Climate variability, climate change and water resource strategies for small municipalities

---

Water resource management strategies in response to climate change in South Africa, drawing on the analysis of coping strategies adopted by vulnerable communities in the Northern Cape province of South Africa in times of climate variability

REPORT TO THE

WATER RESEARCH COMMISSION

P Mukheibir
D Sparks
University of Cape Town

WRC Project: K5/1500

September 2005

Executive summary

Background and motivation

In many parts of the world, variability in climatic conditions is already resulting in wide ranging impacts, especially on water resources and agriculture. Climate variability is already being observed to be increasing, although there remain uncertainties about the link to climate change. However, the link to water management problems is obvious.

Water is a limiting resource for development in South Africa and a change in water supply could have major implications in most sectors of the economy, especially in the agriculture sector. Factors that contribute to vulnerability in water systems in southern Africa include seasonal and inter-annual variations in rainfall, which are amplified by high run-off production and evaporation rates.

Current modelling scenarios suggest that there will be significant climate change[1] impacts in South Africa (Hewitson et al. 2005). Climate change is expected to alter the present hydrological resources in southern Africa and add pressure on the adaptability of future water resources (Schulze & Perks 2000) . During the past 20 years, most of Africa has experienced extensive droughts, the last three being 1986-88, 1991-92 and 1997-98 (after Chenje & Johnson 1996). If the occurrence of drought became more frequent, the impact on water resources and consequently agriculture would be significant.

Notwithstanding the substantial uncertainties around rainfall projects, there is a tendency for the majority of models to suggest a decrease in rainfall over the western part of southern Africa in the coming decades. Based on these projections, the most severe impacts are likely to occur in this region, where small towns and subsistence farmers are most vulnerable. The available literature suggests that it would be prudent to account for climate change in water resource planning to meet the development objectives of South Africa. The Minister of Water Affairs, Mr Ronnie Kasrils, has also acknowledged that "it is possible that the effects of global climate change will influence the availability of water and patterns of use during the next few decades" (Kasrils 2002).

With this in mind, this study investigates the adaptive[2] capacity of small towns and communities in the Northern Cape province to climate variability[3], specifically drought. By testing these strategies against sustainable development criteria, planning policies for national and water resource planning and management are recommended to ensure water security against the impacts of climate change.

Main objectives

1) To demonstrate the change in temperature and rainfall due to climate variability and projected climate change in small towns in the Northern Cape for the past 30 years.
2) To document existing coping strategies in times of climate variability, i.e. drought, in small towns in the Northern Cape.
3) To propose long term strategies for dealing with the impacts of predicted climate change in small towns in the Northern Cape.

---

[1] Climate Change: A change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability over comparable time periods (Midgley et al. 2005). The time scale would be in decades to centuries.

[2] Adaptation: Adjustment in natural or human systems to anew or changing environment. Adaptation to climate change refers to adjustment in natural or human systems in response climatic stimuli and is institutes to moderate the effects of climate change (Midgley et al. 2005).

[3] Climate Variability: Refers to variations in the mean state of the climate on all temporal and spatial scales beyond that of individual events. The time scale could be in months to years. (after IPCC 2001b).

Major results

From the analysis of the climate data and projections for the Northern Cape, an increase in temperature over the entire region can be expected. With this, an increase in evaporation could be expected. However, no clear trends for rainfall in this region can be attributed to climate change. What can be observed, however, is that with climate change rainfall is likely to change and become variable.

Based on this study and the responses obtained from the stakeholder group, the following list of strategies were identified as being feasible when developing a water resource management strategy that takes future climate change impacts into account:

Supply side management:

- Reduction of leaks programmes
- Regional water resource planning
- Local water resource management and monitoring
- Conjunctive use of surface and groundwater
- Rainwater harvesting

Demand side management:

- Dry sanitation systems
- Education programmes
- Tariff structures
- Water restrictions

The main obstacles to the implementation of these strategies were human and financial resources.

Recommendations

A number of recommendations emanate from this study:

1) There is a need for proactive strategies at local and national level to deal with the impacts of drought and climate change on water resources rather than the current reactive strategies.
2) Given the possible implications of climate change on local water resources, it is important that the impact be monitored as a precautionary measure.
3) Strict groundwater management systems should be put in place, with early warning mechanisms to report depleted groundwater reserves. Continual monitoring of the aquifer against climate conditions will provide some knowledge of the future potential under projected climate conditions.
4) Emphasis should be placed on demand side management.
5) In order to successfully implement any of these strategies, the lack of personnel and financial capacity at local level must be overcome.
6) Strategies that are finally identified not only need to be social, environmentally and economically acceptable, but they need to have long-term applicability if they are to provide adequate resilience to climate change impacts.
7) A climate change awareness programme should be developed that is targeted at local government officials to equip them with the necessary tools to engage with this issue and implement the strategies that are identified.
8) Each local authority should develop a locally based strategy, which follows the multi-criteria analysis tool used in this report. These studies should use quantitative data – real costing and water resource data – and not only qualitative information to identify relevant strategies.

Acknowledgements

The authors of the report would like to acknowledge the Water Research Commission for funding the research project and would like to thank the following Steering Committee Members for their contributions and guidance:

Dr K Pietersen	Water Research Commission
Prof RE Schulze	University of KwaZulu-Natal
Mr Louis Snyders	Department of Water Affairs and Forestry (N-Cape)
Prof Colleen Vogel	University of the Witwatersrand
Dr RA Titus	Council for Geoscience
Mr Rashid Khan	Department of Water Affairs and Forestry
Mr G van Zyl	Department of Water Affairs and Forestry

The authors would also like to thank the members of the Drought Task Team in the Northern Cape, as well as those who gave of their time to provide information and assistance viz..

Mr M Myburgh	BVI
Mr D Visser	SRK
Mr K du Plessis	University of Stellenbosch - formerly of West Coast DC
Dr G Midgley	South African National Botanical Institute
Dr R Murray	Groundwater Africa
Mr M Smart	DWAF W-Cape
Mr G van Dyk	DWAF N-Cape
Mr P Havenga	DWAF W-Cape
Mr H van Kleef	DWAF W-Cape
Mr P Ravenscroft	Maluti GSM Consulting Engineers
Prof Theo Stewart	University of Cape Town

Contents

1. Introduction

Much of the Southern African Development Community (SADC) region experiences water scarcity. Poor distribution of water resources and pollution, coupled with frequent droughts and floods, have led to direct hardship for many people, particularly the poor, since it has affected health and food security (SADC 2001). During the past 20 years, most of Africa has experienced extensive droughts, the last three being 1986-88, 1991-92 and 1997-98 (after Chenje & Johnson 1996).

South Africa is classified as a water-stressed country, with an average annual rainfall of around 500mm, which is less than 60% of the world average. Only a narrow region along the south-eastern coastline receives high rainfall, while the greater part of the interior and western part of the country is arid or semi-arid (DWAF 1994). In addition, South Africa's growing water demand is rapidly outstripping its natural availability. Currently 11 of the 19 Water Management Areas (WMAs) in the country are facing water deficits (Otieno FAO & Ochieng GMM 2004). In the Northern Cape for example, many local municipalities resort to tankering water to communities whose groundwater supplies have been reduced due to drought conditions.

Increased climate variability is expected to alter the present hydrological resources in southern Africa and add pressure on the availability of future water resources. Scientific evidence confirms that climate change is already taking place and that most of the warming observed during the past 50 years is due to human activities (IPCC 2001a). Scientists predict that the rate of climate change will be more rapid than previously expected. Droughts, floods and other extreme weather events are projected to become more intense and frequent. If the occurrence of drought were to increase, the impact on water resources, and consequently peoples' livelihoods and health, would become serious.

In the Third Assessment Report of the Intergovernmental Panel on Climate Change, the following key issues in relation to climate and water were presented (IPCC 2001a):

> "Climate change will lead to an intensification of the global hydrological cycle and can have major impacts on regional water resources, affecting both ground and surface water supply for domestic and industrial uses, irrigation, hydropower generation, navigation, in-stream ecosystems and water-based recreation. Changes in the total amount of precipitation and in its frequency and intensity directly affect the magnitude and timing of runoff and the intensity of floods and droughts; however, at present, specific regional effects are uncertain".
>
> "The impacts of climate change will depend on the baseline condition of the water supply system and the ability of water resource managers to respond not only to climate change but also to population growth and changes in demands, technology, and economic, social and legislative conditions. In some cases - particularly in wealthier countries with integrated water management systems - improved management may protect water users from climate change at minimal cost; in many others, however, there could be substantial economic, social and environmental costs, particularly in regions that already are water-limited and where there is considerable competition among users".

Based on the climate projections for South Africa, the most severe drought impacts are likely to occur in the western part, where small towns and subsistence farmers are most vulnerable (Hewitson et al. 2005). The available literature suggests that it would be prudent to account for climate change in water resource planning to meet the development objectives of South Africa. The former Minister of Water Affairs and Forestry, Mr Ronnie Kasrils, also acknowledged that 'it is possible that the effects of global climate change will influence the availability of water and patterns of use during the next few decades' (Kasrils 2002). Climate change is therefore an additional source of uncertainty that will become increasingly relevant to water resource management in the future.

To a large extent, the implications of climate change in South Africa have not yet been fully and explicitly considered in current water policy and decision-making frameworks. The financial, human and ecological impacts of climate change are potentially very high, particularly where water resources are already highly stressed in many areas, while the capacity to cope and adapt is not consistently high (Schulze 2005a).

The challenge for the future is to balance the demand for water with the available supply. Since it is not possible to increase the amount of available water, the opportunity exists to satisfy both urban and rural needs using appropriate management mechanisms. Current water management mechanisms and policies focus on ensuring that the existing supplies of water meet the growing demand. Whilst some of the mechanisms may be appropriate to deal with the future shortage that will be brought about by climate variation, robust long-term strategies are still required to ensure the future supply of water matches demand, even in times of reduced availability. In addressing future projected climate change impacts, some of the measures may need to be introduced sooner than originally planned (Mukheibir & Sparks 2003).

This study investigates the water resource management strategies in response to climate change in South Africa by drawing on the analysis of coping strategies adopted by small local municipalities in the Northern Cape province of South Africa in times of climate variability, specifically drought. To establish which strategies enable long-term resilience to climate change impacts they are measured against various development criteria.

By extrapolating these strategies, planning policies for water resource planning and management are developed to ensure water security against the impacts of climate change. Specifically the study:

- shows the relationship between the change in temperature and rainfall and available water resources in small towns in the Northern Cape for the past 30 years;
- documents existing coping strategies in times of climate variability (drought) in small towns in the Northern Cape;
- proposes long-term strategies for dealing with the impacts of predicted climate change in small towns in the Northern Cape.

2. Methodology for study

The methodology for this study followed the steps outlined below.

a) Literature review
A literature review was conducted to identify the most appropriate local municipalities to be investigated in the Northern Cape. Eight local municipalities (within three district municipalities) were identified which fell within a drought prone area.

Table 1: List of municipal areas investigated

District municipality	*Local municipality*	*Water services authority*	*Population 2001 (SSA 2003)*
Pixley ka-Seme (Karoo) - DC7	Kareeberg	Yes	9 486
Namakwa - DC6	Hantam	Yes	19 814
	Kamiesberg	Yes	10 754
	Khâi-Ma	Yes	11 344
	Nama Khoi	Yes	44 750
	Richtersveld	Yes	10 124
	Karoo Hoogland	Yes	10 512
Siyanda – DC8	Kai! Garib	Yes	5 7684

Further details on each municipality are contained in Appendix C.

b) Meteorological data collection and analysis
Temperature and rainfall figures for the past 30-50 years for representative towns of each identified local municipality were obtained from the South Africa Weather Services (Gill 2004/05). These trends for the past 30 years are analysed.

c) Projection of future scenarios using the historical information
Future climate projections for the Northern Cape were derived using computer model simulations. Four different model outputs are analysed and compared to the South African Weather Service observed data.

d) Field visits and interviews
A number of interviews were held with relevant stakeholders and consultants who operate in this region in order to capture the current measures adopted to ensure an adequate supply of water in times of drought. This was done in person, by telephone and by email correspondence. In addition, the monthly Provincial Drought Task Team Meetings were attended and the stakeholders were participants in the multi-criteria analysis exercise.

e) Analysis of strategies
A list of strategies was compiled that best represented those currently being implemented at a local level. The analysis of the strategies was done using a simple multi-criteria analysis tool developed for this project. This method is further discussed in section 2.2. A set of criteria against which to rate the strategies was developed. These were weighted with input from the stakeholders. A table was developed with the criteria across the top and the strategies down the side. The stakeholders were requested to score each strategy against the each criteria using a prescribed scoring system. The results were standardised and the average scores were used for comparison purposes..

f) Graphical representation
For ease of analysis, the scores for each strategy against the criteria were graphically represented. For comparison purposes, the strategies were plotted graphically against each criteria.

g) Recommendation of replicable strategies
Recommendation of appropriate long-term strategies for dealing with climate change impacts on water resources were proposed, with their costs and benefits.

2.1 Location of study area

The Northern Cape Province is located in the western part of South Africa and borders in the north west with Namibia. It consists of five district municipalities and 26 local municipalities. Table 1 lists the local municipal areas that were investigated in this study; Figure 1 gives a visual sense of their location).

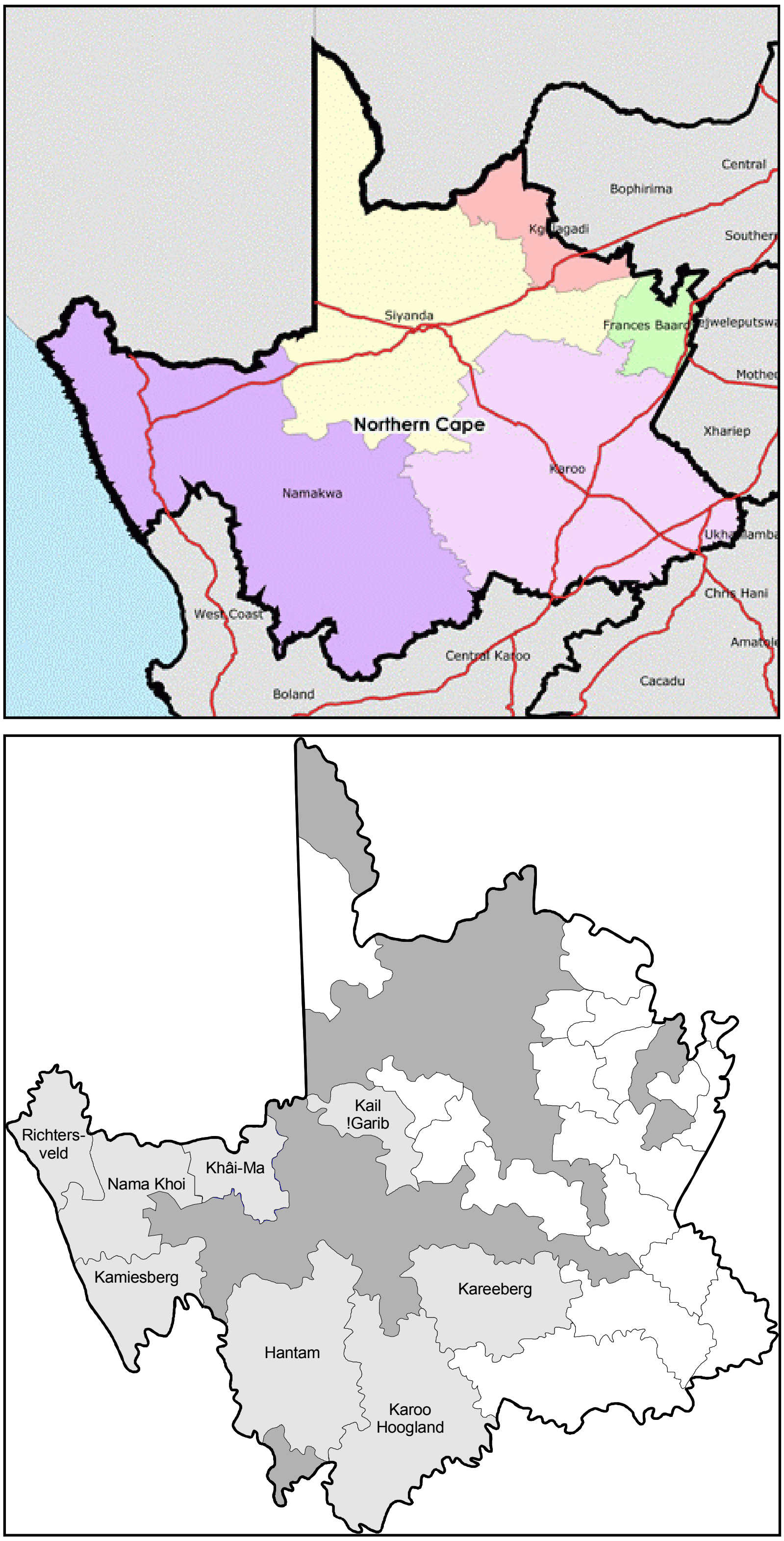


Figure 1: Maps indicating the district and local municipal boundaries

2.2 Simple multi-criteria analysis approach

The approach used in this study to establish which strategies would be most likely to be effective was a simple multi-criteria decision analysis (MCDA) method. Resource management studies usually involve variables which cannot be fully quantified but are nonetheless determinant factors in decision making. In such cases, one must go beyond techniques which use monetary values in order to incorporate all of the important parameters and variables in a comprehensive analysis. This can be best done using multi-criteria decision analysis.

MCDA is a process that incorporates the following key steps (Joubert & Stewart 2004):

- structuring decision making process in terms of well defined criteria;
- evaluating alternative strategies in terms of the extent to which they satisfy each of the identified criteria;
- aggregation across the criteria to produce a measure of the degree to which each strategy satisfies the overall objectives represented by the criteria.

More specifically this study followed the following steps:

a) Contextualisation of the problem

The problem is contextualised in sections 3 and 5.

b) Identification of the criteria

A list of 9 criteria was developed from the literature review and interviews with relevant stakeholders. The criteria reflected social, economic and environmental considerations. The ninth criteria, viz. "long-term applicability", was included as a final screen to establish which strategies have the potential to address long-term climate change impacts.

c) Weighting of the criteria

The stakeholders were requested to apply a weighting to the criteria within a range of 1 to 5, where 5 would indicate that the stakeholder considered the criteria very important and 1 would indicate no importance. The average rating for each criteria was calculated from the stakeholder responses.

d) Identification of the options

A list of 18 strategy options was developed from the literature review and interviews with relevant stakeholders. These were all current climate variability strategies being implemented in the Northern Cape or elsewhere in the country.

e) Standardisation of option values

The stakeholders were requested to rate each strategy against each of the criteria using a scale appropriate each criteria. Some were scored from 1-4 others 1-5. Therefore the scores were standardised to percentages.

f) Weighting of options against the criteria

The weightings obtained (according to step c) were then applied to each strategy value for the corresponding criteria.

g) Analysis of the results

The average score for each strategy was obtained by totalling the weighted criteria values and dividing it by the number of criteria. The strategies were then ranked according to their average scores.

h) Comparative analysis of sectoral results

The responses were obtained per stakeholder sector, viz. local government and the water sector. The local government sector was represented by municipal officials and the Provincial Department of Local Government and Housing, whilst the water sector by the National Department of Water Affairs and Forestry (DWAF). The responses for the agriculture sector were excluded since they were biased towards the agricultural needs. A comparative analysis was made of the two stakeholder group's responses, and these were compared with the results of the combined group.

3. Current hydrological situation

South Africa has a total average annual available surface water of 49 040x$10^6$$m^3$ (this includes the inflow from Lesotho and Swaziland). Approximately 28% of this can be economically harnessed as usable yield (this includes usable return flow). (DWAF 2004b)

Table 2: Usable yield in year 2000 (DWAF 2004b)

Source	*Million m^3/a*
Surface water	10 240
Groundwater	1 088
Usable return flow	1 899
Total	13 227

The total amount of water required for 2000 was 12 871 × $10^6$$m^3$, a figure close to the limits of the available usable yield. Urban and rural domestic demand requirements make up 23% and 4% respectively (DWAF 2004b).

Irrigation makes up 78% of all groundwater use in South Africa (Braune 1996), but the most strategic and vital use of water is for urban and rural domestic water supply. In the drier two thirds of the country, groundwater often represents the only or most important source of water. Over 290 towns and villages in South Africa are in some way dependent on groundwater. Much of the readily available water resources in the deficit areas have already been developed.

The following sections provides an overview of the supply and demand situation in the Northern Cape. Specific supply and demand information on the various local municipalities is provided in Appendix A.

3.1 Overview of Northern Cape supply

The Northern Cape Province largely corresponds with the geographic extent of the Lower Orange Water Management Area. The climate over this region is semi-desert to desert, with the rainfall ranging from 400mm/a to as little as 20mm/a. This region is characterized by prolonged droughts (DWAF 2004b).

The natural mean annual runoff (MAR) is 502 million m^3/a and is allocated per sub-area as follows:

Table 3: Natural MAR (in million m^3/a) (DWAF 2004b)

Sub-area	*Natural MAR*	*Ecological reserve*
Orange	198	32
Orange tributaries	280	35
Orange coastal	24	2
	502	69

In 2000 DWAF estimated the available yield from natural resources to be 34 million m^3/a. In contrast with the national figure of 28%, the Northern Cape Province's available yield is only 6.8% of MAR. Groundwater is the largest and makes up 74% of the available supply viz. 25 million m^3/a. An additional supply of 1092 million m^3/a is provided by the Upper Orange. (DWAF 2004b).

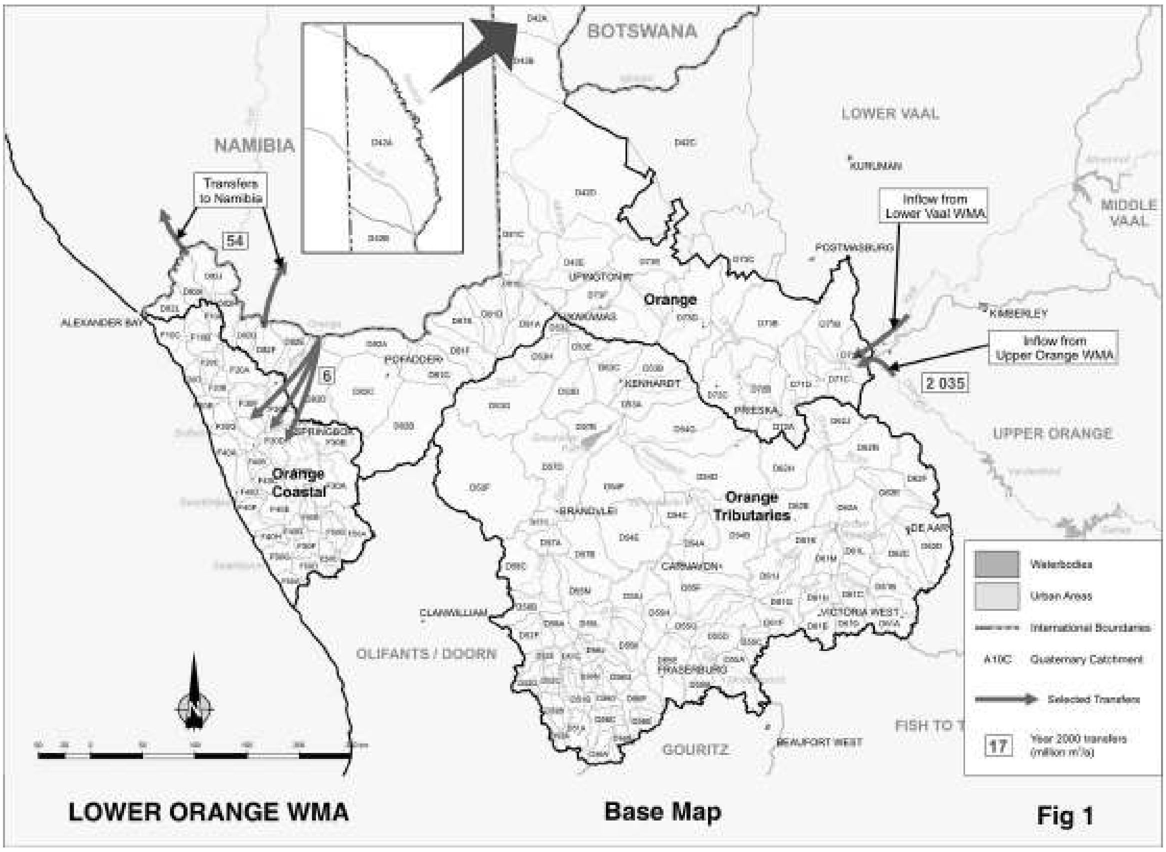


Figure 2: Base map of the Lower Orange water management area(DWAF 2004b)

Table 4: Available yield in the year 2000 (million m³/a) (DWAF 2004b)

Component/ Sub-area	*Natural resource*		*Usable return flow*			*Total local yield[1]*
	Surface water[2]	*Ground-water*	*Irrigation*	*Urban*	*Mining and bulk*	
Orange	(1 092)	9	96	1	0	**(986)**
Orange Tributaries	9	13	0	0	0	**22**
Orange Coastal	0	3	0	0	0	**3**
Total for WMA	(1 083)	**25**	**96**	**1**	**0**	**(961)**

1. After allowance for the impacts on yield of the ecological component of the Reserve, river losses, alien vegetation, rain-fed sugar cane and urban runoff.
2. Negative figures under surface water caused by river losses being larger than the incremental runoff within the water management area.

Although groundwater reserves are limited, they are well used for rural water supplies. It is a most strategic resource providing water to an estimated 30% of the population resident in this province. However, the reliability of groundwater supply in the Northern Cape is not adequate, due to factors such as restricted resource availability, quality of water, erratic precipitation, drought and water management issues (van Dyk et al. 2005). As a result of the low rainfall over this area, recharge of groundwater is limited and only small quantities can be extracted on a sustainable basis.

A distinction needs to be made between water shortages that are due to drought and climate variability and those that are caused by poor infrastructure and management. A large number of towns in this province have experienced water shortages due to broken equipment and poor reticulation systems. For example in Hopetown, which draws its water directly from the Orange River, has experienced water shortages because there is no infrastructure maintenance plan. (Jooste 2005)

A drought is declared by the State President on the advice of the Department of Water Affairs and Forestry (DWAF) or the Department of Agriculture (DoA) and is classified as shown in Table 5.

Table 5: Working classification of drought (DWAF Northern Cape 2005)

Critical	Almost no water available. Water is being transported. Nearest water is more than 1km away.
Urgent	Water restrictions have been implemented. Expected to be critical in 2-3 months
Serious	Water is available but resource is under stress. Water levels have dropped considerably. Expect to be urgent in 2-3 months

3.2 Overview of Northern Cape demand

The urban and rural domestic water requirements only make up 4% of the total demand. The urban demand is generally concentrated along the main stem Orange River as a result of agriculture or at places such as Port Nolloth and Springbok due to mining. The rural communities are widespread and are mostly reliant on groundwater (V3 Consulting & WRP 2002).

In 2000, the Northern Cape Province supply versus demand ratio illustrated the water vulnerability that exists in the province by effectively recording an undersupply of 8 million m^3. If the supply and demand are projected to 2025, the water balance stays constant. This is mainly due to the demographic projections for this Water Management Area, which show a steady decline in population over the next 25 years (DWAF 2004b). Despite this documented water shortage, a survey of the small towns in the Northern Cape revealed that over 90% of the respondents stated that they understood there to be no limit on their demand for water (Macroplan 2000).

Table 6: Reconciliation of water requirements and availability for the year 2000 (million m³/a) (DWAF 2004b)

Component/ Sub-area	*Local yield*	*Transfers In*[2]	*Local requirements*	*Transfers out*	*Balance*[1]
Orange	(986)	2 035	989	60	**0**
Orange Tributaries	22	0	31	0	**(9)**
Orange Coastal	3	6	8	0	**1**
Total for WMA	**(961)**	**2 035**	**1 028**	**54**	**(8)**

1. Brackets around numbers indicate a negative balance. Surpluses are shown in the most upstream sub-area where they first become available.
2. Transfers into and out of sub-areas may include transfers between sub-areas as well as transfers between WMAs. The addition of the quantities transferred per sub-area does therefore not necessarily correspond to total transfers into and out of the WMA.

Table 7: Reconciliation of water requirements and availability for the year 2025 base scenario (million m³/a) (after DWAF 2004b)

Component/ Sub-area	*Local yield*[1]	*Transfers in*	*Local requirements*[2]	*Transfers out*	*Balance*[3]	*Potential for development*[4]
Orange	(981)	2 082	1 042	60	**(1)**	150
Orange Tributaries	22	0	29	0	**(7)**	0
Orange Coastal	2	6	8	0	**0**	0
Total for WMA	(957)	2 088	1 079	60	(8)	150

1. Based on existing infrastructure and infrastructure under construction in the year 2000. Also includes return flows resulting from a growth in requirements.
2. Based on normal growth in water requirements as a result of population growth and general economic development. Includes a 4 000 ha increase in irrigated farming land in the Orange sub-area, which will require 60 million m³/a.
3. Brackets around numbers indicate a negative balance.
4. Based on construction of the Vioolsdrift Dam.

Current utilisation of groundwater in this area is approximately in balance with the sustainable abstraction yield from this source and no significant potential for further development exists (BKS (Pty) Ltd 2003). Demand issues such as increased water use, peak use, seasonal variability, poor demand side management, poor water use planning, poor conservation and water losses have in the past contributed to water shortages in the Northern Cape (van Dyk et al. 2005). Poor planning for emergencies and the lack of structured contingency plans has resulted in water shortages during times of rainfall variability.

This resulted in approximately 25% of the towns in the Northern Cape over-utilising their sustainable groundwater resources in 2000 (see Figure 3). Most notable are Strydenburg, Van Wyksvlei, Kammieskroon, Britstown, Carnavon, Kheis, Kommagas Spoegrivier, Kenhardt and Buffelsrivier. Strydenburg, Van Wyksvlei and Kammieskroon are particularly vulnerable, using up to 180% of the recommended yield. Recent information indicates that Britstown is still using double the available yield from existing boreholes. Van Dyk recommends using 80% of the available sustainable yield to ensure that there are sufficient resources for future growth in demand as well as providing a buffer to drought periods. (van Dyk 2004).

In addition, a predominant problem that occurs in most water scarce towns is that very little co-operation is received from residents with regards to water saving and change of water use patterns (Jooste 2005). The supply of water has become a political issue and elected councilors are reluctant to impose punitive measures on residents to curb the water demand. Currently in Sutherland a tension exists between inadequate supply verses the local demand for flush toilets. Instead, large sums of money are being sourced through the drought relief funding for locating new sources of water where yields have dropped or boreholes have dried up.

