting all over the world and the SADC-region. Stated also is the problem statement which explores and sets the scene for the study. Chapter two provides the conceptual and contextual survey on the presence and management of river flood disasters in the SADC-region. In this chapter the focus is on understanding the definitions that go hand in hand with river flood disasters. To follow is a contextual review on flood risk reduction in the studied countries, namely Zambia, Zimbabwe, Botswana and South Africa. An evaluation on what the governments of these countries have so far done to mitigate the effects of flood disasters is presented. Chapter Three makes a historically review on the occurrence and management of river flood disasters in the SADC-region. Chapter Four identifies existing literature regarding flood prediction research, the use of flood prediction models worldwide and how some of the prediction methods and research may serve as possible instruments to deal with the management of river floods in the SADC-region. The models used include scientific and indigenous ways of predicting river floods. It is these models that guided the writer to develop an improved, if not new river flood prediction model, for the region.

In Chapter Five the emphasis is on scientific and indigenous knowledge in flood prediction. The use of indigenous knowledge in the SADC-region, and in Africa and the rest of the world, is assessed. Success stories on its use are also highlighted in small island countries like Malaysia, Indonesia and Thailand. The realities and practicalities of integrating the indigenous and scientific bases were discussed.

Chapter Six provides the research methodology used in this study. The research focus is on applying the mixed method, the survey design, population, sample and sampling, data collection and instruments, validity and reliability of instruments and data analysis methods. Justification for using the various methods and challenges faced was provided.

In Chapter Seven the findings from a questionnaire and interviews, conducted among experts and affected communities, is discussed. The chapter looked at what governments have so far done to mitigate the effects of disasters in the SADC-region as interpreted from the data collection exercise (primary data). The respondents reflected on their flood disaster experiences and how they thought flood risk reduction could be improved. The chapter covered all the six research questions/objectives of the study.

It is in Chapter Eight that an integration of all the work done during the secondary and primary data collection stages ends as a kind of a climax in this chapter. The chapter takes us towards the development of a flood prediction model. The model has various constituencies mostly made up of the processes of integrating indigenous and scientific knowledge systems to come up with an effective flood prediction. The model also consists of institutional structures that have to be developed from the village level. Other support structures that include training, finance and politics, to name only a few, are also important in supporting an ideal flood prediction for a particular area. Chapter Nine is the closing chapter and engages with a critical integrative analysis on considering sufficient scientific and IKS-knowledge in developing a river flood prediction model for the management of flood disasters, such as in the SADC-region. Conclusions are made and some recommendations offered. An area for further research is also proposed.

1.13 Conclusion

In this chapter, a motivation for the importance of the research was provided. The main problem grappled within this study was that there seem to be no sufficient knowledge integrated river flood prediction models in the management of flood disasters in the SADC-region. The main research question dealt with was "Which IKS considerations and existing dimensions of knowledge should be included in a flood prediction model to improve the functionality and efficiency of river flood predictions in the SADC-region, to reduce river flood risks?" In response to the first objective of the study, a view on the past and present status of river flood disasters was introduced. A literature review showed that the SADC-region suffers from annual recurrent river flood disasters. The visibility and possible utility value of several flood prediction models worldwide form part of the discussion. Some flood prediction methods that are being used in a number of developed countries and the SADC-region were introduced. These methods had aspects that could be benchmarked for use in the SADC-region. Flood prediction models being used were discovered to have shortcomings and one of them is that they could not be locally used. The gaps identified in flood prediction models strengthened the need to develop a model that is fit for purpose in the SADC-region. There was also emphasis on the use of space technologies to enhance flood forecasts. By also considering and acknowledging Indigenous Knowledge Systems (IKS) in flood prediction in combination with the existing flood prediction models, applicable dimensions of IKS could be benchmarked and utilised to develop an approved and workable flood prediction model for the region. The research methodology of the study was mixed and the delimitation was on four countries, namely Zambia, Zimbabwe, Botswana and South Africa, covering the period 2000 to 2013. Limitations and the ethical dimensions used in the study were also highlighted.

In Chapter two an engagement with the conceptual and contextual survey on the current and past management of river flood disasters in the SADC-region is conducted. A comprehension of the concepts used and applied is critical in understanding what flood risk management is, in the context of this study. The contextual survey indicates the policies, structures and legal instruments that are being used in the studied countries' efforts to manage flood risk.

CHAPTER TWO: A CONCEPTUAL AND CONTEXTUAL REVIEW ON THE OCCURRENCE AND MANAGEMENT OF RIVER FLOOD DISASTERS IN THE SADC-REGION

2.1 Introduction

Since the world is being faced by increasing flood disaster problems, current flood risk management strategies have to be reviewed (De Bruijn, 2005:1). Despite increased flood events and an increase in risk due to population growth and economic development in flood-prone areas, many countries are organising flood risk management mostly around flood defences (Mens *et al.*, 2011:1121). However, modern flood risk management needs not only rely on flood defences, but has to consider measures to reduce vulnerability (Mens *et al.*, 2011:1121). Vulnerability can, amongst others, be reduced through effective flood prediction and by means of the development of a flood prediction model which is the rational of this thesis. River flood risk reduction becomes important in preventing or minimising loss of life and damage to areas of economic importance (Eludoyin *et al*. 2007:1). In flood risk reduction, there is use of systematic development and implementation of policies, plans and practices to prevent or mitigate negative impacts of disasters (Malalgoda, *et al.*, 2011:25).

In this chapter, a conceptual and contextual survey on the current and past management of river flood disasters in the SADC-region is conducted. This information corresponds with research question two which aims at understanding what governments of the four selected SADC-countries under discussion have done so far to mitigate the effects of river flood disasters occurring in the region. As already been alluded to in Chapter One the countries Zambia, Zimbabwe, Botswana and South Africa were selected, due to the fact that most of them are affected by floods, either from the Zambezi River Basin (Zambezi Watercourse Commission, 2012:3) or the Limpopo River Basin (WMO, 2012:2; Spaliviero *et al.*, 2014:2027). These countries are border neighbours and carrying out a study on them would not only offer convenience to the researcher in terms of cost, time and distance to be covered, but the outcome of the research can also be easily made relevant to the rest of the SADC-countries as they have a lot in common. In order to create a broader understanding of floods in these selected countries in the region, the conceptual and theoretical issues that will apply are discussed.

A survey is made on the context of floods as well as institutional and legal frameworks used in flood risk reduction by the countries sampled in this study. Discussions in this section help understand and identify disaster risk management gaps in the SADC-region. The discussion in this chapter is concluded by highlighting and analysing problems and needs of the studied countries in managing flood disaster risk. This chapter is regarded as of fundamental value to this research, as it not only provides the needed contextual background to river flood visibility, but also relates to important terms and concepts in disaster risk management and flood prediction that is utilised in the chapters to follow. It also touches on the necessity to develop a flood prediction model in the SADC-region.

2.2 A conceptual survey on the occurrence and management of River Flood Disasters

According to De Groeve and Introini (2014:3); Kundzewicz *et al.* (2014:3); Katarzyna *et al.* (2012:37); Lind *et al*., (2009:143) and Wilby and Keenan (2012:348), about half a billion people worldwide are affected by floods every year, costing the world a third of its humanitarian aid. Floods cause destruction of properties and loss of life and that is being aggravated by unguided development (Eludoyin *et al.,* 2007:274). According to Kundzewicz *et al.,* (2014:1), worldwide economic loss from floods has increased from the late 20th and early 21st centuries, due to the expanding exposure of assets to risk. Further to that, economic loss is also due to growth in populations and the amount of capital at risk (Wilby & Keenan, 2012:348). Due to these destructive challenges, floods together with human influences need to be controlled (Eludoyin *et al.*, 2007:274). On the same note, flood monitoring has been enhanced through the use of satellite remote sensing, meteorological and hydrological modelling (De Groeve & Introini, 2014:3). However, the challenge that is being faced is that these internationally speculated models that can forecast, measure, map and monitor floods for rapid estimation or forecasting of their potential impact have not yet been tested (De Groeve & Introini, 2014:3).

According to Kundzewicz *et al.,* (2014:3), fatal and destructive floods occurred globally in Pakistan, India and China Colombia in 2010 and Australia in 2010/11. In 2011, severe floods affected African countries like Mozambique, Namibia, South Africa and Uganda and also Brazil, Columbia, Mexico, the United States in the Americas, Cambodia, China, India, Korea, Pakistan, the Philippines and Thailand in Asia. In 2012, floods were also fatal in Madagascar, Niger and Nigeria in Africa, Bangladesh, China, India, North and South Korea, the Philippines and Russia in Asia, Argentina, United States and Haiti in the Americas. The highest population and percentage of economy exposed to floods worldwide is in Cambodia, Bangladesh and Vietnam (Kundzewicz *et al*., 2014:4).

From the period 1980 to 2011, flood losses increased from an average of US$7 billion per year in the 1980s to US$24 billion per year in 2001–2011 (Kundzewicz *et al.,* 2014:3). A public global database maintained by Brakenridge at the Dartmouth Flood Observatory indicates that the world had 3 713 floods during the period 1985 to 2010. This information indicates an alarming increase in the number of flood disasters on every continent (Jos van Alphen *et al.*, 2005). In Europe and Asia, floods seem to be the most costly natural hazard (Wilby & Keenan, 2012:348). Climate change in Europe appears to have enhanced the hydrological cycle, leading to increased flood risk (Manfred, 2003:166). In China, floods are causing considerable economic loss and serious damage to towns and farms (Wei Zhang *et al.,* 2011:1069). Scientists, policy makers and development practitioners also agree that climate change is bringing serious challenges to the development of African countries (AMCEN, 2011:ii). There is concern that climate change is influencing shifts in extreme weather events, exacerbating damages and reversing development gains (Wilby & Keenan, 2012:348). In Ghana, for example, there is a problem of recurring river flooding in low-lying areas, threatening livelihoods, causing loss of lives, damage to property and socio-economic dislocation (Dwamena *et al.,* 2011:186). Effective response, alignment with national and regional strategies for development, enhancement of human wellbeing and resilience to climate change are required for these challenges (AMCEN, 2011:ii).

Projected increases in the frequency and intensity of heavy rainfall worldwide will contribute to increases in flooding (Kundzewicz *et al.*, 2014:1). Flood disaster prevention and mitigation methods, like the one being developed in this study, have to be devised to contain flood risk. Community involvement, in disaster risk management, becomes critical in societies facing complex and uncertain flood risks (Stewart & Rashid, 2011:554). Grassroots action is also required as it provides local knowledge, communication networks and social capital needed to reduce vulnerability and collective response (Stewart & Rashid, 2011:554).

There is also urgency for a clear policy focus on dealing with vulnerability as a critical component of flood risk, since flood disasters are exceeding structural protection measures and standards that currently exist (Mens, 2011:1121). Exchange of information on research, developments, policy and management were proposed to enhance flood risk management if attended to immediately (Van Alphen *et al.,* 2005).

2.2.1 Understanding Disaster Risk Management related to floods

Flood hazards are very common and destructive and flood disasters are causing serious losses and social disruption yearly in many countries (Oruonye, 2012:37). This section tries to put into picture Disaster Risk Management (DRM) in the context of flood risk reduction. Some important concepts and words are defined, discussed and analysed. These words and concepts are disaster, flood, flood risk, vulnerability, capacity, mitigation and *"living with floods".*

2.2.1.1 Disaster

According to Corrales and Miquilena, (2008:6), and the UNDP, (2010:21), a disaster is "a serious disruption of the functioning of a community causing widespread development losses in terms of life or injury and setbacks in wellbeing, as well as destruction of key processes' outputs and endogenous capacities, which exceed the capabilities of the affected society or community to cope using its own resources". Others, like Dekens, (2007:x), Van Alphen *et al.,* (2005) and Mulugeta *et al*., (2007:4) also agree to this understanding. Some like Shafiq and Ahsan, (2013:61), in defining a disaster, saw it as an unforeseen occurrence.

The studied countries have also defined what a disaster is. In Zambia, a disaster is defined as "an event that is associated with the impact of a human induced or natural hazard, which causes a serious disruption in the functioning of a community or society, causing widespread human, material or environmental losses which exceeds the ability of the affected community or society to cope with the hazard using its own resources" (Zambia Disaster Management Act, 2010:77; Simwanda, 2001:3). In Zimbabwe, a disaster is "a natural disaster, major accident, disruption of essential services, destruction, pollution and scarcity of essential supplies, refugee influx, epidemic or disease that threaten the wellbeing and lives of people" (The Civil Protection Act, 2001). In South Africa, a disaster is defined as "a progressive or sudden, widespread or localised natural or human-caused occurrence which; causes or threatens to cause, death, injury or disease; damage to property, infrastructure or the environment; or disruption of the life of a community; and is of a magnitude that exceeds the ability of those affected by the disaster to cope with its effects using only their own resources (Disaster Management Act No. 57 of 2002)*".* In Botswana, a disaster is defined as "an event that seriously disrupts the normal pattern of activities in a given area as a result of interaction between a hazard and human population, that results in loss of life and property, injury and economic and social hardships, as well as possible destruction and damage to government systems, buildings, communication and essential services, that requires exceptional measures to be taken both from within the affected community and outside" (Botswana national Policy on Disaster Management, 1996:7).

An analysis of the above definitions identifies three important points on what constitutes a disaster. Firstly, there are potential threats to or injury or loss in terms of people's lives and property damage/loss; secondly, disruption of community and economic activities and thirdly failure by affected communities to cope or recover on their own without external help. In the context of this study, a disaster is defined as a severe change in the normal functioning of a community, due to a river flood interacting with community settlements, leading to widespread adverse human, material, economic or environmental effects that require immediate response and external support to satisfy critical human needs.

Of interest in the studied countries, is that for flood events to be recognised as disasters, they have to be declared at national level in all the studied countries, but in South Africa, declaration is also done at provincial and local level government structures. Reference on disaster declarations is provided for in Sections 27, 41 and 55 of the South African Disaster Management Act 57 of 2002, Section 27 of the Zimbabwe Civil protection Act 2001, Chapter 10:06, Section 36 of the Zambian Disaster Management Act no.13 of 2010 and Section 13 of the Botswana National Policy on Disaster Management, (1996:12) and Section 6.1 of the Botswana National Disaster Risk Reduction Strategy (2013-18:31).

In defining a flood disaster, Nott, (2006:54) points out that a flood event is not considered a natural hazard, unless there is a threat to human life and/or property. Mwape, (2009:21) supports the above statement when she says that floods constitute a hazard only where human encroachment into flood prone areas occurs. In Zambia, the Lozi (Barotse) people of the upper Zambezi wetlands in Western Zambia, shift from the flooded plains around March and April every year to upland homes avoiding floods that threaten their lives and property (Rabalao, 2010:24). When human activity characterized by buildings, roads, pipelines, crops, livestock and other land uses cross the path of forces of nature, flood disasters occur (USAID/OAS, 1997:1). People drown, livestock and crops become obliterated by floods and the level of damage increases with an increase in depth and duration (Elliot & Leggett, 2002:29). Flood disaster impacts also include injury, disease, negative effects on human physical, mental and social well-being (UNISDR, 2009:9). There is damage or destruction to property or assets, social and economic disruption and environmental degradation (Schneidergruber *et al*., 2004:8). In Zimbabwe, the Tokwe-Mukosi floods of 2014 had such a negative impact on victims' social capital, that it was difficult for some to gain social networks and acceptance. The people lost land and had to adapt and prepare their fields to suit their needs. Floods completely submerged homesteads and livelihood assets, such as cattle, chicken, sheep, pigs and goats were either killed or lost (Tarisayi, 2014:3). In January 2013, flooding due to heavy rains affected the Central Province of Botswana. At least 4 210 people were affected and also displaced. The rains and floods caused serious destruction to homes, roads, flooded dams, fields and destroyed livestock and livelihoods (Red Cross, 2013:1).

At times river floods become a disaster, not because of the site itself, but because of economic activity like flood control measures that shift surplus water problems elsewhere, or dams that collapse and cause floods downstream and deforestation which causes change of rate of flow of water into river systems (Cannon, 1990:2 Adebayo, 2014:449). Such activities which influence flood disaster risk are common in the studied countries and are dealt with under each country's environmental laws as discussed in Sections 2.3.4.3, 2.3.4.6, 2.3.4.9 and 2.3.4.12 of this chapter. It then follows that a disaster is a result of a combination of exposure to a hazard, in conditions of vulnerability and insufficient measures to reduce or cope with the potential negative consequences (UNISDR, 2009:9). Dams seem to be of concern only when they collapse. A case in point is the Tokwe–Mukosi Dam in Zimbabwe which collapsed in January/February 2014 and caused floods that affected 12 villages and was declared as a state of disaster by the government (Tarisayi, 2014:1).

A disaster can result in serious disruptions and retarded functioning of a community (Corrales & Miquilen, 2008:6). The flood impacts result in socio-economic impacts that include mass migration of people, food shortages, deterioration of water quality and sanitation facilities and increase in water borne diseases (Pawaringira *et al.,* 2007:7). Floods can also cause disruption of electrical services affecting communities, sometimes for over a number of days (Emergency Survival Programme, 2008:1). Further to that, floods damage agriculture lands (Fabiyi *et al.* 2012:7), disrupt communication and transport, wash away bridges and damage rail tracks and highways (Rabalao, 2010:22). In March 2014, some parts of South Africa were affected by floods in Limpopo, Mpumalanga, Northwest and Gauteng Provinces. In Limpopo Province, main roads, houses, farmland and tourist centres were damaged. Community members were evacuated to community halls, crèches and schools (Red Cross, 2014:1). River systems alter their course during floods, leading to disruption in transport, agriculture and urban land-use (Bryant, 1991:138). According to the World Bank Report (2001a) floods can result in malnutrition and famine, food imports, dependency on food aid and affecting the economic growth potential of affected countries. In Zambia the frequency of floods and heavy rains is a root cause of food insecurity in that country (Campbell *et al.,* 2010:17).

Children are the majority of casualties during floods as they are separated from their parents, get lost in crowds or are swept away (Rabalao, 2010:20). Women are also affected more than men as they lose earning capacity, worry about income, the future of their children and find it difficult to manage households in the absence of male support (Rabalao, 2010:21). In a study carried out in Zimbabwe by Tarisayi, (2014: 3) the Tokwe-Mukosi Basin floods were overwhelming and catastrophic on women with disabilities in particular.

The Centre for Disease Control (CDC) Fact Sheets, (2004-2005) observes that waste-water treatment plants, if flooded, will malfunction and can overload with polluted runoff waters and sewage beyond their disposal capacity, resulting into backflows of raw sewage to homes and low lying grounds. Lemeko, (2011:32) adds that private wells can also be contaminated or damaged severely by flood-waters, while private sewage disposal systems become a cause of infection and illness. According to Bwalya, (2010:4) in Zambia, sustainable livelihoods of communities, food and water security and water quality are affected by floods threatening the availability of food, safe water, good health and sanitation.

Lemeko, (2011:37) also noted that unclean drinking and washing water, bad sanitation caused by floods coupled with lack of adequate sewage treatment, can lead to disease outbreaks such as life-threatening cholera, typhoid and hepatitis. According to Chingombe *et al.,* (2014:5) there were heavy rains in 2007 in Muzarabani area, Zimbabwe. The rains resulted in severe floods affecting a number of villages. The areas became inaccessible by road as bridges were washed away or damaged. Thousands of people were rendered homeless and displaced. Compounding the flood's effects were hazards such as cholera, diarrhoea, food insecurity, malaria and dysentery which manifested and were recorded in the area. Some people died and others went missing. Households also lost their belongings after being washed away. Flood impacts extend to post flooding period and affect the very basis of livelihoods and make communities vulnerable to a vicious cycle of losses, lack of capacity and poverty (Vanneuville *et al.,* 2011).

Since it is impossible to completely eliminate the risk of flooding, severity can be substantially lessened by various strategies and actions and society has to be prepared when flood disasters come (UNISDR, 2009:19). According to Fabiyi *et al.,* (2012:7), continents of the world have suffered untold hardships from flood disasters.

Africa has suffered from a number of natural disasters with little capacities to manage the consequences (Fabiyi *et al.,* 2012:7). The UNEP, (2002:276) noted that the SADC-region is prone to natural and man-made disasters where large numbers of people or infrastructure are affected. Also the growth of informal settlements on flood zones is exposing many people at risk as families are living in shacks below flood lines subjecting them to flooding and cholera outbreaks (UNEP, 2002:276). Some communities live on informal settlements below flood Lines. The settlements are built along the banks of the Rivers and the communities is always affected by floods. Many homes are swept away and property damaged (Drimie and Van Zyl, 2005:24).

2.2.1.2 Hazard

A hazard is any event, phenomenon, or human activity that may cause loss (Mulugeta *et al*., 2007:4). It is also seen as a threat or potential for adverse effects and not the physical event itself (Lavell, 2012:32). Flood hazard in practical terms is the existence of more water than is wanted by a community at a particular place and time (Cannon, 1990:2). Floods become a hazard when humans settle in flood plains or sites near or where rivers flood (Cannon, 1990:2). This means that a hazard has an element of human involvement (OAS, 1991:30). In areas where there are no human interests, natural phenomena do not constitute hazards, nor do they result in disasters (OAS, 1991:30). Floods are a common hazard in Zambia, Zimbabwe, Botswana and South Africa. Flood statistics from 2000 to 2013 on the 4 studied countries (see table 3.5 in Chapter 3) show that floods affected 2 602 703 communities and even killed 515 people. This has a negative impact on peoples' livelihoods in the region in general and in the studied countries in particular.

2.2.1.3 Flood

Floods are classified in many types like river flood, flash flood, storm surge, ice-jam floods, dam and levee failure floods, landslide, debris and mudflow floods (Barredo, 2006:5). However this study focuses on river floods. Several researchers have put forward definitions of what a flood may conceptually imply. Accordingly, flooding is a natural and recurring event for a river as a result of heavy or continuous rainfall exceeding the absorptive capacity of soil and the flow capacity of rivers (Ali *et al.,* 2002:125: Barredo, 2006:5). Barredo, (2006:5) further defines a flood as water temporarily covering land not normally covered by water. During a flood, a river will overflow its banks with high velocity and enormous destructive surge (Eludoyin *et al.,* 2007:1). An important feature of a river flood is that land becomes saturated, exceeding the soil's capacity for water absorption. This produces increased overflow and runoff on land (Barredo, 2006:5), causing destruction and eroding quantities of content (Eludoyin *et al.,* 2007:1). Factors leading to river floods include a combination of the weather and soils conditions, measures for flood protection and land use (Barredo, 2006:5). More factors also include volume, intensity and duration of rains, the capacity of the water course or stream of network to convey runoff, ground cover and topology in a given area (Pawaringira, 2008:3).

The countries under study have river floods as one of the serious hazards. Some flood statistics on the studied countries Zambia, Zimbabwe, Botswana and South Africa are provided in Chapter 3, section 3.2. The countries have many rivers that cause floods nearly every year. This study looks at the Kafue River in Zambia, Tokwe River in Zimbabwe, Chobe River in Botswana and Komati River in South Africa. The topography of these rivers is highlighted Chapter Three.

However, some floods are not directly caused by rainfall, but by earthquakes, landslides or failure of dams and other control works (Chanson, 2005:437: Van den Honert and McAneney, 2011:1157). People also cause floods when they develop land with fertile soils on floodplains, despite the risk of losing property and life (Dekens, 2007:vi; Chingombe *et al*., 2014:8). Floods can also be as a result of backflow of water from dams or a flooding river (Chingombe *et al.,* 2014:8). A study by Chingombe *et al.,* (2014:8) in Chadereka community, Muzarabani, Zimbabwe has revealed that the area has recurring floods. Apart from floods being caused by the normal rainfall triggered by the tropical cyclones from the Indian Ocean and heavy tropical storms, damming at Cahora Bassa causes backflow of the discharge from the Hoya and Musengezi Rivers into the Zambezi River. The backflow in turn causes seasonal river floods in Chadereka village. However, floods are at times welcomed in many communities as they provide rich soil, water and a means of transport, but their unexpected scale with an excessive frequency causes damage to life, livelihoods and the environment (ALNAP, 2008:1).

After a review of the above flood definitions and concepts, this study is persuaded to define a flood as excessive river water that overflows its banks after heavy rains causing destruction of life and property. Floods will also include water overflowing, due to river or dam backflows or failure as a result of earthquakes or landslides causing destruction to people and the environment. The development of reliable flood prediction models becomes an important endeavour to help in preventing and mitigating flood risk. Accordingly the important issues on flood risk are discussed below.

2.2.1.4 Flood risk

A flood disaster is always preceded by physical and social conditions referred to as flood risk (Lavell, 2012:31). Of all disasters, flooding is the most significant in causing loss of life. Its severity has increased several times due to after effects such as disease and starvation (Alexander, 2006:211). In 2009, Botswana experienced serious floods when the Chobe and Okavango River were over flowing into low lying plains. The floods were made worse by natural reservoirs were full from the previous year floods. Many families were displaced and relocated to higher ground. Access roads to schools and clinics were submerged and people were trapped and failed to access them (Mosate, 2010).

The increased frequency and severity of floods are making flood risk reduction a top priority (Jha *et al.*, 2012:146). Rabalao, (2010:18) defines flood risk as the probability of a flood event to cause harm to people, the environment and economic activity. If the loss is measurable flood risk is quantified either in monetary units or loss of life. If not measurable flood risk is described according to its social, environmental or cultural impact (Pistrika & Tsakiris, 2007:5). Risk exists where there are threats of potentially damaging physical events (Lavell, 2012:31). Many researchers, like Kanchan Mishra, (2013:8), De Bruijn, (2005:17), Forster *et al.* (2007) cited in Kanchan Mishra, (2013:9) and De Bruijn, (2004:54) define floods risk as a product of a 'hazard', and 'vulnerability', where 'hazard' relates to the characteristics of the actual flooding and 'vulnerability' refers to the degree of exposure of people and assets to floods. It is only after one has identified and assessed the flood hazard, vulnerability and the people's coping capacity that the flood risk the people face may be determined (Wisner *et al*., 2007:334).

Flood risk also rises with an increased level of exposure of the elements under threat (Jha *et al*., 2012:179). According to Few, (2003:49) it seems that poverty and vulnerability to floods go hand in hand in developing countries. Generally poor people suffer more from floods than the wealthy. Few, (2003:49) goes on to state that poverty drives communities to settle and work in unsafe locations such as river banks in farming areas. It is the poor rural to urban migrants who settle on urban flood plains or flood prone areas as squatters (Wisner *et al.,* 2003:41). Squatters find less danger of eviction by authorities when they settle in undesirable settlement areas. Settling in such areas causes an increase in flood risk. As a response to the 2013 floods in the Central Province of Botswana, the government relocated people to high land and allocated land to displaced families. Unfortunately the area of relocation had no water and lacked sanitation. Due to poverty the people could not sustain themselves in that environment. The flood victims went back to their old homes in the low lying flood areas. Even though the areas are risky to floods, they can live there and sustain themselves (Red Cross, 2013:2).

It is of value to note that, whilst some people in a community may be exposed and vulnerable to the hazard, others may also be exposed but resilient to the same hazard (Jha *et al.*, 2012:135). What that means is that flood risk is subjective and differs from person to person and place to place (Lavell, 2012:33). Factors that contribute to increased flood risk and damage are many but include the reduction of the water storage capacity in watersheds due to deforestation, degradation of vegetation and impermeable surfaces due to urbanization and human activities such as settlements and agriculture in flood-prone areas (Krysanova *et al.,* 2008:2). In order to understand the potential impact of floods on a community and the appropriate response they have to take flood risk maps have to be developed (Jha *et al*., 2012:172).

In this study flood risk should be viewed as the probability or possibility of losing lives, health, livelihoods, assets and services, which might occur to a community or a society over time due to the effects of a river flood. Flood risk determination can be done by identifying and assessing the characteristics of any river flood, extent of the community's exposure to it and the community's capacity to cope or resist the flood impacts. Flood risk is comprised of different types of potential losses that might be difficult to quantify. However, with knowledge of the prevailing state of the flood, patterns of peoples' vulnerability and capacity, flood risks can at least be measured and pro-active measures be developed to reduce river flood impacts. Such a form of proactive measure is efforts in developing an effective river flood prediction model among many other variables. Due to difficulties in understanding technical concepts like disaster risk, this study might make it understood better by discussing the notions of hazard and vulnerability and capacity in the proceeding sub-sections.

2.2.1.5 Flood impact on levels of vulnerability and capacity

Floods have negative impacts when people levels of vulnerability are high and their capacity low or limited. Cutter *et al.,* (2009:2) define vulnerability as the susceptibility of a community, environment or system, to harm when exposed to a hazard. The condition directly affects the ability of a community to prepare, respond, and recover from a hazard. In simple words vulnerability looks at who and what is at risk and the degree of harm. Ferguson, (2005:15) categorises vulnerability into levels such as economic, social, cultural, political and institutional vulnerability, but these were not subjected to discussion in this study. Lemeko, (2011:30) places vulnerability to flood disasters in various forms. These forms include habitation of flood-prone areas, occupation of structures or buildings with little resistance to floods, human weakness due to old age, gender, illness, status and lack of access to financial and material resources. Ferguson, (2005:9) goes further and identifies a number of factors that might make some communities vulnerable to floods. These include lack of knowledge on the origin and cause of floods and how to prepare for them, close proximity of settlements to a river, lack of swimming skills and poor road infrastructure which might make some areas inaccessible to get help.

Analysis of vulnerability is important in this study because it leads to a better understanding as to how river floods become disastrous. In recognising the importance of vulnerability the SADC Regional Water Policy, (2005:34) places emphasises on assessing the vulnerability of people and property in its emergency preparedness plans. The importance of vulnerability helps highlight the contribution of social factors to flood risk (Lavell, 2012:33). This is because there is a close relationship between vulnerability, poverty and disaster risk (Ferguson, 2005:3). Poverty is a cause of livelihood vulnerability which influence flood risk in many rural areas in developing countries (Bang, 2013:7). According to Bouchard *et al*., (2007:i), causes of flood vulnerability are complex. The economic situation of communities is at times even more unbearable than the geographic situation where informal settlements are located. Vulnerability is demonstrated by the continuing population growth in flood risk areas that are recognised as unsuitable for living. As such poverty makes a significant contribution to vulnerability.

Lowering the vulnerability of a community reduces their flood risk. This can be achieved through measures and activities like flood prevention, preparedness, mitigation and risk analysis (Ferguson, 2005:11). The need exists to invest in flood shelters to protect people and their homes and protect drinking water sources to ensure people's health. In order to protect livelihoods, people must have access to land, replacement of land lost through erosion and compensation of animals and assets lost (Wisner *et al*., 2007:233). Analysis of the definitions above shows that vulnerability is the degree of being prone to or exposed to injury or damage. The definition that this study adopts is that vulnerability means the degree of being exposed to flood deaths, injury or damage.

Contrary to vulnerability, capacity includes conditions and characteristics that permit individuals and group access to and use of social, economic, psychological, cultural, and livelihood related natural resources, information and institutions of governance necessary to reduce vulnerability and deal with disaster consequences (Lavell, 2012:33). A capacity difference in communities to manage their vulnerability to floods is one reason why communities with similar levels of exposure may experience different impacts from a particular flood event (Mavhura & Manyena, 2013:2).

In this study capacity is defined as the ability of communities in river flood prone areas to use flood prediction information which is an external source to make the best decisions in protecting themselves from the effects of floods. Capacity will also entail the community or individuals in the community access to education or training as to how they may reduce flood risk. This might be seen in their ability to use the flood predication model to be developed in this study to forecast floods. The model to be developed is advocating for the integration of local knowledge known by such communities and science in flood predictions. Further to that it's also proposing the setting up of flood prediction structures at community and village levels. This is to be done with the rational of capacitating communities to predict floods amongst themselves and take action.

2.2.1.6 Flood mitigation

To consider alleviating floods within flood risk programmes to reduce hazards, levels of vulnerability and strengthening peoples' capacity to be reasonably prepared requires proper flood mitigation. According to Lemeko, (2011:9), flood mitigation is a process of assessing risks from floods, and use the information to implement flood risk mitigation measures. Lemeko, (2011:9) states that flood mitigation includes the management of people, through evacuation and managing the effects of flooding. To mitigate on flood disaster effects, attention is turning towards risk-based approaches based on harmonious government and community interventions (Vanneuville *et al.,* 2011:1).

In Zimbabwe one way of mitigating the effects floods is to provide food security. This is done by the Grain Marketing Board through the maintenance of grain and cash reserves. When the minimum reserve stock is reached grain is imported (Chikoto & Sadiq, 2012:13). The government is also investing in technologies help provide communities with early warning information. This can be through the internet, radio and television broadcast and cell phones. Currently the country is on a digitalization programme. This will improve on the country's radio and broadcast services (The Herald Newspaper, 2014). In Muzarabani, a flood prone area, the Zimbabwe Red Cross society has also installed a radio communication system to ensure easy communication of early warning information (Gomo, 2004).

The management activities during mitigation encompass structural methods in the form of engineering techniques and hazard-resistant construction as well as non-structural methods that include improved environmental policies, hazard vulnerability and risk assessment, public awareness, laws and their enforcement, research and assessment, information resources, practice or agreement to reduce risks and impacts through policies and laws, training and education (Jha, 2012:617; United Nations, 2014:10). Basic methods of flood control that can be practiced include reforestation and the construction of levees, dams, reservoirs, and dykes (Tingsanchali, 2012:25). Drainage system can also be part of the strategic approach to flood management in cities (Jha, 2012:218). Flood mitigation also encompass activities that limit adverse effects of water-borne diseases and lost livelihoods after a disaster (Lavell, 2012:36). In Cape Town, South Africa flood mitigation focuses on a number of prescriptions. They include relocating communities to safe upland areas and restricting migration into flood risk areas especially informal settlements. Authorities also encourage effective communication between stakeholders and mobilization of enough resources to support mitigation programmes. More to that community involvement is also critical in all flood risk management activities. It is also important to formulate or identify a formula or method that can be used to prioritise the areas or communities or community members mostly affected by flooding through flood mapping (Bouchard *et al*., 2007:ii).

It is recognised mitigation has a role in reducing negative environmental, social and economic impacts of floods hazards (Shreve & Kelman, 2014:213), protecting community development investments and helping communities accumulate wealth in spite of hazards (ISDR, 2010:9). There is also need to raise awareness of flood risks among the communities through radio broadcasts, local meetings, newspapers and partnerships between government, community organisations, private parties and non-governmental organisations (ISDR, 2010:17). Flood mitigation also encourages total engagement of at risk communities in the identification, analysis, treatment, monitoring and evaluation of flood risk (Abarquez & Murshed, 2004:12). The community-based approach empowers communities to possess physical safety, have more access and control over resources, participate in decision-making which affect their lives and benefits from an improved environment (ADPC, 2002:7). The need therefore exists to put emphasis on community based flood risk management programmes when it comes to flood mitigation. What this means is that vulnerable people will be involved in all flood mitigation programmes decision making processes together with local, provincial and national institutions. (Abarquez & Murshed, 2004:12).

If flood mitigation measures are developed without the participation of all stakeholders including the affected communities they become unsustainable. This is due to an assumption that they will not meet the interests of relevant stakeholders (Tingsanchali, 2012:35). In Cape Town, South Africa flood mitigation focuses on a number of prescriptions. They include relocating communities to safe upland areas and restricting migration into flood risk areas especially informal settlements. Authorities also encourage effective communication between stakeholders and mobilization of enough resources to support mitigation programmes. More to that community involvement is also critical in all flood risk management activities. It is also important to formulate or identify a formula or method that can be used to prioritise the areas or communities or community members mostly affected by flooding through flood mapping (Bouchard *et al*., 2007:ii).

According to the ADPC, (2002:4) in a community setup mitigation solutions need to reduce the communities' vulnerability to floods and improve their livelihood, in relation to enhanced safety, ease of access and economic benefits. Practical examples of such solutions may be the construction of an emergency evacuation route for the safety of villagers and their livestock, raising roads and construction of bridges for a reliable transportation route. This will increase students' accessibility, allowing them to travel to school and traders to transport their agricultural produce to local markets to say the least. Rebuilt, enlarged or new culverts might also increase the community's control over the flood water flow. According to Mosate, (2010), in Botswana, flood mitigation is done through giving out early warnings through Kgotla meetings at the district or local level. Government also has surveillance teams that ensure that blocked culverts are cleared to allow water to pass through in residential areas. Authorities also conduct public awareness campaigns. The national disaster management office continuously monitors the river flow situation. Authorities also water resources against contamination (Tsheko, 2003:390). According to ADPC (2006:63) mitigation activities like flood forecasts have information that is essential for timely execution of activities like relocation of people to safe areas and deployment of response resources. They also facilitate the dissemination of critical information like "when and where the flood will occur" so that proactive action is made on time in relation with the level of risk identified and conveyed (ADPC, 2002:6).

Knowledge of flood mitigation strategies is important because it is used to proactively manage the characteristics of human environment in a community. Knowledge reduces the negative effects of a flood and if they do occur their magnitude is diluted (USAID/OAS, 1997:1). Flood prediction as a mitigation measure can produce information with longer lead times useful for contingency planning and defining immediate actions in responding to floods (ALNAP, 2008:4). From an economic perspective, a fundamental premise of flood mitigation is that money invested in mitigation will to a great extent reduce the demand for future funds. Investing in flood mitigation now, reduces funding of emergency, recovery, repair and reconstruction after a flood disaster (USAID/OAS, 1997:3). Flood mitigation provides socio-economic continuity in the community as it reduces social and economic disruption caused by flooding (USAID/OAS, 1997:3). Flood mitigation also calls for conservation of natural and ecologically sensitive areas, such as wetlands and floodplains which enable the environment to absorb some of the impact of floods (USAID/OAS, 1997:3) and help in water storage (Krysanova *et al.,* 2008:2).

Flood mitigation helps communities attain a level of sustainability that ensures long-term economic vitality, social and environmental health (USAID/OAS, 1997:3). In that endeavour stakeholders identify various needs required to predict, respond and cope with the effect of floods (ADPC, 2006:61). Flood mitigation also encompasses flood preparedness which are activities identified in advance of floods intended to reduce their impacts (ADPC, 2006:60). Apart from using the normal mitigation strategies like flood forecasting and warning, flood preparedness and flood plain regulation, Zambia has mitigation plans focused on providing food security in flood affected areas. According to APFM, (2007:42-3), in Zambia authorities are supporting and encouraging the use of flood resistant crops like cane sugar, bananas and palms and cropping patterns like growing early maturing crops, such as vegetables and winter maize. Also being encouraged is the utilization of abundant water resources in flood areas for irrigated crop production. The government is also looking at ways of raising the standards of living of all the people. This involves socio-economic development initiatives that improve education and health, access to resources and income generation.

In this study flood mitigation is defined as the process of lessening or limiting the adverse effects of river floods. Since the adverse impacts of floods cannot be prevented fully, their scale or severity can to a great extent be lessened. This study can be used as a mitigation strategy in which there is an attempt to develop a flood prediction model. The model will provide information as to when people should expect river floods and thereby take preventative measures to avoid loss and other flood effects. Information from flood predictions will not work in isolation but needs to be integrated with other variables in the form of structural measures for flood risk reduction which include dams, flood levies and evacuation shelters and non-structural measures namely, building codes, land use planning laws and their enforcement, research and flood assessment, information resources, education, public awareness programmes and flood warnings.

2.2.1.7 The "living with floods"-approach as a risk reduction measure

In Europe and other continents, many countries have repeatedly suffered tragic loss of life and economic damages from frequent and more damaging floods (Schneidergruber *et al.*, 2004:1). The increase in frequency and damage is being attributed to straightening and narrowing of rivers causing them to flow faster and over a small area than they would under natural conditions. What this means is that human activity has interfered with the natural flow of rivers and floodplains that would normally store excess water have been cut off from rivers. Since waters have nowhere to go, they are catastrophically breaking through structural barriers built by man, reclaiming their original course (Schneidergruber *et al.*, 2004:1). Structures like embankments also have adverse effects as they influence decline in soil fertility (Shaw, 1989:13; Hossain *et al.*, 1987:36; Rasid & Paul, 1987:164). Governments and development agencies tend to view flood mitigation in terms of high-tech constructions like embankments and dams (Shaw, 1989:13). According to the Flood Risk Management Strategy (FRMS, 2006:4) traditional flood management focuses on the belief that flooding can be controlled through physical measures. The approach fails to recognise that flood risk is a consequence of the way in which society occupied and settled in flood prone areas (Flood Risk Management Strategy (FRMS, 2006:4).

When talking of floods common images that run minds are the destruction of infrastructure and suffering of people (Van Ogtrop *et al.,* 2005:607). But it rarely comes to mind that floods have benefits, such as bringing fertility, washing away contaminants and refresh ground water stocks (Van Ogtrop *et al.,* 2005:607). Floods are destructive, but are important as a vital link to the ecosystems (Middlemis-Brown, 2010:6). Floodplains and wetlands within a river system are crucial in maintaining the natural water cycle and are key to reducing flood impacts on people's lives and property (Schneidergruber *et al.*, 2004:2).

Living with floods relates to situations where flooding helps to nurture cultures, for example where natural floods bring high levels of water to watershed basins that are used for agriculture (Middlemis-Brown, 2010:6). River flooding has always created flat and fertile land sustaining high population (Few, 2004:12). Egyptian cultures along the Nile River thrive as a result of floods that bring fresh, nutrient-rich waters and sediment every year. Floods have therefore influenced agricultural activities around seasonal flooding which sustain agriculture with limited artificial irrigation (Middlemis-Brown, 2010:6)

In a recent day approach, a policy is followed whereby people live with floods by being prepared and have the proper damage reduction measures in place (Van Ogtrop *et al.,* 2005:607). This approach recognises that people are part of nature, but not superior to it, and that nature has intrinsic value that requires respect because of its hidden strength and superiority in many ways. There is a shift in environmental concern from the dominant view that the environment is an unlimited and abundant dominion of humans to a new view that recognises the environment as limited and fragile (Cordano *et al.*, 2003:23).

The living with floods approach also believes that people cause floods and that floods are human influenced (Penning Rowsell *et al*., 2006:325). The school believes in managing risks equitably and in accordance with the principles of ecologically sustainable development. Structural approaches to flood control are criticised for not adequately solving flood problems and for creating serious environmental impacts.

Environmental problems such as global warming, species collapse, and ozone depletion are being understood as a result of human activity (Cordano *et al.*, 2003:26).

This concept of living with floods is contrary or a paradigm shift from the social dominance theory (SDT) or social dominance orientation (SDO) whereby humans believe that the natural world was created for the benefit of humankind and see themselves as superior (Milfont *et al.*, 2013:1-2). Progress in civilization and technology is being taken for granted and permanent, thus leading to exhaustion of natural resources. Resources are also being rendered non-utilizable without a realistic prospect of restitution (Haber, 2007:359). The SDT also see humans as separate from nature and other organisms thus having dominance rights. The SDO portrays nature as important only for what it contributes to human welfare, but not important in itself. Therefore social dominance orientation is less concerned about environmental issues and has that propensity to exploit the environment in unsustainable ways. Human dominance over nature is thereby central to current environmental problems (Milfont *et al.*, 2013:1-2). Environmental problems are based on the exploitation of natural resources such as fuel for fire, production of food using land, soils and water and utilization of metals for construction and appliances until they are depleted without any replacement (Haber, 2007:359).

Research done by Little, (1973), as cited by Fang, (2008:16), showed that, while significant benefits were being offered by channelization of floods, the projects were often overdesigned or under-designed. The under-designed modifications did not adequately address flood control in the future and the overdesigned projects led to significant environmental impacts to the natural floodplain and downstream areas (Fang, 2008:16). In advancing the living with floods concept, the environmentalism and green movement is advocating for rivers to run unconstrained by any structures like earthworks, embankments and concrete walls. This means that rivers should be allowed to flow freely in valleys and flood plains restored (Benjamin, 2008:49).

On that note and in the SADC-region the regional Water Policy (2005) has a clause that recognises the environment as a legitimate user of water (SADC-regional Water Policy, 2005:vii). According to Paton *et al.,* (2010:183), the growing risk faced by communities in many countries from natural hazard events, has stimulated interest in promoting people's capacity to live with floods. Therefore the adoption of preparedness measures is being encouraged. When people develop their capacity to co-exist with hazardous environmental processes, communities can become resilient. Since hazards can strike with little or no warning, it is important for people and communities to be prepared in ways that increase their ability to cope with, adapt to and recover from hazard impacts (Paton *et al*., 2010:183).

The concept of living with floods is a paradigm shift from flood hazard management to flood risk management where there is a balance between structural and non-structural measures (Kobayashi & Porter, 2012:2). The shift has led to an increased emphasis on non-structural measures to reduce flood risk, which include spatial planning, flood awareness, flood proofing and the use of flood forecasting, warning and response systems (Tinh & Hang, 2003:12; Schneidergruber *et al*., 2004:44). Chowdhury, (2005:723) criticizes structural measures and believes that structural measures take long to effectively mitigate risk and also need huge investments for implementation. This promotes the use of non-structural measures which can be effective in mitigating the damaging effects of floods. Flood prediction can be used to achieve such measures in a highly cost-effective manner.

According to Wilby and Keenan, (2012:363), living with floods means accepting that flood damage is inevitable but can be reduced with the application of appropriate policy and technical instruments. The core idea of "living with floods" is to address community's flood vulnerabilities and making sure that the gap between demand and supply of key services is sustainably met (ALNAP, 2008:4).

After the 1988 disastrous floods in Bangladesh, American and Japanese experts dismissed French proposals to construct massive embankments on major rivers throughout that country. The experts cautioned against such costly engineering schemes and rather proposed the improvement of forecasting techniques and the study and promotion of indigenous ways of living with floods (Zaman, 1993:990). In 1994, Beijiang basin in China was affected by a flood killing 102 and injuring 2000 people (Wong & Zhao, 2001:190). Dykes failed to holdback flood water and collapsed exposing the weakness of flood prevention structures. It became clear that it was difficult to control every element of nature to eliminate risks. People were prepared to live with floods and adopt practical adjustments to lessen flood impact (Wong & Zhao, 2001:190).

A study by Spaliviero *et al.,* (2011:753) in Mozambique after the 2000 floods, highlighted the difficulty faced by the Mozambican government when they resettled people living in low areas on higher grounds. A high percentage of the resettled people returned to the risk areas they had been moved from. The reason advanced by the communities was that the new resettlements were unsuitable locations to live in as they deprived the people of their former livelihoods. More to that, the government also failed to provide basic and social services, social integration and sustainable livelihood mechanisms in the new settlements. The reason for such behaviour by the resettled communities was related to poverty and dependency on subsistence agricultural schemes done on the fertile floodplains. The modern approach to flood management advocates that, in situations where there is resistance for resettlement, people have to be taught to co-exist with floods (Few *et al.*, 2004:11).

Therefore, for people living in floodplains and whose relocation would mean being moved far away from their crops, resettlement is not a viable option. In these cases, adaptive solutions need to be explored, such as living with floods. This is particularly feasible for low-lying areas prone to moderate flooding (Spaliviero *et al.,* 2011:753). In Vietnam, the government introduced the concept of Living with Floods as a policy in the Mekong Delta, since 2000 as a strategy in flood mitigation (Few *et al.*, 2004:11: Tinh & Hang, 2003:2). This concept of Living with Floods, in the Mekong River Delta incorporates flood management strategies of low-tech measures and traditional coping techniques that enhance safety (Tinh & Hang, 2003:1). The approach recognises that flooding cannot be prevented or completely controlled (Few *et al.*, 2004:11: Tinh & Hang, 2003:2). Therefore efforts are directed towards ensuring that communities cope with, co-exist with and even exploit floods (Few *et al.*, 2004:11). ‘Flood exploitation’ means considering flooding as a natural resource that needs to be researched and exploited for local socio-economic development (Tinh & Hang, 2003:2).

On the same note, historically, the communities in Vietnam always co-existed with floods (Tinh & Hang, 2003:2). Despite the Living with Floods government policy, in reality people live with floods as part of their seasonal environment. (Few *et al*., 2004:12). Communities have been evacuating to high grounds during the floods season and planting seasonal crops to avoid floods (Tinh & Hang, 2003:2). They have also developed traditional houses, livelihoods and transportation that suits flood conditions (Few *et al*., 2004:12). In promoting the Living with Floods concept more investment is being put into unstructured activities which include education, income-raising, health promotion, environmental health and child safety than structural activities like dyke construction. More to that the Living with Floods policy message is circulated, acknowledged and widely understood at the grassroots structures (Few *et al*., 2004:11).

When it comes to living with floods in Bangladesh, agriculture is dependent on floods and adjusted to normal levels of flooding. Farmers plant several varieties of rice at different times of the year, in continual adjustment to the variable water levels. Their major rice crop is grown during the flooding season as it needs a certain level of water to survive (Shaw, 1989:11). Bengali peasant life in Bangladesh is premised on predictable and annual monsoon floods that submerge the Deltaic plain for about half a year. The people's worldview is deeply rooted in the relationship of their lives with water. Their staple foods are rice and fish that grow and flourish well in floods. The destructive effects of these floods are limited by communities adjusting to traditional methods of adapting their agricultural practices, cropping patterns, and settlements to the floods (Zaman, 1993:985-6). In Bangladesh, they also keep space for livestock in flood shelters (ALNAP, 2008:4). In Europe the traditional approach of building structures to contain river water has been re-evaluated to an initiative known as 'room for rivers' where river channels are reconnected with flood plains. This is done through the establishment of empty floodable areas on river banks. 'Room for rivers' reflects a change from 'battle against water' to 'living with water' (Middlemis-Brown, 2010:6).

In living with floods, Governments need to raise the awareness of people in relation to floods and to promote education programs, at all levels, so that the population in general becomes more prepared to face large floods and to react adequately when they occur. Insurance although hardly feasible is another measure to minimize the consequences of floods (Carmo Vaz, 2000:13). There is need to complement 'technological fix' strategies for flood control with measures such as adequate warning systems and flood plain zoning, (Shaw, 1989:13; Islam, 1986:8) and the reinforcement of indigenous knowledge systems and community level planning (Shaw, 1989:13; Ralph, 1975:105; Rasid & Paul, 1987:170). Living with floods also includes the rejuvenation of soils, reconnection of rivers with floodplains, and the recharge of alluvial aquifers (Middlemis-Brown, 2010:6).

To enhance the concept of living with floods, flood predictions methods and techniques become paramount and need to be complimented as echoed by Carmo Vaz, (2000:15). Accurate prediction of flooding with sufficient lead time has a value in that it allows for the evacuation of those in danger and the implementation of damage control measures to minimize human and economic losses. Because of the devastating effects of floods, scientists and engineers have over the past years put more effort and resources to the search of accurate prediction tools for flooding (Fang, 2008:3). This study is also making efforts to engage with the possibility of creating accurate prediction tools for flood prediction. According to Wilby and Keenan, (2012:365), integrated real-time hazard forecasts have also become part of living with floods. In the case of the SADC-region, there is demand for strong support and co-operation from neighbouring Regional countries complimented by financial and technical support from the international community. Skilled human resources are also essential, therefore the need for adequate investments in education, training and research. Collaboration between universities and similar institutions from the region will also make the best use of scarce resources in flood risk reduction.

Now that authorities are encouraging people to co-exist with floods, there is need for more precise and reliable river flood prediction models to be developed or for the existing and current methods to be improved. This will help communities that live in flood prone areas to be proactive and avert the negative effects of floods and benefit from their positive effects, especially those who depend on agriculture. This study is part of and one among many of the initiatives towards flood risk reduction. The concept of living with floods as coined by Spaliviero *et al.,* 2011:753; Few *et al*., 2004:11; Shaw, 1989:13; Ralph, 1975:105; Rasid & Paul, 1987:170 and Middlemis-Brown, 2010:6 makes value as it persuades communities, disasters managers and academics to develop flood risk mitigation measures that will make communities co-exist with floods without any risk. Reliable flood prediction methods become one of the paramount ways of addressing flood risk mitigation. The concept of living with floods is discussed and applied under each of the studied countries Zambia, Zimbabwe, Botswana and South Africa in Chapter Three, section 3.2.

2.3 A contextual survey on the management and prediction of river flood disasters in the SADC-region

The Southern African Development Community (SADC) is a regional economic community, established in 1992 and comprising 15 member states (see Figure 1.1: A simplified map showing countries that form part of the SADC by 2016. in Chapter One). The SADC states are Angola, Botswana, Democratic Republic of Congo, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe (Villholth *et al.*, 2013:863). The member states are committed to regional integration and poverty eradication within Southern Africa through economic development and ensuring peace and security (SADC-regional Water Policy, 2005:2; Fisher & Ngoma, 2005:3).

2.3.1 Demographic and topographic features

The SADC-region has a total population of 258 million people based on World Bank Indicators 2012 figures. When one breaks down the regional population figures, the four countries under study officially have the following population: Zimbabwe, 13.7 million, South Africa 51.1 million, Zambia 14.1 million and Botswana 2.0 million people (World Bank Indicators, 2013). According to Davis, (2011:8) climate in the SADC-region is warm and strongly influenced by its position in relation to the major circulation patterns of the southern hemisphere, the complex regional topography and the surrounding ocean currents. The region is located between the equator and the mid-latitudes and is surrounded by the warm Indian Ocean on the east coast and the cold Atlantic Ocean on the west coast. The relief ranges from sea-level to plateau mountains. The combination of these factors leads to different climate types and regimes across the region, namely the coastal desert, a temperate climate, a subtropical climate and Mediterranean climate (Davis, 2011:8).

This tropical weather system is comprised of cyclones, storms or depressions that develop over the Indian Ocean moving into the eastern interior of the Region (Malherbe *et al*., 2012:4). A high degree of variation in rainfall patterns is visible in the SADC-region, with high amounts in the tropics decreasing towards the north-east and to the south-west of the equator, some arid areas receiving less rain than others. Rainfall in the region is generally seasonal with most of it occurring in summer (October to March) but also occurs all year round in areas around the equator. Cyclones and floods are expected to occur with increasing frequency and greater intensity due to global change (Lau *et al.*, 2010:632). Physical and empirical arguments together with the General Circulation Model (GCM) experiments suggest that global warming may increase the frequency and/or magnitude of heavy precipitation in Southern Africa (Faucherear *et al.,* 2003:139). The other determinants of rainfall patterns in the SADC include the Inter-Tropical Convergence Zone (ITCZ) which brings in high rainfall in several countries within the region in summer (Davis, 2011:9).

2.3.2 The impact of floods in the SADC-region

Turning to floods, Mwape, (2009:19), in citing a study by the International Flood Initiative, (2003), observes that floods are the most taxing of water related natural disasters affecting people and their livelihoods and claiming thousands of lives annually worldwide. Borrows and De Bruin, (2006:1) as well as Douben, (2006:1) and Huq *et al*., (2007:6) indicate that globally flooding has claimed more lives than any other single natural hazard and damaging effects of floods are likely to become more frequent, prevalent and serious in the future. In a country like China, floods continue unabated despite a lot of effort made to construct structural engineering projects for flood control (Gao *et al*., 2007:27).

In Africa, floods have not spared the continent. Disasters and disaster risk are on the increase (UNICEF, 2011:1). It is speculated that due to global warming Southern Africa is having floods and droughts as a result of rainfall variability (Faucherear *et. al.,* 2003:139). In for example March 2000, floods caused by cyclone El Nino impacted heavily on the Southern Africa region. It was particularly Mozambique, where more than 900 people died (Lukamba, 2010:484). Lukamba, (2010:484) also argues that climate change is having a direct impact on rainfall. According to AMCEN, (2011:3) and Davis, (2011:4) the continent is more vulnerable to climate change than any other continent as a result of a number of factors that include inadequate financial, institutional and human capacities, lack of access to skills, tools and information on climate change, poverty, poor policy and institutional frameworks, direct dependence on the natural environment for livelihood support and less preparedness of disasters. Changes in climate are also affecting agricultural production as a result of droughts, floods, high temperatures and variation in precipitation patterns (Leichenko & O'Brien, 2001:1-2).

Snoussi *et al.,* (2008:206) state that, climate change and sea level rise will impact seriously upon the natural environment and human society in Africa just like anywhere else in the world. In Africa floodplains are equally important locations for human settlements (Parker, 2000:189). Increased frequency and intensity of floods is expected to negatively affect food security and agricultural production which is the main source of livelihood in most communities in sub-Saharan Africa (Nhemachena & Hassan, 2007:1). In 2008, thousands of people were also affected and displaced by floods in Kenya (IRIN, 2008).

The SADC-regional countries (Figure 1.1: A simplified map showing countries that form part of the SADC by 2016.) are vulnerable to a range of natural disasters that affect several countries simultaneously with floods having increased in their frequency, magnitude and impact (Lukamba, 2010:490). It is assumed that the region will be affected by climate change increasing risks related to floods (Leichenko & O'brien, 2001:6; Brouwer *et al*., 2007:314; Lukamba, 2010:484). In 2007 people affected by rains and floods were more than 194,103 persons (Ismail & Mustaquim, 2013:143). The people affected included 16,680 in Zambia and 15,168 in Zimbabwe. The effects of floods results in loss of life, displacement of many people, destruction of infrastructure such as houses and roads, farms and crops and loss of livestock and disrupted communication in southern Africa (Mwape, 2009:34).

Even though the application of science has improved people's ability to predict, alleviate and survive flood disasters, vulnerability of societies to floods is still poorly understood (Bakker, 2006:1). Floods cannot be prevented, their devastating effects can be minimized through risk reduction strategies like flood prediction and advance warning (Sinclair & Pegram, 2003:1). A need therefore exist among Governments and partners in the Region to develop and implement flood disaster risk reduction measures to ensure community safety and protection of economic assets (UN, 2014:10).

2.3.3 Water and flood management policy in the SADC-region

Literature shows that the SADC-region has abundant water and flood management policies and structures (Ferris & Petz, 2013:48; SADC-regional Water Policy, 2005:33). Since the mid 1990s member states have developed the water sector in the region highlighting the importance of water for socio-economic development, regional integration and poverty reduction. (The SADC-regional Water Policy, 2005:v). There is progress in DRR activities in the Region in the form of policies, institutions and organisations (Ferris & Petz, 2013:48). In a Study by Becker *et al*. (2013:4), it was also observed that the SADC had structures for Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA). The World Bank also supports the existence of Disaster Management (DM) including the management of floods by taking note that DM has been an important component for the overall strategy for regional development initiatives (World Bank, 2008:12). The region has several disaster management initiatives that cover aspects of the SADC Water Policy (2005), the Integrated Water Resource Management (IWRM**),** the Southern Africa Regional Climate Outlook Forum and the Southern African Development Committee (SADC) – Hydrological Cycle Observing System (HYCOS) Project. Each of the initiatives cited above is discussed in the following paragraphs.

2.3.3.1 The SADC-Water Policy

The SADC-regional Water Policy of 2005 is aimed at "providing a framework for sustainable, integrated and coordinated development, utilization, protection and control of national and trans-boundary water resources in the SADC-region, for the promotion of socio-economic development, regional integration and improvement of the quality of life of all people in the Region" (SADC-regional Water Policy, 2005:vii) . It is a product of pronouncements by the SADC Member States formulated over the years like the SADC Declaration and Treaty of 1992, The Southern African Vision for Water, Life and Environment adopted in March 2000, The Revised SADC Protocol on Shared Watercourses, 2003 and the The Dublin Principles, 1992 (SADC-regional Water Policy, 2005:2).

The Region has 15 major river basins (see Figure 2.1) which are trans-boundary or watercourses shared by two or more countries (African Development Fund, 2005:1: Laura, 2007:133).

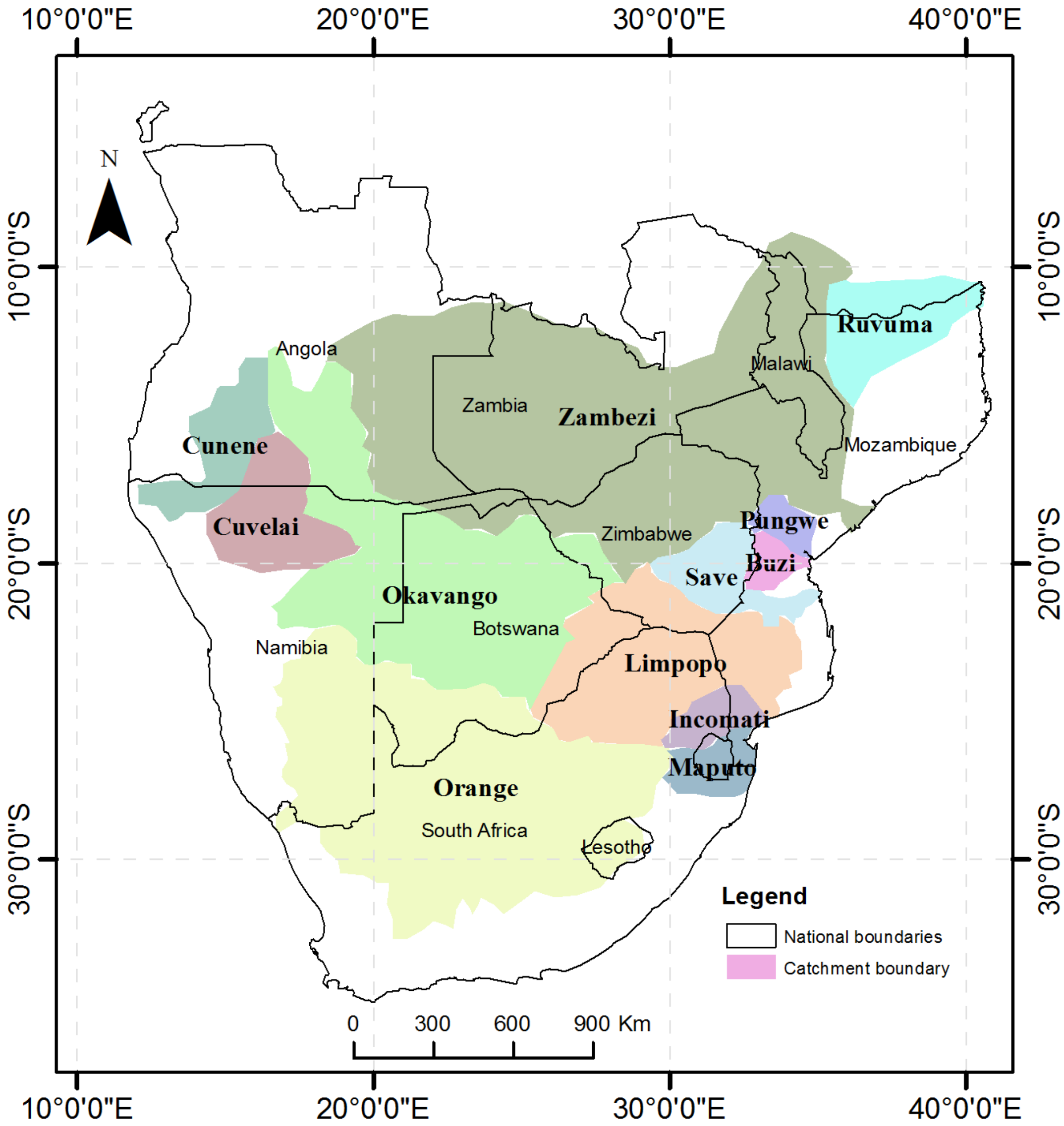

Figure 2.1: SADC-region water basins

Source: Author's depiction, March 2016.

They include the Congo River Basin, 3,800,000 square kilometres, the Zambezi River Basin which is 1,400,000 square kilometres, (covering eight SADC-Member States) and the Umbeluzi River Basin of, 5,500 square kilometres and shared by only two countries (SARDC, 2009:83). Since these rivers are a cause of concern as they flood most of the seasons, member states engaged in consultations on development of the water sector in the region and included their resolutions in the SADC-regional Water Policy (RWP) in 2005. Included in the Water Policy and of concern and importance to this study, the RWP looks at the communal and coordinated management of water related natural disasters within shared watercourses at regional level (SADC -regional Water Policy, 2005:vii). Flooding within a shared watercourse is said to require the development of predictive capabilities for the entire watercourse. Of importance to note for this study is that the SADC-Water Policy advocates for the development of predictive capabilities that include institutional mechanisms and capacity, forecasting systems and technologies (SADC-regional Water Policy, 2005:33).

Furthermore the Water Policy provides guidance on how to manage river floods. Section Six commits member states to protect human life, livestock, property and the environment against the effects of water related disasters. Section Six also gives the Secretariat power to facilitates cooperation and promote regional proactive and integrated prediction, planning and mitigation of floods. Member States are also mandated to actively participate in the processes and develop mechanisms for regional cooperation around disaster management (SADC-regional Water Policy, 2005:33). Stakeholder consultations, development and implementation of integrated and coherent regional and watercourse level management plans and procedures for the management of natural disasters and emergency situations are accentuated in Section Six as mandatory (SADC-regional Water Policy, 2005-34: Savenije & Van der Zaag, 2000:34).

Another important issue of the SADC Water Policy, (2005:35) is Section Seven which makes it obligatory for member states to notify floods and share knowledge and information with affected watercourse States in the event of actual or pending water related disasters (SARDC, 2009:83). Most probably the rationale behind this thought is for member states downstream or upstream to become conscientious and advised and get growing towards always being prepared for an impending floods or flood disaster. This in turn reduces the risk of floods on the down and upward communities in the various states that share the same water course.

Since the SADC-regional Water Policy of 2005 is a Regional Policy to amongst others, improve the region's capacity in predicting flood related disasters under its Section Six, the foregoing policy is supported by this research endeavour as previously mentioned. The focus of the research was regional of nature, with the intention being the development of a regional flood prediction model that could be utilised in the SADC-region. This meant that the developed model would be operated from a common station in the region. The research methodology section of this study was contextualized in terms of community based Disaster risk reduction (Victoria, 2002:269), as the community and other persons or organisations participate in the development of the framework of the regional flood prediction model.

2.3.3.2 The Southern Africa Regional Climate Outlook Forum (SARCOF)

The other platform that is also being used to manage river floods in the region is the Southern Africa Regional Climate Outlook Forum (SARCOF) (Patt *et al.*, 2007:49; Dilley, 2000:70). This is an International forum for seasonal climate forecasting or predictions. SARCOF is said to bring together delegates from the National Meteorological and Hydrological Services (NMHS) in the Southern Africa Development Community (SADC) (Ogallo *et al.*, 2008:94). These experts meet three times annually, with their first meeting usually held in September before the wet season (Cash *et al.*, 2006:478). In December, the Forum also meets where an assessment of the early season forecast is made and an update of forecasts for the remaining wet season period is done (Cash *et al.*, 2006:478). A third meeting takes place in the post-season (in April or May) and in which previous season forecasts are validated for user feedback (Chowdhury, 2005:718).

SARCOF meetings also cater for discussion sessions on global and regional climate dynamics, forecast methodologies, and seasonal forecast presentations achieving a consensus forecast (Ogallo *et al*., 2008:94). This probabilistic product is then distributed to users through the SADC website or directly to the media. The meetings are also said to be important in that they include capacity building technical sessions in which training on climate science and seasonal forecasting methodologies is provided by international and national experts (Chowdhury, 2005:718). The goal of the SADC- Climate and Services Centre is to reduce the negative impacts of adverse weather and climate conditions such as floods and other extreme events on sustainable socio-economic development. The Climate Services Centre aims to achieve this goal through generation and dissemination of meteorological, environmental and hydro-meteorological products (Garanganga, 2011).

2.3.3.3 Integrated Water Resource Management (IWRM)

GWP TAC (2000:22) defines Integrated Water Resources Management (IWRM) as a process that promotes the co-ordinated management and development of water, land and related resources resulting in balanced economic and social welfare without affecting the sustainability of vital ecosystems. In IWRM the primary concern of flood managers is to protect the lives and property of communities including river basins from flood harm and damage (UNESCO, 2009:12). Growing global awareness of increased water-related disasters, has created opportunities and approaches for building strategic alliances and partnerships between government and the private sector to pursue Integrated Water Resources Management (Pilon, 2001:18). Kasbohm (2009:9) sees IWRM in river basins as entailing stakeholder participation in the river basic planning and management. To be effective, flood managers collaborate with managers responsible for IWRM thereby ensuring complete coordination with other sectors and stakeholders (UNESCO, 2009:12).

The importance of IWRM in this study is that it addresses and values the role of flood forecasting and improves the system (Krysanova *et al.,* 2008:16). According to Pilon (2001:50), flood forecasting, warning and response system is an important element of Integrated Water Resources Management. The benefits of river forecasts for power generation, navigation or irrigated agriculture make implementation of IWRM more cost effective and sustainable (Pilon, 2001:50). Flood prediction analysis is important because it aids the design of dams, bridges, culverts and various flood control structures (Demissie & Cunnane, 2002:1). It also helps the estimating of the economic value of the flood control projects and delineation, planning and management of flood plains. Furthermore, in IWRM climatic forecasts can also be used to increase the availability of storage in reservoirs, to influence water management decisions and to create an awareness of the potential for flooding (Pilon *et al*., 2001:29). In IWRM, flooding is a water source and if flows are not captured water will not be available for other human uses. IWRM integrates the efficient use of flood plains and mitigation of loss of life due to flooding (Tingsanchali, 2012:34). IWRM brings opportunities of an investment in combined structural and non-structural flood vulnerability interventions (Tingsanchali, 2012:25). The rehabilitation of infrastructure after floods and the strengthening of effective flood forecasting (Krysanova *et al.,* 2008:20) and warning systems entails stakeholder participation in the basic planning and management (Kasbohm *et al.*, 2009:8; Tingsanchali, 2012:35). Integration of upstream and downstream water related interests and the consideration of conflict of interests is achieved (Kasbohm *et al.*, 2009:5).

The SADC-Water Policy document has become a very instrumental framework in the management of water particularly floods in the SADC-region (Heyns, 2005:59). Of importance to this study in the Water Policy document's nine thematic areas is the issue of regional integrated water resources management (SADC-regional Water Policy, 2005:11; Heyns, 2005:64). The Water Policy of 2005:3 "promotes the co-ordinated management and development of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems". Kasbohm *et al*. (2009:3) see the IWRM as inter-sectoral, representing all stakeholders and physical aspects of water resources taking into account sustainability and environmental considerations*.* This concept started being adopted in the1990s through the SADC secretariat who coordinated the preparation of an action plan for integrated development and management of water resources in the SADC. This was due to the need by the region to integrate 70% of its water resources that are shared by more than one country (The SADC-regional Water Policy, 2005:6). National water polices, water legislation and water regulations of states needed harmonization to enable those sharing a common resource to conform to the requirements for coordinated, joint management of trans-boundary water resources (Heyns, 2005:60). IWRM practises were also influenced by shortage and lack of safe and affordable drinking water and basic sanitation in rural and urban areas (The SADC-regional Water

Policy, 2005:9). Economic sectors like energy and agricultures also put substantial demand on water (Clausen, 2004:10). Shortage of water in urban and rural areas caused water borne diseases and pollution (The SADC-regional Water Policy, 2005:6). It is these water shortages, deterioration in quality and flood impacts that required attention and action in the process of the IWRM with an intention of managing water issues in a cost effective and sustainable way (Kasbohm *et al.*, 2009:3; Clausen, 2004:6).

