THE PATH TO SUCCESSFUL WATER USER ASSOCIATIONS IN THE NORTH WEST DOLOMITE AQUIFERS

Report to the
Water Research Commission

by

Jude Cobbing, Kathy Eales, Theo Rossouw
Jude Cobbing Consulting

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Obtainable from
Water Research Commission
Private Bag X03
Gezina, 0031

orders@wrc.org.za or download from www.wrc.org.za

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K5/2429 FINAL REPORT

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

Abbreviation	Definition
CMA	Catchment Management Agency
DM	District Municipality
DWA	Department of Water Affairs (formerly DWAF)
DWAF	Department of Water Affairs and Forestry (former name of DWA)
DWS	Department of Water and Sanitation (formerly DWA/DWAF)
GMA	Groundwater Management Area
GMU	Groundwater Management Unit
GRIP	Groundwater Resource Information Project
HDI	Historically Disadvantaged Individual
IWRM	Integrated Water Resources Management
L/s	Litres per second
LM	Local Municipality
M^3/day	Cubic metres per day (i.e. thousand litres per day)
ML/d	Mega-litres per day (i.e. million litres per day)
MRCC	Magalies River Crisis Committee
NGA	National Groundwater Archive
NGS	National Groundwater Strategy
NORAD	Norwegian Agency for Development Cooperation
NWA	National Water Act of 1998
NWRS	National Water Resource Strategy
NWRS2	National Water Resource Strategy (Second Edition)
O&M	Operation and Maintenance
PAJA	Promotion of Administrative Justice Act
SAMA	Steenkoppies Aquifer Management Association
UGEP	Utilisable Groundwater Exploitation Potential
WRC	Water Research Commission
WSA	Water Services Authority
WSP	Water Service Provider
WUA	Water User Association

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1 EXECUTIVE SUMMARY

Weathered dolomite rocks of the Transvaal Supergroup form what are arguably South Africa's most important aquifers, supplying large volumes of very good quality water for urban municipal water supply, dispersed rural water supply, irrigated agriculture, industry, and other uses. In general the aquifers formed by the dolomites in North West Province are poorly managed, with consequences including declining groundwater levels, failing springs and the drying of wetlands. These issues in turn impact on the assurance of water supply to towns such as Mahikeng, Zeerust and Lichtenburg, and on the viability of certain agricultural activities and other livelihoods. Thus groundwater assurance of supply from the dolomite aquifers has important backward and forward economic linkages to the regional economy.

Water User Associations (WUAs) are the local-level organisations envisaged by the 1998 National Water Act as playing an important role in water management, but none have come into being in North West Province. The evidence suggests that where WUA applications were received by the then Department of Water Affairs and Forestry (now the Department of Water and Sanitation or DWS), these applications were rejected because they were thought not to have adequate transformative potential in terms of race and gender. DWS ultimately issued a moratorium on the approval of any new WUAs country-wide, and is in the process of formulating a policy for local water governance vested in the regional scale Catchment Management Agencies (CMAs), whose establishment is being fast-tracked.

The lack of viable local-level water management organisations (such as WUAs) has contributed to the poor management outcomes in the dolomites, including the decline of water tables and reduced assurances of supply. This is in the context of widespread mistrust and misunderstanding of the potential of groundwater from the dolomite aquifers, despite the relative wealth of hydrogeological information available for these resources. The failure of the WUAs has also contributed to declining levels of trust and goodwill amongst key groups of participants in the dolomites, which in turn contributes to further over-abstraction and other poor outcomes. At present it appears that a series of sub-optimal equilibria have become established with respect to groundwater use in the NW Dolomites, with implications that include higher costs, lower drought resilience and poorer social outcomes. The institutional issues raised by this situation will need to be taken into account by the future envisaged groundwater management organisations when these become active.

This report focuses on two main case study aquifers, the Grootfontein and Steenkoppies dolomite compartments, and uses a range of research tools including literature review and semi-structured field interviews, to illuminate and describe the issues outlined above.

2 INTRODUCTION

This Water Research Commission project (K5/2429 "The Path to Successful Water User Associations in the NW Dolomites") began in April 2015 and is scheduled to finish in March 2016. This report is the final written deliverable of the project. This project builds on work done in a previous WRC project titled "Favourable Zone Identification for Groundwater Development: Options Analysis for Local Municipalities" (K5/2158), which was completed in early 2014 (Cobbing et al., 2014). This previous project used the municipal water supply to the town of Mahikeng (a.k.a. Mafikeng), the provincial capital of North West Province, as a case study. It became apparent during the course of K5/2158 that a lack of the intermediate and local water management organisations mandated by the National Water Act of 1998 such as Catchment Management Agencies (CMAs) and Water User Associations (WUAs) was part of the reason why groundwater was not favoured by municipalities for domestic water supplies, and was partly to blame for the decline in water levels in important aquifers such as the Grootfontein aquifer supplying Mahikeng. Project K5/2158 also found that the environmental availability of groundwater, as well as the availability of "technical" or hydrogeological information on groundwater resources, did not appear to be primary reasons for the poor performance or failure of groundwater sources for domestic supply, particularly in the more deprived parts of South Africa that K5/2158 focused on. These reasons appeared to be more in the social or "institutional" realm, with poor operation and maintenance (O&M) of groundwater based domestic supplies being an important factor. In general, management provisions for groundwater resources were found to be insufficient or inadequate. In the long term the cost of poor groundwater supply performance is also considerably higher than the cost of maintaining management systems, including provisions for O&M.

This study focuses primarily on two case-study aquifers: the Grootfontein aquifer or dolomite compartment, and the Steenkoppies dolomite compartment. They were chosen because there is a relatively abundant amount of hydrogeological information for both aquifers, and both are also very important groundwater sources. The progress that each had made towards having a governing Water User Association (WUA) was also of interest to the research team.

Mahikeng has three main sources of water for municipal supply – groundwater from a spring (Molopo Eye) and from boreholes (Grootfontein boreholes), and surface water from the Setumo Dam. Since the water in the Setumo Dam is mostly (50-90%) effluent discharge and leakage from the town, Mahikeng is ultimately dependent on groundwater for most of its supply. In recent years the water levels around the Grootfontein boreholes have dropped considerably, threatening the sustainability of these sources. The Grootfontein boreholes pump water from a dolomite aquifer or compartment to the south-east of Mahikeng known as the Grootfontein compartment. This compartment is also heavily utilised for irrigated agriculture. Despite falling groundwater levels that threaten all Grootfontein users, there is currently no local organisation such as a Water User Association (WUA) that is addressing the deteriorating situation.

The Steenkoppies dolomite groundwater compartment is located near Tarlton, just west of Krugersdorp. Groundwater from the Steenkoppies Compartment supports a valuable irrigated agriculture industry, an important local employer. The compartment drains naturally via the Maloney's

Eye spring in the north of the compartment, the source of the ecologically important Magalies River. Drought and over-abstraction in the past have led to falling groundwater levels and diminishing flow at Maloney's Eye, leading to threats of legal action. Irrigating farmers have organised themselves into a proto-WUA, but this has not made the transition into a fully-fledged, legally approved WUA as envisaged in the National Water Act.

Final approval of Water User Associations rests with the Department of Water and Sanitation (DWS). After a period of policy uncertainty during which time no WUAs were approved by DWS, there are now indications that WUAs will never be approved and that existing WUAs will be disbanded. The functions previously held by WUAs will be carried out by the envisaged nine Catchment Management Agencies (CMAs). DWS is currently fast-tracking the establishment of CMAs, a process that will involve the movement of some DWS staff to the new CMAs.

This report describes the research work that was done in an attempt to understand the factors behind the slow progress with respect to local water management organisations such as WUAs. A research strategy based on extensive literature review and data analysis combined with field interviews with stakeholders in the case study areas was followed. Where possible, the principle of triangulation was applied to important research findings – in other words, a single source of evidence or mode of research needed to be backed up and confirmed by other sources and research methods before it was accepted. Research team members attempted to bring insights from the disciplines of economics, law and hydrogeology to bear on the case studies, reflected partly in the professional backgrounds of the research team. In this sense the study can be considered “multidisciplinary”.

This report begins with a summary of the literature review (chapter 2). In chapter 3 it then investigates the hypothesis that more progress was made at Steenkoppies than at Grootfontein towards forming a WUA due to Steenkoppies' higher agricultural value. This necessarily involved an examination of crop types, values and areas irrigated, together with field interviews. Chapter 4 describes the legal background with respect to WUAs in South Africa, and focusing particularly on Grootfontein and Steenkoppies. Finally, chapter 5 discusses evidence from interviews that shed some light on the reasons why no WUAs have been approved in the NW Dolomites aquifers, and discusses some of the apparent institutional consequences of this. This holds lessons for future groundwater management efforts, independent of the organisation mandated to carry this out.

Interviews with a variety of stakeholders were a major research tool in this investigation, and are explained in more detail in chapters 3 and 5. The list of interviewees interviewed for this research is shown as Table 2-1 below:

TABLE 2-1 LIST OF INTERVIEWEES

Province	Date	Location	Interviewee Role	Affiliation	Main interest
NW	6 March 2014	Hartbeespoort	Hydrogeologists (meeting)	Government Department	Groundwater assessment and management
Gauteng	17 March 2014	Pretoria	Hydrogeologist	University	Groundwater assessment and management
Gauteng	11 June 2014	Pretoria	Soil scientist and farmer	University and Water User Association	Groundwater irrigation, Water User Associations
Gauteng	2 November 2014	Pretoria	Executive	SA Irrigation Institute	Groundwater irrigation and energy use
NW	10 April 2015	Hartbeespoort	Hydrogeologist	Government Department	Groundwater assessment and management
Gauteng	22 April 2015	Pretoria	Hydrogeologist	Government Department	Groundwater assessment and management
NW	30 April 2015	Mahikeng	Hydrogeologist	Municipality	Groundwater assessment and management
Gauteng	4 May 2015	Pretoria	Engineer	Government Department	Groundwater licensing
NW	12 May 2015	Lichtenburg	Farmer	Agricultural union	Water and farming
NW	13 May 2015	Mahikeng	Engineer	Private consultancy	Municipal water supplies
NW	13 May 2015	Mahikeng	Hydrogeologists	Government Department	Groundwater assessment and management
NW	13 May 2015	Rooigrond	Farmer	Farmer	Grootfontein water use
NW	13 May 2015	Rooigrond	Farmer	Farmer	Grootfontein water use
NW	14 May 2015	Rooigrond	Farmer	Farmer	Grootfontein water use
Gauteng	26 May 2015	Pretoria	Engineer	Government Department	Groundwater and licensing
Gauteng	8 June 2015	Johannesburg	Engineers (meeting)	Private consultancy	Dam operating rules
NW	9 June 2015	Mahikeng	Various (meeting)	Government Department	Dam operating rules
NW	10 June 2015	Zeerust	Water expert	Government Department	Municipal water supply to Mahikeng
NW	10 June 2015	Groot Marico	Farmer	Farmer	Agricultural water planning
Gauteng	15 June 2015	Pretoria	Hydrogeologist	Private consultancy	Groundwater assessment and management
NW	22 June 2015	Mahikeng	Engineer	Municipality	Urban water supplies
NW	23 June 2015	Mahikeng	Engineer	Water Board	Urban water supplies
NW	24 June 2015	Mahikeng	Farmer	Farmer	Agricultural water use
NW	7 July 2015	Hartbeespoort	Hydrogeologist	Government Department	Water management
NW	9 July 2015	Mahikeng and Zeerust	Various (meetings)	Water Board	Rural groundwater supplies
NW	21 July 2015	Hartbeespoort	Hydrogeologist	Government Department	Groundwater assessment and management
NW	21 July 2015	Mahikeng	Hydrogeologist	Municipality	Groundwater assessment and management

NW	22 July 2015	Mahikeng	Engineer	Municipality	Urban water supplies
NW	22 July 2015	Mahikeng	Hydrogeologists	Government Department	Groundwater assessment and management
NW	22 July 2015	Mahikeng	Engineer	Water Board	Urban water supplies
NW	22 July 2015	Rooigrond	Farmer	Farmer	Agricultural water use
NW	23 July 2015	Rooigrond	Farmer	Farmer	Agricultural water use
NW	23 July 2015	Rooigrond	Farmer	Farmer	Agricultural water use
NW	23 July 2015	Rooigrond	Farmer	Farmer	Agricultural water use
NW	24 July 2015	Mahikeng	Various	Government Department	Regional water management
NW	24 July 2015	Rooigrond	Farmer	Farmer	Agricultural water use
Gauteng	11 August 2015	Pretoria	Hydrogeologist	Government Department	Water use licensing
Gauteng	12 August 2015	Pretoria	Various (meeting)	Government Research Agency	Grootfontein groundwater
NW	17 August 2015	Lichtenburg	Farmer	Farmer	Water management by farmers
Gauteng	12 October 2015	Pretoria	Soil scientist and farmer	University	Groundwater irrigation, economics of WUAs
NW	12 October 2015	Brits	Consultant	Private consultancy	Irrigation remote sensing
NW	12 Nov 2015	Lichtenburg	Farmer / executive	Agricultural union	Water and economic issues
NW	12 Nov 2015	Lichtenburg	Farmer	Agricultural union	Water and economic issues
NW	12 Nov 2015	Lichtenburg	Farmer and medical practitioner	Farmer	Water and health issues

3 LITERATURE REVIEW

3.1 FOCUS AND ORGANISATION OF THIS LITERATURE REVIEW

This literature review has two main strands. The first strand is the physical delineation, quantification and description of groundwater resources in South Africa, in the North West Dolomites, and in the Grootfontein and Steenkoppies dolomite groundwater compartments themselves. The second strand concentrates on the ideas, policies, organisations and other institutions relevant to the management of these groundwater resources.

These issues are organised conceptually in this review, beginning with a brief discussion of our national groundwater resources and the available information, followed by more detail on the groundwater of the dolomite aquifers of North West Province. More detailed discussion of the hydrogeological and management situation in the Grootfontein and Steenkoppies compartments then follows. These things together cover the first strand mentioned above ("technical" strand). The review of literature on the second strand starts with a broad discussion of the over-arching concepts and ideas that inform groundwater governance and policy, followed by a discussion of the organisations and institutions which must put this policy into practise ("institutional" strand).

Published documents on broader groundwater occurrence and governance come from a wide variety of sources including journals and books, research organisations such as the CSIR and the WRC, the World Bank, the Department of Water and Sanitation (DWS), and South African policy white papers, parliamentary proceedings and acts of parliament. Technical material on the Grootfontein and Steenkoppies Compartments on the other hand is mostly confined to a few journal papers and conference proceedings, WRC reports and the Geohydrology Report (GH) Series of the Department of Water and Sanitation.

3.2 GROUNDWATER IN SOUTH AFRICA

3.2.1 INTRODUCTION

This general introduction to groundwater in South Africa is based on, and draws from, the outputs of the WRC project K5/2158 “Favourable Zone Identification for Groundwater Development: Options Analysis for Local Municipalities” (Cobbing et al., 2014).

Groundwater can be called a “hidden resource”, since it can’t usually be seen – in the eyes of policy makers it is occasionally “out of sight and out of mind”. As Margat and van der Gun (2013:120) put it: “Most people have at best an incomplete notion of the groundwater resource they use and influence”. Groundwater is in fact much more important in South Africa and world-wide than most people think (UNESCO, 2004). More than 98 % of the world’s available fresh water is groundwater, and estimates of the global total volume of fresh groundwater in storage range from 7 million km^3 to as much as 60 million km^3 (Price, 1996). Groundwater is also the world’s most extracted raw material, with withdrawal rates in the region of 600 to 800 km^3 a year (UNESCO 2004, Shah et al., 2000). The breakdown of that figure into percentages is distinctly different from that of surface water use, and is biased towards more valuable potable water as follows: drinking water (65%), irrigation and livestock (20%) and industry and mining (15%) (IAH, 2003). At world level – and in proportions that vary widely from one country to the next – groundwater exploitation covers approximately 50% of drinking water needs, 20% of the demand for irrigation water, and 40% of the needs of self-supplied industry (UNESCO 2004). In countries such as Austria and Denmark groundwater supplies almost all drinking water.

Around two-thirds of South Africa’s population depends on groundwater for their domestic needs (Braune and Xu, 2006). Groundwater has been used in Southern Africa by people for millennia, both “directly” from springs and “indirectly” via baseflow to rivers and lakes. Johannesburg’s earliest safe water supply was groundwater, first from springs and then pumped from the dolomite aquifers to the south-west of the city. A major reason for Pretoria’s location is the prolific Pretoria Fountains spring to the south of the city centre, the town’s earliest water source. Both Pretoria and Johannesburg still rely on groundwater for a proportion of their water supply today (Dippenaar, 2013). Perhaps the most important role of groundwater is that it is critical to ecosystems and “environmental goods and services” – an area which has not received enough attention in the past. As Burke and Moench (2000) put it, “Groundwater is an often unnoticed and unacknowledged cornerstone in the foundation of many economic and environmental systems”.

"Of the 780 million [of the global population] not yet served [with a safe water supply], the majority of these predominantly rural people will need to be supplied from groundwater. Groundwater matters to the human race. We misunderstand or mismanage groundwater at our peril. The dispersed nature of groundwater and the generally large quantities in natural storage in aquifers make it particularly suitable for serving rural communities in times of uncertainty about the climate and the natural environment." (RWSN, 2012)

3.2.2 HOW MUCH GROUNDWATER DO WE HAVE IN SOUTH AFRICA?

Surface water resources in South Africa are nearly fully allocated for the country as a whole, and already over-allocated in some catchments (DWA, 2013). There is frequent mention of a potential "water crisis" in the media and elsewhere (e.g. Hedden and Cilliers, 2014). Our average annual rainfall of around 500 mm is well below the international average, and about a fifth of the country by area receives less than 200 mm of rain per year. Groundwater in South Africa is only about half allocated however – according to DWA (2010a) our total Utilisable Groundwater Exploitation Potential or UGEP is about 10.3 km^3/a under non-drought conditions, or about 7.5 km^3/a under drought conditions. UGEP represents the maximum groundwater yield that may be abstracted on a sustainable basis, given an adequate distribution of boreholes (Middleton and Bailey, 2009). Vegter (2001) estimated that in 1999 between 3.3 and 3.5 km^3/a was used in South Africa (Figure 3-1). It is estimated that we currently use between 2 and 4 km^3/a of groundwater in South Africa (DWA, 2010a and Woodford et al., 2006), most of it for agricultural purposes. Groundwater in South Africa is also in the same league, volumetrically, as our stored surface water resources. South Africa's dams have a total capacity of about 32 km^3 when they are full (DWA, 2004a). The "assured yield" of South Africa's surface water resources is considerably less at about 12 km^3 per year, and more than 80% of this is already allocated (Middleton and Bailey, 2009).

South African hydrogeologists have acknowledged for years that groundwater is underutilised in South Africa (e.g. Barnard, 2000). Under these circumstances groundwater would appear to be a viable option for expanding water supplies across the country in general, and the argument that groundwater is insufficient to meet our requirements (particularly for the relatively small volumes needed for domestic supplies) can be challenged. Groundwater is however rarely available in the huge quantities that a dam can provide, being limited by the yield of boreholes or wellfields and the properties of the aquifers. Groundwater development is also hampered by the issue of operation and maintenance of groundwater sources, leading to misconceptions about the reliability of the resource (Cobbing, 2015).

Groundwater availability at local level may be very different to the theoretical national average. Much work has been done in the past twenty years or so to estimate groundwater availability at national, district and local levels, relating groundwater occurrence to aquifer type, to recharge, to baseflow and environmental requirements, to natural groundwater quality, and to other hydrogeological or "technical" factors (see later in this chapter). Several of these efforts have also tackled the issue of "sustainability" – in other words, trying to quantify not only an expected borehole or aquifer yield, but whether that yield can be maintained without negative effects. Physical or hydrogeological groundwater "sustainability" is a study in its own right (e.g. Kalf and Woolley, 2005; Middleton and Bailey, 2009; or Sophocleous, 1997) and is more complex than it might appear. It becomes particularly important where large volumes of groundwater are required (e.g. for irrigation, or for urban water supplies).

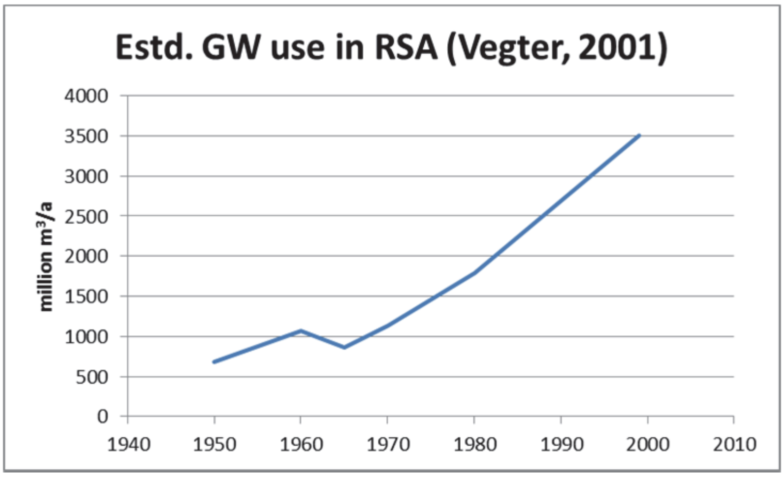

FIGURE 3-1 GROUNDWATER USE IN SOUTH AFRICA SINCE 1950 (AFTER VEGTER, 2001)

3.3 INTRODUCTION TO GROUNDWATER AND LAW IN SOUTH AFRICA

Law and policy concerning groundwater in South Africa has greatly changed since the first democratic elections in the country in 1994 (Braune et al., 2014). Earlier groundwater legislation (e.g. the Water Act of 1956) was based on the principles of Roman-Dutch law. Under this system, the rights to groundwater were held by the owner of the overlying property, who could essentially abstract groundwater with little or no control (DWA, 2010a). In 1912 the Irrigation and Conservation of Waters Act, dealing mainly with irrigation, gave priority to agricultural activities. The Water Act of 1956 entrenched the idea of most groundwater (as well as "private" surface water such as streams) as a private resource, and there was no obligation to share resources equitably (Pietersen, 2004). The state had little control over private groundwater, except where groundwater had been declared part of a "subterranean government water control area", a category applied to relatively few locations. Taken together, these measures greatly complicated regional groundwater assessment and management, since it had the effect of defining groundwater as a local and "private" resource in law if not in reality (DWA, 2010a). Today, South Africa's groundwater is recognised as a common asset whose ownership is vested in the state (Braune et al., 2014). The National Water Act (RSA, 1998) recognised groundwater as public water, a radical change compared with former legislation. A fuller description of modern South African water law is found in chapter 4 of this report.

3.4 AMBIVALENCE TOWARDS GROUNDWATER IN SOUTH AFRICA

In the 1970s Raymond Nace of the United States Geological Survey referred to the tendency amongst government officials and planners to generally ignore groundwater and to skew planning resources and expertise towards surface water as "hydroschizophrenia" (Llamas, 1985). The Spanish hydrogeologist MR Llamas wrote in 1985 that "until recently, groundwater was something of a mystery to most Spanish engineers and scientists, almost a kind of occult science, within the province of water diviners" (Llamas, 1985:161). The same can sometimes be said about South Africa. A practical outcome of hydroschizophrenia is the neglect of groundwater assessment and management at the planning level. In South Africa the regulatory environment may have moved ahead of the technical and engineering community, who still tend to gravitate towards surface water solutions or surface water management approaches (geared to phenomena such as relatively rapid changes in response to rainfall) (Riemann et al., 2012). Essentially, professionals in the technical and planning community in South Africa may still be suffering from hydroschizophrenia. This is partly because our old groundwater laws made regional management difficult, and partly because considerable attention has been paid in South Africa to large surface water schemes (e.g. the Lesotho Highlands Water Project or the Vaal Dam), and surface water inter-basin transfers (which link surface water sources to large conurbations) (Braune et al., 2014). There are also relatively few qualified hydrogeologists working in South Africa. It is worth remembering that our basic water planning unit – the catchment – reflects surface water flow, not necessarily groundwater.

There is also evidence that groundwater sources are seen as less "sophisticated" than surface water sources, particularly where the groundwater source is a hand pump and surface water is delivered via a tap direct to a dwelling (Harvey and Reed, 2004). Reliance on groundwater in rural settlements is also still widely associated with the former 'homelands', where boreholes were the default rural water source in a context of severe under-development; management and maintenance by the designated authorities was generally profoundly under-resourced, and reliable supply was often a function of local initiative rather than formal management.

3.5 ADVANTAGES OF GROUNDWATER

Groundwater has advantages over surface water which can make it suitable for domestic water supply, especially in rural areas where technical skills, funding and materials may be in short supply, or where only small quantities are needed (Pietersen, 2005). These advantages are summarised as follows (Cobbing et al., 2014):

- Groundwater is a "proximal resource", meaning it is usually found close to where it is needed
- Groundwater is resistant to the effects of drought
- The natural microbiological quality of groundwater is usually good – but precautionary treatment is nevertheless usually recommended
- Groundwater can be developed incrementally as funds and skills permit and as increasing demand dictates.

These advantages do not mean that groundwater is a “cheap option”, or that it requires lower levels of skills and planning compared with surface water supplies. Both surface water and groundwater have advantages and disadvantages and these need to be understood in the particular context of each scheme. Groundwater is nevertheless very important for domestic water supplies in South Africa, particularly in rural areas. As Hassan et al put it in their analysis for the World Bank, groundwater in South Africa “represents a key source of water supply especially in rural semi-arid areas and mainly for irrigation and domestic use” (Hassan et al., 2008:5).

3.6 Hydrogeological Assessment and Planning Tools in RSA

It is sometimes said that we cannot properly quantify our groundwater resource in South Africa or that its physical reliability is questionable, and this is sometimes given as a reason for choosing other water supply options such as desalination (Riemann et al., 2012). For example, the Water for Growth and Development Framework published by the Department of Water Affairs stated “Although groundwater is widely accessible and often close to the point of use, planners and consumers frequently either do not recognise it as a resource, or shun it as inferior to surface water” (DWA, 2009:29). The Framework goes on to say (DWA 2009:29) “At present, the country lacks the depth in skills and leadership in hydrogeology to drive the understanding and acceptance of groundwater from national down to local management level. Steps must be taken to strengthen geohydrological skills and build technical training capacity at institutions across the country.”

The implication of this is that it is “technical” skills in groundwater or similar issues that are at least partly to blame for the preference for surface water and the under-utilisation of groundwater. However, a contention of this research is that the problem is considerably more complex than a lack of technical information alone – and that in fact a focus on the technical issues can derail necessary work into the real reasons for the under-utilisation and mismanagement of groundwater in South Africa.

Major past efforts to quantify groundwater resource availability in South Africa have in fact been made, including in some cases tools for decision makers to assess the physical sustainability of groundwater as a supply in any particular area. Most of these resources are available free of charge and can be downloaded from the web. Hydrogeological maps can be purchased from DWA. A list of some of the most important of these tools is given below. (See Cobbing et al (2014) for more details.)

- The DWS National Groundwater Archive and the DWS WARMS database
- The maps and reports on Groundwater Regions initiated by Vegter (2001)
- The National Series Hydrogeological Maps (Vegter, 1995)
- The National Harvest Potential Maps (Baron et al., 1998)
- The NORAD Toolkit for Water Services (DWA, 2004b)
- The DWS Guideline for the Assessment, Planning and Management of Groundwater Resources in South Africa (DWA, 2008a)
- The DWS GRIP databases (Botha, 2005)
- The DWS South African Groundwater Decision Tool (SAGDT) software (DWA, 2006b)

- The National Groundwater Strategy (DWA, 2010a)
- Numerous Water Research Commission outputs including the Groundwater Assessment Methodology (K5/2048) and the Delineation of High Yielding Areas in the Karoo (K5/1763)

These desktop tools available in South Africa described above do not mean that groundwater development can be done without suitable field investigations by qualified hydrogeologists, and they were never intended to replace fieldwork. Such investigations might involve the geophysical siting of boreholes, trial drilling, pumping tests, delineation of protection zones and other fieldwork. Once established, groundwater schemes need to be monitored and the conceptual model updated, in line with the principle of adaptive management (Seward et al., 2006). The following quote by Vegter (2001:xi) summarises the problem:

"*The yield of a geohydrological unit can definitely not be determined or estimated prior to its development – at best it can only be guessed. It is only through exploratory drilling and testing that the hydraulic structure of a geohydrologic unit and its spatially variable hydraulic parameters may be determined. Even then, because the pattern of the permeable fractures in the hard rock formations (comprising 90 % of S.A.'s area) is generally unknown and does not necessarily conform to a simple regular system for which theoretical models have been developed, reliable evaluation of parameters (mostly double-porosity) may be very problematic. Numerical modelling on any such geohydrologic unit requires an inordinate amount of (borehole) data. If, in addition, the wide margin of uncertainty about recharge values is taken into account, prediction of long-term water level response to groundwater abstraction would appear to be highly questionable and a fruitless exercise*."

3.7 MANAGEMENT OF GROUNDWATER RESOURCES IN SOUTH AFRICA

3.7.1 WHAT IS GROUNDWATER MANAGEMENT?

"By far the most serious groundwater challenge facing the world, then, is not in developing the resource but in its sustainable management" (Shah et al., 2000:8)

A hundred years ago borehole drilling and pumping technology was primitive and "management" of groundwater resources rarely entered anyone's thoughts since only small amounts of groundwater were abstracted from shallow aquifers. But in the last fifty years a huge boom in global groundwater development has taken place, most of it for irrigation purposes (Mukherji and Shah, 2005). Konikow and Kendy (2005:317) state that "In the past half-century, ready access to pumped wells has ushered in a worldwide "explosion" of groundwater development for municipal, agricultural and industrial supplies". In 2000 it was estimated that 750-800 km^3 of groundwater was abstracted globally per annum (Shah et al., 2000). More recently, Margat and van der Gun (2013) estimate that 986 km^3 of groundwater is being abstracted worldwide. The South African Groundwater Strategy estimated that between 2 to 4 km^3 was abstracted every year in South Africa, roughly half of the sustainable total (DWA, 2010a). Margat and van der Gun (2013:123) estimate that 2.84 km^3 of groundwater is abstracted annually in South Africa, 10% of this volume for public water supply, 6% for industry and

84% for agriculture (irrigation). Nowadays over-abstraction, salinization and pollution of groundwater are serious problems in many parts of the world, leading to debate about how best to manage groundwater and giving rise to a growing literature on groundwater management or governance. Saline intrusion, land subsidence and ecological damage are other downsides to this “explosion”, but the benefits to people and societies have also been immense. Today most agree that groundwater management / effective governance is needed to slow down or prevent deterioration of this “common pool” resource and that this is in everyone’s long-term interest. Growing populations and climate change complicate the picture.

As a recent publication by USAID puts it: “Subterranean water resources pose particularly acute governance challenges. They require sophisticated technology and significant knowledge to be sustainably managed. By contrast, even when surface water is not systematically measured it can, at a minimum, be visually monitored. As a result, groundwater resources are at heightened risk of unsustainable consumption, pollution, and uninformed perceptions with regard to quantity and quality of available resource.” (USAID, 2014)

Whilst groundwater management must be anchored in a sound scientific understanding of the resource, a multi-disciplinary approach is needed to make sure that chosen management measures are effective, accepted and sustainable (Braune et al., 2014). Insights from other disciplines are vital since groundwater use cuts across many social, economic, political and geographical boundaries, at a variety of time-frames and geographical scales. Much of the work of hydrogeologists is aimed ultimately at better groundwater management, but to see groundwater management as essentially about hydrogeology and not also about the wider context in which groundwater is used is a shortcut to misunderstandings and frustration.

3.7.2 GROUNDWATER DATA AND GROUNDWATER MANAGEMENT

Shah et al (2000) urge a global move towards better groundwater management, pointing to numerous examples of over-abstraction, pollution, salinization and other disbenefits. One essential pillar of management is a physical understanding of the resource. “A major barrier that prevents transition from the groundwater development to management mode is lack of information. Many countries with severe groundwater depletion problems do not have any idea of how much groundwater occurs and who withdraws how much groundwater and where.” (Shah et al., 2000:14). Put another way, “you can’t manage what you don’t measure”.