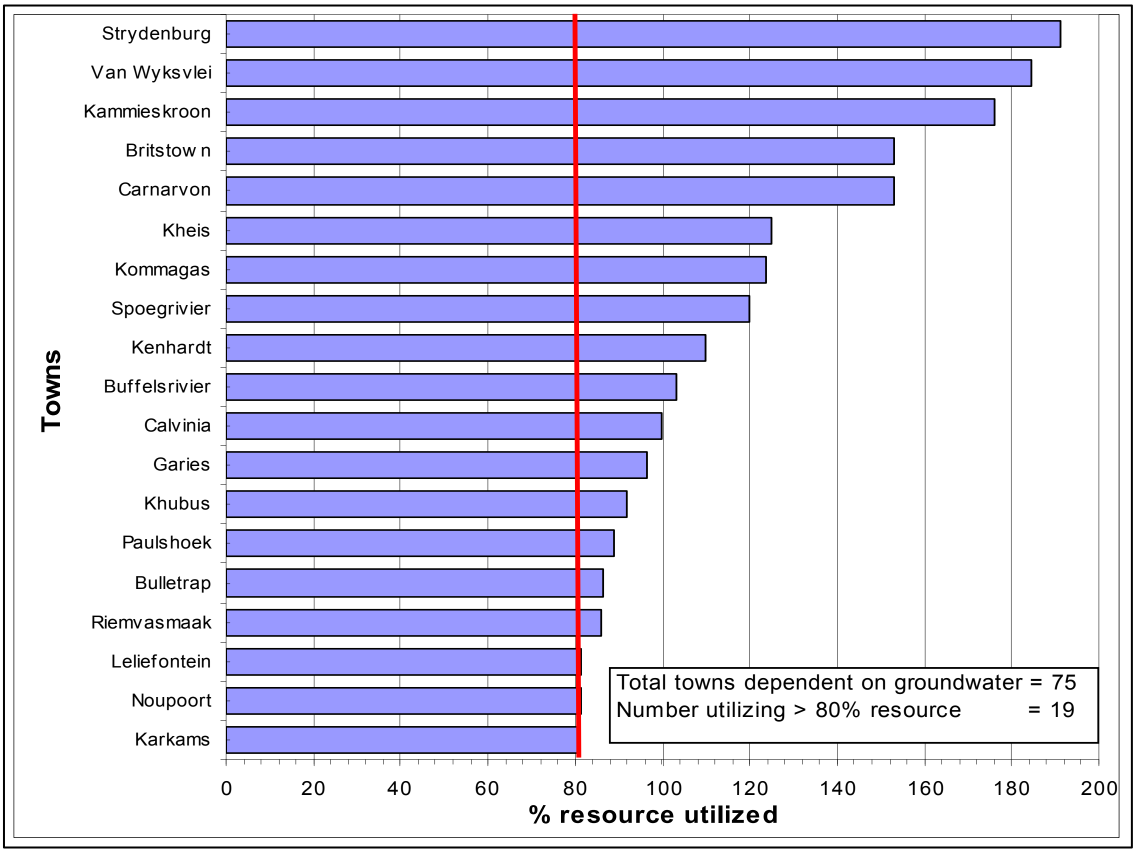


Figure 3: Groundwater resource utilization in 2000
(van Dyk et al. 2005)

It is not clear to local authorities whose responsibility it is to plan for drought conditions – local or national government, water services authorities or providers, or the water catchment management authorities. Water resource planning is generally not a priority until water supplies are strained due to drought conditions. The lack of capacity at local government level results in a dependency on consultants for the planning skills. Recently, however, there have been moves towards resource management as part of water service delivery, where, for example, the Kgalagadi DMA have developed a drought relief strategy whereby they plan to do proactive resource management (Bigen Africa 2004).

Specific details of the selected municipal areas have been included in Appendix C.

4. Current climate information for the Northern Cape

The Northern Cape is characterized by a harsh climate with minimal rainfall and prolonged droughts. The area's arid climate is accompanied by high evaporation due to the intense heat of the summer months. The mean annual temperature is 17.4^{o} C. The mean annual precipitation ranges between 20 mm on the west coast to approximately 300mm on the eastern side. The mean annual evaporation ranges from 2000 mm on the coastal belt to 2350 on the easterly portion (V3 Consulting & WRP 2002).

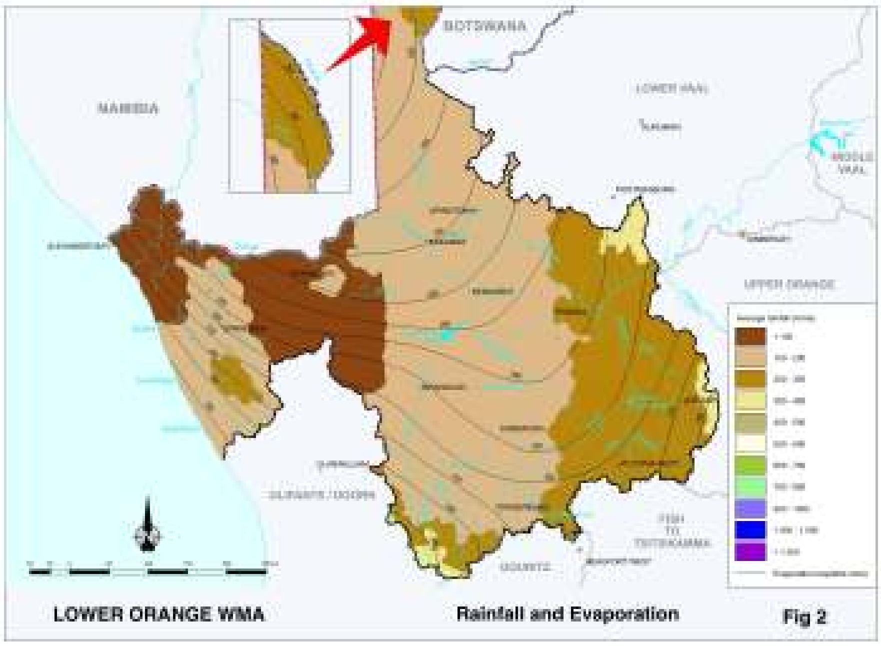


Figure 4: Rainfall and evaporation for the Lower Orange water management area (BKS (Pty) Ltd 2003)

5. Climate variability and scenarios for Northern Cape

5.1 Introduction to climate change and variability

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 characterized by a fairly smooth continuous increase or decrease of the average value during the period of record.[4]

According to the IPCC (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 on the instrumental record. Most of the 0.6°C increase occurred between 1910 and 1945 and since 1976. 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.

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 the finite historical records from which the range of natural variability at different scales of time and space has been defined, 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 gasses.

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

d. *Downscaling*: This is the development of regional scale projections of change from the global models, which introduce an uncertainty that limits the confidence in the magnitude of the project change, although the pattern of change can be interpreted with greater certainty.

5.2 Climate variability in South Africa

South Africa is situated in the sub-tropics and hence is affected by the tropical and temperate latitude circulation systems and is dominated by the semi-permanent high pressure systems. There has been much variability in rainfall over southern Africa since the commencement of the meteorological record in the 1800s. There are a number of weak oscillations that have been identified such as the 18-year oscillation and the 10-12 year oscillation (Tyson 1996). The former oscillation has accounted for 30% of the variance at best and largely in the NE of the country while the latter has predominantly affected the southern Cape (Tyson 1986). There is also the 2-3 year quasi-biennial

---

[4] 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).

oscillation (QBO) associated with the reversal of equatorial westerly winds at the 50hPa stratospheric level and evident mostly in the central interior, and the El-Nino Southern Oscillation phenomenon (Tyson 1996). There are a host of other influences on the climate variability of the region, such as changes in macropressure over the interior and adjacent oceans that impact the weather and climate and result in wet and dry spells, and the location of troughs of standing westerly waves (see (Steyn 1984)).

Rainfall variability is particularly pronounced over the dry western parts of South Africa, where a dry year can have significant repercussions. Furthermore, extreme dry years tend to be more frequent in the driest regions of the country (Tyson 1986). The variability in rainfall is pronounced over the Northern Cape as illustrated in Figure 5 and Figure 6 showing monthly rainfall from 1971 to 1990 for Calvinia and Lekkersing respectively.

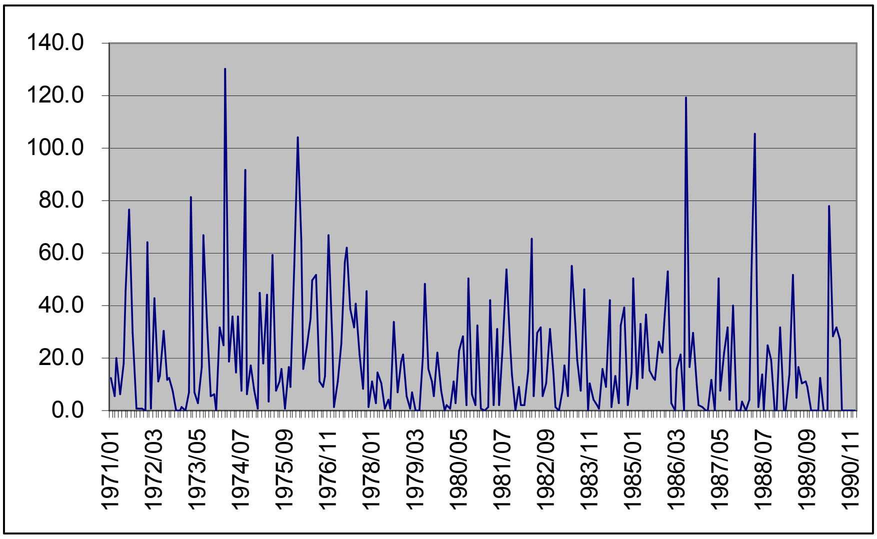


Figure 5: Monthly rainfall for Calvinia (1971-1990)

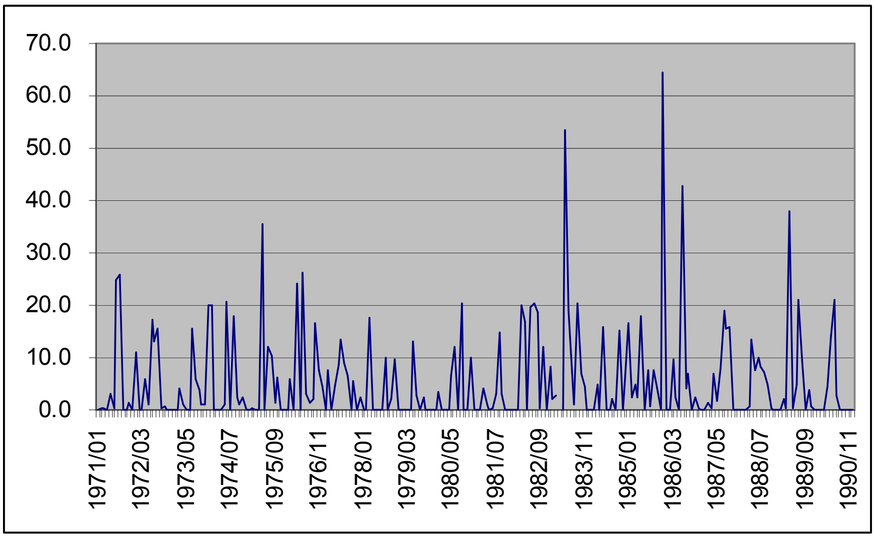


Figure 6: Monthly rainfall for Lekkersing (1971-1990)

5.2.1 Climate variability in the Northern Cape

Historical monthly precipitation data for the Northern Cape have been provided by the South African Weather Services. In order to examine the precipitation variability in the region, a representative town for each local municipality has been chosen. In all cases this represents the town in the local municipality for which there is the longest or most reliable data record available (see Table 8). In the case of the Richtersveld Local Municipality, the only representative town is Lekkersing which has a largely interrupted data set. Calvinia, Leliefontein, Steinkopf, Lekkersing and Sutherland all fall into the winter rainfall region while Pofadder, Van Wyksvlei and Kenhardt all receive predominantly summer rainfall.

Table 8: Representative towns for each local municipality

District municipality	*Local municipality*	*Representative town*
Namakwa	Hantam	Calvinia
	Kamiesberg	Leliefontein
	Nama Khoi	Steinkopf
	Richtersveld	Lekkersing
	Karoo Hoogland	Sutherland
	Khâi-Ma	Pofadder
Karoo	Kareeberg	Van Wyksvlei
Siyanda	!Kai! Garib	Kenhardt

Precipitation displays a high degree of interannual variability, with single extreme events skewing simple analyses, and hence precipitation is difficult to analyse in terms of trends (Midgley et al. 2005). This is demonstrated in the selection of graphs below where the linear regression does not have a very good correlation coefficient (R^2). (Although not presented here, the logarithmic regression does not yield better results). Whilst the trend lines may indicate an decrease in precipitation over the period for most cases, the extreme highs and lows greatly influence the determination of any true trend in the data.

What is particularly evident from all the graphs however, is that rainfall is highly variable from year to year, with periods of more plentiful rainfall followed by periods of drought. This makes planning for times of drought difficult yet essential, since with large interannual variabilities there are no rainfall guarantees in any year.

The recorded summer and winter rainfall records for each of the eight towns for the past 30 years can be found in Appendix A. All the towns exhibit variability in rainfall.

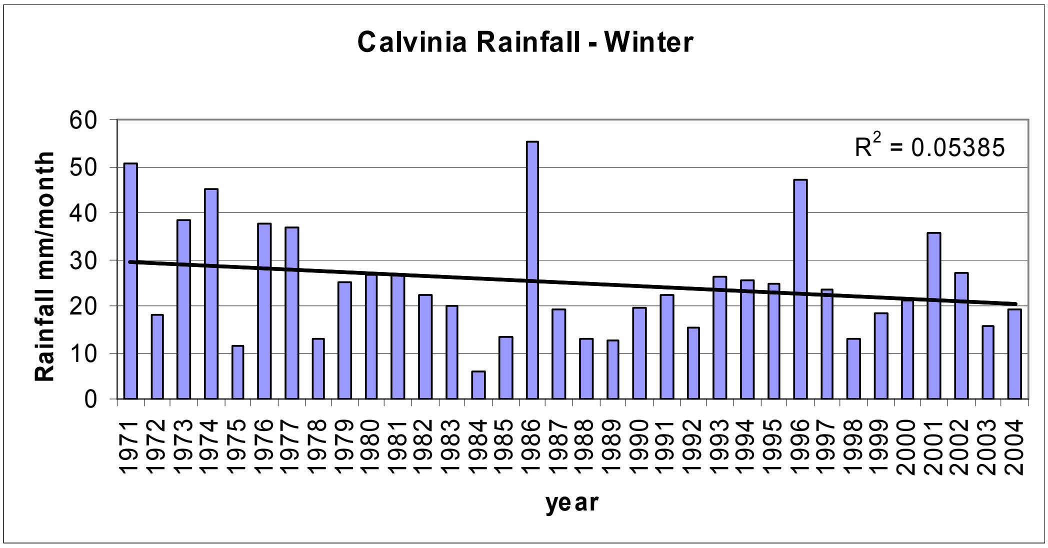


Figure 7: Winter rainfall trends for Calvinia between 1971 and 2004

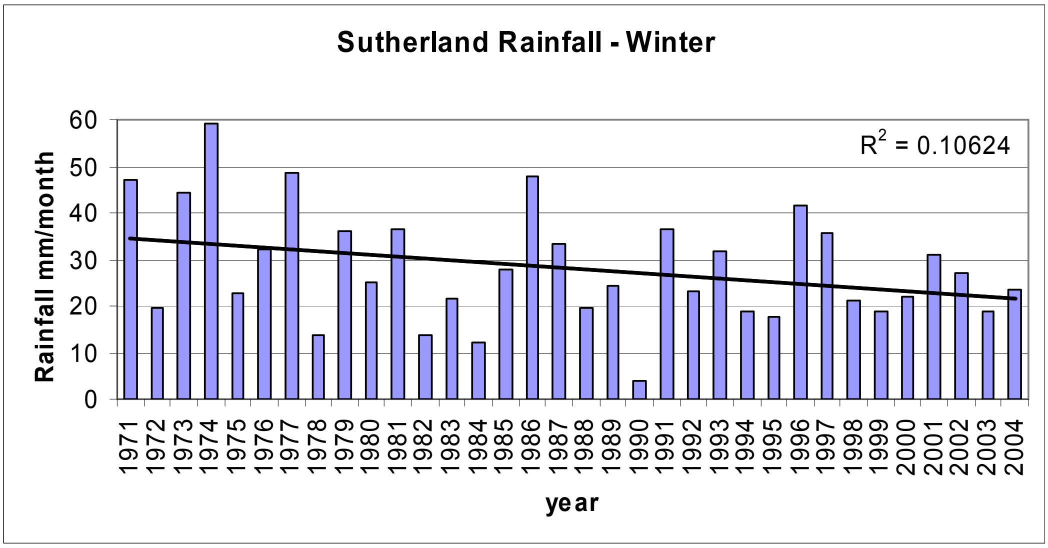


Figure 8: Winter rainfall trends for Sutherland between 1971 and 2004

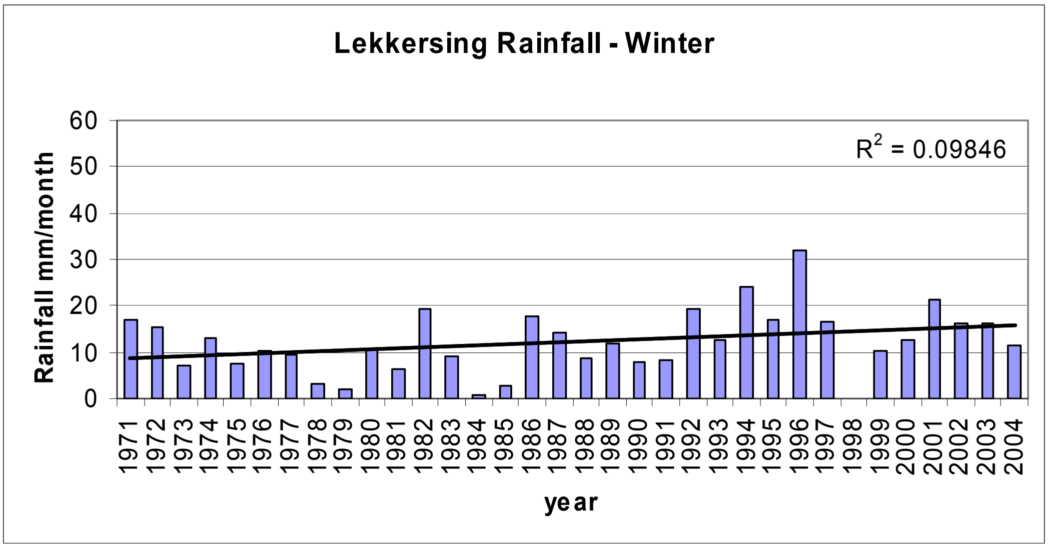


Figure 9: Winter rainfall trends for Lekkersing between 1971 and 2004

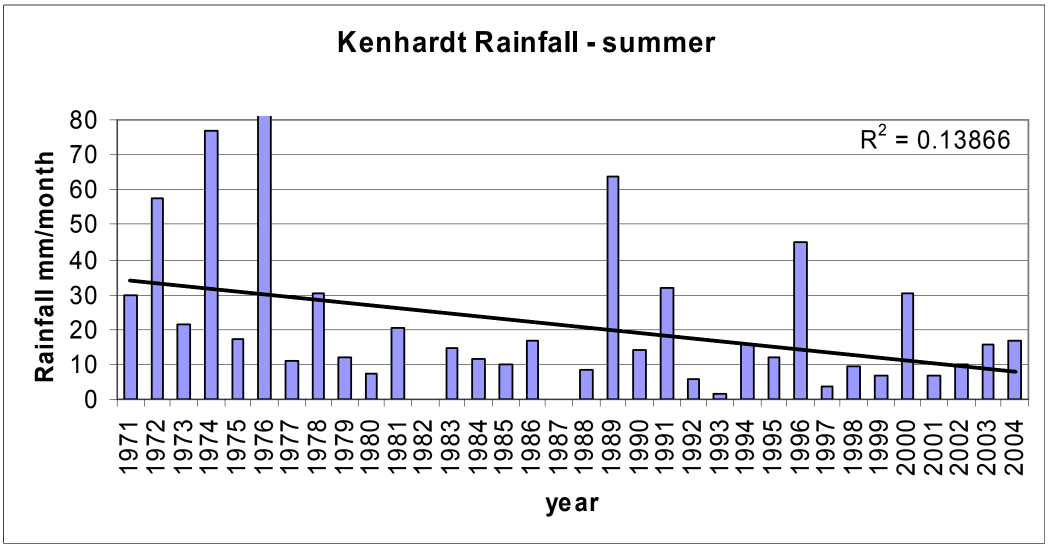


Figure 10: Summer rainfall trends for Kenhardt between 1971 and 2004

5.3 Projected climate change scenarios for the Northern Cape

While planning for climate variability in the Northern Cape is essential, it is also important to take cognisance of, and plan for, a projected climate change over the longer term. In this regard, future climate projections over the Northern Cape are derived from using computer model simulations viz global climate models (GCMs). These models simulate global climate but have poor spatial resolution for resolving regional scale climates, especially for precipitation.

In order to model the regional climate response, in general two approaches may be followed. In the first, a high resolution model of the climate is used, but requires large computing power. A second option is to use empirical relationships between the GCM and the region data. Precipitation results for the latter have been made available by Prof. Bruce Hewitson (Hewitson 2005), and the methodological approach followed is described in Hewitson and Crane (Hewitson & Crane 2005). In essence, the approach is based on self-organising maps (SOMs), which are used to characterize the atmospheric state for each target location (e.g. in this case for each representative town in the Northern Cape), based on the localized surrounding grid. This surrounding grid is based on using NCEP six-hourly re-analysis data from 1979-2002 (these are treated as “observed” data). The relationship is derived by using the variables of surface and 700 hPa u and v wind vectors, specific humidity, relative humidity and surface temperature. It is important to point out that the magnitude of change is uncertain, depending on many factors including how greenhouse gas emissions may change in the future (Midgley et al. 2005).

Future regional temperature scenarios were not available at the time of analysis, but some generalized responses are noted in Midgley et al. (2005). Temperature is expected to increase everywhere, with the greatest increase inland and the least in the coastal regions. Temperature is expected to increase by approximately 1.5° along the coast and 2°-3° inland of the coastal mountains by 2050. Along with temperature increases, changes in evaporation, relative and specific humidity as well as soil moisture are anticipated.

Precipitation projections for southern Africa, as provided by empirical and regional climate model-based downscaling tools, indicate a wetter escarpment in the east, a shorter winter season in the southwest, a slight increase in intensity of precipitation, and drying in the far west (Hewitson et al. 2005). Future precipitation scenarios for the Northern Cape have been derived from extracting and processing the daily values provided by Hewitson. These values are for the period 2071-2100 and have been averaged to present a generalized typical future summer (December, January and February) and winter (June, July and August) season response. Outputs have been made available from four models for two IPCC scenarios[5], viz., CSIRO Mk2 A2 (referred to henceforth as CSIRO A2)[6], CSIRO Mk2 B2 (referred to henceforth as CSIRO B2), ECHAM 4.5 A2 (referred to henceforth as ECHAM A2)[7] and HadAM3 A2 (referred to henceforth as HADAM A2)[8].

In addition to examining the future precipitation scenarios, it is important to examine the present day as represented by each GCM, in order to understand how well the GCMs are doing in capturing present day rainfall amounts as well as seasonality. A change in precipitation amount from the GCM present day control run to the future may be more useful and indicative than a comparison between the GCM future data and actual observed data, particularly when the GCM control run precipitation (also referred to here as the GCM “observed” precipitation) is notably lower or higher than the actual observed. In this instance, the future direction of change may be more beneficial to examine than the exact change in precipitation amount, and it is therefore the direction of change that is examined in more detail here for the 8 representative towns. Hence, GCM control run daily outputs for the 4

---

[5] A2 and B2 refer to the IPCC scenarios for a future world under different driving forces. The story lines are as follows (IPCC 2001b):

A2: A differentiated world with self reliance and preservation of local identities. Economic development is primarily regionally orientated and per capita economic growth and technological change are slower than the other story lines.

B2: A world in which the emphasis is on local solutions to economic, social and environmental sustainability. This is a world orientated towards environmental protection and social equity.

[6] CSIRO – developed by the Commonwealth Scientific and Industrial Research Organisation (Australia)

[7] ECHAM - based on the European Centre for Medium Range Weather Forecasts (ECMWF) weather forecast model. The Max Planck Institute for Meteorology and the German Climate Computing Centre (DKRZ) have made a number of modifications to this forecast model in order to make it suitable for climate forecast.

[8] HADAM – the UK Met Office's Hadley Centre atmospheric model.

GCMS have been averaged over the period 1971-2000 for summer and winter. Monthly observed data are provided by the South African Weather Services (SAWS) for the same period and have been processed into averages for summer and winter as well.

The results for the present day and future scenario analyses for the 8 representative towns follow.

5.3.1 Calvinia

The SAWS observed precipitation is notably higher than the GCM observed precipitation (Figure 11). HADAM A2 and the two CSIRO scenarios get the seasonality correct, while ECHAM A2 reflects a summer rainfall maximum instead of winter rainfall maximum. Given that the GCM observed precipitation is notably lower than that of the SAWS, it is more helpful to examine the directional change in precipitation than the actual amount. In this regard, HADAM A2 shows little future change, while ECHAM A2, CSIRO A2 and CSIRO B2 suggest a precipitation increase (Figure 12).

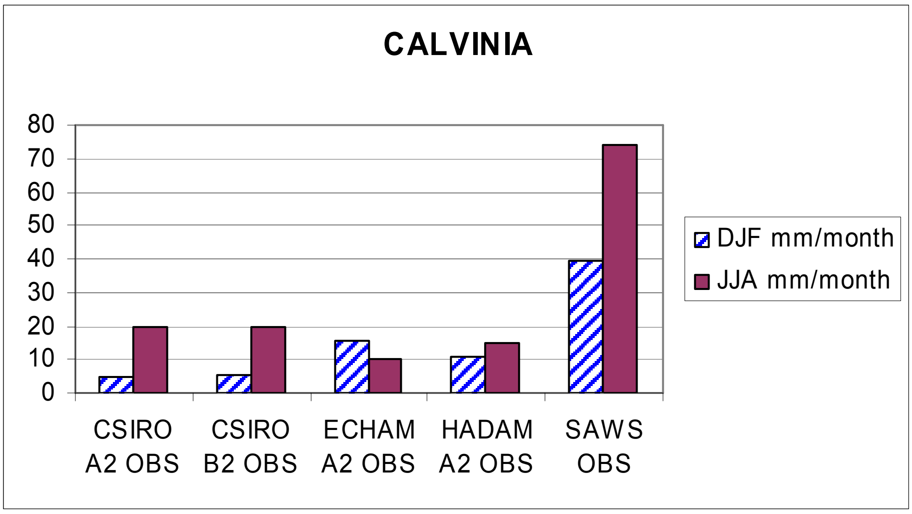


Figure 11: Comparison between GCM observed and SAWS observed precipitation for Calvinia (in mm/mo)

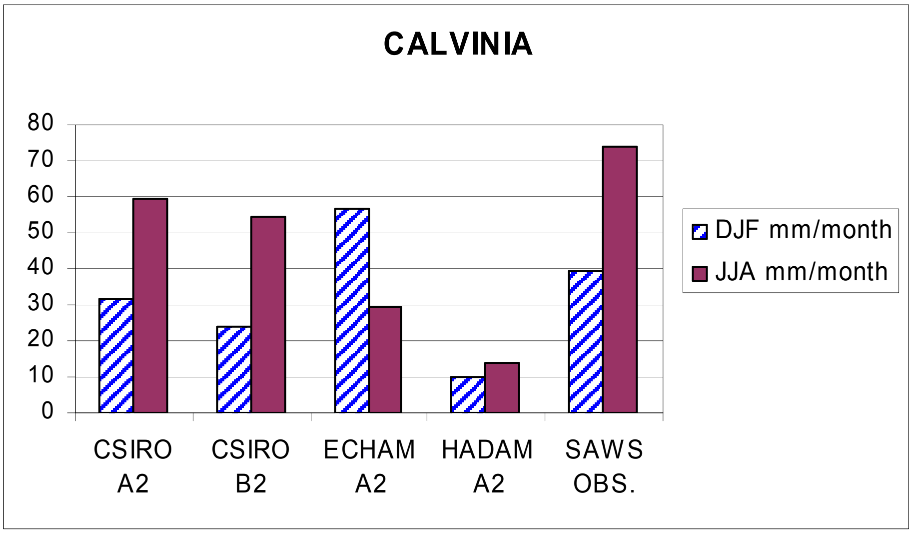


Figure 12: Comparison between GCM future and SAWS observed precipitation for Calvinia (in mm/mo)

5.3.2 Leliefontein

The SAWS observed data for winter shows much higher precipitation levels than the GCM observed data. However, summer precipitation is more comparable, with the SAWS data being slightly higher than HADAM A2, CSIRO A2 and CSIRO B2 and lower than ECHAM A2 (Figure 13). ECHAM A2 gets the seasonality of the precipitation incorrect. HADAM A2 displays a precipitation decrease in both seasons, whereas CSIRO A2, CSIRO B2 and ECHAM A2 all indicate an increase, this being notable in the case of CSIRO A2 and CSIRO B2 (Figure 14). Hence, it is evident that the directional response is unclear.

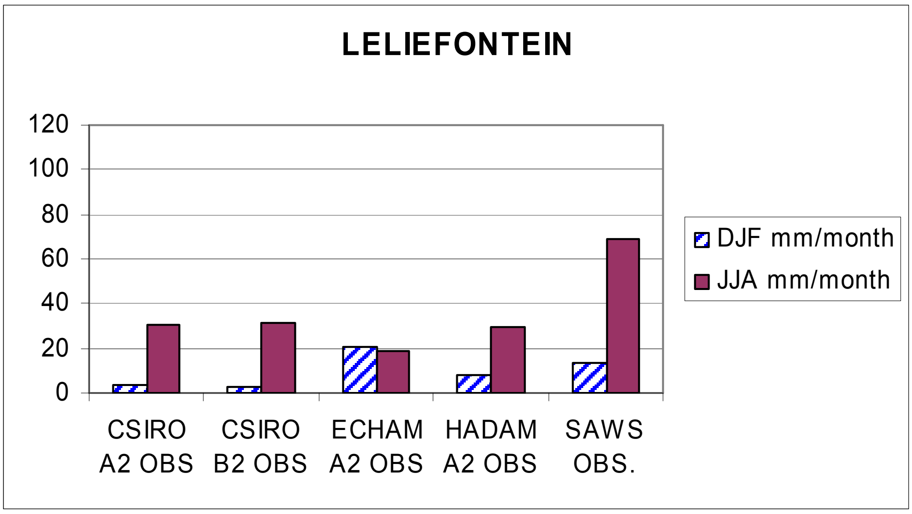


Figure 13: Comparison between GCM observed and SAWS observed precipitation for Leliefontein (in mm/mo)

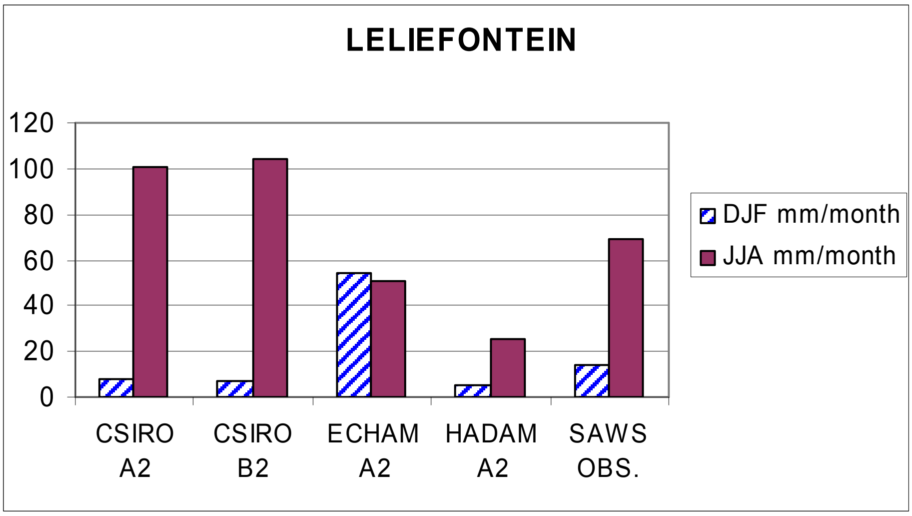


Figure 14: Comparison between GCM future and SAWS observed precipitation for Leliefontein (in mm/mo)

5.3.3 Steinkopf

The SAWS observed winter precipitation is higher than the GCM observed. Summer precipitation values are similar to HADAM A2, higher than the two CSIRO scenarios and lower than ECHAM A2 (Figure 15). ECHAM A2 is again unable to capture the rainfall seasonality correctly. HADAM A2 suggests a summer and winter rainfall decrease, while the 2 CSIRO models and ECHAM A2 suggest an increase (Figure 16).

