LONG TERM ADAPTATION SCENARIOS

TOGETHER DEVELOPING ADAPTATION RESPONSES FOR FUTURE CLIMATES

CLIMATE INFORMATION AND EARLY WARNING SYSTEMS

environmental affairs
Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

giz

On behalf of:
Federal Ministry
for the Environment, Nature Conservation,
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of the Federal Republic of Germany

SANBI
Biodiversity for Life

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LONG-TERM ADAPTATION SCENARIOS
FLAGSHIP RESEARCH PROGRAMME (LTAS)

CLIMATE INFORMATION AND EARLY WARNING SYSTEMS FOR SUPPORTING THE DISASTER RISK REDUCTION AND MANAGEMENT SECTOR IN SOUTH AFRICA UNDER FUTURE CLIMATES

LTAS Phase II, Technical Report (no. 2 of 7)

The project is part of the International Climate Initiative (ICI), which is supported by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

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LIST OF ABBREVIATIONS

ACDS	African Centre for Disaster Studies
ADRMP	Agricultural Disaster Risk and Management Plan
AFIS	Advanced Fire Information System
AusAID	Australian Agency for International Development
AWC	Aviation Weather Centre
AWS	automated weather station
ARC	Agricultural Research Council
CCA	climate change adaptation
CCAM	Conformal Cubic Atmospheric Model
COGTA	Department of Cooperative Governance and Traditional Affairs
CRED	Centre for Research on the Epidemiology of Disasters
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DHI	Drought Hazard Index
DMA	Disaster Management Act
DMISA	Disaster Management Institute of Southern Africa
DPLG	Department of Provincial and Local Government
DRMC	Disaster Risk Management Centre
DRR	disaster risk reduction
DRR-M	disaster risk reduction and management
DST	Department of Science and Technology
ECMF	electrically conducting magnetic fluid
EM-DAT	emergency events database
EWS	early warning system
FFC	Fiscal and Finance Committee
FPA	Fire Protection Association
GCM	global circulation model
GEOSS	Global Earth Observation System of Systems
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ICT	information and communication technology
IDP	integrated development plan
ILRC	Interdepartmental Legislative Review Committee
IPCC	Intergovernmental Panel on Climate Change
ISDR	International Strategy for Disaster Risk Reduction
IWRP	integrated water resource planning
KPA	Key Performance Area
LTAS	Long Term Adaptation Scenarios
MDMC	Municipal disaster management centre
MHEWS	Multi-hazard Early Warning System
MIG	Municipal Infrastructure Grant
MODIS	moderate resolution imaging spectroradiometer

MOS	model output statistics
NAC	National Agro-meteorological Committee
NASA	National Aeronautics and Space Administration
NCCRP	National Climate Change Response Paper
NCEC	National Crop Estimate Committee
NCEP	National Centers for Environmental Prediction
NDMAF	National Disaster Management Advisory Forum
NDMC	National Disaster Management Centre
NDMF	National Disaster Management Framework
NDMIS	National Disaster Management Information System
NFC	National Forecasting Centre
NFDRS	National Fire Danger Rating System
NGO	non-governmental organisation
NISL	National Information Society Learnerships
NOAA	National Oceanic and Atmospheric Administration
NWP	numerical weather prediction
PDMC	provincial disaster management centre
R&D	research and development
RFO	regional forecasting office
SABC	South African Broadcasting Corporation
SAC	Satellite Application Centre
SAEON	South African Earth Observation Network
SAFFG	South African Flash Flood Guidance
SALGA	South African Local Government Association
SANHO	South African Navy Hydrographic Office
SARCOF	Southern Africa Regional Climate Outlook Forum
SARVA	South African Risk and Vulnerability Atlas
SAWS	South African Weather Service
SOOP	ships of opportunity
SPI	standardised precipitation index
SWAN	Simulating Waves Nearshore Model
TTT	technical task team
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations Office for Disaster Risk Reduction
VOS	volunteer observing ship
WAMIS	wide area monitoring information system
WCDMC	Western Cape Disaster Management Centre
WMO	wildfire management overlay (Victoria, Australian)
WMO	World Meteorological Organization
WoF	Working on Fire

REPORT OVERVIEW

This technical report presents the Long Term Adaptation Scenarios (LTAS) Phase 2 findings on the current capacity in South Africa with regard to climate information and early warning systems for disaster risk reduction and management (DRR-M) in the context of projected future climate conditions. A key aim of this report is to develop policy recommendations for strengthening disaster risk management, climate information and early warning systems in South Africa. In light of projected increases in frequency and severity, this report focuses on four main categories of weather-related disasters: floods, droughts, fires and storm surges. These events are considered priority areas for enabling adaptation and improving early warning systems.

The report is primarily based on an academic literature review. Interviews with disaster management experts at the National Disaster Management Centre (NDMC) as well as the South African Weather Service (SAWS) were also conducted. Preliminary findings of this report were presented to stakeholders at an LTAS workshop held from 22 to 24 January 2014 and comments from discussion sessions were subsequently incorporated into the final report. Local case studies of best practice for DRR-M and early warning are presented in the report in order to demonstrate how disasters are successfully being managed.

The report is arranged as follows:

Chapter 1: Introduction

An overview of DRR-M, including early warning systems, in South Africa is provided in the context of a changing climate.

Chapter 2: Climate hazards and socio-economic impacts.

This chapter details the socio-economic impacts of previous weather-related disasters, including costs associated with recovery, in order to provide a context for the current risk and vulnerability profile of the country.

Chapter 3: Disaster risk reduction and management in South Africa.

This chapter investigates the DRR-M systems, including legislative instruments available and the institutional arrangements currently governing DRR-M activities in the country.

Chapter 4: Climate information and early warning in South Africa.

This chapter outlines the mandates for early warning systems and the production of climate information at all levels of government. The current early warning systems capabilities are described for each of the four main weather-related hazards. The production, interpretation, packaging and dissemination of weather forecasts, warnings and advisories are also described.

Chapter 5: Gaps and opportunities for improved DRR-M in South Africa.

This chapter identifies gaps and opportunities in both the current legislation and the climate information and early warning systems. It specifically focuses on the shortcomings of legislative and institutional structures in implementing DRR-M activities.

Chapter 6: Recommendations for enhancing climate information and early warning systems for building climate resilience.

Based on the outcomes of the previous chapter this section of the report presents policy recommendations for strengthening climate information and early warning systems for building climate resilience.

EXECUTIVE SUMMARY

Building a culture of prevention is not easy. While the costs of prevention have to be paid in the present, its benefits lie in a distant future. Moreover, the benefits are not tangible; they are the wars and disasters that did NOT happen

- Kofi Annan (Annan 1999).

Climate change is projected to increase the frequency and magnitude of extreme weather events (IPCC 2012), which, without reductions in vulnerability, will increase the risk of disasters (Vincent et al. 2008). The latest climate change projections for South Africa indicate that the country's exposure to weather-related events, particularly floods, droughts, wildfires and storm surges, will increase into the 21st century (Department of Environmental Affairs (DEA) 2013). South Africa's second national communication to the United Nations Framework Convention on Climate Change (UNFCCC) estimated the total cost of weather-related disasters between 2000 and 2009 to be approximately R9.2 billion (DEA 2013). Based on data from the Centre for Research on the Epidemiology of Disasters (CRED) Emergency Events Database (EM-DAT), this report estimates that the economic losses from weather-related disasters in South Africa between 1900 and 2014 to be in the region of R50.7 billion. While floods resulted in the highest economic cost of damages (approximately R18.7 billion), droughts have affected a larger proportion of the country's population. Between 1900 and 2014 an estimated 17 million people (34% of the population) have been affected by droughts whereas floods have affected an estimated 570 000 people. A reliable assessment of the national extent of the impact of extreme weather events and their trends still remains a challenge, however, due to the paucity of robust data for the country. This is partly due to the lack of consistency in the reporting structures, especially on costs of disasters. Despite these limitations, the frequency and intensity of extreme weather events in South Africa and the myriad of socio-economic impacts highlight the need for investment in proactive disaster risk reduction (DRR) measures, aligned with climate change adaptation programmes, in order to mitigate the impacts of weather-related disasters.

Disaster risk reduction and management legislation in South Africa

South Africa's disaster management legislation has served as a model for other countries (IPCC 2012) and is considered one of the most advanced institutional frameworks for disaster management in the world (Pelling & Holloway 2006; Vermaak & Van Niekerk 2004). The Disaster Management Act of 2002 (Act No. 57 of 2002) (Republic of South Africa (RSA) 2002) and the National Disaster Management Policy Framework (RSA 2005) focus on prevention and decentralisation of DRR governance, mandate the integration of DRR into development planning and require inclusion of stakeholders (IPCC 2012). Each level of government (national, provincial and local) is required to establish structures to ensure that DRR, response and recovery are coordinated and implemented. These efforts are coordinated through the National Disaster Management Centre (NDMC). The functions of the NDMC include monitoring of disasters, mobilisation of resources, coordination and response to disasters, and maintenance of a repository of information relating to disasters, as well as a database of relevant stakeholders.

The implementation of South Africa's benchmark legislation has, however, proven challenging.

Current climate information and early warning system capabilities in South Africa

The Weather Service Act of 2001 (Act No. 8 of 2001) (RSA 2001) mandates the South African Weather Service (SAWS) as the institution legally responsible for weather and climate forecasting and issuing severe weather-related alerts in South Africa. South Africa has a number of early warning systems (EWSs) for different sectors and different weather elements and is in the process of developing more. Examples are the Advanced Fire Information System (AFIS), the South African Weather Service's

Severe Weather Warning System, and the South African Flash Flood Guidance (SAFFG) system. The information and warnings from these systems are made available on websites and are distributed to provincial, district and local municipalities by SMS and email, for them to incorporate into their own EWSs or to take action. SAWS has adopted the multi-hazard EWS (MHEWS) which uses multiple monitoring systems and meteorological, hydrological and climate information to prepare for and respond to multiple weather-related hazards. The SAWS Severe Weather System covers potentially damaging weather events (for example, heavy rain, heat waves and cold weather) that are common in the country. National warnings and advisories are compiled and issued with the longest possible lead-times. Alerts are issued by SAWS and are used by disaster management centres (DMCs) in preparation and readiness for emergency actions, such as evacuation in the face of a hazard. The alerts are also issued directly to the public through the media, internet and cell phone service providers. For example, using the SAFFG, warnings were issued for Gauteng on the night of the 15–16 December 2010 flash floods.

Early warning information does not always reach the people who need it despite a warning being issued, and the reliability of early warning information needs improvement. The packaging of early warning information needs to be improved, including translation into local languages, as do local level response strategies.

Policy recommendations

- Incorporate mainstream disaster risk reduction (not simply disaster response) into policy and planning for all sectors and levels of government.
- Support the continued shift from a reactive to a proactive approach to disaster management.
- Improve collaboration between disaster risk reduction and management (DRR-M) and climate change adaptation line departments.
- Improve DRR-M coordination within and between government departments at all levels of government.
- Improve the delineation of roles and responsibilities around DRR-M, emphasising the importance of DRR within all sectors and levels of government.
- Support the establishment of DRR-M structures, including forums and nodes, at all levels.
- Strengthen institutional capacity to respond to EWS information at all levels and especially support local level engagement in collating and sharing information.
- Provide adequate funding and technical support for DRR-M at all levels:
  - o Provide additional support to assist local government with post disaster costing and reporting, as well as with initiatives such as acquiring finance to support risk reduction.
  - o Further support local municipalities in efforts to map community vulnerability to all weather-related hazards and to integrate this into local planning.
  - o Build capacity in relevant institutions to understand the principles of DRR-M, including continued and enhanced development of standardised guidelines and operational procedures.
  - o Encourage efforts to provide appropriate reports on the costs of the damages caused by disasters at all levels.
- Undertake robust needs assessments and gap analyses at all levels.
- Acknowledge the role of healthy ecosystems and ecological infrastructure in reducing the impacts of climate vulnerability and climate change and integrate this into DRR-M planning.
- Invest in research and development (R&D) for general and tailored forecasting including a specific audit of R&D gaps.

1. INTRODUCTION

At the global scale, the frequency, extent and severity of natural disasters have increased notably over the last several years and economic losses from weather- and climate-related disasters have also increased (IPCC 2012). Climate change is projected to increase the frequency and magnitude of extreme weather events (IPCC 2012), which, without reductions in vulnerability, will increase the risk of disasters (Vincent et al. 2008). Climate change is projected to alter the magnitude, timing, and distribution of storms that produce flood events as well as the frequency and intensity of drought events (Engelbrecht et al. 2013; Fauchereau et al. 2003; Tadross et al. 2011). Projected increases in temperature (DEA 2013; MacKellar et al. 2014; Tadross et al. 2011) combined with dry spells may result in wildfires affecting larger areas and fires of increased intensity and severity (IPCC 2012). Coastal storm surges are expected to increase as a result of sea level rise and increases in the frequency and intensity of sea storms is likely (IPCC 2013). Even if the intensity of sea storms remains unchanged, higher sea levels will mean that smaller storms are likely to have an increased impact on the coastline (Theron 2011).

Southern Africa is widely recognised as one of the most vulnerable regions to climate change, because of low levels of adaptive capacity, particularly among rural communities (IPCC 2007). The expected increase in weather-related disasters as a result of climate change poses significant challenges for South Africa and is expected to negatively impact infrastructure, food security, health and tourism among other things. The primary mechanisms for coping with climate change focus on either mitigation to reduce emissions, or on long-term adaptation. It is being increasingly argued that climate change adaptation and disaster risk management need to be integrated in order to build the resilience of affected communities and to develop effective early warning systems – see Box 2 for definitions (IPCC 2012; Thomalla et al. 2006; Vincent et al. 2008). Climate change adaptation and disaster risk management share a range of complementary approaches for managing the risks of extreme events (IPCC 2012). Both approaches aim to mitigate climate-related risks by reducing and modifying environmental and human factors in order to support sustainable economic and social development (IPCC 2012). In order for disaster risk reduction and management (DRR-M) approaches to be effective into the future, consideration of climate change and adaptation to climate change is essential. The areas of DRR-M and climate change adaptation (CCA) have historically been addressed separately, in terms of concepts, methods, interpretation and institutional arrangements. More recently, these areas are becoming more aligned and integrated. Addressing the preparedness, readiness and response to disasters, while adapting to climate change, is essential and a priority area for policy development in South Africa (Botha et al. 2011).

1.1. Scope and approach of this report

In the context of future projected changes in climate extremes, this report aims to develop recommendations for strengthening climate information and early warning systems in South Africa. The report focuses on four main categories of weather-related disasters: floods, droughts, fires and storm surges. In light of projected increases in frequency and severity, these four types of events are considered key areas of interest and are priority areas for enabling adaptation and improving early warning systems (EWSs).

The report is based on an academic literature review, interviews with disaster management experts at the National Disaster Management Centre (NDMC) as well as the South African Weather Service (SAWS), and focused group discussions with key stakeholders during the Long Term Adaptation Scenarios (LTAS) Phase 2 workshop on 22–24 January 2014. Preliminary findings of this report were also presented at the LTAS stakeholder engagement workshops. Comments and feedback were incorporated into the report. Local case studies of best practice for DRR-M and early warning are presented in order to demonstrate how disasters are successfully being managed.

The report is arranged as follows:

- **Chapter 2** reviews the socio-economic impacts of past extreme weather events in South Africa and includes an estimate of the costs of disaster risk reduction and rehabilitation/recovery based on data obtained from the International Disaster Database (EM-DAT) (Guha-Sapir et al. 2014).
- **Chapter 3** reviews the mandates, capacity and links between national, provincial, municipal and local community levels with regard to DRR-M and EWS.
- **Chapter 4** reviews the current capacity with regard to climate information and early warning systems for floods, droughts, fires and storm surges.
- **Chapter 5** identifies gaps and opportunities in both the current legislation and the climate information and EWSs. Gaps and opportunities for improved EWS and DRR-M systems highlighted in Chapter 3 and 4 provide the foundation for this chapter.
- **Chapter 6** provides policy recommendations for strengthening climate information and EWSs in South Africa in the context of a changing climate.