The following recommendations were made with respect to improving monitoring of groundwater systems in South Africa in the GRA3 component of the work done towards the National Groundwater Strategy (DWA, 2010a):

- Recognition of lateral and vertical heterogeneity of aquifer systems, i.e. borehole clusters targeting different aquifers overlying each other, enabling differentiation of water level and quality data for each aquifer unit as well as the determination of leakage factors, i.e. the hydraulic interaction between these aquifers.
- A higher density of rainfall stations for important catchments is needed

- Determination of specific yield/storativity values will require neighbouring boreholes within the same aquifer unit (vertical and horizontal)
- Monitoring boreholes drilled and equipped according to best practice (e.g. steel, PVC or stainless steel casing, gravel packs, screening depth and prevention of hydraulic shortcuts between aquifers)
- Strategic review of existing monitoring borehole network (spatial distribution and sampling frequency) to increase efficiency of spatial coverage (i.e. some neighbouring boreholes might be omitted while others should be drilled)
- Randomly drilled boreholes for unbiased estimates of aquifer properties
- Usage of springs as integral monitoring point (discharge and quality) for upstream catchments (requires additional early warning boreholes)
- Long-term monitoring must continue (no model will ever replace measurements)

Many of these recommendations are unlikely to be realised in the near future, but they can be regarded as targets to be worked towards. Concentrating on areas where groundwater abstractions are critical (e.g. sole source aquifers or areas of high agricultural value due to groundwater irrigation), or where pollution is a known problem, is recommended. In many parts of South Africa monitoring of groundwater resources is in decline (Pietersen and Lenkoe-Magagula, 2013), but DWS are currently (2016) developing a strategy towards a new, integrated hydrological monitoring system that promises to reverse earlier setbacks.

3.7.3 GROUNDWATER MANAGEMENT VERSUS GROUNDWATER GOVERNANCE

A distinction is made between “management” and “governance”, with the former indicating a narrower range of issues including hydrogeological modelling and the application of laws and regulations, whilst the latter implies a broader range of issues at different levels with a bearing on all stakeholders (Mukherji and Shah, 2005). For example, Mukherji and Shah (2005:339) state that a principle problem in groundwater is “the misallocation of roles and responsibilities assigned to various organisations that are in the business of governing groundwater. Thus, central and provincial governments are very often given responsibilities that are beyond their human and financial resources, while farmers and other stakeholders are asked to participate in aquifer management when their direct interests lie in non-participation”. Another way to think of this is that management is “*de jure*” – following formal laws and procedures, whilst governance is “*de-facto*” – a focus on what really happens in the chaotic business of groundwater, and of which formal laws are only a part.

The project “Groundwater Governance. A Global Framework for Action” is perhaps the flagship international programme investigating mechanisms for better groundwater governance at present. It is funded by the World Bank’s global environment fund (GEF) and implemented by the Food and Agriculture Organization of the United Nations (FAO) together with UNESCO's International Hydrological Programme (UNESCO-IHP), the International Association of Hydrologists (IAH) and the World Bank (GWG, 2014). The 4.5 M USD project, which started in June 2011 and runs until June 2014, is “designed to raise awareness of the importance of groundwater resources for many regions of the world, and identify and promote best practices in groundwater governance as a way to achieve the sustainable management of groundwater resources" (GWG, 2014). After a first project phase in which a review of the global situation with respect to groundwater governance was carried out, a second phase will lead to the main project outcome which is a "Global Framework for Action". The first phase included case studies, thematic papers and five regional consultations. The second phase consists of a set of policy and institutional guidelines, recommendations and best practices aimed at various geographical levels. The five regional consultations done as part of the first phase were divided into Latin America and the Caribbean, sub-Saharan Africa, the Arab States, East and Southeast Asia and the Pacific, and the UNECE region. Resources and outcomes of the project are available at the project website (GWG, 2014).

Groundwater governance, as investigated by Groundwater Governance project members, shares with other water governance a need to be "accountable, transparent and participatory" (GWG, 2012a), but does have requirements that are particular to groundwater, based on the distinguishing characteristics of groundwater and aquifers. These include the common perception that groundwater is a private resource (ironically, groundwater is usually viewed as a classic "common pool" resource (e.g. Ostrom, 2005) by institutional experts), the need for groundwater management to include consideration of baseflow to rivers, the susceptibility of groundwater to diffuse land-use practises, inherent long time-frames, and so on (GWG, 2012a). The general lack of resolution provided by existing groundwater data has led to management approaches that take uncertainty into account such as adaptive management (Seward et al., 2006) but which do not necessarily dovetail with management of other water resources. The Groundwater Governance project has distilled the following definition of groundwater governance, and quote it in their synthesis paper (GWG, 2012a:14):

"Groundwater governance is the process by which groundwater is managed through the application of responsibility, participation, information availability, transparency, custom, and rule of law. It is the art of coordinating administrative actions and decision making between and among different jurisdictional levels – one of which may be global."

3.7.4 INSTITUTIONS AND ORGANISATIONS

Institutions are fundamental to how and why we govern (or try to govern) water resources, including groundwater. Essentially, institutions are the rules that govern our behaviour. As Elinor Ostrom puts it: "Broadly defined, institutions are the prescriptions that humans use to organise all forms of repetitive and structured interactions, including those within families, neighbourhoods, markets, firms, sports leagues, churches, private associations, and governments at all scales. Individuals interacting within rule-structured situations face choices regarding the actions and strategies they take, leading to consequences for themselves and for others" (Ostrom, 2005:3). Institutions and institutional analysis can be a powerful way of analysing social behaviour and the collective "behaviours" (customs, habits, formal rules, etc.) that underpin formal organisations. Institutions can be formal, informal, tangible or abstract. Languages, moral and social norms, customs etc. (informal institutions) are given expression in laws (formal institutions).

Organisations on the other hand are formally constituted, funded and staffed entities, usually with a specific legal mandate and formal tasks and functions. The Department of Water and Sanitation is an organisation which anchors existing institutions (formal and informal) as well as promoting new ones which have been formalised (e.g. the South African Constitution, the National Water Act) elsewhere. Individuals create institutions, and are in turn shaped by them – a chicken / egg situation. We may be tempted to think that individuals' choices matter more than the institutions (often codified choices of individuals around them) that shape, guide and direct them – but this is not so. Nevertheless, individual decisions are often given more prominence or may be easier to understand and debate than the relevant underlying institutions. "Institutional structures constrain or empower individuals, and frame their incentives and disincentives" (Hodgson, 2009). For any complex administrative systems, it's important to understand how different institutions function and interact. Much of what we are doing in South Africa regarding water involves the interaction and change of many institutions. It is tempting to make "right and wrong" judgements about institutions, but that tendency too is an institution, and codified by other institutions in turn.

Some of the literature on water management does not distinguish clearly between "institutions" and "organisations", and the two terms are sometimes used synonymously. All organisations are institutions (comprising nested sets of formal and informal institutions) but only a few institutions can be called "organisations". The confusion may be heightened by the use of the word "institute" as a synonym for an (often academic) organisation. This study uses the word "institution" in the sense of a rule guiding repetitive social behaviour (formal or otherwise), and "organisation" to refer to formal, bricks-and-mortar entities usually with staff bodies or memberships, budgets and premises such as the Department of Water and Sanitation.

3.7.5 ORGANISATIONS MANAGING WATER IN SOUTH AFRICA

Contemporary South African law provides for a number of interlocking organisations, cutting across spheres of government, mandated to manage domestic water supplies and sanitation as well as the overall assessment and management of the national water resource. These include the Department of Water and Sanitation, Water Services Authorities, Water Boards, Water Service Providers, and Professional (water) Services Providers. Some of these organisations are constituted, funded and effective, and some are not. Catchment Management Authorities (CMAs) and Water User Associations (WUAs) as envisaged in the National Water Act are very important, yet are absent in many parts of South Africa. Other government departments, such as Environmental Affairs and Minerals and Energy, have important roles to play in water management too.

A major potential strength of the organisational landscape for water management in South Africa is the fact that water management should theoretically take place with all stakeholders involved, ensuring a more equitable and efficient distribution of benefits and disbenefits, according to the dominant discourse of IWRM in any case. This strength however can easily become a weakness when one considers the sheer size of the organisational effort that needs to be devoted to dialogue, trust-building, budgeting, logistics and other practical matters.

3.7.5.1 Catchment Management Authorities

One of the “elephants in the room” of South African water / groundwater management is the absence of the Catchment Management Authorities (CMAs). CMAs are envisaged as the organisations with the authority to manage water resources on a regional scale, yet with sufficient local input. Originally their boundaries of jurisdiction followed South Africa’s 19 main surface water catchments, in keeping with IWRM principles (and as opposed to municipal, provincial or other “political” boundaries). By about 2014 only two CMAs had been established (i.e. since the 1998 National Water Act). Consequently the overall number of CMAs has recently been reduced to 9 in an attempt to fast-track these organisations (DWA, 2013, and Braune et al., 2013). The National Development Plan states that water resource management institutions should be implemented by 2015 at the latest (RSA, 2012).

In the absence of the CMAs, the DWA regional offices are mandated to carry out the tasks that would otherwise fall to the CMA (DWA, 2004a). It is probably fair to say that establishment of the CMAs has not been a political priority over the last decade and a half – the problem is a complicated one, but the net effect on water management functions at local and regional level has not been positive.

3.7.5.2 Water User Associations

The scarcity of Water User Associations (WUAs) is a second elephant in the already-crowded room that is contemporary South African water governance. WUAs are an important form of cooperative local management of water resources provided for by the National Water Act, envisaged as the key organisations at local level. A Water User Association (WUA) is “a co-operative association of individual water users who wish to undertake water-related activities for their mutual benefit.” (DWA, undated). A WUA is regarded in law as a body corporate, able to borrow money, open bank accounts and enter into legal proceedings. WUAs may represent one sector (e.g. irrigating farmers), or many sectors (e.g. farmers, miners and forestry workers). The Minister of Water Affairs must establish a WUA, once she is satisfied that it is in the public interest and that wide public consultation has taken place (DWA, undated). WUAs are generally funded through charges to their members, although in certain circumstances (e.g. WUAs primarily composed of HDIs) the state may assist with funding. Former irrigation boards and subterranean water control boards are required to become WUAs, and this process must incorporate a measure of transformation in terms of management structure (DWA, 2004a). The final powers and functions of a WUA, once established, are delegated by the Minister, who may also remove functions and even dissolve the WUA under certain circumstances (DWA, undated).

WUAs allow better control of joint finances and equipment; simplify negotiation with regulators and other stakeholders; facilitate debate and collective decisions; and consolidate joint interests. Where over-abstraction is a problem and there is potential for conflict between different groups of water users (e.g. dolomite compartments), a WUA would help to resolve problems before they arose.

A recurring problem with WUAs is the time and effort needed to set one up – as a result they do not exist in many areas where they would be beneficial, including across the whole of North West Province. As mentioned, the policy momentum in South Africa today appears to be towards the dis-establishment of WUAs and their replacement with the newly invigorated CMAs.

3.8 OVERVIEW OF GROUNDWATER IN THE NW DOLOMITES

The dolomite aquifers in North West Province (known as the North West Dolomites) are the main case-study area for this research, particularly the Grootfontein and Steenkoppies groundwater compartments. The following sections briefly summarise some of what is known about these aquifers, and describe some of the ongoing management issues (Cobbing et al., 2014).

The dolomite deposits of the North West Province cover an area of about 5 000 km^2 from the Botswana border near Lobatse, towards Zeerust and Lichtenburg where they broaden into a west-east trending zone from Mafikeng in the west to Ventersdorp in the east. Figure 3-2 shows the outcrop area of the North West dolomites. Whilst the primary porosity and hydraulic conductivity of dolomite is poor, weathering and karstification in the NW dolomites makes them prolific aquifers where the thickness of the deposits allow. Weathering is limited by overburden and at depth aquifer characteristics are generally poor. The NW dolomites are located in the Crocodile West Marico, Middle and Lower Vaal Water Management Areas. More detailed information about the geology and hydrogeology of the NW dolomites is available from Council for Geoscience (2008) and EMA (2003).

The NW dolomites are arguably the most important aquifers in South Africa, supporting not only valuable irrigated agricultural activities, but also underpinning the water supply to several towns (e.g. Zeerust, Groot Marico, Ventersdorp and Lichtenburg – see Stephens et al., 2005). The city of Mahikeng (capital of North West Province) is dependent on groundwater from the Molopo Eye natural spring and the wellfield at Grootfontein. Some re-use of wastewater from the Setumo Dam is also used, but this water originates as water from the two groundwater sources. Water from the Molopo Eye and the Grootfontein wellfield is piped to the Mafikeng Water Treatment Plant, where precautionary chlorination takes place, after which it is pumped to the town. Figure 3-3 shows the main water supply infrastructure at Mafikeng.

3.8.1 GEOLOGY OF THE NW DOLOMITES

Dolomite rocks of the Transvaal Supergroup form curved outcrops to the east and west of Gauteng Province (Malmani Subgroup of the Chuniespoort Group) as well as a triangular plateau east and south of Kuruman in the North Western Cape Province (the Ghaap Group). Formed around 2.7 billion years ago and as much as 2 km thick in places, the dolomites have been tectonically deformed and faulted, and are intruded by volcanic dykes and other structures (Johnson et al., 2006). They are thought to have been deposited in shallow marine environments as a chemical precipitate and also in association with algal mats and structures called stromatolites (some of the earliest recorded life on earth) (McCarthy and Rubidge, 2005). In outcrop, dolomite is a fairly hard, greyish to brown rock which may weather to a surface “elephant skin” texture. They are divided into different formations based partly on the chert content. The NW dolomites are made up of the Eccles, Lyttelton, Monte Christo and Oaktree Formations, which together comprise the Malmani Subgroup of the Chuniespoort Group (Johnson et al., 2006). The Eccles and Monte Christo Formations are chert-rich, whilst the Lyttelton Formation is chert free. The chert-rich Eccles and Monte Christo Formations are more susceptible to weathering and as a result have higher coefficients of storativity and transmissivity, and are better aquifers (Holland and Wiegmans, 2009). The Monte Christo Formation can be divided into three sub-formations or members (Table 3-1). The entire sequence dips to the north underneath the Pretoria Group.

TABLE 3-1 FORMATIONS OF THE MALMANI SUBGROUP (AFTER CGS, 1991)

Symbol	Formation	Description
Vf	Frisco	Stromatolitic dolomite, chert-poor dolomite, shale
Ve	Eccles	Interbanded dolomite and chert
Vl	Lyttleton	Chert-poor dolomite
Vmo_3	Monte Christo	Chert-rich dolomite
Vmo_2	Monte Christo	Interbanded chert and dolomite
Vmo_1	Monte Christo	Oolitic chert and dolomite
Vo	Oaktree	Chert-poor dolomite

Superficial deposits overlie the NW dolomites in places, including the following (Stephens and Bredenkamp, 2002):

- Alluvial gravel (and calcrete) in places over 20 m thick
- Alluvium consisting of black organic clay derived from decomposed reed beds near springs and seepage along stream courses
- Residual chert and red soil covering large parts of the area
- Large parts of the area are covered by good soils that are presently cultivated

3.8.2 Hydrogeology of the NW Dolomites

Fresh or unweathered dolomite has very little permeability or porosity. Dolomite weathers easily however in the presence of water and carbon dioxide, which can combine to produce carbonic acid. Joints, fractures and other features are enlarged by dissolution to form highly permeable conduits (sometimes even caves), and these together with weathered and leached horizons can transform the rock into an excellent aquifer. (The same mechanisms can lead to serious ground instability in dolomitic areas.) Insoluble material such as silica and metal oxides remain as structurally weak and porous "wad" (from "weathered and altered dolomite"). In some cases, weathered and permeable dolomite areas are classed as "karst" areas, with sinkholes, dolines and other distinctive features present.

3.8.2.1 Compartmentalisation

The dolomites are divided into semi-autonomous groundwater units or "compartments" mainly by dolerite dykes, but occasionally also by faults and at contacts with adjacent rocks (Stephens and Bredenkamp, 2002; and Holland and Wiegmans, 2009). These compartments are often used as the basis for hydrogeological characterisation and groundwater management. Compartment boundaries are rarely completely impermeable however, particularly in the upper weathered sections, but the extent of groundwater movement across compartment boundaries can be difficult to quantify. Compartment boundaries are normally marked by a distinct change in water levels, and in some cases force groundwater to the surface as springs or seeps. High yielding springs (e.g. Molopo Eye) found at geological/compartment boundaries or topographic lows are a feature of the dolomite aquifers. The water table or piezometric surface within a compartment may be relatively flat, reflecting the topography and relatively high permeability. Defining compartment boundaries, followed by an assessment of the groundwater conditions (flow direction, water levels and water quality) within the compartment, is an important task in dolomite hydrogeology.

A Council for Geoscience study identified 37 compartments within the NW Dolomites study area, divided into 5 main units (Council for Geoscience, 2008). Work done by Holland and Wiegmans in 2009 (Holland and Wiegmans, 2009) distinguished between Groundwater Management Areas (GMAs) and Groundwater Management Units (GMUs) in the NW dolomites and elsewhere, as follows:

- GMAs generally coincide with surface drainage boundaries (e.g. quaternary catchments). A GMA does not necessarily represent a dolomite compartment or unit (larger area comprising a number of GMU's and GRU's). (Holland and Wiegmans, 2009).
- A GMU is an area of a catchment that requires consistent management actions to maintain the desired level of use or protection of groundwater. GMUs are based on surface water drainage and hydrogeological considerations, each of which represents a hydrogeologically homogeneous zone wherein boreholes tapping the shallow groundwater system will be, to some degree or other, in hydraulic connection. (Holland and Wiegmans, 2009).

Holland and Wiegmans (2009) identified 33 GMUs together making up 10 GMAs, as shown in Figure 3-2 and Figure 3-3. These distinctions were made using previous knowledge, analysis of aeromagnetic data to identify dykes, and analysis of water level changes across proposed compartment boundaries. It is possible that more work that needs to be done to further refine the number and exact extent of GMUs in the NW dolomites, as well as the "leakiness" of compartment boundaries.

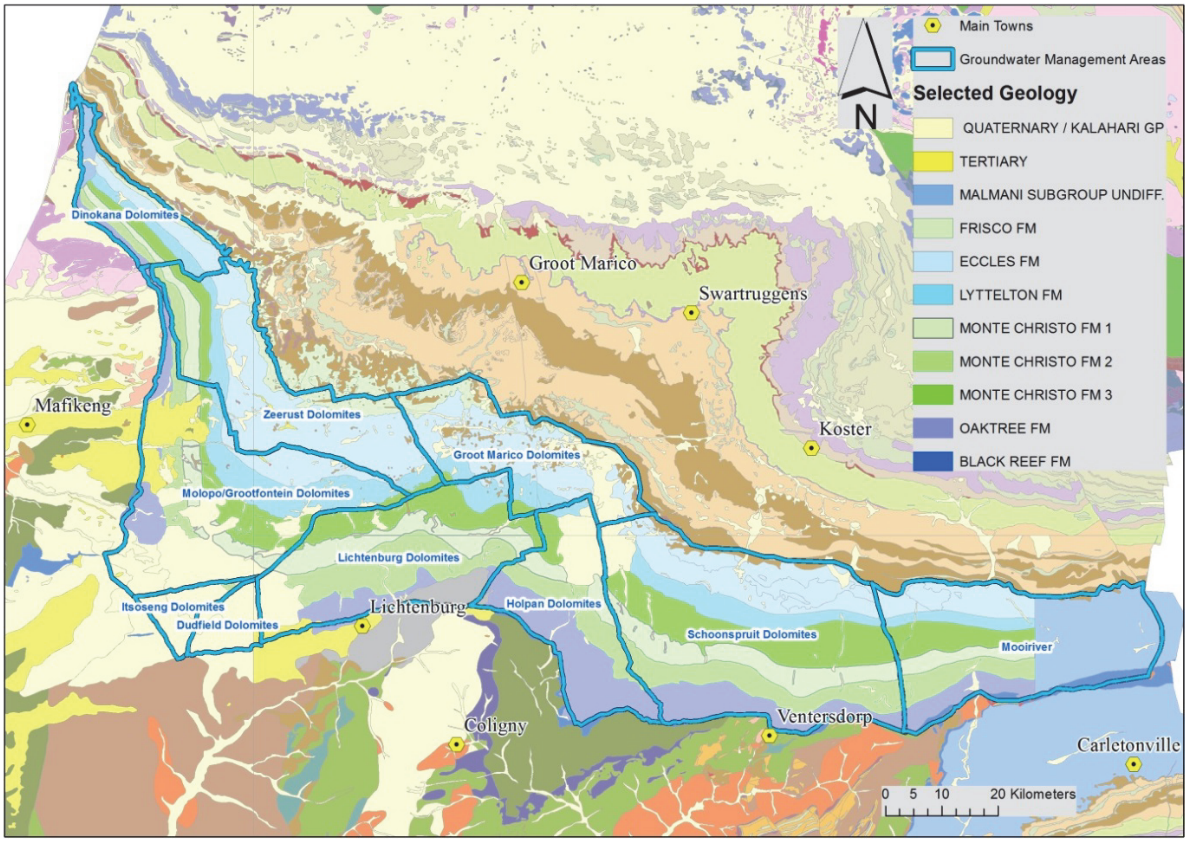

FIGURE 3-2 NW DOLOMITE GMAS (BOUNDARIES AFTER HOLLAND AND WIEGMANS, 2009)

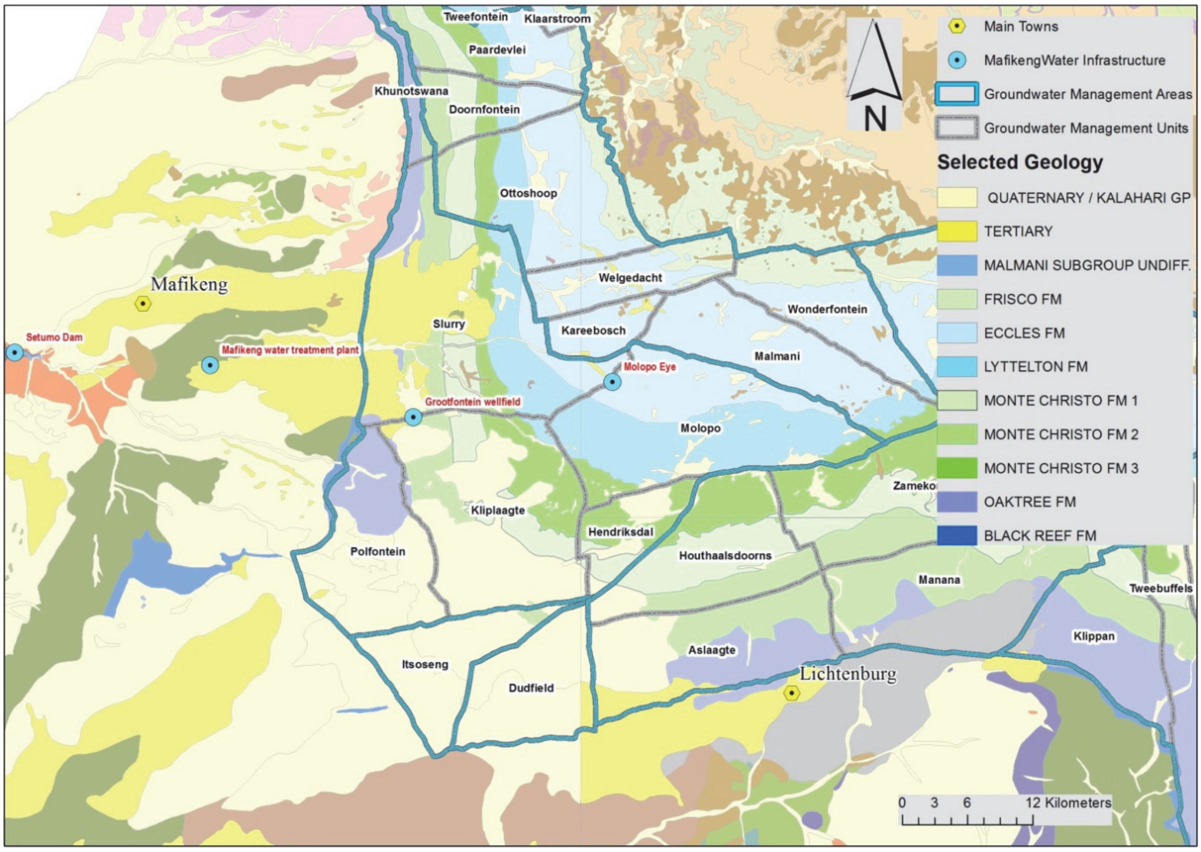

FIGURE 3-3 NW DOLOMITE GMUS NEAR MAHIKENG (BOUNDARIES AFTER HOLLAND AND WIEGMANS, 2009)

3.8.2.2 Aquifer properties

Storativities of South African dolomite aquifers generally vary between 1 and 5% (Barnard, 2000), but this property depends greatly on the extent of weathering and dissolution. Transmissivities can be several hundred m^2/day or more. Groundwater movement in dolomites can, via permeable conduits, be several metres per day or faster. Groundwater flow can be unpredictable, due to the discrete networks of channels, fissures and void spaces. Recharge values as high as 14 % of annual rainfall have been derived (Barnard, 2000). Stephens and Bredenkamp (2002) estimate recharge in the NW dolomites as about 10% of rainfall (i.e. about 300 Mm^3 per year), and the total volume of groundwater stored in the aquifer at about 5 000 Mm^3 if an average thickness of 30 m and a storativity of 0.03 (or 3%) are assumed. Table 3-2 below shows typical transmissivity (T) and storativity (S) values for different geological formations within two dolomitic compartments of the NW dolomites (after Council for Geoscience, 2008).

TABLE 3-2 AQUIFER PROPERTIES OF THE NW DOLOMITES

Formation	Grootfontein T value (m^2/d)	Grootfontein S value	Zeerust T value (m^2/d)	Zeerust S value
Oaktree	35	0.025	87	0.01
Monte Christo	1200	0.08	1200	0.032
Lyttelton	1100	0.008	70	0.18
Eccles	3000	0.12	3000	0.18
Dykes	400	0.11	25	0.11

(After Bredenkamp, 1997 and quoted in Council for Geoscience, 2008)

3.8.2.3 Vulnerability

Although often used in the context of water quality, “vulnerability” can also refer to the quantity of a groundwater resource and the likelihood of this quantity diminishing (e.g. drought vulnerability – see Calow et al., 1997). This sub-section discusses vulnerability to pollution, rather than to over-abstraction. Vulnerability mapping is a way of showing the vulnerability of an aquifer or area to groundwater contamination, and vulnerability maps are generally used as planning tools – they do not usually replace local investigations and assessments. Vulnerability of groundwater to contamination depends on various factors, such as depth to groundwater, nature of the aquifer material, recharge or soil properties. The National Research Council (NRC) has defined groundwater vulnerability to contamination as the likelihood of contaminants reaching a specified position in the groundwater system after introduction at a location above the uppermost aquifer (NRC, 1993). There are various methodologies for assessing vulnerability or constructing vulnerability maps, such as the DRASTIC method (Aller et al., 1985) – the methodology chosen depends on the characteristics of the area being considered, as well as the availability of data. Vulnerability is often depicted as a relative rather than absolute characteristic. The NORAD documents (DWA, 2004b) recommend five relative vulnerability classes, from Negligible to Extreme. Vulnerability maps are also usually “intrinsic” which means they focus on the aquifer properties and do not take into account the properties of the contaminant – strictly speaking, vulnerability changes depending on the properties of the contaminant being considered.

The conduits and weathered zones in dolomites can allow pollutants to move quickly and easily in the aquifer, and relatively little physical filtering of water occurs. Karst landforms such as sinkholes and dolines together with typically thin soils also allow surface pollutants rapid access to the aquifer. Together, these characteristics can make dolomite aquifers very vulnerable to surface pollution of various types. It is generally easier and cheaper to protect groundwater from pollution than it is to remediate or “clean up” the pollution once it has occurred (World Bank, 2002).

Aquifer protection can be divided into “resource protection” methods (e.g. mapping the vulnerability of a whole aquifer) and “source protection” methods that protect individual boreholes or springs (e.g. source protection zones). A combination of the two is usually recommended (World Bank, 2002). A common method that is used world-wide to help protect groundwater quality at source is to establish areas or “protection zones” around groundwater abstraction points (and sometimes well fields and even whole aquifers too) within in which activities that may pollute groundwater are controlled (Lawrence et al., 2001). Protection zones can be defined in various ways, ranging from simple circles drawn around boreholes (assuming a homogeneous, isotropic aquifer and no regional groundwater gradient) to zones of complex shape derived using numerical groundwater modelling and taking into account aquifer properties, topography, groundwater flow direction and recharge. They can vary in size from a few tens of metres around a borehole to hundreds of square kilometres protecting an entire recharge area. The final protection zone or zones that is decided will depend not only on the physical properties of the aquifer and the presence of potential hazards, but also on the skills and resources available to enforce the protection zones and the existing land use in the area to be protected (Lawrence et al., 2001).

There have been limited attempts to date to assess the vulnerability of South Africa's dolomite aquifers. Various options are open to the groundwater planner, ranging from the simple characterisation of all dolomite aquifers as "vulnerable", to the determination of groundwater protection zones, to more sophisticated methods which differentiate between different areas of dolomite aquifers depending on their physical characteristics. Some combination of these is also possible. Work carried out at the University of Pretoria and applied by DWA has adapted the COP vulnerability assessment method to South African conditions, resulting in the VUKA vulnerability index (Leyland and Witthüser, 2009). This was applied to the dolomites in the Sudwala / Pilgrim's Rest area (DWA, 2008b).

3.9 MANAGEMENT ASPECTS AND RESEARCH QUESTIONS FOR THE NW DOLOMITES

The Guideline for the Assessment, Planning and Management of Groundwater Resources in South Africa" (DWA, 2008a) mentioned above was based on an earlier guideline called "A Guideline for the Assessment, Planning and Management of Groundwater Resources within Dolomitic Areas in South Africa" (DWA, 2006a). This dolomitic guideline lays out the various role-players who are responsible for groundwater management, discusses the requirement for public participation, and lays out detailed procedures associated with the three interlinked steps of assessment, planning and management. Other resources such as risk management tools, a model drilling contract, pumping-test formats, etc. are included.

A study was carried out in 2008 to investigate the future research priorities of the NW dolomites (DWA, 2008b). This study drew on previous work by the Council for Geoscience (Council for Geoscience, 2008) and also included interviews with dolomite groundwater experts Dr Dave Bredenkamp and Mr Frans Wiegmans. The following summary of technical and management research questions was compiled as part of this study:

3.9.1 Technical issues in the NW dolomites in need of further work:

1. Groundwater compartments need to be better understood and delineated. This work should include the interaction between compartments, water balances within compartments, and the grouping of compartments into Groundwater Management Units (GMUs).
2. Once compartments and GMUs are better defined, improved water balances should ideally be done for each.
3. Recharge is still not fully understood, but is critical to water balances, and therefore to better management of the aquifer. Better rainfall measurements, as well as measurements of groundwater parameters such as Cl, HCO_3, and C^{14}, will assist in refining recharge calculations.
4. More detailed, local studies are needed in some areas to determine groundwater contours, spring flow variations, etc.
5. More information on abnormal recharge events (i.e. in particularly wet years) is likely to be needed for more accurate sustainability calculations.

