A review of the implementation of groundwater protection measures, in particular Resource Directed Measures, in South Africa in the context of ChinAfrica Water Forum dialogues

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Executive Summary

This review of groundwater protection measures in South Africa focuses on the actual implementation of groundwater protection, in particular the Resource Directed Measures legislated in the National Water Resources Act, 1998 as the key protection measure for all significant water resources. A significant catchment-wide implementation of RDM (Classification of water resources and setting of Resource Quality Objectives) has taken place since 2012. Before this, the process had been initiated through widespread Reserve determination. Approximately R 380 million has been expanded on the catchment-wide implementation. Groundwater was fully part of this regional implementation, with around a third of the funding going to groundwater protection measures. In addition, water management operations in nine provinces also made budget provision to further support the implementation of this function at provincial and local level.

Considerable effort went into refining the RDM methodology, including the groundwater methodology, with strong support from the Water Research Commission. The major finding of the review, even while Resource Quality Objectives have not yet been officially gazetted, is that RDM, in its present form, will not make a significant contribution to groundwater resource protection and the security of groundwater sources. This is a major concern, because the Groundwater Strategy of the Department of Water and Sanitation had declared the protection of groundwater a national priority. Classification and Resource Quality Objectives and the methodologies to achieve these have been defined and developed with a surface water environment focus and thus the practical outcome has also been a lack of protection direction for the groundwater resource itself and for the safeguarding its water service function, despite the fact that almost two thirds of South Africa's population depend on it for their domestic water needs.

Of equal concern is that groundwater resource protection with measures besides a systematic implementation of RDM has also been poor. The existing tools of compulsory licensing, capacity building and compliance enforcement have not been utilized, even where domestic water supplies to small towns and ecosystems of national interest are threatened.

Strong recommendations have been made for completely fresh look at the Groundwater RDM methodology and the required supporting groundwater resource information and assessment tools, taking into account the unique characteristics and role of aquifers and groundwater resources. At the same time the inability to implement the National Water Act, as a result of a lack of sufficient skilled and experienced staff, especially in the government sector – both national and local – needs to be urgently addressed. Most importantly, improved governance of local groundwater resources will require strategic attention. The critically important participation of local water users and other stakeholders and the establishment and support of Water User Associations and Monitoring Committees for this purpose can no longer be neglected.

Given the sustainable natural resources management challenges in both countries, this collaborative study with the People's Republic of China is seen as strategic in overcoming present bottlenecks and thus unlock new areas of cooperation between China and Africa in the water field.

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1. Purpose

The context of study is a 5-year review of the implementation of groundwater protection measures in South Africa. This review also has its focus in strengthening ongoing international water cooperation initiatives between South Africa and China especially through the ChinAfrica Water Forum dialogues as platform. The study focuses on the actual implementation of groundwater protection, particularly given its compulsory legislative context embedded in South Africa's water legislation (i.e. National Water Act, Act 36 of 1998), as well as the noticeable financial investments between 1999 (when the NWA was enacted) and 2015. During this period, an amount of approximately R380 m (inclusive of an estimated R90 m planned for groundwater protection measures) has been allocated to the Department of Water Affairs' (now Department of Water and Sanitation) water resource protection function, as a means to embark on an ambitious journey of developing scientifically robust and legally defensible methods and procedures to determine and implement water resource protection measures. In addition, water management operations in nine provinces also made budget provision to further support the implementation of this function at provincial and local level. Despite some dissimilarity in legislation and financial investments in groundwater protection measures and implementation in China, the Chinese water sector faces similar (to South Africa) groundwater management challenges, purely from a sustainable natural resources management perspective. This study therefore aims to draw comparisons at desktop level, focusing on the implementation of groundwater resource protection measures in South Africa and The People's Republic of China. This review assignment is deemed cooperative and strategic in nature, as it intends to:

(i) both unlock new areas of cooperation while enhancing ongoing collaborative initiatives between China and Africa in the water field.
(ii) create momentum for the Africa Groundwater Commission under the African Ministerial Council on Water (AMCOW).
(iii) achieve strategic review outcomes that further contribute to an adaptive management approach for promoting coherent and integrated implementation of groundwater resource protection measures.

The project is a collective effort between South Africa's the CSIR and UWC, and the IRCK that is based in China.

2. Groundwater resources and development in South Africa

2.1 Introduction

South Africa is the 30th driest country in the world and has less water per person than countries widely considered to be much drier, such as Namibia and Botswana. Many parts of the country are fast approaching the point at which all of the easily accessible freshwater resources are fully utilised. Increasing urbanisation and industrialisation place enormous pressure on our scarce water resource in terms of management and allocation.

