Groundwater Research Needs in the Eastern Karoo Basin of South Africa

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TT 286/06

Water Research Commission

GROUNDWATER RESEARCH NEEDS IN THE EASTERN KAROO BASIN OF SOUTH AFRICA

Prepared for the Water Research Commission

by

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Main cover photo:
A borehole and pumphouse on a large dolerite dyke in the Chris Hani District of the Eastern Cape Province (Photos by P Ravenscroft)

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This synopsis of groundwater research needs in the Eastern Cape Province of South Africa is aimed at those who are interested in supporting poverty alleviation in the Province. It places the need for safe drinking water and sound water resource management within the context of the development needs of the Province. It is not a technical document, although towards the end, where specific research needs are articulated, certain scientific concepts that affect the occurrence and sustainability of groundwater are mentioned.

the dwaf
DEPARTMENT OF WATER AFFAIRS AND FORESTRY
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GROUNDWATER RESEARCH NEEDS IN THE EASTERN CAPE PROVINCE

The Department of Water Affairs and Forestry has the responsibility for managing and protecting our national water resources for the purposes of ensuring sustainable development, equitable access and beneficial use. Water is an essential resource for economic development, job creation and poverty alleviation through the commercial and industrial sectors. Water is essential for food production and food security, particularly in the rural areas where unemployment levels are high. Water is a basic human need for drinking, cooking and washing. Water has a social and an economic value. To meet the demands for social and economic purposes, the environmental integrity of water resources must be protected and maintained. Once the integrity of the resource is compromised, the chances of sustainable development are slim.

Groundwater is a water resource that is increasingly considered as ideal for development in the rural areas. This is particularly true in the Eastern Cape where rural settlement patterns are characteristically dispersed and often located in inaccessible terrain. Groundwater is often not subject to contamination from surface pollution and in times of disease outbreaks such as cholera it is regarded as a safe supply if the borehole is protected. Groundwater is ideal for small scale operations where large construction and engineering works are impractical and unaffordable. With appropriate technology, the maintenance and operation of groundwater pumps and supply systems can be done by community members in many cases. Groundwater is not subject to the extremes of surface water resources such as flooding. In times of drought, groundwater can continue to provide a reliable source of water if properly managed.

To make use of groundwater in a way that is sustainable requires proper management and a thorough understanding of the processes and factors governing the occurrence and movement of water underground. All too often groundwater is developed in an unsuitable manner due to lack of knowledge and understanding. Groundwater systems are then regarded as unreliable and are rejected as an option by communities who have suffered the consequences of poorly managed groundwater. The benefits of groundwater are lost in terms of its safety, reliable supply in times of drought, low cost and easy maintenance.

The Department welcomes any research towards improving management of groundwater in the Eastern Cape, in support of our commitment to ensuring sustainable development of water resources. Greater understanding of this valuable and hidden resource will enable all water users to unlock its potential to render safe, reliable, low cost water supply, as well as to render reliable water for stock

and irrigation farming, water for industrial and commercial activities and water for eco-tourism, recreation and the hospitality industry. Groundwater has the potential to contribute to the growth and development of the Eastern Cape and is uniquely suitable to the circumstances of our geographic, economic and socio-political context. It is our hope that this document will promote research into groundwater and through this research we will find answers to the challenges of sustainable development of groundwater.

Mr Z Keke,
Water Resources Director,
Department of Water Affairs and Forestry,
Eastern Cape Province
May 2006

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GLOSSARY

CMA	Catchment Management Agency. *Agency with responsibility for the management of a WMA. CMAs are presently being set up by DWAF.*
DWAF	Department of Water Affairs and Forestry. *National department with ultimate responsibility for water affairs.*
DM	District Municipality. *Regional administrative body. There are 6 in the Eastern Cape Province, each with a 'seat' or capital town.*
IDP	Integrated Development Plan. *Strategic plan for the development of a municipality.*
ISP	Internal Strategic Perspective. *Document used by stakeholders for guiding water management and development in a WMA until the CMA assumes that responsibility.*
GIS	Geographical Information System. *Computerised system for the display and analysis of spatial (i.e. map-type) data.*
LM	Local Municipality. Each DM is divided into between 2 and 8 LMs in the Eastern Cape Province.
NWRS	National Water Resources Strategy. *National document laying out broad principles for water resources development and management.*
PGDP	Provincial Growth and Development Plan. *Key provincial document intended to guide the development of a province, setting out a provincial vision, targets and programmes.*
PSDP	Provincial Spatial Development Plan. *Related to the PGDP, assesses development constraints and opportunities in a spatial context.*
RDP	Reconstruction and Development Programme. *Set of development principles adopted after 1994, which amongst other things specified that a clean (safe) water supply of at least 25 litres per person per day should be available within 200 metres of each dwelling in South Africa.*
WMA	Water Management Area. *Area designated for the purposes of water management. There are 19 WMAs in South Africa.*
WSA	Water Services Authority. *A municipality (District or Local) with the power to contract water services provision to water service providers.*
WSDP	Water Services Development Plan. *Document designed to promote efficient, affordable, economical and sustainable access to water services in a District or Local Municipality.*
WSP	Water Sector Plan. *Plan drawn up by a Local Municipality not authorised as a Water Services Authority as part of its IDP process.*

1. INTRODUCTION

The purpose of this document is to outline the groundwater research needs in the densely populated, impoverished eastern regions of the Eastern Cape Province. This area includes the thousands of rural villages of the former Transkei and Ciskei 'homelands' - one of the poorest areas of South Africa. Groundwater, from boreholes or springs, is currently used for domestic water supply by most people in the region, and needs to be accessed for the majority of villages that still require improved water supplies.

In the past, boreholes were rarely sited at the best places for groundwater, as the emphasis was to find sites close to the villages that could be equipped with hand- or windpumps. Today, the goal of providing all of the country's citizens with a basic level of service (25 litres per person per day) means that higher yielding boreholes are required, and in most cases the water needs to be supplied using motorised pumps. This higher level of service is now possible since municipal structures have been put in place to ensure the sustainable operation and maintenance of such schemes. But it also raises new challenges regarding the water source. Firstly, higher yielding boreholes need to be located; and secondly, they will need to be pumped in a manner that ensures the long-term sustainability of the resource without causing significant reductions in baseflow to rivers or negatively impacting groundwater dependant ecosystems.

For these reasons, it is necessary to enhance our understanding of 'how the groundwater system works'. We need to identify the high yielding drilling targets and aquifers; we need to establish the controls on long-term sustainability and water quality; and we need to ensure that the users know how to 'look after' or manage this precious resource.

Plate 1: Rural Village
(Photo by P Ravenscroft)

Little groundwater research has been done to date in the eastern regions of the Eastern Cape Province – an area that comprises the Eastern Karoo Basin (the geological term for this region). The focus area of this document is Water Management Area 12, incorporating most of the former Transkei and Ciskei 'homelands' (Figure 1).

Due to the extreme water needs of this region, this is now changing, and the Water Research Commission (WRC) has initiated a three-year research project which aims to start the process of enhancing our knowledge of groundwater in this region. The project started in June 2005, and is entitled '*Flow Conceptualisation, Recharge and Storativity determination in Karoo Aquifers, with special emphasis on the Eastern Cape (Mzimvubu to Keiskamma WMA) and KwaZulu-Natal Province (Mvoti to Umzimkulu WMA)*'. Although it is envisaged that this project will add tremendously to our knowledge of groundwater occurrence in the Eastern Cape, the WRC is not in a position to fund all the necessary work that is required to gauge the water-supply potential of the region, and to develop best management practices for the aquifer systems of the Eastern Cape. There is simply too little scientific information and too much that is not fully understood. This document outlines what is needed in this regard.

This document describes how new research will coincide with national and provincial development priorities. It takes into account past research, proposes broad research areas, and finally, it lists what are considered to be the most important geohydrological research projects completed to date. It was developed after widespread consultation that included officials from the Department of Water Affairs and Forestry (DWAF) in the Eastern Cape Province, and a number of locally-based groundwater and engineering consultants.

2. The Karoo Geological Basin

The Main Karoo Geological Basin, hereafter referred to as the Karoo Basin (see inset map in Figure 2), consists of geological formations that outcrop over more than half of South Africa. The basin is filled with sedimentary strata up to 12 km thick and capped by a 1.4 km thick layer of basaltic lava. The sediments consisting of shale, sandstone and mudstone were deposited from the Late Carboniferous period (310 million years ago) through to the Mid Jurassic period (180 million years ago).

The depositional environments varied over time, changing from glaciers associated with a past ice age to landscapes including plains, rivers, swamps and shallow marine environments. Earlier life forms, including dinosaurs, proliferated and developed during this period.

The break up of Gondwanaland saw the intrusion of basaltic lavas (180 million years ago) that now cap the Lesotho Mountains. The Karoo dolerites, in the form of horizontal sills and saucer-shaped ring structures and vertical dykes, are associated with this magmatic activity. It is the largest intrusive province in the world. These intrusive rocks led, in places, to intensive fracturing in the older Karoo formations, and it is these fractures that are frequently targeted in groundwater exploration. The density of dolerite intrusions is particularly high in the Eastern Karoo Basin (Figure 2).

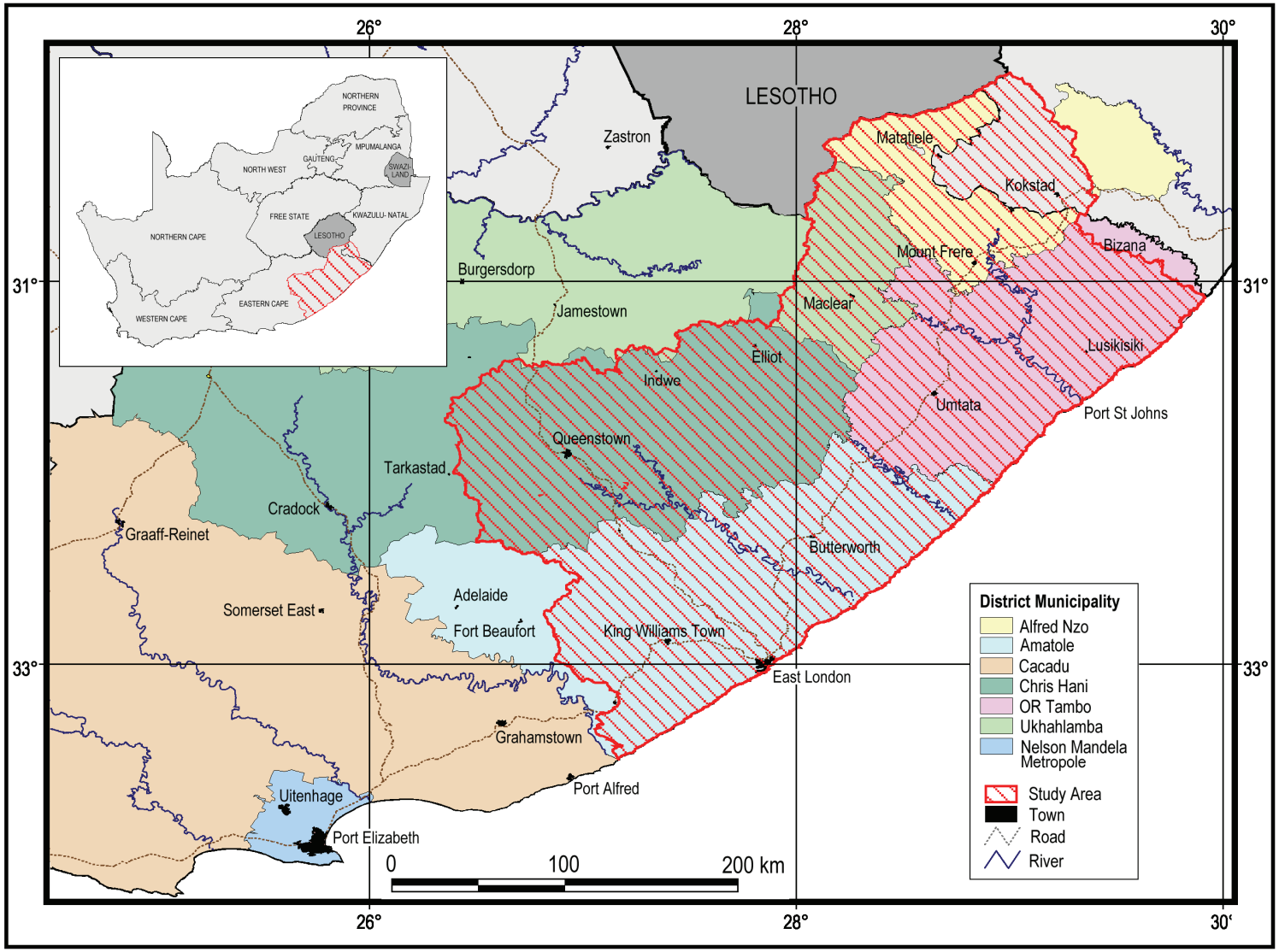

Figure 1: The Study Area (WMA 12) in the Eastern Cape showing the District Municipalities