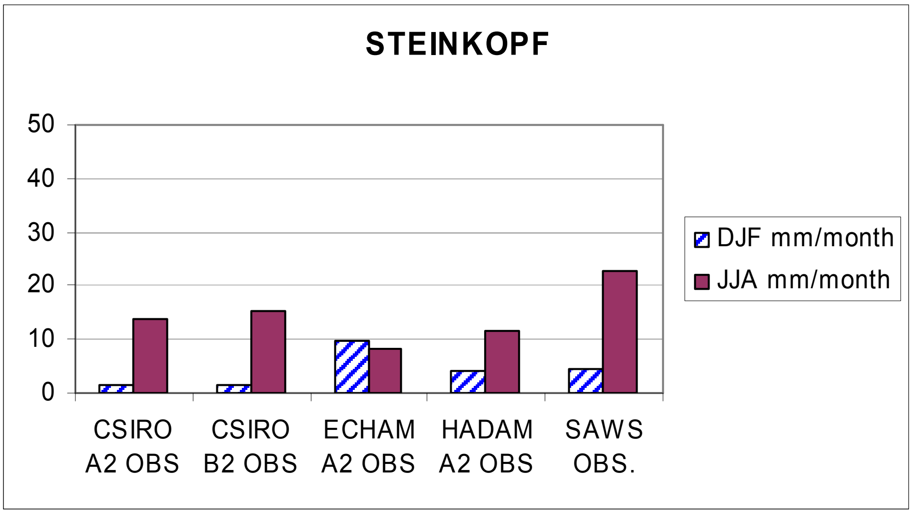


Figure 15: Comparison between GCM observed and SAWS observed precipitation for Steinkopf (in mm/mo)

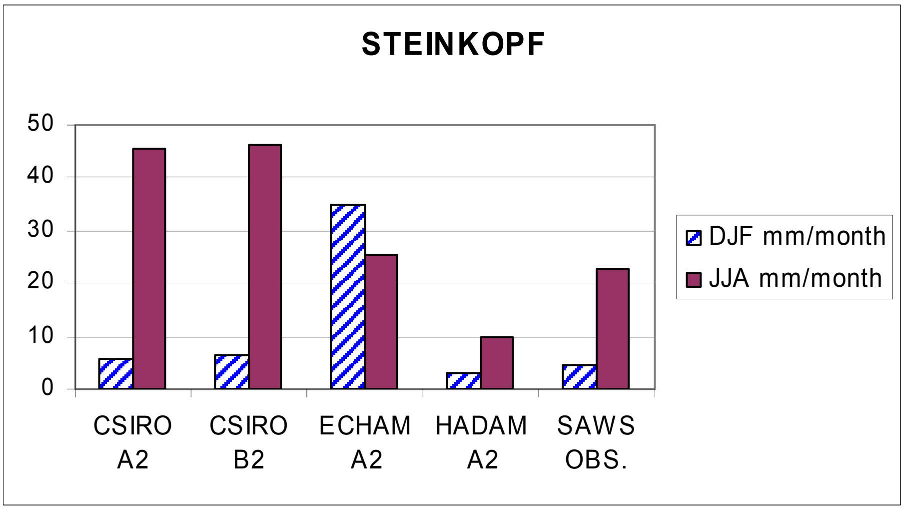


Figure 16: Comparison between GCM future and SAWS observed precipitation for Steinkopf (in mm/mo)

5.3.4 Lekkersing

All GCM observed scenarios capture the rainfall seasonality, but are lower than the SAWS observed precipitation for the winter period (Figure 17). The SAWS summer precipitation falls between the GCM scenarios. The future GCM results suggest an increase in winter precipitation in the CSIRO A2 and CSIRO B2 scenarios and ECHAM A2, while HADAM A2 indicates a decrease (Figure 18). ECHAM A2 suggests a seasonality shift.

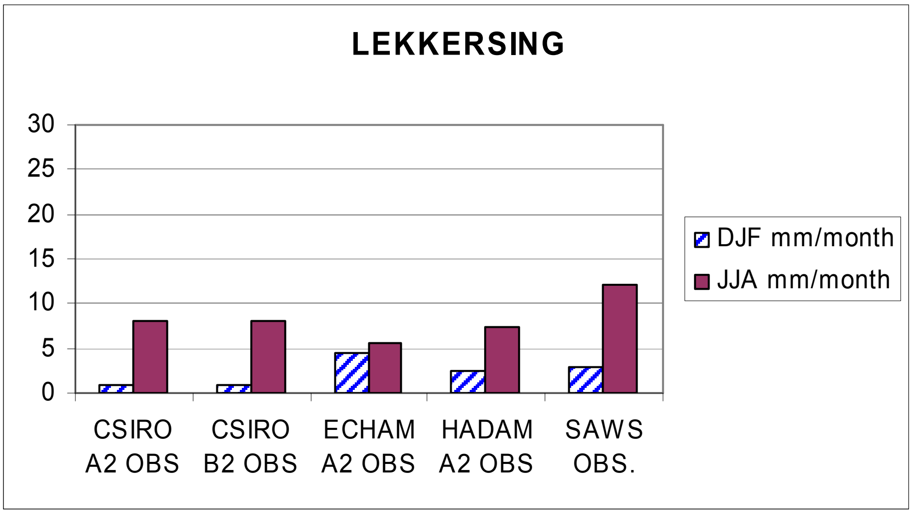


Figure 17: Comparison between GCM observed and SAWS observed precipitation for Lekkersing (in mm/mo)

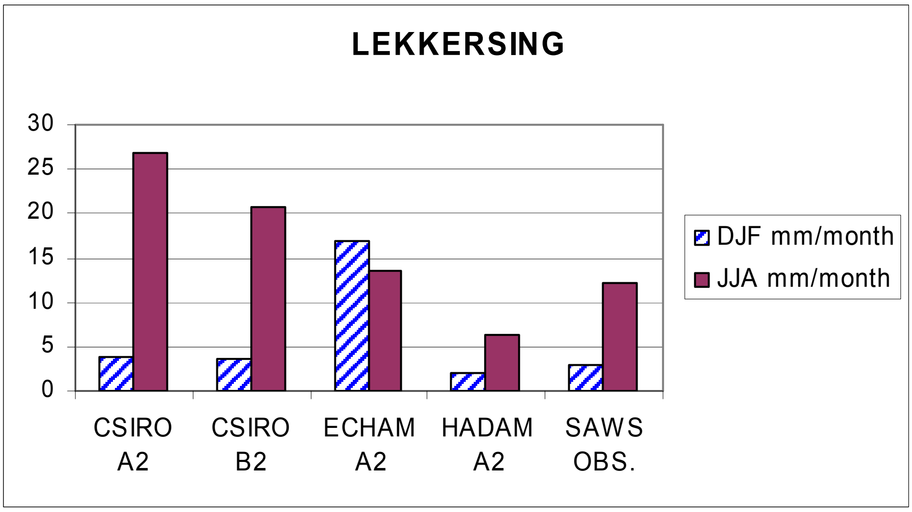


Figure 18: Comparison between GCM future and SAWS observed precipitation for Lekkersing (in mm/mo)

5.3.5 Sutherland

The ECHAM A2 and HADAM A2 models both incorrectly capture the rainfall seasonality. Winter rainfall is under-represented in all scenarios, while summer rainfall is under-represented in CSIRO A2 and B2, and over-represented in the other 2 GCMs (Figure 19). HADAM A2 suggests a slight future decrease in winter rainfall and increase in summer rainfall, while the other GCM scenarios suggest notable increases in both seasons (Figure 20).

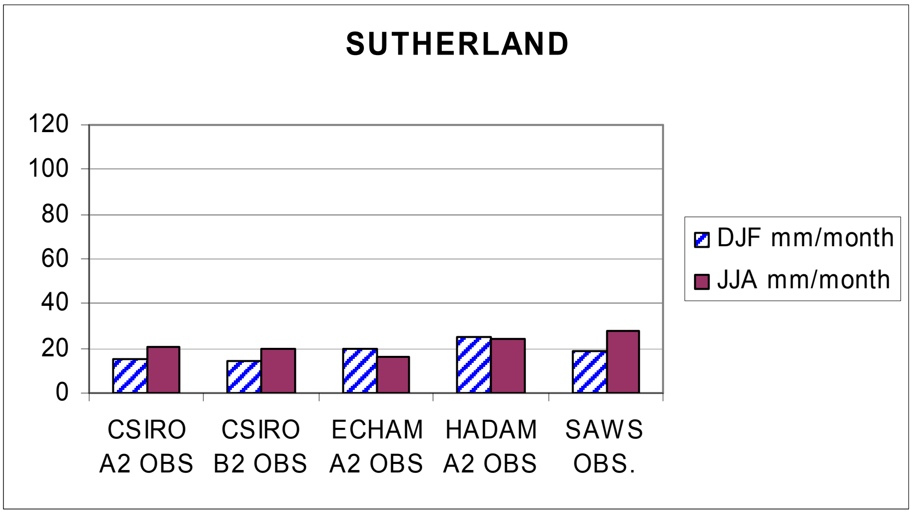


Figure 19: Comparison between GCM observed and SAWS observed precipitation for Sutherland (in mm/mo)

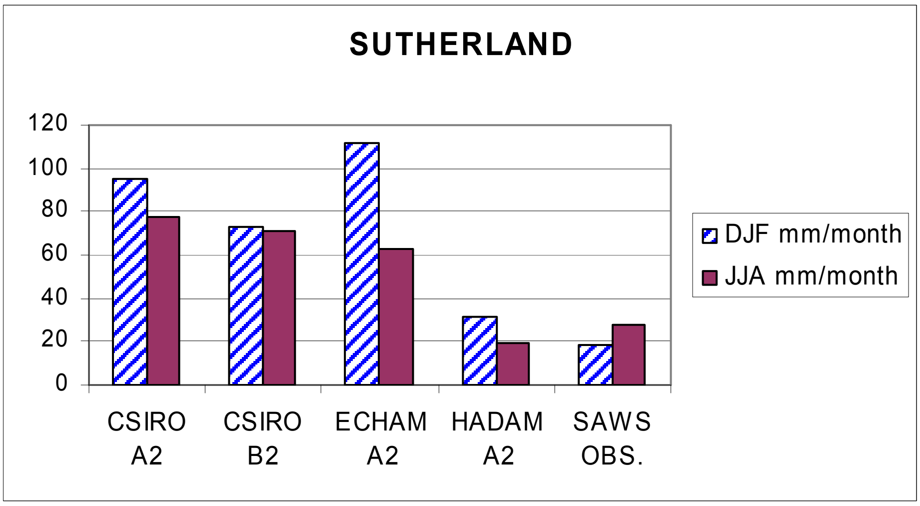


Figure 20: Comparison between GCM future and SAWS observed precipitation for Sutherland (in mm/mo)

5.3.6 Pofadder

All GCM control runs capture the rainfall seasonality represented in the SAWS observed (Figure 21). HADAM A2 slightly over-predicts the observed summer rainfall while CSIRO A2 and CSIRO B2 under-predict the observed. ECHAM A2's summer rainfall is most akin to the SAWS observed. All GCMS have a tendency to slightly under-represent the observed winter precipitation. Summer rainfall increases are suggested in all future GCM scenarios (Figure 22), most notably in the ECHAM A2 model. Winter rainfall decreases are suggested by HADAM A2 and increases by the other three scenarios.

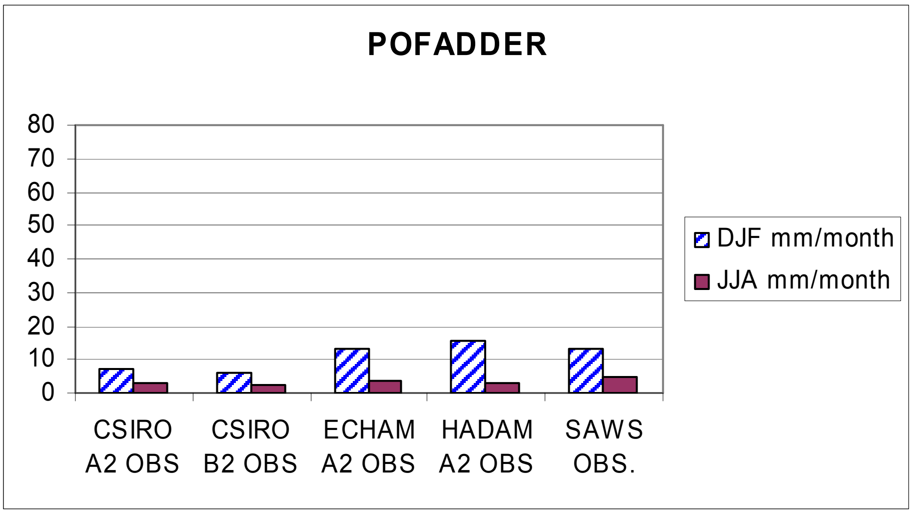


Figure 21: Comparison between GCM observed and SAWS observed precipitation for Pofadder (in mm/mo)

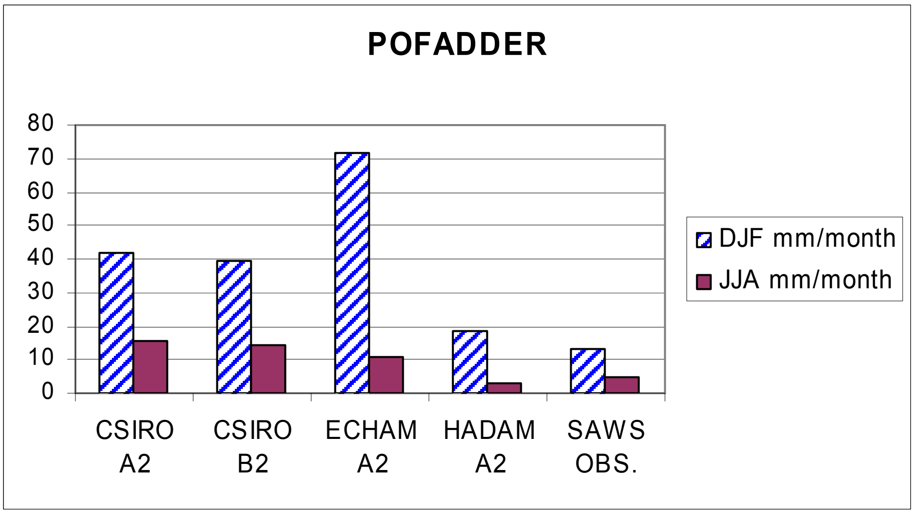


Figure 22: Comparison between GCM future and SAWS observed precipitation for Pofadder (in mm/mo)

5.3.7 Van Wyksvlei

The HADAM A2 control run slightly over-predicts summer rainfall, while ECHAM A2 slightly under-predicts (Figure 23). The CSIRO A2 and CSIRO B2 more notably under-predict summer rainfall. Winter rainfall is similar in all scenarios, but with HADAM A2 being slightly too low. The ECHAM A2, CSIRO A2 and CSIRO B2 models suggest a notable future increase in summer and winter rainfall, while in HADAM A2 the changes are negligible (Figure 24).

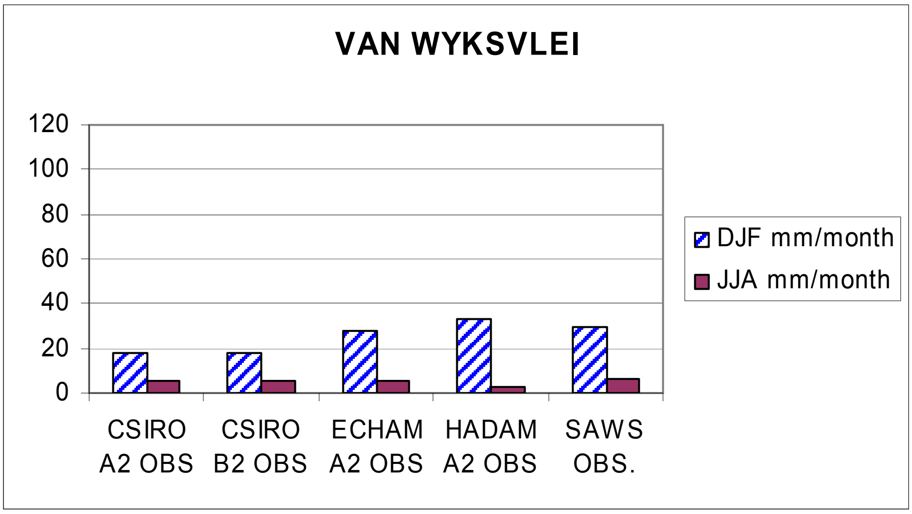


Figure 23: Comparison between GCM observed and SAWS observed precipitation for Van Wyksvlei (in mm/mo)

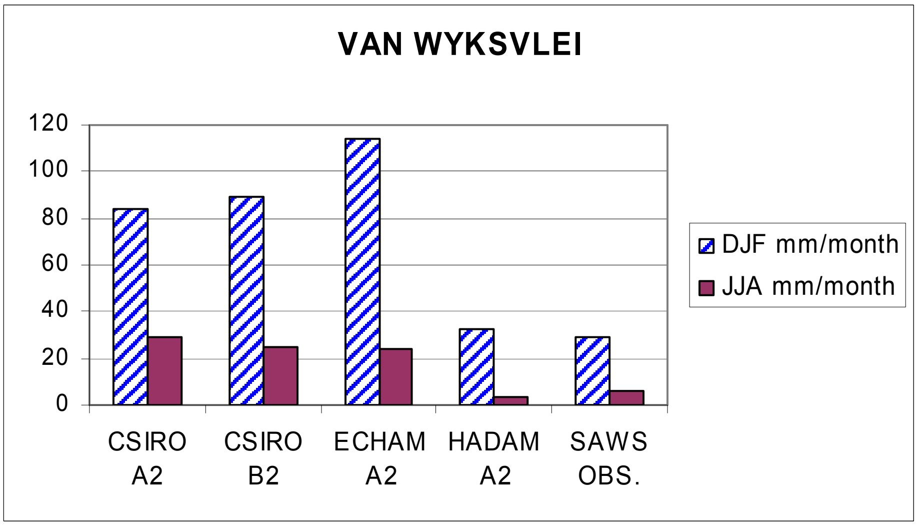


Figure 24: Comparison between GCM future and SAWS observed precipitation for Van Wyksvlei (in mm/mo)

5.3.8 Kenhardt

Observed summer rainfall is under-represented in all GCM scenarios, particularly in the CSIRO A2 and CSIRO B2 control runs Figure 25). The negligible winter precipitation is under-represented in HADAM A2, CSIRO A2 and CSIRO B2. All models suggest a future summer rainfall increase (remarkably so in the case of CSIRO A2 and ECHAM A2) and all but HADAM A2 a winter increase as well (Figure 26).

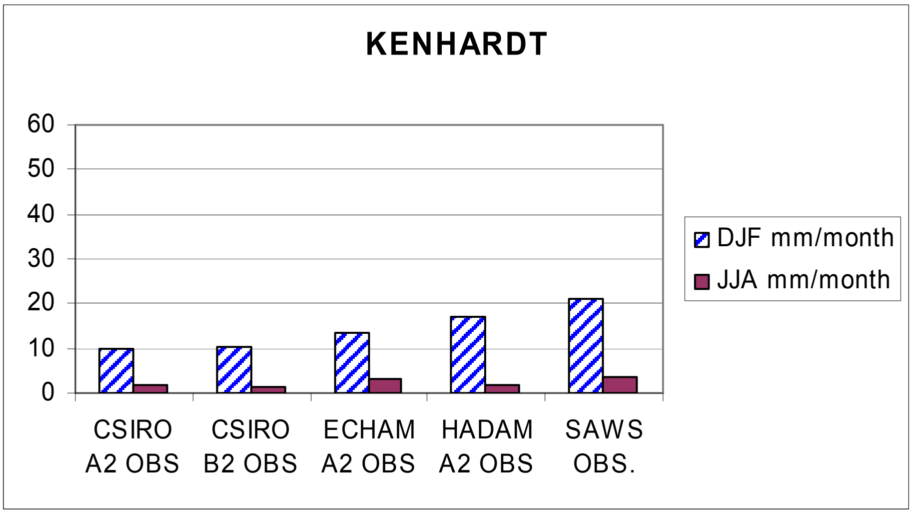


Figure 25: Comparison between GCM observed and SAWS observed precipitation for Kenhardt (in mm/mo)

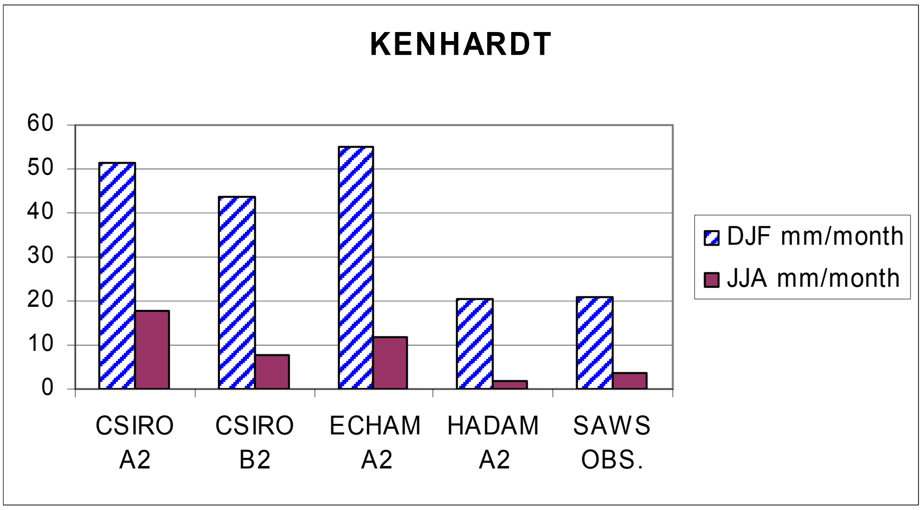


Figure 26: Comparison between GCM future and SAWS observed precipitation for Kenhardt (in mm/mo)

5.3.9 Summary of response

While there is consensus in the literature for an increase in temperature over the entire region, it is clear from the above that there is a degree of inconsistency in precipitation response to climate change between the GCMs used in this analysis. For example, in Steinkopf, HADAM A2 suggests a summer and winter rainfall decrease, while CSIRO A2, CSIRO B2 and ECHAM A2 suggest an increase. Thus, the directional change in response is not clear in many cases, and future climate change could therefore result in an increase or decrease in rainfall, depending on the GCM model used for future projections as well as the local municipality under question.

The mismatch between the GCM observed results and the actual SAWS data could be attributed to the difficulty in comparing point data with the averaged area results of the models.

Further, where annual rainfall amounts are relatively low in the first place, the observed data for the GCMs may quite easily differ from the SAWS observed, and hence increases and decreases may not be too indicative of a climate change response. In areas of winter rainfall, the ECHAM A2 model is in many cases unable to capture the rainfall seasonality. In these areas the future climate change response should therefore be treated with some degree of caution. In summer rainfall regions, ECHAM A2 is better able to capture the seasonality, and hence there is more confidence in the response suggested by the model.

It is therefore apparent from the above that there is no clear certainty of response to climate change in all regions. What is evident, however, is that with climate change, rainfall is likely to change, and this should be factored into planning considerations. Planning at the very least for increased climate variability will go a long way in this regard.

6. Impact of climate change on water resources, specifically groundwater

The impact of climate change on water resources, including groundwater, acts through a modification of the water balance, ranging from the micro to the macro-scale. This included factors such as surface conditions, the soil column, aquifers and catchments (Braune 1996).

In a recent review of the current hydroclimatic "landscape" in southern Africa, Schultze motivates that there is a highly variable and highly sensitive natural hydrological system over southern Africa. He defended the following premises (Schulze 2005b):

1. Even when considering average present climatic conditions, we already live in high risk hydroclimatic environment in southern Africa
2. An already high inter-annual rainfall variability is amplified by the natural hydrological system
3. Intra-annual variabilities of hydrological responses are even higher than inter-annual ones
4. Different components of the hydrological system differ markedly in their responses to rainfall variability
5. Streamflow variability is high in individual external sub-catchments, but in a river system becomes attenuated in internal and mainstem catchments
6. Land use change by intensification or extensification of biomass often increases flow variability because it changes the partitioning of rainfall into stormflow and baseflow components
7. Degradation of the landscape can amplify further any hydrological responses, especially higher order responses

The South African Country Study on Climate Change found that when running GCM and ACRU models, runoff was found to be highly sensitive to changes in precipitation. Groundwater recharge was found to be even more sensitive. Under one of the hotter drier GCM scenarios, decrease in runoff of up to 10% in some areas could be experienced. A decrease of this magnitude could occur in the western area of the country by as early as 2015 (Kiker 2000) (Schulze & Perks 2000).

Groundwater in South Africa usually occurs in secondary aquifers and normally soil cover is shallow. Recharge of the aquifer depends on its type. Some are more responsive to rainfall and recharge is closely linked to higher and persistent rains. Others, such as deep aquifers, are slow to respond and require consistent rain over a period of time (Visser 2004). Studies by Kirchner have shown that before any recharge takes place, a rainfall and soil moisture threshold must be overcome (after Kirchener et al. 1991). The bulk of the recharge takes place in the years in which the average annual rainfall is exceeded and during periods of high rainfall intensity. It stands to reason, then, that the areas that are dependent on groundwater will be most vulnerable to decreases in rainfall and/or variability. In addition, low storage aquifers are the most vulnerable to changes and variability in recharge. This is the situation in 90% of the country (Braune 1996).

Therefore, when considering the impact of drought on the available groundwater for a specific aquifer, it is necessary to determine the recharge regime of the aquifer. The historical recharge data plotted against climate trends for the past 50 years would provide an understanding of the type of rainfall needed to ensure adequate recharge. With this knowledge it will be possible to develop a management system for that specific aquifer. Continual monitoring of the aquifer against climate conditions will provide some knowledge of the future potential under projected climate conditions.

7. Current strategies implemented during climate variability

As stated previously, global temperatures are rising, with some climatic models suggesting that this could cause a decrease in runoff in South Africa, spreading progressively from west to east during the next few decades. A key challenge will be the reconciliation of water demand and supply both for the medium and long terms. While there is planning for future sources of water supply, it appears as if the demand-side of the equation has, until recently, been neglected. Reducing demand can increase excess in supply thereby creating a greater margin of safety for future drought periods

Three basic areas of adaptation for water resources have been suggested (Benioff et al. 1996) in (Schulze & Perks 2000):

- *Increased water supply:* eg modified catchment vegetation, construction of reservoirs and dams, reduction of evaporation, development of groundwater resources and utilisation of inter-basin transfers, desalination of groundwater and sea water.
- *Reduced water demand:* eg demand side management, re-use and recycle water. Demand management is an essential strategy to ensure sustainable development of groundwater resources.
- *Different management of supply and demand:* eg crop substitution, conjunctive use of ground and surface water, application of climate forecasts to manage water resource operations, provision of more versatile inter-basin transfer schemes and more flexible operating rules for water systems.

Planning for the most vulnerable water supply areas should be such that proper monitoring can provide early warning of problems including global change impacts.

It is calculated that the total opportunity in reducing water demand in the water services sector is approximately 39% of the total existing demand. (DWAF 2000)

The efficient use of water should be the driver of any WSDP process. Not only will WDM and WC have significant effect on water resources, but could also ensure effective, affordable and sustainable water services with social, economic and environmental benefits.

7.1 Supply side management strategies

7.1.1 Planning and management

7.1.1.1 Overall water resource planning and management

At a national level, DWAF has developed a National Water Resource Strategy (NWRS) (DWAF 2004b) to address the management of the water resources to meet the development goals of the country. It will be reviewed at least every five years (Kasrils 2002). One of the key objectives of the NWRS is to identify areas of the country where water resources are limited and constrain development as well as development opportunities where water resources are available. In addition, industrial users will be required by December 2005 to develop and submit a water management plan if they draw their water directly from a water source (DWAF 2004b).

DWAF have further stated that they will assist municipalities to anticipate drought cycle conditions and prepare contingency plans for their specific areas through the Water Services Development Plan support (DWAF Northern Cape 2005). During these periods, DWAF state that they will assist municipalities to identify and initiate actions to mitigate the impacts of drought affected areas. Whilst this support is not monetary, DWAF are able to provide technical and planning expertise to the province. With this in mind, in the Northern Cape a database of water resource information is being established by the Water Service Division of DWAF. Currently this information is being housed by a Kimberley-based consultancy. In conjunction with this, DWAF plans to roll out a programme to ensure measuring, storing and interpretation of this water resource information (van

Dyk et al. 2005). This information would ultimately be used by local authorities when doing their Water Service Development Plans.

At a local level, the Kgalagadi District Municipality has prepared a proposal for the development and implementation of a water resource management system within their district (Africon Engineering 2003) (Kgalagadi DM 2004). This initiative has been developed by their health department. To ensure the sustainability of the water resources in their area, they proposed that the following be addressed:

- protection of groundwater resources against over utilization and pollution;
- awareness programmes at different levels.

Long-term planning at local level is essential to ensure future supplies meet future demands. Forward planning of services provides local authorities with better options, as in the case of Garies, where it would not have been possible for them to utilize salt water for the sewage system if the dual infrastructure had not been installed from the start. This has enabled Garies to save the available fresh water for drinking and cooking (Ninham Shand & Octagonal Development 2004a).

In addition to planning, co-ordination of activities and sharing of information at local level is important if a water resource management system is to function adequately. It is important that water authorities be actively involved in the management of water information in order that they deliver a consistent level of service to it's beneficiaries. At present, a number of meetings are convened at local and provincial level viz.:

- SALGA chairs a Provincial Water Sector committee which meets every two months;
- the Department of Housing and Local Government in the Northern Cape Province holds regular (monthly) Provincial Drought Task Team Meetings;
- each District Municipality hosts a District Water Sector Forum each month.

7.1.1.2 Groundwater resource planning and management

Given that the primary water resource of the Northern Cape is groundwater, specific mention is made here of the planning and management of groundwater resources.

Through the NORAD assisted programme for the sustainable development of groundwater sources for the Community Water and Sanitation Programme of South Africa (managed by DWAF), the CSIR has prepared groundwater management framework for rural water supplies (Murray & Ravenscroft 2004). This framework identified four reasons why groundwater should be managed:

- to prevent over-abstraction of the aquifer;
- to optimise the individual pump rates;
- to prevent poor quality groundwater from entering the aquifer;
- to minimise groundwater contamination from surface sources.

The long term goal of DWAF is that local authorities manage their own water supply and demand. This can only be attained if they are informed of the possible supply resources, monthly abstraction volumes and water quality and aquifer levels (van Dyk et al. 2005). It is proposed by DWAF that the following could be supported through the Water Service Authority Capacity Development and Building Programme (WSACDBP):

- aquifer testing and recommendations of the resource potential;
- hydro-geological investigations to determine the resource potential;
- installation of equipment for the monitoring of water levels, volumes abstracted and water quality;
- computer hardware and software to store a database and evaluate the information;
- capacity building and training of personnel to measure, store and evaluate the information.

At provincial level, the Geohydrology section of DWAF in the Northern Cape have promoted the following strategies (van Dyk 2004):

- identify towns with possible water shortages;

- ensure that options are investigated for these towns and ensure infrastructure funding;
- ensure that towns measure the status of their own resources by making resource managers of them;
- ensure a level of assurance of water supply.

They were developed in 2000 but, in van Dyk's opinion, are only now paying off.

The best example of groundwater resource management was the LG&H-funded water management programme in Namakwaland where a database stretching over 10 years was established (Visser 2001). Unfortunately this project was terminated in 2002. Numerous programmes have been tried to establish this capacity at local level with mixed success.

At a local level, Murray and Ravenscroft identify key legal obligations for groundwater management in community water supply, as listed in the following table.