3.9.2 Management issues in the NW dolomites in need of attention:

1. Better coordination of research efforts is needed, to avoid duplication of effort and possible waste of resources.
2. It would be useful to compile technical research done so far on the NW Dolomites into a single document.
3. It is necessary to get better estimates of current groundwater abstractions, particularly from irrigation boreholes (which are heavy users). (The Council for Geoscience (2008) report refers to “A glaring lack of measured abstraction data and records” for the NW Dolomites).
4. Management efforts may need to work on timescales of several years or longer, to take into account recharge following abnormally high rainfall. Average annual values for rainfall and for recharge can be misleading. See van Wyk (2010).
5. Some way of communicating the current “state of the resource” to groundwater users would be useful, in order to assist in regulating abstractions.

Much of the work that has been done on management aspects of the NW dolomites has focused on what needs to be done, and who needs to do it – rather than looking at the thornier question of why many tasks that all agree are necessary (e.g. establishment of actual abstraction quantities by various groundwater users, better rainfall measurements, formation of Water User Associations, replacement of lost monitoring boreholes, etc.) are either not carried out or are done badly.

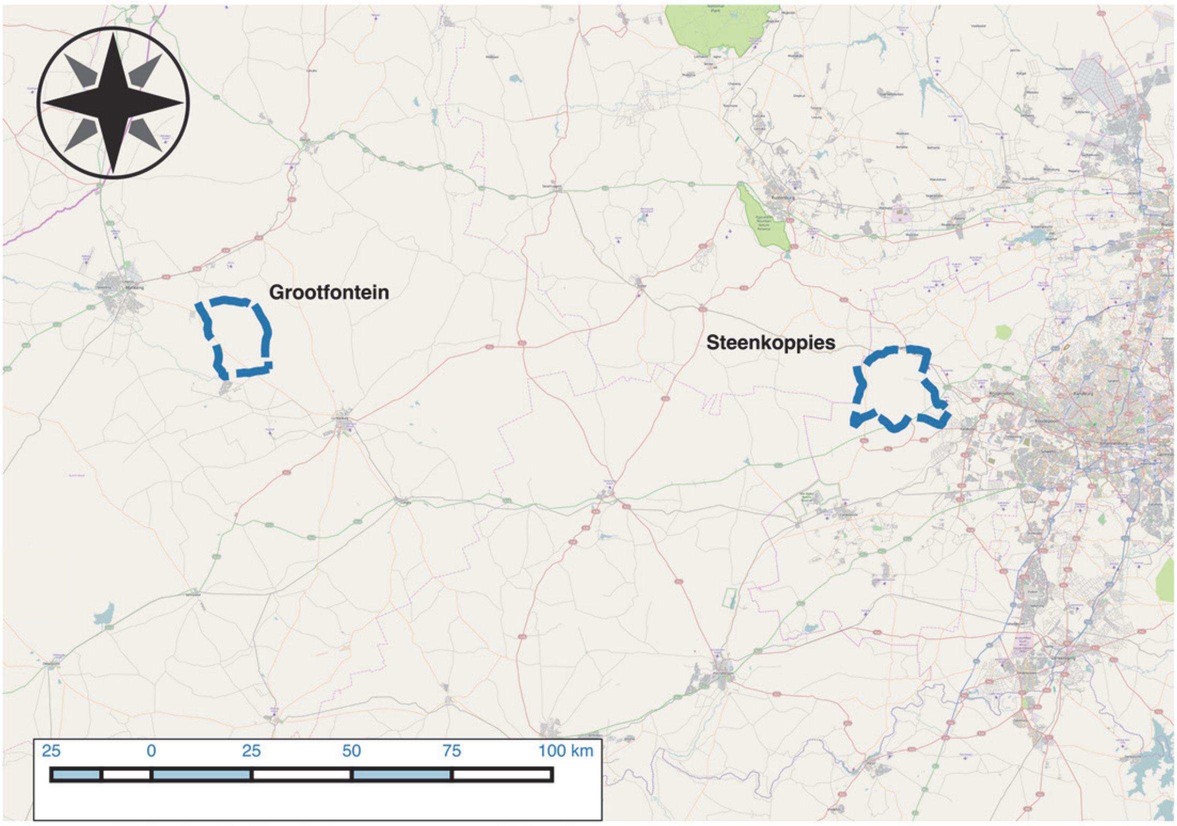

FIGURE 3-4 LOCATIONS OF THE GROOTFONTEIN AND STEENKOPPIES DOLOMITE COMPARTMENTS

3.10 Introduction to the Grootfontein Compartment

The Grootfontein Compartment of the NW Dolomites (sometimes also known as the Kliplaagte Compartment) is located south east of Mahikeng in NW Province. It is one of the best studied aquifers in South Africa with scientific research on it dating back to the 1960s. This is partly because it was the main source of domestic water for the town of Mahikeng until the 1980s as well as being important for irrigation and other uses. It may also have had special political significance since Grootfontein water supplied Mmabatho, the capital of the former "homeland" of Bophuthatswana and located adjacent to Mahikeng.

The Department of Water Affairs has carried out the bulk of the hydrogeological research over the years, and this research has been published mostly as internal reports by the Department of Water Affairs as part of their "GH" (geohydrology) report series. At least ten GH reports exclusively on Grootfontein were written and the compartment is mentioned in several others (e.g. Bredenkamp 1964, Gombar 1974, Vipond 1979, Cogho 1982, Cogho and Bredenkamp 1982, Mulder 1982, Bredenkamp and van Rensburg 1983, Taylor 1983, Bredenkamp 1984, Bredenkamp 1985, Bredenkamp 1986, Bredenkamp and Zwarts 1987, Bredenkamp 1990, and Janse van Rensburg 1992.) Grootfontein is also discussed in several journals and conference proceedings, with a particularly good description found in Van Tonder et al (1986). Adding to earlier geological work by the Council for Geoscience on the boundaries of the Grootfontein Compartment, Holland and Wiegmans (2009) delineated the compartment boundaries as part of the Department of Water Affairs' Dolomite Project and produced as series of compartment maps for the NW Dolomites. Previous work on the Grootfontein Compartment supported by the Water Research Commission includes Cobbing et al 2013, 2014 and 2015.

3.10.1 Topography, drainage and geology of the Grootfontein Compartment

The Grootfontein Compartment is a typical karst landscape with a very flat land surface, sloping gently towards the north-west with a gradient of about 50 m in 16 km (van Tonder et al., 1986). Average annual rainfall is about 560 mm and occurs mainly as thunder storms (Janse van Rensburg, 1992). The Grootfontein Compartment falls entirely within quaternary drainage region D41A. The course of the Dry Molopo River cuts across the far north east corner of the compartment, and marshland shown on the 1:50 000 scale topographic map of the area associated with this water course indicates that groundwater would once have contributed to the Dry Molopo, along with the flow from the Grootfontein Spring. Both the Dry Molopo and the unnamed drainage from the Grootfontein Spring join the Molopo River about 6 km due north of the Grootfontein Compartment boundary. A further area of marshy ground is shown on the topographic map at Blaauwbank near the centre of the compartment. No marshy ground exists today due to the drop in the water table.

The compartment is underlain at depth by crystalline basement rocks of Swazian age (Janse van Rensburg, 1992 and Johnson et al., 2006). The basement is overlain by quartzites, shales and lavas of the Ventersdorp Supergroup, and these are overlain in turn by rocks of the Transvaal Supergroup. The Malmani Subgroup of the Chuniespoort Group crops out at surface, and consists of the Black Reef, Oaktree, Monte Christo and Lyttleton Formations in the Grootfontein Compartment study area

(Council for Geoscience, 1991). The Black Reef and Oaktree Formations outcrop in the western part of the compartment, whilst the Monte Christo Formation, thickening towards the east, occupies the majority of its area and is the most important water-bearing formation (Janse van Rensburg, 1992). The Lyttleton Formation outcrops in the north-eastern corner of the compartment and is a poorer aquifer than the Monte Christo Formation due to its chert-poor nature (Janse van Rensburg, 1992).

Unconsolidated Quaternary deposits of the Gordonia Formation of the Kalahari Group overlie the dolomites in places, and consist of sands, gravels and alluvium. These are diamondiferous in places. Quaternary chert-rich gravels and alluvium make cultivable land that is amenable to irrigation, in contrast to outcropping dolomite devoid of such cover that is referred to as “klipveld” and is of poor agricultural potential (Bredenkamp, 1964).

Vertical to sub-vertical diabase dykes oriented mainly E-W intrude the country rocks of the study area. These dykes vary in thickness from a few metres to tens of metres and show different weathering profiles. Those dykes that are deeply weathered do not affect groundwater flow appreciably (Cogho, 1982).

3.10.2 Extent and thickness of the aquifer

The Grootfontein Compartment is roughly rectangular in shape, is bounded by low permeability dykes on all sides, and covers an area of about 239 km^2. This area was calculated using GIS software using the dyke boundary positions of Holland and Wiegmans (2009) which are recent estimates using both geophysical anomalies and water level changes. Over the years different boundary positions have been inferred by different authors, especially for the southern / south western boundary (for example, Cogho (1982) and Janse van Rensburg (1992) estimated that the Grootfontein Compartment covered about 160 km^2 and 169 km^2 respectively).

The aquifer thickness is a function of the weathering and karstification which give it its favourable hydraulic properties. Cogho (1982) estimated that the average thickness of the weathered (upper) part the Grootfontein Compartment was 56 m. Van Tonder et al (1986) provided contours for the top of the unweathered dolomite in the Grootfontein Compartment as part of their numerical model setup, based on 61 borehole logs with weathering information. These contours indicate an aquifer thickness ranging from roughly 40 m in the north west of the Grootfontein Compartment to 60 m in the south east.

3.10.3 Boundaries

The Grootfontein Compartment is bounded by diabase dykes of varying thicknesses and hydraulic properties. The northern boundary is formed by the Grootfontein and Trekdrift Dykes. The Grootfontein Dyke is more than 20 m thick and is semi-permeable, with a step change in water level across it of about 6 m reported by Van Tonder et al (1986). The Trekdrift Dyke is narrower and also shows water level changes. The point where the two dykes meet is an anomalous depression in the dolomite, interpreted as a fossil sinkhole now filled with low-permeability clay-rich Karoo sediments (van Tonder et al., 1986).

The western boundary of the compartment consists of the Mooimeisjesfontein Dyke which has a low permeability and shows water level changes across it of only about 1 m (van Tonder et al., 1986).

The south western boundary of the compartment consists of the Blaauwbank Dyke, which in 1986 showed water levels on its southern side about 12 m higher than those on its northern side. Testing of boreholes in this 80 m wide dyke indicate an extremely low permeability, and it is thought that little water flows from south to north across it (van Tonder et al., 1986).

The eastern boundary of the compartment is the Elizabeth Dyke, which also has a low permeability and showed a water level change of about 2 m (with the higher level on the eastern side) in 1986 (van Tonder et al., 1986).

Less clear is the south-eastern boundary of the compartment, and it is here that some sources disagree. Van Tonder et al (1986) report that one of at least three dykes may form this boundary (the Blaauwbank, Grasfontein and Stryd Dykes), or some combination of the three. The groundwater contours, which show flow from the south-east towards the north-west, provide some evidence for groundwater flow across this south-eastern boundary of the compartment.

The Verlies Dyke cuts across the compartment from south-west to north-east (Cogho and Bredenkamp, 1982) but is not thought to disrupt groundwater flow substantially (Holland and Wiegmans, 2009).

3.10.4 Transmissivity and Hydraulic Conductivity

Transmissivity (T) values for the Grootfontein Compartment vary considerably, reflecting the heterogeneous nature of the dolomite aquifer. T values from pumping tests in the compartment range from 1 to 23 000 m^2/d, and in the vicinity of the Grootfontein Spring from 11 000 to 23 000 m^2/d (van Tonder et al., 1986). The diabase dykes bounding the compartment are thought to have T values of up to 16 m^2/d (van Tonder et al., 1986), although for modeling purposes they are sometimes assumed to be impermeable (e.g. Janse van Rensburg, 1992). T values for the Monte Christo Formation are thought to be higher than those for the Oaktree and Lyttleton Formations – van Tonder et al (1986) observed that borehole yields in the Monte Christo Formation were generally higher than 15 L/s, and lower than this in the other two dolomite formations.

Hydraulic Conductivity (K) values used by Cogho and Bredenkamp in their early finite-difference model of the compartment ranged from very low to more than 900 m/d.

3.10.5 Storage

Storage values for the dolomite depend on weathering and karstification and can vary greatly across short distances as well as with depth. Enslin (1967) gives specific yield values for weathered dolomite generally of 18%, but average figures across a compartment are likely to be lower due to variation in degree of weathering. Van Tonder et al (1986) report average storage values of 2.8% based on the response of groundwater levels to rainfall and a recharge rate of 8% of rainfall. These authors provide a storage contour map showing storage figures varying from about 1% in the south western part of the compartment to 14% in the north eastern part. Porosity estimates of 2% for the Grootfontein

Compartment are given by Mulder (1982) and Cogho (1982), whilst Bredenkamp and van Rensburg (1983) estimate porosity at 2% across the compartment except near the spring where it is 4%. Janse van Rensburg (1992) estimates porosity values between 2.15% and 2.45% for the Grootfontein Compartment.

Evaluation of storage by pumping tests is complicated by the high yields and heterogeneity of the aquifer, and methods to estimate storage from the response of water levels to rainfall must take into account the uncertainty related to the different recharge pathways (direct and diffuse), the non-linear relationship between rainfall and recharge, and the complications that arise due to the unknown pumping rates of boreholes across the compartment.

3.10.6 Recharge

Van Tonder et al (1986) report recharge in the Grootfontein Compartment as 8% of rainfall, based on work done by Bredenkamp for his PhD thesis in 1978 using tritium isotopes. Cogho (1982) specifies recharge values of 4.5% to 8% of rainfall, whilst Bredenkamp and van Rensburg (1983) use 10% of rainfall in calibration of their early finite-difference numerical model of the compartment. Janse van Rensburg (1992) uses the relationship (recharge = 0.1 x monthly_rainfall – 67 mm) in his study, which requires above average rainfall before any recharge occurs.

More recent work by Bredenkamp on relating recharge to spring flows in the NW dolomites (Bredenkamp 2007 and Bredenkamp et al., 2007) uses tritium and C14 isotopes to describe a "bimodal recharge" model in which some recharge bypasses the soil zone (via macropores) causing the bicarbonate in the water to derive a different C14 signature compared with recharge that infiltrates via the soil. This method relies on an independent estimate of recharge, and Bredenkamp (2007) suggests using the chloride mass-balance method for this. However the chloride mass-balance method suffers from difficulties in incorporating rapid recharge via macropores, from the general lack of data on chloride concentrations in rainfall, and from the non-linear relationship between recharge and the magnitude of individual rainfall events in semi-arid South Africa (including the dolomites). Furthermore, little is known about the effect of lowered water levels due to over-pumping on the rate and mode of recharge. Work by van Wyk (2010), Beekman and Xu (2003) and others has shown that recharge in years of low to average rainfall may be negligible, and that rainfall amounts must cross a "threshold" value before significant recharge takes place – and this can happen as little as every decade or so.

As with storage, it may be best to adopt a sensible range of recharge results and err on the side of caution when using these to plan abstractions or manage an aquifer – this is in line with the adaptive management method advocated by Seward et al (2006).

3.11 Grootfontein Compartment Yields

Groundwater abstractions from the Grootfontein Compartment can be divided into three types – abstractions from boreholes near the Grootfontein Eye by DWS for water supply to Mafikeng (the Grootfontein wellfield), abstractions by irrigating farmers, and other abstractions such as the Itsoseng boreholes, Thusong Hospital, small businesses, etc.

3.11.1 Grootfontein wellfield

Mulder (1982), Cogho (1982) and Bredenkamp (1984) all estimate that the boreholes at the Grootfontein Eye supplying Mahikeng yielded about 15.6 ML/day (about 180 L/s) at that time. Bredenkamp and van Rensburg (1983) record the boreholes as yielding between 15.5 and 24 ML/day (between about 180 and 280 L/s). Van Rensburg (1992) mentions that the permit allocation for the municipal water supply from the Grootfontein boreholes was about 12.4 ML/day (about 143 L/s) at that time.

In 2012 the Grootfontein Wellfield was yielding about 8 ML/day (about 93 L/s), but in previous years it yielded as much as 20 ML/day (about 231 L/s), both estimates according to staff of Botshelo Water Board interviewed at that time (Cobbing et al., 2013). The drop in yield at the wellfield is due to falling water levels which have rendered some of the boreholes dry and reduced the yields on those that remain. There were originally up to nine water supply boreholes drilled at or near the site of the old Grootfontein Eye or spring, but according to DWA (2010b) five of these were no longer operational by 2010. Currently (following a site visit in May 2015) only three of the boreholes operated by DWS near the Grootfontein Eye are operational, the others having gone dry over the last few years. These three boreholes together currently yield about 7.2 ML/day (about 83 L/s), according to the minutes of the Stakeholder Operating Forum meeting held at DWS in Mahikeng on 9 June 2015. Daily volumes of water arriving at the Mafikeng Treatment Plant from both the Grootfontein Wellfield and from the Molopo Eye are recorded by Sedibeng Water Board (who took over from Botshelo Water Board in 2014), but this data has not yet been obtained.

3.11.2 Irrigation abstractions

One of the more difficult questions to answer in the Grootfontein Compartment is how much water is being abstracted for irrigation purposes. This is because verification and validation of the licensed quantities has not been carried out, despite more than four decades of recommendations that this should be done. The situation is also complicated by the fact that irrigation water demand is a function not only of crop type and scheduling, but also of total rainfall and rainfall intensity for any particular year. Writing more than fifty years ago, Bredenkamp (1964) emphasized the importance of the Grootfontein area, recommended that it be included in the subterranean water control area then being considered, and stated that no new abstractions for irrigation should be allowed. Work done in the early 1980s by Bredenkamp and others used electricity consumption figures provided by Eskom to estimate irrigation withdrawals from the Grootfontein Compartment (Bredenkamp, 1985). These established that between 1977 and 1985 an average of about 9 Mm^3/a (about 24.6 ML/d or about 285 L/s) of groundwater was being abstracted for irrigation, but the totals for individual years varied from about 3.2 Mm^3/a to about 10.6 Mm^3/a (i.e. from about 8.8 ML/d or 101 L/s to about 29 ML/d or 336 L/s). Mulder (1982) and Cogho (1982) both estimate that about 22 ML/d or 255 L/s of groundwater was being used for irrigation purposes. Bredenkamp and van Rensburg (1983) used a figure for irrigation abstraction of 38.5 ML/d or 446 L/s to calibrate their finite difference model of the Grootfontein Compartment. Van Rensburg (1992) states that the licensed allocation for irrigation in the Grootfontein Compartment was about 30 ML/d or 349 L/s.

3.11.3 OTHER ABSTRACTIONS

There is little information for other abstractions in the Grootfontein Compartment (i.e. apart from the public water supply abstraction at the Eye and the irrigation), but most of these are likely to be small abstractions for households or small businesses. The largest of these abstractions are likely to be the boreholes for public water supply at Itsoseng. These plot within the Grootfontein Compartment under the dyke boundaries proposed by Holland and Wiegmans (2009). The operational borehole visited at Itsoseng in May 2015 had a yield marked on its data plate of 0.8 ML/d or 9.5 L/s. Even if this borehole pumps continuously it seems likely that it and other miscellaneous abstractions together abstract less than about 10% of the supply abstracted at the Grootfontein Wellfield for supply to Mahikeng. Sedibeng Water will have figures for the Itsoseng boreholes (and for other peri-urban supply schemes in the area) but this data is not publicly available.

3.11.4 FORMER SPRING / EYE FLOW

Cogho and Bredenkamp (1982) quote flow records for the Grootfontein Eye from July 1980 to March 1982. For several of the months during this period the eye was dry, but following rainfall in late 1980 and early 1981 flows ranging from 15.8 ML/d in April 1981 to about 4.6 ML/d in October 1981 were recorded. It is thought that October 1981 was the last time the Grootfontein Eye flowed. Vipond (1979) states that the average flow of the Grootfontein Eye in 1979 was 14.4 ML/d or 167 L/s, and that this figure was likely close to the long-term average flow of the eye.

FIGURE 3-5 SAMPLING IRRIGATION BOREHOLES AT GROOTFONTEIN (L), AND THE DRY EYE (R)

3.12 CURRENT STATE OF THE GROOTFONTEIN COMPARTMENT

The Grootfontein Compartment is being over-utilised at present, and has been for years – for example more than twenty years ago Janse van Rensburg (1992:22) wrote “In the case of the Grootfontein Compartment it is clear that the permit allocations to farmers by far exceed the recharge to the aquifer”. Water levels in the vicinity of the Grootfontein Wellfield were about 28 m below ground level in April 2015, and boreholes previously used for water supply purposes were dry. An analysis of 35 boreholes in or very near the compartment with recent water level data from the DWS National Groundwater Archive (NGA) database shows that 33 of them have water level trends that show a decline over the monitoring period (the average record length for the 35 boreholes is 32 years). The average drop in water level of the 35 boreholes (calculated by subtracting the start water level from the end water level of each borehole’s data series) is 12.7 m.

A very rough calculation based on the area of the compartment (239 km^2), a (conservative) storage coefficient of 2% and an average dewatered depth of 12.7 m suggests that around 61 Mm^3 of water in excess of recharge volumes has been removed from the compartment since water levels began to decline in the early 1980s. If this volume of water was entirely available to Mahikeng, then based on the year 2020 projected water demand for Mafikeng (DWA, 2010b) of about 17 Mm^3/a, this volume of water would be able to sustain the town for more than three years (e.g. during a severe drought which affected the Molopo Eye flow). A policy of sustainable irrigation abstractions and abstractions from the Grootfontein Wellfield and other sources which restored the water levels in the compartment to the levels last seen in the early 1980s would therefore provide Mafikeng with a very valuable "insurance policy" against drought or disruptions to the Molopo Eye source – the town could over-abstract during the drought, using the storage in the Grootfontein Compartment. Such a policy would have the added benefit of ensuring smaller pumping heads and providing higher certainties of supply for all groundwater users.

At present there is *de facto* no management of the groundwater resources of the Grootfontein Compartment, and a lack of real dialogue between major stakeholders. This situation means that stakeholders are unsure about the long-term sustainable potential of the compartment, underpinning sub-optimal outcomes which range from mutual suspicion and mistrust to a reluctance to plan and invest in the area. Intensification of the current drought could see the remaining DWS boreholes at the Grootfontein Eye running dry, leaving Mafikeng to rely entirely on the Molopo Eye.

3.13 INTRODUCTION TO THE STEENKOPPIES COMPARTMENT

The Steenkoppies Groundwater Compartment in the NW Dolomites is located west of Krugersdorp near Tarlton and has a total area of about 311 km^2 (Holland, 2009). According to the classification of Holland and Wiegmans (2009) the compartment is a groundwater management area (GMA) and can be further subdivided into three groundwater management units (GMUs): A21F-01, A21F-02 and A21F-03 with areas of 58, 85 and 168 km^2 respectively. For the purposes of this study the three GMUs will be collectively referred to as the "Steenkoppies Compartment". A major consolidation of previous work together with considerable new data collection and research took place in 2007-2010 as part of the Department of Water Affairs' Dolomite Project (outputs included a report focusing on the Steenkoppies Compartment by M Holland in 2009). This work was drawn on and added to by Meyer (2014) in his study of Groundwater Region 10 (The Karst Belt) for the Water Research Commission. Along with the Grootfontein Compartment, the Steenkoppies Compartment ranks as amongst the best studied of South African aquifers. A book chapter by Vahrmeijer et al (2013) summarises both the physical conditions in the compartment and provides a very good overview of the management challenges and the drivers of change.

The Steenkoppies Groundwater Compartment is of interest to this study for several reasons. Irrigation from the compartment underpins an agricultural industry worth hundreds of millions of rands, and employing thousands of people (Vahrmeijer et al., 2013). Irrigated produce includes higher value crops and activities such as export-quality vegetables, organic vegetables, mushrooms, nurseries, and cut flowers. Vahrmeijer et al (2013) state that groundwater from the compartment supports the largest producers of carrots in Africa, and the largest producers of mushrooms and chrysanthemums in South Africa. Work is provided to more than 4 000 people and salaries of more than USD 900 000 are paid monthly. Annual turnover is approximately USD 66 million (Vahrmeijer et al., 2013). The irrigation also requires considerable investments in agricultural infrastructure such as centre-pivots, poly-tunnels, pumps, reticulation systems, etc. (Vahrmeijer et al (2013) estimate capital investments of the order of USD 100 million). When economic backward and forward linkages are taken into account, the economic implications for the immediate area are clearly profound.

Large-scale irrigation is thought to have begun at Steenkoppies in the mid-1970s (Holland, 2009). The natural discharge point of the Steenkoppies Compartment is a large spring known as Maloney's Eye and this is the source of the Magalies River. The Magalies River flows north and east towards the Hartbeespoort Dam and underpins local tourism and ecology. A low-flow crisis beginning in about 2004 and catalysed by drought led to legal threats and a DWS Directive restricting abstractions for irrigation (see section on management below for more detail), forcing the evolution of the management framework for the groundwater in the compartment. This included serious efforts to establish a Water User Association for the compartment, a multi-year process which has now stalled, but which has nevertheless given rise to one of the most sophisticated local stakeholder organisations aimed at groundwater management in South Africa.

The Steenkoppies Compartment naturally invites comparison with the Grootfontein Compartment, which also supports a sophisticated irrigated farming industry and also suffers from problems of over-abstraction, but where progress towards a management organisation is more modest by comparison, and the stakeholder group is broader and includes the organisations abstracting water for public supply.

3.13.1 Topography and Drainage

The surface topography of the Steenkoppies Compartment is relatively flat, sloping from about 1570 m in the north to roughly 1500 m in the south. The compartment falls within quaternary drainage region A21F. Mean annual precipitation in the area of the compartment is approximately 670 mm/a. In the northern part of the Steenkoppies Compartment the Blaauwbankspruit (also known as the Upper Rietspruit) carries storm water and surface runoff from the town of Randfontein as well as about 8 ML/day of treated sewage effluent from the Randfontein Sewage Works (Holland, 2009). The flow in the Blaauwbankspruit diminishes to nearly zero by the time the drainage reaches a small dam wall near the town of Tarlton, due to leakage into the compartment and irrigation abstractions from the spruit. Inputs to groundwater in the compartment therefore include losses from the Blaauwbankspruit and irrigation returns from water taken from the spruit. The natural drainage point for groundwater in the compartment is at the spring known as Maloney's Eye near the town of Magaliesburg on the northern edge of the compartment. Maloney's Eye is made up of nine separate smaller springs grouped together (Holland, 2009). Discharge records for Maloney's Eye date back about 100 years and show a long-term average flow of 0.455 m^3/s (about 39 ML/day or 14.3 Mm^3/a), with the flow varying between 0.05 and 1.035 m^3/s (Vahrmeijer et al., 2013). Cumulative years of above-average rainfall are required to substantially increase flows from the eye (Vahrmeijer et al., 2013). Maloney's Eye is the source of the Magalies River which supports various activities such as small-scale irrigation and gardening, trout fishing, and fish farming, as well as being vital to the natural ecology of the area.

FIGURE 3-6 MALONEY'S EYE (BULLDOG FOR SCALE)

TABLE 3-3 SUMMARY OF MALONEY'S EYE FLOWS (AFTER HOLLAND, 2009)

Year (Record)	**Min (Mm^3/a)**	**Max (Mm^3/a)**	**10 Percentile (Mm^3/a)**	**90 Percentile (Mm^3/a)**	**Median (Mm^3/a)**	**Average (Mm^3/a)**	**Current (Mm^3/a)**
Pre 1975	10.63	22.04	11.48	18.95	14.13	14.56	-
Post 1975	1.58	32.64	6.34	26.81	12.02	14.01	-
Since 1999	1.58	16.05	3.37	14.82	7.98	8.93	-
1908-2009	1.58	32.64	9.46	20.85	13.81	14.35	**5.49**

3.13.2 Geology and Hydrogeology

The northern boundary of the Steenkoppies Compartment is formed by quartzites and shales of the Black Reef Formation (the basal formation of the Transvaal Supergroup) which mostly have a low permeability. The compartment itself consists of N-NW dipping rocks of the Malmani Subgroup, alternating between chert-rich and chert-poor dolomites, which overlie the Black Reef Formation. The Malmani Subgroup is not further divided into its constituent formations on the Council for Geoscience 1:250 000 geology map of the area. The Rooihoogte and Timeball Hill Formations which overlie the dolomites make up the northern boundary of the compartment, and consist of conglomerates, shales and quartzites of low permeability relative to the dolomite. The eastern boundary is associated with mafic dykes (the Tarlton East and Tarlton West Dykes) and is confirmed by water table elevations and water chemistry (Meyer, 2014). Further work is however needed to confirm the nature of this boundary as a hydraulic barrier. The Wolwekrans and Wolwekrans South Dykes cut across the compartment trending east-west, but based on groundwater level measurements are not thought to be substantial barriers to groundwater flow (Holland, 2009). The western boundary of the compartment is formed by the Eigendom Dyke.

Holland (2009) describes a conceptual hydrogeological model in which groundwater flows towards the north to discharge at the Maloney's Eye spring. The spring is found at the intersection of the Maloney's Eye Dyke and an east-west striking fault zone, juxtaposing rocks of the Malmani Subgroup with low permeability rocks of the overlying formations, forcing groundwater to the surface. The Malmani dolomites making up the compartment show higher transmissivity areas in the centre of the compartment, based on gravity survey data and related to karstification (Holland, 2009). Inputs to the compartment are from natural recharge, effluent discharge from the Randfontein Sewage Works, irrigation return flows, and inputs from the quartzites and shales which make up the southern boundary of the compartment. Recharge estimates for the Steenkoppies Compartment range from about 9% to as much as 21% of mean annual precipitation (Holland, 2009). Holland (2009) summarises the water balance for the compartment in Table 3-4 below.

Holland (2009) and Vahrmeijer et al (2013) demonstrate the reasonable relationship between the cumulative rainfall departure (CRD) and the Maloney's Eye discharge until about 1987, when the actual discharge has been lower than the rainfall records would suggest – indicating the effect of external factors such as irrigation abstractions. Two periods of severe meteorological drought (1990-1992 and 2002-2005) have been followed by consequent periods of hydrological drought (1994-1996 and 2005-2009), worsened by the excessive abstraction of groundwater (Vahrmeijer et al., 2013).

TABLE 3-4 WATER BALANCE SUMMARY FOR THE STEENKOPPIES COMPARTMENT (AFTER HOLLAND, 2009)

Description	Scenario 1 (Low Recharge/WARMS Abstraction)			Scenario 2 (High Recharge/Schoeman Associates Abstraction)		
	Inflows	Outflows	Balance	Inflows	Outflows	Balance
RECHARGE (M^3m/a)						
Dolomite	20.19			24.05		
Pretoria Group	0.81			0.81		
Wits Supergroup	4.63			4.63		
Sub-total	**25.63**			**29.49**		
INFLOWS/OUTFLOWS (M^3m/a)						
Brandvlei run-off	0.12			0.12		
R WWTW-Irrigation	2.61			2.61		
R WWTW-Rietspruit	0.52			0.52		
Maloney's Eye		5.61			5.61	
Abstraction		25.40			33.58	
Abstraction returns	5.14			6.72		
Sub-total	**8.40**	**31.31**		**9.97**	**39.20**	
Balance TOTAL (M^3m/a)	**34.03**	**31.31**	**+2.72**	**39.47**	**39.20**	**+0.27**
Return flow component	9.2%			7.9%		

3.13.3 HISTORY OF GROUNDWATER MANAGEMENT AT STEENKOPPIES

Large-scale irrigation using groundwater from the Steenkoppies compartment is thought to have begun in the mid-1970s. In 2009 the total area under irrigation was about 2 592 Ha (Tarlton, 2007). In 1997 Barnard (Barnard, 1997) estimated that lawful abstraction of groundwater in the Steenkoppies compartment amounted to about 19 Mm^3/a (nineteen million cubic metres per year) in one of the first hydrogeological studies to concentrate on the area. Holland (2009) has discussed the difficulties in estimating irrigation abstractions in the compartment in the absence of data from the irrigating farmers themselves, and estimated irrigation abstraction as between about 25 and 33 Mm^3/a based on consultants' reports to DWS and his own water balance calculations. Consultants to DWS have used satellite images of irrigated areas and knowledge of crop types to estimate irrigation volumes (Holland, 2009).