Ensuring a sustainable water balance requires a multitude of strategies, including water conservation and water demand management, further utilization of groundwater, desalination, water re-use, rain water harvesting and treated acid mine drainage.

Because of the old geological formations of the country and the continent as a whole, South Africa's groundwater occurs mainly in hard-rock aquifers. The simplified geology map (Figure 1) enables a national scale view of the main aquifer types in South Africa based on the aquifer properties of the main lithology (rock type) of the different rock strata.

The distribution of various aquifers according to a classification of major, minor and poor is shown in the Table 1.

Table 1: Aquifer classification system (after Parsons, 1995)

Aquifer System Classification	Coverage of Country (%)	General Location
Major Aquifers	18	Primary aquifer systems along the coast; Dolomitic systems in parts of Gauteng, Mpumalanga, the Northern Cape and North West Province; Rocks of the Table Mountain Group bordering the Cape coast; Parts of the Karoo Supergroup; Cities and towns receiving water from major aquifer systems are Pretoria, Mmabatho, Atlantis, St. Francis Bay and Beaufort West.
Minor Aquifers	67	Minor aquifers occur widely across South Africa with variable borehole yield and water quality. They supply many smaller settlements, eg Nylstroom, Williston, Carnarvon and Richmond.
Poor Aquifers	15	Poor aquifers occur mainly in the dry northern and western parts of the country. The generally low borehole yields of poorer quality are, however, still of critical importance to small rural communities.

