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# GROUNDWATER MANAGEMENT IN DROUGHT PRONE AREAS OF AFRICA: SOUTH AFRICA INCEPTION REPORT

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Children collecting water from a borehole, Northern Province, South Africa



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## Contents

## EXECUTIVE SUMMARY

The subject of drought in drylands has been extensively researched, particularly from food security, meteorological and sociological perspectives. However, relatively little attention has focused on the impact of drought on groundwater resources. In view of the fact that groundwater is often the only perennial source of supply, and that recent African droughts have caused severe water stress, the lack of research in this area is striking. Drought policies with respect to groundwater reflect this: drought is treated as a one-off event rather than a normal and recurring hazard that could be planned for, and 'crisis management' typically follows. It is in this context that the project 'Groundwater management in drought-prone areas of Africa' is set. One of the principal aims of the project is to identify ways in which spatial and temporal information on the impact of drought on groundwater resources can be used to inform groundwater management, with particular emphasis on longer term, proactive planning.

This South Africa Inception Report is one of three such reports produced for the project; others have been produced for Ghana and Malawi. Each report provides country-specific information on: the water resources base and the role of groundwater; recent drought experience with particular reference to groundwater supplies; the spatial and temporal aspects of groundwater drought incidence and impact; policy responses of government and other institutions; and suggestions for ways in which groundwater management might be improved. The result is a common pool of knowledge from which generic and country-specific issues can be drawn.

This report focuses principally on rural water supply and the experience of drought in Northern Province (formerly Northern Transvaal). This an area where the impacts of recent droughts have been particularly severe, and where groundwater resources are expected to meet high and growing demands. Like much of South Africa, the region is characterised by wide disparities in service provision between different areas and sectors of society. To address these imbalances, the Government of South Africa has embarked upon an ambitious programme aimed at meeting the water and sanitation needs of all South Africans. In Northern Province, where surface waters are scarce, this implies a new role for groundwater, and a fresh approach to community water supply based on the principle of 'some for all, rather than all for some'.

Over the last two decades, South Africa has experienced two major droughts, most recently in 1991-92. In Northern Province, the effects of the drought continued to be felt for some years after. In contrast to earlier drought relief efforts which focused almost exclusively on cities and the commercial agriculture sector, attempts were made to mitigate impacts in the former homeland areas. In Northern Province, two major drought relief programmes were organised. Both involved initial reconnaissance work to determine areas of acute water stress, repair and rehabilitation of existing supply systems, significant investment in new infrastructure through emergency drilling programmes and, as a last resort, water tankering. While both programmes undoubtedly eased water stress and saved lives, major difficulties were encountered. Many of these can be related to the shortcomings of emergency programmes in general (echoed in Malawi), and the lack of pre-drought monitoring and planning. They include: inadequate information on the status of rural water supplies and those dependent on them; inadequate information on the causes of supply failures; coordination problems between different organisations involved in relief; rushed siting and drilling of boreholes; and lack of community mobilisation and participation.

The report suggests several ways in which groundwater management could be improved with respect to drought. These emphasise the importance of pre-drought planning to (i) reduce the need for emergency interventions, and (ii) improve the targeting and effectiveness of emergency interventions when needed. Measures discussed include drought vulnerability mapping, groundwater monitoring, early warning and response systems and the development of permanent structures for dealing with disaster avoidance and management in this area.

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## PREFACE

Almost by definition, drought in drylands means that surface waters are scarce and groundwater is the principal, or only, source of supply. In severe drought, yields from these sources may decline markedly at a time when the demand for groundwater typically reaches a peak. The result may be falling numbers of viable water points, and escalating social and economic costs. Set against longer term demographic and economic changes affecting demand and recharge patterns, the availability of perennial groundwater supplies cannot be assumed, as recent drought experience in southern Africa demonstrates.

The subject of drought in drylands has been extensively researched, particularly from food security, meteorological and sociological perspectives. However, relatively little attention has been focused on the impact of drought on groundwater supplies. Drought management strategies reflect this fact. A typical strategy involves an emergency drilling programme in which rigs are imported, international expertise mobilised and large sums of money spent. The execution of these programmes is often poor, however. Wells are poorly sited, community participation is minimal and maintenance of new works is not prepared for. In addition, the response often comes too late, and it is not uncommon to find emergency drought relief wells being sunk after the rains have returned. Within a short space of time, the stock of unsustainable water supply infrastructure is increased, and funds have been diverted from longer-term programmes.

Against this background, the British Overseas Development Administration (ODA) has supported a project entitled 'Groundwater management in drought-prone areas of Africa' (R6233). A key contention of the project is that some wells, and some areas, are much more vulnerable to 'groundwater drought' than others, and that essentially predictable variations are rarely planned for or acted upon. One of the principal aims of the project is therefore to identify ways in which spatial and temporal information on the impact of drought on groundwater supplies can be used to improve groundwater management. Ultimately, the project will identify specific strategies that could be adopted or promoted by government and the donor community to (a) improve responses to groundwater drought *within* drought episodes; and (b) improve longer term planning for groundwater drought *outside* drought episodes.

The project brings together institutions from four countries in an equal partnership. The countries (and institutions) involved are: Malawi (Ministry of Irrigation and Water Development (MIWD)); Ghana (Ghana Water and Sewerage Corporation (GWSC)); South Africa (Department of Water Affairs and Forestry (DWAF)), and the United Kingdom (the Hydrogeology Group of the British Geological Survey (BGS) and the Institute of Hydrology (IH)). Personnel from four of these institutions - MIWD, GWSC, BGS and IH - designed the original project in 1994. DWAF joined the network in 1996 under a sister project funded by the British Development Division South Africa (BDDSA). Initially, the project will examine the experience of drought and groundwater drought in each of the African countries, documented in country-specific inception reports. Drawing from this common pool of experience and knowledge, the focus of the project will then shift towards the identification of management strategies. An international workshop will then be held in Lilongwe in February 1997 to publicise and discuss findings with the government and donor community.

This report is the inception report for South Africa, with particular reference to Northern Province. It is based on information gathered during a BGS visit to South Africa in July 1996, and on project discussions held with DWAF personnel and other project partners in the UK.

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## ACKNOWLEDGEMENTS

This project represents a partnership between different institutions from different countries. The cooperation and enthusiasm of everyone involved, under the leadership of Nick Robins of BGS, has been instrumental in getting the project up and running. Ultimately, it is hoped that the project will contribute to greater awareness of the impact of drought on groundwater resources and the strategies through which impacts can be prevented or mitigated.

Thanks are due to all staff at DWAF, particularly those in the Directorate: Geohydrology, the Branch: Community Water Supply and Sanitation, and those at regional offices who assisted in the compilation of this report. The study tour was undertaken during an exciting but extremely busy period for DWAF, and staff were more than generous with their time. Thanks are also due to those from other ministries, including the Department of Agriculture and the Department of Health; those at non-government organisations including the Mvula Trust and the Independent Development Trust; and those at the Council for Scientific and Industrial Research, Water Research Commission, Development Bank of South Africa, Water Systems Management, and the Department of Civil Engineering at the University of Pretoria, all of whom were welcoming, enthusiastic and supportive.

The authors would also like to thank the innumerable and unnamable others, particularly the villagers and water committee members from many different areas, who were hospitable and who answered our interminable questions about groundwater, wells and drought with patience and good humour.

# 1. INTRODUCTION

## 1.1 Report objectives

This South Africa Inception Report is one of three such reports produced for the project 'Groundwater management in drought-prone areas of Africa' [1]. The report is the product of a study visit to South Africa undertaken by the authors in July 1996, and of ongoing discussions between all project partners.

The aim of each report is to provide a resource of background information which can be drawn on for the remainder of the project, focusing principally on the following:

(a) the water resources context, including the water resources base, approaches to rural water supply and water supply coverage;

(b) recent drought experience and, in particular, the impact of drought on groundwater resources and those dependent on them;

(c) the spatial and temporal aspects of drought incidence and impact;

(d) the response of government and other players in the water sector to groundwater drought, including the nature and targeting of policy interventions; and

(e) ways in which the impact of groundwater drought can be reduced or mitigated through better planning and management.

Each report is a working document designed to raise issues and questions. Taken together, the reports will provide a common pool of knowledge from which generic issues and groundwater management strategies can be identified. It is anticipated that these will be of interest to governments, external support agencies (ESAs) and non-governmental organisations (NGOs) involved in the water sector and/or drought planning. An international workshop scheduled for February 1997 will provide a forum for discussion of regional and country-specific issues.

This report focuses principally, though not exclusively, on groundwater drought experience and management in the rural areas of Northern Province, South Africa. In rural areas, reliance on groundwater as a source of potable supply is greatest, and efforts are being made to accelerate supply coverage to meet government targets. The report concentrates on the experience of Northern Province (formerly Northern Transvaal), an area where the impact of recent drought events has been particularly severe, and where groundwater resources are expected to meet high and growing demands.

## 1.2 Report structure

The report begins by introducing some important drought concepts (Chapter 2). Background information on South Africa's political, economic and institutional transition is then discussed briefly in Chapter 3, as developments here have had a profound effect on water sector activities and the nature and targeting of drought interventions. Contextual information on the water resources base and rural water supplies is then dealt with in Chapters 4 and 5 respectively, with particular emphasis on groundwater availability, development and sustainability issues. Chapter 6 describes the recent experience of drought in South Africa, concentrating on the incidence, nature and responses to groundwater drought in Northern Province between 1992 and 1995. Some of the principal management issues arising are then discussed in Chapter 7.

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[1] Ghana inception report: MacDonald et al, 1996; Malawi inception report: Calow et al, 1996

## 1.3 Report comparisons

As the South African Inception Report is the last country inception report to be published, some attempt has been made to compare and contrast the drought experiences of all three countries within this report. Thus in Chapter 7, management issues arising are discussed in relation to those which have emerged in Ghana and Malawi. A more comprehensive discussion will be contained in the final project report which will be compiled subsequent to the Lilongwe workshop in February 1997.

## 2. DROUGHT DEFINITIONS

### 2.1 Definitions and concepts

The subject of drought in drylands has been extensively researched, particularly from meteorological and food security perspectives. Typically, however, the work of natural and social scientists remains separate, with drought definitions varying accordingly.

Definitions vary according to professional standpoint, and according to whether impact is incorporated into the concept (Box 2.1). Definitions which incorporate some notion of impact are often termed operational definitions. Operational terms may frame impact either in very broad terms (e.g. as a general water deficit), or according to specific sector impacts (e.g. 'agricultural droughts'). Operational concepts begin to capture the idea of drought as a product of a natural system (the physical environment) and a set of human activities and responses. Notions of vulnerability then have to be explored to answer fundamental questions of why certain areas and groups of people may be disproportionately affected.

**Box 2.1 Definitions of drought**

From a *meteorological* standpoint, drought exists when rainfall is abnormally low, i.e. less than a critical precipitation that defines initiation of drought (Bruwer 1990; Solanes 1986). Area-specific definitions abound. For example in South Africa, Chavula (1994) defines drought as occurring when rainfall in any particular period is 70% of normal, becoming severe when this occurs over two or more consecutive seasons.

In *hydrological* terms, drought has been defined as occurring when actual water supply falls below the minimum required for 'normal' operations, reflecting a deficit in the water balance (Bruwer 1990; Solanes 1986). A similar definition, encompassing supply in broad terms in relation to demand, is offered by Hazelton *et al* (1994), when they state that drought occurs when there is a deficit in water, including surface and sub-surface water runoff and storage, as well as rainfall. This brings us to the rather catch-all definition of drought, of arising when demand exceeds supply.

Notions of supply and demand introduce a range of operational definitions of drought. For example, *agricultural drought* can be defined as occurring when soil moisture is depleted to the extent that crop and pasture yields are considerably reduced (Bruwer, 1990; Solanes, 1986).

From the above, it is apparent that drought is a relative concept, defined in terms of a deviation from the norm and/or a notion of requirement. Needless to say sufficient data must exist to help describe the *normal* conditions of any system.

The response of groundwater to meteorological drought is poorly understood, and may be out of phase with other more immediate impacts. This is due in part to the complexity of hydrogeological systems as different types of aquifer in different hydrogeological environments respond in different and unique ways. However, other factors are also important. Groundwater is typically 'out of sight and out of mind', and monitoring programmes often inadequate or non-existent.

Perhaps the most significant aspect of groundwater behaviour in relation to drought is the time lag between changes in recharge and responses in groundwater levels and well yields. This contrasts with the relatively 'flashy' behaviour of surface water sources. The result is that, while some wells and boreholes may respond relatively quickly to rainfall variations, problems in others may take months or even years to emerge, perhaps after several years of low rainfall. Indeed, it is quite conceivable that a decline in well/borehole yield, or a fall in water level, may only materialise after the rains have returned and the meteorological drought is perceived to be over. This emphasises the need to track the long term effects of drought through hydrological and hydrogeological systems.

While the buffering capacity of groundwater systems confers obvious advantages in terms of the reliability of supply, it also creates certain problems. Firstly, it follows that groundwater also recovers more slowly after drought than surface sources. The result may be complex and seemingly unrelated linkages between rainfall events and their impact on groundwater resources. Secondly, it indicates a need for careful management and continuous monitoring of groundwater supplies. Monitoring and assessment programmes which begin and end with meteorological and agricultural droughts - a not untypical situation in many countries - may fail to detect longer term impacts on groundwater, with the result that potentially predictable and manageable problems become emergencies.

## 2.2 The failure of groundwater sources

The exact cause of the failure of wells and boreholes is not always clear, since the lack of water coming out of a pump can be due to many different reasons. Sometimes, it is assumed that an aquifer is being overexploited and groundwater resources are being regionally depleted. However, regional over-exploitation is rarely a problem in African basement aquifers. The abstraction from individual wells and boreholes is generally so low (10-15 $m^3/d$) that abstraction rarely exceeds long term aquifer recharge limits, and wells could be placed within 1 km of each other without causing aquifer depletion (assuming a pessimistic recharge rate of 15 mm/year). Simmers et al (1992) provides a useful summary of overexploitation problems throughout the world.