Groundwater abstraction from the Steenkoppies Compartment appears to have grown steadily through the 1980s and 1990s in terms of volume and the number of boreholes. Vahrmeijer et al (2013) estimate that more than 200 boreholes are currently in use for irrigation in the compartment. In 1994, following low flows in the Magalies River, DWAF (now DWS) ordered that abstraction of water from the Magalies River cease for an interim period, pending review of water allocations from the river. Good rains in 1995-7 led to these demands not being pursued (Vahrmeijer et al., 2013). In the summer of 2004 shallow boreholes used for household water supply in the Steenkoppies Compartment dried up (Vahrmeijer et al., 2013). In September 2004 a group of concerned water users downstream of the Maloney's Eye formed the Magalies River Crisis Committee (MRCC) to "address the problems associated with the flow of the [Magalies] river and to engage DWAF in seeking a solution to the problem and in following up on the promises that had been made." In December 2004 DWAF issued a series of directives aimed at stopping unlawful water use in the Steenkoppies Compartment. Later it was agreed that so-called "illegal pivots" would be allowed to continue operating as long as they took part in a validation process (Vahrmeijer et al., 2013).

In early 2007 Maloney's Eye reportedly ceased to flow for the first time on record (Holland, 2009). This followed a drought period of several years during which time irrigation abstractions did not decrease (in fact may have increased due to the lower rainfall and drier conditions). In 2007 the MRCC was reconvened, and made a submission to the South African Presidency regarding the low flows at Maloney's Eye and the possible impact on the Magalies River, seeking amongst other things a temporary cessation of all groundwater abstractions from the Steenkoppies Compartment to allow the flow at the eye to recover (MRCC, 2007). The submission also raised the risk of sinkholes forming as a consequence of declining water levels in the compartment. Vahrmeijer et al (2013) report that the MRCC also initiated a lawsuit against DWAF in March 2007. Essentially, the 2007 submission / lawsuit by the MRCC stated that the primary cause of low flows at Maloney's Eye (and therefore flow in the Magalies River) was irrigation using groundwater by farmers in the Steenkoppies compartment, and that such irrigation needed to stop or be drastically reduced.

The 2007 actions by the MRCC led to a response by 21 groundwater users (the "Tarlton farmers") in the Steenkoppies Compartment in the form of a submission to the Director-General of DWAF, dated November 2007 (Tarlton, 2007). The Tarlton farmers disputed that irrigation was to blame for the low flows at Maloney's Eye, although they agreed that water resources in the greater Magalies area were under stress. They stated that "no credible evidence has been put forward to show that the water difficulties in the Tarlton and Magalies River area is attributable to the existing lawful use of water by the Tarlton Farmers" (Tarlton, 2007). The Tarlton farmers consequently disputed the restrictions on groundwater irrigation contained in the DWAF directive of 2004. The Tarlton farmers commissioned and paid for a groundwater study by the environmental consultancy ERM (Pty) Ltd (ERM, 2007). This study broadly supported their views. In particular, the ERM report stated that changing rainfall patterns, changing sewage inputs to the compartment, changing water uses downstream of Maloney's Eye, alien vegetation along the banks of the Magalies, mining activities and other factors were also to blame for the decline in flow at the eye and in the Magalies River (ERM, 2007). The study done by Barnard in 1997 estimated a catchment size (177 km^2) and a water balance for the Steenkoppies area (Barnard, 1997). The ERM report stated that the catchment is in fact likely to be considerably larger (about 500 km^2) than the size estimated by Barnard (1997), based on geochemical evidence. The ERM report did however conclude that aquifer management needed to be instituted, and that a detailed hydrogeological study needed to be carried out. The study by Holland (2009) was partly aimed at resolving these and other discrepancies, in effect answering this last recommendation by ERM.

In 2008 DWAF published a notice in the Government Gazette of 14 March 2008 restricting the use of irrigation water in the compartment to certain days and times, and dependent on the volume of flow at Maloney's Eye. When flows at the eye were less than 93 L/s, then all abstractions apart from Schedule 1 use would be prohibited. The notice also called for the details of all irrigators to be submitted to DWAF within 21 days of publication of the notice.

In 2007 the Tarlton farmers started negotiations aimed at the establishment of a Water User's Association (WUA) for the area, with the assistance of the Danish government aid organisation DANIDA. One of the first steps towards the WUA was the formation of the Steenkoppies Aquifer Management Association or SAMA (Vahrmeijer et al., 2013). It was intended that this association would facilitate the institutionalisation of the WUA. The organisation was essentially aimed at furthering the joint interests of users of groundwater from the Steenkoppies Compartment, and a draft constitution for the WUA was prepared.

The Tarlton farmers have stated that restrictions in irrigation amounts will have very serious consequences for their industry, and that even reductions of as little as 10 % of irrigation volumes will need to be phased in slowly (Tarlton, 2007). Ideally the DWAF restrictions should be phased in slowly, as part of a process of dialogue with all stakeholders to avoid damage to the industry as far as possible. It may be possible to initiate smaller restrictions on abstraction, as more information is collected about the aquifer. Vahrmeijer et al (2013) state that "No restrictions on drilling, size of boreholes and pumps or compulsory measuring of water abstraction or monitoring of groundwater levels are currently enforced" (2013:254), but that a limited number of flow meters have been installed by some irrigators on a voluntary basis as part of a pilot study.

The Steenkoppies Water User's Association was never legally constituted, and current DWS policy now looks likely to phase out WUAs altogether. The irrigating farmers (or at least a subset of irrigating farmers) do however continue to cooperate in certain of the functions that a fully-fledged WUA would carry out. Part of the reason that the crisis receded is that better rainfall has returned in recent years, following the below-average rainfall which led to the crisis. However, recent rainfall records indicate that another period of poor recharge may have begun and if this is so then another crisis is likely to commence.

Despite the years of effort that have been put into establishing governance mechanisms to deal with over-abstraction, and the very substantial volumes of research produced for the Steenkoppies Compartment, it is likely that the next dry period will also be marked by legal challenges and threats – a form of expensive, debilitating and retro-active “management” that can increase suspicion and mistrust (e.g. Business Day, 2007). At present droughts have driven the main advances in groundwater management at Steenkoppies (Vahrmeijer et al., 2013), together with the consequent legal actions. There is a need for groundwater governance mechanisms to move from the current reactive position to a proactive and far-sighted model which supports the economic and human potential of the area.

3.14 Literature Review Conclusions and Summary of Identified Issues

Groundwater in South Africa does not get the recognition that its potential deserves, particularly in prolific aquifers such as the NW Dolomites (Adams et al., 2015). The dolomitic groundwater resources close to Mahikeng (Molopo Eye and the Grootfontein Compartment) are capable of supplying the town with an adequate supply of cheap water of excellent quality, even taking into account the projected growth in water demand. Since the Molopo Eye is a spring and is vulnerable to relatively small fluctuations in water level (e.g. during a drought), the Grootfontein Compartment should be regarded as not only an auxiliary supply during times of normal rainfall, but as a potential emergency reserve that could supply Mafikeng during a long / severe drought. The Steenkoppies Compartment near Tarlton is the basis for a valuable irrigated agricultural industry, and underpins the local economy as well as ensuring the flow of the Magalies River. Unfortunately both groundwater compartments suffer from a lack of management and actions tend to be retroactive and contingent on crisis. It is difficult to imagine surface water resources of similar magnitude and importance being managed in the same way.

At present it is not primarily a lack of technical knowledge that prevents sustainable management of the compartments, but an inability or reluctance to apply the groundwater management institutions provided for in South African policy and legislation. This is despite the very great efforts of certain individuals and groups who have attempted to address the issues over the years. The current situation implies significant cost and risk, and can be regarded as a sub-optimal equilibrium or stalemate which harms most stakeholders in the long term. In the Grootfontein Compartment irrigating farmers, pumping from ever-increasing depths, are reluctant to take long-term decisions and must meet the additional pumping costs that deep groundwater levels imply. Stakeholders associated with the municipal supply (DWS, the municipalities and the water board) are aware that the groundwater resource at Grootfontein is threatened, and are considering other options – none of which are particularly promising and all of which are costly. Businesses and the general public in Mahikeng (as well as in groundwater-dependent towns with similar problems such as Lichtenburg and Zeerust) must take reduced assurance of water supply into consideration, which harms economic growth. In the

Steenkoppies area, operating in an atmosphere of policy uncertainty and mistrust, stakeholders await with unease the next hydrological drought and the possible regulatory and legal moves which will follow.

Apart from the direct impacts on the economy and society of poor groundwater management at Mahikeng and at Steenkoppies there is a significant opportunity cost associated with the situation (i.e. the time and energy spent dealing with the negative outcomes and “fire-fighting” could be spent more profitably elsewhere). The current situation and its long-term outcomes will also influence other towns in the NW Dolomites dependent on groundwater, and arguably have important financial implications. Furthermore, if this situation cannot be resolved to ensure better water security for all, it has depressing implications for our attempts to apply modern water law and policy elsewhere in South Africa. Management and allocation of groundwater is fundamental to agricultural policy, land-reform initiatives and the support of emerging or HDI farmers. It is also needed for rural economies and livelihoods, and for guaranteeing water security to many towns and smaller settlements across South Africa. Environmental flows in many sensitive areas also depend on groundwater. The stakes are high, and there is a need for insights into the cases where groundwater management has succeeded, and into the lessons that can be learned from examples where it has been a failure.

Major issues identified in the study so far include:

- Management of some of South Africa’s most important aquifers is very poor, with droughts and legal moves driving management efforts in a reactive or negative way which bears little relation to our existing laws and policies for groundwater management. This situation implies significant risk and entrenches low equilibria or sub-optimal outcomes.
- Lack of “technical” or hydrogeological knowledge is not a major reason for the relative lack of management institutions or progress, but a supposed need for more technical information is sometimes used to explain the lack of management. This is part of the “myth of shortage” in which shortages of rainfall, funds, skills and so on are wrongly seen as the fundamental reasons for failures in water supply and management.
- No one party or group of stakeholders is “to blame” for the situation, but the absence of the envisaged water management organisations (CMAs and WUAs) is a serious issue. At present no single organisation appears to be taking responsibility for the situation.
- There is a relative lack of guidance on South African groundwater management institutions (compared with technical assessments and procedures), and very little experience of successful groundwater management.
- There is a lack of groundwater expertise at local level in South Africa, contributing to misunderstanding and slow progress.

4 ECONOMIC ASPECTS OF THE GROOTFONTEIN AND STEENKOPPIES COMPARTMENTS

4.1 INTRODUCTION

4.1.1 THE ECONOMIC HYPOTHESIS

This chapter explores whether economic factors play a role in explaining the different approach to groundwater governance arrangements in the Steenkoppies and Grootfontein compartments of the North West dolomites, respectively.

A hypothesis was developed previously which ran like this:

- Farmers in the Steenkoppies groundwater compartment co-operated to pursue the establishment of a Water Users' Association (WUA) because of the nature of their economic activities: they are involved in intensive crop production and are heavily capitalised, with long term debt obligations, and have an economic incentive to co-operate in managing abstraction from their common resource sustainably, long-term.
- Conversely, the reason there have not been moves to establish a WUA in the Grootfontein compartment is because of fundamentally different agricultural economics in this north-west compartment: farming is more extensive, focused heavily on grain production and livestock production, and less capitalised. Farmers consequently have a different kind of stake in the sustainability of the compartment, and less pressing motivation to work together to safeguard their investments by managing sustainable yields.

Research was conducted to test this hypothesis. The work focused on assessing the nature of agricultural production in each of the compartments, exploring other water uses in the compartment, and assessing some factors that might motivate greater or lesser co-operation in improving governance and mutual accountability.

Two important early findings shaped the trajectory of the research.

1. *Neither* groundwater compartment has a Water User Association.

2. The Department of Water and Sanitation is abolishing Water User Associations, and Catchment Management Agencies will be the primary forum for decentralised water management. WUA roles and functions will be transferred to CMAs as appropriate, in the interests of supporting greater transformation and equitable water use.

In the Steenkoppies compartment, extensive and protracted efforts to establish a WUA came to nothing when the then Department of Water Affairs (DWA) proposed a moratorium on the establishment of new WUAs in August 2013, and confirmed this as a policy decision in January 2014; CMAs will now be the primary forum for decentralised water management (DWS, 2014). Local role-players maintain that motivation and momentum in working with DWS to formalise good water governance locally has diminished, and there is little prospect of this initiative being revived in the near future. Meanwhile, in the Grootfontein compartment, some consideration was given to mobilising farmers in 2014 in the hopes of improving management of a diminishing resource, but nothing came of this; DWS was asked to bring non-farming parties into discussions about improving local accountability, but when it did not, farmer support faded.

Thus the nature of the investigation has changed: it is not a question of comparing one groundwater compartment that has a WUA, with another that does not, and exploring whether economic factors are relevant in explaining the difference. Rather, the investigation was broadened to explore the different local economies, and how they do and do not support the establishment of formal groundwater governance structures and efforts to improve local accountability among users – and whether other factors might in fact be more relevant.

4.1.2 STRUCTURE OF THIS CHAPTER

Section 2 outlines the fate of WUAs at a policy level: from government's perspective, they have proved too numerous for effective oversight, and poor vehicles for transformation, and are being phased out.

Section 3 outlines some macro-level trends in commercial agriculture, and flags some drivers of growing consolidation, more intensive and extensive production, and greater mechanization. One might assume that these trends predispose commercial farmers reliant on groundwater for irrigation to collaborate to protect their livelihoods and the value of their investments in the face of rising input costs and price squeezes, through good governance of groundwater. One might further expect farmers with a greater level of investment in agricultural infrastructure to be more willing to formalize their voluntary water governance arrangements through the formal structure designed for the purpose: a Water User Association.

Section 4 tests this assumption in two very different groundwater compartments: one, favoured by its location and other factors, is characterized by substantial investment in intensive horticulture for the lucrative markets of Gauteng and beyond; the other is able to use its comparative advantage in maize, grains, oilseeds and livestock production to support more extensive farming.

Section 5 discusses the findings, before drawing some conclusions.

4.1.3 METHODOLOGY

This study draws on a range of secondary sources, key informant interviews and cropping and irrigation data assembled for the Department of Water and Sanitation to support validation of water authorisation and use in 1996-98, and subsequent monitoring of abstraction and irrigation. Satellite and other data was laid over shape files for the Grootfontein and Steenkoppies compartments, and assessed against crop and irrigation data for 1996-98 and 2015.

A limited budget was available to support this investigation, and the findings should consequently be regarded as indicative rather than definitive.

The consent of DWS in granting access to this data is acknowledged with thanks. Even greater thanks

are due to Mr Francois Joubert, of Schoeman & Vennote in Brits, for assembling and analyzing DWS data on the Steenkoppies and Grootfontein compartments relevant to this study. The authors bear sole responsibility for the analysis and findings.

4.2 THE END OF WATER USER ASSOCIATIONS

Water User Associations are voluntary local water management institutions that manage and regulate water use at localised level, in line with the national policy of decentralised water management. Their powers, functions and the scale at which they operate vary considerably. By 2013, a total of 92 had been established: 42 had been from transformed Irrigation Boards, 10 from Government Water Schemes and 40 new WUAs had been established (DWA, 2013a).

During a presentation to the Parliamentary Portfolio Committee on Water and Environmental Affairs in April 2013, the DWA representative expressed concern that many irrigation boards remained untransformed, that WUAs were voluntary associations and difficult to transform, and that DWA did not have the resources to provide adequate oversight of their activities (DWA, 2013a). In response, the chair of the Portfolio Committee proposed that CMAs could take over their functions, and that WUAs should be dissolved (PMG, 2013).

Four months later, in August 2013, the Department published the text of a National Water Policy Review, and called for comment. The Review proposed the abolition of WUAs, and the absorption of their functions into CMAs and regional water utilities. Pending a decision, a moratorium was placed on the establishment of any new WUA. In January 2014, this position was formalised and approved. The Review indicated that oversight of a large number of WUAs was onerous for the Department and the Minister, and that the objectives of transformation and equity would be achieved more effectively if WUA functions were delegated to a CMA or regional water utility (DWA 2014).

The current policy is that CMAs, together with DWS, will decide on the most suitable structures to co-ordinate water activities at local level. DWS will retain regional monitoring and assessment of geo-hydrology functions. In due course the Minister will specify a date by which WUAs will cease to exist (DWS, 2014).

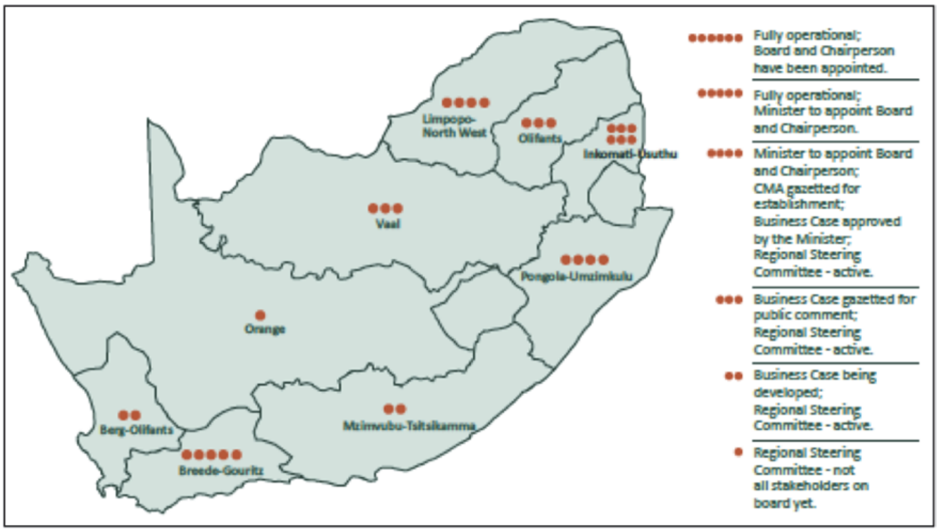

FIGURE 4-1 LOCATION AND STATUS OF CMAS AS AT FEBRUARY 2015. THE STEENKOPPIES AND GROOTFONTEIN COMPARTMENTS NOW FALL UNDER THE JURISDICTION OF THE LIMPOPO-NORTHWEST CMA. SOURCE: DWS, CATCHMENT MANAGEMENT AGENCY QUARTERLY UPDATE, FEBRUARY 2015

In 2014 DWS gazetted and established the Limpopo-North West Catchment Management Agency as the relevant decentralised body to manage water resources in this region, and both the Steenkoppies and Grootfontein compartments fall under its jurisdiction. DWS is in the process of transferring relevant functions from the office of regional department to the CMA. Responsibility for monitoring and assessing abstraction of groundwater will remain with the regional office (Sigwaza, 2015.)

Discussion now turns to a review of agricultural activities in the two compartments. It starts by situating developments there within the larger context of far-reaching changes in commercial agriculture.

4.3 THE LARGER CONTEXT: SOME BROADER ECONOMIC TRENDS RELEVANT TO COMMERCIAL AGRICULTURE IN THE TWO GROUNDWATER COMPARTMENTS

A comprehensive review of recent developments in South Africa's agricultural sector lies well beyond the scope of this report. Nonetheless, a brief summary of key trends and developments provides the essential context for this review of economic determinants underpinning groundwater abstraction for irrigation in the Grootfontein and Steenkoppies groundwater compartments, and their possible relevance for governance arrangements.

South African farmers have come under particular pressure over the past two decades, with a range of force combining to depress the profitability of commercial farming. Market deregulation and the disbanding of single marketing channels has shifted many farmers onto the defensive. The phasing out of tariff protections to farmers and decreases in farm subsidies has occurred alongside increasing consolidation of local and international buying power, with the result that buyers, not producers, are now the primary drivers of most agricultural value chains.

Commercial co-operatives have been transformed into private companies, with round after round of mergers and acquisitions. Pioneer Foods, for example, was formed in 1997 from the merging of Sasko (milling and baking) and Bokomo (poultry, eggs, animal feeds and breakfast foods, and went on to acquire SAD Holdings (dried fruit, Golden Lay (eggs), John Moir's, Ceres, and so on, to become one of the four big agri-food companies in the country. Other examples are Afgri (the former Oos Transvaalse Ko-op – OTK) and Senwes, the former Sentral-Wes Ko-op, which both operate across numerous markets including trading of agricultural commodities, handling and storage facilities, marketing of farming equipment, manufacture and distribution of animal fees, operating retail outlets and financial services. In 2013, Senwes owned 25% of South Africa's grain storage capacity. In 2011 it entered a joint venture with Bunge, one of the world's largest commodity producers (Greenberg, 2013). Senwes is prominent in North West Province.

The prices of most farming inputs have outripped the general level of prices in the economy, especially over the past decade (Visser, 2015). Broadly speaking and depending on the crop, the biggest input costs are typically labour and fertilizers, but rising Eskom tariffs have raised the profile of electricity as a cost driver, from 2-5% of the total to up to 10% or more. In combination, rising input costs and declining real prices for farm products are driving the pursuit of greater scale economies, with greater production by a smaller number of enterprises. The number of commercial farms halved from 90 442 in 1971 to 45 818 in 2002 (Aliber et al., 2007), and declined further to 39 966 by 2007 (DAFF, 2013). According to Frikkie Liebenberg, an agricultural economist at the University of Pretoria, 237 commercial farm units accounted for 33% of total agricultural income in 2007; and 2 330 farm units accounted for 53% of gross agricultural income in 2005 (Greenberg, 2015). Concentration has increased since then, with one informant describing the trend as "Get big, or get out".

Probably the main reason for consolidation has been the exit of struggling farmers, and the objective of those remaining in the sector to achieve economies of size. Another factor, particularly relevant in North West province, has been the consolidation of farms through the land restitution process (Visser, 2015). There was an 8.3% decline in the number of farms in North West Province between 2002 and 2007 (DAFF 2013).

To cope with the increased demands of large-scale production, farmers are making greater use of mechanization, and of casual rather than permanent labour in the context of rising labour costs. On average, average farm labour wages roses by 39% in the four years after the introduction of a statutory minimum wage for farm labourers in 2003 (Stanwix, 2013); but that increase has fuelled substantial job losses as farmers restructure and pursue greater mechanization where feasible, or plant crops that are less labour-intensive – more maize and sunflowers, for example, and fewer groundnuts (interviewee, 2015). According to Stanwix (2013), aggregate employment on farms declined by about 13% in the four years after 2003, and a 52% increase in the minimum wage in March 2013 was expected to lead to even more labour restructuring, with further mechanization and consolidation of farming units.

As Visser argues, state interventions to improve the livelihoods of farm workers since 1994 have largely failed to achieve their objectives, because government has not adequately acknowledged the extent to which the fortunes of farmers and farm-workers are interlinked (Visser, 2015). Farmers' coping strategies have passed risk on to workers, and both groups are increasingly exiting the agricultural sector (ILO, 2015). It is striking to note that farmers in the Grootfontein compartment complain of growing difficulty in recruiting farm labourers.

In tandem with job losses, a 2015 ILO study of farmer workers found that the use of off-farm seasonal workers, and growing reliance on permanent workers who live off-farm, has meant that "many rural towns that used to resemble sleepy hollows have developed into sprawling, underserviced informal settlements" (ILO, 2015). The increase in informal settlement across North West Province is a striking feature of the past decade.

FIGURE 4-2 INFORMAL SETTLEMENTS IN AND AROUND THE STEENKOPPIES COMPARTMENT

4.3.1 GROUNDWATER IRRIGATION IN NORTH WEST PROVINCE

North West province receives summer rains, varying from about 450 mm in the west, where the Grootfontein compartment is located, to about 600 mm closer to Gauteng, site of the Steenkoppies compartment. Erratic rains and uneven distribution are often a more significant challenge than the annual average rainfall (Senwes, 2014). In this context, irrigation overcomes the uncertainties of rain-fed agriculture, makes production of some crops – like cut flowers – viable where otherwise production would be untenable, and boosts yields immensely. Typical maize yields of 3 to 5.5 ha/ ton on dry land typically double under irrigation to 6 to 10 ton / ha or more (Senwes, 2014; Theunissen 2005; Grain-SA, 2015).

As illustrated below in section 4, there has been a steady increase in the volumes of water abstracted for irrigation in the two groundwater compartments in recent decades, driven by a desire to increase yields in a context of weak enforcement of abstraction limits.

Eskom's extensive program of electrifying commercial farmlands, particularly in the 1970s and 1980s, spurred increased irrigation towards the end of the 20th century, as cheap electricity became available to replace diesel-fuelled pumps. The rising price of electricity over the past decade has eroded these energy cost advantages and contributed to higher overall production costs. See Appendix 1 for a brief discussion of energy consumption in irrigation. Despite rising energy costs, irrigation volumes nonetheless continue to rise steadily, because of the wider pressure to increase outputs in the face of rising input costs.

An important further dimension underpinning growing groundwater abstraction is that farmers have learnt that DWS does not give adequate priority to enforcing compliance with authorised abstraction. Moreover, the Department's depth of capacity in procedural administration of the National Water Act now lags behind the growth in compliance enforcement challenges. Speaking of widespread over-abstraction for irrigation, one informant expressed this opinion: "Right now there is every incentive to use as much as you like, because there are no penalties for taking more than you should. People see obvious abuses being condoned, so that starts shaping the behaviour of others. It's easy to avoid prosecution and conviction if you know the law."

There is, however, consensus among sector specialists – including Ingrid van der Stoep, Technical Executive Officer of the South Africa Irrigation Institute (SABO) and Francois Joubert, from the firm Schoeman & Vennote that specializes in analyzing water use for irrigation – that irrigation water is being used more efficiently. Three factors are driving this:

1. Rising input costs – and especially a desire to avoid flushing away costly fertilizers through over-watering
2. Rising electricity costs for pumping
3. More efficient irrigation technologies, and a greater emphasis on optimizing volumes and timing to the specific requirements of the crop

With growing economic pressures, farmers are increasing production to cover overhead costs amidst lower profit margins, and planting larger areas without increasing their formal water allocation. Their water use efficiency (crop per drop) has increased markedly by using centre pivot and micro irrigation application systems, soil moisture monitoring and active water application scheduling to minimize evaporation losses and optimize soil-water uptake in the plant root zone. Nonetheless it is evident that over-abstraction is taking its toll on groundwater sources.

4.4 Economic dimensions of irrigation and governance in the Steenkoppies and Grootfontein compartments

4.4.1 The Steenkoppies compartment

The Steenkoppies compartment falls within the Mogale City Local Municipality and the West Rand District Municipality, and surrounds the small town of Tarlton between Magaliesburg and Krugersdorp. The municipality has a mix or urban and rural areas, with well-developed mining, manufacturing, agriculture and tourism sectors.

Irrigation from the compartment underpins an agricultural industry worth hundreds of millions of rands, and employing thousands of people (Vahrmeijer et al., 2013). The Steenkoppies area is one of South Africa's main vegetable producing areas under irrigation, producing mainly cash crops such as carrots, cabbage, lettuce, beetroot, broccoli and potatoes, as well as mushrooms, cut flowers and nursery plants. Vahrmeijer et al (2013) state that groundwater from the compartment supports the largest producers of carrots in Africa, and the largest producers of mushrooms and chrysanthemums in South Africa.

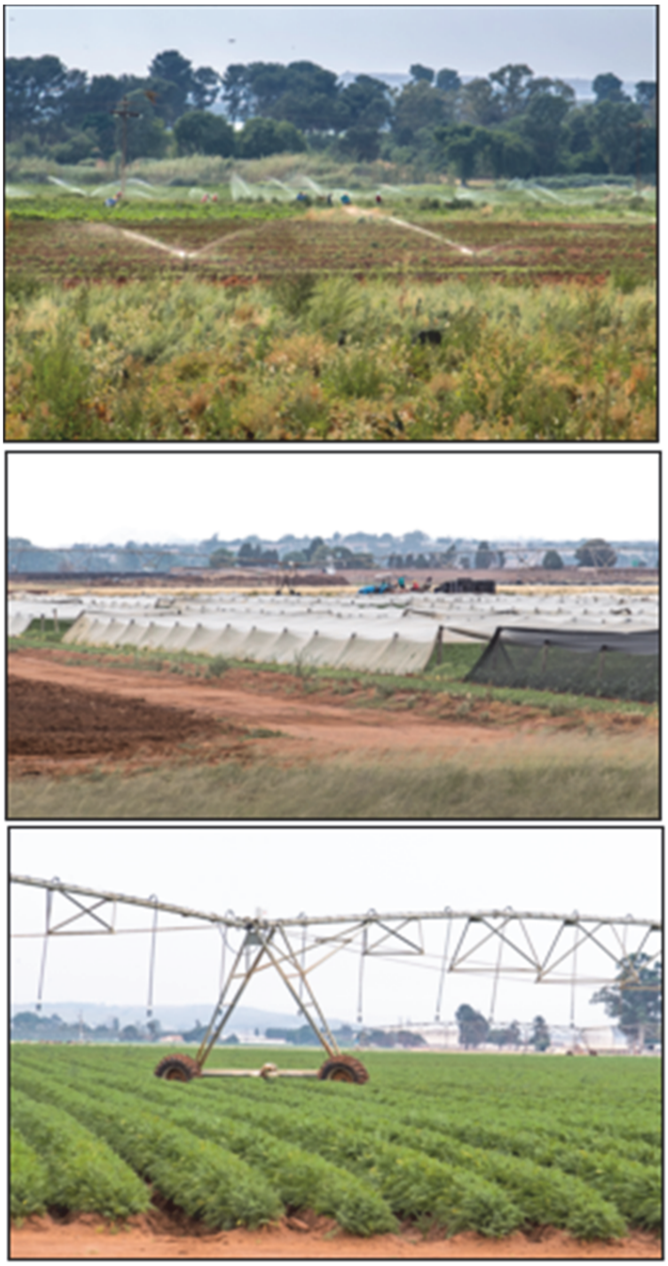

FIGURE 4-3 VEGETABLE PRODUCTION NEAR TARLTON

Overlaying the shape file for the Steenkoppies compartment over satellite and other spatial data for commercial agriculture shows 244 farms drawing directly from the compartment. There has been substantial consolidation in recent years, and an increase in the area owned or managed by a smaller number of owners; the number of owners is now far smaller than the number of discrete farms and land parcels. By far the biggest is Greenway Farms, a major producer of vegetables for local and export markets. According to one source, about 10 big farming enterprises currently use about 60% of the water (interviewee, 2015).

The intensity of agricultural production is evident in the median area under irrigation per farm: 8.65 ha per farm, up from 7.05 ha in 1996-98; the range is from 0.5 ha to 183.9 ha. Compare this to much more extensive farming in the Grootfontein compartment, where the median is 35.1, up from 26.4 ha in 1996-98. More telling is the value of the different crops, with the price increasing exponentially as farmers move from maize, to vegetables to cut flowers and mushrooms.

TABLE 4-1 INDICATIVE CROP PRICES PER IRRIGATED HECTARE, 2015. SOURCE: VAHRMEIJER, PERS. COMM. 2015

Indicative crop prices per irrigated hectare	
Mushrooms	R10 million / ha
Cut flowers	R2 million / ha
Vegetables	R100 000 / ha
Maize	R12-R18 000/ ha

The figure below gives an indication of current crops grown under irrigation in 2015, drawing on data collected by DWS by Schoeman & Vennote. The chart highlights the extent of high-value crops, and implicitly, high-cost investment too.