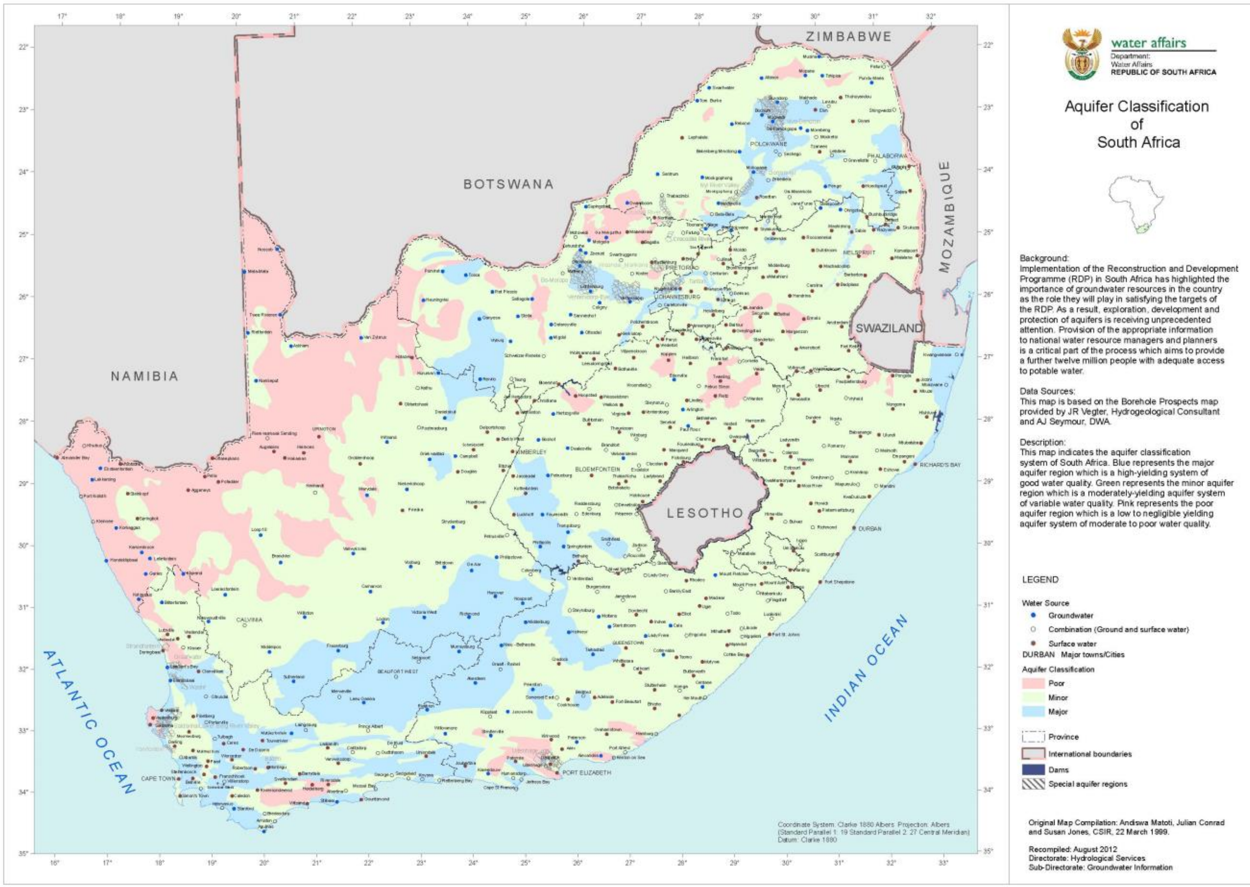

Figure 1: Main aquifer types based on primary lithology

The most recent scientific estimates place groundwater in South Africa in the same league, volumetrically, as the stored surface water resources: The total volume of available, renewable groundwater in South Africa) is 10 000 million m³/a (or 7 500 million m³/a under drought conditions) The current use is between 2 000 and 4 000 million m³/a of this groundwater. Therefore, there is the potential to considerably increase groundwater supplies in South Africa. In contrast, the assured yield of South Africa's surface water resources is approximately 12 000 million m³/a, but more than 80% of this is already allocated. Although most (but not all) large-volume water users rely on surface water, the majority of small water supplies, which are critical to livelihoods and health, depend on groundwater (DWA, 2010).

2.2 Groundwater in national legislation

South Africa entered a new phase in its history with the election of its first non-racial democratic government in 1994. Policy reform in the recent years of South Africa's new democracy has, for obvious reasons of history, been focused upon the promotion of basic human rights and the democratic values of human dignity, equality and freedom throughout the society.

The National Water Act (Act 36 of 1998) was aimed at fundamentally reforming the previous Water Act of 1956 which was not only racially discriminatory in how water was allocated but was based on the legislation of water-rich Europe which was not appropriate for a water-scarce country such as South Africa. The Act is premised on balancing the three legs of social benefit, economic efficiency and environmental sustainability. With its promulgation, groundwater lost its previous status of private water and became public water. It states that water is an indivisible national resource (rivers, streams, dams, and groundwater) for which national government is the custodian. It contains rules about the way the water resource is protected, used, developed, conserved, managed and controlled in an integrated manner.

The law concerning groundwater in South Africa has undergone a momentous shift since democratisation of the country in 1994. Earlier groundwater legislation was based on the "riparian" system, founded partly 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 by State. Today, in terms of the National Water Act 36 of 1998, South Africa's groundwater is recognised as a common asset, whose ownership is vested in the state and which is subject to all the stipulations of the Act.

2.3 Groundwater use

Groundwater sources played a major role in the rapid advancement of the country towards achieving the Millenium Goal for domestic water supply – population using an improved drinking water source improved from 61% in 1996 to over 95% now. This has been the most dramatic achievement for groundwater since the water sector transformation in the country.

A major advance towards improved development and management of the country's groundwater resources has been that groundwater was registered for the first time in terms of the provisions in the National Water Act, 1998. This information, as shown in Table 2, is available on the Departmental WARMS database from which the figure of current registered water use per sector has been developed.

Table 2: Status of Groundwater Use in South Africa

Economic Sectors	Registered Groundwater Use per Sector (%)
Agriculture: Irrigation	59
Agriculture: Watering Livestock	6
Water supply services	13
Mining	13
Other (Industry, Recreation, Aquaculture, Power generation)	3
Schedule 1 (smaller unregistered user)	6

Groundwater is becoming increasingly important for urban water supply. 22% of towns use groundwater as sole source and another 34% in combination with surface water.

Irrigation still presents by far the largest volumetric use of groundwater in South Africa. Like in many other parts of the world, it has mainly happened as a result of private development.

Mines are often in remote areas and provision of an adequate water supply is one of the key challenges of the whole operation. Groundwater sources have always played an important role here.

2.4 Capacity for groundwater management

Important for the management of local groundwater resources are the subsidiarity approaches. The 1997 Water Policy White Paper (DWAF, 1997) stipulates that responsibility for the "development, apportionment and management of available water resources" should be delegated to a "catchment or regional level in such a manner as to enable interested parties to participate." The present generalized lack of technical and managerial expertise led to the decision in 2012 to reduce the number of Catchment Management Agencies (CMAs) to nine from the original proposal of 19 CMAs. Up to now eight of the original nineteen CMAs have been gazetted of which two are operational. Regional level water management is still carried out by the offices of the national department.

It is now vital that groundwater protection and management features strongly in national and regional policy, strategy, planning and management agendas to overcome its past neglect and lay a foundation for its increasingly important role in ensuring national water security.

However, the growing incidence of water interruptions, not just in small rural settlements but in a growing number of urban centres, point to a gap between the intent of policy and strategy, and the available capabilities and systems to give effect to them. This is particularly evident in relation to groundwater and is giving groundwater a bad name. The 2009 Water for Growth and Development Strategy noted that:
"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."