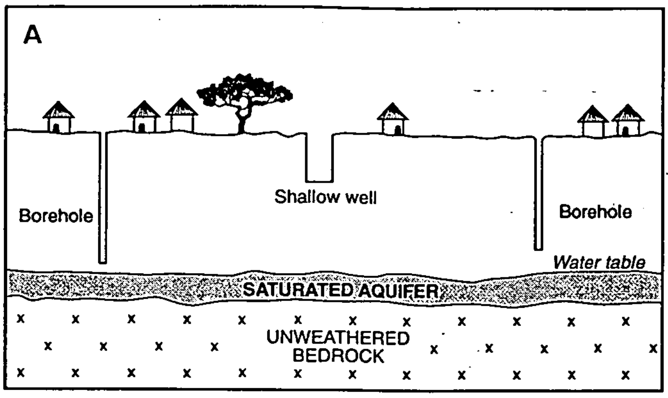
Localised depletion, resulting in falling groundwater levels in the immediate vicinity of a well or borehole, is likely to be the principal problem. This is most likely to occur where the demands being placed on a water source are high, and where the permeability of the aquifer is low (MacDonald and Macdonald, 1996). In these circumstances, groundwater cannot move sufficiently quickly to replenish the water abstracted from the borehole or well, and a dewatered zone may form around the source (a cone of depression) restricting the inflow of water. Figure 2.1 illustrates the distinction between source and resource constraints on abstraction. If, during a drought period, the demand for groundwater from individual sources increases, the yield can actually decrease and the borehole or well may quickly dry up. This effect has been observed in northern Ghana, where boreholes sited on the low permeability Voltaian Shales are only able to support limited abstraction, and where symptoms have been misinterpreted by some as indicating an overexploitation problem (MacDonald et al, 1996). Conversely, boreholes and wells sited in the more permeable basement aquifer to the north are more reliable.

Increased stress on a groundwater source during drought can also lead to the failure of the pump. Prolonged pumping throughout the day can put considerable strain on the pump mechanism leading to breakdowns, especially if water levels are falling and pumping lifts increasing. The result may be increased demand on a neighbouring source, and thus increased stress (and probability of failure) on that source. And so the cycle continues. The problem may be exacerbated by the cessation of maintenance programmes as relief drilling programmes take priority. The use of poorer quality sources as water scarcity increases, and the added strain of travelling long distances for water, may have significant health impacts on affected households and communities. This was the experience of Malawi during and following the severe drought of 1991-92 (Calow et al, 1996).

A preliminary conclusion is that the failure of wells and boreholes during drought is a function of both increased demand on low yielding sources and reduced recharge to the aquifer. Identifying hydrogeological zones that have low permeability, wells and boreholes that are low yielding and areas of high demand might therefore help identify areas which are vulnerable to groundwater drought.

## 2.3 The balance between demand and supply

Figure 2.2 illustrates how short term and longer term variations in demand (abstraction) and supply (well/borehole yield) may inter-relate and cause groundwater drought.



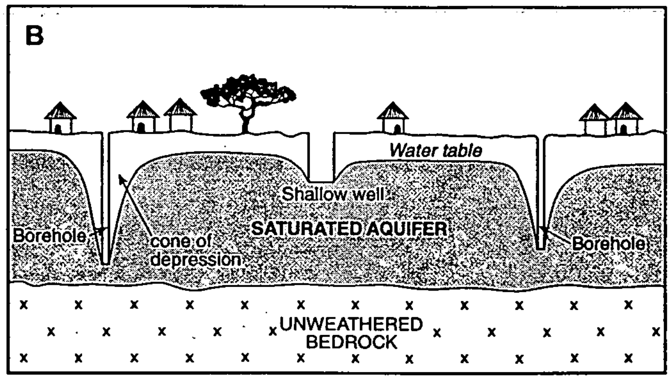




Figure 2.1 Limitations on groundwater abstraction: source versus resource. In both A and B groundwater sources fail. In A this is caused by a regional fall in water levels. In B the cause is source-specific: borehole abstraction has exceeded borehole yield.

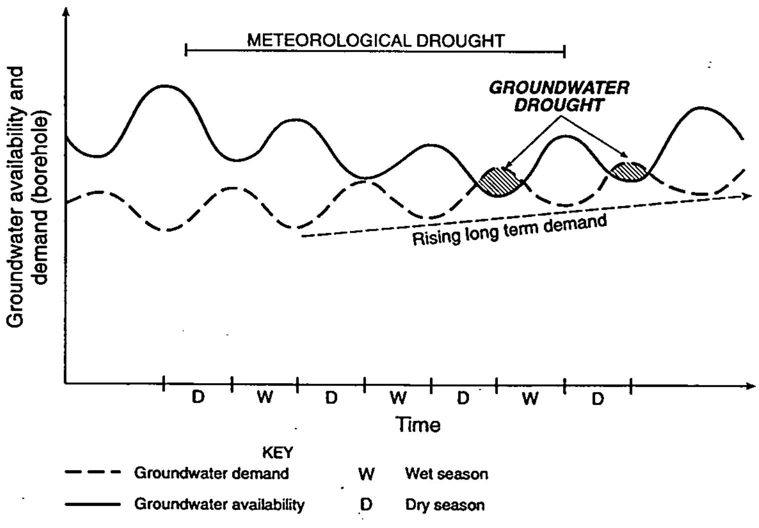



Figure 2.2 Changes in groundwater availability and demand over time. During a normal dry season boreholes may be able to meet demand. During a drought when dry season demands are typically higher and groundwater availability lower, boreholes may dry up. Longer term increases in demand and reductions in groundwater recharge may cause boreholes to dry up in circumstances where previously they would have remained viable.

Over the course of a year, it is clear that demand for groundwater is likely to reach a peak when wells and boreholes are at their most vulnerable, in terms of their yield and ability to provide water (MacDonald and Calow, 1996). Towards the end of the dry season, alternative sources of water from dams and rivers may disappear, leaving communities dependent on groundwater. At the same time, the number of uses to which water is put may increase as families concentrate on brick making and dry season irrigation of small vegetable plots. The combined effect is illustrated in Figure 2.2 as a dry season peak in groundwater demand.

Water levels in an aquifer, however, are naturally at their lowest level at this time, with the result that yields are low. This is illustrated as a dry season yield trough in Figure 2.2 on the water availability curve. It follows that if a well or borehole can only just meet demand for groundwater in a normal year, water availability and demand curves may intersect during a drought year and demand may exceed the supply capacity of the source. Alternatively, an intersection may only occur after several years' poor rainfall, illustrated by the gradual, longer term reduction in groundwater availability in Figure 2.2. The result in either case may be a reduction in water levels, a further decline in yield, and possibly the drying up of the source altogether. Failure of the pump mechanism is also more likely as pumping stresses increase.

Figure 2.2 also illustrates how long term increases in demand can make a source vulnerable to drought that in the past may have provided reliable and perennial supply. In this instance, seasonal and drought-related fluctuations in demand might historically have fallen well below the water availability curve. A long term increase in demand, however, can eventually put the fluctuations above the curve so that demand will exceed supply. The cause may be population growth (natural, or as a result of migration), or possibly increases in per capita consumption resulting from economic change, such as the introduction of irrigation or other water-intensive activities.

The hydrogeology of the aquifer determines the amplitude of the yield fluctuations illustrated in Figure 2.2. If an aquifer is highly permeable and contains a large volume of groundwater, boreholes and wells which penetrate the aquifer are likely to be more productive. In such cases the source may be able to meet even the high demands placed upon it during a drought. If the aquifer properties are poor, on the other hand, or if the aquifer is of limited extent, a source might be unable to meet even normal dry season demand. A thick aquifer would be less susceptible to changes in yield than a thin aquifer, and boreholes and wells could be deepened to tap lower reserves of groundwater keeping the saturated thickness of the borehole or well sufficiently large to maintain yields. Longer term changes in climate (and therefore recharge) could place both the high and low yielding sources at risk.

# 3. POLITICAL, ECONOMIC AND DEMOGRAPHIC BACKGROUND

## 3.1 The political and economic transition

Following the first open election in South Africa in April 1994, an Interim Government of National Unity (IGNU) was inaugurated at national level, with power sharing arrangements brokered between the National Party and the African National Congress. Similar coalitions were formed at lower levels of government to administer the country's newly determined nine provinces[2] (see Figure 3.1). Since the election, the government has emphasised compromise and reconciliation, laying the foundations for strong but equitable development whilst attempting to address more immediate problems such as unemployment, inflation and poverty.

The challenges facing the government are considerable. The policy of apartheid (literally separate development) institutionalised a system of inequitable development of people's lives, most visibly apparent in the establishment of separate self-governing territories, or homelands, for blacks. A number of these were given the status of republics by the South African government. In total, 10 homelands[3] were delineated (see Figure 3.2). The political transition and the abolition of apartheid structures has raised expectations among the majority black population for rapid social and economic transformation, and the government is tasked with addressing disparities, meeting expectations and offering opportunities for participation in the development of a 'new' South Africa.

Addressing these problems whilst at the same time maintaining confidence among the minority white population (where at least economic power still resides), requires compromise and stability. The country has enormous potential: in contrast to many other countries in the region, South Africa boasts extensive infrastructure in roads and communications, and development of the country's substantial natural resources (particularly minerals) has helped generate a reliable source of foreign exchange. Nevertheless, these assets are heavily skewed towards the minority white population, and large areas of the country are essentially underdeveloped. The result is huge structural imbalances in the economy and gross inequality between regions and sectors of society. For this reason, economic averages in the South African context are more or less meaningless. Thus, while South African's are on average better off than anyone else on the continent, with an average GDP/head of around US$3000, black incomes are barely one sixth of white incomes, and regional disparities are such that Gauteng Province alone accounts for roughly 65% of total GDP.

> **Box 3.1 The Reconstruction and Development Programme (RDP)**
>
> The RDP is essentially a programme of social spending and public works. In 1995-96, the RDP fund amounted to a massive $1.5 billion, some 4.4% of the government budget, placing heavy demands on spending departments such as DWAF which were asked to apply for monies and account for all expenditure against RDP objectives.
>
> Key RDP objectives include meeting basic needs, developing human resources and democratising the state and society (a new constitution is due to take effect in 1996). Within the category of basic needs, securing access to adequate water supplies was found to be of the highest priority amongst new voters after jobs and housing (Muller, 1996). Indeed in a report compiled by the South African Labour and Development Research Unit at the University of Cape Town in 1994, over 56% of people in Northern Province listed clean water as the single most important service they expected from a democratic government.

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[2] In the run up to the 1994 elections, the old provinces of Cape, Transvaal, Orange Free State and Natal were reorganised to give the nine 'new' provinces of Gauteng (the urban conglomeration of Pretoria, Witwatersrand and Vereeniging - PWV), Northern Transvaal, Eastern Transvaal, Orange Free Sate, KwaZulu Natal, North West, Northern Cape, Eastern Cape and Western Cape. Following the elections, some have been renamed: Northern Transvaal is now known as Northern Province; Eastern Transvaal is now known as Mpumalanga; and Orange Free State is known as Free State. It is expected that in the near future KwaZulu/Natal will be known as KwaZulu Province.

[3] In this report the term homelands will be used for the self-governing territories, including the 'republics'.

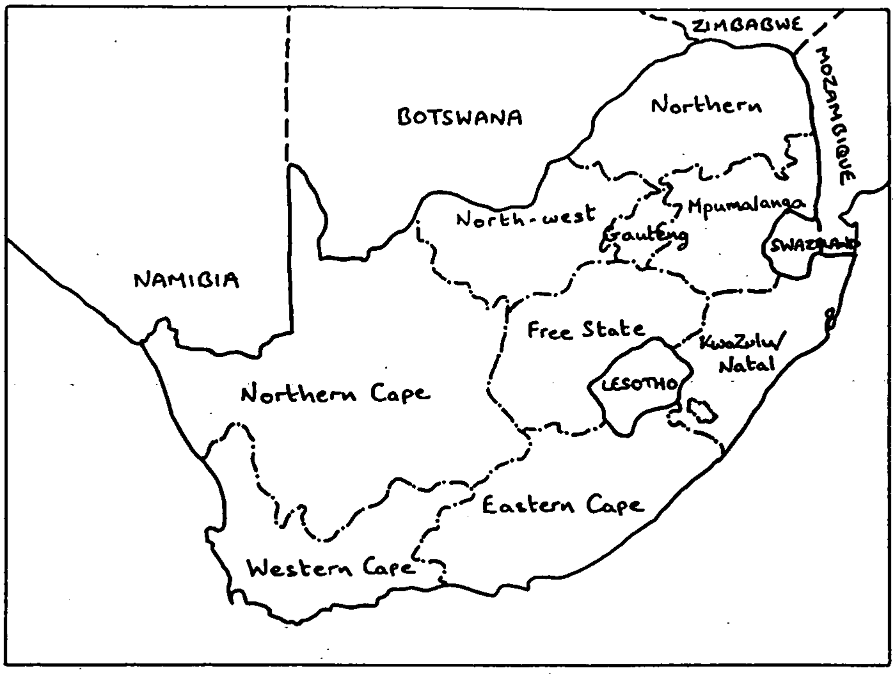


Figure 3.1 Provincial map of South Africa.

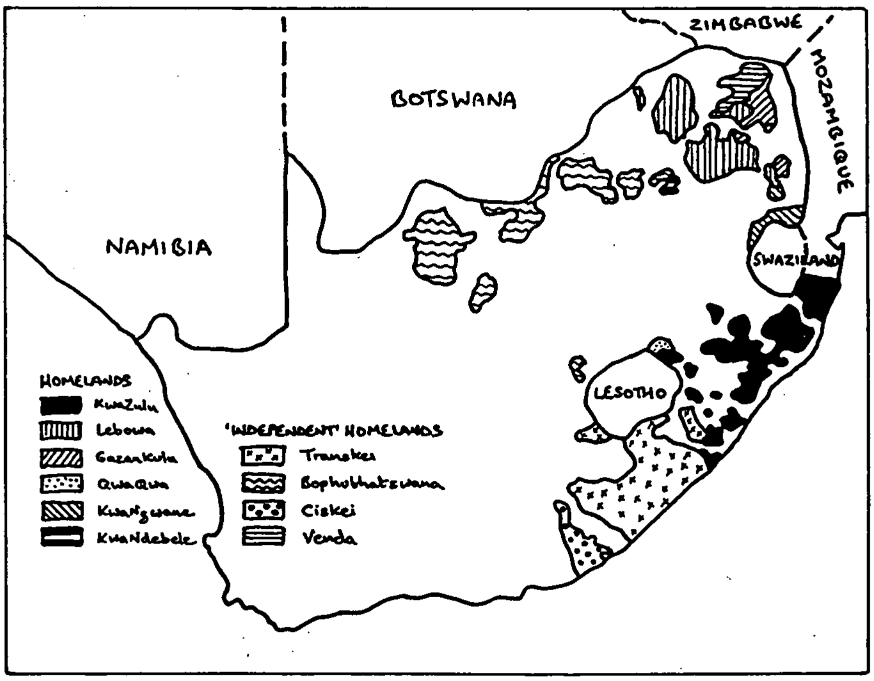


Figure 3.2 Former homeland areas of South Africa.

In order to address these imbalances, the government has embarked on an ambitious programme of social and economic development - the Reconstruction and Development Programme (RDP) - overseen by a minister without portfolio within the office of the President. Within the RDP, meeting the basic needs of all the population is an obvious priority (see Box 3.1 and Chapter 5). The challenge of providing adequate water and sanitation to at least 12 million people currently unserved or poorly served is a daunting one.

