Framework for Adaptation to Climate Change in the City of Cape Town

FAC4T

August 2006

CITY OF CAPE TOWN | ISIXEKO SASEKAPA | STAD KAAPSTAD

THIS CITY WORKS FOR YOU

Framework for Adaptation to Climate Change in the City of Cape Town (FAC^{4}T)

August 2006

Submitted to

City of Cape Town: Environment Resource Management

Prepared by
Pierre Mukheibir and Gina Ziervogel

Energy Research Centre
University of Cape Town

Climate Systems Analysis Group
University of Cape Town

Executive Summary

The 20th century has seen the greatest warning in the past thousand years due to anthropogenic emissions of greenhouse gases (Intergovernmental Panel on Climate Change (IPCC), 2001b). Climate models now predict that the atmosphere's temperature will increase by 1.4ºC to 5.8ºC by 2100. Climate change will continue to occur even if the global greenhouse gas emissions are curtailed significantly in the short- to medium-term. Therefore, while controlling emissions is vital, this should be combined with efforts to minimise the effects of climate change. This is commonly called *adaptation*, and is generally defined as an adjustment in bio-physical, social and/or economic systems in response to an actual or expected climatic impact and its effect .

The effect of climate change increases the likelihood of extreme weather events such as droughts, floods and heat waves. The Northern and Western Cape provinces are projected as the two South African provinces most at risk of climate-induced warming and rainfall change. This makes the City of Cape Town's resource management more challenging.

In response to this challenge, the City of Cape Town's Environmental Planning Department commissioned the development of an Adaptation Framework in response to the potential short- to medium-term impacts of climate change in the metropolitan area. This document presents a Framework for Adaptation to Climate Change in the City of Cape Town (FAC^4T) – an overarching framework for a City-wide consolidated and coordinated approach to reducing vulnerability to climate impacts. By following this framework, a City Adaptation Plan of Action (CAPA) for the City of Cape Town will be developed and the necessary resources mobilised for its implementation.

The required steps of the FAC^{4}T are as follows:

1. Assessment of current climate trends and future projections
2. Undertaking a vulnerability assessment
   a) Identify current vulnerabilities (in each sector and for cross-cutting themes) based on current climate risks and trends
   b) Identify future vulnerabilities based on future climate scenarios and risks
3. Strategy formulation
4. Development of adaptation options
5. Evaluation of priority adaptation strategies
6. Programme and project scoping and design – (CAPA)
7. Implementation
8. Monitoring and evaluation of interventions

An initial step towards developing a City Adaptation Plan of Action (CAPA) would be to consolidate and integrate existing adaptation and climate proofing initiatives of the Western Cape Provincial Government, Cape Peninsula National Park and neighbouring municipalities. This is critical for the CAPA to be effective.

These would include amongst others:

- the City's Biodiversity and Coastal Zone Management strategies;
- the proposed Western Cape Climate Change Response Strategy and Action Plan by the Western Cape Provincial Department of Environmental Affairs and Development Planning;
- the recently initiated Integrated Approach to the Developmental Challenges of Cape Town;
- the City's response to its legal obligations under the National Disaster Management Act; and
- the proposed Provincial Strategic Infrastructure Project for the Western Cape Province.

Therefore, through the adoption of this proposed Framework for Adaptation to Climate Change in the City of Cape Town (FAC4T), a City Adaptation Action Plan (CAPA) would result in the implementation of adaptation initiatives to minimise the vulnerability to climate impacts. Not only would these strategies respond to projected climate impacts, but they would also ensure some resilience to current climate variability.

Based on existing available literature, a number of climate induced impacts and adaptations for the City of Cape Town were identified.

These impacts include:

- increased water stress in the City due to forecast reduction in rainfall and increased evaporation due to increased temperature.
- a rise in sea-level will increase the vulnerability of beaches, shorelines and coastal developments and infrastructure to storm surges and erosion.
- increased temperatures could lead to changes in fire intensity and frequency, which may also trigger the destruction or migration of sensitive plant and animal species that are already at the limits of their temperature and rainfall tolerance.
- the impacts of severe storms may result in damage to infrastructure.
- health and livelihoods may be indirectly affected, especially through the risk of fires and changes in air pollution.

A number of key sectors were identified in this study, and existing and potential adaptation strategies have been listed for further consideration, viz.:

SECTORS	ADAPTATION STRATEGIES
Urban water supplies: Demand management	a. Water restriction b. Water tariffs c. Reduction of leaks programme d. Pressure management e. Awareness campaigns
Urban water supplies: Supply management	a. Berg River WMA schemes b. Table Mountain aquifer c. Re-use of effluent d. Water harvesting e. Seawater use f. Desalination
Storm water management	a. Monitoring and early warning system b. Reduction of impacts through flood reduction infrastructure c. Increasing the flood return period d. Maintenance of storm-water infrastructure e. Design of resilient infrastructure and buildings
Biodiversity	a. Pro-active fire and alien plant management b. Monitoring of indicator species c. Zoning of protected areas d. Impact reduction measures
Fire management	a. Increased training in ecological fire management b. Firefighting capacity c. Removal of plantations d. Control of alien invasive plants e. Installation of fire breaks f. Erosion protection
Coastal zones	a. Coastal vulnerability mapping b. Monitoring of key sites c. Shoreline management plans d. More stringent set-back lines e. Structural mitigation measures
Livelihoods	a. Assessment of vulnerable livelihoods b. Ongoing information and data gathering c. Disaster risk reduction in informal settlements, including improved infrastructure and planning and management d. Municipal strategies to include support for household reduction of water, energy and other resources
Health	a. Increased awareness of climate-related health impacts b. Improved construction and building regulations c. Increased support for health facilities d. Improved sanitation

Contents

1

Introduction and background

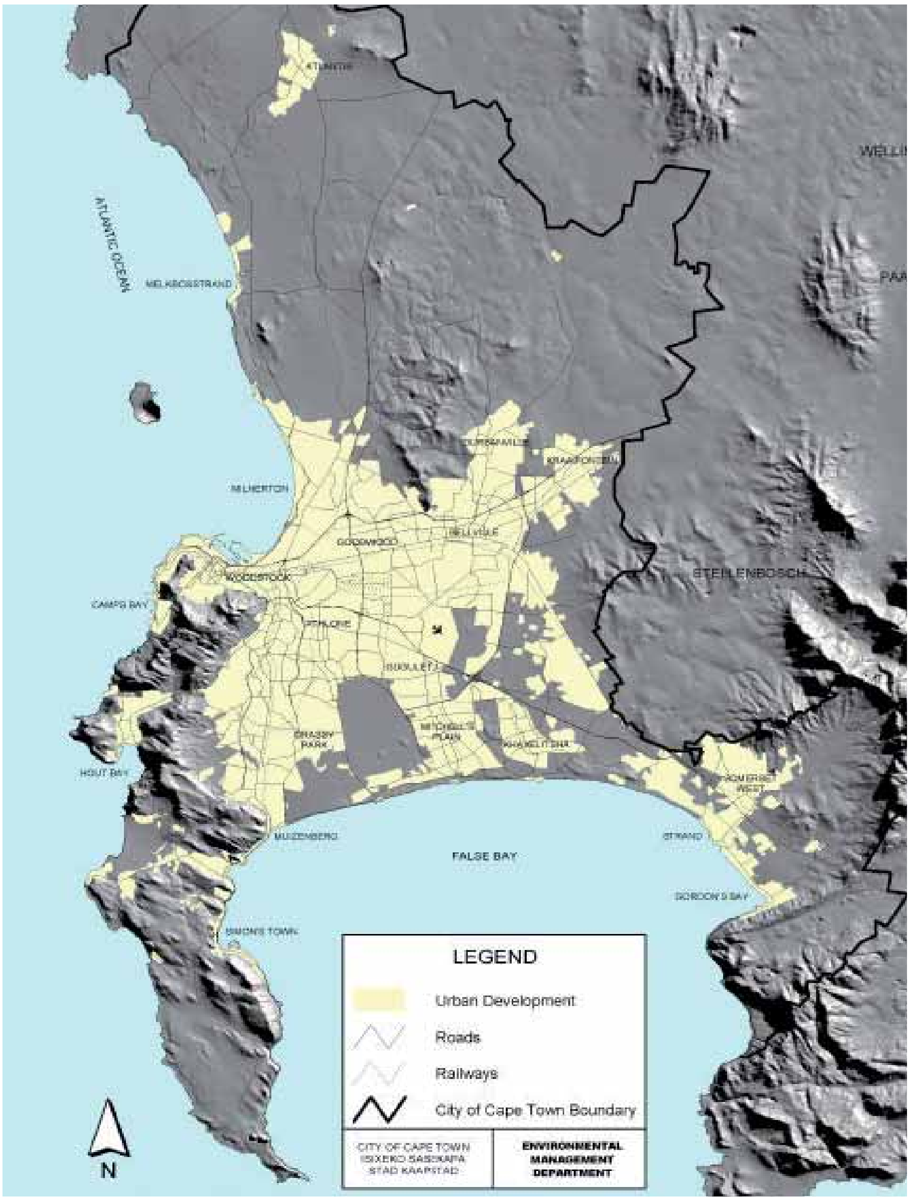


Figure 1: **Map of Cape Town**

Scientific evidence confirms that climate change is already taking place and that most of the warming observed during the past fifty years is due to human activity (IPCC, 2001a). In recent years, reducing vulnerability to climate change has become an urgent issue in developing countries, and is at the forefront of any sustainable development policy agenda. Adaptation is a process whereby individuals and communities seek to cope with the consequences of climate change and vulnerability. This process is not new; throughout history people have adapted to changing climate conditions. What is new is the incorporation of climate change and its potential impacts into policy making.

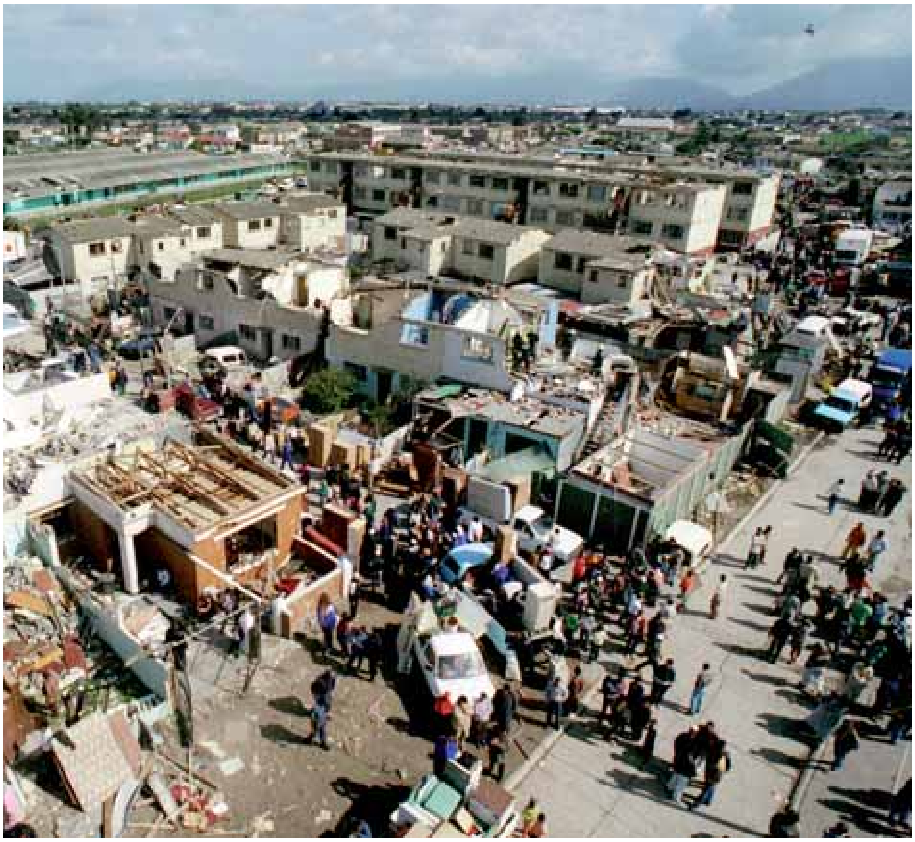
Modelling suggests that there will be significant climate change impacts in South Africa, even if global emissions were to be reduced in accordance with the Kyoto

Protocol. These impacts include general warming, disruption of established rainfall patterns and an increase in the frequency of extreme weather events affecting a wide variety of sectors.

A significant number of previous disasters and events have been associated with weather conditions. These include the Cape Flats floods (1994 and 2001), the Manenberg wind storms (1999 and 2002), South Peninsula fires (2000), Joe Slovo informal settlement fires (2000, 2004, 2005), cut-off low severe storms (2003, 2004, 2005) and recurrent severe drought (2002-2005) (Disaster Mitigation for Sustainable Livelihoods Programme (DiMP), 2000).

This study was therefore commissioned by the City of Cape Town's Environmental Planning Department in response to the potential short- to medium-term impacts of climate change in the metropolitan area. To date there has not been a consolidated or coordinated approach to adaptation to projected climate impacts on a City-wide scale. This is true for most cities internationally. This document presents a Framework for Adaptation to Climate Change in the City of Cape Town (FAC^4T) – an overarching framework for a City-wide, consolidated and coordinated approach to reducing vulnerability to climate impacts.

It is acknowledged that the impact of climate change is a cross-cutting issue affecting a number of sectors. This framework will therefore result in an integrated approach by the City of Cape Town in dealing with adaptation to climate change. This report reviews the direct impact on natural resources, as well as the secondary impacts on the socio-economic environment and the livelihood of communities, and references specific strategies in response to these impacts.



1.1 Background to climate change

According to the IPCC (2001a), global surface temperature is estimated to have increased by 0.6°C since the late nineteenth century, with the 1990s being the warmest decade. Mean daily surface minimum temperatures appear to be increasing at a faster rate than maximum temperatures (0.2°/decade versus 0.1°C/decade). Superimposed on these changes are seasonal, annual and inter-annual variabilities, producing a complex climate variability and change signal.

In this study we consider both climate change and climate variability, and therefore it is important to understand the distinction between the two. Climate variability can be thought of as the way climatic variables (such as temperature and precipitation) depart from some average state, either above or below the average value. Although daily weather data depart from the climatic mean, the climate is considered to be stable if the long-term average does not significantly change. On the other hand, climate change can be defined as a trend in one or more climatic variables characterised by a fairly smooth continuous increase or decrease of the average value during the period of record.[1]

Climate change studies inherently have to consider the significance of uncertainty. This does not mean that there is no confidence in the understanding, or that the understanding is not certain enough to allow for the development of appropriate adaptation strategies and policies for resource management. Rather, current research would suggest that the political and planning response is lagging the understanding of climate change. Four sources of uncertainty currently limit the detail of the regional projects (Midgley et al., 2005):

a. *Natural variability:* Due to the finite historical records from which the range of natural variability has been defined at different scales of time and space, it is not possible to set the definitive limits of natural variability, nor to establish how much of the change in variability is due to anthropogenic factors.

b. *Future emissions:* Much of the projected change is dependent on how society responds to reducing emission of greenhouse gases.

c. *Uncertainty in the science:* Current understanding of the region's notion of the dynamics of the climate system of the African sub-continent is limited.

d. *Downscaling:* This refers to the development of regional-scale projections of change based on global models, which introduces an uncertainty that limits the confidence in the magnitude of the project change, although the pattern of change can be interpreted with greater certainty.