Table 9: Legal obligations for groundwater management
(Murray & Ravenscroft 2004)

Responsibility	CMA	WSA	WSP
Ensuring groundwater monitoring meets the requirements as stipulated in the license agreement	x		
Setting up the groundwater management system	x		
For managing and maintaining the monitoring system		x	
Data collection			x
Sampling at the point of use (standpipes and hand pumps)- could be delegated to the WSP by the WSA.		x	x
Analysing community groundwater monitoring data and ensuring that operational changes are made		x	

The Kareeberg Municipality have developed a capacity development plan to address the water issues in their area (Kwezi/V3 & Africon Engineering 2003). So too have the Karoo Hoogland Municipality commissioned a water resource plan for Sutherland. However, in this case the study has been driven by political promises such as the demand for waterborne sanitation to replace the dry sanitation systems (SRK Consulting 2004). Sutherland should be considering water saving practices since they currently experience water shortages. The Sutherland study also revealed some key issues which hinder the proper planning for future needs. The rainfall data was based on 1997 data which has not been updated to include recent droughts and does not allow for future variation due to climate. The study also revealed that the water meters were not working properly.

Drawing on these two studies, the following planning activities have been proposed and should form part of any groundwater management system:

- design a local groundwater management system;
- conduct borehole tests to determine maximum pump rates and safe yields;
- measure of water levels through a groundwater monitoring programme, with monthly reporting;
- install volume meters on all pumps outlets to measure hourly pump yields;
- install dip meters where necessary;
- develop a record system for monitoring groundwater levels, pump rates and abstraction volumes;
- develop a computer program for capturing data and drawing graphs to monitor the groundwater levels;
- review of monitoring data every six months by a geohydrologist.

7.1.1.3 Assurance of supply

As part of the planning and management of water resources, it has been suggested that each local authority be in a position to guarantee an assurance of water supply to its users under existing climatic conditions (van Dyk et al. 2005). As was illustrated in Figure 3, approximately 25% of the towns in the Northern Cape were using more than 80% of their available groundwater resources in 2000. It is proposed that the peak demand should be 80% of the available yield of the resource. The would allow for a buffer against drought and climate variability. It would also allow the aquifer time to recharge itself (van Dyk 2004).

7.1.1.4 Conjunctive use of surface and groundwater

To avoid the dependence on one source or type of source, some local authorities made use of more than one type of water source, for example using both groundwater and surface water. This is most common where groundwater is found to be too saline for domestic use. One way to increase the available supply is to dilute the saline water with fresh water to acceptable concentrations. Alternatively, the saline water can also be used for flush toilets, whilst the treated water can be used for drinking and cooking. This type of system requires dual water supply and dedicated plumbing for each source, and hence could be costly to install. If identified at an early stage, the infrastructure can be installed in new developments to reduce the reticulation costs.

As is illustrated in the Karkams example in section 7.1.1.5, the conjunctive use of surface and groundwater at local authority level is valuable in increasing the availability of local resources.

7.1.1.5 Artificial groundwater recharge

This is the process of transferring surface water into an aquifer, and could be in the form of rainfall run off, treated wastewater and urban storm runoff. The main reasons for artificial recharge include the following (Murray 2004b):

- to provide security during drought and dry seasons;
- to provide storage of local or imported surplus surface water;
- to manage the operation of surface and groundwater reservoirs;
- to improve the quality of the groundwater, specifically the salinity.

Examples of this practice by municipalities in South Africa include the following:

- Atlantis (> 20 years in operation);
- Polokwane (> 10 years of operation);
- Karkams (> 5 years operation);
- Calvinia (>2 years in operation).

They have demonstrated that this strategy is effective and applicable to both large scale schemes as well as small scale operations. It does require basic maintenance to ensure that the injection rate is optimised.

A specific example that falls within the study area is Karkams (Kamiesberg LM), which has been operating an artificial groundwater recharge scheme for more than five years (Murray 2004b). The aim of this strategy is twofold, namely to reverse the negative dewatering trend and to reduce the salinity by replenishing the aquifer when river runoff is available. During years of good rainfall, the recharge of the aquifer is enhanced by injecting additional water into the aquifer. This scheme provides good quality water and reliable supply to the residents of Karkams. It allows the aquifer to replenish itself and increase its resilience to dewatering during times of low rainfall. The recharge potential for the Karkams aquifer for an injection over a one to six month period could increase the available yield by 0.6 to 3.9 times (Murray & Tredoux 2002). As can be seen in Figure 27, during periods of recharge, which coincide with periods of good rainfall, the groundwater level rose by between 10-25 meters (approximately 25-50%).

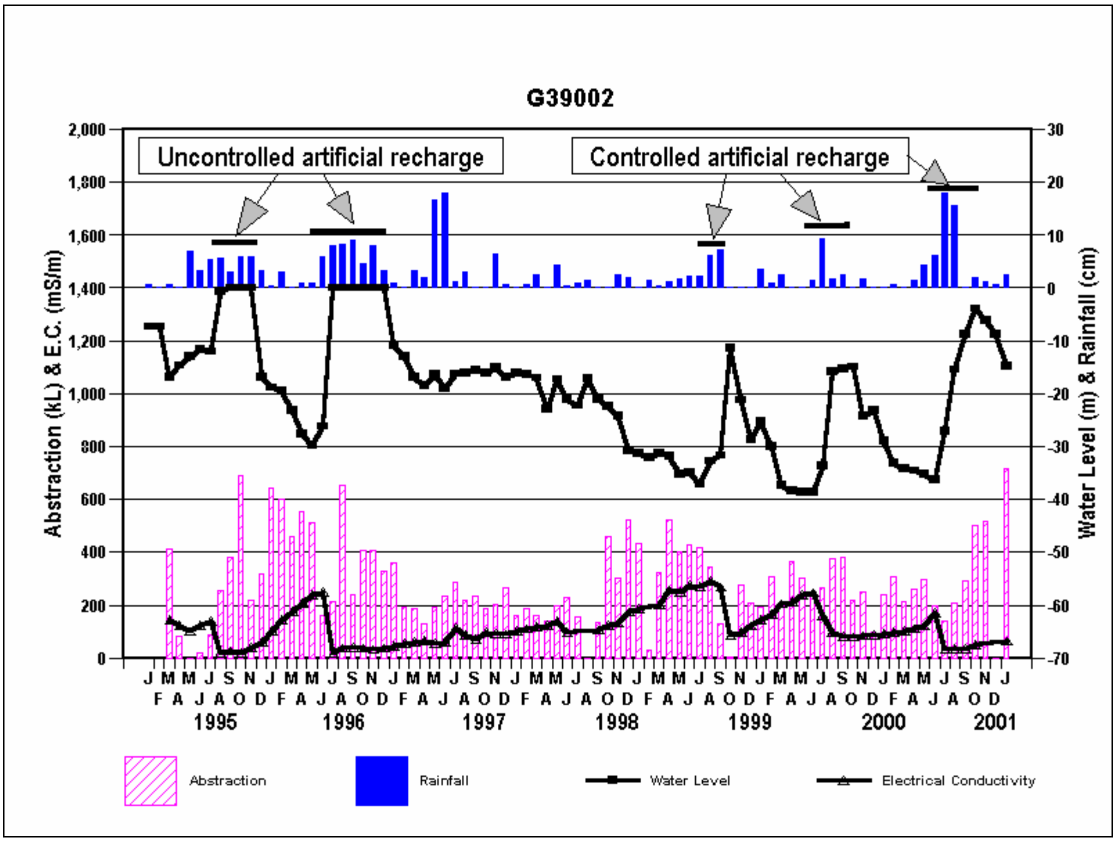


Figure 27: Water level response to artificial recharge at Karkams
(Murray 2004a)

7.1.2 Drought relief

7.1.2.1 Standby relief under critical conditions

The current practice by the Department of Public Works (Department of Housing and Local Government 2005a), is to ensure that there is standby relief for areas which experience abnormal or irregular water shortages. This usually takes the form of tankered water and drought relief funding for basic water infrastructure. This forms part of the National Disaster Management plan, which is co-ordinated by provincial local government. The Disaster Management Act 57 states that each province is charged with the responsibility of preparing a disaster management plan for the province as a whole, coordinating and aligning the implementation of its plans with those of other organizations of state and multinational role-players and regularly reviewing and updating its plan (Republic of South Africa 2003). Likewise, each metropolitan and each district municipality is responsible to establish and implement a framework for disaster management in their municipalities aimed at ensuring an integrated and uniform approach to disaster management in their respective areas. These relief measures should, however, be seen as the exception and not be implemented on an ongoing basis.

7.1.2.2 Water tankering

Water tankers are used during times of drought and breakdown in critical domestic water supply. As stated above, this forms an essential part of standby relief. A most recent example of this is in Kammieskroon where the boreholes have dried up and water is being tankered in from Springbok (Gosling 2005).

At the end of 2004, the Department of Public Works (DPW) indicated that their water tanks had been repaired and could be mobilized on request to municipalities in the Namakwa district when the situation became critical (Department of Housing and Local Government 2005a). In the past, they have received assistance from the South African National Defense Force in this regard. Whilst water tanks would normally be viewed as a re-active measure, ensuring that they are in working order and available when request, shows forward planning on the part of the DPW.

In some cases, however, water tankering has become a regular form of water supply, as in the case of Van Wyksvlei (Kareeberg). During 2003 water was supplied by tanker from Carnarvon (60 km away) and Copperton to Van Wyksvlei and it was proposed to continue with this practice until a more permanent solution had been developed (Department of Housing and Local Government 2005b).

7.1.2.3 Drought relief funding and aid schemes

The Department of Housing and Local Government in the Northern Cape Province holds regular (monthly) Provincial Drought Task Team Meetings. These meetings are attended by Department of Housing (DoH), DWAF, Department of Agriculture, Department of Health and Social Services and the local district municipalities. This Task Team co-ordinates the drought relief efforts for the province and keeps track of the allocation of relief funding from the different departments. The drought of 2003/2004 brought the critical resource problems to DPLG's attention and ensured that limited funding was made available.

In most cases, the drought relief funding has been used to expedite the delivery of basic services and provide co-funding for bulk infrastructure to remote areas. An example of this was the importation of water from the Vaal and the Gariep rivers via pipelines. This was relatively costly and the majority of this funding was through CMIP, the DWAF Water Services CAPEX programme and the 2003/2004 Drought Relief Programme (van Dyk et al. 2005).

In 2004/5 the Department of Agriculture allocated R1 million to the Northern Cape for aid to farmers that experienced critical water shortages for stock watering and human consumption on privately owned farms and on communal land (Department of Agriculture 2005). The main condition set by the National Department of Agriculture to qualify for aid is that the water supply should be less than that needed for a third of the carrying capacity of the farm for stock water plus water needed for human consumption. This has been based on:

- small stock unit: 5 litres per day;
- large stock unit: 50 litres per day;
- human consumption: 20 litres per day.

The amount allocated for human consumption appears to be less than the 25 litres per person recommended by DWAF. Also, the maximum subsidy for drilling a borehole and fitting a pump is R30 000, which means that only 30 applicants can be helped with the R1 million allocated. This allocation is inadequate given that 50 applications for Siyanda and Namaqua alone were received (Department of Agriculture 2005).

7.1.3 Rainwater harvesting

Whilst not considering the agricultural benefits of surface water harvesting, there is also the benefit of improving the recharge of underground water, either by natural infiltration of the soil or by artificial recharge methods. The effectiveness of this does, however, depend on the aquifer type. In the southern tributary catchments of the Lower Orange water management area, the unique use of soil embankments has been employed as a means of rainwater harvesting (DWAF 2004b). This practice enables additional recharging of the aquifer and reduces the runoff. Appropriate measures are required to manage the impacts of these "soomwalle" on downstream users (BKS (Pty) Ltd 2003).

At a domestic level, rainwater harvesting from roofs is an effective way of augmenting drinking water, watering gardens and filling up swimming pools.

In the Northern Cape the following towns have implemented domestic rainwater harvesting schemes: Namaqualand: Rietpoort, Waqu, Paulshoek, Lepelfontein, and Sutherland recently spent R33 000 on rainwater harvesting equipment for domestic housing (Visser 2004; Department of Housing and Local Government 2005b) .

7.1.4 Desalination

Desalination offers an opportunity for coastal municipalities to convert seawater into freshwater. Presently this technology is both a capital- and energy-intensive source of freshwater that would make the cost of water out of the reach of most local municipalities – in some case 3-4 times the cost of conventional sources (Eglal R et al. 2000). However, in places such as the Middle East, where there is no alternative this technology provides a solution. In Dubai, for example, 95% of the drinkable water comes from the sea. In Australia, Perth plans to build a plant with a capacity of 123 Ml/day, using reverse osmosis (Makin 2005).

There are specific locations within South Africa where small-scale desalination has proven to be more cost-effective than transporting fresh water over long distances. In these instances, groundwater with a high saline content is desalinated using small plants. Examples of this in Namakwaland can be found at Bitterfontein, Spoegrivier, Kruis and Klipfontein (Visser 2004) and Kareeberg at Van Wyksvlei (DWAF 2003).

High levels of fluoride are currently treated using defloridation plants at clinics and schools at locations such as Khakams and Leliefontein. (Visser 2004)

7.1.5 Reduction of leaks

In South Africa, the level of unaccounted for water in urban distribution systems is between 15 and 20%, which is viewed as high by international standards (Goldblatt et al. 2002). Unaccounted for water not only amounts to losses in usable water, but also in potential revenue due to additional treatment and distribution costs. These losses are often passed onto the consumer, who are required pay higher tariffs to offset these losses.

With the stress on available water supplies, consumers cannot be expected to increase the available water resource through a reduction in demand alone. Losses in the system need to be addressed as part of supply management. Service providers should see this as one of their main target areas for “creating” more available water. Just as any viable business would aim to reduce their commodity losses in order to maintain their competitiveness, so too should Water Service Providers aim to run an efficient operation. It has been estimated that a saving of up to 15% of demand can be achieved by implementing effective distribution management measures (DWAF 2004c). The following measures have been suggested to water service institutions to reduce distribution leaks:

- leak detection;
- repair of visible and reported leaks;
- pressure management;
- effective zoning of the distribution system;
- pipe replacement programme;
- cathodic protection of pipelines against corrosion.

The implementation of leak detection and repair programmes have been implemented by some municipalities. A wider roll-out of this programme would reduce the water losses from reticulation systems in the province. In addition, the introduction of pressure management systems where water lost from undetected leaks is reduced by reducing the off peak water pressure in the pipes. This also reduces the water lost through leaks within the piping on private property. This is further discussed in section 7.2.6.

7.2 Demand side management strategies

There a number of ways to reduce the water demand by consumers. The first is to influence their consumption behaviour. This could be done through education as well as through persuasive means eg restrictions and tariff structures. The second would be to provide incentives or assistance projects. The implementation of urban water demand management will not make any significant impact on the availability of water on a catchment-wide scale. However, it is a crucial intervention that must be implemented by all local authorities, so as to prolong the life of existing urban sources of supply. To encourage this at local level, DWAF have stated that they will not consider the licensing new water resource developments for any local supply schemes unless water demand management has been implemented (Ninham Shand et al. 2004).

7.2.1 Water restrictions

In a some towns such as Carnavon (Kareeberg) and Calvinia (Hantam), water restrictions have been implemented as means of curbing water demand (Department of Housing and Local Government 2005b). This has been done either through rising block tariffs or the restriction of certain water uses, such as the watering of domestic gardens. In severe cases, users are restricted to a certain volume of water per day. Those exceeding this are fined.

Instituting water restrictions requires additional personnel capacity to police the interventions and to prosecute those who are offenders. The implementation of an education campaign to both inform users of the new measures and to make them aware of water saving practices also requires capacity and funding..

7.2.2 Tariff structures

One of the most effective ways being used by local authorities to encourage consumers to use water more efficiently is through tariff mechanisms. In most cases a rising block tariff has been used to curb excessive use of water. This mechanism is designed along the principle of "the more you use the more you pay", as illustrated below. This mechanism does not usually require additional staffing or resources, but an adjustment to the billing system. An education campaign is also advisable in this instance to make people aware of the new billing systems and also to make them aware of water saving practices. As can be seen from the example for Cape Town (Table 10), the local authority increased the water tariffs substantially in an attempt to curb excessive water use. This measure was implemented as a result of the very low water levels in the dams due the prevailing drought conditions during 2003 and 2004.

Table 10: Example of domestic consumption rising block tariff (City of Cape Town 2005)

Consumption in kl	*Tariff per kl*		
	2004/5	*2005/6*	*increase*
0 – 6	R0.00	R0.00	R0.00
7 – 12	R2.32	R2.46	6%
13 – 20	R6.15	R6.52	6%
21 – 40	R10.41	R11.04	6%
41 – 60	R13.34	R25.00	87%
61 +	R17.20	R50.00	191%

7.2.3 Sanitation systems

7.2.3.1 Dry sanitation systems, low-flow systems

In areas where there is a lack of water to allow conventional flush toilets, dry sanitation, pour flush and low flow systems should be considered. In Van Wyksvlei (Kareeberg), 270 households have been fitted with ventilated improved pit latrines and 75 with conservancy tanks (DWAF 2003). This community also only has yard taps, since the available water will not meet the higher demand that would be generated from household connections. In 2003 the planned flush toilet project for Carnarvon (Kareeberg) was stopped by the Premier and the Minister of Water Affairs and Forestry, and dry sanitation was specified due to the shortage of water in the area (Karoo District Municipality 2003). In areas that are dependent on groundwater, care must be taken to avoid contamination of groundwater source when installing VIP latrines. Composting latrines or lined chambers should be considered if there is a potential for contamination.

7.2.3.2 Saline water for toilets

As discussed under conjunctive use of surface and groundwater, saline water can be used for flush toilets as is the practice in Garies (Kamiesberg). A dual system was adopted where the salt water is used for the sewage system and the fresh water is used for drinking (Mvula Trust 2001). This type of system requires a dual water supply and dedicated plumbing for each source. If identified at an early stage, the infrastructure can be installed in new developments to reduce the reticulation costs, which can be costly if implemented at a later stage.

7.2.4 Water education

Public information and school education programs are key to highlighting the need and benefits of initiating water demand strategies. These programmes could include brochures, advertising, newsletters or magazine and newspaper inserts, exhibits and informative billing.

A good example of this is in Kenhardt (Kai !Garib), which has no new water resource option. They have embarked on a capacity building programme to address demand side management issues.

7.2.5 Re-use of grey water

Grey water utilisation at a domestic level can be beneficial for irrigating small gardens, as is the practice in Carnavon, and to lesser extent assisting in the recharge of groundwater resources. This practice not only reduces the water demand, but also relieves the volume on the waste water treatment works. Municipal byelaws are required to regulate this practice to avoid the contamination of the groundwater and to ensure that pooling of grey water does not take place, which could lead to the spread of diseases. The use of properly constructed French drains should be regulated.

7.2.6 Leak reduction

The average water wastage due to plumbing leaks in the household is estimated at 20% of the total indoor household water use (DWAF 2004c). Consumers should be encouraged to maintain their internal reticulation systems. Whilst no revenue may be lost due these leaks by the service provider, unused water is being wasted through leaking taps, pipes and faulty toilet systems. Together with the education programme and pressure control systems, these internal leaks can be reduced.

A recent study was commissioned in De Aar to investigate the excessively high consumption relative to the population size. The study revealed that a leak, accounting for a third of the water demand, was discovered on the Spoornet premises (van Dyk 2004).

7.3 Other possible strategies not yet implemented in the Northern Cape

7.3.1 Dual flush toilets

This strategy reduces the demand for water for the provision of waterborne sanitation. Studies have shown that toilets account for approximately 30% of total residential indoor water use (Soroczan & Baynes 2003). Some models of dual flush toilets use six litres of water to flush solid waste but only three litres of water to flush liquid waste. These toilets save an average of 26% more water over the single-flush six litre toilets. In places such as Australia and Singapore, this technology is mandatory.

7.3.2 Assistance projects

These are interventions of best management practice, which could be funded or partially funded by the WSA. Examples of this would include projects to repair leaks, to retrofit dual-flush toilets, installation of dual water supply and distribution systems (using saline groundwater for flushing and using treated potable water for drinking and cooking) and replace exotic gardens with waterwise gardens. By providing incentives, more efficient use can be made of recycled water, such as grey water for gardens.

7.3.3 Control of invasive alien vegetation

It has been estimated that close to 3% of the national mean annual runoff is intercepted by invasive alien vegetation. Through the Working for Water programme, large areas are being cleared of alien vegetation as part of local catchment management strategies (DWAF 2004b). The impact of alien vegetation on water resources is difficult to assess because of the lack of available information. Invading alien vegetation is found along some tributary water courses and on the banks of the

Orange River; but this does not seem to be a serious problem in the Northern Cape (BKS (Pty) Ltd 2003). Most of the area has 0-1% invading alien plant cover per quaternary water catchment, with some small areas having 1%-5% coverage (DWAF 2002). Only 5% of the budget spent over the past nine years by the Working for Water programme has been spent in this province (DWAF 2004d).

7.3.4 Rainfall enhancement

Research has shown that only 10% of moisture in atmospheric systems passing over South Africa falls as rain (Shippey K et al. 2004). By using cloud seeding, i.e. the artificial introduction of additional particles into clouds around which raindrops can form, the ability of the clouds to produce rainfall is enhanced. Rainfall enhancement can only stimulate raindrop formation where clouds already exist and meet particular physical criteria. However, these areas are limited to the Eastern and North Eastern parts of South Africa, and there is little scope for this practice in the Northern Cape. Furthermore, the cost implications may make this practice prohibitive for small municipalities (Otieno FAO & Ochieng GMM 2004).

8. Long-term suitability of strategies using multi-criteria analysis

In section 7, various existing strategies to reduce the vulnerability to the impacts of drought (climate variability) were discussed. There are several possible methods to select and prioritise those strategies that would also meet longer-term climate change impacts. However, there would be a number of criteria against which the strategies would need to be rated and in some cases this would result in winners and losers for different criteria. The challenge is to use a tool that deals with conflicting decision making in a structured and systematic manner. The most commonly used are cost benefit analysis (CBA), cost effective analysis (CEA) and multi-criteria decision analysis (MCDA) (LEG 2004). The first two require that costs and benefits are expressed in absolute monetary terms. However, in this study numerous criteria may be included which do not have monetary values. Resource management usually involves variables which cannot be fully quantified, but are nonetheless determinant factors in the decision making. In such cases MCDA is considered to be the quickest and most appropriate method for addressing vulnerability strategies. A detailed description of the methodology has been outlined in section 2.2. Pietersen (2004) cautions that the application of MCDA methods in water resource management should be used circumspectly by planners and decision-makers. The MCDA is a tool and should not be viewed as "black box" (Pietersen 2004). By using the MCDA methodology the strategies most likely to be appropriate to the Northern Cape have been identified. This was done in consultation with representatives of the various Local Municipalities in the Northern Cape province and members of the Provincial Drought Task Team.

8.1 Criteria for analysis

DWAF have set a number of objectives against which strategies by water institutions or consumers to influence the water demand and usage of water should be measured (DWAF 2004a) viz:

- economic efficiency;
- social development;
- social equity;
- environmental protection;
- sustainability of water supply and services;
- political acceptability.

These were further expanded for this study and the list of criteria given in Table 11 was developed and discussed with the stakeholders.

Table 11: Definitions of criteria for strategy analysis

1. Additional yield / saving	How will the intervention impact on water supply through additional yield and/or savings?
2. Technology required	Is the technology for the intervention readily available?
3. Additional capital expenditure	Will the intervention require additional capital expenditure?
4. Additional running costs	Will the intervention incur additional running costs?
5. Local employment	To what extent will the intervention impact on job creation?
6. Local capacity to implement	What level is the institutional capacity currently at with respect to the intervention?
7. Acceptability to local community	What is the consumer acceptability of this intervention in terms of additional cost to them and convenience?
8. Impact on local water resources	What impact will the intervention have on the water resources and the environment in the area?
9. Long term applicability	What is the period of impact of the intervention? (short - long term)

The ninth criteria, long-term applicability, was included as final screen to establish which strategies have the potential to address long term climate change impacts.

The criteria were weighted from 1-5, where 1 was deemed to have a low importance, and 5 a high importance. In Figure 28 the relative weight is provided. As can be seen from the figure, different sectors placed varying importance on the different criteria for evaluating the strategies. A good example of this would be local employment, where the local government officials placed a higher priority on this weight compared to the officials from DWAF. [9]

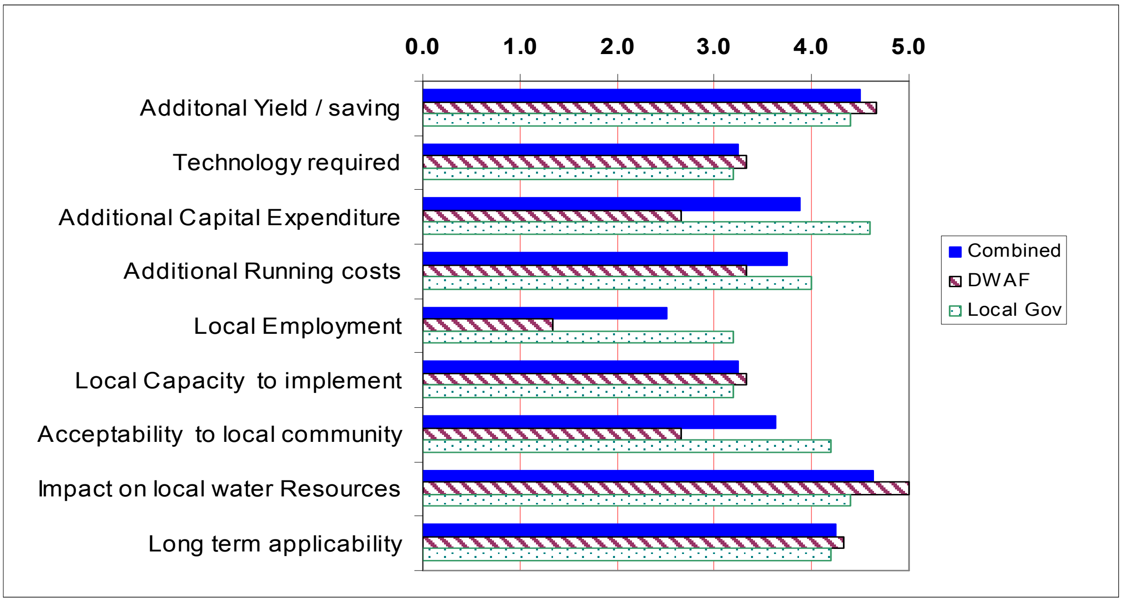


Figure 28: Graphical representation of weightings for criteria

Almost all parties agreed that the following were of highest importance:

- additional yield/saving;
- additional capital expenditure;
- impact on local resources;
- long term applicability.

For each criterion, the strategies were scored against the ranges shown in Table 12.

Table 12: Ranges for scores against the criteria

1. Additional yield / saving	1 = None 2 = Low 3 = Significant 4 = Very high
2. Technology required	1 = Not available 2 = must be imported 3 = available in SA 4 = locally available 5 = already installed
3. Additional capital expenditure	1 = High cost 2 = medium cost 3 = Low cost 4 = No cost

[9] It should be emphasised that the responses received from the stakeholders were their own views and not those of their respective organisations.

4. Additional running costs	1 = High costs 2 = medium costs 3 = Low costs 4 = No O&M costs
5. Local employment	1 = Loss of jobs 2 = Neutral 3 = Few jobs (<10) 4 = Many jobs (10-30)
6. Local capacity to implement	1 = Very low 2 = Low 3 = Adequate 4 = High
7. Acceptability to local community	1 = None (high additional costs) 2 = Low (some additional costs or inconvenient) 3 = Neutral 4 = High (no additional costs)
8. Impact on local water Resources	1 = Negative 2 = Neutral 3 = Positive 4 = Highly positive
9. Long term applicability	1 = <2 years 2 = 2-5 years 3 = 5-15 years 4 = 15-25 years 5 = >25 years

8.2 Strategy analysis

The list of strategies developed in section 5 were rated against the criteria, using the ranges listed above.

- Regional water resource planning
- Local water resource management and monitoring system (incl. telemetry)
- Artificial groundwater recharge
- Conjunctive use of surface and groundwater
- Standby relief under critical conditions
- Tankering of water
- Drought relief and aid funding
- Rainwater harvesting
- Desalination
- Water restrictions
- Dry sanitation systems
- Education programmes
- Tariff structures
- Re use of grey water
- Saline water for toilets
- Reduction of leaks programme
- Dual flush toilets

- Rainfall enhancement

The following discussion is based on the results obtained from the stakeholders who attended the Drought Forum meetings.

8.2.1 Analysis of strategy options against each criteria.

In the following section each of the criteria are used to comparatively analyse the strategies.

8.2.1.1 Additional yield / saving

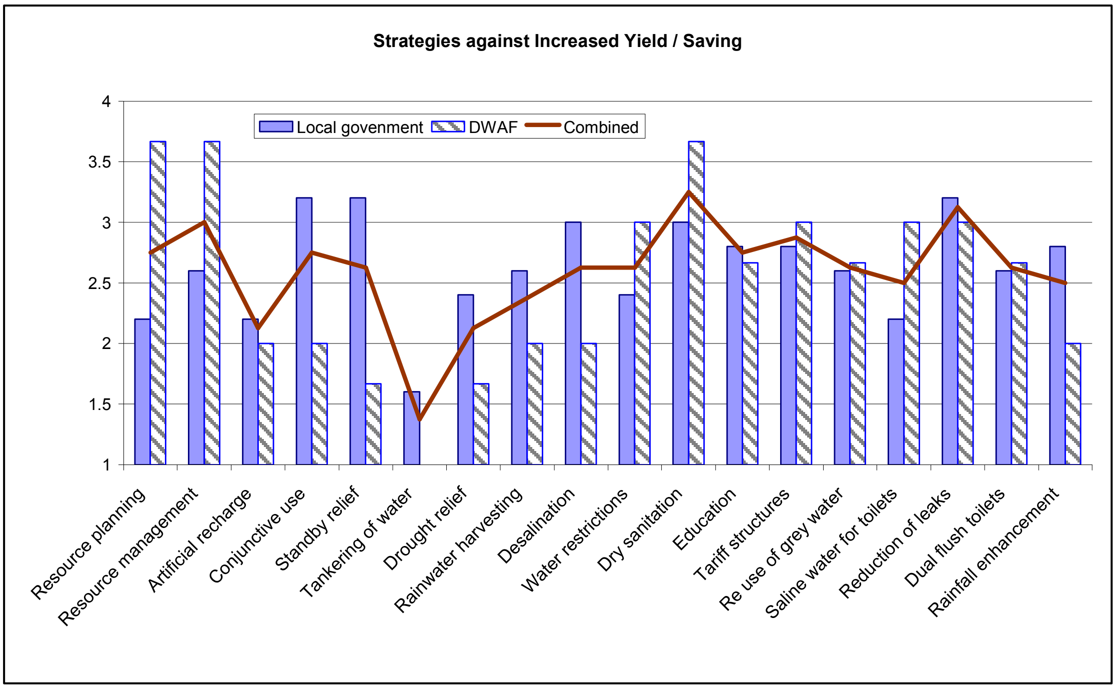


Figure 29: Graphical representation of all strategies against the criteria for *Additional yield / saving*

Table 13: Average scores for strategies against the criteria for *Additional yield / savings*

Strategies: *(Only those scoring ≥ 3 are listed below i.e. a score in the top 1/3)*	*Average scores*		
	Combined	*Local gov*	*DWAF*
Regional water resource planning	2.8	2.2	**3.7**
Local water resource management & monitoring	**3.0**	2.6	**3.7**
Conjunctive use of surface and groundwater	2.8	**3.2**	2.0
Standby relief under critical conditions	2.6	**3.2**	1.7
Desalination	2.6	**3.0**	2.0
Water restrictions	2.6	2.4	**3.0**
Dry sanitation systems	**3.3**	**3.0**	**3.7**
Tariff structures	2.9	2.8	**3.0**
Saline water for toilets	2.5	2.2	**3.0**
Reduction of leaks programme	**3.1**	**3.2**	**3.0**

When considering which strategy would yield an increase in supply or a saving in water consumed, the combined group of stakeholders chose three strategies (all of which scored above 3), viz.:

- Local water resource management and monitoring systems;
- Dry sanitation systems;

- Reduction in leaks programme.