In its IWRM activities the SADC-region has an institution known as the "*Regional Flood Watch*" which focuses on rain and flood watch. This initiative consolidates local and international rainfall and flood information and issues rain and flood information for the region. The regional flood watch has a website http://www.sadc.int/floods/rfw.php available for rain and flood information for the SADC-region (Hattingh, 2008:14). The SADC has also put in place institutional arrangements to manage and reduce floods recurring in the region. The institutional mechanisms also include the SADC Water Sector coordinating Unit which has developed a disaster management strategy to strengthen flood management among others. More to these structures is the Regional Early Warning Unit which produces and disseminates information on flood threats to regional countries (Mahonda, 2011:12). The region is developing Integrated Water Resources Management Strategy and Implementation Plans for its rivers like the Zambezi whose river basin covers eight countries of the region. Among the many strategic objectives of this plan is to Improve flood management and mitigation mechanisms at national and regional level and also adaptation to Climate Variability and Climate Change (SADC, 2008:9). Furthermore, the SADC is currently operating a climate services centre whose mandate is to ensure that a sub-regional mechanism for monitoring and predicting extreme climate condition remains vibrant and that it eventually generates and disseminates meteorological, environmental and hydro-meteorological products (Garanganga, 2011:8).

Although IWRM helps the SADC-region benefit from the building of dams for water storage and flood control (Middlemis-Brown, 2010:7), too much water consumption, land use changes and flood control upstream will reduce river flows downstream. Water quality will also be affected threatening flood dependent livelihoods downstream (Krysanova, *et al.,* 2008:4; The Global Water Partnership, 2000:15). Development in upstream shared rivers, like dam construction, storm water retention (Tingsanchali, 2012:31), the opening of dam gates that might cause floods downstream is also addressed in IWRM (Krysanova *et al.,* 2008:23; The Global Water Partnership, 2000:25).

2.3.3.4 Other disaster risk management initiatives

Even though the SADC has yet not developed its own protocol on disaster risk reduction or management, It is currently using several existing protocols in SADC like Article Two of the Protocol on Politics and Defence Cooperation (2001) and Article 25 of the protocol on Health (1999) These protocols stress the need to coordinate and cooperate when the region or any regional country in the region is in distress due to any type of disaster. According to article two of the Protocol on Politics and Defence Cooperation (2001) one of its objective is to enhance the regions' capacity to manage disasters and coordinate international humanitarian assistance. Article 25 on Emergency Health Services in the Protocol on Health (1999) states that member states shall cooperate and help coordinate disaster and emergency situations, including developing awareness and risk reduction initiatives.

The SADC-region also hosts a global project that is designed to improve the availability of accurate and timely data for water resources planning and management. It is called the Hydrological Cycle Observing System (HYCOS) (The SADC–HYCOS Evaluation Report, 2002). This strategic objective of the HYCOS project is to address flood monitoring, forecast and mitigation. Real-time monitoring of flows from tributaries was considered as important in this project from the start of its activities (The SADC–HYCOS Evaluation Report, 2002:39). According to Ferris and Petz, (2013:48) the following activities by the SADC-region since 1992 are evidence of its commitment in Disaster risk management. The first was the crafting of an institutionalized regional disaster management strategy in 1992. The other activity was the Launch of a Sub-Regional Disaster Management Strategy in 2001 to address food security, climate and environment and water management.

2.3.4 Flood Risk Management efforts in the studied countries: 2000-2013

Zambia, Zimbabwe Botswana, South Africa were counties selected for this study. This was due to their close proximity as they are border countries. More than two of the countries also share the same river basins and are affected by floods from the same river basins that is the Zambezi and Limpopo River Basins (Zambezi Watercourse Commission, 2012:3; WMO, 2012:2; Spaliviero *et al.*, De Dapper and Malo, 2014:2027). In order to create a broader understanding of floods in these selected countries in the region the theoretical issues that apply are discussed. As already been alluded to in the delimitation of the study in Chapter One, section 1.9, the study period was from 2000 to 2013. During that period a number of floods with serious impacts in terms of loss of life, damage to property and infrastructure and the environment had occurred in these countries. The period had justifiable data/information that could be considered in coming up with a flood prediction model for the region.

2.3.4.1 Flood disaster risk management efforts in Zambia: 2000-2013

Zambia is vulnerable to all sorts of hazards that trigger disasters (Disaster Management and Mitigation Unit (DMMU) and Partners, 2008). Its government recognises that it has a fundamental responsibility to protect the lives and property of its citizens during a disaster and has made efforts to create mechanisms to tackle disaster situations in that country (Simwanda, 2001:1).

The country has a legal framework in the form of the Disaster Management Act No. 13/2010 which guides disaster management and risk reduction activities in the country (Disaster Management and Mitigation Unit (DMMU, 2010:1). This law provides for the establishment of an institutional framework referred to as the Disaster Management and Mitigation Unit (DMMU) which has specified powers and functions (Zambia Disaster Management Act 13/2010:81). Act no.13/2010 further sanctioned the formation of structures like the National Disaster Management Council of Ministers and its functions, the National Disaster Management Technical Committee and the Disaster Management Information System that maintains early warning information and inventory of resources. The act also gives guidance as to how to prevent and mitigate disasters and also provides for the establishment of the

National Disaster Relief Trust Fund and a framework for its management. Furthermore Act 13/2010 also sanctions the development of structures at provincial, district and community levels and guides how offences are dealt with.

In order to strengthen disaster management operations at all levels in the country the DMMU has opened offices in all the nine provinces of the country (Mulenga *et al.*, 2011:3). The country has also put in place contingency plans for floods each and every rain season, with likely scenarios of having them (Zambia National Contingency Plan for floods, 2009:iii). The DMMU has developed a disaster management operations manual that summarizes the roles and responsibilities and procedures relating to the management of disasters (Disaster Management Operations Manual, 2005:1). The manual defines "a flood as a high flow of water, which overtops either the natural or artificial banks of the river inducing disasters when human settlements have an overflow of water beyond the normal confines and humans are unable to cope with the calamity, or when they result in the destruction of crops, social and economic infrastructures" (Disaster Management Operations Manual, 2005:2).

In one of its strategic goals statement 2011-13, it is seen that the government and stakeholders have supported community disaster management committees in flood prone areas to build structures on higher ground, equipping them with clean water and adequate sanitation facilities and also building schools and clinics for them. These committees have received training in riverbank protection, flood control and embankment (Mulenga *et al.,* 2011:5).

Early warning in the country is coordinated by the DMMU which whose goal it is to empower individuals and vulnerable communities threatened by floods, to act in sufficient time and in an appropriate manner to avert loss of lives, injury and damage to property and the environment. The institution gets weather related warnings, such as floods from, the Zambian meteorological department and hydrological data which aids the determination of floods from the ministry of Energy and Water Development. There are also Non-Governmental organisations who are helping in the use of Indigenous Knowledge Systems (IKS) for early warning at local levels (Mulenga *et al.,* 2011:10).

Becker *et al*., (2013:4) has noted that, apart from disaster risk reduction structures, Zambia also has climate change adaptation structures. Some government institutions different forms the DMMU have mandates that influence climate change related issues. The Ministry of Tourism, Environment and Natural resources acts as the principle coordinating institution. It oversees activities relating to the environment which are implemented by other departments and other agencies. The country has also established the Zambia climate change facilitation unit which is responsible for the development of the climate change profile and adaptation policy.

2.3.4.2 Challenges and needs for addressing flood risks in Zambia - 2000-2013

Fabiyi, (2012:5) noted that effective management of flood disasters in most countries is hindered by many factors. These include lack of right policies and long-term strategies, absence of appropriate legal framework, inadequate institutional arrangements, ineffective flood forecasting and warning, limited community participation, absence of mechanisms for information or data collection and exchange and inadequate environment concerns. Ward, (1978:2) saw floods disasters as man-made since communities put themselves at risk by settling and developing in flood risk areas. He also stated that agriculture, industry, roads, bridges and railway lines are also found in flood areas. Supporting that view Bush, (1979:31) states that people tend to believe in personal immunity as they think that disaster cannot happen where they live. The consequences of this denial lead people to place themselves and their property in danger as they ignore warnings.

There is also divergence in perceptions of risk and emergencies between the general public and the experts (Haque, 2000:241). There is no involvement of stakeholders in the verification of data and information which allows for the elimination of error or uncertainty and non-incorporation of local knowledge (Maskrey, 1997:14). Accordingly, involvement also serves to increase knowledge of risk patterns by vulnerable groups, consequently enhancing their own confidence in the risk information produced by an early warning system (Maskrey, 1997:14). Flood management is not effective in ensuring the wellbeing and satisfaction of flood plain inhabitants due to, lack of communication and understanding between institutions, a reluctance to implement up to date regulations, and minimal public participation in the emergency decision-making process (Haque, 2000:243). There is a high probability that people at risk will take appropriate action on the basis of information which they have been involved in producing themselves (Maskrey, 1997:14).

There is also increased attention on non-structural vulnerability reduction and the use of both traditional and scientific knowledge bases at community and household level (Few, 2003:47). Disaster affected communities provide the first line of relief using own resources and knowledge when floods strike (Few, 2003:47), but it is these grassroots capacities that have been neglected in flood mitigation solutions in the past. Strengthening community livelihoods (traditional knowledge) approach and science is now emerging as a new focus in flood risk management (Sanderson, 2000:96). In a country like Pakistan, traditional risk reduction measures included tying ropes across fast-flowing rivers with bells attached to warn communities when floods came down the valleys (Davis & Hall, 1999:87). In Asia flood responses include coping mechanisms from flood prediction to recovery after disastrous floods based on an intimate knowledge of hazard risks and viable coping strategies (Blaikie *et al*., 1994:136).

People's understanding of the risk of flood hazard (perceived risk) differs significantly from the experts' risk calculations (objective risks) and if emergency policies aim to succeed, effective public involvement is required before, during and after the disaster (Haque, 2000:240). Disaster management agencies are also being centralised and not involving local power bases like the municipality, civil society and community organisations (Cardona, 2003:4). If stakeholders are not involved in the development of risk information, the credibility level of that information might be low and the possibility of warnings being ignored greater (Maskrey, 1997:14).

The IFRC fact sheet on DRR legislation, (2012:1) suggest ways that might improve disaster risk reduction through crafting of laws that, involve communities and civil society when being drafted, sanction DRR teaching at school, improve land management, set realistic standards for community construction, mandate and ensure adequate funding at community level, and laws that mandate community risk mapping. It has also been noted that Scientists in developing countries like Zambia are to a less extent being involved in disaster risk management research due to limited research finance. This is then calling for the need to have cooperating partners that can financially support African researchers (Ziervogel, 2008:6). It is also expressed that it does not help to wait until another part of the world finds scientific ways of mitigating flood disaster problems in Zambia and there is a possibility that such findings might become irrelevant as flood problems might have progressed to other forms and levels (Ziervogel, 2008).

2.3.4.3 Environmental legislation and flood mitigation: Zambia

Internationally it has been noted that there has been a paradigm shift from a response and relief or hazard centric approach to a mitigation and preparedness or vulnerability centric approach when it comes to flood risk reduction. As lessons are being drawn from flood management experiences the second paradigm shift is emerging which is centred on an environmental centric approach as another flood risk reduction strategy (Gupta & Nair, 2012:8).

Zambia has an environmental policy that aims to promote sustainable environmental protection. The policy aspires for management of the environment and natural resources with the aim of protecting future generations (Walmsley & Patel, 2011:461). The country's environmental and natural resources management framework includes the Environmental Management Act (EMA), No 12 of 2011, National Conservation Strategy of 1985, National Environmental Action Plan of 1994 and the National Policy on the Environment of 2007 (Campbell *et al.,* 2010:9; EMA, 2011).

According to the Environmental Management Act (EMA), No 12 of 2011 of Zambia, every person living in that country has the right to a clean, safe and healthy environment. Furthermore the inhabitants have a duty to safeguard the environment against any activity or phenomenon that affects or may affects. The environment is a common heritage of present and future generations (Walmsley & Patel, 2011:461). Natural resources in Zambia are managed by several departments some housed in the many Ministries including the Department of Forestry in the Ministry of Tourism, Environment and Natural Resources and the Department of Water Affairs in the Ministry of Energy and Water Development (Campbell *et al.,* 2010:9).

Environmental, issues in Zambia cut across a range of sectors, as such there are other several laws that have a bearing on the environment (Walmsley & Patel, 2011:480). Regulations that might be of interest to this study consist of the Water Resources Management Act, 2011 which provides for the ownership, control and use of water. The act also regulates for the sustainable use of water resources. The Public Health Act, No. 22 of 1995 which looks at issues to do with prevention and suppression of diseases. In the context of floods these might be in the form of water borne diseases. Town and Country Planning Act, Chapter 283 of 1962 which provides for the planning, preparation, approval and revocation of development plans and control the development of land. The act has a bearing on prohibiting developments on wetlands, near rivers dams, river catchment areas and other flood risk areas (Walmsley & Patel, 2011:480).

The National Policy on Wetlands Conservation, September 2001 provides for the conservation and wise use of wetland ecosystems. According to SADC, (2008:63) wetlands support river flow and groundwater recharge. They are also important in flood regulation. They reduce the flood peaks and flow velocity due to as they can store large quantities of water. Wetlands of importance in Zambia are the Kafue flats. SADC, (2008:64).

Osei-Hwedie, (1996:58) identifies some environmental problems in Zambia that include: (a) deforestation a result of tree cutting in order to provide energy for poor urban and rural communities, timber for construction purposes, clearing of land for cultivation and animal grazing; (b) desertification due to deforestation arising from extensive crop production, over-grazing and cutting down of forests. Land becomes bare, dry land unsuitable for human sustenance and (c) soil erosion caused by tree cutting, over-grazing, shifting cultivation and burning of forests depriving the soil of its nutrients.

The country has large tracts of forests and trees that are very critical in the control of floods and soil erosion (SADC, 2008:63). Apart from conserving resources for sustainable use by local people, forests also play a big role of protecting major water catchment areas (Campbell *et al.,* 2010:6). The Forest Act, No.7 of 1999 and the Local Forests Control and Management Regulations address the conservation and sustainable use of forests and trees (SADC, 2008:63). However, there is lack of enforcement of existing laws as well as a lack of plans for sustainable management of forests (Campbell *et al.,* 2010:6).

An average figure of 80 % of the population is involved in agriculture therefore the agro-ecological sustainability of the soil is paramount. This means minimizing soil erosion so that fertile soil is not transported by floods or runoff to rivers, dams and lakes. (Campbell *et al.,* 2010:15). The country also has structures for environmental management at Provincial and District levels. Communities also have successful Community-Based Natural Resource Management (CBNRM) programs that devolve authority and involve the communities in decision making and make them accountable (Campbell *et al*., 2010:10). According to Mweshi, (2004:111) environmental education and awareness are key factors in successful environmental management. Communities need enlightenment on dangers of environmental mismanagement, their roles and responsibilities in environmental management and the need for them to participate in solving environmental problems (Mweshi, 2004:111). This will lead to better management of flood risk.

2.3.4.4 Flood Disaster Risk Management efforts in Zimbabwe: 2000 to 2013

According to Chikoto and Sadiq, (2012:8), Zimbabwe has institutions that are responsible for disaster management activities at National, Province and District levels. Disaster activities are guided by legislation mainly the Civil Protection Act of 2001 chap 10.06, (Chikoto & Sadiq, 2012:8). The Civil Protection Act (Chapter 10:06) spells out the legal instruments for disaster management as well as the power that individuals and organisations have during flood disaster events (Government of Zimbabwe, 2005).The Act defines a disaster as “a natural disaster, major accident, disruption of essential services, destruction, pollution and scarcity of essential supplies, refugee influx, epidemic or disease that threaten the wellbeing and lives of people” (The Civil Protection Act, 2001). The National policy for disaster management in Zimbabwe is that every citizen of the country should assist wherever possible to avert or limit the effects of disaster (Madamombe, 2004:9). The Civil Protection Act gets support from sections of different sector legislation such as the

Police Act, the Defence Act, Rural District Councils Act, Regional Town and Country Planning Act, Public Health Act and the Environment Act (Mahonda, 2011:39).

The other legal instruments used are the Water Act (1998) which promotes Integrated Water Resources Management and has been adopted to cater for water resources management in the country and the Meteorological Services Bill (2003) of Zimbabwe, which mandates the Meteorological Services Department to issue weather and climate forecasts, and advance warnings on weather conditions likely to cause danger to life and property (Madamombe, 2004:7). Due to greater frequency and intensity of disasters in the country, communities in flood prone areas have devised their own means of monitoring surface water levels using features such as trees and other objects. When flood water reaches certain marked points flooding alert messages are disseminated to affected community members (Manikai, 2010:13). Disaster management legislation in Zimbabwe also created the Civil Protection Unit which is responsible for preparing, preventing and mitigating disasters and coordinating all national response efforts (UNISDR, 2005). Chikoto and Sadiq, (2012:1) also highlight the formation of this institution by saying that the Government of Zimbabwe created the Department of Civil Protection through the Civil Protection Act (1998) and charged it with the onus of coordinating and managing disasters and reducing hazards. The Civil Protection Organization of Zimbabwe has the overall responsibility for the management and coordination of flood emergencies (Pawaringira, 2008:5).

According to Becker *et al.,* (2013:4), Disaster Risk Reduction in Zimbabwe is the responsibility of the Department of Civil Protection, under the Ministry of Local Government, Rural and Urban Development. The unit is also engaged in resource mobilization, information dissemination, and training for disaster response activities (Chikoko & Sadiq, 2012:8). The department appoints officers at national, provincial and district levels, as heads and chair civil protection committees that assist in planning, implementing and evaluating disaster management response programmes (Chikoko & Sadiq, 2012:8). The engagement of these actors is strategic in nature as it allows for sharing of tasks and resources. In pursuance to reduce the risk of disasters, there is also the National Climate Change Office, under the Ministry Of Environment and Natural Resources Management, which has the responsibility for climate change and adaptation activities (Becker *et al.*, 2013:4). The office has a committee on climate change composed of experts from various government departments, industry and environmental research (Becker *et al.*, 2013:4).

The disaster management structures in Zimbabwe have a working party comprising of Government departments and other private organisations co-opted as and when required. The working party has subcommittees namely the early warning unit, weather and flood forecast represented by experts from the Meteorological Department and the Zimbabwe National Water Authority, the rescue and security subcommittee represented professionals from the Zimbabwe Defence Forces, Zimbabwe Republic Police, Civil Aviation and Ambulance services and the health and social services unit represented by members of the Ministry of Health (Pawaringira, 2008:5).

To be efficient civil protection authorities in Zimbabwe rely on additional information from hydrological service experts, underlining the need of strong interaction between the Meteorological Services Department, the Zimbabwe National Water Authority (ZINWA) and the Department of Civil Protection before, during and after the severe weather event (WMO, 2007). A study by Mahonda, (2011:52) in Kanyemba, Zimbabwe, discovered that the community understudy had informal structures and indigenous knowledge systems on flood management. They use behaviour of certain types of birds and river water levels to predict floods. This brings into light that, apart from formal structures, communities also have informal structures and use indigenous knowledge to manage flood disasters in the country.

However the Civil Protection Act, Chapter 10:06 is apparently undergoing revision and there are proposals to rename it, the Emergency Preparedness and Disaster Management Act whose main thrust will be to address structural and organisational gaps that ensure a multi sectorial representation (Madamombe, 2004:7). The first draft was produced in 2007, revised in 2011 and circulated among stakeholders for their input. In 2012 the Civil Protection Unit hired a consultant to finalise the policy framework which awaits the final outcome of all these processes (Bongo *et al.,* 2013:3). What is important in the Draft National Disaster Risk Management policy is that it proposes a comprehensive information management system that takes into account indigenous knowledge on disaster risk management (Zimbabwe Draft National Disaster Management Policy, 2011).

2.3.4.5 Current challenges and needs for addressing flood risks in Zimbabwe

Looking at policy and legislation, a study, by Manyena *et al*., (2013:1786) on the effectiveness of disaster legislation in five countries around the world including South Africa and Zimbabwe concluded that, to a large extent, legislations from these countries has centralised institutional frameworks leading to limited community participation. Spaliviero *et al.,* (2011:745) have the view (although it contradicts other authorities in this research) that relevant disaster management legislation does not exist in Mozambique and Botswana, difficult to enforce in Zimbabwe due to its formulation, and is more advanced in South Africa.

Mahonda, (2011:12) identified limitations that hinder effective management of floods in the Zimbabwe legislative framework. He stated that the disaster management policy and Act centre on response at the expense of comprehensive flood risk reduction. In a study by Bongo *et al.,* (2013:2), they discovered that disaster risk reduction activities in Zimbabwe were spear headed by Non-Governmental Organizations, United Nations agencies and Disaster Risk Reduction specialists with little room for the government and affected communities. Community leaders need to encourage active involvement of communities and value their contributions and ideas so that they can see the benefits of being involved and take ownership of such projects (Gwimbi, 2009:75).

Mahonda, (2011:40) goes further and criticizes disaster legislation in Zimbabwe in that, it has no clear provision for funding the department of civil protection and its structures. Furthermore, local traditional mechanisms for floods management and control are not adequately included and supported by legislative framework. Gender issues are a fundamental element in disaster management and are not addressed, to enhance resilience on the part of women to disasters as they are affected differently from men (Muhonda, 2011:41). The current disaster policy in Zimbabwe does not create an enabling environment to include affected communities, where DRR activities are the sole preserve of specialists and does not incorporate the daily activities of affected communities (Bongo *et al.,* 2013:2).

In a study by Schad *et al.,* (2012:232-35) in Vietnam, it was noted that people under-estimated flood warnings because ‘‘the weather was so diversified and that forecasts were never really precise”. This was noted earlier by Cardona, (2003:4) as he was of the view that despite having technological advancement in this world, it was not easy to predict the occurrence of future natural events with precision. Despite all efforts to manage flood disasters some problems arise that impede the efficient and effective management of floods (Carmo Vaz, 2000:12). Madamombe, (2004:5) notes that, lead-time between the flood forecast and the flood event is limited as models being used for meteorological forecasts can only provide very short forecasts accurately. What this means is that there will be limited time to respond and reduce the impact of the disaster. Recipients are often uncertain about the accuracy of the risk-related message due to past history of deceit or lack of credibility, as such selective use of information has been practiced (Haque, 2000:241). Due to previous false alarms, people no longer took forecasts seriously (Matsimbe, 2003:27). More to that there is a problem in accuracy of forecasts, as people no longer have trust and faith in flood predictions as what also happened during the Eline cyclone, where an accurate forecast was issued by the meteorological office but was not taken seriously until people started dying as a result of floods (Madamombe, 2004:5). One approach to reducing false alarms is to use reliable local hazard indicators, such as animal behaviour or vegetation changes, to verify scientific indicators of upcoming hazards (Pearson, 2012).

Many countries had inadequate allocation of resource and focusing more on the hazard than the other constituencies of risk like vulnerability and resilience (Manyena *et al*., 2013:1793). It is suggested that strengthened laws and policies will support the allocation of adequate funding for work with vulnerable people and their communities, risk mapping, access to disaster information, development planning, enforceable building codes and land use planning, and accountability for results, of which non conformity should be punishably or carry a penalty (IFRC, 2012). The United Nations Children’s Fund (UNICEF, 2006:31) is of the view that “approach to disaster programming stresses participatory approaches that engage communities in planning, implementation and monitoring processes”. What this means is that disaster management programmes should be built on what people already know and recognise the social and cultural strengths in their experiences. Participation empowers community members with knowledge and skills, which will further strengthen their capacity to contribute to development initiatives (Gwimbi, 2009:76). Participation by communities also calls for the integration of indigenous knowledge systems in disaster preparedness especially flood risk communication among local communities (Alverez, 2006). The legal framework in Zimbabwe, should mandate involvement of affected people in communities, government and the private sector in risk reduction (Bongo *et al.,* 2013:10).

According to Haque (2000:239), there is a common perception that people living in flood-prone areas are helpless victims. Contrary to this, one finds that, by using their common sense, experience, and by having a general perception of the hazard, people often succeed in protecting themselves (Haque, 2000:239). According to the UNDP/IFRC, (2014:16), national institutional framework, legislative and policy instruments, community participation and allocation of resources are important pillars and a basis for analysing effective disaster legislation. These pillars are used by Manyena *et al.,* (2013) in their study which analyses the effectiveness of disaster legislation in five countries around the world including Zimbabwe. In the study, they concluded that to large extent legislations from these countries and Zimbabwe included have centralised institutional framework, limited community participation and inadequate allocation of resource, focusing more on the hazard than on other constituencies of risk like vulnerability and resilience or capacity. There is also need for statistical capacity in the country to enhance evidence based policy and decision making. Policies and decisions based on wrong statistics will fail as wrong projections will be made for implementation (Scott, 2005).

2.3.4.6 Environmental legislation and flood mitigation: Zimbabwe

The natural resource dependant rural communities in Zimbabwe comprise 70% of the population. The challenge for law and policy makers (legislators) is on how best to address past abuses and promote more democratic and sustainable resource management in the communities (Mtisi, 2004:2). In Zimbabwe the environment is mostly managed using the concept of Integrated Environmental Management (IEM) through the Environmental Management Act (EMA) of 2002 (Naome *et al.*, 2012:408). Integrated Environmental Management (IEM) is defined as a productive or preventive measure that maintains the environment in a good condition for a variety of long-range sustainable uses (Naome *et al.,* 2012:409).

According to section four of the Environmental Management Act (EMA, 2002, Chapter 20:27) of Zimbabwe, citizens have a right to live in a clean environment that does not harm their health and to protect it for the benefit of present and future generations (Walmsley & Patel, 2011:494). The Environmental Management Agency (EMA) under the Ministry of Environment, Water and Climate change is responsible for Environmental Management in the country. One of the objectives of the EMA is to promote sustainable management of natural and physical resources (Naome *et al.,* 2012:409).

One serious problem concerning the environment in Zimbabwe is uncontrolled fires. They cause a reduction of bio-diversity through destruction of flora and fauna. Moreover, fires reduce soil fertility, increase erosion and decrease infiltration, which lead to flooding (Nyamadzawo *et al.*, 2013:1). Fires also increase runoff losses due to loss of vegetative cover. As such post-fire hydrological behaviour influences low infiltration and enhanced runoff (Nyamadzawo *et al.,* 2013:7). The Forest Act, (Chapter 19:05) regulates the management of forests and burning of vegetation. Forest are helpful in controlling floods and soil erosion.

It is important to note that Environmental issues in Zimbabwe cut across a range of sectors (Walmsley & Patel, 2011:511). As such there are other laws that also have a bearing on environmental management and sustainable development issues. In managing the environment the Zimbabwe Government has several legislative provisions to manage and control activities in the environment. These regulations include the Environmental Management Act (CAP 20:27), Parks and Wildlife Act, (CAP 20:14) of 1996, Forest Act, (CAP 19:05) of 1996 and the Traditional Leaders Act of 1998. The country also has a National Environmental Policy and Strategies of 2009 that aims at the avoidance of irreversible environmental damage, maintenance and sustenance of environmental processes that lead to meet basic human needs, reduction of poverty and improvement of the general standard of living of Zimbabweans (Walmsley & Patel, 2011:511). The Water Act, 2003 (Chapter, 20:24) provides for the use, management and water development plans for river systems.

This might include the issues to do with unconstrained flow of rivers which assists in controlling floods.

Although there is legislation to manage the environment authorities need to improve their preparedness to it. They need to acquire equipment for environmental management in communities (Nyamadzawo *et al.,* 2013:10). Authorities also lack adequate human and financial resources to enforce the laws. There is need for a comprehensive environmental management strategy that has enough institutional support, funding and administration to ensure successful implementation (Naome *et al.,* 2012:408).

According to Mtisi, (2004:2), issues of environmental management ranging from land use, forest management, water management, wildlife production and pollution are not prioritized in Zimbabwe. Environmental management is not taken as a matter of national importance (Mtisi, 2004:2). The environment is only thought of by decision makers or politicians when it brings about publicity to them or when there is an environmental crisis whereof they would want to be identified as having addressed or solved the problem (Mtisi, 2004:2). There is also lack of political will. Politicians are reluctant to enforce unpopular regulations for fear of destroying their political base. local authorities are using old by-laws or regulations which do not reflect the scope of environmental problems in urban and rural areas. There are also queries to the relevance of some legislation to environmental protection as the fines imposed are too little for deterrence and at a fixed rate irrespective of the damage that has been caused (Naome *et al.,* 2012:412).

There is therefore need to enhance conservation-based development facilitating the reduction of water run-off and erosion which perpetuate flood disasters. Agro-forestry and reforestation nurseries have to be established for environmental promotion. To mitigate threats of flood water harvesting techniques that include digging of pits, wells and trenches must be introduced. Communities especially the youths have to be educated and encouraged to plant trees near the river basin where land is exposed to soil erosion and long-term degradation (Red Cross, 2009:18). Since flood mitigation also calls for conserving wetlands within a river system, conservation maintains the natural water cycle and reduces flood impacts on people’s lives and property (Schneidergruber *et al.*, 2004:2). City and Rural District Councils in Zimbabwe have by-laws they use to protect wetlands. They are fencing some of the wetlands to stop livestock trampling on them and other unsustainable human activities (EMA, 2014:11). They have also involved communities in projects aimed at mitigating unsustainable wetland cultivation and in adopting alternative sources of livelihood other than agricultural activities on the wetland (EMA, 2014:6).

2.3.4.7 Flood Disaster Risk Management efforts in Botswana: 2000 to 2013

Botswana has both a legal and institutional framework for disaster risk management (International Federation of the Red Cross, (IFRC), 2013:23). The current legal framework that address issues of disaster risk management in that country, is comprised of the National Policy on Disaster Management (1996), National Disaster Risk Management Plan (2009), Finance and Audit Act 1996, the Emergency Powers Act and other sector legislation (Botswana National Disaster Risk Reduction Strategy 2013-18). The country has an institutional framework for Disaster risk management covering three levels of management namely national, district and village (Botswana National Disaster Risk Management Plan, 2009:10). The overall coordination of the flood response rests with the Government's Office of the President, through the National Disaster Management Office (Botswana Country Report, 2004:3).The SADC-region and Botswana national organisations like the Department of Water Affairs (DWA) and Department of Meteorological Services (DMS) make country hydro-meteorological observation. The country has also been included the World Meteorological Organization's (WMO) Hydrologic Cycle Observing System (HYCOS) network of stream-gauging stations that report in near real-time format through SADC networking (Turnipseed, 2003:3).

In its institutional framework Botswana also has two important committees, a National Committee on Disaster Management (NCDM) which is made up of Deputy Permanent Secretaries from ministries and personnel from the police, army, red cross, Non-Governmental Organizations and the United Nations, that acts as a policy formulation body and a national platform for disaster risk reduction strategies. The National Committee on Disaster Management (NCDM) gets support from the multi-sectoral National Disaster Management Technical Committee (NDMTC) which has professionals and is a technical advisory body on all disaster management issues (Botswana National Disaster Risk Reduction Strategy 2013-18:10). The National Disaster Management Technical Committee is chaired by the Director, National Disaster Management Office and also has members from Government departments, private organisations, the Police, Army, Non-Governmental Organisations, Community Organisations and a representative of the United Nations Development Programme (Botswana National Disaster Risk Management Plan, 2009:12).

Becker *et al*., (2013:4) also allude to the fact that the main coordinating bodies for disaster management at the national level are the National Committee on Disaster Management (NCDM) and the National Disaster Management Technical Committee (NDMTC). The authorities cited above also go further and identify the National Climate Change Committee (NCCC) as the main body coordinating issues to do with Climate Change Adaptation (CCA) in Botswana since climate change is very topical in disaster management. The committee is administered through the Department of Meteorological Services, in the Ministry of Environment, Wildlife and Tourism. The Ministry has a National Climate Change Coordinator who enhances climate change knowledge and skills within that Ministry.

The institutional framework is set in such a way that the National Disaster Management Office (NDMO) directs and coordinates flood response. Disaster response is then implemented by the District Disaster Management Coordinators (DDMCs) led by District Commissioners. The district level also brings on board disaster relief stakeholders like, the Botswana Defence Forces, Botswana Red Cross Society, Botswana Police Service, fire departments, and other district government departments. Hydrological and meteorological observations for the country are done by the Department of Water Affairs (DWA) and the Department of Meteorological Services (DMS) both at national and regional (SADC) levels (Turnipseed, 2003:3).

More to that Section 17 of that country's Constitution grants the President power "at any time to declare a state of public emergency and places some limitations such as the period and requirement for approval by Parliament" (Botswana Country Report, 2004). The country is also guided by a National Disaster Risk Management Plan.

This plan has its roots from the National Policy on Disaster Management (1996), Finance and Audit Act (1996) and Hyogo Framework of Action (2005-15). The plan provides guidelines to plan and implement disaster responses, identifies risks, and reduces vulnerability in the contexts of various hazards, defines management structures through which disaster risk management is to be implemented, coordinated and facilitated and identifies roles and responsibilities of government and nongovernment actors for disaster risk assessment, preparation and risk reduction.

The Department of Meteorological Services (DMS) which has an operational forecasting role and the Department of Water Affairs (DWA) which gives stream flow data, both provide critical hydro-meteorological data to the National Disaster Management Office (NDMO) who incorporate all this data into their messages as information to the public. Recognising that there were limitations, inadequacy and untimely hydrological and meteorological information which is crucial to decision makers at the national level, USAID an international organisation also initiated the Village Flood Watch project in Botswana (Turnipseed, 2003:3).The country also has a National Disaster Relief Fund (NDRF) which was established in 1996 and is administered by the National Disaster Management Office (NDMO). Its purpose is to provide assistance to natural disaster victims so that they meet their life sustaining needs such as shelter, food and provision of sanitary facilities (Botswana Country Report, 2004:6).

In 2013 the Botswana Red Cross Society commissioned a legal audit on disaster management in Botswana. The purpose of the legal audit was to investigate Botswana's legal preparedness to facilitate and regulate international disaster assistance in the event of a disaster and to review their current legal framework, policies and practice in disaster response. The audit generally established that Botswana had a number of laws relevant to disaster risk reduction namely the National Policy on Disaster Management and a National Disaster Risk Management Plan. Strengths in disaster management were noted in that as the focal point of these activities, the National Disaster Management Office was housed in the Office of the President.

The audit also identified that Botswana had no legal instrument that addressed disaster response, had not acceded to or domesticated most major treaties in Disaster Risk Management, had no National Disaster Risk Management legislation and had no legislation governing the facilitation and regulation of international disaster assistance. The audit also noted with concern that existing disaster management legislation was fragmented, took valuable time and resources and was burdensome on Government and international actors offering assistance even though it could be used to assist in disaster situations. It was recommended that Botswana should consider enacting national Disaster Risk Management legislation in order to provide a legal and institutional framework for disaster management in the country (IFRC, 2013:12).

Since 2011, the Red Cross in that country has been working with communities along the Zambezi River basin in the region enhancing disaster preparedness, strengthening community capacity on early warning systems, implementing small-scale resiliency projects such as improving drainage in flood-prone areas, helping to flood-proof homes and planting trees to slow erosion and storm runoff since 2011 (IFRC: Botswana, 2010).

2.3.4.8 Current challenges and needs for addressing flood disasters in Botswana

Being critical, Dixit, (2003) points out that, policy makers, donors and relief and development agencies treat flood disaster as isolated events and interventions to disasters are responses made under the assumption that an emergency support in the form of relief will help overcome the situation. The frameworks in the regional countries tend to focus on response mechanisms (Muhonda, 2011:12). As such Flood management is highly reactive and relief oriented (Muhonda, 2011:12). Due to disaster relief approaches, natural disasters occurring in African countries are undermining the economic survival of poor communities (Lukamba, 2010:478). Bakker, (2006:143) observed that during most floods traditional authorities do not believe in flood warnings as they went against their experiences. Further to that flood warnings are and were too technical for common people to understand. Mwando (2013) for example indicates that “forecasts have been regularly revised as rainfall patterns have deviated from initial predictions.” A study by Schad *et al.,* (2012:235) observed that although communities have plans to prevent flooding, the quick onset of floods prevents people from taking action because, “when it really comes to strong rain, one forgets about the plan and does nothing.”

An analysis of past floods, was difficult because data was not systematically collected, compiled, analysed and reported (Carmo Vaz, 2000:13). There is lack of support in terms of resources and expertise from the administration as little assistance provided shows a clear tendency toward restoring the pre-flood conditions rather than helping to adapt to future flood risks (Schad *et al.*, 2012:237). At times lack of support might be caused by constraints in terms of financial and qualified human resources (Carmo Vaz, 2000:14). An institutional arrangement at national, provincial, district and in a few areas at community/village level exists and is functional in the SADC, even though with financial, human, material and equipment capacity challenges (Manikai, 2010:6).

According to Howell, (2003:4), many people ignore flood warnings for several reasons which include economic, lack of understanding, failure by official flood warnings and high level warnings given when the storm is weak. According to Pearson, (2012) high false alarm rates can undermine public confidence, breed mistrust, dilute the impact of alerts and reduce the credibility of future warnings. There are also many other obstacles to disaster preparedness and survival in communities in the form of religious beliefs, superstition, rigid gender roles, lack of protective infrastructure and local insecurity (Howell, 2003:4). When the 2000 floods hit southern Africa, information exchange, communication and coordination was reportedly hindered by limited government participation (Gwimbi, 2007:156). Unless flood mitigation is adopted as a regular activity by a relevant government department, it will remain an activity without budget and will therefore be side-lined (Masiyandima, 2008:20). Warnings are too technical to be understood by people in rural areas (Carmo Vaz, 2000:31). Scientific jargon relating to uncertainty regularly causes users not to act as statements such as "there is a 20 per cent chance that rainfall will be above the inter-annual mean" present information in an unfamiliar language (Pearson, 2012). More to that people are less likely to respond to a warning if the previous alerts did not result in a serious disaster or if they have never experienced such a serious event (Matsimbe, 2003:26). Flood planning and implementation decisions are based on mathematical and statistical models and on physical parameters ignoring the people who are the main players in disaster management, who in turn become sets of statistics, as victims (Haque, 2000:240).

There are various approaches to mitigate the impacts of flooding which may be structural or non-structural actions before, during or after flood events (Few, 2003:47). Structural approaches have achieved mixed successes and some have proved costly and even exacerbated flood hazards (Few, 2003:47). Non-structural solutions are now being encouraged as engineered solutions have shown limitations (Ishiwatari & Sagara, 2012:3). These measures are not designed to prevent floods but to reduce their short and long-term impacts (Few, 2003:47). These include floodplain conservation (Kousky & Walls, 2013), flood prediction and warning systems, (European Union, 2003) evacuation or relocation programmes, land use controls on flood-prone sites, building regulations, insurance schemes (Few, 2003:47) and empowering communities to implement home grown flood mitigation and preparation strategies (ADPC, 2002:1). There is also need to develop fast and reliable internet and cell phone communication especially in the remote areas so that flood forecast communication and updates of such information become effective (Sahu, 2007:16).

2.3.4.9 Environmental legislation and flood mitigation: Botswana

Floods are a natural occurrence but, human activities and interventions in the natural processes like the alterations of drainage patterns due to urbanization, agricultural practices and deforestation, have eroded the functions of river basins. As a result this is resulting in constant exposure of communities to risk and vulnerability in flood-prone areas. Good environmental practice might eliminate or limit this risk (UN/ECE, 2002:4). At the global level, there is now need to link flood Risk Reduction with environmental management (Gupta and Nair, 2012:7).

Botswana has large body of legislation concerned with environmental protection (Botswana Government, 2006:21). The country has a constitutional requirement to protect the environment (Walmsley and Patel, 2011:69). The Department of Environmental Affairs in the Ministry of Environment, Wildlife and Tourism has the overall responsibility of protecting the environment (Walmsley & Patel, 2011:69).

Environmental legislation is also administered by different Ministries and Department different for implementation (Botswana Government, 2006:21).

Botswana has enacted the Environmental Assessment Act, (Act No. 10 of 2011) and the Environmental Assessment Regulations of 2012 as the main regulations to manage its environment (Environmental Assessment Act, 2011:2). The government also has a National Development Plan (NDP), which identifies and integrates issues relating to the environment and sustainable development, Environmental Impact Assessments (EIA) legislation and the development of management plans for some priority ecosystem areas (Government of Botswana, 2002).

However there are other relevant environmental legislation laws found in various Acts. This study cited only laws that are related to flood risk management. They include and not limited to the Environmental Impact Assessment Act, Forest Protection Act, Agricultural Resources Conservation Act and Water Act, (Botswana Government, 2006:21).The Botswana Forest Act of 1976 and Forest Regulations, 2006, provide for the conservation of forestry reserves. Forests are very important in controlling floods and bind soils from erosion (Walmsley and Patel, 2011:87). Forest Policy, 2011, governs the management, utilisation of forest resources and the protection of forests from fires. Forest Management can arrest soil degradation and manage water runoff therefore reducing flood impacts (Sathaye, 2007:727).

The Public Health Act of 1981 provides for the compulsory notification and prevention of diseases. Disease related to this study come in the form of water borne diseases. The State Land Act, (1966) provides for settlement, land allocation, land management and land use. This act regulates and controls where people stay including flood risk areas. The Agricultural Resources (Conservation) Act, (1973) promotes agricultural development and the conservation of agricultural resources. Of importance to note is the protection of soils from erosion during floods. The Botswana National Water Master Plan, 2006 and the Water Act, 1968 are important for water resources planning and management (Walmsley & Patel, 2011:86). The Town and Country Planning Act, 1977 provides for the planning, zoning and orderly development of rural and urban land.

Land degradation is a serious environmental problem that is fuelled the growing human population, increased number of livestock, overgrazing, tree-felling and inappropriate farming techniques only to name a few (Wingqvist & Dahlberg, 2008:2). Therefore monitoring and observing environmental factors that enhance the onset of a flood are fundamental to flood prediction and early warning systems in Botswana (Gupta & Nair, 2012:8). However some laws governing environmental management and access to resources in the country are now old and not in sync with today environmental activities (Makonese, 2008:45). Many of these laws are not fully implemented because of fragmentation both in substance and in terms of implementation, inadequate coordination between authorities and capacity limitations (Botswana Government, 2006:21).

2.3.4.10 Flood Disaster Risk Management efforts in South Africa: 2000 to 2013

According to the Disaster Management Act 2002 (Act 57), South Africa has some structures that it uses in its disaster risk reduction activities. The activities fall under the concept of integrated development planning. The strategy emphasizes an integrated and co-ordinated approach to disaster risk reduction focusing on preventing or reducing the severity of disasters. These activities are divided into forums and committees, that is, the Disaster Management Advisory Forums (DMAF) and Disaster Management Centres (DMC) that both have establishments at national, provincial and municipal levels. According to the Municipal Systems Act, (2000) every municipality is mandated to have a disaster management plan as part of its Integrated Development Plans. The plan must set up the structure and mechanisms for dealing with disasters and it must anticipate future disasters. Plans must be developed to deal with disasters that occur regularly for example flooding of informal settlements and roads.

Though it is stipulated in the Disaster Management Act 57 of (2002) that the operational modalities of disaster management must be done by the creation of structures at all levels of government, it is silent on how a preparedness for disaster risk reduction must be organised (Van Niekerk, 2005:4). The Act also requires that spheres of government apply disaster management uniformly (Disaster management

Act, 2002: sec 7). According to Van Niekerk, (2005:4), such a framework will assist decision makers to direct development projects that enhance disaster risk reduction.

In Alexandra Township, where summer floods occur yearly as many homes are near the Juskei River, the community is in the process of recognising its vulnerability to floods. The community has introduced early warning systems like warning bells, door-to-door warnings, and radio alerts. More to that, they learn first aid techniques, have formed response groups and have identified a safe house where flood victims are evacuated and sheltered during flood disasters (IDNDR, 1996:23).

The South African Weather Service (SAWS) has developed a proposal to set up a regional flood warning system to cater for the region (Poolman, 2006). The proposal is motivated by the recurrence of cyclones that trigger floods across the whole sub region. For example, in 2000 cyclone Eline caused floods in Mozambique, South Africa, Zimbabwe, Malawi, Botswana and Namibia. Poolman, (2006:1) also noted that "even though the South African Weather Service (SAWS) has a weather radar network, and can issue warnings of potential heavy rain, a proper flood warning system that can warn the disaster management authorities and the communities at risk does not exist in the region". That observation identifies a gap and a weakness in disaster risk reduction in that country.

2.3.4.11 Current challenges and needs for addressing floods risks in South Africa

National policy and legislation for some regional countries centre on prescription for the functions, management and related institutional issues of national disaster Management organisations (Muhonda, 2011:12). Muhonda, (2011:13) also noted that, in most countries in the SADC, institutional frameworks for floods management do not emphasize sustainable efforts to reduce disaster vulnerability. Lack of funding, budget polices for risk mitigation and capacity to mainstream DRR were also noted as constraints in translating momentum into sustainable programs and investments that reduce long-term vulnerability (Ferris & Petz, 2013:38). Hulse, (2014:13) expressed concerns that SADC as an organisation operates on a weak budget and relies on donor funds undermining its autonomy as an actor.

The magnitude of some rain seasons stretched local authorities and humanitarian partners' capacity to the limit (OCHA, 2007:2). Rabalao, (2010:26) also found that there was limited interest in flood hazard, poor involvement in flood issues and sentimental rather than logical reasoning for living in areas at risk of flooding among other things. According to Bryant, (1991:259) and Rabalao, (2010:300), people find it difficult to give up the historic identity with the area, maintaining links with the past or with ancestors and to sustain their roots. Malele, (2009:29) argues that poor urban governance often make urban dwellers, their properties and the environment more vulnerable to the impacts of a number of hazards like flooding. Parker, (2000:10) identified lack of protection from floods, inability to avoid, withstand or recover from floods, powerlessness through an inability to influence one's own safety level of protection or relief, as contributory social factors to flood disasters. Deforestation, land degradation and resource exhaustion processes contributed to disaster vulnerability (Wisner, 2004:81).

On the technical side there are problems associated with the installation and operation of flood warning systems, insufficient rainfall and hydrometric networks and redundancy of recording equipment (Carmo Vaz, 2000:13). There is no or ineffective communications during floods and risk information is not credible to those people at risk as they are not involved in its production (Maskrey, 1997:14). There is also uncertainty inherent in scientific information and forecasts are often in a language or format that is not easily understood by humanitarian workers or the local communities that need it (Pearson, 2012: Online). It is also noted that, failure to get good results in disaster risk reduction is being made worse by the absence of feasibility, a response and aid approach with less in prevention and mitigation (Cardona, 2003:14). According to Gwimbi, (2009:74), there is lack or no political will in the SADC to manage flood disasters. Political will, in developing countries, rests in the hands of the government and ruling political parties and is a big challenge for these countries (Asek, 2006:1).

Disaster risk management is receiving increased support at the policy level in the country but the commitment and ability to act on the ground is still limited (Ziervogel & Taylor, 2008:45). Due to many problems affecting effective Disaster risk reduction in South Africa stakeholders need to attend to many issues that include the following so that there is reduced flood risk. Focus must be placed on investigating risks and vulnerabilities during flooding and improving the dissemination of the disaster-related information at national level (Zuma, 2012:130). The Provision of early warning information and advice to households on flood response is an important resilient strategy to reduce risks (Gwimbi, 2009:75). Growth of the urban population is placing excess pressure on public services decreasing disaster resilience of households calling for a need of strengthening research into vulnerabilities and risk (Zuma *et al*., 2012:127). There is also need for stakeholders to develop simplified community-based disaster risk reduction methods (Victoria, 2002:269). Due to financial constraints the Government cannot address all flood risk management needs, as such public-private partnerships and private-sector initiatives need to be explored and encouraged (Ziervogel *et al*., 2008:6).

According to Van Riet and Van Niekerk, (2012:2), research shows that community based disaster risk management enhances the best results and trustworthy in understanding the disaster risk of communities and how they have dealt with them. The aim is not only to make a community safer and more resilient, but also to identify, assess and monitor risk at a community level with the objective of informing the design of locally appropriate risk reduction programmes. There is a general desire for disaster risk reduction to be accomplished by enhancing the skills, knowledge and capacities of local communities. In relation to the foregoing, in this research the community and other stake holders were involved through making contributions and proposals for the development of a common regional flood prediction model.

2.3.4.12 Environmental legislation and flood mitigation: South Africa

One of the world challenges and South Africa included is to improve the quality of human life for the present generations, without depleting natural resources for future generations (South Africa Yearbook, 2003/04:234). In South Africa, there is heavy reliance on natural resources due to high levels of poverty and unemployment, making communities vulnerable to environmental changes (Middleton *et al.*, 2011:4). Environmental management in that country is from the onset provided in the Bill of Rights, in Chapter Two of the Constitution of South

Africa Act, No.108 of 1996 (Walmsley & Patel, 2011:316). In terms of the constitution everyone has a right to an environment that is not harmful to their health or well-being. The same section also gives individuals the right to protect the environment for the benefit of the present and future generations. Sustaining natural resources can be achieved through preserving the natural environment for the supply of raw material; absorption and treatment of waste products and maintenance of water, soil and air quality (South Africa Yearbook, 2003/04:234).

Generally environmental management in South Africa is through the use of National Environmental Management Act (NEMA) 107 of 1998 (Walmsley and Patel, 2011:323). The preamble of the NEMA 107 of 1998 is motivated by the fact that communities live in an environment with risks to their health and wellbeing. As such inhabitants have a right to an environment that is not harmful to their health or wellbeing (NEMA, 1998). The Act also recognises public participation in environmental decision making and community roles in managing the environment and accessing resources in the environment (Makonese, 2008:45). Apart from NEMA, 1998, the country has other relevant environmental laws. Related to this study is the Mountain Catchment Areas Act, No. 63 of 1970 which provides for the conservation, use, management and control of land situated in mountain catchment areas. It is now common to read. This has a relationship to issues to do with flood controls as such areas help in containing flood flow. The National Water Act, No. 36 of 1998 provides for matters related to dam safety in the light of possible floods due to dam failure and free water flow in rivers. The National Water Act, (Act 36 of 1998) also has important sections with respect to flood management. It outlines the legal requirements of catchment management strategies. Chapter Seven of the act is concerned with catchment management agencies and Section 80 particular, outlines the functions of the catchment management agencies. Section 144 highlights the importance of flood lines on township plans and Section 145 calls for making flood related information available to the public. (Benjamin, 2008:84).

The Municipal Systems Act (Act 32 of 2000) requires municipalities to draw up and review Integrated Development Plans (IDP) annually in consultation with local communities and stakeholders. This act is important for flood risk management as disaster management plans form part of the IDP. What this means is that efforts to reduce flood risk are incorporated into the IDPS (Benjamin, 2008:85). Related to the Municipals Systems Act is the Development Facilitation Act, No.67 of 1995 that regulates the planning, zoning and development of land in Municipal regions (Walmsley & Patel, 2011:348). Town Planning and Townships Ordinance (Ordinance 15 of 1986) makes provision for the extension of flood line areas up to 32 metres from the centre of a stream in cases where the 1:50 year floodline is less than 62 metres wide in total (Benjamin, 2008:85). The Conservation of Agricultural Resources Act, No. 43 of 1983 guides and controls the cultivation of wetlands and the management of soil erosion. In regard to flood management the National Building Regulations and Building Standards Act (Act 103 of 1977) provides and guides for development within the 1:50 year flood line area and requirements are based on safety considerations. However the act is criticized for considering safety without putting into consideration and understanding the underlying natural stream flow process (Benjamin, 2008:85). Apart from the environmental laws cited above South Africa is also reforming its environmental policies, ratifying international agreements and taking part in global sustainable development initiatives (South Africa Yearbook, 2003/04:234).

2.4 Conclusion

A conceptual and contextual survey on the current and past management of river flood disasters in the SADC-region was conducted in Chapter Two. The review firstly had specific emphasis on important terms and concepts in disaster risk management and flood prediction utilised in the study. These concepts are disaster, flood, flood risk, vulnerability, capacity, mitigation and living with floods. Secondly the context of floods, as well as institutional and legal frameworks used in flood risk reduction, by the sampled countries were also discussed. There is evidence that the region is making frantic efforts to try and manage floods disasters as discussed in Section 2.3. This can be seen in the various disaster management policies and structures that have been set up by the countries under study but how successful this has been remains to be seen and needs some evaluation in any further study that may be done. Literature shows that the SADC-region has an abundance of water and flood management policies. Substantial efforts in managing flood disasters are visible from the inclusion of the studied countries in flood disaster management issues in platforms like the SADC Water Policy 2005, Integrated Water Resource Management (IWRM), the Southern Africa Regional Climate Outlook Forum and the Southern African Development Committee (SADC) – Hydrological Cycle Observing System (HYCOS) Project. Important ideas from these forums can be benchmarked and be incorporated in developing a better flood prediction model for the region. These platforms assist managing, observing and providing weather forecast information which help in preparing for and mitigating flood effects in the studied countries.

It was also observed in the chapter that the SADC had structures for Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA). More to that, all the studied countries have legislative framework for managing disasters in the form of Disaster Managements Acts, Environmental legislation and other various legislative acts related to IWRM. All these efforts outlined above compliment the study focus as they help in giving an insight on: "What the governments of the four SADC-countries under discussion (Zambia, Zimbabwe, Botswana, South Africa) have done so far to mitigate the effects of river flood disasters occurring in the Region?".

Discussions in this section help to conceptually and contextually understand and identify disaster risk management gaps with regards to flood prediction in the SADC. Despite considerable efforts being made by governments in the countries under study to mitigate the effects of flood disasters, there are various challenges being faced in effectively and efficiently mitigating flood effects. Challenges as mentioned bring out the shortcomings that need to be addressed by this and other studies that might be instituted. These include lack of right policies and long-term strategies and absence of effective legal frameworks. Flood management is mainly focused on response at the expense of flood risk reduction. The studied countries also had inadequate allocation of resources and it is suggested in the study that the crafting of strengthened laws and policies will support the allocation of adequate funding flood risk reduction. There are inadequate institutional arrangements at all levels due to financial, human, material, equipment and capacity challenges. Flood forecasting and warning is at times ineffective due to false flood predictions and warning. Flood management is also not effective due to reluctance in implementing up to date regulations. Minimal public participation in flood risk reduction decision-making processes are also observed. Resistance from flood communities to move away from risk areas is also a major challenge. Flood prediction methods are ineffective at local level as the ones being used are top-down and disregard local knowledge systems.

There are also queries to the relevance of some flood risk management legislation as the fines imposed are too little for deterrence, are fixed irrespective of the damage that has been caused. Some of the legislation does not penalise for any wrong doing. Lack of funding, budget polices for risk mitigation and capacity to mainstream DRR were also noted as constraints in translating momentum into sustainable programs and investments that reduce long-term vulnerability. On the technical side there are problems associated with the installation and operation of flood warning systems, insufficient rainfall and hydrometric networks and redundancy of recording equipment. Further to that, flood warnings are too technical for common people to understand. There is absence of mechanisms for effective information or data collection and exchange. There is lack of or no political will in the SADC to manage flood disasters. Although there is increased support at policy level in the studied countries the commitment and ability to act on the ground is still limited. These are some of the problems that have to be grappled with if the SADC-region has to predict floods effectively and mitigate their effects. To a great extent all the countries under study have disaster management policies, structures and legislation but these instruments have weaknesses that need thorough attention. Importantly it is the ineffectiveness of flood prediction at the community level and lack of integrating IKS in flood prediction models in the studied countries that motivated this study. These gaps have triggered the need for the development of an effective river flood model for the SADC-region.

Chapter Two is regarded as of fundamental value to frame the research, as it not only provides the needed contextual background to river flood management visibility but also relates to important terms and concepts in disaster risk management and flood prediction.. Chapter Three follows as an engagement with a historical view on the occurrence and management of river flood disasters in the four selected countries: Zambia, Zimbabwe, Botswana and South Africa as possible exemplary of the SADC-region in general. In this Chapter the focus a detailed study (with the inclusion of statistics) on the research question that addresses the past and present status of river flood disasters in the SADC-region. The importance of this chapter especially lies in exposing meaningful context on the research focus under study.

CHAPTER THREE: A HISTORICAL REVIEW ON THE OCCURRENCE AND MANAGEMENT OF RIVER FLOOD DISASTERS IN THE SADC-REGION

3.1 Introduction

An Investigation into the past and present status of river flood disasters in the SADC-region is critical and addresses one of the research questions. Having access to past content and context information will be helpful in structuring a flood prediction model for the Region. A critical part of improving flood risk reduction in the SADC-region is by gaining a detailed understanding of the statistics on the frequency of flood disasters and their impacts on communities in the studied countries. Research is important in this process. This chapter makes effort to address the research question on the current and past management of river flood disasters in the SADC-region is conducted.

In a report submitted at the 28th General Assembly of the International council of science in 2005, indications were that risk posed by disaster hazards was rapidly increasing worldwide (Malugeta *et al.,* 2007:1). Weather related disasters were also increasing beyond explanation (Mohleji & Pielke, 2014:1). Global loss related to floods disasters has increased (Nyakundi 2010:2). Reports in Africa also indicate that disasters are increasing and that there is high vulnerability due to factors that include a high population growth rate, high poverty levels, failure of policy and institutional frameworks and food insecurity only to name a few (Malugeta *et al.,* 2007:1). In the SADC-region, water related events constitute most of the disasters in that region and affect nearly every country. The water events include floods, cyclones and extremely high temperatures due to global warming (Malugeta *et al.,* 2007:5). Effective strategies to manage floods and mitigate flood risk are therefore required to make a lasting contribution to the quality of life and sustainable livelihoods. (ICSU, 2005:7).

In Chapter Three the emphasis is a historical perspective on the appearance and nature of floods in Zambia, Zimbabwe, Botswana and South Africa mostly focusing on the period 2000 and 2013 (see Section 1.9, Chapter One). Information on floods before the year 2000 is also provided as a build-up to the period of focus. This information is included to show that the trend of floods and their effects before the period under review are continuing unabated and that the world has failed to contain floods up to date. As such, the need exists to review flood management methods and develop new or improve current methods. This study was done in an effort to try and improve flood risk reduction through the development or improvement of flood prediction methods. The historical trends and impacts of floods also help disaster practitioners and the researcher make reasonable decisions on flood risk using such abundant information. The concept of living with floods is also explored in the context of the studied countries. As it has already been alluded to in Chapter Two living with floods is a better way of reducing flood risk that is being advocated for by disaster risk management experts. In living with floods, what is considered in mitigating flood effects are not only the physical methods but also how man has interacted with and can co-exist with the natural environment.

3.2 The manifestation of flood disasters in selected SADC-countries: A historical review

After reviewing the conceptual and contextual management of river floods in the SADC-region in recent times (see Chapter Two) as the natural context required to understand the occurrence of river floods, this section engages extensively with the general topography, demography and past manifestations of floods related to man in the selected SADC-countries as they are of equal value and outlined in sub-sections 3.2.3 to 3.2.6. Four SADC-countries were selected for this research, namely Zambia, Zimbabwe, Botswana and South Africa, and so far the reason of choice has not been extensively outlined, Section 3.2.1 is such an effort.

3.2.1 Rationale for selecting the studied countries

The rationale for the selection of these particular countries was mainly due to the fact that they constitute much flooding in the region as indicated by statistics in some sections that follow in this chapter. Zambia, Zimbabwe and Botswana also share the Zambezi Basin which is also heavily impacted by extensive floods during the wet season (Shela, 2000:65). The Chobe and Kafue Rivers that flow through the studied communities of Satau in Botswana and Chanyanya in Zambia respectively are located in the Basin and are tributaries of the Zambezi River (Shela, 2000:67). Rainfall in the Kafue and Chobe Basins where the studied communities are located mainly falls October and March or April (Halley & Mari, 2004:106; Hughes, 2006:401). Furthermore, Kafue River also has a gorge used for electricity generation (Shela, 2000:69).

The Komati River is in the Komati Basin shared by South Africa, Mozambique and Swaziland (Slinger *et al.*, 2010:1; Riddell & Jewitt, 2014:15). In this basin along the Komati River is Tonga which is one of the studied communities in South Africa. In the basin, rains are brought about by the South Indian anticyclone and cyclones from Mozambique (Riddell & Jewitt (Editors), 2014:25). The area has its rainfall season between October and March. Water on the river is used for electricity generation, stored in dams for agriculture and domestic use (Turton, 2010:28). The Tokwe River, in Zimbabwe is found in the Save Basin and is a tributary of the Lundi River (Tafangenyasha *et al.,* 2010:149). In this Basin is the Tokwe river along which are 12 villages namely Chekai, Jahwa, Zifunzi, Mharadzano, Chkandigwa, Vhomo, Tagwirei, Ndove, Matandizvo, Chikosi, Mashenjere and Nongera which were affected by floods in 2014 (Tarisayi, 2014:166). Agriculture is the main form of livelihood by the villages (Tarisayi, 2014:166). The area is wet due to rains wet from mid-November to April (Tafangenyasha *et al.,* 2010:150), receiving on average 600 mm of rainfall per year (Mutowo & Chikodzi, 2013:23). Along the river is also a dam, the Tokwe-Mukosi dam, which had been built and was the cause of floods in 2014. The dam is used for agriculture irrigation, tourism and energy (The Herald Newspaper, 2014).

An analysis of the study areas which also forms part of the motivation to study the four countries indicates that the countries both have a similar rainfall and flood season which ranges from October and March/April (Chaguta, 2008:01). The determinants of rainfall patterns in the four countries include the Inter-Tropical Convergence Zone (ITCZ), La Nina (Chaguta, 2008:1) and the El Nino (Lukamba, 2010:484) all of which bring in high rainfall in summer (Davis, 2011:9). The studied communities are located along rivers with considerably high water demand used for agriculture, fishing or electricity generation. All the studied communities are affected by heavy rainfall and cyclones. Looking at the activities engaged by the communities these rivers seem to be major rivers and are perennial. The disaster management programmes of the countries understudy are also related and are coordinated by the

SADC-regional water policy and under various forums like the Southern Africa Regional Climate Outlook Forum (SARCOF), the Integrated Water Resource Management (IWRM**),** and the Southern African Development Committee (SADC) – Hydrological Cycle Observing System (HYCOS) project only to name a few. The communities live in flood prone areas for the same survival and economic needs especially agriculture. The selection choice of the four countries was also made out of practical choice, its closeness to the researcher's basis of research and because of financial reasons to undertake the research (sees also Chapter One).

3.2.2 The topography of the four studied countries

The topography of the countries under study (see Figure 3.1) includes some rivers. Amongst others the Kafue River that floods the Chanyanya community in Zambia. Chanyanya village is located on the banks of Kafue River in Kafue District in Zambia (Kanyamuna, 2010:11). The area is mostly flooded during the rainy season (Kanyamuna, 2010:11). The Tokwe River floods the Tokwe-Mukosi community in Zimbabwe. The community stays in areas surrounding Tokwe Mukosi dam at the confluence of Tokwe and Mukosi rivers. Floods have been occurring in the communities since the 1990s when the Tokwe - Mukosi dam underwent construction (Mazarire, 2008:757). The Chobe River floods Satau community in Botswana. Satau village is found on the Chobe enclave in Botswana (Van der Jagt *et al.*, 2000:12; Gilmore, 1979:97). The Chobe River provides for Satau community's livelihoods as the people live along the basin (IFRC, 2011:3). However floodwaters bring health and livelihoods problems and destroy peoples' property (IFRC, 2011:3). The Komati River floods the Tonga community in South Africa Tonga Village in South Africa is in Nkomazi district, Mpumalanga province near the Komati River. The village is situated in the Lowveld, south of Kruger National park, west of Mozambique, northwest of Swaziland (Maclachlan & Swartx, 2009:192). The community suffers from recurring Komati river floods that kill people and damage homes and bridges (South African Weather Service, 2013; Business Day Live, 2013; NEWS24, 2012; Government of South Africa, 2014).

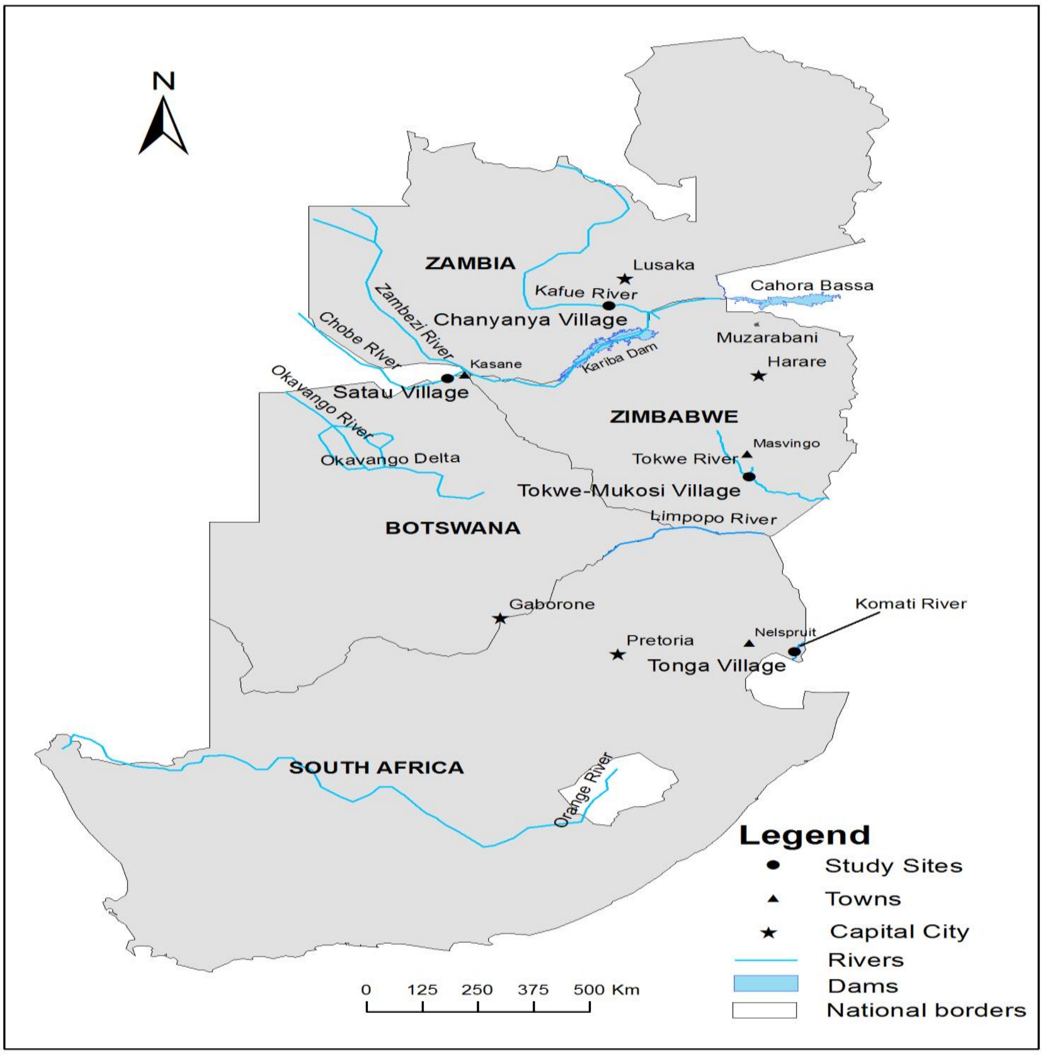

Figure 3.1: The SADC-countries understudy: Zambia, Zimbabwe, Botswana and South Africa.

Source: Author's depiction, April 2015.

3.2.3 Zambia

In this section is a discussion on the history of floods in Zambia specifically the period 2000 to 2013. Also highlighted are flood events before the year 2000. The particular focus is on the frequency and impact of the floods and how communities are managing to live with the floods.

3.2.3.1 Background

Zambia is a land locked country with its western and central regions located in the great South Central Africa plateau (Kaminsa, 2008). Zambia is surrounded by the following countries: Democratic Republic of Congo, Tanzania, Malawi, Mozambique, Zimbabwe, Botswana, Namibia and Angola (Annett, 2007:1095). The country became independent in 1964 (Beuran *et al.*, 2011:1) and has a population of 13 166 392 based on the 2010 census (Meki, 2015:12). The President of Zambia by 2015 was now Edgar Lungu, after the death of President Michael Sata, on 28 October 2014 (Cowell, 2015). The country uses the Disaster Management Act No. 13/2010 for managing disasters (Zambia Disaster Management Act 13/2010). Zambia has an environmental policy that aims to promote sustainable environmental protection. The policy aspires for management of the environment and natural resources with the aim of protecting future generations (Walmsley and Patel, 2011:461).

3.2.3.2 Topography

The country has two large river catchment areas, the Zambezi (see Figure 3.2) which covers almost two thirds of the country along the south-central area and the Congo, which covers the northern part (Zambia Strategic Climate Resilience Document, 2011:8). The main drainage systems also include (see Figure 3.2) the Luangwa, Luapula or Chambeshi and Kafue Rivers (FAO, 2005:1). The rainy season is influenced by the Inter-Tropical Conversion Zone (ITCZ) which oscillates between the northern and southern tropics over the course of a year and the El Nino/Southern oscillation (ENSO) phenomenon (UNDP-Zambia project document, 2010:9).

These bring variations in rain due to altitude, latitude, temperature, relative humidity and control of air masses between November and April (FAO, 2005:2). Variability in the movement of the ITCZ leads to variability in the rainfall received from one year to the next (McSweeney *et al.*, 2010:1). The country is also vulnerable to climate change and climate variability as extreme weather events such as floods and heavy rainfall are happening and are expected to increase in intensity and frequency (Zambia Strategic Climate Resilience Document, 2011:10).

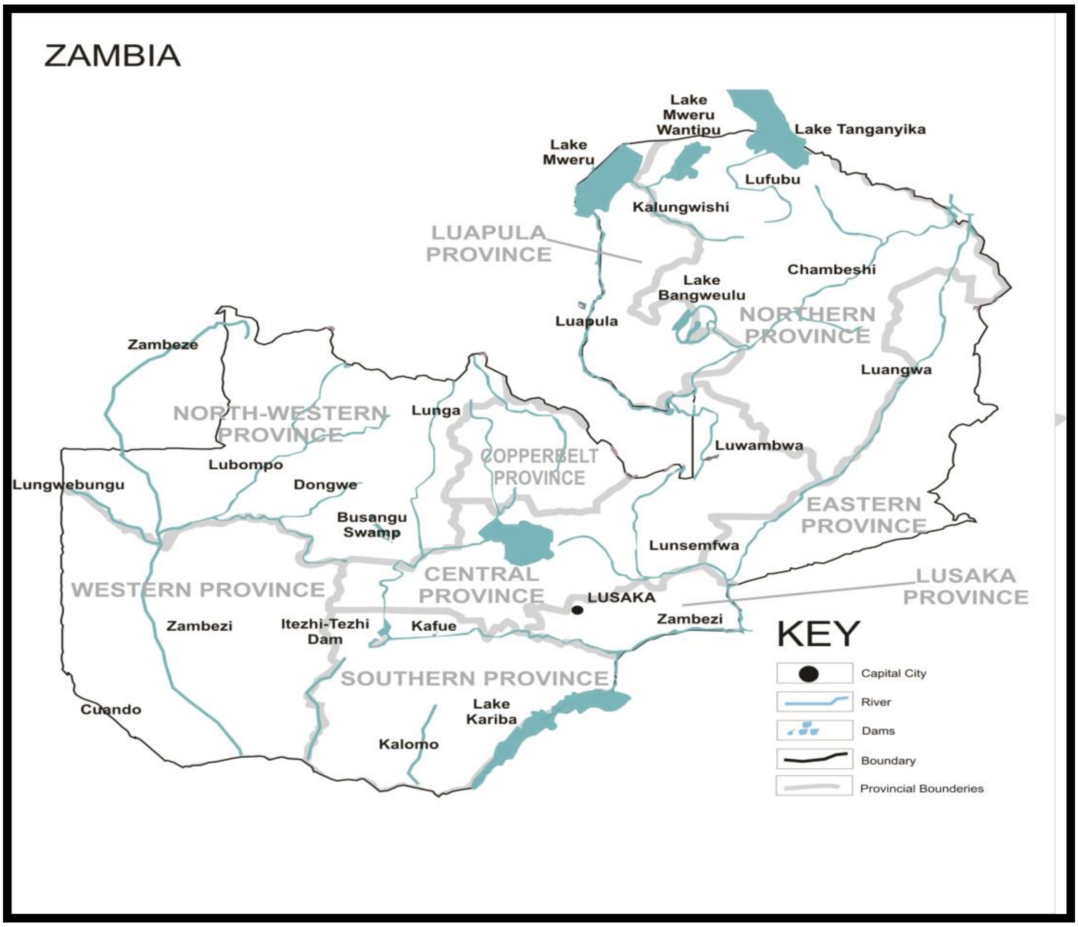

Figure 3.2: Map showing Zambia's major rivers

Source: Author's depiction, May 2015.