3. Approaches and mechanisms for groundwater resource protection

The vision of the National Water Act is Integrated Water Resource Management (IWRM). Protection of groundwater resources should thus not happen in isolation, but integrated with the protection measures of all significant water resources. The National Water Resource Strategy (see 3.1) initiated an integrated roll-out of protection measures. An early Groundwater Protection Strategy (DWA, 2000) was largely neglected until recently, because it had been developed before the more systematic focus on integrated approaches.

3.1 NWRS (National Water Resource Strategy)

The National Water Resource Strategy (NWRS), which was established in 2005, is an implementation strategy for the National Water Act, 1998 and provides a 'general guide' on the priorities for water use, and puts provision for water resource protection measures (inclusive of groundwater) at the head of a list of priorities in descending order of importance. It goes on to say, however, that the order may vary under particular circumstances, without making an exception of the mentioned protection measures.

The first edition of the NWRS is internationally acclaimed as an excellent document, but at the same time, major knowledge gaps were identified at the time of writing. After the establishment of the first NWRS the Department should have embarked on a process to address those identified knowledge gaps through well-coordinated processes of strategy development. Unfortunately, since 2005, this has never happened. However, a strategy development process did commence in respect of a number of water resource management issues, such as water allocation reform, but such developments were largely isolated, driven by relevant line-functions within the Department. In 2009, a revision approach of the NWRS commenced, outlining the process to identify (through a gap analysis) those key strategic areas that require attention as part of the NWRS revision process. Through this gap analysis exercise, it became evident that crucial areas of water resource management were only superficially addressed or not addressed at all. Examples of these are water conservation and demand management, groundwater management, water quality management, coping with global warming and climate change, etc. Relevant sub-strategies for these areas still needed to be developed and/or finalised and aligned and various identified shortcomings have since been addressed in the revised national water resource strategy (i.e. 2nd edition NWRS).

3.2 Resource-directed measures and source directed controls

Protection principles are contained in Chapter 3 of the National Water Act (Act 36 of 1998). The Reserve, the Classification System and Resource Quality Objectives (RQOs) are protection-based measures that together form the Resource Directed Measures (RDM). RDM is a water resource management strategy with the objective of ensuring sustainable utilisation of water resources. The strategy specifically addresses the determination of the level of protection that should be afforded to a water resource to ensure that it continues to function at a certain desired ecological state. Another strategy exists for managing impacts of land use activities on water resources, which is referred to as the Source Directed Control (SDC) strategy. As shown in Fig 2, RDM should be implemented in conjunction with the SDC strategy to ensure that an integrated and balanced approach is taken in water resource utilisation decision-making that looks at the social, economic and environmental requirements. Through RDM and SDC, an integrated approach to water resource protection and management was envisaged, in order to:

- ensure long-term sustainable use of water resources, and to
- balance the need for long-term protection against the need for social and economic aspirations.