1.2. Disaster risk management in South Africa

In South Africa, there has been an emphasis on moving from reactive, crisis management approaches to proactive, risk management approaches (Pelling & Holloway 2006). According to Vermaak and Van Niekerk (2004), South Africa has an advanced institutional framework for disaster management. South Africa's Disaster Management Act, 2002 (Act No. 57 of 2002) (DMA) (RSA 2002) and the National Disaster Management Framework (NDMF) (RSA 2005) guide DRR-M in the country (see Box 1 for detailed information on the Acts). DRR-M is the responsibility of the NDMC, whose objective is to coordinate and promote integrated disaster management at all levels of government as well as with other role players. Functions of the NDMC include monitoring of disasters, mobilisation of resources, coordination and response to disasters and the maintenance of a repository of information relating to disasters and a database of relevant stakeholders (Pelling & Holloway 2006; Van Riet & Diedericks 2010; Vermaak & Van Niekerk 2004).

In spite of the National Climate Change Response Paper (NCCRP) (RSA 2011) and the second national communication (DEA 2011) highlighting disaster management as an important area of development for building resilience, climate change is currently not mentioned in the DMA. Furthermore, the implementation of the Act and Framework, including integration of DRR-M in development planning, has been problematic. According to a review conducted by the South African Local Government Association (SALGA), and the African Centre for Disaster Studies (ACDS) gaps exist within the Act that hinder effective implementation (Botha & Van Niekerk 2013).

An amendment process for the DMA is currently underway. This process aims to address key issues identified by practitioners and stakeholders in the field of disaster management which have limited the implementation of the existing legislation. It will seek to amend the definitions so that they are in line with those used by the International Strategy for Disaster Reduction (ISDR) and to include risk assessments, mapping of vulnerable areas, measures to adapt to climate change and development of early warning mechanisms (DMISA 2014).

1.3. Climate Information and Early Warning Systems in South Africa

An important area for building resilience to expected increases in the frequency and intensity of extreme weather-related hazards is the strengthening of EWSs (see ***Box 2*** for definitions). In order for EWSs to be effective they should address four key elements as defined by the

United Nations International Strategy for Disaster Risk Reduction (UNISDR): 1) risk identification, 2) monitoring and warning systems, 3) warning dissemination, and 4) response actions (Chang Seng 2012). Globally, EWSs have evolved considerably over the last two decades and there are a myriad of systems in operation, covering the majority of natural hazards (Glantz 2003; Grasso 2014). EWSs provide an important mechanism for improved alignment between climate change and DRR-M – they are an example of a 'low regrets' measure that provides co-benefits for DRR-M and climate change adaptation (IPCC 2012).

South Africa has a number of EWSs for different sectors and different weather-related hazards and is in the process of developing more. SAWS is the legally mandated institution, as per the Weather Service Act of 2001 (Act No. 8 of 2001) (RSA 2001), responsible for weather and climate forecasting and issuing severe weather related alerts. The institution is a paid service provider for weather- and climate-related information for many users in Africa and is a member of the World Meteorological Organisation. SAWS has adopted a multi-hazard EWS (MHEWS), which makes use of multiple monitoring systems and meteorological, hydrological and climate information to prepare for and respond to multiple weather-related hazards. The SAWS Severe Weather Warning System disseminates early warning information to affected communities about potentially damaging weather events (for example, heavy rain, heat waves and cold weather). SAWS have collaborated with a number of research institutions and government departments to develop a number of other EWSs. Examples include the Advanced Fire Information System (AFIS) and the South African Flash Flood Guidance (SAFFG) system. A variety of efforts are underway, by both government and research institutions, to improve EWSs in South Africa in order to improve the communication and dissemination of information at the local municipality and community level.

Box 1: National legislation and strategies linked to disaster risk management in South Africa

The national **Disaster Management Act, 2002** (Act No. 57 of 2002) calls for:

- an integrated and coordinated disaster management policy that focuses on preventing or reducing the risk of disasters, mitigating the severity of disasters, emergency preparedness, rapid and effective response to disasters and post disaster recovery
- the establishment of national, provincial and municipal disaster management centres
- disaster risk management volunteers (RSA 2002).

The **National Disaster Management Framework** (2005) is the legal instrument specified by the Act to address the need for consistency across multiple interest groups, by providing 'a coherent, transparent and inclusive policy on disaster management appropriate for the Republic as a whole' (RSA 2002). The framework is structured according to key performance areas (KPAs) such as institutional capacity for disaster risk reduction, disaster risk assessment, reduction and recovery. Enablers, which are components that need to be in place to implement the KPAs include: 1) information management and communication; 2) education, training, public awareness and research; and 3) funding structures for disaster risk management (RSA 2005).

The **Drought Management Plan** of 2005 seeks to reduce the impacts of droughts, by providing an information management, monitoring and evaluating system for drought situations. A specific drought policy is currently under development (Ngaka 2012).

The **National Veld and Forest Fire Act, 1998** (Act No. 101 of 1998) provides a variety of mechanisms, institutions, methods and practices for the prevention, combating and management of veld, forest and mountain fires in South Africa (RSA 1998). These include the formation of fire protection associations, which are voluntary organisations comprising land owners responsible for the prevention, suppression and management of veldfires in their areas of jurisdiction. Fire management entails three key activities:

- suppression of wild fires
- implementation of control burns
- the preparation of firebreaks.

The **Weather Service Act, 2001** (RSA 2001) constitutes the South African Weather Service as the national weather forecasting body. The Weather Service is responsible for weather and climate forecasting and issuing severe weather related alerts.

Box 2: Key terminology

Adaptation is a means of responding to the impacts of climate change. It aims to moderate the impacts as well as to take advantage of new opportunities or to cope with the consequences of new conditions. The capacity to adapt depends on a region's socio-economic and environmental situation as well as the availability of information and technology. At the individual level, a person's characteristics (such as their age, gender, education level and so on) will influence their ability to adapt successfully to changes in climate conditions (Davis 2011).

Adaptive capacity, or its opposite, **social vulnerability**, refers to the varying social characteristics of people (at various units of analysis, from individual to community to country) that determine how hazard exposure is experienced. Adaptive capacity/ social vulnerability can reflect the status of poverty, health, knowledge/ education, and governance (at collective levels). A high adaptive capacity is equivalent to low social vulnerability, and a low adaptive capacity is equivalent to high social vulnerability (Davis 2011).

Climate extreme (extreme weather or climate event) is the occurrence of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of historical observed values. Extreme events include unusual, severe or unseasonal weather (IPCC 2012).

A **natural hazard** refers to a "Natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (UNISDR 2009). Natural hazard events can be characterized by their magnitude or intensity, speed of onset, duration, and area of extent (UNISDR, 2009).

A **disaster** is defined by the Centre for Research on the Epidemiology of Disasters as "a situation or event which overwhelms local capacity, necessitating a request to national or international level for external assistance, an unforeseen and often sudden event that causes great damage, destruction and human suffering" (Guha-Sapir et al. 2014). Furthermore, a disaster is a negative outcome brought about by high vulnerability (or low adaptive capacity) in the face of exposure to an extreme weather event. It is for this reason that an event of similar magnitude in one place may translate into a disaster, but in another may not, depending on the capacity of the population to cope (Davis 2011).

Risk is the result of the relationship between hazard exposure, sensitivity (biophysical vulnerability) and adaptive capacity (or social vulnerability), and refers to the likelihood of an adverse impact from an event (IPCC 2007).

Sensitivity, or **biophysical vulnerability**, refers to the extent to which any unit of analysis (ranging, for example, from one tree to a whole forest) reacts to hazard exposure (Davis 2011). Systems that are highly exposed, sensitive and less able to adapt are vulnerable.

Disaster risk reduction/management is defined as "The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster." (UNISDR, 2009).

An **early warning system** refers to "the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss" (UNISDR, 2009).

2. PAST EXTREME WEATHER EVENTS IN SOUTH AFRICA

South Africa is susceptible to a number of extreme weather events (Figure 1) with the most common being floods, droughts, fires and large storms (refer to Box 3 for descriptions). This section of the report details the socio-economic impacts of previous weather-related events, including costs associated with recovery, in order to provide a context for the current risk and vulnerability profile of the country.

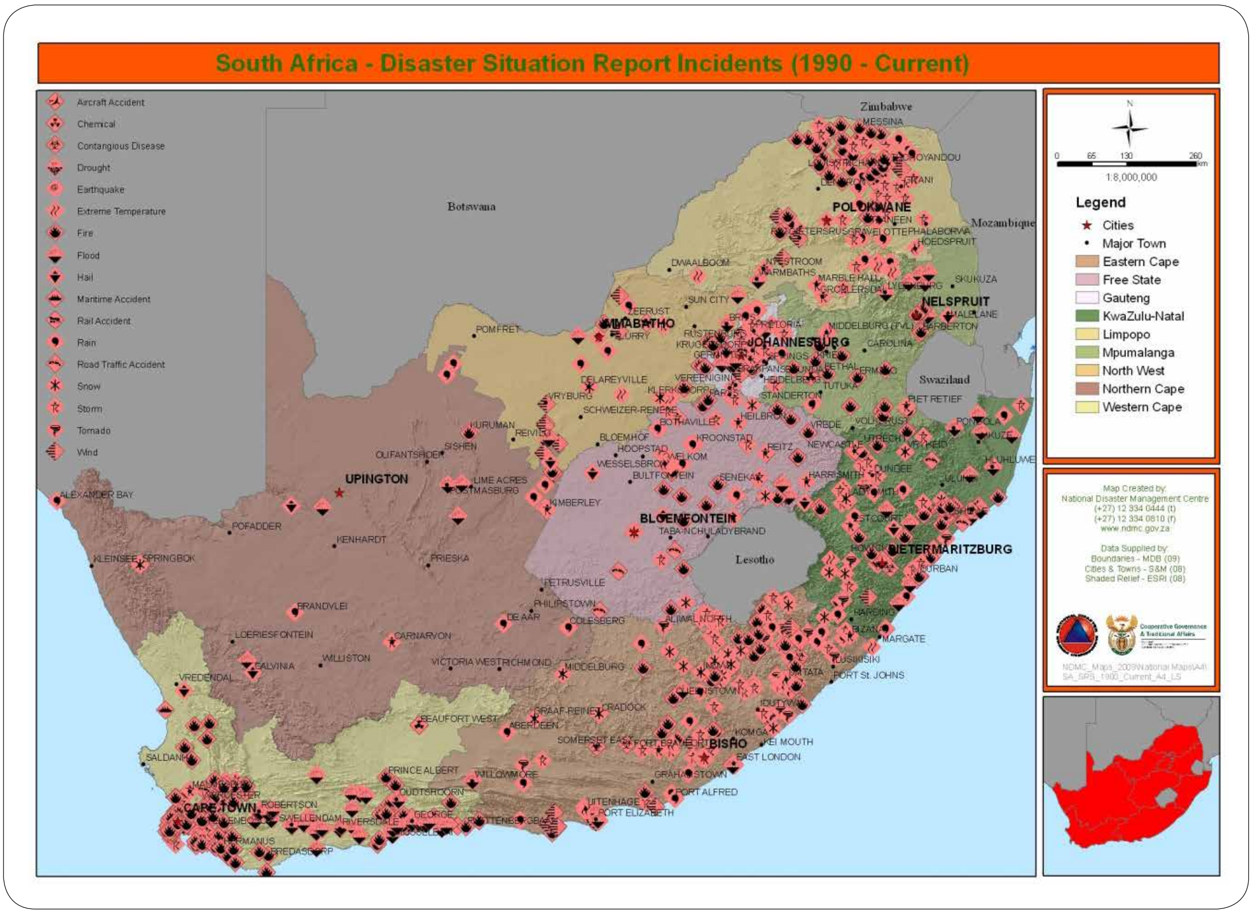


Figure 1: Example of a National Disaster Management Centre (NDMC) disaster situation report showing the extreme events incidents that have occurred across the country from 1990 to date
Source: NDMC (2009b).

Box 3: Description of the four major categories of weather-related events included in this study

Disaster type	Description
Flood	*Rapid-onset flood:* these include flash floods, tidal surges, floods provoked by cyclones or accompanied by strong winds, high runoff from heavy rainfall, dam bursts and overtopping, canals and rivers bursting their banks. Typically water rising to dangerous levels within 48 hours (Smith 2009).
	Slow-onset floods: prolonged rainfall causing low-lying areas to gradually become flooded over a period of days or weeks (Smith 2009).
Drought	*Meteorological drought:* less than 70% of normal rainfall received (Bruwer 1993).
	Agricultural drought: a reduction in water availability below the optimal level required by a crop during each different growth stage, resulting in impaired growth and reduced yields (Wilhite & Glantz 1985).
Wildfires[1]	The occurrence of fires is closely linked with high temperatures and dry spells, for example during berg wind conditions. Originally most fires were caused by lightning but today, more than 90% of fires are lit by people, either deliberately or accidentally (Forsyth et al. 2010).
Storms	The classification of storms includes severe thunderstorms, cyclones, tornados, convective storms, frontal systems and cut-off low events (DEA 2011) which often cause flash floods. In this report we include in the classification of storms, storm surges, hail storms and severe cold fronts including some instances of snow. Storm surges are an irregular rise in sea level produced by a storm and characterised by heavy rains and high winds (Theron 2011).

2.1. Socio-economic impacts of past extreme weather events

The impacts of extreme weather events are wide ranging and affect multiple sectors. The impacts range from primary or direct effects, such as damage to infrastructure and death, to secondary or indirect effects, such as health issues and the loss of livelihoods (Easterling et al. 2000). Studies have shown that disasters have long-term secondary effects on societies, regardless of their level of development. High exposure and vulnerability levels will transform even small-scale (slow-onset) events into disasters for some affected communities. Recurrent small or medium-scale events affecting the same communities may have cumulative effects which lead to serious

1 Also referred to as veldfires in South Africa.

erosion of the development base and livelihood options, thus increasing vulnerability (IPCC 2012); (see Box 2 for definition of vulnerability). The poor, in particular, will be most vulnerable because of their limited access to livelihood opportunities, infrastructure, information, technology and assets. In addition they are often forced, through economic circumstances, to inhabit areas that are susceptible to natural disasters. Consequently the poor will be more exposed to these increases in climate-related hazards. This vulnerability is exacerbated by inadequate comprehensive planning, implementation and insurance cover for disaster losses which will further add pressure to the public resources (Botha et al. 2011; Botha & Van Niekerk 2013). Some of the impacts of weather related hazards on different sectors are demonstrated using a vulnerability matrix in Table 1 below.

Weather-related events have caused extensive damage to the economy and society at large and have resulted in significant increases in direct and recovery costs. South Africa's second national communication to the UNFCCC estimated the total cost of weather-related disasters between 2000 and 2009 to be approximately R9.2 billion. According to the NDMC annual reports from 2006 to 2011, provincial and district municipalities carry the greatest financial burden from disasters, with up to R1 596 billion spent for rehabilitation and recovery in the 2010/2011 financial year (NDMC 2011). A reliable assessment of the national extent of the impact of extreme weather events and their trends still, however, remains a challenge due to the paucity of robust data for the country. This is partly due to the lack of consistency in reporting structures, especially on costs of disasters. A conservative indication can, however, be produced based on studies which have assessed the costs and on international databases such as EM-DAT (Guha-Sapir et al. 2014).

Figures 2–5 are based on data obtained from the Emergency Events Database (EM-DAT) of the Office of Foreign Disaster Assistance/ Centre for Research on the Epidemiology of Disasters (OFDA/CRED) International Disaster Database (www.emdat.be). Figure 2 provides a breakdown of the costs for the top 10 natural disasters in South Africa between 1990 and 2014 and Figure 3 provides a summary of the cost for each of the four major categories: droughts, floods, fires and storms. The number of people affected by the top 10 natural disasters in each of the major categories is shown in Figure 4 and Figure 5. While floods have resulted in the highest economic cost of damages, droughts have affected a larger proportion of the country's population. Between 1900 and 2014 an estimated 17 million people (34% of the population) have been affected by drought, whereas floods have affected an estimated 570 000 people. This can be attributed to the nature of droughts, which are slow onset disasters and affect more than just the people in the immediate locality. The four categories of disasters have resulted in approximately US$4.6 billion (R50.7 billion) in economic damages with costs associated with floods amounting to approximately US$1.7 billion (R18.7 billion); (based on data from EM-DAT). These damage and recovery/rehabilitation costs reflect the reactive costs of disasters and highlight the need for more investment in proactive measures and disaster risk reduction in order to mitigate the impacts of disasters.