Dry sanitation systems was put forward by both groups as the best strategy to increase the available water resource. It is interesting to note that both *Regional water resource planning* and *Local water resource management & monitoring systems* scored very high with the DWAF officials, but relatively lower for the local government officials. The converse is true of *Conjunctive use of surface and groundwater* and *Standby relief*, where the local government officials gave them relative high scores. *Tankering of water* was considered by all as being the least effective in increasing the available yield or saving water resources.

8.2.1.2 Technology required

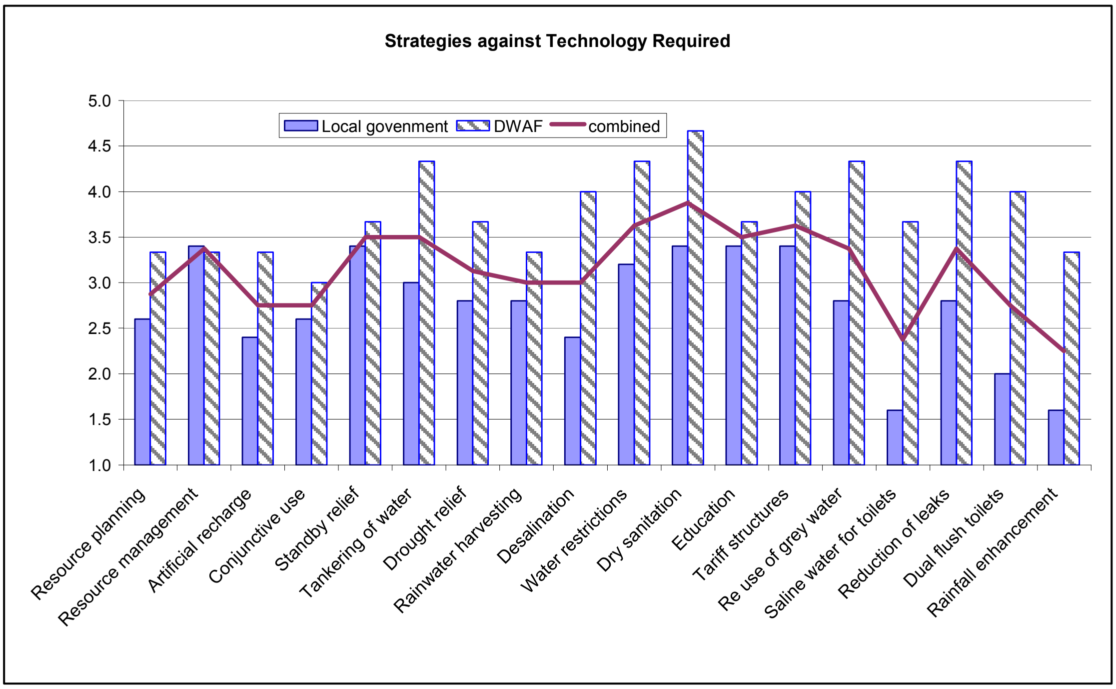


Figure 30: Graphical representation of all strategies against the criteria for *Technology required*

Table 14: Average scores for strategies against the criteria for *Technology required*

Strategies: (Only those scoring ≥ 4 are listed below i.e. a score in the top 1/4)	*Average scores*		
	Combined	*Local gov*	*DWAF*
Tankering of water	3.5	3.0	**4.3**
Desalination	3.0	2.4	**4.0**
Water restrictions	3.6	3.2	**4.3**
Dry sanitation systems	3.9	3.4	**4.7**
Tariff structures	3.6	3.4	**4.0**
Re use of grey water	3.4	2.8	**4.3**
Reduction of leaks programme	3.4	2.8	**4.3**
Dual flush toilets	2.8	2.0	**4.0**

The combined group of stakeholders did not consider that the technical skills were locally available to implement any of the strategies, although *Dry sanitations systems* came close. It is interesting to note that for almost all the strategies, the Local government officials scored them lower than the DWAF officials. All eight of the strategies listed in the table above, were considered by the DWAF officials to be technically viable at the local level. *Rainfall enhancement* was considered by the combined group as being the strategy that required most outside input of technical skills, however, the DWAF officials did give it an above average score.

8.2.1.3 Additional capital expenditure

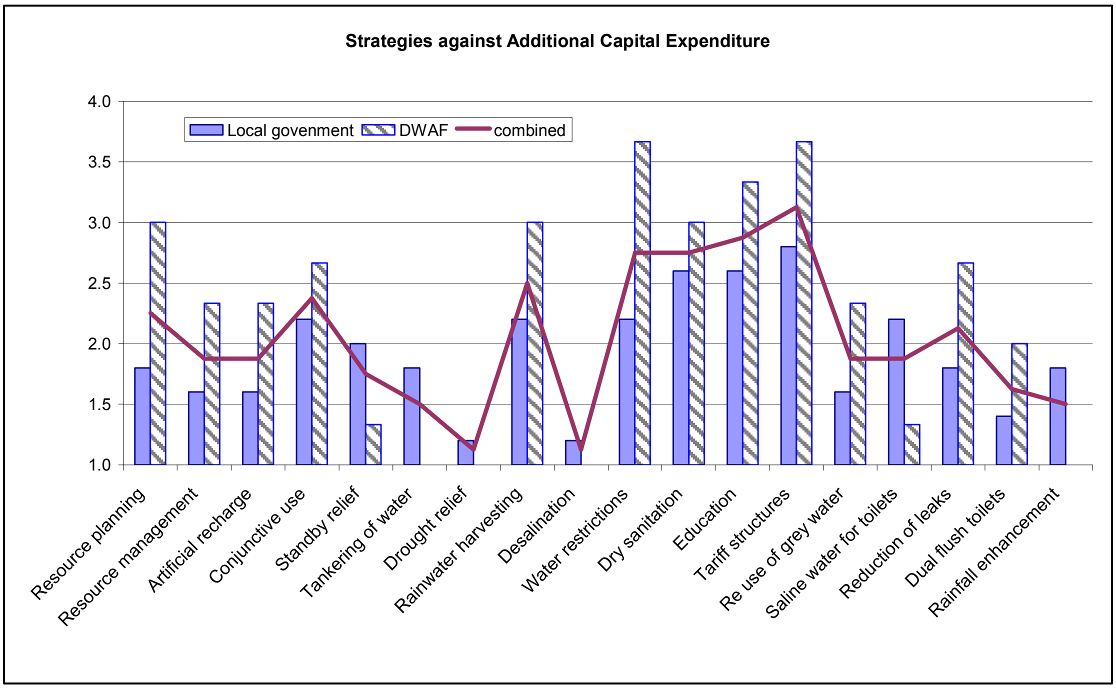


Figure 31: Graphical representation of all strategies against the criteria for *Additional capital expenditure*

Table 15: Average scores for strategies against the criteria for *Additional capital expenditure*

Strategies: (Only those scoring ≥ 3 are listed below i.e. a score in the top 1/3)	*Average scores*		
	Combined	*Local gov*	*DWAF*
Regional water resource planning	2.3	1.8	**3.0**
Rainwater harvesting	2.5	2.2	**3.0**
Water restrictions	2.8	2.2	**3.7**
Dry sanitation systems	2.8	2.6	**3.0**
Education programmes	2.9	2.6	**3.3**
Tariff structures	**3.1**	2.8	**3.7**

The combined group only considered *Tariff structures* as being the least capital intensive strategy. In addition, the DWAF officials provided high scores to the rest of the strategies listed in the table. All the stakeholders considered the following strategies too capital extensive to be considered as viable strategies:

- Tankering of water;
- Drought relief and aid funding;
- Desalination;
- Rainfall enhancement.

8.2.1.4 Additional running costs

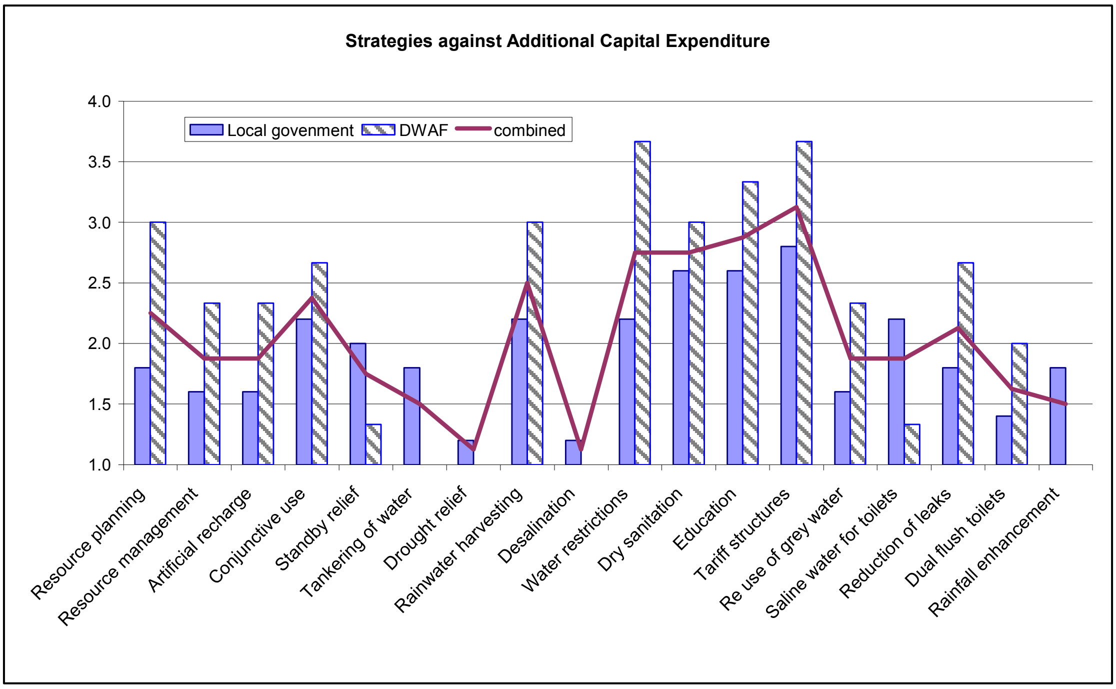


Figure 32: Graphical representation of all strategies against the criteria for *Additional running costs*

Table 16: Average scores for strategies against the criteria for *Additional running costs*

Strategies: *(Only those scoring ≥ 3 are listed below i.e. a score in the top 1/3)*	*Average scores*		
	Combined	*Local gov*	*DWAF*
Regional water resource planning	2.4	1.8	**3.3**
Water restrictions	2.9	2.4	**3.7**
Dry sanitation systems	2.6	2.4	**3.0**
Tariff structures	**3.0**	2.6	**3.7**

The combined group only considered *Tariff structures* as the strategy which would provide a low additional running cost. In addition, the DWAF officials considered the other three strategies listed in the table, as having low operating costs. All the stakeholders considered the following strategies too capital extensive to be considered as viable strategies:

- Tankering of water;
- Drought relief and aid funding;
- Desalination;
- Saline water for toilets.

8.2.1.5 Local employment

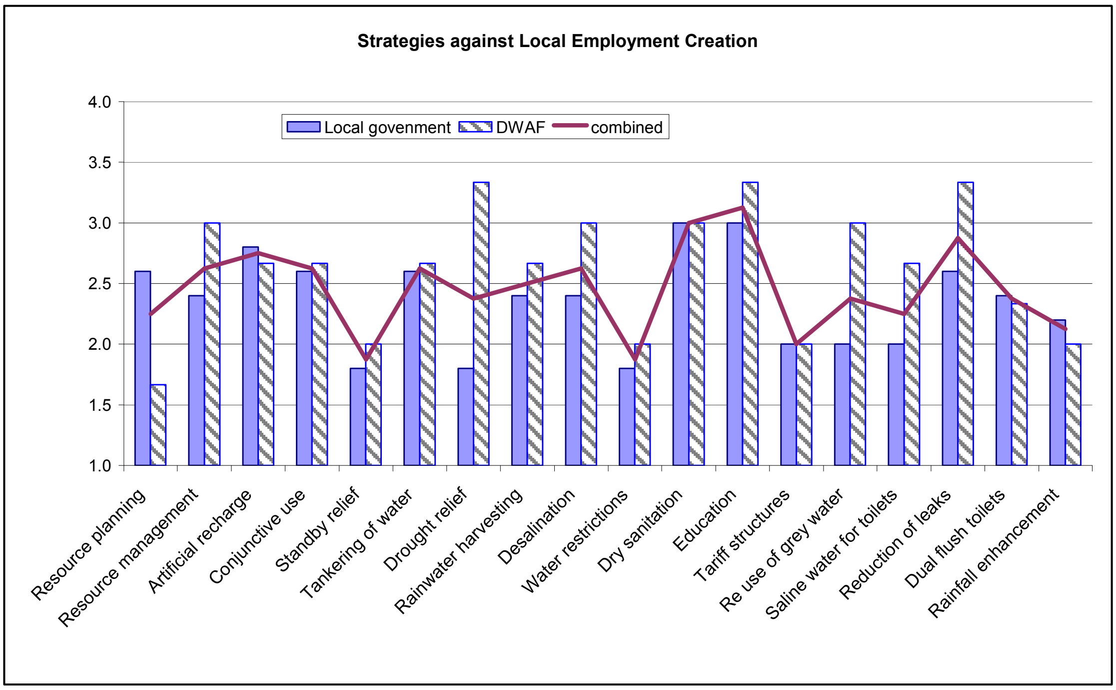


Figure 33: Graphical representation of all strategies against the criteria for *Local employment creation*

Table 17: Average scores for strategies against the criteria for *Local employment creation*

Strategies: *(Only those scoring ≥ 3 are listed below i.e. a score in the top 1/3)*	*Average scores*		
	Combined	*Local gov*	*DWAF*
Local water resource management & monitoring system	2.6	2.4	**3.0**
Drought relief and aid funding	2.4	1.8	**3.3**
Desalination	2.6	2.4	**3.0**
Dry sanitation systems	**3.0**	**3.0**	**3.0**
Education programmes	**3.1**	**3.0**	**3.3**
Re use of grey water	2.4	2.0	**3.0**
Reduction of leaks programme	2.9	2.6	**3.3**

When determining which strategy would yield an increase in local employment, the combined group of stakeholder scored the following two strategies scored above 3, viz.:

- Dry sanitation systems;
- Education programmes.

The DWAF officials considered the other strategies listed in the table as also being strong candidates to increase local employment. None of the strategies stand out as having negative impact on local employment. All the strategies would have a positive impact on the local employment.

8.2.1.6 Local capacity to implement

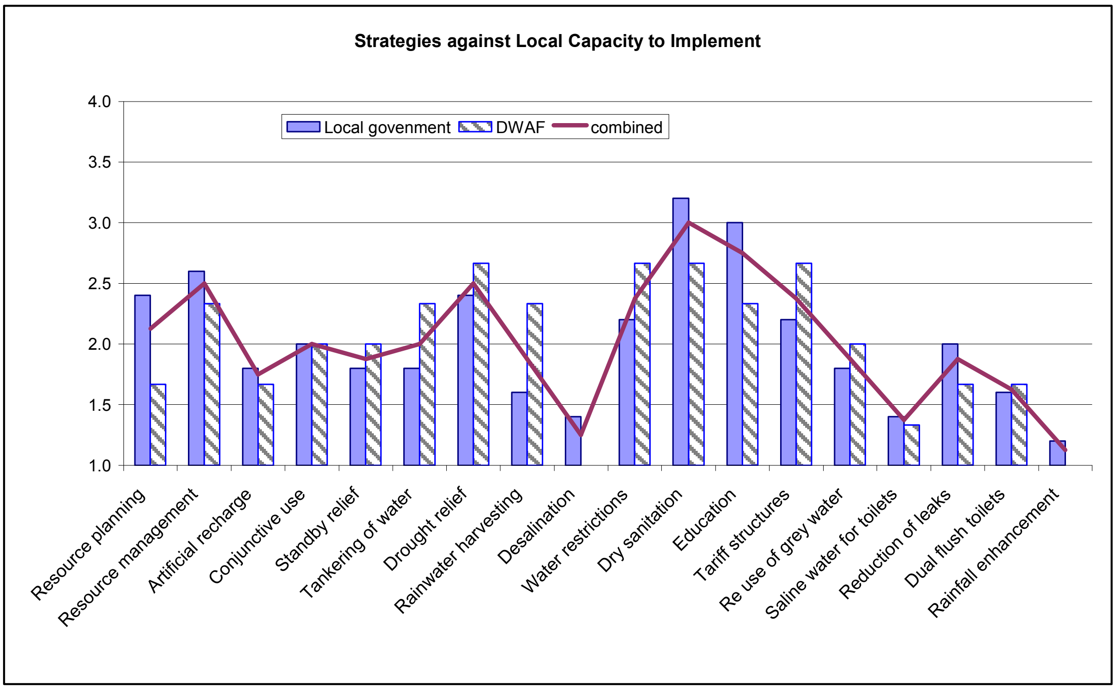


Figure 34: Graphical representation of all strategies against the criteria for *Local capacity to implement*

Table 18: Average scores for strategies against the criteria for *Local capacity to implement*

Strategies: *(Only those scoring ≥ 3 are listed below i.e. a score in the top 1/3)*	*Average scores*		
	Combined	*Local gov*	*DWAF*
Dry sanitation systems	**3.0**	**3.2**	2.7
Education programmes	2.8	**3.0**	2.3

The combined group only considered *Dry sanitation systems* as the strategy which would have the local capacity to implement it. The local government officials also considered that *Education programmes* could be implemented at a local level with out there being a capacity deficit. Three strategies were scored very low to indicate that there is little or no local capacity to implement them, viz.:

- Desalination;
- Saline water for toilets;
- Rainfall enhancement.

It is interesting to note that this criterion resulted in generally low scores for all the strategies. One would also have expected the evaluation of the strategies against the availability of technology locally to closely match the results against the local capacity to implement. However, the latter resulted in lower scores generally.

8.2.1.7 Acceptability to local community

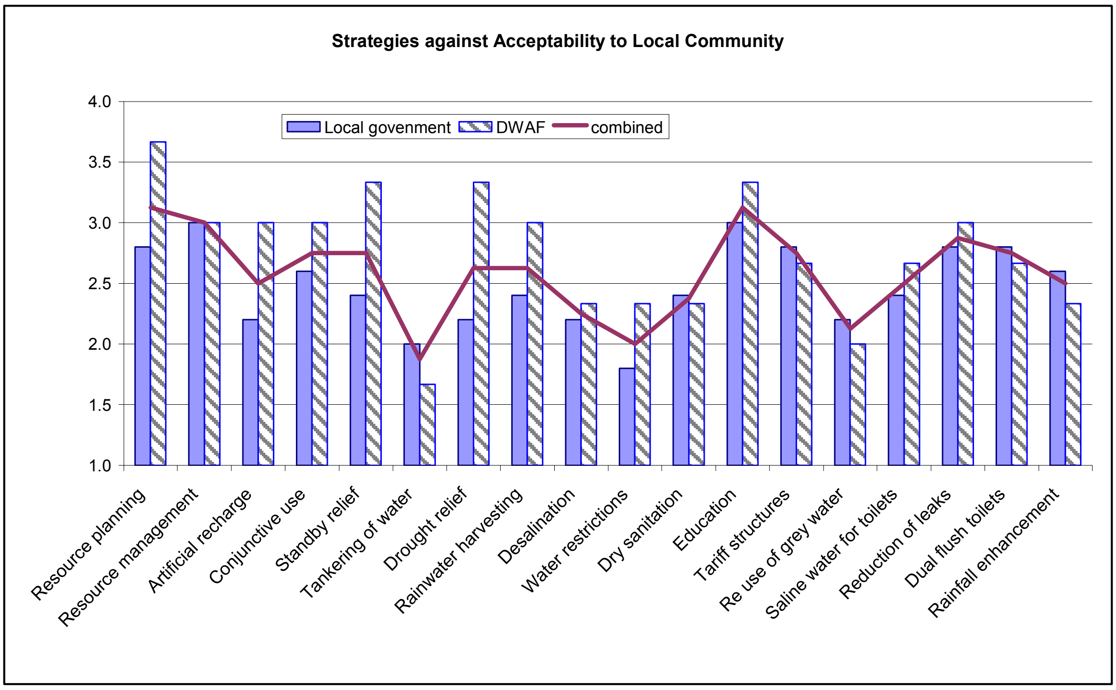


Figure 35: Graphical representation of all strategies against the criteria for *Acceptability to local community*

Table 19: Average scores for strategies against the criteria for *Acceptability to local community*

Strategies: *(Only those scoring ≥ 3 are listed below i.e. a score in the top 1/3)*	*Average scores*		
	Combined	*Local gov*	*DWAF*
Regional water resource planning	**3.1**	2.8	**3.7**
Local water resource management & monitoring	**3.0**	**3.0**	**3.0**
Artificial groundwater recharge	**2.5**	**2.2**	**3.0**
Conjunctive use of surface and groundwater	2.8	2.6	**3.0**
Standby relief under critical conditions	2.8	2.4	**3.3**
Drought relief and aid funding	2.6	2.2	**3.3**
Rainwater harvesting	2.6	2.4	**3.0**
Education programmes	**3.1**	**3.0**	**3.3**
Reduction of leaks programme	2.9	2.8	**3.0**

The combined group of stakeholders considered the following three strategies as being most acceptable to the local community:

- Regional water resource planning;
- Local water resource management & monitoring system;
- Education programmes.

The rest of the strategies on the list were rated high by the DWAF officials. Whilst overall the strategies did not score very low against this criterion, the following five were considered unpopular to the local community:

- Tankering of water;
- Desalination;

- Water restrictions;
- Dry sanitation systems;
- Re-use of grey water.

It is interesting to note that *Dry sanitation systems* scored relatively low and it was put forward as the best strategy given that it had the highest overall combined rating against all the criteria.

8.2.1.8 Impact on local water resources

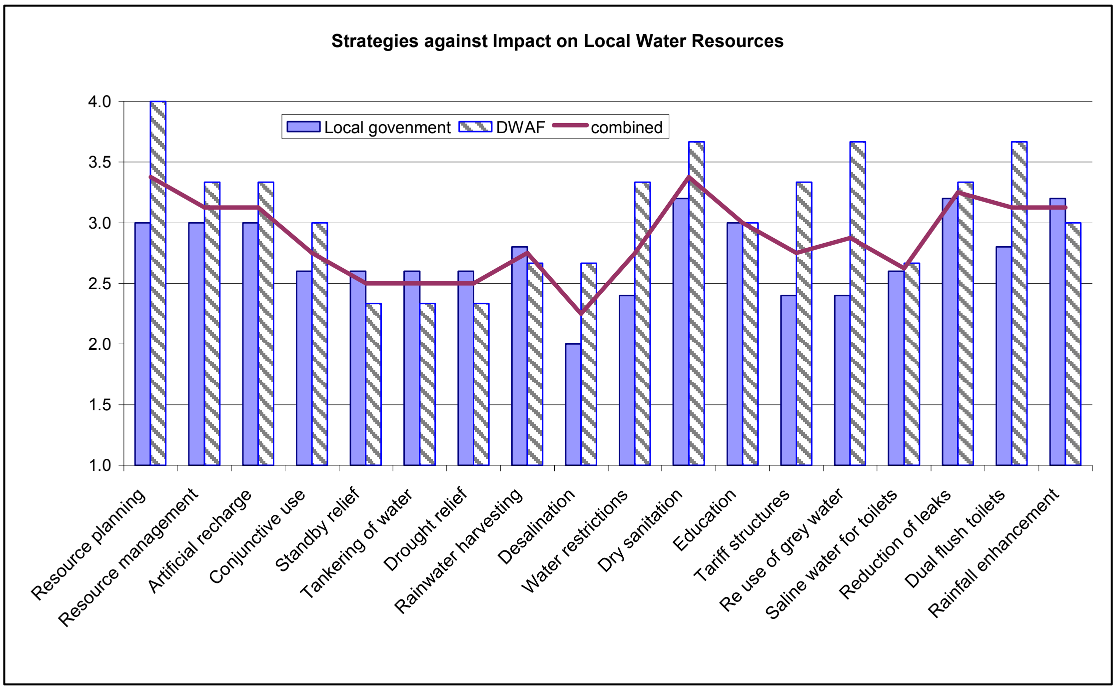


Figure 36: Graphical representation of all strategies against the criteria for *Impact on local water resources*

Table 20: Average scores for strategies against the criteria for *Impact on local water resources*

Strategies: *(Only those scoring ≥ 3 are listed below i.e. a score in the top 1/3)*	*Average scores*		
	Combined	*Local gov*	*DWAF*
Regional water resource planning	**3.4**	**3.0**	**4.0**
Local water resource management & monitoring	**3.1**	**3.0**	**3.3**
Artificial groundwater recharge	**3.1**	**3.0**	**3.3**
Conjunctive use of surface and groundwater	2.8	2.6	3.0
Water restrictions	2.8	2.4	3.3
Dry sanitation systems	**3.4**	**3.2**	**3.7**
Education programmes	**3.0**	**3.0**	**3.0**
Tariff structures	2.8	2.4	3.3
Re use of grey water	2.9	2.4	3.7
Reduction of leaks programme	**3.3**	**3.2**	**3.3**
Dual flush toilets	**3.1**	2.8	**3.7**
Rainfall enhancement	**3.1**	**3.2**	**3.0**

A large number of strategies (listed in bold) were considered to have a positive impact on the local water resources. The DWAF officials included the other four strategies in their portfolio of positive contributors to the local water resources.

None of the strategies stand out as having negative impact on local water resources. They all appear to a have positive impact.

8.2.1.9 Long-term applicability

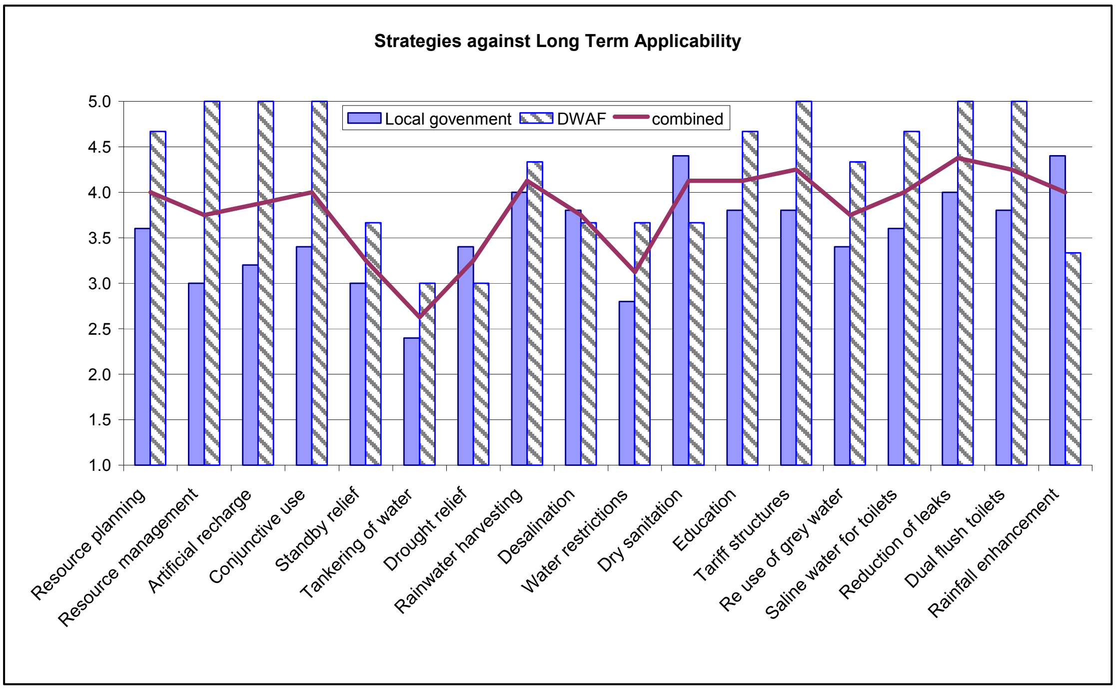


Figure 37: Graphical representation of all strategies against the criteria for *Long-term applicability*

Table 21: Average scores for strategies against the criteria for *Long-term applicability*

Strategies: (Only those scoring ≥ 4 are listed below i.e. a score in the top 1/4)	*Averagescores*		
	Combined	*Local gov*	*DWAF*
Regional water resource planning	**4.0**	3.6	**4.7**
Local water resource management & monitoring system	3.8	3.0	**5.0**
Artificial groundwater recharge	3.9	3.2	**5.0**
Conjunctive use of surface and groundwater	**4.0**	3.4	**5.0**
Rainwater harvesting	**4.1**	**4.0**	**4.3**
Dry sanitation systems	**4.1**	**4.4**	3.7
Education programmes	**4.1**	3.8	**4.7**
Tariff structures	**4.3**	3.8	**5.0**
Re use of grey water	3.8	3.4	**4.3**
Saline water for toilets	**4.0**	3.6	**4.7**
Reduction of leaks programme	**4.4**	**4.0**	**5.0**
Dual flush toilets	**4.3**	3.8	**5.0**
Rainfall enhancement	**4.0**	**4.4**	3.3

Ten of the strategies were regarded by the stakeholders as being long term strategies i.e. having the potential to be implemented for 15-25 years, with an additional three being added by the DWAF officials. The *reduction in leaks programme*, *dual flush toilets* and *tariff structures* obtaining the highest ratings. It is also interesting to note that there is an equal split between DSM and SSM strategies for those scoring above 4.

Whilst the general trend was for most strategies to be applicable in the long term, five strategies were considered to be only applicable for the next 5-15 years, with *Tankering of water* being the least applicable:

- Standby relief under critical conditions;
- Tankering of water;
- Drought relief and aid funding;
- Desalination;
- Water restrictions.

8.2.2 Analysis of strategies against combined criteria

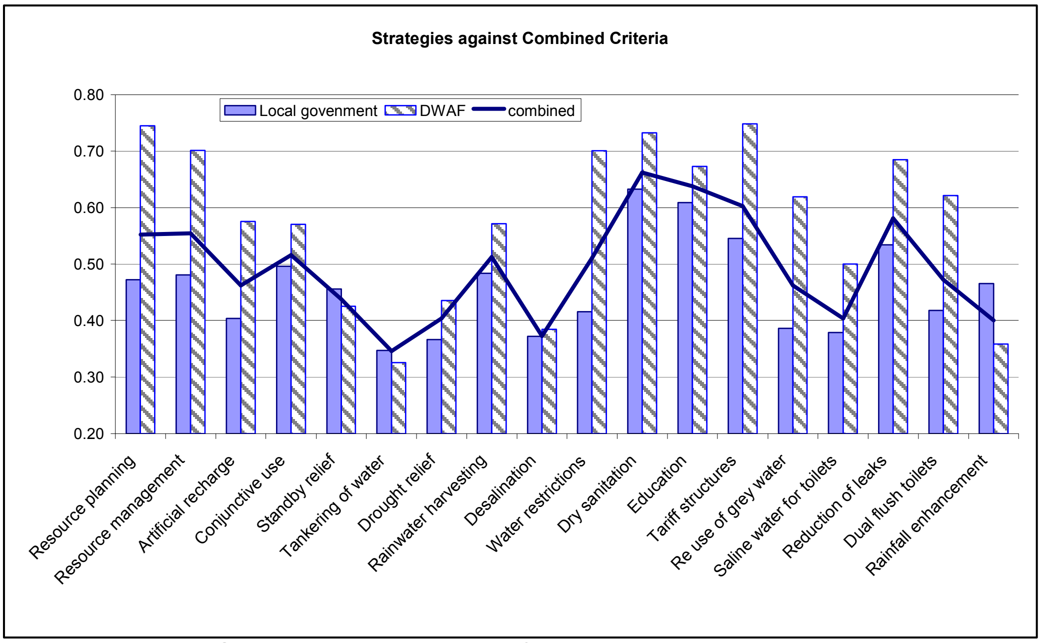


Figure 38: Graphical representation of all strategies using weighted average against all criteria

As can be seen from Figure 38, the following three strategies came out on top, scoring above 60% on the weighted combined rating scale:

- Dry sanitation systems (1)
- Education programmes (2)
- Tariff structures (3)

The following six strategies scored between 50% and 60%:

- Reduction of leaks programmes (4)
- Regional water resource planning (5)
- Local water resource management and monitoring (6)
- Conjunctive use of surface and groundwater (7)
- Rainwater harvesting (8)
- Water restrictions (8)

The following six strategies fell between 40% and 50%:

- Artificial groundwater recharge (10)
- Re use of grey water (11)
- Dual flush toilets (11)
- Standby relief under critical conditions (13)
- Saline water for toilets (14)
- Rainfall enhancement (14)

The final three fell below the 40% score:

- Tankering of water (16)
- Drought relief and aid funding (17)
- Desalination (18)

8.2.3 Detailed analysis of the top nine strategies

The following section contains an analysis of the nine strategies that exceeded a combined score of 0.50. The criteria where the strategy is strongest and weakest in the opinion of the stakeholders surveyed, are discussed. Reference should be made to Appendix B.