### 3.2 Demographic and institutional change

The total population of South Africa in 1996 is estimated as 41 million (The Economist, 1996), with population growth at around 2.1% (one of the lowest rates of growth in Africa). Blacks make up 75% of the total population, whites 13%, coloureds 9% and Indian 3%. The majority of Africans live in the former homeland areas which, following the 1994 elections, ceased to exist as political entities. The rural-urban split is approximately 60:40 (Water and Sanitation 2000, 1991), although estimates vary according to the definitions of 'urban' and 'rural' used. In the South African context, definitions and data are particularly problematic: settlements in areas defined as rural may contain many thousands of people living in units still termed villages, and lack of accurate census data adds further uncertainty to population and water supply coverage estimates (see section 5.1).[4]

Northern Province contains the old homeland areas of Venda, Lebowa, Gazankulu, with the province itself accounting for roughly 10% of the total population. During the apartheid era, Venda was nominally independent, and therefore responsible for developing and managing its own water supplies. Northern Province is a new (post election) administrative region, forming the northern part of the old Transvaal Province, with Pietersburg as its capital.

Rapid and far-reaching institutional changes are occurring in South Africa as undemocratic structures are replaced and the roles and responsibilities of different organisations are clarified. Such change forms the context for transformation in the water sector, particularly as it relates to the delivery and management of water supply and sanitation services (see Chapter 5). During the apartheid era, undemocratic institutional structures and mass protest led to the formation of a diverse range of community-based organisations (the civics), which often operated in opposition to appointed and unrecognised local government structures. Although local government elections have now been held, institutional arrangements are still in a state of flux. It will be some time before community level organisations begin to work effectively with local government structures in rural areas and local government departments have sufficient capacity to operate independently of provincial and central governments.

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[4] In Water and Sanitation 2000 (1991), rural populations are defined as: (a) scattered homesteads relying wholly or partially on agriculture; (b) villages in agricultural areas where the majority of residents are involved in some agriculture-related activities; and (c) villages remote from urban centres (20 km minimum) where significant industrial and commercial activities are not taking place and the number of residents is less than 20 000.

## 4. WATER RESOURCES

South Africa is a water scarce country, and scarcity is growing. Contributory factors include rising per capita use and population growth, uneven distribution of resources relative to patterns of demand, declining water quality, and an obligation to share water with other countries.

Although in 1990, annual renewable freshwater availability per person was estimated at roughly 1300 $m^3$, just above the 1000 $m^3$ 'water scarcity' threshold, this figure is expected to decline markedly in the years ahead. Indeed by 2025, based on a UN medium population growth scenario, it is expected to fall to around 700 $m^3$ per person (World Resources Institute, 1992). While this figure is higher than that projected for most other African countries, in South Africa major engineering schemes have already harnessed much of the available surface water, and the most productive aquifers are, in certain areas, heavily exploited already for commercial agriculture.

### 4.1 Topography

South Africa occupies the southern part of the African continent. It has a long coastline on the Atlantic Ocean to the west and the Indian Ocean to the east. The interior of the country consists of a plateau which slopes gradually downwards from a height of 3500 m in the eastern peripheral highlands (Drakensberg) to 900 m in the interior Kalahari Basin in North West Province (Figure 4.1). The plateau for the most part is flat or slightly undulating with lines of hills occurring locally. In general the south-east of the plateau is higher (highveld) while the north and east are lower (lowveld). The plateau terminates near the sea in fairly narrow coastal plains; in some places these plains rise sharply towards the interior.

### 4.2 Climate

South Africa is situated within the high pressure belt of the middle latitudes of the Southern Hemisphere where warm dry descending air associated with high pressure systems is unfavourable for the formation of rain. Climates in these regions are characterised by a high degree of intra and inter-annual variability as a result of the interaction of temperate and tropical disturbances. The climate in South Africa is modified by the influence of the warm southward-flowing currents along the east coast and cold northward-flowing currents along the west coast. The warmer east coast air masses are less stable and more likely to give rise to precipitation.

The mean annual rainfall in South Africa is shown in Figure 4.2a. This shows the isohyets to have a general north to south trend decreasing from more than 800 mm in the east to almost complete aridity in the Namib desert in the west. Sixty five per cent of the country receives less than 500 mm of rainfall annually, considered to be the minimum requirement for dryland farming. In all areas topography exerts a strong control on rainfall, producing clear orographic anomalies, with mountains enhancing and valleys diminishing rainfall. Most of the major deep river valleys of southern Africa are associated with local aridity.

Figure 4.2b indicates the percentage deviation from mean annual rainfall. The higher the percentage deviation the more susceptible an area is to both drought and floods. Droughts have been broadly defined as occurring when annual rainfall falls below 70% of the annual mean, becoming severe when this occurs over two or more consecutive years (Bruwer, 1990). Over recent years, agricultural droughts have been declared in the wetter areas in the east and extreme south of the country less than 30% of the time. In contrast, such droughts have been declared up to 70% of the time in some districts of the drier north, north-east and west of the country (Hazelton et al., 1994).

Rainfall over most of southern Africa is highly seasonal. Precipitation over the northern interior regions of South Africa follow an annual cycle which is almost entirely a summer phenomenon. More than 80% of the annual rainfall in these regions occurs between October and March. This seasonality decreases to the south and to the west (Figure 4.2c) with the contribution of winter rainfall increasing.

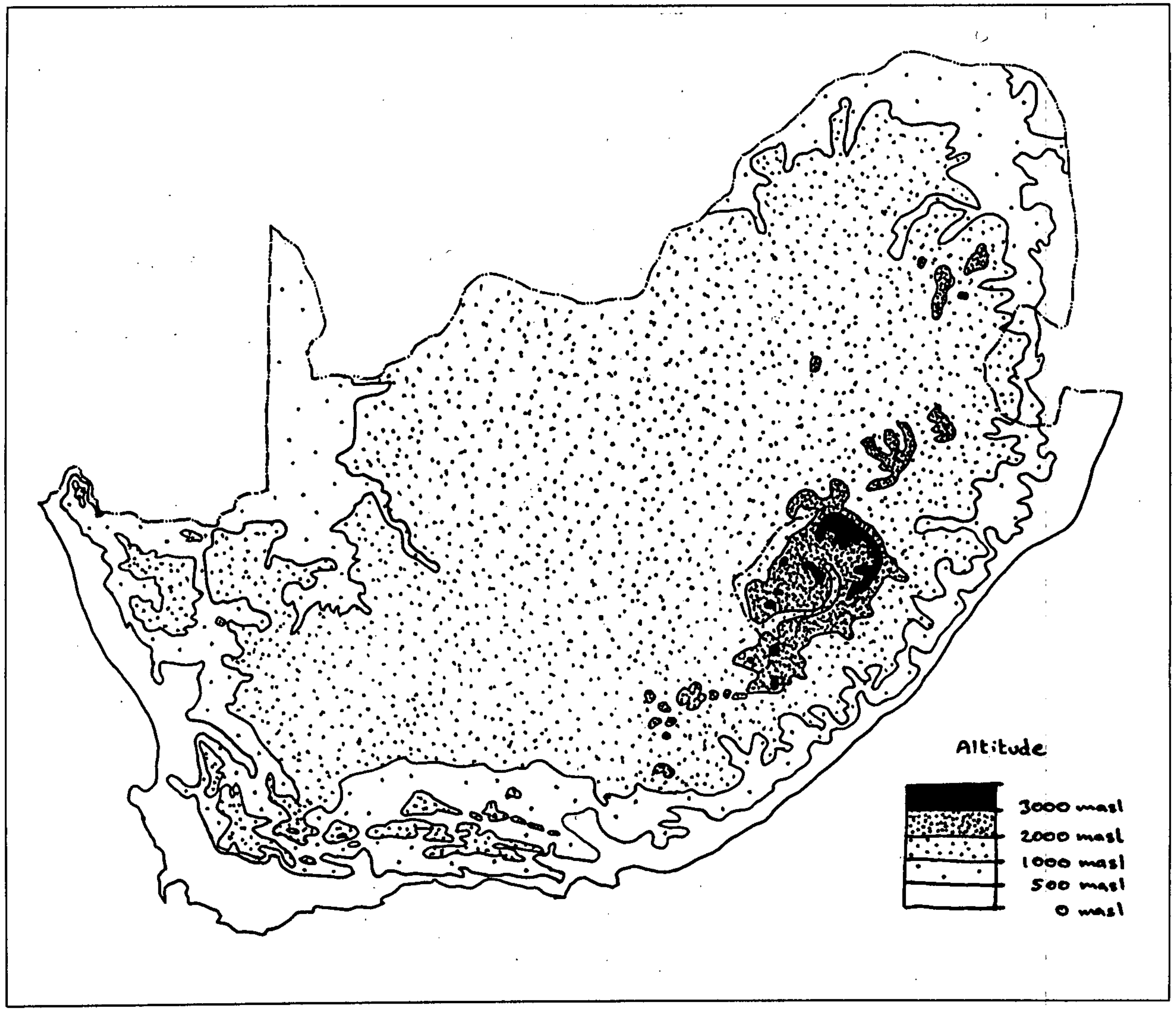


Figure 4.1 Topographic map of South Africa

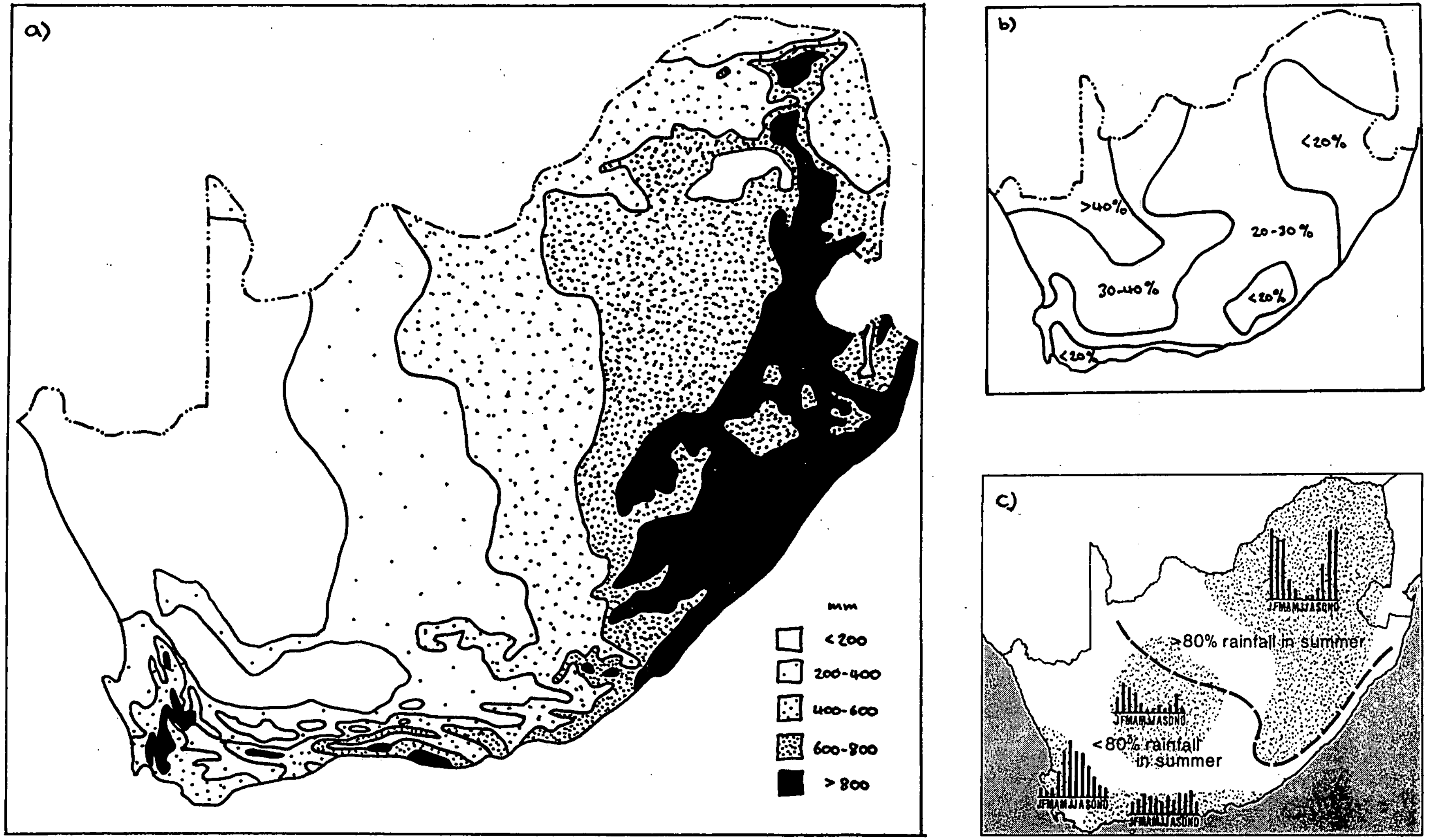


Figure 4.2 a) mean annual precipitation; b) percentage deviation from mean annual rainfall; c) seasonal rainfall regimes (after DWAF (1986) and Tyson (1986)).

The temporal variability in rainfall is marked over all of South Africa but particularly in the summer rainfall region in the north. This variability shows a remarkably regular series of alternating wet and dry spells (Figure 4.3). Severe droughts have accompanied these dry spells, particularly in the early 1930s, the mid-1960s, the mid-1980s and, most recently, in the early 1990s.

### 4.3 Surface water resources

It is estimated that only 9% of rainfall over South Africa reaches the river system as runoff. However, the majority of water supplies in the country (in terms of quantity) come from surface water sources. The average annual runoff is approximately 53.5 x $10^9$ $m^3/a$. Figure 4.4 shows how this runoff is distributed across the country's major river systems. Of the annual total runoff it is estimated 33.0 x $10^9$ $m^3$ (62%) is exploited, 50% being held within the many dams. However, the geographical mismatch of water availability and demand is causing major water supply problems. About 75% of the surface water resources in South Africa are located in 32% of the country. The majority of this originates in a 400 km wide strip along the eastern coast, to the east of the great escarpment divide (Figure 4.1). Only 15% originates from the vast drier areas in the north and the west.

Twenty five per cent of the population and 60% of industrial and mining activities are concentrated in Gauteng Province. In the past, this area has relied on the waters of the Vaal River. However, demand for water here is expected to reach 5.3 x $10^9$ $m^3/a$ by 2010, compared with the present yield of the Vaal River of 2.2 x $10^9$ $m^3/a$. To address this and other water supply problems in the country, a number of large and sophisticated water transfer schemes have been implemented. In addition, the Lesotho Highlands Water Project is currently under construction. This project alone will allow the transfer of 70 $m^3/s$ of water from the upper reaches of the Orange River into the Vaal River catchment. However, it is unlikely that even this scheme will be able to meet the demand for water in this region in the future, and plans are already being discussed to transfer water from the Zambesi River across eastern Botswana, and also from the rivers of Mozambique.