---

1 The IPCC defines climate variability as "variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability) or to variations in natural or anthropogenic external forcing (external variability)".

In contrast, climate change "refers to the statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use." (IPCC, 2001a).

1.2 Relevance to City of Cape Town

The South African climate change response strategy (Department of Environmental Affairs and Tourism (DEAT), 2004) identified the key climate change adaptation issues in the country to be health, water, agriculture, rangelands and biodiversity. Of these, agriculture and rangelands are of lesser importance to the City of Cape Town. We have therefore discussed climate change impacts in the City under these headings as well as livelihoods and, in lesser detail, fires and coastal zone management.

City of Cape Town's vision and long-term goals

The strategic priorities for the City of Cape Town are set out in the Integrated Development Plan (IDP), which is reviewed on an annual basis and substantially revised every five years as prescribed by legislation (City of Cape Town, 2005b).

The City of Cape Town's vision is to establish Cape Town as:

- a sustainable City that offers a future to our children and their children;
- a dignified City that is tolerant, non-racist and non-sexist;
- an accessible City that extends the benefits of urban society to all, and builds the capacity of its people;
- a credible City that is well governed and trusted by its people;
- a competent City with skills, capabilities and a competitive edge;
- a safe and caring City that cares for its citizens, and values the safety and security of all who live, work and play in it;
- a prosperous City known for its ability to compete globally in the 21st century and its commitments to tackling the challenges facing South Africa, the Southern African Development Community and the African continent; and
- a City known for its leadership in Africa and the developing world.

The City of Cape Town integrated development plan

The City's Integrated Development Plan (IDP) contains a set of long-term goals for Cape Town for the year 2020. The following list relates to climate impacts:

- 100% improvement in key human development indicators
- Universal access to basic services
- Water use and waste production down 30%
- Renewable energy share equal to 10% of energy consumed

1.3 Legislation and international obligations

National legislation that is relevant to this Framework for Adaptation to Climate Change in Cape Town is mentioned below (unless stated, these extracts are based on City of Cape Town, 2003a):

1. The Constitution of South Africa (Act No. 108 of 1996)

The Constitution presents an overarching obligation to sustainable environmental management, which requires that local government provide services in a sustainable manner, provide a safe and healthy environment for all communities, promote social and economic development, and ensure transparent governance.

2. Municipal Systems Act (Act No. 32 of 2000)

The Municipal Systems Act (MSA) has certain implications and obligations for environmental management by local government, which must be accommodated and reflected in the institutional framework and policies of the local government authority. It provides the core principles, mechanisms and processes that are necessary to enable municipalities to move progressively towards the social and economic upliftment of local communities.

3. Integrated Development Plan (IDP)

In terms of the Municipal Systems Act, municipalities are required to lead and manage an Integrated Development Plan. This IDP includes the allocation of resources, not only to concentrate on the provision of fundamental municipal services, but also to eradicate poverty, boost local economic development, create employment and promote the process of reconstruction and development.

4. National Water Act (Act No. 36 of 1998) and Water Services Act (Act No. 108 of 1997)

In response to the National Water Act, the Department of Water Affairs and Forestry (DWAF) has developed a draft National Water Resource Strategy (NWRS) (DWAF, 2004) to address the management of water resources to meet the development goals of the country. One of the key objectives of the NWRS is to identify areas of the country where water resources are limited and thereby constrain development, as well as areas where water resources are available to support development opportunities. In addition, industrial users are now required to develop and submit water management plans if they draw their water directly from a water source (DWAF, 2004).

5. National Environmental Management Act (Act No. 107 of 1998)

The National Environmental Management Act states that local government should develop strategies to protect natural and cultural resources but at the same time proactively address poverty.

6. Environmental Conservation Act (Act No. 73 of 1989)

The objectives of this Act are to reduce potential negative environmental impacts of activities related to development and to promote sustainable development. Specific sections of this Act set out procedures for Environmental Impact Assessment that must be complied with, in order for activities as defined in the Act, such as water supply and wastewater treatment works, to commence.

7. Disaster Management Act (Act No. 57 of 2002)

This Act focuses on preventing and reducing the risk of disasters, mitigating their severity, emergency preparedness, rapid and effective response and post-disaster recovery. Further guidance is provided by the National Disaster Management Framework (2005). Several critical obligations for municipalities related to infrastructure management and development flow from these documents, (Holloway, 2005) viz.:

- Preparation of disaster management plans
- Integration of disaster risk reduction into development planning frameworks and mechanisms
- Requirement to undertake disaster risk assessments as an integral component of development planning
- Specifications on responsibilities for reconstruction costs to damaged and destroyed infrastructure

8. Biodiversity Act (Act No. 10 of 2004)

The National Environmental Management: Biodiversity Act aims to provide a regulatory framework to protect South Africa's valuable species, ecosystems and biological wealth. It also provides for the development of a National Biodiversity Framework. Municipalities must align their Integrated Development Plans (IDPs), and thus their Spatial Development Frameworks (SDFs), with the National Biodiversity Framework and any published bioregional plans.

9. Other Acts that relate to local authorities and potential climate impacts

(list is not exhaustive):

- Atmospheric Pollution Prevention Act (Act No. 45 of 1965)
- Conservation of Agricultural Resources Act (Act No. 43 of 1983)
- Health Act (Act No. 63 of 1977)
- Marine Living Resources Act (Act No. 18 of 1998)
- National Heritage Resources Act (Act No. 25 of 1999)
- National Veld and Forest Fire Act (Act No. 101 of 1998)
- Nature Conservation Ordinance (Ordinance No. 19 of 1974)
- Seashore Act (Act No. 1 of 1935)
- World Heritage Convention Act (Act No. 49 of 1999)

Further, as a party to the United Nations Framework Convention on Climate Change (UNFCCC), South Africa has to fulfil certain obligations in terms of adaptation, which include the following (DEAT, 2004):

- To cooperate in preparing for adaptation to the impacts of climate change
- To take climate change considerations into account in the relevant social, economic and environmental policies and actions with a view to minimising adverse effects on the economy, public health and on the quality of the environment.
- To promote and cooperate in scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives related to the climate system and intended to further the understanding and to reduce or eliminate uncertainties.
- To promote and cooperate in the full, open and prompt exchange of relevant scientific, technological, technical, socio-economic and legal information related to the climate system and climate change.
- To promote and cooperate in education, training and public awareness related to climate change.

2

Towards a framework for adaptation to climate change in the City of Cape Town

Developing a framework for adaptation to climate change is necessary in order to prioritise the most urgent adaptation activities. If climate variability and extremes are changing, it is necessary to understand how climate impacts on sectors, and the resultant vulnerabilities. This can help to focus on where priority intervention might reduce the impacts of climate change, and help the City of Cape Town to adapt, rather than react when the damage has been done.

The Adaptation Policy Framework developed by the United Nations Development Programme (UNDP), is structured around four major principles from which actions to adapt to climate change can be developed (Lim et al., 2005), viz.:

- Adaptation to short-term climate variability and extreme events is included as a basis for reducing vulnerability to longer-term climate change.
- Adaptation policies and measures are assessed in a developmental context.
- Adaptation occurs at different levels of society.
- The strategy and the process by which adaptation is implemented are equally important.

Continual reflection upon these principles will ensure that adaptation activities are achieving their desired goals.

In order to develop an appropriate adaptation strategy, the following eight steps should guide the adaptation strategy framework for the City of Cape Town:

1. Assess current climate trends and future projections.
2. Undertake a vulnerability assessment.
   a. Identify current vulnerabilities (in each sector and for cross-cutting themes) based on current climate risks and trends.
   b. Identify future vulnerabilities based on future climate scenarios and risks.
3. Formulate a strategy.
4. Develop adaptation options.
5. Evaluate priority adaptation strategies.
6. Undertake programme and project scoping and design – CAPA.
7. Implement.
8. Monitor and evaluate interventions.

The components should be complemented by two cross-cutting processes (Lim et al., 2005):

- **Stakeholder engagement** to identify vulnerable sectors and existing and potential adaptation initiatives.

- **Adaptive capacity assessment** of the various sectors that would be affected by the impacts and their capacity to reduce their vulnerability. This should include an assessment of local government's capacity to address these issues.

It is critical to understand the nature of the current climate and the expected changes in climate, in order to have boundaries within which to assess the current ability to cope, and identify future areas of concern where thresholds of coping may be exceeded.

The City has a number of strategies and plans where key issues are prioritised and socio-economic vulnerabilities identified. These vulnerabilities should be overlain with a vulnerability assessment that identifies key vulnerabilities with regard to climate impacts, where there is an identification of how climate variability and change might increase vulnerability in different sectors. This overlay should identify hotspots of where to focus adaptation activities and contribute to the CAPA (City Adaptation Plan of Action), as illustrated in Figure 2.

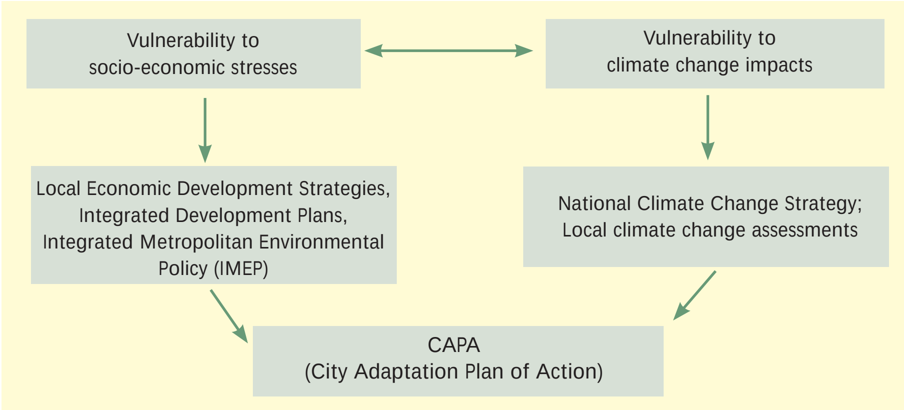


Figure 2: **Process for developing City Adaptation Plan of Action** [Adapted from NAPA (2004)]

Many tools and methods exist for undertaking vulnerability and adaptation assessments, including qualitative and quantitative methods. For example, there are tools to assess how one group or sector might be vulnerable to different types of climate variability, using matrices and expert opinion or focus groups. Other tools might use formal assessments, such as vulnerability maps and agent-based models. It is important to recognise the nature of vulnerability and the concepts behind adaptation to climate variability in order to be able to choose tools that are appropriate and assess what is needed.

Once the key vulnerabilities are identified, it is necessary to formulate a strategy. Adaptation strategies need to be developed. They should be developed with key stakeholders, including those directly affected, experts in the sectors, and climate specialists who can comment on the nature of the climate variability.

Once adaptation strategies have been identified, they will need to be prioritised. One method of evaluating which strategies might be pursued first, is multi-criterion analysis (MCA). MCA enables options to be evaluated using a range of criterion that includes unquantifiable analysis, especially when distributional implications need to be considered. The purpose of using MCA is to aid decision-making rather than to evaluate options in monetary terms. It is useful for assessing options for adapting to climate change as there are many factors that need to be considered, including equity, efficiency, short or long-term benefits as well as many other non-monetary factors. Appendix A gives a detailed example of MCA.

A key component of the framework for the climate change strategy is the ongoing monitoring of the programmes and the projects that are prioritised and implemented. The effectiveness of the interventions should be regularly assessed, and modifications made if necessary. Adaptation to climate change is not an event, it is an ongoing process.

In addition, the ongoing monitoring of critical infrastructure is important to ensure an early warning of pending impacts and potential disasters. The table below provides an indicative summary of the information sources for such a monitoring system. A communication protocol is required to ensure that early warnings from the relevant entities are effectively communicated to the affected authority and communities.

TABLE 1: Indicative summary of critical infrastructure for monitoring and mitigating City of Cape Town disaster risks (Holloway, 2005)

DISASTER RISK CATEGORY	RISK MONITORING INFRASTRUCTURE	RISK MANAGEMENT INFRASTRUCTURE	RESPONSIBLE ENTITY	LOCATION AND/OR NUMBER OF SITES
Wildfire	Weather stations		SAWS	129 automated weather stations
Extreme weather events	Weather stations		SAWS	129 automated weather stations
Meteorological drought	Weather stations		SAWS ARC	Widely distributed 150 AWS and 60 manual stations
Hydrological and agricultural drought (incl. urban drought)	Storage dams	Storage dams	DWAF Irrigation boards Private land owners	Widely distributed
Coastal storm surge and wave action		Breakwaters Sea walls Rock armouring	CCT Municipalities DEAT/MCM PGWC	Widely dispersed along coastline

Due to the limited nature of this study, the following sections provide a desk-top assessment of current and future vulnerability to climate variability and change for the City of Cape Town, which goes part way to addressing Step 2. Some indicative strategies have taken place, and possible interventions suggested. No stakeholder consultation or assessment of the City's capacity to plan and implement an adaptation programme has taken place. This is necessary in order to assess the secondary impacts of pursuing certain adaptation strategies, and to ensure there is equity and sustainability given the complex institutional arrangements of the city and its inhabitants.

3

Climate change trends and projections for the Western Cape

The material from this section is summarised from the work commissioned by the Western Cape Provincial Department of Environmental Affairs and Development Planning, which assessed the vulnerability and adaptation of the physical and socio-economic sectors due to climate change in the Western Cape (Midgley et al., 2005).[2] Whilst it is important to note that *trends* in the recent climate record are no guarantee that these will continue into the future, the historical change is valuable in providing a context. Regional *projections* are based on computer model simulations of the future. These models are global in extent, and have poor spatial resolution for resolving regional-scale climates (especially for precipitation). However, the models are skilful in resolving the large-scale circulation of the atmosphere (high and low-pressure feature, etc.), and as these determine the regional climate to a large degree, it is possible to downscale the projections of climate change on the large-scale to the complementary regional-scale response.

3.1 Trends in atmospheric circulation over the Cape Peninsula

During the period 1958-2001 there have been significant changes in the frequency of daily atmospheric circulation patterns (high and low pressures found in the region of the Western Cape). Trends in the frequency of different patterns vary depending on the pattern and time of year (Tadross et al., 2005).

The most relevant change in atmospheric circulation for the Western Cape has been a decrease in the frequency of low pressures, typically associated with winter storms, during early winter, e.g. April and June (also during January). These trends have resulted in spatially varying trends in precipitation. Additionally the trend for less winter low-pressure systems during early winter can lead to weaker synoptic forcing and conditions conducive to brown haze and smog in the Cape Town area (Tadross, 2006).