8.2.3.1 Dry sanitation systems

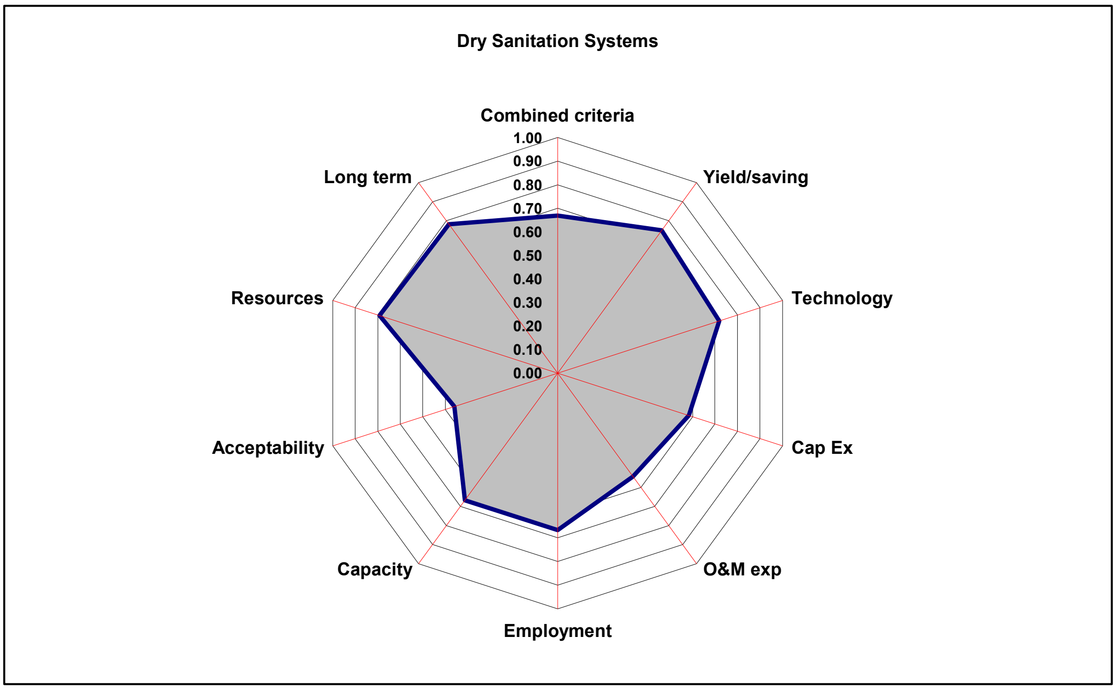


Figure 39: Graphical representation of *Dry sanitation systems* against all the criteria

This strategy was ranked as the top option of the proposed strategies. It strategy scores particularly high for almost all the criteria. It is viewed as having long-term applicability and has a positive impact on the local water resources, since it contributes significantly additional water saving. The local skills and technology are available locally to implement such a strategy and it will provide local employment. This strategy scores lowest on acceptability to the local community.

It is surprising that this strategy ranked on top, given the general low acceptance for non-flush latrines. This type of technology is usually considered a poor persons solution. There is a real tension between the demand for flush toilets in poor communities and the vulnerability of having scarce water resources. Given the political pressures being faced by local authorities it is unlikely that this strategy will be given any serious thought, despite its top ranking.

8.2.3.2 Education programmes

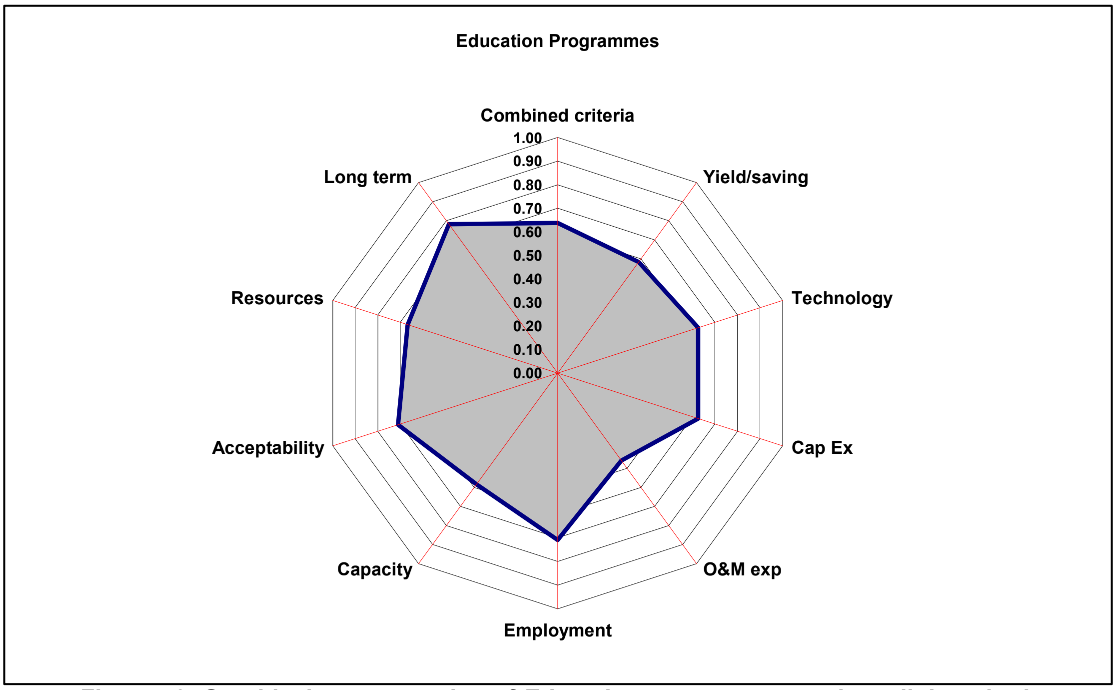


Figure 40: Graphical representation of *Education programmes* against all the criteria

This strategy was ranked second in this list of proposed strategies. It has long-term applicability since its purpose is to change the behaviour and consumptive patterns of consumers. It does not cost the consumers in a direct manner and therefore would have a high local community acceptability. It is also perceived to contribute favourably to employment creation and impact positively to local water supplies. This strategy has a relatively low running costs rating, since it would have medium level operating costs to sustain an education programme. An education programme focused on water efficiency is a proactive way to get local communities to reduce their water consumption.

8.2.3.3 Tariff structures

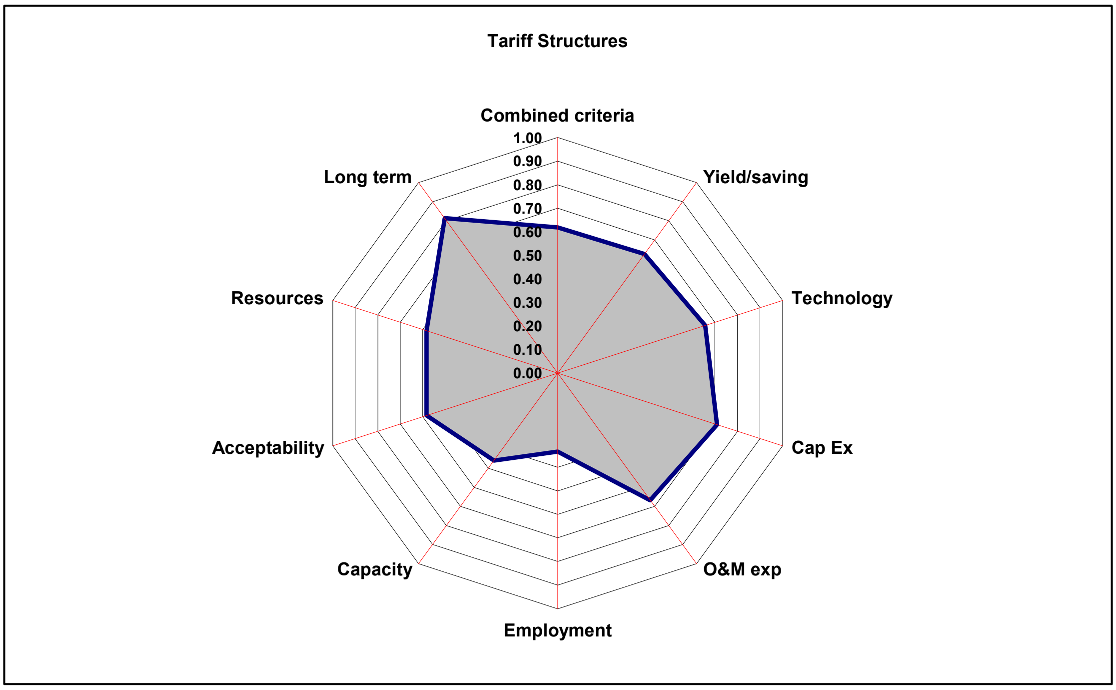


Figure 41: Graphical representation of *Tariff structures* against all the criteria

This strategy was ranked third in this list of proposed strategies. Introducing a tariff structure that curbs high water consumption would have long-term applicability. Once the system is in place, the tariff calculations are automatically generated. It would also require low capital and operating costs. It would in the long run increase the available volume of water for further usage by other consumers. It is unlikely, however, that any new local employment would be generated.

8.2.3.4 Reduction of leaks programme

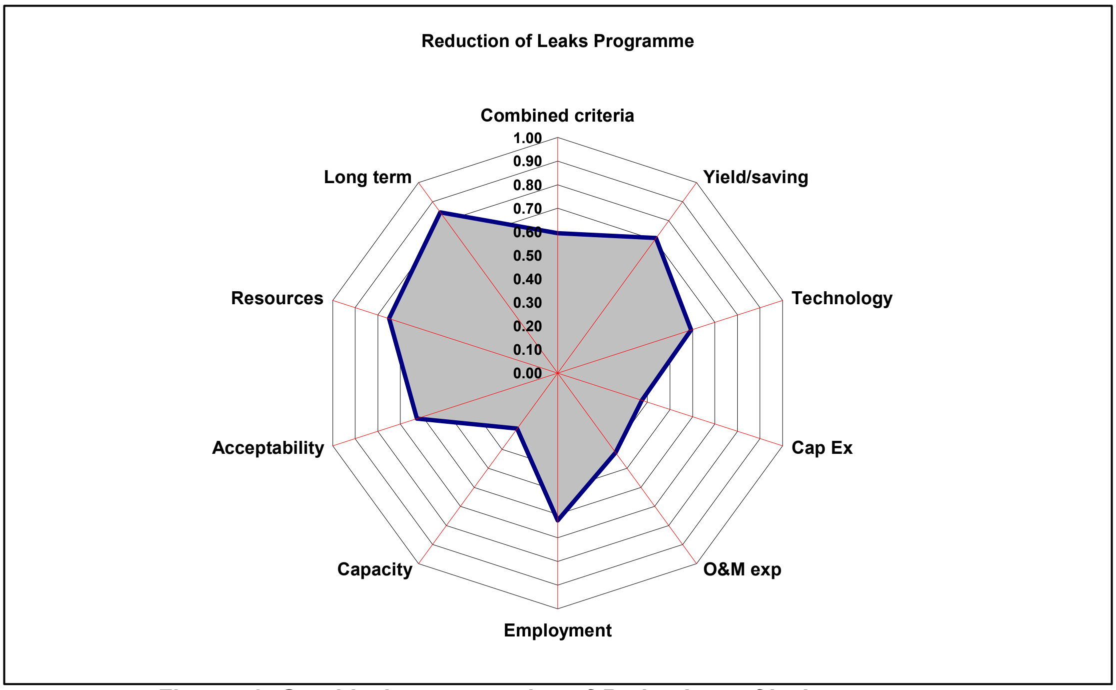


Figure 42: Graphical representation of *Reductions of leaks programme* against all the criteria

This strategy was ranked fourth in this list of proposed strategies. It obtained the highest score of all the strategies for long term applicability. A leak reduction programme should be an ongoing routine maintenance programme that the water service providers regularly undertake. It has the potential to provide local employment, and significantly increase the useable volume of water and hence will have a positive impact on the local water resources. The local capacity to implement such a leak reduction programme is low and the capital investment to set up the programme would be moderate. The operating costs would also be additional, but these could be offset by the saving in lost revenue from unaccounted water.

8.2.3.5 Regional water resource planning

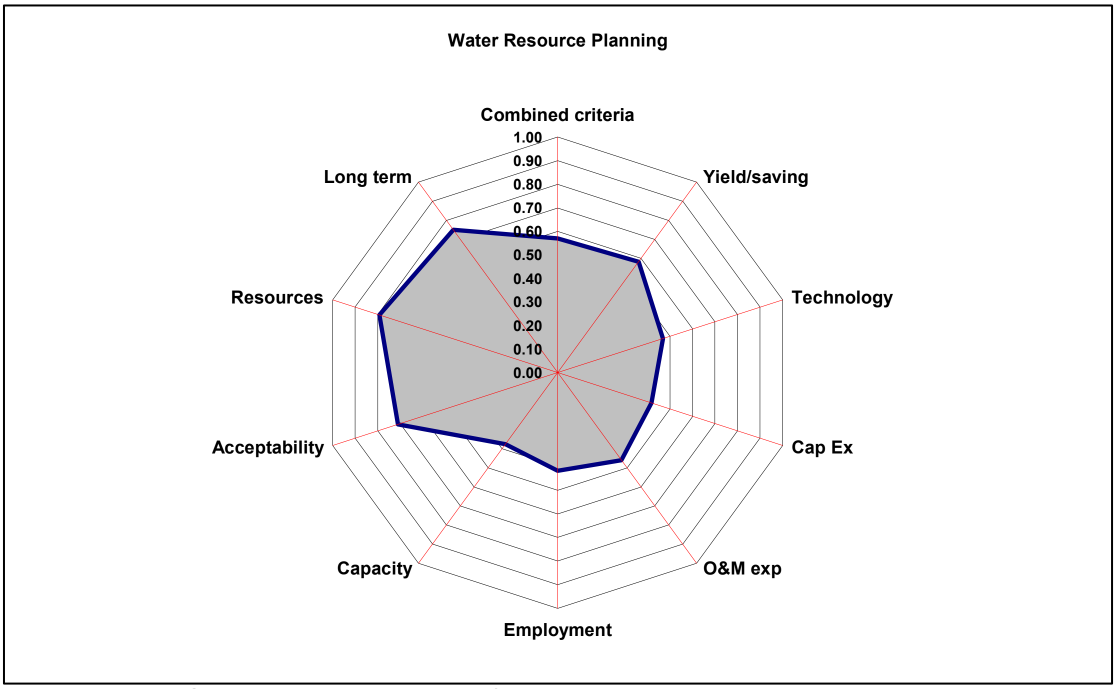


Figure 43: Graphical representation of *Water resource planning* against all the criteria

This strategy was ranked fifth in the list of proposed strategies. It has good potential for long term applicability viz. 15-25 years. Its impact on local water resources is also positive. It is envisaged that the community would have a neutral response to such an intervention, since they would not be directly affected. Such an intervention would have a positive influence on their water security, although there may be a increased financial burden that that gets passed onto the price of water for the region.

Local municipalities do not have the personnel resources to implement such a strategy since it is perceived that the local capacity is low. It also does not have much scope for local employment opportunities as it is likely that skilled personnel would need to be imported to address the low capacity levels in this field. This strategy has relatively medium-level costs, but these should be quantified to obtain a realistic idea of the actual capital investment required and ongoing running costs.

8.2.3.6 Local water resource management and monitoring system

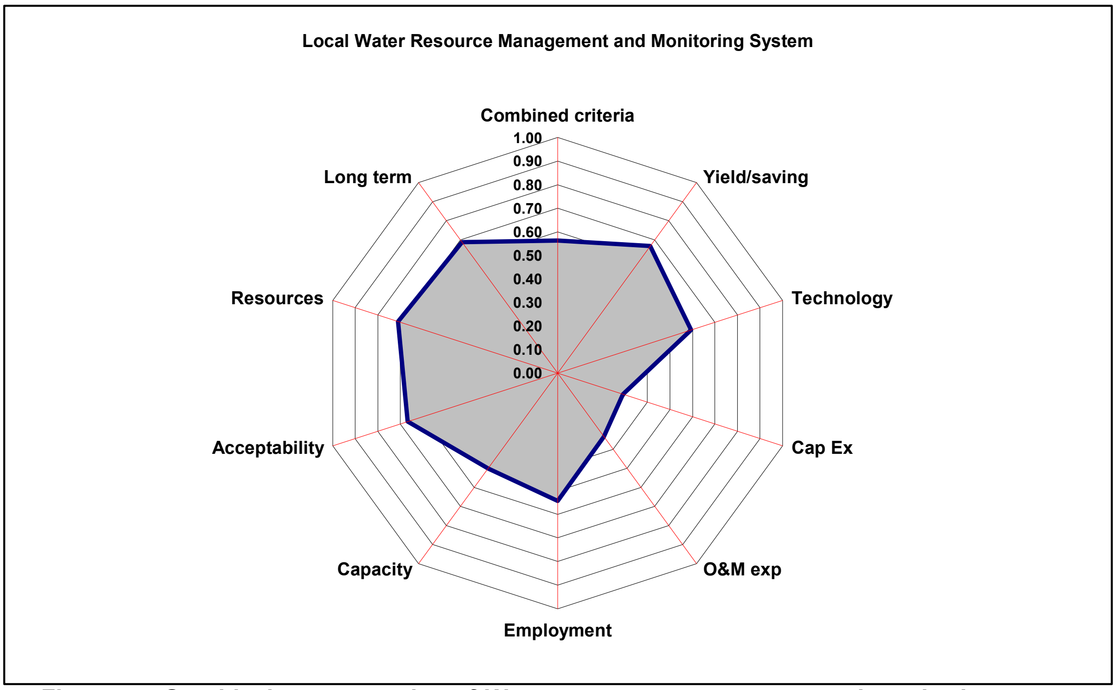


Figure 44: Graphical representation of *Water resource management and monitoring system* against all the criteria

This strategy was ranked sixth in the list of proposed strategies and tied with Regional water resource planning. This would be expected since these two strategies are two parts of the same approach. First the water resources need to be quantified and the supply system planned. Ongoing management and monitoring of this resource would be important to ensure that they are sustainable utilized. The key strength of this strategy, similar to the Regional water resource planning strategy, is the long term applicability of 15-25 years and the positive impact on local water resources. In addition it has significant potential to improve the yield and reduce consumption.

Once again the local acceptability of the strategy is neutral, even though such an intervention would have a positive influence on their water security. There may be a increased financial burden that that gets passed onto the price of local water. This is significant given that the capital and running costs are perceived to be medium.

8.2.3.7 Conjunctive use of surface and groundwater

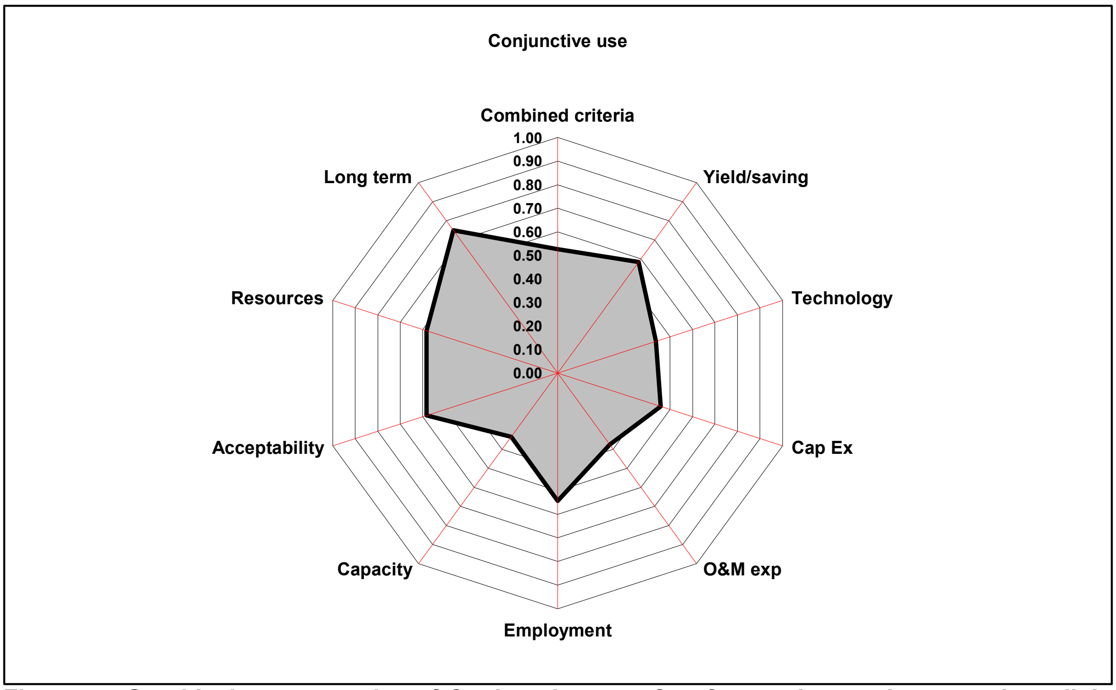


Figure 45: Graphical representation of *Conjunctive use of surface and groundwater* against all the criteria

This strategy was ranked seventh in this list of proposed strategies. The criterion that stands out for this strategy is the long-term applicability of 15-25 years. A fairly positive impact on the local water resources can be expected given that management of the water resources will be improved, which will result in an improvement in the local yield, as can be observed in the survey results. The local acceptability of the strategy by the community is neutral. A small number of jobs will be realized if the approach is implemented.

As for the previous two strategies, the local capacity to implement this water resource management approach is considered an obstacle.

8.2.3.8 Rainwater harvesting

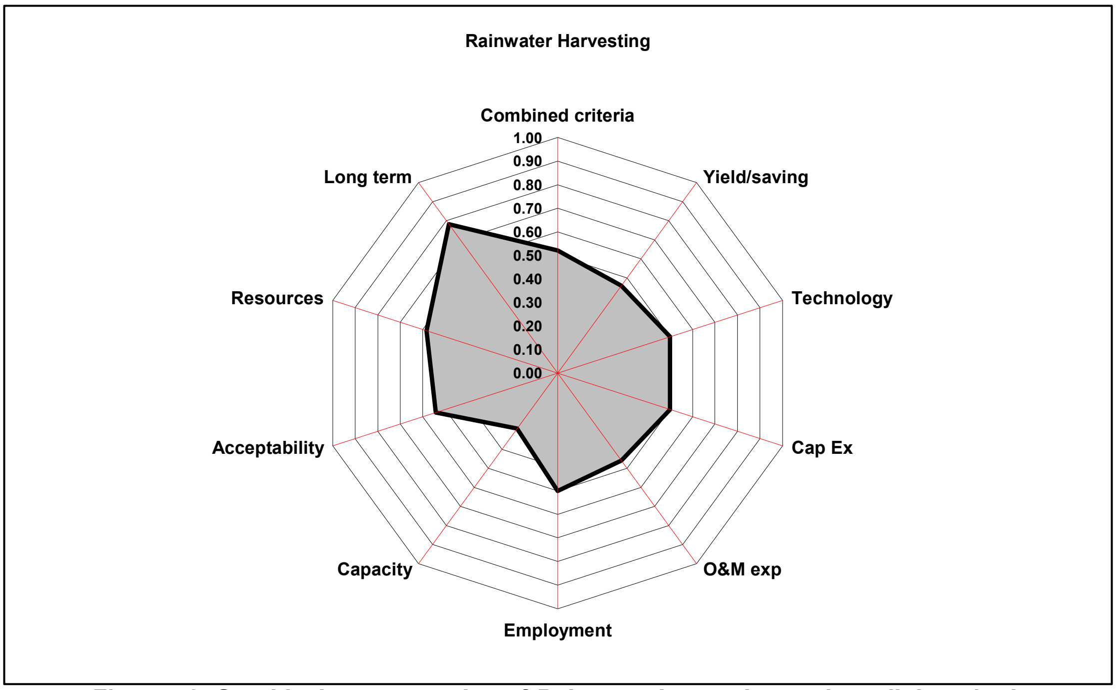


Figure 46: Graphical representation of *Rainwater harvesting* against all the criteria

This strategy was ranked eighth together with *Water restrictions* in this list of proposed strategies. The two significant criteria that stand out for this strategy are the very high long-term applicability viz. 15-12 years, and the poor local capacity to implement such a strategy. The perception that the capacity is low may be due to a lack of knowledge of the technology. Basic rainwater harvesting is basic intervention and could be implemented by simply installing rainwater tanks and creating swales on agricultural lands. Simple education at a local level is required. All the other criteria provided average scores.

8.2.3.9 Water restrictions

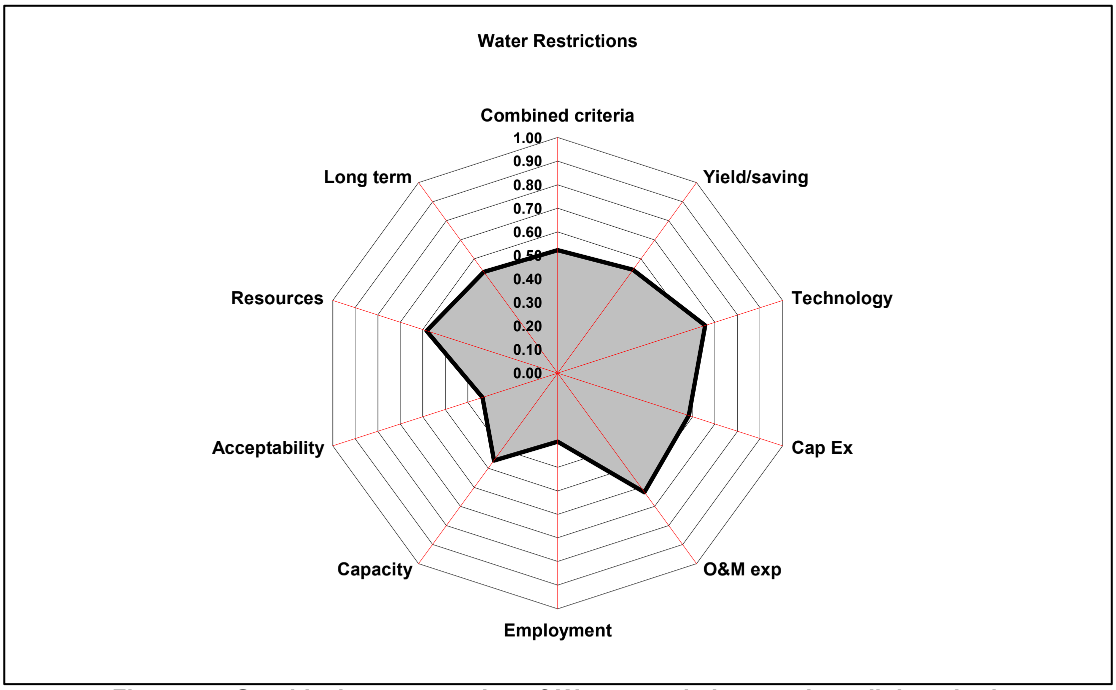


Figure 47: Graphical representation of *Water restrictions* against all the criteria

This strategy was ranked eighth, together with *Rainwater harvesting,* in this list of proposed strategies. It does not rank very highly in terms of its long term applicability, viz. 5-15 years. Nothing particular stands out, given that most of the criteria obtained mid-range scores. Acceptability by the community and local employment score low and neutral respectively. Water restriction a generally not a popular intervention and require a behavioral change by the consumers. There is not much scope for the employment of additional local labour at municipal level.

8.2.4 Summary of the top nine strategies

The table below summarises the obstacles and limitations to implementing these strategies at a local level. The most notable factor affecting the viability of these strategies is the perceived lack of local capacity to implement them. This is further exacerbated by the low financial resource base to cover the capital and running costs of most of the strategies. Implementing water restrictions and dry sanitation would require the local authority to address user acceptability of the strategies. Some of these strategies do not contribute much to local employment and this would need to be addressed in some other ways.

Table 22: Summary of obstacles and limitations for the top nine strategies

Strategy	*Local capacity*	*Capital expenditure*	*O&M expenditure*	*Acceptability*	*Employment*	*Technology*
Dry sanitation systems				**X**		
Education programmes	**X**		**X**			
Tariff structures	**X**				**X**	
Reduction of leaks programmes	**X**	**X**	**X**			
Regional water resource planning	**X**	**X**	**X**		**X**	
Local water resource management	**X**	**X**	**X**			
Conjunctive use of surface & groundwater	**X**	**X**	**X**			**X**
Rainwater harvesting	**X**					
Water restrictions				**X**	**X**	

9. Key recommendations and conclusions

From the analysis of the climate data and projections for the Northern Cape, an increase in temperature over the entire region can be expected. With this an increase in evaporation could also be expected. However, from model projections no definite future trends for rainfall in this region can be attributed to climate change. What can be observed, however, is that with climate change rainfall is likely to change and become more variable.

Climate change models are not predictions of the future, but are rather projections of how the future global and local climates may evolve and how these scenarios could affect local water resources. It is therefore important that planners, investors and decision-makers take into account the potential effects of climate change on the water resources and in so doing, adopt strategies that ensure the long-term sustainability of the water supplies and the local resources.

Vulnerable communities in southern Africa already have to cope with multiple stresses, of which climate variability is but one. Climate change will add an additional layer of stress, to which adaptive strategies and adaptation policies will have to be directed.Therefore there is a need for proactive strategies at local and national level to deal with the impacts of drought and climate change on water resources rather than the current reactive strategies. Further, the planning and management strategies in place at present take into account the projected population growth and the increased demand on the water resources, but not the impact of climate variability and change on supply.

Given the possible implications of climate change on local water resources, it is important that the impact be monitored as a precautionary measure. Special attention should be given to long term monitoring of hydro-meteorological parameters.

Based on this study and the responses obtained from the stakeholder group, the following portfolio of strategies should be further investigated when developing a water resource management strategy that takes future climate change impacts into account:

a. Supply side management:
   - Reduction of leaks programmes
   - Regional water resource planning
   - Local water resource management and monitoring
   - Conjunctive use of surface and groundwater
   - Rainwater harvesting

b. Demand side management:
   - Dry sanitation systems
   - Education programmes
   - Tariff structures
   - Water restrictions

Emphasis should be placed on demand side management given the finite amount of water. This is reinforced by the fact that the top three strategies rated by the stakeholders were all on the demand side. However, that is not to reduce the responsibility for better management by the water service providers to reduce wastage and losses in the delivery systems.