It is important to note that EM-DAT is likely to underestimate the scope and prevalence of hazard events in South Africa as it only records data on events where ten or more people are reported killed; 100 or more people need to be evacuated, provided with humanitarian assistance or otherwise affected; or the State declares an emergency or calls for international assistance. This conceals the diversity of the hazard landscape in South Africa, which experiences a far broader range of small and everyday hazards (Pharoah et al. 2013). For example, the tornado in October 2011 in Duduza, located on the East Rand of Gauteng, resulted in the death of one child, the injury of 160 people and left hundreds homeless (Extreme Planet 2012).

Disaster	Date	Damage (US$ x 1,000)	
Drought	1991	$	1 000 000.00
Flood	25/09/1987	$	765 305.00
Wildfire	30/08/2008	$	430 000.00
Storm	20/03/1990	$	393 000.00
Flood	01/01/2011	$	211 000.00
Flood	24/10/2012	$	200 000.00
Storm	15/12/1998	$	165 000.00
Flood	26/01/2000	$	160 000.00
Flood	02/08/2006	$	145 000.00
Storm	28/01/1984	$	92 000.00

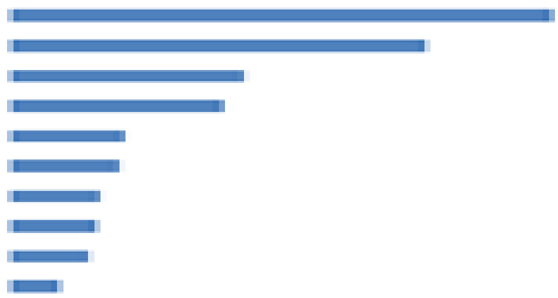


Figure 2: The economic impact of the top 10 disasters in South Africa from 1900 to 2014
Source: EM-DAT (n.d.)

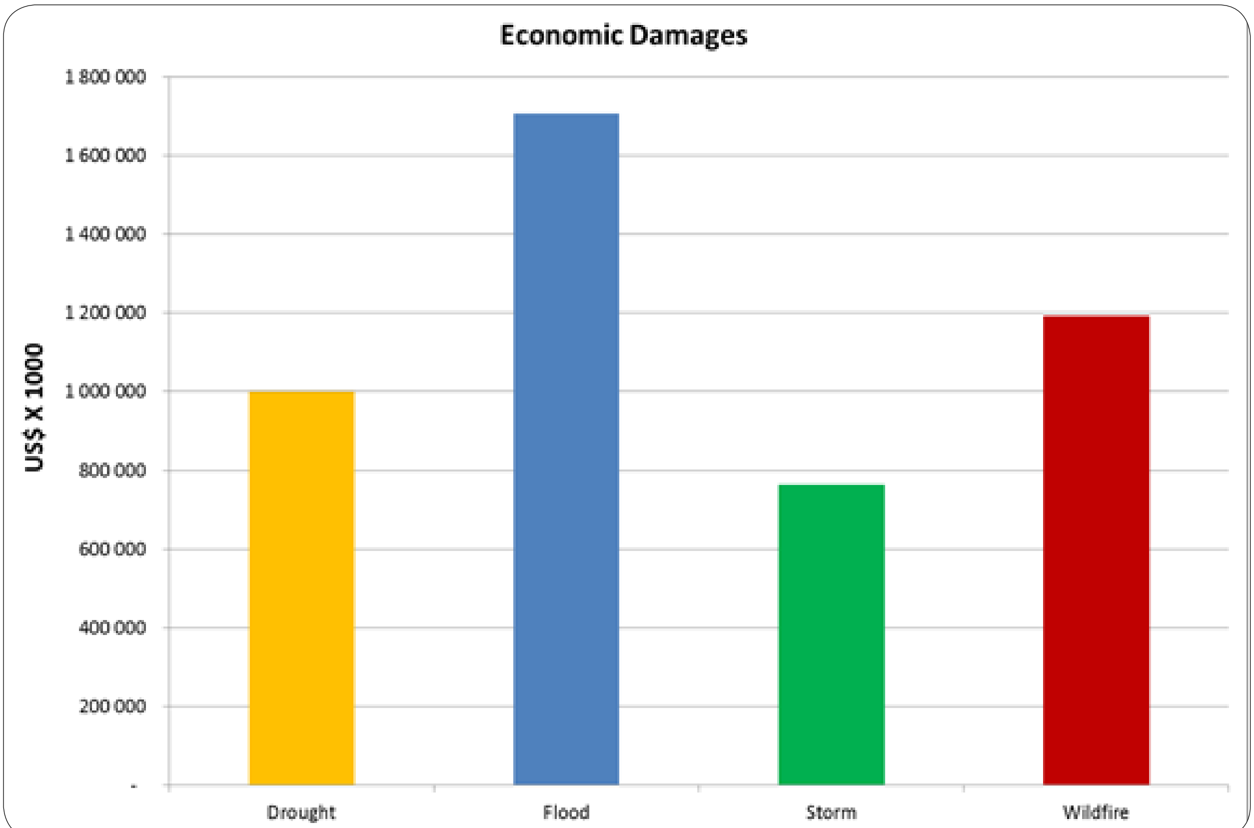


Figure 3: Summary of the relative cost of the four major categories of weather-related events; droughts, floods, storms and fires in South Africa between 1900 and 2014.
Source: EM-DAT (n.d.)

Disaster	Date	No. Total Affected
Drought	01/2004	15000000
Drought	10/1988	1320000
Drought	05/1986	850000
Storm	28/01/1984	500000
Drought	12/1995	300000
Flood	1/01/2011	200000
Flood	24/10/2012	125000
Storm	15/07/2002	100000
Epidemic	19/08/2000	86107
Flood	25/09/1987	65000

Figure 4: The number of people affected by the top 10 disasters in South Africa from 1900 to 2014
Source: EM-DAT (n.d.).

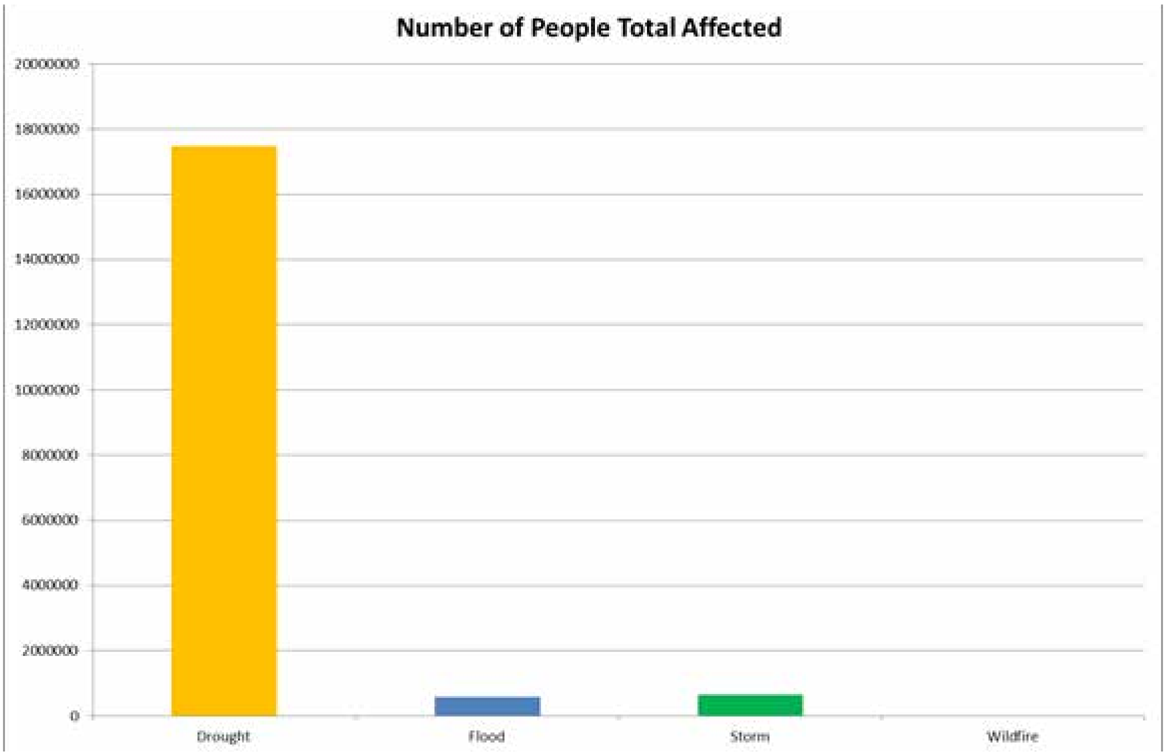


Figure 5: Summary of the number of people affected by each of the four major categories of weather-related events; droughts, floods, fires and storms in South Africa between 1900 and 2014.
Source: EM-DAT (n.d.)

Table 1: Vulnerability matrix outlining exposure of key sectors to the four major weather-related hazards: droughts, floods, fires and storm surges. The risks are ranked according to three categories: low, moderate and high. The information is based on published studies (see examples in the table) and input from stakeholder workshops conducted as part of the LTAS process.

Exposure unit	Climate Risks				Examples
	Drought	Wild-fires	Floods	Storm surges	
Health	High	Moderate	High	Moderate	Flooding often results in stagnant water and increases the risk of water borne diseases such as cholera (Hales et al. 2003).
Human settlements	Low	High	High	High	Impacts on human settlements include damage to property, access to basic services, resettlement and forced-migration (Mukheibir & Ziervogel 2007).
Agriculture	High	High	High	Low	Rainfall variability has significant consequences for agriculture and food security (Gbetibouo et al. 2010).
Tourism	High	Moderate	High	High	Extreme weather events affect tourism and livelihoods that depend on the sector (Mukheibir & Ziervogel 2007).
Infra-structure	Low	Moderate	High	High	Impacts of extreme rainfall events on public and private infrastructure, resulting in costly repairs, road closures, limited or no access to electricity, and failure of sewage and storm water systems (Mukheibir & Ziervogel 2007).

Table 1: Continued

Exposure unit	Climate Risks				Examples
	Drought	Wild-fires	Floods	Storm surges	
Ecosystems	High	High	High	Moderate	Extreme rainfall can result in soil erosion, land degradation, loss of ecosystem services, alien species invasion, salinisation of groundwater and flood trails containing pesticides and fertiliser (Scholes et al. 2004).
Forestry	Moderate	High	Low	Low	During the 1991/1992 drought the forestry industry lost approximately R450 million, with the repercussions of that drought still being felt 10 years later when the trees were harvested (Warburton & Schulze 2006).

2.2. Examples of some of the worst weather-related disasters in South Africa

2.2.1. Drought

The 1991/1992 drought is ranked as the worst natural disaster in South Africa. It resulted in approximately 70% of crops failing and maize having to be imported into the country (DEA 2011; Mniki 2009). Crop failure resulted in farm labour lay-offs, increased farm debt and farm closures and caused knock-on effects for households that depended on the agricultural sector. It has been estimated that 50 000 jobs were lost in the agricultural sector, with a further 20 000 in related sectors, affecting about 250 000 people (Mniki 2009). According to the Reserve Bank the loss of GDP during the 1992 drought was approximately 1.8%, representing US$500 million (Pretorius & Smal 1992).

2.2.2. Floods

In 1987 the flooding in KwaZulu-Natal, ranked second on the EM-DAT list (Figure 2), caused severe damages to thousands of kilometres of roads, with 14 bridges being washed away and all entrance routes to Durban being closed. Approximately 68 000 people were left homeless and 388 people were killed (Grobler 2001). In March 2003 and April 2005 the Western Cape experienced floods, as a result of cut-off lows, which resulted in up to R260 million in damages (Mukheibir & Ziervogel 2007). Not included in the EM-DAT statistics are slow-onset flood events which occur regularly in informal settlements, such as Masiphumelele located on the Cape Flats and Alexandra located adjacent to the Juksei River. These areas are considered high risk as they are often located in low-lying, flood prone areas. Houses are regularly flooded or destroyed leaving families displaced, and resultant stagnant water has led to outbreaks of cholera, for example in 1999 in Alexandra (Dixon & Ramutsindela 2006).

2.2.3. Wildfires

Fires are a frequent occurrence, particularly in the eastern part of the country which has a strong dry season lasting for up to five months. In 2002, fires in Mpumalanga destroyed 24 000 ha of pasture and left four people dead, with damages amounting to more than R32 million (Forsyth et al. 2010). Between 2007 and 2008 KwaZulu-Natal and Mpumalanga experienced fires that resulted in significant loss of revenue, estimated at US$430 million (**Figure 2**). As much as 61 700 ha of plantation forest was burnt, equating to 2.9% and 9.5% of the total area of plantations in these two provinces, respectively. Forestry SA estimated the value of standing timber burnt to be R1.33 billion (2007 prices) and that 40% of this was unsalvageable (Forsyth et al. 2010).

2.2.4. Storm surges

The South African coastal provinces have been threatened numerous times by storm surges causing huge damage to infrastructure such as sea walls, railway lines, harbours and coastal properties (Box 4). In 2007 and 2008 the damage to coastal property and infrastructure was estimated at R1 billion (Smith et al. 2013). In March 2007 storms caused substantial damage to property and erosion of about 350 kilometres of the KwaZulu-Natal coastline (Breetze et al. 2008). In the Western Cape, Cape Nature has experienced losses of up to R12.5 million between 2003 and 2007 (Holloway 2012).

Box 4: The impact of a storm surge along the KwaZulu-Natal coastline in March 2007

Photo: Simon Bundy

As evidenced by the frequency and intensity of extreme weather events in South Africa, there is a great need for proactive investment in DRR-M activities to deal with disasters. This is essential given the escalating costs of damage from disasters and the focus by most institutions on recovery and rehabilitation after a disaster, rather than on DRR-M. Quantifying the cost effectiveness of DRR-M, including investments in effective climate information and EWSs, remains a challenge due to limited data and robust information on costs such as recovery and rehabilitation. This situation is not unique to South Africa and internationally sound cost-benefit analyses of investments in improved climate monitoring and effective EWSs are scarce (Moench et al. 2007). Moreover, the full impacts of weather and climate related extremes in developing countries are not fully understood, and a lack of comprehensive studies on damage, adaptation, and residual costs indicates that the full costs are underestimated (IPCC 2012). Despite this the evidence suggests that investment in prevention is more cost-effective than spending on relief (Hallegatte 2012; Rogers & Tsirkunov 2011).

3. DISASTER RISK REDUCTION AND MANAGEMENT IN SOUTH AFRICA

As stated in the Introduction (Chapter 1), DRR-M is guided by the DMA and the NDMF, hereafter referred to as the Act and the Framework, respectively. The Act and the Framework promote disaster reduction, prevention and mitigation. According to the DMA, disaster risk management should adopt an integrated, multi-sectoral and multi-disciplinary method of decreasing risk associated with hazards and vulnerability, making it key in the development planning process, especially for local government (Visser & Van Niekerk 2009).

The Disaster Management Institute of South Africa (2014) has recommended that the disaster framework be reviewed, especially to rectify terminology which is currently confusing. In addition, the Framework will need to be aligned to any amendments to the Act.

3.1. Institutional arrangements for DRR- M

A key feature of the Act is the decentralisation (national, provincial, and local) of disaster risk reduction activities (Van Riet & Diedericks 2010; Vermaak & Van Niekerk 2004).The three tiers of government (national, provincial and local) all play a role in disaster risk management which is coordinated through the NDMC (Figure 6). The Act provides for the inclusion of 'at risk' communities, as well as the private sector, parastatal entities such as the utilities companies, research and academic institutions, non-governmental organisations (NGOs) and traditional leadership (Van Niekerk 2011). In terms of decentralisation of disaster reduction activities, the Act provides comprehensive guidelines on the establishment of disaster risk management centres and intergovernmental structures. Both the Act and the Framework emphasise the creation of appropriate institutional structures of DRR-M to support the various actions and actors that need to be involved. While most of the DRR-M systems are established at national level, district, local and metropolitan spheres of government and communities have established, or are carrying out, DRR-M activities in their respective places. The following sections outline the key mandates for DRR-M at all levels of government and provide some examples and case studies of DRR-M activities, which could be used as guidelines for best practise.