During late winter/early spring (October-December), there has been an increase in the frequency of high pressures over the continent which, when sufficiently intense, can lead to an increase in hot, dry berg winds. This may lead to increased fire risk, especially if the winter period is dry. If the strength of the wind field over the Cape Town metropolitan region is low, then this hot, dry air could lead to inversions, capping cooler air below and trapping emissions from factories and cars (Midgley et al., 2005).

2. It has been updated with contributions from Professor Hewitson and Dr Tadross of the University of Cape Town's Climate Systems Analysis Group (CSAG).

3.2 Temperature

3.2.1 Trends in temperature

Daily minimum (Tmin) and maximum (Tmax) surface air temperatures were averaged over every month, and the highest daily maximum temperature of each month (Highmax), and monthly rainfall were analysed for twelve meteorological stations across the Southwestern Cape for the time period 1967 to 2000 (Midgley et al., 2005). The analysis showed that very warm days have become warmer or have occurred more regularly during the last decade, particularly during January, April (months indicating changes in atmospheric circulation, see above) and August. Mean annual Tmin and Tmax over the same time period showed significant warming trends at most stations.

3.2.2 Projected changes in temperature

Downscaling of temperature changes is not yet available. However, temperatures can be expected to rise everywhere, least on the coast and more as one moves inland. Typical ranges to expect by 2050 are ~1.5º on the coast, and 2-3º inland of the coastal mountains. The absolute magnitude will depend on a number of factors (e.g. topography, land use, etc.) and these values should be treated as a median value within a range.

3.3 Precipitation

3.3.1 Trends in precipitation

Precipitation is generally a difficult parameter to analyse for trends, in that there is a high degree of inter-annual variability, and single extreme events can readily skew a simple analysis and hence lead to a misleading conclusion. For the analysis of historical precipitation, the work of Hewitson et al. (2005) was used and is based on the gridded precipitation data set of Hewitson and Crane (2005).

The regional historical change is complex. Firstly, the trends in mountainous regions are different from and, in places, contrary to the trends in the lowland regions. In general, over the years mountainous regions show positive trends, while lowland regions have negative trends. Sub-annually, however, the trends are more complex, with distinct patterns of trend particularly in summer (especially late summer) versus early and late winter.

These changes are consistent with the understanding of the rainfall processes, namely, increased moist atmosphere (resulting from a warmer world) with the propensity to increase the orographic precipitation as a result of more frequent cloud formation on the mountains. Conversely, suggestions from the study of the atmospheric circulation support the evidence for the regions of drying, as well as further supporting the sub-annual patterns of increase.

3.3.2 Downscaled scenario projections for precipitation

Presented in Figure 3 are results from the empirical downscaling approach conducted by Hewitson et al, (2005). In each case the regional projections are drawn from downscaling the projected circulation changes as simulated by six global models, each using a scenario of increases in greenhouse gases that assumes that society will continue to use fossil fuels at a moderate growth rate. Figure 3a shows the changes projected for the Western Cape. It is clear that the models differ in the projected magnitude of change, yet there are clear messages of consensus in the pattern of change. Two dominant messages may be identified:

a) Late summer increases in precipitation in the interior and to the east of the province, with the strongest changes associated with topography. This agrees with the understanding of climate change for a more moist atmosphere in the future, leading to more orographic rain, and an increased possibility of convective rainfall events.

b) A decrease in early and later winter precipitation for the south-west of the province, with a less clear message during the mid-winter period where the models disagree on the direction of change. This would suggest that the change in the core south-west winter rains, dominantly a function of cold fronts, is likely to shorten in duration.

Figure 3b shows the changes in the magnitude of the median rainfall event in a month. The median rainfall event may be considered the typical, or most common, rainfall event. The projected changes mirror, to a large degree, the patterns in the changes of monthly total rainfall. Notable, however, are the projected increases in magnitude of the rainfall events in the mountains, and to the east of the mountains in the mid to late summer.

The most consistent predictions (from the statistical downscaling of six general circulation models (GCMs) are for an increase in total rainfall over the eastern regions of the Western Cape during late summer (January to March) and a decrease in rainfall, particularly over the western regions of the Western Cape, during early winter (April to June). This tendency for decreased rainfall, though not as large as during the early part of the season, continues throughout the winter season. Variations in the timing of these shifts occur for individual models, and very weak increases in rainfall are suggested for individual months, but on the whole there is a consensus for winter drying.

For impact researchers it may be advisable in the short term (10-15 years) to use the observed trends as suggestions for change in the near future. As changes in the climate begin to accelerate (as they are predicted to do) the projections will become more apparent for the long term.

Figure 3: Projected precipitation changes

Each column represents the regional projection from one global model simulation of the future. The rows are the months of the year (January at the top, December at the bottom).

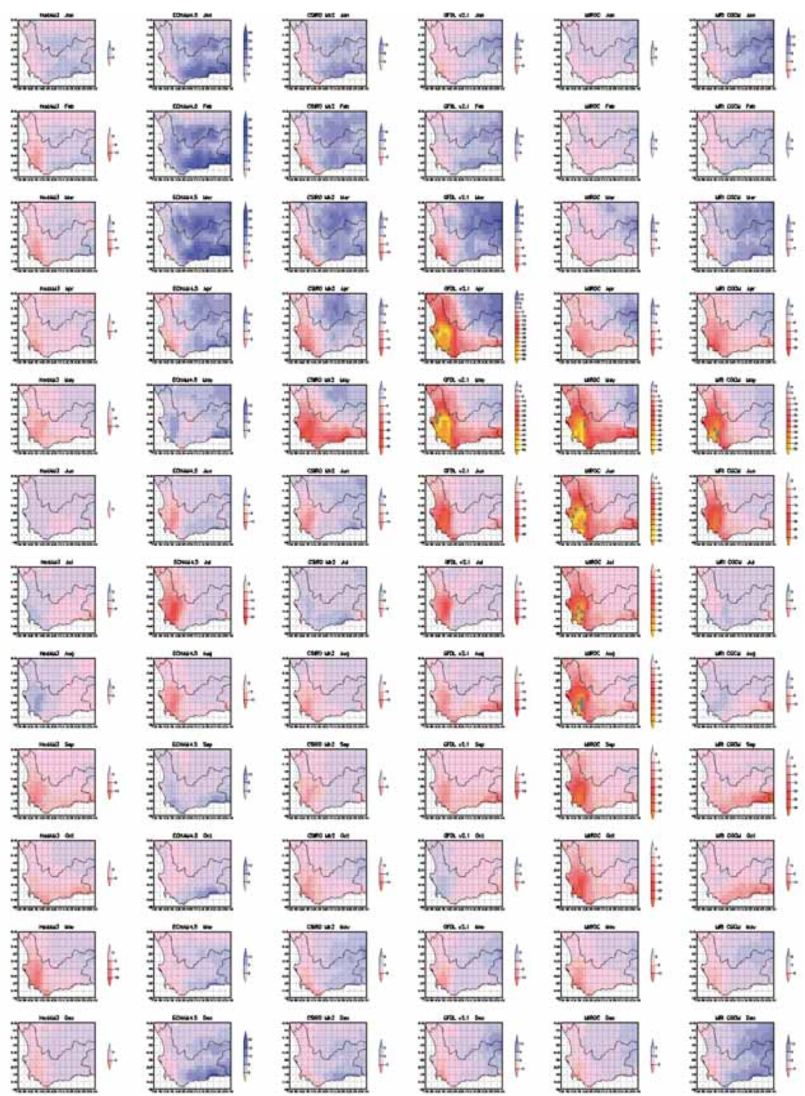


Figure 3a: Projected changes in monthly total precipitation for, nominally, the period around 2070

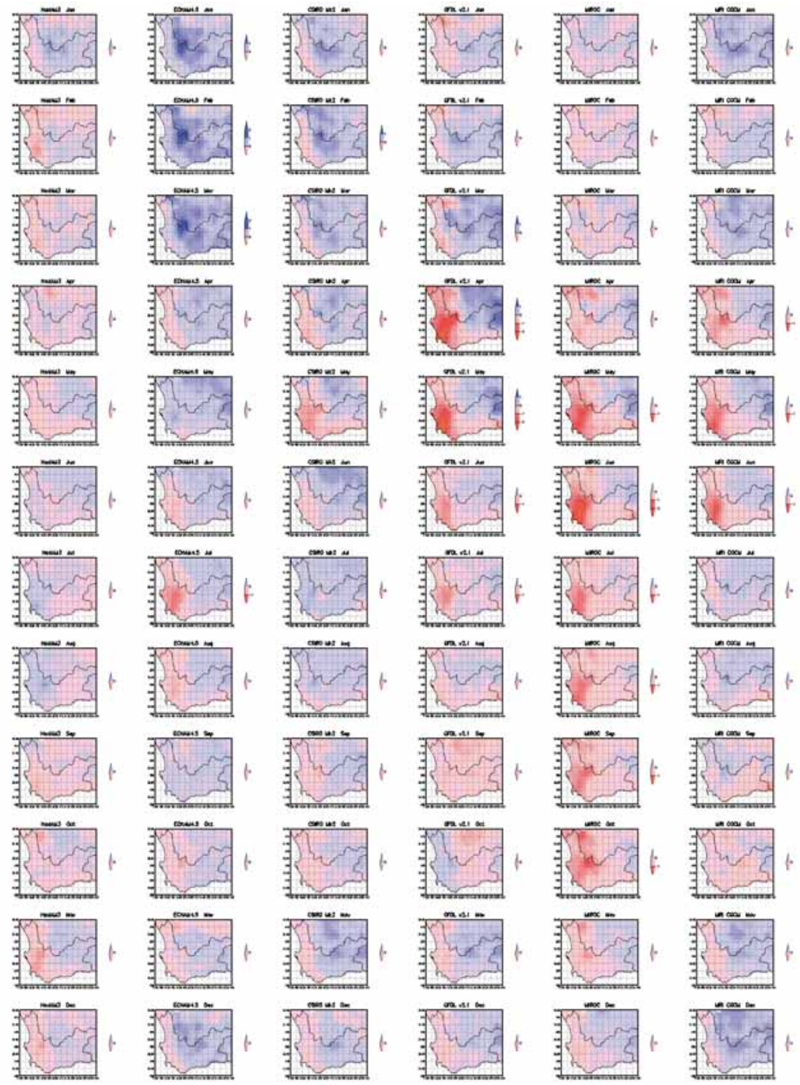


Figure 3b: Projected change in the magnitude of the median ("typical") rainfall event in a month

4

Sectoral analysis of current and future impacts

The key sectors as identified by the authors are discussed in this section. Through further stakeholder consultation and prioritisation, additional sectors may become apparent. The sectors discussed here are:

1. Urban water supplies
2. Storm water
3. Biodiversity
4. Fires
5. Coastal zones
6. Livelihoods
7. Health

4.1 Urban water Supplies

4.1.1 Background

The supply of water services in Cape Town faces a number of challenges, viz. the eradication of the basic service backlog, achieving the essential target for reducing demand, meeting wastewater effluent standards and thereby reducing the impact on water quality on the urban rivers, asset management, and ensuring that development growth demands are met (City of Cape Town, 2006a). Further, the Greater Cape Town area has been identified by the Department of Water Affairs and Forestry (DWAF) as the first major urban region in South Africa where the demand for water will exceed the total potential yield for the area if growth scenarios are realised or the impact of projected climate change manifests itself (DWAF, 2004). The Berg River Catchment Management Area has been specifically identified in this regard.

Water supply

The Western Cape is a region characterised by great variability in water resources. Both surface and groundwater resources are exploited and in some places, the rate of exploitation is unsustainable. At the same time, sufficient water must be left in the rivers to maintain acceptable levels of ecological integrity. The growing metropolitan area of Cape Town demands a greater share of the water resources, and new ways of meeting these demands will have to be found within the short- to medium-term future. The projected general drying of the Western Cape region has serious implications for further socio-economic development as well as maintaining the ecological integrity of the wetlands, rivers and estuaries which also depend on that same water.

Two catchment areas service the City of Cape Town, viz. the Breede and Berg Water Management Areas.

Breede WMA 18:

The Breede Water Management Area is of crucial importance to the Western Cape Metropolitan Area. Water from the Berg Water Management Area is stored in the Breede Water Management Area, while large quantities of water are transferred from the Breede Water Management Area for high-value (urban, industrial) uses in the Berg Water Management Area. The key reservoir is the Theewaterskloof Dam, from which water is mostly transferred into the Berg River scheme. Additional transfers to the Berg Water Management Area are likely to be required in future to serve the Greater Cape Town area.

Substantial potential for further development of (mainly) surface water resources exists in the water management area. The extent to which these will be feasible for development will depend on affordability and the requirements for the reserve.

Climate change may have a major impact on the future availability of, as well as requirements for water in the water management area (BKS (Pty) Ltd., 2003b).

Berg WMA 19:

The Berg Water Management Area is the major water supplier to the Western Cape Metropolitan Area, and contains the Western Cape Water Supply System, which includes the Steenbras Upper and Lower, Wemmershoek, Voëlvlei and Theewaterskloof Dams. Under current climate conditions, the Berg WMA in general is already in deficit and necessitates the need for augmentation of the existing water supply capabilities from the Breede WMA.

This is also the water management area that is expected to show the highest population growth, which is already responsible for the increased demands for water. There is very little potential for further local water development, and therefore additional transfers of water into the water management area will be required, as well as the exploration of other options such as the possible exploitation of the Table Mountain Group aquifers (BKS (Pty) Ltd., 2003a).

The following table details the surface water resources utilised by the City of Cape Town. In addition to this, a yield of 6.64 mm^3 is available from groundwater resources. The groundwater abstracted by residences is not known (City of Cape Town, 2006a).

TABLE 2: Surface water resources (City of Cape Town, 2006a)

DAMS AND RIVERS	OWNED & OPERATED BY	APPROX. % TOTAL SUPPLY REQ**	FIRM YIELD* (1:50 YEAR) mm^3	CCT REG. USAGE (mm^3)
MAJOR SOURCES				
Theewaterskloof Dam	DWAF	48.3%	219	120
Kleinplaas Dam	DWAF			
Voëlvlei Dam	DWAF	23.2%	105	70.5
Palmiet River	DWAF	5.0%	22.5	22.5
Wemmershoek Dam	CMC	11.9%	54	54
Steenbras Upper	CMC	8.8%	40	40
Steenbras Lower Dam	CMC			
TOTAL		97.1%	440.5	307
DAMS AND RIVERS	OWNED & OPERATED BY	APPROX. % TOTAL SUPPLY REQ**	APPROXIMATE YIELDS	CCT REG. USAGE (mm^3)
MINOR SOURCES				
Simon's Town:		0.4%	1.85	1.85
Lewis Gay Dam	CMC			
Kleinplaas				
Land en Zeezicht Dam (from Lourens River)	CMC	0.1%	0.5	0.5
Table Mountain:		0.9%	4	4
Woodhead	CMC			
Hely-Hutchinson				
De Villiers Dam				
Victoria Dam				
Alexandra Dam				
GRAND TOTAL *		98.5%	446.86	313.35

** Excludes the Atlantis Aquifer and Albion Springs*
*** Approximate % of total supply requirement and firm yield includes Agriculture and other Water Service Authorities.*

Water demand

As can be seen in the graph below, domestic consumption accounts for two thirds of the City of Cape Town's demand. Any demand-side management strategy should initially focus on this sector.