The major reservoirs in South Africa generally supply large urban centres and commercial (white) agricultural communities. Smaller dams and river abstraction schemes have been constructed in rural areas but these are often unreliable, particularly during low rainfall periods. All rivers in South Africa have significant seasonal variation in flow, including the few perennial rivers in the southern, south-western and eastern marginal slopes. Rivers may receive up to ten consecutive years of less than average flow. As a result, in the north of the country where much of the rural population is located, groundwater resources are the most important source of supply.

There is one example, however, where major surface water schemes has been used to supply rural communities. In KwaZulu/Natal Province, Umgeni Water (one of the 17 major water supply boards operating in South Africa) has an expansive approach to water supply and has gone out of its way to accommodate rural communities through either direct piped water supplies, or through the development of local services. It has been estimated that this may result in an 8% increase in its water supply costs, though finance from other sources (e.g. trusts) may be made available to cover capital costs.

### 4.4 Groundwater resources

Historically, groundwater resources have played a relatively minor role in meeting water supply needs, at least in terms of overall quantity, providing less than 15% of total supply (Vegter, 1987; UN, 1989). Of this, approximately 80% has been used for irrigation on large commercial farms. This reflects the historical preference for large scale, engineering-led solutions which harness the major rivers, and the imperative to supply only formal urban centres and white farming areas. Since the drafting of the Government White Paper on Water Supply and Sanitation, however, development of groundwater has come to be seen as the only solution to fulfilling RDP objectives, in terms of meeting dispersed rural demands at relatively low cost (see Section 5.2).

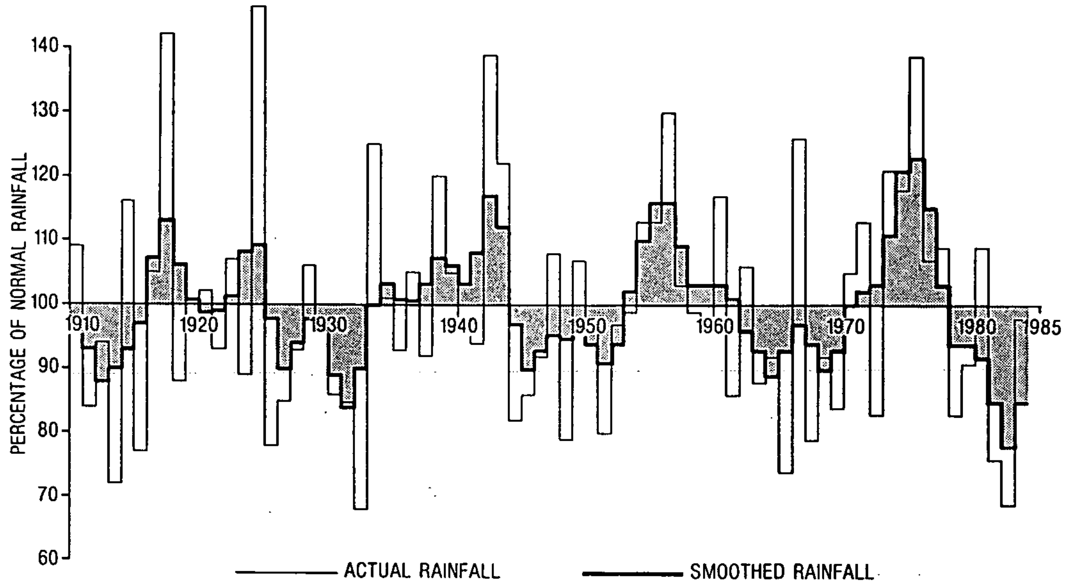


Figure 4.3 An areally-averaged rainfall series for the October-September rainfall year in the summer rainfall region of South Africa for the period 1910-11 to 1983-84 (after Tyson, 1986).

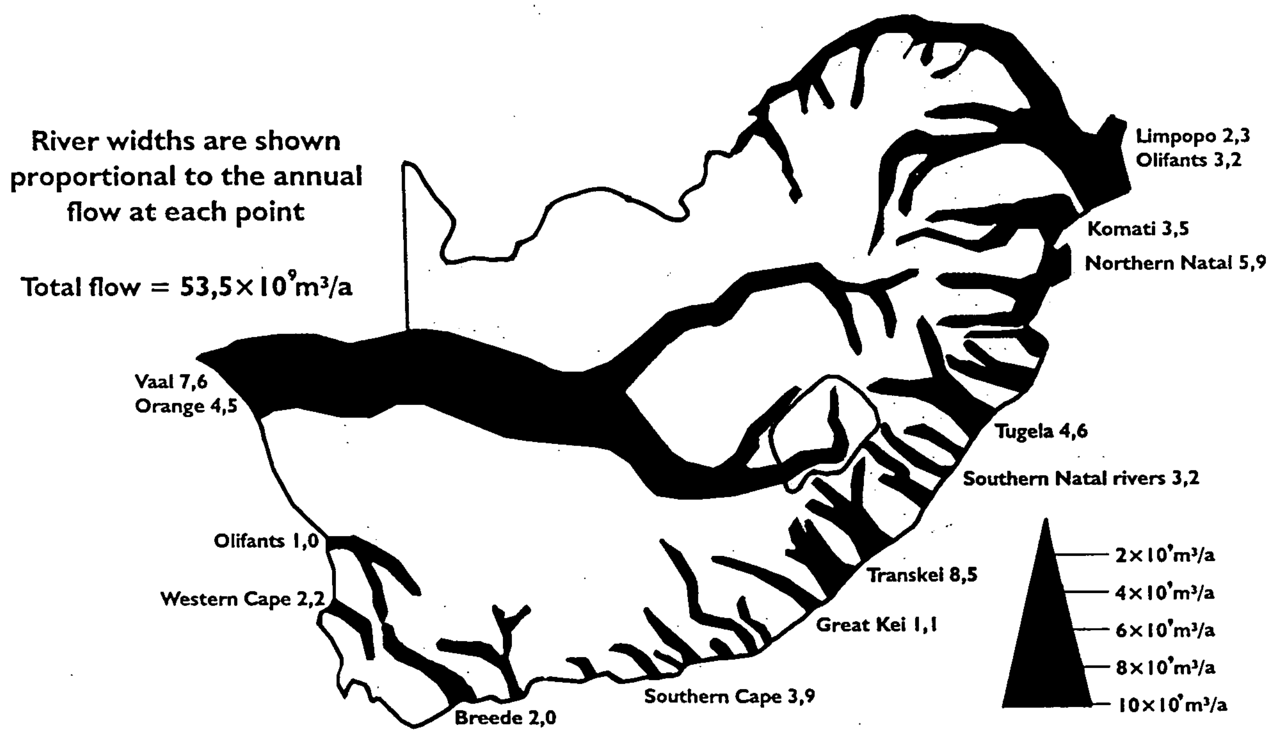


Figure 4.4 Illustration of relative cumulative annual river runoff.

### 4.4.1 *Hydrogeology*

Approximately 90% of South Africa is underlain by secondary aquifers, formed as a result of fracturing and weathering. Storage and transmissivity within these aquifers is typically low. The majority of the areas containing the rural population are underlain by these secondary aquifers, particularly Precambrian basement rocks and the sedimentary and volcanic rocks of the Karoo Super Group. South Africa lacks the Cretaceous and Cainozoic aquifers that elsewhere tend to form the best aquifers: sand rivers and coastal plains are only localised sources; coastal plain aquifers are not extensive; and the Kalahari sands have low levels of groundwater recharge.

Precambrian basement

Precambrian basement rocks outcrop in the north-west of the country along the border with Namibia, in two masses in the north, close to the Botswana border, and in the north-east along the borders with Mozambique and Zimbabwe. As a consequence they underlie much of Northern Province (Figure 4.5), which will be used in this and the following section to illustrate groundwater potential in rural areas. The basement rocks not only include intrusive, extrusive and metamorphosed crystalline rocks such as intensely metamorphosed granitogneisses, lavas, schists and granites, but also ancient sedimentary rocks many of which have been metamorphosed over time. These sedimentary rocks include the gold-bearing conglomerates of the Witwatersrand sequence (the source of much of South Africa's gold), the Waterberg sandstones and the dolomites of the Transvaal sequence (the country's major aquifer).

The karstified dolomites are by far the most prolific aquifers in South Africa due both to their high storage (Table 4.1) and transmissity, though they are not widely distributed. Their importance originally stemmed from their location in relation to the major gold producing areas of the country in what is now Gauteng Province. They now also provide a source of domestic water in this highly populated region, helping to bridge prolonged periods of low rainfall. The aquifers are also used extensively as a source of irrigation water on large commercial farms. Due to their economic importance much work has been carried out on these aquifers to estimate groundwater recharge and to monitor fluctuations in groundwater levels (Bredenkamp et al, 1995). It is clear that in some areas these aquifers are being overexploited.

Karoo Super Group

The Karoo Super Group spans the geological period from Upper Carboniferous to Lower Jurassic. It underlies more than half the country. The major part of the formation is contained within a basin, 1300 km long from south-west to north-east, with a maximum width of 600 km and a thickness of up to 7000 m in the south. The formation includes sandstones, metamorphosed shales, clays and glacial deposits and basaltic lavas. The lavas form the high ground of the Drakensberg mountains which lie mostly within the Kingdom of Lesotho. The Karoo does extend beyond the basin to the north into Northern Province where the basaltic lavas form a significant aquifer and produce fertile soils where many of the large commercial farms are located. Here, as in the dolomites, monitoring of groundwater levels has shown overexploitation of the resource to be taking place in some areas.

In comparison to the productive aquifers of the main agricultural areas, the less productive aquifers, which underlie the majority of the former homeland areas, have received little attention. This, to a certain extent, reflects the difficulties in estimating recharge and interpreting groundwater level fluctuation in heterogeneous, patchy, secondary aquifers. More importantly, however, it reflects the skewed priorities of government in the apartheid era, and the low priority attached to meeting water supply needs in areas of little perceived economic or social importance. As a result comparatively little information is available for these areas, though there is a lot of knowledge held by local consultants. In an effort to formalise this knowledge and collate it with existing data, a series of hydrogeological maps have been planned (Braune, 1995), the first of which, the Pietersburg map sheet (1:500 000) of Northern Province, was published in 1995 (DWAF, 1995). This map highlights the particularly low groundwater potential of some aquifers, for example the younger granites of the Bushveld complex, the sediments of the Karoo formation (except in the hardened contact

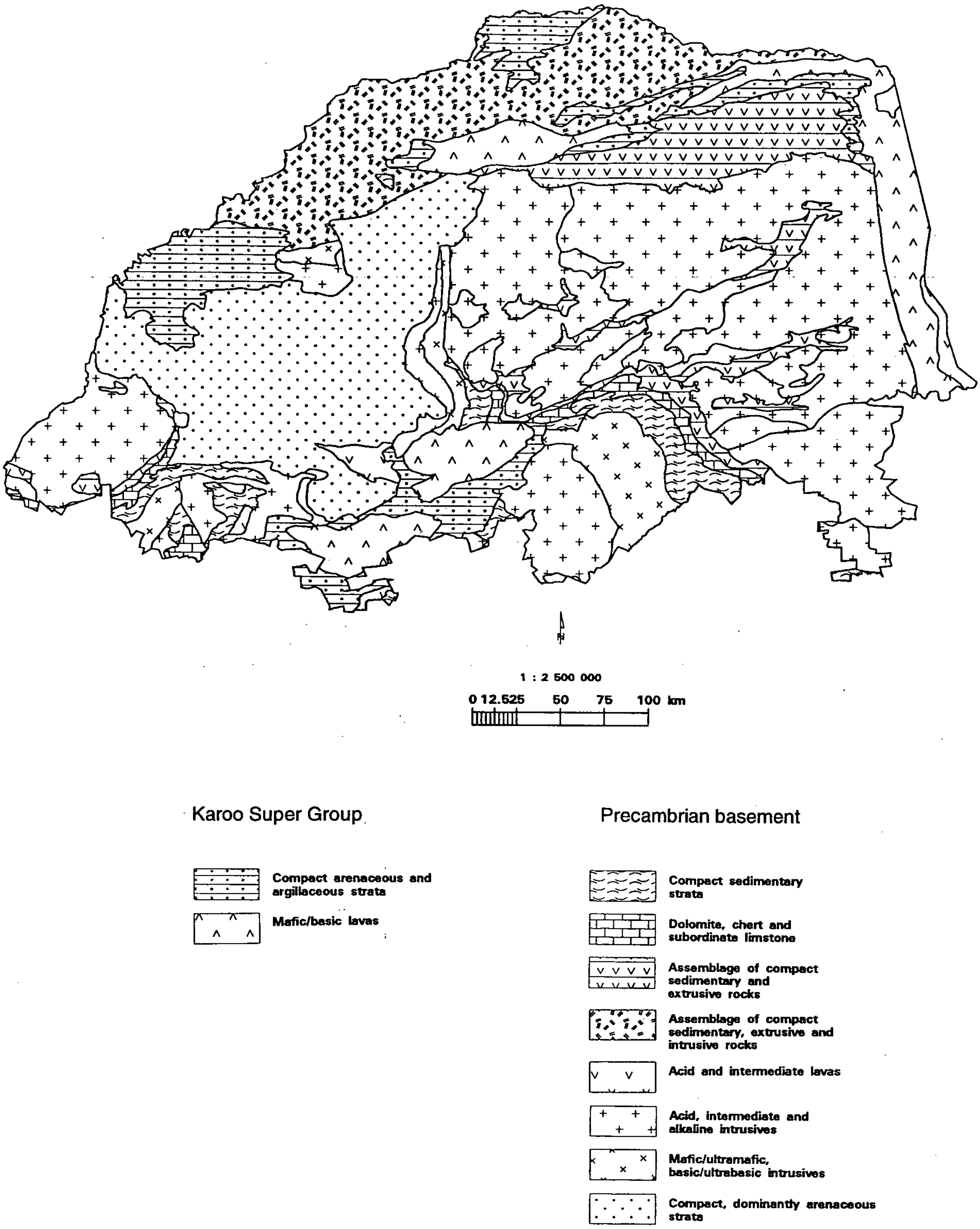


Figure 4.5 Geology of Northern Province, South Africa.

zones with dolerite dykes) and the Waterberg sandstones. The majority of boreholes drilled in these formations yield less than 0.1 l/s. These aquifers underlie areas of significant rural populations, illustrating a significant conundrum: the majority of the population, and the poorest people, are living in the areas of lowest water availability.

The explanatory document that goes with the hydrogeological map also indicates the water quality issues related to each geological unit. As across most of rural South Africa, water quality problems in Northern Province arise primarily from high fluoride, nitrate and salinity levels. Fluoride is associated with acidic and alkaline igneous rocks (Vegter, 1995), or the sedimentary rocks derived from these (e.g. Karoo sediments). High nitrate concentrations may be due to natural processes but are more likely linked to the increasing use of fertilisers in agriculture (e.g. Karoo basalts). The occurrence of salinity problems are not correlated so much with geology as with present and historic climatic conditions. In general, water quality problems are patchy but do have a significant impact on safe groundwater provision.