3.1.1. National Government Sphere

The NDMC has the mandate to create the required institutional activities for integrated and coordinated disaster risk management, focusing on prevention and mitigation at all levels of government (including legislative functionaries), with other role-players involved in disaster management, and within communities. Other objectives include building and enhancing capacity and accountability of provincial and local municipalities as they perform their constitutional mandate according to the Act, as well as forestalling and responding to disasters. The NDMC's mandate is to enhance the general resilience to disaster of communities and infrastructure, and to reinforce the capacity of other levels of government in disaster response. Furthermore, the NDMC is required to create a repository of disaster and disaster management information, as well as develop and maintain an electronic database. The NDMC is also responsible for the dissemination of information to communities that are vulnerable to the identified disasters.

In essence, the NDMC is responsible for guiding and developing frameworks for government's disaster risk management policy and legislation, facilitating and monitoring their implementation, as well as facilitating and guiding cross-functional and multidisciplinary disaster risk management activities among the various organs of state (NDMC 2006).

To assist with this mandate, the NDMC established the National Disaster Management Information System

(NDMIS). The system aims to be an all-encompassing information technology (IT) solution that relates to various aspects of hazard analysis, vulnerability assessment, contingency planning, reporting systems and EWSs (NDMC 2011). The main priorities of the NDMIS are related to:

- establishing and improving EWSs
- subsequent dissemination of these warnings
- establishing risk and vulnerability profiling, moving towards establishing a national indicative risk profile
- building a GIS portal with the aim of disseminating relevant information to key stakeholders as required by the Act.

The NDMIS is designed to include aspects that are related to communication, managing a stakeholder database, document management, system workflow, event and incident reporting, and planning and resource management. The status of these aspects of the system was not clear at the time of writing this report.

Also operating at the national government level is a technical forum, the National Disaster Management Advisory Forum (NDMAF), which was established in 2007 and includes all the players from government to communities involved in disaster risk management. The forum has been instrumental in establishing technical task teams (TTTs) for areas of work required on different types of hazards, for example, disaster response, fires and energy-related disasters (NDMC 2006). The forum also plays a key role in disaster risk reduction, in accordance with the UNISDR's Hyogo Framework for Action, and facilitates the discussion of other cross-cutting matters regarding DRR.

3.1.2. Provincial Government Sphere

Each province is required to develop a disaster management framework consistent with the provisions of the Act and the Framework. This should be an integrated and coordinated process involving provincial organs of state, provincial legislative representatives, NGOs and the private sector. Furthermore, each province must establish a disaster management centre. The provincial disaster management centre (PDMC) is the primary functional unit for DRR-M in each province. A key responsibility is to promote disaster related research in the province and to build capacity of local stakeholders to prepare and respond to disasters. In the event of a disaster potentially or actually occurring, the PDMC must provide support and guidance to the relevant municipal disaster management centre.

By 2008, five fully functional PDMCs had been established in the Eastern Cape, the Western Cape (see Box 5 for a case study), the Free State, Gauteng and Limpopo provinces. Some of the established centres are reported to be fully functional and with disaster plans in place, whilst others are less successful (Van Niekerk & Visser 2010).

Provinces are also strongly recommended to establish provincial disaster management advisory forums; however, in the event that a province elects not to do so, appropriate existing alternative structures must be identified for this purpose.

Box 5: DRR-M in the Western Cape Province

The Western Cape Province is a winter rainfall area with unique biodiversity. It is, however, prone to climate related hazards such as floods, wildfires and droughts (Raju & Van Niekerk 2013). Coastal zones in the province are particularly vulnerable to climate related hazards which have the potential to affect tourism, coastal properties and infrastructure, and fisheries-based livelihoods (Western Cape Province 2014). The climate in the province is expected to change with a warming and drying trend. The annual average temperature is expected to increase by 1°C by 2050; rainfall is likely to decline with a resultant decrease in available water sources and soil moisture. The frequency and intensity of extreme weather events will possibly increase, and the risk of wildfires will also increase. These will negatively impact on crops, infrastructure, the coastline, the built environment and tourism, and have the potential to increase the vulnerability of poor communities (Western Cape Government 2014).

As a coordinating function, Western Cape Disaster Management maintains an early warning database and disseminates warnings to relevant stakeholders (namely district heads of disaster management centres and other relevant provincial departments) by email and/or SMS. These warnings are largely for weather-related hazards received from the South African Weather Service by email and/or SMS. The informed officials are required to disseminate the warning where applicable, prepare and act accordingly. The Western Cape also makes use of fire and flash flood EWSs, but no details about these systems were made available (Nicole Wagner, Western Cape Provincial Government, personal communication, 14 January 2014). The Western Cape Disaster Management Centre (WCDMC) also has a risk reduction outreach programme.

3.1.3. Local Government Sphere

DRR-M incorporates a range of activities and consequently many actors, apart from government institutions, need to be involved in the implementation of disaster risk measurements. Activities may include vulnerability and risk assessments, capacity building, establishing social and economic infrastructure as well as the use of EWSs. These activities require technical expertise and other skills which may not be found in government, therefore partnerships and collaboration between government, the private sector and communities are important (Botha et al. 2011; Botha & Van Niekerk 2013).

The Act requires that metropolitan and district municipalities establish a disaster management centre for the relevant municipal area. Some such disaster management centres have been established (see Box 6 and Box 7 for examples), but there are no clear guidelines for the establishment of centres at local municipalities. Each municipal disaster risk management centre should have in place a disaster risk management policy framework, an advisory forum and a disaster risk management committee that integrates all stakeholders (Visser & Van Niekerk 2009). Disaster risk management plans have to be integrated into the integrated development plan (IDP) for the municipality. This would enhance the mainstreaming of DRR-M into local government planning, which will also facilitate access to funding for DRR-M (Botha et al. 2011). It is important to note, however, that some of these disaster centres are poorly capacitated and in many areas they are dysfunctional. As with the provincial government sphere, the Act leaves it to the discretion of a municipality to constitute a municipal disaster management advisory forum for the purposes of external stakeholder participation (NDMC 2006).

The envisaged amendments to the Act provide an opportunity to strengthen policy implementation at local, district and metropolitan municipality levels. This would be achieved should the amendments state that disaster management plans should include disaster risk assessments, GIS mapping of risk and reporting of disaster occurrence, and expenditure on response and recovery.

Box 6: City of Cape Town Disaster Management

The Cape Town metropolitan area's disaster risk information system incorporates the Disaster Risk Management Centre (DRMC), a branch of the City Emergency Services Department, which in turn is part of the Safety & Security Directorate of the City of Cape Town. The Disaster Risk Management office website contains information on many natural and man-made hazards affecting the province and the different disaster centres in the province and collaborates with the different district municipalities which have their own systems in place. The centre runs various awareness programmes on disasters and keeps the public informed through their website (http://www.capetown.gov.za/en/DRM/Pages/default.aspx).

The City of Cape Town works with neighbouring municipalities, the private sector, organs of state and communities through mutual assistance agreements on early warnings, response and recovery activities. Community members are encouraged to inform authorities of any imminent threats such as blocked drains and storm water systems. Community awareness includes providing residents at risk with pamphlets in IsiXhosa, English and Afrikaans with tips on how to raise their floor levels, divert flood water and reduce health hazards that result from stagnant water (Hweshe 2012). The Swartland Municipality has developed an EWS, which is shared with the City of Cape Town, as heavy rains in the municipality can result in the flooding of the Diep River and affect residents of the Du Noon's Doornbach informal settlement (Hweshe 2012).

Box 7: Nelson Mandela Bay Metropolitan Municipality

In 2010 the Disaster Management Centre of the Nelson Mandela Bay Metropolitan Municipality identified the top rated risks as:

- Floods, especially affecting informal settlements and infrastructure
- The effects of fire, explosions and spillage of hazardous materials
- Severe storms
- Human disease (This category includes diseases that can lead to rapid onset as well as slow onset disasters. Diseases and conditions included under this category include HIV and AIDS, tuberculosis, cholera and asthma.)
- Drought, as is evident from the 2010 experience (Nelson Mandela Bay Disaster Management Centre, 2013).

The risk for the metropolitan area of floods and severe wind has been categorised as very severe (Henry Lansdown, Nelson Mandela Bay Disaster Management Centre, personal communication, 14 January 2014). An EWS consisting of 29 CCTV cameras at strategic remote sites has been installed to monitor potential high-risk flooding areas in the metro. In partnership with SAWS, four fully automatic weather stations were also installed at four existing CCTV sites. These four sites provide both images and weather information at the surveillance centre. Surveillance is done at the Joint Operations Centre (in adverse conditions a member of the local SAWS joins the centre) and runs on the wireless backbone infrastructure of the metro but also has a fibre optic link with the local SAWS. Eight extra SAWS automatic rain stations (funded by the NDMC) were installed across the metro as part of the Flash Flood Guidance System (see Section 4.2.1 in Chapter 4) and to enhance the capacity of the Port

Elizabeth branch of SAWS to predict flooding. This system detects and monitors adverse weather phenomena and issues warnings to affected communities. Some river crossings are also fitted with an alarm system to alert users to any risks (Nelson Mandela Bay Disaster Management Centre 2013). Communication and dissemination of the information is conducted through the media and through various key institutions such as disaster management practitioners, NGOs, and organs of state.

3.1.4. Local community participation

Local government authorities need to work with stakeholders, including with communities at risk, to establish a strategic and operational partnership (NDMC 2011). Municipalities need to facilitate community participation through training, preparedness planning and awareness raising activities and programmes. According to Section 58 of the Act, members of the community who meet the prescribed minimum requirements can apply to enrol as volunteers in the relevant municipal unit.

Various government departments at national, provincial and local level engage in different community outreach activities. For example, the Extended Public Works Programme's Working on Fire (WoF) programme (see Box 8) encourages public participation in responding to fires and provides local community members with fire management training, fire-fighting and record-keeping skills. The Department of Agriculture, Forestry and Fisheries (DAFF) conducts many awareness programmes targeted at farming communities to provide farmers with knowledge on their risks, disaster preparedness and response strategies when an alert or warning is given.

Community response also includes the uptake of weather and climate information by the public and engaging in appropriate community adaptation projects by combining such information with indigenous knowledge to increase the resilience and diversity of their livelihoods. DAFF has been working on improving the uptake of weather and climate information by packaging and translating the information into formats and languages that are easily understood by communities.

Other known initiatives include:

- The City of Tshwane has developed a primary school disaster management guide pack to raise awareness in schools.
- Disaster Mitigation for Sustainable Livelihoods, based at the University of Stellenbosch, engages in community risk reduction work that can be used by local authorities to plan and respond to disasters.

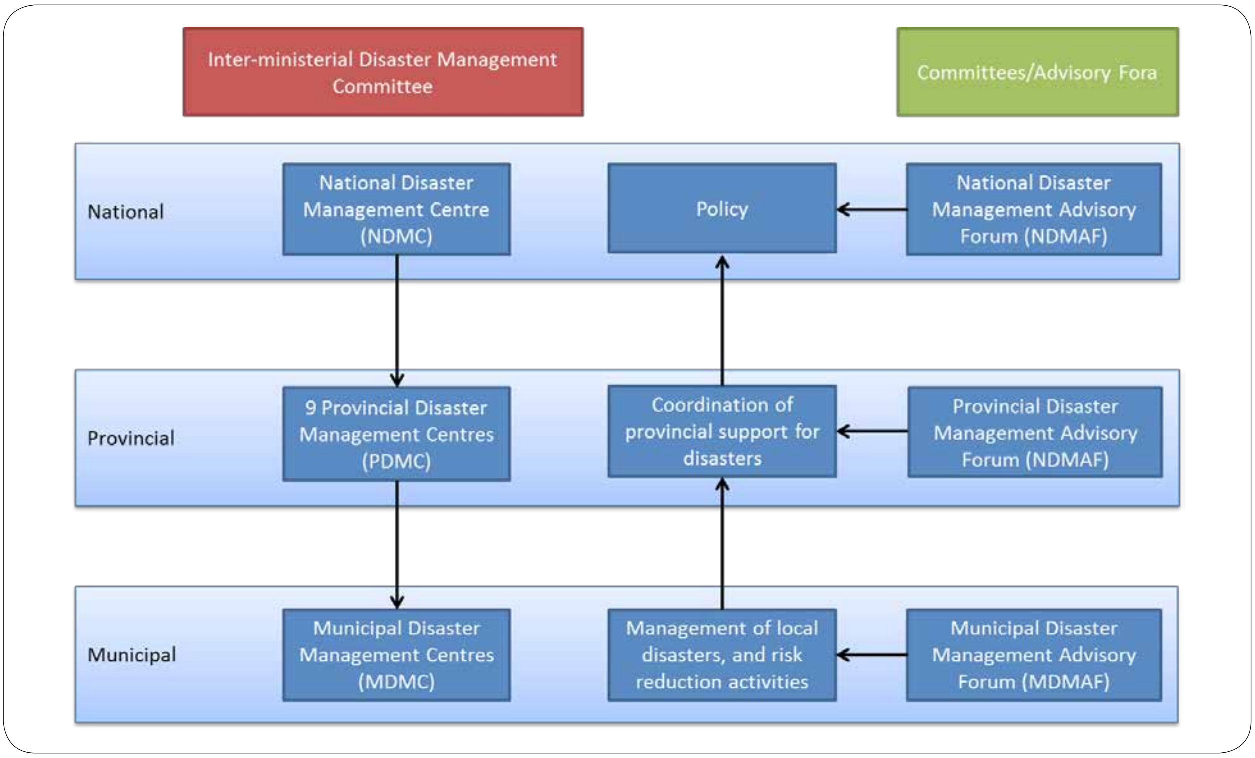


Figure 6: Structures and responsibilities of disaster risk management across all spheres of governance in South Africa
Source: adapted from SAWS (2012).

Box 8: Working on Fire

Working on Fire (WoF), a programme of the Department of Environmental Affairs, is mandated to implement integrated fire management in South Africa, which includes supporting the development of the fire protection association (FPA) structure under the National Veld and Forest Fire Act, 1998 (Act No. 101 of 1998). WoF also assists with the development of fire protection measures, reduction of fire hazards, improved veldfire control, the implementation of appropriate veld management strategies and the empowerment of communities that are affected by fire. It is an amalgamation of national, provincial and local government with the private sector. To date, the programme has trained over 5 000 fire-fighters both in the prevention and suppression of fires (Vosloo & Frost 2006; Van Wilgen et al. 2012).

3.1.5. Funding mechanisms for DRR-M

Funding for disaster management at national level includes funds for DRR and prevention as well as disaster rehabilitation and recovery, with a major focus on rehabilitation and recovery. The availability of funding for DRR-M would facilitate the capacitating, both financially and in human resources, of local municipalities in building resilience to the impacts of climate variability and change (Scorgie & Cumming 2014). An important factor in building resilience includes developing financial measures to fund and incentivise activities that promote resilience as well as DRR-M (Scorgie & Cumming 2014).

The increasingly high costs of disasters, the significant losses covered by insurance companies and the pressure put on governments when dealing with post-disaster recovery urges governments to reconsider DRR (FFC 2012). A study by the Financial and Fiscal Commission (FFC) (2012) on alternative financing mechanisms for disaster management in South Africa found that since 2005 the funding focus has disproportionately been on post-disasters rather than on integrating funding into development initiatives that reduce the risk of disasters happening. Earlier studies on DRR in South Africa found that there was no specific funding for DRR-M at local government level, and where such funding did exist, it was reserved for disaster recovery (FFC 2012).

The issue of limited funding has been raised as a constraint on the implementation of DRR-M at local and provincial level. DRR-M funding encompasses start-up costs for municipalities, disaster response and recovery as well as continuous disaster risk reduction activities. According to Van Niekerk and Visser (2011), access to funding for DRR-M is a critical challenge for municipalities. Despite the availability of funding mechanisms for various levels of government and the various DRR-M activities as outlined in the framework, the funds have not been accessed or used (FFC 2012). The reasons for this need further investigation.

4. CLIMATE INFORMATION AND EARLY WARNING SYSTEMS IN SOUTH AFRICA

4.1. National early warning capabilities

4.1.1. National Disaster Management Centre

The NDMC collaborates with other national and provincial departments that have early warning systems as well as programmes and projects aimed at assisting victims of hazards with recovery (Table 2).

Table 2: National government department linkages with DRR-M and early warning systems.