3.2.3.3 Flooding

Zambia has abundant surface and groundwater resources. There is average rainfall over the whole country making Zambia a well-watered country in the SADC-region (APFM, 2007:14). Zambian communities are also vulnerable to floods which in the past have resulted in deaths, crop and property/infrastructure damage or destruction, and the displacement of human populations (UNDP, 2010:10).

<u>Flooding before 2000</u>

According to a study by Lwando (2013:140) there were floods in the 1972/3 and 1998 rainfall seasons in the Sesheke district in Western Zambia. The floods had direct impacts on people's livelihoods, the loss of livestock and crops as well as damage to infrastructure. The study also found out that there were indirect impacts caused namely stress and anxiety. In 1988/1989, there was urban flooding in the

Kafue Basin towns of Kitwe, Ndola, Kapiri Mposhi, Kabwe, Lusaka and Mazabuka leaving more than 50,000 people homeless (APFM, 2007:7). Kasali, (2008:5) identified the seasons of heavy precipitation and flooding in some areas in Zambia as 1973/1974, 1977/1978, 1980/1981, 1989/1990, 1999/2000, 2005/2006 and 2006/2007. Flooding was also experienced in 1992/1993, 2000/2001 and 2005/2006 (APFM, 2007:7). In 1994 the Kafue Basin had severe floods that affected and displaced communities in fishing camps, bridges were washed away and mud brick houses collapsed (APFM, 2007:7). In February 1998 Zambia suffered from severe floods in some areas in the country's northern section. Communities had their crops and homes either destroyed or damaged (OCHA, 1998).

Flooding during 2000-2013

The incidence of recorded floods and flood disasters in Zambia from the year 2000 to 2013 as borrowed from the Centre for Research Epidemiology of Disasters is as shown in Table 3.1. The table displays the year of flood, the annual number of floods, the total number of deceased people affected and the total deceased as a result of the floods. The areas shown in the table are the most floods prone in the past as well as the present. Flood incidence and information is also highlighted and discussed as recorded from other sources apart from the Centre for Research Epidemiology of Disasters. These sources complement each other and enhance the quality of flood information.

In 2000, Chiawa Region was hit by floods affecting 12 000 people (see Table 3.1), but there were no people killed (Centre for Research Epidemiology of Disasters). In 2001 floods occurred in a number of regions namely Eastern, Northern, Central and Copper belt regions (see Table 3.1).

A total of 617 900 people were affected and 5 died (Centre for Research Epidemiology of Disasters). In 2003, Lusaka and Gwembe district had a total of 11 000 people affected by floods and four people were killed (see Table 3.1). Further to that, Mongu area in the Barotse Plain of Western Zambia had the worst floods in fifty years during the December 2002 and March 2003 rain season. Twenty five villages were washed away during the flood (Kadomura, 2005:175). In 2003 to 2004 rain season the country had floods in the western and North-western provinces**.** Areas that were affected are Senanga, Mongu, Kalabo where 196 398 people were affected and there were two deaths (see Table 3.1). Lukulu in Western Province and Chavuma and Zambezi in North-western Province also had floods that affected 39 277 households and submerged crops (OCHA, 2004; FEWS Zambia Report, 2004).

Table 3.1: Flood trends in Zambia from 2000 to 2013

YEAR OF FLOOD	REGION, PROVINCE, DISTRICT AFFECTED	ANNUAL FLOODS	ANNUAL TOTAL AFFECTED	ANNUAL TOTAL DIED
2000	Chiawa Region	1	12000	0
2001	Eastern, Northern, North-Western Regions, Copper belt, Central, Lusaka	1	617900	5
2003	Lusaka, Gwembe District	2	11000	4
2004	Senanga, Mongu, Kalabo	1	196 398	2
2005	Kazungula	1	4000	0
2007	Mpulunga and Solwezi districts, North- Western Region	2	140000	4
2008	Mazabuka, Siavonga, Sinazongwe, Western and North-Western Region	2	49766	14
2009	Western Province, Shangombo, Mongu, Kalabo	1	614 814	31
2010	North Western, Lusaka Province, Sinazongwe, Livingstone	1	1200	0
2011	....	1	1375	0
2013	Mumbwa District, Nagoma, Kabulwebulwe	1	1800	0
TOTAL		**14**	**1650253**	**60**

Source: the international disaster database: centre for research epidemiology of disasters http://www.emdat.be/search-details-disaster-list accessed 13/12/2013 and glide number http://www.glidenumber.net/glide/public/search/search.jsp accessed on 13/12/2013.

In 2005, floods hit Kazungula and affected 4000 people (Centre for Research Epidemiology of Disasters, 2013). Table 3.1 shows that floods killed four people and affected a total of 140 000 in Mpulunga and Solwezi districts and the North-Western region (Centre for Research Epidemiology of Disasters, 2013). More to that, the 2006 to 2007 rainy season resulted in floods that affected a total about 1.5 million people in Zambia (Gannon *et al*., 2014:3). The floods caused houses and buildings to collapse. There were also damages to roads and sanitation facilities, waterlogged agricultural fields, destruction of crops, contaminated water and increased human diseases (Gannon *et al*., 2014:3). During the floods of 2007, 65 percent of the households were affected by the floods, 33 percent on the Zambezi plains were displaced and another 17 percent had to relocate to uplands (Bwalya, 2010:3).

Kasali, (2008:20) summarises the impacts of floods that occurred in two consecutive seasons, namely the 2005/06 and the 2006/07. These floods were widespread throughout the whole of Zambia and can be described as follows:

In both the 2005/2006 and 2006/2007 floods, a total of 1,443,583 people in 41 districts were affected (UNDP, Zambia, 2007:1; Kasali, 2008:21). The floods damaged/destroyed 10 954 houses, toilets, water wells, schools, clinics, roads and other infrastructure. The livelihoods of 295,148 people were threatened. Water was contaminated by faeces affecting 1,012,540 people in 78% of the flooded areas. This was as a result of collapsing toilets and contaminated water flow into unprotected shallow wells. The floods also brought about the risk of malaria as 14 districts had outbreaks and 28 853 people fell sick. The education sector was also affected as classrooms, staff houses and toilets of 160 schools in 31 districts of six provinces were destroyed or damaged. The education of about 150 000 children was affected. There was an outbreak of 5000 cases of cholera in some places resulting in the deaths of 137 people. Reports of outbreaks of rabies, plague, and *trypanosomiasis*[1] were recorded in some areas (Kasali, 2008:20-21). The floods further restricted people to health facilities due to damaged roads, bridges and flooded rivers (Kasali, 2008:22).

In 2008, Mazabuka, Siavonga, Sinazongwe and Western Regions were hit by floods (see Table 3.1). A total of 14 people lost their lives and 49766 (Centre for Research Epidemiology of Disasters, 2013). The 2009 rains in Zambia caused rivers to fill and overflow and the Zambezi River reached its highest level since 1969 (WMO, 2010:4). It should be noted that the Zambezi River routinely floods during the annual rainy season, but in 2009, the floods were more extensive than normal affecting the western province, Shangombo, Mongu and Kalabo, with a total of 614 814 people affected and 31 dying (see Table 3.1). Homes and cropped were damaged and nearly one million people affected (WMO, 2010:4). Damage to infrastructure totalled US$ five million. The floods affected 20 000 households and destroyed 5000 homes in the Southern Province. Shangombo District was completely cut off from external help (Lumba, 2015). According to Smith, (2009) there were floods in Zambia’s Western Province, killing 31 people, destroyed homes and washed away maize fields.

In 2010 floods also hit and affected a total of 1200 people from areas like North-western, Lusaka, Sinazongwe and Livingstone (see Table 3.1). A total of 1375 people were also affected by floods in 2011 (Centre for Research Epidemiology of Disasters, 2013). In January 2013 there were floods in Zambia with Mumbwa District in the Central province being the mostly affected (Red Cross, 2013:2). Other areas affected were Nagoma and Kabulwebulwe (see Table 3.1). The flood impacts included destruction and damage of agricultural fields, property and infrastructure. There was also contamination of water. The floods affected 1800 people (Red Cross, 2013:2; Centre for Research Epidemiology of Disasters, 2013).

Flood analysis 2000 to 2013

Analysis of Table 3.1 shows that Zambia recorded high deaths due to floods in 2008 and 2009. The highest number of people affected was in 2001 and 2009. The table also shows that floods are evenly distributed all over the country. Table 3.1 shows that the country experiences at least one flood all most each year. A total of 1.65 million people were affected by floods in the period 2000-2013, which is 11.34% of the total population of 14.54 million (2013). This is a significant percentage which points to the government and NGOs to set up mitigation measures to reduce the effect of floods in this country.

Comparing the period 2000-2005 and 2006-2010, Table 3.1 shows that 7.3% of the total population were affected compared to 6.09%, respectively. There seem to be a seasonal pattern of three years, that the country experience severe floods with peaks at 2001, 2004, 2007, 2009, in the last decade. This suggests that the floods management unit can come up with measures and strategies to prepare for the likelihood of floods. Less than 0.5% (0.039%) of people died due to floods, which is an insignificant amount over the total number of people affected. The number of people who died due to floods as a percentage of the total country population is insignificant (0.00041%). Zambia is therefore included in this study to accentuate the value of flood prediction in low risk and high risk areas. The intention is to reduce or lower the levels of affectedness and ensuring a healthy flow towards enhancing livelihoods, food security and development in the country.

According to Simwanda (2001:2) floods in Zambia are characteristic of prevailing structural conditions found in everyday people's lives. Therefore mitigation of floods can be achieved from within and through people's experiences. Flood risk reduction also requires a shift towards proactive approaches involving preparedness and mitigation measures. According to Mwape, (2009:10) studies undertaken in Zambia around 2006, show that the frequency of disasters increased rendering the poor populations more vulnerable. Floods and heavy rainfall are a problem and are expected to increase in intensity and frequency (GRZ, 2010:10). Damages to infrastructure, housing, and loss of livelihoods are concentrated on communities that live along the major river basins, Zambezi and the Congo and other areas (Zambia Strategic Programme Document, 2011:1).

According to Bwalya (2010:v) Zambia has been registering floods of a high intensity and magnitude for seven consecutive years. Extreme event floods occurred in the 2007 and 2008 affecting a wide geographical area (ZVAC, 2008). An assessment done by Zambia Vulnerability Assessment Committee (ZVAC) shows that floods destroyed health centres, school buildings, crops, bridges, culverts and homes. The Road Development Agency (RDA) estimated flood costs on infrastructure emergency repairs in 2007 and 2008 as standing at 43.7 billion kwacha, a significant cost to the economy and as a public resource, could have been used for other development programs (RDA, 2008).

Since water is a key factor in people's lives and supports development, it has influenced human settlement patterns and the location of activities such as agriculture, mining and manufacturing industries. On the same note water causes destruction and damage resulting in loss of lives, crop destruction and associated economic loss (APFM, 2007:12). To address this flood prediction is important that communities are able to avoid floods in time.

3.2.3.4 Living with floods in Zambia

Population growth is causing overcrowding pushing communities close to water sources. More to that Industries and agriculture that rely on water sources have also crowded water sources (Middlemis-Brown, 2010:6). There is no doubt that floods have become a disaster due to human mismanagement of rivers, their flood plains and catchments (Schneidergruber *et al*., 2004:1). During the period under study, Zambia had 11.35% of its population affected by floods (see Table 3.5). The country is being hindered to effectively manage flood disasters due to many problems as discussed in section 2.3.4.2. To be effective in its flood risk reduction strategies, the country has to adopt the basic building block of integrated flood risk management. The approach looks at the flood hazard, people's vulnerability and sustainable environmental management. Managing the environment will go a long way in helping communities live with floods (Schneidergruber *et al*., 2004:13).

Settling in flood prone areas in Zambia has exposed human activities to flood risk and the need for flood control structures. Unfortunately structural controls in use have disconnected rivers from their floodplains and have also been subject to failure leading to floods and other disastrous consequences in the environment (Middlemis-Brown, 2010:6). Communities in Zambia need to live with floods to mitigate flood impacts. The concept of living with risk entails that communities need to recognise that flood risks cannot be eliminated entirely (Kobayashi and Porter, 2012:vii).Therefore, the concept of living with floods explores practical ways of living with floods without or with limited flood control structures (Middlemis-Brown, 2010:6).

In advancing that shift to living with floods, it is important to note that some communities have traditionally organised, produced, and survived within the physical constrain of floods for a long time (Zaman, 1993:987). For example, when it comes to living with floods, the Bengali peasants in Bangladesh limit the destructive impact of flooding by using historical methods to adjust the floodplain and adapt their agricultural practices, cropping patterns, and settlements (Zaman, 1993:986). Zambia has many traditional communities whose local knowledge can be identified and improved so that people use it to co-exist with floods.

Crafting and enforcing effective environmental laws also helps in mitigating flood disasters. Preventing the cutting down of trees, soil erosion and developing structures away from wetlands has a very positive effect on flood controls. As pro-active action to flooding, countries and Zambian included need to make serious efforts in managing the environment through relevant legislative means. This will also enhance the concept of living with floods. Trees or forests will control the speed of runoff water and will also heighten the chance of rain water percolating into the ground.

3.2.4 Zimbabwe

The history of floods in Zimbabwe is analysed in this section with highlights stretching from before the study period, 2000 to 2013. Of importance in this section is the rate of flood incidence in the country, flood effects on the communities and how they have been resilient or survived during flood disasters.

3.2.4.1 Background

Zimbabwe is a landlocked country located in southern Africa, with a population of around 13 million, based on its population censes conducted in 2012 (World Fact Book, 2013). The country became independent from Britain in 1980 (Dansereau, 2000). The country's President, by 2014, was Robert Gabriel Mugabe (Africa Research Bulletin, 2014). Zimbabwe has several laws to manage floods and the environment in the form of the Civil Protection Act and other sector relevant statutes (Madamombe, 2004:3).

3.2.4.2 Topography

Zimbabwe is a country, situated (see Figure 3.3) between the Limpopo and Zambezi Rivers, (Markram, 2014). Other major rivers include the Runde and Save (see Figure 3.3) (Moore *et al*., 2009). Zimbabwe has borders with Zambia in the north and Northwest, Mozambique in the east, South Africa in the south, and Botswana in the southwest (CIA World Fact Book, 2004). The terrain consists of high plateau, with mountains in the east that enhance rainfall leading to an east–west and north–south rainfall gradient with the maximum rainfall over the Eastern Border mountains (Dinku *et al.*, 2008). The country's climate is mostly subtropical, and its terrain is composed of desert and savannah (Chigwada, 2005:106).

3.2.4.3 Flooding

In Zimbabwe flooding is caused by heavy precipitation during the November to April rain season and also by cyclones from the Indian Ocean (Chikoto & Sadiq 2012:3).

These floods cause loss of life, destroy livestock, crops and property and bring outbreaks of diseases, such as cholera and malaria.

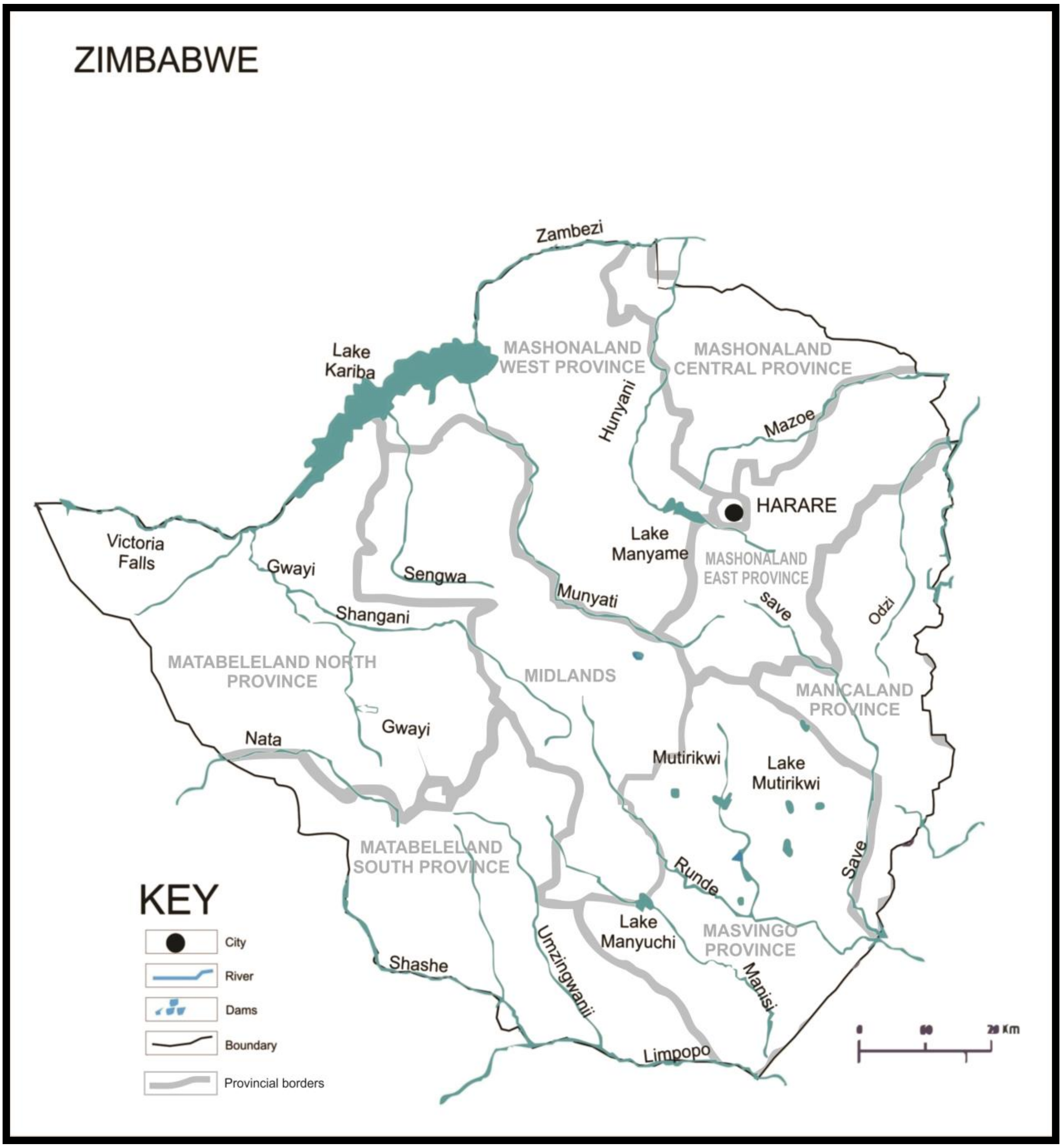

Figure 3.3: Map showing some of Zimbabwe's major rivers

Source: Author's depiction, May 2015.

<u>Flooding before 2000</u>

Looking back the country has a long history of floods. Musarurwa and Lunga (2012:27) identify those floods that occurred particularly in 1955, 1967, 1972, 1975, 1977, 1981 and 2000 in Matabeleland South Province. According to Bango *et al.,* (2013:2), there were floods in the southern part of Zimbabwe in 1998. There were also floods in Kanyembe district in 1982, 1988, 1993 and 1996. The floods resulted in livestock mainly goats being washed away. Homes were destroyed and people rescued and relocated to schools where they were assisted with food, blankets and other emergency products. The floods reduced household food availability as crops were washed away and income from crop sales was reduced. Household income was also affected as the price of grain at local markets increased (Bola *et al.,* 2013:4). The floods in the 1970s, 1980s and 1990s still resemble floods during the study period of 2000 to 2013. The effects are still the same whereby people are drowned and livestock, crops and homes are destroyed.

Flooding during 2000-2013

The incidence of recorded floods and flood disasters in Zimbabwe from the year 2000 to 2013 as borrowed from the Centre for Research Epidemiology of Disasters is as shown in Table 3.2. It displays the year of flood, the annual number of floods, the total number of deceased people affected and the total deceased as a result of the floods. The areas shown in the table are the most floods prone in the past as well as the present. Flood incidence and information is also highlighted and discussed as recorded from other sources apart from the Centre for Research Epidemiology of Disasters. These sources complement each other and enhance the quality of flood information.

Floods are mostly brought about by rainfall and occasionally by cyclones Eline as in February 2000 and Japhet as in March 2003 (Madamombe, 2004:5; Gwimbi, 2007:155). Musarurwa and Lunga (2012:27) described the floods in 2000 as the worst in the history of the country in terms of very high water levels they had. An analysis of Table 3.2, as adopted from the Centre for Research Epidemiology of Disasters, shows that during the study period 2000 to 2013 the highest number of 266 000 people were affected by floods in 2000. Some of the floods occurred in an area like Matobo a District in Matabeleland South Province (see Table 3.2). Although not indicated in Table 3.2 the other areas affected by floods in 2000 in Matabeleland South were Shashi, Chituripasi, Mphoengs, Madabe, Tshitshi, Ngwanyana and Plumtree.

Table 3.2: The annual flood trend in Zimbabwe, 2000 to 2013

YEAR	PROVINCE / DISTRICT AFFECTED	ANNUAL FLOODS	ANNUAL TOTAL AFFECTED	ANNUAL TOTAL DIED
2000	Chimanimani, Mutare, Chiredzi, Matabo, Midlands Districts.	1	266,000	70
2001	Muzarabani, Guruve Tsholotsho District.	1	30 000	13
2003	Muzarabani District.	1	18 000	2
2007	Muzarabani, Chiredzi, Chivi Districts.	2	17 000	27
2008	Muzarabani, Chipinge, Chiredzi, Masvingo, Mwenezi Districts.	1	0	0
2010	Kanyemba (Mbire district)	1	820	0
2011	Kanyemba (Mbire district)	1	0	0
2013	Matabeleland South, Matabeleland North, Manicaland, Mashonaland Central, Masvingo and Midlands Provinces	1	9 700	125
TOTAL		**9**	**341 520**	**237**

Source: The International Disaster Database: Centre for Research Epidemiology of Disasters http://www.emdat.be/search-details-disaster-list accessed 13/12/2013 and glide number http://www.glidenumber.net/glide/public/search/search.jsp accessed on 13/12/2013.

The inhabitants of these areas are involved in farming activities in the Limpopo basin. The floods are said to have been made worse by poor land management, serious erosion of wet lands and overgrazing of grasslands (Musarurwa & Lunga, 2012:27). More to that, the following areas are very prone to recurring floods Mashonaland Central, Mashonaland West, Midlands, Masvingo and Matabeleland North provinces (Manikai, 2010:10). There was also flooding in the Zambezi Valley due to Cyclone Eline in 2000 affecting Muzarabani and Guruve (Madamombe, 2004:5: Gwimbi, 2007:155).

Cyclone Eline, resulted to 266,000 people being affected and 70 people in Zimbabwe (Centre for Research Epidemiology of Disasters, 2013). More than 70 000 hectares of agricultural land and thousands of tonnes of stored food were destroyed (Gwimbi 2007:155). The impact of the 2000 floods left many in the broader region homeless (Tumbare, 2000:1; Kreimer *et al.*, 2003:197; Madamombe, 2004:5). Cyclone Eline also affected some areas in Manicaland, Matabeleland South and Midlands. The heavy rain caused flooding of the big rivers like the Limpopo, Save and Runde, causing damage to infrastructure, residences, and food crops. The eastern part of Zimbabwe was also affected. Districts in Chimanimani, Chipinge, Chiredzi and Mutare, had their road network damaged. The southern parts of the country were not spared as roads in some districts of Beitbridge, Bulilimamangwe, Mberengwa and Mwenezi had extensive damages. Dam walls and bridges were also swept away in Bulilimamangwe (OCHA, 2000).

In 2001, Muzarabani, Guruve and Tsholothso District were hit by floods (see Table 3.2). In total the floods affected 30 000 people and 13 people lost their lives. In March 2003, the country was hit, again by cyclone Japhet causing flooding in the country with Guruve and Muzarabani districts in the Zambezi Basin the worst affected (Gwimbi, 2007:155). Table 3.2 reflects that cyclone Japhet floods killed two people and affected 18000. In 2007 floods affected the Muzarabani area. Several bridges were damaged or swept away, notably the Hoya River Bridge linking Muzarabani and Mukumbura, Nzoumvunda Bridge connecting Chadereka and Chimoyo and Kadzurure River Bridge connecting Muzarabani and Dambakurima communal areas (Zimbabwe Newsday Newspaper, 2014:on-line).

Serious floods were recorded in 2000, 2001, 2007 and 2013 (see Table 3.2). This assertion is on the backdrop of the number of people who lost their lives and those affected as compared to the other years. A total of 266 000, 30 000, 17 000 and 9700 people were affected respectively. More to that, 70, 13, 27 and 125 people lost their lives, (see Table 3.2) as a result of these floods (Centre for Research Epidemiology of Disasters, 2013). The years 2008, 2010 and 2011 also had floods (see Table 3.2), but there were no flood impacts with the exception the year 2010 where 820 people were affected (Centre for Research Epidemiology of Disasters, 2013). A number of incidences of flooding also occurred in the 2010-11 rain season, affecting hundreds of people (Zimbabwe Newsday Newspaper, 2014).

Areas Mashonaland Central, Mashonaland West, Masvingo South and Midlands province experienced occasional floods since cyclone Eline up to 2013 (see Table 3.2) (Centre for Research Epidemiology of Disasters, 2013). In 2013 1.3% (125) of the 9700 people affected by floods in Matebeleland South, Matabeleland North, Manicaland, Mashonaland Central, Masvingo and Midlands provinces died. Even though the percentage figure of deaths and those affected for the whole period under study (namely 0,069% deaths and 2.41% of the Zimbabwe population) may be regarded as low, the aim in risk reduction is to prevent deaths and a high percentage of people being affected. This is required because river flood situations are not instant events like earthquakes, cyclones or tsunamis (Pawarangira 2008:4). Zimbabwe is therefore included in this study to accentuate the value of flood prediction in low risk and high risk areas. The intention is to reduce or lower the levels of affectedness and ensuring a healthy flow towards enhancing livelihoods, food security and development in the country.

Muzarabani the focus point of flooding

The area called Muzarabani in Mashonaland Central Province (see Table 3.2) is a name that suggests the prominence of floods in the area (Chingombe *et al.,* 2014:4, Mudavanhu, 2014:4). Muzarabani was mostly affected by the total floods (44%) experienced in Zimbabwe in the period 2000-2013. Muzarabani is in the lower Zambezi and is highly vulnerable to flooding (Madamombe, 2004:1). The area suffers from perennial flooding caused by localised rains and run-off, which in turn flood the Zambezi River and its tributaries. According to Madamombe, (2004:4), floods in Muzarabani is caused by both seasonal rainfall and frequent cyclones. Muzarabani is also affected by floods because its location. It's located downstream of Kariba dam (shared by Zimbabwe and Zambia), upstream of Cabora Basa Dam (in Mozambique) and at the confluence of Manyame and Msengezi Rivers.

Floods are therefore caused by substantial release of water from Kariba Dam to avoid dam failure. This causes the discharge in the Zambezi to increase substantially. Manyame and Msengezi rivers then fail to discharge water into the Zambezi when full and water accumulates at the confluence of the two rivers leading to flooding in the area due to backflow. The Cabora Basa dam levels also rise due to releases from Kariba and Zambezi tributaries and this also causes floods through backflow. Flooding leads to loss of human life, livestock, destruction of crops and infrastructure leaving the communities in the area poorer (Madamombe 2004:4). When it comes to flood risk reduction and management this becomes a priority area where serious flood risk reduction activities have to be intensified. As a disaster mitigation measure the Civil Protection Unit (CPU) of Zimbabwe and Zambezi River

Authority annually issue flood warnings in the Muzarabani area (The Herald, 2012: B7).

Based on the flood outcome for the years 2000 to 2013 as outlined in Table 3.2 the highest number of 125 deaths were recorded during the 2013 flood more than the 2000 cyclone Eline floods. The number is very high as flood risk methods are assumed to have improved since 2000. This then brings to question flood risk management methods being used in the country. Failure by current flood risk reduction methods to contain flood impacts calls for a paradigm shift from controlling floods to living with them (Spaliviero, *et al.,* 2011:753; Few. *et al*., 2004:11; Shaw, 1989:13; Ralph, 1975:105; Rasid & Paul, 1987:170; Middlemis-Brown, 2010:6). Literature also reveals that people, who settle in flood risk areas, should be helped from being victims of a situation they themselves create (Penning-Rowsell *et al*., 2006:325; ALNAP, 2008:4; Few *et al*., 2004:11; Yoshiaki & Porter, 2012:30).

3.2.4.4 Living with floods in Zimbabwe

Land use practice in river basins or catchments is increasing flood risk. The ways of land development and farming have an influence on the amount and speed of runoff water into streams and rivers. Other activities like overgrazing, deforestation, land compaction and a surface increase in impermeable areas due to tarmac and concrete are also enhancing flood risk (Schneidergruber *et al*., 2004:1). Due to such developments floodwaters have nowhere to go and floodplains that normally store excess water are now cut off from rivers (Schneidergruber *et al*., 2004:1). This is resulting in more and more flood disasters in Zimbabwe. There is need to also introduce other strategies that may help the prevalence of floods in both urban and rural environments. One strategy being advocated the world over is the idea of living with floods which was thoroughly discussed in Section 2.2.1.7. Such an approach seems to be lacking in Zimbabwe's flood risk reduction strategies.

The idea of living with floods has worked and has been a reality in Egypt. The Egyptians have been living with floods for thousands of years. Instead of controlling floods along the Nile River, communities accepted flooding as a tool for agriculture. These have coexisted with floods meaning lived with floods (Middlemis-Brown, 2010:4). Another argument for advancing the concept of living with floods in

Zimbabwe is that flood plains and wetlands play a significant role in maintaining a river's proper functioning and reduce human and property flood impacts (Schneidergruber *et al*., 2004:1).

Another approach to live with floods which can be used in the country is to turn flood prone areas into parks and recreation areas. The concept of living with floods also concerns accepting flooding and build accommodating structures. Using flood friendly designs like floating houses, structures can built in flood prone areas (Middlemis-Brown, 2010:7).

3.2.5 Botswana

Botswana is also affected by fatal and devastating floods. Statistics from even before the years 2000 to 2013 indicate that the country frequently suffers from damaging floods. This section gives an overview on how floods have and are impacting on that countries communities

3.2.5.1 Background

Botswana is a landlocked country in the centre of Southern Africa (Fermet-Quinet *et al*., 2010:9). The country population is 1.8 million people (IFRC, 2011), and got independent in 1966 (Worldmark Encyclopedia of Nation, 2007). The current president of the country is Lieutenant General Seretse Ian Khama (Inside the Presidency, 2013). The Government uses the National Policy on Disaster Management of 1996, the National Disaster Risk Management Plan of 2009, and other Sector Specific Legislation (Acts) to manage disasters in that country (National Disaster Risk Reduction Strategy, 2013-18). The country also uses the Environmental Assessment Act No. 10 of 2011 and Environmental Assessment Regulations of 2012 for the protection of the environment and conservation of natural resources (The Environmental Assessment Act No. 10 of 2011).

3.2.5.2 Topography

Botswana shares borders with South Africa, Namibia, Zambia and Zimbabwe and 70 % of the country is occupied by the Kalahari Desert (Worldmark Encyclopedia of Nation, 2007).

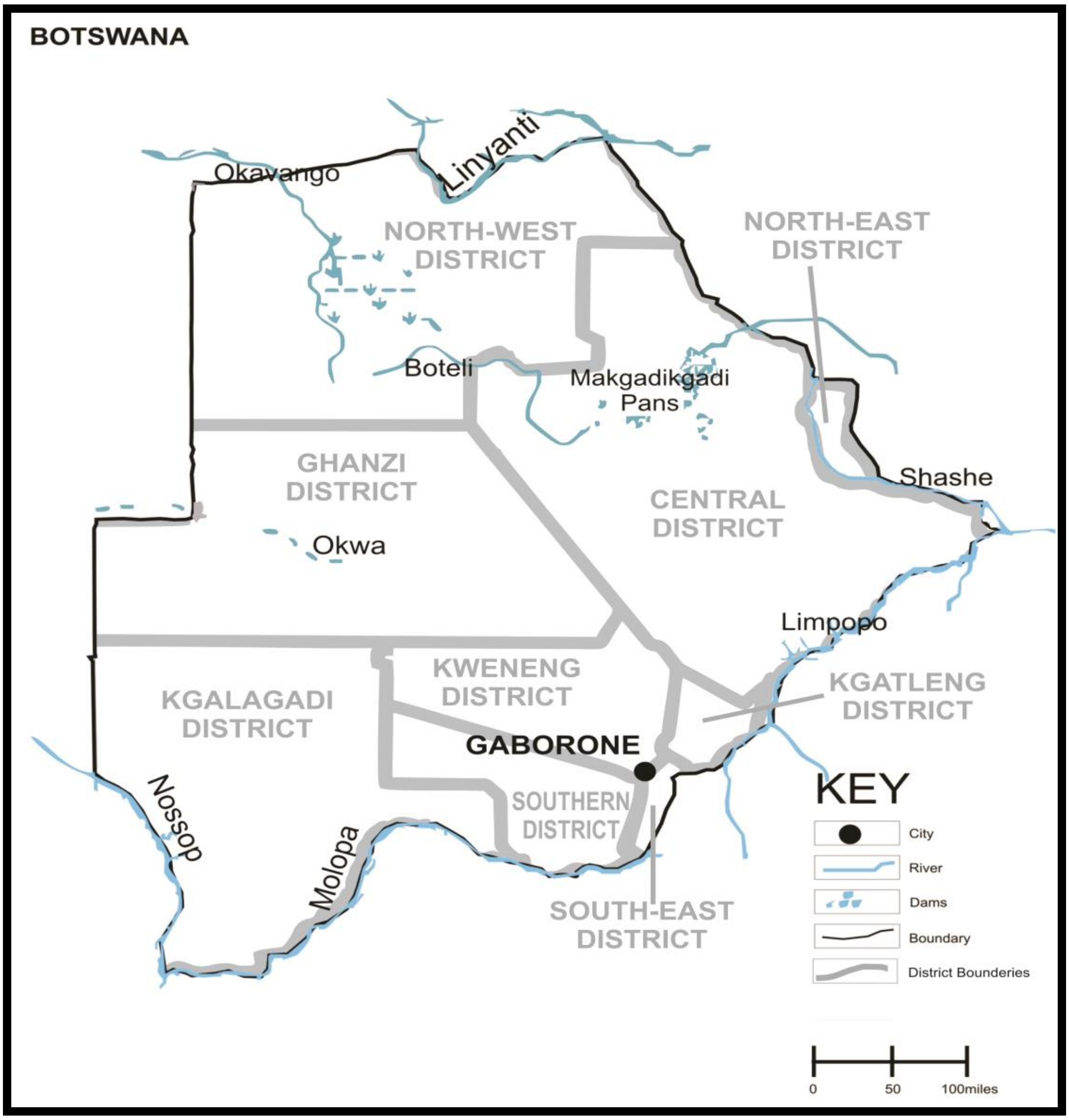

Figure 3.4: Map showing Botswana's major rivers

Source: Author's depiction, May 2015.

There are six drainage basins that differ in catchment areas and flow system and the country's main rivers (see Figure 3.4) are the Okavango and Linyanti or Chobe rivers in the northern part of the country (Botswana Water Accounts Report, 2006:11). Most of the rainfall occurs during the summer months from November to March with

January and February generally regarded as the wettest months (Fermet-Quinet *et al*., 2010:10).

3.2.5.3 Flooding

Generally rainfall in Botswana is unreliable, erratic and low. However the country suffers from severe river floods that result in a great deal of human suffering (Tskeko, 2003:389). Floods mostly occur during the rainy season from October to March and are mainly caused by heavy rains in the country and shared rivers with other countries in the region (National Disaster Risk Reduction Strategy, 2013-2018). The floods are influenced by factors like river topology and land use (Tskeko, 2003:389). The country has an area known as the Okavango Delta that floods annually. The Okavango Delta has two thirds of its annual flood waters from Angola (Molefe *et al., 2014:* 27). Seasonal flooding is also influenced by local rainfall (McCarthy et al., 2000:25). The known reliable record of floods in Botswana starts in 1995. The flood affected areas like Palapye, Serowe, Mahalapye and Boteti. The areas had fatalities and 128 farmers were affected. Further to that lost were 26 cattle, 1 139 goats, 20 sheep, 90 donkeys and 3 535 chickens (Tskeko, 2003:390). During the 1995 floods, 87% of people affected were in Palapye and Serowe.

Floods during 2000 to 2013

The incidence of recorded floods and flood disasters in Botswana from the year 2000 to 2013 as borrowed from the Centre for Research Epidemiology of Disasters is as shown in Table 3.3. It displays the year of flood, the annual number of floods, the total number of deceased people affected and the total deceased as a result of the floods. The areas shown in the table are the most floods prone in the past as well as the present. Flood incidence and information is also highlighted and discussed as recorded from other sources apart from the Centre for Research Epidemiology of Disasters. These sources complement each other and enhance the quality of flood information.

In February 2000, the country like some of the countries in the region was affected by floods causing extensive damage to property and infrastructure (Batisani, 2011:420). These floods during the 1999/2000 rainfall season accounted to the death of 13 people (see Table 3.3), with extensive damage to public and private infrastructure, assets and the environment, leading to displacement of thousands of people and damage to crops and death of animals (Botswana Country Report, 2004). Table 3.3 also shows that the worst floods were recorded in year 2000, of which 13 people died while 138 776 were affected. However the damage of the 2000 flood was less severe than that of the 1995 floods in terms of damage caused (Tskeko, 2003:390). The severity of floods in the country can not be expected since three quarters of the country has Kalahari sands and less than five percent of the land is suitable for agriculture pointing to the fact that it is a semi arid country (Hove *et al*., 2011:3-4). This also shows that the severity of floods in Botswana differs from time to time and place to place with different impacts ranging from minor to severe.

Table 3.3: Flood trend in Botswana, 2000 to 2013

YEAR OF FLOOD	DISTRICTS, VILLAGES AFFECTED	ANNUAL FLOODS	ANNUAL TOTAL AFFECTED	ANNUAL TOTAL KILLED
2000	Selibe-Phikwe, Bobirwa, Boteti, Francistown, Serowe, Palapye, Mahalapye, Gaborone, Tlokweng, Lobaste, Mabutsane, Kgarleng, Kgalagadi, Kweneng, Lethalkeng	1	138,776	13
2004	Ngamiland District	1	4,960	0
2009	Serowe/Palapye, Kweneng, Central District, North-Western Districts	3	4,656	0
2011	North	1	0	0
2013	North-East and Central Districts. Dukwi, Lephashe, Zoroga.	1	4,210	0
Total		**7**	**152,602**	**13**

Source: The international disaster database: Centre for Research Epidemiology of Disasters http://www.emdat.be/search-details-disaster-list accessed 13/12/2013 and glide number http://www.glidenumber.net/glide/public/search/search.jsp Accessed on 13/12/2013.

As already been alluded to the country also suffers seasonal flooding on the Okavango River (Delta) due to rainfall and two rivers draining from Angola (McCarthy *et al*., 2000:25; Gumbrich *et al.,* 2004:3). In 2004 floods hit Ngamiland district and affected 4960 people (Centre for Research Epidemiology of Disasters, 2013). In 2009 the country experienced a flood disaster when the Okavango and

Chobe rivers were overflowing into low lying plains that had been dormant for years (Mosate, 2010). Floods also affected some areas in the Central district, and North-Western district where 4656 people were affected (see Table 3.3). In 2011 there were floods in the Northern part of the country but nothing was affected (see Table 3.3). In 2013 there were floods in the North-East and Central districts and 4210 people were affected (Centre for Research Epidemiology of Disasters, 2013).

Botswana is country that is mostly desert, but it is periodically affected by serious and fatal floods (see Table 3.3). In relation to the country's population of 2.021 million people, 7.5% were affected by floods in the period 2000-2013, which is quite significant. Therefore Botswana needs to review and improve on its disaster risk management approach as the country is being found wanting. From 2004 to 2013 there were no deaths due to floods (see Table 3.3), which perhaps suggest a change in weather or improvement in early warning systems or flood risk management.

3.2.5.4 Living with floods in Botswana

In Botswana floods can be seen from both a negative and positive. On one hand they are seen as natural hazards or related to disaster. The other angle sees floods as nature, not about threat, hazard and damage but about periodic renewal of important ecological processes. It is therefore important to note that naturally functioning flood plains provide environmental and socio-economic services in the form of flood water storage and mitigation during flood peaks. (Schneidergruber *et al*., 2004:3). Structural mitigation like dams and dikes are also not safe as they at times break causing flood disasters (Schneidergruber *et al*., 2004:1). In Netherlands structural flood mitigation has been criticised as raising a false sense of security (Middlemis-Brown, 2010:6). There is now a paradigm shift from building tall walls to contain river water to an initiative known as "*Room for Rivers*". This approach reconnects the rivers with the surrounding floodplain and establishes empty, floodable areas on the riverbanks (Middlemis-Brown, 2010:6).

According to Kobayashi and Porter, (2012:vii) communities should learn to accept some degree of flood risks so that they derive benefits such as improved soil fertility and the richness of the whole river environment. People in flood risk areas will benefit if they learn to live in harmony with the flood cycle. This means having a balanced mix of structural and non-structural measures (Kobayashi and Porter, 2012:vii). Creating a space for river overflow enhances the concept of living with floods. “Room for Rivers” is a paradigm shift from the “*battle against water*” to “*living with water.”* This view points towards a scenario where communities live or spend time near the river and feel attached to its wellbeing (Middlemis-Brown, 2010:6).

In living with floods communities stay in flood zones and develop appropriate responses to flood events. Local practices such as relocating valuable assets from flood areas, construction of platforms to protect livestock, planting water/flood resistant crops and the use of traditional early warning can reduce the impact of floods in the communities (Basongo, 2010:6). In order to eliminate flood risk in Botswana, living with floods is a good strategy when it comes to flood risk reduction.

3.2.6 South Africa

The country has registered a considerable number of floods in the period dating back from the period understudy. The floods have had impacts on people’s lives as significant damages on property are being caused. People have also lost their lives due to flood disasters. Information on flood impacts is outlined in this section,

3.2.6.1 Background

South Africa is located at the southern tip of the continent of Africa (McSweeney *et al.*, 2010:1). The country has a surface area of 1 219 602 square kilometres (South Africa Year Book, 2012/13:2). There is a population of 50.59 million based on the 2011 statistics and the country became fully democratic in 1994 (Background Notes: South Africa, 2011). The current president of the country is Jacob Zuma. He has been in this position since 2009. The country has disaster management legislation like the Disaster Management Act 2002 (Act 57) to manage its disasters. Environmental management issues are enshrined in Section 24 of the South African Constitution. It gives citizens a right to an environment that is not harmful to their health or well-being. The legislation also gives citizens a right to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that prevent pollution and ecological degradation (Kotzé, 2007).

3.2.6.2 Topography

The country has physical features ranging from bush veld, deserts, forests, grasslands, mountains, beaches and coastal wetlands. It shares its border with Botswana, Mozambique, Namibia, Swaziland, Lesotho and Zimbabwe (Byrnes, 1996). The country is surrounded by the Atlantic and Indian oceans (South Africa Year Book, 2012/13).

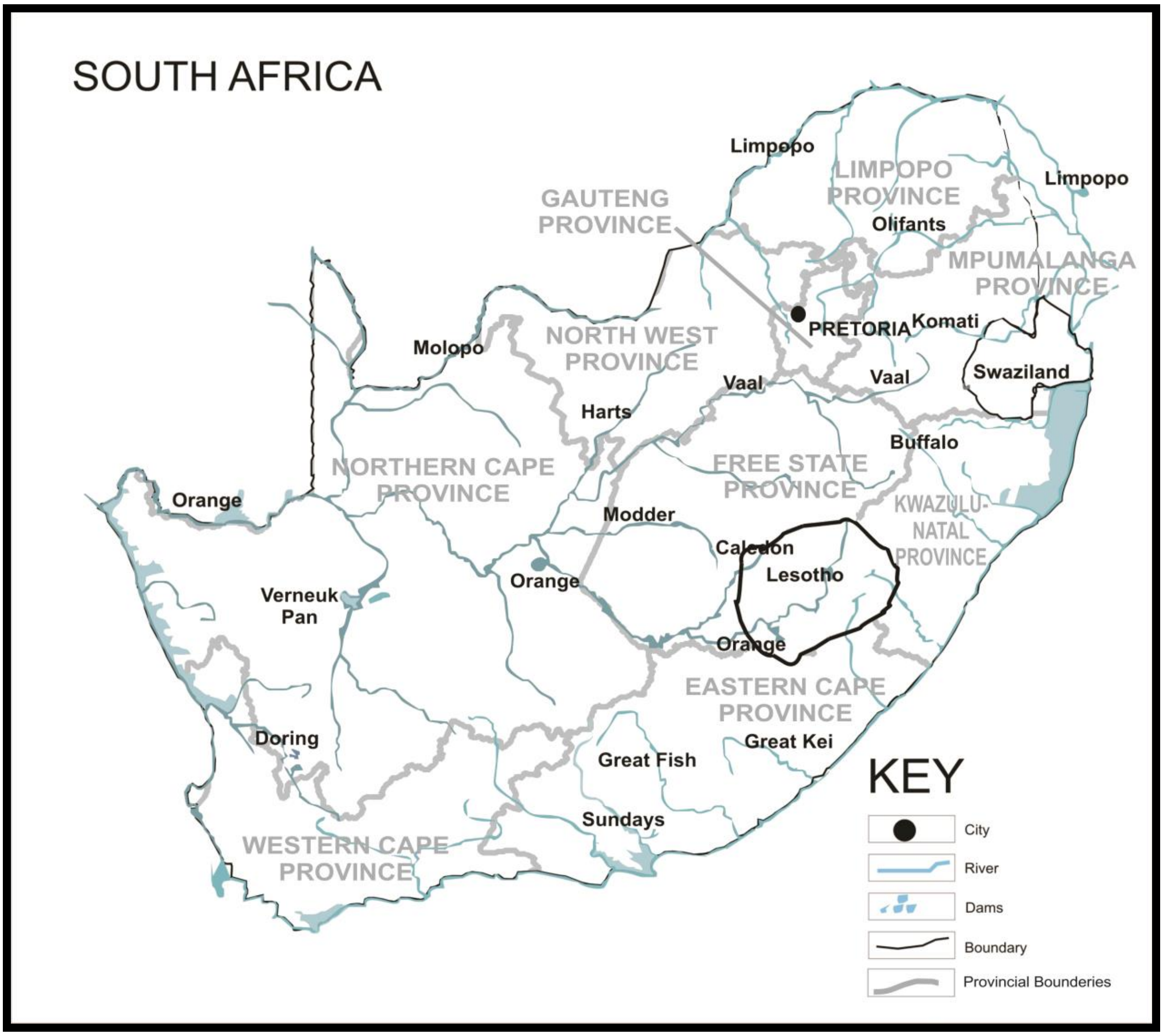

Figure 3.5: Map showing South Africa's major rivers

Source: Author's depiction, May 2015.

The country's rivers (see Figure 3.5) include the Komati River which is subject of this study, the Orange river which is the largest and other major rivers like the Vaal, Breede, Komati, Lepelle, Tugela, Umzimvubu, Limpopo and Molopo (Byrnes, 1996).

3.2.6.3 Flooding

South Africa has a climate influenced by variations in elevations, the Indian Ocean to the southeast, the Atlantic Ocean to the southwest and the different rainfall regimes in summer and winter occurring over the country (McSweeney *et al.*, 2010:1). The country has physical features ranging from bush veld, deserts, forests, grasslands, mountains, beaches and coastal wetlands (Byrnes, 1996). The shoreline stretches for 3000km from the Mozambican border in the east to the Namibian border in the west (South Africa year book, 2012/13). Most damaging floods in South Africa are a caused by prolonged, severe and widespread rainfall events (Alexander, 2006:222).

<u>Flooding before 2000</u>

The country has a long history of floods. According to Odiyo, Makungo and Nkuna (2011:4) a number of studies on rainfall changes have been done in South Africa. These changes led to floods in some areas during the hydrological periods 1976/77, 1995/96 and 1999/00. In December 1995, floods caused the death of 150 people in Edenvale, an informal settlement near Pietermaritzburg. The settlement is one of the most vulnerable to floods in South Africa (Alexander, 2005:13). The Southern Cape coast in South Africa has had floods during the years 1847, 1867, 1875, 1905, 1910, 1916, 1929, 1931, 1932, 1940, 1954, 1961, 1967, 1977, 1981, 1998 and 2003 (Tempelhoff *et al.*, 2009:98).The damages caused were mostly economic. The country had also had severe and widespread floods in 1981, 1984, 1987 and 1988. The floods resulted in high loss of life of between 10 to 200 people, several thousand lost their livelihoods, tens of thousands were displaced and damage to overland communication routes and water supply projects (Alexander, 2006:218).

<u>Floods during 2000 and 2013</u>

The incidence of recorded floods and flood disasters in South Africa from the year 2000 to 2013 as borrowed from the Centre for Research Epidemiology of Disasters is as shown in Table 3.4. It displays the year of flood, the annual number of floods, the total number of deceased people affected and the total deceased as a result of the floods. The areas shown in the table are the most floods prone in the past as well as the present. Flood incidence and information is also highlighted and discussed as recorded from other sources apart from the Centre for Research Epidemiology of Disasters. These sources complement each other and enhance the quality of flood information.

Table 3.4: Flood trends in South Africa from 2000 to 2013

YEAR OF FLOOD	PROVINCE, MUNICIPALITY, TOWN AFFECTED	ANNUAL FLOODS	ANNUAL TOTAL AFFECTED	ANNUAL TOTAL DIED
2000	Northern Province, Mpumalanga Province, KwaZulu-Natal Province	3	3 200	93
2001	Cape Town, Mpumalanga Province	2	42 668	5
2002	East London (Western Cape Province)	1	2 500	16
2003	Montagu area, Western Cape	1	500	1
2004	Cape Town Region	1	15 000	0
2006	Taung Municipality, Eastern and Southern Cape	2	7 160	12
2007	Cape Town	1	38 000	0
2008	KwaZulu-Natal, Cape Peninsula	2	4 000	11
2009	KwaZulu-Natal	2	20 300	14
2011	Eastern Cape, Free State	1	200 000	40
2012	Ndiambe, Port Alfred	1	125 000	13
Total		**17**	**458 328**	**205**

Source: The international disaster database: centre for research epidemiology of disasters http://www.emdat.be/search-details-disaster-list accessed 13/12/2013 and glide number http://www.glidenumber.net/glide/public/search/search.jsp Accessed on 13/12/2013.

South Africa, like any of the surrounding countries was hit hard three times by floods in year 2000, causing 93 deaths (see Table 3.4), which is the highest ever recorded and 3 200 people affected (Centre for Research Epidemiology of Disasters, 2013). Like Zimbabwe, Botswana and Mozambique, South Africa was also hit by cyclone Eline in that year (Davis, 2011:18; Vyas-Doorgapersad & Lukamba, 2012:777; WMO, 2012:4).

The 2000 cyclone Eline induced floods in South Africa hit the North Eastern part of South Africa (Smithers, 2011:1). The floods of 2000 also affected the Northern, Mpumalanga and KwaZulu-Natal provinces (see Table 3.4). In total 93 people lost their lives as a result of the floods and 3200 people were affected (Centre for Research Epidemiology of Disasters, 2013). In 2001 Cape Town and Mpumalanga Province were affected by floods (see Table 3.4). In those floods five people died and 42 668 were affected (Centre for Research Epidemiology of Disasters, 2013).In 2002 floods in the Western Cape Province affected 2500 people and 16 people lost their lives (see Table 3.4).

In 2002 and 2003, 2500 and 500 people respectively were affected by floods in the Western Cape. The 2002 floods were more severe as they killed 16 people. Only one person was killed in the 2003 floods in the Western Cape. The Cape Town region had floods that affected 15000 people in 2004 (Centre for Research Epidemiology of Disasters, 2013). The Southern Cape coast was hit by floods in December 2004 to January 2005 (Tempelhoff *et al*., 2009:98). The Southern Cape coast flood had a serious impact on the local tourist industry as there were structural damages to product facilities, damage to infrastructure and water pollution, psychological impacts and the safety and protection of tourists (Tempelhoff *et al*., 2009:99).

There was also flooding in the Western Cape in 2005 (Smithers, 2011:1). In 2006 the Eastern and Southern Cape was hit by floods that killed 12 people affecting 7160 (see Table 3.4). According to the NDMC Annual report, (2006/2007:130-131) in 2006 South Africa had serious floods in Nelson Mandela Bay in the Eastern Cape Province, Southern Cape in the Western Cape province and Taung Local Municipality in Northwest province. In Nelson Mandela Bay in the Eastern Cape floods killed 6 people, damaged a number of roads and 25 000 families residing in shacks in low-lying flood areas were affected. In Southern Cape in the Western Cape Province floods killed seven people. There was also damage to roads, housing, bridges, dams and sewerage infrastructure.

Floods in Taung Local Municipality in Northwest province seriously affected 12 villages in which 1 032 houses either collapsed or had serious structural damage. Some bridges were seriously damaged with one being rebuilt. Some of the bridges and roads that were damaged needed rehabilitation. The cost to repair road infrastructure was R41 million and, replacement of collapsed and damaged houses was R35 million. The 12 affected villages were cut off from clinics and household water supply was polluted causing diarrhoea. Farmland and equipment was severely affected and animal diseases became widespread. Education was disrupted as schools were severely affected and teachers and scholars were cut off from their schools by the floods. Affected communities were given flood relief in the form of tents, blankets and food supplies.

In 2007 Cape Town flooded and 3800 people were affected. In 2008 KwaZulu Natal and the Cape Peninsula floods killed 11 people and affected 4000 (Centre for Research Epidemiology of Disasters, 2013). In 2009 KwaZulu Natal was again affected by floods that killed 14 people and affected. Floods also hit the Free State and Eastern Cape in 2011 (Smithers, 2011:1). Table 3.4 also shows that, in 2011 the Eastern Cape and Orange Free State areas were affected by floods of which 40 died and 200 000 people were affected. Meteorologists believe the floods are caused by a natural weather cycle known as La Niña and the Southern Oscillation mechanism, which has been linked to recent flooding in Australia and the Philippines (SA Country report, 2011). During the 2010-2011 rain season, 33 districts and municipalities in eight of the nine provinces were destructed by floods where 91 people died and 20,000 were affected (FAO/GIEWS Global Watch, 2011). In April 2011, several farms and crops were devastated when early January floods hit South Africa (Zimela, 2011). In 2012 there were floods in Ndlambe, Port Alfred where 13 people lost their lives and 125 000 were affected. In 2012 tropical storm Dando brought heavy rains over the north-eastern parts of the country causing floods, road damage and the displacement of people (WMO, 2013:14).

Analysis of Table 3.4 shows that the country experiences flood disasters nearly every year for the past 13 years. A significant number of people died due to floods the highest figures recorded in the year 2000 as 93 and 2011 as 40. These are very high figures considering the fact that the country is said to have the most efficient disaster management systems in the region (International Federation of the Red Cross, (IFRC) 2012:74; Roth and Becker, 2011:443). A total of 17 flood disasters were recorded between 2001 and 2013. 458 328 people were affected and 205 died due to floods in the period understudy (see Table 3.4). If compared with the country's population of 52.98 million people, 0.87% (458 328) was affected and 0.0447% (205) of the affected died during the period 2000-2013. This is an insignificant figure, which perhaps points out to the healthy level of disaster management.

This constitutes 43.6% of the total number of people affected in the period understudy 2000 to 2013. In 2012 the Ndlambe Local Municipality, with its capital Port Alfred were hit hard by floods. Flooding caused 13 deaths and 125 000 people were affected, which constitutes 27.3% of the total number of people affected in the period understudy.

3.2.6.4 Living with floods in South Africa

In South Africa, rivers have an important role in the social and economic lives of communities both in towns and rural areas. They provide water for drinking, farming, industrial processes, provision of electricity, are transport corridors and provide fish and recreational activities (Schneidergruber *et al*., 2004:1). Unfortunately having human activities within rivers and water sheds has exposed people to flood risk. On the same note removing people from river environments also creates other human economic and social problems. Living with floods might be another good strategy among many to reduce flood risk in South Africa.

Many countries are now making strides towards the living with floods paradigm shift. After having suffered heavy losses of life as a result of floods and lost billions of dollars in structural flood mitigation measures, China has introduced a new integrated policy towards natural resources and flood management. In 2005 the Ministry of Water Resources in China prepared a national flood management strategy in 2005 which reflects a shift from depending on structural measures to a balanced approach using both structural and non-structural measures. Core to this approach is “learning to live with flood risks” (Kobayashi and Porter, 2012:vii).

Flooding has helped nurture cultures worldwide. In Mekong and Chao Phraya watershed basins use flooding to grow rice as natural floods bring in the required amounts of water. Egyptian communities along the Nile River thrived through nutrient-rich floodwaters and sediment which were able to sustain agriculture with limited artificial irrigation (Middlemis-Brown, 2010:6). These examples clearly show that the concept of living with flood is realistic and can therefore be adopted and used in South Africa.

3.3 Flood analysis: Zambia, Zimbabwe, Botswana and South Africa

As already been alluded to in the literature review, Zambia is generally a well-watered country. During the period under review as in Table 3.5, Zambia had 14 floods that affected about 1 650 253 people and accounting for 11.35% of its population.

Table 3.5: Summary of floods: 2000 to 2013

Name of Country	Total Floods	Total Affected	Total Death	Country Population	% age Affected
Zimbabwe	9	341,520	237	14,150,000	2.41
Zambia	14	1,650,253	60	14,540,000	11.35
South Africa	17	458,328	205	52,980,000	0.87
Botswana	7	152,602	13	2,021,000	7.55
Total	**47**	**2,602,703**	**515**	**83,691,000**	**3.11**

Source: The international disaster database: centre for research epidemiology of disasters http://www.emdat.be/search-details-disaster-list accessed 13/12/2013 and glide number http://www.glidenumber.net/glide/public/search/search.jsp Accessed on 13/12/2013.

Zambia has the highest number of people affected by floods as compared to the other countries under review. What this means is that a lot of work needs to be done to reduce flood risk reduction in that country. One way of doing it might be to improve on their flood prediction methods so that people are quickly advised and proactive measures taken before floods.

Zimbabwe had the highest number of 237 people who died over a period of 14 years as a result of floods during the period under review as indicated in Table 3.5. This is a very high figure considering that the country has a population far less than South Africa which had 205 deaths when the two countries are analysed. The percentage number 2.41% of people who were affected by these floods in Zimbabwe is low considering its population of 14 150 000. More action is required and flood deaths might be eradicated if the country seriously considers and uses flood forcasting as a pro-active and mitigation approach. This will make the country a low risk area where people would unnecessarily lose their lives due to floods.

Botswana is a very small country when the population figures are taken into consideration as shown in Table 3.5. However the country also had a high percentage of 7.55% of its population being victims of floods during the period 2000 to 2013. Attention also needs to be focussed on serious flood risk reduction measures. Flood prediction must also be taken on board as a priority in reducing flood risk.

South Africa is a very big country in terms of size and population. The country had the highest number of seventeen floods during the period under review as shown in Table 3.5. However to a very small percentage of 0.87% of its people were affected by flood disasters. This might be due to the reason that the country has a well developed Disaster Management Act with a framework that has a strong focus on proactive disaster risk reduction (Roth & Becker, 2011:443-444)

The overall percentage number of people affected by floods in Table 3.5 of 3.11% in the four countries is low for the period under review. What this means is that to a great extent the countries are managing to manage floods and keeping flood risk minimum. However the percentage figure can also be reduced if most of the short comings in flood risk reduction are addressed. Zambia and Botswana need to improve more on their flood risk reduction measures as these countries reflect high percentages of 11.35% and 7.55% respectively on numbers of people affected by floods. Flood prediction is a necessary strategy to address the issue of flood risk reduction.

3.4 Conclusion

In this chapter historical reconsiderations on the occurrence and management of river flood disasters in four SADC-countries were discussed. Addressed in the chapter is the research question “What is the past and present status of river flood disasters in the SADC-region?” With all the statistical information discussed under each study country, there is a clear sign that flood disasters are abundant and are continuing unabated in the SADC-region.

There are indications that the SADC-regional countries are vulnerable to floods which have increased in their frequency and impact. An analysis of the studied countries and areas indicates that countries seem to have similar rainfall and flood seasons which range from October and March/April. Even though the study is delimited to the period 2000 to 2013, information indicated the occurrence of serious flood disasters before the year 2000. The studied communities live in flood prone areas for the same survival and economic needs especially agriculture and fishing. Due to their location communities are constantly being affected by river floods caused by heavy rains and at times cyclones. Some of the floods are being registered as being of high intensity and magnitude.

Statistics also indicate that floods resulted in loss of life, displacement of many people, destruction of infrastructure such as houses and roads, farms and crops and loss of livestock and disrupted communication. Apart from that sanitation facilities are also damaged, water is contaminated and there is increase in human disease. Despite these challenges communities are staying put in flood risk areas. This simply accentuates that water is a key factor in people's lives and has influenced human settlement patterns and the location of activities such as agriculture and fishing for the studied countries and the SADC-region. Against this background, it appears floods cannot be predicted. Therefore which IKS considerations and existing dimensions of knowledge should be included in a flood prediction model to improve the functionality and efficiency of river flood predictions in the SADC-region, to reduce river flood risks?

Such a status quo, calls for a serious review of current flood risk management strategies as they seem to be failing to contain measurements against flood impacts. The introduction of non-structural measures such as flood prediction (Fang, 2008:14), education, training and insurance (Carmo Vaz, 2000:13), are being advocated by many authorities. Supported in the study is the use of non-structural measures through the development of a flood prediction method for the SADC-region. On the same note, communities are being encouraged to live with floods (Paton, *et al.,* 2010:183: Van Ogtrop, *et al.,* 2005:607). The concept of living with risk entails that communities need to recognise that flood risks cannot be eliminated and must explore practical ways of living with floods without, or with limited flood control structures (Haber, 2007:359). Crafting and enforcing effective flood management laws and regulations also help in mitigating flood disasters (Ologunorisa, 2009:19). Preventing the cutting down of trees, soil erosion and developing structures away from wetlands (Manuta, *et al*., 2005:11), has a very positive effect on flood controls.

These non-structural means will compliment structural measures that were discussed in Chapter Two, section 2.2.1.6, of this study.. As a starting point to mitigate flood effects, developing a flood prediction model for the Region with an integration of IKS and SKS will be a critical measure towards reducing flood risk in the Region. Chapter Four engages the reader in flood prediction research and flood prediction models worldwide. Addressed in the chapter is the research question identifying any specific prediction models being used to help in river flood disaster risk reduction, and how they may serve as possible flood management instruments? Another research question also addressed in Chapter Four evaluates the extent to which past research provided guidance in river flood prediction possibilities.

CHAPTER FOUR: LEARNING FROM FLOOD PREDICTION RESEARCH AND MODELS WORLDWIDE

4.1 Introduction

There is pressure to enhance flood forecasting performance the world over (Parker, 2003:1). This is due to the fact that with climate change there is going to be an increase in the frequency of floods (Parker, 2003:1). Climate change mitigation emphasizes the need for effective flood prediction mostly in immediate and high flood risk areas (European Union (EU), 2003:23). Business competition and the lack of residential space is also leading to more development on floodplains (Parker ,2003:1). Therefore focused efforts are critical to reduce flood risk on communities (Pilon, 2001: ii). One important objective of Flood Forecasting is to help people and agencies to prepare and take appropriate measures and counteractions that mitigate flood effects before and during floods (Tingsanchali, 2012:25). This is thereby meant to save lives and property, and reduces damage and livelihood disruptions. (Rabalao, 2010:25). The degree of flood damages also depends on the quality of flood predictions (Bates *et al*., 2008:46). Flood forecasting also provides information on water availability for integrated water resources management thereby reducing water conflict and also for planning optimal water usage (Pilon 2001:9). Therefore flood research and the development or improvement of available flood prediction models will enhance flood risk reduction all over the world.

In Chapter Four prominence is given to existing literature regarding flood prediction research. Flood prediction research assisted this study to gauge the extent to which it can provide guidance in river flood prediction possibilities. Flood research was also used to identify gaps in river flood predictions that need to be addressed. Research was also used to identify models or elements of models that might be used to develop and improve flood predictions in the SADC-region. The use of flood prediction models worldwide and how some of the prediction methods and research may serve as possible instruments to deal with the management of river floods in the SADC-region were another point of focus. The discussions on flood predictions were dovetailed to scientific models, namely the Meteorological Organization World (WMO) model, Pilon Model, Golnaraghi and Power Model, Parker Model, Chowdhury Model, Yadete model and Haggets Model all in Section 4.3. The flood prediction models also included the integrated scientific and indigenous flood prediction model (Section 4.4.1), Community Hydrologic Prediction Systems (Section 4.4.2) and the LIVE scientific knowledge method (Section 4.4.3). It is these models or part of their elements that guided the writer to develop an improved, if not new, river flood prediction model for the region.

4.2 A literature survey on river flood prediction research and the use thereof for present day mitigation in SADC-countries

This section identifies and explores some research studies that have been done on river flood prediction. The models have been used in different countries and different contexts to mitigate flood impacts. This section helps to expose that indeed there are flood prediction models in use worldwide, inclusive of the SADC-region. The choice of models that may be incorporated in an ideal flood prediction model for the SADC-region are numerous but most of them discussed in this section are interrelated as they relate to calculation of estimated rainfall and excess water flows on land during and after rains.The models or some of their components were benchmarked and used in the development of a flood prediction model for the SADC-region.

4.2.1 Reviewed research on scientific methods of river flood prediction

Flood prediction or forecasting is a subsystem of an early warning system (Yadete, 2004:4). Forecasting consists of data gathering, data transmission to the forecasting centre, and data conversion into a forecast which is sent to a decision maker. (Yadete, 2004:4). The best possible forecast, completely and identically describes a process which will occur in the future. According to the European Union (EU) (2003:3) flood forecasting is a precondition for successful of flood risk mitigation. Accurate prediction is also prerequisite for the credibility of warnings to the public and the faith placed in the early warning system (Sadoff & Muller, 2009:75). The effectiveness of flood forecasting depends on the preparedness level and correct response (European Union, (EU) 2003:3). Since forecasts are not precise, a forecast used needs to be with minimum variance of forecast errors (Yadete, 2004:4). Therefore timely and reliable flood warning and flood forecasting information must be provided (European Union, (EU) 2003:3). As such flood prediction information needs to be supported by modelling, ground and satellite data (Sadoff and Muller 2009:75). Forecasting/prediction assist the process of decision making under uncertainty (Yadete, 2004:4).

4.2.1.1 Forecasting ideas from outside the SADC region

In many parts of the world many countries have developed various flood prediction systems and technologies. These systems and technologies need studying and if feasible in their implementation they may as well be bench marked for flood forecasting in the SADC-region. This section looks at the flood forecasting models, firstly with a summary of the earlier models, then followed by later and present models in detail and lastly flood prediction technologies being used.

Bedient and Huber (2002), as cited in Fang, (2008:14), give a summary of the early and modern developments in the field of Hydrology. The early models comprise of formulas and theories like Green and Ampt infiltration equations (1911), Sherman's unit hydrograph (1932), Horton's infiltration model (1938), Snyder's synthetic unit hydrograph (1938), Henderson and Wooding (1964) that applied the concept of the kinematic wave to overland and channel flow calculations and the Stanford watershed model (1970) the first comprehensive hydrologic computer model.

<u>The Unit Hydro Graph Model</u>

Szöllösi-Nagy (2009:30) developed the hydrological forecasting using the Unit Hydro Graph Model. The forecast looks at the identification of the expected occurrence of a specified hydrological event with respect to its actual time of occurrence, its quantitative measure and its reliability as conditioned by available past, and present information. As the lead time of the forecast increases so does the level of uncertainty. The longer the lead time, the less reliable forecasts are (Szöllösi-Nagy, 2011).

The use of the Unit Hydrograph Model is also described by Dooge, (1959), who stated that the model assumed that a river catchment acts on an input of effective precipitation in a linear and time-invariant manner to produce an output of direct storm runoff. In another observation Dooge, (1973) stated that the main purpose of the Unit Hydrograph Model is its use to predict the direct runoff due to any excess precipitation event which has not been used in the estimation of the unit hydrograph.

This model is relevant to this study and the development of the SADC flood prediction model as it is designed to measure and predict the effects of any excess rain water. It is this excess run off which causes floods in most situations in the SADC-region and the studied countries. The flood prediction developed in this study will also use information on access rainfall to help predict river floods (see Figure 8.1 under scientific knowledge processing).

Flood forecasting initiative (FFI)

The Flood Forecasting Initiative (FFI) is a major flood-forecasting initiative operated under the World Meteorological Organization (WMO). It is a global network launched in 2003 and incorporates 58 countries and over 300 participants from national meteorological and hydrological services. The project analyses the strengths and weaknesses of the current flood forecasting systems in the member states. The network then endeavours to improve the flood forecasting and warning. This is done by improving the capacity of meteorological and hydrological services through joint and timely delivery of accurate flood predictions for decision-makers and communities. Although not yet in the SADC-region, the FFI has projects in the Nile River Basin and in Ghana. The project is identifying technical and administrative flood prediction challenges and offering solutions (Thiemig, 2011:65-66).

What the research brings to people's attention is that there is increased focus on flood management in Africa. This shows a positive move as there will be potential to significantly improve flood prediction in the region. That will only be if there is information on the work being undertaken by different stakeholders. Flood prediction will also succeed when there is effective and efficient coordination of work being done, knowledge and data sharing. Unfortunately one drawback cited in this study was lack of coordination of research and implementation efforts as there are many different institutions focusing on flood management. In the flood prediction being developed in this study, the element of coordinating activities and stakeholders is identified as critical (see Figure 8.1 under coordination).

Flood forecasting system based on grid technologies

Hluchy *et al*., (2004:51) researched on a prototype of flood forecasting system based on grid technologies. The research involved modelling and simulation of floods with the intention of making flood forecasts. Simulations involved intensive computing activities using high performance computing along large areas along rivers. The use of high performance computers reduced the computational time of flood simulations. In the study meteorological and hydrological simulations were integrated for accurate flood forecast.

The use of integrated hydrological and meteorological data or information is very critical in flood prediction as the information can complement each other. The involvement of hydrologists and meteorologists has to be coordinated in such a way that when the data they collect, which is related to floods is integrated, it's expected that the flood forecast that are produced are efficient and effective. The flood prediction developed also emphasise that the two groups of professionals work together by collecting, sharing and have an integrated product that predicts river floods. Therefore sharing information is very important between the two (see Figure 8.1 under scientific knowledge processing), and this way to do it, will also be considered in a model for the SADC-countries.

Hydrologic simulation

Xiang, (2004:1) states that hydrologic simulation (rainfall runoff) modelling began in the 1950s with the application of a digital computer. The purpose was to predict stream flow for a given observed precipitation and other meteorological variables over time. The applications of hydrological simulations models include stream flow forecasting. This might make it a necessary model to use and might be applicable to this study. The model is not different from others discussed in this section as it use integrated hydrological and meteorological data and information (see Figure 8.1 under scientific knowledge processing).