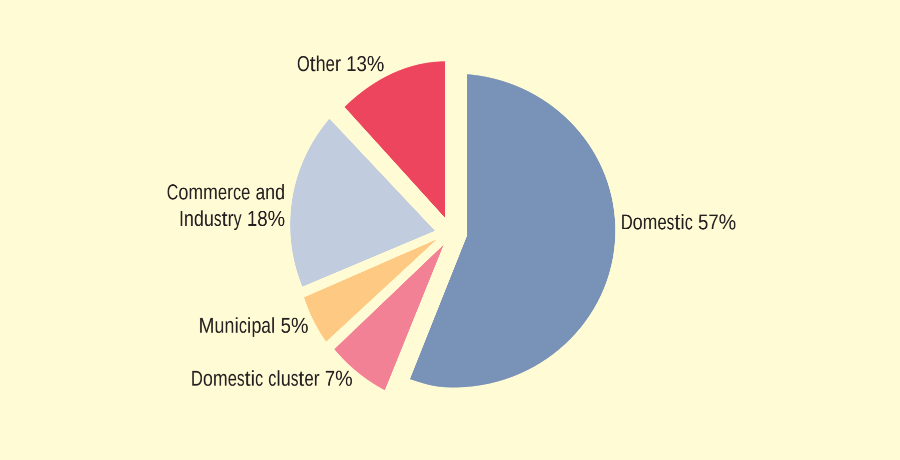


FIGURE 4: **Water distribution for CCT** City of Cape Town (2006a)

Based on the potential economic growth and population growth, it is estimated that the unconstrained water demand growth in the City will vary between 2.7% and 3.7% per annum (City of Cape Town, 2006a). This needs to be matched by the available supply. The graph showing the projected demand also illustrates the relief that the Berg Water Project will bring under "low water demand curve". Under this scenario, however, the City will have a water deficit by 2013. The demand management initiatives have been effective in bringing the current demand under the available supply.

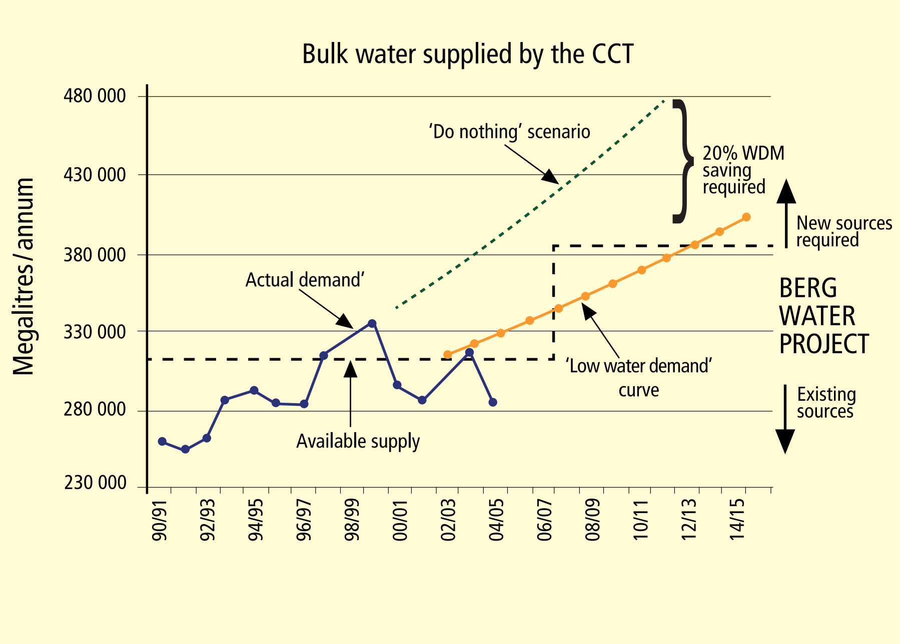


FIGURE 5: **Water Demand Projections** City of Cape Town (2006a)

The following tables illustrate the limited resources available to the City of Cape Town from the two key water management areas under future scenario cases. The Berg River, which already imports water, will be further reliant on imports from neighbouring catchments.

TABLE 3: Reconciliation of water requirements and availability for year 2000 (million m^3/a) (DWAF, 2004)

WATER MANAGEMENT AREA		LOCAL YIELD	TRANSFERS IN	LOCAL REQUIREMENTS	TRANSFERS OUT	BALANCE
18	Breede	868	1	633	196	38
19	Berg	505	194	704	0	(5)

TABLE 4: Reconciliation of water requirements and availability for year 2025 base scenario (million m^3/a) (DWAF, 2004)

WATER MANAGEMENT AREA		LOCAL YIELD	TRANSFERS IN	LOCAL REQ'S	TRANSFERS OUT	BALANCE	POTENTIAL FOR DEV.
18	Breede	869	1	638	196	36	124
19	Berg	586	194	829	0	(67)	127

TABLE 5: Reconciliation of water requirements and availability for year 2025 high scenario (million m^3/a) (DWAF, 2004)

WATER MANAGEMENT AREA		LOCAL YIELD	TRANSFERS IN	LOCAL REQ'S	TRANSFERS OUT	BALANCE	POTENTIAL FOR DEV.
18	Breede	897	1	704	196	(2)	124
19	Berg	602	194	1 304	0	(508)	127

4.1.2 Impacts and vulnerabilities

The Western Cape has recently experienced a drought, which can be attributed to climate variability. Climate variability is expected to alter the present hydrological resources in Southern Africa and add pressure on the adaptability of future water resources. During the past twenty years, most of Southern Africa has experienced extensive droughts, the last four being 1986-1988, 1991-1992, 2000-2001 and 2004-2005. Dam levels in the Western Cape were at their lowest levels in five years during 2005. This drought-induced shortage of water placed stress on the water supply and management in the City of Cape Town.

TABLE 6: Storage levels for the period 1 May 2001-2006 (City of Cape Town, 2006c)

DAMS	CAPACITY (ml)	2001 (%)	2002 (%)	2003 (%)	2004 (%)	2005 (%)	2006 (%)
Wemmershoek	58 644	36.5	50.4	43.6	48.1	36.1	45.1
Steenbras Lower	33 517	30.7	46.7	43.5	40.3	40.6	33
Steenbras Upper	31 767	42.5	42.5	48.3	47.1	53.5	48.2
Voëlvlei	164 122	27	62.8	61.7	36.4	21.6	37.9
Theewaterskloof	480 250	44.1	74.8	62	35.7	28.7	42.5
TOTAL STORAGE	768 300	39.2	67.8	59.1	37.5	29.3	41.5

4.1.3 Adaptation initiatives

Current water management practice has in the past been developed to ensure that the existing supply of water meets the growing projected demand. Some of the mechanisms may be appropriate to deal with the future intermittent shortages that will be brought about by climate variation, but robust long-term strategies are required to ensure that the demand for water matches the supply, even in times of reduced availability. In addressing future projected climate change impacts, some of the proposed measures may need to be introduced sooner than originally planned.

The **Integrated Water Resource Planning** study, commissioned by the former Cape Metropolitan Council (CMC), identified the need to adopt an integrated water resource planning approach to manage the changing water demand, as well as address the effects of population, economic growth and stresses on supply of water (Geustyn Loubser Streicher & Palmer Development Group, 2001). The stresses on the supply of water should include projected climate impacts. In addition, a strong focus on the defense of the ecological reserve should be stressed to ensure sustainability of wetland and river ecosystems. It has been proposed in the Berg WMA assessment study that no development or investment decisions should be made without taking into account the actual or potential effects of climate change on water resources (BKS (Pty) Ltd., 2003a).

In addition, it is important that the impacts due to the climate change be monitored as a precautionary measure. Special attention is to be given to **long-term monitoring** of hydro-meteorological parameters in selected, benchmark sub-catchments. Water planners and managers need to use the available climate data to make strategic decisions on an ongoing basis.

Effective **water demand-side management** would be strategic before under-taking further capital expenditure on developing additional sources of water. To this end, the Cape Metropolitan Council accepted in 1997 the following policy statement (ARUP, 2002): "To develop and manage, in a participatory manner, the implementation of a socially beneficial, technically feasible, economically effective, ecologically sustainable water demand management strategy, which will reduce the projected demand (DWAF, 1994) in greater Cape Town by 20% (or more) by the year 2010". The City of Cape Town has since outlined a Ten-Point Plan (in 2004) for achieving greater water conservation to complement the existing City of Cape Town's Water Demand Management Strategy, and to achieve the objectives of the long-term, sustainable Water Conservation Strategy (currently being developed by the City of Cape Town in partnership with the Department of Water Affairs and Forestry) (City of Cape Town, 2006a).

These initiatives include the following:

1. Water restrictions

In the past, the City of Cape Town has used measures such as restricting the use of water for some activities to specific times, and disallowing other activities to reduce the demand on the limited water resources.

2. Water tariffs

Market-based allocations are able to respond more rapidly to changing conditions of supply, and also tend to lower the water demand, conserve water and consequently increase both the robustness and resilience of the water supply system (Schulze & Perks, 2000). Water tariffs were effectively used during the 2005 water shortage to reduce the demand by the City of Cape Town.

3. Reduction of leaks programme

In Cape Town the water unaccounted for was estimated at 23% and 18% for 2000 and 2001 respectively (Geustyn Loubser Streicher & Palmer Development Group, 2001; City of Cape Town, 2006a). The upgrading and improvement of water supply lines would bring these losses to within acceptable limits. Further, the efficient use of water would reduce treatment and distribution costs. Initiatives such as the Water Leaks Project, could be rolled out to other parts of the City of Cape Town. The Water Leaks Project aims to repair household leaks in Khayelitsha to reduce water and financial wastage. Implementation is expected to start in July 2006 and to be completed in June 2008.

4. Pressure management

With the introduction of pressure management systems, as is the case in Khayalitsha, water lost from undetected leaks is reduced by reducing the off-peak water pressure in the pipes. This also reduces the water lost (not used) through leaks within the piping on private property. The City plans to implement this system in other areas such as Mfuleni (City of Cape Town, 2005c).

5. Awareness campaigns

Through the media and knock-and-drop pamphlets, the City of Cape Town also embarked on an awareness campaign in an attempt to reduce the consumption of domestic water.

A number of **policies and measures** could be implemented by the City of Cape Town to reduce water demand. The associated cost implications would however require further investigation.

- **Incentives:** These could be in the form of rebates for ratepayers and businesses who install rainwater tanks, re-use their grey water and install low-flush toilets.
- **Regulations:** Building regulations should require that all new buildings be installed with water saving devices, such as low-flush toilets and rainwater tanks.

However, given the high growth rates projected for the area, and the already insufficient resource capability, water demand management alone will not be sufficient to meet future water requirements. Other **supply-side** interventions will have to be resorted to. Some of these are discussed below:

1. **Berg WMA schemes** – Two schemes located on the Berg River are being developed (BKS (Pty) Ltd., 2003a), viz.:
   - Berg River Project ($81m^3 \times 10^6$) – completion date: 2007
   - Voëlvlei Dam augmentation ($30m^3 \times 10^6$) – completion date: 2015
2. **The Table Mountain Group Aquifer** – The current belief is that the Table Mountain Group aquifer has great potential for water productivity, and is already significantly utilised for irrigation and municipal use throughout the Western Cape. This option is also being considered for water supply to the Cape

Town Metropolitan area. However, much uncertainty still exists regarding the productivity, rate of recharge and sustainability of the aquifer.

3. **Other augmentation schemes** – Other schemes that could be developed in the short- to medium-term include the Cape Flats Aquifer, the Lourens River Diversion Scheme and the Eerste River Diversion Scheme (City of Cape Town, 2006a).

4. **Re-use of effluent** – Currently the City of Cape Town re-uses 9% of its treated effluent (Geustyn Loubser Streicher & Palmer Development Group, 2001). A large portion of the City of Cape Town's effluent is pumped out to sea as raw sewage. This presents a good opportunity for investment in recycling technology and the installation of recycling infrastructure. Industries and other wet processing systems should be incentivised to recycle their waste water. At a domestic level, the re-use of grey water should be encouraged.

5. **Water harvesting** – Rainwater tanks installed in homes and commercial buildings for use on gardens, in swimming pools and sewage could be encouraged and incentivised.

6. **Sea-water** – The supply of sea-water for certain domestic uses (e.g. swimming pools and sewage) should be further investigated.

7. **Desalination** – The energy intensity and high financial costs of production have, so far, made this technology unviable. However, the unit price of desalinated water is dropping continually as technology improves. The major stumbling block is that the Western Cape is projected to face an "energy crunch" in 2007 (Midgley et al., 2005). A possible solution is to follow the example of Perth, Australia, which has undertaken to use fifty giant wind turbines to power an eco-friendly desalination plant to make Perth drought-proof and provide its two million people with their biggest single source of water. The $387 million venture will produce 130 million ℓ/day by the end of 2006. The capital cost to build the plant and ancillary infrastructure is $387 million. Annual operating costs will be less than $20 million a year. This means that the potential cost impact on each household remains under $1 per week at $44 per year (Water Corporation, 2006).

4.2 Storm water

4.2.1 Background

In March 2003 and April 2005 we experienced damaging floods due to cut-off lows, which cause heavy rainfall in a short period of time and gale force winds. The extent of the damage for the Western Cape province during this period exceeded R260 million (Holloway, 2005). Furthermore, due to variations in the rainfall patterns, storm-water drains are prone to blockages. Sand from the Cape Flats is blown into the drains during the dry summer months and then obstructs the drainage of the rainwater during the rainy seasons (winter), and more specifically during times of unpredicted heavy storms and intense rainfalls. In the "leafy" suburbs, the drains get blocked by leaves, particularly in autumn, with the same result. The blocked drains cause flooding of property and infrastructure, with consequential damage.

4.2.2 Impacts and vulnerabilities

The intensity of rainfall in the Western Cape can be expected to change due to climate variability. An increase in the number of extreme events will cause substantial increases in the cost of losses to the public and private sectors, as well as increasing personal hardship for the people directly affected.

4.2.3 Adaptation initiatives

The extensiveness of the storm-water and flood risk infrastructure in the City of Cape Town is reflected in the following statistics (Holloway, 2005):

- 150 000 gullies/intakes;
- 5 500 km of pipes and culverts;
- extensive surface channel systems in both formal and informal areas; and
- 650 detention ponds.

The need for such extensive infrastructure is partly driven by the rapid growth of the city, combined with the presence of 1 200 km rivers and streams – of which 300 km are actively maintained by the Department of Transport, Roads and Storm Water. The Metro is also supported by an elaborate hydrological monitoring network, comprising 62 rainfall and river flow stations, including those connected to a telemetry network to facilitate effective riverine flood management during heavy rain days.