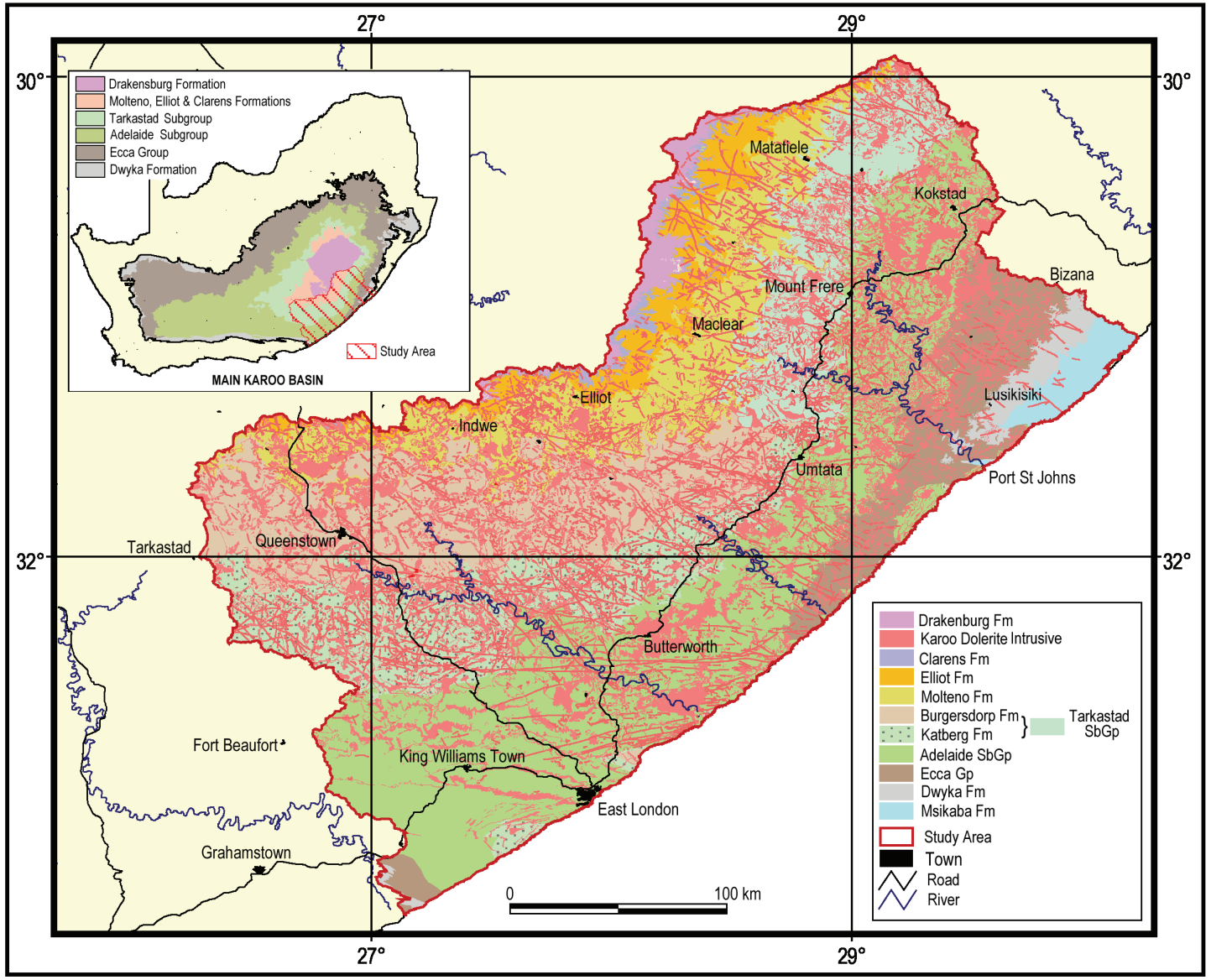

Figure 2: Geology of Water Management Area 12 in the Main Karoo Basin

3. The Water Supply Problem in the Eastern Cape Province

3.1 Preamble

Approximately 14% of the national population reside in the Eastern Cape Province, which equates to about 6.2 million people (Figure 3). More than 85% of the population of the province is black. Only a third of the population lives in urban centres, compared with the national average of 54%, and in the former 'homeland' areas the proportion of rural people is much higher. There is a large disparity in the province between the relatively affluent urban areas and the commercial agricultural areas, particularly in the west of the province, and impoverished rural areas and informal peri-urban areas in the former 'homeland' regions. The highest levels of underdevelopment are found in the former 'homeland' areas, where some of the most severe levels of poverty in South Africa are found. These areas constitute 30% of the land area of the Eastern Cape Province, but 67% of the population.

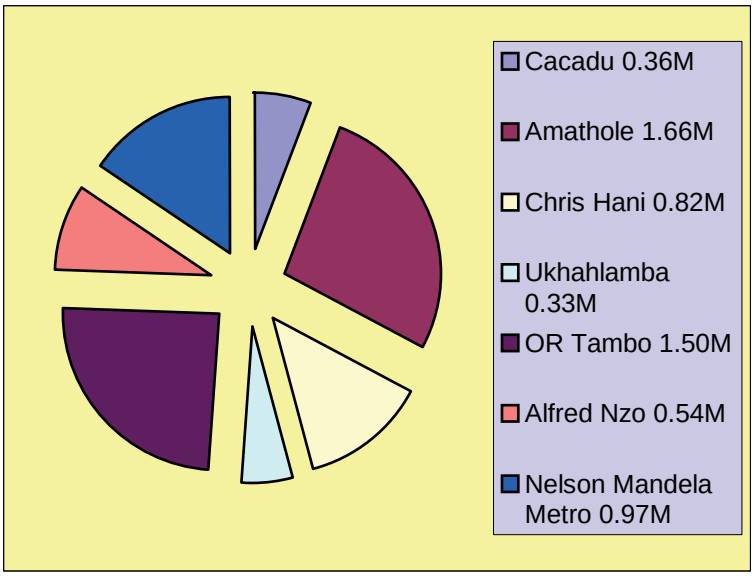

Figure 3: Eastern Cape Province population distribution by District Municipality

The Eastern Cape Province has a proud history of resistance to colonialism and to apartheid, but these policies have left it deeply scarred. Unemployment averages about 50%, and rises to more than 75% in parts of the former 'homelands'. The province suffers from a very high incidence of HIV/AIDS, estimated at over 20% of the population in 2000. Almost half of the population is illiterate, and almost 40% of the province's population are dependent children (under the age of 15).

The Human Development Index (HDI) is a composite index measuring average achievement in three basic dimensions of human development – a long and healthy life (life expectancy at birth), knowledge (a composite of the adult literacy rate and the combined primary, secondary and tertiary gross enrolment ratio) and a decent standard of living (GDP per capita).

The HDI for all provinces in South Africa is declining, and was 0.6175 in the Eastern Cape in 2003 (Figure 4). The only provinces with lower HDIs were Limpopo (0.5900) and North West (0.6062), however both these regions have significantly lower populations than the Eastern Cape.

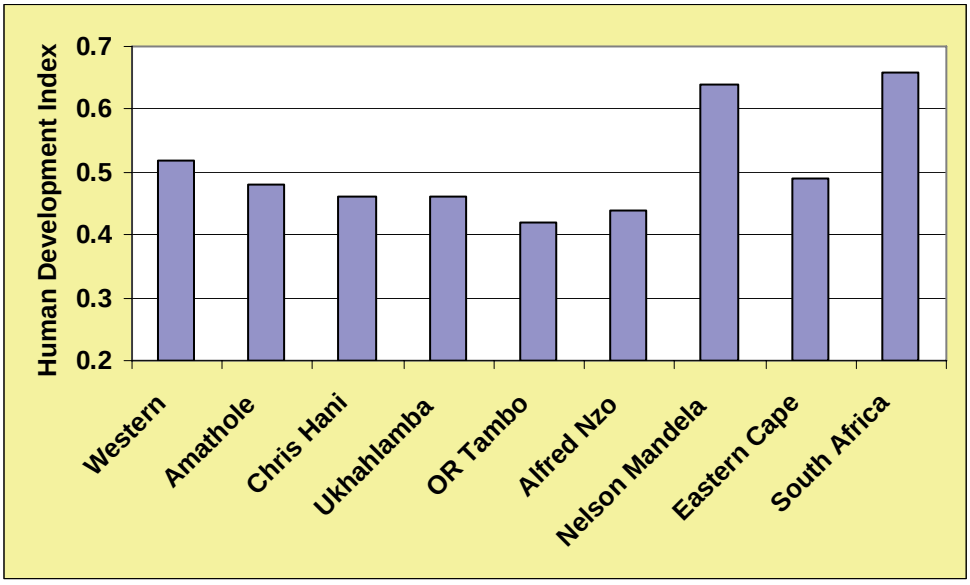

Figure 4: Human Development Indices by Municipality in the Eastern Cape (source PGDP)

The HDI figures in the chart above illustrate the discrepancies in income and access to resources in South Africa. The Human Development Index for South Africa as a whole is 0.666, higher than any municipality in the Eastern Cape. If the Eastern Cape Province was a country, it would rank below Togo and Uganda on the HDI scale, with an HDI index of around the average for Sub-Saharan Africa. Thus although it is part of a relatively prosperous country, the Eastern Cape Province has very considerable levels of deprivation, and pockets of severe poverty.

3.2 Water Supply in the Eastern Cape

One of the most pressing problems in the Eastern Cape Province is the lack of access to clean drinking water. The Eastern Cape Province is the worst ranked province in terms of access to both basic and higher levels of water and sanitation services (DBSA, 2006). More than a third of all people in the Eastern Cape are without these basic human rights. This bestows a grim legacy of disease, hardship and suffering. Provision of essential services such as healthcare, education and basic food production all depend to some degree on an adequate supply of water, and efforts to provide these services are often hampered by the lack of water supplies. Whilst inadequate water supplies harm everyone in a community, women frequently suffer most. The responsibility for fetching water from distant sources falls onto them, as does the care of those (particularly children) who become ill through drinking unsafe water. An adequate and reliable water supply is also necessary for many forms of grassroots economic development such as market gardening, brick-making, stock and dairy farming. The Eastern Cape Provincial Government has made it a target to provide clean water to all by 2014.

Plate 2: Queuing for water in a village near Queenstown (Photo by R Murray)

3.3 The Advantages of Groundwater for Rural Water Supply

Difficulties inherent in providing clean water to people in the Eastern Cape include a dispersed rural population, steep topography, seasonal surface water problems, and a lack of the basic infrastructure necessary to operate centralised surface water schemes. While not all areas are suitable for groundwater development, most of the rural water supply requirements can be met using this resource. It is usually found close to where it is needed, and it is generally of a high quality and can be used with little or no treatment. Groundwater is available in the dry season, and even during prolonged droughts. In contrast, surface water resources are rarely available where they are most needed, and require more expensive infrastructure such as dams, major pipelines and water treatment works. Surface water always needs to be treated before it can be used, and is much more vulnerable to drought. The potential for groundwater to meet the basic needs of large numbers of people in the Eastern Cape is now widely recognised.

3.4 The Need for Groundwater Research

In order to access groundwater, it is necessary to understand where it occurs. In some places, groundwater occurs throughout the subsurface, and it is relatively easy to locate. However, most of the Eastern Cape is underlain by rocks of the Karoo Supergroup. These rocks are mainly hard sedimentary rocks such as mudstones, sandstones and shales, and are not normally regarded as good aquifers because water cannot move easily through them. However, the Karoo rocks can yield large amounts of groundwater where they are weathered, fractured or otherwise altered. The challenge of developing the groundwater resources of these rocks is to understand where and how the

groundwater occurs. Given the pressing water supply problems in the Province, the need to understand the nature and occurrence of groundwater in the Eastern Cape is greater than ever.

3.5 The Study Area

South Africa has been divided into 19 separate Water Management Areas (WMAs) for management purposes. The boundaries of the WMAs do not follow provincial or other administrative boundaries, but are based on water catchments. The main water supply needs, and groundwater research needs, in the Eastern Cape Province is in WMA 12, known as the Mzimvubu to Keiskamma WMA (Figure 1). WMA 12 covers almost the whole of the former Transkei and Ciskei 'homeland' areas, or approximately the north-eastern half of the Eastern Cape Province, and is almost entirely underlain by Karoo sediments (Figure 5). The bulk of the population of the Eastern Cape live within WMA 12 (Figure 3).