It seems as if a trust in the value of the preceding prediction models is low and to a great extent authorities like Akbari *et al*., (2011:73) and Yadete, (2004:4) indicate that these models might not be reliable and allow for prediction errors. If the prediction models discussed above are not regarded as trustworthy, the need to improve them or develop new prediction models that are better and more reliable is required. With the advent of global warming prediction models should be evaluated and adjusted to suit the changing climatic and weather environment (UNESCO, 2006:3).

Convective rainfall prediction methods

According to Warner *et al.,* (2000:799) prediction of floods caused by convection rainfall was done through accurate estimates or predictions of rainfall distribution in space and time. This surface hydrologic model was capable of predicting river discharge based on rainfall rate input data. This study by Warner used different techniques for the estimation and prediction of convectional rainfall in a complex terrain. Estimation of precipitation was done using high resolution data from a Radar station. There was also the use of numerical weather prediction models that produce research simulations and operational forecasts of precipitation. The model also used the Automated Algorithmic systems for precipitation prediction. It utilized information from radar, surface observations and produced very short range rain forecasts. (Warner *et al*., 2000:800). This method used both numerical data and space technology to predict rainfall. The model emphasised the same methods as already been discussed in the other foregoing studies in this section but was good for convectional rainfall types which are also common in many countries in the SADC-region.

Rain gauge networks

Another form of flood prediction research is on the use of rain gauge networks (Yates *et al*., 1999:816). This approach used statistical relationships between precipitation and elevation that are used to interpolate precipitation between rain gauge observations in complex terrain for use in rainfall runoff models (Warner *et al*., 2000:800). The use of rain gauges to measure the amount of rainfall is very common in many countries. Intensification of rain gauge use is very important to collect rainfall data especially at community or village levels. Rain gauge use for collecting and monitoring the amount of rainfall was also considered in developing the flood prediction model for the Region (see Figure 8.1 under scientific knowledge processing).

Dynamic Model and the Automated Algorithmic System

Yates *et al.* (1999:815) did a comparison of flood discharge simulations using rainfall input from Radar, the Dynamic model and the Automated Algorithmic system. Their findings were that the rainfall estimates from the weather radar aided in simulating a watershed's response to rainfall. The simulated peak discharge was similar to that estimated. What this means is that this approach can be used to predict the amount of rainfall that will fall in a watershed and cause floods (Warner *et al.,* 2000:797).

The Dynamic Model was more promising in providing a significant forecast lead time for flood events than the algorithmic system. However the discharge forecasts of the Dynamic and Algorithmic model improve the ability to forecast convective storms, especially if they are to be used in operational flood forecasting (Yates *et al.*, 1999:815: Warner *et al.,* 2000:797). Unfortunately all techniques for precipitation estimation and prediction are handicapped in areas of complexity in the terrain (Warner *et al.,* 2000:797), even though they have a contribution in providing input to hydrologic models for flood prediction under these conditions. Generally the Radar, the Dynamic model and the Automated Algorithmic system demonstrated the potential for application to estimate thunderstorm related precipitation (Yates *et al.*, 1999:816). These three methods may also be used to collect data for flood prediction through rainfall estimates in the SADC-region and the studied countries.

Artificial Neural Network (ANN) flow predictions

Yadete, (2004:iii) did a research on early flood warning system for the Glenmore reservoir in Canada with Artificial Neural Network (ANN) flow predictions. The objective of the study was to develop an early warning system for the Glenmore reservoir in the Elbow watershed, Canada. The ANN-model was developed to predict stream flows into the Elbow River. The model is very useful framework for modelling non-linear, dynamic and hydrologic processes that influence stream flows and flood events. Real-time measurements of flows, temperatures and rainfall in the elbow watershed were used as inputs to the prediction model. The prediction capability of the model was improved with the use of multiple gauging stations, rather than data from a single station.

The results of the study showed that there was improved warning time, prediction of stream flows and the identification of appropriate action to mitigate the predicted event (Yadete, 2004). This model appears simple to use as it uses real-time stream flows, temperature and rainfall measurements from various stations as inputs in the prediction of floods. It also uses measurement from various gauging stations which are commonly used in the SADC-region. The use of rain gauges to measure rainfall and thermometers to measure temperature is the current method being currently used in the SADC making this model appropriate to benchmark.

Water movement through channel systems

According to a study by Lettenmaier *et al.,* (2006), accurate flood forecasts for large river basins depend on a combination of the ability to accurately forecast the movement of water through the channel system, the ability to translate precipitation and other surface meteorological conditions into runoff entering the channel system and the accuracy with which meteorological conditions during the forecast period can be predicted. The importance of these three elements to flood prediction accuracy depends on a number of factors that include, the geometry and size of the river network, the number and location of stream gauging points, antecedent hydrological conditions like soil moisture and factors that influence the hydrological response of the watershed like the soil, topography, vegetation and geology. This method is simple to use and only requires accurate numerical data calculations. The method will be considered in the flood prediction model developed in this study (see Figure 8.1 in Chapter Eight).

The use of space technology in enhancing flood predictions

There have been recent advances in technology giving rise to modern models in the field of applied hydrology by expanding the capabilities of data acquisition and analysis. There is remote sensing through the use of radar technologies, powerful computers that receive and handle data in a timely manner, software such as Geographical Information Systems (G.I.S) that link information with location. These modern tools maximize the benefits to be gained from forecasting under severe weather conditions (Fang, 2008:15). These modern methods among many may also be usable in the SADC-region as they use modern technology like remote sensing and G.I.S. that aggregate all the sources of information and produce disaster risk maps (Głosińska and Lechowski, 2013:120). Other advantage of GIS include low or no acquisition and mapping costs, and allows to map over large and inaccessible regions (Ireland *et al.*, 2015:3373). The use of technologies is critical in the development of the flood prediction in this study (see Figure 8.1 in Chapter Eight).

Jeyaseelan, (2004:291-2) states that space technology makes contributions to the management of flood disasters. The technology uses earth observation satellites that provide comprehensive coverage of large areas both in real time and frequent intervals. Satellites continuously monitor atmospheric and surface parameters related to floods. Advances in remote sensing technology and geographical information systems also helps in real-time monitoring. However due to limitations of technology, some of the most severe floods are not recognised until after they strike and cause havoc. Limitations of technology become a curse to reliable flood prediction (Gruntfest & Huber, 1991). Satellite imagery is at times affected by clouds, haze and smoke that might cause distortions on the image resulting in gaps in data (Gillespie, Chu, Frankenberg and Thomas, 2007:7).

Reilly, (2009) developed the Gravity Recovery and Climate Experiment (GRACE) satellite which improves flood prediction time and allows authorities to issue flood warning on the high risk of flooding up to a month in advance (Szöllösi-Nagy, 2011). However, it appears the satellite will not be able to be utilised efficiently within a decade due to some technicalities (Szöllösi-Nagy, 2011).These disappointing findings accentuate the complicated and problematic nature of the focus of this research, and there is a strong need for another methodology to be meaningfully utilised as a model for the efficient management of river flood disasters. But still given the opportunity, the use of space technology in flood prediction in the SADC-region is the best way forward.

One could even refer to Gregoire and Kohl, (1986:287), as they developed a river flood prediction model in which space techniques can measure and collect data on the ground using data-collecting platforms and telecommunication techniques. The model also gives a dynamic description of ground surface characters on the river catchment areas like vegetation cover, free surface water areas and swamps. The model helps in monitoring natural indicators of both rainfall and river water through remote sensing techniques. Overall the method integrates data transmission and remote sensing for river flood prediction. This method might also be good for the region but it's the issue of technology which becomes inhibiting as the setting up of technological structures might be expensive. However as already been alluded to there is need to invest highly in space technology in the region for efficiency and effectiveness in flood predictions.

Hossain and Lettenmaier, (2006:1) talks of the Global Precipitation Measurement (GPM) mission which is a constellation of satellites consisting of a fleet of passive microwave (PMW) sensors augmented by a single precipitation radar (PR). It provides high-resolution global precipitation products including rainfall and snow with temporal sampling rates ranging from three to six hours. GPM provides improvement over current state-of-the-art satellite precipitation products with coverage over most of the global land areas. The global nature of coherent and more accurate satellite precipitation products from GPM offer hydrologists tremendous opportunities to improve flood monitoring in medium to large river basins especially in underdeveloped or remote areas where rainfall is abundant but in situ measurement networks are inadequate. This model goes a long way in improved flood prediction all over the world, Africa and the SADC included. The model covers underdeveloped and remote areas of which some countries and areas in the SADC are in that category.

The use of space technology on paper appears to be good but the question is how applicable would it be in the SADC-region where investment or advances in technology might be a drawback. Even though with resources for such technology being provided the use of space technology would to a great extent assist in improving flood predictions in the SADC-Region. The use of space technology in collecting data was also considered in developing the flood prediction method for the SADC-region (see Figure 8.1 under scientific knowledge processing).

All the flood prediction models and technologies discussed in this section have one thing in common, namely that they are being or have been used in river flood prediction. Their development and use shows that river flood prediction models and technologies are not fixed. In reviewing these flood prediction models and technologies, some elements could be benchmarked and utilised in developing a comprehensive river flood prediction mechanism useful for disaster risk reduction for the SADC-region.

The flood predictions methods and technologies being used give us a starting point of evaluating and making the necessary changes to them to improve by modifying or completely changing them, if they are failing to meet their purpose. This may be through being completely inapplicable or because of unreliability due to errors they make. Research from authorities cited in this section has to an extent showed us that most of the models have got errors, therefore the need to improve on them or entirely developing new methods. That justifies the aim of this study which is towards the development of an efficient and effective river flood prediction model. A literature survey on past River flood prediction possibilities having been done gives value to present day mitigation. It can be noted that past and present day flood prediction models have value to an extent on recent day flood mitigation as they may be used in the SADC, but they are compromised by errors that at times make them unreliable. This discovery of such errors and unreliability motivates the need for this and more research to be done and in order to perfect current and past river flood prediction methods.

The development of capabilities for flood prediction and early warning must therefore include the design and implementation of flood preparedness and mitigation strategies, targeted at specific vulnerable groups, indicating the most appropriate action to be taken to mitigate loss and damage. Flood prediction and warning about impending hazards, without providing information on what actions to take, may be counter-productive and create either panic or apathy (Maskrey, 1997:14).

4.2.1.2 Forecasting ideas from the SADC-region

According to Vera Thiemig, (2011:64), flood forecasting in Africa has not received extensive focus in the scientific literature, despite recognition of its importance. The accuracy and lead time of flood forecasts in Africa, the SADC-region included is either limited or questionable (Mulugeta *et al.,* 2007:6). Every country of the Southern African region is always being reported to be on alert for potentially disastrous flooding every rain season (Haile, 2011:1). For example OCHA in 2011 warned and forecasted that severe floods in Botswana, Mozambique, Namibia, Zambia and Zimbabwe could affect tens of thousands of people, damage infrastructure, crops, homes and lead to food shortages. (United Nations News Centre (UNNC), 2011). Several flood prediction methods, which are described in the previous section, have been developed and are being used in a number of developed countries. These methods may be adopted and used in the SADC-region. However, disaster prediction methods must also be developed that are specifically crafted for the SADC-region. Due to limitations, uncertainties and errors in some of the flood prediction models this was not yet possible (Akbari *et al*., 2011:73). Akbari's view is also supported by Khamal, (2008) who noted that the collection of data is hard and expensive as needed data scales vary over a wide range. As such data may not be available in required scales, may be missing for some period or other areas, or data for a particular process of the hydrological cycle may be absent. The quality of forecasts influences the success and failure of real-time forecasting. Short term and long term forecasting techniques should be improved by not only improving known methods but by also developing new ones (Yadete, 2004:50).

<u>SERVIR-Africa remote system</u>

Flooding in Southern Africa has a serious effect on socio-economic structures, infrastructure including loss of human life, livelihoods and displacement (Macharia, 2010:4). To enhance flood prediction activities Southern Africa is using SERVIR-Africa remote system. SERVIR-Africa is a regional visualization and monitoring system for predicting floods (Macharia, 2010:1). Its focus is on an integrated platform for data acquisition, sharing, use and service discovery (Thiemig, 2011:66). The process involves identification of both flood potential and flood area using remote sensed data and predictive models and field data based for the analysis of socio-economic and ecological conditions (Macharia, 2010:1). It's now possible to mitigate flood effects through flood prediction using satellite rainfall analysis using time and space resolutions. The prediction requires indication of the timing (when), geographical area (where), water level and velocity as key variables. These indicators are monitored through satellite and ground observations (Macharia, 2010:6). This method is of value to this study as the process of using remote sensed data is ideal for the flood prediction model being developed in this study. Therefore remote sensing was included as a way of gathering data for flood prediction (see Figure 8.1, Chapter Eight under scientific knowledge processing).

Regional Flood Frequency Analysis (RFFA)

Southern Africa including countries like Zambia, Zimbabwe, Botswana and South Africa is using the Regional Flood Frequency Analysis (RFFA) which uses the combination of the L-moments and the index-flood method (Haile, 2011:2). The RFFA model is based on recorded observations from sites in a similar region and then a single form distribution is fitted to the pooled data. Flood frequency analysis estimates the magnitude of a flood in relation to a return period of occurrence. The approach is based on Hydrologists trying to formalize people's experiences and ideas on how often floods of a given size occur at given places. This formalization involves establishing a network of gauging stations and then analysing the recorded information. RFFA is practiced in a joint use of at-site and regional data. This method assumes that flood events at several sites in a region might have similar statistical characteristics.

Since hydrological events have numerous and unpredictable sources of uncertainties, the flood frequency analysis model is important and desirable as it estimates how often a specified event will occur on average in a particular area. This is as a result that statistical methods are acknowledging the existence of uncertainties and this enable its effects to be quantified by confidence intervals (Haile, 2011:2). The RFFA approach has the following advantages:

- Due to short and uneven record lengths, data from similar regions has smaller standard errors than those estimated at individual stations.
- It estimates design floods for similar regions and allows flood estimation from gauged sites to un-gauged sites (Haile, 2011:2).

Part of this method was also included in the flood prediction model being designed in this study. The important part would be that of setting on site gauging stations at community level in areas that have a risk of river floods. Information obtained at these levels would then be used for flood predictions specifically in affected areas (see Figure 8.1, Chapter Eight, under scientific knowledge processing).

Statistical and numerical flood prediction models in Mozambique

Jury and Lucio, (2004) did research on the Mozambique floods of 2000 that were due to torrential rains influenced by cyclone Eline in February 2000. It affected 65000 people in the country, caused more than 700 deaths and an estimate of one billion in property and infrastructure damage (Jury and Lucio, 2004:141). This statistics illustrate the vulnerability of countries like Mozambique bordering the Ocean to severe weather. Even though Mozambique is not part of the studied countries, it is part of the study area the SADC-region and therefore, flood prediction in that country motivates an interest in developing a flood prediction model for the SADC. The historical analysis of tropical cyclones in southern Mozambique was done to determine the probability of similar events occurring in future. The study made use of monthly and daily rainfall and information from global weather models to provide a back ground on the flood scenario. Rainfall data was collected from various data bases focusing on the summer season December to March when Tropical Cyclone flooding is prevalent. The analysis was over a period of many years.

During the cyclone Eline the monthly rainfall for most of the stations north of Maputo exceeded all past records. The flow levels of certain rivers were analysed and indicated that rivers had exceeded their historical peak. Based on a flood risk analysis of southern Mozambique and direct evidence of global warning it is estimated that a tropical cyclone generated flood of similar magnitude is probable somewhere over southern Mozambique once every ten years. The study by Jury and Lucio, (2004) concluded that the El Nino Southern Oscillation (ENSO) phase and seasonal rainfall can be predicted reliably at more than three months lead time with statistical models and at less than three months lead time with numerical models. The value of this research is that it was an indicator for the possibility of predicting floods in time to avoid flood disasters, provided victims had faith in the predictions and early warning systems.

What can be learnt from this study is that flood prediction can be done using both statistical and numerical models. More to that data was being collected from December to March the same period that most of the countries in the SADC-region in general and the studied countries in particular also receive their rains. As such, the idea of using statistical and numerical models was also considered or formed part of the flood prediction model developed in Chapter Eight of this study (see Figure 8.1, Chapter Eight under scientific knowledge processing).

<u>Meteorological early warning system/model for the SADC-region</u>

According to the WMO (2007), the SADC- region has also been in the process of developing a meteorological early warning system through the influence of the World meteorological organisation's (WMO) known as the Severe Weather Forecast Demonstration Project (SWFDP) in an effort to enhance weather forecasts globally.

.The project was specifically concerned with improving severe weather forecasts in National Meteorological and Hydrological Services (NMHSs) where sophisticated model products are not effectively used and increasing the lead time of warnings. What this meant was that the region had a structure to monitor and issue warnings involving global, regional and national centres and received support to use new forecasting technology that enables to issue warnings up to five days in advance. This encouraged the building of links between forecasters and global, regional and national disaster management structures. The view of the WMO was the need to build a multi hazard early warning system.

The emphasis of this model is on coordination, cooperation and collaboration on issues of flood predictions. The advantage is that less technological countries will benefit from technology and expertise from the developed world through data collection, analysis and dissemination. There is information sharing and the information output is regional or country specific. Countries in the SADC-region would benefit as technology in other countries would be used to collect and process flood data. As such coordination, cooperation and collaboration also formed part of the flood prediction model developed for the region (see Chapter Eight, Figure 8.1).

4.2.2 Importance of flood prediction for the SADC-region

Flood prediction in the SADC-region is important in flood risk reduction as it provides additional time to prepare before a flood event (Thiemig *et al*., 2011:64). More to that flood predictions are an essential means for optimal use of water resources, enhance the efficiency of hydroelectric dams and other water management operations (Thiemig *et al*., 2011:64). Thiemig (2011:64) cites several authors that include Al-Zu'bi *et al*., (2010), Artan *et al.,* (2007a), Grimes and Diop (2003), Li *et al., (*2008) and Yawson *et al*., (2005), as having emphasized on the importance of high quality real time and short range flow forecasts that cannot be dispensed with to mitigate loss of life and property during floods. Flood forecasts will not be of benefit if the forecast information is not effectively used to prevention and mitigate flood impacts (Macharia, 2010:70). Further to that information on the frequency of floods is required to plan for engineering problems, floods, reservoir management, pollution control and insurance risk calculations (Haile, 2011:1). Therefore flood estimation must be accurate for preventing catastrophes and limiting excessive costs in situations where flood magnitude is overestimated or where flood potential is underestimated leading to excessive damage (Haile, 2011:1).

4.2.2.1 Flood forecasting – the case of Zambia

As already been alluded to in section 4.2.1.2 of this study, Zambia also uses the Regional Flood Frequency Analysis (RFFA) (Haile, 2011:2). The flood prediction method involves the identification of similar regions and suitable regional frequency distributions for the regions. A hydro-meteorological forecasting system was also introduced in the Kafue Basin. Rainfall conditions are the inputs for predicting future flood flows and river levels. The meteorological stations in the basin transmit data to the meteorological Headquarters every three hours through radio and telephones where it is processed. The rainfall warning is then issued to the Disaster Mitigation and Management Unit (DMMU) by hand and to the electronic and print media through email (WMO, 2007:75).

4.2.2.2 Flood forecasting – the case of Zimbabwe

In Zimbabwe there is evidence to show that flood predictions are done especially in the Zambezi valley area of Muzarabani and Guruve. According to Madamombe, (2004:2) meteorological forecasts are issued throughout the year and during the wet season and rainfall amounts predicted. Information exchange has significantly improved. Data collection of rainfall and discharge in rivers is done by the relevant national agencies in the Ministry of Water. Other sources of information are satellite or radar observations, forecasts from other institutions, information from the local communities and local authorities. The information is used to forecast river flows and predict floods. Based on the predictions the institutions take the necessary steps to ensure the information is disseminated and potential victims evacuated before or during the flood events (Madamombe, 2004:2). Dissemination of information is normally through the newspapers, radio, television, telephone, Internet, and awareness programs by Government and non-governmental organisations.

4.2.2.3 Flood forecasting – the case of Botswana

According to Gumbricht *et al.*, (2004:178) Botswana has a flood prediction model that it uses in the Okavango Delta. The statistical model, apart from predicting the extent of wetland loss arising from water abstraction, also permits prediction of floods in an area and its spatial distribution, three months in advance of the flood maximum. The model is calibrated using maximum areas of seasonal inundation. The calibration is extracted from satellite imagery which is correlated with rainfall and total flood discharge. The modelled flood area is then developed into a flood map. The model can predict with 90% accuracy the maximum area of flooding and its distribution.

4.2.2.4 Flood forecasting – the case of South Africa

According to Du Plessis, (2012:134) there is absence of a formal and effective flood forecast, warning and response system (FFWRS) in South Africa. Even though the country uses a flood warning communication system installed by the Department of Water Affairs and Forestry (DWAF) in June 1993. The system the country uses is based on daily rainfall data and antecedent precipitation indices. Unfortunately the system has fallen into disuse but DWAF is working and improving another advanced FFWRS in the Vaal and Orange River systems. The system operates during river floods with an office that opens in Pretoria to co-ordinate dam operations and information dissemination. Communities are also part of the system as they also watch and disseminate river flood information amongst themselves.

A study by Kjeldsen *et al.*, (2002:322) recommended the use of a regional frequency analysis of Annual Maximum Series (AMS) of flood flows from relatively unregulated rivers in KwaZulu-Natal province, South Africa. As already been alluded to in section 4.2.1.1 of this study, the flood prediction method includes the identification of similar regions and suitable regional frequency distributions for the regions. The South African Weather Service is also involved in forecasting of floods using rainfall statistics (Du Plessis, 2012:134). They use three systems to forecast floods namely a mathematical weather model, geostationary satellite images and a radar observation station. To limit forecasting and warning errors the mathematical weather models have managed to forecast major flood incidents correctly five days ahead of occurrence.

However, there is still loss of life during floods as there is no effective response to the forecasts. More to that, the radar equipment currently used is obsolete and communication is bad between measuring stations and the SA Weather Service during floods. Flood warning is being issued by national authorities instead of being issued at local government level where they refine the information for local level area use. Flood forecasting and warning is a highly cost effective, non-structural measure that has benefits to national life and potential in improving the national economy (Du Plessis, 2012:134-135).

4.3 Scientific flood prediction and warning models

Globally development in flood plains is increasingly exposing many people to flood disasters (Parker, 1999:193). Risks and costs of disasters are snowballing due to global, social and environmental changes (WMO, 2011:1-2; Linnerooth-Bayer & Amendola, 2003). Climate change is also producing enlarged flood activity (Parker, 2003:1). As a result stakeholders are advocating for responsibility, liability and appropriate measures for mitigating losses and providing relief to victims

(Linnerooth-Bayer & Amendola, 2003; WMO, 2011:1-2). This has seen an upward trend on reliance upon disaster prediction and warning systems. This growing reliance has been recognised by the United Nations, (1995) which called for better systems for prediction and early warning of flood disasters (Parker, 1999:193). Pressure is therefore building on the need to improve the performance of flood forecasting, warning and response systems (Parker, 2003:1; Collier, 2007:3).

Flood risk reduction is moving away from controlling floods through structural interventions towards an integrated approach that includes flood forecasting and warning (WMO, 2011:1-2). That development has emphasis on improving operational flood forecasting and the enhancement and refinement of flood risk management systems (Arduino, *et al*., 2005*).* Lovei, (2012:v) is of the view that natural hazards cannot be avoided but sees timely and accurate prediction and early warning of hydro and climate extremes integrated with public awareness, education and preparedness as important activities to prepare for and mitigate disasters impacts.

The reality of economic limits to the provision of flood mitigation, the possibility that the capacity of defence systems may be exceeded or may fail and recognition that there are flood plains that are occupied requires that other effective non-structural flood mitigation measures be put in place (WMO, 2011:1-5). What the preceding statement means is that there are no preventative or defensive measures that can be completely effective. As such and among many one non-structural measure that may be used to mitigate floods is a flood forecasting and warning system. Flood prediction is described together with early warning as they are part of the same continuous system. Flood Forecasting and Early Warning Systems **(**FFEWS) are used to predict floods and warn people living in or near flood prone areas to evacuate with their property before flooding (Hafiz, 2013:1; WMO, 2011:1-5). The system provides a basis for people to make informed decisions to reduce loss and damage by floods (Parker, Tunstall and Wilson, 2005:1). This is achieved through the provision of as much advance information as possible on an impending flood to authorities and affected communities (WMO, 2011:1-8). Early warnings to floods also enable authorities to evacuate and shelter many people in advance, provide information on the occurrence of public health hazards and they enable fast response to problems of food and water insecurity (World Bank, 2010).

This section identifies and discusses various scientific models for flood prediction. Flood prediction models are abundant and are used at different institutional levels world-wide. This section explores these various models indicating how they function. The most valuable elements of the models to this study are discussed and adopted for the flood prediction model developed in Chapter Eight. The section discuss the flowing six scientific models comprising of, the Meteorological Organization World (WMO) model, Pilon Model, Golnaraghi and Power Model, Parker Model, Chowdhury Model, Yadete Model and Haggets Model.

The models discuss scientific ways of predicting river floods. However models that use indigenous knowledge are analysed in the next Section 4.4. It is these models discussed in this section and others identified during the data collection exercise which guided the research to develop an improved, if not new river flood prediction model for the SADC-region. Many authorities discussed below identify and describe a number of elements and processes that they consider important when developing an effective flood prediction and warning system. The elements that fit integration into the flood prediction model being developed in this study will be highlighted and used in Chapter Eight. This section is very important as it guides the development of a flood prediction model for the SADC-region, which is the major objective of this study.

4.3.1 The Meteorological Organization World (WMO)

The World Meteorological Organization, (WMO) (2011:xi) identified four important components of a flood warning system as the design of the flood forecasting system, implementation and operation of the forecast system and flood warning and training. When making a national flood forecasting and warning system the organisation takes serious consideration in the collection of real time data for the prediction of flood severity. What this means is that there will be the inclusion of real time data collection as an important constituency of the flood prediction model developed in this study, as indicated in Figure 8.1, Chapter Eight.

4.3.2 Pilon and others Model

Pilon *et al*., (2001:iv) highlight how a flood forecast system has to be developed. He states that a community, country or region has to conduct an assessment of the existing flood forecast programme. Each of the links or components of the forecast system should be evaluated for its effectiveness. After the existing system has been assessed, a new and improved system can be designed. The new system design should strengthen the weak links of the existing forecast system, meet the needs of the users, and provide sufficient accuracy and lead time to reduce flood losses to the maximum possible extent. Like any other project, the new forecast system will be subject to cost constraints and must therefore concentrate on those improvements that will yield the greatest benefits in terms of reducing human and economic losses.

One short coming of flood predictions in the SADC-region and countries under study in particular is that flood predictions are done mainly at a national level only (see Chapter Two, section 2.3.4). In the flood prediction developed, the emphasis was on flood predictions being done at both National, Provincial, District and local or village level. These predictions will be consolidated and level specific flood predictions made or given/issued (see Figure 8.1, Chapter Eight).

4.3.3 Golnaraghi and Power Model

According to Golnaraghi and Power, (2012:5), and as shown in Figure 4.1 early warning systems includes four elements, supported by governance, coordination mechanisms and appropriate infrastructure from national to local levels. These four elements include, observing, detecting and developing hazard forecasts and warnings; risk assessments; communication and dissemination of warning to all stakeholders and preparedness and response to warnings at all levels to minimize risk. It is important to note that failure of one component or lack of coordination among stakeholders may fail the system.

The elements worth bench marking from this system and which were included in the flood prediction method developed in this study are risk assessment and data collection and forecast, including stage one and two of Figure 4.1. These are also reflected in Figure 8.1 of this study.

Figure 4.1: Elements of an effective early warning system
Source: Golnaraghi and Power (2012).

4.3.4 Parker's Model

Parker, (2003) developed a Flood Forecasting Warning and Response System (FFRWS). The model is portrayed as a five stage process for reducing the impacts of floods. Of value to this study are stages one, three and five. The first stage deals with the detection of environmental conditions leading to flooding (Parker, 2003:3). The second stage is on forecasting and effective understanding and interpretation of forecasts. Stage five is the learning process.

The stages of detection (stage one) and forecasting (stage two) in Parkers model are significant and worth being incorporating in the flood prediction model being developed in Chapter Eight (see Chapter Eight, Figure 8.1.) The stages involve activities like data acquisition, transmission, modelling and interpretation which produce the flood forecast. Data input is a critical element in flood prediction and of value to the flood prediction model being developed in this study. Effective flood forecasts must determine the time and the duration of the flood before the actual flood happens (Hafiz, 2013:1).

Just merely making flood predictions is not enough as they need to be communicated to beneficiaries Parker, (2003:9). Therefore for flood predictions to be effective flood information has to be disseminated timeously so that proactive measures are taken by susceptible communities before floods strike. Therefore, communication and dissemination of flood information are also important constituencies of the flood prediction model in Chapter Eight, Figure 8.1.

Stage five of Parkers' model focuses on the learning process in which the flood forecast and warning system is always being refined on the basis of monitoring performance and lessons learnt from operational experience (Chowdhury, 2005:718). As part of the learning process, monitoring and evaluation in the flood prediction model developed in this study will also be an important activity (see Chapter Eight, Figure 8.1). These processes will help in identifying shortcomings of the flood prediction model and thereby calling for its improvement. During that process there will be generation of new knowledge and learning will be taking place. In evaluating the performance of the flood forecasting and warning. Parker, (2003:3) was of the view that more work, needed to be done to improve detection, measurement and the conditions leading to floods. What this means is the model was not an end to itself but was open for improvement. The statement by Parker, (2003) also shows that the model was not perfect and needed refinement thereby motivating its improvement or the development of better models. Improvement on Parkers model is seen in the next section where Chowdhury, (2005) revisits the model with the primary objective of modifying it in the context of Bangladesh. As already been alluded to in the previous chapters, this study intends to develop a flood prediction model for the SADC-region, but benchmarking what works and is applicable from established models.

4.3.5 Chowdhury's Model

Chowdhury, (2005) wrote a paper whose primary objective was to revisit and modify Bangladesh's flood forecasting framework with an ideal warning response based on agreed seasonal flood forecasts. The model was a five-stage Flood Forecasting and Warning Response System (henceforth, FFWRS) and a modification of the flood forecast and warning system by Parker, (2003) that was discussed in the preceding section. The stages of Chowdhury's model that are of value to this study include flood forecasting, forecast interpretation, communication and review and analysis (Chowdhury, 2005:720). The concept of consensus or agreed forecast, in the model resembles the Southern African Regional Climate Outlook Forum (SARCOF) discussed in Chapter Two, Section 2.3.3.2.

Stage one of the model on forecast preparation entails predicting the seasonal occurrence and magnitude of floods in advance (Du Plessis, 2002:132). The process is coordinated and is achieved through data exchange, close cooperation and a consensus between local, regional and international institutions (Ziervogel & Opere, 2010:9). Flood forecasts must be sufficiently accurate to promote confidence and if inaccurate their credibility will be questioned and no response actions will occur (WMO, 2011:3-7). This means that flood warning systems must be reliable and designed to operate during the most serious floods (Pilon, *et al.,* 2001:48). According to the Chowdhury model, a probalistic estimate is then shared to the main users like government and research institutions. A seasonal and consensus forecast is arrived at through the involvement of regional, national and the forecast users (Chowdhury, 2005:720). An integrated global observation of the weather like the World Meterological Organiztion (WMO) is important as weather forecasts produced by the most advanced weather services are availed to forecasters in many flood affected countries (WMO, 2014:5; WMO, 2014:29). Such a process is initiated in the flood prediction model in Chapter Eight, Figure 8.1. All stakeholders that include professionals and affected communities and their leaders were involved in information gathering. Flood prediction from the Village to the National level vice-versa will be shared both up and downwards. Flood predictions will be a product of integration and community involvement.

Stage two, the interpretation stage identifies the probable effects of floods on communities with the aim to warn people about the floods and probable impact. The approach takes into consideration the characteristics of the vulnerable people. The information that is given to communities has to be clear and area specific indicating what is likely to happen, what it means to the people and the action they can take. These are essential elements to attract the people's attention and consideration to flood warning. The stage outlines how information may be used effectively to minimize flood risk. Specific areas need information on the height, time and duration of forecasted floods (Ziervogel & Opere, 2010:11).

This stage is also incorporated in the flood prediction (see Chapter Eight, Figure 8.1). Information was interpreted at all levels of government. What this means is that communities will interpret flood information and come up with their own flood predictions which will be disseminated to district, provincial and national levels for analysis and consideration. This will be after thorough research has been done. This approach will help in giving area (village or community) specific flood predictions.

Stage three focuses on communication of the warning messages to disaster management agencies and vulnerable communities. The dissemination of information has to be timely so that people make effective decisions. People must be trained to clearly understand the meaning of forecasts and understand the risk posed. Forecast messages are sent to villages/communities through megaphones, drum beating, poster, drama, documentary and local training (Du Plessis, 2002:132). As already been alluded to in the previous section, flood predictions have to be communicated so that flood risk communities prepare and mitigate against their effect (see Chapter Eight, Figure 8.1). Various local media may also be used in the communities affected by floods.

Stage four develops response actions by agencies and communities for flood protection. The response actions are disseminated as options as situations vary. Users must be given an opportunity to understand the information as they will take critical decisions based on it. Feedback is also important at this stage. There is therefore need for constant monitoring and periodic coordination of meetings and seminars by all stakeholders to enhance the utility of flood forecasts. The stage also evaluates the accuracy and promptness of forecasts, public awareness and response to warnings and interactions and communication between stakeholders (Chowdhury 2005:722).

Stage five of the model, focuses on review and analysis of the flood prediction system. There is continuous monitoring for improvement of various activities. This process may be done through surveys on the various stakeholders. There is therefore need for constant monitoring and periodic coordination of meetings and seminars by all stakeholders to enhance the usefulness of flood forecasts. The stage also evaluates the accuracy and promptness of forecasts, public awareness and response to warnings and interactions and communication between stakeholders (Chowdhury, 2005:722; Du Plessis, 2002:132).

There is final validation of the flood forecast and warning product by stakeholders at post season meetings. This allows processes, aims and methods to be synchronised to user requirements of the stakeholders (Laiolo, 3467:48; Chowdhury, 2005:723). Review and analysis are also of value to this study and are included in the flood prediction as shown in Chapter Eight, Figure 8.1. Feedback, monitoring and evaluating the proposed flood prediction model helps in continously improving the processes and ultimately delivering effective flood predictions. The emphasis of the framework is that seasonal forecasts require closer cooperation and information sharing between the forecast providers and the forecast users. These elements are also considered in the proposed flood forecast model. In the proposed model, agreed forecast also mean the consideration of flood information from all levels of government and the integration of local knowledge before a forecast is made.

4.3.6 Yadete Model

In a study Yadete, (2004) proposed an ideal flood warning system as one with a flood prediction as a subsystem. The objective of that study was to improve the forecasting system of the Glenmore reservoir in Canada. He states that the design of a warning system includes setting up data collection systems, model development and testing, setting up the telemetry network for information communication, and training of decision makers and the public to respond to the warning. The first task is real-time or on line data collection. The data from the pre-identified remote meteorological and hydrological stations are collected and transmitted to the forecasting station. The next stage is data processing where the data are adjusted and formatted to the required system specifications. The prepared data is then input to the flood forecasting model resulting into a flood forecast. Even though a forecast of the event is important what matters most is the use of the forecast to make a good decision.

This model by Yadete is also very important as it emphasises the collection of data and the ultimate use of the flood prediction. Flood predictions not disseminated and whose warnings are not responded to, are just as good as no flood predictions at all. The element of real time data collection also plays a pivotal role in effective flood predictions. These issues that had already been alluded to were considered in the development of the flood prediction model in Figure 8.1.

4.3.7 Hagget's Model

Hagget, (1998:425) developed a model aimed at reducing the risk of flooding and provide timely warning for people and property against flooding from rivers. Flood forecasting and warning was being given the highest priority within the flood defence function in Europe. The important elements of a flood forecasting and warning system were identified as; Detection (data acquisition), a stage that involves the evaluation of hydrological and meteorological processes; Forecasting which involves the prediction of rainfall; Warning which involves the making of decisions concerning the issue of flood forecasts and warnings. Flood warnings should be communicated to those at risk and the recipients of warnings must be capable of acting and responding effectively within the available time window (Parker, *et al*., 2005:1). The last stage is response an activity encompassing public response to a flood warning and their reaction to flood risk. Of value to this study is detection and forecasting.

The model was integrated such that it also included issues dealing with institutional arrangements, technology, information management, supportive legislation, securing political commitment, coordination and cooperation between stakeholders. Of interest to note was that, technology that matched local circumstances was needed in the flood prediction system. Also indicated as critical in a flood prediction model was the recruitment of expert staff, free flow and access of information (indigenous knowledge) and developing legally binding cooperative agreements between organisations.

The approach by Hugget, (1998) shows the interrelatedness of an effective flood prediction system. Merely having a flood prediction without interacting with other related support activities will not be effective. Flood prediction needs to be imbedded into an interactive and supportive system which includes activates like political will, laws, the use of technology, training, networking, community involvement, institutional structures, funding and other elements that are too many to mention. These support functions made up some of the important elements of the flood prediction model that was developed in Chapter Eight.

One benefit of a flood forecasting and warning system is that there is more emphasis on non-structural means of flood management which include flood-inundation mapping and flood plain zoning (Rabalao, 2010:27). What is common on all the flood prediction and warning systems cited above is that their main focus is on scientific methods of flood prediction. It has already been highlighted by the researcher in the previous sections and chapter that the thrust of this investigation is to develop a new flood prediction method or to improve on the existing ones. One thing proposed and that will make the model different or unique, is the inclusion of indigenous knowledge in the model.

Flood forecasts must be sufficiently accurate to promote confidence and if inaccurate their credibility will be questioned and no response actions will occur (WMO, 2011:3-7). This means that flood warning systems must be reliable and designed to operate during the most serious floods (Pilon *et al.,* 2001:48). Effective flood forecasts must determine the time and the duration of the flood before the actual flood happens (Hafiz, 2013:1). Effective flood prediction will also be enhanced by the use and integration of Indigenous Knowledge Systems (see Chapter Five and Eight). Many indigenous communities rely on traditional flood forecasting knowledge, often based on early warning signs related to the appearance of the sky or sea, and changes in animal behaviour (Mclean, 2009:15). It is also important to note that accurate forecasting will depend on a network of national, regional, and global remote and in situ observations of the atmosphere, oceans, and land operated by National Meteorological and Hydrological Services (NMHSs) and their partners (Zillman, 2005b). An integrated global observation of the weather is important as weather forecasts produced by the most advanced weather services are availed to forecasters in many flood affected countries (WMO, 2014:5; WMO, 2014:29) (see Chapter Eight).

4.4 Integrated indigenous and scientific knowledge disaster risk reduction model

In the 20th century, Western scientific knowledge and scientific and policy oriented research in development were losing respect for IKS advocating the full adoption of Western scientific models as the best solution to development problems (Schafer, *et al.*, 2004:62). Since IKS was being ignored, flood mitigation or risk reduction solutions were not economically feasible or culturally acceptable in the flood risk communities. As such this did not help to reduce flood risk (Puffer, 1995:1). By the mid-1980s, Africa had not responded to this modernist development approach. Scholarship in Africa shared and developed renewed interest in participatory development through the integration of IKS in development practice (Schafer *et al.,* 2004:62).

According to Ocholla and Onyancha (2005:248), IKS has been marginalized, neglected and suppressed due to ignorance and arrogance and politics. However, review of literature by This model appears simple to use as it uses real-time stream flows, temperature and rainfall measurements from various stations as inputs in the prediction of floods. It also uses measurement from various gauging stations which are commonly used and will be easy to use in the SADC-region.

Chakravarty, 2010; Mawere, 2010; Arunachallam, 2007; Kargbo, 2006; Briggs, 2005; Pidatala & Khan, 2003 reveals that IKS has been successfully applied in disciplines like Agriculture, Education, Environmental Conservation, Natural disaster management, Natural resource management only to name a few. Indigenous ideas once regarded as primitive and misguided are now being valued as appropriate (Nyong *et al.,* 2007:795). It was being realized that, locals in communities have developed and used mitigation and adaptation strategies through indigenous knowledge enabling them reduce risk to climate change, which exceed that predicted by some scientific models (Nyong *et al.*, 2007:787). Culture and the beliefs of indigenous communities influences their response to flood disaster (Makinde & Shorunke, 2013:10). Incorporating indigenous knowledge into formal flood prediction, adds value to the development of sustainable flood prediction strategies rich in local content and developed in conjunction with local people (Nyong *et al.*, 2007:787). Incorporation of IK in flood prediction will increase participation rate in flood risk reduction by community members and proffer environmentally sound approaches to development (Nyong *et al.,* 2007:794).

A study carried out by Rautela, (2005:233) on disaster prevention and management using Indigenous technical knowledge revealed the relevance of IK in that it assisted communities in devising ways of reducing their vulnerability to natural hazards and mitigating disaster effects. However, this knowledge is rarely taken into consideration in the design and implementation of modern mitigation and adaptation strategies (Nyong *et al*., 2007:787). Indigenous knowledge sustains communities and their culture (Makinde and Shorunke, 2013). Valuing IK strengthens cultural identity and enhances use of such knowledge for social and development goals. It is an essential resource for any human development process (Jabulani, 2007:117). IK enhances the way communities live and manage their environment (Dei, 2000:5). Tella (2007:186) values IK in that it proffers problem solving strategies in communities, contributes to global development knowledge and also stated that it is an under-utilized resource in the development process. Local knowledge creates a moral economy as a person is identified within a cultural context that provides decision-making processes that are based on observed indicators or a relationships that provide people with a sense of community, belonging and stability (Nyong *et al*., 2007:795). Use of indigenous knowledge encourages participatory approaches a critical requirement in the sustenance of flood risk reduction. The local population must be seen as partners in flood risk reduction projects as joint owners (Nyong *et al*., 2007:795).

The integration of Indigenous knowledge and western based knowledge creates flood mitigation solutions that are culturally acceptable to the society in stress (Puffer, 1995:1). Interaction between IK and SK can create an atmosphere for dialogue between local populations and flood risk professionals. This will help in designing flood mitigation projects that reflect people's aspirations and actively involve them. (Nyong *et al.,* 2007:795). The value of indigenous knowledge if integrated with modern knowledge systems, is that, it can help to alleviate poverty (Mwaura, 2008:9).

However, not all IK is beneficial to the communities as some of it may not provide the right solution for a given problem. Therefore, before adopting and integrating or disseminating indigenous knowledge in flood mitigation programs, there is need to scrutinize for its scientific appropriateness just as any other technology. Apart from the scientific proof, local evidence and the socio-cultural background embedded in the practice need consideration in the process of validation and evaluation (Nyong *et al.,* 2007:795). Many indigenous communities rely on traditional flood forecasting knowledge, often based on early warning signs related to the appearance of the sky or sea, and changes in animal behaviour (Mclean, 2009:15). Effective flood prediction can be enhanced by the use and integration of indigenous knowledge (see Chapter Five and Eight).

Up to this juncture literature review has shown that although many methods are scientifically based, there are some models that have been developed to incorporate indigenous methods in their disaster reduction approach. The methods include the following; indigenous and scientific knowledge by Mercer *et al*., (2010), Community Hydrologic Prediction Systems and the LIVE scientific knowledge method. These models are discussed in the next sub-sections.

4.4.1 Integrated indigenous and scientific knowledge model

In trying to engage both indigenous and scientific knowledge within disaster risk reduction, Mercer *et al*., (2010:219) developed the Process Framework in Figure 4.2 the model aims at building a sustainable combination between the scientific and indigenous knowledge bases. According to Mercer *et al*., (2010:222), before developing an integrated framework research must be conducted in relation to a communities' cultural values and norms, ensuring that it contributes to their needs. Mercer *et al.,* (2010:222) emphasized that the researcher and the community must work and identify flood problems together. In case of problems determined, the two must improve flood predictions in an effective integrated manner. Mercer *et al*., (2010:223), writes that the Process Framework involves a series of steps that are briefly outlined below:

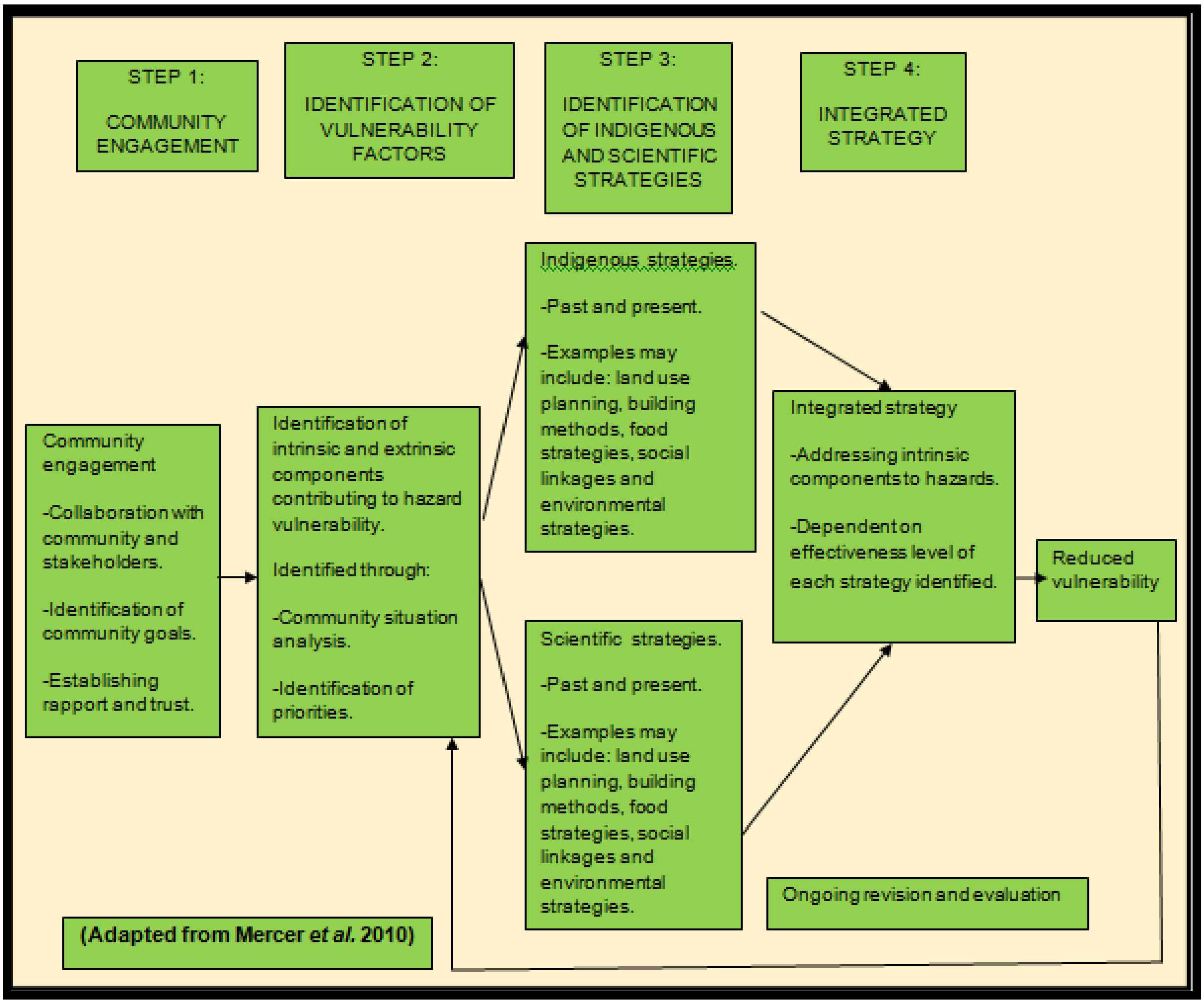

Figure 4.2: Integrated indigenous and scientific knowledge disaster risk reduction model
Source: Mercer *et al.*, (2010).

Step One looks at engaging the community in identifying and discussing their risks to environmental hazards and the benefits of both knowledge bases. The activities within the Process Framework need to have community management and ownership. In the set up the community and the researcher need to develop a good rapport and identify community goals and objectives. For example, in this study, community engagement will be achieved through data collection using the survey methods. Step Two involves identifying vulnerability factors and their effect on affected communities. The identification of vulnerability consists of both factors inside and outside community control. There is also identification of the results of inside factors a community could address or take control. Step three goes to identify indigenous and scientific strategies for flood risk reduction. The community will identify workable strategies within them and experts will bring scientific knowledge from outside the community. Step four is a process of integrating information gathered from the previous three steps. In identifying indigenous and scientific strategies the communities need to determine the effectiveness of each knowledge base in militating against intrinsic risk components.

Most of these issues discussed in this model (Figure 4.2) will be considered in a flood prediction model to be used for effective flood prediction in the SADC-region. The issues will include collecting both local and western methods of flood prediction at and from village level and integrating them up to the regional level. Community engagement and ownership are very critical success factors in producing an effective flood prediction (see Figure 8.1.in Chapter Eight).

4.4.2 United States and Jamaica Community Hydrologic Prediction Systems

Some countries in the developed world have also developed some simple community flood prediction systems as shown in Figure 4.3. These models focus on how flood predictions should be done on the community or village level. In reviewing literature it was indicated that scientific flood prediction models had a challenge in that they were not area specific. This is a gap that the community models are addressing. The methods process flood predictions for a specific area or location. The processing is done by community members themselves (see Figure 4.3).

According to WMO, (2011:8/13) in the United States they have developed a flood prediction model under the Community Hydrologic Prediction System whose aim is to reduce flood disaster risk in the community. The system uses a self-help method that is inexpensive and simple to operate and is integrated into both a forecasting and warning system. The self-help system is comprised of a local data collection system, a community flood coordinator, a flood forecast procedure and a communication network to disseminate warning and response plan to the community. For data collection the system recruits volunteer observers to collect rainfall, stream and river stage data using plastic rain gauges. They report rainfall amounts to the flood coordinator who maintains the volunteer network register.

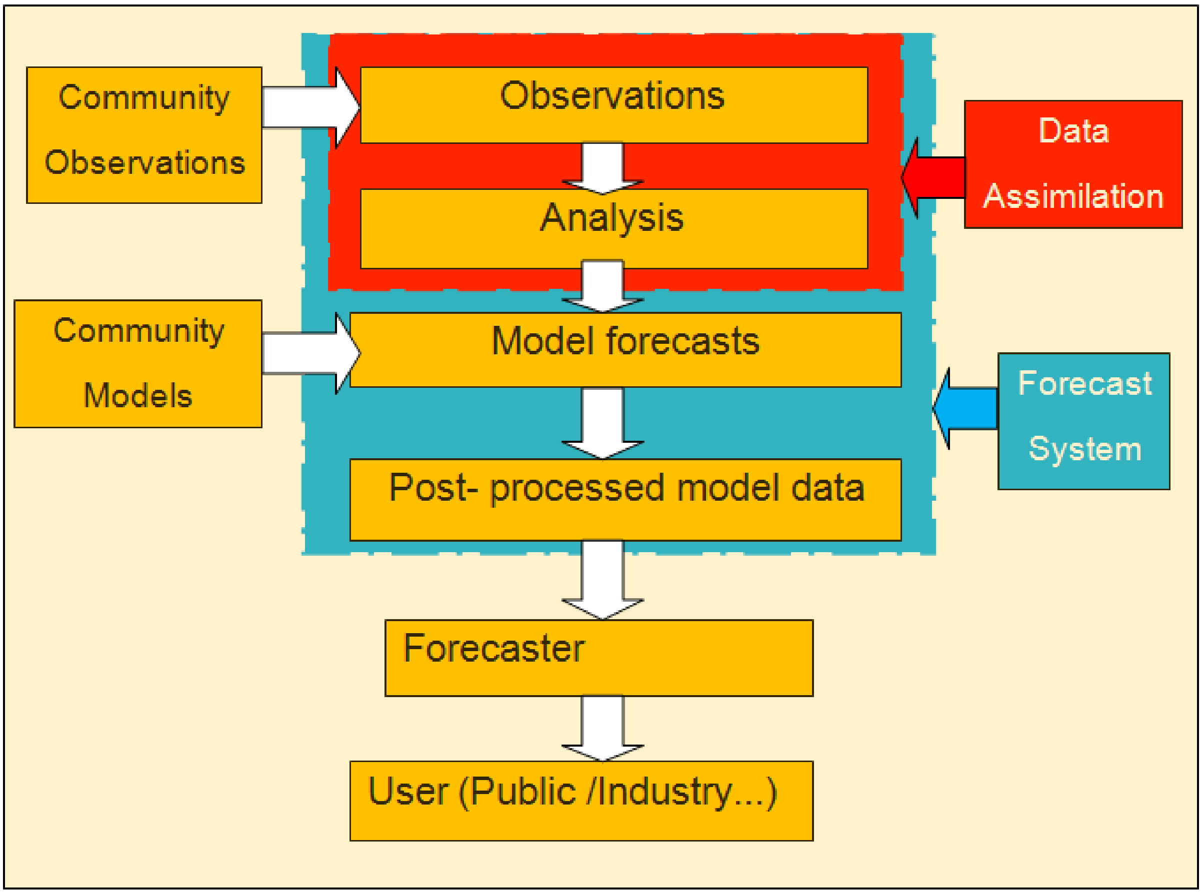

Figure 4.3: United States Community Hydrologic Prediction System
Source: WMO, (2011).

In Jamaica rural communities also use another community flood prediction and warning system which is similar to the one used in the United States (see Figure 4.4). Weather experts will release forecasts on adverse weather conditions to the community. Community members trained to be readers will start observing and recording rainfall and water levels every 15 minutes. If the critical levels are reached they will inform callers and runners. The callers will raise alarm by informing the disaster management and response office. The runners will then get into the community and inform them about the imminent floods. Decisions (even to evacuate) are made and people move away from danger. The readers will continue to make observations until conditions return to normal and the next made.

The methods are very simple and basic to understand and use for and by communities. These two community flood prediction models clearly show that with the necessary arrangements communities are able to record rainfall and monitor river water levels on their own on prescribed intervals.

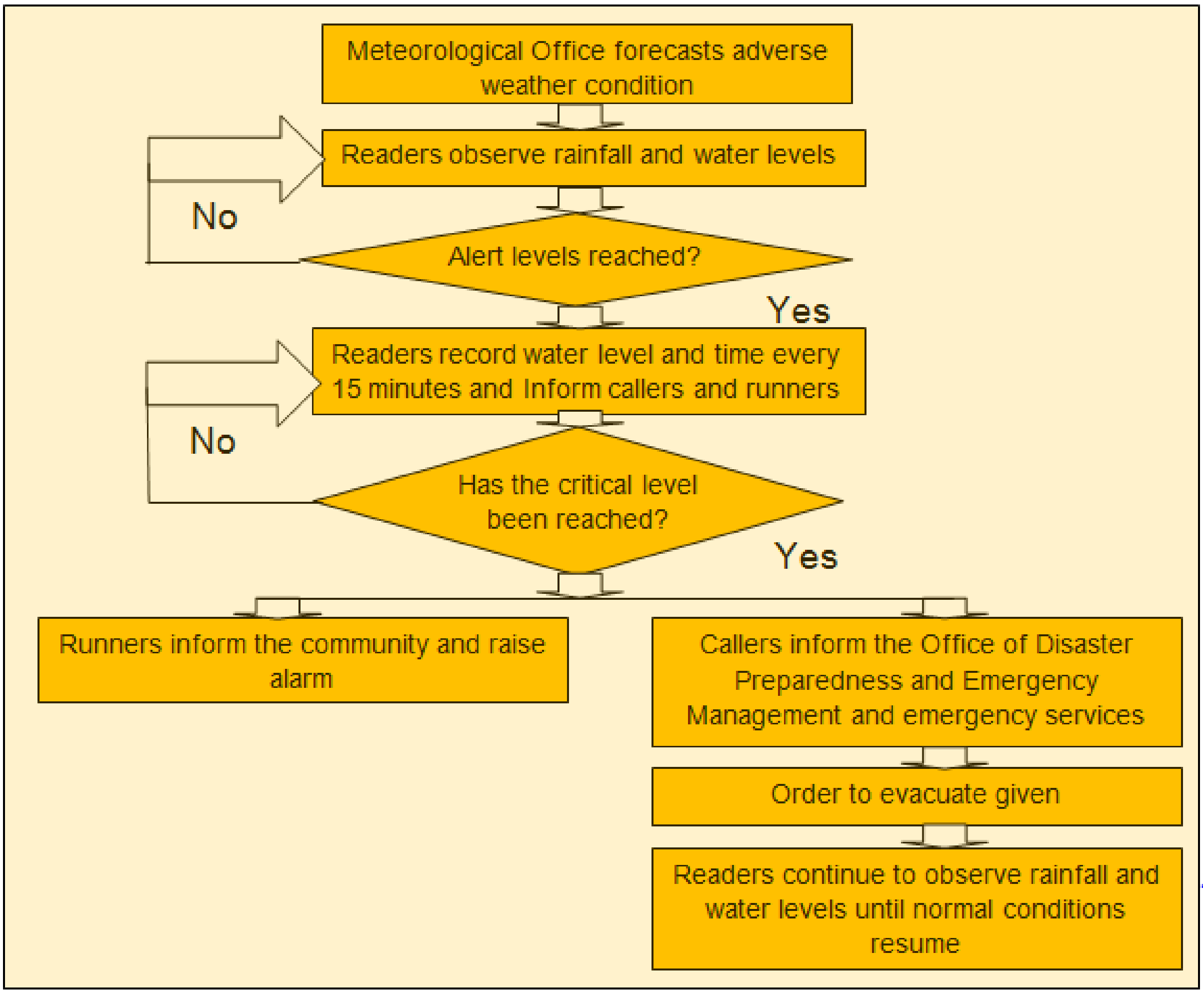

Figure 4.4: Jamaica Community Hydrologic Prediction System

Source WMO, (2011).

This makes the mitigation of floods easy and the communities will never get flooded unaware. The model starts and is implemented at local level which the best starting point in mitigating floods. There is also coordination of activities between a coordinator in the community or disaster management offices and the affected community. These models are of great value to the SADC-region. Communities mostly rely on local knowledge to manage and mitigate flood risk. The model being developed for the SADC-region will also incorporate such user friendly models (Figure 4.3 & 4.4) with activities so simple to comprehend at the local level (see Figure 8.1 in Chapter Eight). As already alluded to in Section 4.4 indigenous knowledge is very valuable especially if it is integrated with scientific knowledge. It is a knowledge base deeply imbedded in many communities in the SADC-region. Since it has been indicated in this section that it is valuable, the development or modification of flood predictions in the region must also have the IK flavour for effective flood prediction and flood risk mitigation. More on IK is discussed in Chapter Five which specifically analyses the knowledge base.

4.4.3 The LIVE scientific knowledge method

Hiwasaki *et al.*, (2014:15) discussed a process for integrating local and Indigenous knowledge related water related hazards with science (Figure 4.5). The process was developed in a project implemented among coastal and small island communities in Indonesia, the Philippines and Timor-Leste. The process involves observation, documentation, validation, and categorization and selection of indigenous knowledge which is integrated with science. The process allowed communities to identify knowledge that can be integrated with science and be used by communities, scientists, practitioners and policy-makers. The knowledge would be used to develop plans for information, education, and communication materials for disaster risk management. The process also promotes and values local knowledge for integration even when it cannot be scientifically explained (Hiwasaki *et al.,* 2014:15).

The first phase of preparation in Figure 4.5 is gender balanced where community members are chosen to become researchers. They are trained on the jargon, process and methodology. On the same phase forms are prepared to gather data on each type of indigenous knowledge.

The second phase in Figure 4.5 is data gathering. During this stage the researchers identify informants. They collect indigenous knowledge through interviews and group discussions from community members. The collected local knowledge data is then observed in the same communities and observations documented.

The third phase in Figure 4.5 involves analysis and validation of local knowledge by communities and scientists. Local people have the ability to observe and monitor changes in their environment like the sea, clouds, animals, plants, and insects. They also use the moon, sun and stars to predict water related hazards. Communities also develop disaster preventative or mitigation measures for hazards. They adapt to and prepare for them, using local materials and methods. They further use customary regulations that governed behaviour like prohibition of deforestation.

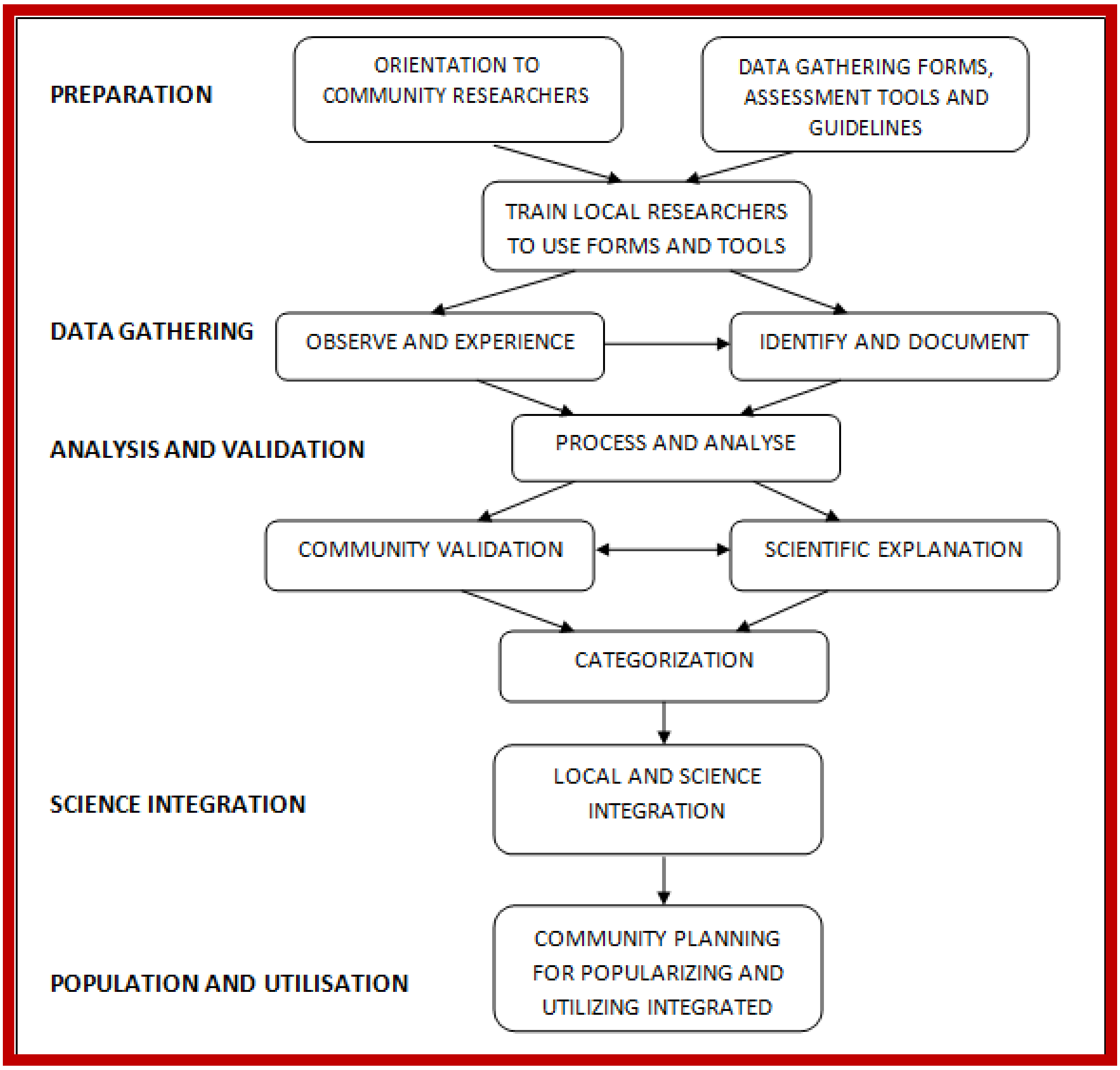

Figure 4.5: LIVE scientific knowledge method
Adapted from Hiwasaki *et al*. (2015).

The stage involves assigning meaning to the observations and confirming that the expected event took place. There is then the analysis of trends, comparison of outcomes and giving explanations to the outcomes. These are documented and presented to the community. The community then validates the results using key informant interviews and focus group discussions. Validation is done to determine and consider the most effective and commonly used knowledge and practice (Hiwasaki *et al*., 2014:21). In validating there is need to satisfy that a practice existed and was widely practiced in the area for more than one generation. It also have to be proved that the community is still effectively using the knowledge or practise in preventing, mitigating, predicting and adapting to water hazards (Hiwasaki *et al*., 2014:21).

The process of scientific explanation begins after community validation results are presented at workshops to scientists and experts. Natural scientists assess, identify and document the presence or absence of any scientific explanation to the local knowledge. This is meant to enhance the credibility of local knowledge in their eyes. Social scientists will analyse, assess and give social relevance to local knowledge with little or no scientific basis. Its validity would be determined in terms of how people's resilience against floods could be enhanced. That then leads to the next stage of integration.

In phase four of Figure 4.5 above, the scientists will then deliberate and agree on how to integrate and use scientific and indigenous knowledge to reduce flood risk. Local knowledge that has any scientific explanation has to be integrated with science. The hybrid knowledge can then be promoted through education, information and communication materials and awareness campaigns. The last phase as shown in Figure 4.5 provides feedback to the community on the results of the scientific workshop. This is meant to help the community understand scientific explanation to their knowledge and practices. They also need to know the relevance and value of any of their knowledge that cannot be scientifically explained to disaster risk reduction.

The model in Figure 4.5 shows the importance of identifying, analysing, validating, practicing and adopting local knowledge for flood risk reduction. The process in this model strengthens the relevance of local knowledge to science. This shows that several models in flood prediction consider local knowledge as IKS, but not necessarily within the ambit of the SADC-approach towards predicting regional floods. Scientists are therefore encouraged to investigate indigenous knowledge, revitalize and strengthen it. Local knowledge can be used to predict and mitigate floods and can be transmitted from one generation and community to another. Many aspects in Figure 4.5 are critical in the identification, validation and integration of local knowledge and western science in flood prediction. Some of the components in the model in Figure 4.5 will also be considered in developing a flood prediction model for the SADC-region. The model is relevant and thorough for use in the SADC-region as it clearly explains all the processes involved in integrating IKS and SKS. What will be important is to integrate local knowledge that has been tried, tested and that works, with scientific findings. The method is thus inclusive of all stakeholders.

4.5 Conclusion

In Chapter Four a literature survey was done on what can be learnt from flood prediction research and models and the use thereof worldwide. The chapter addressed two research questions “Have any specific prediction models as dimensions of knowledge been used in the SADC-region to help in river flood disaster risk reduction, and how can they serve as possible flood management instruments?” and “To what extent has past research provided guidance in river flood prediction possibilities?”

Some of the flood models being used worldwide as indicated in this chapter, and later discussions, were of great value to this study. They assisted in identifying those important components, ideas and processes that were fit for inclusion in the flood prediction model developed in in this study. The components were identified through a strength/weakness analysis of which the strong components in terms of applicability were considered for model development. There are several models in flood prediction that do consider local knowledge as IKS, but not necessarily within the ambit of the SADC-approach towards predicting regional floods. An analysis was also done on the how aspects of the prediction methods and research done may serve as possible instruments to deal with the management of river floods in the SADC- region. Some of the elements in the models have been used to improve flood prediction methods in the region and the world over. However, some have shortcomings like being area specific, making it difficult to adopt them for use in the SADC-region. The analysis also put particular emphasis on the countries under study, that is, Zambia, Zimbabwe, Botswana and South Africa as some of the particular flood prediction models these countries apply were identified and briefly discussed (see Sections 4.2.2.1 to 4.2.2.4). The models are used in these countries mostly at national level and are scientific in their approach, exposing their lack of sufficient IKS inclusiveness.

Of interest from the worldwide models which were discussed and learnt from are various activities that enhance flood prediction namely administration, coordination, legal support and political will, use of technology, community involvement, scientific and indigenous methods integration . These factors identified are of valued to this study as there indicate the multidimentional approach to improving flood prediction. So many factors are involved in flood prediction effectiveness as such these were integrated and included in the flood prediction model developed in this study.

In some models it was also learnt how flood prediction and warning can be improved through the integration of all the knowledge bases. Models in Section 4.4 on integrating IKS and SKS were different from the models introduced in Section 4.3 which mostly focused on the scientific approach of flood prediction. The integrated models included the fusion of IKS in disaster predictions making all inclusive. The experience and knowledge of communities in flood prediction and mitigation is adopted in the IKS models and in most environments in which it was used as shown in the models discussed in this chapter. This integration seems to have been the difference between efficient mitigation and effective flood prediction management. Instead of being merely passive recipients of flood forecasts the affected communities also directly participate in the flood prediction process through their own structures and resources. The indigenous models would be utilised better to improve the generic flood prediction models discussed in this chapter. The scientific models in Section 4.3 focus on SKS and are relatively divorced from community methods and participation.

The critical issues and components identified in flood research and the flood prediction models in the chapter were considered in the development of the flood prediction model for the SADC-region. Development of flood prediction models needs the input of all stakeholders including the victims themselves. Victims don’t have to be seen as if they are passive recipients of flood predictions and as if they only need to be helped. Through their flood experiences, victims have various ideas and ways and means on how they can, deal with flood disasters in terms of their prediction and mitigation. Such an approach is found in some of the models that were discussed in Sections 4.3.7 and 4.4 on models on both scientific and the integrated model approaches.

Research questions addressed in the chapter included analysing the extent to which past research provided guidance in river flood prediction possibilities. To a great extent past research has helped in identifying specific aspects or elements that are important in making effective flood predictions. Research also identified gaps in flood prediction models and encouraged the revision of flood prediction models as some have their shortcomings. Another research question addressed in this chapter was on the identification of specific flood prediction models being used to help in river flood risk reduction. Several of these were identified and include both scientific models and those that integrate both IKS and SKS. Although much was learnt from both types of models this study is advocating for models that favour the integration of both knowledge bases.

Since IKS is a critical area for consideration in the development of an inclusive, and envisaged as a more effective, flood prediction model, justice is done by thoroughly analysing its value in reducing flood risk in Chapter Five. Of interest in this chapter is how successful this knowledge base has been used internationally, in Africa, in the SADC and in the studied countries. The realities and practicalities of integrating indigenous and scientific knowledge bases are also discussed.

CHAPTER FIVE: INTEGRATION OF INDIGENOUS AND SCIENTIFIC KNOWLEDGE SYSTEMS

5.1 Introduction

Before the advent of advanced technology for flood prediction and early warning systems, local communities worldwide used and predicted floods using indigenous methods passed on for generations (ISDR, 2008:iii). As such, the important role, that local knowledge and practices can play, in reducing flood risk must be seriously considered even though its value is slowly being acknowledged by some stakeholders. Indigenous Knowledge is not yet that commonly used by communities, scientists, practitioners and policymakers (Hiwasaki, 2014:15). Even though local knowledge may be used on its own, integrating it with science will result in effective flood risk reduction (Hiwasaki, 2014:15). On the same note, despite its acknowledgement there continues a gap for indigenous knowledge to reach the right people and be used as a correct strategy for flood risk reduction. (Mercer *et al*., 2007:245). Strategies for flood risk reduction need to identify and maintain indigenous knowledge which can be proved to have worked in communities and integrate it with scientific knowledge. Evidence on the successful integration and use of indigenous knowledge can be seen in many flood incidences. One of such incidence is the 26th November 1999 tsunamis in Pentecost Island, Vanuatu, South Pacific where five fatalities were recorded from a threatened 300 people. The survival rate was attributed to both indigenous knowledge and a video about tsunamis (scientific knowledge) shown to the community weeks earlier (Walshe & Nunn, 2012:185).