Further risk reduction initiatives would include:

1. Ongoing **monitoring and warning** of impending disaster risks, with the help of the provincial weather and hydrological monitoring stations.
2. **Reducing the impacts** of these natural hazards through infrastructural means, such as flood detention ponds and weirs.
3. **Increasing the flood event return period** for which sufficient structures are designed.
4. The ongoing **maintenance** of storm-water drains to clear them of sand build-up and rubbish.
5. The development of **resilient infrastructure** to include appropriately designed and constructed low-income homes, storm-water drainage and sewage treatment installations to cope with flash-floods.

4.3 Biodiversity

4.3.1 Background

Relatively few studies have addressed the impact of climate change on biodiversity in the Western Cape, and those that have focused on plant species and vegetation types. Less is known about the impact of climate change on the City of Cape Town. Yet, biodiversity is important to the City, which is located within the Cape Floristic Kingdom. Cape Town contains remnants of renosterveld vegetation (3% remains of the original extent) which is threatened and one of the most endangered vegetation types in South Africa (CT Biodiversity Strategy). The City of Cape Town is home to an entire National Park, the Cape Peninsula National Park (CPNP), overlaps with the Kogelberg and West Coast Biosphere Reserves, and administers 22 conservation areas (City of Cape Town, 2003a).

The key regional conservation initiative, Cape Action Plan for People and the Environment (CAPE) funded by the Global Environment Facility (GEF) – published a report in 1999 for terrestrial ecosystems which showed that all of the habitat types found on the Cape Town Lowlands were of maximum conservation value. The report recommended that all of the remaining remnant habitat was required in order to achieve a modest regional conservation target. Further, the CAPE programme has identified broad habitat units (BHUs) in its regional conservation planning programme; four of these BHUs exist nowhere else but within the City of Cape Town boundaries (City of Cape Town, 2003a).

4.3.2 Impacts and vulnerabilities

The impact of climate change manifested by a warmer and dryer climate will be a contraction of fynbos, which is a biodiverse hotspot. Estuaries, which need fresh water for flushing and maintaining salinity profiles, will face increased competition for water from agricultural and urban demands. It should be remembered that South

Africa has the second highest number of plant extinctions in the world (City of Cape Town, 2003a) and the City of Cape Town is part of the southern extent of the Cape Floral Kingdom. There are also numerous fauna in Cape Town, many endemic, whose environment should be conserved.

Little is known about how alien invasive species would respond to climate change. A drier environment would restrict their spread, but increasing carbon and especially nitrogen fertilisation would enhance growth. Alien trees would continue to utilise water amidst increasing water scarcity. As stated by Midgley et al., (2005):

> The impact of climate change manifested by a warmer and drier climate is likely to be a progressive impoverishment in species richness in the internationally recognised biodiversity hotspots, the Fynbos and Succulent Karoo Biomes, but projections are limited by high levels of uncertainty due to a lack of understanding of species tolerance limits. Species losses estimated to be ultimately as high as 30% under worst-case scenario assumptions, may occur both as a direct response to warming and drying, but also as an indirect response to changing fire regimes and interactions with invasive alien species. High altitude marshes that host some highly endemic and isolated species (e.g. ghost frog) are particularly vulnerable to desiccation.

Alien invasives

Detailed studies have not been undertaken on how the spread and distribution of alien species would respond to climate change. Reduced precipitation would limit their expansion, but increasing atmospheric CO_2 content and nitrogen fertilisation would enhance growth. Although not all invasives use more water than the plants they replace, many alien trees use large amounts of water as they replace grass and shrubs. This is a key concern for the Western Cape if water scarcity increases. Another concern is that alien expansion could fuel more intense and frequent fires (Van Wilgen et al., 1997; Midgley et al., 2005).

4.3.3 Adaptation initiatives

Particular conservation focus is needed on the Cape Town Lowlands area, which supports more than 1 466 plant species, and is an area that to date has been under-conserved.

Adaptation to climate change in the biodiversity sector could entail a number of things:

1. Prioritising **alien plant management** and associated **fire management** for the current and future health of indigenous terrestrial ecosystems.
2. **Monitoring** indicator species and populations that will enable improved understanding of how species respond to climate variability and change, and identifying how species are impacted.
3. Assessing current **protected areas** in terms of their potential expansion where possible, as well as reducing other human-induced stresses on ecosystems.
4. Increasing public sector involvement, including supporting commercial land managers in **reducing impacts**.

If climate change impacts on habitats and stresses the ecosystem significantly, it may be necessary to transfer key threatened species to new sites in the wild in extreme cases (Midgley et al., 2005). It is therefore critical that terrestrial and aquatic ecosystems are healthy, and that there are intact ecological corridors linking different parts of the landscape as this will help to mitigate the impacts of climate change. This should be seen as a crucial element of South Africa's climate change adaptation strategy, and is therefore necessary at City level (Driver et al., 2005).

4.3 Fires

4.4.1 Background

On average, fires in the Western Cape normally occur every 15 years or so, with actual intervals between fires ranging between four and forty years. The prevailing warm, dry summers are conducive to fires, which are common between November and March each year, especially when hot, dry and windy conditions prevail for several days (Midgley et al., 2005). These fires, while necessary for the regeneration of the fynbos and renosterveld, sometimes get out of control and cause damage to urban infrastructure.

Due to rapid urban growth, specifically in the informal settlements, the exposure of poor families to personal and infrastructure loss due to fires has increased in the City of Cape Town. More than 41 000 informal homes were damaged or destroyed in fires between 1990-2004 (Holloway, 2005). Figure 6 clearly depicts this increase, which has mainly been due to the increased densities of the informal settlements.

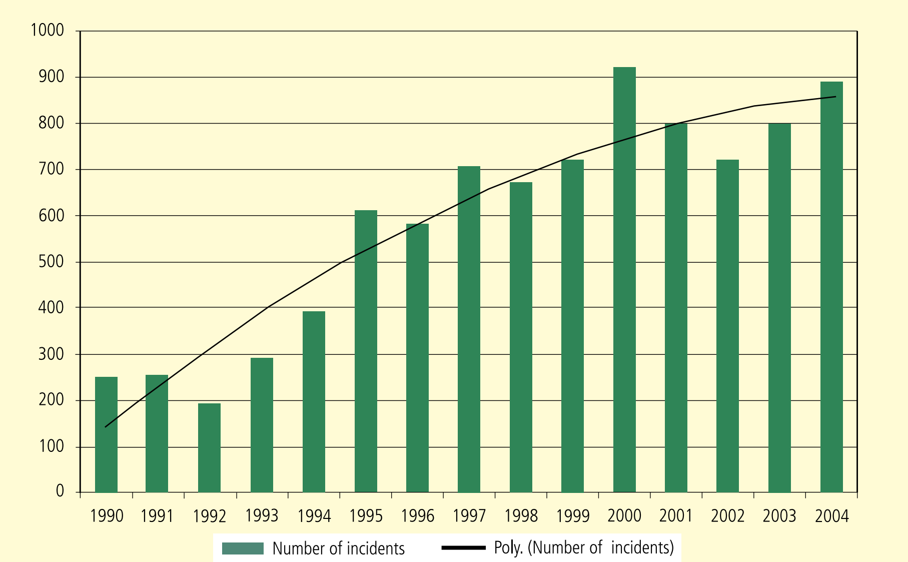


FIGURE 6: **Number of informal dwelling fires for the CCT, 1990-2004** *Holloway (2005)*

4.4.2 Impacts and vulnerabilities

The frequency and intensity of wildfires is modelled to increase substantially due to lower rainfall (reducing the moisture content of fuels), lower relative humidity, longer droughts, and higher wind speeds. High fire risk conditions are projected to almost triple in the west of the province. This will have a negative effect on biodiversity, soil structure and the spread of fire-adapted alien invasive plants, which would further alter and enhance fuel loads and make wildfires more intense. Plantations and buildings will be subject to increased risk (Midgley et al., 2005).

If the frequency of fires is reduced from once in fifteen years to once in five years, many plant species that are killed by fire, and that rely on re-seeding to survive, would become extinct as they would not have enough time to mature and set seeds between fires (Van Wilgen et al., 1992). Plantations which are located along the slopes of mountain ranges will be highly vulnerable. In addition, many alien plants, whilst being less flammable than fynbos due to the higher moisture content in their foliage, burn readily once ignited because they tend to have greater biomass than the indigenous fynbos. They have also adapted to fire and hence spread when fires become more frequent (particularly species such as the Australian acacias). Therefore a future climate which has more frequent and intense fires would favour alien invasions, raising the fire hazard.

The consequential soil erosion caused by winter rains after the summer fires further reduces the chances of indigenous vegetation recovering. For example: six tonnes of soil per hectare was lost following fires in pine stands compared to 0.1 tonnes per hectare following a fire in an adjacent fynbos areas (Scott et al., 1998).

It is not clear at this point whether or not climate change will impact directly on the incidence of informal dwelling fires. A drier climate may cause building materials to be more volatile, especially if accompanied by high winds.

4.4.3 Adaptation initiatives

Since management strategies to influence the frequency and intensity of fires in fynbos have been unsuccessful in the past, it may be appropriate to adopt defensive measures as well.

Some adaptation responses to fire risks would include the following:

1. In order to control the necessary burning of the fynbos vegetation, increased **training in ecological fire management** is required.
2. **Increased firefighting capabilities**, including greater training and investment in capacity for firefighting, as well as rapid and effective response to fires, for example through the use of aircraft.
3. Tohe **removal of plantations**, especially in areas where future climate change might make them less productive.
4. The **control of alien invading plants** would be a specific focus for managing damage caused by wildfires.
5. Appropriate **fire breaks** between vegetation and residential areas.
6. **Erosion protection** is needed to avoid loss of top soil due to post fire rains.

4.5 Coastal zones

4.5.1 Background

A change in global surface temperature should be accompanied by a worldwide sea-level rise through three main mechanisms, the warming and associated thermal expansion of the oceans, melting of glaciers and to a much lesser extent, the polar ice balance (Greenland and Antarctic; IPCC, 2001a).

It is suggested that specific locations are carefully evaluated in terms of their vulnerability to the five potential impacts listed below (Midgley et al., 2005):

- increased exposure to extreme events (which themselves might increase in frequency or intensity);
- increased saltwater intrusion and raised groundwater tables;
- greater tidal influence;
- increased flooding (frequency and extent); and
- increased coastal erosion.

4.5.2 Impacts and vulnerabilities

The City of Cape Town coastline has many sandy areas that have high potential for erosion as a result of the high energy wave regime. In addition, the most significant impacts of sea-level rise are expected where problems are already experienced. In most cases these are the areas where development has exceeded the high-water line by far, or is at a too-low elevation above mean sea-level.

TABLE 5: Identification of some of the most vulnerable areas where the impacts will potentially be the most severe (Midgley et al., 2005)

SPECIFIC AND GENERAL AREA/LOCATION	IMPACT	EXTENT
Strand	The coastal road is very close to the high-water mark. Thus, the low wall on the pavement is overtopped, even if only a moderate storm occurs during spring high tides. This results in temporary road safety problems, and necessitates regular maintenance. Both sea-level rise and increased storminess will increase the number of occurrences and the scale of the impact.	Small area
Northern False Bay	Baden Powell Drive, parking areas and ablution facilities have been located within the littoral zone. The continuous influx of windblown sand off the beach has resulted in a costly, ongoing sand clearing exercise that peaks during the summer period when the south-easterly and southerly winds prevail. More mechanical effort will be required to clear the road. From Cemetery Beach to Strandfontein Point the road itself and structures seawards of the road are often inundated and are vulnerable to storm damage.	Relatively longer stretch of coastline, but mainly limited to impacts to the road
Table Bay (Diep River mouth – Milnerton – Blaauwberg)	Existing problems with shoreline erosion, aeolian sand transport and storm-water drain outlets on the beach will be aggravated; due to sea-level rise, as well as increased storminess.	Relatively long stretch of coastline, but incremental impact still small
Table Bay	Koeberg Nuclear Power Station seawater intakes could potentially be affected.	Relatively insignificant impact
All ports/harbours (recreational, commercial, industrial, etc.)	More damage to breakwaters due to increased wave impacts through higher water levels & increased storminess (sea & swell components).	Incremental increase due to climate change probably small
Many coastal areas susceptible to windblown sand problems, e.g. Strand, Macassar, Blouberg	Increased storminess, thus more marine sediment transport, thus more sand deposited on upper beach for potential aeolian sediment transport. Additional increase due to more & stronger winds.	Incremental increase due to climate change possibly small

Case study examples: (Hughes, 1992)

The predicted sea-level rise assumed in these examples is beyond the range predicted by the IPCC this century, but on the other hand the impacts of extreme events are not considered. The valuation does not take into account the lost infrastructure (which would not be replaced), nor the increased value of other properties that are subsequently on the sea-front.

a) Woodbridge Island (Milnerton, Cape Town):

Woodbridge Island in Cape Town exemplifies a partially developed shoreline with river mouth, estuaries and backing wetlands and lagoon. The most serious problems arising from a 500 mm increase in sea-level would be storm flood damage to the spit protecting the lagoon, the town margin and developing margins of the vlei, as well as potential increased erosion. Storm erosion after a 1 m rise in sea-level would probably be sufficient to erode half of Woodbridge Island. Flooding after a storm of the type that occurs once every fifty years would completely swamp the island.

The average price of properties on Woodbridge Island was estimated by estate agents to be R750 000. Assuming that approximately half (or all) of the 350 properties on Woodbridge Island will be affected by the sea-level rise (with storm surge), the total damage would be R131 million (R263 million). Given the uncertainties in the estimates of house prices and exact number of houses affected, one could say that the damage from sea-level rise may be in the order of magnitude of hundreds of millions of rands.

FIGURE 7: **Muizenberg after 1.5m sea-level rise**

b) Muizenberg (False Bay):

False Bay has a developed coastline with some room for manoeuvring coastal buffer zones, being exposed and low-lying, with development close to sandy beaches in many places. A 500 mm rise in sea-level would lead to increased erosion, storm flooding and groundwater flooding in the Fish Hoek, Muizenberg/Sandvlei and Zeekoeivlei areas.

A 1 m rise in sea-level would increase coastal erosion, and put the new mean high-water mark back by about 100 m, beyond the first block of property on the western side of Muizenberg. The average price in Muizenberg for three-bedroomed houses was estimated by estate agents at R285 000, while "big houses" were in the region of R800 000. An average of R500 000 per house appears to be reasonable, given that these are by definition properties close to the beachfront. Estimating approximately forty houses in the flooded area, this would amount to damages of R20 million. This estimate does not add the impacts of a 1.5 m storm surge, which would threaten a much larger area of property, as shown in Figure 7.