**Table 4.1** **Groundwater storage in South African geological formations, expressed as the equivalent depth of free water (after DWAF, 1986)**

| Formation | Equivalent depth of free water (m) |
|---|---|
| Dolomite | |
| - Far West Rand | 4.9 - 8.3 |
| - Grootfontein | 1.9 |
| Coastal sand deposits | 2.5 - 5.0 |
| Typical alluvial river deposits | 2.0 |
| Weathered granite | 0.5 - 1.0 |
| Karoo sedimentary rocks | 0.1 - 0.5 |

### 4.4.2 *Groundwater exploitation*

Unlike in many other African countries, the use of hand-dug wells has more or less died out in South Africa. Groundwater is therefore supplied primarily from boreholes. Handpumps are still found in less densely populated areas; in Northern Province they make up approximately 25-30% of the total (pers.comm., C Haupt), but motorised pumps (diesel and electric) are in the majority. Most boreholes are drilled by government or government sponsored contractors, but many private boreholes also exist. Where boreholes are motorised, water is normally supplied via gravity-fed reticulation systems. Springs also provide an important source of water in some areas. Where these occupy high ground, water is also distributed to communities via gravity-fed reticulation systems.

In secondary aquifers, linearities provide preferential target sites for boreholes. These include fractures, faults, shear zones, dykes and contact zones. Zones of deep weathering are also used to site boreholes. It is estimated that in the majority of basement aquifers, the productive depth of aquifers is between 10 and 50 m (UN, 1989). Boreholes are normally drilled to between 30 and 65 m. The siting of productive boreholes is dependent on the application of geophysical techniques such as magnetic, electromagnetic and resistivity surveying. These techniques are used as standard by government departments and consultants, but have not always been employed in the former homeland areas. This has contributed to lower success rates in these areas and a perception amongst the local population that groundwater is an unreliable source of supply.

### 4.4.3 *Groundwater information base*

A comprehensive groundwater information system incorporating spatial and time-series data is an essential base upon which to develop both proactive and reactive policies for dealing with drought. South Africa has gone some way towards providing this base, though in terms of monitoring data there are significant areas where data are scarce.

Groundwater databases

Government borehole records are held on a digital database - the National Groundwater Data Bank (NGDB). This has, at present, a total of 175,000 boreholes with approximately 900 boreholes being added per month from the archives. The database was initially designed by the Institute of Groundwater Studies, Bloemfontein, and has over 100 fields relating to the location, geology, construction, use, and other borehole features. A PC version of the NGDB, called HydroCom, which includes graphical facilities, has also been developed by IGS. Over 100 copies are being used throughout South Africa by consultants and DWAF staff in the regional and main offices. This software was also used by former homeland governments prior to 1994.

However, though HydroCom data can be accessed from the NGDB, the national database does not incorporate all the borehole information available within the country. This is partly because the NGDB includes a number of fields which must contain data; these are often blank within the non-DWAF HydroCom databases. There is also a problem with unreliable data within these HydroCom databases, which are picked up by internal checks within the NGDB. The failure of the NGDB to capture borehole information may also be due to the comprehensiveness of the database (ie the large number of data fields) which can discourage drillers and consultants from submitting borehole data. It is estimated that only 2000 of the 40,000 boreholes that are drilled in South Africa annually are added to the NGDB. The inclusion of a statutory obligation for companies to provide borehole information has been dropped from the new water law which is presently under review.

Though a significant amount of borehole information is available on the NGDB, the failure to capture data from the former homelands has meant that coverage is still sparse in many rural areas where its use, at present, would be most beneficial. Figure 4.6 shows the coverage for Northern Province, with the former homeland boundaries added.

A database separate to HydroCom and NGDB is being tested by some local governments to manage water resources and water disposal. MuniWater, which contains a groundwater module, is based on the MicroSoft Access package. Data from MuniWater will be fed back into the NGDB. The groundwater module of MuniWater has also been used to develop an agriculturally based database, AgriWater. This is being used as a management tool in a number of overexploited aquifers in South Africa.

National groundwater maps

Technically South Africa is well advanced in groundwater studies. This includes the national coverage of groundwater data. In 1995 this information was brought together in a National Groundwater Resources Map (Vegter, 1995). At present a further map is being produced (Harvest Potential Map) which portrays safe levels of groundwater abstraction. All these maps are listed and the data on which they are based, described in Box 4.1

These national maps do not provide site specific information for borehole siting but do offer a useful basis from which to develop local water supply planning maps. In addition to the national groundwater maps the hydrogeology of the country is also being mapped on a 1:500,000 scale (see section 4.4.1). These maps will incorporate data available within the NGDB as well as the knowledge of consultants working in the area.

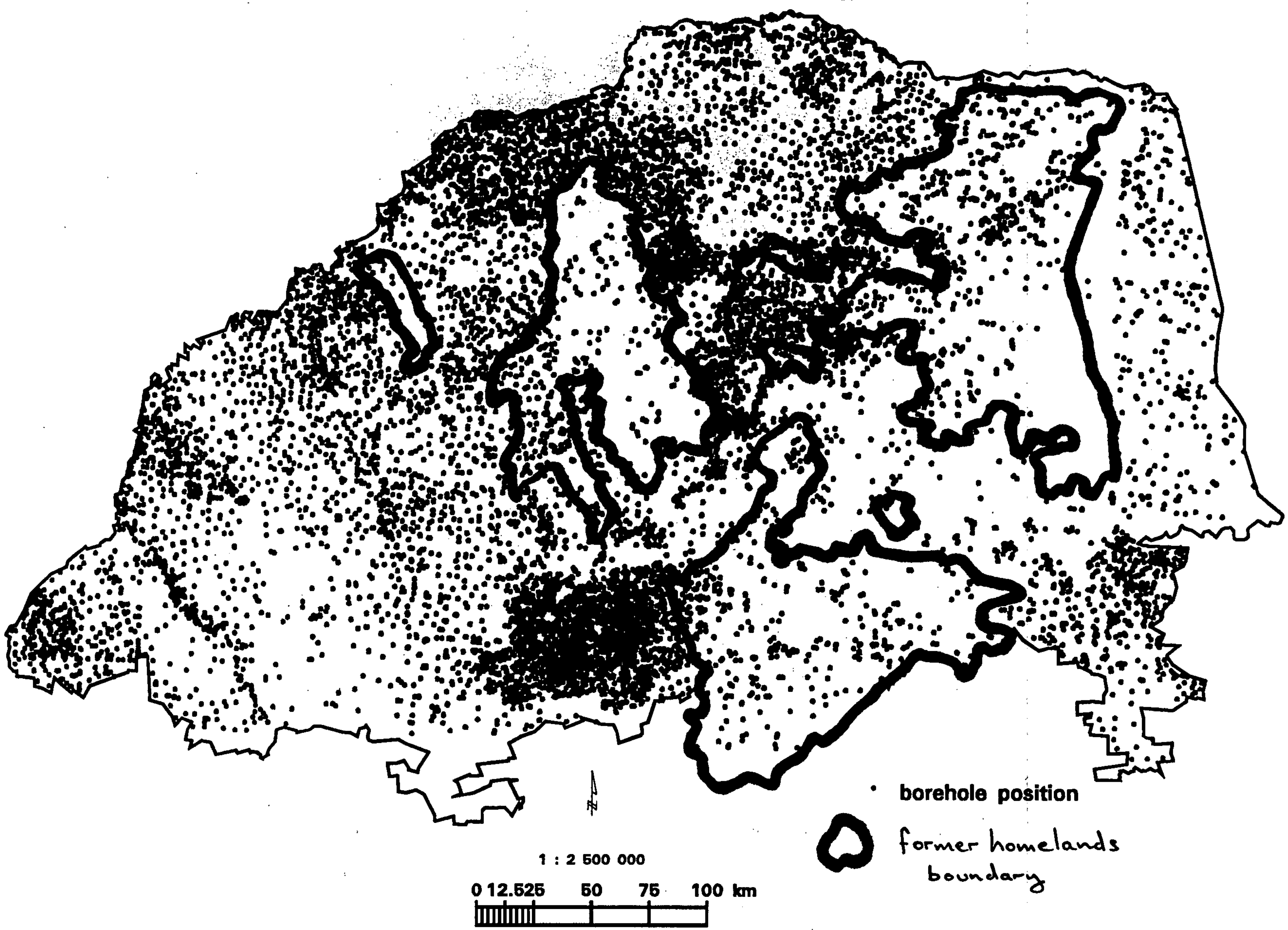


Figure 4.6 Positions of boreholes held on National Groundwater Data Bank in Northern Province. The boundaries of the former homelands of Venda, Lebowa and Gazankulu are shown to illustrate the relative lack of monitoring stations in these areas.

A national vulnerability to pollution map has also been produced (Lynch et al, 1994). This is based on the DRASTIC methodology which uses **D**epth to groundwater, **R**echarge from rainfall, **A**quifer media, **S**oil media, **T**opography, **I**mpact of the vadose zone and the hydraulic **C**onductivity to delimit zones of aquifer vulnerability to pollution from surface sources. This has been created using GIS based on a grid of 0.4 $km^2$.

**Box 4.1 South African national groundwater maps**

**National Groundwater Map Sheet 1**

***Borehole prospects 1:2,500,000***
Borehole prospects are depicted by a matrix of the probability of drilling a successful borehole (ie. yields more than 0.1 l/s) and the probability that the successful borehole has a yield of greater than 2 l/s. The probabilities were based on a statistical analysis of results from boreholes that were not sited scientifically.

**National Groundwater Map Sheet 2**

***Saturated interstices 1:4,000,000***
This map presents a matrix of aquifer storage and recommended drilling depth below groundwater level. The aquifer storage gives ranges of order of magnitude scale. The recommended drilling depth is based on a statistical analysis of water strike depth and frequency, coupled with depth to groundwater level.
***Depth to groundwater level 1:7,500,000***
The groundwater levels used for this map were a combination of the latest measured groundwater levels at the time of compiling the map, where available, and otherwise the static water-level measured when the borehole was completed.
***Mean annual recharge 1:7,500,000***
This map is a combination of two coverages. In the eastern and southern regions where groundwater makes a significant contribution to river flow, recharge is calculated from river flow using baseflow separation. Elsewhere the recharge is taken as the effective rainfall estimated using the ACRU model (Schulze, 1995) with some point data from site-specific recharge studies.
***Groundwater component of river flow (base flow) 1:7,500,000***
For the majority of the country baseflow is negligible, it is only in the east and a small portion of the south of the country that baseflow is significant.
***Groundwater quality 1:7,500,000***
This is represented by contours of total dissolved solids (mg/l). Areas of high nitrate and fluoride concentrations are overlain. These areas are defined as having high concentrations if more than 20% of the samples analysed have values of nitrate (as N) greater than 10 mg/l and fluoride greater than 1.5 mg/l.
***Hydrochemical types 1:7,500,000***
Areas with one or a combination of the four principal hydrochemical types are indicated.

**National Groundwater Harvest Potential Map (draft)**

***Groundwater harvest potential (draft) 1:3,000,000***
This map indicates long-term sustainable groundwater abstraction levels in $m^3/km^2/a$. It uses coverages of storage, obtained from the saturated interstices map, and drought recharge. Drought recharge is calculated from mean annual recharge by multiplying it by the ratio of the 20$^{th}$ percentile rainfall and the mean annual rainfall.
***Factors restricting available harvest (draft) 1:8,500,000***
This map divides the country into three regions where:
1. the storage vastly exceeds the annual recharge;
2. storage is limited and annual recharge is variable;
3. storage is limited and is sufficient to accept all the potential recharge.

***Potential borehole yield (draft) 1:8,500,000***
The average yield for optimally sited water boreholes. The average is over an area rather than time. This is different to the harvest potential as the yield is not necessarily sustainable in the long-term.
***Groundwater quality (draft) 1:8,500,000***
Groundwater quality is indicated by the average electrical conductivity.

## Monitoring

Monitoring data is available from more than 300 autographic groundwater level recorders and more than 1000 open boreholes (monitored manually on a monthly basis) across the country. In some cases this data dates back to 1956. Monitoring sites are generally in areas where extensive groundwater investigations were previously undertaken for municipal water supplies or irrigation schemes and have been retained pending further investigations. Analysis carried out on the data generated indicates a close correlation between groundwater and cumulative rainfall departure (Bredenkamp et al, 1995). Further analysis may be possible but the extrapolation to groundwater conditions in the rural areas is limited as little data are available for the low permeable secondary aquifers. Plans are being discussed to address the need for more comprehensive monitoring. These will be discussed in Chapter 7.

# 5. RURAL WATER SUPPLY

## 5.1 Coverage

It is estimated that approximately 30% of South Africa's population, now estimated at over 40 million, are without an adequate supply of water, and over 55% lack basic sanitation (Van der Merwe, 1995). While such coverage estimates need to be treated with a degree of caution, it is clear that service provision is poorest in rural areas, particularly in the former homeland areas where over 70% of the rural population reside. Water and Sanitation 2000 (1991) estimated that in 1990, 46% of the homeland population had an inadequate supply of water, as defined by RDP criteria (see Box 5.1).

**Box 5.1 RDP water sector goals**

Securing access to a safe water supply is a priority for many South Africans, and there is a strong political imperative to improve service provision to communities which have hitherto been marginalised and disenfranchised. Above all, the government is under pressure to achieve quick results and demonstrate a commitment to bridging the service gap between different regions and sectors of society.

The RDP sets out a framework of policy objectives for the provision of water supply and sanitation for all. The overall objective is to assist communities in securing a safe water supply of at least 25 l/c/d within a distance of 200 m, as well as safe sanitation facilities. An ambitious time frame of seven years has been set for the attainment of water supply goals.

Coverage figures for three of the major homelands that were within the borders of the present Northern Province are shown in Table 5.1. The figures indicate that in Gazankulu, for example, up to 95% of the population is estimated as being without an adequate supply of water. Inadequate service provision in such areas is essentially the legacy of apartheid, under which resources were targeted on the larger urban (formal) centres and major (commercial) agricultural regions. The drought of 1991-92 served to highlight coverage deficiencies, as well as a backlog of maintenance problems.

**Table 5.1 Percentage in 1990 of population in former homelands within the present Northern Province without an adequate supply of water (Water and Sanitation 2000, 1991)**

| Former homeland | Population | Percentage without adequate water supply |
|---|---|---|
| Gazankulu | 750,000 | 95% |
| Lebowa | 2,500,000 | 50% |
| Venda | 400,000 | 80% |

Note: coverage figures are uncertain and vary between reports.