The chapter starts by defining indigenous knowledge and distinguishing it with scientific knowledge. The chapter then looks at how indigenous knowledge is being used in the SADC-region, in Africa and the rest of the world to predict floods. The success stories on the use of IK in flood prediction are highlighted on literature in small island countries like Malaysia, Indonesia and Thailand. These success stories are proof that indigenous knowledge may be successfully used for flood prediction, even in the SADC-region. The reality and practicality of integrating indigenous and scientific knowledge bases is also analysed. Indigenous knowledge exists and is being used by some communities although its wider relevance and value within a scientific context has mostly being ignored (Baumwoll, 2008:64: Maferetlhane, 2012:61).

More to that its use and success is not recorded for future use by other generations (Fabiyi & Oloukoi, 2013:14). This seems to be presenting challenges in predicting floods in localised areas as national flood predictions are many a time ineffective or false. In a study carried out by Elia, (2014) in Maluga and Chibelela villages in Tanzania, the respondents perceived conventional information on weather as unreliable and untimely and instead turned to IKS to predict weather patterns (Elia, *et al.*, 2014:18). Disaster experts are of the view that weather reports, in this case flood predictions by national meteorological services can be enhanced by integrating IKS on predicting floods. This cooperation of knowledge and observations from two different angles is expected to have a positive impact on the mitigation of floods than solely depending on meteorological forecasts that are at times misleading (Elia, *et al.*, 2014:18).

5.2 Understanding Indigenous Knowledge Systems (IKS) and Scientific Knowledge Systems (SKS) from literature

Literature informs that before the advent of technology and scientific flood prediction and warning systems, local communities have responded to floods using IKS developed from one generation to the other (ISDR, 2008:iii). When Africa was colonized, ”IKS started disappearing due to cultural repression, misrepresentations, misinterpretations and devaluation” (Shizha, 2013:3). Colonization transformed Africa's indigenous knowledge systems to their detriment (Jenjekwa, 2016:188). SKS criticized IKS as unscientific, untried and untested for education and social development (Shizha, 2013:4). Colonization made the IKS “alienated, irrelevant and constantly subverted by the new system” (Jenjekwa, 2016:188).

After gaining independence and faced by insistent technological and socio-economic problems, Africa countries now have a new thrust towards solving its problems based on the concept of “home grown solutions” (Jenjekwa, 2016:189). The concept is borrowed from the successes stories of local (indigenous) solutions to developmental challenges in the Asian Tigers namely China, Korea, India and Japan (Katola, 2014:3). Challenges have been addressed in these countries by integrating indigenous knowledge systems (Jenjekwa, 2016:189). According to Mawere, (2010:211) IKS is an “adhesive” that holds the African community together. Therefore indigenous knowledge systems might help with solutions to Africa’s developmental problems.

According to Mercer, (2009:214) a growing body of literature is now emphasizing the importance of integrating IKS and practice into development projects since the 1970s. In the 1980s, some forms of IKS came to being and were commonly accepted by scientists in agriculture, pharmacology, water Engineering and many other disciplines (Alexander, *et al*., 2011:477). The critical role played by local knowledge and practices in risk reduction is being acknowledged by disaster risk reduction specialists, especially since the 2004 Indian Ocean tsunami (Hiwasaki, *et al*., 2014:15). Shizha, (2013:3) also supported the assertion that interest by academics in IKS has grown since the 1980s. However IKS is not yet commonly used by stakeholders who include communities, scientists, practitioners and policymakers (Hiwasaki, *et al*., 2014:15).

Literature also provides a variety of definitions on Indigenous Knowledge Systems (IKS). Indigenous knowledge is a body of knowledge acquired through experience by local people over time and passed down through generations (Mapara, 2009:140; Ocholla & Onyancha, 2005:247). It’s also a form of knowledge that originates locally and naturally or spontaneously (compare Altieri, 1995:114). It is local knowledge that is unique to a given community (Warren, 1991: 151). It is also seen as the information base for a society that helps for their effective communication and decision-making (Njiraine, 2012:2). Indigenous Knowledge is also known as local knowledge, traditional knowledge, indigenous technical knowledge, rural knowledge and ethno-science (Altieri, 1995:114).

According to Meichtry, (1999:3), science is a process through which natural phenomena problems, issues and questions are identified, defined, and solutions proposed, tested or validated. What this means is that scientific knowledge is a particular type of knowledge based on scientific methods that are tested and validated. It is a form of knowledge “generated through scientific traditions of enquiry and teaching” (Huntington, 2002:65). Driver *et al*., (1994:6) define scientific knowledge as “constructs that have been invented and imposed on phenomena in attempts to interpret and explain them, as a result of considerable intellectual struggles”. Therefore, scientific knowledge has tried and tested tools, methods or materials. (Mercer *et al.,* 2009:158). Factors that are used to determine if scientific evidence amount to scientific knowledge, includes whether the evidence has been tested (Meichtry, 1999:3), the degree of acceptance within the scientific community (Driver*, et al*.,1994:6), whether it has been peer reviewed or published and the known or potential rate of error.

However from a common sense point of view both IKS and scientific knowledge consciously or unconsciously have to do with a form of observation. The IKS may come from a longer term of spontaneous observation while scientific knoeledge system usually relies on a shorter term of observation and is bounded to timeframes to produce scientific-driven outcomes. Influenced by the definitions of IKS by Mapara, 2009:140 and Ocholla & Onyancha, 2005:247, IKS in the context of this study IKS will be defined as flood and rain prediction methods or knowledge that includes people’s skills, experiences and insights that they have been used and handed down to them overtime to establish, maintain and improve their livelihoods. Scientific knowledge will be taken as technology and techniques used by National meteorological stations and other stakeholders to predict floods and rainfall.

5.3 Integrating Scientific and Indigenous Knowledge for flood prediction

Before the colonization of Africa, the indigenous communities in Africa have successful lived in flood risk areas, withstood environmental changes and adapted to loss in their populations and livelihoods over a period of time (Mercer *et al*., 2007:251). According to Mapara, (2009:140), generations of indigenous people have developed traditional ways of weather forecasting that help them predict the weather (Mapara, 2009:140). Communities rely on Indigenous Knowledge to predict weather through observation and monitoring the behaviour of animals, birds, plants and insects (Kijazi *et al*., 2013:275) and even through daily observation of river levels (Dekens, 2007:3). Such resilience by communities raises the question why science usually ignores (even though contentious) the indigenous knowledge of such populations, preferring to focus and use technocratic and scientific solutions to manage floods denying the historical and social dimensions of flood risk reduction (Mercer *et al*., 2007:251).

To the detriment of communities indigenous knowledge was being rejected, ignored neglected, stigmatized, and suppressed due to ignorance and arrogance by scientists (Ocholla & Onyancha, 2005:248; Ziervogel & Opere, 2010:7) They saw it as primitive, non-quantitative, employing non-conventional methods and unscientific (Ziervogel & Opere, 2010:7). Flood effects are also being made worse by climate change whose projections show increased climate variability the world over (IPCC, 2007). In many African countries climate variability has also increased uncertainty in seasonal rainfall prediction posing a challenge to scientists in their efforts to improve forecast accuracy and reliability (Changa *et al.,* 2010:66). The increase in climate change projections calls for more efforts to improve accuracy and reliability of seasonal forecast (IPCC, 2007).

Since the 2004 Indian Ocean earthquake and tsunami, disaster risk reduction specialists now acknowledge the important role played by local knowledge and practices in reducing risk and improving disaster preparedness (Hiwasaki *et al.*, 2014:15; Mercer *et al*., 2007:252). It is therefore important to close the gap between scientific and indigenous knowledge by integrating them into a culturally compatible and sustainable way which benefits both scientists and communities (Mercer *et al*., 2007:252). There are many technical and scientific solutions that are being used to mitigate disasters but these need to be complemented by local knowledge as a way of increasing people's resilience (Hiwasaki *et al.*, 2014:16). In order to reduce disaster risk it is essential that new and sustainable relationships are built upon strengths of both knowledge bases (Mercer *et al*., 2008; Mercer *et al.,* 2009). The idea of enhancing recognition that integrating IKS and SKS will improve preparedness strategies is critical (Hiwasaki *et al*., 2014:16). What this means is that combining the latest technology, science and local knowledge offers communities and disaster practitioners a broad knowledge base for effective decision making on disaster risk issues they face (Hiwasaki *et al*., 2014:16).

In support of this assertion, the World Bank, (2004:1) states that indigenous knowledge is being underutilized in the development process. The Hyogo Framework, (2005–2015) also recognises traditional and indigenous knowledge as a source of knowledge, innovation and education that build a culture of safety and resilience for communities (UNISDR, 2007:09). The World Bank, (2004:1) has proposed investigating what local communities know and have (indigenous knowledge) with an objective to improve understanding of people's conditions and provide a platform to design activities that help them. Adapting and integrating international practices (science) to local conditions will help improve the impact and sustainability of development (Njiraine, 2012:4).

Authorities like Hiwasaki *et al.,* (2014:15) have developed methods that allow communities to identify knowledge that can be integrated with science and be used by them, scientists, practitioners and policy-makers. The process also promotes and values local knowledge for integration even when it cannot be scientifically explained (Hiwasaki *et al.,* 2014:15). The development of such processes indicates that the importance of indigenous knowledge is becoming recognised and practiced by some countries in their disaster risk management activities. According to Okonya and Kroschel, (2012:641) integration of Indigenous knowledge and meteorological forecasts could be useful in effective rainfall forecasting and decision making at village level. If new and old methods of disaster reduction are combined the resilience of communities affected will be enhanced (Hiwasaki *et al*., 2014:16). As such effective rainfall forecasts will be used to mitigate loss of life and property from floods (Okonya & Kroschel, 2012:641). However as much as the integration IKS and SKS is being propounded it has to be realized that the process of integration also has its problems. A discussion of these challenges is expounded later in Section 5.6.

5.4 Indigenous flood prediction research and its use for flood mitigation in SADC-countries

According to Dekens, (2007:9-10), authorities like Paul, 1984; Rasid and Paul, 1987; Haque, 1988 and Zaman, 1991 have been promoting the importance of research that builds upon the possibilities of integrating indigenous and scientific knowledge. This is being done in an effort to enhance the reduction of river flood risks (Nyakundi, 2010:5; Hiwasaki *et al*., 2014:15). This section highlights research and case studies that have been done on the use of indigenous knowledge in flood prediction, and their influence in this study as far as it concerns the development of the region's river flood prediction model.

5.4.1 Indigenous rain and flood prediction methods in Africa

In Africa extreme climatic variability has an effect on crops and livestock and people's livelihoods putting food security at risk (Ziervogel & Opere, 2010:1). According to Ouma *et al.,* (2015:1), there has been significant improvement in climate science and technology but most early warning strategies used in African countries do not include local knowledge, needs and priority inputs from vulnerable communities. To Ouma this has to a great extent led to non-use of available early warning products. Since climate variability is likely to increase due to greenhouse gas emissions (Ziervogel & Opere, 2010:1), it is critical to understand how to manage and reduce its negative consequences. According to Krysanova *et al.,* (2008:1) climate change has partially increased economic loss, intensive rainfall and disastrous floods world-wide. In order to deal with flood risk, modern flood reduction strategies have an integrated approach that includes flood prediction as one of the measures and which is the focus of this study (Krysanova *et al.,* 2008:1). Rainfall and flood forecast information can be used to mitigate flood impacts by reducing loss of lives, property, and illness (Okonya & Krosche, 2013:641).

According to Ziervogel and Opere, (2010:1) reducing the impact of climate variability in sub-Saharan Africa may be partially achieved by using available climate information to predict and manage annual climate-related risks. Climate information is said to be available from meteorological seasonal climate forecasts (SCFs) and indigenous knowledge-based seasonal forecasts (IKFs). An increased attention to indigenous knowledge based information on a local understanding of the environment and how this informs livelihood strategies is observable (Ziervogel & Opere, 2010:3).

5.4.2 Application of Indigenous Knowledge Systems (IKS) in rainfall and flood prediction in the broader SADC-region

Some communities in countries in the SADC-region use IKS for forecasting floods (Speranza, *et al*., 2010:297; Soropa, *et al.,* 2015:1067). These countries include the countries under study, namely Zambia, Zimbabwe, South Africa and others like Tanzania and Swaziland. A study by Mwaura (2008) noted that some communities in the SADC-countries used the heights of nests of (*Ploceusspp*) Emahlokohloko birds near rivers (Mwaura, 2008:9), the position of the sun and the cry of a specific Phezukwemkono (*Cuculus solitaries*) bird on trees next to rivers and the moon crescent to predict the onset of the rainy season and flooding (Mwaura, 2008:68).

In a study by Lunga, (2014) the use of IKS and various flood prediction indicators were identified in some communities in Zimbabwe. These included change of wind direction in summer, the sudden surge of the small brown cricket called Ndororo (*Curtilla Africana*) into highland areas, incessant howling of dogs and turning of leaves of Mopane (*Colophospermum mopane*) trees upside down and the movement of ants to higher ground or climbing trees (Lunga, 2014:146-7). The following sections present some of the SADC-countries and how they use IKS to predict floods. The use of IKS to predict floods in the studied countries is discussed first.

5.4.2.1 Zambia

Johnston, (2010) has found hat the Lozi community of western Zambia use signs like the colour of the sand beaches which turn brown to determine when a flood is coming. The Lozi people also use the position of the moon and water levels to predict river floods (Mutonga, 2013:6). The community also observed the colour of sand on the beach, which when it turned brown it signaled the coming of a flood (Johnston, 2010:5). According to Soropa *et al*., (2015:1068), farmers in Zambia use several flood prediction indicators such as floods or excessive rains in the preceding season, strong winds around October, abundance and scarcity of fruits and a cold season that extends to August or September. According to Kasali, (2011:263) in Zambia when Mango trees and other wild fruit trees have excessive flowering towards the rain season it was an indicator that the rain season would be bad for food production. Zambian communities also associate types of clouds and wind direction to wet weather (Kasali, 2011:263).

5.4.2.2 Zimbabwe

Since time immemorial, IKS has been used in Zimbabwe to control, master and predict early indicators of disaster risks (Mawere, 2015:26). The indigenous people developed traditional ways of weather forecasting that help them to plan for floods two to three days in advance (Mapara, 2009:140). In 2010, Soropa *et al.,* (2015:1067) carried out a study in three districts in Zimbabwe to explore IKS weather forecasts as a climate change adaptation strategy. Some respondents indicated that they were using IKS weather indicators such as wild fruits, trees, worms and wind for meteorological forecasts. In south east Zimbabwe some birds are able to predict weather changes. The Dendera (*Hornbill*) bird's, hooting is used to predict drizzle. In the same area another bird the Teererwa is used to predict floods. This bird normally lays its eggs in holes along river beds but when a flood is impending it changes and lays the eggs on trees (Mawere, 2015:26).

In Chimanimani east of Zimbabwe, Swallow (Psalidoprocne pristoptera) Birds flying at low altitude and the singing of the stock (Riti) and Haya (cuckoo) birds is a sign of imminent rains (Risiro *et al.,* 2010:563). In south eastern Zimbabwe the weather can also be predicted by observing wind patterns. The blow of a type of wind called the *Nhurura* from the Northwest is a sign of imminent heavy rains with thunder and lightning (Mawere, 2015:27). Northerly winds in the east of Zimbabwe signify high rainfall covering a wide area (Risiro *et al.,* 2010:564). An incessant wind from the south eastern direction is observed as contributing to drizzle (*Guti*) Mawere, 2015:28. In Chimanimani, the wispy feathery cirrus clouds are a sign of a rain storm coming (Risiro *et al.,* 2010:564). In south eastern Zimbabwe the colour of clouds is associated with a white, thick and stable cloud (*Mvumi Yemvura*) which looks like a pool of water around the sun or moon to predict imminent heavy rains. Thick black clouds normally bring hailstones with thunder and lightning (Mawere, 2015:29).

East of the country the crescent moon is also observed as a sign of the coming of wet weather. A halo moon or sun symbolizes continuous rains (Risiro *et al.,* 2010:564). In south eastern Zimbabwe, the crescent moon which is upside down or in a sliding position warns of an impending pandemic like malaria, fever and influenza (Mawere, 2015:29). According to Rusiro *et al.,* (2012:563) in Chimanimani east of Zimbabwe the blooming of plants, breeding of goats, the presence of stock birds and when ants were seen sealing off their holes all signalled the onset of the rains. Communities of Mangwe, Lupane and Guruve in Zimbabwe also apply IKS to predict rainfall or floods (Lunga, 2014:146). In a study by Mutasa, (2015:4) in Buhera and Chikomba communities have traditional rain making ceremonies known as "Mukwerera". During these ceremonies spirit mediums (masvikiro) deliver messages from the ancestors (midzimu) in relation to the amount of rains to be received making it possible to predict floods. There is a traditional belief that these spirit mediums have power communicate with the ancestors, who help them to see into the future, thereby communicate messages to the community. Though some recordings had been made there is still need for proper documentation, dissemination and integration of IKS with scientific seasonal climate forecasts as a climate change adaptation strategy (Soropa *et al.,* 2015:1067). Therefore, before adopting and integrating or disseminating IKS in flood mitigation programs, its scientific appropriateness should be assessed just as any other technology. Apart from the scientific proof, local evidence and the socio-cultural background embedded in the practice require consideration in the process of validation and evaluation (Nyong *et al.,* 2007:795).

Simply put, IKS must be tested to determine if these signs local communities embrace to predict possibilities of a flood are consistent and can thus be considered as reliable from a scientific point of view. This supported by Howell, (2003:7) who emphasised in research done on indigenous early warning indicators of cyclones in Bangladesh, that it was helpful to focus on flood indicators that are widely used and could be monitored near people's homes. These indicators included ants climbing trees with their eggs. Howell also believes that if a combination of two or more indigenous indicators are used and gave extra validation to official (scientific) warning signals, then more accurate and believable early warning can be achieved.

5.4.2.3 Botswana

In Botswana local knowledge plays a complementary role in generating climate information and flood prediction (Speranza *et al*., 2010:297). IKS also forms the foundation of environmental education (Van Damme & Neluvhalani, 2004:359). Farmers in Botswana believe that IKS are more accurate and simple to use and understand than scientific forecasts that are sophisticated and need formal education, training and financial investment (Jiri *et al.,* 2016:160). Farmers in the Okavango Delta use IK to predict floods through the flow of rivers in the Delta (Kolawole *et al*., 2014:46-7). They observed that, any year they received plenty of rains and harvests, that year was preceded by free flow of rivers. When rivers are flowing in a spiral like manner the agricultural season will have limited rains and less or no harvests. The logic behind this observation is that high volumes of water (the free flow of rivers) suggested Angola receiving plenty of rains in its uplands. The spiral movement or flow of water in rivers was a sign that they would receive less rains and the Okavango would gradually dry up (Kolawole *et al.,* 2010:44).

According to Kolawole *et al.,* (2012:42) farmers in some villages in the Okavango delta of Botswana also predict rains and floods using natural indicators/signals from trees, clouds type and colour, star constellations, bird movement and appearance. When the Moretlhwa tree (Brandy bush/Raisin bush or Grewia flava) bears fruits around February and March it's a sign of plenty or more rainfall during that season (Jiri *et al.,* 2016:160).

5.4.2.4 South Africa

There is a framework and an established National Office on IKS (NOIKS) within the Department of Science and Technology. The office's function is to recognise and promote IK and knowledge systems. They also advise government on matters related to the promotion, protection, recognition, development and affirmation of IK (Domfeh, 2007:50).

The importance of IKS is also reflected in the initiatives under the authority of the country's research hub, the National Research Foundation (NRF). Recording IKS are one of the priority research focus areas of the foundation. The NRF seeks to develop understanding and research capacity on specific characteristics of IKS. The foundation also aims at enunciating the role of IKS in nation building (NRF, 2005:1). This shows that South Africa has an IKS policy and structures that promote, preserve, protect and disseminate Indigenous knowledge (Mosimege, 2005:1). The policy aims to stimulate and strengthen the contribution of local community knowledge to their social and economic development (WIPO, 2006:4). Since 1996 the country has conducted audits to determine the kinds of technologies especially on what poor and marginalized communities had used to survive over the years. The aim of these audits was to record, benchmark and innovate IKS for the benefit of communities (Njiraine, 2012:9).

Communities in South Africa use a number of climate and weather prediction indicators. They use tree phenology, for instance the flowering of the peach tree (*Prunus persica*), apricot (*Prunus armeniaca*) was a signal of the onset of rains(Zuma-Netshiukhwi *et al.,* 2013:399). Insect and bird behaviour indicated the coming of good rains like the appearance of both red ants and swallows (*Psalidoprocne pristoptera)* preceding dark clouds (Zuma-Netshiukhwi *et al.,* 2013:394). The moon crescent facing downwards and Star pattern and movement signal rain falling within three days (Jiri *et al*., 2016:164).

A study by Mwaura, (2008:66) in South Africa identified that some communities in that country believe that, hydrological hazards like floods, are an act of god and do occur as punishment for human misbehaviour in the form of raping elderly women and children. Mitigating the effects of such floods was sought in acts of repentance which were required to “restore the divine balance” (Mwaura, 2008:66). The communities also believe that rain prediction could be sought from rain Queen Mujaji by pleasing her, through offerings and prayers by traditional healers and leaders. More to that there was also a traditional belief that the Raruwafemi Royal family could moderate the impact of floods and droughts (Mwaura, 2008:66).

Further to that, the study also noted that a red moon announces the coming of floods, the cry of the Vlera bird signifies floods (Mwaura, 2008:67). Communities in the country also predict floods from the heights of nests of Emahlokohloko birds (*Ploceusspp*) near rivers. They again use the position of the sun and the cry of a specific bird (*Phezukwemkono bird*) on trees near rivers to predict the onset of rainfall (Mclean, 2009:63).

5.4.2.5 Features of IKS in flood prediction in other SADC-countries

Countries so far discussed in this chapter indicate that some of their communities use signals or indicators from the behaviour of animals, birds, trees, clouds, stars and other natural signals to predict excessive rainfall and river floods. literature reviewed on IKS from two more SADC-countries which are not part of the countries being studied shows that they also use IKS in flood predictions. Evidence from the two countries picked (Tanzania and Swaziland) helps to support that indeed the SADC is endowed with various forms and ways of predicting floods using IKS as the case in Zambia, Zimbabwe, Botswana and South Africa.

<u>Tanzania</u>

According to the Mwaura, (2008:69) Tanzanian communities have a wealth of early warning indicators in the form of behaviours exhibited by animals, birds, vegetation, wind movements, temperatures, clouds, the moon and many other features to forecast disasters. In a study by Chang'a *et al*., (2010:66) in Rungwe and Kilolo districts in Mbeya and Iringa regions of Tanzania it was found that they use plant phenology for seasonal rainfall forecasting. A good rainfall season was signalled by the Early and significant flowering of Mihemi (*Erythrina abyssinica*) and Mikwe (*Brachystegia speciformis*) trees from July to November. The Dudumizi (*White-browed Coucal*) bird's behaviour also identified as one good indicator for rainfall (Chang'a *et al*., 2010:66).

In Tanzania, the indigenous people also predicted climatic conditions using animals' intestine of which intestines with dung predicted heavy rainfall (Hussein and Armitage, 2014:4). In a study carried out by Elia, (2014) to determine how communities in Maluga and Chibelela villages in Tanzania adapted to climate change and variability through the use of indigenous Knowledge, it was revealed that the local people used the knowledge of birds, insects, plants, animals, wind and astronomical indicators to predict the weather (Elia *et al.*, 014:18). These study are clear evidence that indigenous knowledge is being put to use by many communities to mitigate floods. Also in Tanzania the culture and belief system of the

Mfangano Island community in Lake Victoria, influenced their responses to flood hazards. The community believed that floods disasters “only came when one was not at peace with God and the spirits” (Mwaura, 2008:57).

Swaziland

In Swaziland, the Mwaura, (2008:68) also established that some communities use a variety of methods or indicators based on environmental cues and the behaviour of animals and birds to predict the weather. A specific example would be the height of the nests of the Emahlokohloko (*Ploceusspp*) bird, which is used to predict floods. The interpretation of the position of the nests is that, when floods are likely to occur the nesting of these birds are very high up the trees next to the river and when floods are unlikely the nests are down and low as observed in Figure 5.1.

Figure 5.1: Floods indicator using the height of nests of the Emahlokohloko *(Ploceusspp)* bird in Swaziland

Source: Mwaura, 2008.

5.4.2.6 Scientific research on application of IKS knowledge on rain/flood prediction in the SADC-region

Scientific studies by Changa *et al.,* (2010) in Tanzania and by Mwaura, (2008) in South Africa, Swaziland and Tanzania on IKS in rainfall and flood early warning indicators show that local communities often rely on indigenous knowledge for seasonal rainfall forecasting. Both these scientists recommend the proper documentation and integration of IKS knowledge into conventional weather forecasting systems as a strategy that could help to improve the accuracy of seasonal rainfall forecasts under changing climate conditions. Their findings are summarised in Table 5.1.

Table 5.1: Local indicators based on behaviour of insects/birds/animals and others

Knowledge Base	Sign used to relate to heavy rain / floods
Weather patterns	Sky turns gloomy and overcast Black rolls of clouds Weather unusually hot and humid Hot spells after rain Strong wind blows from the south/ south east (Bangladesh) East wind blows at full-moon (Bangladesh)
Sea or river patterns	Big waves/dark rolls of water Goroom goroom noise in the river Smokey or cloudy shapes in the sea Pond and river water becomes hot
Animal behaviour	Cattle become restless and stop grazing Cattle/dogs wail continuously at night Fish jump in rivers and ponds Frogs call constantly making noise Foxes bark during the day Crabs come into the house and courtyard Appearance of a pangolin Pigs restless and noisy
Insect behaviour	Ants climb trees with eggs on their backs Bees move around in clusters Increased number of flies and mosquitoes Insects attack cattle Appearance of many butterflies Appearances of many termites Appearances of flying ants Appearance of army worms on trees

Bird behaviour	Kurpals (type of gull) fly high and cry Birds fly without destination Crows/cockerels call/fly at night Singing of the Dudumizi (*White-browed Coucal*) especially early in the morning around 5.00 hrs When swallow (*Psalidoprocne pristoptera*) bird flock is seen flying all over in the atmosphere. When Emahlokohloko (*Ploceusspp*) bird nests are very high up the tree next to a river Changing cries and songs of the Robin bird When Weaver (*Ploceidae)* birds make more/ new nests When the Vlera bird cries When the Umfuku (*Centropus burchellie*) bird chirps during the farming season Ducks noisy and restless
Plant behaviour	Bending trees Water hyacinth in the canal New leaves of trees fall to the ground Leaves of the Mandar (*Calotropis Gigantea*) and cotton trees turn upside down When the Kaffir Boom (*Erythrina lysistemon*) starts flowering from July through October When the Mpegele (*Syzygium Cordatum*) plant gives a lot of sap during the dry season
Moon, sun, wind or clouds behaviour	Muddy smell on the wind Wind direction for a particular area Hot in low land areas High temperatures in October to November Change in wind direction and temperature Red moon in south Africa When slightly tilted to the west and crescent facing down in September or October on Swaziland Towering dark clouds

Adapted from Mwaura (2008) and Changa *et al.,* (2010).

Table marked 5.1 shows that local and rural communities, over time, have observed that several changes in the natural habitat of plants, animals and other forms of life allow for predicting heavy rains and floods. According to Mercer e*t al.,* (2010), oral narratives of survival through these indigenous practices have influenced the challenge of scientific views that sometimes or in the past ignored the potential of IKS to reduce disaster risk. Some flood prediction models like the scientific knowledge by Mercer *et al*., (2010), Community Hydrologic Prediction Systems (WMO, 2011) and the LIVE scientific knowledge method (Hawasaki, 2015) as discussed in Chapter Four provides indicators on how IKS and SKS can be integrated for flood disaster risk reduction.

5.4.3 The rest of Africa as indicator of IKS in flood prediction

Many countries and communities outside the SADC-region have also been using local and IKS for survival, including forecasting of local hazards. The knowledge has been passed orally from generation to generation. These forecasts are based on indicators derived from local behaviour of animals, plants, atmospheric conditions and astronomic features among others (Ouma, 2015:1).The following few countries Kenya, Burkina Faso, Papua New Guinea and Uganda were picked up as a reference on their use of IKS to predict floods and rainfall and are form the proceeding discussion.

As a way of supporting IKS, Kenya's Constitution of 2010 gives prominence to Indigenous Knowledge in terms of its recognition, appreciation, promotion and protection. In the preamble of the constitution Indigenous knowledge is seen as the foundation of the nation (Njiraine, 2012:7).The Intergovernmental Authority on Development, Climate Prediction and Applications Centre (ICPAC), together with the Kenya Meteorological Department (KMD) and several other partners, are trying to integrate local knowledge into climate models with the aim of making seasonal forecasts understandable to farmers (Mallapaty, 2012). The ICPAC and parners are learning and realizing that the wind, clouds, rain patterns and animal behaviour are good traditional ways of forecasting and preparing for disasters (Mclean, 2009:15). Ayayo, (2004:40) highlighted the use and application of local knowledge in Nyanza, Kenya. The Nyanza community forecasts the coming of rains through the use wind patterns, cloud, rain patterns and animal behaviour.

Communities also have an interesting way of predicting rains and drought using the intestines of a goat. In Figure 5.2 the guts of goats are examined by a specialized Maasai elder. If the guts are found to be having watery cysts on them during the month of August, this is seen as a sign of an imminent season with a lot of rains. On the contrary, if the small intestine were found to be empty, it is a forecast for drought. Furthermore, if more goats than usual are seen mating in August-September that is regarded as a sign that the season was going to have excessive rain. The UNEP, (2007) in its Environmental Emergencies News issue 6, April 2007, observed that, when crocodiles in Kenya started laying their eggs on river banks on higher ground that is a sign to impending floods.

Figure 5.2: A Maasai elder reading signs on a goat intestine
Source: Mwaura (2008).

Even though these methods are used they need to be scientifically validated so that they are scientifically accepted.

Okonya and Kroschel, (2013) did some research to identify indigenous knowledge for seasonal weather forecasting for some farmers in Uganda. The research identified a number of indicators that are used to forecast the weather. The indicators included wind direction, appearance and movement of clouds, sounds of birds, and the appearance of algae, cows becoming restless, sight of a group of stars, appearance of millipedes and the presence of dew on grass (Okonya & Kroschel, 2013:645).

In Burkina Faso, a study on indigenous forecasting by farmers discovered that they (the farmers) predicted rainfall using temperature, plant, birds, animals, insects and the production of fruit by certain local trees. Good yields from the Taanga and Sibga trees were indicators of a good rainy season (Elia *et al.*, 2014:24). According to Mercer and Kelman, (2008:49), the Singas community in Papua New Guinea (PNG) identifies floods by observing the amount of rain in the hills. If there are heavy rains it's a sign for floods and they prepare to evacuate. They also send people upstream (Spotters) to observe the river/water behaviour. They also use markers to gauge the changes on water heights in the river. Whilst these observations are being done flood risk messages are sent back to the community through personal contact (Mercer & Kelman, 2008:49). It is clear from literature reviewed that many countries in Africa make use of IKS to predict floods and rain.

5.4.4 Other IKS features globally

The use of IKS in flood prediction is not only limited to Africa but globally. Countries in Asia and Europe namely India, Indonesia, Philippines, Bangladesh, Pakistan, Russia, Japan and Australia just to name afew, also have communities that use IKS to predict floods. The signals used are also the ones commoly used in Africa like the behaviour of animals, birds, trees and other natural phenomena.

According to Pareek and Trivedi, (2011:3) tribes in India predict flood through observing the colour of clouds and the location, intensity and frequency of rains. They also listen to unusual sounds and observe changes in water flow, water colour, the direction of wind and the unusual behaviour of wildlife that include ants, birds, rats and snakes. According to Hiwasaki *et al.*, (2014:18), research undertaken on coastal and small island states in Indonesia and the Philippines, shows that communities are able to closely observe and monitor the sea, clouds, animals, plants, insects, the moon, sun and stars to predict hydro-meteorological hazards. In predicting heavy rains the communities observe the behaviour of clouds, waves, winds, sun, and the stars. Communities use clouds for hydro-meteorological prediction by observing their texture, colour, location, direction of movement, speed and direction. When it comes to waves they interpret changes in colour, direction and height. Predictions on the wind will be based on its direction and temperature. Further to these signs in Indonesia a foul odour emanating from the sea was a sign of the coming of a storm or typhoon. The communities combine these observations with other changes in the environment and the time of the year and are extremely effective in predicting hydro-meteorological hazards (Hiwasaki *et al.,* 2014:18).

According to Hassan, (2000:3), research in Bangladesh showed that they use indigenous knowledge to anticipate cyclones through indicators such as wind direction, temperature, salinity of sea water, colour of clouds, appearance of a rainbow and behaviour of certain bird species and animals. In the study by Howell, (2003:4) one of the respondents gave the response that "......... I can predict any disaster coming when the sky turns gloomy, bees moving around in clusters, the cattle become restless and the wind blowing from the south." In Sri Lanka, Pakistan traditional farmers use short range weather forecasts that are based on personal experiences, animal behaviour, instincts, and visual indicators such as humidity, heat, the sky and the movement of clouds to predict the weather (Mclean, 2009:90).

In a study on floods in Russia, it was concluded that some indigenous people were able to predict storms by observing the behaviour of sea birds, such as sea gulls, the colour of clouds and the wind direction (Mclean, 2009:39). In another project in Russia early warning signs related to animal behaviour and appearance of the sky were identified (Mclean, 2009:40). In a study in Japan, Hassan, (2000) discovered that, they also used predictive indicators like wind direction, colour and movement of clouds, fishing potential, abnormal sound of waves and the behaviour of birds and honey bees. Aboriginals of Australia are able to successfully predict seasonal events in the natural world though these animal and plant cycles (Green *et al.*, 2010).

5.4.5 Common application of IKS in case studies

An analysis of the flood prediction indicators in the case studies discussed in this chapter shows common application on some of them worldwide. The indicator commonly used is the behaviour of animals which seems to dominate in all the case countries. The behaviour of birds and colour and movement of clouds also seem to be widely used to forecast floods. Indicators like the behaviour of insects and the movement of wind also appears to be fairly used. Thus if many international countries use similar IKS then obviously there must be some truth in using them. It is this common use that may among others be easily used to select IKS that is integrated with SKS to improve flood prediction models internationally.

An analysis of the African case studies indicates that the most common indicator for floods is Birds behaviour. The use of animal behaviour, wind direction and speed and also cloud colour and movement is common in predicting floods. When making flood models that are relevant to Africa these indicators can also be taken into consideration. In the SADC region and studied countries the use of bird behaviour in flood forecasts is outstanding. Also fairly used are cloud, wind, animal, moon and fruit indicators. These IKS indicators are influential and critical in the development of a flood prediction model for the SADC-region. These indicators may be commonly used in the region but when looking at specific areas those that are not common to the region may also be included.

Abundant literature review in sections 5.3, 5.4 and 5.5 with supporting research case studies, show that indigenous knowledge can be adopted to compliment scientific methods in flood predictions. This can be seen from successes stories of predicting floods using indigenous knowledge that were highlighted by authorities like Hiwasaki, *et al.,* (2014:16); Mercer *et al*., (2007:252); Grilli, *et al*., (2007:3); Walshe and Nunn, (2012:185); Arunotai, (2006:143); UNESCO, (2007:53) and ISDR, (2008:67). (Okonya & Kroschel, 2013:646).

Since indigenous knowledge is a way of life for communities and has been used overtime it makes sense to explore the role of IKS in relation to SKS. This will be helpful if SKS is seen as external knowledge, too general, and of questionable relevance to local communities (Ziervogel & Opere, 2010:7). It is also important to note that observations for forecasting the weather based on the sun, moon, sky, clouds, dew, or fog may be the same the world over and may be adopted if validated and used in most countries since they refer to the same planet earth (Okonya & Kroschel, 2013:646; Hiwasaki *et al*., (2014:23). Used together with realistic meteorological forecasts, validated traditional signs could be very useful in rain and flood forecasting and improve the timing to flood response after warning (Okonya & Kroschel, 2013:641). Indigenous Knowledge can provide significant value and boosts in the improvement of forecasting accuracy and reliability if it is systematically documented, researched and subsequently integrated in conventional forecasting system (Changa *et al.,* 2010:67).

The use of IKS is also justified by authorities like Hiwasaki *et al*., (2014:23) who shares the opinion that apart from indigenous knowledge that can be explained by science such as community observations of the moon, sun, winds; clouds, plants, animal behaviour and prohibition of deforestation (Hiwasaki *et al*., 2014:23), the other type of IKS consists of faith-based beliefs, traditional rituals and songs. This type of knowledge cannot be explained by science but is practised and helps communities build their resilience. Through faith and prayer people are able to have peace despite having difficult times and suffering when disasters strike. Beliefs and rituals provide psychological support and strength that makes communities more resistant and adaptive. These practises need to be protected and maintained for more generations to come as communities still rely on them before and during disasters. This knowledge also increases a community's awareness and preparedness for possible hazards (Hiwasaki *et al*., 2014:23). The use of IKS also empowers communities to use their knowledge and make better and informed decisions on flood risk reduction (Hiwasaki *et al*., 2014:25). There is also need to categorise separately Indigenous Knowledge that help communities reduce risk but cannot be explained or integrated with science. Such knowledge must continue to be used by communities without any scrutiny and interference by scientists, policy-makers and practitioners (Hiwasaki *et al*., 2014:25).

It therefore follows that systematic documentation and integration of Indigenous Knowledge in seasonal rainfall forecasting is one initiative that needs to be explored (Changa *et al.,* 2010:67). In Zimbabwe local communities have been coping with drought by integrating contemporary and Indigenous climate forecasting (Makwara, 2013:101). Through the use of indigenous Knowledge in weather and climate prediction, local communities in different parts of Tanzania have been coping and adapting to increased climate variability normally manifested in the form of an increased frequency of floods (Mwaura, 2008). Early warning systems have become very important to prepare for climatic events like the floods. (Okonya & Kroschel, 2012:641). What this means is that, indigenous knowledge hidden in communities, has to be identified and developed to form warning systems that might save future generations from destruction by natural forces (SMDC, 2008). Howell, (2003:8) concluded that “we cannot afford to ignore any potential low cost strategy which might improve survival and mitigate property losses. There is need to explore whether certain combinations of the best indigenous indicators and the best scientific indicators can offer a more appropriate, reliable and comprehensive warning system for vulnerable communities." Mercer, *et al*., (2012:81) stress and state that "the most effective strategies from each knowledge base need to be identified to generate a 'safety culture', as opposed to relying on one knowledge base alone to reduce risk among 'at-risk' communities." Pearson, (2012) also supports the use of IKS as it improves forecasts and increase acceptance, ownership and sustainability of early warning systems.

5.5 Successful application/use of IKS

Literature has documented cases of communities that have responded to hazards using indigenous knowledge and survived their threats (Mercer *et al*., 2007:252).The 2004 Indian Ocean earthquake and tsunami and other disasters, have triggered recognition and acknowledgement by disaster risk reduction practitioners that local knowledge can play a critical part in disaster risk reduction and preparedness (Hiwasaki *et al.*, 2014:15). There has been an increase in indigenous knowledge studies since mid-2000s (Hiwasaki *et al.,* 2014:16; Mercer *et al*., 2007:252). This is particularly after the 2004 Indian Ocean earthquake and tsunami (Mercer *et al*., 2007:252), that affected countries like Malaysia, Indonesia, Sumatra and others bordering the Indian Ocean (Grilli *et al*., 2007:3). In these studies it is claimed that indigenous knowledge helped communities survive tsunamis on Solomon island (Mercer *et al*., 2007:252), Thailand and on the Vanuatu Islands (Hiwasaki *et al.,* 2014:16). Vanuatu is an island group located on the western part of the South Pacific Ocean. It is the seventh most vulnerable country in the world to tropical cyclones. (Walshe & Nunn, 2012:186). In 1999 a tsunami destroyed settlements causing five deaths from a population of about 300 people in Vanuatu islands. By applying IKS the people survived as they fled inland and uphill before the waves struck (Walshe & Nunn, 2012:185).

In 2004 elders from a tribe in Thailand, noticed water in the sea receding and moving in an unusual way (Arunotai, 2006:143; Hiwasaki *et al.,* 2014:16). The receding tide was recognised as a sign of an approaching tsunami (UNESCO, 2007:53). Alarm was raised and the inhabitants took refuge further inland. A tsunami came and swept away the village reducing it a heap of wood and debris. Even though hundreds of thousands of people perished on the coast stuck by the tsunami, not a single life was lost in the Surin Islands which were also stuck, as local knowledge of the sea saved their lives (Arunotai, 2006:143; Hiwasaki *et al.,* 2014:16).

ISDR, (2008:67) gives an account of how the 2007 tsunami in the Solomon's island that killed fifty people occurred. The number of deaths is said to have been minimised due to appropriate and timely response by local communities using indigenous knowledge. Those who died are said to have been immigrants who did not recognise signs of the impending tsunami. Water was said to have rushed out of the lagoons into the sea exposing the seafloor after an earthquake. The immigrants became excited and responded by going to sea to investigate and explore the emptied lagoon. That response demonstrated that the immigrants were ignorant on how tsunamis develop.

On the other hand the local people responded by evacuating inland from the sea shores after noticing that the lagoon had emptied after the shaking. As such there was no death on the local community when the tsunami stuck as they had moved away from danger. The local people had traditional knowledge on what to do when an earthquake stuck and was followed by an empty lagoon. The only response was to evacuate in and up land as the event indicated the coming of a tsunami (ISDR, 2008:67).

After analysing the successful cases above it then flows that, the indigenous knowledge of communities must be considered a primary source of information (Mercer *et al*., 2007:252). This is due to the fact that indigenous communities have more knowledge about the flood hazards they encounter and their occurrence than outsiders (Mercer *et al*., 2007:252). More to that the success stories show that indigenous Knowledge for weather forecasting is also useful in decision making at village or local level (Okonya and Kroschel, 2013:641). Since their livelihoods often revolve around land use in flood risk areas, communities are generally aware of and know how to deal with flood hazards that may be detrimental to their survival (Mercer *et al*., 2007:252). Lewis, (1982:245) states that, ‘‘a multidisciplinary, comprehensive, environmental and locally integrated approach by indigenous authorities and organisations will be more effective for disaster mitigation than partial, sectoral, mono-disciplinary, policy separation by exogenous agencies and government bodies.''

According to Hiwasaki *et al*., (2014:29) the 2004 Indian Ocean tsunami influenced people's interest in integrating local and scientific knowledge for disaster risk reduction. In Vanuatu, disaster preparedness now incorporates traditional knowledge and volcanology in its volcanic hazard awareness and education (Hiwasaki *et al*., 2014:19).

5.6 Former and current challenges associated with integrating IKS and SKS

The biggest challenge in integrating IKS and SKS is as a result of deep seated differences in the way people perceive the character of these knowledge bases which "influence opinions of the extent to which there is a 'universal truth' of what counts as evidence and ultimately which forms of knowledge are believed to be valid" (Raymond *et al*., 2010:1770). According to Mercer *et al.,* (2007:252) ideas of disaster risk reduction used to advocate for the scientific approach, ignoring the importance of local knowledge. This was due to the fact that scientific and IK bases were often entrapped within and dependent upon power relationships (Mercer *et al*., 2009:158). The former being dominant, overpowered and dismissed the importance of the later (Shizha, 2013:4). It is Mercer *et al*.'s (2007) belief that non acceptance of IK was as a result of some scientists and some educated experts finding it difficult to accept that poor communities understood their situations better than them (Mercer *et al*., 2007:252).

Resolutions towards this have been made at international platforms which include the Sendai Framework of 2015. According to UNISDR, (2015:15) section 24(i) of the Sendai Framework advocates for the use of appropriate traditional, indigenous and local knowledge and practices to complement scientific knowledge in disaster risk management programmes which should be tailored to localities and contexts. Furthermore, Section 36 (a)(v) of the Sendai Framework states that "indigenous peoples, through their experience and traditional knowledge, provide an important contribution to the development and implementation of plans and mechanisms, including early warning" (UNISDR, 2015:23).

Apart from the problems cited above the following issues are current problems when it comes to integrating IKS and SKS. Even though intentions are towards integrating the use of IK and SK there is a challenge in bringing IKS and SKS together in a way that respects their different values and builds on their strengths (Ziervogel & Opere, 2010:7). Literature on traditional IK systems is scarce. This therefore calls for the need to document location based traditional knowledge for climatic and weather events which might not be easy to attain (Okonya & Kroschel, 2013:644). IK lacks systematic documentation, lacks coordinated research in investigating its accuracy and reliability, and the knowledge is lost when the old people (main custodians of the knowledge) pass on (Mohoo, 2015:8). Forecasting indicators like watching the behaviour of cows might not be effective as they need patience and are used in a combination with two or more other signs to make an accurate weather forecast (Okonya & Kroschel, 2013:646). Observations based on indicators of birds, plants, insects, and animals vary as they are unique or specific to certain areas and regions. There is also variation of indicators for weather prediction in various areas or regions as a result of different individual experiences, knowledge, and cultures of communities or people (Okonya & Kroschel, 2013:646). This makes the application of IK over a wide area difficult. However, despite all these constraints IK can be made more useful by integrating it with science to predict floods. The prospects of integrating the two knowledge bases flow in the next section 5.7.

Abundant literature review in sections 5.3, 5.4 and 5.5 with supporting research case studies, show that IK can be adopted to compliment scientific methods in flood predictions. This can be seen from success stories of predicting floods using IKS that were highlighted by authorities like Hiwasaki, *et al.,* (2014:16); Mercer *et al*., (2007:252); Grilli *et al*., (2007:3); Walshe and Nunn, (2012:185); Arunotai, (2006:143); UNESCO, (2007:53) and ISDR, (2008:67).

Since IKS is a way of life for communities and has been used overtime it makes sense to explore the role of IKS in relation to SKS. This will be helpful if SKS is seen as external knowledge, too general, and of questionable relevance to local communities (Ziervogel & Opere, 2010:7). It is also important to note that observations for forecasting the weather based on the sun, moon, sky, clouds, dew, or fog may be the same the world over and may be adopted if validated and used in most countries since they refer to the same planet earth (Okonya & Kroschel, 2013:646; Hiwasaki *et al*., (2014:23). Used together with realistic meteorological forecasts, validated traditional signs could be very useful in rain and flood forecasting and improve the timing to flood response after warning (Okonya & Kroschel, 2013:641). Indigenous Knowledge can provide significant value and boosts in the improvement of forecasting accuracy and reliability if it is systematically documented, researched and subsequently integrated in conventional forecasting system (Changa *et al.,* 2010:67).

The use of IKS is also justified by authorities like Hiwasaki *et al*., (2014:23) who shares the opinion that apart from IKS that can be explained by science such as community observations of the moon, sun, winds; clouds, plants, animal behaviour and prohibition of deforestation (Hiwasaki *et al*., 2014:23), the other type of IKS consists of faith-based beliefs, traditional rituals and songs. This type of knowledge cannot be explained by science but is practised and helps communities build their resilience. Through faith and prayer people are able to have peace despite having difficult times and suffering when disasters strike. Beliefs and rituals provide psychological support and strength that makes communities more resistant and adaptive. These practises need to be protected and maintained for more generations to come as communities still rely on them before and during disasters. This knowledge also increases a community's awareness and preparedness for possible hazards (Hiwasaki *et al*., 2014:23). Integration promotes the use of IKS. It also empowers communities to use their knowledge and make better and informed decisions on flood risk reduction (Hiwasaki *et al*., 2014:25). There is also need to categorise separately Indigenous Knowledge that help communities reduce risk but cannot be explained or integrated with science. Such knowledge must continue to be used by communities without any scrutiny and interference by scientists, policy-makers and practitioners (Hiwasaki *et al*., 2014:25).

It therefore follows that systematic documentation and integration of Indigenous Knowledge in seasonal rainfall forecasting is one initiative that needs to be explored (Changa *et al.,* 2010:67). In Zimbabwe local communities have been coping with drought by integrating contemporary and Indigenous climate forecasting (Makwara, 2013:101). Through the use of indigenous Knowledge in weather and climate prediction, local communities in different parts of Tanzania have been coping and adapting to increased climate variability normally manifested in the form of an increased frequency of floods (Mwaura, 2008). Early warning systems have become very important to prepare for climatic events like the floods. (Okonya & Kroschel, 2012:641). What this means is that, IKS hidden in communities, has to be identified and developed to form warning systems that might save future generations from destruction by natural forces (SMDC, 2008). In support of the integration of scientific and IK in disaster risk reduction, Howell, (2003:8) concluded that “we cannot afford to ignore any potential low cost strategy which might improve survival and mitigate property losses. There is need to explore whether certain combinations of the best indigenous indicators and the best scientific indicators can offer a more appropriate, reliable and comprehensive warning system for vulnerable communities.” Mercer *et al*., (2012:81) stress and state that "the most effective strategies from each knowledge base need to be identified to generate a 'safety culture', as opposed to relying on one knowledge base alone to reduce risk among 'at-risk' communities." Pearson, (2012) also supports the use of IKS and states that there is a need for local knowledge and practices to be integrated with those of the science community, to improve forecasts and increase acceptance, ownership and sustainability of early warning systems.

5.7 Conclusion

This chapter reviewed literature on the integration of indigenous and scientific knowledge systems. The research questions addressed are “What is the relevance of considering Indigenous Knowledge Systems (IKS) in river flood prediction possibilities?” and “Are there any possibilities of working towards developing a river flood prediction model to serve as a feasible procedure in managing river flood risks?”. Historically and up to present day communities continue to rely on IKS to deal with flood risk mitigation with one of the systems being flood forecasting. The knowledge is gained through observation and study and experience handed down from generations. Of importance was the empirical research so far done by some researchers on both scientific and indigenous methods of flood prediction. It was noted in the literature that the integration of IKS and SKS into a flood prediction model is very possible and would be a good step towards developing an efficient and effective flood prediction model for SADC region. Several sources point out that IKS should be applied with SKS in an integrated effort towards establishing a flood prediction model as it is locally focused and based in the reality of a specific community. IKS could form the basis for decision-making on any community's flood disaster survival strategies. The communities have knowledge in the form of strategies or know-how in predicting floods thereby providing methods for flood risk mitigation.

The inclusion of IKS in the flood prediction model helped communities in each flood affected area increase their participation and take a leading role in flood risk mitigation. IKS was used as a cost-effective and sustainable strategy as local resources were used and the community members mitigated flood disasters as a community service and at no cost. Being involved in flood risk reduction would also become a source employment for the community members which might become a source of their livelihood. The use of indigenous knowledge in the flood prediction model provided understanding of practices and contexts of specific areas or communities by stakeholders. A project that considers people's culture will be more acceptable and easy to implement as people will take its ownership and responsibility.

In the past and up to date, many different communities globally continue to rely on indigenous knowledge than scientific knowledge to predict the amount of rainfall and flood disasters. This is due to among other things, difficulty in accessibility and interpretation of conventional weather forecasts. Literature has also indicated that despite its usefulness, local knowledge is threatened with disappearance. That is being caused by lack of its systematic documentation and lack of a coordinated approach to research its accuracy and the reliability of its forecasts. . It is interesting to note that, there is also a dilemma being faced in the integration of indigenous knowledge and science as to which knowledge is "new," which is "existing," which one "works" and who decides about what on the two knowledge bases.The importance of indigenous knowledge need not be underestimated as its relevance has been clearly shown in the vast literature review done and documented in this research project under study. Indigenous Knowledge is abundant in flood communities' although it is getting ignored and becoming extinct. Therefore harnessing, repackaging and integrating science and local knowledge systems will present the people of Africa and the SADC-region in particular with a major contribution to a less flood risk free area.

Research and cases described in this chapter accentuate the value of Indigenous Knowledge internationally. The common trend in all the cases highlighted, is that traditionally many forecasts are made through interpretation the behaviour of animals, plants, winds, clouds just to name a few. To a great extent many traditional communities the world over have the capacity to predict rains and also floods through tried and tested means over generations, using the behaviour of natural phenomena. As already been alluded to by many authorities in preceding sections, the fact that indigenous knowledge has worked before means that there is faith in using it again although not as an independent entity, but by integrating it with the scientific knowledge of the local area. It was therefore the intention of this project to identify how river floods are being predicted using both scientific and indigenous forms of knowledge so that it facilitates the development of an integrated flood prediction model in the SADC-region.

Integration of local/indigenous knowledge with science is an important process which enables practitioners and scientists to implement activities and research to increase resilience in flood communities. This will influences decision makers put into practice policies that support community flood prediction activities. Indigenous Knowledge is very relevant in predicting floods in communities and it was possible to integrate IK in the flood prediction model being developed in this study. The Hyogo Framework for Action (2005) and Sendai framework, (2015) equally emphasizes the importance of encouraging the use of traditional knowledge. This shows that the use of IKS is now globally accepted. It’s now a matter of how to effectively do it (implementation) and assess the efficiency and effectiveness of the system in the SADC-region.

The next chapter brings into picture the research methodology used in this study. The focus is on qualitative and quantitative research, the survey design, population, sample and sampling, data collection and instruments used validity and reliability of instruments and data analysis methods.

CHAPTER SIX: RESEARCH METHODOLOGY

6.1 Introduction

Developing a river flood prediction method for the SADC-region, required both theoretical and empirical information on river flood prediction methods or models. The first part of achieving the goal of this study was data collection through a review of literature. In Chapter Four and Five of this study, literature was surveyed and theoretical data collected on world-wide research and the use of both scientific and Indigenous Knowledge (IK) river flood prediction and warning models. Furthermore, the relevance and usefulness of indigenous knowledge and how and why it can be integrated into the river flood prediction method being developed in the study was discussed.

This chapter is concerned with the second part of achieving the goals of this research. It deals with the methods of collecting empirical data on the use of river flood prediction methods/models and IK in the SADC-region. The data was collected through interviews from selected disaster risk management practitioners (government and private) and communities normally affected by river floods in Zambia, Zimbabwe, Botswana and South Africa. Relevant information from both the theoretical and empirical data collection exercises was adopted and used for the development of the Regional river flood prediction model in Chapter Eight. The information helped to form the format or design of an integrated river flood prediction model for the SADC-region.

6.2 Research methodology

Research methodology is a method, technique or procedure used in conducting research (Lichtman, 2006:219). It is also defined from another angle as a logical basis for collecting and interpreting data followed by an analysis of the findings (McNeill, 1990:14). In this study, the research methodology focused on the design, sampling, data collection and analysis used. The study also used primary data (See Chapter Seven) and secondary data (see section Three and Five). Chapter Three presented flood history and Chapter Five was on indigenous knowledge and its application in flood prediction in the SADC-region and the world.

6.3 Research philosophical approach

This study applied the mixed method research philosophy or paradigm. The study collected and analysed both numerical data (quantitative) and textual/narrative data (qualitative) in order to address the research questions in the entire structured interview schedules (see Appendix A and B) and the questionnaire (Appendix C). In order to collect a mixture of data, the questionnaire and interview schedules contained both closed and open ended questions (Williams, 2007:70). The research approach involved recording data on flood disasters in recent times, how they happened and also why they happen. Firstly, qualitative data was collected from people's experiences, perceptions, attitudes and beliefs (Jogulu & Pansiri, 2011:691: Dilshad & Latif, 2013:190). Two structured interview schedules with thirty six and twenty six questions each were developed. The two schedules were used to collect data from disaster risk managers/professionals at national offices and some community leaders and private/government social workers who reside in the selected study areas. The questionnaire was used to collect data from community members who are river flood victims. The questionnaire had 47 open and closed ended questions. Data was also quantitatively gathered from samples to describe, compare and predict knowledge, attitudes and behaviour. According to Creswell, (2003:153) quantitative research entails collecting data in order to quantify and subject information to statistical treatment so as to support or refute alternate knowledge claims.

6.4 Research design

The study used the descriptive survey design. Descriptive research is the process of describing the characteristics of any selected phenomenon (Bellis, 2003:436). The purpose of survey designs is to produce an accurate or real or factual representation of persons, events or situations (Saunders *et al.,* 2009:590). This study focused on "which" and "what" questions, making it mostly a descriptive study. This is reflected by the research questions of this study, set out in Section 1.4. Guiding the study was the fact that the study population and sample had historical experiences on floods and their management. Failure to have such historical experiences would render the data they gave invalid for this study. These experiences and the proposals made by experts and victims helped the researcher in developing a river flood model in Chapter Eight (see Figure 8.1) that took into consideration the experiences, concerns and proposed ideas of those who were affected and managing disasters. This created a sense of cooperation and ownership in the development of the river flood prediction model. When local indicators combine with scientific systems, a more effective river flood prediction system that is understood and controlled by affected communities is created (Howell, 2003:5). Involving stakeholders enhanced the efficient and effective implementation of the flood prediction model. The victims' and managers' experience and thoughts also brought out other issues that could be areas for further research.

6.5 Sampling methods

Sampling is defined as the collection of data from a sub-group than all possible cases or elements (Saunders *et al.,* 2009:210). A non-probability sampling approach was used in this study. According to Saunders *et al.,* (2009:213), non-probability sampling is the selection of elements using sampling techniques in which the probability of each case being selected from a population is not known. The methods of non-probability sampling that were used are convenience and purposive.

6.5.1 Convenience sampling

This process involves the random selection of cases that are easiest to obtain for a sample (Saunders *et al.,* 2009:241). This method of sampling uses available or close at hand or accessible subjects (Berg, 2001:32). In the present study, this was done until a required sample size was reached (Saunders *et al.,* 2009:241). The method was also used to sample (see Section 6.6.1) community members as questionnaire respondents affected by recurrent river floods in some communities in the studied countries (see Section 6.6.1). The national disaster managers helped in identifying the communities in flood disaster problem areas. The community participants who were identified as having stayed in the communities for a long time and who had thorough knowledge of river flood disasters were a priority for this questionnaire data collection exercise. Village heads, councillors or community development officers were used to help identify key persons for the data collection exercise.

Convenience was also used to select extra participants for interviews (see Section 6.6.1) as the study required key informants from government or private organisations who were in a way involved in flood risk management in the studied communities. This was done to improve the quality of information collected on floods in the selected communities. This group of respondents consisted of community leaders and community private/government workers who stayed and worked within the flood affected communities.

6.5.2 Purposive sampling

This method is also known as judgmental sampling (Saunders *et al.,* 2009:237). Purposive sampling enables a researcher to use own judgment to select respondents who would enable him/her to answer the research questions (Saunders *et al.,* 2009:237). By using this method, the researcher used knowledge or expertise about a group and chose a sample out of that population. This was meant to include certain persons with particular attributes in the study. This method was used to choose disaster risk managers and meteorologists. Disaster risk managers are usually coordinators of disaster situations in their countries. They work with weather experts like climatologists or meteorologists and water experts like hydrologists. Effective flood risk management would generally require the integrated activities of these three groups of people. As a result, the respondents were handpicked by virtue of being national disaster risk experts or private specialists, as their expertise was relevant to this study. The respondents were selected on the basis of this expertise and their job responsibility. However, purposive sampling had a disadvantage that it lacks wider generalisability. In this study, generalisability was possible since flood management activities in the region are more or less similar (see Chapter Two and Three). The various experts used as respondents in the study also met at or were part of various Regional forums to address water and climate related issues as outlined in Chapter Two.

6.6 Population and study sample

A population is a complete set of cases or group members from which a sample is taken (Saunders *et al.*, 2009:212). The SADC-region consists of 15 countries which make up the population of the study. De Vos *et al*., (2011:224) defined a sample as a subset of a population considered for inclusion in the study. Choosing a sample in this study involved selecting the research countries and participants from the 15 SADC-countries. How this was done follows in the next section.

6.6.1 Study areas

Four SADC-countries, namely Zambia, Zimbabwe, Botswana and South Africa were selected from the regional group as the study sample. Data collection focused on river flood disasters that had occurred over the past fourteen years from 2000 to 2013. The countries were selected on the ground that they had both a similar rainfall season and flood season, which ranged from October to March/April. (Chaguta, 2008:01). The determinants of rainfall patterns in the four countries included the Inter-Tropical Convergence Zone (ITCZ), La Niña (Chaguta, 2008:1) and the El Niño phenomena (Lukamba, 2010:484), all of which bring in high rainfall in the summer (Davis, 2011:9). The flood risk management programmes of the countries selected for study are also related and are coordinated by the SADC-regional water policy and under various forums like the Southern Africa Regional Climate Outlook Forum (SARCOF), the Integrated Water Resource Management (IWRM**)** and the Southern African Development Committee (SADC) – Hydrological Cycle Observing System (HYCOS) project only to name a few. The selection choice of the four countries was also made from a practical point of view, its closeness to the researcher's basis of research and because of financial reasons to undertake the research.

Four communities were identified in the studied countries, namely Chanyanya Village in Zambia, Tokwe-Mukosi Village in Zimbabwe, Satau Village in Botswana and Tonga Village in South Africa. The communities were identified with the assistance of the national disaster risk managers. They are located along major rivers and experience recurrent floods that negatively affect the community members.

Chanyanya village is located on the banks of Kafue River in Kafue District in Zambia (Kanyamuna, 2010:11). The area is mostly flooded during the rainy season. The general livelihood of the community is based on fishing and small-scale farming (Mwelwa 2013:83; Kanyamuna, 2010:11).

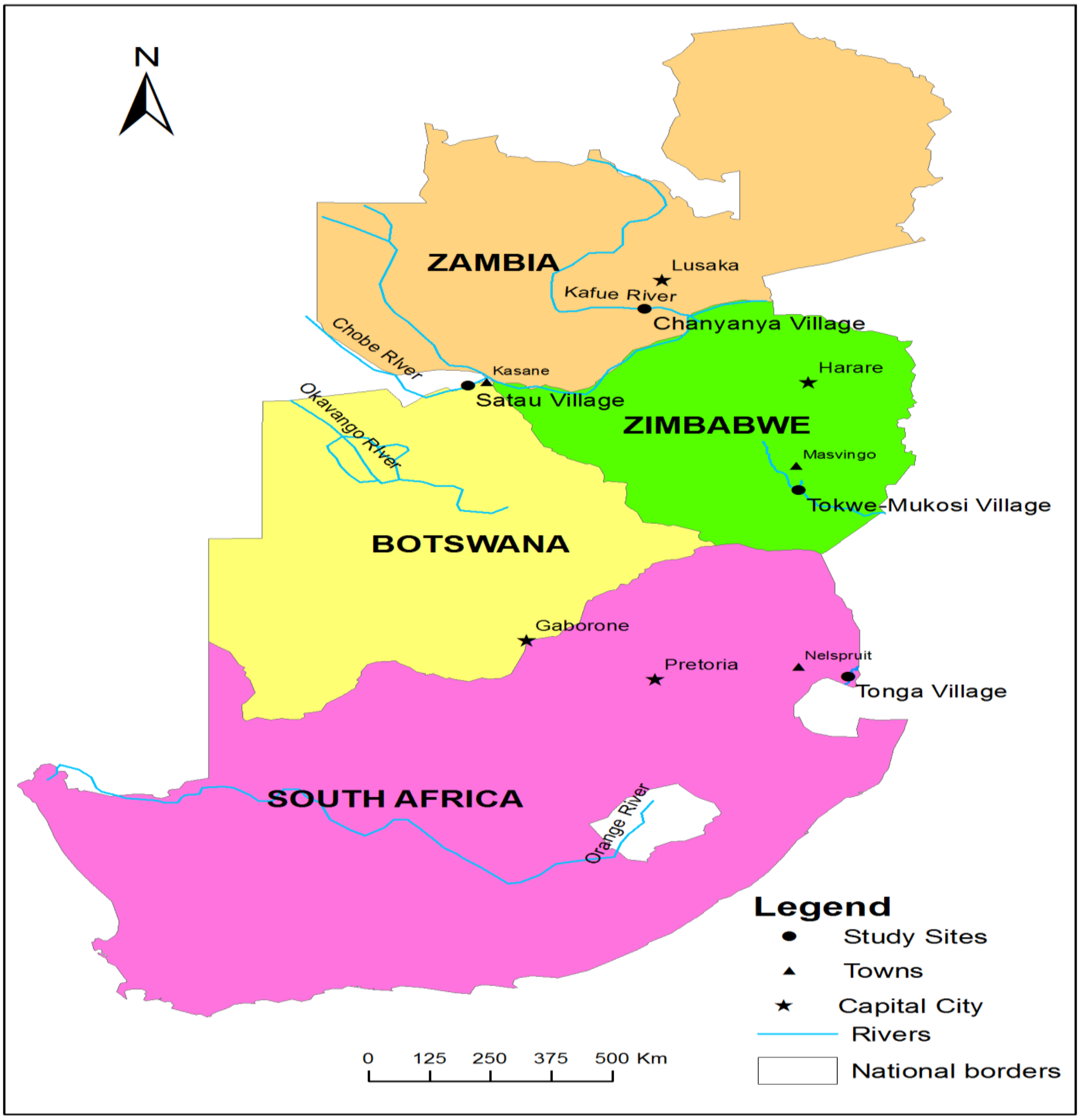

Figure 6.1: Map showing study area and sites
Source: Authors depiction, June 2015.

Tokwe Mukosi community is located nearly 100 km from Masvingo town, in Zimbabwe (Nyanga, 2013:25). The community stays in areas surrounding Tokwe Mukosi dam at the confluence of Tokwe and Mukosi rivers, in Chivi District. Floods have been occurring in the communities since the 1990s when the Tokwe Mukosi dam underwent construction (Mazarire, 2008:757). Agriculture is the main source of their livelihoods (Tarisayi, 2014:166). Floods cause destruction of crops, livestock, houses, assets and social networks (Tarisayi, 2014:166).

Satau village is found on the Chobe enclave in Botswana (Van der Jagt *et al.*, 2000:12; Gilmore, 1979:97). The Chobe River provides for Satau community's livelihoods as the people live along the basin (IFRC, 2011:3). They live by way of crop production, livestock husbandry, fishing and handicraft production (Gilmore, 1979:97). However, floodwaters bring health and livelihood problems and destroy peoples' property (IFRC, 2011:3). Unfortunately, the people are surrounded by forest reserves and a National Park, making it difficult for them to find alternative land thereby risking by living adjacent to Chobe River. Floods in the area are annual and affect communities living along the basin in varying degrees (IFRC, 2011:3).

Tonga Village in South Africa is in Nkomazi district, Mpumalanga province near the Komati River (Skosana, 2013). The village is situated in the Lowveld, south of the Kruger National park, west of Mozambique, northwest of Swaziland (Maclachlan & Schwartz, 2009:192). The community suffers from recurring Komati river floods that kill people and damage homes and bridges (South African Weather Service, 2013; Business Day Live, 2013; NEWS24, 2012; Government of South Africa, 2014).

6.6.2 Study data collection

There were three groups of respondents in the study. The first group was mainly approached in a qualitative manner, using structured interviews. This group included national disaster managers and meteorologists in both private and public organisations. Interviews were carried out on eight respondents of this group (a minimum average of one respondent per each country under study). They comprised of four national disaster managers each from Zambia, Zimbabwe, Botswana and South Africa, two disaster managers each from a private organisation like the Red Cross in Zambia and the private sector in South Africa and two government meteorologists each from Zambia and Zimbabwe. These experts were asked about the status of river flood disasters, prediction models being used, what governments had done to help, flood prediction research and models in use, Indigenous Knowledge systems and any possibilities of and suggestions for inclusion in the river flood prediction model that was being developed in the study.

The determination of the sample size (eight disaster management experts) for qualitative studies in this group had "no hard and fast rules" (Nastasi, 1999:4). The sampling method used (purposive sampling) for the group did not aim to generate a statistically representative sample nor draw a statistical inference (Wilmot, 2005:3). The sample was homogeneous, therefore, for a phenomenon to be considered for analysis, it only needed to appear or be identified once to be of value to the research (Wilmot, 2005:3). All the data collected in this study was thus important, even if only said once or by one respondent. What was important, was to get facts on the ground. The sample included only participants with a particular experience (flood risk management) and the goal was to get "*in-depth understanding*" on this phenomenon (Nastasi, 1999:1). In purposive sampling, the number of people interviewed is not critical but the criteria used to select them are (Wilmot, 2005:3). In this study, the characteristics of individuals, that is, being a disaster risk manager at national level or for a particular country, were used as the basis for selecting participants. The interviews used aimed for depth and breadth of content on flood issues under investigation (Wilmot, 2005:3). What this means is that there was need to extract large quantities that would be manageable for analysis. The sample size only needed to reach a "saturation or redundancy point" (Nastasi, 1999:4). With these eight participants, consistent patterns in the gathered data were identified. In other words, when data was collected from the eight disaster risk managers "nothing was left to learn" (Nastasi, 1999:4), as there were no new concepts emerging leading to redundancy or saturation. Therefore, the sample was large or big enough to generalize (Nastasi, 1999:4). The sample was also determined by researchers' time available for data gathering (Baker & Edwards, 2012:10) which is a critical factor in determining a qualitative sample size.

The interviews of the disaster risk managers complied with the ethical standards requirements as reflected in Section 6.13. The respondents were advised that the study was purely for academic purposes and could also be used to improve flood prediction in their countries and communities. There was no need for interviewees to identify themselves in any way during the interview. They were also kindly asked to express their views and opinions freely as the information they were giving was to be held private and confidential and no names were to be mentioned or written. To show consent they were asked to sign a consent form (see Appendix D - Consent form) prior to interviews.

The structured interviews (see Appendix A for Questions) were recorded using an electronic recording devise. The respondents were visited at their work places after having made an appointment by phone, email or personal visit. With some, the researcher firstly sought permission to conduct the structured interview from heads or Ministry offices, by sending a letter (see Appendix E for interview request) that was written and sent before the data collection exercise and also through verbal requests during the data collection exercise. The eight interviews were later transcribed on paper by a professional transcriber. These respondents provided the study with the relevant data and information on the management of flood risk in the region and at national level as they were involved in the planning, implementation, evaluation and coordination of flood management programmes. The data collected was valid and reliable in all the interview processes as respondents were experts in the field of study and also held office at national and local level. Data from this group was collected from both the government and private sector.

Within the mixed data gathering method, the second group consisted of 80 respondents, 20 from each of the studied countries. Data was collected from them through structured questionnaires (see Appendix C). These respondents included the victims of river floods. They were asked about their experiences of flood disasters, their expectations, how they managed flood disasters and how they think flood disasters should be managed. Though victims may not be qualified to provide substantial information in efficiently addressing the problem of food river disasters, they were included in the research because victims are the first respondents to floods and they have their local ways of managing them. All the questionnaires distributed were returned to the researcher.

This second group of respondents was from particular communities, namely Chanyanya Village in Zambia, Tokwe-Mukosi Village in Zimbabwe, Satau Village in Botswana and Tonga Village in South Africa, all areas that are affected by recurring river flood disasters (see Figure 6.1). The studied communities are located along rivers with considerably high water demand for agriculture, fishing and other livelihood activities. All the studied communities are affected by heavy rainfall and cyclones. Looking at the activities engaged by the communities, these rivers seem to be major rivers and are perennial. The communities live in flood prone areas for survival and economic needs like agriculture. Apart from using SKS, these communities also apply IKS and traditional beliefs systems to predict rain and floods. They get information to predict rain and floods through spirit mediums (*masvikiro)* that get messages from ancestors (*vadzimu*) (Mutasa 2015:4). However the use of these traditional beliefs is now being diffused by western culture. The young generation is also shunning traditional culture for modernisation and religion. Christianity is also questioning , the spirit mediums' relevance and reliability in predicting rainfall and floods(Mutasa 2015:4). Traditional belief systems are difficult to prove or verify as such they were not gathered from the study communities.