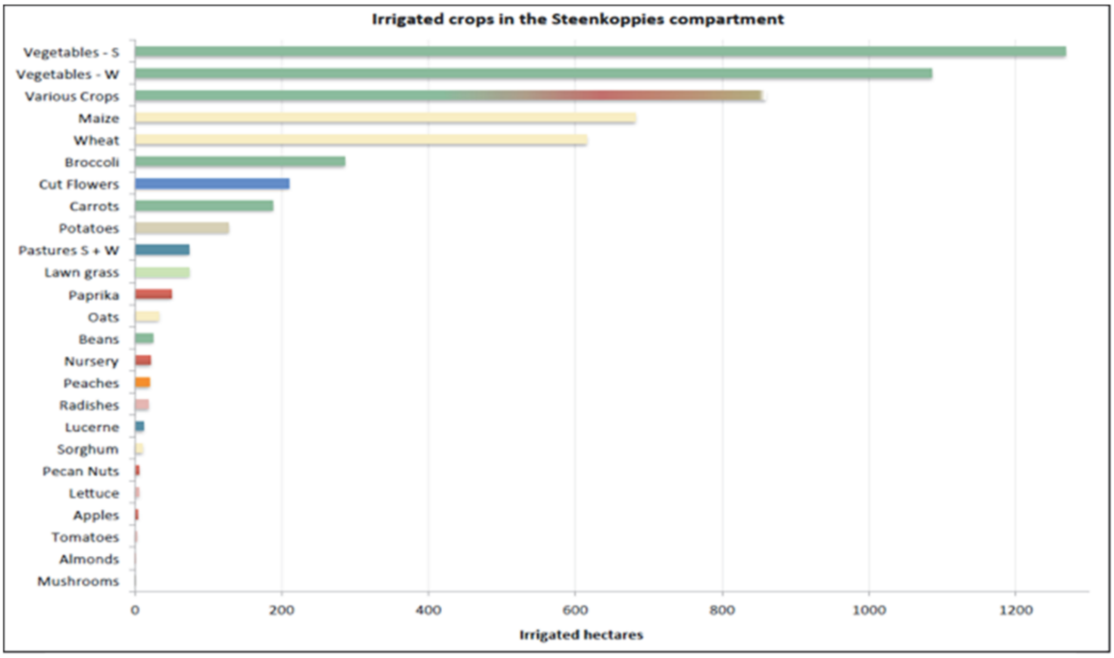

FIGURE 4-4 IRRIGATED CROPS IN THE STEENKOPPIES COMPARTMENT. SOURCE: DERIVED FROM DATA COLLECTED BY SCHOEMAN AND VENNOTE FOR DWS

Intensive production in farms irrigating from the Steenkoppies compartment provides jobs for more than 4 000 people, and salaries of more than USD 900 000 were paid monthly in 2012; given currency depreciation, the current figure would be considerably higher. Annual turnover was approximately USD 66 million (Vahrmeijer et al., 2012). This scale of intensive production also required considerable investments in agricultural infrastructure such as centre-pivots, poly-tunnels, pumps, reticulation systems, as well as package houses, mechanized conveyance and so on. Capital investments were estimated to be in the order of USD 100 million in 2012 (Ibid.)

TABLE 4-2 SNAPSHOT OF IRRIGATED FARMING IN THE STEENKOPPIES COMPARTMENT. SOURCE: VAHRMEIJER ET AL., 2012

Type of crops grown	Vegetables, maize, wheat and flowers
Total Ha under irrigation	3 786
Groundwater abstraction (WARMS)	$27.3 \times 10^6 m^3.a^{-1}$
Groundwater abstraction prelim. Validation	$22.4 \times 10^6 m^3.a^{-1}$
Permanent workers	2945
Temporary workers	1072
Managers	177
Living on farm	1475
Monthly salaries	US$ 900 000
Turnover	US$ 66 000 000
Capital investment	US$ 102 000 000

The area of land under irrigation has increased by 40% since 1996-98, and the data suggests that nearly a third (29.3%) of land currently under irrigation is not authorised. There is now irrigation on 56 farms where there was none in 1996-98; on one farm there is now irrigation on 181 ha, from zero in 1996-98. A further 47 farms have increased their area under irrigation beyond the area they are authorised to irrigate, with six each adding more than 50 additional hectares of unauthorized. One farm has increased the area under irrigation from 11.2 Ha in 1996-98 to 196.8 Ha in 2015, representing a 1757% increase.

The figure below shows changes in the number of irrigated hectares between 1996-98 and 2015. The red bars show the variance, i.e. the ratio of current use to use in 1996-98.

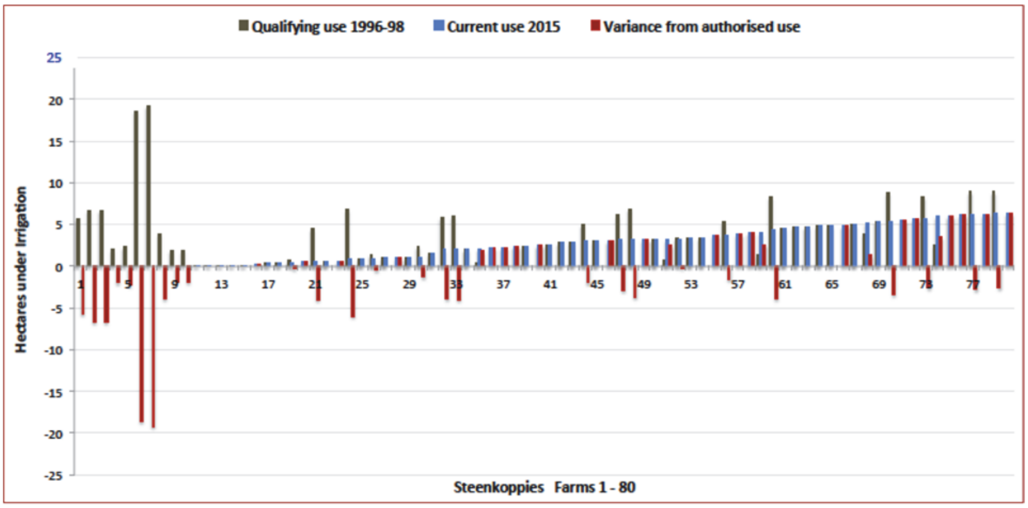

FIGURE 4-5 AREA UNDER IRRIGATION IN THE STEENKOPPIES COMPARTMENT, 1996-98 AND 2015, SHOWING THE VARIANCE. SOURCE: DERIVED FROM DATA COLLECTED BY SCHOEMAN AND VENNOTE FOR DWS

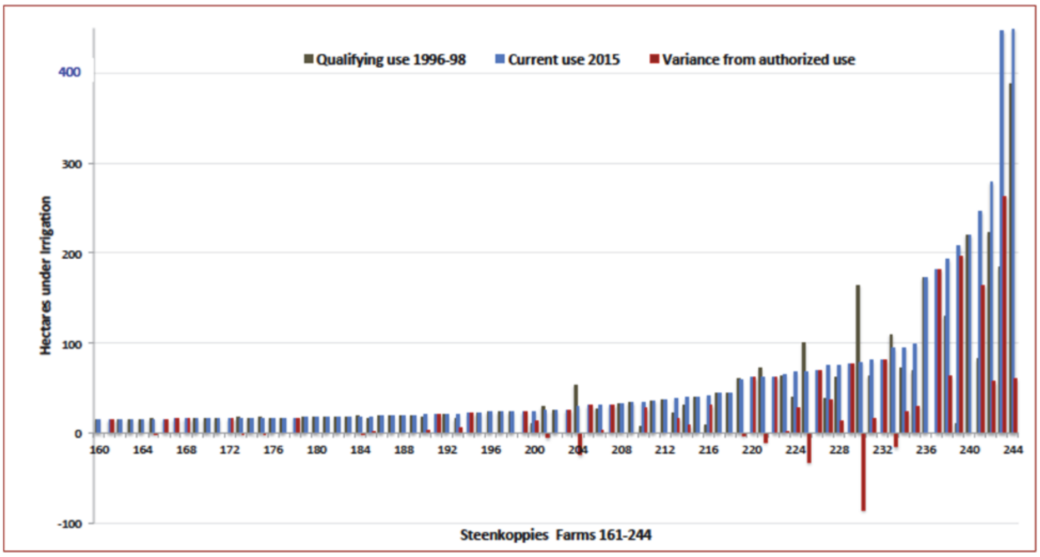

FIGURE 4-6 AREA UNDER IRRIGATION IN THE STEENKOPPIES COMPARTMENT, 1996-98 AND 2015, SHOWING THE VARIANCE. SOURCE: DERIVED FROM DATA COLLECTED BY SCHOEMAN AND VENNOTE FOR DWS

The total volume used for irrigation has increased by 28%, against a 40% increase in the land under cultivation. This suggests improved water use efficiency, even though the absolute increase in abstraction is nonetheless substantial.

Over the past two decades there has been a decisive shift away from ‘grow cheap and sell cheap’ – i.e. selling produce per box, not in prepacks – towards mechanization, investment in cold storage and packing sheds to reduce production costs per unit and increase the share of the final price that producers receive. One consequence is a net loss in jobs, as farmers have responded to statutory farm labour wages by restructuring; one big tractor and planter does the work of 80 people, and the cost of that investment can be recouped in two years. Another is that investment of millions in centre pivots, plant machinery and plant might take 20 to 30 years to pay off, so producers are looking for long-term security. A desire to safeguard the value of investments is a significant potential driver of co-operation; thus one might expect to see that those with 'more skin in the game' – i.e. major investors in intensive agriculture, particularly horticulture – being more willing to form a WUA than those with less exposure.

4.4.2 TOWARDS THE ESTABLISHMENT OF A WATER USER ASSOCIATION AT STEENKOPPIES

Insight into groundwater management in the Steenkoppies compartment has been deepened by substantial investment in a number of investigations and research projects by the Danish Government, Water Research Commission, CSIRO and others, and the work of a number of researchers. Key findings of this work have been documented elsewhere (Vahrmeijer, 2013 and Van der Stoep et al., 2012) and are also summarized in chapter 2 of this report. This section recaps this material briefly before moving to a broader discussion.

In 1995, a reduction in flow from Maloney's Eye led to a petition to the Minister of Water Affairs from downstream farmers, demanding that DWA intervene to stop all groundwater abstraction. Good rains in 1995-7 eased water pressures in the catchment, and no curtailment of abstraction was enforced. In 2004, yields from the Eye fell again, and shallow boreholes dried up. In September 2004 a group of concerned water users downstream of the Eye, who depended on flows in the Magalies River, formed the Magalies River Crisis Committee (MRCC), and engaged DWAF to take action against unlawful water use in the Steenkoppies compartment.

In March 2007, after a period of several years of drought, eight of the nine springs at Maloney's Eye stopped flowing altogether. The MRCC reconvened, and this time appealed directly to the Presidency, seeking a temporary halt to all groundwater abstraction in the compartment to allow the flow at the eye to recover. The MRCC also took legal action against the DWAF, to compel it to take act against farmers irrigating with groundwater in the Steenkoppies compartment to compel them to reduce or stop irrigation.

In May 2007, farmers from the Steenkoppies compartment established the Steenkoppies Aquifer Management Authority, and appointed Teunis Vahrmeijer, a local farmer and crop scientist, to start negotiations for the establishment of a WUA in the area. Verification of their registered water use was on going at the time, and measurement of water abstracted from the aquifer was identified as a possible solution to proving their lawful water use. While incurring nearly a million rand in legal fees, they argued that a range of factors were affecting the flow of the Eye, including mining activities and encroachment of alien vegetation. With the subsequent support of the Water Research Commission and Danish government, farmers were mobilized to co-operate in a major survey of boreholes and abstraction to determine actual irrigation volumes against authorized use; this information was to be used to validate existing use, and to provide an objective basis for managing the resource sustainably in the interests of all. When technical problems subsequently emerged with the meters installed to measure abstraction, many farmers proved unwilling to invest in replacement meters, as they did not want the information to be used against them by DWA (Van der Stoep, 2012).

The process of setting up a WUA proved to be time-consuming, tedious and ultimately fruitless. Discussions among local farmers and with DWA continued over six years. In October 2010, DWA rejected the WUA application on the ground that previously disadvantaged groups were not represented adequately on the management committee of the proposed WUA. Representatives from three local municipalities were subsequently brought into the committee, and eventually all DWA's concerns and procedural requirements were satisfied. But then, in 2013, the Department declared a moratorium on the establishment of all new WUAs; the Department is now moving in the direction of dissolving those that exist.

Teunis Vahrmeijer, who took the lead in initiating the establishment of the WUA and in keeping the process moving, maintains that all motivation and momentum was then lost, with little chance that farmers will co-operate to organize themselves in a similar way again. Mr Vahrmeijer himself is no longer willing to drive the process, after many years of voluntary service and hard work, and there is little to incentivize anyone else to take the lead.

Meanwhile, good rains in 2010 had reduced demand both for irrigation water from the Steenkoppies compartment and the Magalies River – and with that the external threat from downstream surface water irrigators that had catalyzed the counter-organization of the Tarlton farmers in the first place, from 2007, dissipated.

It seems unlikely that the MRCC will mobilize again against the Tarlton farmers: land-use activities downstream of the Steenkoppies compartment are changing, and a decade after surface water farmers mobilized to compel DWAF to act, there is less farming and more investment in leisure, residential and conference developments. Linked to this, agricultural production within the compartment has changed: alongside further consolidation, several Tarlton farmers have diversified their risk by shifting their winter crops to other locations – in Limpopo and Mpumalanga – where they are less vulnerable to winter water shortages.

Thus while objectively an economic rationale exists for the Tarlton farmers to work together to manage a common resource to protect their substantial investments and long-term interests, in practice the compelling external reasons (the MRCC and DWA interventions) to collaborate have largely fallen away. The source is perceived to be adequate, and the driver for a formal, explicit accountability and management mechanisms has largely fallen away. Until circumstances change in ways that compel farmers *within* the compartment to collaborate because of *internal* drivers, a revival in local organisation seems unlikely.

4.4.3 THE GROOTFONTEIN COMPARTMENT

The Grootfontein compartment falls within the Upper Molopo Subterranean Government Water Control Area, and abstraction in the area has required a permit since 1963. In recent years the water levels around the Grootfontein boreholes have dropped considerably, threatening the sustainability of this supply. At present there is no local organization such as a Water User Association that is addressing the deteriorating situation at Grootfontein.

The compartment straddles two local municipalities – the south-eastern portion of Mahikeng Local Municipality south of the town of Mahikeng, and the north-western portion of Ditsobotla Local Municipality, with Lichtenburg lying further south-east. Less than 2% of the area of the two municipalities is urban, and the Mahikeng Local Municipality's IDP for 2014/15 categorizes much of the Mahikeng area as 'traditional'. Current IDP documents indicate that both municipalities are characterized by severe poverty and unemployment, with a majority of residents living below a R1600 per month poverty line.

Broad economic activities in the area are characterized by agriculture, mining, some manufacturing, government services, trade and tourism. Especially in the provincial capital, Mahikeng, government is the biggest employer, and government transfers dominate the local economy . Major limestone deposits around Lichtenburg have spurred development of three huge cement factories. Beyond limestone, mining includes manganese ore, fluorspar, andalusite, diamonds and building sand. Mining of fluorspar, lime and slate is growing, and government is encouraging new prospecting in the area in the hopes of attracting investment and spurring job creation.

The Mahikeng area is served by good road and rail infrastructure, but farmers using the Grootfontein compartment are about 300 km from the big markets of Gauteng and the high-value export opportunities available there. In contrast to the Steenkoppies farmers, who are situated within 50 km of a range of major buyers, Grootfontein farmers do not have the locational advantages that Steenkoppies farmers enjoy. The additional distance and transport costs puts them at a competitive disadvantage in supplying fresh produce to Gauteng. Production focuses more on goods for local consumption or better suited for long-haul transportation. In theory, farmers could use the airport outside Mahikeng to air freight produce to enable a shift to higher value, more-intensive crops; but the combination of the hotter, drier climate, soil types and uncertainty about the long-term yields of the compartment in the face of rapidly rising municipal and domestic use weigh against this.

There has been some consolidation of farm ownership in the area, but this been offset by the sale of some farms to emerging farmers; government is keen to buy irrigated land for redistribution in support of transformation in the agricultural sector.

4.4.4 GROWING MUNICIPAL WATER USE AT GROOTFONTEIN

In 1978, the Bophuthatswana government gained rights to the excess water running from the Grootfontein Eye to augment supply to Mafikeng. Since then the number of boreholes drilled in and around the Eye has increased to supply Mafikeng. The original agreement was to use the Grootfontein Eye for municipal use only in time of acute shortage, and to develop alternative sources at the Molapo Eye. Use of the Grootfontein water has been continuous. There are now 23 boreholes in and around the Eye, and the Eye itself has dried up; just three of the boreholes remain functional.

Demands on the compartment are increasing as settlements expand steadily and new plots are allocated and developed for housing in Mahikeng's peri-urban areas and around Rooiground and elsewhere. StatsSA census data shows a comparatively modest increase in population between 1996 and 2011 (242 194 to 291 527) and just a 2% increase in access to piped water. Rising population and service levels do not adequately account for the extent of increased water demand and increasing pressure on available water sources; Grootfontein farmers tell anecdotes about unattended bursts, leaks, overflowing municipal reservoirs and taps that are left to run.

Mahikeng is currently gearing up to become a 21st Century world class city, following the launch of the Mahikeng Rebranding, Repositioning and Renewal Programme (MRRRP) in May 2015 by the Provincial Premier (Office of the North West Premier, 2015). The initiative has 23 components, ranging from road and storm water network upgrading, to the development of a new stadium which meets FIFA standards, construction of a new five star hotel, upgrading the airport, reviving the passenger rail link to Gauteng, and so on. All of these activities will raise demand for water in a context where existing sources are far from secure.

4.4.5 CURRENT CROPPING IN THE GROOTFONTEIN COMPARTMENT

The figure below shows that white maize – mainly genetically modified maize – is by far the biggest crop produced under irrigation in the Grootfontein compartment. The chart does not differentiate between white and yellow maize; yellow maize is used primarily as food for animals and poultry, and there is extensive cattle farming in the Grootfontein area. As one informant observed, ‘There is a lot of irrigated cattle there’. Other crops grown in the area include wheat, pastures and vegetables, plus some limited cotton production.

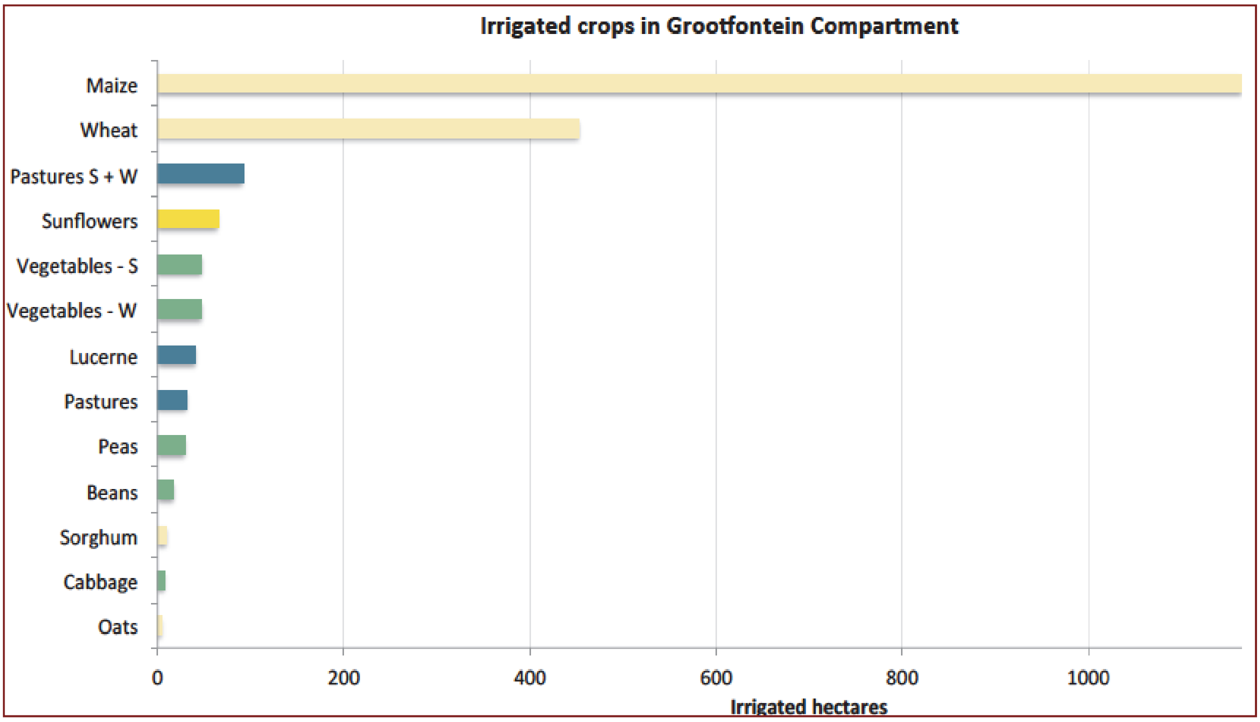

FIGURE 4-7 IRRIGATED CROPS IN THE GROOTFONTEIN COMPARTMENT, 2015. SOURCE: DERIVED FROM DATA COLLECTED BY SCHOEMAN & VENNOTE FOR DWS

Monsanto, one of the world's biggest suppliers of seed and pesticides, has an enormous maize storage and packaging depot outside of Lichtenburg, and many farmers in the Grootfontein compartment are contracted by Monsanto to produce seed maize. Monsanto takes responsibility for most harvesting and transportation itself; this reduces the need for farmers to invest in this plant and equipment themselves. This contrasts markedly with vegetable production and packaging in the Tarlton area, where here many farmers have invested heavily in pack houses, cooling plants and transportation to increase the value of their output and their share of the final price.

FIGURE 4-8 AFTER THE HARVEST: MAIZE PRODUCED UNDER IRRIGATION IN THE GROOTFONTEIN COMPARTMENT

4.4.6 IRRIGATION TRENDS AT GROOTFONTEIN

Extensive work has been done previously mapping groundwater resources in use in the Grootfontein compartment (see Cobbing, 2015 for a review), and declining yields in the compartment impact on all users. Emerging farmers are at particular risk, as they have fewer assets to use as collateral to expand production or buffer themselves against shocks. Equitable management of groundwater resources is a prerequisite not only for sustainable irrigated farming, but viable agricultural transformation more broadly.

How does current water use for irrigation compare with authorized use, based on usage in 1996-98 when the National Water Act was introduced? What factors in current usage might prompt local farmers to manage their usage more collaboratively in their common interest?

The figure below shows changes in the number of irrigated hectares between 1996-98 and 2015. The red bars show the variance, i.e. the ratio of current use to use in 1996-98.

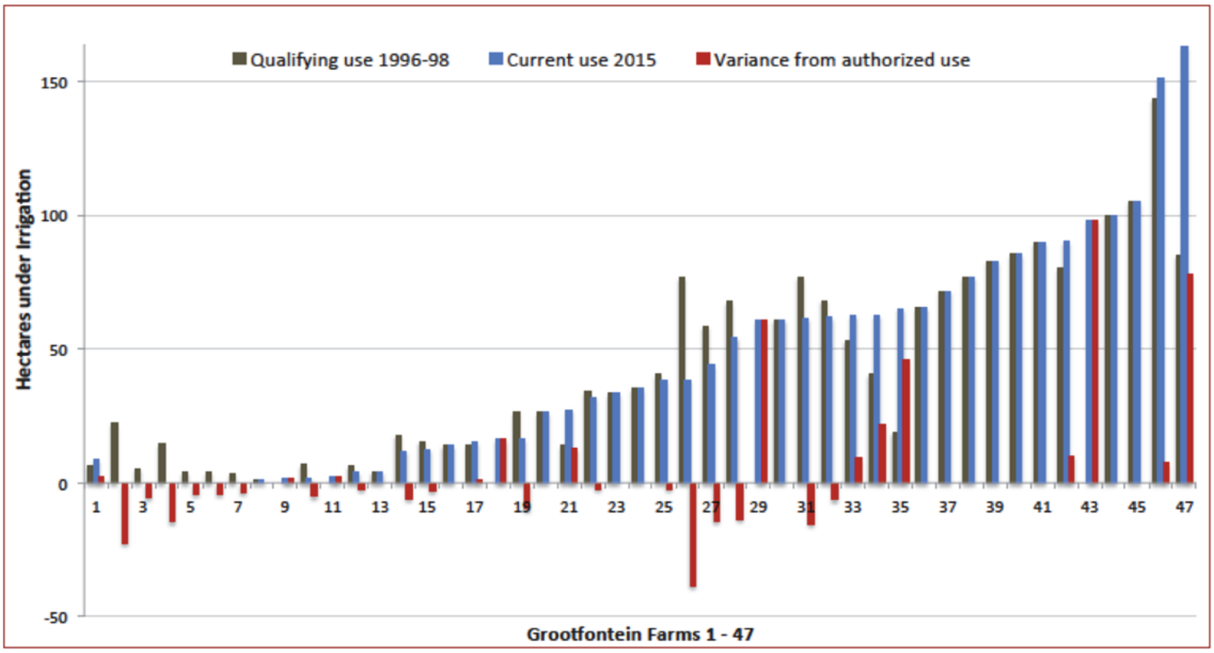

FIGURE 4-9 IRRIGATED HECTARES IN GROOTFONTEIN, 1996-98 VERSUS 2015. SOURCE: DERIVED FROM DATA COLLECTED BY SCHOEMAN & VENNOTE FOR DWS

Across the 47 farms straddling the compartment, the number of hectares under irrigation has risen by 19.7% since 1996-98. Five farms which were not irrigated in 1996-98 are now under irrigation, while the available data suggests that 9 are now irrigating more land than they are authorised to. The median number of hectares irrigated per farm has risen from 26.4 to 35.1 Ha.

Volumes of water used for irrigation have increased less sharply than the *area* of land under irrigation. Across 47 farms, the assessed volume of water used for irrigation is 9% greater than in 1996-98, against a 19.7% increase in irrigated area. This suggests far greater water use efficiencies.

What is less clear is how this affects the return flows and recharge of the aquifer. Greater irrigation efficiency – for example, using drip irrigation rather than sprinklers – can reduce the volume required per unit of area, but equally it can also reduce the run-off and return flow, which can affect overall aquifer re-charge. Compounding this uncertainty about the sustainability of current yields is that the authorised use was determined on the basis of what was being used at a particular time (1996-98, the two years preceding the promulgation of the National Water Act) rather than the sustainable yields; the authorised use, based on 1996-98 usage, may already have been more than the aquifer could supply sustainably, and hence the impacts of increased abstraction might be more severe than the volumes and areas suggest.

Close to the Grootfontein Eye, the level of the water table is now 33 m below ground level. But reliable yields are only found at around 65 m, representing a fall of over 60 m relative to 20 or 30 years ago (interviewee, 2015). This significantly increases pumping costs. But even greater are the implications of increased uncertainty about future aquifer yields. In a context where there is declining confidence in broader accountability, governance and management of groundwater, one likely outcome is increased short-termism and expedience in use, irrespective of the long-term consequences.

Irrespective of the net impact, there is little debate that over-abstraction causes conflict between farmers. Farm values fall sharply, pumping costs rise, boreholes fail, and those who rely on dry land grazing feel particularly aggrieved when springs, eyes and wetlands dry up. But the reasons for over-abstracting are straightforward: in a context of sharply rising input costs, irrigation increases yields substantially. As one informant put it, the explanation is 'simply the entrepreneurial spirit of farmers': the application process for a formal increase in irrigation rights is slow, with no assurance of success, and in the absence of firm deterrents against unlawful use, farmers help themselves. By the time DWS intervenes, the farmer will have harvested several crops and made a good return, even after they have paid off any investment in additional pivots costing about R1-m per tower.

4.4.7 NON-AGRICULTURAL USE OF GROUNDWATER FROM THE GROOTFONTEIN COMPARTMENT

There is consensus across a range of sources that a generation ago, water used to overflow from the Grootfontein Eye; it was this surplus that was made available for municipal use in the mid-1970s. Forty years later, the Grootfontein eye is dry, and the water table has sunk to 33 metres below the surface. In late 2015, reliable yields can only be found around the eye at depths of 65 m and more. There have been numerous meetings between farmers, organized agriculture, DWS and provincial role-players to discuss the deteriorating water supply, but few decisions have been taken and to date these discussions have not resulted in any appreciable change in practice.

Reliable data is not available on abstraction per sector or user. At a meeting between DWS, provincial role-players and representatives of commercial farmers in early 2014, DWS proposed a validation process to assess actual agricultural use against authorized use. Farmers "rebelled", in the words of one farmer whose family have farmed the land around the now-dry Grootfontein eye for over a hundred years, and said they would participate in a validation exercise only if there was greater accountability amongst all users around water use. Mahikeng Local Municipality is the biggest user beyond the agricultural sector, but other users include mining companies and small-scale prospectors.

Representatives of the Premier's Office and provincial government allegedly made commitments to act to limit wastage by municipalities. It seems nothing came of this, and there has been no change in the trend of municipal usage or progress towards validating farmers' use.

According to a prominent local farmer, a number of farmers in the Grootfontein compartment subsequently agreed amongst themselves to reduce their consumption to their authorized entitlement, and to reduce irrigation in winter in the hope that the water table would rise and the eye would be replenished. He alleges that any benefit to the compartment was compromised by the practices of Mahikeng municipality, which, he maintains, simply pumped more.

DWS is now using satellite imagery to improve compliance by farmers, and is closing down 'illegal' pivots – i.e. pivots irrigating land beyond the authorized limit. Farmers are now much more compliant, says the informant, but it remains a source of bitterness to them that "what you don't irrigate, the municipality takes."

"We want users to be disciplined and manage themselves better and monitor each other, and we need an organized structure to monitor and manage water use. But this structure needs to be part of something bigger, with rules and sanctions, and that's just not there", said one informant. "Water Affairs is just not playing its role, and farmers are abusing this weakness. But it's not just about farmers. We need all users – municipalities, mines, industry and agriculture, to work together." Key informant, Lichtenburg, October 2015.

4.5 DISCUSSION OF FINDINGS

Better water governance in the two compartments would obviously serve all users well. A quick comparison of irrigated land areas and volumes shows that over-abstraction by local farmers is more severe in the Steenkoppies compartment. This would support the hypothesis that the Tarlton farmers producing high-value goods through intensive horticulture and substantial infrastructure investment have a greater interest in organizing themselves to protect their enterprises through a WUA. Except they haven't: the process of establishing a WUA went nowhere when DWS policy changed, and their interest in organizing themselves dissipated when the external threat from downstream surface water irrigators fell away.

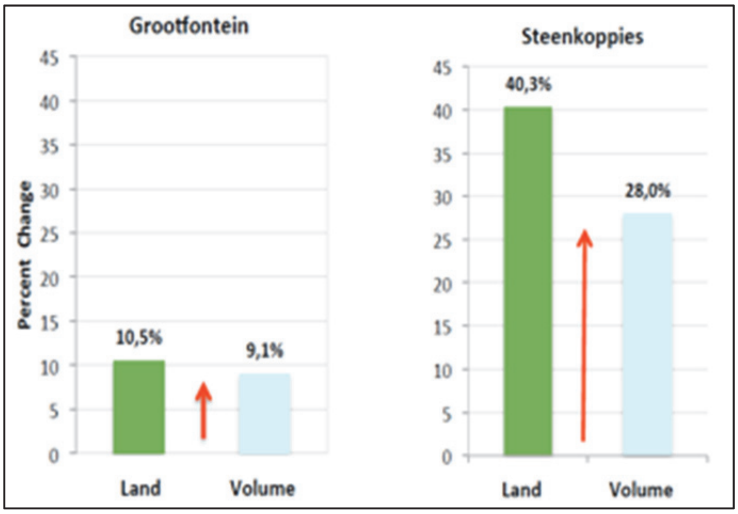

FIGURE 4-10 LAND (IRRIGATED HECTARES) VERSUS VOLUMES IRRIGATED: SUMMARISED SHIFTS OVER TIME IN THE GROOTFONTEIN AND STEENKOPPIES COMPARTMENTS, 1996-8 AND 2015

In the Steenkoppies compartment, farmers are the primary users of the groundwater. In the Grootfontein compartment, no-farm users have become increasingly significant. What Figure 4-10 does *not* show is the extent of over-abstraction by municipal and other users in the Grootfontein users. Farmers there contend that there is relatively little over-abstraction by irrigators in the Grootfontein area (which the figure confirms), and that the real problem lies beyond agriculture – specifically with the water management practices of Mahikeng Local Municipality. Their perceived impotence in the face of unregulated abstraction by the municipality is a powerful dis-incentive for farmers to reduce pumping, as they maintain that the municipality will simply take whatever they do not. Unless *all* users, within and beyond agriculture, agree to hold themselves mutually accountable and abide with agreed limits, farmers have little motivation to irrigate less.