Government Department/institution	Mandate
National Agro-meteorological Committee (NAC)	Interpret data on early warning for the agricultural sector.
National Agricultural Disaster Management Forum (NADMF)	Advise and decide on disaster intervention strategies and procedures.
National Drought Task team	Advise the NADMF on drought related issues.
National Agricultural Disaster Risk Management Committee	Advise the national department on disaster risk management.
Department of Water Affairs	Responsible for the flood management of the Vaal and Orange River Systems (Maswuma 2011). Real time flow data is collected and disseminated by the department.
Department of Agriculture, Forestry and Fisheries	Have three policy documents namely Agricultural Disaster Risk Management Plan, Climate Change Sector Plan and the Drought Management Plan (NDMC 2009).
Department of Health	The Emergency Medical Services and Disaster Management Directorate focus on post-disaster phase recovery.

Department of Energy	Use of early warning information as power supply is often affected by extreme weather events such as floods, storms and strong winds. Have an EWS for nuclear power and the Radiological Emergency Monitoring Working Group is responsible for monitoring and the development of an action plan to prevent any radioactive contamination.
Department of Human Settlements	Emergency Housing Policy which assists victims of disasters by providing them with temporary shelter, providing access to land and basic municipal engineering services through grants to affected municipalities. Provincial disaster management centres together with provincial human settlement departments manage the provincial disaster response (NDMC 2011).
Department of Public Works	Though not weather or climate related the department focuses on dolomite disaster. They have a Dolomite Risk Management Strategy and conduct awareness raising workshops for vulnerable stakeholders who occupy dolomitic land (NDMC 2011).
Department of Communication	Supports information and communication technology (ICT) on weather and EWS, response and recovery.
Department of Science and Technology	Financially supports a number of students to enrol for a post-graduate course in Disaster Risk Management at the University of the Free State. The course curriculum includes EWS and disaster management.
The South African Earth Observation Strategy	Captures South Africa's response to the Global Earth Observation System of Systems (GEOSS), coordinates the collection, assimilation and dissemination of earth observation data to support planning and decision making in South Africa (NDMC 2008). Several initiatives such as the South African Earth Observation Network (SAEON) also align their activities to this strategy.
Department of Safety and Security	The South African Police Service (SAPS) has developed a disaster management strategy, disaster management policy and a contingency plan in line with the DMA and the NDMF. The SAPS Disaster Management Strategy will be rolled out to all provinces (NDMC 2009).
South African Risk and Vulnerability Atlas (SARVA)	Has a portal that provides the public with free access to a large collection of scientific data and knowledge about global and climate change related vulnerability, risks and impact (http://www.sarva.org.za/. The project has a dedicated climate and weather information theme page where climate information ranging from weather to seasonal forecasts to dynamically-downscaled climate projections from SAWS is interpreted.

4.1.2. South African Weather Service

As outlined in Chapter 1, SAWS is mandated by the Weather Service Act to produce weather and climate information as well as provide early warning alerts. SAWS is the main source of early warning information, and feeds this information to various metropolitan municipalities and other government sectors. SAWS is mandated by law to earn income from the provision of commercial services and thus has both a public and private role in producing and disseminating weather forecasts and warnings.

SAWS collects weather and climate information from the following sources:

- 25 regional weather offices
- 166 automatic weather stations
- 169 automatic rainfall stations
- 1 214 manual rainfall stations
- 112 climate stations
- 1 512 rainfall stations.

The types of forecasts produced by SAWS and the sectors that use the data are illustrated in Figure 7. Weather forecasting is performed by the SAWS network of forecasting offices:

- The National Forecasting Centre (NFC) in Pretoria is responsible for national guidance on potentially hazardous weather of a general as well as maritime nature (seven days in advance). The NFC cooperates with the NDMC and the flood forecasting service of the Department of Water Affairs.
- The Aviation Weather Centre (AWC) in Johannesburg is responsible for aviation related warnings on a national scale and operates on a 24 hour, seven days a week basis.
- Regional forecasting offices (RFOs) at the major airports are responsible for the detailed forecasts and warnings within their regions. RFOs liaise with the provincial and municipal disaster management centres in their regions.
- The Innovation and Research Division of SAWS is responsible for research activities to support the enhancement of the EWSs (Department of Environmental Affairs 2011).

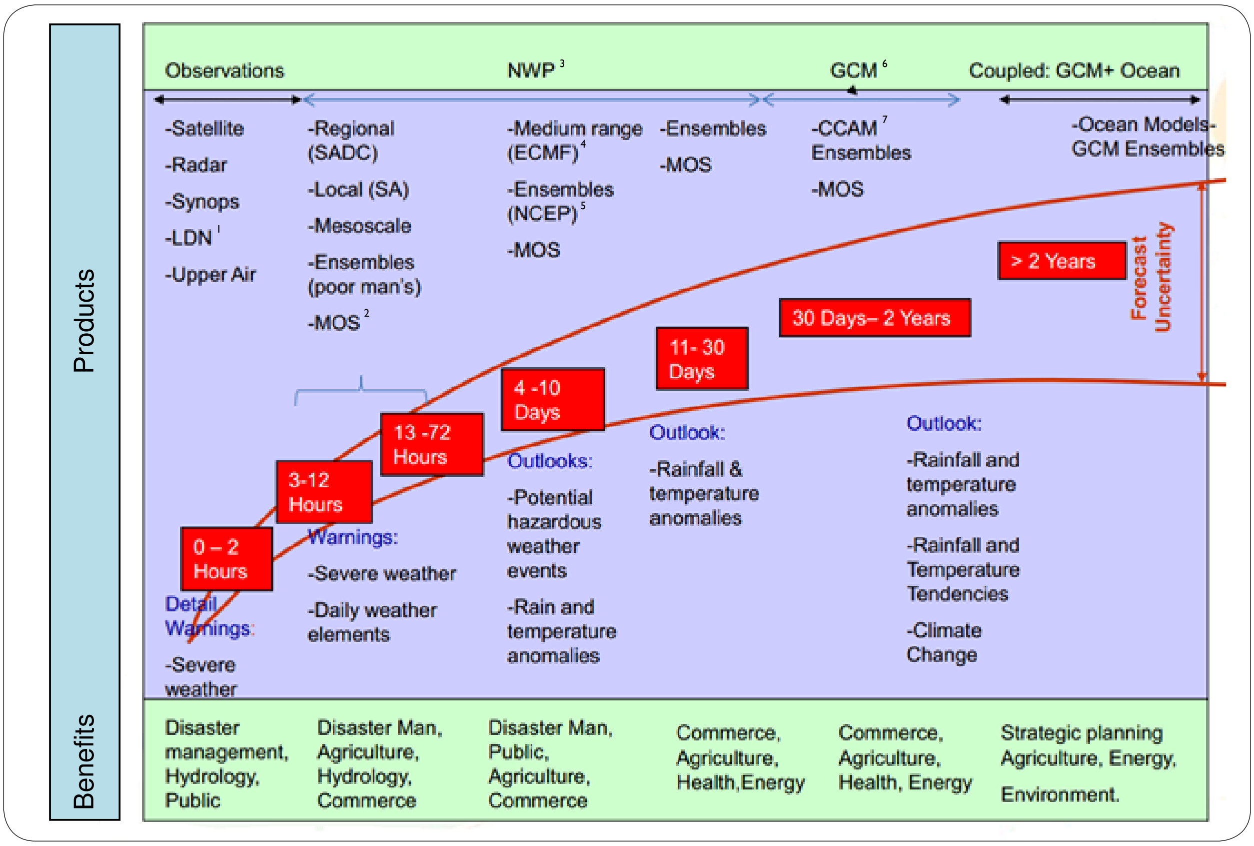


Figure 7: SAWS forecasting system

[1] LDN lightning detection network; [2] MOS model output statistics; [3] NWP numerical weather prediction; [4] ECMF electrically conducting magnetic fluid; [5] NCEP National Centers for Environmental Prediction; [6] GCM global circulation model; [7] CCAM Conformal Cubic Atmospheric Model

Source: Makuleni (2011)

Multi-Hazard Early Warning System (MHEWS)

South Africa has adopted a MHEWS which is based on international best practice and maintains the standards of the World Meteorological Organisation and International Weather Services (Poolman et al. 2008). It makes use of multiple monitoring systems and uses meteorological, hydrological and climate information to prepare for and respond to multiple hazards. Hazards included in this system are floods, heavy rain, wild fires, storm surges and wind storms (SAWS 2012). The NDMC is mandated in the NDMF to be the custodian of MHEWS. MHEWS requires collaboration between disaster management structures at all levels of governance, namely national, provincial and local level, to plan and respond together. Weather advisories, watches and warnings from the EWS inform stakeholders at different levels of government, NGOs and communities at risk to prepare for impending hazards. SAWS operates the MHEWS and is the custodian of the South African climate databank and the Severe Weather Warning System which forms part of the MHEWS (Makuleni 2011; SAWS 2010).

Severe Weather Warning System

SAWS Severe Weather System covers potentially damaging weather events (such as heavy rain, heat waves and cold weather) that are common in the country and can result in severe impacts. National warnings and advisories are compiled and issued with the longest possible lead time. Severe weather hazards include extremely hot conditions, heat waves, very cold conditions, snow, heavy rain, flash floods, destructive coastal waves, veldfires, gale force winds and severe thunderstorms. The weather alerts are based on four levels (SAWS 2010) (Figure 8):

- no alert: no hazard expected
- advisory: a potential hazard may occur in the next 2 to 6 days
- watch: hazardous weather is likely to occur in the next 1 to 3 days
- warning: hazardous conditions are occurring or are about to occur in the next 1 to 24 hours.

No Alert	Advisory	Watch	No Alert
	Be Aware!	Be Prepared!	Take Action!
No hazardous weather expected in the next few days	Early warning of potential hazardous weather	Weather conditions are likely to deteriorate to hazardous levels	Hazard is already occurring somewhere or is about to occur with a very high confidence
	2 to 6 days period	1 to 3 days period	Next 24 hours, 3hrs for FF [1], TS[2]

Figure 8: South African Weather Service Weather Alerts
[1] FF – flash flood; [2] TS – Thunder Storms
Source: SAWS (2010)

4.2. Existing early warning system by hazard

4.2.1 Floods

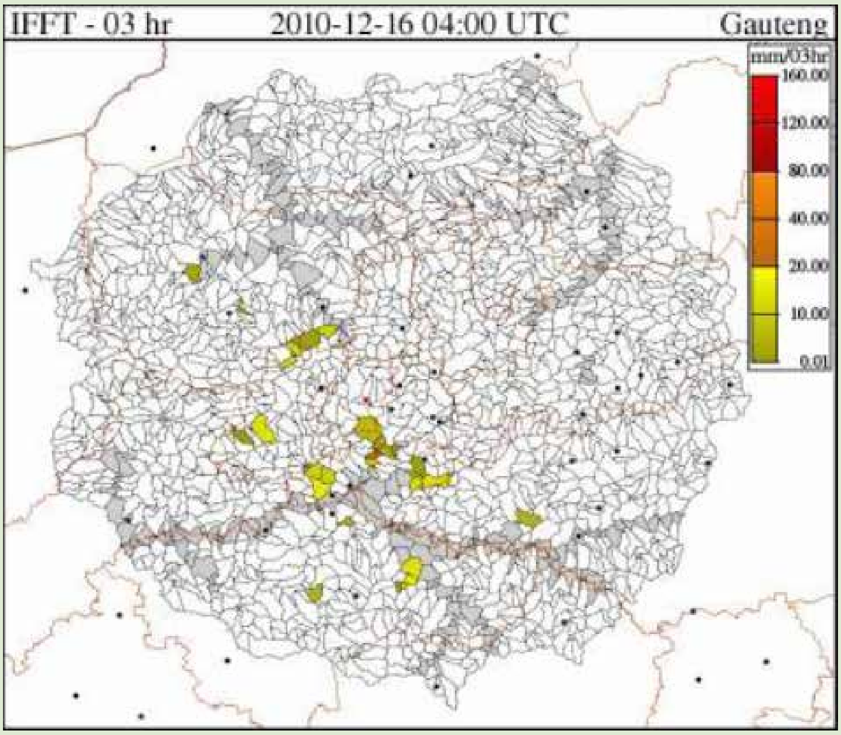
SAWS is primarily responsible for rainfall forecasting, which is based on mathematical weather models, geostationary satellite images and radar observation stations (Du Plessis 2004). EWS for flash floods were initially based on the projected impact of heavy rain over a wide area, but these warnings were not sufficient for high risk areas such as small river basins. Consequently, SAWS and the NDMC developed the South African Flash Flood Guidance (SAFFG) system (Coning & Poolman 2010) which provides guidance on potential flash flood watches and warnings within one to six hours. It models the likely hydrologic response of small river basins to rainfall and estimates how much rainfall is needed to cause flooding. The SAFFG has been successfully used to provide warnings in Gauteng (see Box 9).

In terms of hydrological flood events, tools include the Severe Weather Forecasting Demonstration Project, which forecasts the intensity and movement of rainfall events and severe winds across southern Africa (Poolman et al. 2008). The Department of Water Affairs (DWA) is responsible for flood management in the Vaal and Orange River System (Maswuma 2011). Real time flow data is collected and disseminated by the Department. In addition, the DWA uses river flow gauges and river flow measurements in combination with rainfall information from SAWS to determine the timing of the opening of dam gates to release water during high rainfall events. NDMC and DWA collaborate in dealing with disasters related to water issues.

Box 9: Gauteng flash floods 15–16 December 2010

Over 133 mm of rain fell overnight in Gauteng and severe flash flooding occurred, which resulted in a few fatalities, people being displaced and severe disruption and infrastructure damage. Forecasters issued flash flood warnings throughout the night initially for southern Gauteng and later central and northern Gauteng. Warnings were disseminated by SMS to disaster managers in the relevant municipalities and metropolitan areas. Warnings were issued to the NDMC, including an hourly breakdown.

Snap shot at six hourly alert of basins where flooding is expected



An hourly breakdown of alerts for floods issued by SAWS

Watches (orange) and Warnings (red) issued during the night of 15/16 Dec 2010

		Hours of the night of 15th to morning of 16th															
District	Incidents	21	22	23	00	01	02	03	04	05	06	07	08	09	10	11	12
Sedibeng	16			orange	orange	red	orange	red	red	red	red	red	red				
West Rand	5							red	red	red	red	red	red				
Ekurhuleni	13										red	red	red	red	red	red	
City of Johannesburg	7	red									red	red	red	red	red	red	
City of Tshwane	10	red									red	red	red	red	red	red	

4.2.2 Droughts

An Agricultural Drought Management Plan was drafted in 2005. It seeks to reduce the impacts of droughts by providing information management, monitoring and evaluation systems for drought early warning (Ngaka 2012). Another example of a drought EWS is the Umlindi system developed by the Agricultural Research Council (ARC) which provides information on drought conditions based on the interpretation of satellite and climate data. This information is translated and packaged by DAFF into monthly newsletters with understandable key messages. The information is used for crop estimation by the National Crop Estimates Committee (NCEC) and is disseminated through the provincial departments, the National Agro-meteorological Committee (NAC) and subsequently to the farming community. Experimental work is also currently under way through a partnership between ARC, the Council for Scientific and Industrial Research (CSIR) and the University of Pretoria, which will start adding a suite of tailored forecasts for livestock.

The Drought Monitoring Desk at SAWS provides information on long range seasonal forecasts, observed rainfall as well as maps of the Standardised Precipitation Index (SPI). The SPI has been successfully used as an indicator of drought conditions and is used to assess the severity of a drought – the higher the negative number the more severe the drought (McKee et al. 1993). Predicting extreme climate anomalies in advance for the coming season gives disaster management authorities the ability to prepare and respond in time. In southern Africa, seasonal rainfall forecasts have been made for almost two decades. These forecasts were developed to improve the ability of users to cope with fluctuations in rainfall on a seasonal time scale.

4.2.3 Fires

The National Veld and Forest Fire Act provides for the prevention of fires through the development of a National Fire Danger Rating System (NFDRS), launched in 2005. The National Veld and Forest Fire Act, 1998 (Act No. 101 of 1998) provides for the prevention of fires through the development of a National Fire Danger Rating System (NFDRS) launched in 2005. The NFDRS is an early warning system for predicting conditions conducive to occurrences of veldfires. This tool is aimed at increasing the capacity of fire protection associations (FPAs), veldfire managers and municipalities to manage veldfires appropriately by being aware in advance of the likelihood of fires occurring (Willis et al. 2001). The system generates a fire danger index by taking into account variables such as the weather and fuel factors. When predictions indicate that the fire danger rating will be high or extreme, SAWS issues a warning to the FPAs, Disaster Management Centres and to the public through television, radio and local newspapers.