4.5.3 Adaptation initiatives

Proposed planning and mitigation measures to manage the potential coastal impacts should include:

1. Development of a **coastal vulnerability map** using geographic information systems (GIS), where sites are assessed according to scale of potential impacts with respect to sea-level rise. A point rating system whereby the vulnerability of sites can be evaluated objectively, should be developed.
2. Draw up a **shoreline management plan** to include the protection of the **ecological water** reserve for estuaries. Ribbon development close to the shore should be avoided, and buffer zones should be maintained.
3. A review of the existing regulations and by-laws, for example more stringent **set-back lines** for developments, could be instituted.
4. Develop a **maintenance and monitoring programme** for existing coastal infrastructure (City of Cape Town, 2003b).
5. Design coastal protection/developments/structures specifically to compensate for the effects of sea-level rise. There are a wide range of **structural mitigation measures** in place to minimise the impact of storm surges and extreme wave action. These include (Holloway, 2005):
   - Breakwaters which provide shelter to boats/ships/vessels at fishing harbours and commercial ports such as Cape Town and Kalk Bay.
   - Revetments and sea walls which protect infrastructure such as housing, promenades, pavements, parking areas, etc. from direct wave action and underscouring, e.g. at Sea Point, Strand, etc.
   - In some instances, roads and railway lines have been located too close to the sea. Their embankments and foundations thus have to be protected by e.g. rock armouring at Clovelly, Hout Bay, etc.

The question arises as to when and to what extent coastal protection measures should be implemented to compensate for a possible future sea-level rise. Economic models have been developed to calculate the optimal height of sea defenses in the case of a sea-level rise, as well as the optimal strategy for heightening of sea defenses in the case of an uncertain sea-level rise (Vrijling & van Beurden, 1990).

4.6 Livelihoods

4.6.1 Background

Livelihoods consist of the bundle of different types of assets, abilities and activities that enable a person or a household to survive (Chambers & Conway G, 1991). These assets include physical assets such as infrastructure and household items; financial assets that include stocks of money, savings and pensions; natural assets that include natural resources; social assets that are based on the cohesiveness of people and societies, and human assets that depend on the status of individuals and can involve education and skills. These assets change over time and are different for different households and communities. The ability to access these assets is a key determinant of sustainability and resilience.

In the context of livelihoods, climate can manifest itself as a shock or a stress (Ziervogel & Calder, 2003). Discrete climate events that are significantly different to the average conditions, such as tropical cyclones, tsunamis, floods or drought, can be classed as shocks. More gradual changes in the climate, such as long-term climate variability or a few months of above or below-normal rainfall, can be classed as stresses. These shocks and stresses fluctuate over space and time, and contribute to patterns of household vulnerability (Francis, 2000). The level of stress or the impact of a shock will also depend on the coping strategies available to the household to respond to or buffer the impact (Blaikie et al., 1994; Bohle et al., 1994; Carney, 1998).

4.6.2 Impacts and vulnerabilities

A range of hazards associated with climate change may affect the livelihoods of people living in the city. These range from the prospect of increasingly poor health which could result from increased air pollution (the projected increase in the number of inversions will trap pollutants in the atmosphere close to the ground), heat stress (the number of very hot days may increase) and the possibility of increased flooding (rainfall events may become fewer but heavier) (Midgley et al., 2005).

Economic sectors such as insurance, banks (through the underlying secured assets), transport and communication infrastructure and construction may all be affected to some degree by climate change.

The livelihoods of people who may be most severely affected, are those whose asset bases (homes, household items, money, pensions, savings, natural assets, social assets (e.g. support networks) and food security are damaged or destroyed. The first people to suffer these consequences are the poor, who are usually constrained to live in risk-prone areas.

It might be challenging for the City to address livelihoods *per se*. What is important, is that when certain sectors target the vulnerable, they recognise the multi-faceted nature of the livelihoods of people whom they are targeting. For example, informal settlement dwellers might be vulnerable to climate variability and extremes. The poor physical and social conditions make these settlements particularly vulnerably to the negative impact of physical hazards (United Nations Environment Programme (UNEP), 2002). If there is an increase in intensity of heavy rainfall events in the Western Cape, particularly in late summer, this could lead to increased flooding. In Cape Town many of the informal settlements are situated on the Cape Flats, where the high water table and inadequate infrastructure make them particularly vulnerable to flooding. The quality of housing in informal settlements is often poor and therefore easily washed away during floods, and people's access to the range of services is more limited than that of people in formal housing areas, making them more vulnerable to the climate impacts (Moser, 1998). If there is flooding the dirt roads usually found in informal settlements may wash away which reduces access to areas; sewage and storm-water infrastructure may be poor, and stagnant pools of water can lead to disease outbreaks. The post-event trauma is very costly and requires large amounts of time and money to address.

An increase in temperature is also of great significance in informal settlements as it could be linked to increased fires. There are two main forms of fires in informal settlements: large fires destroying many dwellings, and smaller ones affecting a few people but still leading to livelihood loss (Napier & Rubin, 2002). One of the reasons for the high frequency of fires is the housing density found in informal settlements. An holistic approach to adapting to an increased fire risk would therefore have to focus on livelihood options as well as housing policy, and how informal settlements will be developed at the same time as acknowledging the impact of increased temperature.

It is important to assess people's access to resources within informal areas to enable them to cope with and adapt to the shock of having their home washed away or burnt down. Access to finance or social networks is often important. In the City of Cape Town there are many people who originally come from other countries or provinces. This can limit the social networks to which people have access, particularly when needed during disasters. Access to finance is also important as a means to recover from shock. In the informal areas unemployment is particularly high and levels of income low. It is important to note that the source of employment for people might also be impacted by climate variability. Formal employment may not be directly linked to climate, but may have indirect links where climate extremes might cause working hours to be disrupted or might increase costs, which could lead to job losses. Informal activities can also be affected by climate. Informal traders may not be able to access trading areas if they are flooded, or they may have to pay higher prices for agricultural produce if there is a drought. It is these linkages across all aspects of the livelihoods of those in informal settlements that make them particularly vulnerable to climate impacts. Adaptation therefore has to focus on the nature of vulnerability, and should follow an integrated approach.

4.6.3 Adaptation initiatives

1. An **assessment of livelihoods** underpinned by threatened natural resources would usefully guide policy to improve adaptive capacity at the individual and household level and at City level, where it supports the most vulnerable.
2. Improved **management and eventual elimination of informal settlements**, electrification and improved public transport in urban areas will reduce local pollution levels and improve the quality of life of the poor, and will reduce their vulnerability to extreme climate events.
3. Improved **information and data gathering** and use is one way of adapting to change. The MANDISA database, managed by the Disaster Management for Sustainable Livelihoods Programme, University of Cape Town, has a record of informal settlement fires in the Cape Town Metropolitan area (DiMP, 2004). This helps to show the trends in fire events, and where they are occurring. This type of information system needs to be integrated into management and response strategies at the same time as integrating with other information systems. This enables holistic management, which reduces vulnerability and risk.

4. **Response strategies** need to be broadened to include adaptation strategies, which reduce the need for emergency response and anticipate projected climatic change. For example, on 15 and 16 January 2005 large fires in Langa/Joe Slovo left 12 000 people homeless. The Mayor's office issued a statement (City of Cape Town, 2005a) outlining how they would deal with it: emergency shelter and meals, followed by prefabricated fire-resistant structures and more formal housing in the long term. The strategy shows that there are disaster response and risk reduction measures in place, but it is critical that the victims are consulted and the broader impact on livelihoods understood.

4.7 Health (with a specific focus on air pollution)

4.7.1 Background

Climate can affect human health in three ways (IPCC, 2001b). Firstly, there are direct health impacts, which are usually caused by extreme weather events, such as tsunamis, flooding and heat waves. Secondly, processes of environmental change and ecological disruption that occur in response to climate change can have health consequences. And lastly there are those with diverse health consequences, including traumatic, infectious, nutritional, psychological and other, which occur in vulnerable populations in the wake of climate-induced economic dislocation and environmental decline.

4.7.2 Impacts and vulnerabilities

Insufficient research has been done to fully understand what health effects a change in temperature and rainfall would have in the Western Cape, although it is clear that air pollution could be an appropriate initial focus. Warmer average temperatures combined with a change in precipitation can alter the pattern of exposure to temperature extremes and resultant health impacts, in both summer and winter. This is of particular importance for people living in informal housing, where there is little insulation. Infectious diseases that include vector-borne infections such as malaria and dengue fever are linked to one of the most detectable changes in human health (World Health Organisation (WHO), 2003). In the Western Cape this is not a key concern, although the range of malaria could spread southwards in future and should not be ignored. It should be noted that food-borne infections (e.g. salmonellosis) have been known to peak in warmer months.

An increase in extreme events is an important consideration as it increases exposure to the hazard. Flooding is a key concern in the Western Cape, because there are many vulnerable groups living on or near the poverty line and that are susceptible to flooding because of the high water table in the Cape Flats area. Flooding often stresses sewage and stormwater systems, and can lead to water pollution associated with excessive levels of micro-organisms and the subsequent increase in water-borne diseases which manifests as diarrhoea and dehydration. The impacts can be widespread and are particularly important to monitor for children's health, as they can lead to death if there is not adequate health care. The World Health Organisation estimated that climate change was responsible for approximately 2.4% of worldwide diarrhoea in 2000 (WHO, 2002). Flooding can also lead to loss of human life.

It is highly likely that flooding will continue and possibly increase in frequency, as rainfall is likely to become more intense. The clear demand for disaster assistance when intense rainfall occurs in the Western Cape, suggests that the current system is not adequately equipped to deal with flooding. An increase in flooding would place an increased burden on flood response and the associated health stress. The Directorate of Pollution and Waste Management is responsible for ensuring that pollution is managed as best as possible, and the Directorate of Environmental Management is responsible for managing situations that are conducive to diarrhoea, cholera and tuberculosis. They therefore need to address the risk of increased flooding.

Food security is both directly and indirectly related to climate variability. It is particularly important that food security is monitored, given the numbers of HIV/AIDS infected people in the Western Cape that are more susceptible to malnutrition and opportunistic infections.

Increased health impacts can affect the social system. Increased mortality and increased deaths can have a direct burden on the health system. Increased morbidity can impact on treatment costs (direct cost) and days of work lost (indirect cost) (Turpie et al., 2002). The value of the loss of human life is hard to quantify, but impacts at many levels. An increase in disease associated with climate change can therefore have widespread economic and health costs.

Air pollution

In Cape Town, one of the most urgent health threats from climate change is air pollution. This has historically been a minor problem due to the frequency of the south-easterly winds in summer and frequent rain events in winter. As the amount of industry has grown, various hot-spots have been identified, such as central Cape Town, and high-polluting sources such as the power station and other light industries were shut down or moved away. The rapid growth of motor vehicle transport in the city has changed the spatial nature of the pollutants. Over 500 000 commuters from all over the Peninsula drive to and from work every day. Most of them use buses or private vehicles. Every day approximately 15 000 tons of industrial and domestic by-products, e.g. CO_2, SO_2, NO_2 and PM_{10} are emitted into Cape Town's atmosphere (Wicking-Baird et al., 1997).

Pollution becomes a problem when it is visible or begins to affect human health. For example, during "brown haze" episodes, the build-up of photochemical smog reduces visibility, and is undesirable from both a health and aesthetic standpoint. Brown haze episodes occur frequently when a temperature inversion exists over the city. Exceedances of the accepted international standards for pollutants are found to occur during the brown haze days.

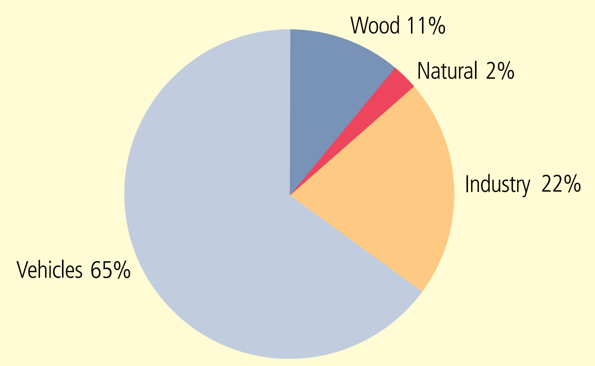


Figure 8: **Contributors to poor air quality in CCT**

Climate change projections indicate two trends: firstly, a reduction in the number of days on which it rains, and secondly an increase in the number of days with a temperature inversion. Both of these trends will increase the frequency of brown haze days. Inversion frequencies are higher in drier winters, and with a doubling of CO_2 are expected to increase by 25% (Shannon & Hewitson, 1996). The annual average of exceedance days from 2001-2004 was 117 days. In 2003 (a particularly dry year) 162 brown haze days occurred where pollutant levels exceeded international guidelines (City of Cape Town, 2005d). This may be due to different measurement standards.

Of the pollutants, particulate matter poses the most serious health risk as it can penetrate deep into the lungs and has been linked to respiratory problems and cancer (Kinney, 1999). Since 2002 concentrations of PM10 in Khayelitsha have consistently exceeded guidelines during winter.

Assuming "business as usual", it was estimated that health effects due to exposure to ambient pollutant concentrations resulting from burning emissions, will increase during the next decade in the range of 3-22% for Cape Town (Scorgie & Watson, 2004). From the current trends and forecasts it can be assumed that climate change will lead to an increase of 5-10% in inversions over the next fifty years, which in turn will lead to 5-10% more brown haze days or pollution episodes.

4.7.3 Adaptation initiatives

Health adaptations

- **Increased awareness** of how to manage heat-related stress and other climate-related illnesses
- **Improved construction and regulations for building** informal housing in order to minimise health impacts of poor living conditions
- **Increased support for public health facilities** in dealing with diarrhoea and dehydration
- **Improved sanitation** in informal settlements

Air pollution adaptations

The key strategy for the City of Cape Town to reduce the brown haze, is the **reduction of greenhouse gas emissions**. This has been prioritised by the City of Cape Town, as is evident from the recently drafted Energy and Climate Change Strategy for the City (City of Cape Town, 2006b).

Several other recommendations have also been made (Wicking-Baird et al., 1997):

- Enforce the diesel black smoke legislation.
- Introduce measures to reduce the number of smoking petrol vehicles.
- Enforce the industrial black smoke legislation.
- Initiate discussions with the oil industry about the potential benefits from fuel reformulation.
- Initiate the upgrading of air pollution control capacity in the Cape Metropolitan Council.
- Initiate the development of an air quality management system for Cape Town.
- Existing national air pollution legislation should be re-assessed, as much of it is outdated.
- Human resources at the Air Pollution Division should be increased.
- Adequately qualified and experienced human resources should be obtained.
- The necessary budget should be allocated for facilities to test and monitor emissions.
- The Air Pollution Division should be given sufficient power to be able to enforce standards and have a say in metropolitan planning.

5

Towards the integration of adaptation initiatives

5.1 Within the City of Cape Town

One of the first steps towards developing a City Adaptation Plan of Action (CAPA) would be to consolidate and integrate existing adaptation initiatives. This report goes some way to achieving this, but through a stakeholder consultation process, additional initiatives will be identified. Linkages and integration with the City's Biodiversity and Coastal Zone Management strategies are of the utmost importance to avoid duplication and to work within budgetary and capacity constraints.

5.2 Within national and provincial government initiatives

In developing its climate change adaptation strategy, the City of Cape Town should liaise directly with the Western Cape Provincial Department of Environmental Affairs and Development Planning, who has recently put out a call for the development of "A Western Cape Climate Change Response Strategy and Action Plan". This plan would have specific overlaps with a CAPA, specifically in sectors such as water resources, coastal zone management, environment, health and livelihoods. Strategies developed by these spheres of government should be complementary and co-operative.