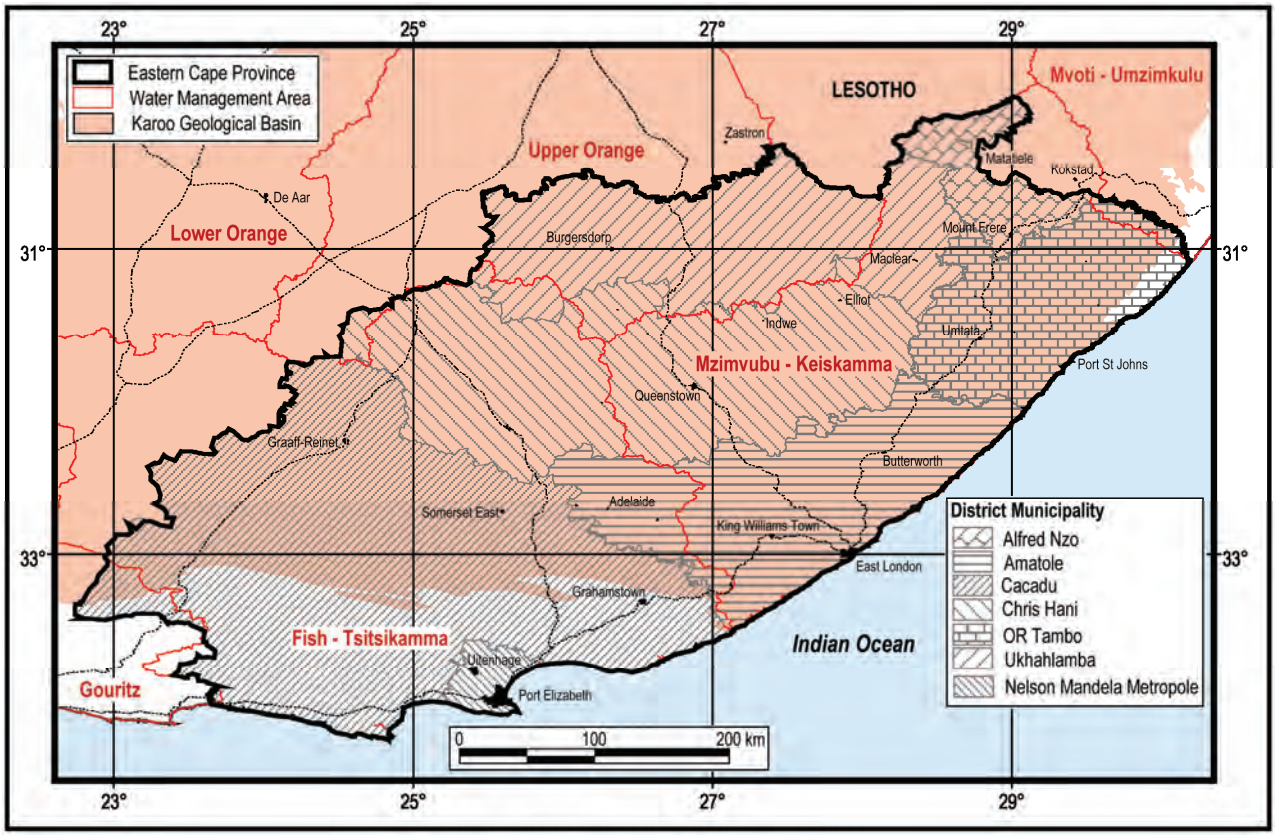

Figure 5: District Municipalities of the Eastern Cape Province showing extent of the Main Karoo Geological Basin and Water Management Areas

WMA 12 is a summer rainfall area with precipitation between 700 and 1500 mm/a. The topography is rolling hills, with deeply incised river valleys. The highest points lie on the border with Lesotho (Figure 6). Three main rivers drain the area, the Mzimvubu, the Mbashe and the Mthatha, and smaller rivers and coastal streams are common. Generally speaking, the surface water resources in the area are underdeveloped. No significant dams have been constructed in the Mzimvubu catchment, and

development potential also exists in the Mbashe catchment. WMA 12 is the only water management area which does not participate in any significant inter-basin water transfers. The area is considered to have a surplus of surface water resources. However, despite the relatively high rainfall and abundant surface water, WMA 12 has some of the highest numbers of people without access to clean water in the country.

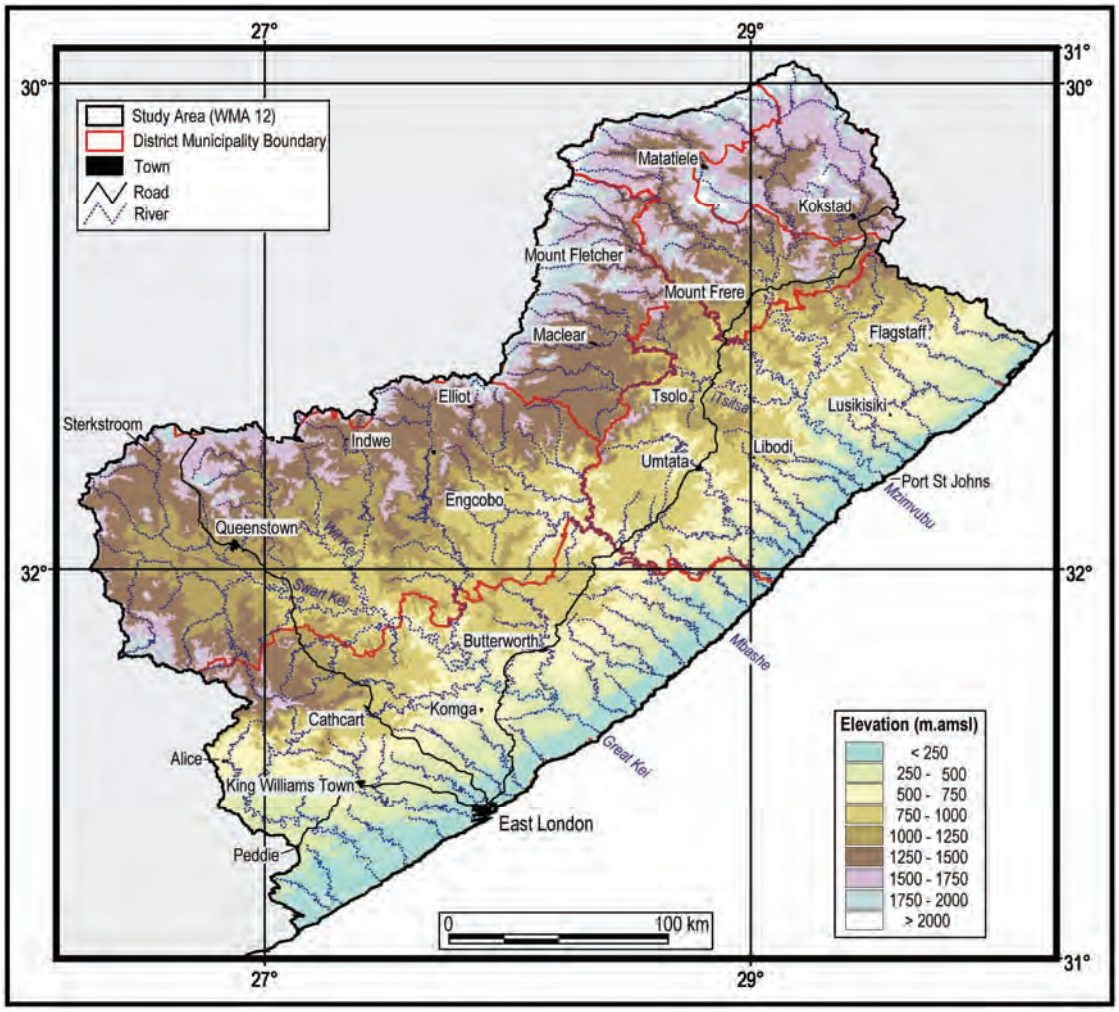

Figure 6: Physiography of the Study Area

4. Review of Development Plans for Water in the Eastern Cape Province

4.1 Introduction

There has been a fundamental change in the way water resources in South Africa are managed, from the old 'riparian' scheme based on land ownership to a system that seeks to distribute water fairly and in the public interest. The new system recognises that the basic needs of people (potable water and adequate sanitation) must first be met, followed by the allocation of sufficient water to sustain the environment. These essential quantities of water are termed the 'Reserve', and are of primary importance. A sustainable water supply is also needed for food security and for economic development, and can greatly transform the lives of impoverished communities.

It is essential that groundwater research in the Eastern Cape (and WMA 12) be located within the framework of broader development plans at the different administrative levels (Figure 7). This will help the research to address those areas of greatest need. Consequently, National, Provincial and Local Government planning documents relevant to each tier of administration have been studied, and their recommendations concerning groundwater development are outlined below.

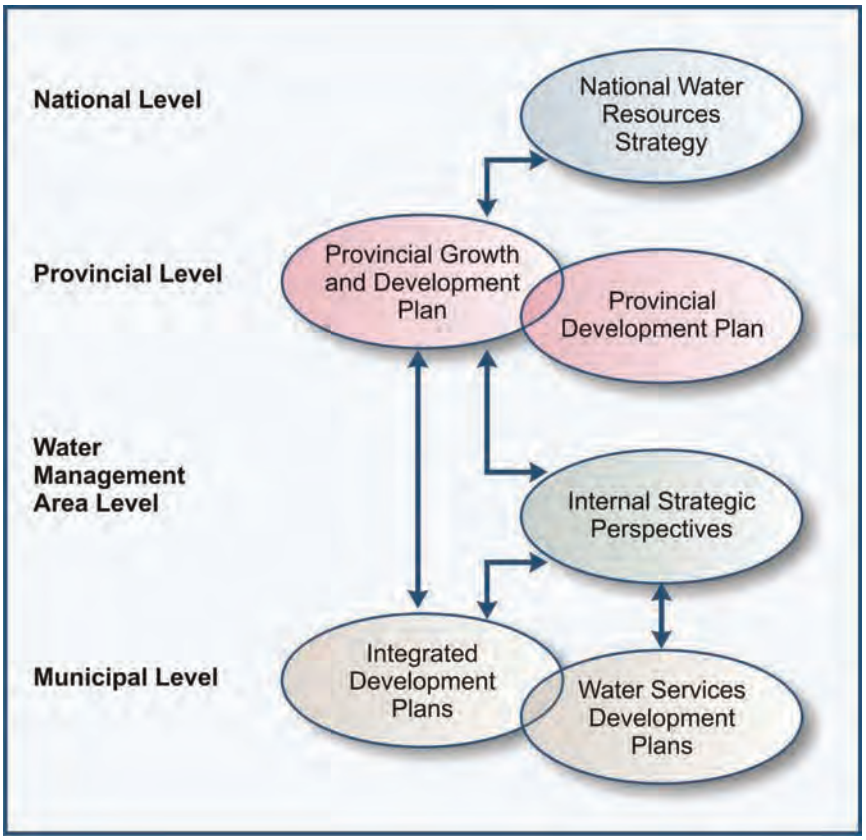

Figure 7: Levels of water resources and services planning in South Africa

4.2 National Level: The National Water Resources Strategy (NWRS)

The National Water Resources Strategy (NWRS), published in September 2004, is the document which describes how South Africa's water resources will be 'protected, used, developed, conserved, managed and controlled' in accordance with the National Water Policy (1997) and the National Water Act (1998).

Nineteen Water Management Areas (WMAs) covering the entire country were established in 1999 in order to facilitate water resource planning and management. The NWRS states that responsibility for water management is to be progressively devolved from a national level to Catchment Management Agencies or CMA (one for each WMA), and to local associations.

South Africa's surface water resources are nearly fully allocated, and South Africa is among the world leaders in surface water resource management. South Africa's groundwater resources, on the other hand, are underutilised. This is partly because groundwater in South Africa occurs mainly in fractured aquifers where water can be difficult to find and borehole yields are often low. The potential of these aquifers is not yet fully understood. The NWRS states that 'a systematic approach to groundwater was neglected in the past' (*p44)*. As a result, there is a lack of groundwater data and information in South Africa.

Today, groundwater in South Africa is recognized as an integral part of the water cycle and as an important national asset. Since the cost of supplying dispersed rural communities with surface water is often prohibitively high, groundwater is often the only realistic option for a sustainable supply of safe water in many areas. The NWRS states that 'groundwater has the potential to contribute significantly to meeting the needs for water in rural areas, particularly for domestic supply' (*p105*) The NWRS estimates that an amount of 21 million m^3/a of groundwater is available in WMA 12, only a tiny fraction of which is currently exploited. The challenge is to use and manage this resource with the greatest possible efficiency.

'The provision of basic water and sanitation services is an essential element of water's contribution to poverty eradication, because it addresses issues of health and hygiene, and the effort required in collecting and carrying water from remote, often polluted water sources.' *NWRS p.11*

4.3 Provincial Level: The Provincial Growth and Development Plan

The Eastern Cape Province is in the process of compiling a Provincial Growth and Development Plan (PGDP). This document is intended to guide all aspects of the development of the province over the next ten years. Whilst the PGDP is not intended to provide the details of water resource planning, amongst the Provincial Targets for Growth and Development are the following water-supply related targets:

- To provide clean water to all in the province by 2014
- To eliminate sanitation problems by 2014
- To reduce by two thirds the under-five mortality rate by 2014

- To reduce by between 60% and 80% the proportion of people suffering from hunger by 2014.

The Water and Sanitation Programme falls under the Fighting Poverty Programme Area, and the first programme objective is to provide basic water supply and sanitation. The stated target is to supply 906 000 people per year with basic water supplies in the three years leading up to 2006/2007. A big increase in the contribution from groundwater will be needed if this target is to be met.