In partnership with Eskom, the University of Maryland and the National Aeronautics and Space Administration (NASA), the CSIR developed an Advanced Fire Information System (AFIS) to locate fires in near-real time over southern Africa (Frost & Annegarn 2007; Davies et al. 2008), (see Box 10).

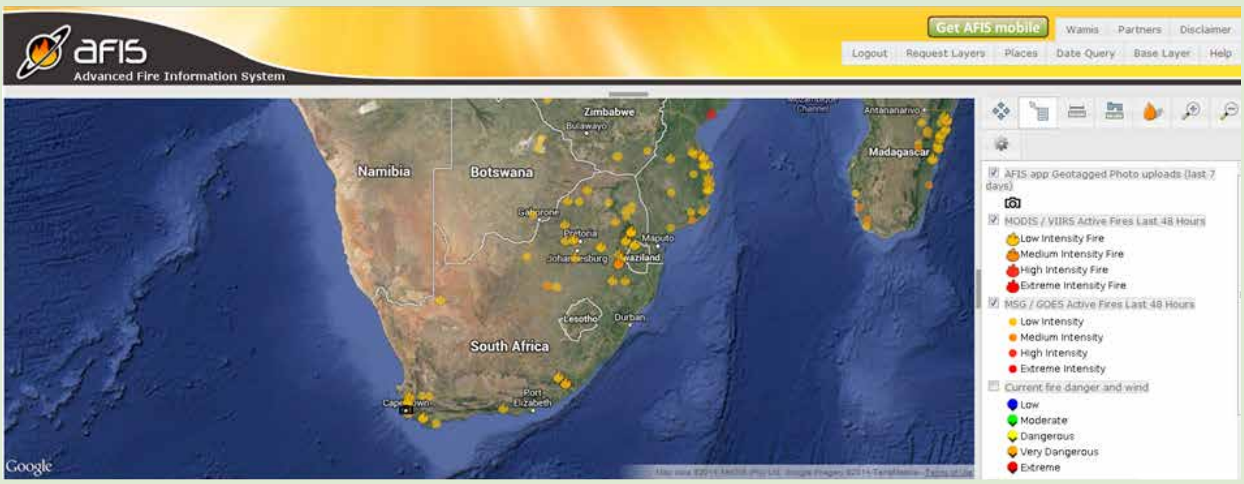
Box 10: Real-time fire monitoring system for South Africa

Frequent fires beneath and near transmission lines pose a substantial problem for Eskom and account for approximately 20% of faults. Line faults cause interruptions in the supply of power and these have major financial implication for customers. In 2002 power supply to Cape Town was lost because two major Eskom lines went out as a result of two separate fires 295 km apart. On average Eskom has to find and fix between 70 and 150 line faults a year caused by fires, and with 28 000 km of line, this problem is time-consuming and expensive.

In partnership with Eskom and the Council for Scientific and Industrial Research (CSIR) the Satellite Application Centre (SAC) has developed the Advanced Fire Information System (AFIS) to monitor fires across South Africa in real time (Frost & Annegarn 2007; Davies et al. 2008). AFIS determines the exact location of active fires on a map and sends a text message (SMS) to field staff, which allows Eskom to respond quickly to fires in the proximity of transmission line to reduce damage and power supply disruptions.

AFIS is the first near-real time operational satellite-based fire monitoring system of its kind in South Africa (for more information see http://www.afis.co.za/). Active fires are detected using data from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensors on NASA's Aqua and Terra satellites. The benefits of AFIS have moved beyond that of a dedicated warning system for Eskom. In 2006 the South African Broadcasting Corporation (SABC) began to show fire maps, based on the CSIR-supplied fire location information, as part of the weather bulletin and since then has broadcast them once a week to alert viewers to the presence and prevalence of fires throughout the country. Recently, upgrades of the AFIS system have made it possible for SMS alerts to be sent to members of Fire Protection Associations (FPAs) and the officers of the Working on Fire (WoF) programme. Furthermore, a mobile application for both Google Android and Apple iOS platforms was launched in September 2013. Active fires are also immediately published on a web page.

AFIS Fire map on 15/01/2014 showing active fires in the last 48 hours



4.2.4 *Storm surges*

As part of the National Storm Surge Workshop held in Knysna in 2011, "Guidelines for a storm surge EWS for South Africa" (Stander 2011) were developed. This document sets out key elements in the design of a new National Storm Surge EWS dealing with the necessary monitoring for an operational warning system, and the dissemination of the appropriate alerts to vulnerable communities. These guidelines are used by the NDMC and local municipalities when dealing with extreme climate events in coastal zones. The storm surge alert process for South Africa is outlined in Figure 9.

Real time observations of the state of the marine environment (such as wind and wave data) are provided through the activities of the South African Navy Hydrographic Office (SANHO), the CSIR for the National Ports Authority, and the Marine Office of the South African Weather Service. This includes the automated weather stations (AWS), the drifting weather buoy programme, the Ship of Opportunity (SOOP) programme's volunteer observing ships (VOS), as well as related information from satellites and numerical models. These observations enable the forecasting of extreme conditions at sea and along the coastline of South Africa and provide information for issuing storm surge alerts (Rossouw et al. 2011). Additional maritime weather information is available from international weather institutes such as the National Weather Service of the USA.

SANHO is responsible for the installation and maintenance of tide gauges in the principal harbours of South Africa as well as the acquisition, processing, archiving and dissemination of sea level data from these tide gauges (Rossouw et al. 2011). The CSIR Coastal System is responsible for the installation and maintenance of wave recorders as well as the collection of data. Numerical wave models (such as Simulating Waves Nearshore (SWAN) are used to provide wave information for locations where no buoys are located (Booij et al. 1999). The SAWS Coastal Network System provides weather and warning forecast services for the southern African oceans (Rossouw et al. 2011). As previously mentioned, SAWS is responsible for the dissemination of weather alerts to all the primary role players outlined in the following section.

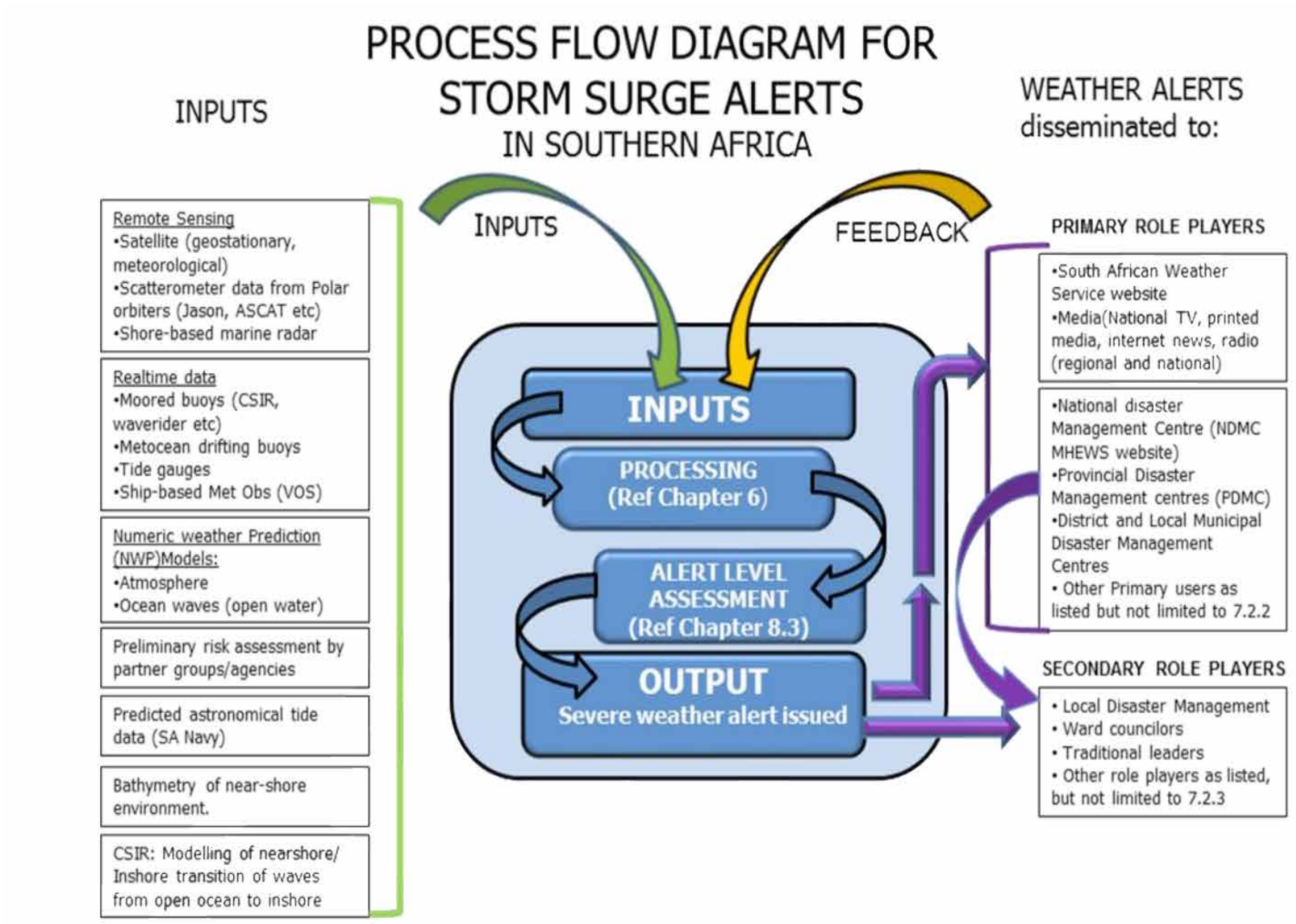


Figure 9: Storm surge alert process
Source: Stander (2011)

4.3. Interpretation, dissemination and packaging of climate information and EWS

SAWS provides severe weather warnings and advisories to the NDMC, provincial government departments, municipalities, communities and all potentially affected members of the public. The alerts are issued directly to the public through the printed and electronic media, internet and cell phone service providers. The weather advisories, watches and warnings are issued by SAWS and are used by disaster management centres in preparation and readiness for emergency actions such as evacuation in the face of a hazard. The NDMC is tasked with the dissemination of alerts to:

- national, provincial and local government, and NGOs
- all potentially affected members of the public
- councillors and traditional leaders

The general warning process is outlined in Figure 10. The National Forecasting Centre (NFC) is responsible for synchronising warning with the regional forecasting offices (RFOs) as well as with the NDMC and the flood forecasting unit of the DWA. In order to prevent false alarms no warnings are issued without agreement between the forecasting offices. The RFOs are responsible for issuing detailed warnings to the provincial and municipal disaster management centres (PDMCs and MDMCs). A case study of Eden District Municipality (see Box 11) provides a practical example of how warnings are disseminated to affected communities.

4.4. Institutional collaboration in EWS

SAWS collaborates with government departments, private institutions, community and research organisations to produce, interpret, package and disseminate climate information and advisories for different hazards and extreme weather events. Table 3 highlights the research institutions with which SAWS collaborates and the type of early warning information they generate.

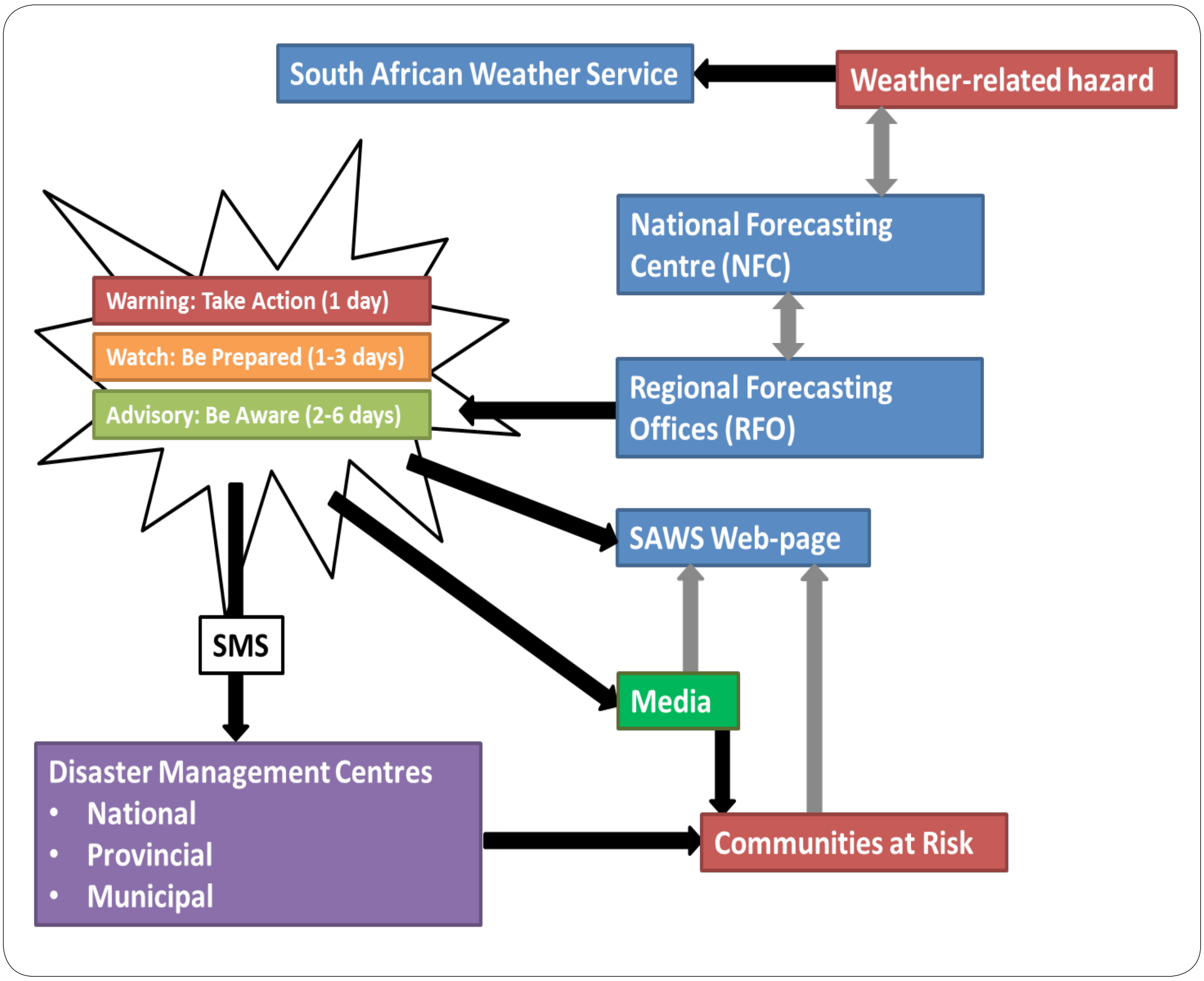


Figure 10: Flow of information from SAWS to DMCs and the public
Source: Makuleni (2011)

Box 11: The dissemination of weather warnings and alerts in the Eden District Municipality

Eden District Municipality covering the area around Mossel Bay and George in the Western Cape Province is plagued by both floods and droughts. These events have a severe impact on the economy, tourism, the environment and local development, and the district has been declared a disaster area on numerous occasions (Raju & Van Niekerk 2013).

Eden Municipality subscribes to the SAWS EWS and receives all the information about weather watch and severe weather events from this system. Combined with information received from automatic rain stations and information about the flow of the rivers and the level of dams, action is taken by the district and warnings and alerts are sent out to the public, councils and councillors. An early warning display system, designed by the Eden Municipality and funded by SANTAM, was installed to warn and alert the public of severe weather. It may also be used for brief notifications of community meetings or other public alerts. This LED display system is linked to the Eden Disaster Management Centre in George from where information is uploaded on the early warning display units (Eden District Municipality Disaster Management Centre, n.d.).

As part of the EWS, the Eden District Municipality also sends bulk SMS warnings about severe weather to the various municipal disaster management advisory forums and to councillors of the affected wards. The councillors are in the best position to ensure the warnings reach citizens (Gerhard Otto, Eden District Disaster Management Centre, personal communication, 14 January 2014). Eden Municipality also subscribes to the Advanced Fire Information System (AFIS), an EWS that alerts users to any risk of wildfires (Gerhard Otto, Eden District Disaster Management Centre, personal communication, 14 January 2014).