In Grootfontein, whatever complaints farmers may have about their neighbours, these are less than their sense of grievance about the combination of poorly regulated abstraction by municipalities, and wasteful use within municipalities, because of unattended bursts, leaks and overflowing reservoirs. "At we're producing food with this water," said one farmer. Farmers and representatives of organized agriculture who were interviewed in the Grootfontein compartment maintain that municipalities in the area are ungovernable when it comes to water management, and that DWS is unwilling to take action against them. Compounding this, DWS is issuing prospecting licences to would-be miners for diamonds and other resources; given the dire need for economic development and job creation in the area, it is unlikely that protection of local aquifers would be given primacy over mining developments. Tragically, in the Grootfontein compartment, the consequences may well mean a race to the bottom.

There is persuasive evidence that DWS is not managing compliance adequately in either compartment; data is being collected, but is not being analyzed or acted on to the extent required. One consequence is that authorized users are penalized through higher pumping costs, reduced water availability and boreholes that fail. Local farmers tell stories of how the absence of monitoring is creating opportunities for corruption: farms are sold at a premium on the understanding that they have authorization for irrigation, but subsequently prove to have no water available. Elsewhere, mining companies are said to be buying up farms in order to access their water entitlements, but their actual use is not monitored by DWS. Agri-North West maintains it has raised its concerns around poor oversight by DWS repeatedly with the Department, but has been told by Departmental personnel that the Department lacks the personnel or capacity to fulfill its mandate.

For any governance arrangement or structure to be effective or even relevant, all parties would need to acknowledge their mutual accountability, and be willing to be held to account. To date, DWS has shown little appetite to engage with municipal and mining role-players at the level required, let alone to act against excessive abstraction where its own monitoring systems show this is happening.

Meanwhile, DWS has established the Limpopo-North West Catchment Management Agency as the relevant decentralised body to manage water resources in this region, and both the Steenkoppies and Grootfontein compartments fall under its jurisdiction. DWS is in the process of transferring relevant functions from the office of regional department to the CMA. Responsibility for monitoring and assessing abstraction of groundwater will remain with the regional office (Sigwaza, 2015).

4.6 CONCLUSIONS

This study did not find compelling evidence that the significant differences in the economic profile of agricultural production in the two compartments adequately explain why Steenkoppies farmers pursued the establishment of a WUA, and Grootfontein farmers did not.

The findings of this study suggest that in the two compartments under investigation, external threats were a more significant driver of efforts to improve groundwater governance by farmers, than a desire to strengthen mutual accountabilities between farmers within the compartment. Subsequent developments in each compartment have served to demotivate the primary users – farmers – from organizing themselves into a local governance structure, and prospects for reviving any initiative look bleak for the foreseeable future.

While there is evidently some resentment among farmers of excessive abstraction by other local farmers, the biggest perceived threat to their livelihoods is not other farmers irrigating with groundwater.

In the case of Steenkoppies, farmers irrigating with groundwater mobilised and organised themselves to try to form a WUA to demonstrate their *bona fides* because of the threat of curtailed abstraction and legal action when downstream surface water farmers mobilized against them. Thus while objectively an economic rationale exists for the Tarlton farmers to work together to manage a common resource to protect their substantial investments and long-term interests, in practice the compelling reasons to collaborate have largely fallen away. The source is perceived to be adequate, and the need for formal, explicit accountability and management mechanisms has largely fallen away. Until circumstances change in ways that compel farmers *within* the compartment to collaborate, a revival in local organisation is unlikely.

In Grootfontein, in late 2015 groundwater-dependent farmers said they felt under acute threat from poorly managed and growing municipal use, as well as unregulated mining activity. Greater collaboration among irrigating farmers is objectively unlikely to mitigate what is arguably an equally serious threat facing the water supply: unaccountable abstraction by a municipality. As a result of the sharp drop in the water table, the Grootfontein eye has dried up, a growing number of boreholes have failed and pumping costs for some have virtually doubled. Local farmers perceive the reasons as lying beyond agriculture, and consequently see little reason to organize themselves to reduce their abstraction and increase their accountability to fellow farmers. The major downstream user is a municipality, and is unlikely to challenge the practices of irrigation farmers; it is more likely the status quo will continue, until perhaps surface water sources are mobilised to address ever-growing demand.

These realities flag the importance of the role of DWAF / DWA / DWS in maintaining the credibility and integrity of the sector's accountability framework, whether at the level of routine monitoring and compliance management, or at the more politically loaded level of acting decisively when abuses are revealed.

Voluntary association takes time, commitment and hard work, and a weakness of WUA structures has been that they have very limited teeth; their power to compel co-operation or impose sanctions is very limited, and rests on an essential underlying willingness to subordinate individual interests to the common good. A key test for the new CMAs – in the Limpopo-North West catchment and elsewhere – will be their willingness to take unpopular decisions, and to challenge abuses wherever they lie. In theory they have substantially more clout than a WUA; but in practice, will they be willing and able to take on municipalities who flout national water policy?

Ultimately, groundwater needs a combination of mutual accountability between neighbours, diligent monitoring with analysis of the findings, and a commitment to act when abuses are found. The best monitoring is likely to be between adjacent users, as the draw down from excessive pumping will be noticed locally. But where DWS does not act – whether against greedy irrigators or weak municipalities – groundwater management is at risk of becoming a free-for-all, irrespective of more abstract economic self-interest.

5 THE LEGAL FRAMEWORK AND WATER USER ASSOCIATIONS

5.1 INTRODUCTION

This report explores the legal framework of the Water Users Associations (WUAs) in the Grootfontein, Lichtenburg / Itsoseng and Steenkoppies groundwater compartments of the North West dolomites. The legal and procedural issues or milestones that need to be addressed in the formation of a successful WUA in these compartments are briefly discussed. The background to the failure to establish the WUAs in the Grootfontein, Lichtenburg / Itsoseng and Steenkoppies comportments is provided in summary, including the legal backdrop on the right to water in South Africa.

5.2 LEGAL BACKGROUND AND HISTORY AS IT APPLIES TO GROUNDWATER

The Constitution of South Africa (1996) contains a Bill of Rights (Chapter 2) that ensures rights of individuals to a safe environment and to adequate water. Two fundamental entitlements form the backbone of South African water law. Section 24 provides that ‘Everyone has the right (a) to an environment that is not harmful to their health or wellbeing; and (b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that (i) prevent pollution and ecological degradation; (ii) promote conservation; (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development. And Section 27 provides for the right to water as follows: ‘(1) Everyone has the right to have access to (a) healthcare services…(b) sufficient food and water; ...(2) The state must take reasonable legislative and other measures , within its available resources, to achieve the progressive realisation of each of these rights.’

Additionally, the Water Services Act and National Water Act govern the right to water. The two main acts governing the right to water as found in the Constitution 1996 are the Water Services Act 108 of 1997 (WSA) and the National Water Act 36 of 1998 (NWA). The Constitution allocates the management of water resources to the national government, while local governments (municipalities) are responsible for the management of water and sanitation services (IELRC, 2007-03). The NWA is a legal framework for the management of water resources; rivers, streams, dams and groundwater, which is the responsibility of the national government. The WSA regulates water services which remain the responsibility of local government. This covers drinking water and sanitation services supplied by municipalities to households and other municipal water users. The Strategic Framework of Water Services (2003) in South Africa regulates the right of access to water.

The NWA includes management to ‘ensure that the nation’s water resources are protected, used, developed, conserved, managed and controlled in ways which take into account amongst other factors: ‘meeting the basic human needs of present and future generations’; ‘promoting equitable access to water’; ‘promoting the efficient, sustainable and beneficial use of water in the public interest’; ‘facilitating social and economic development’; and ‘protecting aquatic and associated ecosystems and their biological diversity’.

The NWA is based on the principle of the hydrological cycle. It does not recognise a distinction between surface water and groundwater and includes all water resources such as watercourses, surface waters, estuaries and aquifers. The Department of Water and Sanitation (DWS) is the national agency responsible for the formulation and implementation of the water policy. The NWA also specifies that the nation's water resources are managed through a public trust which is created to replace private ownership. The national government acting through the Minister of Water and Sanitation is the public trustee. According to the DWS 'public trustee means that the Minister has authority over water throughout the country. Water is a natural resource that belongs to all people. As the public trustee of the nation's water resources, the Minister is responsible for the public interest and must ensure that all water everywhere in the country is managed for the benefit of all people, including future generations.' As the trustee, the government must ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all persons, and in accordance with its constitutional mandate. Furthermore, the NWA protects all water resources as part of the need to protect basic human and ecological needs and create a water reserve. Also, the NWA re-establishes water entitlements to anyone – previously water rights were governed and owned by the land owner – thus ensuring that those not owning or controlling land have equal access and use of water.

The WSA regulates the accessibility of water. As indicated by section 27 (1)(b) of the Constitution the WSA develops the right of access to basic water supply and basic sanitation necessary to ensure sufficient water and an environment not harmful to health or well-being. Based on the White Paper (1997) it has been determined that the minimum standard for basic water supply services includes inter alia a minimum quantity of potable water of 25 litres per person per day or 6 kilolitres per household per month, available within 200 metres of a household and with an effectiveness such that no consumer is without a supply for more than seven full days in any year including the criteria applicable to the quality of water.

5.3 WATER USER ASSOCIATIONS

The Minster of Water and Sanitation (first tier) is the custodian of water resources and has the ultimate responsibility to ensure that water resources are protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner for the benefit of all persons, and that water is allocated equitably and used beneficially in the public interest while promoting environmental values. The Department of Water and Sanitation (DWS), formerly the Department of Water Affairs and Forestry (DWAF), is now fully responsible for administering all aspects of the Act on the Minister's behalf. It is envisaged that this role will diminish as regional and local water management institutions are established. The eventual role of the DWS will be to provide national policy and a regulatory framework and to maintain general oversight of the institutions' activities and performance. In the long run, the responsibility for operating and maintaining infrastructure will be transferred to the Catchment Management Agencies (CMAs) (second tier) and Water Use Associations (WUAs) (third tier). Each CMA is to develop a catchment management strategy for managing water and that management can be delegated to regional and catchment level. The primary purpose of the CMA is to involve communities and seek co-operation between different stakeholders and interested persons. The local execution of the catchment management strategy is done by the local organizations such as WUAs and others. The WUA is a co-operative association of individual users who act to undertake water related activities for their mutual benefit.

The WUA has the full power of a natural person of full capacity except those that can only be attached to natural persons or are inconsistent with the NWA.

The WUA is established by the Minister of Water and Sanitation according to the procedures set out in the NWA. Either the Minister or the stakeholders proposing the WUA can initiate the process to establish the WUA. The Minister may initiate the establishment of the WUA which will be in the public interest. This includes local control of a government scheme, support of emerging farmers and/or to promote co-ordinated development of a resource. The WUA is established after public consultation has taken place. A proposal is submitted to the Minister for the establishment of the WUA as set out in section 91 of the NWA. A list of actions that need to be addressed in the proposal are listed in sections 92 to 94 of the NWA. The Minister will approve the establishment of the WUA if it promotes the objectives set out under the purpose of the NWA (section 2) and these are consistent with the CMA. One of the issues to be included in the proposal is to include a proposed constitution of the WUA as specified in section 93 of the NWA. A model constitution is provided in Schedule 5 of the NWA. However, it should be noted that the model constitution is based on the legal framework for the management of all water resources, including rivers, streams, dams and groundwater, and not only groundwater

A schematic representation of the process for the establishment of a WUA is illustrated in Figure 5-1 below:

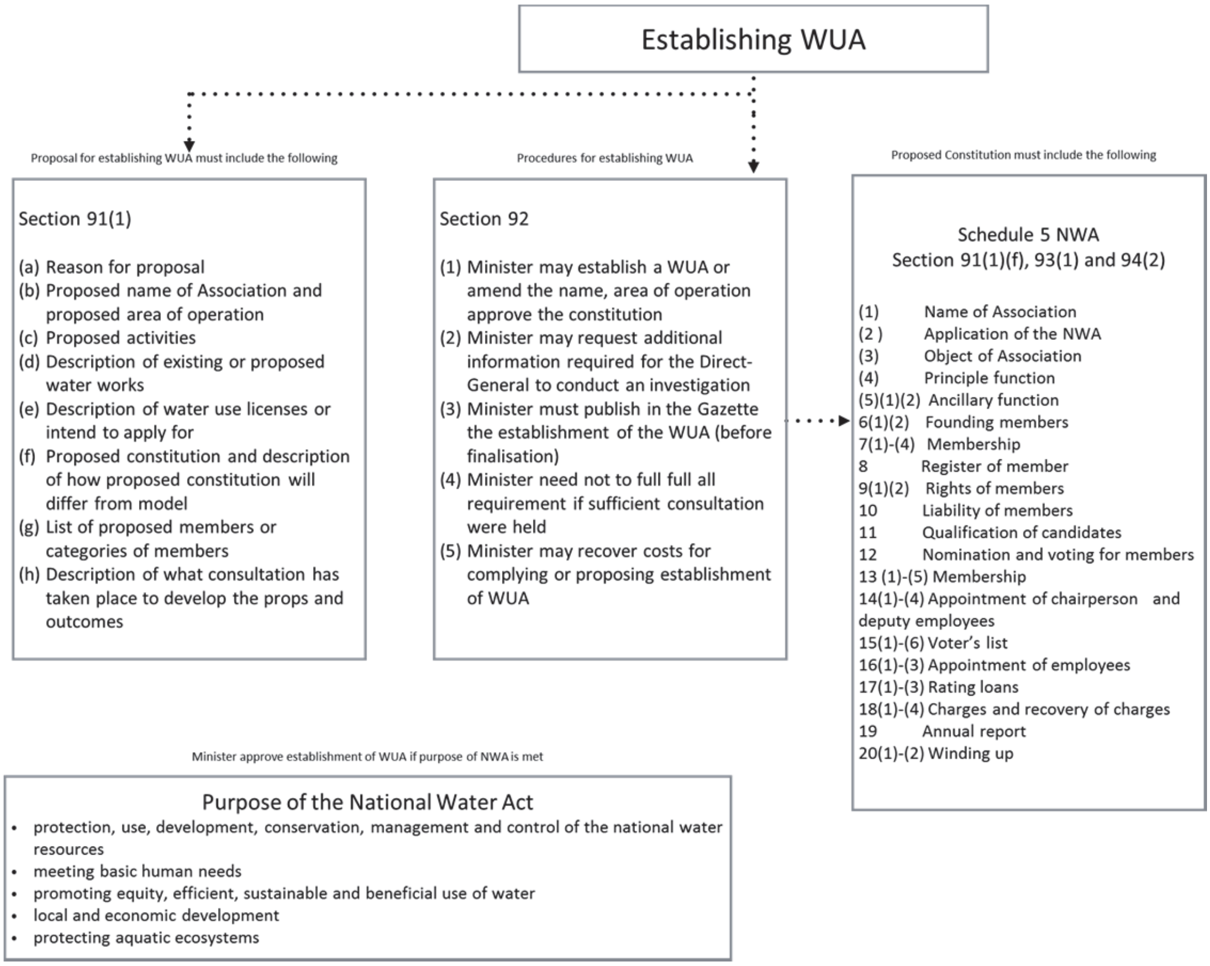

FIGURE 5-1 PROCESS TO ESTABLISH A WATER USER ASSOCIATION

5.3.1 CURRENT POLICY AND THE LAW

As of 2015 however it should be noted that the Department of Water and Sanitation is considering abolishing Water User Associations, and Catchment Management Agencies are now envisaged as the primary forum or implementing agent for decentralised water management. WUA roles and functions will be transferred to CMAs as appropriate, in the interests of supporting greater transformation and equitable water use. However this policy is still in the process of being formulated and the Department of Water and Sanitation is engaged in a technical and public consultation process to examine the issue from the various relevant policy and legal angles.

5.4 THE CASE STUDY COMPARTMENTS

5.4.1 THE GROOTFONTEIN COMPARTMENT

The Grootfontein compartment straddles two local municipalities – the south-eastern portion of Mahikeng Local Municipality south of the town of Mahikeng, and the north-western portion of Ditsobotla Local Municipality, with Lichtenburg lying further south-east.

Farmers in and around the Grootfontein groundwater compartment proposed the establishment of the Grootfontein Dolomitic Water User Association in the early 2000s mainly to establish a statutory body responsible for the effective management of the abstraction of water in the Grootfontein dolomitic compartment and to prevent further decreasing groundwater levels in the Grootfontein compartment as the Grootfontein eye dried up due to over-exploitation of the groundwater resource. The Grootfontein compartment stakeholders include municipal representatives from the district municipality (DM) and the local municipality (LM) who regulate municipal abstractions from the compartment.

The Department of Water Affairs and Forestry (as DWS was then known) rejected the Grootfontein WUA application on mostly unknown grounds – however based on a number of interviews with farmers and other stakeholders the WUA application was rejected due to the observation that previously disadvantaged groups were not represented adequately on the management committee of the proposed WUA. Plans to proceed with the WUA then appear to have fallen apart, and today there is no local organisation exclusively mandated to managing or reducing groundwater abstractions from the Grootfontein compartment.

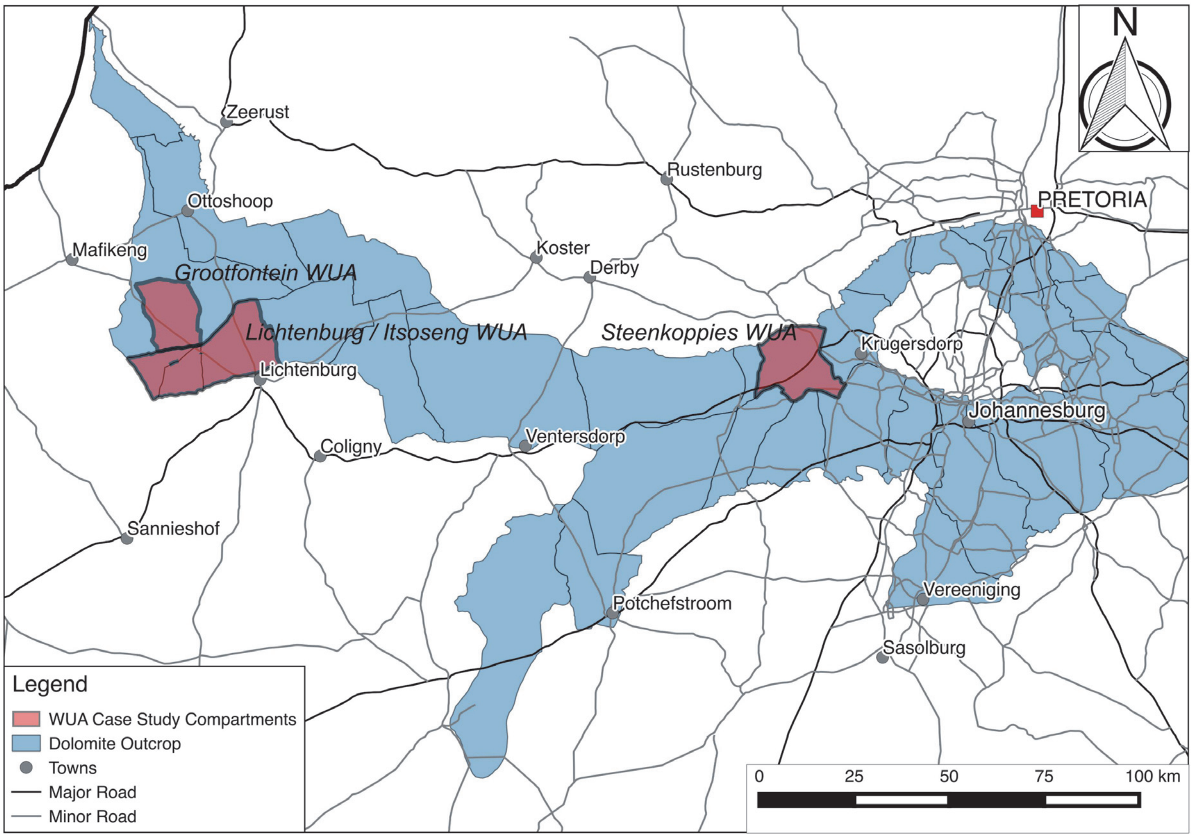

FIGURE 5-2 LOCATIONS OF THE CASE STUDY COMPARTMENTS

5.4.2 THE LICHTENBURG / ITSOSENG COMPARTMENT

The Lichtenburg / Itsoseng compartment falls within the Ditsobotla Local Municipality and the Central District Municipality; and surrounds the small towns of Lichtenburg and Itsoseng. The municipality has a mix of urban and rural areas, with well-developed mining, manufacturing, agriculture and tourism sectors. At present there is no local organization such as a Water User Association that is managing the groundwater situation in the Lichtenburg / Itsoseng compartment.

Stakeholders in the Lichtenburg / Itsoseng groundwater compartments proposed the establishment of the Lichtenburg / Itsoseng Water User Association in the late 1990s, mainly to establish a statutory body responsible for the effective management of the abstraction of water. The process reached an advanced stage. Concerns were driven partly by agricultural abstractions, but also by pollution concerns and the increasing footprint of large industrial users of groundwater in the area (cement factories).

The Department rejected the Lichtenburg / Itsoseng WUA application on mostly unknown grounds, in a process reportedly similar to the experience of the Grootfontein WUA described above. Based on a number of interviews with stakeholders the WUA application was rejected due to previously disadvantaged groups not being represented adequately on the management committee of the proposed WUA. Interviewees stated that it was difficult to find irrigating farmers of the required profile who were willing to serve on the WUA, and the process seems to have stalled at that stage. Similar to the Grootfontein compartment, there is today no local organisation engaging with the management of the groundwater resources in the Lichtenburg / Itsoseng groundwater compartment. Both compartments can be regarded as currently being in a state of "managerial limbo" in which users attempt to self-regulate but lack an appropriate forum and associated institutions to bring about effective management.

5.4.3 The Steenkoppies Compartment

The Steenkoppies compartment falls within the Mogale City Local Municipality and the West Rand District Municipality, and surrounds the small town of Tarlton between Magaliesburg and Krugersdorp. The municipality has a mix or urban and rural areas, with well-developed mining, manufacturing, agriculture and tourism sectors.

Irrigation from the compartment underpins a valuable agricultural industry employing thousands of people, and it is one of South Africa's main vegetable producing areas (Vahrmeijer et al., 2013). Vahrmeijer et al (2013) state that groundwater from the compartment supports the largest producers of carrots in Africa, and the largest producers of mushrooms and chrysanthemums in South Africa.

Farmers from the Steenkoppies compartment established the Steenkoppies Aquifer Management Authority, and appointed Teunis Vahrmeijer, a local farmer and crop scientist, to start negotiations for the establishment of a WUA in the area to prevent a water crisis, as occurred in the past. This process arose partly out of a low-flow crisis at the Maloney's Eye spring and the legal and other moves that this occasioned. The process of setting up a WUA proved to be time-consuming and ultimately unsuccessful. Discussions among local farmers and with DWA continued over six years. In October 2010, DWA rejected the WUA application on the grounds that previously disadvantaged groups (race and sex) were not represented adequately on the management committee of the proposed WUA. Local government was reached to nominate personnel to correct this issue, however nothing came of this initiative. The DWA involved consultants to fast track the process for the nominations of previously disadvantaged groups. However, in 2013, the Department declared a moratorium on the establishment of all new WUAs; the Department is now (2016) moving in the direction of dissolving those that exist. After this no further moves were made towards the establishment of the Steenkoppies compartment WUA. Respondents report that the farmers are currently self-regulating their groundwater withdrawals, operating in some ways as a *de facto* WUA.

5.5 Issues Arising from the Case Studies

5.5.1 Administrative involvement

One of the limiting factors in identifying the reasons why the WUAs in question could not be established is due to limited knowledge in providing any "reason" to the WUA applicants including farmers and government personnel. This may imply that the right of the WUA to have notice of the administrative actions taken could have been inadequate. The right to adequate notice in administrative action forms part of the Constitution of 1996 and the Promotion of Administrative Justice Act No. 3 of 2000 (PAJA). The perception exists among several interview respondents that inadequate reasons for the refusal to approve or endorse the WUAs by DWS were provided, and furthermore that a clear "way forward" was not communicated following the refusals.

Administrative law, forming part of public law, regulates the activities of organs of state and natural or juristic persons that exercise a public power or perform a public function. Regulating activities of state organs and natural or juristic persons includes prescribing the procedures that need to be followed when exercising a public power or performing a public function. Administrative law is therefore used to protect the public from unfair administrative actions. During the establishment of WUAs certain procedures need to be followed by the organ of state (Minister). If these procedures are not followed accordingly the applicants of the WUA may act on unfair administrative actions from the Minister, which may include inadequate notice of the administrative action, unreasonable opportunity to make representation, unclear statement of the administrative action, etc. In the following paragraphs the potential path of legal 'outcome' during the WUA application will be set out according to the Constitution of 1996 and the Promotion of Administrative Justice Act No. 3 of 2000 (PAJA).

Article 1 of the PAJA defines administrative action that is taken by an organ of state or natural or juristic person exercising a public power or performing a public function. The Minister of the Department of Water and Sanitation, DWS and CMA all form part of organs of state exerting an administrative action. The administrative action referred to in this study is to "making a decision on the acceptance of the establishment of a WUA".

An administrative action must be fair as indicated in article 33(1) of the Constitution and article 3 of PAJA. Also, article 195 of the Constitution provide principles and values regarding righteous administrative actions. Therefore, reading articles 33 and 195 creates a duty on fair administrative actions. Article 3(2)(b) of PAJA sets out the minimum core requirements for a fair procedural action which includes adequate notice of the nature and purpose of the proposed administrative action, reasonable opportunity to make representation, clear statement of administrative action, adequate notice of any right of review of internal appeal and adequate notice of the right to request reasons.

Based on a number of interview, from farmers to government personnel, it is unclear as to why the WUAs could not have been established. The WUAs have the right to adequate notice as set out in articles 33(2) of the Constitution and article 5 of PAJA. In the case of Minster of Environmental Affairs and Tourism v Phambili Fisheries (Pty) Ltd; Minister of Environmental Affairs and Tourism v Bato Star Fishing (Pty) Ltd [2003] 2 All SA616 (HHA); 2003 6 SA 407 (HHA) stated that adequate notice or reason "is apparent that reasons are not really reasons unless they are properly informative. They must explain why action was taken or not then, otherwise they are better described as findings or other information". If unfair administrative action was taken and adequate reason was not provided the WUA can act on administrative remedies as set out in articles 6 and 8 of PAJA including review of the administrative action. Therefore if unfair administrative action occurred the applicants of the WUA may apply for a review of the establishment of the WUA or adequate reason. However, this must be done within 90 days after the date on which applicants became aware of the action or might reasonably been aware of the action.

However, these rights, including not providing adequate notice for the administrative action, can be limited as set out in article 3(4)(b) referring to the factors that needs to be considered when these rights are aside. These limiting factors are paraphrases of limitation clause, article 36, of the Constitution. The limitation clause specifies that the limitation must be justifiable and fair in an open and democratic society founded on dignity, equality and freedom and needs to include factors such as the nature of the law, importance of intent of the limitation, the nature and size of limitation, the link between the limitation and the purpose and a less restricted manner to reach the purpose. If the limitation clause was followed then no unfair administrative action took place.

In all three case studies it seems that administrative involvement is a key challenge in the establishment of a WUA. The capacity of the government to perform the task of providing adequate reason for not allowing the establishment of a WUA or involving local government to provide nominees for previously disadvantaged groups, due to a lack in training or being understaffed, becomes a key challenge between private and governmental sectors and the motivation to establish a WUA.

5.5.2 Involvement of the Private Sector

What proves an obstacle to the right to water is the involvement of the private sector in water management, referred to as 'corporatisation' of institutions or privatisation mechanisms (IELRC, 2007-03). In corporations of institutions water services are owned and operated by the local government. Following the private sector mechanism the management of state-owned water services is delegated (although not fully delegated) to private corporations. Corporatisation of services is commonly the first step towards direct involvement of the private sector. Delegation by the government of the provision of basic services to private actors does not mean that the state can delegate its human rights obligations and a policy to privatise or corporatise water services to any extent must still comply with the duty to progressively realise socio-economic rights.

The NWA is to ensure that the water resources are protected, used, developed, conserved, managed and controlled in ways that take into account aspects based on section 2 of the NWA such as 'redressing the results of past racial and gender discrimination, social and economic development'.

Also, it is to be noted that licenses or permits are temporary in nature and are issued at the discretion of the Minister. The permits or licenses are not transferable. That means that the present owner cannot pass the rights on to his/her successor-in-title. This is especially important with respect to irrigation where an owner may lose interest in developing his/her land. This may decrease long term investment in water infrastructure, in particular in that which is in private hands.

5.5.3 Remarks on the Issues from the Case Studies

Some key issues regarding the involvement of the governmental and private sector are briefly discussed below:

The lack of capacity in the government (referred to as Capacity Gap) becomes complex due to the socio-economic, political and institutional state. The use and misuse of services together with how services are provided by and in government is further complicated by the history of South Africa. This includes the government's organisational capacity, technical capacity, procedural capacity, and networking capacity as well as their financial resources. Limited feedback from government and a lack of involvement of government personnel identified in the three case studies in the establishment of a WUA raises questions regarding groundwater management in both governmental and private sectors. If a capacity gap is identified in government, management of water could be mandated to private sectors to prevent long-term unsustainable water service.

The model constitution provided in Schedule 5 of the NWA is based on the legal framework for the management of all water resources, including rivers, streams, dams and groundwater. Although the model constitution focuses largely on administrative factors, i.e. basic information on the WUA, inclusion of sections specifically for surface water and groundwater management might promote using the model constitution and not amending the model constitution saving time and money on the development of an amended constitution in the private sector as the Lichtenburg / Itsoseng compartment stakeholders had to do.

Section 2(c) of the NWA specifies the purpose of the Act, in particular redressing the results of past racial and gender discrimination, and therefore should include the support of emerging farmers into the WUA. Including and redressing emerging farmers into the WUA could lead to better coordination and development of a particular resource such as the groundwater resource supplying Mafikeng. This will furthermore benefit socio-economic rights and development, such as redressing past racial and gender discrimination (article 2(c) of the NWA). Addressing the potential issue that previously disadvantaged groups are not represented adequately on the management committee of proposed WUAs is vital. The lack in involving previously disadvantaged groups seems to be the major influence in not establishing the WUA in the three case studies. However, the Steenkoppies compartment tried to involve the local government to address this issue.

A WUA is intended to be mostly self-funded and is therefore self-supporting. The establishment of the WUA is only possible if members are able to pay for the administrative costs of the WUA as well as the operation and maintenance costs of any capital works associated with the WUA. The WUA is normally funded through charges levied on its members (water use charges). Other potential sources of funding include the proceeds for operating waterworks and direct financial assistance for the DWS or from the CMA. However, these sources of funds are only potential sources and the main funding lies with the WUA (i.e. members). Potential development of more WUAs could be established if financial aid was to be provided for the establishment of the associated management and maintenance of infrastructure. With the development of infrastructure, sustainable management of the resources will provide efficient sustainable and beneficial use of water (section 2(d)) and water for a growing demand (section 2(f)).