Groundwater is likely to be most severely affected, with the groundwater table dropping due to reduced recharge. Strict groundwater management systems should be put in place with early warning mechanisms to report depleted groundwater reserves. Continual monitoring of the aquifer against climate conditions will provide some knowledge of the future potential under projected climate conditions.

Strategies that are finally identified not only need to be socially, environmentally and economically acceptable, but they need to have long-term applicability if they are to provide adequate resilience to climate change impacts.

In order to successfully implement any of these strategies, key obstacles and local limitations need to be overcome, viz. local personnel capacity and financial capacity. The local capacity generally scored low and if any sustainable efforts are to be made in developing resilience to climate impacts, this will need to addressed through either training or recruitment. Capital and running costs were also identified by the stakeholders as some of the main financial obstacles. A climate change awareness programme should be developed that could be rolled out at local level to provide local government officials with the necessary tools to engage with this issue and implement the strategies that are identified.

Finally, in order to make this study relevant at a local level, further studies need to be commissioned to develop local strategies for each local authority, which follow the multi-criteria analysis tool used in this report. The local officials should understand the methodology and the outputs of the MCA tool. These studies should however, use quantitative data – real costing and water resource data – and not only qualitative information to identify relevant strategies.

References

Africon Engineering 2003. Project Proposal for Development and implementation of water resource management system within the Kgalagadi District, Kgalagadi District Municipality.

Benioff, R, Guill, S & Lee, J 1996. Vulnerability and Adaptation Assessments. An International Handbook. Dordrecht, Kluwer Academic Publishers. Version 1.1.

Bigen Africa 2004. Kgalagadi District Municipality, Drought relief strategy - Scoping report - first draft. Mafikeng, Kgalagadi District Municipality. October 2004.

BKS (Pty) Ltd 2003. Lower Orange Water Management Area. Overview of the water resources availability and utilisation, DWAF.

Braune, E 1996. Chapter 6.5 Groundwater resources. L Y Shackleton, S J Lennon and G R Tosen (Eds). Global Climate Change and South Africa. Johannesburg, Environmental Scientific Association: 152pp.

Chenje, M & Johnson, P (Eds) 1996. Water in Southern Africa. Harare, SADC Environment and Land Sector Coordination Unit.

City of Cape Town 2005. Development and Infrastructure (Tariff funded) - Water Services - 20% restriction tariff. http://www.capetown.gov.za/tariffs/.

Department of Agriculture 2005. Drought aid scheme for water supply: situation report Department of Agriculture, Department of Agriculture - Northern Cape.

Department of Housing and Local Government 2005a. Provincial Drought Task Team Meeting minutes 02/12/2004. Kimberley.

Department of Housing and Local Government 2005b. Provincial Drought Task Team Meeting minutes 13/01/2005. Kimberley.

DWAF 1994. Water Supply and Sanitation Policy - White Paper. Water - an indivisible national asset. Cape Town.

DWAF 2000. DRAFT Water conservation and demand management strategy for the water services sector.

DWAF 2002. The Working for Water Programme annual report 2001/2. Cape Town, DWAF.

DWAF 2003. Drought Relief Funds - Application for funding for Van Wyksvlei for funding to eliminate the present drought conditions, DWAF Northern Cape.

DWAF 2004a. DWAF's framework and checklist for the development of water services development plans. 21 September 2004.

DWAF 2004b. National Water Resource Strategy. First Edition. September 2004.

DWAF 2004c. Water conservation and demand management strategy for the water services sector.

DWAF 2004d. The working for water programme annual report 2003/4. Pretoria, DWAF.

DWAF Northern Cape 2005. Contingency Plan guideline. DWAF. 13 January 2005.

Eglal R, Rathgeber E & Brookes DB 2000. Water management in Africa and the Middle East: Challenges and opportunities, IDRC.

Element Raadgewende Ingenieurs 2001. Hantam waterdienste onwikkelingsplan, Hantam Municipality.

Gill, T 2004/05. Personal communication. South African Weather Service.

Goldblatt, M, Gelb, S & Davies, G 2002. Macroeconomics and sustainable development in Southern Africa. Development Bank of Southern Africa.

Gosling, M 2005. Drought blights dream of Namaqualand blooming. Cape Times.

Hewitson, B 2005. Personal communication. Climate Systems Analysis Group, University of Cape Town.

Hewitson, B, Tadross, M & Jack, C 2005. Scenarios from the University of Cape Town. In:Schulze, R.E. (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, P 39 - 56.

Hewitson, B C & Crane, R G 2005. Consensus between GCM climate change projections with empirical downscaling. Submitted to International Journal of Climatology.

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.

IPCC 2001b. Climate Change 2001: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Third Assessment Report. J J McCarthy, O F Canziania, N A Leary, D J Dokken and K S White. Cambridge, Cambridge University Press for Intergovernmental Panel on Climate Change.

Jooste, J 2005. Karoo Distriksmunisipaliteit - rampdroogte verslag. 15 February 2005.

Joubert, A & Stewart, T 2004. Guidelines for the use of Multicriteria Decision Analysis in the implementation of the National Water Act. Water Research Commission. July 2004.

Karoo District Municipality 2003. Water Services Development Plan - The Status Quo - Kareeberg Municipality, Funded by DWAF Directorate: Macro Planning.

Kasrils, R 2002. Parliamentary Media Briefing, DWAF.

Kgalagadi DM 2004. Water Resources Management Strategy - Situation assessment - Draft TOR. Kgalagadi District Municipality. July 2004.

Kiker, G A 2000. Synthesis report for the vulnerability and adaptation assessment section: South African Country Study on Climate Change. Pretoria, Department of Environmental Affairs and Tourism.

Kirchener, J, van Tonder, G J & Lukas, E 1991. Exploitation potential of Karoo aquifers. WRC Report No 170/1/191. Pretoria, Water Research Commission.

Kwezi/V3 & Africon Engineering 2003. Kareeberg Municipality - Water services authority capacity development. Kimberley, DWAF. October 2003.

LEG (Least Developed Countries Expert Group) 2004. National Adaptation Programmes of Action (NAPA): Selection of examples and exercises drawn from regional NAPA workshops. Bonn & Geneva, UNFCCC LEG, UNDP, UNEP and UNITAR.

Macroplan 2000. Socio-economic survey of various communities in the Northern Cape. Upington. Feb 2000.

Makin, A 2005. Desalination in focus. News Drop February 2005. Vol 22 Issue 1.

Midgley, G F, Chapman, R A, 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, R J & Forsyth, G G 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.

Mukheibir, P & Sparks, D 2003. Water resource management and climate change in South Africa: Visions, driving factors and sustainable development indicators. EDRC, University of Cape Town.

Murray, E C 2004a. Personal communication. Artificial recharge at Karkams.

Murray, E C 2004b. Wise water management for towns and cities - Artificial groundwater recharge. Report No TT219/03. Pretoria, Water Research Commission. January 2004.

Murray, E C & Ravenscroft, P 2004. A framework for groundwater management of community water supplies. CSIR Environmentek. Forthcoming.

Murray, E C & Tredoux, G 2002. Pilot artificial recharge schemes: Testing sustainable water resource development in fractures aquifers. Report No 967/1/02. Pretoria, Water Research Commission.

Mvula Trust 2001. Prioritising planning: The importance of water services development plans and integrated plans. Water and Sanitation Diary 2001.

Ninham Shand, Asch Consulting Engineers & Jackoet & Associates 2004. Clanwilliam Dam Raising Study Specialist Screening Workshop. Workshop starter document.

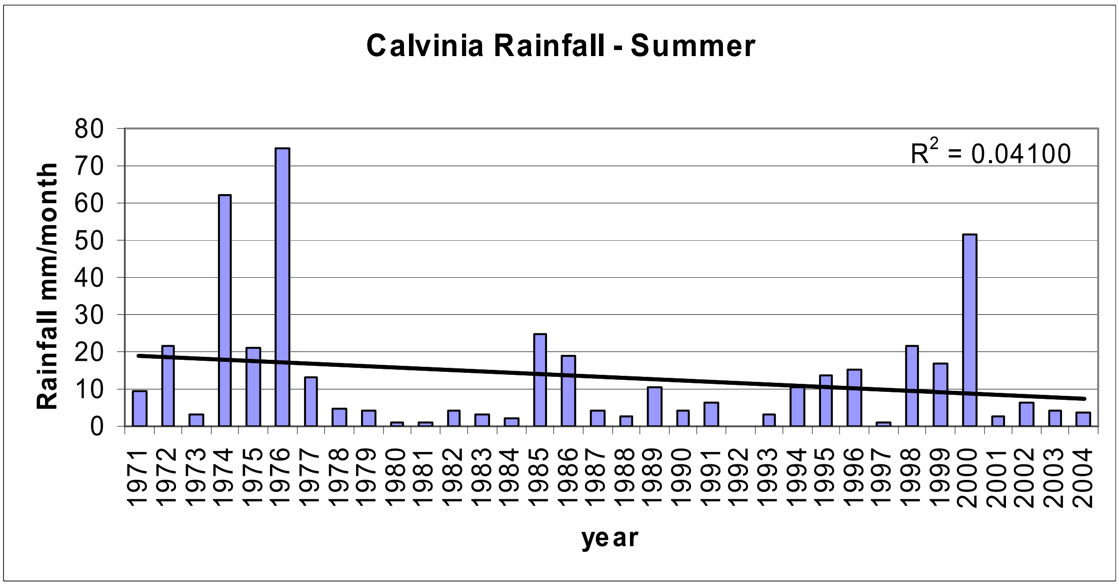
Ninham Shand & Octagonal Development 2004a. Assessment report of the water services development plan - Kamiesberg WSA, commissioned by DWAF Directorate: Planning and Information.

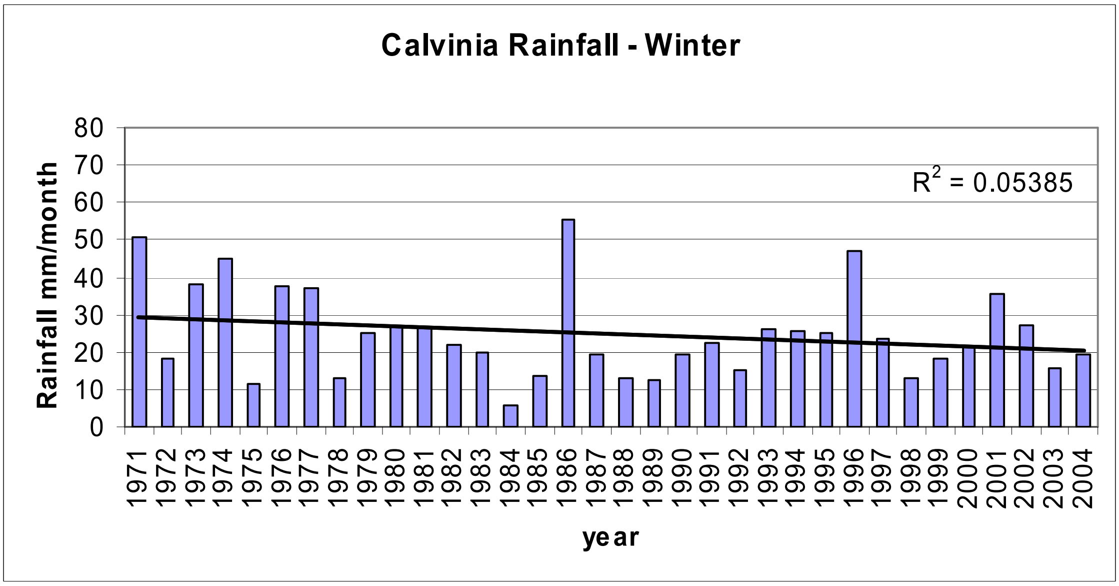
Ninham Shand & Octagonal Development 2004b. Assessment report of the water services development plan - Karoo Hoogland WSA, commissioned by DWAF Directorate: Planning and Information.

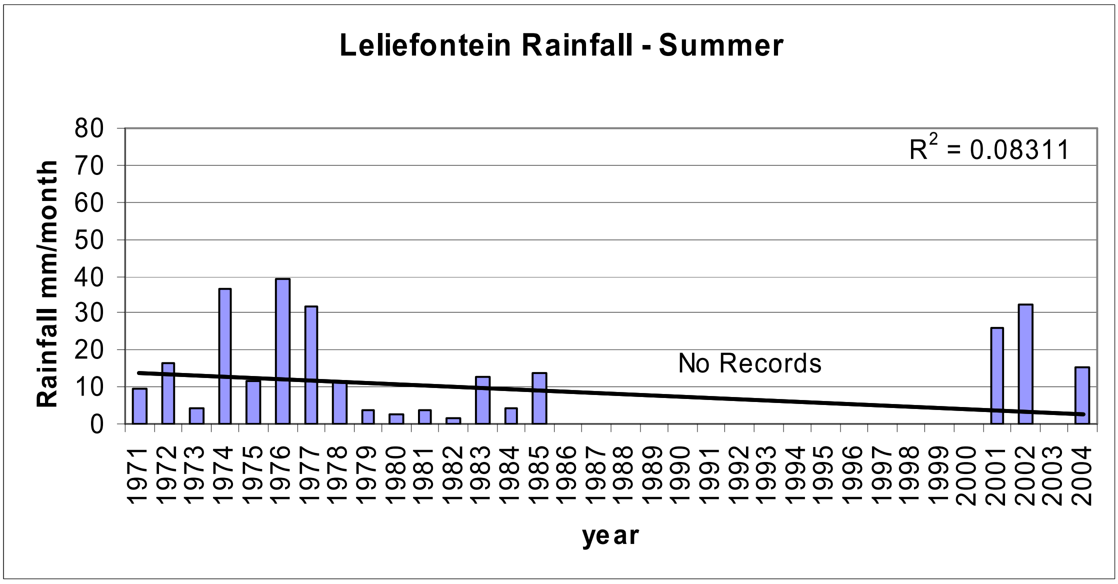
Ninham Shand & Octagonal Development 2004c. Assessment report of the water services development plan - Khai-Ma WSA, commissioned by DWAF Directorate: Planning and Information.
Ninham Shand & Octagonal Development 2004d. Assessment report of the water services development plan - Nama Khoi WSA, commissioned by DWAF Directorate: Planning and Information.
Ninham Shand & Octagonal Development 2004e. Assessment report of the water services development plan - Richterveld WSA, commissioned by DWAF Directorate: Planning and Information.
Ninham Shand & Octagonal Development Aug 2004. Assessment report of the water services development plan - Kai!Garib WSA, commissioned by DWAF Directorate: Planning and Information.
Otieno FAO & Ochieng GMM 2004. Water management tools as a means of averting a possible water scarcity in South Africa by the year 2025. Water SA 30 (5): 668 - 672.
Pietersen, K 2004. A discision-making framework for groundwater management in arid zones (with a case study in Namaqualand). University of the Western Cape.
Republic of South Africa 2003. Disaster Management Act 57 of 2002. Government Gazette 24252 of 15 January 2003.
SADC 2001. Key Priorities for SADC. SADC Sub Regional consultations in preparation for the WSSD, Mauritius.
Schulze, R & Perks, L 2000. Assessment of the Impact of Climate Change on Hydrology and Water Resources in South Africa. ACRUcons report 33. Pietermaritzburg, School of Bioresources Engineering and Environmental Hydrology, University of Natal. January 2000.
Schulze, R E 2005a. Looking Into the Future: Why Research Impacts of Possible Climate Change on Hydrological Responses in Southern Africa? In: Schulze, R.E. (Ed) Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation. Pretoria, Water Research Commission: Chapter 1, pp 3 - 17.
Schulze, R E 2005b. Setting the Scene: The Current Hydroclimatic "Landscape" in Southern Africa. In: Schulze, R.E. (Ed) Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation. Pretoria, Water Research Commission: Chapter 6, pp 83 - 94.
Shippey K, Gorgens A, Terblanche D & Luger M 2004. Environmental challenges to operationalisation of south African rainfall enhancement. Water SA 30 (5): 636 - 640.
Soroczan, C & Baynes, S 2003. Dual-flush Toilet Testing. Canadian Mortgage Housing Corporation.
SRK Consulting 2004. A preliminary assessment of groundwater resources and production boreholes at Sutherland. SRK 342224. Cape Town. October 2004.
SSA 2003. Census 2001: Digital census atlas. http://www.statssa.gov.za/census2001/digiAtlas/index.html. Pretoria.
Steyn, P C L 1984. The relationship between the 300hPa circulation patterns and rainfall classification in the Bethlehem region Bethlehem Precipitation Research. Project Report No.24. Pretoria, South African Weather Bureau. (referenced in Tyson, 1996).
V3 Consulting & WRP 2002. Lower Orange Water Management Area. Water Resource situation Assessment. P WMA 14/000/00/0101. DWAF. March 2002.
van Dyk, G 2004. Personal communication. Geohydrology, DWAF Northern Cape. 03/06/04.
van Dyk, G, Peters, R & Fourie, S 2005. Water provision from Groundwater in the Northern Cape: Balancing demand and supply. Biennial Groundwater Conference, March 2005. pp. 381 -391.
Visser, D 2001. Grondwater monitering & bestuur van waterstelsels in Namakwaland, Toens & Partners.
Visser, D 2004. Personal communication. SRK Consulting.
Visser, H 2005. Namakwa District Municipality Drought Report. 13 Janaury 2005.

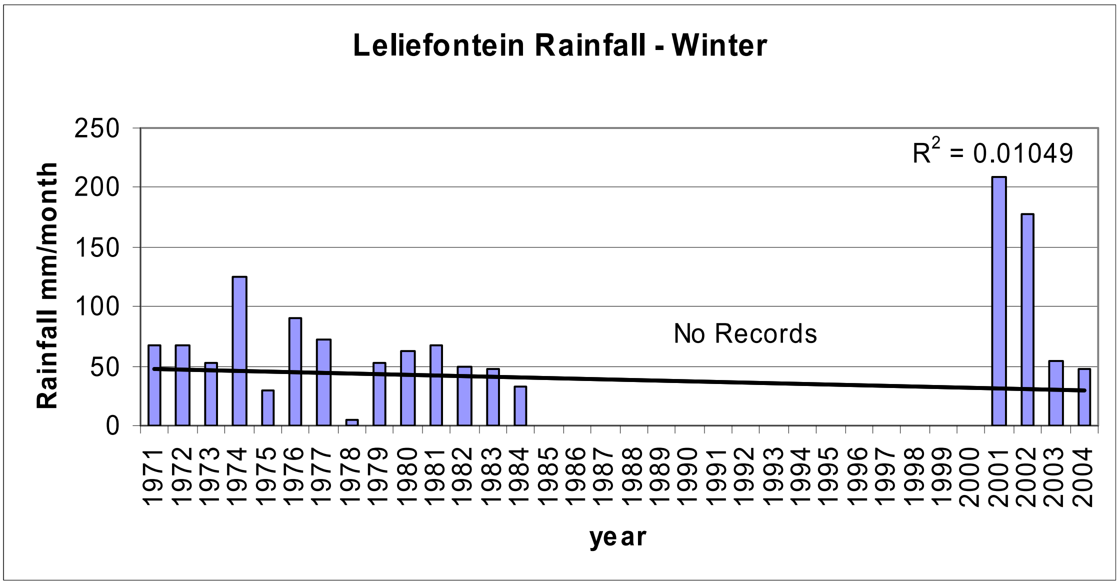
Appendix A
Climatological data

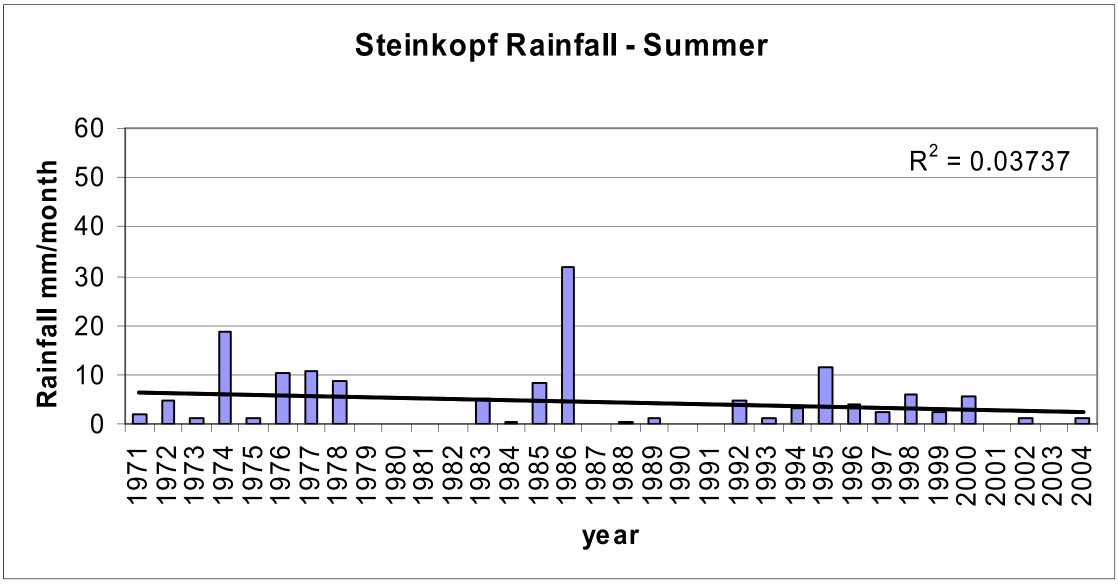
Average rainfall per month for the summer and winter rainfall periods:

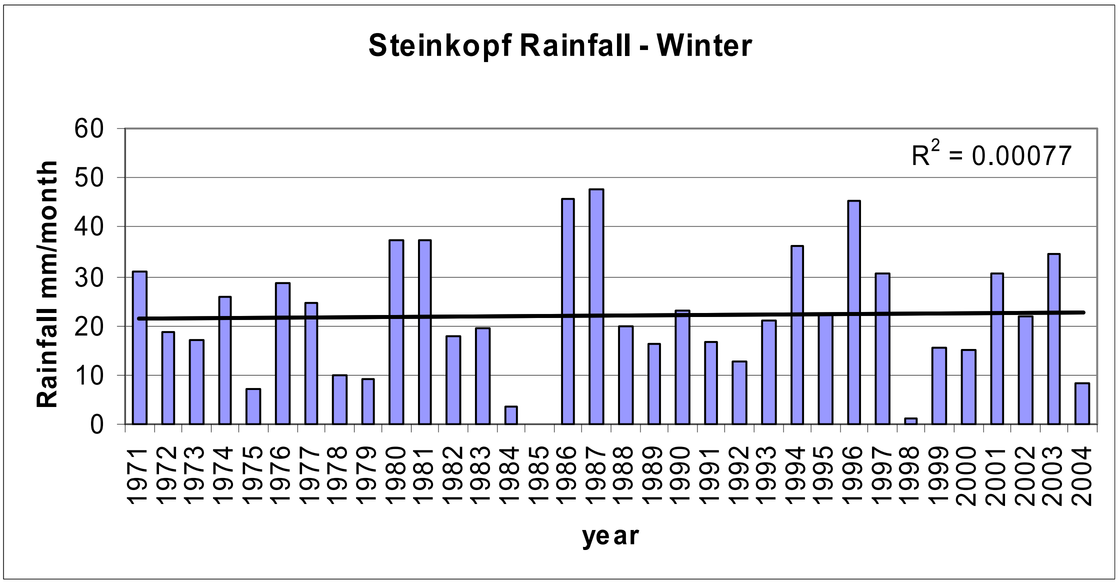


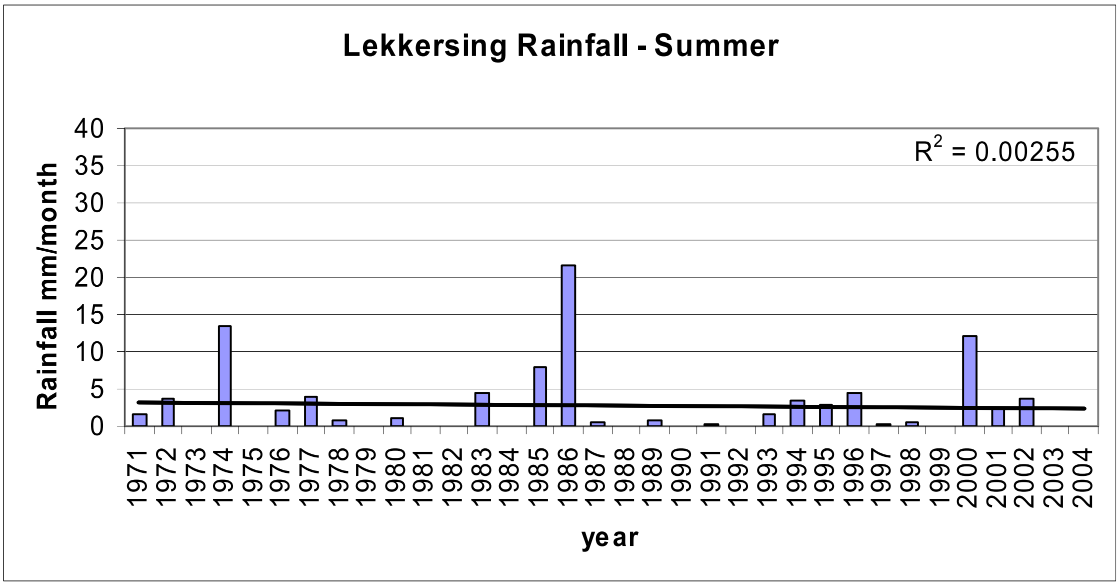


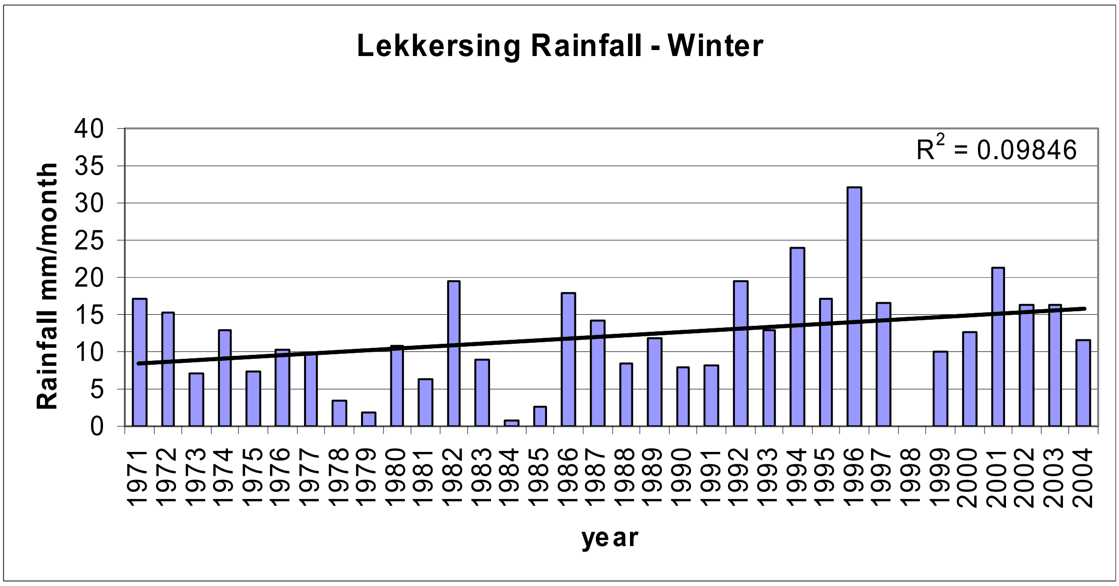

Leliefontein Rainfall - Summer
Rainfall mm/month
0
10
20
30
40
50
60
70
80
R^2 = 0.08311
No Records
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
year

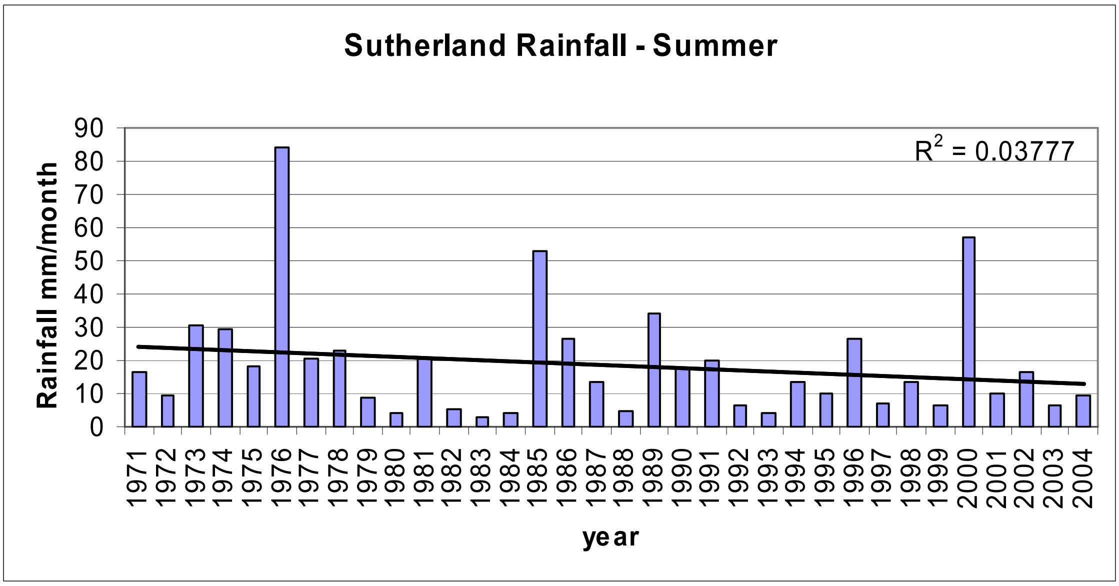

Leliefontein Rainfall - Winter
Rainfall mm/month
0
50
100
150
200
250
R^2 = 0.01049
No Records
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
year

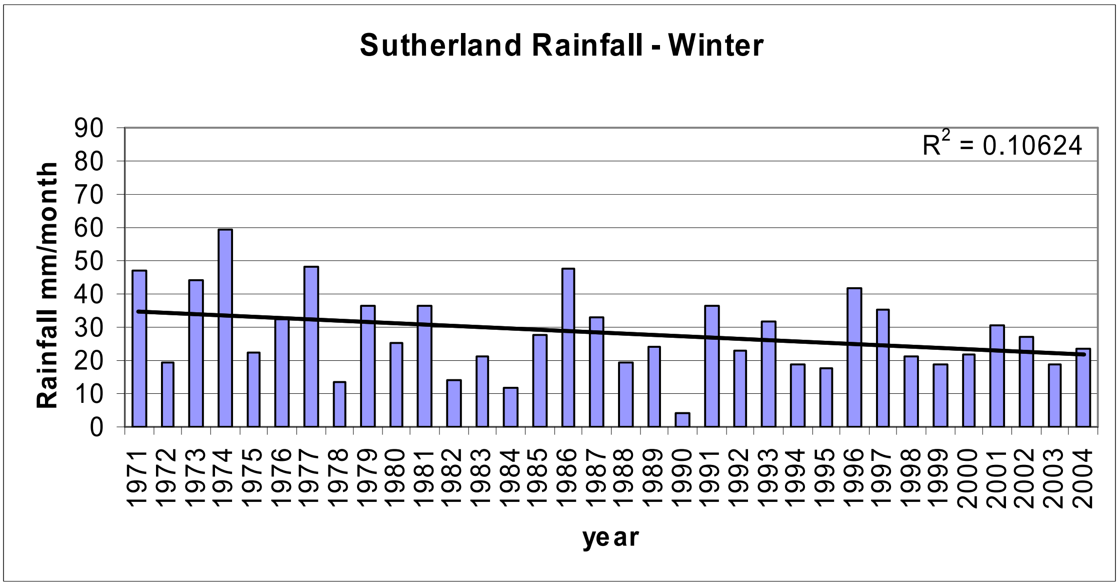

Steinkopf Rainfall - Summer
Rainfall mm/month
0
10
20
30
40
50
60
R^2 = 0.03737
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
year