Furthermore, the recently initiated "Integrated Approach to the Developmental Challenges of Cape Town" should be engaged. The Intergovernmental Task Team identified that critical, economic, social and ecological challenges can only be effectively addressed on a regional scale (Intergovernmental Integrated Development Task Team for the Cape Town Functional Region, 2006).

In order to fulfil its legal obligations in terms of the National Disaster Management Act, and to minimise the likelihood of development-undermining, disaster-related hardship and loss, the City of Cape Town should do the following (Holloway, 2005):

1. **Examine the requirements of the Disaster Management Act and National Disaster Management Framework** in order to define the City's role and responsibility in implementing the Act. This includes the development of an **appropriate disaster management plan**. The implementation requirements of the Act state that these steps should have been undertaken **before 1 April 2006**.
2. Team up with key role-players in the province, other municipal departments, the private sector and research entities to develop a **robust infrastructure risk assessment planning and implementation methodology** to determine the relative benefits of risk-proofing infrastructure.
3. Collaboratively initiate with other key municipal departments and the province a **systematic disaster risk assessment of critical public infrastructure** to identify critical protective and enabling provincial and municipal infrastructure with high-risk potentials.
4. Investigate and implement strategies **to risk-proof existing high-risk public infrastructure** within the CCT and incorporate risk-proofing where applicable as a critical component of future infrastructure development.

Further, the City of Cape Town should liaise with the proposed Provincial Strategic Infrastructure Project. This project will be implemented as a research and development undertaking to build the resilience and sustainability of critical public infrastructure as well as those that protect the well-being and assets of poor households. It will result in an amended methodology for infrastructure assessment and planning, that will incorporate expected exposure to future risks, including those triggered by extreme weather and climate variability. One of the case studies will be a low-income suburb within the City, which contains mixed formal and informal infrastructure, and which has sustained recorded recurrent infrastructure losses due to flooding and fires (Holloway, 2005).

5.3 Within national parks

The City of Cape Town has a National Park within its boundaries, and issues such as biodiversity, fires and coastal zone management should be integrated and co-ordinated between the City and the Cape Peninsula National Park.

6

Recommendations – The way forward

This report presents an initial, broad overview of the problem posed by projected climate change, and requires further attention to detail in many areas before clear adaptive strategies can be developed. Further focused study is required, mainly to reduce uncertainties in many areas relating to the climate projections themselves, and of inferences from impacts and sectoral vulnerabilities (especially water, urban development, environment, health and livelihoods). More detailed assessments of the vulnerability of key threatened areas, together with likely timelines of impacts should be undertaken.

In order to properly and comprehensively address the potential impacts of projected climate change, a Framework for Adaptation to Climate Change in the City of Cape Town (FAC^{4}T) has been presented in this report (Section 2). The adoption and implementation of this framework by the City of Cape Town will lead to the development of a City Adaptation Action Plan (CAPA), which will result in the implementation of adaptation initiatives to minimise the vulnerability to climate impacts. These initiatives are not only in response to projected climate impacts, but will also ensure some resilience to current climate variability.

Notwithstanding this cautious approach, adaptation strategies for the identified sectors have been proposed that may alleviate or avoid the worst effects of climate change. These are initiatives which each sector could begin to consider as a starting point towards the development of a CAPA.

References

ARUP 2002. Berg Water Project – Background Information.

BKS (Pty) Ltd., 2003a. Berg Water Management Area. Overview of the Water Resources Availability and Utilisation, DWAF. P WMA 19/000/00/0203.

BKS (Pty) Ltd., 2003b. Breede Water Management Area. Overview of the Water Resources Availability and Utilisation, DWAF. P WMA 18/000/00/0203.

Blaikie P, Cannon T, Davis I & Wisner B, 1994. At Risk – Natural Hazards, People's Vulnerability, and Disasters. London, Routledge.

Bohle HG, Downing T & Watts J, 1994. Climate Change and Social Vulnerability. Global Environmental Change 4: 37-48.

Carney D, 1998. Approaches to Sustainable Livelihoods for the Rural Poor. Overseas Development Institute (ODI) Poverty Briefing.

Chambers R & Conway G, 1991. Sustainable Rural Livelihoods: Practical Concepts for the 21st Century, IDS Discussion Paper 296.

City of Cape Town 2003a. Biodiversity Strategy.

City of Cape Town 2003b. Coastal Zone Management Strategy.

City of Cape Town 2005a. http://www.capetown.gov.za/clusters/viewarticle3.asp? conid=10080.

City of Cape Town 2005b. Annual Report 2004/2005.

City of Cape Town 2005c. Cape Town Announces Strategies to Ensure Future Water Supply. Cape Gateway. 15 Sept 2005.

City of Cape Town 2005d. Draft Air Quality Plan. City Health Directorate – Air Pollution Control Section.

City of Cape Town 2006a. Draft Water Services Development Plan 2006/07. 8 February 2006.

City of Cape Town 2006b. Energy and Climate Change Strategy.

City of Cape Town 2006c. Weekly Dam Levels. http://www.capetown.gov.za/water/waterresources.asp 9/5/2006,

Department of Environmental Affairs and Tourism (DEAT), 2004. A National Climate Change Response Strategy for South Africa. Pretoria. September 2004.

Disaster Mitigation for Sustainable Livelihoods Programme (DiMP), 2000. Draft Risk and Vulnerability Assessment for the Western Cape, Commissioned by the Department of Local Government, Province of the Western Cape.

DiMP 2004. Report on Informal Settlement Fire Occurrence and Loss: Cape Town Metropolitan Area 1995-1999, unpublished.

Driver M, Smith T & Maze K, 2005. Specialist Review Paper on Biodiversity for the National Strategy for Sustainable Development, South African National Biodiversity Institute.

Department of Water Affairs and Forestry (DWAF), 1994. Water Supply and Sanitation Policy – White Paper. Water – An Indivisible National Asset. Cape Town. November 1994.

Department of Water Affairs and Forestry (DWAF), 2004. National Water Resource Strategy. First Edition. September 2004.

Francis E, 2000. Making a Living: Changing Livelihoods in Rural Africa. London, Routledge.

Geustyn Loubser Streicher & Palmer Development Group, 2001. Water Services Development Plan, City of Cape Town.

Hewitson B, Tadross M & Jack C, 2005. Scenarios from the University of Cape Town. In:Schulze RE (Ed.) Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation. Pretoria, Water Research Commission. WRC Report 1430/1/05: Chapter 3, p39-p56.

Hewitson BC & Crane RG, 2005. Consensus between GCM Climate Change Projections with Empirical Downscaling. Submitted to International Journal of Climatology.

Holloway A, 2005. Risk Reduction and Emergency Management Component, Strategic Infrastructure Plan, Province of the Western Cape: Second Draft. DiMP, UCT. 5 December 2005.

Hughes P, 1992. The Impacts of Sea-level Rise on the South African Coastal Environment. PhD Thesis. Department of Oceanography, University of Cape Town.

Intergovernmental Integrated Development Task Team for the Cape Town Functional Region 2006. A Proposed Agenda for Action: An Intergovernmental Approach to the Development Challenges of Cape Town. South African Government, Western Cape Provincial Government & City of Cape Town. 28 February 2006.

Intergovernmental Panel on Climate Change (IPCC), 2001a. Climate change 2001: Synthesis report. A contribution of Working Groups I, II and III to the Third Assessment Report of the Intergovernment Panel on Climate Change. [Watson RT and the Core Writing Team (eds)]. Cambridge, Cambridge University Press: 398.

Intergovernmental Panel on Climate Change (IPCC), 2001b. Climate Change 2001: IPCC Third Assessment Report. IPCC Secretariat.

Kinney PL, 1999. The Pulmonary Effects of Ozone and Particle Poluttion. Respiratory and Critical Care Medicine, Thieme Medical Publishers, New York. pp. 601-607.

Lim B, Spanger-Siegfried E, Burton I, Malone E & Huq S, 2005. Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures. Cambridge University Press, UNDP.

Midgley GF, Chapman RA, Hewitson B, Johnston P, De Wit M, Ziervogel G, Mukheibir P, Van Niekerk L, Tadross M, Van Wilgen B W, Kgope B, Morant P, Theron A, Scholes RJ & Forsyth GG, 2005. A Status Quo, Vulnerability and Adaptation Assessment of the Physical and Socio-Economic Effects of Climate Change in the Western Cape, Report to the Western Cape Government, Cape Town, South Africa. Report No. ENV-S-C 2005-073. Stellenbosch, CSIR.

Munasinghe, M. 1992. Environmental Economics and Sustainable Development. Paper presented at the UN Earth Summit, Rio de Janeiro, Brazil, and reproduced as Environment Paper No. 3, World Bank, Washington DC, USA.

Munasinghe Institute for Development (MIND), 2005.

Moser CON, 1998. The asset vulnerability framework: Reassessing Urban Poverty Reduction Strategies. World Development 26 (1).

Munasinghe, 1992 1994, 1997,2002a,2002b, 2005

Napier M & Rubin M, 2002. Managing Environmental and Disaster Risks Affecting Informal Settlements: Lessons in Innovative Practice from South African Local Authorities. <http://www.livelihoods.org/lessons/project_summaries/urban4_projsum.html>. 20 May 2005,

Schulze & Perks, 2000. R.E. Schulze and L.A. Perks, Assessment of the Impact of Climate Change on Hydrology and Water Resources in South Africa, Report to South African Country Studies for Climate Change Programme, School of Bioresources Engineering and Environmental Hydrology, University of Natal, Pietermaritzburg, 2000.

Scorgie Y & Watson R, 2004. Updated Air Quality Situation Assessment for the City of Cape Town. Report No.: APP/04/CCT-02.

Scott DF, Versfeld DB & Lesch W, 1998. Erosion and Sediment Yield in Relation to Afforestation and Fire in the Mountains of the Western Cape Province, South Africa. South African Geographical Journal 80: 52-59.

Shannon D & Hewitson B, 1996. Cross-scale Relationships Regarding Local Temperature Inversions at Cape Town and Global Climate Change Implications. South African Journal of Science 92:4: 213-216.

Tadross M, 2006. Personal Communication. June 2006.

Tadross M, Jack C & Hewitson B, 2005. On RCM-based Projections of Change in Southern African Summer Climate. Pending.

Turpie J, Winkler H, Spalding-Fecher R & Midgley GF, 2002. Economic Impacts of Climate Change in South Africa: A Preliminary Analysis of Unmitigated Damage Costs. Cape Town, Southern Waters Ecological Research & Consulting and Energy & Development Research Centre. December.

United Nations Environment Programme (UNEP), 2002. Africa Environment Outlook: Past, Present and Future Perspectives, UNEP.

Van Wilgen BW, Bond WJ & Richardson DM, 1992. Ecosystem Management. The Ecology of Fynbos: Nutients, Fire and Diversity. Cape Town, Oxford University Press.

Van Wilgen BW, Little PR, Chapman RA, Gorgens AHM, Willems T & Marais C, 1997. The Sustainable Development of Water Resources: History, Financial Costs and Benefits of Alien Plant Control Programmes. South African Journal of Science 93: 404 – 411.

Vrijling J A & van Beurden, 1990. Sea-level Rise: A Probabilistic Design Problem. International Conference on Coastal Engineering, Delft.

Water Corporation 2006. Perth Seawater Desalination Project. http://www.watercorporation.com.au/water/water_sources_desalination.cfm. May 2006.

World Health Organisation (WHO), 2002. World Health Report 2002: Reducing Risks, Promoting Healthy Life. Geneva, WHO.

World Health Organisation (WHO), 2003. Climate Change and Human Health – Risks and Responses. Summary. Geneva, WHO.

Wicking-Baird M C, Dutkiewitz R K & De Villiers M, 1997. Cape Town Brown Haze Study. Report No. GEN 182. Cape Town, Energy Research Institute, University of Cape Town.

Ziervogel G & Calder R, 2003. Climate Variability and Rural Livelihoods: Assessing the Impact of Seasonal Climate Forecasts. Area 35. 4: 403-417.

Appendix A

Vulnerability and adaptation assessment methodologies

Multi-criterion analysis

Summary:

Scoring and weighting of options using indicators and more than one decision criteria

Description:

Multi-criterion analysis (MCA) enables options to be evaluated using a range of criterion that includes unquantifiable analysis, especially when distributional implications need to be considered. The purpose of using MCA is to aid decision-making rather than to evaluate options in monetary terms. It is useful for assessing options for adapting to climate change as there are many factors that need to be considered including equity, efficiency, short or long-term benefits as well as many other non-monetary factors.

Method:

In order to undertake MCA, the following steps should be completed:

1. Clarify decision context
2. Identification of objectives
3. Options for reaching objectives
4. Criteria to evaluate options
5. Analysis of options
6. Analysis of results
7. Evaluation and feedback

In the first case the decision should be clarified and the potential options identified. In order to choose an option, criteria should be established by which to evaluate each of the options. It is important to note that the criteria can be both qualitative and quantitative. A criterion can be seen as a "standard" or "indicator". It is important that the criteria are relevant to the decision context, and that they are sensitive to the cultural, social and economic factors for each country or area for which adaptation options are being considered. The criteria often relate to advantages or disadvantages, whether quantitative or qualitative. In the context of climate change, the options might be assessed in terms of their ability to decrease the risk of climate change impacts, and the contribution to sustainable development. The options can be entered into a matrix, whereafter each option can be assessed based on a range of criteria. A score may be used to evaluate each option, or absolute units might be used (such as cost or number of people affected). Each criteria can have a different unit. All the units are then standardised by interpolating and ranking, e.g. from 0 to 100, increasing for benefits. The scores can then be averaged and the options ranked. The criteria can also be weighted if some are seen as more important than others.

Example:

MCA example from NAPA guidelines: Cape Verde

In Cape Verde, among the poverty alleviation (PRSP) objectives proposed, the creation of opportunities for increasing income through sustained economic growth, as well as for improving the living standards of the local populations constitute major strategic orientations. Poor, economically and socially vulnerable populations currently represent a third of the total Cape Verdean population, whereas ten years ago 15% of the population were considered very poor.

Exploration of livelihood exposure and sensitivity to climatic hazards identified the following clusters as the principal concerns:

- Coastal, traditional fishing communities exposed to coastal storms, sea-level rise and coastal erosion – small-scale agriculturalists exposed to drought
- Urban poor exposed to drought, intense rainfall and flooding

Also of concern, but somewhat lower in priority (in this hypothetical example) might be:

- Critical sectoral infrastructure, such as bridges between ports and agricultural areas
- Sensitive ecosystems, such as coastal wetlands, that provide services for priority economic activities

The following preliminary list might provide potential interventions options:

Option 1:
Developing fodder crop cultivation in areas with the least agricultural potential.

Option 2:
Developing intensive livestock farming (especially goats) in arid zones.

Option 3:
Building reservoirs to capture and channel excess superficial water runoff from rainfall.

Option 4:
Introducing drip-irrigation, particularly in horticulture.