5.6 THE WAY FORWARD AFTER WUAS

Due to the unsuccessful establishment of WUAs in the Grootfontein, Lichtenburg/ Itsoseng and Steenkoppies compartments a forthcoming issue is the management of water between individuals. If no statutory organisation governs the water rights between individuals, which the WUA would have achieved, no private individual may force sustainable management of water onto another private individual. The question now arises as to who will manage the water use between individuals to successfully manage a sustainable water resource for long term use.

Another concern is water security. Who becomes the responsible partner for water security? The Steenkoppies compartment is very sensitive to fluctuating groundwater levels. Allocating a registered volume of water to a groundwater user will allow him/her to use specified volume per annum. In dry seasons the water user's right is to use the same registered volume of water compared to a wet season. The management of groundwater in such detail therefore on regional governmental level becomes questionable. In addition the proposed idea of "use it or lose it" as water right needs to be readdressed. If 20% of the registered water use is not used per annum, this is seen as lost water for the water user. In dry rain seasons with limited groundwater recharge the 20% saved by a groundwater user in a wet rain season during high groundwater recharge should then be allocated for sustainable groundwater management during the dry rain season. Therefore, future policy needs to address detailed water security.

Based on discussions with DWS personnel in January 2016 the future of the WUA policy is uncertain, and questions remain as to how effective a regional body such as the CMA will be in addressing local issues as described above. The risk exists that the hiatus will be filled by *ad hoc* arrangements which more closely replicate former patterns of water ownership and management, and that sub-optimal equilibria will become further entrenched. Over time these *ad hoc* arrangements become difficult to dislodge, and any new policy would need to take into account the loss of momentum which is a practical consequence of the uncertainty and long time frames which have characterised the WUA policy to date. Some stakeholders interviewed are now considerably less inclined to support a new local water management policy, particularly one which relies partly on goodwill and collaborative informal social institutions to achieve the kind of socio-economic transition envisaged in the Water Act.

5.7 CONCLUSIONS

The integration of such concepts as cost- recovery and privatisation in water policy have contributed to maintain the poorest segments of the population with little or no access to water for household needs and sanitation, and limited water infrastructure. This creates tensions that underpin the management of water resources at the national level. In terms of water policy, it seems therefore that radical legal change has not translated into significant, substantive improvements for the majority of the poorest citizens.

The Constitutional Court decided on our socio-economic right, including water rights, in Mazibuko and Others v City of Johannesburg CCT/39/09 (8 October 2009) on section 27(1)(b) of the Constitution, stipulating that everyone has the right of access to sufficient water. The case decided on the volume of free basic water, i.e. six kilolitres per month. The case addressed what is entailed by the obligation of the state to take reasonable legislative and other measures within the available resources of the state so as to progressively fulfil socio-economic rights. The case is important in describing how state policies can be reviewed by a court on the basis of what is reasonable. The reasonableness inquiry examines first whether responsibilities and tasks have been allocated to the different spheres of government and whether appropriate financial and human resources are available. Second, it dictates that programmes for socio-economic rights (e.g. the right to access to sufficient water) and obligations must be balanced and flexible, and include the appropriate provision for responding to crisis situations. While the Constitutional Court has found that socio-economic rights are justiciable (Government of the Republic of South Africa v Grootboom), its case-law shows that it is difficult to prove a violation of the Constitution, in particular because the plaintiff bears the burden of proving that the government's actions are unreasonable. This might constitute a significant obstacle to bringing a case based on alleged violations of the constitutional right to water. Due to the involvement of the private sectors to develop the true purpose, management and development of sustainable water sources, as set out in section 2 of the NWA, becomes even more important.

The Grootfontein, Lichtenburg / Itsoseng and Steenkoppies compartment applications for WUAs were rejected on mostly unknown grounds or reasons which were believed by some participants to be unclear. However based on a number of interviews with farmers and other water users the WUA application was rejected due to previously disadvantaged groups were not being represented adequately on the management committee of the proposed WUA. Involving the government and private sectors also played a role in the unsuccessful establishment of the WUAs. In all three case studies it seems that administrative involvement is a key challenge in the establishment of a WUA. The capacity of the government to perform tasks such as providing adequate reasons for not allowing the establishment of a WUA or involving local government to provide nominees for previously disadvantaged groups, due to a lack in training or being understaffed, becomes a key challenge, and makes it more difficult to establish a WUA.

If no statutory organisation governs the water rights between individuals, which the WUA would have achieved, no private individual may force sustainable management of water onto another private individual. The question now arises on who will manage the water use between individuals to successfully manage a sustainable water resource for long term use and who becomes the responsible partner for water security? It seems that the future of the relationship between the private sector and state oversight remains uncertain in the light of the recent decision to halt WUA approvals.

6 INSTITUTIONAL DISCUSSION

6.1 INTRODUCTION

The NW Dolomites are also amongst the most intensely studied aquifers in South Africa, with technical reports and other scientific material dating back to the 1960s and before, as discussed in the literature review. Technical or hydrogeological studies continue to the present day, and we might be forgiven if it sometimes appears as if the answer to better utilisation and management of the groundwater resources of the NW Dolomites lies in this technical realm. After all, this is where our major research efforts and investments have been made. In general, and as discussed in the literature review, we have a relative wealth of hydrogeological maps, guidelines and other planning tools at our disposal. By contrast, much less research is done on the management and governance of the dolomite groundwater resources, and on groundwater governance in general.

Despite our relatively sophisticated technical understanding of the dolomite hydrogeology, our approaches to management lag behind, and we derive poor management outcomes (this view is confirmed by Pietersen et al., 2011). There is a contrast between the well-understood hydrogeology, with its sophisticated isotope-based models of recharge and numerical mathematical models, and the reality of declining water levels, failing springs and falling assurance of domestic water supplies to small towns. Since it seemed obvious to this research team that the root cause of poor management was not primarily a lack of technical knowledge, the question arose as to how to conduct research into the wider socio-institutional context. This context is harder to define than the physical boundaries of an aquifer.

Elinor Ostrom (2005) describes the “action-arena”, a metaphysical space in which institutional transactions and interactions occur. Occupying this action-arena is a number of “participants”, who exercise their options according to sets of institutional rules that depend partly on the material conditions of the situation under discussion, and partly on their own internalised institutional modes of behaviour. Interactions between participants in the action-arena, known as action-situations, lead to outcomes that in turn can affect future action situations as well as the material conditions and institutional rules themselves. Participants can also be grouped into “corporate actors”, depending on affiliation and other characteristics. It is helpful to think of the various individuals and groups participating in groundwater use and management in the NW Dolomites in these terms because it emphasises both formal “rules” such as those needed for setting up a WUA, as well as informal institutions, as essential to understanding the outcomes that we see. It also emphasises interactions between participants, rather than the agency and power of any one participant. *De jure*, one or other participant may have the final legal responsibility for a water management outcome, but *de facto* this outcome is usually defined by success or failure of the interactions between participants.

6.2 PARTICIPANTS

In the NW Dolomites, irrigating farmers withdraw most of the groundwater that is pumped from the aquifers and are therefore an important group of participants. Farmers are also central to any effort to create a self-funding, self-starting, semi-autonomous local organisation such as a Water User Association, since they are currently the main users of the resource and are physically closest to it in most cases. The Department of Water and Sanitation (DWS), as the custodian of the nation's water, and the local and district municipalities, are also essential participants in the many action-situations that together constitute the governance landscape in the NW Dolomites. The district municipalities (e.g. Ngaka Modiri Molema DM in the Grootfontein area) are also important, especially where they are the Water Services Authorities in the area of interest. Private sector consultants are also an important group of participants in water management in the North West Province, carrying out specialist work for the municipalities and for DWS, and in some cases influencing the range of technical options in terms of water supply and treatment. Finally, Water Boards are increasingly becoming central participants – for example in the Mahikeng area Sedibeng Water Board has responsibility for urban and rural water supply as the Water Services Provider, having taken over from Botshelo Water Board in early 2015. All of these participants must interact or collaborate in some way if groundwater management is to be achieved, either voluntarily or under duress. Many of the participants have the additional capacity to free-ride or even to stall a participative water management process, and there may be many incentives not to collaborate especially over short time frames.

The modes of cooperation or collaboration between participants, or the reasons for non-collaboration, are based on complex systems of formal and informal institutions that can have unexpected outcomes. For example, one participant organisation may call a meeting of groundwater stakeholders in order to discuss water management – something that is within its legal remit and is a normal part of any water management process. Other participants may however choose not to attend, or may send only a junior delegate with no decision making power. The reasons for not supporting the meeting may be related to previous experiences with meetings, or may be due to issues completely unrelated to water such as previous funding disputes. The meeting may, however, be hailed by those who attended as the official means of water management, despite in reality having very little power or agency. In the worst cases, the process of meetings may unintentionally preoccupy some participants, who lose sight of the end goal of water management.

6.3 INSTITUTIONAL RESEARCH STRATEGY

Institutional issues are difficult to study because there is frequently no objective data on them, and radically different points of view are found. And a point of view – no matter whether it is factually correct or not – can be a deciding factor in a management outcome. In some cases progress can be made by studying social institutions by their effect or outcomes on physical variables such as water levels, budgets or audit results that are easier to measure. This project team developed a research strategy based around interviews, to elicit information on all of the possible constraints on WUA formation in the NW Dolomites. The interviewees are listed in Table 2-1, in chapter 2. Interviews took place in Pretoria, Mahikeng, Lichtenburg, Hartbeespoort, and on farms and small holdings in the area, over the course of several field visits by the research team. The interviews were based on a generic set of questions, but were adapted to fit the situation and the particular participant. Care was taken not to cut off lines of discussion, but to allow the interview to develop or unfold, taking into account the issues that the participant considered most important. The interviews can therefore be considered to be semi-structured. The in-built bias and world-view of the research team were considered, in particular the danger that the interviews would be "steered", consciously or subconsciously, towards existing lines of enquiry and modes of thought. This was another reason for a semi-structured rather than a more rigid or questionnaire-based approach to the interviews. The downside of a semi-structured or more discursive approach is of course that it is more difficult to compare interviewee responses, or to rank or otherwise statistically analyse interviews.

In certain cases interviews were also recorded and later transcribed. Most of the interviews were conducted in English, but a few were conducted in Afrikaans or in a mixture of English and Afrikaans. Where Afrikaans interviews were recorded, the transcriptions were made in Afrikaans and then translated into English. Most of the interviews required a fair amount of preliminary work including email introductions, phone-calls and so on, before an actual interview date and place were arranged. The research team aimed to interview what it considered to be key stakeholders or participants in all of the groups or organisations mentioned above. However beyond this rather broad sampling strategy, the selection of actual interviewees themselves was more a function of one interviewee recommending another, the availability of interviewees, the willingness of interviewees to be interviewed, and other factors beyond the control of the project team. The team does not argue that the range of participants interviewed constitutes a "representative" sample, rather that the interview results reflect as wide a set of viewpoints as could be obtained within the boundaries of funding, time and luck. In certain cases permission for an interview from the interviewee's superiors was needed before an interview. In at least one case (for a potentially key municipal informant) this permission was sought but not granted and the interview did not go ahead. This WRC research project was first described to interviewees before interview, and they were assured of confidentiality.

Research team members are also on friendly professional terms with several of the DWS participants and with certain of the private-sector consultants and, when this is combined with the professional background of the research team, this may predispose research team members to see a particular DWS or consultant "point of view" more clearly than that of other groups of participants. It has also not escaped the research team that institutions built around race, class, gender, language and age (some of these institutions additionally having uniquely South African properties) must necessarily affect any interview situation such as this one, and that even if these issues could be overcome on the part of the research team, the responses of interviewees are undoubtedly swayed to some (unknown) extent by these things. Under these circumstances it seems that a truly "unbiased" approach is nothing more than a chimera. The research team therefore tried as far as possible to utilise a triangulated approach to key issues – for example, instead of only relying on interviewee information describing a failing aquifer, the team would also access official DWS records to confirm this, and also take water level measurements themselves. In the case of the WUAs, apart from the contention of interviewees that the process of WUA formation was challenging and lengthy, there is also objective evidence in the form of DWS directives, draft constitutions, minutes of meetings and other documentary sources stretching over several years.

In certain cases members of the research team took part in meetings with key organisations in which many participants were present (such as DWS-convened Water User Forum meetings), with the full knowledge of the meeting that the participation was part of a Water Research Commission research project. Members of the research team can be considered as participant-observers in these cases, since as mentioned all of the research team members have had a professional interest at some time or another in the issue of groundwater governance in South Africa.

All interviewees were assured that they would not be identified in any subsequent publications. The list of interviewees shown in Table 2-1 therefore provides only the professional affiliation or group of each interviewee.

The results of the interviews have been combined with other data to examine the question of the groundwater WUAs in the NW Dolomites more closely. In particular, the research aimed to understand why WUAs in the NW Dolomites had not come into being, and what the effects of this might be.

6.4 WHAT BECAME OF THE NW DOLOMITES WUAS?

A primary research question for this part of the research was to find out what had happened to the various efforts to establish WUAs following the National Water Act in 1998, particularly the efforts of former irrigation boards to transform into WUAs. According to DWS (2013a) there were 20 irrigation boards in North West Province when the National Water Act was passed, but none of these has been successfully changed into a WUA to date. Furthermore, no other WUAs have come into being in this time. In fact, North West Province appears to have no WUAs at all (DWS, 2013a). The travails of the Steenkoppies WUA have been described in a previous section of this report – essentially a multi-year process of negotiation and proto-WUA formation was eventually unsuccessful in obtaining approval of the proposed WUA constitution. The story of the Grootfontein WUA is less well known. A group of farmers in the Grootfontein area did collaborate to form a WUA, but the Department of Water Affairs and Forestry (as it then was) ultimately did not approve the process. One farmer who was involved at the time explained it as follows:

> "Everything was done, the consultant, which has been, which worked on it, was [name withheld], everything was done, the constitution was finished, it was presented to the Minister – Kader Asmal at that time – and that's where everything stopped." (Source: Farmer, July 2015).

When asked what the reason for this was, this farmer said:

> "No I don't know what the reason was, everything was submitted to him, everything was done, we only needed his signature, and that's where everything stopped." (Source: Farmer, July 2015).

According to interviewees, DWS did not provide reasons for the rejection of the proposed Grootfontein WUA, but other interviewees and experiences with other WUAs in the North West Dolomites (e.g. Steenkoppies) suggest that DWS was not satisfied with the composition of the proposed WUA in terms of participation by historically disadvantaged individuals and by women, and considered that the proposed Grootfontein WUA would only entrench patterns of apartheid inequality and water use. A retired DWS employee was asked about the fate of the Grootfontein WUA:

> "You see in fact Water Affairs, Water and Sanitation now, they, they are very prescriptive in the establishment of a water user association. There must be, if, um, if possible a majority of, um black people, and now they are not users except now through the municipality…" (Source: former DWS employee, June 2015).

As far as is known however there has not been a formal statement or report by DWS stating its reasons for not approving the dolomite WUAs, and the interviewee information provided above may not be correct. DWS technical staff members (hydrogeologists and hydrologists) were active participants in the many meetings needed to agree on a draft constitution for some of the dolomite WUAs – for example minutes of meeting designed to support the formation of the Lichtenburg WUA show that the then Director of Geohydrology at DWS and supporting staff attended these meetings. Whilst some participants, including farmers, may feel that DWS as an organisation was indifferent and ultimately unsupportive of dolomite WUAs, the reality appears to be more complex.

The Lichtenburg WUA was one of the earliest WUAs to be proposed in the NW Dolomites, driven (according to interviewees) by genuine concern for falling water levels and illegal abstractions. Minutes of the meetings leading up to the final proposed constitution, as well as a copy of the final draft constitution itself, are still available on-line. Commenting on the eventual rejection of the Lichtenburg WUA application by DWS, a farmer who was heavily involved in the process stated:

> "Look it was never approved. We were at a very advanced stage with the, with that application, to register. At that stage I knew of several areas that were busy with water user associations and I don't know of one of them that was successful. I heard later that Komatipoort did register, and, so we were far advanced, I mean we were in the last stages of such an association, our constitution was drawn up, the members were involved, we had all the people who were supposed to be there, and then the application was, submitted to the Department of Water Affairs, the only feedback that we've ever got was that we didn't have a woman on the users' association." (Source: Farmer, August 2015).

A prolonged effort to form a Water User Association in the Groot Marico area (focusing mainly on surface water resources, which originate in the dolomite aquifers) soon after the finalisation of the National Water Act reportedly went through four different applications, with each application rejected by DWS for a different reason. A farmer in that area who was involved commented:

> "So they contracted [name withheld] to come and train us, to make sure we'd, we were going to become a water users association, and this is for the fourth time, ok, and once again all these feasibility studies, and, and they asked for the previous studies because

> they didn't want to do all the work again, and it got to the point of being ready and the Minister said, and this was under Minister Edna Molewa, she said no more water users associations would be approved." (Source: farmer, May 2015).

The failure to register the Steenkoppies WUA, as described, has led to a certain level of cynicism amongst participants in that area regarding future such initiatives. In Steenkoppies the irrigating farmers continue to manage the groundwater resource informally between themselves, knowing that long-term decline in water levels in not in their best interests. In other dolomite compartments this level of self-organisation has not occurred and in some cases (e.g. Grootfontein and Itsoseng / Lichtenburg) a "race for the pumps" is underway with impacts that include lowering water supply assurances to all users as well as increasing pumping costs.

6.5 OUTCOMES OF THE FAILURES TO ESTABLISH WUAS

6.5.1 IRRIGATED AGRICULTURE

Apart from the obvious (and objectively verifiable) impact on groundwater levels and sustainability, one subtler outcome of the failure to finalise the WUAs has been a more general erosion of trust on the part of farmers for meetings and interaction with government departments and agencies. This decline in trust and increase in pessimism parallels the physical decline in groundwater levels, but may be harder to reverse. One farmer commented:

> "… it's straightforward, the administrative burden is such that you cannot keep up with everything, keeping up with lobbying via the farmers' association, keeping up talking to Eskom about this and that, talking about water, and nothing comes of anything. Meetings are a futile exercise." (Source: farmer, May 2015).

Another farmer stated:

> "It doesn't even help mentioning [water problems in Mahikeng] to [the DWS employee seen as responsible], he's not doing anything, nothing, nothing at all." (Source: farmer, May 2015).

Asked whether he was going to attend a water management stakeholder meeting at Water Affairs a few days before it happened, one farmer replied:

> "No, definitely not… As I said we attended the first meeting, but it was a complete waste." (Source: farmer, July 2015).

Members of the research team subsequently attended this meeting, and can confirm that no farmers were present – a major omission which all but rendered the meeting pointless. More serious than the cynicism regarding meetings with government bodies and the perception that these interactions are a waste of time, is a more general feeling of discontent amongst commercial irrigating farmers (predominantly white) that the state does not support them, or even that the state wishes them ill. As one farmer noted:

> "The political atmosphere now I think is the most worrying thing. I'm saying, and it's my own personal view, that we standing on the cliff. And I'm not, I'm not quite sure if there's, I dunno if we are able to turn the ship around, it's becoming very late" (source: farmer, May 2015).

Several commercial farmers expressed concern regarding the land reform process, and said that the uncertainty was making them diversify incomes, look into other farming options (including moving to a neighbouring country), or otherwise hedge against what they perceived as an increasingly uncertain future. Some of the farmers stated that they knew people who were abstracting groundwater above their licensed limits, or even admitted to doing so themselves. This was seen as a sensible short-term policy, or "making hay while the sun shines". As one farmer put it:

> "You know, if you know something is gonna be destroyed, and I can give you examples of such guys, ride the horse while it's there. Alright? If we run out of water, so be it." (Source: farmer, May 2015).

This point of view is not limited to white commercial farmers either – one black commercial farmer said:

> "…because everyone is just doing their own thing hoping that Water Affairs does not come and catch them out…" (Source: farmer, June 2015).

A key informant in the Steenkoppies area described an environment in which communication between different government departments was "by court order". The current situation is one of mistrust between the major abstractors, irrigating farmers, and the other participants in the various dolomite groundwater areas. This causes participants to make more conservative choices for the future, potentially having knock-on effects in other areas. There is a view amongst farmers in Grootfontein that the municipal abstractions for Mahikeng, operated by DWS, are withdrawing more than their fair share of the water (this may not be the case in reality – but in these situations perceptions matter, and also may reflect an underlying lack of access to reliable information – see later in this section). A private groundwater consultant with long experience in the area stated:

> "… the arguments from the farmers in the Grootvlei [*sic*] is that Mafikeng has increased their abstraction without consulting them and that's why it seems to me they are now a bit *hardegat* [stubborn] and say well ok if Mafikeng can pump two point five the amount which they originally were authorized – we can also do that." (Source: private sector consultant, June 2015).

One Grootfontein farmer operating irrigation pivots stated:

> "…why should we now reduce below what we're entitled to and below what we know is sustainable if the public sector is destroying the infrastructure? And it's a simple thing, the public sector, the municipality, should stick to the regulation, and we'll stick to the regulation." (Source: farmer, May 2015).

6.5.2 STATE AFFILIATED ORGANISATIONS

Although some of the irrigating farmers sometimes see themselves as set against a monolithic state that is hostile towards them, the various organisations at the different spheres of government are in fact far from united. In the Mahikeng area the various state organisations (water boards, government departments, local and district municipalities) charged with water management are not all collaborating effectively and in some cases relations between state organisations have deteriorated to a point where little trust and reciprocity appear to remain. State organisations should therefore by no means be considered as a single participant, and in fact the breakdown in relations between and within certain state organisations may be more difficult to address than the more obvious problems related to the lack of trust between irrigating farmers and the state in general.

Asked in 2013 what his/her main wish would be regarding water management in Mahikeng, a private engineering consultant with long experience in the town said that s/he would wish only for all parties to sit down at the same table and discuss the issues. More than one source described the very poor relations that have prevailed at times between the district municipality, the water board (at that time Botshelo Water Board) and the Department of Water and Sanitation. These relations are said to have contributed to the bankruptcy of Botshelo Water Board. Suspicions remain: when asked about improving collaboration between the various stakeholders, a current DWS employee stated:

> “But you know to some extent the farmers may be easier because my personal view is that the municipalities don’t really have the skills or the knowledge to make good decisions.” (Source: DWS employee, May 2015).

At a stakeholder meeting attended by members of the research team in mid-2015, it became clear that an important outcome for some of the state affiliated participants was to transfer responsibility onto other state affiliated participants – all seemed to know that water resources were precarious but did not want to, or more likely were unable to, take responsibility for the situation. These meetings are now not easy to convene, partly because they are seen to be a waste of time by various of the other role players. Asked whether it was easy to get role players around the same meeting table, one DWS employee put it this way:

> Er, it’s not easy because you know what, each and every water users they’ve got a different interest. Er, other forums, if I have to compare with other forums you find that the main challenges there is illegal abstraction. You go to other forums you find that it’s not illegal abstraction per se, but it’s groundwater issues or pollution issues. So it differs from forum to forum, so with regard to [a locally convened forum], so far, because we only had meetings, we just revitalised that forum recently, but we had this forum previously even before I joined this forum, but the Department I think they weren’t what we call IRR – institutional realignment and reform, because previously this side it was Crocodile West Marico now they’ve matched Crocodile West Marico with Limpopo side to form er Limpopo North West Water Management Area. (Source: DWS employee, July 2015).

Asked whether the municipality should be driving the local water management process, and whether their lack of commitment to this was a reason why such a local organisation did not exist, one municipal employee disagreed, saying:

> When people ask why not, maybe Water and Sanitation Department they need to be the champion for this. (Source: municipal employee, July 2015).

A recent employee of the district municipality commented on some of the difficulties of coordination around water management and the problem of final responsibility that s/he had experienced:

> But now in terms of this directive Sedibeng's [i.e. the new Water Board] going to take everything. But I maintain it would be a challenge because there's a Section seventy-eight process which needs to be followed, and then er Ngaka Modiri Molema was actually get a water authority in two thousand and three, we've been struggling with the completion of the Section seventy-eight because apparently there's no buy-in from the local municipalities, so I don't know what will prevail in terms of the current arrangements…. We don't know how influential or effective is the directive because the legislation hasn't been amended. So whenever it becomes hot, they will say no, no but you are water authority… (Source: former municipal employee, June 2015).

6.5.3 TRANSPARENCY

All of these problems of collaboration, trust and cooperation alluded to above are exacerbated by a lack of easy access to transparent and reliable information on groundwater levels, groundwater abstraction quantities, license amounts, leakage volumes for towns such as Mahikeng, and other quantities. In particular, no attempt is made by any of the participants to synthesise such information into a widely available report, poster, website or other format that ordinary people would understand. Under these circumstances, rumour and innuendo flourish. What starts as speculation morphs into "fact".

This is not to say that some of this information is not available. For example, DWS keeps generally excellent records on groundwater levels and groundwater quality, and these are readily available through their National Groundwater Archive (NGA), accessible to anyone with an internet connection. The Georequests team at DWS is on standby to assist anyone who cannot access the water level data that they need. In contrast, data on borehole abstractions in the NW Dolomites is very hard to access – either because it is not measured (e.g. irrigation abstractions) or because it does not find its way into the public domain (e.g. public water supply abstractions). Rainfall data is now private and must be bought from the South African Weather Service.

The intentions of major participants such as DWS in terms of developing further water resources are the subject of speculation and rumour, much of it negative. For example, some believe that DWS is currently prospecting for groundwater in the Ottoshoop area and that this will eventually lead to over-abstraction in that area. One farmer commented:

> "And now Mafikeng started focusing their eyes on this water now. They trying with very clever things, buying specific portions of land, and making a lot of, um, huge promises,

> they trying to get their hands on these waters now, these waters surrounding Ottoshoop." (Source: farmer, May 2015).

More than one participant interviewed for this research stated that if groundwater resources for towns such as Mahikeng, Zeerust and Lichtenburg disappeared, then a pipeline to the Vaal River would solve the problem. In some cases this appears to follow a widely held idea that groundwater resources are inherently unsustainable and that abstractions from the dolomites are merely irretrievably emptying one groundwater compartment after another. The idea that groundwater resources can be inherently "sustainable" is unfortunately rare. No official confirmation could be obtained on the viability of a pipeline from the Vaal River, but such a project would undoubtedly be expensive and would also probably require water use licenses in the Vaal catchment to be reduced or revoked.

A huge amount of ill-will could be avoided by publicly stating basic abstraction quantities, and providing information on long-term water supply plans. This task would naturally fall to DWS, as the organisation currently best placed to address it, and the legal custodian of water resources. The various municipalities are widely believed to "not care" about leaks or the discharge of partially treated sewage into surface water systems – a public campaign to show that this was not the case would probably be money well spent. This research team speculated on the necessity for a public aquifer level information board at key roads traversing dolomite compartments – such an information source could show current groundwater levels, current rates of abstraction, current water quality, show current rainfall, and plot a basic hydrograph for all to see. This kind of "citizen science" is gaining traction elsewhere in the world and would be welcome in the NW Dolomites as a way of encouraging collaboration and the general view that "we are all in it together".

6.6 Conclusions to this chapter

There are few if any aquifers in the NW Dolomites that can be considered "well-managed". An exception might be the Steenkoppies Compartment, where an informal proto-WUA monitors groundwater levels and assists in reaching collective agreement on abstraction amounts. As described however, this development in the Steenkoppies Compartment can be considered exceptional for reasons that include the response of irrigating farmers to external legal threats and their need to protect substantial agricultural investments. This failure of groundwater management has led to falling water levels in various areas and the drying of wetlands and large springs or "eyes" that once flowed. The assurance of domestic water supply to several towns (including Mahikeng, Zeerust and Lichtenburg) is also threatened by groundwater over-abstraction.

One reason for the failure of management is a lack of the local level organisations – Water User Associations (WUAs) – envisaged in the National Water Act as an important part of decentralised water management in modern South Africa. However there is no guarantee that if WUAs existed, they would be effective in reversing water level declines – after all, declines in the Grootfontein and Lichtenburg areas and several other dolomite compartments long pre-date the National Water Act. WUAs are the currently legislated organisational form that is supposed to nurture and give rise to sets of formal and informal institutions that will lead to groundwater management outcomes. Their mere existence of course does not guarantee any of these institutions, and may even discourage them (for example, by providing an ineffective forum that is widely considered to be a sham, but which crowds out other possibilities). This of course has implications for other organisational forms (such as the modified CMAs) that will purportedly succeed where WUAs have failed.

The experience of many stakeholders (not only the irrigating farmers) with the failure of the WUAs in the nearly two decades since the National Water Act in 1998 has had a big impact on levels of trust, goodwill and reciprocity in the area, and this may make it more difficult to bring about new organisational forms – especially if these are also expected to be partly self-financed or self-starting. There has also been an impact on morale in several of the state organisations, with obvious groundwater management failures confirming an already-held view that groundwater is inherently unreliable.

It may be that the goal of sustainably managing the dolomite aquifers to optimise the benefits to all users is an impossible one, given all of the constraints. In this case we need to plan for the disbenefits and inequalities that will arise, including lower assurances of public water supplies, less secure agricultural outlooks and higher vulnerability to drought.

7 CONCLUSIONS

Writing about groundwater governance, Mukherji and Shah (2005) draw a distinction between “hard” or more authoritarian states such as China and “soft” states such as India where democratic and populist institutions dominate. The former can arguably achieve social change faster and with lower expenditure of bureaucratic resources, but changes more laboriously achieved by the latter are more consultative and respectful of human rights. With our history of apartheid oppression and the guarantees vested in our National Water Act and our Constitution, South Africa today falls firmly into the latter category. A national government department, seeking to regulate and govern a common-pool natural resource such as groundwater in which many people have a stake and which has a complex history of use and appropriation, must negotiate a complex set of social institutions if this task is to be achieved whilst maintaining an acceptable level of participation and harmony.

The task is arguably made harder by the additional requirement to decentralise governance and management of groundwater in line with the tenets of integrated water resource management (IWRM), since in effect much of the work must be done by encouragement and proxy rather than directly by the government department itself. Further complicating matters – already beginning to resemble the herding of cats – is the ephemeral and often misunderstood nature of groundwater itself. On one hand is the requirement for broad participation, on the other is the fact that few understand the potential and limitations of the resource and therefore the physical basis on which management actions partially rest.

As a “soft” democratic state, and furthermore one in which a technical and scientific-materialist approach to water management was formerly used to prop up illegitimate institutions, the argument that a specialist technical understanding should be a key plank of groundwater governance is unpopular in South Africa today and one can sometimes understand why. A government department that is in addition beset by “capacity shortages”, leadership crises, in-fighting and almost constant reorganisation and change is therefore hard pressed to deliver on its participative groundwater governance mandate.

This is the position in which the Department of Water and Sanitation (DWS) finds itself today. Looking for a way to cleanly break with its past failure to shepherd decentralised water management organisations such as CMAs and WUAs into being, indications are that DWS now wishes to embark on radical change. The new policy (yet to be confirmed) to de-legitimise and dissolve WUAs and hand over their functions to the newly rationalised nine CMAs is presented as a mode of decentralisation, but in fact will make local structures accountable to organisations that are comparable to the provinces in size and remoteness. This is unquestionably a move back towards the centre, and a partial hardening of “soft state” attributes.

A second strand in the current DWS thinking is to “fast-track” water allocation reform (purposely referred to by the acronym “WAR”), since the continued disproportionate utilisation of water resources by white men is seen as a key impediment to achieving the social transformation mandate of the National Water Act (van Koppen and Schreiner, 2014). This WAR-path that DWS is marching down represents a further tightening or hardening, and also speaks to the convenient and popular idea that absolute shortage – of water, rainfall, funding, skills or "capacity" – is at the bottom of our current predicament. A kind of zero-sum thinking threatens, along with an increasing emphasis on race, amenable to easy political summary.

A major difficulty that presents itself regarding the proposed new organisational arrangements is that they will still require high levels of cooperation, cohesion, understanding, organisational functioning and technical knowledge to implement – the very attributes whose lack arguably lies behind the dire state of the water organisational landscape today. In South Africa we are far from possessing (or wanting) the "hard state" attributes necessary to seize control, punish offenders and partially re-centralise power – not least the formidable and efficient bureaucratic apparatus with which such campaigns must be waged.