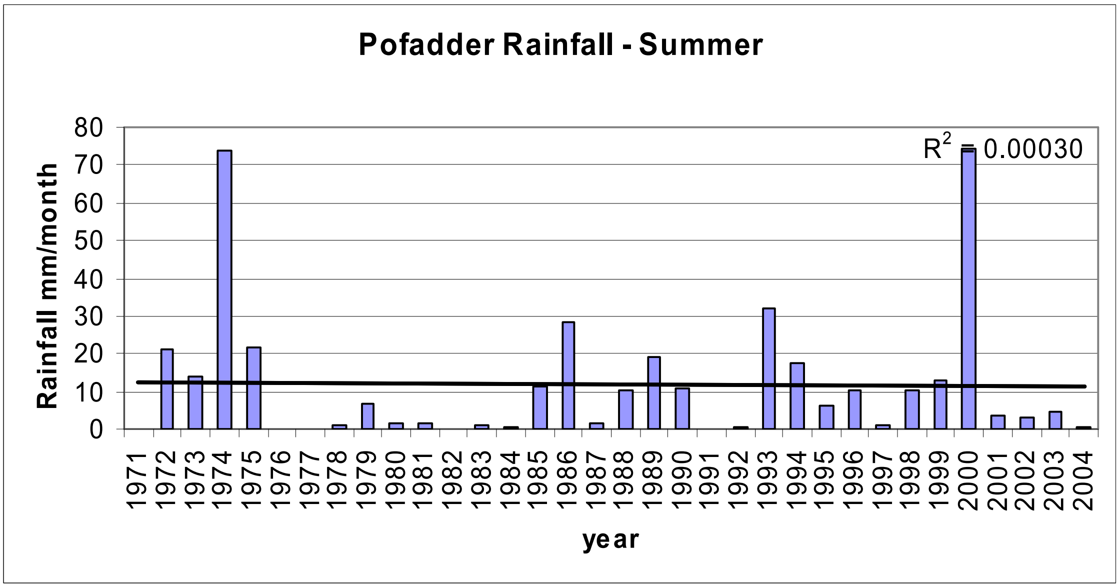

Steinkopf Rainfall - Winter
Rainfall mm/month
0
10
20
30
40
50
60
R^2 = 0.00077
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
year

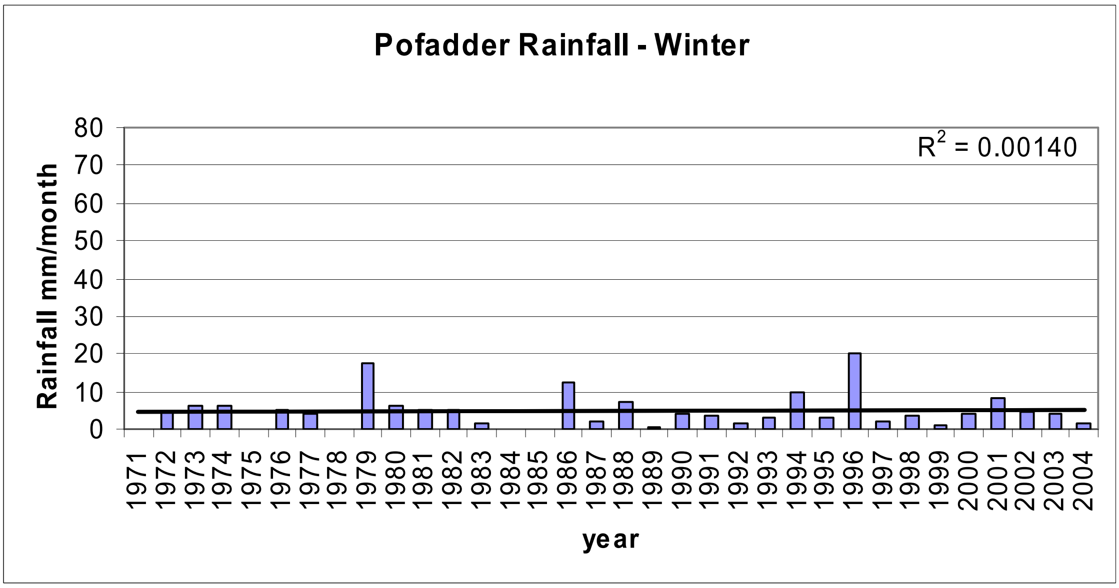

Lekkersing Rainfall - Summer
Rainfall mm/month
0
5
10
15
20
25
30
35
40
R^2 = 0.00255
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
year

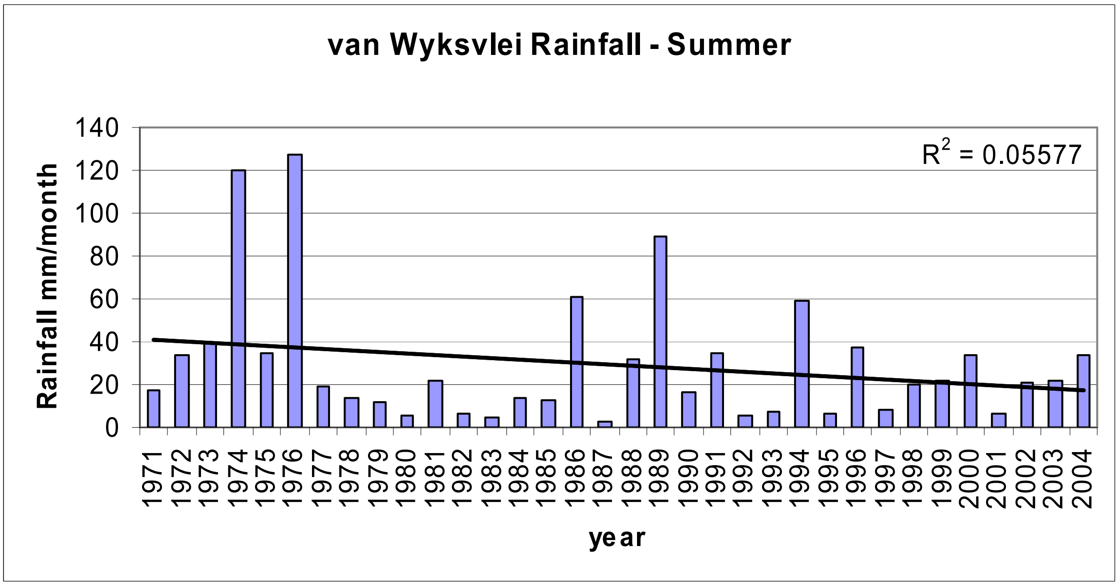

Lekkersing Rainfall - Winter
Rainfall mm/month
0
5
10
15
20
25
30
35
40
R^2 = 0.09846
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
year

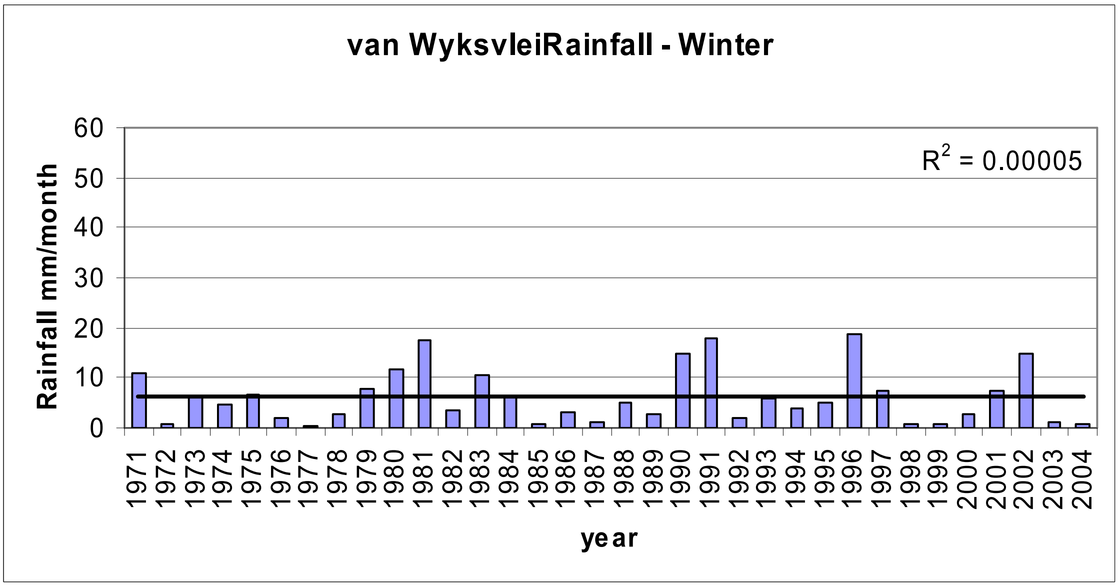

Sutherland Rainfall - Summer
Rainfall mm/month
year
R^2 = 0.03777
0 10 20 30 40 50 60 70 80 90
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004

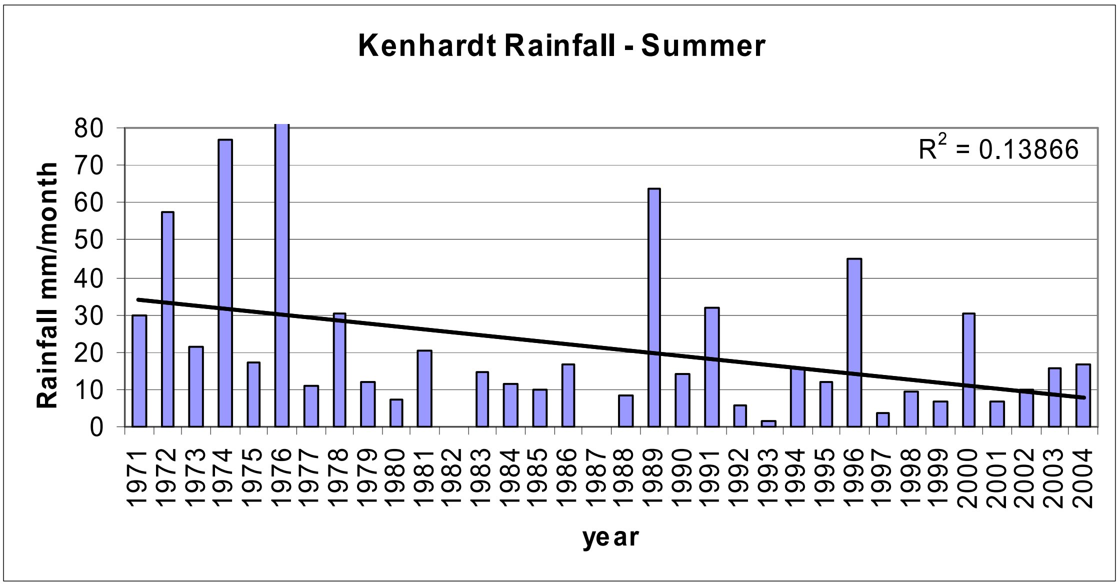

Sutherland Rainfall - Winter
Rainfall mm/month
year
R^2 = 0.10624
0 10 20 30 40 50 60 70 80 90
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004

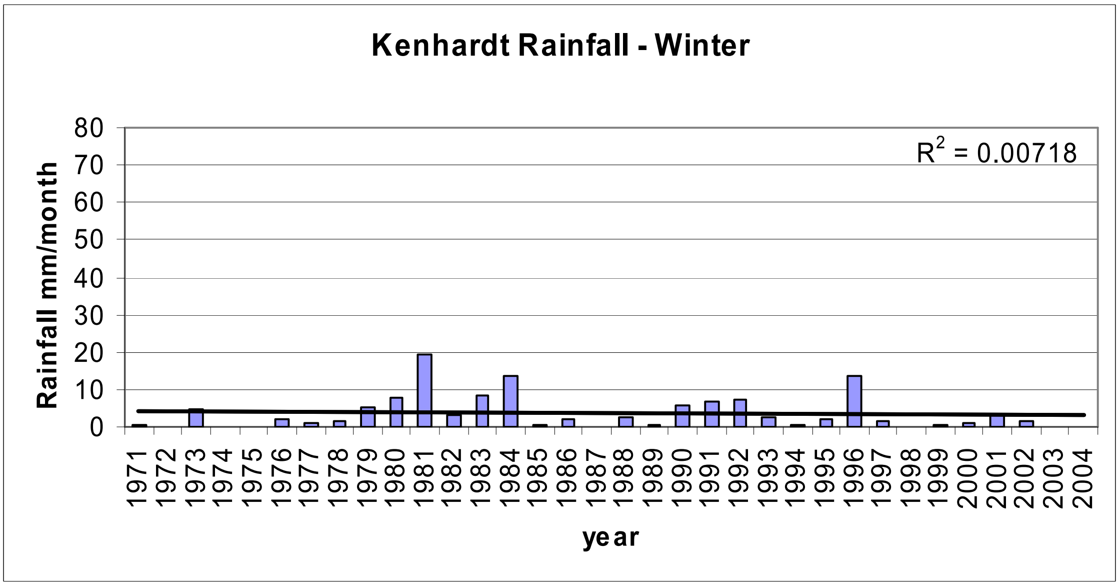

Pofadder Rainfall - Summer
Rainfall mm/month
0
10
20
30
40
50
60
70
80
R^2 = 0.00030
year
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004


Pofadder Rainfall - Winter
Rainfall mm/month
0
10
20
30
40
50
60
70
80
R^2 = 0.00140
year
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004


van Wyksvlei Rainfall - Summer
Rainfall mm/month
0
20
40
60
80
100
120
140
R2 = 0.05577
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
year


van WyksvleiRainfall - Winter
Rainfall mm/month
0
10
20
30
40
50
60
R2 = 0.00005
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
year


Kenhardt Rainfall - Summer
Rainfall mm/month
0
10
20
30
40
50
60
70
80
R^2 = 0.13866
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
year


Kenhardt Rainfall - Winter
Rainfall mm/month
0
10
20
30
40
50
60
70
80
R^2 = 0.00718
1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
year

Appendix B
Consolidated tables of the survey results

B1. Combined average scores of all responses

Criteria	Additonal Yield / saving	Technology	Additional Capital Expenditure	Additional Running costs	Local Employment	Local Capacity to implement	Acceptability to local community	Impact on local water Resources	Long term applicability	Combined
Scale	1 None 2 Low 3 Significant 4 Very high	1 Not available 2 must be imported 3 available in SA 4 locally available 5 already installed	1 High cost 2 medium cost 3 Low cost 4 No cost	1 High costs 2 medium costs 3 Low costs 4 No O&M costs	1 Loss of jobs 2 Neutral 3 Few jobs (<10) 4 Many jobs (10-30)	1 Very low 2 Low 3 Adequate 4 High	1 None (high additional costs) 2 Low (some additional costs) 2 Low (inconvenient) 3 Neutral 4 High (no additional costs)	1 Negative 2 Neutral 3 Positive 4 Highly positive	1 <2 years 2 2-5 years 3 5-15 years 4 15-25 years 5 >25 years	
Options	1 - 4	1 - 5	1 - 4	1 - 4	1 - 4	1 - 4	1 - 4	1 - 4	1 - 5	1.00
Resource planning	2.8	2.9	2.3	2.4	2.3	2.1	3.1	3.4	4.0	0.57
Resource management	3.0	3.4	1.9	2.0	2.6	2.5	3.0	3.1	3.8	0.56
Artificial recharge	2.1	2.8	1.9	1.9	2.8	1.8	2.5	3.1	3.9	0.47
Conjunctive use	2.8	2.8	2.4	2.1	2.6	2.0	2.8	2.8	4.0	0.53
Standby relief	2.6	3.5	1.8	1.9	1.9	1.9	2.8	2.5	3.3	0.45
Tankering of water	1.4	3.5	1.5	1.4	2.6	2.0	1.9	2.5	2.6	0.33
Drought relief	2.1	3.1	1.1	1.4	2.4	2.5	2.6	2.5	3.3	0.40
Rainwater harvesting	2.4	3.0	2.5	2.4	2.5	1.9	2.6	2.8	4.1	0.52
Desalination	2.6	3.0	1.1	1.4	2.6	1.3	2.3	2.3	3.8	0.38
Water restrictions	2.6	3.6	2.8	2.9	1.9	2.4	2.0	2.8	3.1	0.52
Dry sanitation	3.3	3.9	2.8	2.6	3.0	3.0	2.4	3.4	4.1	0.67
Education	2.8	3.5	2.9	2.4	3.1	2.8	3.1	3.0	4.1	0.64
Tariff structures	2.9	3.6	3.1	3.0	2.0	2.4	2.8	2.8	4.3	0.62
Re use of grey water	2.6	3.4	1.9	1.9	2.4	1.9	2.1	2.9	3.8	0.47
Saline water for toilets	2.5	2.4	1.9	1.5	2.3	1.4	2.5	2.6	4.0	0.42
Reduction of leaks	3.1	3.4	2.1	2.3	2.9	1.9	2.9	3.3	4.4	0.59
Dual flush toilets	2.6	2.8	1.6	1.9	2.4	1.6	2.8	3.1	4.3	0.49
Rainfall enhancement	2.5	2.3	1.5	1.8	2.1	1.1	2.5	3.1	4.0	0.42

B2. Average scores for local government officials

Criteria	Additonal Yield / saving	Technology	Additional Capital Expenditure	Additional Running costs	Local Employment	Local Capacity to implement	Acceptability to local community	Impact on local water Resources	Long term applicability	Combined
Scale	1 None 2 Low 3 Significant 4 Very high	1 Not available 2 must be imported 3 available in SA 4 locally available 5 already installed	1 High cost 2 medium cost 3 Low cost 4 No cost	1 High costs 2 medium costs 3 Low costs 4 No O&M costs	1 Loss of jobs 2 Neutral 3 Few jobs (<10) 4 Many jobs (10-30)	1 Very low 2 Low 3 Adequate 4 High	1 None (high additional costs) 2 Low (some additional costs) 2 Low (inconvenient) 3 Neutral 4 High (no additional costs)	1 Negative 2 Neutral 3 Positive 4 Highly positive	1 <2 years 2 2-5 years 3 5-15 years 4 15-25 years 5 >25 years	
Options	1 - 4	1 - 5	1 - 4	1 - 4	1 - 4	1 - 4	1 - 4	1 - 4	1 - 5	1.00
Resource planning	2.2	2.6	1.8	1.8	2.6	2.4	2.8	3.0	3.6	0.47
Resource management	2.6	3.4	1.6	1.6	2.4	2.6	3.0	3.0	3.0	0.48
Artificial recharge	2.2	2.4	1.6	1.6	2.8	1.8	2.2	3.0	3.2	0.40
Conjunctive use	3.2	2.6	2.2	2.0	2.6	2.0	2.6	2.6	3.4	0.50
Standby relief	3.2	3.4	2.0	2.0	1.8	1.8	2.4	2.6	3.0	0.46
Tankering of water	1.6	3.0	1.8	1.6	2.6	1.8	2.0	2.6	2.4	0.35
Drought relief	2.4	2.8	1.2	1.2	1.8	2.4	2.2	2.6	3.4	0.37
Rainwater harvesting	2.6	2.8	2.2	2.2	2.4	1.6	2.4	2.8	4.0	0.48
Desalination	3.0	2.4	1.2	1.6	2.4	1.4	2.2	2.0	3.8	0.37
Water restrictions	2.4	3.2	2.2	2.4	1.8	2.2	1.8	2.4	2.8	0.42
Dry sanitation	3.0	3.4	2.6	2.4	3.0	3.2	2.4	3.2	4.4	0.63
Education	2.8	3.4	2.6	2.2	3.0	3.0	3.0	3.0	3.8	0.61
Tariff structures	2.8	3.4	2.8	2.6	2.0	2.2	2.8	2.4	3.8	0.55
Re use of grey water	2.6	2.8	1.6	1.6	2.0	1.8	2.2	2.4	3.4	0.39
Saline water for toilets	2.2	1.6	2.2	1.6	2.0	1.4	2.4	2.6	3.6	0.38
Reduction of leaks	3.2	2.8	1.8	2.0	2.6	2.0	2.8	3.2	4.0	0.53
Dual flush toilets	2.6	2.0	1.4	1.6	2.4	1.6	2.8	2.8	3.8	0.42
Rainfall enhancement	2.8	1.6	1.8	2.2	2.2	1.2	2.6	3.2	4.4	0.47

B3. Average scores for DWAF officials

Criteria	Additonal Yield / saving	Technology	Additional Capital Expenditure	Additional Running costs	Local Employment	Local Capacity to implement	Acceptability to local community	Impact on local water Resources	Long term applicability	Combined
Scale	1 None 2 Low 3 Significant 4 Very high	1 Not available 2 must be imported 3 available in SA 4 locally available 5 already installed	1 High cost 2 medium cost 3 Low cost 4 No cost	1 High costs 2 medium costs 3 Low costs 4 No O&M costs	1 Loss of jobs 2 Neutral 3 Few jobs (<10) 4 Many jobs (10-30)	1 Very low 2 Low 3 Adequate 4 High	1 None (high additional costs) 2 Low (some additional costs) 2 Low (inconvenient) 3 Neutral 4 High (no additional costs)	1 Negative 2 Neutral 3 Positive 4 Highly positive	1 <2 years 2 2-5 years 3 5-15 years 4 15-25 years 5 >25 years	
Options	1 - 4	1 - 5	1 - 4	1 - 4	1 - 4	1 - 4	1 - 4	1 - 4	1 - 5	1.00
Resource planning	3.7	3.3	3.0	3.3	1.7	1.7	3.7	4.0	4.7	0.74
Resource management	3.7	3.3	2.3	2.7	3.0	2.3	3.0	3.3	5.0	0.70
Artificial recharge	2.0	3.3	2.3	2.3	2.7	1.7	3.0	3.3	5.0	0.58
Conjunctive use	2.0	3.0	2.7	2.3	2.7	2.0	3.0	3.0	5.0	0.57
Standby relief	1.7	3.7	1.3	1.7	2.0	2.0	3.3	2.3	3.7	0.43
Tankering of water	1.0	4.3	1.0	1.0	2.7	2.3	1.7	2.3	3.0	0.33
Drought relief	1.7	3.7	1.0	1.7	3.3	2.7	3.3	2.3	3.0	0.44
Rainwater harvesting	2.0	3.3	3.0	2.7	2.7	2.3	3.0	2.7	4.3	0.57
Desalination	2.0	4.0	1.0	1.0	3.0	1.0	2.3	2.7	3.7	0.38
Water restrictions	3.0	4.3	3.7	3.7	2.0	2.7	2.3	3.3	3.7	0.70
Dry sanitation	3.7	4.7	3.0	3.0	3.0	2.7	2.3	3.7	3.7	0.73
Education	2.7	3.7	3.3	2.7	3.3	2.3	3.3	3.0	4.7	0.67
Tariff structures	3.0	4.0	3.7	3.7	2.0	2.7	2.7	3.3	5.0	0.75
Re use of grey water	2.7	4.3	2.3	2.3	3.0	2.0	2.0	3.7	4.3	0.62
Saline water for toilets	3.0	3.7	1.3	1.3	2.7	1.3	2.7	2.7	4.7	0.50
Reduction of leaks	3.0	4.3	2.7	2.7	3.3	1.7	3.0	3.3	5.0	0.68
Dual flush toilets	2.7	4.0	2.0	2.3	2.3	1.7	2.7	3.7	5.0	0.62
Rainfall enhancement	2.0	3.3	1.0	1.0	2.0	1.0	2.3	3.0	3.3	0.36

Appendix C
Specific information for selected local municipalities

A. Pixley ka-Seme (Karoo) – Kareeberg

Relevant issues related to climate induced water stress (Karoo District Municipality 2003) (Jooste 2005)

Water resources management:
Historic water consumption and bulk water extraction figures for Carnavon, Vosburg and Van Wyksvlei are not available at the Municipality. Currently at Van Wyksvlei the groundwater levels are being constantly monitored.
The water quality is poor at Van Wyksvlei and the water supply was not sufficient to meet the demand in 2003 (DWAF 2003). During 2003, water was supplied by tanker from Carnarvon (60 km away).
The Kareeburg municipality does not have the a programme or the resources to ensure efficient use of water in these three towns..
No education programmes are planned.

Critical issues:
At Van Wyksvlei water restrictions are in place, but poor co-operation from the residents is being experienced.

Priority areas proposed for improvements:
Planned upgrading of the existing dam, located on the Van Wyksvlei River. It is however, not clear how this will relieve the water supply situation since it has only reached 25% of capacity 7 times in the past 30 years. It currently does not contribute to water supply during times of drought.

B. Namakwa – Hantam

Relevant issues related to climate induced water stress (Element Raadgewende Ingenieurs 2001) (Visser 2005)

Water resources management:
The yield from the Kareedam in Calvinia is not reliable which results in water shortages in the summer months and drought periods. Calvinia is mainly dependent on groundwater. The instituting of water restrictions gets them through these times.
Artificial recharge system has been installed in Calvinia (1 year in operation)

Critical issues:
The Kareedam that provides water to Calvinia was reported to be empty in January 2005 and they were dependent on the existing boreholes. When necessary, they plan to cart water from Nieuwoudtville.

Priority areas proposed for improvements:
Water balance analysis is still outstanding, due to insufficient water metering in the municipal area. A programme to regularly monitor the water quality needs to be established. Calvinia received an allocation funding for the 2005/06 financial year to address the water shortage.

C. Namakwa – Kamiesberg

Relevant issues related to climate induced water stress (Ninham Shand & Octagonal Development 2004a)

Water resources management:
There are no surface water resources, this area is totally dependant on groundwater.
The current available water resources in Hondeklipbaai are insufficient to meet the demand. Serious water shortages are experienced in summer. No proposals to address this have been made.
Conservation and demand side management need to be addressed
No education programmes are planned.
Garies has 210 kl/d of saline water at its disposal which is used for flushing of toilets. Houses have rainwater tanks which are used for drinking water.
At Kharkams the natural groundwater recharge is very low and as a result of abstraction since the mid 1990's, the level of the groundwater has dropped dramatically as well as the salinity has increased significantly.
Leliefontein is a small community, who previously experienced a problem with their available water supply, but is now fine since new boreholes were drilled.
Garies was recorded as having 96% of use of its available resource (van Dyk et al. 2005). The alternative resources where explored in 1998 and an additional 150kl/day would be available. A 7km pipeline was proposed to bring water to Garies by 2005 at a cost of R3million.

Critical issues:
Drought management is seen to be of critical importance.

Priority areas proposed for improvements:
- Outstanding data for abstraction and quality.
- Capacity building interventions.
- Water demand management.
- Improvements to strategic planning.
- Support to put necessary information and decision-making systems in place.

D. Namakwa – Kai-Ma

Relevant issues related to climate induced water stress (Ninham Shand & Octagonal Development 2004c)

Water resources management:
Need to develop an integrated resource management plan.
Need to address the quality of the water being extracted from the Orange river at Onseepkands and Witbank.
No groundwater is used in this municipal area.

Critical issues:
Drought management is seen to be of critical importance.

Priority areas proposed for improvements:
- Outstanding data for river abstraction and quality.
- Capacity building interventions.
- Water demand management.
- Improvements to strategic planning.
- Support to put necessary information and decision-making systems in place.

E. Namakwa – Nama Khoi

Relevant issues related to climate induced water stress (Ninham Shand & Octagonal Development 2004d)

Water resources management:
This area utilises both river and groundwater abstraction.
Integrated water resource management. Future uses at Kommagas, Buffelsivier and Bulletrap do not correspond with permitted abstraction of some of the boreholes. Groundwater monitoring data is not regularly processed by a qualified geohydrologist. Records for Buffelsrivier and Rooiwinkel are incomplete.
Abstraction figures from the Orange River at Steinkopf, Kommagas Buffelsrivier, Bulletrap, Fonteinjie and Rooiwinkel are not complete.
Buffelsrivier has no specific resource problem, but rather one of poor infrastructure, however the demand during summer, the dry months, is greater than 80% of available supply. During times of drought, supply will become critical.
No education programmes are planned.

Critical issues:
Drought management is seen to be of critical importance.

Priority areas proposed for improvements:
- Outstanding data for abstraction and quality
- Capacity building interventions
- Water demand management
- Improvements to strategic planning
- Support to put necessary information and decision-making systems in place

F. Namakwa – Karoo Hoogland

Relevant issues related to climate induced water stress (Ninham Shand & Octagonal Development 2004b)

Water resources management:
No surface water is used, only groundwater.
Bulk water meters not installed in most towns.
Conservation and demand management not adequately addressed, especially in Fraserburg and Sutherland.
No education programmes are planned.
Groundwater monitoring not in place. Water levels measured irregularly in Sutherland and Williston.

Critical issues:
Drought .anagement is seen to be of critical importance.

Priority areas proposed for improvements:
WSDP still needs to address the following:

- Integrated water resource management
- More information on groundwater resources
- Specific data on quality of water taken from source
- Long term sustainability of boreholes
- Future availability of groundwater, especially for Fraserburg and Sutherland
- Installation of bulk water meters, especially on the boreholes and bulk supply lines in Fraserburg and Sutherland.
- Capacity building interventions
- Water demand management

G. Namakwa – Richtersveld

Relevant issues related to climate induced water stress (Ninham Shand & Octagonal Development 2004e)

Water resources management:
Groundwater the primary source of bulk water.
Data tables need to be updated and completed. Groundwater abstraction monitoring data is not regularly processed and reported on by a qualified hydro-geologist eg Lekkersing, Eksteensfontein, Sanddrift and Rooiwal..
Monitoring of groundwater quality not done at Port Nolloth, Khubus and Alexander Bay.
Pollution contingencies need to be put in place.
Physical water losses are not adequately addressed.
Leak and meter repair programme not in place.
No education programmes are planned.

Critical issues:
Drought Management is seen to be of critical importance
Port Nolloth is dependent on water from Alexander Bay which is inconsistent at times resulting in low levels in the Port Nolloth reservoirs.

Priority areas proposed for improvements:

- Outstanding data for abstraction and quality
- Capacity building interventions
- Water demand management
- Improvements to strategic planning
- Support to put necessary information and decision-making systems in place.

H. Siyanda – Kai !Garib

Relevant issues related to climate induced water stress (Ninham Shand & Octagonal Development Aug 2004)

Water resources management:
Monitoring of groundwater only started in 2001.
Brandvlei and Kommagas are over-pumping their boreholes.
The only town where water losses can be measured is Kenhardt. It is not possible to do water balances in the other towns, for example Kakemas and Keimoes abstractions are based on estimates.
No leakage detection programmes are currently in place.
No education programmes are planned.
During winter and summer, Kommagas is over pumping it's resource. In Summer this is more than 120 %. This situation allows no capacity to deal with drought periods. Kommagas plans to drill new boreholes under the drought relief programme.

Critical issues:
Drought management is seen to be of critical importance.
There is no emergency water storage for Alheit village.

Priority areas proposed for improvements:

- Outstanding data
- Installation of bulk water meters
- Capacity building interventions
- Water demand management
- Improvements to strategic planning
- Support to put necessary information and decision-making systems in place.

Appendix D
List of Stakeholders

Stakeholders who attended the Provincial Drought Task Team Meeting on 21 April 2005 and participated in the strategy ranking exercise. It should be noted that these stakeholders engaged with the exercise in their individual capacities and their responses should in no way be seen to be representing the view point of their respective organisations.

NAME	ORGANISATION
Mr M.Mafa	Chairperson of PDTT
Ms R Hoogbaard	Department of Housing and Local Government
Mr P March	Department of Housing and Local Government
Mr S Jooste	Pixley Ka-Seme DM
Mr P de Wet	Kgalagadi District Municipality
Mr CB Jones	Frances Baard District Municipality
Mr F Fourie	Department of Water Affairs and Forestry
Mr R Peters	Department of Water Affairs and Forestry
Mr J Streuders	Department of Water Affairs and Forestry
Mr E Ramaforo	Department of Agriculture and Land Reform
Mr L Terblanche	Department of Agriculture
Mr P de Bruyn	Department of Agriculture
Mr T Duvenhage	Agri-NCape