Option 5:
Developing more resilient crop species.

Option 6:
Developing chemical fertilisers for use in combination with organic manure.

Option 7:
Developing a joint management system for forest resources.

Option 8:
Developing renewable energy resources and Liquefied Propane Gas (LPG).

Option 9:
Protecting the industrial and tourist complexes of Sao Vicente in the Santa Maria Bay.

Option 10:
Rationalising sand and gravel extraction.

Obviously, not all of these options can be implemented due to financial constraints and/or lack of capacity to take on the activities. Some of them may be discarded or amended. Options are selected based on certain criteria. The different criteria are not all expressed in the same unit of measure. Some are expressed in absolute values, but not necessarily in the same units (costs, rates etc.), whilst others are awarded scores. Binary choices (such as yes or no) are also possible, as well as a variety of different scoring scales. Thus, the values must now be standardised; i.e., expressed in one common unit according to one common scale. This standardisation is done by plotting each criterion value on an axis (linear interpolation), ranging from 0 to 1, or from 0 to 100, increasing in value when it concerns "benefits" (advantages) and decreasing in value based upon the cost criterion (disadvantages). This standardisation process is then undertaken for all options and criteria, thereby clearly showing the most suitable option to follow.

References:

Eder G,Duckstein L and Nachtnebel HP
"Ranking Water Resources Projects and Evaluating Criteria by Multicriterion Q-Analysis: An Austrian Case Study", J. of Multi-Criteria Decision Analysis, 6 (5): 259-271, 1997.

Raju KS and Pillai CRS
1999. Multicriterion decision making in river basin planning and development. European Journal of Operational Research, 112:249-257.

Tecle A and Duckstein L
"Concepts of Multicriterion Decision-Making." In: H.P. Nachtnebel (Ed.): Decision Support Systems in Water Resources Management, Chapter 3, pp. 33-62, UNESCO Press, Paris, 1994.

Links:

Presentation of Approaches to Prioritising Adaptation Option:
http://www.unitar.org/ccp/samoa/boschkhan.pdf

Example of Flood Risk
http://www.waterbouw.tudelft.nl/public/gelder/paper137a-0853.pdf

Example of Prioritising Uganda's Parks for Ecotourism
http://www.rri.wvu.edu/pdffiles/bukenya2012.pdf

Appendix B

Action impact matrix (AIM): Application to climate change adaptations

Introduction:

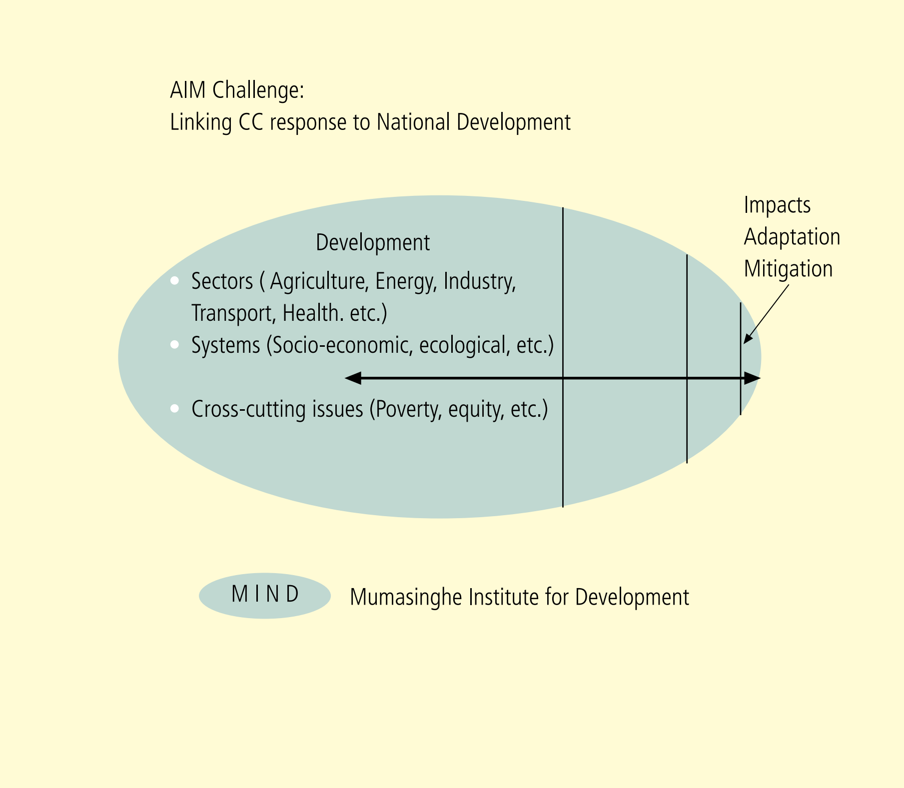


Figure 1: **AIM challenge: Linking CC response to national development**

Decision-makers normally focus their attention on conventional development strategies like growth and poverty alleviation. As shown in Figure 1 above, sustainable development (SD) is considered a special (and rather obscure) subset of conventional development. The environment is only one aspect of SD, and finally climate change (including adaptation and mitigation or AM) is in itself seen as a minor subset of the environment.

Need for action impact matrix (AIM) based approach

Climate change adaptation measures must ultimately be implemented by nations, and will receive attention from decision-makers only if they are successfully integrated into a national sustainable development (SD) strategy. To facilitate this process, this guide describes how we use the Action Impact Matrix (AIM) as a strategic tool to better understand interactions among three key elements at the country-specific level:

a) national development policies and goals;

b) key vulnerability areas (VA) – economic sectors, ecological systems, etc.; and

c) climate change adaptation.

Firstly, the two-way linkages between elements (a) and (b) are explored in the context of natural climate variability. Then we impose the additional impacts of element (c) on the interactions between elements (a) and (b).

The AIM approach analyses key economic-environmental-social interactions to identify potential barriers to making development more sustainable (MDMS) – including climate change. It also helps to determine the priority macro policies and strategies in economic, environmental and social spheres that facilitate the implementation of climate change adaptation and mitigation to overcome the effects of climate change. Such a matrix therefore helps to promote an integrated view, meshing both development decisions and climate change effects.

The AIM methodology consists of the following key steps (see Figure 2):

a) Determine the most important national goals and policies.
b) Determine critically vulnerable areas (VA) relevant to climate change.
c) Incorporating climate change into the AIM.
d) Determine status of VA subject to only natural climate variability.
e) Determine impacts of climate change on VA (Impact 1 in Figure 2).
f) Identify how development goals/policies might affect VA (Effect 2 in Figure 2).
g) Identify how VA might affect development goals/policies (Effect 3 in Figure 2).
h) Prioritise most important interactions, and determine appropriate remedial policies and measures.
i) Perform more detailed studies and analysis of key interactions and policy options identified in Step f) above.
j) Update and refine Steps c) to f) above.

Two matrices are derived as shown in Figure 2:

1. DEV – development effects on VA (effect 2 + impact 1)
2. VED – VA effects on development (effect 3 + impact 1)

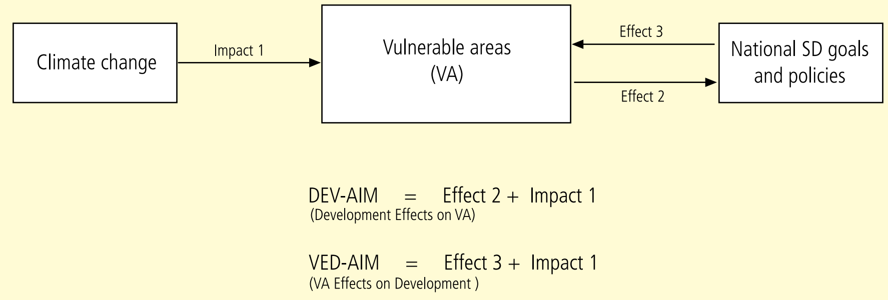


Figure 2: **Interaction between climate change, vulnerable areas and development, showing derivation of DEV and VED Action Impact Matrices**

The preliminary matrices identify broad relationships, provide a qualitative idea of the magnitudes of the key interactions, help to prioritise the most important links, and facilitate integration of climate change adaptation responses within the overall national sustainable development strategy.

The AIM methodology relies on a fully participative stakeholder exercise to generate the AIM itself. Up to 35 experts are drawn from government, academia, civil society and the private sector, who represent various disciplines and sectors relevant to both sustainable development and climate change. In the initial exercise, they usually interact intensively over a period of about two days to build a preliminary AIM. This participative process is as important as the product (i.e. the AIM), since important synergies and cooperative team-building activities emerge. The collaboration helps participants to better understand opposing viewpoints, resolves conflicts, and ultimately facilitates implementation of agreed policy remedies. On subsequent occasions, the updating or fine-tuning of the initial AIM can be done within a few hours by the same group, since they are already conversant with the methodology.

Action impact matrix (AIM) methodology and applications

The AIM is a strategic tool policy analysis which helps to study the inter-linkages among seemingly independent elements, such as for example macro-economic policies, key vulnerability areas (VA) and climate change.

At national level the linkage may be made in two complementary and interlinked ways:

a) Upward link: Where vulnerable areas are embedded in the macro-level national development strategy of a country via the medium to long-term sustainable development path, including building-up of adaptive capacity.

b) Downward link: Where vulnerable areas are integrated into the subnational-level development strategy in the short- to medium-term, by carrying out sustainable development assessments aimed at making specific projects and policies more sustainable.

The AIM has been widely used since the early 1990s, and originally was presented as part of the Sustainomics Methodological Framework, at the 1992 Rio Earth Summit – see Annex 1 (Munasinghe, 1992). Initially, it was used in Brazil, Chile, Ghana, Philippines and Sri Lanka to integrate a range of environmental concerns into development planning (Munasinghe, 1994, 1997, 2002a, 2005). Subsequently, expanding and “adapting” the AIM approach to address ecosystem-SD interactions, was a logical next step (Munasinghe 2002b; MIND 2005, URL: www.mindlanka.org).

The AIM approach may be used to better understand two-way interactions between (a) development policies and goals; and (b) key vulnerable areas relevant to climate change. Firstly, the effects of development policies and goals on vulnerable areas are explored, and then the reverse effects of vulnerable areas on sustainable development prospects are identified. The AIM cells provide a qualitative idea of the magnitude of the row-column interactions, so that appropriate policy interventions could be formulated. Each AIM exercise would require two matrices in order to look at linkages flowing both ways (i.e. impacts of columns on rows, and vice versa).

The AIM approach analyses key economic-environmental-social interactions to identify potential barriers to making development more sustainable (MDMS), including progressive degradation of already vulnerable areas. It also helps to determine the priority strategies, policies and projects in the economic, environmental and social spheres that facilitate implementation of measures to manage vulnerable areas, and restore damaged ecosystem services. After completing a national level AIM exercise, it is possible to apply the process at a regional or community level to fine-tune the analysis.

A national-level AIM is generated through a fully participative, consensus-building stakeholder exercise involving ten to fifty experts drawn from government, academia, civil society and the private sector, who represent various disciplines and sectors relevant to both sustainable development and climate change. In the initial exercise, they usually interact intensively over a period of about two days, to build a preliminary AIM. This participative process is as important as the product (i.e. the AIM), since important synergies and cooperative team-building activities emerge. The transparent stakeholder collaboration helps participants to better understand opposing viewpoints, and resolves conflicts. It promotes cooperation and ownership across decision-making agencies, and ultimately facilitates implementation of agreed policy remedies.

Appendix C

SouthSouthNorth (SSN) adaptation project protocol methodology

Based on the SSN project experience, a specific methodology is proposed to achieve the outputs as stated above:

1. Identify the "hotspots" where interventions will be undertaken, will include the use of the following parameters:

Disaggregating Parameters for Analysis

- **Climate change: Top-down**
  - i. UNFCC reports
  - ii. IPCC third assessment reports
  - iii. Regional-level impact assessment reports
  - iv. Country-level impacts, Vulnerability and adaptation assessment report
  - v. National development plans
- **Vulnerability and adaptation: Vulnerability to climate (variability and shocks)**
  - i. Erratic behaviour of climate (rainfall and temperature), and shocks (flood, drought, cyclone and storm surges, heat stress), etc.
  - ii. Climate change vulnerability, if available
  - iii. Adaptation to current and past climate variability and shocks
  - iv. Existing indigenous and endogenous coping strategies and mechanisms
- **Poverty**
  - i. Existing poverty mapping (national, sub-national, etc.)
  - ii. Disaggregated poverty analysis (social and occupational)
  - iii. Poor people living in climate-vulnerable areas
- **Poverty Reduction**
  - i. Ongoing development activities related to direct poverty reduction (national, sub-national, local and community level)
- **Project**
  - i. Community-based

2. Undertake institutional mapping affecting development within the identified "hotspot" near the project boundary and/or "hot spot", i.e. identification of and linkages between other existing institutions which are undertaking development work in the identified area

3. Institution selection: Identify the key potential project practitioner partner (using the SSN Eligibility Criteria for selecting partner institutions as a guideline; SSN in country implementing agencies to change as required) who will undertake the project on the ground

i Describe the institutional relationships:

1. Relationship with climate focal point in country/countries of operation?
2. What is the existing basis of trust with SSN, its constituent organisations or individuals?
3. Is the institution part of a community/network dealing with the environment?

Other institutions to answer:

4. What do other institutions in the sector say about the institution being considered?
5. Is the institution likely to deliver on the project requirements?

ii Institutional capacity

1. Does the institution have the appropriate capacity to undertake the work? (Are there technical specialists associated with institutions?)
2. Is the institution networked with local capacity to do the work?
3. Does the institution have the capacity to raise extra funding to do the work?
4. What is the institution's history of undertaking similar work?
5. What is the institution's ability to manage finance (manage project finance and understand development finance)?
6. What is the ability of the institution to manage contractors?
7. Does the institution have the ability to focus on work for a prolonged period?
8. What type of institution (private commercial, NGO, private, not-for-profit, academic, parastatal, government agency, new institution dedicated)?
9. Do environment and development (adaptation) constitute core business of the institution?
10. Can the institution be considered an applied research development agency (not advocacy, research, or policy)?
11. Is the institution likely to become a champion in adaptation?
12. Is the institution mature?
13. Is the institution's leadership capacity over-subscribed?
14. Is the institution a DGIS partnership/DGIS/NCAP/Dutch-funded or an international NGO?

4. **Undertake project selection with the project practioner:**

Basic parameters for project selection include the following key activities:

Selected Climate Change Adaptation Project Activities should clearly:

- indicate a relationship between direct poverty reduction and climate change;
- illustrate a clear project boundary;
- illustrate additionality i.e. an intervention due to climate change should be highlighted and the project owner should illustrate that the climate change intervention would not have happened in a business-as-usual environment (baseline for the project activity);
- have a linkage to an organised community, where a project owner/or beneficiary and other stakeholders are part of the project development and project implementation process;
- be able to access the new funding dedicated to adaptation to climate change;
- contribute towards national/provincial/local development and climate change strategy or policy; and
- adhere to relevant funding pre-conditions and/or available climate change adaptation funding opportunities.