The respondents included 45 males and 35 females between the ages of 30 to 60. The participant's answers were recorded using hand written responses. Participants who did not understand the English language were assisted by an interpreter. The respondents were selected using convenient sampling. On the first day of arrival in a community the researcher familiarised himself with the community leaders and people in the village or settlement which made it easy to access the respondents. One community leader in the village was singled out who helped with identifying, grouping or directing the researcher to the required respondents for questionnaire distribution. The questionnaire data from the community members was also collected from the people who suffered from river floods. The victims gave responses in relation to the flood risk reduction activities in their areas. The community members who responded to the questionnaires included victims of floods and their accounts and experiences supported each other. They also disclosed where they felt the government was failing.

The last group of respondents had 40 participants from the four studied countries, who were successfully interviewed. Community leaders, government officials, teachers, police officers, nurses, development officers and others were targeted. These respondents were residents and working in the same community groups. Data was collected from this group using structured interviews (see Appendix B) with a recording devise. The respondents were visited at their offices or official places of work. The information sought included flood statistics, flood management, flood prediction and IKS systems at that community level. The data was later transcribed for analysis and interpretation. These respondents were required for this study as they were professionals who worked and were based in flood prone areas. They also worked with the affected communities on a day to day basis and shared the same experiences with them. Data was required from them as it was assumed that they would give an account of it from their experience and professional point of view. This helped in complimenting and verifying information from the other groups discussed above. The study used a total of 128 respondents. In general, the mixed method used in collecting data from various sources was meant to eliminate bias from managers of National Disaster Management Centres. This made the research credible as most parties, including victims of flood disasters, were involved.

Data collection lasted for an hour per respondent at the most, depending on whether the respondent understood and could respond in English and also whether there was need for translation. Before collecting data, the participants were invited to participate if they so wished. They were also asked to sign a letter of consent (see Appendix D). Most people that were approached consented and seemed motivated by their personal circumstances of being flood victims and because of the friendship created on the first day of familiarization with the researcher.

Data collection was carried out with the help of research assistants, one from each of the studied countries. The research assistants were selected through their educational qualifications, research experience and language. They all had at least a first degree and had worked or were working for organisations where they had done research a number of times. They were fluent in the language of the identified communities for easy translation as the questionnaires and interviews were in English. The research assistants were identified long before the data collection exercise and travelled to the research area. The interview and questionnaire schedules used were developed through the assistance of the research supervisor and a professional statistician identified by the supervisor for professional assistance. They were also pretested and validated by the researcher's supervisor, the professional statistician and colleagues who determined if they reflected the purpose and objectives of the study.

6.7 Validity and reliability of research instruments

Validity can be defined as the extent to which a research instrument measures what it is supposed to be measured (Leedy & Ormrod, 2005:31). Best and Khan (2003) defined validity as the correct methods used to find answers for questions. The research instruments were tested for their validity. Expert opinion on the validity of the research instruments was sought from the study supervisor and a professional statistician. Suggestions made by them were noted and changes were made to the data collection instruments which were then pretested. The pretest involved handing the data collection instruments and research objectives to five colleagues who had completed their PhDs. They were asked to complete them and make comments where they felt the questions were not clear and could be improved. Suggestions made by these colleagues were again noted and the necessary changes made. The pretest helped the researcher to ensure that the structured questions were fit for the purpose. Through this process, the researcher could identify and correct questions that respondents could misunderstand, questions that were ambiguous, unnecessary, missing and general reactions to the questions put to the test through pre-testing (Babbie & Mouton, 2001:119). The questions were also drawn such that they provided answers to the various research objectives.

Reliability means the consistency of measurements (Drummond, 2003:79). It is the extent to which data collection or analysis procedures yield consistent findings (Easterby–Smith *et al.,* 2008:109). The use of consistent and systematic questions during the interviews and in questionnaires was important for reliability and any possible replication of this study (Klaas, 2008:56; Berg, 2001:93). Data was also collected from reliable sources, that is, respondents like disaster risk managers and meteorologists who were experts in their own areas. Further to that, data was collected from flood victims. The instruments used had the same questions for consistency in eliciting data.

6.8 Trustworthiness

There are a number of methods that evaluate the rigor, assess the trustworthiness, establish credibility of qualitative data and critically appraise qualitative research

(Baxter & Jack, 2008:554). In this study, a number of elements (listed below) were integrated to enhance overall study quality and trustworthiness of the collected data:

- The main research question and sub-questions were clearly written and complimented by accompanying research objectives that were thoroughly satisfied at the end of the study. This was done as the researcher was under the supervision of other professional researchers who gave utmost and thorough guidance and advice on all the processes involved. The data gathering instruments were developed by using the six research questions/objectives. The purpose was to gather data that answered the overall research question.
- The survey design was found appropriate for the research questions and the study as discussed in Section 6.4.
- Purposive and convenience sampling strategies, appropriate for the study, were used and their use was discussed in Section 6.5.1 and 6.5.2.

The strength of this study also lay in the promotion of data credibility or truth value. This was done through mixing data types. As already alluded to, primary and secondary data sources were used as reflected in Section 6.7 of this chapter. Further to that, mixing of data sources took place. Quantitative data was collected from different data bases, as highlighted in subsection 1.7.1 in Chapter One. The data was used to analyse the historical view on the manifestation of flood disasters in selected SADC-countries in Section 3.2 of Chapter Three. Empirical data was also collected from different stakeholders who included government and private disaster management experts, both at local and national level. An account on the management of flood disasters was also collected from the victims of flood disasters. This was meant to compare and validate data from all these parties. In the data collection exercise, rapport was firstly established with participants on the date of arrival. This was done in order to create an atmosphere of friendship and trust. It made participants open up, feeling free giving their views openly without any mistrust of the researcher or the process. This in return enhanced the truthfulness of the data collected.

6.9 Data Organisation and Analysis

The data analysis process in this study involved activities that included data organisation, storage, retrieval and analysis. Extraction of meaning from the data and integrating it with the views of other authorities in the development of flood prediction models ensured that there was a generation of new knowledge. The processes involved are discussed below.

6.9.1 Data organisation

Data organisation refers to the method of classifying and organising data so that users find, identify, select and obtain the data they require (Berg, 2001:34). In this study, raw data was collected using recorded interviews and questionnaires. The data in questionnaires was in textual form and recorded interviews in voice form. However, the voice data was later transcribed into textual form by a professional transcriber. The textual data from the transcriptions, field notes and questionnaires was corrected and edited.

6.9.2 Analysis

Data analysis can be defined as the process of the systematic evaluation of data, using statistical, analytical and logical reasoning to describe, illustrate, evaluate and examine each component of the data provided (Jandagh & Matin, 2010:67). The process involves making sense out of textual or imagery data (Creswell, 2003:190). According to Ausband (2006:767), data analysis consists of three concurrent processes of data reduction, namely data display, conclusions and verification. These are discussed below.

6.9.2.1 Data reduction

Qualitative data comes in volumes, directing focus on simplifying and transforming raw data into a more manageable form. The process of doing that is referred to as data reduction. Data reduction means reducing and transforming qualitative data, making it readily accessible, understandable and developing themes and patterns (Johnson & Onwuegbuzie, 2004:22). In this research, data reduction and transformation was done by listening and transcribing recorded interviews into textual form. The process further continued with written summaries, identification of analytic themes and consideration of relevant theoretical explanations.

6.9.2.2 Data display/presentation

Data display involves presenting data in tables, tally sheets, graphs, pie charts, maps and summary statements, to mention only a few (Johnson & Onwuegbuzie, 2004:22). In this study, data presentation was made in textual form and through tables. This assisted the researcher in understanding certain data patterns, making analyses and interpretation of the data into information easy. Displaying data showed that data could be presented as an organised and compressed way of showing information. Data presentation allowed conclusions to be drawn and this in turn helped in answering the research questions and satisfied the study objectives (see Section 9.3 and 9.4).

6.10 Ethical considerations

Since the study involved gathering information from people, the researcher had to follow an ethical clearance process. The intended research process was cleared by the Ethical Committee of the faculty of arts at the North-West University, Potchefstroom and an ethics number, NWU-00131-12-S0, was issued for this study.

The researcher had the responsibility to do the enquiry openly, with honesty and in an ethically justifiable manner (Hedge, 1987:414). The rationale was to protect and preserve respondent's rights and dignity in this study (Jenkins *et al. 2003*, Price & Straker, 2003:46). A letter was drawn up to register their consent to participate (see Appendix D). The respondents signed the consent form only after being informed and assured that anonymity privacy and confidentiality were to be up held. The nature and purpose of the investigation was explained as required (Leedy & Ormrod, 2001:107). The research subjects were also informed of their right to withdraw from the study at any time. Respondents were also protected from any harm during data collection (Leedy & Ormrod, 2001:107). There was no discrimination based on gender as both men and women participated. The respondents were not influenced to give any particular responses to the study and the benefits of the research described to them.

6.11 Challenges experienced in primary data collection

The data collection exercise also had its limitations. It was not easy to quickly access the respondents because of processes the researcher had to go through to get authority to collect data. Some heads of sections were even afraid or hesitant to give such authority despite the fact that the researcher had a letter (see Appendix E) from the North-West University confirming that the researcher was a student doing research as part of his studies. This problem was faced both at national and community level. With patience the researcher succeed after following the required procedures.

In the communities, there were also cases where some participants saw themselves less knowledgeable and were afraid to take part. They were left out even if they had very useful information, as this exercise was solely voluntary. Some had a perception that the exercise was for purposes of food aid and other relief items. These participants did not volunteer to participate after realising that they would not receive any food. However, capable and information rich participants were identified with the help of the local leadership.

Other limitations on thte side of the communities were a language barrier and accessibility. The researcher could not speak the local languages. As such, it was not easy to obtain reliable impressions of the respondents. Even though the problem was averted by engaging interpreters to assist, it made the study more costly. Transport was also a challenge as it was very limited to and from some of the villages. Despite the above limitations, the researcher is confident that the study generated data which can add value and make a significant contribution to disaster risk management in general and flood prediction in particular.

6.12 Conclusion

In Chapter Six, the research methodology used in the study was outlined. The main research question of this study was "Which IKS considerations and existing dimensions of knowledge should be included in a flood prediction model to improve the functionality and efficiency of river flood predictions in the SADC-region, to reduce river flood risks?" In finding information to articulate the research question, the study mostly applied a qualitative approach, although some quantitative data were also required. The descriptive survey design was used, supported by two forms of sampling, namely convenience and purposive sampling. The data collection was done through structured interviews and questionnaires.

Four SADC-countries, namely Zambia, Zimbabwe, Botswana and South Africa were selected from the regional group as the study sample. Data collection focused on river flood disasters that had occurred over the past fourteen years from 2000 to 2013. Data gathering was carried out with the help of research assistants, one from each of the countries studied countries. Four communities were identified in the studied countries, namely Chanyanya Village in Zambia, Tokwe-Mukosi Village in Zimbabwe, Satau Village in Botswana and Tonga Village in South Africa. The communities identified were selected on the grounds that they are located along major rivers and experience recurrent floods that negatively affect the community members. The study used a total of 128 respondents comprising of Disaster Risk Managers, community leaders, community members, civil servants and Non-Governmental Organisation workers. The justification of methods used and challenges faced were also explained. Challenges included shortage of transport, language barrier and fear to give information by some community members. Ethical considerations related to this study were deliberated upon. These were Informed consent, right to privacy, honesty and integrity with professional colleagues and community report back and acknowledgement (see Section 6.10. and Chapter One, Section 1.11).

In Chapter Seven an analysis and interpretation of data gathered in the study are discussed. The oral voice and knowledge on managing and/or reducing river flood disasters which is a discussion on the findings from a questionnaire and interviews conducted among experts and affected communities is analysed. The chapter also looks at what governments have so far done to mitigate the effects of disasters in the SADC-region.

CHAPTER SEVEN: DATA PRESENTATION, ANALYSIS AND INTERPRETATION

7.1 Introduction

This chapter is a discussion of the empirical findings of the study. The empirical study was crucial in completing the study. It provided information and views necessary for the development of a comprehensive flood prediction model for the region.

In detail, the chapter provides an "*oral voice*" and knowledge on managing or/and reducing river flood disasters in the studied communities and at national level. It is a discussion on the findings from a questionnaire and interviews conducted among affected disaster risk managers, community leaders, social workers, development workers and communities respectively. The chapter looks at what governments and other stakeholders, including communities, have done so far to mitigate the effects of disasters in the SADC-region, as interpreted from the data collection exercise (primary data).

General information on the research participants, the importance of gender and community participation in this study are first presented. Thereafter, six themes whose formulation is based on the research objectives and questions are discussed. Furthermore, the presentation is in two categories, relating firstly to information collected from disaster risk managers from national platforms and secondly to the community composed of the general community members and community leaders/social/development workers based in the four study areas affected by floods. The research questions/objectives served as guiding points in the data gathering exercise of this study and the results are presented in this chapter. Apart from the general information on the research participants, themes deduced are discussed in the order of the study's research objectives as:

- Theme One : The prevalence of flood risk in the SADC.
- Theme Two : Government efforts in mitigating flood disasters.
- Theme Three : Research on river flood prediction possibilities.
- Theme Four : Flood prediction and models in use.
- Theme Five : Relevance of IKS in river flood prediction.

- Theme Six : Developing a flood prediction model for the region.

7.2 Biographical information

Data was collected from both male and female participants. The determination of the ratio of participants in terms of gender was important in this study. Gender was relevant as data was collected from people affected, who had experience of floods and flood management. Thirty two of the 128 respondents were females whilst 96 were males. Two women were interviewed whilst collecting data from disaster risk managers and 30 females completed questionnaires in the studied communities. More males were interviewed due to the fact that males were in leadership positions in communities/villages. That might also have been due to the sampling method where the community leaders were more comfortable to refer the male researcher to male participants. Male dominance could also indicate that communities practiced patriarchy in their villages.

7.3 The prevalence of flood risk in the SADC

This section deals with issues related to the prevalence of floods, the major floods and flood impacts in Zambia, Zimbabwe, Botswana and South Africa, using data collected from all the study participants. The primary data is also supported by information by various authorities from reviewed literature. The study period 2000 to 2013 had justifiable data/information that could be considered in evaluating flood effects and management and in coming up with a flood prediction model for the region. During that period, a number of floods with serious impacts in terms of loss of life, damage to property and infrastructure and the environment had occurred in these countries.

7.3.1 Zambia

The information under theme one relates firstly to the history of floods in the country as was sought by the research instruments attached as Appendix A, B and C of this thesis. Secondary data that is relevant and supports the primary data collection is also highlighted.

7.3.1.1 Flood prevalence

Disaster risk managers and other experts

The participants indicated that floods are prevalent in Zambia during the rainy season between December and February and mostly when the country receives above normal rainfall. The participants further stated that many floods are mostly common on the Zambezi, Kafue and Luangwa River. Responses on the criteria of a major flood varied and depended on the degree of damage, displacement of people and heavy rain flows into lowland and narrow areas of streams. According to one respondent, apart from being natural, *"floods in Zambia are also being influenced by human actions like deforestation, agricultural activities in flood areas, geographical locations, mining activities, dam overflows".*

These assertions by the respondents were supported by many authorities, who indicated the extent and impact of floods during the period under review. The authorities include the Centre for Research Epidemiology of Disasters database., 2013; Red Cross., 2013:2; Gannon *et al*., 2014:3; UNDP Zambia, 2007:1; Kasali, 2008:21; Kadomura., 2005:175; and OCHA., 2004; According to Mwape (2009:10), studies undertaken in Zambia around 2006, showed that the frequency of disasters increased rendering the poor populations more vulnerable. Bwalya (2010:v) also stated that Zambia had been registering floods of a high intensity and magnitude for seven consecutive years.

Community members

According to the respondents, Chanyanya community suffers from flood disasters between every two to four years. All the community respondents indicated that they had stayed in the village for a period of more than ten years. The respondents' long stay gives credibility to the study as all the information was collected from people who had first-hand information and experience of river floods. The respondents cited the possible causes of floods in the area as too much rain and settling in flood areas. This information from respondents shows that floods are a recurring phenomenon in the area under study. The people seem not to relocate despite the fact that they suffer from floods regularly. This goes to show that people are resilient and manage to stay in flood prone areas. According to Paton *et al.,* (2010:183), the growing risk of flood events that communities are faced with, has stimulated an interest in promoting people’s capability to live with floods. They therefore need help to co-exist with floods in their areas by means of effective flood risk methods. Their survival strategies need to be investigated, recorded and strengthened. Flood prediction becomes critical in helping the community reduce flood risk.

Literature reviewed indicated that frequent flooding is very possible in Chanyanya as the village is located on the banks of Kafue River in Kafue District (Kanyamuna, 2010:11). According to Ward (1978:2), communities put themselves at risk by settling in flood risk areas. In the view of Middlemis-Brown (2010:6), settling in flood prone areas has exposed human activities to flood risk. Apart from the factors identified by the respondents, flood authorities state that factors leading to river floods include a combination of the weather and soils conditions, measures for flood protection and land use (Barredo, 2006:5). More factors also include volume, intensity and duration of rains, the capacity of the water course or stream of network to convey runoff, ground cover and topology in a given area (Pawaringira, 2008:3).

7.3.1.2 Major river floods

Disaster managers and other experts

The characterization of a major flood by respondents varied and depended on the degree of damage, displacement of people and heavy rain flows into lowland and narrow areas of streams. According to one respondent, apart from being natural, “floods in Zambia are also being influenced by human actions like deforestation, agricultural activities in flood areas, geographical locations, mining activities, dam overflows”. Zambia had 12 major flood disasters countrywide according to the respondents. They stated that major floods were mostly found on the Zambezi Basin, Kafue Basin and Lower Zambezi area. The Chanyanya Community which was the subject of this study is located along the Kafue River in the Kafue Basin, one of the major flood prone areas in that country.

The information from respondents that Zambia suffers from a number of major river floods is also supported by literature, as indicated by Kasali (2008:5); APFM

(2007:7); WMO (2010:4); Lumba (2015); Smith (2009); Centre for Research Epidemiology of Disasters (2013) and Red Cross (2013:2). The impacts of these floods are analysed in Section 7.3.1.3.

Community members

The respondents indicated that they stayed or lived near and along Kafue River a major and perennial river in that area. The participants also stated that the community had last experienced major floods in 2013. The respondents in the village had exposure to major floods ranging from one to five times when the Kafue River flooded during the period under review. Many authors share the opinion that floods are caused by people when they develop land with fertile soils on floodplains (Dekens, 2007:vi; Chingombe *et al*., 2014:8). However, these floods are at times welcomed in many communities as they provide rich soil, water and a means of transport, but their unexpected scale with an excessive frequency causes damage to structures, livelihoods and the environment (ALNAP, 2008:1).

7.3.1.3 Flood effects/impacts

Disaster managers and other experts

Respondents confirmed that floods had negative impacts on communities as some of the floods were fatal. Homes and assets were affected including domestic animals of which many went missing or were washed away. According to a response by a participant "[*G]oats, chicken and cattle are submerged. Grazing areas are submerged too and at times livestock mix with wild animals".* The floods also had effects on the environment such as leaching, soil erosion, trees were uprooted and waterlogging that lead to disruption of farming activities.

The negative impacts of floods were also echoed when reviewing literature. A summary of flood effects in Zambia by authorities indicated that lives were lost, homes collapsed or were washed away, crops were submerged, agricultural fields were waterlogged, water was contaminated, there was increase in human diseases and infrastructure like toilets, water wells, schools, clinics, roads were destroyed or damaged and loss of livelihoods in communities that lived along the major river basins, Zambezi and Congo (Zambia Strategic Programme Document, 2011:1;

Gannon *et al*., 2014:3; OCHA, 2004; Kadomura, 2005:175; UNDP Zambia, 2007:1; Kasali, 2008:21). The information highlighted above clearly shows the negative impacts of floods thereby calling for increased efforts to reduce flood effects in Zambia.

Community members

Respondents in Chanyanya indicated that floods in the community ranged from minor to severe. Information gathered showed that between the years 2000 and 2013 about three people died due to floods. There were also damage and loss of property during flood events. Homes (some made of grass, pole and mud) and schools were submerged, livelihoods and school programmes disrupted. Livestock were also lost or drowned or were relocated or taken to friends who were safe. Because of this, some community members have decided not to keep livestock at all. Some of the respondents have gone to an extent of selling their livestock at give-away prices to avoid losing them. Crops were washed away during this period of floods. Some of the floods were fatal, causing a bad scenario that needs to be avoided. This has a negative impact on the community, societies and families, especially if the person who dies is a bread winner or a skilled person or professional. It affects the family or the community that depends on them and retards development in that village.

7.3.2 Zimbabwe

This section culminates in the consolidation of information by all the study respondents from Zimbabwe. The information relates to the history of floods which is followed by the other themes cited in the next sections.

7.3.2.1 Flood prevalence

Disaster managers and other experts

The respondents indicated that floods normally occur between October to March, when the country receives above normal rainfall. The country has many major rivers of which the two biggest ones are the Zambezi and the Limpopo. The rivers are classified as major because they affect communities living alongside and near them, causing damage to human settlements and property and affecting livelihoods. Manmade circumstances contributing to floods were cited as poor drainage in cities and dams, poor environmental practices leading to silting of rivers and settling in flood areas.

Literature reviewed showed that in Zimbabwe flooding is also caused by cyclones from the Indian Ocean (Chikoto & Sadiq, 2012:3; Madamombe, 2004:5; Gwimbi, 2007:155). The country has a long history of river floods dating back to 1955 and flood years were indicated from then to 2013 by many authorities (Musarurwa & Lunga, 2012:27; Bango *et al.,* 2013:2; Bola *et al.,* 2013:4; Centre for Research Epidemiology of Disasters, 2013; Mudavanhu, 2014:4). Due to the recurring number of floods in Zimbabwe, there is need for a paradigm shift from controlling floods to living with them (Spaliviero, *et al.,* 2011:753; Few *et al*., 2004:11; Shaw, 1989:13; Ralph, 1975:105; Rasid & Paul, 1987:170; Middlemis-Brown, 2010:6). Literature also revealed that people, who settle in flood risk areas, should be freed from being victims of a situation they themselves created (Penning-Rowsell *et al*., 2006:325; ALNAP, 2008:4; Few *et al*., 2004:11; Yoshiaki & Porter, 2012:30). Therefore, improving flood prediction in Zimbabwe goes a long way in reducing flood disasters.

Community members

There was an overwhelming response by respondents on the occurrence of river floods at tokwe-Mukosi community. Some of the responses were not specified in time frames but as general statements like *“once in a short while, during summer time, during heavy rains, occasionally and during December to January”.* However, most of the community members confirmed that Tokwe–Mukosi community experiences floods once in every four years. Therefore flood prevention measures must be improved. All the community respondents indicated that they had been living in the village for more than ten years and some since birth. In 2013, for those living upstream, the floods were caused by dam overflow and later on a dam burst and flooded those living downstream. Since data from communities points to the fact that these communities suffer from recurring floods, this goes to show that river floods are a problem in Zimbabwe. Floods therefore need to be effectively managed to reduce flood risk. It is the impact of these floods that this study intended to mitigate by developing a flood prediction model for the region. Thorough flood preparedness and mitigation to reduce flood risk are paramount in the region.

7.3.2.2 Major river floods

Disaster managers and other experts

According to the respondents, classification of major floods also depended on the degree of damage to property, settlements and displacement of people. Some also used flow lines and the size of the river like "*flooding of big rivers*" to classify the floods as major. These floods are major in Muzarabani, Save Valley, Limpopo, Gwayi, Manyame and Sabi catchment areas.

Major river floods were said to be experienced as one respondent put it *"in the traditional flood prone areas of the country, for example the catchments of Limpopo, Gwayi, Manyame, Sabi and Muzarabani an area in the Zambezi Valley"*. The Tokwe-Mukosi Community which was the subject of the community study is located in the Sabi catchment area, one of the major flood prone areas in the country. The number of flood disasters that were said to have occurred in the country during the period under study extended up to ten. The areas identified by respondents that experience prevalent floods are Middle Sabi, Muzarabani and Tokwe-Mukosi. The effects of these floods are discussed in section 7.3.2.3.

Community members

Respondents stated that floods are experienced from both the Tokwe and Mukosi River, mostly as a result of backflow water when the Tokwe-Mukosi Dam is filling up. The community last had floods in the area in 2013 as a result of the Tokwe-Mukosi dam overflowing and later bursting through its dam wall. The community members experienced flood events ranging from one to more than three during the period under study. It was also indicated by respondents that floods in Tokwe-Mukosi were so serious that most of the people who stayed around the area were forcibly and permanently relocated to other safer places by the government.

7.3.2.3 Flood effects / impacts

Disaster managers and other experts

In responding to whether people were affected by these floods, one of the respondents said *"Yes, there were displacements, deaths and injuries when huts/houses they were sleeping in collapsed due to excessive moisture. Some children missed schooling for quite some time as they could not cross flooded rivers whilst some villagers/communities were cut off from social institutions such as health and grocery shops".* Apart from houses and homesteads that were destroyed, the built environment comprising of bridges, schools and churches was seriously harmed. People's wealth, usually invested in domestic animals, was destroyed. Chicken, goats, livestock/cattle, sheep and even dogs were displaced, lost or killed after being washed away. In relation to animal loss, a comment made by a respondent was that *"The smaller animals were the most affected as they can be easily swept away by the floods, but cattle have a higher degree of resilience. It is not easy to get detailed reports on how animals are affected because the affected people do not normally report as there is no compensation for losing domestic animals. There is no compensation due to funding constraints on the part of government".* This statement highlights the challenges of funding, faced in flood risk management. Funding was an element that was included in the flood prediction model (see Figure 8.1). The environment is also affected as floods cause environmental degradation, increased siltation of rivers and changing of some river courses and water logging of crops leading to food shortages.

Literature review also showed the extent of flood effects. They included loss of life, destruction of homes and infrastructure, harming of agricultural land and loss of tonnes of stored food (Centre for Research Epidemiology of Disasters., 2013; Gwimbi, 2007:155; Tumbare, 2000:1; Kreimer, Arnold & Carlin, 2003:197; Madamombe, 2004:5 and OCHA, 2000). Serious measures need to be taken to reduce flood disaster effects and the number of people who become victims. Improving flood prediction models is one way of improving flood mitigation in Zimbabwe.

Community members

The magnitude of floods ranges from severe to fatal. During the period under review, it is said that more than ten people died in the Tokwe-Mukosi community due to floods. Flood severity and damages therefore need to be reduced to minimum levels.

Flood risk reduction methods like flood prediction among others are important. The community respondents also indicated that they suffered flood damages to their homes which were submerged, animals drowned and crops under cultivation were destroyed. They also lost household goods or furniture such as kitchen utensils, beds, tables and chairs. Furthermore, they also suffered social disturbances as families were separated. Sanitation facilities became unserviceable leading to the spread of diseases. Most homes are built from grass, pole and dagga making them weak structures which cannot resist flooding and easily gives in. In order to improve the resilience of flood victims, structural measures with regard to structures and building material need to be strengthened, along with other measures like flood prediction.

7.3.3 Botswana

This section dovetails to the consolidation of information by all the study participants from Botswana. The information reveals the history of floods in the country.

7.3.3.1 Flood prevalence

Disaster risk managers and other experts

Botswana suffers from floods and they occur "*nearly every year*", according to one of the respondents who has been a disaster risk manager for more than five years. Information gathered from this group of respondents indicates that the main criterion of a major flood is the notion of *"an area with continuous floods*". The unnatural circumstances that contribute to floods in that country were cited mostly as settling in flood plains. The respondents cited a number of manmade circumstances that contribute to flooding. These include building and settling in flood plains or catchment areas, damming, poor town planning, drainage and deforestation. What this means is that management of river floods has to be comprehensive. Flood impacts will be reduced in Botswana if the focus shifts to the management of forests or trees, agricultural methods, town planning and environmental issues.

Literature reviewed showed that most of the rainfall occurs during the summer months from November to March with January and February generally regarded as the wettest months (Fermet-Quinet *et al*., 2010:10). The country has an area known as the Okavango Delta that floods annually. The Okavango Delta gets two thirds of its annual flood waters from Angola (Molefe *et al., 2014:* 27). Seasonal flooding is also influenced by local rainfall (McCarthy *et al*., 2000:25). The history of floods from 2000 to 2013 was cited by various authorities, namely Batisani (2011:420); Centre for Research Epidemiology of Disasters (2013) and Mosate (2010). The impacts of these floods are highlighted in sub-section 7.3.3.3.

<u>Community members</u>

The community respondents indicated that Satau Village experiences recurring floods every one to two years. Respondents had been staying in the village for more than ten years. This indicates that they probably witnessed two to three floods during their lifetime. The possible causes of flood disasters were identified by community respondents as too much rain, staying in flood risk areas and poor housing structures. The study area last had floods in 2012. Improving flood prediction will help people to make informed decisions before a flood, thereby reducing flood risk. Respondents indicated that too much rain was a major cause of floods in that community.

Literature reviewed on Botswana indicated that floods were mainly caused by heavy rains although some floods were brought by shared rivers from other countries in the region (National Disaster Risk Reduction Strategy, 2013-2018:15). Other reasons for too much floods include deforestation, improper land use planning, inadequate structural and non-structural flood measures (Carmo vaz, 2000:15; Tingsanchali, 2012:25; Chisola, 2012:15).

7.3.3.2 ***Major river floods***

<u>Disaster managers and other experts</u>

Respondents stated that major floods in Botswana occur in the Chobe and Okavango areas. The respondents indicated that the country had experienced five flood disasters since 2008 which affected many people. Satau Village which was the subject of this study is located along the Chobe River, in one of the major flood prone areas in the country. However, literature review showed that there were major floods in the 1999/2000, 2004, 2009, 2011 and 2013 rain seasons (Centre for

Research Epidemiology of Disasters, 2013). The impacts of these floods are analysed in section 7.3.3.3.

Community members

The community members who participated in the study had been staying in Satau Village for periods ranging from ten to over sixty years. The Chobe River floods the area and the respondents experienced from one to more than five floods during the period under review. Therefore thorough flood preparedness and mitigation to reduce flood risk are paramount in the area. Flood prediction becomes a good starting point among other processes.

7.3.3.3 Flood effects / impacts

Disaster managers and other experts

The effects of floods in Botswana were that people were displaced and government buildings, people's homes and schools were damaged. Community members lost goats and cattle as they were submerged. The environment also got affected *"as trees were submerged and many dried up",* as stated by one respondent.

Literature review also supports the view that floods in Botswana have negative impacts on communities. They have caused loss of life and displacement of people, damage to crops and death of animals (Botswana Country Report, 2004). They also caused extensive damage to public and private infrastructure, assets and the environment (Batisani, 2011:420). Botswana consists mainly of desert, but it is periodically affected by serious and fatal floods. Therefore Botswana needs to review and improve its disaster risk management approach. Local practices such as relocating valuable assets from flood areas, construction of platforms to protect livestock, planting water/flood resistant crops and early warning can reduce the impact of floods in the communities (Basongo, 2010:6). In order to eliminate flood risk in Botswana, adaptation to living conditions is a good strategy when it comes to flood risk reduction. Improving flood prediction methods can definitely help communities to adapt to living with floods.

Community members

The magnitude of floods in Satau Village ranges from damaging to severe. It is said that two people died as a result of floods in the area between 2000 and 2013. As with other studied countries, the community lost crops and livestock like cattle and donkeys due to floods. Homes were also damaged or destroyed including various household products/property. The people also lost cash and clothing items. The floods destroyed the fields and thus affected crop production. The majority of people in this community are farmers and farming is their livelihood. According to one respondent *"villages become inaccessible as they are surrounded by water and they fail to receive essential service".* Some of the houses are built of reed and grass which is not strong material to resist floods.

7.3.4 South Africa

This section consolidates information by the study respondents from South Africa and elaborates on the history of floods in this country.

7.3.4.1 Flood prevalence

Disaster managers and other experts

South Africa experiences floods nearly every year and "*a number of them is major*", according to one respondent. Major floods are classified according to flow lines. Related to that, another responded stated that *"A major flood is the kind of flood that results in declaration by national government as a disaster in an area where it occurs"*. Respondents indicated that unnatural circumstances contributing to floods included damming, poor drainage, poor town planning, building in catchment areas, dam failures and structural failures.

The literature study shows that South Africa has a long history of floods, dating back to 1847 and during the time period of this study, floods were occuring from time to time (Tempelhoff *et al.*, 2009:98; Odiyo *et al.*, 2011:4; Centre for Research Epidemiology of Disasters, 2013; Smithers, 2011:1; WMO, 2013:14). The country is also affected by cyclones (Davis, 2011:18; Vyas-Doorgapersad & Lukamba, 2012:777; WMO, 2012:4).

Community members

Tonga Village experiences floods along the Komati River once every one to three years. The possible causes of flood disasters in this village were identified as too much rains, poor housing structures, settling in flood risk areas and no flood prevention measures. The community last experienced floods in 2013. Since too much rain is clearly indicated as the leading cause of floods in South Africa and the other countries under study, it justifies this study as it seeks to develop a flood prediction model for the SADC-region.

7.3.4.2 Major river floods

Disaster managers and other experts

Respondents indicated that rivers that mostly experienced major floods in South Africa are the Vaal River, Orange River, Oliphant's River, Crocodile River, Limpopo Rriver, Kei River, Komati River, Tugela River and Pongola River. During the period of study, the country was said to have experienced more than 12 floods. Tonga Village, which was the subject of this study, is located along the Komati River in Mpumalanga area, one of the major flood prone areas in the country. Literature reviewed showed that the country experiences major floods nearly every year. Most of the floods in South Africa are fatal (Centre for Research Epidemiology of Disasters, 2013). The impacts of these floods are analysed in section 7.3.4.3.

Community members

At the time of the study, the community respondents had been staying in the village for a period of more than ten years. The area was confirmed to be a flood area as the village is built along and around the Komati River. The respondents experienced from one to more than five floods in the area/village during the time period of the study. The community therefore needs help to co-exist with floods in their areas through effective flood risk methods such as improved flood forecasts.

7.3.4.3 Flood effects / impacts

Disaster managers and other experts

The information collected revealed that floods had serious impacts on the affected communities. According to one respondent *"many houses were washed away, people lost their lives. In the last floods more than 33 people lost their lives across the country".* Furthermore, bridges were also damaged and domestic animals were affected as "*some are struck by lightning, some washed away by floods, some drown, some get stuck in the mud and die there"* according to another respondent. The floods also had effects on the environment *"to a very high degree, the environment gets eroded, livelihoods are lost, there is siltation, inundation and the infrastructure damaged"*, as stated by another respondent.

A literature review indicated some of the serious impacts of floods in South Africa. These include flooding of shacks in low-lying flood areas, damage to roads, housing, bridges, dams and sewerage infrastructure. Villages were cut off from clinics and household water supply was polluted causing diarrhoea. Farmland and equipment were severely affected and animal diseases became widespread. Education was disrupted because teachers and scholars were cut off from their schools by the floods. Crops were devastated and people displaced (Centre for Research Epidemiology of Disasters, 2013; NDMC Annual report., 2006/2007:130-131; SA Country report., 2011; FAO/GIEWS Global Watch, 2011; Zimela, 2011 and WMO, 2013:14).

Community members

According to the community respondents, floods in Tonga Village range from minor to fatal. The good thing about flood prediction is that it enables flood warning which in turn makes people decide on what to do before floods occur. The total number of people who died between 2000 and 2013 due to floods was estimated to be ten. Apart from destroying homes and infrastructure like roads and bridges, people lost boats, canoes, computers and DVDs. Crops and livestock were washed away. Some took their livestock for safekeeping at friends. The floods also affected farming activities because some fields are along the river. Floods in Tonga Village and the other areas under study, as well as the SADC- region are seriously impacted as people are losing lives and their property. This information collected during the empirical study in Tonga Village is consistent with the secondary data collected in Chapter Three of this study. Floods destroy people's homes, livestock, crops and livelihoods, infrastructure and displace people.

7.3.5 Summary on the prevalence of floods in the studied countries

Data and information collected from the countries under study through both secondary (see Chapter Three, Section 3.2.3 to 3.2.6) and primary data collection, generally shows that these countries and communities have a high prevalence of floods that are distructive to human life, infrastructure and activities. This high prevalance of floods and their degree of impact was one of the motivations behind this study with the ultimate aim of reducing flood disasters and their negative impacts. Chapter Two, Section 2.2.1 put into picture Disaster Risk Management (DRM) in the context of flood risk reduction. Some important concepts and words were defined, discussed and analysed. On of these words and concepts is mitigation. According to Lemeko (2011:9), flood mitigation is a process of assessing risks from floods and using the information to implement flood risk mitigation measures. In this study, flood mitigation is defined as the process of lessening or limiting the adverse effects of river floods. Since the adverse impacts of floods cannot be fully prevented, their scale or severity can to a great extent be lessened. Therefore this study can be used as a mitigation strategy within which an attempt is made to develop a flood prediction model. The model will provide information as to when people should expect river floods, thereby enabling them to take preventative measures to avoid loss and other flood effects. Flood mitigation and prevention is included in the flood prediction model in Chapter Eight, Figure 8.1.

7.4 Government Efforts in Mitigating Flood Disasters

This section looks at Government's participation in the countries under study when it comes to flood risk management. Areas that were covered included the Government's mandate, disaster management structures, disaster legislation and funding.

7.4.1 Zambia

Information collected in Zambia showed that the government is taking action to reduce the effects of flood risk. These efforts are discussed in the following sub-sections.

7.4.1.1 Government and community involvement in Disaster Risk Management

Disaster managers and other experts

The respondents indicated that the Zambian Government was involved in disaster risk management, through the Disaster Management and Mitigation Unit (DMMU), which had a coordination function. They also indicated that the DMMU managed disaster camps, evacuates flood victims and was involved in DRR training and preparedness and awareness programmes. In order to co-exist with floods and be resilient, respondents indicated that flood risk communities were being encouraged to grow rice in some of the flooded areas. The communities were also encouraged to keep ducks instead of chicken as part of their livestock and to use early maturing crops. The attitude of the Government towards disaster management was said to be good and positive. According to one respondent *"the attitude is good, but there are problems of information sharing, politicians override technocrats decisions and people listen more to politicians".* This is a drawback and people will miss out on expert knowledge regarding disaster risk reduction. This therefore calls for political will or commitment.

Community members

Responses from Chanyanya Village indicated that Government was playing an active role in flood mitigation. They have a disaster management office 30 to 40km away that they can access. The community also has a resident Development Officer who is always there to assist on flood related issues. After floods, the Government provides affected community members places to stay, safe learning centres for school children as well as a health centre. The Government also *"provides information in terms of warnings of eminent flood disasters, followed by movement of people to safer places".* Other respondents pointed out that nothing was being done in terms of mitigation. These sentiments by some of the respondents cannot be ignored. If Government is indeed active in flood risk reduction activities, it has to do more so that they satisfy disgruntled community members. More Government activities on flood risk reduction as indicated by Chanyanya community respondents are summarized in Table 7.1. The table shows actions before, during and after flood disasters.

Table 7.1: Zambian government flood risk management activities before, during and after floods

Period of activity	**Type of activities: Zambia**
Before floods	Education and sensitization. Talk to people on how they can protect themselves. Reach out to the people and forewarn them. Flood risk assessment.
During floods	Government and NGO embark on programmes of providing relief in terms of food, medical supplies and tents to the needy. Relief is provided to the victims. Move them to higher areas. Relief support is sustained.
After floods	Providing food relief and tents. Giving community education. Relocation to permanent and safer higher areas.

Source: Author's depiction, December 2015.

The responsibility to mitigate flood effects for the Chanyanya community was placed on the Government, private organisations and other stakeholders. In such a scenario, communities have to be part of the process. They need to be involved and should be aware that they are important stakeholders in flood risk management (see Figure 8.1). In Zambia, the protective measures against flood disasters that were taken by the respondents from the Chanyanya community, included moving away from the flood prone places, developing drainage systems or furrows to protect houses, taking heed of Government advice to move to safer places (i.e. less flood prone areas), shifting permanently to a safe place away from flood dangers and moving from lower places to higher places where floods cannot reach them.

7.4.1.2 Disaster management structures

Disaster managers and other experts

The Government has disaster management structures at National, Provincial, District and community/satellite level. These structures are coordinated by the Government through the Disaster Management and Mitigation Unit (DMMU). The National Disaster Management Committee is composed of Permanent Secretaries, the DMMU, Meteorologist, Hydrologists, NGOs, Red Cross and Stakeholders (civil and private community). By means of these structures, the community is involved in disaster management at satellite level represented by teachers, headmen, councillors and agricultural officers. According to the literature reviewed, Zambia has administrative structures for flood risk management. In the community structure, members are also encouraged to keep ducks instead of chicken as part of their livestock and to use early maturing crops.

Linked to these primary findings from the respondents is the secondary data as outlined in Chapter Two, Sections 2.3.4.1, where it is stated that Zambia has disaster management structures at national, provincial, district and community levels. The country has contingency plans for floods each and every rainy season (Zambia National Contingency Plan for floods, 2009:iii; Zambia Disaster Management Act 13/2010). Act no.13/2010 further sanctions the formation of structures like the National Disaster Management Council of Ministers and its functions, the National Disaster Management Technical Committee and the Disaster Management Information System that maintain early warning information. The DMMU opened offices in all the nine provinces of the country (Mulenga *et al.*, 2011:3). The country also established the Zambia climate change facilitation unit which is responsible for the development of the climate change profile and adaptation policy (Becker *et al*., 2013:4).

Community members

In Chanyanya Village, the respondents indicated that their community held flood planning meetings. Some of the respondents confirmed attending these meetings that were chaired by any one of the community leaders including the Village

Chairman, Headman, Councillor or leaders from the Safety Committee. They also indicated that at times their inputs during the meetings were accepted and integrated in the flood plans. At these meetings, people discussed and educated each other on flood effects, dangers and protection, especially the best ways to avoid floods (particularly the children). The community members also discussed and advised each other to evacuate to safe places when floods were imminent. Structural measures or ways to prevent floods like constructing drainage systems and temporal structures for life protection were also discussed. When flooding occurs, the community has a shelter or plan of action which includes making furrows for drainage moving and being temporarily accommodated at the school and church. Some get accommodated on the football pitch where tents are erected with the help of the Government and other stakeholders.

7.4.1.3 Disaster legislation and Funding

<u>Disaster managers and other experts</u>

According to the respondents, the country has disaster legislation mainly in the form of the Disaster Management Act of 2010. The legislation focuses on disasters in general and does not specify flood management. The respondents stated that they did not know of and were not sure about penalties that were provided if flood management rules and regulations were flouted. In relation to funding, the Government of Zambia has contingency plan funds for disaster response. Unfortunately it appears that the fund is not used for funding pre-disaster activities like mitigation. Apart from government funding, one respondent indicated that the Red Cross in Zambia also helps the government and has a Disaster Relief Emergency Fund for flood victims.

Literature reviewed in Chapter Two, Section 2.3.4.1 indicated that the country had a legal framework in the form of the Disaster Management Act No. 13/2010 used for managing disasters (Zambia Disaster Management Act 13/2010). The act gives guidance as to how to prevent and mitigate disasters and also provides for the establishment of the National Disaster Relief Trust Fund and a framework for its management. This law further provides for the establishment of an institutional framework referred to as the Disaster Management and Mitigation Unit (DMMU) which has specified powers and functions (Zambia Disaster Management Act 13/2010:81). The country also manages the environment and natural resources through the Environmental Management Act (EMA), No 12 of 2011, National Conservation Strategy of 1985, National Environmental Action Plan of 1994 and the National Policy on the Environment of 2007 (Campbell *et al.*, 2010:9; EMA, 2011; Walmsley & Patel, 2011:461) (see Chapter Two, Section 2.3.4.3).

7.4.2 Zimbabwe

As already discussed in section 7.3.2, Zimbabwe also suffers from flood disasters. Information collected shows that Government is making efforts to mitigate the impacts of floods. These efforts are discussed in the following sub-sections.

7.4.2.1 Government and community involvement in Disaster Management

Disaster managers and other experts

The Zimbabwean Government is not standing idle doing nothing about flood disasters in the country. The national perspective on the management of flood disasters was discussed from a literature point of view in Chapter Two, Section 2.3.4.4. The fact that the state is making efforts to reduce flood risk in the country is complimented in this section by the various respondents. This can be shown by some of the operations and objectives of the Civil Protection Unit (CPU). One of the respondents in an interview stated that *"The government has the primary and sovereign responsibility to protect its citizens against any natural or human induced disaster. One of the functions of the Department of Civil Protection is to raise awareness on rainfall hazards through conducting public awareness campaigns in flood prone areas (i.e. schools and communities). We developed an operational guide of management of flood emergencies for the Civil Protection Organisation in Zimbabwe. We also coordinate the activities of responders of flood emergencies in line with our mandate derived from the Civil Protection Act of 1989. We are also involved in reconstruction and rehabilitation of affected elements".* This indicates that Government is at least involved in flood risk reduction activities in the form of awareness campaigns and also flood response.

Further to that, the respondents stated that all flood prone or at risk communities have Disaster Risk Management (DRM) plans which are developed with their participation following some DRM training. The use of IKS is also recognised and encouraged by the Department of Civil Protection and partners/stakeholders so that communities can co-exist with or be resilient towards floods. Through the use of IKS, at risk communities are able to share or disseminate early warning systems for prompt emergency response.

Review of literature also indicated that Government is taking actions towards disaster risk management in Zimbabwe (see Chapter Two, Section 2.3.4.4). According to Madamombe (2004:4), flood mitigation by the Government includes the implementation of structural measures like the building of dams to store runoff. The amount of runoff/discharge in rivers is reduced when storage is available. Furthermore, the country also does flood forecasting, rescue operations and the resettling of flood victims. During the rainy season the meteorological office issues weather forecasts, predicts the amount of rainfall and the possibility of floods. The information is then disseminated to potential flood risk communities by authorities like the Meteorological Office and Civil Protection Unit. The unit is also engaged in resource mobilization, information dissemination and training for disaster response activities (Chikoko & Sadiq, 2012:8; Madamombe, 2004:5).

Community members

The Tokwe-Mukosi community members indicated that government is also playing a role in mitigating flood risk. They chair flood sensitisation meetings and issue warnings. They also evacuate flood victims, offer food and alternative shelter. The area also has a Civil Protection Office at Ngundu about 40km away that assists with awareness campaigns and evacuation during floods. Other respondents pointed out that nothing is being done in terms of mitigation. This becomes a challenge and Government has to do more in terms of flood risk reduction to be effective. One good strategy for Government’s work to be recognised is to involve the flood risk communities in flood risk programmes. More government activities on flood risk reduction as indicated by Tokwe-Mukosi community respondents are summarized in Table 7.2. The table shows actions before, during and after flood disasters.

Table 7.2: Zimbabwean government flood risk management activities before, during and after floods

Period of activity	**Type of activities: Zimbabwe**
Before floods	Holding sensitisation meetings, flood awareness campaigns, flood warnings.
During floods	Provision of basic needs like food supplies, buckets, soap and blankets.
After floods	Supplying inputs and distributing food. Helping with transport and shelter. Engaging other stakeholders to help with food, shelter and other necessary supplies.

Source: Author's depiction, December 2015.

According to the community respondents in Tokwe-Mukosi Village, flood prevention and mitigation is the responsibility of many parties that include Government, other stakeholders and the community. The community members indicated that they built strong structures, relocated from low lying areas to higher grounds, made use of experienced builders in the construction of new houses, stayed on high ground in stronger structures as protective measures against floods. They also reinforced structures to withstand future shocks and they indulged in proper farming methods. "*We store enough food supplies and protect ourselves against water borne diseases*", as stated by one respondent. However, there were respondents who said that they had no means to engage in protective measures. These community members should be approached first as they will not be able to help themselves in DRR activities.

7.4.2.2 Disaster management structures

Disaster managers and other experts

The Government of Zimbabwe has disaster management structures in place. The levels of disaster management include the National and Provincial district. There are also community civil protection structures like district and ward committees whose membership is multi-sectoral. The structures are coordinated by the relevant Ministry of Local Government systems, for example at national level it is the Director Civil Protection, the Provincial Administrator at Provincial level, the District Administrator at District level and Councillors at Ward/community level. The structures have a multi-sectoral composition. At national level all traditional ministries are represented. There are also selected Parastatals that include National Aids Council (NAC), Zimbabwe Electricity Supply Authority (ZESA), National Railways of Zimbabwe (NRZ), District Development Fund (DDF), and Environmental Management Agency (EMA). A representative of tertiary institutions, private sector, United Nations (UN) agencies, Non-Governmental Organizations (NGOs) and Zimbabwe Red Cross Society (ZRCS) make up part of the composition.

At Provincial level, the disaster management committee is comprised of all heads of Ministries, Parastatals, Private Sector, representatives of Faith Based organisations, NGOs, Zimbabwe Red Cross Society and a Local Authority representative. At District level, the same committees are also made up of all heads of Ministries, Parastatals, Private Sector, NGOs, Zimbabwe Red Cross Society, Local authority and a representative of Faith Based Organisations. Lastly, at Community level, there are Local government structures, Government extension workers, Community Based Organization (CBOs), NGOs, Local Authority representative (Councillor) and a representative of Faith Based Organizations, Community leader and community members. At this juncture it is pleasing to note that the disaster management structures also involve or include community members and village heads in their composition. This goes along with one best practice in DRR which encourages community involvement in disaster risk reduction problem identification, problem solving and decision making.

Reviewed literature on disaster management structures in Zimbabwe (see Chapter Two, Section 2.3.4.4) indicated that Disaster Risk Reduction in Zimbabwe is the responsibility of the Department of Civil Protection, under the Ministry of Local Government, Rural and Urban Development (Becker *et al.,* 2013:4). According to Chikoto and Sadiq (2012:8), Zimbabwe has institutions that are responsible for disaster management activities at National, Province and District levels. Chikoto and Sadiq (2012:1) also highlight the formation of this institution by saying that the Government of Zimbabwe created the Department of Civil Protection through the

Civil Protection Act (1998) and charged it with the onus of coordinating and managing disasters and reducing hazards. The Civil Protection Organization of Zimbabwe has the overall responsibility of the management and coordination of flood emergencies (Pawaringira, 2008:5). The department appoints officers at national, provincial and district levels as heads and chairs civil protection committees that assist in planning, implementing and evaluating disaster management response programmes (Chikoko & Sadiq, 2012:8). The working party has sub-committees, namely the early warning unit, weather and flood forecast represented by experts from the Meteorological Department and the Zimbabwe National Water Authority, the rescue and security sub-committee represented by professionals from the Zimbabwe Defence Forces, Zimbabwe Republic Police, Civil Aviation and Ambulance services and the health and social services unit represented by members of the Ministry of Health (Pawaringira, 2008:5).

The Civil Protection Unit therefore overseas the management of disasters whilst the Meteorological Services Department issues weather forecasts (Gwimbi, 2007:152). The Directorate of Civil Protection under the Ministry of Local Government, Public Works and National Housing handles the disaster risk reduction function (Tau, 2014:12).

Community members

The Tokwe-Mukosi community holds flood planning meetings that are chaired by either the Councillor, Village Heads and Health Workers. Some of the respondents confirmed attending these meetings whilst some did not. All community members should be encouraged to attend flood planning meetings so that flood risk reduction improves within that community. At these meetings, there are flood risk awareness campaigns and people are educated on flood mitigation measures and preparedness methods. They are also educated on flood warnings and evacuation procedures. Those affected also register for relief assistance. The community furthermore has a plan of action and shelter when the area floods. The community evacuates and is sheltered at the schools and clinic.

7.4.2.3 Disaster legislation and Funding

Disaster managers and other experts

From responses it was indicated that the country has disaster legislation mainly in the form of the Civil Protection Act of 1989 which empowers the Department of Civil Protection with the overall coordination of disaster risk management actors. In addition to this, almost all Ministries and key Parastatals administer acts with DRR provisions. The Civil Protection Act is being revised for comprehensive Disaster Risk Management (DRM). The DRM Bill is undergoing the normal regulatory processes by the Attorney General's Office. There is the draft national DRM strategy which will be legal once the DRM Bill becomes law. The Civil Protection Act has provisions for a multi hazards approach. In general, disaster legislation in the country has rules on human settlements but lacks enforcement.

According to Section 29 of the Civil Protection Act, disaster management is funded in the country under the National Civil Protection Fund. However, with regard to funding, one of the respondents stated that "*the Department of Civil Protection is supposed to maintain and administer the National Civil Protection Fund but most of the times funding is too little to cater for affected people*". This statement indicates that there is funding but it seems as if the funds are only used to respond to disasters. What this might entail is that disaster management is more focused on response activities. This view is supported by one of the respondents who stated that disaster management is "*reactive most of the time*" and funding is not even enough for these response activities. From the information gathered it is indicated that families are given only one hundred dollars (US$100.00) in the event of damages, injury or any loss, provided there is money in the fund. This information brings another dimension to the issue of funding, that even if there is provision for funding at times, the funds are not available. What this means is that the government has to make serious considerations when it comes to funding disaster response let alone disaster risk management.

Tau (2014:212) stated that the Zimbabwean Government has promulgated and adopted the following frameworks as legal structures for disaster risk management: the Civil Protection Act 1989; The National Disaster Risk Management Policy of

2011 and The Zimbabwe National Contingency Plan 2012 – 2013. The Civil Protection Act (Chapter 10:06) spells out the legal instruments for disaster management as well as the power that individuals and organisations have during flood disaster events (Government of Zimbabwe, 2005). The Act defines a disaster as *“a natural disaster, major accident, disruption of essential services, destruction, pollution and scarcity of essential supplies, refugee influx, epidemic or disease that threaten the wellbeing and lives of people”* (The Civil Protection Act, 2001). The National policy for disaster management in Zimbabwe is that every citizen of the country should assist wherever possible to avert or limit the effects of disaster (Madamombe, 2004:9). The Civil Protection Act gets support from sections of the Police Act, the Defence Act, Rural District Councils Act, Regional Town and Country Planning Act, Public Health Act and the Environment Act (Mahonda, 2011:39).

7.4.3 Botswana

Botswana also suffers from flood risk. Information gathered in this study shows that the Government is making efforts to mitigate the impacts of flood risk. These efforts are discussed in the following subsections.

7.4.3.1 Government and community involvement in Disaster Risk Management

<u>Disaster managers and other experts</u>

The Government of Botswana is involved in flood management through its Department of Water Affairs but the handicap is funding such activities. Communities are encouraged to co-exist with floods and be resilient to flood effects through awareness campaigns and meetings. Since 2011, the Red Cross in that country has been working with communities along the Zambezi River basin in the region, enhancing disaster preparedness, strengthening community capacity on early warning systems, implementing small-scale resiliency projects such as improving drainage in flood-prone areas, helping to flood-proof homes and planting trees to slow erosion and storm runoff (IFRC: Botswana, 2010).

Literature shows that the Government is also involved in the conservation of forestry reserves as forests are very important in controlling floods and bind soils from erosion (Walmsley & Patel, 2011:87). It also governs the management and utilisation of forest resources and the protection of forests from fires. Forest Management can arrest soil degradation and manage water runoff, thereby reducing flood impacts (Sathaye, 2007:727). The Government also has a National Development Plan (NDP), which identifies and integrates issues relating to the environment and sustainable development, Environmental Impact Assessments (EIA) legislation and the development of management plans for some priority ecosystem areas (Government of Botswana, 2002).

Community members

In Satau Village, the government provides food and tents and helps to relocate flood victims. ”*They also come with their volunteers to help the communities*”, according to one respondent. They influence or encourage the community to build on highlands and repair damaged roads. They also bring education programmes ”*teaching some of the youths about flood disaster on how and what they must do to stop death and diseases*”. Apart from the Government, organisations like the Red Cross also relay flood prediction and warning messages. More government activities on flood risk reduction as indicated by Satau community respondents are summarized in Table 7.3 below. The table shows actions before, during and after flood disasters.

Table 7.3: Botswana government flood risk management activities before, during and after floods

Period of activity	Type of activities: Botswana
Before floods	Advises them to relocate to higher places.
During floods	Helps them to get some of their goods out of the floods. Offer accommodation and food. Gives shelter to those whose compounds are affected. Gives tents, food and helps them to relocate. Advises them about and shows them flood dangers. Provide shelter (tents) and blankets.
After floods	They provide food, help in rebuilding homes and infrastructure.

Source: Author’s depiction, December 2015.

The protective measures that were taken by the respondents included reminding each other to be alert, managing themselves after floods, building on highlands or high ground, building houses using bricks, cement and corrugated iron and relocating the grazing area. They also watch water levels on rivers or use water level warnings from the Department of Water Affairs. The community also blocks and diverts water with divert walls and sand bags during floods. In relation to these safety measures, one respondent stated that "*we relocate to higher grounds during flood seasons on a temporary basis observing the water level in our rivers, dams and neighbouring country*". The community also has a plan of action where "*tents are provided to affected people during floods and people are moved to areas on higher ground until the water has subdued but most of the locals don't want to move*", according to another respondent.

7.4.3.2 Disaster management structures

<u>Disaster managers and other experts</u>

Botswana has disaster management structures at National, District and Village level, comprising of committees. One respondent disclosed that the structures are composed of "*Government officials, chiefs, traditional leaders, social workers, councillors and community members*". District commissioners and administrators coordinate the disaster management committees. Communities are also involved in these committees but at village/local level.

Complimenting the above information from respondents, the country has an institutional framework for Disaster Risk Management (see Chapter Two, Section 2.2.4.7) covering three levels of management, namely national, district and village (Botswana National Disaster Risk Management Plan, 2009:10). The overall coordination of the flood response rests with the Government's Office of the President, through the National Disaster Management Office (Botswana Country Report, 2004:3). The SADC-region and Botswana national organisations like the Department of Water Affairs (DWA) and Department of Meteorological Services (DMS) carry out country hydro-meteorological observation.

The country has also been included in the World Meteorological Organization's (WMO) Hydrologic Cycle Observing System (HYCOS), a network of stream-gauging stations that report in real-time format through SADC networking (Turnipseed, 2003:3). The Department of Meteorological Services (DMS) which has an operational forecasting role and the Department of Water Affairs (DWA) which gives stream flow data, both provide critical hydro-meteorological data to the National Disaster Management Office (NDMO) who then incorporate all this data into their messages as information to the public. Recognising that there were limitations, inadequacy and untimely hydrological and meteorological information which is crucial to decision makers at national level, USAID, an international organisation, also initiated the Village Flood Watch project in Botswana (Turnipseed, 2003:3).

The country is also guided by a National Disaster Risk Management Plan. This plan has its roots in the National Policy on Disaster Management (1996), Finance and Audit Act (1996) and Hyogo Framework of Action (2005-15). The plan provides guidelines to plan and implement disaster responses, identifies risks and reduces vulnerability in the contexts of various hazards, defines management structures through which disaster risk management is to be implemented, coordinates, facilitates and identifies roles and responsibilities of Government and non-Government actors for disaster risk assessment, preparation and risk reduction.

Community members

In Satau Village, they hold Kgotla meetings where they discuss and educate each other on issues relating to flood predictions, warning and other similar issues. The Village also has a disaster committee in the flood prone area. According to Magole *et al. (*2009:10), communities in the Okavango Delta have a Disaster and Environmental management plan, the Okavango Delta Management Plan (ODMP), which is pro-active in its implementation. They have a committee, namely the Okavango Wetlands Management, which is composed of representatives from the government, civil society, communities and other stakeholders. Communities or villages select or elect community/village focal persons to represent them in all planning and implementation activities.

7.4.3.3 Disaster legislation and Funding

Disaster managers and other experts

The country did not have specific disaster management legislation at the time when the study was carried out and "depended on other legislation". The Government relies on the National Policy on Disaster Management of 1996, the National Disaster Risk Management Plan of 2009 and other Sector Specific Legislation (Acts) like the Environmental Assessment Act No. 10 of 2011 and Environmental Assessment Regulations of 2012 to manage disasters in that country (see Section 3.2.5.1). The secondary legislation the country uses *"provides penalties if flood management rules and regulations are broken"*. Among the countries under study, Botswana is the only country which does not have proper disaster management legislation. The country therefore needs to craft legislation to deal with disasters. Disaster legislation is very important as is outlined in the flood prediction model in Figure 8.1.

In literature (see Chapter Two, Section 2.3.4.9) it is stated that the Government uses the National Policy on Disaster Management of 1996, the National Disaster Risk Management Plan of 2009 and other Sector Specific Legislation (Acts) to manage disasters in that country (National Disaster Risk Reduction Strategy 2013-18). The country also uses the Environmental Assessment Act No. 10 of 2011 and Environmental Assessment Regulations of 2012 for the protection of the environment and conservation of natural resources (The Environmental Assessment Act No. 10 of 2011).

The legal framework also includes the Finance and Audit Act 1996, the Emergency Powers Act and other sector legislation (Botswana National Disaster Risk Reduction Strategy 2013-18). Botswana has a large body of legislation concerned with environmental protection (Botswana Government, 2006:21). The country is also constitutionally required to protect the environment (Walmsley & Patel, 2011:69). Botswana has enacted the Environmental Assessment Act (Act No. 10 of 2011) and the Environmental Assessment Regulations of 2012 as the main regulations to manage its environment (Environmental Assessment Act, 2011:2). The government also has a National Development Plan (NDP), which identifies and integrates issues relating to the environment and sustainable development, Environmental Impact Assessments (EIA) legislation and the development of management plans for some priority ecosystem areas (Government of Botswana, 2002).

It is disturbing to note that the country does not have funding for disaster management activities, as stated by a respondent. The Government needs to have a re-look at this anomaly and must introduce a disaster management fund to be used for disaster risk management activities. Funding is also a critical factor in disaster risk reduction and this is one of the critical elements in the flood prediction model discussed in Chapter Eight.

7.4.4 South Africa

South Africa suffers from flood risk every year (see Table 3.4 in Chapter Three). Information gathered from respondents in this study shows that the Government is making efforts to mitigate the impacts of flood risk. These efforts are discussed in the following sub-sections.

7.4.4.1 Government and community involvement in Disaster Management

Disaster managers and other experts

South Africa has a very positive attitude towards disaster risk management and is putting in a lot of effort to deal with flood risk. Related to this, one of the government respondents stated that *"I specialise on flood risk management and am involved with national government, provincial government and local government on several projects across the country on flood remediation and mitigation measures".* Another respondent from the private sector stated that he was involved in the national coordination of disasters and interventions through the disbursement of funds for damages or response. What this shows is that as much as the Government is involved in disaster management, their efforts are complimented by private organisations that are also involved.

According to the Disaster Management Act 2002 (Act 57), South Africa has some disaster risk reduction activities that fall under the concept of integrated development planning. The strategy emphasizes an integrated and co-ordinated approach to disaster risk reduction, focusing on preventing or reducing the severity of disasters. These activities are divided into forums and committees, that is, the Disaster Management Advisory Forums (DMAF) and Disaster Management Centres (DMC) that both have establishments at national, provincial and municipal levels. According to the Municipal Systems Act (2000), every municipality is mandated to have a Disaster Management Plan as part of its Integrated Development Plans. The plan must set up the structure and mechanisms for dealing with disasters and it must anticipate future disasters. Plans must be developed to deal with disasters that occur regularly, for example flooding of informal settlements and roads.

Community members

The Government helps Tonga Village in flood risk reduction by moving people from flood prone areas, building strong and restoring damaged bridges, roads, dams and evacuating affected people. When there are flood deaths and injuries, the Government takes responsibility and also provides clothes and shelter to victims. The Government goes further and advocates for the conservation of the environment. The community also has a disaster management office nearby, managed by the Nkomati Municipality. More government activities on flood risk reduction as indicated by Tonga community respondents are summarized in Table 7.4. The table shows actions before, during and after flood disasters.

Table 7.4: South African government flood risk management activities before, during and after floods

Period of activity	Type of activities: South Africa
Before floods	Increasing preparedness for disasters, improving response, dissemination of relevant information, awareness creation, education and training programmes.
During floods	Temporary shelter, provide food and blankets. Repairing of damaged infrastructure, help to drowning people, moving affected people to safe areas, transport to safer areas.
After floods	Temporary shelter, provide food and blankets. Repairing of damaged infrastructure e.g. rebuilding of bridges, the community take charge by filling up potholes in the roads with stone and sand.

Source: Author’s depiction, December 2015.

Protective measures from flood disasters taken by the respondents in Tonga Village include building stronger houses, staying indoors, repairing houses, for example by sealing roof damages, using heavy tiles and moving away from the most flood prone areas to higher places. The community also follows the weather forecast, plants trees and grass around houses and avoids driving until the rain subsides. In order to protect themselves, one respondent stated that they do this by *“going to our relatives’ houses until the floods stops”* or they relocate. They also dig trenches or open furrows to try and control the water.

7.4.4.2 Disaster management structures

Disaster managers and other experts

According to a respondent ***“****The country has Disaster management centres across the country for every district municipality or metropolitan municipality”.* The disaster management structures are coordinated by the Disaster Management offices at National, Provincial and District levels under the Department of Cooperative Governance and Traditional Affairs (CoGTA). The structures consist of Disaster managers reporting to the Heads of department who has sub-ordinates under them. These centres report to the Minister of Cooperative Governance and Traditional Affairs (CoGTA). Disaster management committees also consist of Disaster Managers, the Police, Army, transport organisations, Department of Housing, Air Organisations, NGOs and communities that are affected by floods.

Literature review (see Chapter Two, Section 2.3.4.10) indicates that South Africa has some structures that are used in its disaster risk reduction activities (Disaster Management Act 2002 (Act 57). The activities fall under the concept of integrated development planning. The strategy emphasizes an integrated and co-ordinated approach to disaster risk reduction, focusing on preventing or reducing the severity of disasters. These activities are divided into forums and committees,that is the Disaster Management Advisory Forums (DMAF) and Disaster Management Centres (DMC) that both have establishments at national, provincial and municipal levels. According to the Municipal Systems Act (2000), every municipality is mandated to have a disaster management plan as part of its Integrated Development Plans. The plan must set up the structure and mechanisms for dealing with disasters and it must anticipate future disasters. Plans must be developed to deal with disasters that occur regularly, for example flooding of informal settlements and roads.

Though it is stipulated in the Disaster Management Act 57 of (2002) that the operational modalities of disaster management must be done by the creation of structures at all levels of government, it is silent on how a preparedness for disaster risk reduction must be organised (Van Niekerk, 2005:4). The Act also requires that spheres of government apply disaster management uniformly (Disaster management Act, 2002: sec 7). According to Van Niekerk (2005:4), such a framework will assist decision makers to direct development projects that enhance disaster risk reduction.

Community members

In Tonga Village, flood planning meetings are held and coordinated by the Chief or Councillor. The community is educated on flood safety issues. Some respondents confirmed having some of their ideas and contributions included in some of the flood plans. According to one respondent "*they warn us about the bridge and advise us to watch on our kids not to play by the river during floods*". Community involvement in flood planning is highly commendable as it gives the community ownership of flood risk reduction programmes. In such a setup the community is empowered to identify its flood problems and proffer local or home based solutions to the problems, using available local resources.

7.4.4.3 Disaster legislation and funding

Disaster managers and other experts

Information collected showed that the local municipalities promulgated by-laws which help to make sure that people do not settle in flood prone areas. Although legislation provides penal provision, one respondent felt that it was *"to a small degree yes and a lot still needs to be done to improve on that".* Disasters are also funded in the country through a government fund. "*If the area is declared as a disaster area a special budget is allocated to quantify the damage and most of the losses are paid for by the government*", according to one respondent. Section 56 of the Disaster Management Act provides for such funding but it's unfortunate that, just like in the other countries under study, the fund only provides for disaster response activities. This makes the disaster management act weak as it does not prescribe for the funding of DRR activities. This shortcoming is addressed in the flood prediction model developed for the region in this study. Funding must be for all disaster risk management activities, especially DRR funding.

To add to data collected from the respondents, the literature review in this study indicated that the country uses the Disaster Management Act (Act 57 of 2002) to manage disasters. The country is said to have the most efficient disaster management systems in the SADC-region (International Federation of the Red Cross, (IFRC) 2012:74; Roth and Becker, 2011:443). Environmental management issues are enshrined in Section 24 of the South African Constitution. It gives citizens a right to an environment that is not harmful to their health or well-being. The legislation also gives citizens a right to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that prevent pollution and ecological degradation (Kotzé, 2007).

Generally, environmental management in South Africa (see Chapter Two, Section 2.3.4.12) takes place through the use of National Environmental Management Act (NEMA) 107 of 1998 (Walmsley & Patel, 2011:323). The preamble of the NEMA 107 of 1998 is motivated by the fact that communities live in an environment with risks to their health. As such, inhabitants have a right to an environment that is not harmful to their health or well-being (NEMA, 1998). The Act also recognises public participation in environmental decision making and community roles in managing the environment and accessing resources in the environment (Makonese, 2008:45). Apart from NEMA, 1998, the country has other relevant environmental laws. Related to this study is the Mountain Catchment Areas Act, No. 63 of 1970 which provides for the conservation, use, management and control of land situated in mountain catchment areas. This has a relationship with issues that deal with flood controls as such areas help in containing flood flow. The National Water Act, No. 36 of 1998 provides for matters related to dam safety in light of possible floods due to dam failure and free water flow in rivers. The National Water Act (Act 36 of 1998) also has important sections with respect to flood management. It outlines the legal requirements of catchment management strategies. Chapter Seven of the act is concerned with catchment management agencies and Section 80 in particular outlines the functions of the catchment management agencies. Section 144 highlights the importance of flood lines on township plans and Section 145 calls for making flood related information available to the public (Benjamin, 2008:84).

7.4.5 Summary on Government Efforts in Mitigating Flood Disasters

There is overwhelming evidence from data collected and literature reviewed on the studied countries that Governments in the SADC-region are making frantic efforts to mitigate flood disasters (see Chapter Two, Section 2.3.4). The studied countries have various administrative structures for disaster management. The structures are from national level down to village and ward level. There are also various committees that have been appointed within each specific country to deal with various disaster management issues. Apart from the administrative structures, Governments have various legal instruments for addressing disaster management issues. The legal instruments include disaster management acts, enviromental management acts and other secondary legislation. The secondary legislation might be from Municipalities and Enviromental Management Agencies as by-laws or statutary instruments. The region also boosts water and flood management policies and structures (see Chapter Two, Section 2.3.3), namely the SADC-Water Policy (Section 2.3.3.1), the Southern Africa Regional Climate Outlook Forum (SARCOF) (Section 2.3.3.2), Integrated Water Resource Management (IWRM) (Section 2.3.3.3), the Hydrological Cycle Observing System (HYCOS), Article Two of the Protocol on Politics and Defence Cooperation (2001) and Article 25 of the protocol on Health (1999) (Section 2.3.3.4).

7.5 Research on River Flood Prediction Possibilities

This section addresses questions on research being done or done by Governments or any other organisations meant to improve river flood prediction in the studied countries Zambia, Zimbabwe, Botswana and South Africa. Also covered, is research that was done by other authorities both in and out of the SADC-region. Particular aspects of all this research are identified for inclusion in the flood prediction model developed in this study.

7.5.1 Zambia

The respondents indicated that other organisations like the Department of Water Affairs, Meteorology, NGOs and the University of Zambia were said to be involved in research that mostly focused on scientific methods of flood prediction. Victims of floods were also involved in flood prediction research, one of which focused on the use of river water levels to predict floods. This method may be classified as indigenous as it uses local methods or knowledge. The flood prediction model developed will incorporate such indigenous ways of predicting floods (Chapter Eight, Figure .8.1).