Table 3: Research institutions involved in interpretation, packaging and dissemination of early warning and climate information.

Institution/ Programme	Hazard	Interpretation and packaging	Means of dissemination
CSIR Meraka Institute: **Advanced Fire Information System (AFIS)**	Fire	The fire monitoring is used to locate fires in near-real time over southern Africa and prevent loss of exposed human life, biodiversity, settlements and infrastructure.	Fire maps are broadcast to the public weekly as part of the television weather bulletin on SABC channels. Fire location information from AFIS is also distributed through email, Twitter, XMPP (such as Google Talk, and jabber.org) and cell phone text messages worldwide.
CSIR Meraka Institute: **Wide Area Monitoring Information System (WAMIS)**	Fire, floods and drought	Interpret fire, flood, and drought information collected from satellite-based information services. They provide near real-time monitoring and mapping capabilities of natural events in Southern Africa.	WAMIS data portal that displays and makes available select Moderate Resolution Imaging Spectroradiometer (MODIS) products. For example one can download the burned area data, the active fire text files as well as download the true and false colour composites in GEOtiff[1].
Seasonal Forecasts (CSIR and SAWS)	Floods and drought	Maps show the likelihood of predicted rainfall and temperature anomalies exceeding certain pre-determined thresholds.	Forecasts are usually issued for a period of six months and suggest the total amount of rainfall expected over that period, but not the distribution of rainfall within that period or the initiation of the rainy season (Landman et al. 2011). Forecasts are issued by SAWS and through the annual Southern Africa Regional Climate Outlook Forum (SARCOF) meeting as well as posted on the South African Risk and Vulnerability Atlas (SARVA) Portal.
Climate Systems Analysis Group (CSAG) University of Cape Town	Rainfall anomalies, surface temperature anomalies, wind vector anomalies, east west wind anomalies, north-south wind anomalies	Among the leading research institutions that produce regional climate change information including long-range global forecasts.	CSAG hosts a data portal (http://cip.csag.uct.ac.za) which includes support materials and analysis tools for users. It also provides training to build capacity for different stakeholder groups.

[1] Public domain metadata standard for embedding georeferencing information in tiff files

5. IDENTIFIED GAPS AND OPPORTUNITIES

5.1. Legislative, institutional, and mandate aspects

TSeveral legislative institutional and mandate gaps were identified in this study and are discussed below.

Improve delineation of roles and responsibilities

A study by van Niekerk and Visser (2010) found that the DMA is not explicit on the roles and responsibilities of local municipalities when compared to district and metropolitan municipalities, leading to ineffective DRR-M. This adversely affects the implementation of DRR-M and disaster response at local municipality level.

Focal points for DRR-M have not been identified at many government levels, despite this being required by the NDMF. In some cases, disaster risk is assigned to junior officers who do not have the capacity to make decisions. In the event of a disaster, disaster management roles are often assigned to civil defence structures in local municipalities resulting in the fire and police services becoming overburdened (Botha et al. 2011).

Improve understanding of the principles of DRR-M

Limited capacity and a poor understanding of DRR-M prevent mainstreaming of DRR-M activities at both national and local level. Currently there is a lack of a common understanding of the core principles of DRR at the local level and within the responsible national government departments. This understanding is essential given the multi- sectoral nature of DRR-M, and consequently this has been cited as a challenge affecting implementation.

Improve DRR-M structures at all levels

At national level, not all essential government departments have implemented the required disaster risk reduction activities. Added to this, most of the structures outlined in the Act and the Framework are not present in the centres, and where they are present they are not adequately resourced, with the consequence that their functionality, especially at provincial and district level is inadequate (van Niekerk and Visser, 2010).

Many district municipalities have not established the required systems for DRR-M. This includes the non-establishment of disaster management centres, advisory forums, interdepartmental committees for cross-sectoral collaboration and integration of DRR in planning. SALGA's 2011 assessment of the status of disaster risk management at municipalities found that currently provinces are at different stages of developing and implementing DRR-M and most DMC's are not at full functionality (Botha et al. 2011). The assessment found that 50% of local municipalities in South Africa lacked disaster management structures, while 68% of local and 25% of district municipalities did not have disaster management advisory forums (Botha et al. 2011). The individual challenges faced in each of the provinces are summarised in Table 4.

Allocate adequate funding

DRR-M at the local level, including district and metropolitan municipalities is not adequately funded or incentivised, suggesting that DRR-M is not perceived as a high priority (van Niekerk 2011).

Improve coordination and collaboration between line departments

Despite the link between DRR-M and climate change adaptation, these two aspects are driven by two different ministries which can result in certain coordination challenges. Consideration could be given to the integrative role of the NDMC, given its coordinating role across various sectors (van Niekerk & Visser 2010). Cross institutional and integrated responses are still inadequate, partly as a result of different units in the same department being involved in different projects with little or no coordination between them. Table 5 below highlights some of the capacity challenges faced by disaster management centres in fulfilling their mandate as stipulated in the DMA.

Table 4: Summary of challenges experienced by local, district and provincial governments

Province	Challenges
Eastern Cape	• Inadequate funding • Non-availability of a budget for disaster mitigation • Poor participation of stakeholders and communities due to the lack of coordination of activities • Non-prioritisation of disaster management • Non-existence of disaster management units in sector departments • Guidelines for incorporating disaster management programmes and initiatives into current activities have not been developed and implemented due to poor awareness of the impacts of climate change • Disaster management focal points have not been identified • Risk-related information has not been incorporated into spatial development frameworks
Free State	• Limited financial resources • Municipalities do not budget for disaster risk reduction programmes • Local municipalities do not appoint dedicated disaster management officials • Lack of an integrated information management and communication system
Gauteng	• Lack of funding • Lack of budgets for disaster management • Lack of cooperation with local municipalities to establish and maintain advisory forums • Lack of training of officials and councillors in basic disaster management
KwaZulu Natal	• Disaster management plans are not aligned with the IDPs • Municipalities do not plan and allocate enough resources for disaster management
Limpopo	• Incapacity of sector departments to deal with disasters when they occur • Lack of communication between stakeholders • Lack of funding • Lack of cooperation and commitment from local municipalities
Mpumalanga	*No information available*

North West	• Lack of funding • Shortages of capacity for monitoring, reporting and evaluation • Municipal IDP projects do not address vulnerability indicators • Poor participation of key stakeholders during disasters • Lack of budgeting by sector departments • Sector departments have not submitted disaster risk management plans to the PDMC • Poor reporting systems • Limited political leadership
Northern Cape	• Establishing coordination forums • Establishing an inter-departmental disaster management committee which could be addressed by creating more nodes for DRR-M • Identification of disaster management focal points
Western Cape	• Lack of capacity and funding • Formalities, procedures and legislation delay post-disaster recovery • Lack of communication between the NDMC, PDMCs and MDMCs

Sources: NDMC (2009, 2010 & 2011)

Table 5: Capacity challenges faced by disaster centres in fulfilling their mandate at different levels of government according to the DMA.

Government level	Capacity challenge
National Disaster Management Centres	The national office is functional but requires more human capacity.
Provincial Disaster Management Centres	Functional in all provinces however some provinces such as the Western Cape and KwaZulu-Natal have advanced systems and officials who also work with sector departments. Provincial centres require more human capacity, technical equipment and funding for training, capacity building and community volunteer projects.
Municipal Disaster Management Centres	Functional in most metropolitan and district municipalities. Require more human capacity to ensure efficiency as well as funding and training of disaster officials.
Local community	All provinces have trained some community members to be volunteers as stipulated in the DMA; however, there are often not enough volunteers to meet the numbers required per community/local municipality. A SALGA report showed that in 2011, 72% of local municipalities and 50% of district municipalities did not have volunteer units in place.

Sources: NDMC (2009, 2010 & 2011)

Opportunities exist to amend the existing DMA, not only to address the issues that have been raised about the gaps in implementing the Act, but also to align the DMA with other sectoral legislative instruments that are under development.

5.2. Technical aspects

IDPs are often developed by consultants. In these cases capacitation of local government officials is limited in this legislated process. In such cases consultants are not involved in the public forums, especially on DRR and the integration of climate change into planning and decision-making, resulting in relevant information sometimes not being included in the IDP.

Information on different aspects of the environment is collected at national level for use at local level. This has the potential to result in misrepresentation of the local experiences. Information needs to be collected at the local level and local municipalities as well as other organisations operating at local level can play a key role in facilitating this process.

Effective dissemination of warnings remains challenging and needs significant coordination with other structures, including disaster management, the media and other role players. Even when warnings are disseminated effectively, local officials and communities have inadequate knowledge of how to respond to the warnings (Du Plessis 2002). This can be attributed to the challenges faced with the interpretation and translation of climate information and warnings at local level. The EWS process at municipal level needs to be simplified to enhance dissemination of warnings in local languages in an appropriate format.

Legislation and policies in South Africa, such as the DMA and the National Climate Change Policy, have permitted the country to be among the leading players in DRR-M on the continent. South Africa has also made significant investments in technology and architectural information systems such as SARVA and the DWA's Integrated Water Resource Planning (IWRP) website (https://www6.dwa.gov.za/iwrp/).

The Let's Respond Toolkit, which was developed in collaboration with the DEA, SALGA and COGTA and supported by Sustainable Energy Africa (SAE) and funded by GIZ, has been designed to assist local government to integrate DRR and climate change adaptation into IDPs. It is being applied in various district and local municipalities with support from among others SALGA, the DEA and NGOs. The Let's Respond Toolkit is an important tool for mainstreaming climate change into IDPs and supporting local government ownership and leadership in this process.

5.3. Socio-ecological aspects

National government and grassroots organisations collect DRR-M information using top down and bottom up approaches, respectively. Alignment of these approaches could improve the accuracy and reliability of this data.

Vulnerable communities need to be actively engaged in community-based risk and vulnerability assessments. Communities should be given the opportunity to inform the disaster risk profiles of their municipalities by identifying their needs and priorities (Reddy 2011).

The role of social media is growing rapidly and is becoming an important vehicle for providing easily accessible information. Social media can be used to disseminate early warning information to a wider audience in the 11 official languages.

Civil society with support of NGOs could play a role in disseminating early warning information in communities and could also play a role in collecting local level climate change related data that can be used by local, provincial and national government.

There are examples of good sources of information that are not yet adequately used. For example the Department of Water and Sanitation has an information system that captures all information on South Africa's water catchments at local level. Communities often have rich local and indigenous knowledge which can be used to supplement scientific and technical information in disaster risk assessments (Reddy 2011).

There are also examples of emerging effective approaches in DRR activities, for example the Working on Fire business model. This example involves all levels of government, and, notably the private sector including insurance companies.

Increasingly, the role of ecosystems and ecological infrastructure in the context of disaster mitigation is being recognised. Healthy and well managed ecosystems, such as wetlands and coral reefs, can serve as a natural infrastructure buffer against natural hazards. Ecological infrastructure also supports local resilience through sustaining ecosystem based livelihoods (Thiaw 2012).

6. RECOMMENDATIONS

The policy recommendations that are suggested are based on literature (including NDMC's own reporting, and analyses of SAWS's mandate and functioning, for example) as well as the gaps and opportunities identified in this document.

These findings are preliminary and are intended to highlight areas that need further investigation and analysis.

6.1. Policy recommendations

- Mainstream disaster risk reduction (not simply disaster response) into policy and planning for all sectors and levels of government.
- Support the continued shift from a reactive to a proactive approach to disaster management.
- Improve collaboration between DRR-M and climate change adaptation line departments.
- Improve DRR-M coordination within and between government departments at all levels of government.
- Improve the delineation of roles and responsibilities around DRR-M, emphasising the importance of DRR within all sectors and levels of government.
- Support the establishment of DRR-M structures, including forums and nodes, at all levels.
- Strengthen institutional capacity to respond to EWS information at all levels and especially support local level engagement in collating and sharing information.
- Provide adequate funding and technical support for DRR-M at all levels:
    - Provide additional support to assist local government with post disaster costing and reporting, as well as with initiatives such as acquiring finance to support risk reduction.
    - Further support local municipalities in efforts to map community vulnerability to all weather-related hazards and to integrate this into local planning.
    - Build capacity in relevant institutions to understand the principles of DRR-M, including continued and enhanced development of standardised guidelines and operational procedures.
    - Encourage efforts to provide appropriate reports on the costs of the damages caused by disasters at all levels.
- Undertake robust needs assessments and gap analyses at all levels.
- Acknowledge the role of healthy ecosystems and ecological infrastructure in reducing the impacts of climate vulnerability and climate change and integrate this into DRR-M planning.
- Invest in R&D for general and tailored forecasting including a specific audit of R&D gaps.

REFERENCES

Annan K 1999, Report of the Secretary-General on the Work of the Organization. General Assembly Official Records Fifty-fourth Session Supplement No. 1 (A/54/1), United Nations, New York
http://www.un.org/documents/ga/docs/54/plenary/a54-1.pdf

Archer van Garderen E 2013, Are we disabling climate science in southern Africa? A brief consideration of the draft South African Weather Service Amendment Bill, Technical report, CSIR, Stellenbosch.
http://www.researchgate.net/publication/258840886_Are_we_disabling_climate_science_in_southern_Africa___a_brief_consideration_of_the_draft_South_African_Weather_Service_Amendment_Bill

Booij N, Ris RC & Holthuijsen LH 1999, A third-generation wave model for coastal regions: 1. Model description and validation, *Journal of Geophysical Research: Oceans (1978–2012)*, 104: C4, pp. 7649–66.

Botha D & Van Niekerk D 2013, Views from the Frontline: a critical assessment of local risk governance in South Africa: original research, *Jamba: Journal of Disaster Risk Studies*, 5:2, pp. 1–10.
http://dx.doi. org/10.4102/jamba.v5i2.82

Botha D, Van Niekerk D, Wentink G, Tshona T, Maartens Y, Forbes K, Annandale E, Coetzee C & Raju E 2011, Disaster risk management status assessment at municipalities in South Africa, Report to the South African Local Government Association (SALGA), SALGA, Pretoria, viewed, vol. 24. ipcc-wg2.gov/njlite_download.php?id=6992

Breetze T, Parak O, Celliers L, Mather A & Colenbrander D 2008, Living with coastal erosion in KwaZulu-Natal: a short-term best practice guide, KwaZulu-Natal Department of Agriculture and Environmental Affairs, Cedara, Pietermaritzburg.

Bruwer J 1993, Drought policy in the Republic of South Africa, in DA Whilhite (ed.) *Drought Assessment, Management, and Planning: Theory and Case Studies*, Springer Science+Business Media, New York, pp. 199–212.

Chang Seng D 2012, Improving the Governance Context and Framework Conditions of Natural Hazard Early Warning Systems' *IDRiM Journal*, 2: 1.
http://www.idrimjournal.com/index.php/idrim/article/view/20/15

Davies DK, Vosloo HF, Vannan SS & Frost PE 2008, Near real-time fire alert system in South Africa: from desktop to mobile service, Proceedings of the 7th ACM conference on Designing interactive systems Cape Town, South Africa, p. 315.

Davis C (ed.) 2011, *Climate Risk and Vulnerability: A handbook for Southern Africa*, first edition, Council for Scientific and Industrial Research, Pretoria, South Africa.

De Coning E & Poolman ER 2010, South African Weather Service operational satellite based precipitation estimation technique: applications and improvements, *Hydrology and Earth System Sciences Discussions*, 7: 6, pp. 8837–8871.

Department of Environmental Affairs (DEA) 2011, *South Africa's Second National Communication under the United Nations Framework Convention on Climate Change*, Department of Environmental Affairs, Pretoria, South Africa.

DEA 2013, *Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa: Climate trends and scenarios for South Africa*, Department of Environmental Affairs, Pretoria, South Africa.

Disaster Management Institute of Southern Africa (DMISA) 2014, The Disaster Management Act may change: Provide your inputs into the challenges faced by the act in its current form.
http://www.disaster.co.za/index.php?id=56

Dixon J & Ramutsindela M 2006, Urban resettlement and environmental justice in Cape Town, Cities, 23: 2, pp. 129–139.

Du Plessis L 2002, A review of effective flood forecasting, warning and response system for application in South Africa, *Water SA*, 28: 2, pp. 129–138.

Easterling DR, Meehl GA, Parmesan C, Changnon SA, Karl TR & Mearns LO 2000, Climate extremes: observations, modelling, and impacts, *Science* 289: 5487, pp. 2068–2074.