Informing the PGDP is the Provincial Spatial Development Plan (PSDP). This document sets out the spatial framework for development in all sectors in the province. The PSDP identifies 'basic needs' including water supply and sanitation as a first priority (*p2*). 70% of the Eastern Cape Province is considered 'rural' (*p24*), and it is this part of the population that is most deprived in terms of access to water and sanitation. The PSDP estimates that almost half of the population of the Eastern Cape do not have access to adequate water supplies (*p53*). Fewer still have access to adequate sanitation. The PSDP recognises that whilst groundwater is widely used for rural supply, borehole yields are low (*p53*). A 'large proportion' of the additional water supplies the province requires will be needed for rural villages (*p54*). A better understanding of the underlying Karoo aquifers will be necessary if higher-yielding boreholes and more reliable supplies are to be gained in the most cost-effective way. In the Eastern Cape, 'adequate potential water resources are available, although detailed design and implementation schemes are required' (*p54*).

4.4 Water Management Area (WMA) Level: Internal Strategic Perspectives (ISPs)

4.4.1 Introduction to ISPs

The Department of Water Affairs and Forestry (DWAF) is in the process of devolving responsibility for water management from a national level to regional Catchment Management Agencies (CMAs), one for each of the nineteen Water Management Areas (WMAs). In order to manage the water resources in each WMA, DWAF have developed documents called Internal Strategic Perspectives (ISPs), which will be used by stakeholders until such time as the CMAs are functional. Each WMA has at least one ISP. WMA 12 has two ISPs, one for the Amathole-Kei sub-area, and one for the Mzimvubu-Keiskamma sub-area. The ISPs are intended to guide all stakeholders in the development and management of the water resources in each WMA.

4.4.2 Importance of Groundwater

The Amathole-Kei ISP recommends that the significant quantities of groundwater that exist in the sub-area should be used for rural supply: 'Many small communities and subsistence farmers can avail themselves of groundwater when it would otherwise be impossible or impractical to lay on piped supplies' (*p1.14*).

'The realisation in this and other ISPs is that groundwater offers a huge resource of water which can be tapped and that this can be a very significant supplement to the national water resource.' *Amathole-Kei ISP, p1.14*

4.4.3 Need for Groundwater Research

However, there is a need for research into the groundwater resources of the region: The Amathole-Kei ISP confirms the importance of dolerite intrusions in the occurrence of groundwater, but states that the dolerite sill and ring complexes have not been adequately explored in the area to the north of East London (*p 2.19*). Boreholes have frequently been randomly sited, making studies of existing data problematic. In addition, whilst the ISP recognises that Karoo fractured-rock aquifers are potentially easily contaminated, there is very little knowledge of the vulnerability of aquifers in the area, nor of baseline water quality. The Mzimvubu-Keiskamma ISP states that the groundwater resources across most of the sub-area are under-utilised, but estimates that 28% of the resource is not potable due to salinity problems. (*p.139*).

'While it is recognised that the groundwater resources of the region must play an important part in securing the future water supplies, the lack of knowledge, understanding and data on this valuable resource needs to be urgently addressed if this resource is to play a meaningful role.' *Amathole-Kei ISP, pxiii*

4.4.4 Environmental Importance of Groundwater

The ISP states that the environmental impact of groundwater use is not well understood: '*There is limited understanding of variation in spring discharge with climate variations, snowfall and natural impacts on base flow versus anthropogenic or abstraction influence. Current understanding of the relationship of different aquifers to spring flow and base flow is undocumented and not considered in either surface water or groundwater management or regulatory decisions*.' (*p2.20*) As a result, it is currently impossible to determine the groundwater component of the Reserve with any accuracy.

Plate 3: Gathering water from an unprotected spring near Cofimvaba(Photo by R Murray)

4.5 Municipal Level: Integrated Development Plans (IDPs) and Water Services Development Plans (WSDPs)

Each Municipality (District and Local) is required to develop an Integrated Development Plan (IDP), which is a five-year strategic plan for the development of the municipality, drawing on the Provincial Growth and Development Plan. IDPs assess the development and infrastructure needs of the municipality, establish goals and strategies, guide implementation, and finally specify mechanisms for monitoring.

All District Municipalities and some Local Municipalities are authorised as Water Services Authorities (WSAs). WSAs have responsibilities for water supply and sanitation and are able to sign contracts with Water Service Providers (WSPs). A Water Services Development Plan (WSDP) must be developed by each Water Services Authority (WSA). The primary purpose of a WSDP is to ensure efficient, affordable, economical and sustainable access to water services. (Thus both District and Local Municipalities must prepare IDPs and WSDPs (Figure 8), except those Local Municipalities not authorised as WSAs who must prepare Water Sector Plans (WSPs) as part of their IDPs.)

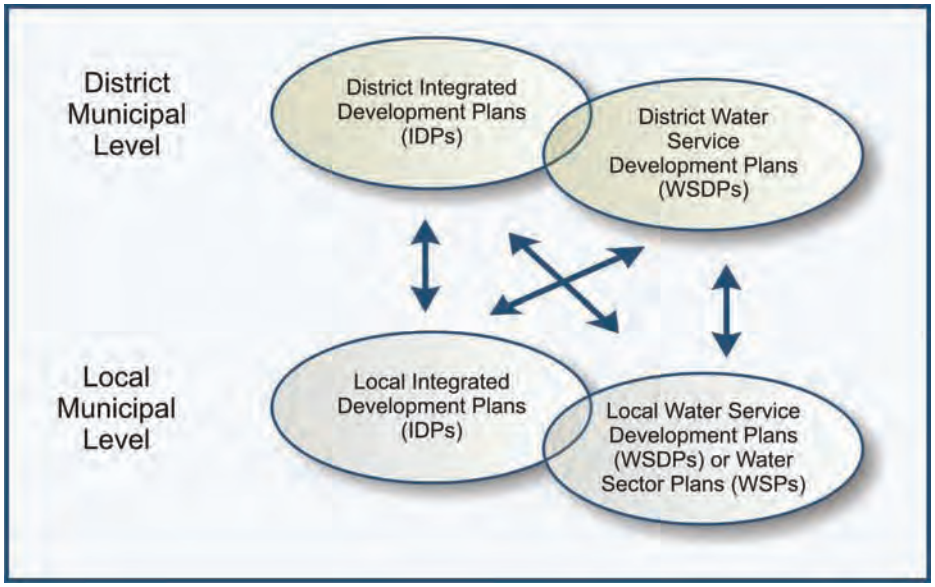

Figure 8: Relationship between District and Local Municipal IDPs and WSDPs

The WSDP is part of the municipality's IDP process and should inform the IDP regarding specific requirements in terms of water and sanitation. Equally, the IDP must inform the WSDP of the municipality of the key issues and objectives derived from the IDP process as they relate to water and sanitation issues. Municipal planning is thus an iterative process whereby the multi-sectoral IDPs can both inform and take direction from the WSDPs. There are nineteen WSDPs for the Eastern Cape Province.

The various WSDPs for the Eastern Cape confirm the urgent need for better water and sanitation services in the province. For example, the Amathole District Municipality WSDP states that 58% of people in the DM do not have water supply services to RDP standards, and 91% of people do not have access to acceptable levels of sanitation services. The Alfred Nzo District Municipality has the highest poverty levels in South Africa, and the WSDP for the Umzimkulu Local Municipality (one of the two LMs in the Alfred Nzo DM) states that only 4% of residents have access to 'a RDP level of service' in terms of water supply, and only about 2% having the same level of service in terms of sanitation. Many residents have no level of service at all. The District has the most dire health status in the country.

The WSDPs comment only in very general terms on the amount and availability of groundwater in the respective areas. The potential amounts of groundwater available and the technical problems of accessing the resource are not covered in any detail. The need for groundwater monitoring is also identified as an important requirement.

'The demand on borehole water supply will increase with time. Additional boreholes will have to be drilled to supply the required demand.'
Ukhahlamba WSDP, p.21

4.6 Key Conclusions from Planning Documents and Research Needs

The planning documents at the different levels describe the considerable challenges relating to water supply and sanitation in the Eastern Cape Province. Most rural populations do not have access to adequate water supply and sanitation services. The more detailed Catchment Level and Municipal Level planning documents confirm the potential role of groundwater in meeting those needs, and reiterate the need for a greater understanding of groundwater resources in the Province.

The key research areas arising from water and sanitation services planning are:

- **Borehole information.** Most of the previous work has been in the western and central parts of the Karoo Basin, which has only a small fraction of the population of the eastern part. Although thousands of boreholes have been drilled in the eastern parts, the data, such as borehole depths, depths of water strikes, drilling yields, etc, does not exist in a useful and readily available format. In order to develop reasonable conceptual models describing the occurrence and flow dynamics of groundwater in the Eastern Karoo Basin, this data will need to be captured in a manner that enables spatial and statistical analysis.

- **Scientific borehole-siting.** Most boreholes drilled into the Karoo rocks to date have been for small supplies such as stock-watering and small-scale domestic needs (hand- and windpumps). Boreholes were sited wherever it was most convenient, or with the help of water dowsers. It is now recognised that if large numbers of rural inhabitants are to be adequately served, higher yielding boreholes suitable for powered pumps are needed. This will include assessing new groundwater targets, including deeper-seated fracture zones associated with regional structures that to date have not been adequately assessed.

- **Wellfield development.** With the need to supply greater quantities of water than previously, it is now necessary to assess the feasibility of establishing wellfields that can supply the larger settlements or clusters of smaller villages. This requires identifying areas not only where borehole yields are expected to be high, but also aquifers that can sustain higher abstraction rates on a long-term basis. This also requires understanding the controls on aquifer sustainability (recharge and storage).

- **Groundwater protection.** With increasing groundwater use and sanitation facilities, it is necessary to establish controls on and risks of groundwater contamination.

- **Environmental impacts.** The role of groundwater in maintaining groundwater dependant ecosystems, as well as the relationship between groundwater and river baseflow needs to be established on a catchment scale. This is particularly important in areas of high groundwater abstraction.

- **Context of regional development.** Past research has not always commenced with an assessment of the domestic water needs of the study area, nor has it always taken into account the relevant broader development issues. In certain high-yielding groundwater areas it may be possible to transfer water from one catchment to another, and thereby meet the needs of nearby 'water poor' areas.

- **Practical outputs.** Contemporary research needs to have a practical focus, aimed at the problems of poor or unreliable water supply in the Eastern Karoo Basin. Research outputs should include easily accessible information that can be put to practical use by groundwater professionals, Water Service Authorities and other stakeholders. These considerations have not always been priorities in the past research projects.

Plate 4: Motorised pumps are now replacing wind- and handpumps in rural water supplies (Photo by R Murray)

5. Previous Geohydrological Research and Regional Studies

The hydrogeology of the Karoo Basin has been the subject of numerous studies, several of the most important of which are examined below. A short summary is followed by the principal recommendations for each.

Chevallier L *et al*, 2005. Geological and hydro-morpho-structural analysis for groundwater potential in rural water-stressed areas in the Mzimvubu to Keiskamma Mater Management Area (WMA No 12). Council for Geoscience report 2005_078.

Mapping and spatial modelling of discrete features such as fractures, intrusions and geological lineaments was used to define the occurrence groundwater and locate possible areas of high development potential in the study area. A GIS was used to interrogate the size, orientation, density, interconnectivity and other properties of these features, and relate them to the hydrogeology. The results were two folded, namely:

Qualitative Structural Domain Maps were prepared based upon the occurrence and (theoretical) weighting of the lithological and structural features. These maps show potential zones for the development of shallow and deeper-seat fracturing and therefore possible areas for the development of high-yielding boreholes.

Most of the boreholes drilled in the catchment were found to not have targeted these high potential structural domains, and that borehole siting was mainly controlled by topographical factors. However, borehole productivity analysis using borehole information from DWAF's National Groundwater Database (NGDB) showed that lithostratigraphy and density of dolerite sills are the most important factors controlling regional variations in the yield of boreholes. Lineaments of certain orientations often produced higher yields. However, the study highlighted important gaps in our understanding of the hydrogeology of the area. For example, there are numerous high-yielding boreholes that are located away form dolerite intrusions such as dykes and ring-complexes. The reasons for this still needs to be understood and it also needs to be established whether the proposed optimal drilling target areas are widespread throughout the Eastern Cape Province, and if they can be adequately located using remote-sensing and/ or geophysical methods.

The conceptual models of Karoo hydrogeology need to be revisited in certain geological areas. The study also highlighted the paucity of borehole data, as well as the lack of spatial accuracy in the dataset.