7.5.2 Zimbabwe

The responses indicated that there was at least some research on floods in the country. The research was mostly being done by NGOs and academic institutions. One of the recommendations from such research activities was to encourage local communities to use IKS in flood prediction. Some of these activities are coordinated by the Government through the Civil Protection Unit. Through research, some areas prone to flooding have been delineated depending on the level of flooding. Research also facilitated the crafting of Disaster Management Plans (DRM) in some flood prone areas. According to a respondent, *"DRM plans, whether documented or not, include the use of IKS as early warning for prediction of weather patterns".* What this means is that the Government realizes the importance of indigenous knowledge and is thereby encouraging its use. As such, communities must play a significant role and use their IK to predict floods in Zimbabwe. The use of IK in flood forecasts is incorporated in Chapter Eight, Figure 8.1.

7.5.3 Botswana

The respondents in Botswana indicated that they were not aware of any research on flood predictions being done by the Government or any organisation during the time of this study. What this means is that, in Botswana and maybe in other SADC-countries, it might be that no research was being done to improve flood predictions in the region. The flood prediction model developed will have an element on flood research (see Chapter Eight, Figure 8.1) as one of its critical components to improve flood predictions in the region.

7.5.4 South Africa

The responses from the study participants indicated that the Government is also involved in flood research. Apart from the Government, private organisations were also involved in flood prediction research. Unfortunately this information was not elaborated on to determine the status and progress of such research. A respondent from a private organisation stated that "*Our research usually aims at preventing floods from happening again but not dealing with the affected individuals*". It was not clear from the respondents whether affected communities are also involved in flood prediction research and activities. It was alluded to in this chapter that flood prediction can be enhanced by involving flood communities or victims. The research done also made some meaningful contributions to change the country's river flood management systems.

7.5.5 Research and Flood Forecasting Ideas

In order to complement information on flood research from the data collection exercise of this study, important points to benchmark from literature reviewed on ideas and research on river flood prediction (see Sections 4.2.1.1. and 4.2.1.2) are discussed in this section. These ideas strengthen information discussed in Sections 7.5.1. to 7.5.4.

Macharia, (2010:1) talks of the SERVIR-Africa remote system, a regional visualization and monitoring system for predicting floods. The system uses remote sensing (remote sensed data) and is ideal for a flood prediction model. Therefore, remote sensing was included as a way of gathering data for flood prediction (see Figure 8.1 under scientific knowledge processing). Haile (2011:2) talks of the Regional Flood Frequency Analysis (RFFA). The method focuses on the Intensification of rain gauge use to collect rainfall data especially at community or village levels. Rain gauge use for collecting and monitoring the amount of rainfall was also considered in developing the flood prediction model for the region (see Figure 8.1 under scientific knowledge processing). A study by Jury and Lucio (2004) made use of information from global weather statistical and numerical models to provide a background on the flood scenario. As such, the idea of using statistical and numerical models was also considered or formed part of the flood prediction model developed in Chapter Eight of this study (see Figure 8.1 under scientific knowledge processing).

The Unit Hydro Graph Model developed by Szöllösi-Nagy (2009:30) measures and predicts direct runoff access rainfall in river catchment areas. This model is relevant to this study and the development of the SADC flood prediction model as it is designed to measure and predict the effects of any excess rain water. Another similar method is discussed by Yates *et al.* (1999:815) which is used to predict the amount of rainfall that will fall in a watershed and cause floods. This method also calculates estimated rainfall and excess water flows on land during and after rains.

The flood prediction model developed in this study will also use information on excess rainfall to help predict river floods (see Figure 8.1 under scientific knowledge processing).

Thiemig (2011:65-66) also discussed the Flood Forecasting Initiative (FFI), a major global network flood-forecasting initiative operated under the World Meteorological Organization (WMO). Its emphasis is on improving the capacity of meteorological and hydrological services through joint and timely delivery of accurate flood predictions for decision-makers and communities. It also ensures flood prediction success through effective and efficient coordination of work being done, knowledge and data sharing. In the flood prediction model developed in this study, the element of coordinating activities and stakeholders is identified as critical (see Figure 8.1 under coordination). Hluchy *et al*. (2004:51) researched on a flood forecasting system based on the use of integrated hydrological and meteorological data or information. Sharing of information is very important between hydrologists and meteorologists. This model is also applicable to this study and is used in Chapter Eight (see Figure 8.1 under scientific knowledge processing).

Warner *et al.* (2000:799) did a study on prediction of floods using different techniques for the estimation and prediction of convectional rainfall. It utilized information from radar and surface observations and produced very short range rain forecasts (Warner *et al*., 2000:800). This method uses both numerical data and space technology to predict rainfall. The model is good for predicting floods caused by convectional rainfall which are also common in many countries in the SADC-region. The use of space technology was included in the flood prediction model developed in Chapter Eight.

Yadete (2004:iii) did research on flood prediction and early flood warning using Real-time measurements of flows, temperatures and rainfall in a watershed. There was emphasis on improving flood predictions with the use of multiple gauging stations, rather than data from a single station. This model appeared to be a good and simple model to use in the SADC-region and was incorporated in the flood prediction model developed in this study. According to Lettenmaier *et al.,* (2006) accurate flood forecasts for large river basins, depend on a combination of, the ability to forecast accurately the movement of water through the channel system, the ability to translate precipitation and other surface meteorological conditions into runoff entering the channel system and the accuracy with which meteorological conditions during the forecast period can be predicted. This method can also be used in the SADC-region and the countries under study. It’s simple to use and only requires accurate numerical data calculations. The method was considered in the flood prediction model developed in this study (see Figure 8.1 in Chapter Eight).

Some research and models by Hossain and Lettenmaier (2006:1), Reilly (2009) and Jeyaseelan (2004) emphasised the use of space technology to improve flood prediction. This technology includes the use of remote sensing through the use of radar technologies, powerful computers and software such as Geographical Information Systems (G.I.S) that link information with location (Fang, 2008:15). There is also the use of earth observation satellites that provides comprehensive coverage of large areas in real time. Satellites continuously monitor atmospheric and surface parameters related to floods. Remote sensing technology and geographical information systems measure and collect data on the ground using data-collecting platforms and telecommunication techniques (Gregoire & Kohl, (1986:2870). The use of technology was critical in the development of the flood prediction in this study (see Figure 8.1 in Chapter Eight). The use of space technology in collecting data was also considered in developing the flood prediction model for the SADC-region (see Figure 8.1 under scientific knowledge processing).

7.6 Flood Prediction and Models in Use and relevance of IKS

This section has responses that centre on identifying specific flood prediction models being used to reduce flood risk in the countries under study. Once identified, their effectiveness could also be established and the useful ones were adopted and incorporated in the flood prediction model developed.

7.6.1 Zambia

Zambia uses scientific and indigenous methods of flood prediction. Apart from their use there are also challenges faced by authorities and communities in using, managing and implementing these flood prediction and warning methods.

7.6.1.1Scientific and indigenous flood prediction and models

Disaster managers and other experts

The respondents indicated that the country relied mostly on information from the national Meteorological Services and the Department of Water Affairs for flood prediction. This shows that the country uses scientific methods to predict floods (see Section 4.2.2.1 and 4.2.1.2). The respondents were also aware of some IK methods used in the country to predict floods. Communities marked trees as flood indicators and many others relied on the behaviour of birds, insects and ants to signal floods. Floods were also signalled by tree behaviour (mango tree) and the type of clouds. It is pleasing to note that the affected communities themselves are involved in flood prediction activities using IK methods. As one respondent put it, “*they are urged to identify water marks, observe and communicate the flood levels to authorities*”. The communities are also involved in flood preparedness planning.

As already been alluded to in section 4.2.1.2 of this study, Zambia also uses the Regional Flood Frequency Analysis (RFFA) (Haile, 2011:2). The flood prediction method involves the identification of similar regions and suitable regional frequency distributions for the regions. A hydro-meteorological forecasting system was also introduced in the Kafue Basin. Rainfall conditions are the inputs for predicting future flood flows and river levels. The meteorological stations in the basin transmit data to the meteorological headquarters every three hours through radio and telephones where it is processed. The rainfall warning is then issued to the Disaster Mitigation and Management Unit (DMMU) by hand and to electronic and printed media through email (WMO, 2007:75).

Community members

In Chanyanya Village, Zambia, the flood prediction techniques that are used by the community include monitoring bird movements in the air that signal imminent floods. In addition to this use a respondent stated that, "*If this year there is no rain then it will be most probably that the oncoming year would result in floods*". Some predict floods using the shape of the moon, amount of rain, colour of water flowing in the river, changes in climate/temperature, type of clouds and wind direction. Relating to flood predictions in the village, another respondent stated that "*we also tell from the look of the water levels in the river if it keeps rising*". On the same note, some people in the community use predictions from ancestral spirits. There is a type of fire seen in the mountains during November and December that signals floods. Local knowledge was said to be abundant but is not documented for official use. The behaviour of birds, insects, ants, clouds and mango trees and water level are used.

Flood warnings in the community are issued through meetings called by community leaders, at prayer gatherings, meetings and public forums. Flyers are also distributed to community members. Warnings are also sent out through radio programmes. People are mobilised to one place and flood warnings are made by word of mouth. Most of these methods being used by the community are indigenous methods of flood prediction that are still being used and critical to the affected community. The use of some of these methods needs to be formalized, especially if they are reliable. Reliable local methods are the ones that this study is advocating for integration with science in the model that was developed (see Figure 8.1).

Johnston (2010) indicated that the Lozi community of western Zambia uses indigenous knowledge to predict floods and relocate to high ground. They use signs like the colour of the sand or beaches which turns brown when a flood is coming. They also use the position of the moon and water levels to predict river floods (Mutonga, 2013:6). According to Soropa *et al*., (2015:1068), farmers in Zambia use several signals for weather prediction. The indicators used are floods or excessive rains in the preceding season, strong winds around October, abundance and scarcity of fruits and a cold season that extends to August or September. According to Kasali (2011:263), in Zambia, when mango trees and other wild fruit trees have excessive flowering towards the rain season it is an indicator that the rain season will be bad for food production. The communities also associate types of clouds and wind direction to wet weather (Kasali, 2011:263). Therefore it can be seen that Zambian communities also use indigenous knowledge to predict floods and heavy rain using local indicators.

7.6.1.2 Relevance of IKS in River Flood Prediction in Zambia

Indigenous Knowledge is a relevant theme in flood prediction in Zambia. As indicated in section 7.6.1.1 the relevance of local knowledge is being recognised by the Government. Apart from communities being seen as using local knowledge in flood prediction, government authorities also are encouraging its use. Section 5.3 and 5.4 discuss in detail the relevance and importance of integrating scientific and indigenous methods of flood prediction. Integration of the two knowledge bases is seen as one way to improve flood prediction and early warning in affected communities (see Figure 8.1).

7.6.1.3 Flood prediction and warning response and challenges

<u>Disaster managers and other experts</u>

People generally respond to flood predictions and early warning but there are times that they do not. The main reasons for failing to respond are **“***some don't want to leave behind their crops, assets and animals. At times warning is mistimed*”. Furthermore, it was also indicated that “*some had a negative attitude*” towards flood prediction and warning. Although community members might have reasons for this,

this is a drawback and one of the challenges towards effective flood prediction and warning. Therefore, there is need to educate flood communities so that they appreciate and understand the importance of flood predictions and warning. Flood prediction and education were thus included as critical elements in the flood prediction model developed (see Figure 8.1).

Authorities also have challenges in managing and implementing flood prediction and warning methods. This was due to "*changes in terrain because of human activities. There is no robust early warning and therefore the need to localise early warning*" as stated by one of the respondents. This idea of localising early warning and flood prediction was addressed in the flood prediction model developed in Chapter Eight, where all such activities were done at local/village/community levels and information relayed to higher levels like the District and Province.

The literature review also highlighted a number of challenges in flood prediction and warning. Fabiyi (2012:5) noted concerns such as lack of the right policies and long-term strategies, absence of appropriate legal framework, inadequate institutional arrangements, ineffective flood forecasting and warning, limited community participation, absence of mechanisms for information or data collection and exchange and inadequate environment. People tend to believe in personal immunity as they think that disaster cannot happen where they live (Bush, 1979:31). This denial leads people to place themselves and their property in danger as they ignore warnings (Bush, 1979:31). Flood management is not effective in ensuring the well-being and satisfaction of flood plain inhabitants due to lack of communication and understanding between institutions, a reluctance to implement up to date regulations and minimal public participation in the emergency decision-making process (Haque, 2000:243).

There is a high probability that people at risk will take appropriate action on the basis of decisions which they have been involved in producing themselves (Maskrey, 1997:14). People's understanding of the risk of flood hazard (perceived risk) differs significantly from the experts' risk calculations (objective risks) and if emergency policies aim to succeed, effective public involvement is required before, during and after the disaster (Haque, 2000:240). Disaster management agencies are also being centralised and not involving local power bases like the municipality, civil society and community organisations (Cardona, 2003:4). If stakeholders are not involved in the development of risk information, the credibility level of that information might be low and the possibility of warnings being ignored greater (Maskrey, 1997:14).

Community members

The community respondents indicated that they respond positively to floods in Chanyanya Village. They do this by "*moving away from the flood areas to safe areas like higher places where floods hardly reach as advised by government*" as put by one respondent. The respondents also indicated that they reacted to resolutions made at meetings, in that case warning to move to safer places. This community's response to floods as stated by the respondents is pleasing but it's also important to note that disaster experts in Zambia expressed concern that in general, some community members ignore flood predictions and warning. This is a drawback to DRR, but can be resolved through education and awareness campaigns (see Figure 8.1). The next section analyses flood prediction and models in Zimbabwe.

7.6.2 Zimbabwe

Zimbabwe also uses various methods of flood prediction and warning, even at community levels. The country is also not spared from challenges affecting flood prediction and early warning.

7.6.2.1 Scientific and indigenous flood prediction and models

Disaster managers and other experts

The respondents indicated that scientific flood prediction and models used were the prerogative of The Meteorological department and the Zimbabwe National Water Authority (ZINWA). The theoretical review of literature in this study (see Section 4.2.1.2) showed that scientific flood predictions are also used in the country. The country, just like Zambia, predicts floods by using the Regional Flood Frequency Analysis (RFFA) model which uses the combination of the L-moments and the index-flood method (Haile, 2011:2). However, as already been alluded to, some communities are using indigenous methods which vary from community to community. This fact is supported by the following statement by one of the respondents: "*In Mashonaland Central Province, Muzarabani area, namely Chareka community, there is a river, Nzoumvunda River which is pegged by the community. Once the river levels reach a certain peg, the people responsible for monitoring then disseminate emergency alert warnings so that at risk villages evacuate. In addition, elephants relocate from low lying areas to higher ground as signal for floods. There are certain species of birds and ants that forecast above normal rainfall. In Tsholotsho in Matabeleland North Province, there is a certain local tree which produces white flowers if the area is to receive above normal rainfall and yellow flowers if there is impending drought*". What this shows is that communities are using various IK methods for predicting floods. The methods range from water level observations to the actions of animals, birds and trees which are said to signal flooding. Apart from local communities, flood prediction is also done by the Zimbabwe National Water Authority (ZINWA) and the Meteorological Services.

There is also evidence in literature to show that flood predictions are done especially in the Zambezi valley area of Muzarabani and Guruve. According to Madamombe (2004:2), meteorological forecasts are issued throughout the year and during the wet season and rainfall amounts are predicted. Information exchange has significantly improved. Data collection of rainfall and discharge in rivers is done by the relevant national agencies in the Ministry of Water. Other sources of information are satellite or radar observations, forecasts from other institutions and information from the local communities and local authorities. The information is used to forecast river flows and predict floods. Based on the predictions, the institutions take the necessary steps to ensure that the information is disseminated and potential victims evacuated before or during the flood events (Madamombe, 2004:2). Dissemination of information is normally done by means of newspapers, radio, television, telephone, internet and awareness programs by Government and non-governmental organisations.

Community members

In Tokwe-Mukosi Village, Zimbabwe, the flood prediction techniques that are used by some of the study respondents were said to include observing Mount Chidzidzi's mist that signals floods. Rainfall patterns and wind directions are some of the major signs of possible floods. Rainfall patterns were also said to determine the nature of floods. Spiritual mediums, although not reliable, "zvieraera" (omens) and the appearance or behaviour of the Dendera and Haya birds are also used to predict floods. The community also uses the Mukakwe and Mushuma tree to predict floods. When the Mushuma tree sheds its leaves, it's a sign that there will be floods. Communities are also predicting floods using river pegs or markings, animal behaviour like elephants relocating to higher ground, birds, ants and tree behaviour. These methods were said to differ from community to community in Zimbabwe.

A literature review showed that, since time, immemorial, indigenous knowledge has been used in Zimbabwe to control, master and predict early indicators of disaster risks (Mawere, 2015:26). The indigenous people developed traditional ways of weather forecasting that help them to plan for floods two to three days in advance (Mapara, 2009:140). In 2010, Soropa *et al.* (2015:1067) carried out a study in three districts in Zimbabwe to explore Indigenous Knowledge Systems (IKS) for weather forecasts as a climate change adaptation strategy. Some respondents indicated that they were using IKS weather indicators such as wild fruits, trees, worms and wind for meteorological forecasts. In the southeast of Zimbabwe, some birds are able to predict weather changes. The Dendera (Hornbill) bird's hooting is used to predict a drizzle. In the same area, another bird, the Teererwa is used to predict floods. This bird normally lays its eggs in holes along river beds but when a flood is impending it lays the eggs on trees (Mawere, 2015:26).

In Chimanimani, east of Zimbabwe, Swallow (Psalidoprocne pristoptera) flying at low altitude and the singing of the Stock (Riti) and Haya (cuckoo) birds are signs of imminent rains (Risiro *et al.,* 2010:563). In southeast Zimbabwe, the weather can also be predicted by observing wind patterns. The blow of a type of wind (Nhurura) from the northwest is a sign of imminent heavy rains with thunder and lightning (Mawere, 2015:27). Northerly winds in the east of Zimbabwe signify high rainfall covering a wide area (Risiro *et al.,* 2010:564). Incessant winds from the southeast bring drizzle (Guti) (Mawere, 2015:28). In Chimanimani, the wispy feathery cirrus clouds are a sign of a rainstorm coming (Risiro *et al.,* 2010:564). In southeast Zimbabwe the colour of clouds is associated with the type of rain. They use a white, thick and stable cloud (Mvumi yemvura) which looks like a pool of water around the sun or moon to predict imminent heavy rains. Thick black clouds normally bring hailstones along with thunder and lightning (Mawere, 2015:29).

East of the country the crescent moon also signifies wet weather. A halo moon or sun symbolizes continuous rains (Risiro *et al.,* 2010:564). On the same note and in southeast Zimbabwe, the crescent moon which is upside down or in a sliding position warns of an impending pandemic like malaria, fever and influenza (Mawere, 2015:29). According to Rusiro *et al.* (2012:563), in Chimanimani, east of Zimbabwe, the blooming of plants, breeding of goats, presence of stock birds and when ants are seen sealing off their holes all signal the onset of the summer season. Communities of Mangwe, Lupane and Guruve in Zimbabwe use indigenous knowledge to predict rainfall or floods (Lunga, 2014:146). There is need for proper documentation, dissemination and integration of IKS with scientific seasonal climate forecasts as a climate change adaptation strategy (Soropa *et al.,* 2015:1067). Therefore, before adopting and integrating or disseminating indigenous knowledge in flood mitigation programs, there is first need to scrutinize its scientific appropriateness just as any other technology. Apart from the scientific proof, local evidence and the socio-cultural background embedded in the practice also need consideration in the process of validation and evaluation (Nyong *et al.,* 2007:795). Simply put, there is a need to test IK to see if it is consistent and can thus be considered a “truth”. This assertion is supported by Howell (2003:7) who emphasisesd that it is helpful to focus on flood indicators that are widely used and could be monitored near people’s homes. These indicators include animal behaviour such as ants climbing trees with their eggs. Howell (2003:6) also believes that if a combination of two or more indigenous indicators is used and gives extra validation to official (scientific) warning signals, then more accurate and believable early warnings could be achieved.

Flood warnings in the community are done through awareness campaigns, for example by ZINWA. Warnings are also sent out by means of cell phones and ceremonies like Mukwerera. They hold community meetings and make housecalls. Apart from warnings that the community receives from the meteorological department and public media, warnings are also made at community gatherings as sensitization. The community uses whistle blowing for urgent community mobilization and gatherings and sends out warnings by word of mouth. Just like the community of Zambia, the Tokwe-Mukosi community also values the use of indigenous knowledge in flood prediction. What this means is that communities have faith in indigenous knowledge systems. Therefore, formally using and enhancing the use of indigenous knowledge in flood prediction at all Government levels is important (see Chapter Eight, Figure 8.1).

7.6.2.2 Relevance of IKS in River Flood Prediction in Zimbabwe

Local knowledge is relevant in flood prediction at local level. This can be seen by the support being given by the Government through the CPU (see section 7.5 and 7.4.1). It is also important that IK be integrated with science and used at all levels up to the regional level such that flood prediction is improved. The two knowledge bases will support each other. The use and integration of indigenous knowledge were included in the flood prediction model developed (see Figure 8.1 in Chapter Eight).

7.6.2.3 Flood prediction and warning responses and challenges

<u>Disaster managers and other experts</u>

The respondents also indicated that, at times there is a challenge where communities fail to understand and also do not respond to flood prediction and warning. This is due to the fact that the language (jargon) used is sometimes too technical for users to understand the meaning. Even if they respond, "*not everyone responds the same way*" as stated by one respondent. Those who do respond "*understand as we call for community meetings and use user friendly terms to decode the seasonal forecast every year before the onset of rains. The villagers engage in interactive discussions and besides, they would have known the forecast through IKS*". Despite the challenges, it needs to be acknowledged that at least on the ground, Government has activities that it is doing through Civil Protection to help some communities understand or decode and respond to flood predictions.

Looking at policy and legislation, a study by Manyena *et al*. (2013:1786) on the effectiveness of disaster legislation in five countries around the world, including Zimbabwe, concluded that, to a large extent, legislation from these countries has centralised institutional frameworks leading to limited community participation.

Spaliviero *et al.* (2011:745) have the view that disaster management legislation is difficult to enforce in Zimbabwe due to its formulation. Mahonda (2011:12) identified limitations that hinder effective management of floods in the Zimbabwian legislative framework. He stated that the disaster management policy and Act centre on response at the expense of comprehensive flood risk reduction. In a study done by Bongo *et al.* (2013:2), they discovered that disaster risk reduction activities in Zimbabwe are spear headed by Non-Governmental Organizations (NGO's), United Nations agencies and Disaster Risk Reduction specialists with little room for the Government and affected communities. Community leaders need to encourage active involvement of communities and value their contributions and ideas so that they see the benefits of being involved and take ownership of such projects (Gwimbi, 2009:75). Gender issues are a fundamental element in disaster management that are not addressed. Resilience from disasters on the part of women must be enhanced as they are affected differently than men (Muhonda, 2011:41). Current disaster policy in Zimbabwe does not create an enabling environment to include affected communities, where DRR activities are the sole preserve of specialists and do not incorporate the daily activities of affected communities (Bongo *et al.,* 2013:2).

Community members

The community members in Tokwe-Mukosi indicated that they take heed of flood warnings form the Meteorological Department and evacuate immediately from flood areas. There were incidents when some stayed prepared and alert to move to higher places. It was also indicated that, although some responded to warnings, others resisted but were forcibly evacuated by the police and army. On the same note those who resist or ignore flood warnings need to be educated about the dangers (see Figure 8.1). There is need for more public awareness and education in order to take flood warnings seriously. At the same time flood predictions and warnings have to be realistic and effective so that communities have faith in such systems.

However, due to previous false alarms, people in some communities no longer take forecasts seriously (Matsimbe, 2003:27). Furthermore, there is a problem with the accuracy of forecasts and people no longer have trust and faith in flood predictions, for example during the Eline cyclone, where an accurate forecast was issued by the meteorological office but was not taken serious until people started dying as a result of floods (Madamombe, 2004:5). One approach to reduce false alarms is to use reliable local hazard indicators, such as animal behaviour or vegetation changes, to verify scientific indicators of upcoming hazards (Pearson, 2012). Participation empowers community members with knowledge and skills, which will further strengthen their capacity to contribute to development initiatives (Gwimbi, 2009:76). Participation by communities also calls for the integration of indigenous knowledge systems in disaster preparedness, especially flood risk communication among local communities (Alverez, 2006). The legal framework in Zimbabwe should mandate the involvement of affected people in communities, Government and the private sector in risk reduction (Bongo *et al.,* 2013:10). The next section analyses flood prediction and models in Botswana.

7.6.3 Botswana

Botswana also uses various methods of flood prediction and warning. The country is also not spared from flood prediction and early warning challenges . These issues are discussed in the following sub-sections.

7.6.3.1 Scientific and indigenous flood prediction and models

Disaster managers and other experts

The respondents rely on the meteorological services and the Department of Water for scientific flood predictions. They are also knowledgeable of the indigenous flood prediction methods used by other communities. Furthermore, a literature review (Section 4.2.1.2 and 4.2.2.3) indicated that the country uses the Regional Flood Frequency Analysis (RFFA) (Haile, 2011:2) and a Statistical model to predict floods in the Okavango delta respectively. According to the empirical data collected, the local way of predicting floods was identified as that of using animal behaviour. Indeed, as with the other studied countries, there is evidence from the respondents that communities in the SADC-region are using indigenous methods of flood prediction. Such evidence supports the views expressed in Chapter Five on the relevance of indigenous flood prediction on present day flood forecasts. What this shows, is that the country uses both knowledge bases to predict floods, but separately.

According to Gumbricht *et al.,* (2004:178), Botswana has a flood prediction model that it uses in the Okavango Delta. The statistical model, apart from predicting the extent of wetland loss arising from water abstraction, also permits prediction of floods in an area and its spatial distribution, three months in advance of the flood. The model is calibrated using areas of seasonal inundation. The calibration is extracted from satellite imagery which is correlated with rainfall and total flood discharge. The modelled flood area is then developed into a flood map. The model can predict the maximum area of flooding and its distribution with 90% accuracy.

Community members

In Satau Village in Botswana, the flood prediction techniques that are used by the community include the use of walls to control water movements but this is mostly done by business people. The respondents indicated the use of the amount and duration of rainfall and a black cloud and animal behaviour to forecast floods. The community also makes use of weather observations and information from the media like radio, television and newspapers. They also listen to news from other neighbouring countries like Namibia and Zambia on river floods as floods from these countries also affect them. They then concentrate on checking river water levels. Flood warnings for the community are even issued through Kgotla meetings and public announcements by government officers. The community therefore uses both science and local knowledge to predict floods. Integrating the knowledge bases will be beneficial for the community (see Chapter Eight, Figure 8.1).

In Botswana, local knowledge plays a complementary role in generating climate information and flood prediction (Speranza *et al*., 2010:297). Farmers in the Okavango Delta use IK to predict floods through the flow of rivers in the Delta (Kolawole *et al*., 2014:46-7). They observed that per year they receive plenty of rains and harvest is preceded by free flow of rivers. When rivers are flowing in a spiral-like manner, the agricultural season will have limited rains and less or no harvests. The logic behind this observation is that high volumes of water (the free flow of rivers) suggested that Angola received plenty of rains in its uplands. The spiral movement or flow of water in rivers was a sign that they would receive less rains and the Okavango would gradually dry up (Kolawole *et al.,* 2010:44).

According to Kolawole *et al.* (2012:42), farmers in some villages in the Okavango delta of Botswana also predict rains and floods using natural indicators/signals from trees, clouds' type and colour, star constellations, bird movement and appearance. When the Moretlhwa tree (Brandy bush/Raisin bush or Grewia flava) bears fruits around February and March, it's a sign of plenty or more rainfall during that season.

7.6.3.2 Relevance of IKS in River Flood Prediction in Botswana

The use of Indigenous Knowledge is also being taken as relevant in this country. As information collected indicates, some communities use animal behaviour to predict floods in their areas. The use of local knowledge was an important component of the flood prediction model developed in Figure 8.1.

7.6.3.3 Flood prediction and warning responses and challenges

Disaster managers and other experts

The participants indicated that flood prediction and early warnings are at times understood and responded to. When it comes to challenges in understanding, managing and implementing flood predictions and early warning, one respondent stated that "*People fail to understand the language (jargon) used, there are no good communication technologies and no cell phone network services*". What this means is that there must be serious considerations to use information technologies to improve flood prediction in Botswana and other countries in the region. The issue of using communication technologies was discussed and emphasized in Section 4.2.1.2 of this study. In developing a flood prediction model for the region, the use of communication technologies was also included as a critical element.

Being critical, Dixit (2003) points out that policy makers, donors and relief and development agencies treat flood disaster as isolated events and interventions to disasters are responses made under the assumption that an emergency support in the form of relief will help overcome the situation. The frameworks in the regional countries tend to focus on response mechanisms (Muhonda, 2011:12). As such, flood management is highly reactive and relief-oriented (Muhonda, 2011:12). Due to disaster relief approaches, natural disasters occurring in African countries are undermining the economic survival of poor communities (Lukamba, 2010:478).

Bakker (2006:143) observed that, during most floods, traditional authorities do not believe in flood warnings because they are against their experiences. Further to that, flood warnings and are still too technical for common people to understand. Mwando (2013) indicates that "*forecasts have been regularly revised as rainfall patterns have deviated from initial predictions*".

Community members

In Satau village, the respondents indicated that they respond to flood warnings by evacuating to safe places. This method is a safe route, provided the warnings are given in time. Unfortunately respondents also indicated that some community members resist evacuation and they stay put in the flood prone areas. These are the people who usually become victims of floods. They are the ones who get swept away or are marooned on islands after floods and get rescued by boats or are air lifted. Some resist as they fear to lose their property and animals. They chose to stay behind as a security measure. However, with proper flood planning, preparedness, education, training and awareness, the incidences of resistance to relocation may be minimised or eradicated.

Howell (2003:4) states that many people ignore flood warnings for several reasons which include economic reasons, lack of understanding, false flood warnings and danger flood warnings given when the storm is weak. According to Pearson (2012) high false alarm rates can undermine public confidence, breed mistrust, dilute the impact of alerts and reduce the credibility of future warnings. There are also many other obstacles to disaster preparedness and survival in communities in the form of religious beliefs, superstition, rigid gender roles, lack of protective infrastructure and local insecurity (Howell, 2003:4). When the 2000 floods hit southern Africa, information exchange, communication and coordination were reportedly hindered by limited government participation (Gwimbi, 2007:156). Unless flood mitigation is adopted as a regular activity by a relevant government department, it will remain an activity without budget and will therefore be side-lined (Masiyandima, 2008:20). Warnings are too technical to be understood by people in rural areas (Carmo Vaz, 2000:31). Scientific jargon relating to uncertainty regularly causes users not to act as statements such as "*there is a 20 per cent chance that rainfall will be above the inter-annual mean*" present information in an unfamiliar language (Pearson, 2012).

Furthermore, people are less likely to respond to a warning if the previous alerts did not result in a serious disaster or if they have never experienced such a serious event (Matsimbe, 2003:26). Flood planning and implementation decisions are based on mathematical and statistical models and on physical parameters ignoring the people who are the main players in disaster management, who in turn become sets of statistics, as victims (Haque, 2000:240). The next section analyses flood prediction and models in South Africa.

7.6.4 South Africa

As with the other countries under study, South Africa uses various methods of flood prediction and warning. The country also faces challenges in flood prediction and early warning activities. These issues are outlined in the proceeding sub-sections.

7.6.4.1 Scientific and indigenous flood prediction and models

Disaster managers and other experts

When it comes to flood predictions using scientific methods, one government respondent as an expert observed that the HECRAS (River Analyses Model) had been used: "*to predict where certain flood events will happen in terms of flood depth, we do not necessarily predict when, but we also have early warning systems in certain areas to alert flood prone dwellers*". Apart from the HECRAS, there are other models also used in the country (see Section 4.2.2.4 on literature review). Affected community members are involved in the flood prediction methods in use: "*They help in giving incident areas where flood re-occurs and we can take that into account in our models*", in the words of one disaster manager. Communities and organisations also contribute towards flood prediction and early warning "*through community forums*".

According to Du Plessis (2012:134), there is an absence of a formal and effective Flood Forecast, Warning and Response System (FFWRS) in South Africa. The country uses a flood warning communication system installed by the Department of Water Affairs and Forestry (DWAF) in June 1993. This system is based on daily rainfall data and antecedent precipitation indices. Apparently the system fell into disuse due to various unconfirmed reasons but DWAF is working and improving another advanced FFWRS in the Vaal and Orange River systems. The system operates during river floods with an office that opened in Pretoria to co-ordinate dam operations and information dissemination. Communities are also part of the system as they watch and disseminate river flood information amongst themselves.

Community members

In South Africa, the flood prediction techniques that are used by the Tonga Village community were said to include taking note of the weather patterns and the duration of rainfall, .i.e. non-stop rains are an indicator of the coming of floods. The community uses the wind, clouds, temperature and bird movements and migrations to predict floods. In South Africa, a study by Mwaura (2008:66) identified that a red moon announces the coming of floods and the cry of the Vlera bird signifies floods. The community also uses community radio stations and disaster management centres in Nkomazi for flood prediction and warning. The municipality also makes broadcasts through word of mouth and places road signs at flooded streams and the Komati River. Weather forecasts through the radio and television also play an important role in warning the Tonga community about anticipated floods. It's good to note that the Tonga community also uses both science and local knowledge to predict floods. Such efforts need to be supported by formally integrating the two knowledge bases for reliable flood forecasts (see Chapter Eight, Figure 8.1).

South Africa has an IKS policy, adopted in 2004. There is a framework and an established National Office on IKS (NOIKS) within the Department of Science. The office's function is to recognise and promote IK and knowledge systems. They also advise Government on matters related to the promotion, protection, recognition, development and affirmation of IK (Domfeh, 2007:50). The importance of indigenous knowledge is also reflected in the work of South Africa's National Research Foundation (NRF). Indigenous Knowledge systems are one of the priority focus areas of the foundation. The NRF seeks to develop understanding and research capacity on specific characteristics of indigenous knowledge systems. The foundation also aims at enunciating the role of Iindigenous knowledge in nation building (NRF, 2005:1). This shows that South Africa has an Indigenous Knowledge System (IKS) policy and structures that promote, preserve, protect and disseminate Indigenous Knowledge (Mosimege, 2005:1). The policy aims to stimulate and strengthen the contribution of local community knowledge to their social and economic development (WIPO, 2006:4). Since 1996 the country has conducted audits to determine the kinds of technologies, especially on what poor and marginalized communities used to survive over the years. The aim of these audits was to record, benchmark and innovate indigenous knowledge for the benefit of communities (Njiraine, 2012:9).

A study by Mwaura (2008:66) in South Africa identified that some communities in this country believe that hydrological hazards like floods are an act of God and do occur as punishment for human misbehaviour in the form of raping elderly women and children. Further to that, the study also noted that a red moon announces the coming of floods and the cry of the Vlera bird signifies floods (Mwaura, 2008:67). Communities in the country also predict floods from the heights of nests of Emahlokohloko birds (*Ploceusspp*) near rivers. They again use the position of the sun, the cry of a specific bird (Phezukwemkono bird) on trees near rivers and the position of the moon crescent to predict the onset of rainfall (Mclean, 2009:63).

7.6.4.2 Relevance of IKS in River Flood Prediction in South Africa

Although the expert respondents in this study were not aware or sure of the use and relevance of local knowledge in South Africa, the country recognises its importance. The importance of IKS is reflected in the work of South Africa's National Research Foundation (NRF). Section 5.3.2.4 on literature review discussed the use and the importance of IKS in detail. As with the other studied countries, this knowledge base was also integrated in the flood prediction model developed.

7.6.4.3 Flood prediction and warning responses and challenges

Disaster managers and other experts

In relation to flood prediction and warning response, one respondent said that "*Most of them do respond, only a few say they have never been flooded and they won't move until it's too late*". This statement also brings out the issue of people who have a negative attitude towards flood prediction and early warning as alluded to earlier on and as the case with other studied countries like Zambia. The issue of attitude can also be addressed by educating flood communities on the importance of responding to flood prediction and warning in this country (see Figure 8.1). The country also faces some problems in managing flood prediction and early warning. On that issue, one respondent stated "*Yes, we do, a lot of areas where flooding occurs one has to move the people, people don't want to move, and it becomes a legal issue, which drags for years*". One way that might be helpful in making people respond to flood prediction and warning is community involvement in all flood prediction and early warning activities. This element of community involvement was included in the flood prediction model in Figure 8.1.

A review of literature showed that the magnitude of some rain seasons stretched local authorities' and humanitarian partners' capacity to the limit (OCHA, 2007:2). Rabalao (2010:26) also found that there are limited interest in flood hazard, poor involvement in flood issues and sentimental rather than logical reasoning for living in areas at risk of flooding among other things. According to Bryant (1991:259) and Rabalao (2010:300), people find it difficult to give up the historic identity of the area, maintain links with the past or with ancestors and sustain their roots. Malele (2009:29) argues that poor urban governance often makes urban dwellers, their properties and the environment more vulnerable to the impacts of a number of hazards like flooding. Parker (2000:10) identified lack of protection from floods, inability to avoid, withstand or recover from floods and powerlessness through an inability to influence one's own safety level of protection or relief as contributory social factors to flood disasters. Deforestation, land degradation and resource exhaustion processes contribute to disaster vulnerability (Wisner, 2004:81).

Community members

A community member in Tonga Village responded to flood warning by "*preparing myself and my children to be on the safe side*". Some community members did this by avoiding all possible flood areas. Another respondent stated that they respond to flood warning "*by staying alert and prepare the houses and not use damaged bridges*". Another responded avoids flood risk "*by staying away from danger, tell my friends about it and stay indoors or park my car in a safe place*". Other respondents stated that they prepare their houses to resist more damage, some prepare their houses to be safe and avoid using damaged roads. "*We tell others about the coming floods, or rain so that they stay alert*", according to one respondent. When flood warnings are issued, ambulances are also placed on standby at or near flood risk areas.

Literature review indicated that, on the technical side, there are problems associated with the installation and operation of flood warning systems, insufficient rainfall and hydrometric networks and redundancy of recording equipment (Carmo Vaz, 2000:13). There is no or ineffective communications during floods and risk information is not credible to those people at risk as they are not involved in its production (Maskrey, 1997:14). There is also uncertainty inherent in scientific information and forecasts are often in a language or format that is not easily understood by workers or the local communities that need it (Pearson, 2012). It is also noted that failure to get good results in disaster risk reduction is being made worse by the absence of feasibility, a response and aid approach with less prevention and mitigation (Cardona, 2003:14). According to Gwimbi (2009:74), there is lack or no political will in the SADC-region to manage flood disasters. Political will in developing countries rests in the hands of the Government and ruling political parties and is a big challenge for these countries (Asek, 2006:1).

7.7 Developing a Flood Prediction Model for the Region

The intention of this study was to develop a flood prediction method for the region. This was done by collecting as much information as possible from many stakeholders on what they thought were the most important components that needed to be included in the model. This section is the climax of the study where the information obtained from the participants is considered. The section also helps in developing the most ideal and user friendly flood prediction method for communities in the region. Some critical aspects of a flood prediction model are complimented and were identified in Chapters Two, Three, Four and Five for integration into the model developed (Chapter Eight). The flood prediction model is an integration of components of reviewed scientific models (see Chapter Four, Sections 4.3.1 to 4.3.7) and integrated Scientific and Indigenous Systems flood prediction models (see Chapter Four, Sections 4.4.1 to 4.4.3). These include activities like interpretation, validation, evaluation and modelling. Data on hazards, risk, capacity and vulnerability also had to be collected for data and information processing. The model includes other variables like Information Communication Technology, Community involvement, Governance and Decentralisation, Research and Development and risks assessment. There must also be structures from the community or ward to the national level and flood predictions has to start from the lowest level. The IKS identified include the use of animal, bird, insect and plant behaviour to predict floods.

7.7.1 Zambia

Disaster managers and other experts

Respondents in Zambia were of the idea that to develop a flood prediction model for the region there was need to "*Combine information from the Meteorological office and IKS"* (see Figure 8.1). It was also proposed that there was need to improve on flood prediction and warning notices. Flood prediction was centralized and a proposal was made to decentralize flood prediction to provinces. In flood prediction (Figure 8.1) decentralization goes further to the district and village and is also indicated as a support activity. The respondents also indicated that flood prediction and warning helped in the development of the country and its people as "people make timely decisions". In the words of one respondent, "*Flood prediction is preventative, saves lives, property and the environment from destruction*". Flood predictions and warning were also said to save time, resources and lives. Further to that, people are warned to take action in advance. It reduces hunger, poverty and promotes development.

Community members

Respondents in Chanyanya Village gave the following responses or suggestions on what they thought would improve flood predictions in their community. The original responses are captured without any editing in Table 7.5.

Table 7.5: Ideas from Zambia community members on improving flood predictions in their area

Country	Response
Zambia	Enhance outreach to people so as to effectively communicate flood predictions.

	The methods being used are effective.
	They should continue the same way they are doing by providing the services they give.

Source: Author's depiction, December 2015.

The issue of effective communication stated in Table 7.5 and also as identified in Chapter Four, Section 4.2.1) is a very important success factor in flood predictions. This element was a critical factor and included in the flood prediction model developed (see Chapter Eight, Figure 8.1).

7.7.2 Zimbabwe

<u>Disaster managers and other experts</u>

This section solicited information that would assist in developing an ideal and effective flood prediction model for flood communities in the SADC-region. One proposal put forward in Zimbabwe was to include a Geographical Information System (GIS) and remote sensing based approach in developing a flood prediction method or some of its aspects. What it means is that the flood prediction model developed should include the use of technology in its data collection and processing. These aspects were included in the flood prediction model in Figure 8.1 of this study under effective communication and Information Communication Technology (ICT).

The information collected also seemed to point out that the process of flood prediction is centralized and was the sole responsibility of the Meteorological Services at national level. Decentralizing flood prediction to other levels up to the community level is therefore critical to effectively predict floods at all levels as indicated in Figure 8.1 under decentalization. The government has to consider decentralizing flood prediction through the coordination of its arms, the Meteorological Services and the Civil Protection Unit. Respondents also highlighted the importance of a flood prediction model in that it was crucial for early warning, prompt response to flooding emergencies and for saving lives and property. The early warning activity is included in the flood prediction in Figure 8.1 and is indicated as a direct and instant feedback after the intergrated flood prediction.

Community members

Respondents in the Tokwe-Mukosi Village gave the following responses or suggestions on what they thought would improve flood predictions in their community. The responses shown in Table 7.6 are original and unedited.

Table 7.6: Ideas from Zimbabwe community members on improving flood predictions in their area

Country	Response
Zimbabwe	Engage technical experts to device mechanisms that tell us in advance if we will have floods or not.
	Equip the meteorological department with reliable machinery for more accurate readings and also sink machinery that signals when the dam is full.
	Sensitisation from technocrats.
	Study rainfall patterns at community level and give accurate readings.

Source: Author's depiction, December 2015.

The responses in Table 7.6 were mostly focused on the introduction or improving the use of machines/technology in effective flood prediction (see Figure 8.1 on effective communication and ICT). There is also a proposal for sensitization or awareness campaigns for the study community (see Figure 8.1 on education, training and awareness). The other responses focused on improving local level flood predictions using rainfall patterns. All these factors identified by the community are critical and are part of the flood prediction model in Figure 8.1.

7.7.3 Botswana

Disaster managers and other experts

In Botswana, the respondents emphasised on the thorough use of cell phones, television and radio in flood prediction (see Figure 8.1 on effective communication and information communication technology). They also indicated that flood prediction was centralized, an issue that can be solved by decentralization as indicated in the flood model in Figure 8.1. Disaster prediction and warning were said to be helpful in preparedness planning (see early warning and preparedness in Figure 8.1). Proposals from Botswana indicated the need to improve the technology in flood prediction and warning. This aspect is captured in the flood prediction model developed in Chapter Eight of this study on effective communication and ICT.

Community members

Respondents in Satau Village gave the following responses or suggestions on what they thought would improve flood predictions in their community. The responses are captured without editing as shown in Table 7.7.

Table 7.7: Ideas from Botswana community members on improving flood predictions in their area

Country	Responses
Botswana	All the communication media must be used.
	Be informed on water levels from local rivers e.g. update on the water level of the Chobe river or the Zambezi River so that we be alert.
	Radio announcements from Namibia should be shared with local community.
	The government must bring us a highway road because this is the most important thing which affects us during floods because we are not able to go where most of the valuable things are found.
	They have to survey a good place to stay off the flood plain.
	Use of technologies, use of structures that is strong.
	We need bridges.

Source: Author's depiction, December 2015.

The respondents identified the need for effective communication media and use of technology in effective flood predictions in their Village. This aspect is covered in Figure 8.1 under communication and ICT. They also included strengthening and building strong structures like bridges and homes and relocation to minimize flood risk (see Figure 8.1 on infrastructure). They also advocated for improved information sharing when it comes to flood updates from neighbouring countries (see communication and early warning in Figure 8.1). Once more, as already been alluded to, these contributions by community members are important in improving flood prediction at these local levels and were therefore incorporated in the flood prediction model in Chapter Eight.

7.7.4 South Africa

Disaster managers and other experts

In South Africa, it was proposed that the presented flood prediction model for the region was supposed to "include flood frequencies" and also involve the weather services for flood forecasting (see scientific flood knowledge processing in Chapter Eight, Figure 8.1). The proposal hinged mostly on the use of science to predict floods. Science is integrated with local knowledge to predict floods in the flood prediction model developed (see Figure 8.1). Flood prediction was said to be both centralized and decentralized. Decentralized flood prediction is good as it gives localised flood predictions. Flood prediction and warning was said to help in the development of the country and communities as it helps people to prepare and mitigate flood effects as indicated in the flood model in Figure 8.1. *"People are safeguarded against flooding if they respond well to the warning*", as one respondent claimed (see early warning in Figure 8.1)

Community members

Respondents in Tonga Village gave the following responses or suggestions on what they thought would improve flood predictions in their community. These responses are captured in Table 7.8. below.

Table 7.8: Ideas from South Africa community members on improving flood predictions in their area

Country	**Responses**
South Africa	At least they should be some ways that try to inform the community about possible coming floods.
	Have the Met. Dept. assists the government in flood prediction.
	Our government should help in accurate weather forecast.
	Technology.
	We should have community meetings and discuss floods issues so that we can have solutions.

Source: Author's depiction, December 2015.

The respondents hinted on improved accurate flood forecasts which are the basis of this study and effective communication on flood prediction and warning (see integrated flood forecast and early warning in Figure 8.1). They also reiterated on the use of technology and accurate weather forecasts (see ICT in Figure 8.1). Community involvement by having flood meetings where they participate and proffer solutions was also mentioined. Community involvement and participation were important elements for inclusion in the flood prediction method (see Figure 8.1).

7.8 Conclusion

This chapter presented the findings of the study with regards to the main research question "Which IKS considerations and existing dimensions of knowledge should be included in a flood prediction model to improve the functionality and efficiency of river flood predictions in the SADC-region, to reduce river flood risks?" Data was collected from three different types of respondents, namely disaster experts from disaster management centres, community leaders from the different communities where data was gathered and the community members from the four countries under study. It is this primary data collected during the empirical research and literature review (see Chapter Two, Three, Four and Five) that were used to develop a flood prediction model for the region. Of importance was the identification of aspects or activities that the respondents felt should be included in a flood prediction model, as discussed in Section 7.7.

The information obtained from the study participants, namely community members and disaster managers, generally complimented each other. Floods were very prevalent in all the countries and had a fatal and damaging impact on the studied communities. Information obtained from the data collection exercise was supported by information from the literature review. The countries generally had flood management structures from the district to the national level. Flood prediction was centralized and was done from the National Level by the National Weather Forecast stations and National Water Ministries or Departments. The centralized approach has challenges in that the predictions that are made are generalized and not area specific. This leads to inaccurate predictions in other areas making people lose confidence in meteorological flood forecasts. A decentralized flood prediction is good as it gives localised flood predictions. The studied countries also have flood legislation to manage flood disasters but the shortcoming was that enforcement of most of the laws was weak. Non-enforcement is contributing negatively to flood impacts.

From the local level it was established that communities also have their own ways of predicting floods. This is through the use of IKS that has been learned over generations in each area. The knowledge involves reading or interpreting signs or signals from the behaviour of animals, birds, insects, plants, clouds, wind, moon, temperature, stars and water levels (see Sections 7.6.1 to 7.6.4). The successful use of IKS was confirmed by the communities under study and the literature reviewed in Chapter Five. In order to improve on flood predictions models apart from the use of IKS, communities proposed the extended use of information communication technology, communication media and community involvement.

It is against these research findings that the integrated use of the IKS and SKS was advocated by both respondents in all countries in Chapter Seven and via authorities in Chapter Four and Five. The rationale being that there is a high probability of these various knowledge systems complementing each other. Some IKS was proved to work in Chapter Five and through the testimonies of the study participants. The next chapter forms the climax of the study and layers out a flood prediction model that could be considered to predict river floods in the SADC-region.

CHAPTER EIGHT: TOWARDS A RIVER FLOOD PREDICTION MODEL FOR THE SADC REGION

8.1 Introduction

The problem of this study, as pointed out in Chapter One, is founded on the development of an integrated IKS cum SKS prediction model for managing river flood disasters in the SADC-region. Chapters Two to Five and Chapter Seven are streamlined to contribute to the development of the river flood prediction model. To achieve this, the theoretical and empirical perspectives of the study are merged. Critical information obtained from both primary and secondary data collection is factored into one user friendly framework. The framework is not isolated to flood prediction but includes other variables such as Information Communication Technology, Community Involvement, Governance and Decentralisation, Research and Development and Risks Assessment (see Section 8.8.1 to 8.8.11), that support and make flood predictions efficient and effective. All chapters mutually support each other to expose, contextualise, identify what is available and done to assist the researcher in developing a river flood prediction model for using in the SADC-countries. The numbers in brackets on each of the elements in Figure 8.1 represent the various sections in chapters where these ideas were picked up during the theoretical and empirical discussions.

The flood prediction model is an integration of components of reviewed scientific models (see Chapter Four, Sections 4.3.1 to 4.3.7) and integrated Scientific and Indigenous Systems flood prediction models (see Chapter Four, Sections 4.4.1 to 4.4.3). Furthermore, ideas, gaps identified and proposals made by the respondents (see Chapter Seven), reviewed flood prediction literature (Chapters Two to Four) and researchers (see Chapter Four, Sections 4.2.1.1. and 4.2.1.2) are incorporated. Chapter Five of this study is also critical as it takes us through the importance, successes and the various international, regional and local flood indicators used by flood communities. By using such an approach, the study is geared towards developing a better, improved and more reliable model for river flood prediction for the SADC-region.

The main guiding principle that the researcher adopted in the model design is that the resultant model should enable the SADC Member States to achieve their objectives of managing river flood disaster in the 15 SADC-countries. In addition, the model should promote the participation of Member States and therefore contribute towards regional integration. Since the participation of Member States in the project is a key issue, the design of the model was therefore participatory and transparent so that it is owned by the Member States and flood communities. The model will also be useable at all levels of governance including villages or wards. The numbers in brackets in the boxes represent the sections in the thesis where relevant discussions are found or where the ideas were picked.

8.2 Regional River Flood Prediction Model Development Process

The flood forecasting model in Figure 8.1 was developed from both empirical (Chapter Seven) and theoretical research (Chapters Two to Six). The model was built on the basis that the integration of traditional and scientific knowledge into one system would improve flood prediction and reduce flood risk in the SADC region. It was not built in isolation from international and continental flood forecast systems by other bodies like the World Meteorological Organization and what has been recorded in literature on integrated IKS and SKS currently in use, though limited. The development process included integrated scientific and indigenous models for river flood prediction. In addition to those identified, were scientific models, indigenous models and ideas from various authorities and communities on elements that are critical to include in a river flood prediction model. Models and ideas in the field of flood prediction were researched on a worldwide-scale, inclusive of Africa and the SADC-region, through a literature review and primary data collection.

What is new in the model is that the SADC will have its own home grown flood prediction model developed through the integration of components from international models and flood research. It was also developed with the integration of ideas and experiences of flood risk experts that include disaster risk managers and meteorologists in the studied countries and various communities that are affected by these floods. Of critical importance in the model is that it advocates a down to top approach to river flood predictions where flood predictions start in the community at ward and village level up to the national level through the district and provincial levels. Villages or wards, districts and provinces will be able to give their own local flood predictions and warnings that they send to the national office for verification and validation. If the national office authenticates, official flood predictions are communicated through a feedback process to the specific lower administrative levels via various platforms so that communities can prepare and mitigate the possible negative impacts of such floods. The structural and operational setup will also mean that each and every lower administrative level (Province, District and Village/ward level) will have a satellite meteorological office that will consider flood predictions at these levels. A meteorological officer will be found and based at village or ward level.

8.3 Institutional Framework

The framework of the model was influenced by disaster prediction models like the Process Framework by Mercer *et al.*, (2010), discussed in Chapter Four, Section 4.4.1 and the LIVE Scientific Knowledge Method (see Chapter Four, Section 4.4.3). The process model aims at building a sustainable combination between the scientific and IKS bases. The LIVE model discusses a process for integrating local and IKS water related hazards with science. The models reveal that it is possible to integrate the two knowledge bases to improve flood prediction. This is due to the growing awareness of the value of IKS in disaster risk reduction. There is a participatory approach using relevant indigenous and scientific knowledge. Such knowledge may be integrated to reduce a community's vulnerability to floods. Therefore the frameworks lay the foundation of river flood prediction at four levels, namely National, Provincial, District and Village levels, as indicated in Figure 8.1.

These levels are generally used to administer disaster management activities in the studied countries. A review of literature in Chapter Two, Sections 2.3.4.1 and Chapter Seven, Section 7.4.1.2 (the empirical section) revealed that Zambia's Disaster Management Act 13/2010 sanctions the development of structures at Provincial, District and Community levels for the proper administration of Disaster management activities.

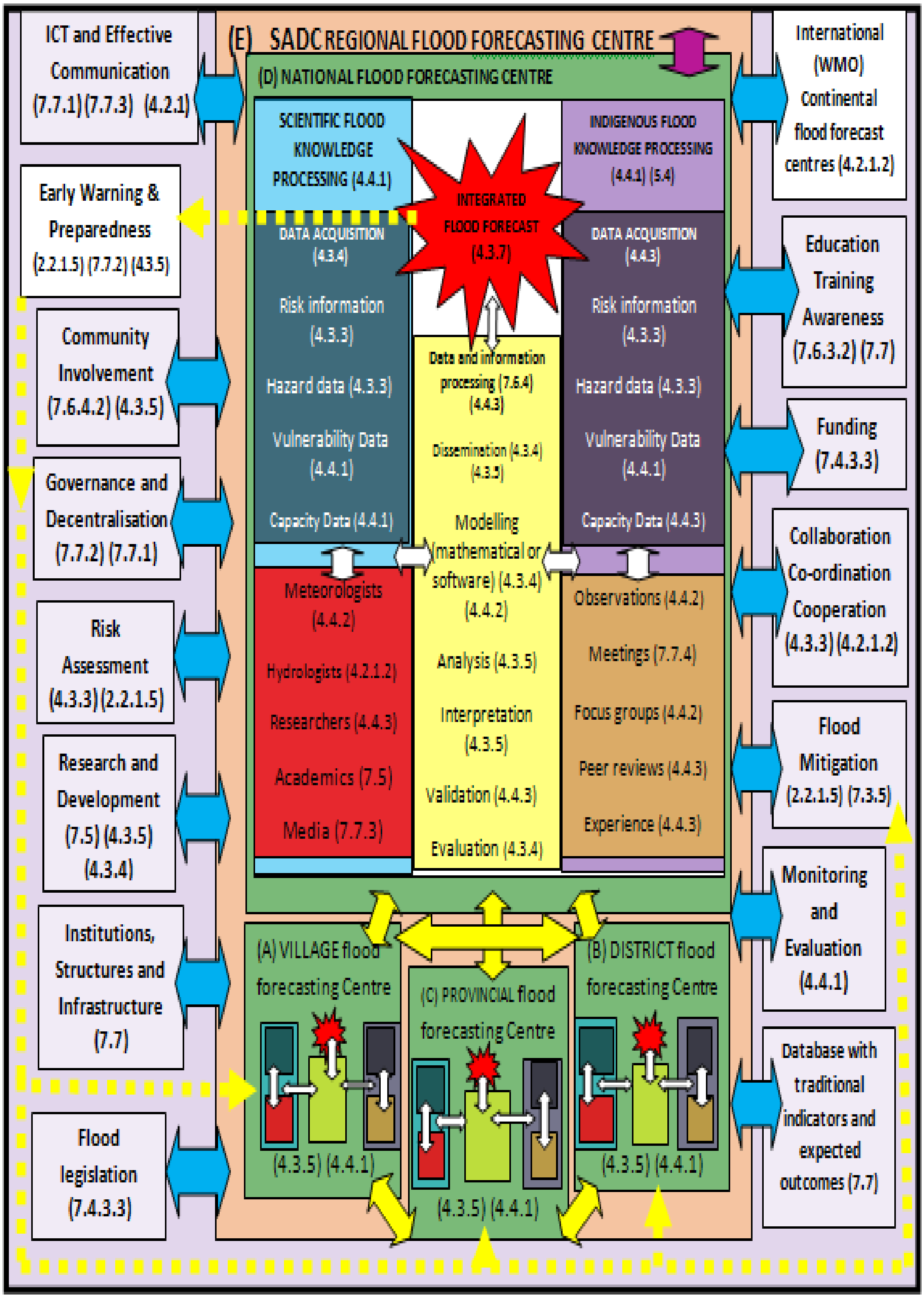

Figure 8.1: The Integrated IKS-SKS- model for Flood Prediction and Mitigation in the SADC-region

Source: Author's depiction, December 2015.

The same applies to Chapter Two, Section 2.3.4.4 and Chapter Seven, Section 7.4.2.2 of this study in which the Civil Protection Act of Zimbabwe (Chapter 10:06), outlines the institutional management of disasters through the National, Provincial and District levels. In Botswana (see Chapter Two, Section 2.3.4.7 and Chapter Seven, Section 7.4.3.2) they have disaster management structures at National, District and Village levels composed of Government officials, chiefs, traditional leaders, social workers, councillors and community members. In South Africa, disaster management structures are coordinated by the Disaster Management offices at National, Provincial and District levels (see Chapter Two, Section 2.3.4.10 and Chapter Seven, Section 7.4.4.2).

These levels (green boxes in Figure 8.1) were identified as the most ideal and basic structures found in the studied countries although they may differ at the bottom where some have villages and even wards. These must be connected (synergized) as shown by the yellow arrows such that they share all the relevant information on rainfall and predicted river floods. Since this model is being developed for the region, the same set-up must be found between the SADC-regional flood forecasting centre (indicated in the tan colour in Figure 8.1) and the national flood forecasting centre’s (green colour) of the regional countries. The structures have to collaborate and cooperate in developing and disseminating information on flood predictions. Collaboration and cooperation are some of the important constituencies of the flood prediction model in Figure 8.1.

According to Golnaraghi and Power (2012:5) lack of coordination and cooperation will fail a flood prediction and warning system (see Chapter Four, Section 4.3.3). The WMO encouraged the building of links (see Chapter Four, Section 4.2.1.2) between forecasters and global, regional and national disaster management structures to improve flood forecasts and warnings (WMO, 2007). Co-operation and coordination have to be understood and based on the participation of community groups and civil society. Local alliances have to be built to ensure that all parties understand their role in flood disaster risk reduction and preparedness activities (UNISDR, 2012:25). A need also exists to cooperate locally, nationally, regionally and internationally so as to assess and monitor trans-boundary floods and the management of river basins exchanging flood prediction information (Hyogo Framework, 2005:8). A transparent and inclusive process enables stakeholders to participate effectively (Shi, 2012:142). As such, Governments or the region has to coordinate different organisations to form a joint response force to flood risks and maximize the utilization and benefits of flood reduction resources (Shi, 2012:142).

After setting up the required institutional structure that is at Village/Ward, District, Provincial and National levels, Flood Forecasting Centres at all these various levels, that is, at National level, in Provinces, in Districts and in Villages/Wards need to be set up. In Figure 8.1, these appear as the green boxes. Moore and Beer (2015:1) propose a flood forecasting centre which houses meteorologists, climatologists, hydrologist for integrated and centralized scientific forecast production. On the same note, the various disaster management centres must link with the local knowledge and flood communities for the collection and processing of indigenous data/information (Moore & Beer, 2015:1).

The flood forecasting centres at the four institutional levels, that is, National, Province, District and Village/Ward will consist of the three main activities, namely scientific knowledge processing (blue colour) where scientific flood data is processed into information (see Chapter Four, Section 4.4.1), Indigenous Knowledge processing (purple colour, see Chapter Four, Section 4.4.1) and data and information processing in (yellow colour, see Chapter Four and Seven, Sections 4.4.3 and 7.6.4 respectively). All these processes will compliment and rely on each other as indicated by the white arrows.

8.4 Scientific Knowledge Processing

Scientific knowledge processing (see Figure 8.1 and Section 4.4.1) will have data acquisition activities in navy blue colour. Flood risk experts will bring scientific knowledge from outside the community. Before developing the integrated framework, research must be conducted in relation to a communities' cultural values and norms, ensuring that it contributes to their needs. The researcher and the community must work and identify flood problems together. This participatory approach enables communities to develop and define their own methodologies, drawing on their own conclusions and developing strategies that will work best for them. That will improve flood predictions in an effective and integrated manner.

8.4.1 Data Acquisition

Chapter Four, Section 4.3.4 exposed that data acquisition helps to produce flood forecast (see Figure 8.1). As such, data input is therefore a critical element in flood prediction and of value to the flood prediction model developed in this study. Chapter Four, Section 4.4.3 also revealed that, in the community, IKS is collected through interviews and group discussions from community members. The collected local knowledge and information must be documented.

The data to be acquired during data acquisition consists of risk information (Chapter Four, Section 4.3.3), hazard data (Chapter Four, Section 4.3.3), vulnerability data (Chapter Four, Section 4.4.1) and capacity data (Chapter Four, Section 4.4.1). The sources of this data will be meteorologists (Chapter Four, Section 4.4.2), who are weather experts and release adverse weather conditions information. The inputs will consist of risk, hazard, vulnerability and capacity information which will be part of the scientific data acquisition process. Chapter Four, Section 4.2.1.2 revealed the task of hydrologists in flood prediction. They often give information and ideas on how frequently floods of a given size occur at given places. They also provide information regarding dam levels and when dams are expected to be full, after which they might release water from them down stream. Hydrologists will also have to establish a network of gauging stations and release the recorded information. It is important to note that disaster risk management authorities' capacity to give preparedness and response actions will be dependent on the availability of accurate and timely meteorological and hydrological forecasts. Flood forecasts must be sufficiently accurate to promote confidence and if inaccurate, their credibility will be questioned and no response actions will occur. This means that flood prediction must be reliable and designed to operate during the most serious floods.

Chapter Four, Section 4.4.3 highlighted the importance of research in flood prediction. Central is the idea that community members must be identified and trained as researchers focusing on different methodologies and key scientific terms. The researchers must be able to carry out observations on animal behaviours and celestial bodies, to mention only a few. Chapter Seven, Section 7.5 revealed that research by academics will be helpful in assisting communities to integrate IK in flood predictions. As was the case in Zambia, this will assist in using river water levels to predict floods. It will also help people to delineate flood prone areas depending on the level of flooding as in Zimbabwe. Chapter Four, Section 7.5.4 revealed that research in South Africa aims at flood prevention. Chapter Seven, Section 7.8.3, on the use of media in Botswana, emphasized the thorough use of cell phones, television and radio in flood warning. The media has a very important role in informing communities. The media will be effective if given timely and authoritative forecasts. The media should also encourage appropriate public response. The place of which the forecast will apply must be clearly identified by name and if it's a large community, well-known points within that community have to be specified. Communication systems in the most remote communities must be upgraded for timely communication of warnings. Utilization of disseminated information is loaded with challenges emanating from its unreliability and difficult interpretative nature, at times making it irrelevant at the local level. Traditional media such as radio, television and the internet have to be complemented by newer media offered social networks such as Facebook and Twitter. The media has to be promoted and engaged in stimulating a culture of flood resilience and community involvement in sustainable public education campaigns and consultations at all levels of society.

8.5 Indigenous Knowledge Processing

Indigenous Knowledge processing (see Chapter Four, Section 4.4.1), indicated in purple, has activities consisting of data acquisition (Chapter Four, Section 4.4.3), in dark purple. The data to be collected also consists of risk information (Chapter Four, Section 4.3.3), hazard data (Chapter Four, Section 4.3.3), vulnerability data (Chapter Four, Section 4.4.1) and capacity data (Section 4.4.3).

8.5.1 Risk Information

Chapter Four, Section 4.3.3 reveals critical constituencies of an effective flood prediction and warning system. These include risk information. Risk exists where there are threats of potentially damaging physical events. Risk information must be collected and used to predict flood events and the degree of their possible consequences. It is only after one has identified and assessed the flood hazard, vulnerability and the people's coping capacity, that the flood risk is realized. The information will assist stakeholders to determine the nature and degree of risk in relation to floods, conditions of vulnerability that threatens people and the environment they depend on (ISDR, 2009:26). When assessing and interpreting flood risk, one must understand how communities interpret and perceive risk based on their own experience, personal feelings, values and cultural beliefs. (Eiser *et al.,* 2012:5). Moreover, information can be very helpful for the avoidance, prevention, reduction and mitigation of flood disasters. Risk information can also be used for contingency planning, flood preparedness and prioritizing measures to mitigate flood risk. Risk information will identify areas where flood risk management is most needed. All the studied communities live in flood risk areas, that is, along, around or near major rivers (see Chapter Six, Section 6.6.1). Flood risk information will inform communities about the physical characteristics such as the flood depth in metres, duration in hours, frequency and elevation of flood in metres and the social economics that include characteristics such as proximity to flood river, land use, the dominant economic activity, expected flood damage and adequacy of flood reserves (Kanchan, 2013:20). Risk information has to be incorporated into flood prediction, emergency planning and warning. This will also help flood communities to live with floods as they will be aware of their risk (see Chapter Three, Section 3.2.3.4, 3.2.4.4, 3.2.5.4, 3.2.6.4) and mitigate flood risk or flood disasters.

8.5.2 Hazard Data

In Chapter Four, Section 4.3.3, another important constituency of an effective flood prediction and warning system was disclosed. This is hazard data which will also be collected for flood prediction. Flood hazard in practical terms is the existence of more water than what is wanted by a community at a particular place and time (see Chapter Two, Section 2.2.1.2). Floods become a hazard when humans settle in flood plains or sites where rivers flood or nearby. This means that a hazard has an element of human involvement. In areas where there are no human interests, natural phenomena do not constitute hazards nor do they result in flood disasters. Flood disasters have a negative impact on people's livelihoods in the region in general and in the studied countries in particular, as revealed in Chapter Three. Therefore, accessing the hazards in a particular area is critical so that people know the hazards that affect them and take precautionary measures. All the risk information must be integrated into warning messages after the flood forecast.

8.5.3 Vulnerability Data

Chapter Four, Section 4.4.1 recognised the importance of vulnerability data in an integrated flood prediction model. Chapter Two, Section 2.2.1.5 indicated that vulnerability looks at who and what is at risk and the degree of harm. It is also stated that floods have negative impacts when people's levels of vulnerability are high and their capacity low or limited. A community vulnerability analysis has to be done. This involves understanding the locality and community in order to identify factors that impact on flood victims. The process involves identifying vulnerability factors and their effect on affected communities. The identification of vulnerability will consist of factors within and outside community control. There will also be identification of the results of inside factors that a community could address or take control of.

8.5.4 Capacity Data

In Chapter Two, Section 2.2.1.5 it was exposed that capacity data includes conditions and characteristics that permit individual and group access to and use of social, economic, psychological, cultural and livelihood related natural resources, information and institutions of governance necessary to reduce vulnerability and deal with disaster consequences. Capacity is the ability of communities in river flood prone areas to use flood prediction information which is an external source to make the best decisions in protecting themselves from the effects of floods. Capacity also entails the community or individual access to education or training in how they may reduce flood risk. This will be seen in their ability to use the flood predication developed in this study to forecast floods. This model is advocating for the integration of local knowledge known by such communities and science in flood predictions. Further to that, it's also proposing the setting up of flood prediction structures at community and village levels. This is to be done with the rationale of capacitating communities to predict floods amongst themselves and to take action.

8.5.5 Observations

Data can also be collected using personal observations. Chapter Four, Section 4.4.2 showed the importance of observations in gathering data in flood prediction. Since the study deals with river floods, apart from observing the behaviour of natural phenomena like birds and animals as flood indicators, it's also important to observe levels of flooding rivers (see Figure 4.3). When critical levels are reached, the responsible authority must be informed and alarm must be raised. The community will then be informed about the imminent floods. Decisions (even to evacuate) will be made and people will move away from danger. River water levels will continually be observed until conditions return to normal.

8.5.6 Meetings

Meetings are important for flood risk management. Chapter Seven, Section 7.8.4 indicated that communities are involved in flood meetings where they participate and proffer solutions. Community involvement or participations and these meetings are important elements in the flood prediction method. These meetings will be used by communities to review, discuss and collect ideas and information on flood prediction and management. Community members must be urged to get involved in meetings, as IKS is important in understanding what the impacts are that floods can have on communities at risk. The meetings must focus on recording community members' flood stories and how flooding affects them. Apart from discussing flood prediction issues, communities can also use the platform to improve land use planning, emergency planning and community preparation for floods. Community meetings are also an important part of the flood mapping program. Therefore, residents' knowledge can help communities to be better prepared for future flood events.

8.5.7 Focus Groups

In communities, data can be collected through focus group discussions and many other ways. Chapter Four, Section 4.4.2 disclosed that, in order to gain a deep insight into the attitudes and perceptions among flood communities, focus groups must be used. This will help in elucidating a laymen's view on flood and prediction in more depth on what they think and why as a complement to scientific methods.

People must discuss topics on flood risk management and particularly flood prediction and indicators used which must be documented. People should also talk about their flood experiences such as structural effects on floods, feelings of stress and frustration over losses and failure to get help and emotional concern about their safety.

8.5.8 Peer Reviews

Data collected must be peer reviewed. Chapter Four, Section 4.4.3 stated that, when scientific and IKS data is collected, it is further peer reviewed. This is done during the stages of community validation and scientific explanation (see Figure 4.5). In the flood prediction model developed (see Figure 8.1), peer review will be the process of subjecting indigenous flood prediction methods and findings to experts in the field. Independent and objective peer review is critical in ensuring the reliability of scientific analysis. This will be meant to prevent dissemination of irrelevant flood prediction methods or flood indicators, unwarranted claims, unacceptable interpretations and personal views. Peer reviews will also rely on colleagues that review findings from meetings and focus group discussions making informed decision about whether results are scientific or not and if results add to the larger dialogue or findings in the field.

8.6 Data and Information Processing

The yellow box in Figure 8.1 represents data and information processing (Chapter Four, Section 4.4.3). The activities for processing the data include dissemination, modelling, interpretation, analysis, validation and evaluation.

8.6.1 Dissemination

Information dissemination (Chapter Four, Section 4.3.4) revealed that merely making flood predictions is not enough as they need to be communicated to beneficiaries. For flood predictions to be effective, flood information has to be disseminated timeously so that proactive measures are taken by susceptible communities before floods strike. Chapter Four, Section 4.3.5 revealed that the dissemination of information has to be timely so that people make effective decisions. People must be trained to clearly understand the meaning of forecasts and understand the risk posed. Forecast messages are sent to villages/communities through megaphones, drum beating, poster, drama, documentary and local training.