Eden District Municipality Disaster Management Centre no date, Technical specifications: Early warning display system. George: Eden District Municipality Disaster Management Centre.

Engelbrecht CJ, Engelbrecht FA & Dyson LL 2013, High-resolution model-projected changes in mid-tropospheric closed-lows and extreme rainfall events over southern Africa, *International Journal of Climatology*, 33: 1, pp. 173–187.

Extreme Planet 2012. *Powerful Tornadoes Outside the United States – Violent Tornadoes in France, Russia, South Africa, Poland, Canada and Japan*.
http://extremeplanet.me/tag/duduza-tornado/

Fauchereau N, Trzaska S, Rouault M & Richard Y 2003, Rainfall variability and changes in southern Africa during the 20th century in the global warming context, *Natural Hazards*, 29: 2, pp. 139–154.

Financial and Fiscal Commission (FFC) 2012, Chapter 5: Alternative Financing Mechanisms for Disaster Management in South Africa, in Submission for the 2013/14 Division of Revenue, FFC, Midrand, South Africa, http://www.ffc.co.za/index.php/submissions/commission-submissions

Forsyth G, Kruger F & Le Maitre D 2010, National veldfire risk assessment: Analysis of exposure of social, economic and environmental assets to veldfire hazards in South Africa, CSIR report no: CSIR/NRE/ECO/ER/2010/0023/C, CSIR Natural Resources and the Environment, Pretoria.

United Nations International Strategy for Disaster Reduction (UNISDR) 2007, Hyogo framework for action 2005–2015: Building the resilience of nations and communities to disasters, extract from the final report of the World Conference on Disaster Reduction.
http://www.unisdr.org/we/inform/publications/1037

Frost P & Annegarn H 2007, Providing satellite-based early warnings of fires to reduce fire flashovers on South Africa's transmission lines, Geoscience and Remote Sensing Symposium, 2007. IGARSS 2007. IEEE International , pp. 2443. DOI 10.1109/IGARSS.2007.4423336

Gbetibouo GA, Ringler C & Hassan R 2010, Vulnerability of the South African farming sector to climate change and variability: An indicator approach, *Natural Resources Forum*, 34:3, pp. 175-187.

Glantz MH 2003, Usable science 8: Early warning systems: Do's and don'ts, Usable Science Workshop, 20–23 October 2003, Shanghai China.
http://www.ilankelman.org/glantz/Glantz2003Shanghai.pdf

Grasso VF 2014, The state of early warning systems, in A Singh & Z Zommers (eds) *Reducing Disaster: Early Warning Systems For Climate Change*, Springer, Dordrecht, Heidelberg, New York, London, pp. 109–125.

Grobler RR 2001, A framework for modelling losses arising from natural catastrophes in South Africa, MCom dissertation, University of Pretoria, Pretoria.

Guha-Sapir D, Below R, Hoyois Ph. 2014, EM-DAT: International Disaster Database, Université Catholique de Louvain, Brussels, Belgium
http://www.emdat.be

Hales S, Edwards S & Kovats R 2003, Impacts on health of climate extremes, in AJ McMichael, D Campbell-Lendrum, K Ebi, C Corvalan (eds) *Climate Change and Health: Risks and responses*, Geneva, World Health Organization.

Hallegatte S 2012, A cost effective solution to reduce disaster losses in developing countries: Hydro-meteorological services, early warning, and evacuation, World Bank Policy Research Working Paper, no. 6058, World Bank, Washington DC.
http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2051341

Holloway A, 2012, Disaster risk in Africa: Dynamic discourse or dysfunctional dialogue? In L Bloemertz, M Dovenspeck, E Macamo & D Muller-Mahn (eds) *Risk and Africa: Multi-disciplinary empirical approaches*, Lit Verlag, Germany, vol. 51, pp. 17–34.

Hweshe F 2012, City reveals plans to minimise winter flooding. *West Cape News*.
http://westcapenews.com/?p=4297

IPCC 2007, *Summary for Policymakers, in Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [S Solomon, D Qin, M Manning, Z Chen, M Marquis, KB Averyt, MTignor and HL Miller (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf

IPCC 2012, *Summary for Policymakers, in Managing the risks of extreme events and disasters to advance climate change adaptation* [CB Field, V Barros, T Stocker, D Quin, DJ Dokken, KL Ebi, MD Mastrandrea, KJ Mach, GK Plattner, SK Allen, M Tignor and PM Midgely (eds)]. A special report of Working Groups I and II of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, pp. 1–19.

IPCC 2013, *Summary for Policymakers, in Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [TF Stocker, D Qin, GK Plattner, M Tignor, S K Allen, J Boschung, A Nauels, Y Xia, V Bex and P. M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA,

Landman W, Tadross M, Engelbrecht F, Archer van Garderen E & Joubert A 2011, Seasonal forecasts: Communicating current climate variability in southern Africa, in C Davis (ed.) *Climate Risk and Vulnerability: A handbook for Southern Africa*, Council for Scientific and Industrial Research, Pretoria, South Africa, pp. 23–27.
http://researchspace.csir.co.za/dspace/handle/10204/5798

MacKellar N, New M & Jack C 2014, Observed and modelled trends in rainfall and temperature for South Africa: 1960–2010, *South African Journal of Science*, 110:7 & 8, pp. 51–63.

Makuleni L 2011, SAWS activities in weather and climate forecasting: Climate is what you expect – Weather is what you get, *DMISA Conference*, 14–15 September 2011.

Maswuma Z 2011, Flood management in South Africa (Real time data collection points in the Vaal / Orange River System), WMO Workshop on Intercomparison of Flood Forecasting Models, Koblenz, Germany, 14–16 September.
http://www.wmo.int/pages/prog/hwrp/chy/chy14/documents/ms/INTERCOMAPRISON_FLOOD_FORECASTING_MODELS_DRAFT.pdf

McKee TB, Doesken NJ & Kleist J 1993, The relationship of drought frequency and duration to time scales, Proceedings of the 8th Conference on Applied Climatology, 17–22 January, Anaheim, CA. American Meteorological Society, Boston, MA. pp. 179–184.

Mniki S 2009, Socio-economic impact of drought induced disasters on farm owners of Nkonkobe Local Municipality, dissertation, Masters in Disaster Management, Faculty of Agricultural and Natural Sciences, University of the Free State.

Moench M, Mechle R & Stapleton S 2007, Guidance note on the costs and benefits of disaster risk reduction, Paper for UNISDR Global Platform for Disaster Risk Reduction. http://www.preventionweb.net/globalplatform/2007/first-session/docs/media_docs/Info_Note_3_HL_dialogue_Costs_and_Benefits.pdf

Mukheibir P & Ziervogel G 2007, Developing a Municipal Adaptation Plan (MAP) for climate change: the city of Cape Town, *Environment and Urbanization*, 19:1, pp. 143–158.

National Disaster Management Centre (NDMC) 2006, National Disaster Management Centre Inaugural Annual Report 2006/2007, Pretoria Department of Cooperative Governance and Traditional Affairs.
http://www.ndmc.gov.za/Documents/tabid/255/ctl/ViewDocument/mid/634/ItemID/1/Default.aspx

NDMC 2009a. National Disaster Management Centre Annual Report 2008/2009, Pretoria, Department of Cooperative Governance and Traditional Affairs,
http://www.ndmc.gov.za/Documents/AnnualReports/tabid/256/ctl/ViewDocument/mid/625/ItemID/149/Default.aspx

NDMC 2009b. GIS Portal 2009.
http://gisportal.ndmc.gov.za/DesktopModules/GISMaps/ViewA3map.aspx?id=236

NDMC 2011. National Disaster Management Centre: Annual report 2010/2011, Pretoria Department of Cooperative Governance and Traditional Affairs.
http://www.ndmc.gov.za/Documents/AnnualReports/tabid/256/ctl/ViewDocument/mid/625/ItemID/151/Default.aspx

Nelson Mandela Bay Disaster Management Centre 2013, Report to budget and treasury on the status of the disaster management early warning system, Port Elizabeth, Nelson Mandela Bay Metropolitan Municipality.

Ngaka MJ 2012, Drought preparedness, impact and response: A case of the Eastern Cape and Free State provinces of South Africa, *Jàmbá: Journal of Disaster Risk Studies*, 4:1, pp. 10 pages.
http://www.jamba.org.za/index.php/jamba/article/view/47/66#13

Pelling M & Holloway A 2006, Legislation for mainstreaming disaster risk reduction, Tearfund, Teddington, UK, 36pp.

Pharoah R, Fortune G, Chasi V & Holloway A 2013, The environment & risk reduction: focus on urban risk. Stellenbosch University: Disaster Mitigation for Sustainable Livelihoods Programme (DiMP).

Poolman E, Chikoore H & Lucio F 2008, Public benefits of the Severe Weather Forecasting Demonstration Project in south-eastern Africa, *MeteoWorld*, December 2008. http://www.wmo.int/pages/publications/meteoworld/archive/dec08/index_en.html [accessed 15 January 2014].

Pretorius C & Smal M 1992, Notes on the macro-economic effects of the drought, *Quarterly Bulletin SA Reserve Bank*, 184, June 1992, pp. 31–38.

Price P 2014, Reviewer Comments on the draft report: Climate Information and Early Warning Systems to Support Disaster Risk Reduction and Management under Future Climate Conditions in South Africa [unpublished personal communication].

Raju E & Van Niekerk D 2013, Intra-governmental coordination for sustainable disaster recovery: A case-study of the Eden District Municipality, South Africa, *International Journal of Disaster Risk Reduction*, 4, pp. 92–99.

Reddy M 2011, An integrated disaster risk assessment model for local government in South Africa, PhD thesis, North-West University, Potchefstroom.

Republic of South Africa (RSA) 1998, National Veld and Forest Fire Act, 1998 (Act No. 101 of 1998), Pretoria, Government Printer.

RSA 2001, Weather Service Act , 2001 (Act No. 8 of 2001), Pretoria, Government Printer.

RSA 2002, Disaster Management Act, 2002 (Act No. 57 of 2002), Pretoria, Government Printer.

RSA 2005, National Disaster Management Policy Framework, Pretoria, Government Printer.

RSA 2011, *National Climate Change Response White Paper*, Pretoria Government Printer.

Rogers D & Tsirkunov V 2010, *Costs and benefits of early warning systems*, Global Assessment Report on Disaster Risk Reduction, United Nations International Strategy for Disaster Risk Reduction (UNISDR) and the World Bank, Geneva, Switzerland and Washington DC. http://www.preventionweb.net/english/hyogo/gar/2011/en/bgdocs/Rogers_&_Tsirkunov_2011.pdf

Rossouw M, Stander J, Farre R & Brundrit G 2011, *Real Time Observations and Forecasts in the South African Coastal Ocean*. http://www.cfoo.co.za/docs/stormsurge/Item%202%20Real%20time%20observations%20and%20forecasts%20MR%20et%20al.pdf

South African Weather Services (SAWS) 2012, Early Warning Systems. Prepared by Eugene Poolman FCAST-PRE-20120517.1.

SAWS 30 September 2010, *Improvements to the Severe Weather Warning System*, South African Weather Service.

Scholes RJ & Biggs R (eds) 2004, *Ecosystem Services in Southern Africa: A Regional Assessment*, The regional-scale component of the Southern African millennium ecosystem assessment 2004, Council for Scientific and Industrial Research, Pretoria, South Africa.

Scorgie S & Cumming T 2014, Workshop Report: Disaster Risk Reduction Funding Think Tank, SANBI, Pretoria, Workshop Report

Smith A, Guastella LA, Mather AA, Bundy SC & Haigh ID 2013, KwaZulu-Natal coastal erosion events of 2006/2007 and 2011: A predictive tool?, *South African Journal of Science*, 109:3–4, pp. 1–4.

Smith MD 2009, Lessons learned in WASH response during urban flood emergencies, The Global WASH Learning Project, Global Wash Cluster, New York, 21pp. https://dspace.lboro.ac.uk/dspace-jspui/bitstream/2134/12699/3/Urban_Floods_WASH_Lessons_Learned.pdf

Stander J 2011, Guidelines: Storm surge early warning system for South Africa, Disaster Risk Reduction Conference 14–15 September 2011, Disaster Management Institute of Southern Africa.

Tadross M, Davis C, Engelbrecht F, Joubert A & Archer van Garderen E 2011, Regional scenarios of future climate change over southern Africa, in C Davis (ed.) *Climate Risk and Vulnerability: a handbook for Southern Africa*, CSIR, Pretoria, South Africa, pp. 28–49. http://start.org/download/2011/sadc-handbook-11.pdf

Thiaw I 2012, Applying Ecosystem Based Approached for Disaster Risk Reduction and Climate Change Adaptation, UNEP. http://www.un.org/en/ga/president/66/Issues/drr/panellists/04-12-2012%20Ibrahim%20Thiaw.pdf

Theron AK 2011, Climate Change: Sea level rise and the southern African coastal zone, in L Zietsman (ed.) *Observations on Environmental Change in South Africa*, 1st edition, Sun Press, Stellenbosch, pp. 212–217.

Thomalla F, Downing T, Spanger-Siegfried E, Han G & Rockström J 2006, Reducing hazard vulnerability: towards a common approach between disaster risk reduction and climate adaptation, *Disasters*, 30:1, pp. 39–48.

Twigg J 2004, *Disaster risk reduction: mitigation and preparedness in development and emergency programming*, Good Practice Review, Humanitarian Practice Network, Overseas Development Institute, London.
http://www.ifrc.org/PageFiles/95743/B.a.05.%20Disaster%20risk%20reduction_%20Good%20Practice%20Review_HPN.pdf

United Nations Office for Disaster Risk Reduction (UNISDR) 2009,. Terminology: Basic terms of disaster risk reduction. UNISDR. Geneva, Switzerland.
http://www.unisdr.org/files/7817_7819isdrterminology11.pdf

Van Niekerk D and Visser R 2010, Experience on decentralised mechanism and funding for Disaster Risk Reduction in South Africa, Theme 2: Towards a Funding Mechanism for Disaster Risk Reduction in Africa: Second Ministerial Conference on Disaster Risk Reduction in Africa, Nairobi.
http://acds.co.za/uploads/Conf_Papers/DRR_local_gov_Dewald_van_Niekerk.pdf

Van Niekerk D 2011, The South African disaster risk management policy and legislation: a critique.
http://acds.co.za/uploads/research_reports/SA_law_2011.pdf.

Van Riet G & Diedericks M 2010, The placement of the disaster management function within district, metropolitan and provincial government structures in South Africa, *Administratio Publica*, 18:4, pp. 155–173.

Van Wilgen BW, Forsyth GG & Prins P 2012, The management of fire-adapted ecosystems in an urban setting: the case of Table Mountain National Park, South Africa. *Ecology and Society* 17:1, p. 8.
http://dx.doi.org/10.5751/ES-04526-170108

Vermaak J & Van Niekerk D 2004, Disaster risk reduction initiatives in South Africa, *Development Southern Africa*, 21: 3, pp. 555–574.

Vincent K, Tanner T & Devereux S 2008, Climate change, food security and disaster risk management, Input paper to the Expert Meeting on Climate Change and Disaster Risk Management, FAO, Rome, 28–29 February 2008. Institute of Development Studies, Brighton, UK.

Visser R & Van Niekerk D 2009, A funding model for the disaster risk management function of municipalities, National Disaster Management Centre, Pretoria.

Vosloo H & Frost P 2006, Protecting transmission, *Quest, Science for South Africa*, 2:3, pp. 6–7.

Warburton M & Schulze R 2006, Climate change and the South African commercial forestry sector. An initial study, Report to Forestry SA, ACRUcons Report 54, School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal, Pietermaritzburg, South Africa

Western Cape Government 2014, Western Cape Climate Change Response Strategy. Department of Environmental Affairs and Development Planning, Western Cape Government.

Wilhite DA & Glantz MH 1985, Understanding: the drought phenomenon: the role of definitions, Water International, 10:3, pp. 111–120.

Willis C, Van Wilgen B, Tolhurst K, Everson C, D'Abreton P, Pero L & Fleming G 2001, The development of a national fire danger rating system for South Africa, CSIR Environmentek, Pretoria, Report no. ENV-P-C 2000-073, 81 pages. Client: Department of Water Affairs and Forestry, and Department for International Development, U.K.

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