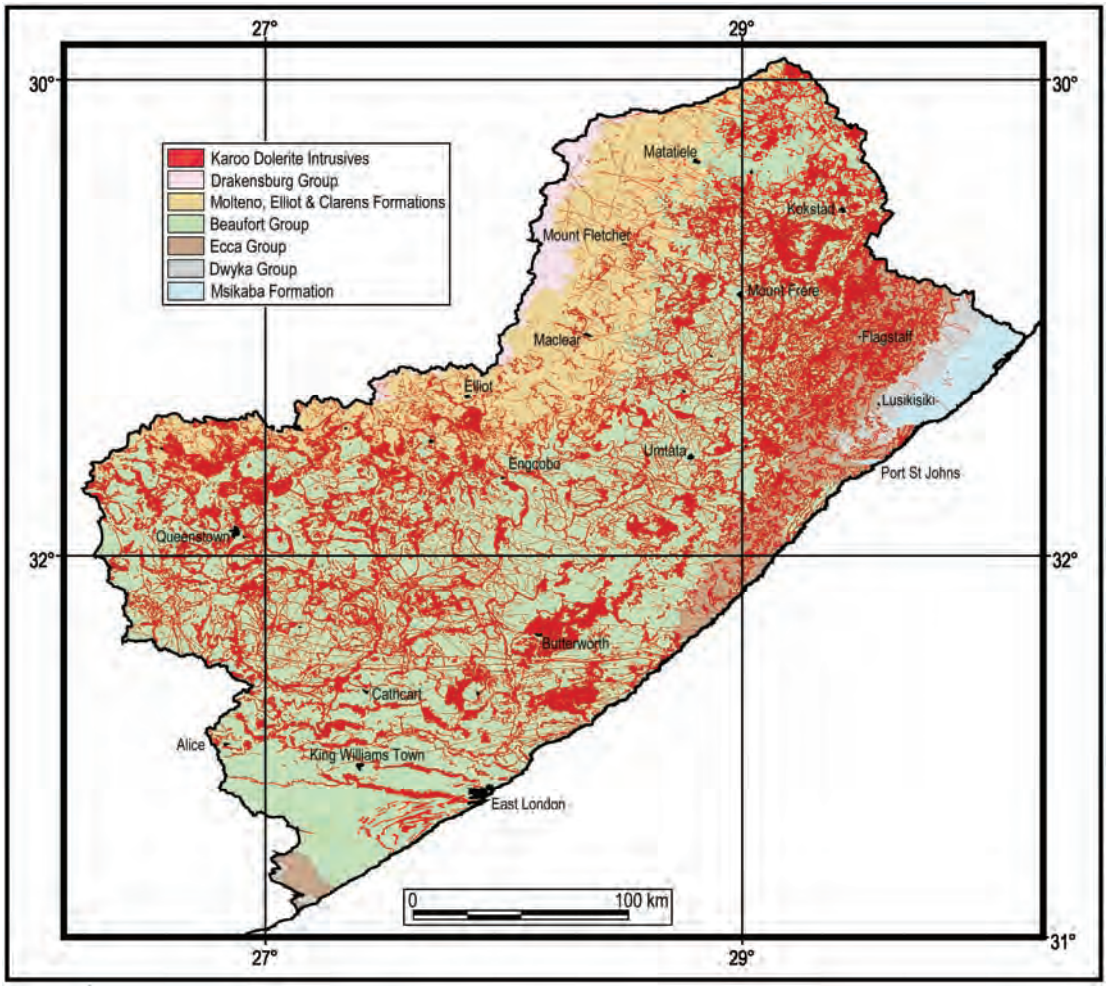

Figure 9: Karoo dolerite dykes, sills and ring-complexes in WMA 12

Chevallier *et al*., 2004. Hydrogeology of fractured-rock aquifers and related ecosystems within the Qoqodala dolerite ring and sill complex, Great Kei catchment, Eastern Cape. WRC report No. 1238/1/04.

Dolerite sill and ring complexes were investigated at Qoqodala, in the Great Kei catchment, to the northeast of Queenstown. The work included structural and morphological analysis, spring hydrocensus, mapping of groundwater dependent ecosystems and wetland using remote-sensing, time-domain electromagnetic survey, exploration drilling, pump- and injection-testing, and monitoring.

The dolerite ring complexes control, to a very large extend, the geomorphology, surface drainage patterns, aquifer recharge and location of many springs and seepages in such areas. Fracture zones, occurring at depths ranging from between 30 m to 300 m were identified. These fractured-rock aquifer systems appear to be relatively extensive. The eco-hydrogeological model of the Qoqodala dolerite ring and sill complex showed that many of the springs and related ecosystems may be vulnerable to large-scale groundwater abstraction.

Plate 5: Research drilling in Qoqodala dolerite sill and ring complex, north of Queenstown (Photo by R Murray)

Botha JF and Cloot AHJ, 2004. Karoo Aquifers. Deformations, Hydraulic and Mechanical Properties. WRC Report No. 936/1/04.

This report asserts that the permeability of Karoo fractured-rock aquifers is largely controlled by the presence of horizontal fractures or bedding-plane joints in sediments. It is argued that over-stressing of such aquifer systems by over-pumping can cause the aquifer to permanently deform, leading to the 'closing' of water-bearing fractures and an irreversible decline in permeability. A numerical model of a hypothetical Karoo fractured-rock aquifer was developed, and tested using pumping-test data from a single test site. It has so far proved impossible to directly observe aquifer deformation in the field.

The authors recommend that further studies on this topic, including field investigations, be undertaken and argue that too little is currently known about the hydraulic properties of Karoo aquifers to determine 'safe' pumping-rates that will not permanently 'damage' such aquifers.

Plate 6: Fractured and baked sandstones overlying a dolerite sill (Photo by R Murray)

Woodford, A.C. & Chevallier, L. (eds.) 2002: Hydrogeology of the Main Karoo Basin: Current Knowledge and Future Research Needs. WRC Report No. TT 179/02.

Karoo fractured-rock aquifers are broadly characterised in the introduction as being '*complex and unpredictable*' in behaviour (*p1*). This comprehensive report summarises geohydrological work in the Karoo Basin, discusses various techniques, and sets out recommendations for future research. The report recommends topics that need further work. For example it is stated that groundwater in dolerite sills and ring complexes has, to date, been 'largely overlooked' (*p90*).

Recommended research techniques include field investigations, geophysical and geochemical surveys, conceptual and numerical modelling, GIS and statistical analysis of all available information on a regional scale, and the integration of hydrogeological techniques with other environmental disciplines to enhance the management of Karoo aquifer systems. Research should combine knowledge gained in the past with a structured programme focused on present needs. Identified research priorities include:

- Quantification of groundwater reserves; including regional flow evaluation, the investigation of deeper-seated aquifers, the delineation of aquifer geometry and questions of sustainability and recharge. Pumping-tests and the investigation of deeper-seated aquifers are specifically mentioned (*p462*).

- Groundwater development and its impact on the environment; it is recommended that future research should take into account allocations of groundwater for human needs, and for the environment. The dependency of ecosystems on groundwater should be studied, particularly

when considering large scale groundwater abstraction schemes. These topics have been largely ignored in the past.

- Groundwater quality and monitoring; research is needed with an emphasis on water quality changes over time. Isotopes are likely to be useful.

- The report also recommends better transfer and sharing of technologies and knowledge between groundwater professionals, as well as with water resource planners, developers and ultimately the users.

Plate 7: A thin dolerite dyke intruding Karoo mudstones and sandstones (Photo by R Murray)

Chevallier, L. *et al*, 2001. The Influences of Dolerite Sill and Ring Complexes on the Occurrence of Groundwater in Karoo Fractured Aquifers: A Morpho-Tectonic Approach. WRC Report No. 937/1/01.

Dolerite ring and sill complexes (Figure 10) in the Karoo Basin have largely been overlooked in the past as potential high-yielding groundwater exploration targets. The authors aimed to study the geometry and mechanics of these intrusions, and to determine how groundwater is associated with them. Using a variety of investigative techniques, they proposed a hydro-morpho-tectonic model showing the different types of water-bearing fracture zones that are commonly associated with these intrusions (Figure 11). Borehole information indicated that groundwater is partly dependent on terrain slope. Water-bearing fractures were shown to be developed at certain structurally controlled positions. A detailed local field investigation was carried out in the area between Loxton and Victoria West, involving an assessment of existing geohydrological data, geological and structural mapping, and the

drilling of 67 exploration boreholes. Many of the boreholes were high yielding (13 to 85 ℓ/s), and an increase in yield with depth was recorded.

The authors recommend that the wider scale and deeper-seated geometry of these intrusions be studied using geophysical techniques (high resolution aeromagnetic imaging and time-domain electro-magnetic profiling). Further research should also concentrate on the role of groundwater in the maintenance of ecosystems, and on the vulnerability of different hydrogeological domains to over-abstraction.

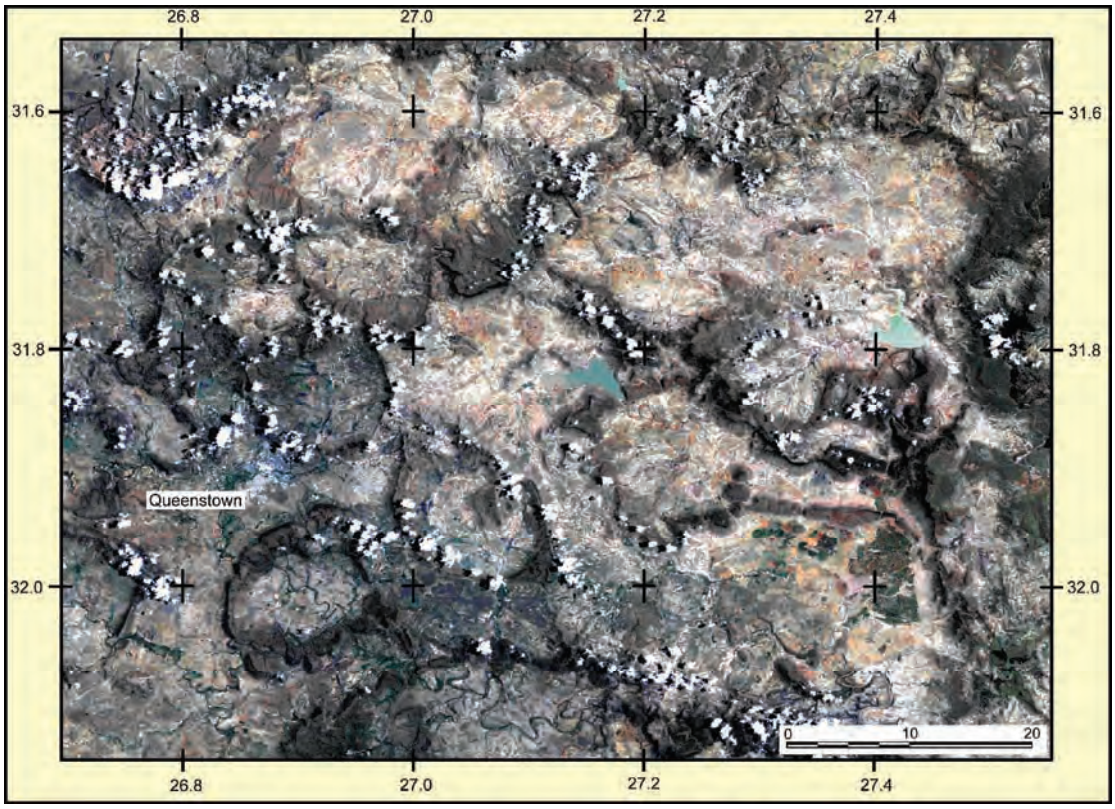

Figure 10: Landsat satellite image of dolerite ring and sill complexes in the Queenstown area

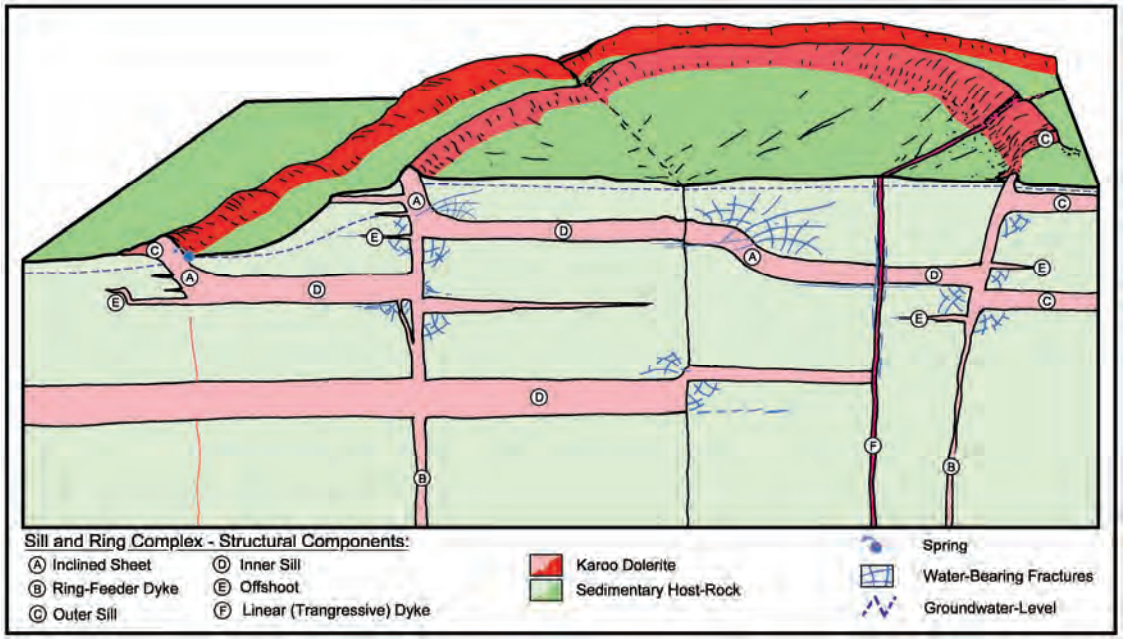

Figure 11: Schematic Hydro-morphotectonic Model of a Dolerite Sill and Ring Complex

Kirchner, *et al*, 1991. Exploitation Potential of Karoo Aquifers. WRC Report No. 170/1/91.