8.6.2 Modelling

Parkers' model in Chapter Four, Section 4.3.4 and the United States Community Hydrologic Prediction System (Figure 4.3 in Chapter Four) identified flood modelling as a necessary activity in flood predictions. Modelling involves limiting real phenomena or a process with a set of mathematical formulas or the use of software. The reduction to mathematical data and equations is then simulated on a computer. Flood modelling will consist of hydrological and hydraulic modelling. Hydrologic modelling will determine the amount of runoff after rainfall events. The hydraulic model will calculate flood levels and flow patterns. These activities will be done by experts such as hydrologists or flood engineers with extensive experience in hydrologic and hydraulic modelling.

8.6.3 Analysis

Chapter Four, Section 4.3.5 highlighted the importance of analysis in flood prediction. During data analysis, frequencies of the observations made are tabulated, trends analysed, outcomes compared and explanations on outcomes provided. In addition to this, there must be continuous monitoring for improvement of various activities. This process may be done through surveys on the various stakeholders. A need for constant monitoring and periodic coordination of meetings and seminars by all stakeholders therefore exists to enhance the usefulness of flood forecasts. The activity also evaluates the accuracy and promptness of forecasts, public awareness and response to warnings and interactions and communication between stakeholders.

8.6.4 Interpretation

In Parker's model (Chapter Four, Section 4.3.4), it is shown that interpretation is an important element in flood prediction. The assertion is also supported by Chowdhury's model in Chapter Four, Section 4.3.5. It was revealed that interpretation of information produces the flood. Furthermore, Chapter Four, Section 4.4.3 indicated that interpretation involves assigning meaning to the observations and confirming that the expected event took place. There is then the analysis of trends, comparison of outcomes and giving explanations to the outcomes. These are documented and presented to the community. The community then validates the results using key informant interviews and focus group discussions. During this activity, the probable impacts of floods on vulnerable communities are identified and people are warned about them. The information must be effectively used to minimize flood risk.

8.6.5 Validation

Validation is another factor that is included in the flood prediction. Chapter Four, Section 4.4.3 revealed that, during validation, documented IKS is analysed by the community to determine the knowledge and practices commonly used and considered effective. The participants confirmed whether the IKS was widely used in the community and not just by a few individuals. The community also had to determine if the knowledge was still in use and had existed in the community for more than one generation. The effectiveness of the IK in flood prediction, mitigation, preparedness and prevention was also assessed.

8.6.6 Evaluation

Chapter Four, Section 4.3.4 identified evaluation as a necessary component in flood prediction. This factor is included in Figure 8.1. The flood forecast will always be refined on the basis of monitoring performance and lessons learned from operational experience. This process will help in identifying shortcomings of the flood prediction model and thereby calling for its improvement. During the process, there will be generation of new knowledge and learning will take place. What this means is that the model is not an end to itself but open for improvement. The performance of institutions, organisations, methods and processes in the flood prediction model mitigation should be monitored and evaluated. Evaluation also measures change over time, looking at the strengths and weaknesses of the project.

8.7 Integrated Flood Forecast

Lastly, within the integration of IKS and SKS is the product, an integrated flood forecast. Chapter Four, Section 4.3.7, highlighted that forecasting involves the prediction of rainfall and floods. This stage involves the prediction of rainfall, floods, river levels and flows. The flood prediction also predicts the time of occurrence, flood severity and duration. Methods involved in all these processes were discussed in the previous sections and also include techniques like rudimentary correlation that is based on experience and mathematical models.

8.8 Feedback Loop and Arrows

The model represents five distinct structures. These are the Regional Flood Forecasting Centre (E), National Flood Forecasting Centre (D), Provincial Flood Forecasting Centre (C), District Flood Forecasting Centre (B) and Village Flood Forecasting Centre (A). Data and information are shared and feedback given between the Regional and National flood forecasting centre as indicated by the bidirectional purple arrow. Within each country, there are four structures at national, provincial, district and village levels (green boxes) that share information and give feedback to each other as indicated by the bidirectional yellow arrows. The dotted yellow line also acts as feed back of flood early warning information to specific Villages, Districts and Provinces that will be directly affected by river floods. The integrated flood prediction at National level is also linked to flood mitigation and early warning and preparedness in Figure 8.1. As already been alluded to in Chapter Seven, Section 7.3.5 and Chapter Two, Section 2.2.1.6, the ultimate aim of the Flood prediction model is to mitigate the effects of floods.

The activities that occur in the flood forecasting centres in all the structures (Village to Region), Scientific Flood Knowledge Processing (blue box), Indigenous Flood Knowledge Processing (purple box), Data and Information Processing (yellow box) and the Integrated Flood Forecast (red star) also share data and information giving feedback to each other as shown by the white bidirectional arrows.

The flood prediction exercise will not be merely done in isolation. Other disaster risk support activities (white boxes) are also incorporated that include risk assessment, flood legislation, governance and community involvement to name but a few. The information from these support activities and the necessary feedback are linked to the flood prediction exercise by the bidirectional arrows in blue.

8.8 Flood Prediction Support Activities

However, flood forecasting on its own will not achieve its objectives without the support of other important activities in flood mitigation. What this means is that the operational efficiency and effectiveness of the model are enhanced in an environment where there are a number of supporting variables. Chapter Four, Section 4.3.7 also revealed that the model must be integrated such that it also includes issues dealing with institutional arrangements, technology, information management, supportive legislation, securing political commitment, coordination and cooperation between stakeholders. Of interest to note is that technology that matches local circumstances is needed in the flood prediction system. Also indicated as critical in a flood prediction model is the recruitment of expert staff, free flow and access of information (IKS) and developing legally binding cooperative agreements between organisations.

8.8.1 Information Communication Technology and Communication

During the data collection exercise, respondents spoke of the need to improve information communication technologies (ICT). Chapter Seven, Section 7.8.3 emphasized on the need to thoroughly use cell-phones, television and radio. According to Chapter Four, Section 4.2., there have been recent advances in technology giving rise to modern models in the field of applied hydrology by expanding the capabilities of data acquisition and analysis. There is remote sensing through the use of radar technologies, powerful computers that receive and handle data in a timely manner and software such as Geographical Information Systems (G.I.S) that link information with location. These modern tools also maximize the benefits to be gained from forecasting under severe weather conditions. Due to ITC, an integrated global observation of the weather like the World Meteorological

Organisation (WMO) will improve flood predictions. The MWO will be important as weather forecasts produced by the most advanced weather services will be availed to forecasters in many flood affected countries including the SADC. The WMO will be a great source of information for input into the flood prediction model.

8.8.2 Community Involvement

Community involvement is critical in all disaster risk management endeavours. Chapter Seven, Section 7.6.4.2 revealed the need to involve flood victims in all flood risk reduction processes. Communities also need to be involved in the planning, implementation, evaluation and decision-making process of flood mitigation. Community participation enhances flood mitigation as the communities will claim ownership of the flood mitigation processes. Chapter Four, Section 4.3.5 revealed that seasonal and consensus forecasts are arrived at through the involvement of regional, national and the forecast users.

8.8.3 Governance and Decentralisation

Chapter Seven, Section 7.8.1 and 7.8.2 showed that flood prediction is centralized and the responsibility of the meteorological services at national level. Decentralizing flood prediction to other levels up to the community level is critical to effectively predict floods at all levels. The government has to consider decentralizing flood prediction through the coordination of its arms, the Meteorological Services and the Civil Protection Unit.

8.8.4 Risk Assessment

Chapter Four, Section 4.3.3 highlighted the importance of risk assessment in flood prediction. Risk assessment was identified as a helpful aid to reduce flood risk. Risk assessment includes the use of information to determine the likelihood of flood events occurring and the degree of their possible consequences. Risk assessment will help in identifying and mapping high flood risk zones and flood risk reduction priority areas in the region. In flood risk reduction, communities have to participate in risk assessment and also make their own appraisals of the local floods, their impacts, local resources to reduce risk and evacuation or relocation of route maps.

They also need to develop their own flood risk reducing measures. Flood risk assessment information, awareness and knowledge are important as they enhance communities' state of preparedness and mitigation of flood effects.

8.8.5 Research and Development

It was indicated in Chapter Seven, Section 7.5 and Chapter Four, Section 4.3.5 that flood prediction will always be improved through research and development. Research is very critical in identifying effective indigenous indicators for flood prediction. As been alluded to in this study, most IK is not documented. The older generations are its custodians, therefore there is need to identify those knowledgeable in communities, extract such knowledge and document it.

8.8.6 Structures and Infrastructure

In order to mitigate flood impacts, Chapter Seven, Section 7.8.3 suggested the building of strong structures like homes and infrastructure like bridges. It has been noted that these structures are also weak and easily affected or destroyed by most floods. Building strong structures will mitigate the effects of floods. Building codes also has to be considered as an essential component of flood disaster prevention. The codes need to regulate specifications for design, constructions, operations and maintenance of buildings and other structures to sustain their strength and durability. Strong structures lessen the toll of human suffering, structural damages and property losses during floods.

8.8.7 Flood legislation

Chapter Seven, Section 7.4.1 to 7.4.4 revealed that the studied countries have flood legislation. Even though flood legislation is available, it is weak, especially when it comes to implantation and penal provisions. It is important for each country to have adequate legislation that addresses and firmly establishes clear responsibilities, coordination and penalties to enforce flood risk management. Laws promote sustainable development of settlements and reduce exposure to frequent flood risk.

8.8.8 International WMO and Continental Flood Forecast Centres

Chapter Four, Section 4.2.1.2 described how global approaches can be harnessed into effective flood prediction in the SADC-region. This must be done by developing a meteorological early warning system through the influence of the World meteorological organisation's (WMO) in an effort to enhance weather forecasts globally. Through such platforms, the region has a structure to monitor and issue warnings involving global, regional and national centres and receives support to use new forecasting technology that enables it to issue early warnings. This encourages the building of links between forecasters and global, regional and national disaster management structures.

8.8.9 Education, Training and Awareness

Education, training and awareness are important constituencies for flood prediction. Chapter Seven, Section 7.6.3.2 and 7.8 revealed problems that are faced when flood predictions are made. It has been shown that people at times ignore flood prediction and warnings due to its ineffectiveness. In brief, some of the reasons for such behaviour are financial, lack of understanding, failure of official flood warnings and high level warnings given when the storm is weak. Some of these problems may be resolved through education, training and awareness programmes.

8.8.10 Funding

Chapter Seven, Section 7.4.3.3 indicated some government efforts to mitigate flood disasters. These efforts include flood funding. It was shown that, although some of the studied countries had legislation providing for disaster funding, it has become common that failure by some governments to deliver appropriate and reasonable resources and assistance in flood risk reduction is always accompanied with a plea for lack of resources and capacity. Furthermore, if flood risk reduction funds are available they are not used for that, but rather for response activities such as saving lives and distributing relief supplies. To get relief, governments need to assign flood risk reduction budgets and offer incentives to communities, businesses and the public sector that invest in reducing the risks they face. To control corruption and embezzlement, finance and material for flood risk management activities should be managed by committees rather than individuals. Communities and other stakeholders must be included in flood planning.

8.8.11 Collaboration, Coordination and Cooperation

Flood prediction is not a one man or one organisation activity. There are many players involved. Since flood prediction is a communal activity, Chapter Four, Sections 4.3.3 and 4.2.1.2 indicated that collaboration, coordination and cooperation are important in its success. Due to globalization and a network society, Government, apart from playing a leading role in flood risk management, has to design a system that can create an open environment for different stakeholders to realize their maximum efforts in achieving flood risk prevention and reduction. Coordination is important in flood risk management as it overcomes fragmentation that results from specializations of various parties and geographic boundaries of operation. Local Governments should partner with other stakeholders in order to expand resource mobilization, use and share information to strengthen their flood risk reduction strategies. The advantage is that less technological countries will benefit from the information and expertise from the developed world through data collection, analysis and dissemination.

8.8.12 Database of Traditional Indicators

All the institutional structures (levels) in the model must have a record (database) of information on indigenous river flood indicators. This database must be available and communicable from village to the SADC-level. The database must have a record of all the valid and reliable indigenous or traditional or local indicators/signs for floods for that particular structural level or area. An example of this might be as illustrated in the flowing matrix that links traditional indicators and expected outcomes for each structural level or local area as shown in Table 8.1.

Table 8.1: Database for traditional indicators and expected outcomes at National level

Name	**Indicator**	**Expected outcomes**	**Region/Place**
River	Groom sound in the river	Floods	Muzarabani

Clouds	Black rolls of clouds	Heavy rain	Chinhoyi town
Animal (Cattle)	Restless and not grazing	Heavy rains imminent	Hope Farm
Insect (Ants)	Climb trees with eggs on their backs	Heavy and rains imminent	Masvingo
Bird (Swallow)	Flock seen flying all over the atmosphere	Heavy and continuous rains imminent	Mrewa

Source: Author's depiction, December 2015.

8.9 Conclusion

Chapter Eight in essence marks the climax of the study. The chapter was concerned with working towards an integrative river flood prediction model for the SADC-region in which IKS and SKS feature. The research question deliberated on in this chapter was: "Are there any possibilities of working towards developing a river flood prediction model to serve as a feasible procedure in managing river flood risks?" The main problem grappled within this study was that there seemed to be no sufficient knowledge integrated river flood prediction models in the management of flood disasters in the SADC-region. The development of a revised or combined river flood prediction model from existing models, and inclusive of IKS together with SKS for the SADC-region *per se* might serve as a pro-active point of departure to efficiently consider record, manage and eventually reduce the effects of river flood disasters.

The structure of a proposed flood prediction model as a structural consideration and way forward for the SADC-region is outlined as a framework. In "The Integrated IKS-SKS- model for Flood Prediction and Mitigation in the SADC-region"-framework, both indigenous and scientific methods are considered for predicting floods. These methods are both experienced and used to the extreme. Scientific prediction methods for example are mostly applied at national level. In the proposed model, meteorological and hydrological offices should be considered to be established at a much lower operational level like districts, villages or wards, because it's on these levels that scientific knowledge and traditional knowledge could be properly integrated. Equally so IKS that are ingrained at village and ward levels will be required to be transmitted and utilised at national level together with scientific obtained knowledge.

As already been alluded to, flood predictions have to be supported by flood mitigation strategies, so that flood risk reduction becomes an integrated and effective effort. Other strategies to be considered at regional (SADC-level) and national as well as lower community level were also suggested in this chapter, such as flood legislation, structures and infrastructure, community involvement, governance and decentralisation, research and development, education, training, awareness and funding (see Section 8.8.1 to 8.8.11). These strategies are part of the model developed in this chapter meant to compliment the IKS and SKS that formulate the basic structure of the model.

In Chapter Nine to follow, the study is summarised, analysed and some recommendations proposed.

CHAPTER NINE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

9.1 Introduction

River flood disasters are a reality in the SADC-region, let alone in the studied communities of Chanyanya (in Zambia), Tokwe-Mukosi (in Zimbabwe), Satau (in Botswana) and Tonga (in South Africa) in the southern sub region. These floods bring loss of life to people and negative effects on people's livelihoods. Governments are making some efforts to manage flood risk within communities but much more still needs to be done to reduce flood risk and to better the lives of people living in flood affected areas. Better ways and new methods of managing floods through both structural and non-structural means have to be advocated and adopted. Among others is the non-structural method of having effective flood predictions so that communities are better prepared and can be able to effectively mitigate flood impacts. Let it be borne in mind that flood risk reduction is not anyone's job but everybody's business. Therefore, every stakeholder has an equal role to play in reducing flood risk.

The main problem grappled within this study was that there seemed to be no inclusively considered IKS cum SKS integrated river flood prediction model in the management of flood disasters in the SADC-region, specifically in the southern sub regional area as indicated by the studied countries. The main research question dealt with in this study was: "Which IKS considerations and existing dimensions of knowledge should be included in a flood prediction model to improve the functionality and efficiency of river flood predictions in the SADC-region, to reduce river flood risks?" The main research question was answered through the development of a revised or combined river flood prediction model from existing models, and inclusive of Indigenous Knowledge Systems for the SADC-region. The model serves as a pro-active point of departure to efficiently consider record, manage and eventually reduce the effects of river flood disasters.

A survey was done in the context of the management and prediction of river flood disasters in the SADC-region. The literature review shows that the SADC-region suffers from annual recurrent river flood disasters. The studied communities live in flood prone areas for the same survival and economic needs especially agriculture and fishing. Due to their location communities are constantly being affected by river floods caused by heavy rains and at times cyclones. Some of the floods are being registered as being of high intensity and magnitude. Statistics indicate that floods are continually causing deaths and destruction of infrastructure, agriculture and domestic animals. Apart from that sanitation facilities are also damaged, water is contaminated and there is increase in human disease. Despite these challenges communities are staying put in flood risk areas. This simply accentuates that water is a key factor in people's lives and has influenced human settlement patterns and the location of activities such as agriculture and fishing for the studied countries and the SADC-region. Therefore the devastating effects of floods can be minimized through risk reduction strategies like flood prediction and advance warning. The literature reviewed and discussions helped understand and identify disaster risk management gaps in the SADC specifically the southern sub region.

It was found that some flood prediction methods/models are being used in a number of developed countries and the SADC-region. The models discussed in this study include scientific flood prediction and warning models and integrated indigenous and scientific knowledge disaster risk reduction model. All these models were important to the study as various aspects from each of them were identified as valuable inputs that were included in this study's developed flood prediction. The most important of the models were the ones that integrate both scientific and indigenous knowledge namely, the Integrated indigenous and scientific knowledge model, the United States Community Hydrologic Prediction System and the Jamaica Community Hydrologic Prediction System. These models assited in developing the frame work for the Integrated IKS-SKS- model for Flood Prediction and Mitigation in the SADC-region specifically the southern sub region. The United States Community Hydrologic Prediction System and the Jamaica Community Hydrologic Prediction System were even more relevant to the study as these were community based flood prediction models.

Of interest from the worldwide models which were discussed and learnt are various factors that were identified related to administration, coordination, legal support and political will , use of technology, community involvement, scientific and indigenous methods integration and the use of space technologies that enhance flood forecasts. These factors identified were of value to this study as they indicated the multidimensional approach to improving flood prediction. So many factors are involved in flood prediction effectiveness as such these were benchmarked for use in the SADC-region and included in the model developed in this study.

The contextual literature survey indicated the SADC-region has flood management policies like, the SADC-regional Water Policy of 2005 and regional platforms like the Southern Africa Regional Climate Outlook Forum (SARCOF). The studied countries also have flood risk management structures at village, district, provincial and national levels. The countries also have and legal instruments like the Disaster Management Acts, Environmental Management Act and other sector legislation that are being used in the studied countries' efforts to manage flood risk.

Also learnt is that In the past and up to date, many different communities globally continue to rely on Indigenous Knowledge than scientific knowledge to predict the amount of rainfall and flood disasters. This is due to among other things, difficulty in accessibility and interpretation of conventional weather forecasts. The common trend in all the cases discussed in this study, is that, traditionally many forecasts are made through interpretation of the behaviour of animals, plants, winds, clouds just to name a few. To a great extent many traditional communities the world over have the capacity to predict rains and also floods through tried and tested means over generations, using the behaviour of natural phenomena.

It is noted in the literature that the integration of IKS and SKS into a flood prediction model is very possible and would be a good step towards developing an efficient and effective flood prediction model for SADC region specifically the southern sub region. Several sources pointed out that IKS should be applied with SKS in an integrated effort towards establishing a flood prediction model as it is locally focused and based in the reality of a specific community. IKS could form the basis for decision-making on any community's flood disaster survival strategies. The communities have knowledge in the form of strategies or know-how in predicting floods thereby providing methods for flood risk mitigation.

Despite considerable efforts being made by governments in the countries under study to mitigate the effects of flood disasters, there are various challenges being faced in effectively and efficiently mitigating flood effects. These challenges bring out the gaps that need to be addressed by this and other studies that might be instituted. These include lack of right policies and long-term strategies and absence of effective legal frameworks. Flood management is mainly focused on response at the expense of flood risk reduction (pro-action). The studied countries also had inadequate allocation of resources and it is suggested in the study that the crafting of strengthened laws and policies will support the allocation of adequate funding flood risk reduction. There are inadequate institutional arrangements at all levels due to financial, human, material, equipment and capacity challenges. Flood forecasting and warning is at times ineffective due to false flood predictions and warning. Flood management is also not effective due to reluctance in implementing up to date regulations. There is also minimal public participation in the flood risk reduction decision-making processes. Resistance from flood communities to move away from risk areas is also a major challenge. Flood prediction methods are ineffective at local level as the ones being used are top-down and disregard local knowledge systems. It is the ineffectiveness of flood prediction at the community level and lack of integrating IKS in flood prediction models in the studied countries that motivated this study.

There are also queries to the relevance of some flood risk management legislation as the fines imposed are too little for deterrence and are fixed irrespective of the damage that has been caused. Some of the legislation does not penalise for any wrong doing. Lack of funding, budget polices for risk mitigation and capacity to mainstream DRR were also noted as constraints in translating momentum into sustainable programs and investments that reduce long-term vulnerability. On the technical side there are problems associated with the installation and operation of flood warning systems, insufficient rainfall and hydrometric networks and redundancy of recording equipment. Further to that, flood warnings are too technical for common people to understand. There is absence of mechanisms for effective information or data collection and exchange. There is lack of or no political will in the SADC to manage flood disasters. Although there is increased support at policy level in the studied countries the commitment and ability to act on the ground is still limited.

These are some of the problems that have to be grappled with if the SADC-region, especially the southern sub region has to predict floods effectively and mitigate their effects. To a great extent all the countries under study have disaster management policies, structures and legislation but these instruments have weaknesses that need thorough attention. These gaps have triggered the need for the development of an effective river flood model for the SADC-region, specifically the southern sub region.

Literature has also indicated that despite its usefulness, local knowledge is threatened with disappearance. That is being caused by lack of its systematic documentation and lack of a coordinated approach to research its accuracy and the reliability of its forecasts. Therefore harnessing, repackaging and integrating science and local knowledge systems will present the people of Africa and the SADC-region in particular with a major contribution to a less flood risk free area. All the four studied countries are showing substantial progress in the mitigation of flood disasters. Although some of the country activities are independent, the countries also communally engage each other at regional level, and share resources, ideas and information towards managing floods disasters. Even though some communities in the studied countries use Indigenous knowledge in predicting floods this form of knowledge is not yet fully formalised.

This chapter gives the summary, major conclusions and recommendations of the study**.** In the summary, the objectives of the study are questioned to determine whether they have been achieved or not. In case of the non-achievement of specific objectives, reasons are provided. The chapter also makes recommendations and a proposal for continuous study in this field.

9.2 Integrating major features from the research questions explored

This section presents the chapter summaries of the study from Chapters One to Nine. Chapter One highlights the research motivation on the past and present status of river flood disasters in the SADC-region, specifically the southern sub region.

Chapter Two focuses on the conceptual and contextual survey of the presence and management of river flood disasters in the SADC-region. In this chapter, the focus is on conceptually understanding the definitions that go hand in hand with river flood disasters. Following this discussion, is a contextual review on flood risk reduction as a disaster risk management element in the studied southern sub regional countries, namely Zambia, Zimbabwe, Botswana and South Africa. Amongst others, the emphasis is on what the governments of these countries have so far done to mitigate the effects of flood disasters as stated in the reviewed literature (Secondary Data). Current challenges and requisites for flood risk reduction and prediction in the region are outlined. The chapter helps to address the study's research question: "What have the governments of the four SADC-countries under discussion done so far to mitigate the effects of river flood disasters occurring in the region?"

Chapter Three concerns the historical review of the occurrence and management of river flood disasters in the SADC-region, and the southern sub region in particular. The historical perspective focused on floods in Zambia, Zimbabwe, Mozambique and South Africa during the period 2000 and 2013. The historical trends and impacts of floods helped disaster practitioners and the researcher to make reasonable decisions on flood risk using abundant information. The chapter addresses the research question: "What is the past and present status of river flood disasters in the SADC-region?"

In Chapter Four, prominence is given on existing literature regarding flood prediction research, the use of flood prediction models worldwide and how some of the prediction methods and research may serve as possible instruments to deal with the management of river floods in the SADC-region. The models used included scientific and indigenous ways of predicting river floods. It is these models that guided the writer to develop an improved, if not new river flood prediction model for the region. Flood prediction research assisted this study to identify any specific flood prediction models being used in the SADC-Region with as particular focus the southern sub region and the extent to which it can provide guidance in river flood prediction possibilities.

Chapter Five is a focus on Indigenous Knowledge Systems (IKS) and how it is being used in the SADC-region, in Africa and the rest of the world. Success stories on its purposefulness are also highlighted in small island countries like Malaysia, Indonesia and Thailand as their flood prediction models integrate IKS. Their approach (integration of IKS and SKS) was also benchmarked in the flood prediction model in Figure 8.1. The realities and practicalities of integrating indigenous and scientific knowledge bases are discussed. The chapter discusses the relevance of Indigenous Knowledge in river flood prediction and the possibilities of working towards developing a river flood prediction model to serve as a feasible procedure in managing river flood risks in the southern sub region.

In Chapter Six, the research methodology used in this study is discussed. This focuses on qualitative research, the mixed method, the survey design, population, sample and sampling, data collection and instruments used, pilot testing, validity and reliability of instruments and data analysis methods. Justification for using the various methods and challenges faced are provided.

Chapter Seven presents the oral voice and knowledge on managing or/and reducing river flood disasters. This is a discussion on the findings from a questionnaire and interviews conducted among experts and affected communities in the southern sub region. The chapter also looks at what governments have so far done to mitigate the effects of disasters in the SADC-region, with as emphasis the southern sub region as interpreted from the data collection exercise (primary data). This chapter covers all the six research objectives of the study.

Chapter Eight culminated into the climax of this study. All the work done during the secondary and primary data collection stages ended in the chapter. The chapter takes us towards the development of a flood prediction model. The model has various constituencies, mostly made up of the processes of integrating indigenous and scientific knowledge systems to come up with an effective flood prediction. The model also consists of institutional structures that have to be developed from the village level. Other support structures that include training, financial and political, to name only a few are also important in supporting an ideal flood prediction for a particular area. The whole effort in the study was towards the development of a revised or combined river flood prediction model from existing models for use as a flood risk management procedure, method or model for the SADC-region, and foremostly the southern sub region. This chapter identifies and discusses the various aspects or dimensions that are and should be included in a flood prediction model to improve the functionality and efficiency of river flood predictions in the SADC-region to reduce river flood risks especially in the studied countries.

Chapter Nine is the closing chapter of this study. It summaries and concludes the study makes recommendations. An area for further research is also proposed.

Using the theoretical and empirical findings of this study, it can therefore be concluded that the following objectives were achieved:

9.2.1 Objective one: Investigate the past and present status of river flood disasters in the SADC region with as emphasis the southern sub region

This objective was achieved through both a literature review (see Chapter Three, Section 3.2 and 3.3) and empirical studies (see Chapter Seven, Section 7.3). Findings include that river flood disasters continue unabated in the four studied countries Zambia, Zimbabwe, Botswana and South Africa. All of these countries overwhelmingly indicated that they have recurring river floods with some of them having river flood disasters nearly every year. From the information given about the occurrence of floods it is undoubtedly clear that the SADC-region has floods nearly each and every year, exposing communities to flood risk. In general, floods depend on rainfall amounts and are area specific. There are also manmade circumstances that contribute to flooding. These include building and settling in flood plains or catchment areas, damming, poor town planning and drainage, deforestation and mining. Also singled out as flood factors are poor agricultural practices, dam overflows, geographical location and poor environmental management activities that lead to silting of rivers.

Past flood disasters in the studied countries resulted in people being killed, injured and displaced. Homes were damaged and destroyed. Further to that, school children missed school due to flooded rivers and people were cut off from social institutions like shops and clinics. Domestic or livestock animals were also affected in several ways that include being submerged, swept away, struck by lighting and stuck in the mud. Some livestock got lost or mixed up with wild animals. Cattle goats and sheep play an important role in the socio-economic life of communities. Apart from being a form of wealth, these animals are the main or supplementary forms of income for most rural communities or farmers. They also provide a form of self-employment. During flood disasters, when these animals and especially cattle die, so does wealth. Grazing land was also submerged and the natural environment also got affected. Trees got submerged and uprooted, there was siltation, soil erosion, water logging, leaching and disruption of farming activities and loss of livelihoods. Some rivers also changed their course.

9.2.2 Objective two: Government efforts in mitigating flood disasters

This objective was achieved using a literature review and empirical findings. The SADC-region has abundant water and flood management structures. These are comprised of the SADC-regional Water Policy, The Southern Africa Regional Climate Outlook Forum (SARCOF), Integrated Water Resource Management (IWRM), Article Two of the Protocol on Politics and Defence Cooperation (2001) and Article 25 of the protocol on Health (1999) (see Chapter Two, Sections 2.3.3.1 to 2.3.3.4). Governments have the responsibility of protecting its citizens against flood disasters. The attitude of Governments towards flood risk management is positive. This can be seen in that the studied countries have disaster management structures from national level to ward/village or community level. The structures are composed of Government, communities, private players and Non-Governmental Organizations. The government players include chiefs, councillors, social workers, meteorologists, hydrologists, government departments like the police and the army, provincial and district administrators and some ministers. Communities are also part of the structures/committees (see Chapter Two, Section 2.3.4 and Chapter Seven, Section 7.4.1 to 7.4.4).

Governments and private organisations are providing training, awareness campaigns and meetings to make communities aware of flood risks and response (see Chapter Two, Section 2.3.4 and Chapter Seven, Section 7.4). Authorities are also encouraging the formation of disaster risk reduction committees within the communities. At risk communities also have disaster risk management plans that they developed. Those who are into agriculture are being educated and encouraged to grow early maturing crops that might not be affected by floods. Others, in minor flooded areas, are being encouraged to grow rice. Indigenous Knowledge systems are being recognised and communities are being urged to use them, share or communicate early warnings of floods. People are also being encouraged to keep ducks that are more resilient to floods than chicken.

All the countries, with the exception of Botswana, indicated that they have substantial disaster management legislation (see Chapter Two, Sections 2.3.4 and Chapter Seven, Sections 7.4.1 to 7.4.4). Botswana was using or was depending on other sector legislation to manage flood disasters at the time of data collection. Unfortunately legislation in all the studied countries does not provide any penalties for breaking any flood management regulations. Crafting legislation with penal provisions is paramount if flood risk is to be reduced. The countries under study, apart from Botswana, have funding provided for their flood disaster management activities. Funding is secured from both private organisations and the government (see Chapter Two, Sections 2.3.4 and Chapter Seven, Section 7.4.1 to 7.4.4). This is a positive step towards disaster management because such activities need money to be workable. However, funding is mostly provided for disaster damages and losses of to affected families and individuals. Most of the time, when flood disasters strike, the funds are not enough or not readily available. This means that Governments must be serious and set aside national budgets for disaster risk management activities. Governments and private organisations are providing training, awareness campaigns and meetings to conscientise communities of flood risks and response. Through such programmes, some communities and members are preparing for and mitigating flood effects by being proactive (see Chapter Seven, Sections 7.4.1 to 7.4.4).

However, there seem to be challenges regarding government's interest and responsibility towards flood risk management. Sufficient funding was cited as a big challenge in this study. Some of the other problems cited were lack of proper information sharing and interference by politicians who override technocratic decisions. Communities were also said to have an inclination towards listening more to politicians. Governments are concentrating more on response than proactive disaster activities. There are many problems that practitioners come across when implementing flood prediction and warning. The first is the language issue where flood prediction and the warning language are not user friendly. People fail to understand the jargon used. There is also lack of communication technology in some of the communities. Some people do not have cell phones and if they do have, the network becomes the challenge. The other problem faced is that people resist relocation. There is also no robust early warning system in the communities. Further to that, early warning is not localised. This shows that serious efforts need to be made to educate and train people on the importance of flood prediction, early warning and relocation. Governments also need to invest much in information technology to make communication easy and accessible. Language that is localised and understood by communities needs to be coined.

9.2.3 Objective three: Determine the extent to which research has provided guidance in river flood prediction possibilities

This objective was achieved using a literature review and empirical findings (see Chapter Four, Sections 4.2 and Chapter Seven, Section 7.5). There are at least signals that river flood prediction research is being carried out in the studied countries, although indications were that no research was being done in Botswana. This study is also confirmation that the studied countries, including Botswana, had some river flood prediction research as their disaster management centres and some communities were visited to gather data on floods and how they were being managed. Results from the flood research worldwide indicated that flood prediction models were not very precise. This meant that there was a need for the development of a flood prediction model. Setting up technological stations was expensive in the low developed countries. Some of the research literature highlighted the importance of using and improving the use of technologies like satellites, remote sensing and geographical information systems (see Chapter Four, section 4.2.1). The research studies also emphasised the use of statistical and numerical models and setting up weather observatory stations at lower levels like the community level. Research is also advocating for the use of local/indigenous/traditional knowledge in flood prediction (see Chapter Five, Sections 5.3 and Chapter Seven, Section 7.6). The idea being propagated is that scientific and effective indigenous methods of flood prediction must be integrated for effective flood forecasts. Research on floods is very important as it helps with identifying and scientifically solving flood risk problems.

Flood impacts will be reduced if research also focuses on the management of forests or trees, agricultural methods, town planning and environmental issues. Research further indicated the need to collect and document how communities in these areas manage floods, especially when it comes to Indigenous Knowledge systems for future use. Although there is evidence that there is river flood research in the region, such an activity has to be enhanced through the provision of research funds.

Apart from the Government, there is evidence that there are also other organisations that are into river flood prediction research. Research is being done by Universities, water ministries or departments, meteorologists and Non-Governmental Organisations. Areas prone to floods are being identified and delineated according to the degree of flooding. The recommendation of these research activities has been to encourage local communities to use IKS in flood prediction (see Chapter Seven, Section 7.4). As already been alluded to, this study also makes a contribution towards such research. Research strengthens the flood risk reduction exercise. This also shows that the region is serious about flood risk management. Although the results might not be favourable, the fact that there are such initiatives puts the region on the positive side of having the inclination to reduce floods through research initiatives.

Some communities in the studied countries are also involved in some of the flood research in their countries (see Chapter Seven, Section 7.5). These communities or flood victims have vast and rich knowledge on flood prediction and risk management. Involving them in flood research will enhance research endeavours and information sharing improving managing flood prediction methods. Through the research process, communities will learn and get educated on how to identify and solve flood prediction issues and problems on their own. Participation, as enunciated by literature, will give communities a sense of ownership when it comes to river flood risk reduction activities. Flood victims or communities need to be embraced in river flood prediction research as critical stakeholders. To a great extent, research is providing guidance in improving river flood predictions.

9.2.4 Objective four: Identify any specific prediction models as dimensions of knowledge been used in the southern sub region of the SADC to help in river flood disaster risk reduction and how can they serve as possible flood management instruments

This objective was achieved using a literature review and empirical findings (see Chapter Four, Sections 4.3 and 4.4, Chapter Five, Section 5.3.2 and Chapter Seven, Section 7.6). Respondents from all the studied countries indicated that they have some knowledge on the flood prediction models that their countries are using. South Africa uses the HECRAS (River Analyses Model) to predict where certain flood events will happen in terms of flood depth and the flood flow line model for dams and major rivers. Apart from the countries using mostly scientific methods of flood prediction, many communities are knowledgeable and use mostly local flood prediction methods. In Botswana, the flood prediction techniques that are known by the communities include building of structures like walls to control water movements, weather observation and information from the media both local and from neighbouring countries.

In South Africa, the flood prediction techniques known by some of the community members include taking note of the duration of heavy rainfall i.e. non-stop heavy rain being an indicator of the coming of floods. Some rely on flood information from community radio stations, local disaster management authorities and weather forecasts given through the radio and on television. In Zambia, some of the community members predicted floods using birds and their movement patterns, the shape of the moon, the intensity of rains, river water levels, temperature and wind behaviour and direction. In Zimbabwe, the flood prediction techniques known by the study community are the appearance of mist at a nearby mountain which signals impending floods, rainfall patterns which determine the nature of floods, the appearance of the Dendera bird and the use of spirit mediums although the reliability of their forecasts are doubted. These responses indicated that the community members use both scientific and indigenous methods of flood prediction.

An abundant literature review in Chapter Five, ections 5.3 with supporting research case studies, show that IKS can and should be adopted to compliment scientific methods in flood prediction. This can be seen from success stories of predicting floods using IKS, as highlighted by authorities like Hiwasaki *et al.,* (2014:16); Mercer *et al*., (2007:252); Grilli *et al*., (2007:3); Walshe and Nunn, (2012:185); Arunotai, (2006:143); UNESCO, (2007:53) and ISDR, (2008:67).

Through further review of literature (see Chapter Four, Sections 4.3 and 4.4), a number of flood prediction methods were discussed. They included the Flood forecasting, warning and response system model by Parker, (2003), Flood Forecasting and Warning Response system in Bangladesh by Chowdhury, (2005), Integrated indigenous and scientific knowledge disaster risk reduction model by Mercer *et al.,* (2010), United States Community Hydrologic Prediction System and Jamaica Community Hydrologic Prediction System by WMO, (2011), LIVE scientific knowledge method by Hiwasaki *et al*., (2015) and the Meteorological early warning system by Poolman of the South African Weather Services.

Some components from these models were identified as ideal to include and were integrated into the flood prediction model (see Figure 8.1) that was developed for the SADC-region. The Integrated indigenous and scientific knowledge disaster risk reduction model by Mercer *et al.,* (2010) and the LIVE scientific knowledge method by Hiwasaki *et al*., (2015) were identified as effective in flood predictions as they considered IKS in the flood prediction process. The United States Community Hydrologic Prediction System and Jamaica Community Hydrologic Prediction System by WMO (2011) were identified as better because they mostly focused and worked on predicting local floods. These were the most ideal and effective for local flood prediction use.

9.2.5 Objective five: Investigate the relevance of Indigenous Knowledge in river flood prediction possibilities

This objective was achieved using a literature review and empirical findings (see Chapter Five, Section 5.3). Many indigenous communities rely on traditional flood forecasting knowledge, often based on early warning signs related to the appearance of the sky or sea and changes in animal behaviour (Mclean, 2009:15). There is evidence to suggest that historically and to date, traditional local communities in different parts of the world have continued to rely on indigenous knowledge to conserve the environment and deal with flood disasters (see Chapter Five, Section 5.3). It is said that, before the establishment of conventional weather and climate forecasting, older generations, especially in the rural communities, have largely relied on Indigenous Knowledge to predict weather through observing and monitoring the local behaviour of animals, plants, atmospheric conditions and astronomic features among others. Communities, particularly those in disaster prone areas, have generated a vast body of Indigenous Knowledge on disaster prevention and mitigation through early warning and preparedness. IKS is a precious resource that can facilitate the process of disaster prevention.

In Zimbabwe, they predict floods using river pegs or markings, animal behaviour like elephants relocating to higher ground, birds, ant and tree behaviour. These methods differ from community to community in Zimbabwe. In South Africa, a study by Mwaura (2008:66) identified that a red moon announces the coming of floods and the cry of the Vlera bird signifies floods. Indigenous flood prediction in Botswana relies on animal behaviour. In Zambia, local knowledge is said to be abundant but is not documented for official use. Birds, insects, ants, cloud and mango tree behaviour and water level markings on trees are used in Zambia. The respondents indicated that they value these methods as they effectively work for them which is also the motivation for their continual use (see Chapter Seven, Sections 7.6.1 to 7.6.4).

Evidence on the importance and successful integration and use of indigenous knowledge can be seen in many flood incidences (see Chapter Five, Section 5.4). One of such incidence is the 26th November 1999 tsunamis in Pentecost Island, Vanuatu, South Pacific which suffered five fatalities from a threatened 300 people. The survival rate was attributed to both indigenous knowledge and a video about tsunamis (scientific knowledge) shown to the community weeks earlier (Walshe and Nunn, 2012:185). More to that there have also been an increase in indigenous knowledge studies since mid-2000s (Hiwasaki *et al.,* 2014:16; Mercer *et al*., 2007:252). In these studies it is claimed that indigenous knowledge helped communities survive tsunamis on Solomon island (Mercer *et al*., 2007:252), Thailand and on the Vanuatu Islands (Hiwasaki *et al.,* 2014:16). Traditional knowledge related to water hazards was also successfully used to predict floods in Pakistan, Mexico, and Bangladesh (Hiwasaki *et al.,* 2014:16).

In the studied countries and communities, the relevance of local knowledge is being recognised by the Government (see Chapter Seven, Section 7.7). In Zambia, information gathered indicated that, in addition to communities using local knowledge in flood prediction, Government authorities are also encouraging its use. In Zimbabwe (see Chapter Seven, Sections 7.5 and 7.4.1 and 7.7.2), the relevance of local knowledge is also being recognised and communities are being encouraged to use it to forecast floods by the Civil Protection Unit. The importance of IKS is reflected in the work of South Africa's National Research Foundation (NRF). Communities in Botswana also use the behaviour of animals for flood prediction. Indigenous Knowledge is to a great extent relevant in flood prediction.

9.2.6 Objective six: Identifying possibilities of working towards the development of a prediction model that could serve as a feasible procedure in managing river flood risks

This objective was achieved using a literature review and empirical findings (see Chapter Three, Four, Five and Seven). The study was successful in identifying ideas and some models of which the components were applicable to the SADC-region. The components were mostly focused on the idea of integrating indigenous and scientific methods of river flood prediction, the use of technology in flood detection and information processing. Community members and disaster managers advocated for many strategies (see Chapter Seven, Section 7.8) that include the integration of a Meteorological office and IKS, decentralization of flood prediction, effective communication, use of technology like G.I.S, remote sensing, flood awareness campaigns and the use of local level flood predictions. The other respondents also proposed the use of effective communication media in flood broadcast, improved information sharing and community involvement.

What was also important was the involvement of communities in all flood mitigation processes from planning to evaluation. This was done by involving the flood communities in the studied countries to propose what they wanted to be included in the flood prediction model developed in this study. Their inputs were taken on board and their proposals integrated on the model. What also came out clear was the need for decentralization of flood prediction centres from national to all the government and administration levels of each country. The model in Figure 8.1 shows that all flood prediction activities including the use of science and local knowledge were to start from the village level and cascade to the national level and vice versa. What this means is that flood prediction has to be completely decentralized so that communities are also included in the processes of flood prediction in their areas. The conclusion related to this objective was presented in the whole of Chapter Eight (see Chapter Eight).

9.3 Recommendations towards improving flood predictions in the SADC-region, and particularly the southern sub region

This study identified weaknesses and challenges that need strengthening and opportunities that need to be exploited so that flood prediction may be perfected and effectively used in the SADC-region. It is therefore against this background that the following recommendations are made in relation to all the objectives of this study:

9.3.1 Objective one: To investigate the past and present status of river flood disasters

Literature review and empirical study results indicate that the studied countries have recurring flood disasters. This means that effective methods of reducing flood risk in communities have to be developed. Literature also shows that people do not want to move from flood risk areas. Therefore methods that help people live with floods might be viable to help them survive in their flood communities. The development of effective flood prediction methods as was the objective of this study might help in mitigating flood effects.

Apart from staying in flood areas and too much rain as causes of flood disasters in communities, the study also singled out poor agricultural practice, dam overflows, geographical location and poor environmental management activities. This means that management of river floods has to be extensive. Flood impacts will be reduced if focus is cast extensively to management of forests or trees, agricultural methods, town planning and environmental issues. Relocating communities from flood prone areas needs to be done with caution as it might fail or create even more problems and disasters.

Information collected from the countries under study indicates that there are areas including the studied communities that experience major floods (see Chapter Seven, Section 7.3.1 to 7.3.4). Governments and other related flood management practitioners should seriously target and put in place effective flood reduction methods in these major flood areas or rivers. Research should also be carried out to collect and document how communities in these areas manage floods especially when it comes to IKS. The SADC-region needs to be pro-active and use flood mitigation, prevention and preparedness methods to reduce flood risk. Among other models that the region may use, developing an effective flood prediction model would be a very good starting point to contain flood risk.

9.3.2 Objective two: To find out what the governments of the countries under discussion have done to mitigate the effects of river flood disasters

Information from the studied countries indicates that Governments are putting considerable effort in trying to mitigate flood effects. They have put in place flood management structures form the ward to national level. This means that there is serious effort to engage every stakeholder in flood risk management. Communities must be involved and be part of the structures so that flood risk activities are not imposed on them. The participation of many stakeholders enhances transparency. When knowledge and information are disseminated, it encourages community participation. Pearce (2003:211) is of the view that community participation in decision making at the local level enhances the success of mitigation strategies. Involving communities is becoming one of the best practices in flood risk reduction. Flood prediction, monitoring and early warning systems also have to be strengthened by increasing the number of stations for monitoring meteorological and hydrological conditions up to the community level. The stations also need effective gadgets and regular maintenance to obtain real time data for accurate predictions. Countries also have to invest in technology like remote sensing, satellites and geographical information systems to enhance flood forecasts.

The studied countries also have disaster management legislation and funding supported by such legislation. However, flood disaster legislation per se is not there in all the studied countries. Maybe this is where sector regulations come in and flood management regulations have to be crafted using the general Disaster Management Act guidelines. Legislation is also weak as it does not apply punishment for any wrongdoing and if it does there is a challenge in enforcing it. Flood Disaster Risk Management laws need to be developed or improved in the region to make people accountable through the inclusion of penal provision for some acts of commission or omission.

Funding for flood management seems to be supported by Disaster Management Acts in the studied countries. However, when flood disasters strike, financing response activities is always a challenge as funds are not available or short. Failing to fund flood risk reduction draws back flood risk management efforts. There is need for legislation to give clear financial provisions to support flood risk management at all levels up to community level. Enough funds and material resources have to be provided for preparedness and mitigation rather than concentrating on response activities only.

Governments in the region are therefore encouraged or advised to set aside funds for flood risk reduction both nationally and in the region. These funds have to be set aside in national budgets. Flood risk reduction must be taken as a precaution measure that might save money and the adverse effects of flood disasters in the SADC-countries.

Governments and private organisations are encouraged to broaden the provision of training, awareness campaigns and meetings to conscientise communities on flood risks reduction. Authorities also have to encourage all their communities to form disaster risk reduction committees and have disaster risk management plans in place. Since agriculture is an activity in flood prone areas, those who are into agriculture must be educated and encouraged to grow early maturing crops that might not be affected by floods. Those in minor flooded areas must be encouraged to grow riceand keep ducks that are more resilient to floods than chicken.

Communication systems for flood prediction and early warning must be improved by collaborating with mobile phone network providers. This will help in timely dissemination of information and warnings to communities using text messages. There is also need to adapt communication strategies to local understanding and perceptions. Furthermore, flood forecast information must be made simple, non-technical and easy to use or interpret. It would be best if flood predictions are presented in the local language of the communities affected. All these issues will result in good quality and locally specific information when managing flood risks.

9.3.3 Objective three: To determine the extent to which research has provided guidance in river flood prediction possibilities

Serious research must be done on indigenous flood prediction and how best to integrate it with the scientific flood forecasting. It is important to document, learn, revive and replicate such IKS and practices. Before integration, Indigenous Knowledge systems must be validated. The knowledge base has to be documented and published to the affected community. There also has to be an understanding on how the public interprets and reacts to warning messages during the studies. Flood risk research has to be tailored to people's capacities in the form of local knowledge and practices, their assets and needs and on building their trust. The critical analysis of indigenous knowledge also has to be approached objectively without any prejudices.

Although there is evidence that there is river flood research being conducted in the region, such an activity has to be enhanced through the provision of research funds. Flood research must also be taken as a pro-active measure to manage flood risk. There is need for a change of mind-set and practice within disaster management experts and academic and scientific research institutions with regard to the value and use of flood indigenous knowledge. Research must be done, especially in academic institutions so that effective flood risk reduction methods and solutions are developed. Academic institutions need to develop departments and educational programmes and engage in research that promotes Indigenous Knowledge in their countries and in the SADC-region. The current systems of education should be reviewed and school curricula that adapt to local flood needs and realities should be considered. Education needs to also incorporate and foster IKS and practices.

Research on flood prediction must involve victims and concentrates mostly on flood prevention, preparedness and mitigation. Communities or flood victims have vast and rich knowledge on flood prediction and risk management. Involving them in flood research will enhance research endeavours and information sharing, thereby improving flood prediction methods. Through the research process communities will learn and get educated on how to identify and solve flood prediction issues and problems on their own. Participation, as always been enunciated by literature, will give communities a sense of ownership when it comes to river flood risk reduction activities. Flood victims or communities need to be embraced in river flood prediction research as critical stakeholders.

9.3.4 Objective Four: To investigate the relevance of IKS in river flood prediction possibilities

Diverse communities in flood prone areas have traditionally learned to cope with and reduce the risks of flood disasters through time tested experience in indigenous knowledge inherited from generations. Literature review and research studies done on flood predictions indicate that scientific knowledge in flood prediction is to an extent less reliable and too general as it is not tailored to specific communities. As a remedy to this applying indigenous knowledge in flood prediction using traditional indicators becomes very relevant. Flood forecasting in the region needs more improvement to enable localised forecasts that will meet the needs of specific communities.

The study also identified that local knowledge is relevant in flood prediction as traditional communities rely on it. The importance of indigenous knowledge must also be recognised since local knowledge and practices help to identify and capitalise people's existing strengths in managing flood risk. Understanding and accounting for local perceptions of flood hazards influences how people perceive and respond to natural hazards, risks and disasters. Indigenous flood forecasting methods are fuelled by need, focused locally, the timing of rains and are communicated in local languages. This in turn offers a foundation for improving the value of modern seasonal forecasts. IK contributes to filling gaps in formal seasonal forecasts that are made mostly at broader spatial and temporal scales (Speranza *et al*., 2010:297).

It can also be said that learning from local knowledge helps to create new concepts, methods or strategies for improved flood disaster risk management in the studied countries and in the SADC-region. Using local knowledge helps foster community confidence as communities themselves need to be convinced that some of their local knowledge and practices are of relevance to disaster preparedness. Flood IKS must be legitimatised and validated on its own terms. It is crucial in developing rural communities. The local skills and cultures of people in communities must be harnessed for the good of all. Conditions have to be created under which the highest values of flood IKS have to be identified and exploited to shape Science and Technology policies and promote benefit sharing for indigenous innovation.

Therefore, it is necessary and prudent to integrate community/local knowledge systems with scientific knowledge and emerging technologies in flood prediction. Indigenous Knowledge has to be incorporated in governmental policies and must receive priority or honour in communities where it is being used. Governments, regional and international bodies must also create independent ministries or departments to deal with IKS and ensure that it is put to best use. The created bodies/ministries must educate and conduct awareness campaigns about the importance and use of indigenous knowledge as a complimentary strategy to generate climate information and make flood predictions.

Like the application of any knowledge system, indigenous knowledge has limitations that must be recognised if its integration with scientific knowledge has to be worthwhile. There is always the tendency of approaching local knowledge issues from a biased point of view which negates the usefulness of the exercise. Therefore a strong case can be made for integrating IKS into conventional flood forecasts if it is well researched and validated and found useful for flood prediction purposes. Thus flood risk management decisions mainly based on IK without accompanying scientific processing should be handled with caution.

9.3.5 Objective five: Identify any specific flood prediction models as dimensions of knowledge been used in the southern sub region of the SADC to help in river flood disaster risk reduction, and how can they serve as possible flood management instruments

More work has to be done in the region to develop local flood prediction models that suit our local conditions. Although many flood prediction models exist in this world, the challenge in the SADC-region is that flood prediction models that suited the region's conditions had formally been recognised. Some elements of flood prediction models discussed in this study (see Chapter Four, Sections 4.3 and 4.4 and Chapter Seven, Section 7.6) were identified and regarded as valuable for use in the region. They were then infused in the flood prediction model developed in Chapter Eight. There is need to identify flood models used in the region (if there are any) and to improve their effectiveness or develop new models that go along with climatic change trends in the region.

9.3.6 Objective six: To identify possibilities of working towards the development of a prediction model that could serve as a feasible procedure in managing river flood risks

Communities must be involved in establishing local flood prediction and warning systems. The role of social networks and informal arrangements in flood prediction and warning dissemination must be assessed and implemented. Community based hazard identification, mitigation, hazard mapping and an increase in community participation in flood risk reduction has to be considered. All stakeholders comprising of policy makers, scientists, practitioners and communities must jointly make observations, documentations and validations of indigenous flood prediction knowledge and should integrate local values into decision-making processes.

Training must be regular for the communities to enhance knowledge and skills. It will also enhance competencies to monitor, coordinate and implement community flood risk management activities. Communities must also be given the necessary education and public awareness programmes to improve on flood risk reduction.

The overarching recommendation of this study is that the flood prediction model developed in this study (see Figure 8.1) be adopted and be used by the SADC-region and regional countries as a basis for flood prediction. The model can be adopted and used at all institutional levels, from local to regional. It is also important to recognise that adapting this flood prediction model that includes the use IKS for flood risk reduction, might not be the only solution to reduce or prevent the impacts of flood disasters. The model, like others might have its limitations. The goal of this study was to initiate the idea of developing a flood prediction model that can promote an integrated approach to river flood risk reduction. It might not be the best and is open to improvement but its development is a step *“towards the development of a flood prediction model for the SADC-region”*” as the research topic of this study reads.

9.4 Recommendations suggested for further research

The flood prediction model, namely “The Integrated IKS-SKS- model for Flood Prediction and Mitigation in the SADC-region”, as developed in this study mostly rely on indigenous knowledge which is not readily formally available as one of its inputs. Yet it does not ignore SKS findings on which a mutual relationship for flood disaster prediction and prevention mechanisms can be built. It is therefore critical for the region, countries, communities and disaster risk management practitioners to recognise and seriously initiate research to also capture intellectual goods embedded in indigenous knowledge. Indigenous knowledge information/techniques for flood prediction must be recorded, documented and promoted from the community level up wards. A lack of indigenous knowledge application in the communities prone to disasters is an indicator that local knowledge is not received with seriousness and a sense of value, and as such tends to become extinct or eroded. Elders who are still alive and knowledgeable in IKS should be approached, data collected and documented so that it is integrated with SKS for inclusive flood predictions as a way towards being more effective in this effort. Also some continuous research is required to explore improved ways to blend indigenous knowledge and modern science and technology to solve current flood problems.

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APPENDIX A - Disaster Experts Interviews Schedule

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Question schedule for Disaster Managers / Hydrologist / Climatologist / Meteorologist.

My name is **Tichaona Muzuwa**, a Phd student at **North-West University**, **Potchefstroom**. I wish to gather your views as to how best we can prevent or reduce the impact of river floods in your community. With your help we need to develop a disaster flood prediction model that will assist in prevention or reducing river flood problems brought to this community. You are kindly requested to respond to the following questions which will help us in the development of the best possible way to predict disasters.

Please note that this study is purely for academic and developmental purposes. You are kindly asked to express your views and opinions freely after signing a consent form. The information you give will be held private and confidential.

I thank you very much for your understanding, cooperation and support.

Section A. Questions on the past and present status of river flood disasters in the SADC region

1. How familiar are you with the area/country?

2. For how long have you been the Disaster Risk Manager / Hydrologist/ Climatologist/Meteorologist in the area/country?

3. Do you have river floods in this country?

4. How frequently/occasionally do river floods in the country feature?

5. How many of the river floods are major?

6. Shortly explain your criteria for a MAJOR river flood?

7. Do you have any unnatural (manmade) circumstances you know or think contribute to flooding?

8. Where do you experience MAJOR river floods in your country?

9. How many flood disasters have you had during the last 12 years?

10. Were any people affected, died, displaced during MAJOR floods?

11. Was any property damaged? Elaborate if YES please

12. At times people loose animals during floods, Were any domestic animal affected in the MAJOR floods?? Elaborate please, what were they and how were they affected.

13. To what extent were the rest of the living and natural environment affected?

14. Are you currently involved/already involved in flood management/prevention activities/measurements? Please elaborate.

Section B. Questions to determine what the governments of the countries under discussion have done to mitigate the effects of river flood disasters occurring in the SADC region.

15. Are there any disaster management structures in place in the country and in the areas affected by MAJOR river floods? Is yes, what are they?

16. Who coordinates these structures?

17. What is the composition of these structures?

18. Do the structures involve the communities affected?

19. Is there any disaster management legislation in the country?

20. Does the legislation specify any ways or means or any rules regulations to deal with flood management?

21. Does government and local legislation provide any penalties if flood management rules and regulations are broken?

22. Is there any funding set aside by any governing body or private organisation for flood disaster activities? If yes, what funding and how is it done?

23. What is being done for/by and with people to co-exist or live with/or being resilient towards floods?

24. What is the attitude of government towards disaster management?

Section C. Questions to determine the extent to which research has provided guidance in river flood prediction possibilities in this particular country?

25. Are you as an organisation doing or have you done any research on river flood prediction?

26. Are there any other organisations that did or are doing research in river flood prediction in your area/region? if so please elaborate on their status/process/progress?

27. Do you know if victims of MAJOR flood disasters are included in the aforementioned research?/perhaps your own research? Please elaborate.

28. Has any past/recent research/observations/Indigenous Knowledge experiences in your region/other regions made any meaningful contribution to change this region's MAJOR river flood management?/Precautionary measurements/ Insights on prediction possibilities?

Section D. Questions to identify and determine the effectiveness of any specific prediction models/methods being used to help in river flood disaster risk reduction

29. Are you aware of any scientific flood prediction models/methods that are being used in the country? Elaborate, if known, on its working/procedure or implementation?

30. Are you aware of any indigenous flood prediction models/methods that are being used in the country? Elaborate, if known, on its working/procedure or implementation?

31. Are the affected communities or/and other communities/people or organisations in any way involved/contributing to river flood predictions or/and early warning? If yes, how?

32. Do the people understand and respond to the flood predictions or early warning? If no, elaborate why?

33. Do you experience any limitations/problems in understanding/managing/implementing these flood prediction/early warning methods?

34. What flood prediction methods used in this country or region would you consider or propose to be important and be part of or be included in an integrated regional flood prediction model.

35. Is the process of flood prediction centralised or decentralised?

36. How does the flood prediction/ early warning method(s) help in the development of the people and the country?

End of Questions.
Thank you for your time.

APPENDIX B - Community Leaders Interviews

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Question schedule for community leaders including teachers, police, NGOs and other govt / private groups or organizations

My name is **Tichaona Muzuwa**, a PhD student at **North-West University**, **Potchefstroom**. I wish to gather your views as to how best we can prevent or reduce the impact of river floods in your community. With your help we need to develop a disaster flood prediction model that will assist in prevention or reducing river flood problems brought to this community. You are kindly requested to respond to the following questions which will help us in the development of the best possible way to predict disasters.

Please note that this study is purely for academic and developmental purposes. You are kindly asked to express your views and opinions freely after signing a consent form. The information you give will be held private and confidential.

I thank you very much for your understanding, cooperation and support.

1. How familiar are you with the area?

2. How long have you lived in the area up to now?

3. Do you have river floods in this area?

4. How frequently/occasionally does river floods in the area feature?

5. How many of the river floods are major?

6. How did flood disasters affect your life?

7. Do you live close to the river?

8. How close in terms of distance?

9. Is it on low or high ground?

10. Are you familiar with the 50 and 100 year flood lines?

11. Do you do any farming activities?
12. How far are they from the river?
13. Do you farm on fields on low or high ground?
14. Do you have a house to stay?
15. Is it built of any strong material?
16. What material was used to build your house?
17. Are there any precautionary measures that you/your household usually / normally take against floods?
18. If YES, elaborate please. If NO, motivate why not?
19. Is there any shelter and plan of action in your community in case of MAJOR floods?
20. If yes, what is the plan and where is the shelter situated?
21. What do you do with your livestock (cattle, chicken, goats, etc) during a flood disaster?
22. Are you supported by local/provincial/national government during instances of major floods?
23. Are you aware of a/the Disaster Risk Management Office/Officer close by and their doings?
24. if yes how far is it from here and what do they do?
25. Do you know of any indigenous ways of predicting floods used in this community?
26. If yes, name them.

End of Questions.

Thank you for your time.

APPENDIX C - Community Questionnaire

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

My name is Tichaona **Muzuwa**, a PhD student at **North-West University**, **Potchefstroom**. I wish to gather your views as to how best we can prevent or reduce the impact of river floods in your community. With your help and knowledge about the features of environment before a disaster? we need to develop a disaster flood prediction model that will assist in prevention or reducing river flood problems brought to this community. You are kindly requested to respond to the following questions which will help us in the development of the best possible way to do it.

Please note that this study is purely for academic and developmental purposes. There is no need to identify yourself in any way on the form. You are kindly asked to express your views and opinions freely by putting an X in the boxes or write in the space provided. The information you give will be held private and confidential.

I thank you very much for your understanding, cooperation and support.

Yours faithfully

Tichaona Muzuwa

Section A: Demographics

Answer the following questions by making a tick in the appropriate block

A1	How old are you?	Below 25 years	26-30 years	31-35 years	36-40 years	41 years +

A2	Your gender?	Male	Female

Section B: Questions related to the past and present status of river flood disasters

B1	Do you experience river flood disasters in this area?	Yes	No

B2	If the answer to the above question was "yes", how often do you have them?				
	Every year	Every two years	Every three years	Every four years	Less often
B3	What do you think are the possible causes?				
	Too much rains	Staying in flood	No flood	Poor house	

		areas	prevention measures	structures
	Other (Please specify)			

B4	Who is responsible for preventing or mitigating them?			
	Community	Private organisations	Government	All stakeholders

B5	For how long have you been staying in this area?				
	Less than 1 year	2-5 years	6-10 years	11-15 four years	16 years +

B6	Do you have any major rivers in the area?	Yes	No

B7	If the answer to the above question is “yes”, do the rivers flood?	Yes	No

B8	When last did you have floods?					
	Did not floods	2013	2012	2011	2010	Don’t know

B9	Since you started staying in this area how many floods have you experienced?						
	None	One	Two	Three	Four	Five	More than five

B10	Of what magnitude were these floods?			
	Minor	Damaging	severe	Fatal

B11	Did any people die?	Yes	No

B12	If the answer to the above question was "yes", how many people died?	

B13	Did you lose any property?	Yes	No

B14	If the answer to the above question was "yes", what did you lose?

B15	Did you have any damaged property?	Yes	No

B16	What are you doing to protect yourselves from flood disasters?

Section C: Questions related to local and scientific flood prediction models/ methods being used and their effectiveness in flood risk reduction

C1	Does the community have any flood prediction techniques/methods (signs) that you know?	Yes	No

C2	If the answer to the above question was yes, what are they (name them)?

C3	Does the community use the flood prediction techniques/methods?	Yes	No

C4	If the answer to the above question was yes, how do you use them?

C5	How often do you use the flood prediction techniques/methods?				
	Almost always	Most of the time	Some time	Rarely	Almost never

C6	To what extent do the flood prediction techniques/methods work?				
	A very large extent	Large extent	Some extent	Very little	Not at all

C7	Does the community issue any flood warnings?	Yes	No

C8	If the answer to the above question was “yes”, how do you issue flood warnings?

C9	Does the community respond to the flood warnings?	Yes	No

C10	If the answer to the above question was ‘yes”, how do you respond?

C11	Who else helps the community in flood prediction?			
	Government	Private	Both	None

		organisations		
	Other (Please specify)			

C12	How do they do it?

C13	Who else helps the community in flood warning?			
	Government	Private organisations	Both	None
	Other (Please specify)			

C14	How do they do it?

C15	Do you have a radio/television?	Yes	No

C16	How often do you listen / watch the radio/television?				
	Almost always	Most of the time	Some time	Rarely	Almost never

C17	. Do they have any flood prediction and alert programmes?	Yes	No	Not sure

SECTION D: Questions on what governments have done to mitigate the effects of river flood disasters occurring in the SADC region

D1	Does the government or other responsible authorities assist in flood management?	Yes	No

D2	What are they doing to help mitigate flood disasters?

D3	What are they doing to help before, during and after flood disasters?

Section E: Questions to identify possibilities of working towards the development of a prediction model that could serve as a feasible procedure in managing river flood risks

E1	What do you think should be done to improve flood predictions?

E2	Do you hold any flood planning meetings?	Yes	No

E3	If the answer to the above question was ‘yes”, what is discussed there?

E4	Do you participate?	Yes	No

E5	Are your inputs taken on board?	Yes	No

E6	If the answer to the above question was “no”, why are they not taken?

E7	Who chairs the meetings?

E8	Do you have any other traditional ways of flood prediction that you know?	Yes	No

E9	If the answer to the above question was “yes” name them.

THANK YOU

THE END

APPENDIX D - Consent form

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Research Focus Area: Social Transformation
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18/09/2013

Consent Forms for Data Collection

Title of the study: Towards developing a prediction model for managing flood disasters in the SADC-region. (Ethics number: NWU-00131-12-S0)

Researcher: Tichaona Muzuwa, PhD. Student, Development and Management Studies, Student # 23200200 (tichaonamuzuwa@yahoo.com)

Supervisor: Prof. Elize S. van Eeden , Historian & Research Consultant, School of Basic Sciences, Vaal Triangle Campus, PO Box 1174, Northwest University, Vanderbijlpark 1900, SOUTH AFRICA, Cell: 082 752 8839,Work: 016 910 3469 Elize.VanEeden@nwu.ac.za

Co-Supervisor Prof. Dewald van Niekerk, Director of the African Centre for Disaster Studies, Faculty of Arts, Social Transformation (Tel: 018 299 1634, dewald.vanniekerk@nwu.ac.za)

Invitation to Participate: Strategic persons involved in the direct or indirect planning and implementation of River flood Risk Reduction activities in five SADC-countries Zimbabwe, South Africa, Namibia, Mozambique and Botswana and members of communities that are continuously affected by these floods, will be invited to participate in the abovementioned research study conducted Tichaona Muzuwa.

The Study: The purpose of the study is to identify aspects/dimensions that should be included in a flood prediction model so as to improve the functionality and efficiency of reducing river flood risks in the SADC region.

Participation: We are asking for your assistance through consenting to completing a questionnaire or have a recorded interview with the researcher wherein questions will be asked about river floods in your area. The interviews will take place in a venue suitable to both yourself and the researcher. Depending on your answers and your involvement in the project, the interview session should take no longer than 60 minutes of your time.

Risks: Your participation in this study may involve you expressing personal opinions about river floods and other issues related to it. In submitting the form you have the commitment from the researcher that every effort will be made to protect your identity including: Not using your name or any contact details in the final report, as well as the safe storage of all documents and interview transcripts, in a secure area at North-West University.

Benefits: My participation in this study will help researcher understand the issue of river floods Prediction and Flood risk management including some issues and concerns that we (as managers, community leaders and stakeholders) have which need to considered in order to enable the development of an ideal Flood prediction method in the region. The recommendations will be submitted to various governments, community members, stakeholders and any interested parties as a tool for guiding people in river flood predictions. It must be understood that there is **no** individual who participates in the interviewing and questionnaire processes will be paid (cash or kind) for their involvement. Your involvement in the interview is purely voluntary and must be seen as a contribution to advancing your community. The payment of research participants is unethical in research.

Confidentiality and anonymity: You have assurance from the researcher that the information you will share will remain strictly confidential. You should understand that the data you provide will be used to develop a flood prediction method that will be useful to flood managers and communities that are always affected by river floods. Your personal confidentiality will be protected through the use of 'coding' (i.e. Mr X or Participant 12)*,* however the use of organisational names (i.e., North-West University, the District Disaster Centre e.t.c.) may be used for establishing context.

Conservation of data: The data collected (tape recordings of interviews, transcripts, notes, questionnaires etc.*)* will be kept in a secure manner in a locked storage room on the North-West University Campus only accessible by the researcher, the supervisor and the Director of the Research Focus Area *(*Prof*.* Dewald van Niekerk*).* The data will be retained for a period of seven years before being destroyed.

Voluntary Participation: You are not under any obligation to participate and if you accept the opportunity, you may still withdraw from the study at any time and/or refuse to answer any questions, without suffering any negative consequences.

Acceptance: I, ______________________________ (Name of participant), agree to participate in the above research study conducted by: Tichaona Muzuwa of the African Centre for Disaster Studies, Faculty of the Arts, Research Focus Area Social Transformation, which is under the supervision of Prof. Dewald van Niekerk. If I have any questions about the study, I may contact the researcher or his Supervisors.

If I have any questions regarding the ethical conduct of this study, I may contact the Research Officer, Mr Willie van Wyk, Social Transformation Focus Area, Faculty of the Arts, North-West University, Potchefstroom Campus, North- West University, Potchefstroom, North- West Province, Republic of South Africa 2531 Tel.: (+27) 018 299 1751, Email: willie.vanwyk@nwu.ac.za.

There are two copies of the consent form, one of which is mine to keep.
Researcher's signature: Tichaona Muzuwa..

Supervisor's signature: (1) Prof. Elize S. van Eeden..

(2) Prof. D. Van Niekerk...

Participant's Name: ____

Participants Signature: ____________________________________

Date: _________________________________

APPENDIX E - Request to collect data

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Researcher: **Tichaona Muzuwa**

Student Number 23200200

Module DIMA 971

African Centre for Disaster Studies

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e-mail- tichaonamuzuwa@yahoo.com

22 August 2012

Dear Sir/Madam

Application for permission to carry out a research and assistance in your country

I am a student at Northwest University doing a Doctor of Philosophy Degree (PhD) in Development and Management. I am focusing on Disaster Risk Reduction looking at developing a common or revised Flood Disaster Prediction model for the SADC-region in Africa.

I am kindly requesting for permission and also your assistance in carrying out part of my research in your country soon and on dates to be advised.

I intend to interview an expert such as the manager of the National Disaster Management centre in your country. He will be asked about the status of river flood disasters, prediction models being used, what your government has done or is doing to help, any possibilities to serve as alternatives and suggestions for flood prediction models.

The researcher also intends to visit an area in your country where they experience a recurrence of river flood disasters. There data will be gathered from 20 members of the community in the disaster area, using questionnaires and another 10 members using interviews. These members will be asked about their experiences of flood disasters, their expectations and how best they have managed and think flood disasters may be managed focusing on prediction measures they have been using and which might be used.

The importance of this study is as follows:

Disaster managers: The success of the study will make a large contribution to the body of knowledge of Disaster Risk Reduction. Effective prediction of river flood disasters will help in preventing or reducing loss of life and damage of the environment and structures.

Government: Disaster response is a very expensive exercise especially if one responds to river flood disasters every time they occur. The study will help government and other interested parties to reduce spending on river flood disasters through flood risk reduction measures. Money saved and time spent in responding to disasters could be put to other good uses.

SADC-countries: It is anticipated that the recommendations of the study will be applicable to the SADC-countries or any other developing countries that are experiencing similar river flood problems.

General: This study is inspired to enlighten and encourage SADC-countries to seriously recognise the usefulness of predicting river flood disasters. The implementation aspect is very important. The researcher has a vision of a future in which water-related disasters like river floods are predicted and effectively mitigated so that they do not impact negatively on the people's quality of life and the environment.

The following ethical issues will take centre stage:

Informed consent

Research participants will be told of the nature of the study to be conducted and be given the choice of participating or not. They will also be told that, if they agree to participate, they have the right to withdraw from the study at any time. Participation in the study needs to be voluntary.

Right to privacy

The study will respect participants' right to privacy. The research report (oral or written) will not be presented in such a way that others become aware of how a particular participant responded.

Honesty with professional colleagues

Findings will be reported in a complete and honest way, without misrepresenting what has been done, or intentionally misleading others as to the nature of findings
No data will be fabricated to support a particular conclusion, no matter how noble it might be.

I will be very grateful to you if my application is considered and successful. May I be advised and be given authority or permission in writing.

Yours faithfully

Tichaona MUZUWA
(PhD Student NWU)