Against a background of considerable uncertainty over coverages, the locations, sizes and names of rural communities and infrastructural endowments, one of the first priorities of DWAF has been to conduct rapid rural surveys to establish an RDP 'baseline'. Using the information gathered, the aim is to identify communities which fall below RDP standards, and evaluate options available for meeting water supply goals. The exercise is currently underway in an area of North West Province as a pilot for the rest of the country, and planning maps for groundwater supply potential have already been produced. These maps present data which include: borehole numbers per community; required number of boreholes per community, assuming a safe level of groundwater abstraction taken from the national groundwater harvest potential map; and local groundwater quality concerns.

## 5.2 The importance of groundwater

While groundwater is currently less important than surface water in terms of the overall quantity of water supplied, growing competition for surface water and the need to meet the basic water needs of large numbers of rural residents will give groundwater an increasingly important role in the years ahead. In short, development of groundwater resources offers the only way of meeting dispersed rural demands at relatively low cost. Estimates of the potential contribution of groundwater to rural water supplies are given in Table 5.2. Estimates are given for each province with a significant rural population.

Following the lead of some NGOs in the 1980s, the emphasis is on small-scale water supply schemes including spring protection, boreholes fitted with hand or diesel/electric pumps, and local surface water schemes. Such schemes can respond in the short term to water supply needs and can help build institutional capacity and self-reliance at local level. While such community based developments are the institutional solution of choice throughout much of Africa, the South African situation does present certain unique challenges in terms of service delivery (Box 5.2).

**Box 5.2 Groundwater supplies: technological choices and consumer perceptions**

Whereas rural communities in countries such as Ghana and Malawi are generally small, in South Africa a rural village may contain as many as 20 000 homes. Thus in a Malawian village, one groundwater borehole equipped with a handpump is often all that is needed, whereas in a South African 'village', yields from handpumps may be wholly inadequate. As a result, water supply schemes in South Africa normally include a reticulation system with water accessible from standpipes, running from a reservoir/tank serviced by energised pumps. The requirement of the RDP for water supply within 200 m also prohibits the use of handpumps in larger settlements.

Even where the use of handpumps is feasible, community expectations may be such that handpump based schemes are viewed as a form of 'poverty entrenchment'. During the recent drought, for example, some drought relief boreholes equipped with handpumps were vandalised, apparently seen as a threat to the provision of higher level services with household connections. Interestingly, groundwater sources are often regarded as unreliable by villagers. This may relate more to maintenance failures than source failure, however.

**Table 5.2 Percentage of rural water needs that could potentially be supplied from groundwater, for provinces with significant rural population (pers.comm. S.Marais)**

| Province | Percentage of rural water supply potentially from groundwater |
|---|---|
| Eastern Cape | 70% |
| Free State | 65% |
| KwaZulu/Natal | 65% |
| Mpumalanga | 30% |
| North-west | 90% |
| Northern | 70% |
| Northern Cape | 80% |
| Western Cape | 40% |

Secondary aquifers underlie 80% of South Africa. In these aquifers, siting of boreholes benefits greatly from the use of geophysical surveying to identify linearities. This was demonstrated in the former homeland areas during the recent drought relief programmes, when the widespread use of such techniques, often for the first time, significantly increased success rates (Braune, 1995). The use of reticulated water supplies also allows more freedom for the hydrogeologist to locate a high yielding borehole, as the position of the borehole is not dictated to such a degree by the population centre.

## 5.3 Institutional arrangements

> *"Political transition has opened a window of opportunity for the water sector in South Africa. It has required a fundamental review of all institutions of governance at national, provincial and local level. It has also required the elaboration of new development policies. The blank canvas, zero budget approach has created tremendous opportunities for policy innovation as the evolution of the new water sector has demonstrated"*
> *(Muller, 1996).*

One of the first tasks undertaken by the IGNU was to set targets for the provision of basic rural water supply and sanitation services (see Box 5.3). Not surprisingly, changing government priorities have led to institutional upheaval and, like Ghana and Malawi, South Africa is focusing on demand-driven approaches which emphasise community mobilisation and participation.

The institutional framework for the sector is complex and undergoing rapid transformation (see Figure 5.1). In the long term, the White Paper proposes that the delivery and management of water supply and sanitation form part of the mandate of local authorities. In the urban sector, where DWAF overseas bulk supplies, some transitional local governments, integrating white towns with their townships, are already in place. In rural areas, however, the formation of fully functioning local authorities is still some way away, although some transitional local councils have already been formed. In the longer term, it is envisaged that the entry point for DWAF support will be at provincial level, in the form of technical and strategic input to provincial and area (sub provincial) planning forums, integrating water and sanitation with other priority areas. In the meantime, however, DWAF is helping to support service provision at local government level with a variety of other institutions, including private consultancies, NGOs and trusts. At community level, village water committees are expected to lobby local councils for project support through village development forums and elected ward representatives. The establishment of a water committee is a prerequisite for any project funding, with funds themselves secured through local councils from a variety of different sources.

**Box 5.3 Sector policy and financing**

The RDP sets out a framework of policy objectives for the water sector, including coverage targets. At a national level, DWAF is the custodian of water services, and is charged with defining sector policy in accordance with the goals of the RDP. A new branch of DWAF, Community Water Supply and Sanitation (CWSS), has been established to drive and manage service provision in rural areas.

The White Paper produced by DWAF, 'Water: an indivisible national asset', is a comprehensive statement of sector policy. The paper sets out eight policy principles:

(a) development demand driven and community based;
(b) basic services are a human right;
(c) 'some for all', rather than 'all for some';
(d) equitable regional allocation of resources;
(e) water has an economic value;
(f) the user pays;
(g) integrated development; and
(h) environmental integrity.

In the water sector, the government kick-started the RDP by launching a number of Presidential Lead Projects. Funding has subsequently been channelled into area based schemes better able to integrate water supply with other priorities. At community level, those receiving services are expected to contribute money to cover recurrent costs.

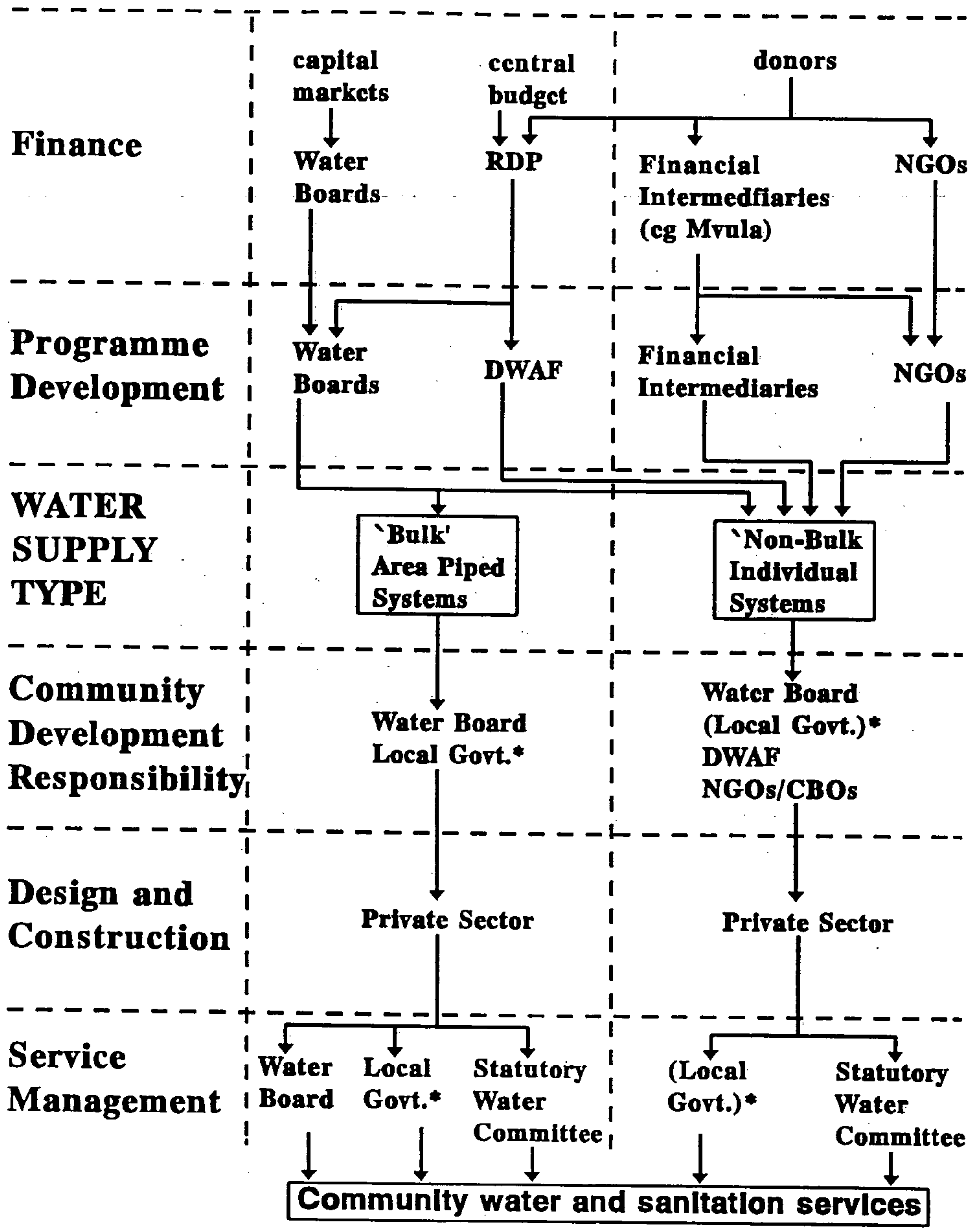


Figure 5.1 Water and sanitation service delivery. Source: UNICEF (1994).

Note: * Municipality in urban areas. In rural areas, some transitional local councils have been formed though they will not be fully functioning for some time.

Within the new institutional frameworks that are emerging, responsibilities for groundwater monitoring have yet to be clarified. The authors visited a number of villages where water committee members were collecting well water level data on the instructions of the private consultants involved in setting up the village water supply projects. However, it was not clear how such information would be used.

## 6. RECENT DROUGHT EXPERIENCE IN SOUTH AFRICA

South Africa is periodically afflicted by severe and prolonged meteorological droughts. The greater part of the country was drought-stricken from 1960 to 1966, while the longest drought on record occurred from 1925 to 1933 (DWAF, 1986). In more recent years, serious droughts have occurred in the 1980s and, most recently, between 1991 and 1995. Indeed the wet seasons of 1981-82, 1982-83 and 1991-92, 1992-93 are the only periods in the last 70 years when two consecutive seasons have been seriously inadequate, i.e. annual rainfall only 75% of the long-term mean (Laing, 1994).

South Africa has a long history of providing drought relief to the commercial farming sector. However, the plight of rural communities received virtually no attention until 1991-92 (see Box 6.1). As a result of the change in policy of the South African government in the early 1990s, a response was made to the drought crisis that afflicted rural areas in the 1991-92 season, and which has only ended as a result of heavy wet season rains of 1995-96.

> **Box 6.1 Drought policy in South Africa**
>
> Historically, drought policy in South Africa has focused on commercial agriculture, particularly the livestock sector. Sophisticated monitoring and relief structures have been put in but early warning systems are geared towards larger farmers, and are not designed to monitor the income and expenditure patterns of smaller farmers.
>
> In 1983-84, concern widened to the urban sector as water shortages threatened household supplies and power generation. Little is known about impacts in rural (non-commercial) areas, though presumably they were severe.
>
> In 1991-92, few towns and cities experienced severe water stress, largely because of the infrastructural investments that followed the earlier droughts. For the first time, however, the experience of rural communities triggered a major drought relief programme aimed at easing water stress in hitherto neglected areas. At the onset of the drought, no formal structures for early warning or disaster management existed for these areas.

The impact of the drought that occurred during this period and the response that was made are discussed below. Although this discussion will include experiences from across South Africa, examples will concentrate on Northern Province.

### 6.1 Rainfall

In the 12 years that followed the end of the drought of the early 1980s, eight were below the national long-term average rainfall and only four were above (Laing, 1994). This prolonged period of below average rainfall had a cumulative affect on the water resources of the country and, as a result, the impact of the serious failure of rains in the 1991-92 season was devastating. The drought impacted most severely on the north and east of the country. In Northern Province, many areas received less than 50% of average rainfall, with some areas receiving less than 25%.

The total seasonal rainfall for 1992-93 was even worse than that of 1991-92. Though adequate rainfall did fall on the main summer cropping areas of the country (one exception being the sugar cane growing areas of the normally wet area, now part of KwaZulu/Natal) the regions that suffered from a second consecutive year of rainfall below 75% (Figure 6.1) did have significant rural populations. The rains of 1993-94 were relatively good, but were followed again by a below average wet season in 1994-95.

### 6.2 The impact of drought

Even before the drought of 1991-92, the water supply to many of South Africa's rural communities was inadequate. The drought clearly exacerbated these problems, leading to widespread water stress, particularly in northern and eastern regions. Food insecurity was also a significant, though largely undocumented problem, at least for households in rural areas not receiving remittances from migrant workers in urban areas. In areas such as Venda, Gazankulu and Lebowa, loss of livestock led to meat and milk shortages, and depleted the stock of household assets available as insurance against future droughts (NCFD, 1992).