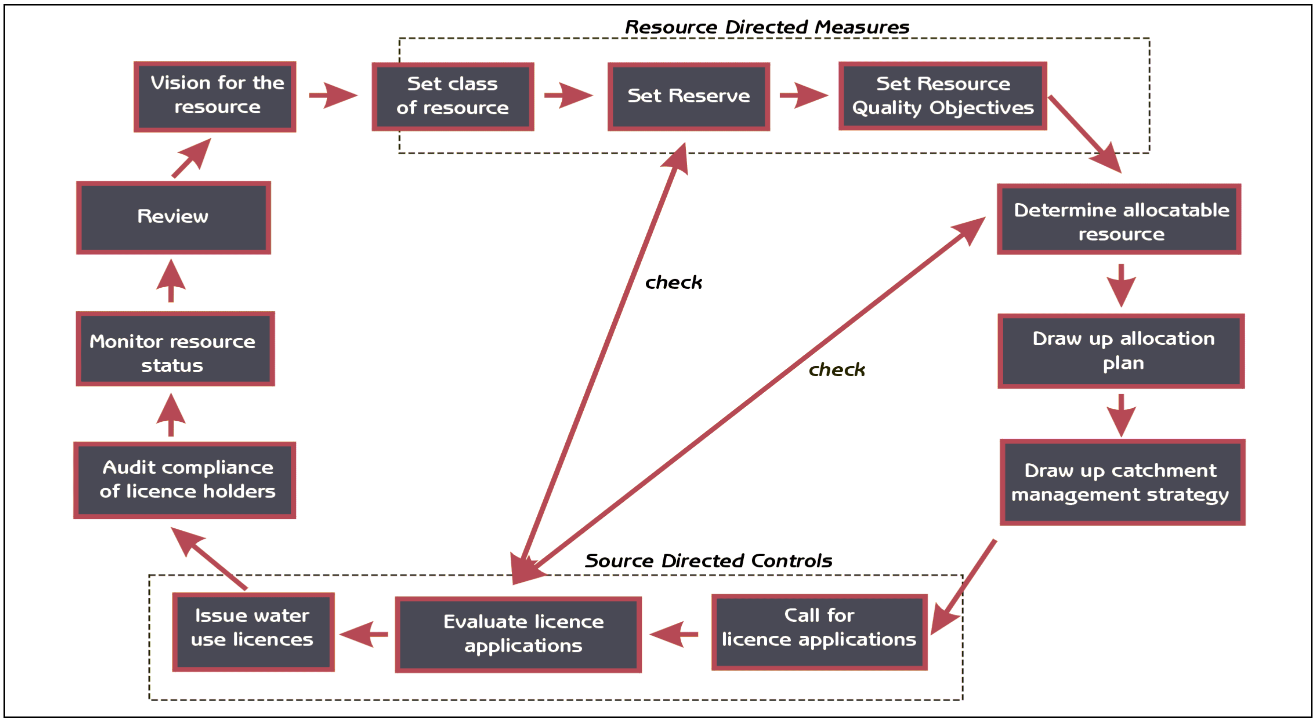

Figure 2: Role of resource directed measures and source directed controls in integrated catchment management

3.3 Planning mechanisms (RDM determinations factored into planning)

Critical water resource protection challenges in South Africa are well recognized and documented. There is a worsening of water resource quality in many water resource systems with a deterioration of reservoirs and ecosystems and especially rural communities face growing risks of water shortages and the health impacts of contamination. Key initiatives to address these water resource protection measures have been considered by a number of role-players. For instance, the Integrated Water Quality Management Strategy of the DWS was commenced in 2015. However, a fragmented and isolated approach in responding to these water challenges is still evident, despite efforts by the Department of Water and Sanitation to realise a more holistic response based on an IWRM approach (Figure 3).