This report aimed to develop a method for assessing the exploitation potential of Karoo aquifers, and hence considered recharge in some detail. Mean annual recharge in the Karoo Basin was estimated to vary between 2 and 4% of annual rainfall, although this was shown to change considerably depending on the nature of surface material (e.g. alluvium increases recharge). Recharge was found to take place mainly via preferred pathways in the subsurface and to especially occur following 'extreme' rainfall events every few years or so. Three different equations for recharge were developed, depending upon the material overlying the aquifer. The programme of field research included the drilling of 96 exploration boreholes, a series of pump-, step- and packer-tests, the installation of neutron moisture probes in the vadose zone, and the monitoring of daily precipitation. Groundwater chemistry is presented but not discussed in any detail.

The report recommends further work to determine whether the proposed methodologies are applicable in other climatic zones, i.e. outside of the semi-arid zone in which the research was conducted. Also recommended are further research into the total thickness of Karoo aquifer systems, and the changes in the hydraulic properties of these aquifers with depth. ('*Both the aquifer thickness and the storativity of the fractured Karoo aquifers could not be determined accurately*' – *p. IX [executive summary]*).

Botha, J.F. *et al*, 1998. Karoo Aquifers: Their Geology, Geometry and Physical Properties. WRC Report No. 487/1/98.

This report aimed to investigate Karoo aquifers, with special reference to the applicability of existing theoretical aquifer-flow models, and to develop techniques for assessing the results of pumping-tests conducted in these units. Karoo aquifers are found to have a very complex geometry, which ultimately

controls their hydraulic behaviour. Modelling was carried out based on data from a single test site in Bloemfontain, although it proved impossible to develop a new numerical model for the analysis of groundwater flow in Karoo aquifers.

Recommendations include the 'proper management of aquifers', based on the concept of aquifer safe yield. '*It is imperative that the geometry of a Karoo aquifer must be known before the aquifer is developed for the supply of water to larger communities*' (*pviii*). More information is needed on dolerite ring complexes (*p35*). The collection of more reliable and accurate information, including detailed geological logs, discharge rates and piezometric levels, is also recommended.

5.1 Key Research Needs based on Past Studies of Karoo Aquifers

The groundwater resources of the Eastern Karoo Basin have a vital part to play in the development of the region, but the nature and dynamics of these aquifer systems needs to be understood before it can be properly exploited. Several preliminary points can be made regarding the research needs of the Eastern Karoo Basin, namely:

- Little research has been done in the eastern part of the Basin, where most of the people live. This is also the area where there is the greatest need for basic water and sanitation services. The coastal strip in particular, with its large rural population, is poorly understood.
- Data on groundwater has not been collected systematically in the past, and in particular little is known about higher yielding Karoo boreholes (yields greater than about 5 litres per second).
- Geological structures that are capable of yielding copious amounts of groundwater, such as fractured dolerite ring complexes and dykes, are as yet improperly understood in this region.
- Little is known about the presence and /or extent of deep-seated groundwater in the Karoo Basin (more than about 150 m bgl).
- Little is known about groundwater sustainability (particularly higher yielding boreholes), about the age and chemical characteristics of (particularly deeper) Karoo groundwater, or on the effect of prolonged pumping on the environment, and about possible management options such as artificial recharge.

6. Future water requirements in areas of high groundwater exploration potential

Chevallier *et al* (2005) developed a preliminary groundwater exploration potential coverage for WMA 12 (Figure 12), based upon borehole productivity analyses in terms of regional geomorphological, lithological, structural and tectonic considerations. The exploration potential rating provides a qualitative indication of the likelihood of developing a relatively high-yielding borehole within a given region. Yield information from 4 976 waterpoints in DWAF's national database were used in the study. The positional accuracy of these waterpoints are highly variable and the reliability of the results obtained in the former Transkei area is severely restricted by a lack of widespread, accurate yield information. The mean and median yield of all the waterpoints investigated is 2.0 and 1.0 ℓ/s, respectively.

The study showed that the interior of WMA 12 has the greatest exploration potential (ratings 5 to 7), where rocks of the Tarkastad Subgroup and particularly the Burgersdorp Formation outcrop (Figure 12). The coastal zone extending up to 90 km inland to the northeast of Butterworth has the lowest potential rating. This reflects the strong influence of Karoo dolerite intrusives, lithostratigraphy and geomorphology upon the occurrence of groundwater in the area.

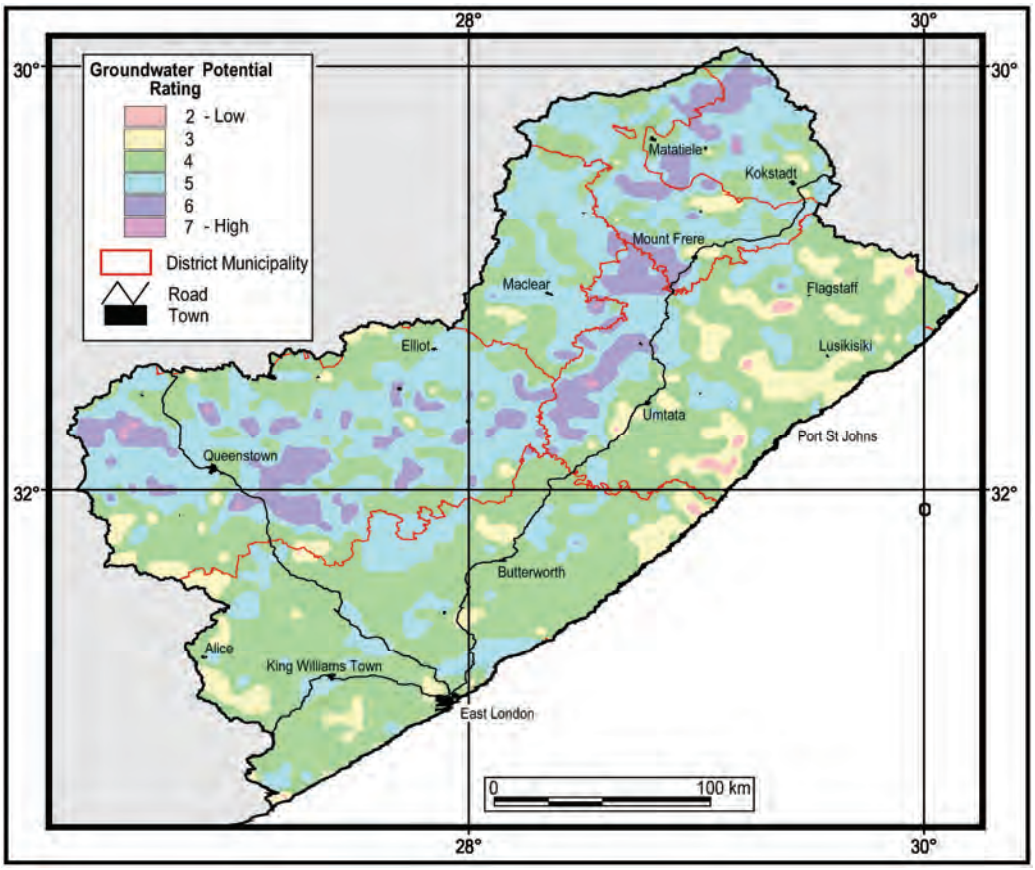

Figure 12: Groundwater Potential of Water Management Area 12

The mean and median groundwater exploration potential per District Municipality are presented in Table 1, indicating a moderate to good potential within all the Municipalities. However, the groundwater exploration potential is lowest in the Amatole and OR Tambo DM areas where the water needs are the greatest (Table 1).

Table 1: Groundwater Exploration Potential per District Municipality

District Municipality	Groundwater Potential Rating		
	Mean	Standard Deviation	Median
Alfred Nzo	4.73	0.77	5
Amatole District Municipality	4.08	0.54	4
OR Tambo	4.18	0.91	4
Chris Hani District Municipality	4.74	0.77	5
Siskonke	4.85	0.79	5
Ukhahlamba District Municipality	4.59	0.62	5

The relationship between the estimated water shortfall below RDP standards of 25 litres per person per day per settlement and the groundwater exploration potential of WMA 12 is graphically illustrated in Figure 13. Settlements with water supply shortfalls in excess of 10 000 m^3/annum below the prescribed RDP standard that occur to the north of Umtata, extending towards Mount Fletcher and Matatiele all lie on areas of medium to high groundwater potential. The potential exists for clusters of relatively high-yielding boreholes or wellfields to be established in these areas, with the aim of supplying a number of nearby settlements from a single wellfield. Development of the local groundwater resources should be given priority in such areas. However, a large number of settlements lying between Umtata and Port St Johns have water supply shortfalls in excess of 10 000 m^3/annum and occur in an area that is currently classified as having a low groundwater exploration potential (Figure 13). This area, as well as almost the entire coastal strip extending some 30 km inland, has been classed as having a low groundwater potential (Figure 13 and15) based upon the sparse borehole information in DWAF's data base. Research is required to properly understand the occurrence of groundwater in this zone, where groundwater recharge is expected to be high.

Chevallier *et al* (2005) developed a GIS dataset indicating areas of high potential for the development of deeper-seated groundwater (> 150 m below surface) based purely upon regional tectonic-structural analysis of mapped dolerite intrusives and geological lineaments, as well as a conceptualisation of possible deep-seated water-bearing structural features (Figure 14). Further detailed research and ultimately deep exploration drilling is required to test the validity of this dataset, but if correct, would indicate that the problems of groundwater development along the coastal zone associated could be overcome by drilling deeper boreholes (150 to 300 m) on specific regional structural features. Figure 12 essentially indicates the potential for developing successful production boreholes within the shallow aquifer systems of WMA 12 as it is based partly upon yield analysis of boreholes that generally do not exceed a depth of 100 m. Comparing these two datasets would imply that the zone of high groundwater exploration potential to the east of Queenstown (Figure 12) is mostly associated with shallow water-bearing fractures, whilst high borehole yields in the area

between Mount Frere and Matatiele are likely to be associated with both shallow and deep-seated fracturing along specific structures.

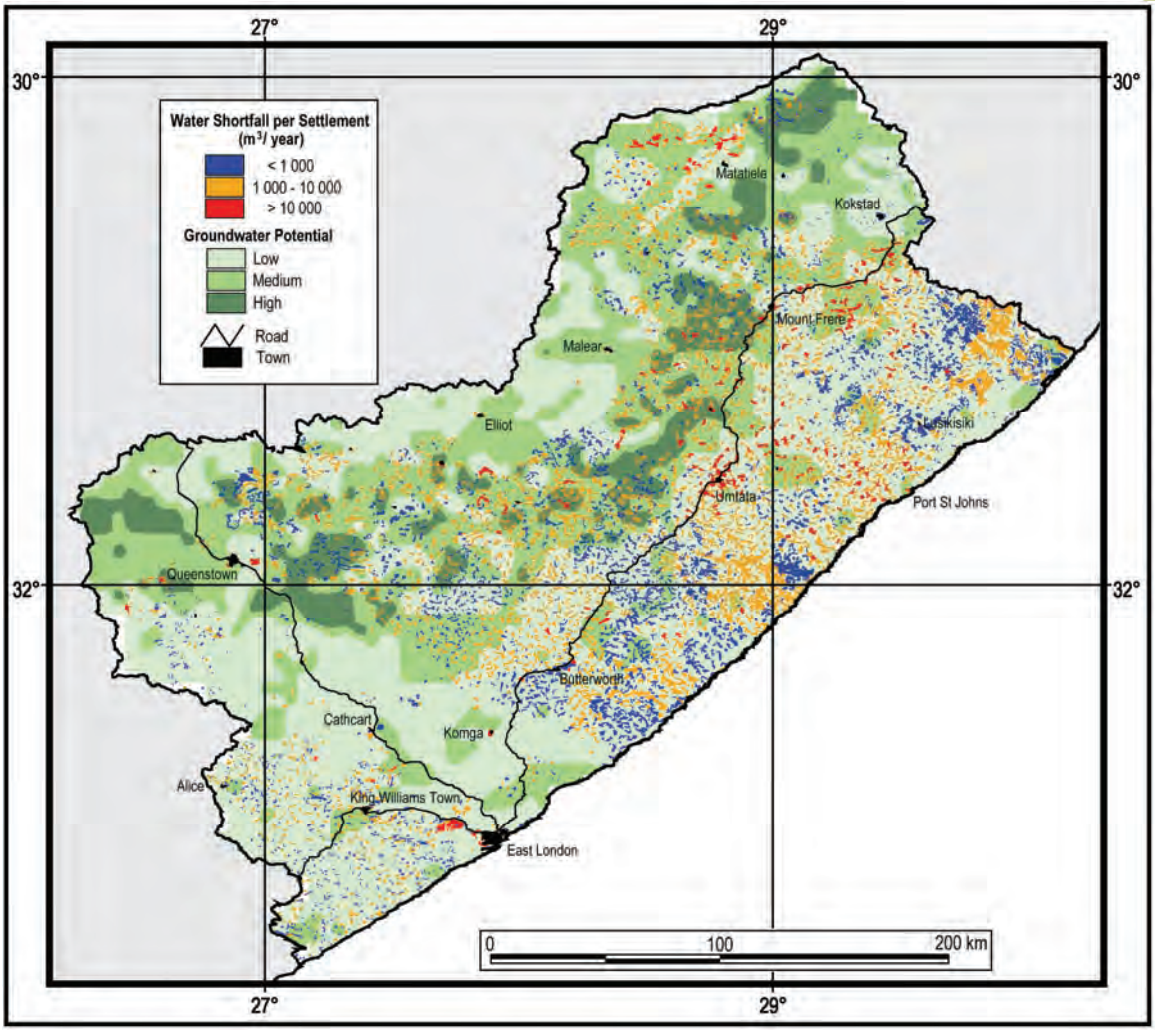

Figure 13 Annual Water Supply Shortfall below RDP Standards per Settlement versus Groundwater Exploration Potential for WMA 12