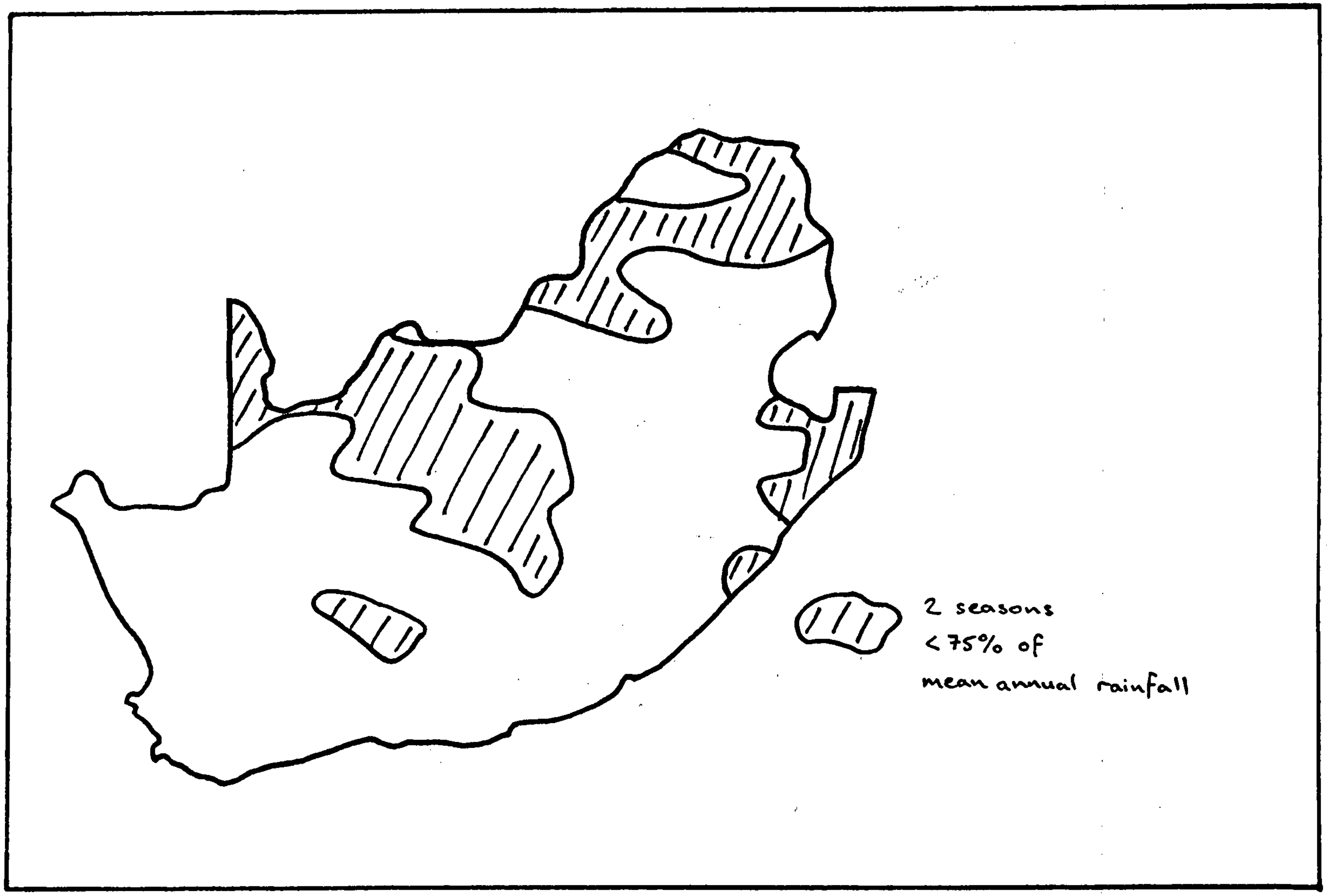


Figure 6.1 Areas with less than 75% of normal rainfall for two consecutive seasons, 1991-92 and 1992-93 (after Laing, 1994).

Fleshing out the water resources picture in greater detail in water-stressed areas is extremely difficult. There are several constraints. Firstly, information on the status of rural water supplies and those dependent on them, and the exact causes of water stress, was largely absent at the onset of the drought, or at least not known to many of the parties involved in the relief programmes. Indeed lack of the most basic, baseline data on settlement names, locations, sizes, existing water infrastructure and water security status proved a serious handicap to relief operations (see section 6.3). Secondly, the rushed nature of the programmes and the reconnaissance surveys carried out, together with the problems of coordination between the different institutions involved, led to information fragmentation and loss. On the latter point, it is instructive that the drought overview presented here could only be put together after discussions with different institutions involved in the relief operations; no overall evaluation of relief operations was ever carried out, and much remains undocumented.

**Box 6.2 A problem of access or absolute scarcity?**

The causes of borehole failure are not always clear, and without monitoring programmes it can be difficult to determine whether sources have dried up, or whether there is a technical problem with, for example, the pump mechanism.

In South Africa, most of those involved in the recent drought relief programmes agree that the majority of borehole failures resulted from technical failures arising from inadequate maintenance; the drought simply served to highlight these problems as demand pressures on operational sources increased. Indeed the ODA withdrew its engineers from the first drought relief programme because the problems they were encountering "were not as a result of emergency conditions brought about by drought; rather they were the long term problems of neglect" (NCFD, 1992).

Despite these constraints, several important conclusions on the impact of drought on rural water supplies can be drawn:

- significant water stress was experienced in a number of areas. In Northern Province, for example, the National Consultative Forum for Drought reported in September 1992 that the majority of communities in Venda were depending on less than 15 l/c/d, and in some cases as little as 3 l/c/d. Reports of people (mainly women and children) travelling distances of 10-15 km daily to fetch water were not uncommon;

- many rivers, streams and springs either dried up completely, or were significantly affected by the drought. One result was even greater reliance on groundwater sources, although in Northern Province as a whole, groundwater already forms the principal source of supply, particularly in the former homeland areas of Venda and Lebowa;

- while groundwater systems also failed, the precise causes of failure can be complex and difficult to determine (see Box 6.2). du Toit (1996) states that, "The growing demand for water and prolonged drought placed existing sources under tremendous strain, which eventually must have led to a gradual lowering of the water table and subsequent complaints from communities of weakening and drying up of springs and boreholes". However, du Toit and others (e.g. NCFD, 1992; Hazelton et al, 1994) suggest that the principal problem was not one of absolute water scarcity, but of inadequate maintenance, with perhaps 70-80% of 'borehole failures' caused by pump problems. Discussions with those involved in the relief programmes held during the study tour tended to reinforce this conclusion, although it is important to note that falling groundwater levels and greater demands on individual sources may have contributed to system breakdowns;

- in contrast to the water stress experienced by many rural residents, larger farms continued to pump groundwater for irrigation, sometimes alongside water scarce villages. Such apparent inequities have not gone unnoticed by government, and plans are currently underway to change the legal status of groundwater. Under new water laws, the doctrine of absolute sovereignty (conferred by land ownership) will be replaced by a system under which the state allocates user rights and priority is given to meeting basic needs.

In Northern Province the greatest impact of the drought was felt in those areas underlain by aquifers for which the success rate for borehole drilling is low. In particular these were:

- the southern districts of the Lebowa homeland underlain by the younger Bushveld granites. Here, where normally rainfall is relatively high for the province, there was some dependence on rivers and springs which dried up during the drought;

- the north of Venda, an area underlain by Karoo sediments. Here rainfall is normally low, in the order of 350 mm/a.

- in the areas of Lebowa in the north-west of the province underlain by the ancient sandstones of Waterberg sequence.

### 6.3 Response to 1990s drought

> *"What is clear is that despite best efforts, from the perspective of the victims of the drought, the response is too little, too late, with too many constraints"*
> *(National Consultative Forum on Drought, 1992).*

Two drought relief programmes were organised to mitigate the worst impacts of the 1990s drought. Both aimed to target the most vulnerable sections of South African society - the rural poor - including many of those living in the former homeland areas. The first relief effort brought together a loose grouping of government and non-governmental organisations under a Water Supply Task Force (WSTF). Activities began towards the end of the rainy season in 1992, terminating in December 1993. A second programme was launched in September 1994, organised and conducted by DWAF, and terminating in March 1996.

#### 6.3.1 *First drought programme*

Following reports of widespread water stress in the homelands in Northern Province, Eastern Cape and, later, KwaZulu/Natal, and appeals for assistance from the homeland authorities, a workshop was convened in May 1992 to examine ways of relieving hardship and coordinating responses. The result was the establishment of a National Consultative Forum on Drought (NCFD) and the formation of five task forces dealing with food and nutrition, agriculture, employment programmes, longer term development and water supply. The WSTF, convened by one government body (DWAF) and one non-government body (the Rural Advice Centre), was charged with providing immediate relief to the most vulnerable, in accordance with the principles agreed at the May workshop. Specifically:

- to respond rapidly, flexibly and innovatively in locations of critical water shortages to firstly ensure survival, then to secure stabilised water sources and storage facilities, and to address longer term water security;

- to carry out as much work as possible on a labour intensive public works basis to generate some form of income for those affected, thereby decreasing dependency on food aid; and

- to promote greater awareness of rural issues among the general public.

The first priority of the WSTF was to identify which areas were experiencing water supply problems. Specifically, the aim was to identify communities forced to depend on less than 15 l/c/d (so called 'red villages'). With little baseline information on rural homeland areas available (see Section 5.1), and with no monitoring systems in place, eleven survey teams were deployed to identify vulnerable communities. Each team comprised a South African engineer (with local knowledge and experience), an overseas engineer (providing disaster relief experience), and a community liaison officer (to bridge the linguistic and cultural divide). The need and opportunity to respond to water shortages was identified in Venda, the southern district

**Box 6.3 Financial, technical and manpower support**

Both drought relief programmes involved inventory/water stress surveys, pump repairs or replacement, siting of new boreholes, drilling, testing, installation of pipelines and standpipes with taps and, as a last resort, water tankering.

Financial, technical and manpower support for the first programme was received from a variety of different institutions, from both within and outside South Africa. The WSTF was supported financially by the Independent Development Trust of South Africa, the Development Bank of South Africa, and the European Union, with some R3 million (roughly US$700,000) made available to DWAF to cover equipment costs. Total funds allocated (internal and external) exceeded US$ 1.5 million. Equipment, including drilling rigs and water tankers, was provided by various government departments (including DWAF, the Department of Agriculture, and the South African Defence Force), by the homeland governments, and by NGOs such as World Vision, Operation Hunger and RED-R (Register of Engineers for Disaster Relief). NGOs and ESAs (e.g. ODA) also provided manpower support, as it was initially felt that South African personnel lacked experience in providing water at community level.

No external support was available for the second relief programme, organised and driven by DWAF with the assistance of the Department of Agriculture. Internal financial support amounted to over R85 million (some US $10 million) according to du Toit (1996).

of Lebowa and the homelands now within the provinces of KwaZulu/Natal and Eastern Cape. Those regions where help was not given included: Bophuthatswana, where it was felt that the homeland government was coping well with the crisis; Gazankulu, where surveys showed problems were less severe, though the local government did ask for help; the homelands roughly within the boundary of the new Mpumalanga Province, within the area covered by the NGO Medicine Sans Frontiers; and the rural areas of Western Cape.

**Box 6.4 Forms of relief work undertaken in the first drought programme**

***Borehole rehabilitation***
DWAF directly carried out the rehabilitation of 302 boreholes. In the Transkei homeland (Eastern Cape), this constituted the majority of work undertaken. In addition, over 500 sites were visited by contractors employed through the WSTF. The need for this scale of assistance highlighted the inadequacies of previous maintenance regimes, the consequence of consistent under-financing and inadequate training. A restriction on this aspect of the drought relief programme, and on borehole drilling, was the availability of pumps and pump parts, as manufacturers could not keep up with the demand.

In addition, DWAF also undertook 33 spring protection schemes, mostly in KwaZulu/Natal, and supervised further spring protection at over 100 other locations across Venda, Lebowa and KwaZulu/Natal.

***Borehole drilling***
In villages where new or supplementary sources of water were required, boreholes were drilled. Where this work was carried out by DWAF, boreholes were sited using geophysical surveys. However, the success rate (based on yield of more than 0.1 l/s) for the drilling programme was still often below 50%. In Venda, 253 boreholes were drilled, of which 117 were successful; in southern Lebowa, 211 boreholes were drilled, of which 104 were successful. In addition 115 successful boreholes were drilled by DWAF in KwaZulu.

***Tankering***
Water tankering operations were carried out as a measure of last resort in some areas, with efforts concentrated in the north of Venda, southern Lebowa, and in the KwaZulu homelands. Equipment and human resources were supplied by DWAF, homeland 'governments', the South African Defence Force and, when necessary, contractors.

Of the 225 communities investigated in Venda, 135 (60%) were dependent on 15 l/c/d or less; in Lebowa of the 230 communities surveyed, 91 (40%) were dependent on 15 l/c/d or less. Following the surveys, different forms of relief work were undertaken depending on the nature and the seriousness of water supply problems (see Box 6.4). The WSTF maintained a coordinating role, attempting to organise and synchronise the activities of numerous private consultants, NGOs and DWAF teams. This proved extremely difficult, owing to the number of organisations involved and their differing agendas (see Section 6.4).

### 6.3.2 *Second drought relief programme*

The work of the WSTF terminated in December 1993, subsequent to the good early rains of the 1993-94 wet season. However, water supply problems were not solved by this one good wet season, and the first drought relief programme probably ended more for financial reasons than the reduced need for relief.

Following the change of government and the provision of funds through the RDP, a second programme was launched in September 1994. Although the overall objective of the programme remained the same, the second programme differed from the first in several important respects: firstly, DWAF was the organiser and carried out the majority of the work themselves; and secondly, the relief approach changed somewhat, following lessons learned from the first programme. In particular:

- crisis procedures were brought in to short circuit the layers of bureaucracy that had held up the purchase of equipment and the appointment of contractors and consultants in the first programme;

- greater emphasis was placed on the involvement of communities in the provision and maintenance of water supplies;

- the programme was based on information obtained from local government and communities through localised crisis committees;

- the restriction on boreholes being sited within 500 m of recipient villages was relaxed. Although this may have increased the distances that villagers had to travel to collect water, the potential for finding an adequate source of water was increased;

- pumping-tests were undertaken on newly drilled boreholes to ensure the capacity of the pump fitted to the borehole matched the predicted sustainable yield;

- water quality issues were given greater importance. Samples were taken from existing and newly drilled boreholes (up to December 1995, a total of 1132 boreholes had been tested), and health hazards detected.

The second programme targeted the same areas as the first, with the addition of Mpumalanga Province. In total, 854 new boreholes were drilled, of which 546 (66%) yielded at least 0.1 l/s.

## 6.4 The effectiveness of drought relief

The effectiveness of the two relief programmes in relieving water stress is difficult to judge, and no formal evaluation of relief efforts was ever made. However, it seems clear that both programmes, and particularly the first, encountered many problems:

- little was known about either the rural population in the old homeland areas, or about water supply assets and operational status. As a result, valuable time was lost conducting baseline socio-economic surveys and identifying affected areas and communities;

- both programmes bore all the hallmarks of 'crisis management', with teams rushed to the field without proper equipment, vehicles, existing borehole information or planning (du Toit, 1996). In addition, time pressures left little time for community mobilisation and participation, and relief teams were under great pressure to stay ahead of the drilling rigs. du Toit (1996), looking to the future, concludes that, "Proper monitoring and planning and using available technology will contribute tremendously in alerting authorities in advance to take precautionary measures, without falling into the trap of crisis management."

- major coordination problems were encountered, particularly during the first programme when many different organisations were involved. As a result, information was lost and time and money wasted. In Venda, for example, boreholes drilled during the first programme had to be revisited during the second because they had never been properly equipped. Different agencies also had their own agendas, and some confusion emerged over roles and responsibilities.

- while some surface and groundwater systems failed because of lack of water, many others had simply fallen into disrepair. This led some to conclude that emergency conditions resulted more from long term neglect of water supply in affected areas than from drought conditions (see Boxes 6.2 and 6.5).

- little is known about the current status of emergency boreholes, but reports suggest that some have fallen into disrepair and been abandoned. Only now, with rural baseline surveys in the old homeland areas underway, is a proper inventory of water supply infrastructure being conducted.