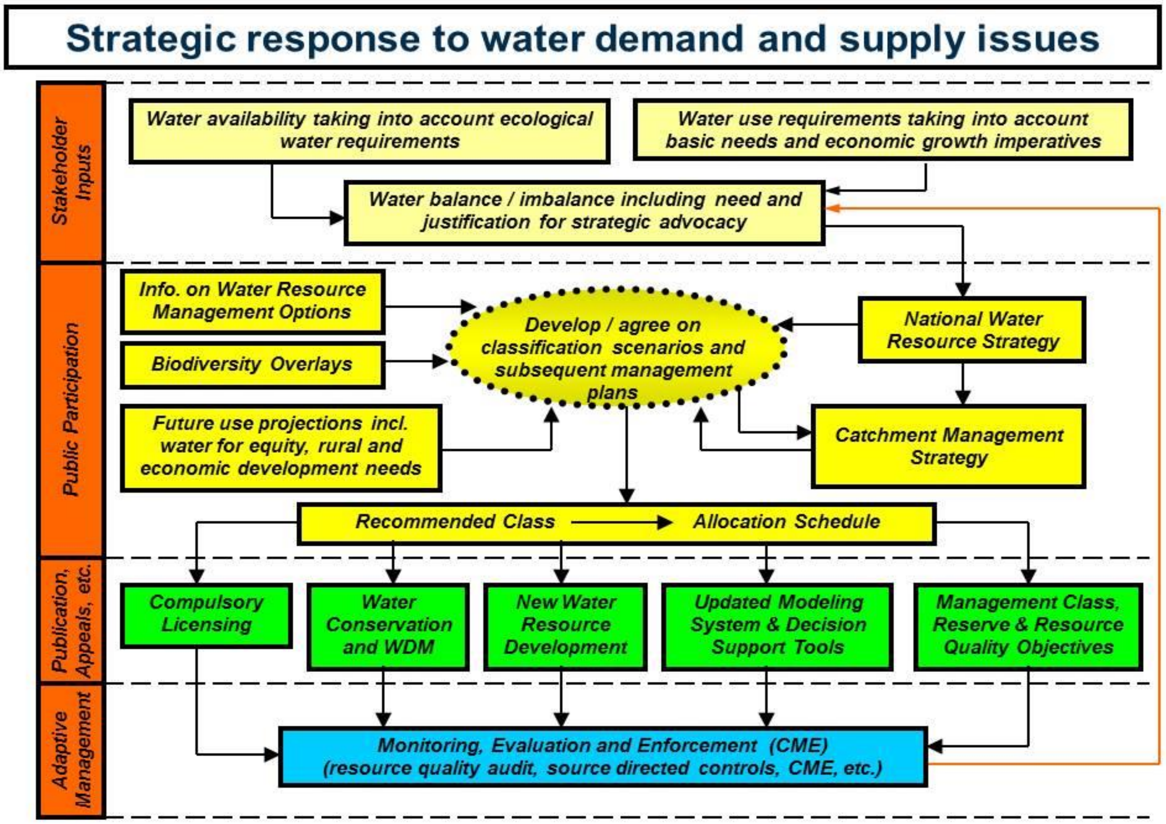

Figure 3: Strategic response to water quantity and quality problems

3.4 Financial measures

The NWA provides for three types of water use charges: funding water resource management, including activities such as water resource protection and monitoring; funding water resource development and use of waterworks; and economic incentives to encourage the equitable and efficient allocation of water. The objective of the water use charges is to contribute to achieving equitable and sustainable water use by promoting financial sustainability and economic efficiency in water use. Water use charges are also in place for the abstraction and storage of water, and for stream flow reduction activities (commercial forestry) in order to encourage more efficient water use and not place unnecessary demand on water resources, thereby protecting the resource. The charge system for waste discharges is currently being developed. It will deal with charges for all aspects of waste discharges, such as the irrigation of wastewater, the discharge of waste or water containing waste into a water resource and the disposal of waste in a manner that may detrimentally impact on a water resource.

The waste discharge charging system (WDCS) is based on the polluter pays principle and addresses both point and diffuse sources of pollution. It supplements a regulatory approach to water quality management, in which standards and objectives are set and enforced, by introducing financial and economic incentives and disincentives to ensure that the costs of polluting activities are, as far as possible, borne by the polluter in order to encourage the minimisation of waste discharges and promote sustainable, efficient and effective water use. Charges made under the system are intended to reflect, and recover from users, the direct and indirect costs associated with the discharge or disposal of waste.

Revenues from the charges will be used to fund water quality management activities related to waste discharge or disposal, such as impact monitoring and mitigation, rehabilitation of degraded areas, dealing with the effects of spills, and system management.

3.5 Groundwater protection strategy

Conceptually, finding a balance between resource protection and resource utilization, can be illustrated in the Figure 4.