Most water resources related information and regional planning takes place at a Quaternary catchment scale and therefore the 'average' groundwater potential per catchment was estimated from the GIS coverage shown in Figure 12. Figure 15 is a visual presentation of the resultant 'average' groundwater potential and the number of persons within a Quaternary catchment without access to the RDP standard of 25 litres per day.

A large number of people in Quaternary catchments T60A, T60K, T36B and T80B (Figure 15) do not have access to a basic water supply of 25 litres per day. Locating sufficient groundwater to meet the water supply needs in this area may prove more difficult and costly than other areas as the groundwater potential is generally low (Figure 12). These results are based on regional assessment of

WMA12, where in some areas the data is either insufficient or totally absent. New, detailed geohydrological information for WMA12 is currently being captured by DWAF, as part of a groundwater information project initiative and Chevallier *et al* (2005) findings should be verified and possibly updated using this dataset – especially in areas known to be problematic for groundwater development and areas where previously no information was available.

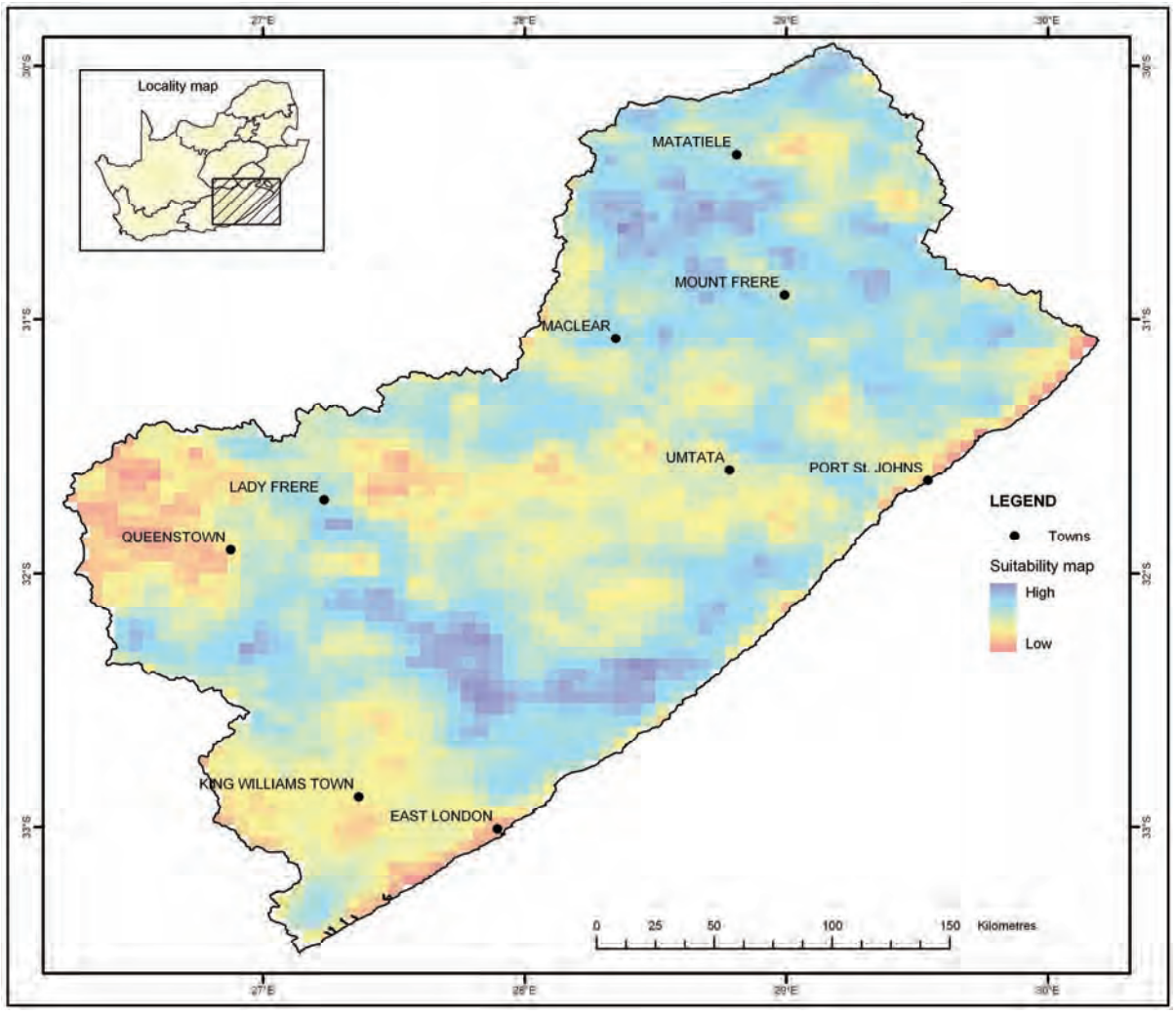

Figure 14: Suitability rating for the development of deeper-seated groundwater in WMA 12

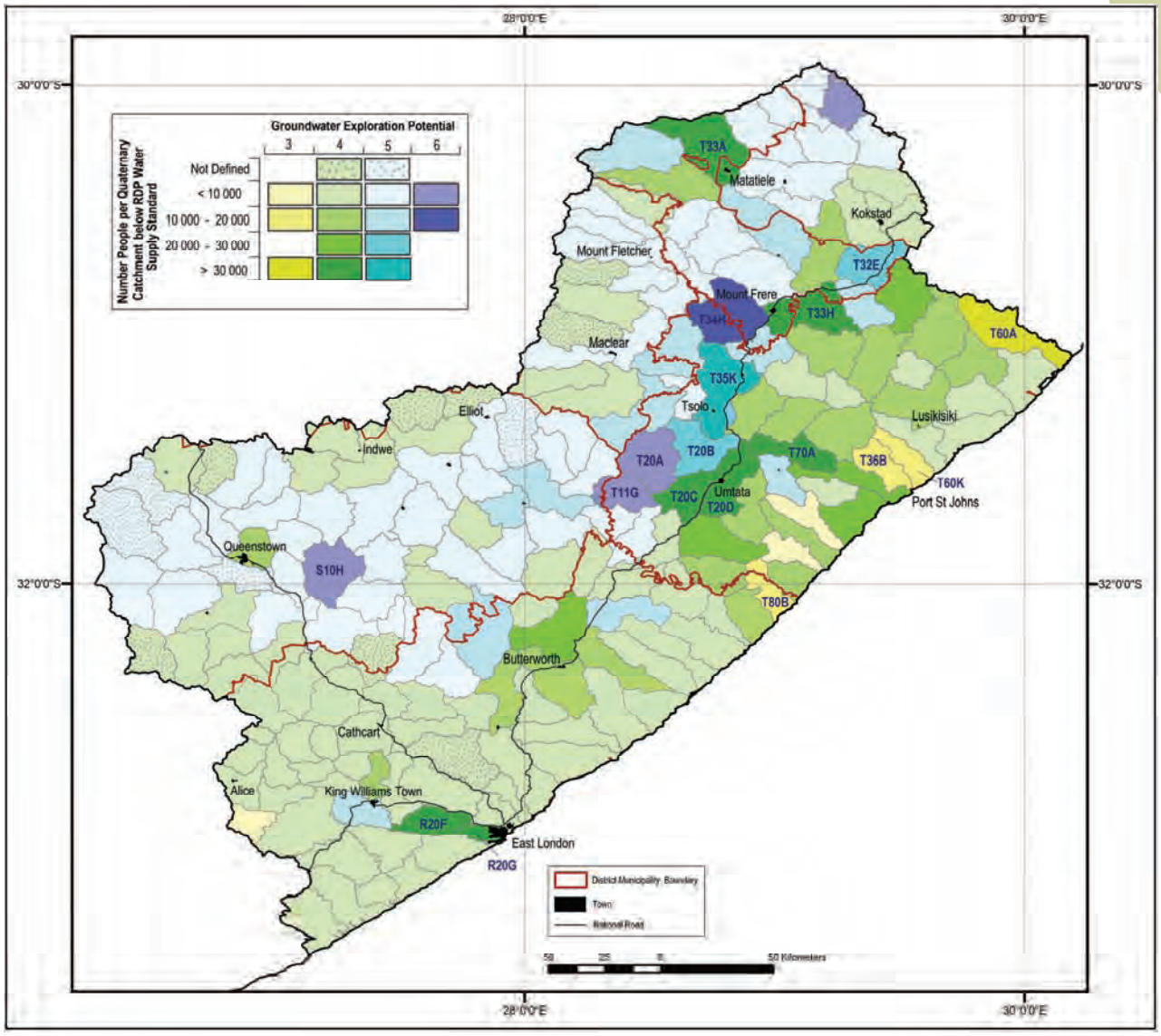

Figure 15: Mean groundwater exploration potential versus number of people per Quaternary Catchment with below RDP water supplies

7. Current Groundwater Projects

Groundwater resources in some parts of the Eastern Cape Province are currently being developed to provide clean drinking water. These projects are part of the on-going work of Water Service Authorities in providing and upgrading water supply infrastructure. The work is usually done by private contractors, working to the specifications of the relevant authority. These projects are aimed at specific communities and are intended to alleviate immediate water supply difficulties rather than to function as research. However, much useful data and information is currently being generated during the course of these projects, and this should not be ignored in any future research. This data needs to be assessed and incorporated, on an on-going basis, into the data sets to be used for research purposes. A good example of this is the current groundwater exploration in the northern parts of WMA 12, where borehole yields in excess of 30 ℓ/s have been obtained.

Two current projects are specifically aimed at enhancing our understanding of groundwater in the Eastern Karoo Basin, namely:

1) The Water Research Commission (WRC) is currently funding a three-year research project. The title of the project is '*Flow Conceptualisation, Recharge and Storativity determination in Karoo Aquifers, with special emphasis on the Eastern Cape (Mzimvubu to Keiskamma WMA) and KwaZulu-Natal Province (Mvoti to Umzimkulu WMA)*'. The project, which started in June 2005, will largely use existing data, although it does allow for limited field testing. Further work will be required in on-the-ground verification of the various hypotheses relating to groundwater occurrence and flow. DWAF is supporting this research initiative by providing drilling services (see Plate 8).

2) The GRIP project (Groundwater Resource Information Project) seeks to source and capture all groundwater information in the Eastern Cape Province onto a central database. The first phase of the project has been completed, and some 974 reports have been sourced by DWAF's Eastern Cape office. The data from these reports (e.g. borehole locations, yields, water quality, etc) need to be assessed and captured in a GIS system. It will need to be captured onto DWAF new groundwater archiving system, the NGA (National Groundwater Archive).

Plate 8 Exploration drilling on a large dyke (Photo by D Gqiba)

8. Future Groundwater Research in the Eastern Karoo Basin

Future regional geohydrological research projects in the Eastern Karoo Basin should focus on resolving the following two basic questions, namely:

1. *Where and how does groundwater occur?* Research should focus on delineating and understanding the different hydrogeological-tectonic domains, as well as flow dynamics within each domain.

2. *How sustainable are the groundwater resources?* This information is needed in order to optimally manage the resource, and to ensure sustainability from both a human and an environmental perspective. This includes both reliability and water quality issues.