**Box 6.5 Contrasting views on relief**

The first drought programme appears to have come in for much criticism, at least from non-governmental organisations and ESAs. Remarks from the ODAs Africa desk, quoted in NCFD (1992), are particularly damming, and led to the withdrawal of British engineers (see also Box 6.2):

"The comment of the (foreign) engineers is that in all their substantial experience in places such as Ethiopia, Somalia and Iraq, they have never worked in a situation so chaotic and with less support. The state has used its structures of the homeland administrators to channel public drought relief funds where they are to be managed by the same bureaucracy that is responsible for the problems, and largely spent by the same consultants who have designed the systems that are presently failing."

DWAF themselves admit to going through a very steep learning curve during the first programme, but du Toit concludes that, overall, "...DWAF and the other organisations achieved what they set out to achieve and that was to supply emergency water to as many people as possible in the drought-stricken areas. However, the consensus view from all parties is that the worst elements of 'crisis management' could have been avoided with better planning, monitoring, and pre-drought contingencies."

# 7. MANAGEMENT ISSUES ARISING

## 7.1 Role and importance of groundwater

The importance of groundwater in rural areas is likely to grow in South Africa as the government strives to meet RDP objectives. A major constraint on development is uncertainty about yields, which DWAF is currently addressing through a major mapping programme.

In South Africa, there is an obvious preference amongst engineers for surface water schemes, with groundwater schemes sometimes viewed as unreliable. The experience of the drought relief programmes, in which some emergency drilling programmes met with limited success, may have contributed to this perception (du Toit, 1996). In other African countries such as such as Ghana and Malawi, groundwater is typically the only perennial source of supply, and groundwater development is seen as the only cost-effective way of meeting dispersed rural demand at low cost.

The expectations of rural communities are high, and DWAF is under considerable pressure to bridge the gap in service provision between different regions and sectors of society. Simple technologies such as boreholes equipped with hand pumps are the low cost solution of choice in many rural African contexts. In South Africa, however, residents often expect more, and RDP objectives effectively preclude such technologies in the large village settlements that characterise the old homeland areas.

## 7.2 Planning for drought

In both South Africa and Malawi, drought policy was entirely reactive, early indicators of water stress were not or could not be detected, and the nature, severity, and geographical distribution of water supply problems was more or less unknown. In both countries, the effectiveness of crisis programmes has been contested because of their:

(a) questionable effectiveness in relieving immediate stress;

(b) questionable effectiveness in putting in place sustainable water supply infrastructure; and

(c) expense.

One of the key contentions of this project is that greater emphasis on drought planning is likely to reduce the need for reactive and costly crisis programmes, and improve the targeting and timeliness of emergency relief programmes that are needed. In short, much can be done in pre-drought periods to ensure early detection and mitigation of problems (what Hazelton et al (1994) describe as proactive drought management).

### 7.2.1 *Determining the status of rural water supplies*

The need for a clear understanding of the resource base is essential if development of groundwater is to proceed in an appropriate and sustainable way. Similarly, the need for reliable, timely and comprehensive information on the status of rural water supplies and those dependent on them would seem fundamental to any form of drought planning. In South Africa, as in Malawi, the lack of this information seriously handicapped relief operations, and is an ongoing constraint on sector planning more generally.

The problem is being addressed to some extent through groundwater mapping programmes and rural surveys, the Community Water Supply and Sanitation branch of DWAF are gathering baseline information on settlement characteristics and water supply status. Planning maps (and the databases that underpin them) will be used at regional and area planning forums to help prioritise and integrate development work, and it is anticipated that, with the incorporation of some hydrogeological indices, they will go a long way towards drought vulnerability mapping. It is essential, however, that the information gathered must be kept up-to-date by maintaining the inventory of water supply boreholes.

The experience of South Africa in collecting and manipulating data to produce planning maps is of much interest to counterparts in Malawi and Ghana, where sector planning and drought planning is similarly constrained. In these countries, lack of funds, the shrinking role of government in operational matters, and the low priority placed on information gathering (as opposed to resolving immediate water supply crises) have prevented similar exercises being undertaken.

### 7.2.2 *Groundwater drought vulnerability mapping*

While maintenance problems may have caused the majority of water supply problems during the recent droughts, it seems clear that some groundwater sources did dry up altogether because of falling water levels. In addition, it seems likely that breakdowns and falling water levels are not wholly unrelated; breakdowns are more likely when water levels are falling and pumping lifts increasing. Against this background, it would seem important to identify areas which are inherently more vulnerable to groundwater drought. These areas may be the first to experience water supply difficulties during drought periods. Key determinants of vulnerability to drought include aquifer thickness, depth of the weathered zone, borehole yields and rainfall (amount and variability).

By themselves, these factors describe drought proneness. However, the distribution of human settlement and the degree of access to groundwater (coverage) would also seem important in describing vulnerability to the impacts of groundwater drought. A simplistic conclusion is that those areas inherently vulnerable to drought from a hydrogeological and meteorological standpoint, and which have significant human population and low coverage, are likely to be more vulnerable (see Figure 7.1 and Box 7.1).

Drought vulnerability maps could be used in a variety of different ways. They could be used to help target resources to sensitive areas in pre-drought periods to help 'drought-proof' vulnerable communities. They could also be used to help guide technical choices in different areas, and to target monitoring programmes. For example, areas defined as highly vulnerable to the incidence and impacts of groundwater drought could also be defined as critical monitoring areas.

A further development on the mapping theme could include the zoning of areas according to rainfall - groundwater lag times. However, data demands for any meaningful drought sensitivity map of this sort are likely to be heavy and, in South Africa, hydrograph data are not available for large parts of the country.

**Box 7.1 Developing drought vulnerability maps for Northern Province within this project**

A drought vulnerability map is presently being developed for Northern Province within this project to show which areas are likely to be more vulnerable to groundwater drought than others. This will be produced by combining maps of physical vulnerability, demand and access to groundwater.

The physical vulnerability maps are a combination of mean recharge, recharge variability, aquifer storage, and permeability. These use the significant base of information that is already available within South Africa (see section 4.4). The demand map will be based on population, and the access to groundwater map on borehole coverage. It is hoped the accuracy of these maps will be improved as new baseline data is gathered in rural areas.

### 7.2.3 *Groundwater monitoring*

While maps and associated databases provide useful planning tools, they cannot provide the kind of detailed, site-specific, time series data needed to detect (and predict) water supply problems as they arise. For this reason, monitoring systems are needed which track meteorological and hydrological conditions, and extend to the groundwater environment. Ideally, data generated should allow distinctions to be made between different types of problem. In particular, distinctions between source and resource stresses, and between source/resource and maintenance related problems would seem important.

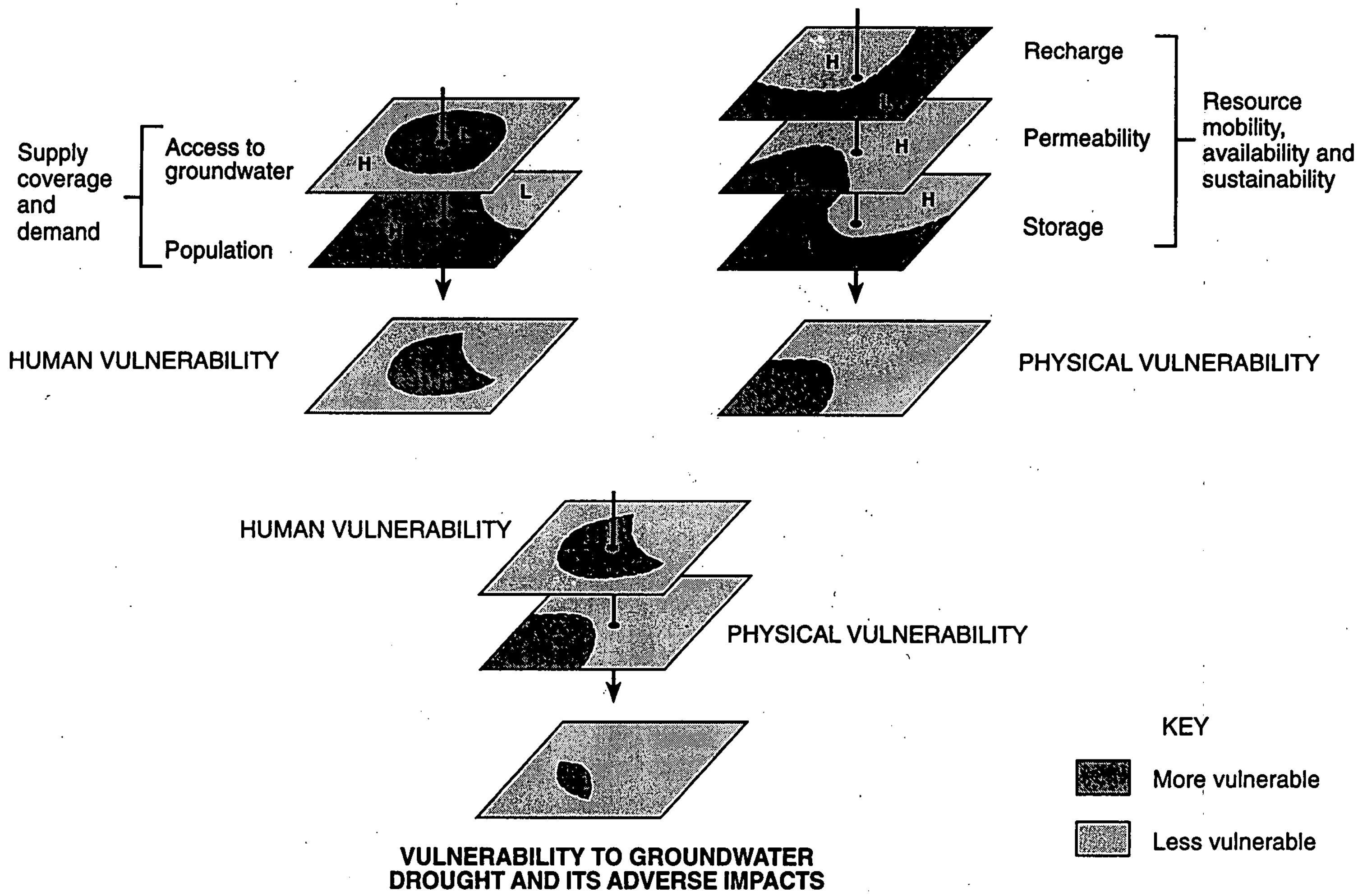


Figure 7.1 Conceptual framework for groundwater drought vulnerability mapping. Human vulnerability to drought is determined by factors such as population density and well/borehole coverage. Physical vulnerability is determined by aquifer characteristics and recharge. Together, human and physical factors determine vulnerability to groundwater drought and its impacts.

The experience of the drought relief programmes clearly indicates how lack of monitoring in pre-drought and drought periods hampered relief efforts. The first priority of relief teams was to gather information on water supplies that, ideally, should already have been available. As it was, relief teams 'went in blind', unable to determine whether problems were related to the drying up of boreholes, or to technical problems with equipment.

While the need for monitoring seems clear, support for this sort of work is often difficult to secure. Governments, ESAs and NGOs typically place a low priority on monitoring, for reasons which include difficulties in quantifying benefits and verifiable indicators of success, and a preference for infrastructure projects (e.g. borehole drilling) which address immediate needs. In South Africa, where DWAF is under considerable pressure to meet RDP goals, monitoring might therefore be considered a low priority. In addition, difficult questions on what, how and where to monitor remain (see Box 7.2).

**Box 7.2 Monitoring needs and constraints**

Effective monitoring of groundwater levels is required to assess groundwater resources and the general operational status of boreholes. This monitoring must be incorporated into a system for identifying, at an early stage, the likelihood of water stress as a result of drought conditions. However, for such a monitoring network to be sustainable, an effective institutional structure must be in place to collect, process and act upon monitoring data. Any attempt to introduce community responsibility will break down if information collected does not generate a response.

In addition, there are significant technical difficulties in setting up an effective monitoring network. Much of South Africa is underlain by basement aquifers that are characterised by low permeability. In such aquifers there is often localised dewatering in the vicinity of wells and boreholes following pumping. As a result water levels measured in operational sources may not indicate the status of groundwater resources regionally. Conversely, water levels measured in piezometers may not indicate how an increase in demand during drought periods affects water levels in wells and boreholes. It is therefore likely that some combination of regional and local monitoring of water-levels will be necessary. However, the heterogeneous nature of basement aquifers and rainfall patterns in arid and semi-arid regions make the siting of monitoring networks difficult if the data collected are to be representative of the conditions across a large enough area.

On the question of 'how', there is a need to ensure that responsibilities for collecting, processing and acting upon data are clearly defined. Institutional upheaval in South Africa (mirrored in Ghana and Malawi) makes this difficult at present. In Malawi and Ghana, where rural water supply is supported primarily with external assistance, monitoring is sporadic and often project specific; when a project ends, so does the monitoring. Nevertheless, central government has retained responsibility for processing and storing records and, in Malawi at least, MIWD does have a small monitoring programme of its own with dedicated sites. In both countries, however, donors do not view monitoring as a priority and it receives little support. In South Africa, it was evident that some village water committees were carrying out their own monitoring, probably on the instructions of consultants. Community involvement is an attractive proposition, but willingness to collect and pass on data to consultants, NGOs or DWAF is likely to dwindle if communities do not perceive any benefits.

### 7.2.4 *Early warning systems*

In terms of drought prediction, there is a need to develop national drought plans for community as well as commercial water supply, which include simple early warning systems to warn of groundwater problems and associated impacts (Box 7.3). Here, developments are very much tied to progress made in establishing long term monitoring and assessment programmes.

**Box 7.3 Key elements of an early warning system**

In South Africa, Hazelton et al (1994) suggest that a key element of any drought plan should be the establishment of a Water Inventory Outlook Committee, whose principal aims would be to:

(a) compile and analyse data from observational networks operated by government and NGOs, enhancing those networks where necessary;
(b) determine user needs in terms of specific data requirements, format and presentation;
(c) develop triggers and an early warning system, using a combination of indices to initiate specific and timely actions by different organisations; and
(d) identify drought affected areas for targeting.

Any system would need to monitor antecedent meteorological and hydrological conditions as well as groundwater indicators (e.g. groundwater levels and borehole yields). Thresholds would also need to be established such that once exceeded, actions defined in the drought plan are triggered. Indicators of water stress could also be incorporated, for example incidence of water-related diseases from clinics. In this way, the system could be strengthened through incorporation of data generated by other departments and by other (non-water) projects. Experience from other countries in the region (e.g. Zimbabwe) indicates that responses need to be flexible and not centrally prescribed; problems may be highly localised, and it is only at lower levels (the lowest level at which capacity exists) that problems can be assessed in the proper context and solutions recommended.

As a caveat, it should be noted that information by itself will not guarantee an early response. Experience with early warning systems established to monitor food security indicate how the response can be too little and too late, despite the existence of a well established warning system (Buchanan-Smith and Davies, 1995). Reasons include the politicised nature of the information generated, and failure to link early warning to response systems. Monitoring, early warning systems and responses all need to be incorporated into an effective national drought intervention policy.

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