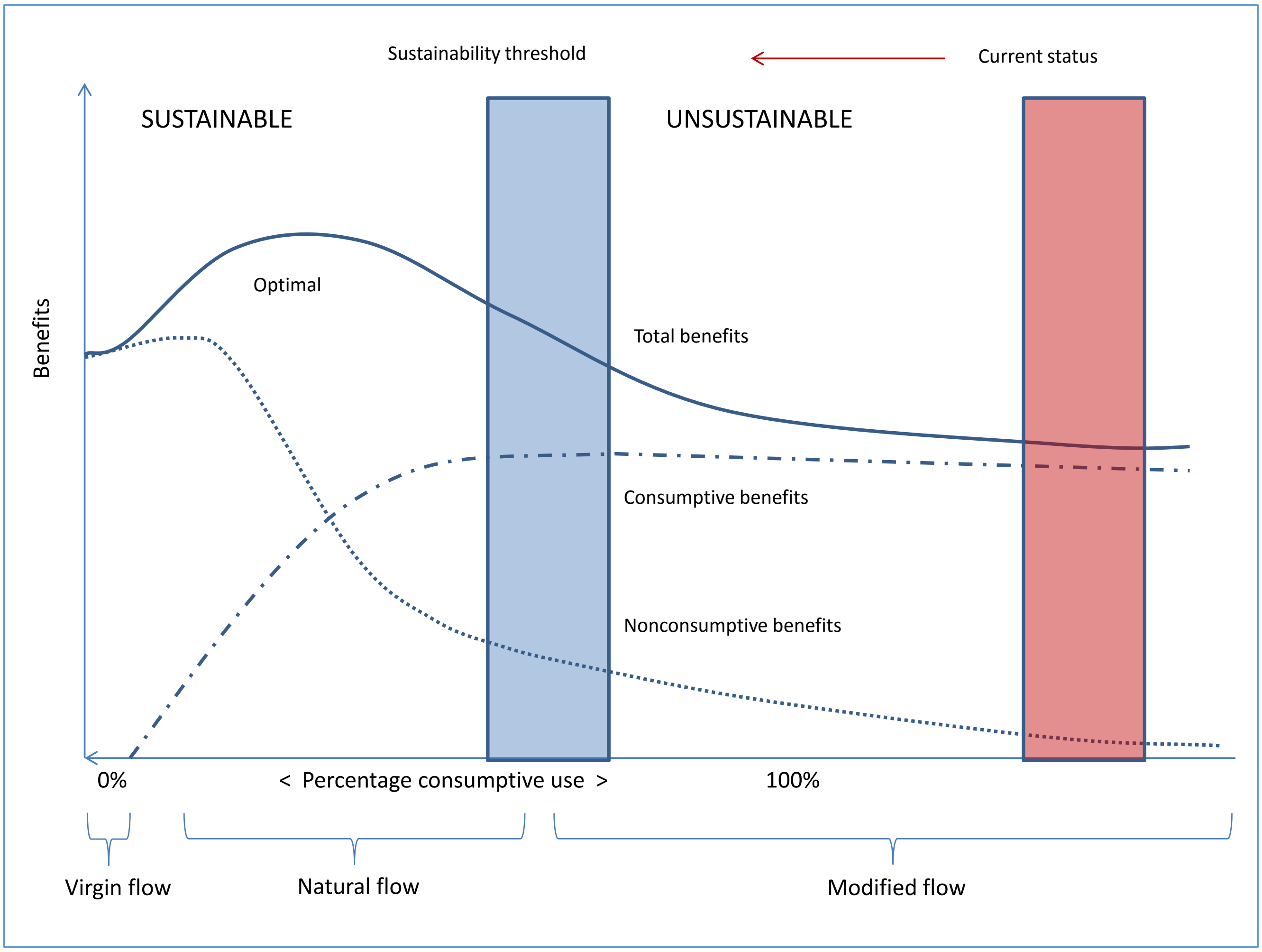

Figure 4: Benefits over various flow regimes with possible range of sustainability and management intervention (adapted from McCartney et al., 2000)

Like surface water, the groundwater flow regime may have gone through various stages in terms of virgin flow, natural flow and modified flow, dependent upon mankind's impact on it. The benefit of water utilization is always associated with impacts on the environment, especially on normal ecological functioning within the hydrologic cycle. Hence an optimization must be sought after. As shown in Fig 4, a blue bar on left indicates a possible range of division between sustainability and unsustainability for the sake of both mankind's use and environmental use. The red bar on the right, on the other hand, indicates the current position of over-utilization against ecological usage. Various mechanisms are used to change the resource utilization position for the sake of sustainability.

Already in 2000, the Department developed a groundwater quality protection strategy, which states (DWAF, 2000): "As the country's people start depending more and more on groundwater, so the need grows to provide for the security of its supply. Protection of groundwater has, therefore, now become a national priority."

The strategy foresaw three main functional groupings (pollution) source-directed controls, resource-directed strategies and remediation strategies and a fourth group to integrate and support the work of the three (monitoring, research, guidelines, auditing). The highest priority foreseen at that time was a programme of special protection of vulnerable groundwater sources supplying domestic water to communities.

3.6 Groundwater scientific methods and information

Since the first considerations for the groundwater component of RDM was developed (Xu et al., 2000; Parsons and MacKay, 2000; Xu et al., 2003), more specific guidelines were developed for comprehensive RDM methodology Reserve determination, Classification and Resource Quality Objectives (Wentzel, 2008; Dennis et al, 2013). These will be discussed in greater detail under 4.7 and 5.3.

As shown in Fig 5, the foundation for all groundwater resource assessment and mapping is the National Groundwater Archive (NGA), previously called the National Groundwater Database (NGDB), presently containing about 250 000 borehole records. Based on these records, the first hydrogeological mapping in South Africa was undertaken:

- Groundwater Resources of South Africa (consisting of a report and accompanying set of groundwater maps) was published by the WRC (Vegter, 1995).
- Groundwater Resources Assessment in 2003 after the publication of a series of 21 hydrogeological maps by the Department of Water Affairs and Forestry.
- Groundwater Resources Assessment (GRA2) by the Department of Water Affairs and Forestry, completed in 2005, which was for the first time incorporated into the 'Water Resources of South Africa' (WR2005).

Various terminologies that are used in GRDM determinations are as summarized in detail in a report on Groundwater Resource Assessment II by DWAF (2004).