In order to properly conduct the above research and ultimately implement the results, the following supporting issues need to be addressed:

1. *Data management*, and
2. *Awareness and education relating to groundwater use and management*

8.1 Primary Research Needs

8.1.1 Groundwater Exploration: Geological controls on groundwater potential

High yielding boreholes associated with Karoo dolerite intrusions

It is known that higher yields are often obtained from boreholes associated with dolerite intrusions such as dykes, rings and sills. The yields appear to differ depending on the geographical, geological and structural setting of the intrusions. Future research needs to build on past studies to answer certain important questions: What controls the occurrence of groundwater near or within dolerite intrusions in the Eastern Karoo Basin? Can the intrusions be hydrogeologically categorised according to type, size, depth or geographic location? Is it possible to identify optimum drilling targets in each type of intrusion? What is the interaction between regional tectonics and the formation of 'open' water-bearing fractures in or close to such intrusions?

Conceptual models on groundwater occurrence and flow need to be verified and enhanced. For example, it has been postulated that the major east-west dolerite dykes north of East London are capable of yielding significant quantities of groundwater, and at the same time, act as major regional barriers to flow. This type of hypothesis needs to be tested by scientific exploration drilling. This will include, among other things:

- Re-visiting and assessing boreholes of known high yields. Structural mapping and surface geophysical profiling in the vicinity of such boreholes, as well as pump-testing, in order to establish their geohydrological context.
- Detailed air-borne geophysics and geological mapping on selected areas.
- Exploratory drilling to confirm the existence of deeper-seated aquifers associated with regional fracture zones and dolerite intrusions, etc. Coring of selected holes.
- Water-strike analysis and assessment of water quality during drilling.
- Down-hole geophysical logging of boreholes to establish inflow horizons (water-bearing fractures), as well as to confirm the depth and geometry of dolerite intrusions, and to accurately determine lithological boundaries.
- Investigate the feasibility of hydro-fracturing marginal boreholes to increase their immediate yields by enhancing the fracture permeability in the vicinity of the hole and thereby increasing the overall drilling success rates of water supply projects.

It is envisaged that an output from such research could be a practical guide for borehole siting on Karoo dolerite intrusions.

High yielding boreholes associated with the country rock

In other words, do high yielding boreholes occur at localities away from any dolerite intrusions? Past research has indicated that such boreholes do exist. In such instances, what are the main controls on occurrence of 'open', water-bearing fractured zones in the Karoo country rock? If and how can such 'open' fractures be optimally located? Where are the best places to drill? Are there differences in groundwater occurrence depending on the lithostratigraphy (i.e. formation type)? Can our understanding of regional tectonics be put to practical use in locating water-bearing fracture zones?

Plate 9: Joints in sandstones showing evidence of past groundwater flow (Photo by R Murray)

Deeper-seated aquifer systems and regional groundwater flow

Several past studies have indicated that groundwater may exist in deeper-seated Karoo aquifer, possibly even exhibiting a more regional flow regime. This needs to be investigated. If present, how can such deep drilling targets be located? To what degree are deeper-seated aquifers in hydraulic connection with the shallower groundwater system, and how widespread are they? Are deep aquifer systems being actively recharged and would large-scale abstraction be sustainable? What is the quality of the deep-seated groundwater?

The permeability of Karoo aquifers is generally controlled by the nature and extent of fracturing. An understanding of fracture interconnectivity and networks assists in assessing sustainable groundwater use. How extensive are such fracture networks (for the various hydrogeological environments)? To what depth beneath the surface do typical water-bearing fractures extend? What are their orientations? Does regional groundwater flow occur in the Karoo Basin? Do deep-seated fractures contribute significant quantities of groundwater? How does water quality vary with fracture depth (or other fracture characteristics)? What, if any, are the topographical controls on the water-bearing properties of fractures? Amongst other things, such reserach would greatly aid in the conceptual and numerical modelling of the Karoo aquifers.

Plate 10 Artesian borehole at Makhoba near Matatiele (Photo by R Murray)

Complex hydrogeological environments

The coastal areas of the Eastern Cape are particularly problematic in terms of groundwater exploration and supply. This problem is particularly evident in the high population density areas between the Kei and Umzimvubu Rivers in the former Transkei. There is however a fairly high occurrence of dolerite intrusions and fracturing along this coastal strip. Have all the potential drilling targets been adequately assessed? Likewise, there are other problematic areas where the water needs are high, and where the potential for groundwater development still needs to be properly established.

Primary aquifers

Large quantities of groundwater are known to be stored in unconsolidated material such as alluvium and coastal dunes, as well as the underlying weathered bedrock elsewhere in the Karoo Basin. Do such environments exist in the Eastern Karoo Basin, and where do they occur? What is their extent? What is the relationship between them and the underlying Karoo fractured-rock aquifers? What is the quality of this groundwater?

Plate 11: Well in coastal dunes at Kleinemonde near Port Alfred (Photo by R Murray)

High-yielding aquifers (as opposed to high-yielding boreholes)

Known high-yielding aquifers need to be assessed to establish their geometry and maximum exploitable potential. These aquifers include those where storage and/or recharge seems to be far higher than the regional averages. Such aquifers could be developed for large-scale water supply schemes.

Plate 12: Centre-pivot irrigation from groundwater (Photo by R Murray)

Groundwater quality

Water quality needs to be studied for the purpose of enhancing groundwater occurrence and flow models, for delineating poor groundwater quality areas, for setting resource quality objectives, and to assist in protecting the groundwater resources from contamination.

Plate 13: A poorly sited borehole near a school pit latrine (Photo by R Murray)

Information on the age and geochemical evolution of groundwater in Karoo fractured-rocks will aid in the development of hydro-geochemical models and enhance the delineation of aquifer domains. This needs to include the analyses of stable and radio-isotopes, as well as CFCs.

It is known that poor groundwater quality, particularly high salinity, is a problem in parts of the Eastern Karoo Basin. This needs to be further investigated. Why is the quality poor – is it related to geological formations alone? These areas need to be mapped and causes of the poor water quality better understood. Saline intrusion has been recorded in some areas. What is the potential for saline intrusion along the Wild Coast? Can simple guidelines be established to guide drilling and pumping-rates to avoid saline intrusion? Are there other potential water quality problems that should be investigated before further development of the resource (e.g. trace elements such as fluoride or arsenic)? The topic of water quality is also closely related to the sustainability of the resource.

8.1.2 Sustainability and environmental impact: Environmental and anthropogenic controls on groundwater development

Recharge, aquifer storage and sustainable yields

An assessment of aquifer storage and recharge is critical for assessing sustainability and 'safe' abstraction rates. Past work on these areas needs to be applied and tested on conditions encountered in the Eastern Karoo Basin.

What are the main recharge mechanisms, and what confidence can be put on our quantification of each? Does the approach to assessing borehole yields need to be re-visited - especially when considering higher-yielding borehole or wellfields? This may need to take into account our understanding of the extent of local versus regional flow mechanisms.

Are there preferential areas of for enhanced recharge and aquifer storage (e.g. aquifers receptive to receiving snow-melts, deeply weathered zones, etc.) – how can these areas be located and qualitatively investigated?

Conduct pilot studies within different geohydrological settings to establish the maximum groundwater abstraction potential without any detrimental effects on the environment. These will include detailed monitoring of all factors that affect groundwater sustainability. Recharge, aquifer storage, permeability, discharge, waterlevel fluctuations, etc will need to be monitored over several seasons. This data, together with the other components of the water balance, such as rainfall and surface water flow, should be integrated into Quaternary catchment based water balance studies.

Long-term pumping-tests need to be conducted to verify the assumptions concerning aquifer sustainability. Besides groundwater levels, environmental indicators such as stream and spring flows will need to be monitored whilst pumping and during the recovery phases.

Plate 14: Test pumping a borehole in a water scarce village near Matatiele (Photo by R Murray)

Environmental impact

Little is known about the relationship between surface and groundwater, and on the impact of groundwater abstraction upon groundwater dependent ecosystems. These include springs, seepages, wetlands, vegetated zones, and baseflow to streams and rivers. What are these impacts and how can they be quantified? How much information do we have on groundwater dependent ecosystems in the Eastern Karoo Basin?

Groundwater dependent ecosystems could be mapped and monitored during trial abstractions in controlled study areas. Can guidelines be produced with the current status of our knowledge? Can alternatives be found (e.g. drilling to deeper aquifers and casing off the shallow zone) in more sensitive areas?

Changes in water quality

Stressing of an aquifer by pumping is known to affect groundwater quality. However, very few comprehensive studies have focused on the groundwater quality in the Eastern Karoo Basin.

What quality changes can be expected, and what are the controls on quality changes over time? (e.g. does older, deeper-seated, more saline, groundwater slowly begin to replace shallower groundwater). Given our conceptual understanding of Karoo aquifers, what are the possible impacts of anthropogenic sources of contamination (pit latrines, waste disposal excavations, etc.), particularly in more densely populated areas? Can simple source protection zones be simply delineated, and what guidelines can be established for the siting of boreholes close to sources of contamination? What are the possible impacts of industrial sources of contamination on groundwater, particularly given the planned industrial and economic development of certain key areas (e.g. the Buffalo corridor or Butterworth area)? How does the contamination of rivers from industrial areas affect groundwater (especially when considering potentially high yielding alluvial aquifers located beneath major river systems)? What is the fate of anthropogenic contaminants in fractured Karoo environments?

8.2 Support projects

8.2.1 Borehole and groundwater information (data capture and analysis)

The collection of appropriate data is essential not only for research purposes but also for the day-to-day aquifer management, as well as for developing long-term water resource planning strategies. In relation to groundwater occurrence, borehole information including depths, water strikes, drilling yields, geology and water quality needs to be captured in a spatially and statistically useable format. This will require updating and integrating various data sets, including the older National Groundwater Database (NGDB) and its replacement the National Groundwater Archive (NGA), as well as local initiatives such as the Eastern Cape Province's Groundwater Information (GRIP) Project.

In relation to sustainability, waterlevel, abstraction and water quality time-series data needs to collected. This information is crucial if aquifers are to be developed to their maximum capacity and managed in a sustainable manner. The following types of questions need to be addressed: What data should be collected, and how often? How should the data be assessed and presented in order to

provide useful information for Water Service Authorities? What other support in terms of data collection and analysis can groundwater professionals provide to the Water Service Authorities?

8.2.2 Knowledge transfer

The challenge is to develop accessible and workable tools and information that will aid the planners of the Province, as well as the groundwater practitioners, engineers and municipal administrators, in understanding their groundwater resources and how to manage them. This should not be an event that happens at the end of a research project, but an on-going activity that involves all stakeholders in the project so that learning and understanding evolves with time and becomes entrenched in the day-to-day work.

Skilled personnel are needed to operate, monitor and maintain borehole, wellfields and reticulation systems, and a system is needed to support and encourage the development of such skills. Unfortunately, much past research has only been accessible to a limited audience of groundwater professionals. What is needed is a shift to integrate the science of groundwater exploration and management into the mainstream of water supply and sanitation. More specifically, what is needed is to:

- Recognise that groundwater development takes place in a multi-disciplinary environment, and that inputs from other disciplines will enhance the work.
- Support university students in conducting MSc and PhD level research on groundwater topics in the Eastern Karoo Basin.
- Develop a field site for education and training purposes.
- Support the training of people (and if necessary organisations) in research techniques and data collection methods.
- Support the production of accessible guidelines and other material suitable for non-professionals, including universities and schools.
- Share all new information, for example, on high-yielding areas, with those in the water sector.
- Develop standard and accessible procedures for data collection and groundwater monitoring.
- Create a general awareness on groundwater occurrence and management.

9. Afterword

South Africa is a relatively dry, semi-arid country, and gets only about half as much annual rainfall as the international average. Water management and conservation is therefore of great importance. Groundwater, long neglected, is now being recognised as a valuable resource and as forming an integral part of the broader water cycle. The most important use for the water resources of South Africa is to provide basic domestic water supplies to people and communities, and this is now enshrined in the Constitution.

Some of the most poverty stricken and deprived areas in the country are to be found in the Eastern Cape Province. In some areas more than 90% of people lack access to safe, clean water and to acceptable levels of sanitation. This is a great hindrance to the development of the Province, and is a cause of huge suffering. The water problem has been clearly prioritised in the various planning documents as requiring urgent attention.

Groundwater has the potential to meet many of the requirements of the rural communities of the Eastern Cape Province. This is because it can be found close to where it is needed, it is generally of good quality, it is resistant to drought, and it requires little or no treatment before it can be used. Unfortunately, the Karoo fractured-rock aquifers underlying most of the Eastern Cape Province can be difficult to get water from and the resource is not well understood.

Researchers have studied the groundwater of the Karoo Basin in the past, and have produced much useful work. However, most of the work has been done in the western and central parts of the Basin. The majority of the population, and the most pressing water supply problems, are to be found in the eastern part of the Basin. Previous work has not always concentrated on the specific requirements of modern rural water supply schemes. Fundamental questions which still need to be clearly answered in the Eastern Karoo Basin include:

- Where are the best aquifers?
- How much groundwater can be used without harming the resource or the environment?

Current research initiatives are starting to address these questions. This needs to be supported on a scale that will contribute to the social and economic upliftment of the Eastern Cape Province.

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