The lessons of this research project – originally designed to engage with the technical and social impediments to WUA formation – are therefore still of considerable value. Many of the social institutions required to form a WUA and make it work will be the same institutions needed to achieve and sustain successful collaboration with CMAs. The scientific understanding of aquifer functioning that is needed to underpin groundwater management will still be required, regardless of the final identity of the management organisation. If levels of trust and cooperation between groundwater users (or appropriators) and the state bureaucracy need to be high to ensure better outcomes today, they will still need to be high tomorrow – arguably more so, since pressures on the national water resource are increasing. There appears to be no short cut to successful groundwater management – soft institutions are surprisingly hard to change.

8 REFERENCES

Adams S, Braune E, Cobbing JE, Fourie F and Riemann K (2015) Critical reflections on 20 years of groundwater research, development and implementation in South Africa. South African Journal of Geology Vol. 118.1 pp 5-16.

African Centre for Biosafety (2011) Heavy Hands – Monsanto's control in SA. Available at: http://acbio.org.za/wp-content/uploads/2015/02/GMO-Monsantos-May2011.pdf

Aller L, Bennet T, Lehr JH and Petty RJ (1985) DRASTIC: A standardized system for evaluating groundwater pollution potential using hydrogeologic settings. EPA/600/2-85/018, U.S. Environmental Protection Agency, Ada, Oklahoma, USA.

Baker K and Dennis R (2012) Aquifer Firm Yield Model Manual. Water Research Commission Report No: 1763/1/11. Water Research Commission, Pretoria.

Barnard HC (1997) Geohydrological investigation of the catchment of Maloney's eye. M.Sc Thesis (unpublished). University of the Free State, Bloemfontein, RSA.

Barnard HC (2000) An Explanation of the 1:500 000 General Hydrogeological Map Johannesburg 2526. Department of Water Affairs and Forestry, Pretoria.

Baron J, Seward P and Seymour A (1998) The Groundwater Harvest Potential Map of the Republic of South Africa. Technical Report GH 3917. Directorate Geohydrology, Department of Water Affairs, Pretoria.

Beekman, HE and Xu Y (2003) Review of groundwater recharge estimation in arid and semi-arid Southern Africa. In 'Groundwater recharge estimation in Southern Africa', Xu Y and Beekman HE (eds.), UNESCO IHP Series No. 64, 3-18.

Botha F (2005) A Proposed Method to implement a Groundwater Resource Information Project (GRIP) in Rural Communities, South Africa. Unpublished PhD Thesis, University of the Free State, Bloemfontein.

Braune E and Xu Y (2006) A South African perspective on the protection of groundwater resources, in: Xu Y and Usher B (Eds) Groundwater Pollution in Africa. London: Taylor and Francis.

Braune E, Adams S and Fourie F (2014) 20 Years of Groundwater Research, Development and Implementation in South Africa 1994-2014. Water Research Commission Publication SP 78/14. Water Research Commission, Pretoria.

Bredenkamp DB (1964) Verslag van hidrologiese opname in die Bo-Molopo Ondergrondse Waterbeheergebied. Report No. GH 1283, Department of Water Affairs and Sanitation, Pretoria.

Bredenkamp DB (1984) Effek van grootskaalse pompery op die grootfontein kompartement. Report No. GH 3321, Department of Water Affairs and Sanitation, Pretoria.

Bredenkamp DB (1985) Grondwateronttrekking in die Grootfontein Kompartement. Report No. GH 3421, Department of Water Affairs and Sanitation, Pretoria.

Bredenkamp DB (1986) Quantitative estimation of ground water recharge in dolomite. Report No. GH 3497, Department of Water Affairs and Sanitation, Pretoria.

Bredenkamp DB (1990) Quantitative estimation of ground-water recharge by means of a simple rainfall – recharge relationship. Report No. GH 3572, Department of Water Affairs and Sanitation, Pretoria.

Bredenkamp DB (1995) Dolomitic Groundwater Resources of The Republic of South Africa: Part I. Critical aspects in the management of dolomitic aquifers. Report No. GH 3857, Department of Water Affairs and Forestry (DWAF)

Bredenkamp DB (1997) Modelling of the Zeerust-Dinokana Dolomitic Compartments with a View to More Effective Management of the Groundwater Resources. Report by Water Resources Evaluation and Management (WREM), Pretoria.

Bredenkamp DB and van Rensburg JH (1983) Ondersoek na die lewering van die Grootfontein and Polfonteinkompartemente aan die hand van n eindige verskil model. Report No. GH 3291, Department of Water Affairs and Sanitation, Pretoria.

Bredenkamp DB and Zwarts A (1987) Reconstruction of the flow of springs by means of annual recharge estimates. Report No. GH 3525, Department of Water Affairs and Sanitation, Pretoria.

Burke JJ and Moench MH (2000) Groundwater and Society: Resources, Tensions and Opportunities. New York: United Nations Publication

Business Day (2007) South Africa: People Sold Down the River by Neglect and Greed. Business Day opinion article dated 18 April 2007.

Calow RC, Robins NS, MacDonald AM, Macdonald DMJ, Gibbs BR, Orpen, WRG, Mtembezeka P, Andrews AJ and Appiah SO (1997) Groundwater Management in drought-prone areas of Africa. International Journal of Water Resources Management, 13, 241-61.

Carter RC (2009) Operation and maintenance of rural water supplies. Challenging the Community Based O&M Paradigm. Published as Perspectives No. 2 of the Rural Water Supply Network. St Gallen, Switzerland. Available at: http://www.rural-water-supply.net/en/resources/details/207. Last accessed in March 2016.

Cobbing JE (2015) 'The path to successful Water User Associations in the NW Dolomites. Deliverable Two: Literature Review Report.' WRC K5/2429 July 2015.

Cobbing JE, Eales K, Gibson J, Lenkoe K and Cobbing BL (2015) Operation and Maintenance (O&M) and the perceived unreliability of domestic groundwater supplies in South Africa. South African Journal of Geology Vol. 118.1 pp17-32

Cobbing JE, Eales K, Lenkoe K, Gibson J and Rossouw T (2014) An appraisal of diverse factors influencing the long-term success of groundwater schemes for domestic water supplies, focusing on priority areas in South Africa. Water Research Commission report No. 2158/1/14. Water Research Commission, Pretoria.

Cobbing JE, Eales K, Lenkoe-Magagula K, Gibson J and Kgaoda P (2013) Target Zone Report; taking into account socio-economic and technical considerations. Deliverable 3 of WRC Project K5/2158. Unpublished report, Water Research Commission, Pretoria.

Cogho VE (1982) Die Ontginbare Grondwaterpotensiaal van die grootfonteinkompartement. Report No. GH 3242, Department of Water Affairs and Sanitation, Pretoria.

Cogho VE and Bredenkamp DB (1982) Grondwaterpotensiaal van die Grootfontein Kompartement volgens n wiskundige model. Paper presented at Groundwater 82 conference, Ground Water Division of the Geological Society of South Africa, Johannesburg.

Council for Geoscience (1991) 1:250 000 Geological Map Sheet 2524 Mafikeng. Council for Geoscience, Pretoria.

Council for Geoscience (2008) North-West Dolomites – Coordination and Integration of Projects. Report prepared by the Council for Geoscience, Pretoria.

Department of Agriculture, Forestry and Fisheries (2013) Trends in the agricultural sector, 2012.

Dippenaar M 2013 Hydrogeological Heritage Overview: Pretoria's Fountains – Arteries of Life. Water Research Commission publication SP44/13, Pretoria.

Ditsobotla Local Municipality (2015) Reviewed Integrated Development Plan 2014/15

DWA (2004a) National Water Resource Strategy. First Edition, September 2004. Department of Water Affairs, Pretoria.

DWA (2004b) A Framework for Groundwater Management of Community Water Supply. Toolkit for Water Services: Number 1.1. Norwegian Agency for Development Cooperation (NORAD) and Department of Water Affairs (DWA), Pretoria.

DWA (2006a) A Guideline for the Assessment, Planning and Management of Groundwater Resources within Dolomitic Areas in South Africa, Volumes 1-3. Department of Water Affairs and Forestry. Pretoria.

DWA (2006b) The South African Groundwater Decision Tool (SAGDT) Manual Version 1.0. Department of Water Affairs, Pretoria.

DWA (2008a) A Guideline for the Assessment, Planning and Management of Groundwater Resources in South Africa. (Final Draft, March 2008). Department of Water Affairs, Pretoria.

DWA (2008b) Geohydrology Guideline Development: Activity 20 Desktop study of future research priorities for the NW Dolomites. Report prepared for the Department of Water Affairs by Water Geosciences Consulting as part of DWA Project Number: 14/14/5/2 Implementation of Dolomite Guideline. Department of Water Affairs, Pretoria.

DWA (2009) Water for Growth and Development Framework. Version 7. Department of Water Affairs, Pretoria.

DWA (2010a) Groundwater Strategy 2010. Department of Water Affairs, Pretoria.

DWA (2010b) Development of a Reconciliation Strategy for All Towns in the Northern Region. Ngaka Modiri Molema District Municipality and Mafikeng Local Municipality. Prepared by SRK Consulting for the Department of Water Affairs, Pretoria.

DWA (2013) National Water Resource Strategy Second Edition. Department of Water Affairs, Pretoria.

DWA (undated) Water Management Institutions Overview. Department of Water Affairs and Forestry, Pretoria.

DWS (2013a) 'Status Report on Water User Associations in South Africa', presentation to the Portfolio Committee on Water and Environmental Affairs. Department of Water and Sanitation, Pretoria. 24 April 2013

DWS (2013b) National Water Policy Review: Invitation for General Public Comment 30 August 2013. Government Gazette 36798.

DWS (2014) National Water Policy Review (NWPR). Approved Water Policy Positions, 31 January 2014. Department of Water and Sanitation, Pretoria. Available at: https://www.dwa.gov.za/Documents/Policies/APPROVED%20POLICY%20POSITION%20DOCUMENT%20-%2031-01-2014%20TR.pdf

EMA (2003) Project Management and Technical Co-ordination of North West Dolomitic Areas – Inception Report. Report No. 1061/1, E. Martinelli and Associates

Enslin JF (1967) Dolomitic Water Supplies in the Transvaal, Republic of South Africa. Memoirs of International Association of Hydrogeologists Vol. VIII Congress of Istanbul.

ERM (2007) Steenkoppies Aquifer Management Association – Hydrogeological Review, Maloney's Eye Catchment Area. Unpublished report by ERM (Pty) Ltd. dated November 2007.

Gombar O (1974) Pomptoets op n boorgat in die grootfonteinkompartement, dist. Mafikeng. Report No. GH 1882, Department of Water Affairs and Sanitation, Pretoria.

Grain SA (2015), Production Reports. http://www.grainsa.co.za/pages/industry-reports/production-reports

Greenberg S (2013) The disjunctures of land and agricultural reform in South Africa. Implications for the agri-food system. Working Paper 26, Institute for Poverty, Land and Agrarian Studies (PLAAS), University of the Western Cape.

Greenberg S (2015), 'Why size matters for farmers', in Mail & Guardian, 13 March 2015.

GWG (2012a) Groundwater Governance. Synthesis of Thematic Papers / Case Studies. Working draft for regional consultations, 30 April 2012. Available from the project website at www.groundwatergovernance.org

GWG (2012b) Trends in local groundwater management institutions. Thematic Paper No. 7. Available from the project website at www.groundwatergovernance.org

GWG (2014) Website of the "Groundwater Governance. A Global Framework for Action" project at http://www.groundwatergovernance.org/ and accessed March 2016.

GWP (2012) What is IWRM? Website of the Global Water Partnership (GWP). Accessed March 2016 at http://www.gwp.org/The-Challenge/What-is-IWRM/

Harvey P and Reed B (2004) Rural Water Supply in Africa. Building Blocks for Handpump Sustainability. WEDC, Loughborough University, UK.

Hassan R Thurlow J Roe T Diao X Chumi S and Tsur Y (2008) Macro-Micro Feedback Links of Water Management in South Africa. CGE Analyses of Selected Policy Regimes. World Bank Policy Research Working Paper 4768. World Bank, Washington DC. Accessed March 2016 at: http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2008/11/04/000158349_20081104093521/Rendered/PDF/WPS4768.pdf

Hedden S and Cilliers J (2014) Parched Prospects. The Emerging Water Crisis in South Africa. Institute for Security Studies, Pretoria. African Futures Paper 11. Available at https://www.issafrica.org/publications/papers/parched-prospects-the-emerging-water-crisis-in-south-africa and last accessed in March 2016.

Hobbs PJ (2002) Groundwater situation assessment Crocodile West / Marico WMA. Geohydrological report by VSA Earth Resource Consultants (Pty) Ltd for Ninham Shand North (Pty) Ltd.

Hodgson GM 2009 Institutional Economics in the Twenty-First Century. Studi e Note di Economia, Anno XIV, n. 1-2009, pp 03-26

Holland M (2009) Geohydrology Guideline Development: Activity 25 Geohydrological Assessment of the Steenkoppies Dolomite Compartment. Report prepared for the Department of Water Affairs by Water Geosciences Consulting as part of DWA Project Number: 14/14/5/2 Implementation of Dolomite Guideline. Department of Water Affairs, Pretoria.

Holland M and Wiegmans F (2009) Geohydrology Guideline Development: Activity 18&19 Desktop development of a Dolomite hydrogeological compartment map and explanation booklet (Report). Report prepared for the Department of Water Affairs by Water Geosciences Consulting as part of DWA Project Number: 14/14/5/2 Implementation of Dolomite Guideline. Department of Water Affairs, Pretoria.

IAH (2003) Groundwater: From Development to Management. Briefing paper prepared for the Third World Water Forum, Kyoto, Japan. International Association of Hydrogeologists. Goring, United Kingdom.

IELRC (2007). South Africa's Water Law and Policy Framework. Implications for the right to water. Auth. Alix Gowlland-Gualteiri. IELRC working papers 2007-03.

ILO (2015) 'On farm workers' living and working conditions in SA: Report says lack of state support to producers has reduced their ability to resist pressures in the value chain and hurt workers' 21 July 2015, http://www.politicsweb.co.za/documents/on-farm-workers-living-and-working-conditions-in-s

Janse van Rensburg H (1992) Re-evaluation of the exploitation potential of the Grootfontein compartment (Western Transvaal). Report No. GH 3788, Department of Water Affairs and Sanitation, Pretoria.

Johnson MR, Anhaeusser CR and Thomas RJ (eds) (2006) The Geology of South Africa. The Geological Society of South Africa and the South African Council for Geoscience, Johannesburg.

Joubert F (2013) 'Determining lawful use within the Upper-Molopo Subterranean Government Water Control Area.' Unpublished memorandum prepared for DWA.

Kalf FRP and Woolley DR (2005) Applicability and methodology of determining sustainable yield in groundwater systems. Hydrogeol J (2005) 13:295-312

Konikow LF and Kendy E (2005) Groundwater depletion: A Global Problem. Hydrogeology Journal (2005) 13:317-320

Lawrence AR, MacDonald DMJ, Howard AG, Barrett MH, Pedley S, Ahmed KM and Nalubega M (2001) ARGOSS 2001 Guidelines for Assessing the Risk to Groundwater from On-Site Sanitation. British Geological Survey Commissioned Report CR/01/142. British Geological Survey, Keyworth, UK.

Leyland RC and Witthüser KT (2009) VUKA: a modified COP vulnerability mapping method for karst terrains in South Africa. Quarterly Journal of Engineering Geology and Hydrogeology 43.1

Llamas MR (1985) Spanish Water Resources Policy: The illogical influence of certain physical and administrative factors. In: Hydrogeology in the Service of Man, Mémoires of the 18th Congress of the International Association of Hydrogeologists, Cambridge, 1985.

Lockwood H and Smits S (2011) Supporting Rural Water Supply. Moving Towards a Service Delivery Approach. Practical Action Publishing Limited, Rugby. Available at http://www.aguaconsult.co.uk/uploads/pdfs/Supporting%20Rural%20Water%20Supply.pdf and accessed October 2013.

Mafikeng Local Municipality (2014). Reviewed Integrated Development Plan 2014/15.

Margat J and van der Gun J (2013) Groundwater around the World – a Geographic Synopsis. CRC Press/Balkema. Leiden, The Netherlands.

McCarthy T and Rubidge B (2005) The Story of Earth & Life. A southern African perspective on a 4.6-billion-year journey. Struik Publishers, Cape Town.

Middleton BJ and Bailey AK (2009) Water Resources of South Africa, 2005 Study (WR2005). WRC Report Number TT380/08. Water Research Commission, Pretoria.

Mogale City Local Municipality (2014) 2014/15 Draft Integrated Development Plan.

MRCC (2007) Summary of submissions and requests by concerned institutions of civil society and directly affected stake holders in Magaliesburg and Orient to the Department of Water Affairs and Forestry and the Department of Environmental Affairs and Tourism pertaining to the Magalies River/Maloney's Eye/Steenkoppies Compartment water resource. Unpublished submission by the Magalies River Crisis Committee (MRCC).

Mukherji A and Shah T (2005) Groundwater socio-ecology and governance: a review of institutions and policies in selected countries. Hydrogeology Journal (2005) 13:328-345

Mulder MP (1982) Opsomming van resultate verkry vir in voorlopige raming van die grondwaterpotensiaal van die Grootfontein staatswaterwerke. Report No. GH 3220, Department of Water Affairs and Sanitation, Pretoria.

North West Office of the Premier (2015), 'North West on Mahikeng's Rebranding, Repositioning and Renewal Programme (MRRRP)'. Press release, 27 May 2015. http://www.gov.za/speeches/mahikeng-geared-become-world-class-city-following-launch-mrrrp-27-may-2015-0000

NRC (2003) Ground Water Vulnerability Assessment – Contamination Potential Under Conditions of Uncertainty. National Research Council of the United States of America. Washington DC. Accessed June 2015 at http://www.nap.edu/download.php?record_id=2050#

Ntsebeza L (2002) Decentralisation and natural resource management in rural South Africa: Problems and prospects. Occasional Paper published by the Programme for Land and Agrarian Studies (PLAAS), University of the Western Cape, Cape Town.

Ostrom E (2005) Understanding Institutional Diversity. Princeton University Press, New Jersey, USA.

Parliamentary Monitoring Group, (2013). Minutes of the meeting of the Portfolio Committee on Water and Environmental Affairs, 24 April 2013. https://pmg.org.za/committee-meeting/15757/

Pietersen K (2004) A decision-making framework for groundwater management in arid zones (with a case study in Namaqualand). Unpublished PhD thesis, University of the Western Cape, South Africa.

Pietersen K, Beekman HE and Holland M (2011) South African Groundwater Governance Case Study. WRC Report No. KV 273/11. Water Research Commission, Pretoria.

Pietersen K and Lenkoe-Magagula K (2013) Addressing illegal water use in the Vaal River System: Groundwater Options Report. Unpublished report to the Department of Water Affairs by SLR Consulting (South Africa) (Pty) Ltd. Department of Water Affairs, Pretoria.

Price M (1996) Introducing Groundwater (Second Edition). Taylor and Francis, Abingdon, UK.

Riemann K, Chimboza N and Fubesi M (2012) A proposed groundwater management framework for municipalities in South Africa. Water SA Vol. 38 No. 3 International Conference on Groundwater Special Edition 2012

RSA (1996) Act No. 108 of 1996: Constitution of the Republic of South Africa. Republic of South Africa Government Gazette Cape Town, South Africa.

RSA (1997) Act No. 108 of 1997: Water Services Act. Republic of South Africa. Government Gazette Cape Town, South Africa.

RSA (1998) Act No. 36 of 1998: National Water Act. Republic of South Africa. Government Gazette Cape Town, South Africa.

RSA (2000) Act No. 3 of 2000: Promotion of the Administrative Justice Act. Government Gazette Cape Town, South Africa.

RSA (2012) National Development Plan 2030 – Our Future – Make it Work. National Planning Commission, Pretoria, Republic of South Africa.

RWSN (2012) October 2012 Newsletter of the Rural Water Supply Network. Downloaded May 2014 at http://tinyurl.com/bvs8set

Senwes (2014). 'Senwes: Noordwes & Gauteng'. Available at: www.senwes.co.za/af-ZA/Korporatief/streeksprofiel/noordwes#Klimaat

Seward P, Xu Y and Brendonck L (2006) Sustainable groundwater use, the capture principle, and adaptive management. Water SA Vol. 32 No. 4 October 2006.

Shah T, Molden D, Sakthivadivel R and Seckler D (2000) The Global Groundwater Situation: Overview of Opportunities and Challenges. International Water Management Institute (IWMI), Colombo.

Sigwaza T (2015), 'Institutional Oversight'. Unpublished presentation to the DWA Regulation Imbizo, 13 May 2015. Avaiable at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&ved=0ahUKEwi8sPXRw7zJAhXJthoKHYIDDaoQFggwMAM&url=https%3A%2F%2Fwww.dwa.gov.za%2FIO%2FDocs%2FCMA%2FCMA%2520Functions%2FRegulation%2520imbizo%2520CD%2520IO%252012%2520May%2520final%2520version.pptx&usg=AFQjCNGH3iH689dDHXWS3R7iwC3nHTs1Ew&bvm=bv.108538919,d.d2s

Sophocleous M (1997) Managing water resources systems: why "safe yield" is not sustainable. Ground Water 35(4): 561

Stanwix B (2013). Minimum wages and compliance in South African agriculture, Development Policy Research Unit, University of Cape Town. http://www.econ3x3.org/article/minimum-wages-and-compliance-south-african-agriculture

Stephens A and Bredenkamp DB (2002) Institutional arrangements for groundwater management in dolomitic terrains: situation analysis. WRC Report No KV140/02. Water Research Commission, Pretoria.

Stephens A, Newton L, Mischker CA, Bredenkamp DB and Reid KO (2005) Situational Analysis for the Preparation of Institutional Arrangements for Groundwater Management in the NWDWA. WRC Report No. 1324/1/05. 81 pp. Water Research Commission, Pretoria.

Tarlton (2007) Submission by the Tarlton Farmers to the Director-General, Department of Water Affairs and Forestry regarding restrictions on the taking of water for all purposes except those contained in schedule 1 to the National Water Act 1998, from the Steenkoppies Dolomitic Compartment (Quaternary Drainage Regions). Unpublished submission by water users in the Tarlton area.

Taylor CJ (1983) A geohydrological investigation in the Lichtenburg area, Bo-Molopo Subterranean Water Control Area. Report No. GH 3277, Department of Water Affairs and Sanitation, Pretoria.

Theunissen P (2005). 'Has irrigation caused the maize surplus?'. Unpublished paper, http://www.computus.co.za/Artikels/Irrigation2.PDF

UNESCO (2004) Groundwater Resources of the World and their Use. IHP-VI Series on Groundwater No. 6. Zekster IS and Everett LG (eds.) United Nations Educational, Scientific and Cultural Organisation (UNESCO), Paris.

USACE (2014) Building Strong Collaborative Relationships for a Sustainable Water Resources Future. Understanding Integrated Water Resources Management (IWRM). United States Army Corps of Engineers, Washington.

USAID (2014) Water and Conflict. A toolkit for Programming. United States Agency for International Development, Washington. Accessed February 2014 at http://aquadoc.typepad.com/files/usaid_water_and_conflict_toolkit.pdf

Vahrmeijer JT, Annandale JG , Steyn JM , van der Stoep I and Bristow KL (2012), Water users and government collaboration: A recipe for successful groundwater governance. Unpublished conference presentation, 'Fresh water governance for sustainable development', Pretoria, November 2012.

Vahrmeijer JT, Annandale JG, Bristow KL, Steyn JM and Holland M (2013) Drought as a catalyst for change: A Case Study of the Steenkoppies Dolomite Compartment. Chapter 14 in: K Schwabe et al (eds.), Drought in Arid and Semi-Arid Regions. Springer, Dordrecht

Van der Stoep I (2014) 'Key irrigation design variables influencing energy use.' Unpublished South African Irrigation Institute / SABI presentation, 15 October 2014.

Van der Stoep I, Pott A, Viljoen JH and van Vuuren AMJ (2012) Guidance for Sustainable On-Farm and On-scheme irrigation water measurement. WRC Report TT550/12. Water Research Commission, Pretoria

Van Koppen B and Schreiner B (2014) Priority General Authorisations in rights-based water use authorisation in South Africa. Water Policy 00 (2014) pp 1-19

Van Tonder GH, Janse van Rensburg H, Botha JF en Bredenkamp DB (1986) Die modellering van grondwatervlakke in die Grootfonteinkompartement in Wes-Transvaal. Water SA Vol 12 No 3 July 1986

Van Wyk E (2010) Estimation of episodic groundwater recharge in semi-arid fractured hard-rock aquifers. Unpublished dissertation submitted in the fulfilment of the requirements for the degree of Doctor of Philosophy in the Department of Geohydrology, University of the Free State, Bloemfontein.

Vegter JR (1995) An explanation of a set of national groundwater maps. WRC Report No TT74/95. Water Research Commission, Pretoria.

Vegter JR (2001) Groundwater development in South Africa and an introduction to the hydrogeology of groundwater regions. WRC Report No TT134/00. Water Research Commission, Pretoria.

Vipond SH (1979) Increased groundwater abstraction at Grootfontein – water supply to Mafikeng and Mmabatho. Report No. GH 3091, Department of Water Affairs and Sanitation, Pretoria.

Visser M and Ferrer S (2015) Farm Workers' Living and Working Conditions in South Africa: key trends, emergent issues, and underlying and structural problems. Report based on a research project commissioned by the Pretoria office of the International Labour Organization.

Woodford A, Rosewarne P and Girman J 2006 'How much groundwater does South Africa have?' Internal discussion document. Accessed March 2014 at: http://www.srk.co.za/files/File/newsletters/groundwater/PDFs/1_A_Woodford.pdf

World Bank 2002 Groundwater Quality Protection: A guide for water utilities, municipal authorities, and environment agencies. Groundwater Management Advisory Team (GW-MATE) World Bank, Washington DC

9 APPENDIX 1: ENERGY IMPACTS OF A FALLING WATER TABLE ON IRRIGATION AND INPUT COSTS

Before the 1980s, farmers relied mainly on diesel pumps for irrigation. Widespread rural electrification is comparatively recent, and this has played a big role in expanding the area under mechanized irrigation – with pivots, sprinklers and micro-irrigation drippers. Irrigated agriculture in South African is now among the most mechanized in the world (Van der Stoep, pers. comm, 2015.)

In an irrigation system powered by electricity, energy costs account for between 87-93% of total lifecycle costs, relative to initial capital cost (5-8%) and maintenance cost (2-5%) (Grundfos, 2004).

Irrigation energy costs are determined using the following formula:

$$k{\downarrow}p = \mathrm{P} \times \mathrm{t} \times k{\downarrow}e$$

Where

P_i = Input power requirement of the electrical motor in kW

T = Total number of hours the pump is operated for, at P_i

k_e = Energy tariff, in Rand per kWh

A wide range of variables shape the actual cost, as summarised in Figure 9-1 below.

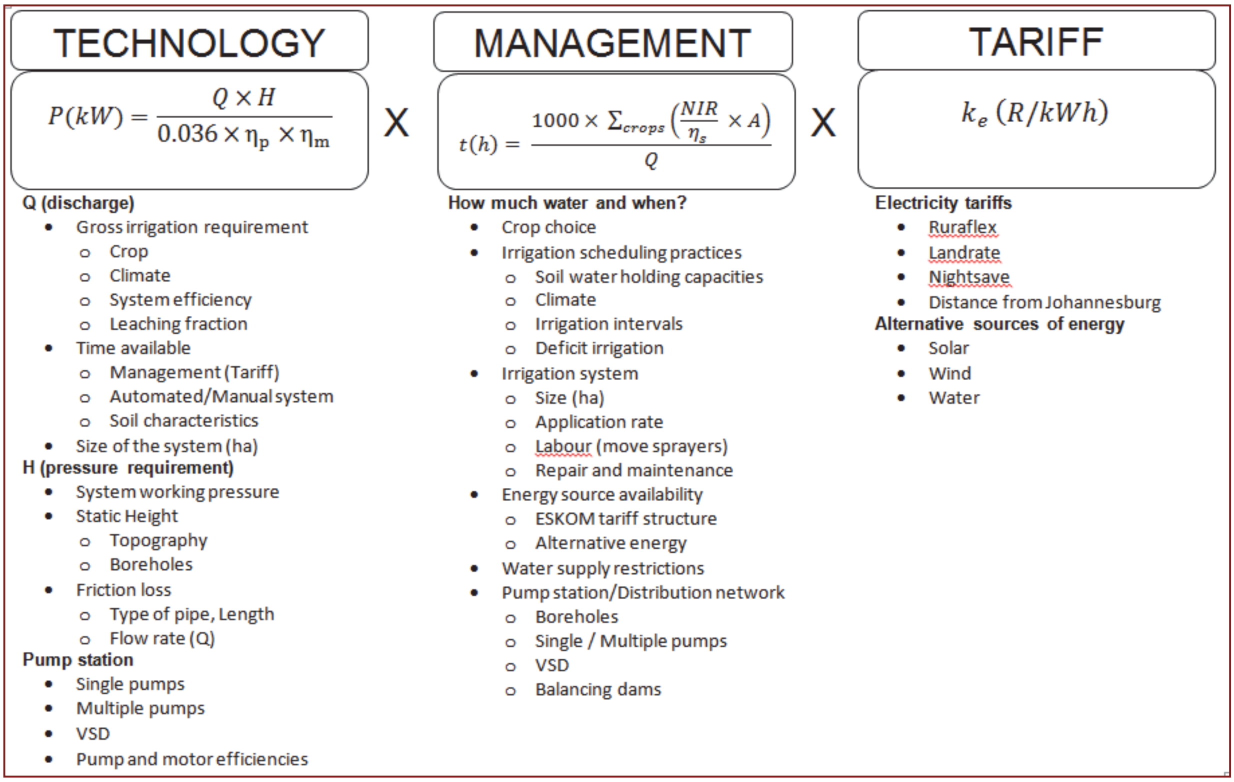

FIGURE 9-1 VARIABLES AFFECTING THE COST OF IRRIGATION. SOURCE: VAN DER STOEP, 2014.

To illustrate what this means in real terms, consider this scenario:

- 10 ha dragline sprinkler system
- A crop requiring 600 mm of irrigation over the season
- Static head of 25 m
- 3rd Quarter 2014 Eskom tariffs
- 'Normal' annual rainfall

Application of the formula yields an energy cost for pumping of R2 834 per hectare per year.

Increasing the static head by 1 metre is equivalent to compensation for a 1 metre fall in the water table. In the scenario described above, each additional 1 m in height raises the cost of pumping by R51 / ha / yr.

Applying this formula and indicative scenario in the Grootfontein compartment, a 13 metre fall drop in the water table the by 2015 would consequently raise pumping costs to R3 497 relative (R51 x 13 m = R663 / ha / yr). This would represent an increase of 23,4% in annual energy costs per hectare. Extending the scenario further to illustrate the point, consider that the median area irrigated annually per farm in the Grootfontein compartment was 31,5 ha in 2015. Increased pumping costs over this area would add an additional R20 884,5 to the illustrative figure of R89 271.

In the more severe fall in water table level described by an informant at Grootfontein Eye in the context of a second year of drought and poor recharge, reliable yields must now be pumped from 60 m deeper down. The additional cost per irrigated hectare would be R3 060 (R51 / ha x 60), assuming the same pump specs were applicable. In this instance, pumping costs would be double, and reflect a 208% increase.

How significant is this increased pumping cost in the bigger picture of production cost? Overall energy cost of irrigation are typically 5-10% of the total cost of production. This is significantly less than the cost of fertilizers and labour; the amounts vary significantly depending on the nature, timing and location of the crop, but fertilizer inputs typically account for 30 to 50% of the total production cost per hectare.

Consequently an increase in pumping costs as a result of a 13 m fall in the water table might add 1 to 2% to overall production costs; for a 60 m fall, the impact is substantial, and could raise overall production costs by 10% or more.