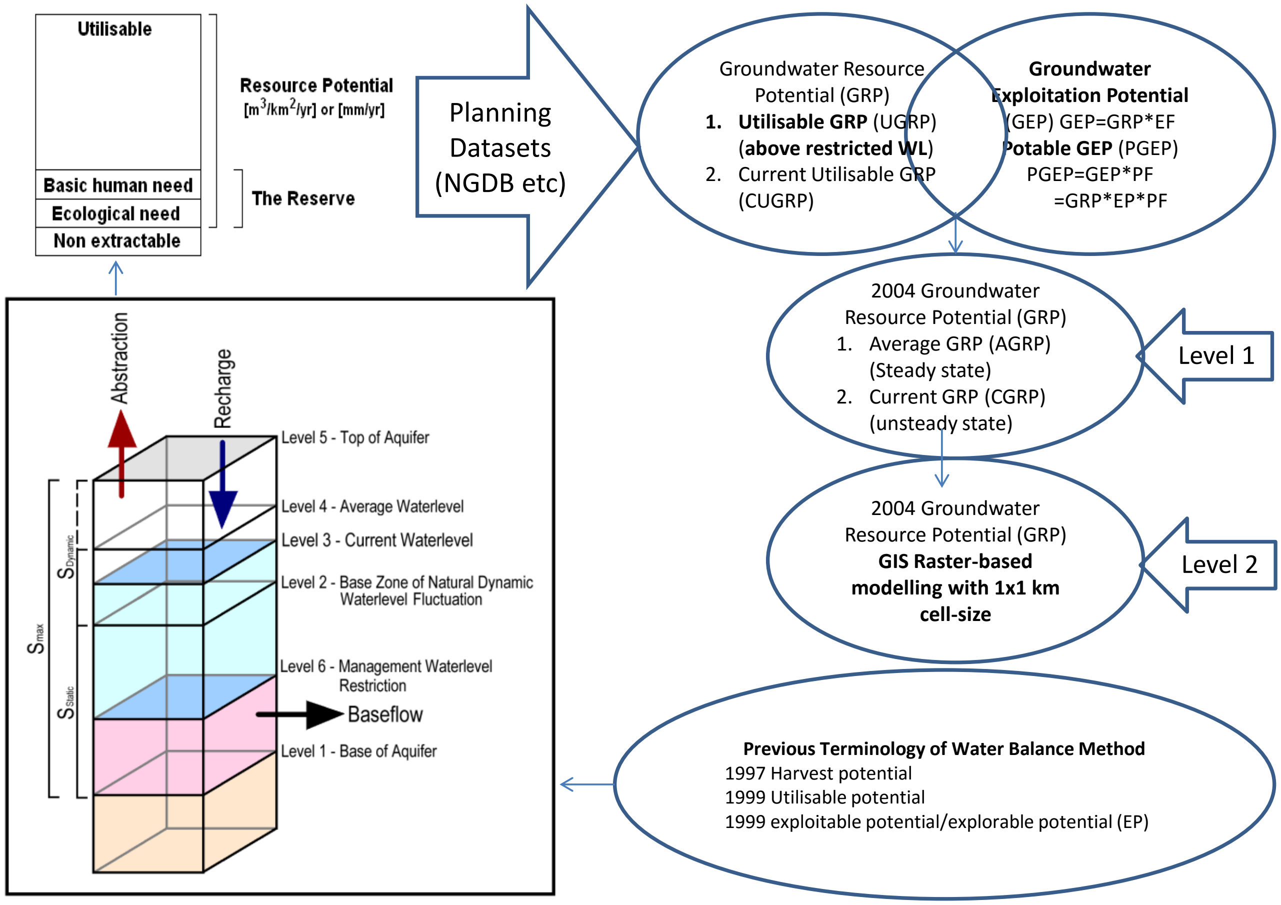

Figure 5: A flow chart of various terminologies being used in GRDM determinations as summarized from Groundwater Resource Assessment II (adapted from DWAF, 2004b)

3.7 Decision support tools (WARMS, etc.)

A water use entitlement cannot be issued without considering groundwater resource protection measures (under RDM), as specified by the NWA. A water use license application is typically submitted to DWA's regional offices. A request for a Reserve determination (surface and / or groundwater component) is then submitted to the RDM directorate (now called Directorate: Reserve Determination) by the regional office. In consideration of the Reserve, the following are taken into account:

- the magnitude of the impact,
- the present Ecological State of the resource,
- the ecological sensitivity and importance of the resource, and
- previous Ecological Water Requirements (EWR) studies.

The National Water Resources Strategy (NWRS) also makes provision for water use allocation planning (compulsory licensing) in any catchment area in which current levels of use exceeds the availability of water or other circumstances prevails. The process of water allocation planning allows the Department with an opportunity to rectify existing situations in order to ensure equitable and sustainable utilisation of the relevant water resource. This is achieved through a formalised process of verifying existing lawful use (verification and validation of water use registration data) and allocation of water in such a way as to ensure compliance with the Reserve requirements. This might take a number of years to achieve but the Reserve requirement is a key consideration during any process of water use allocation planning. Water use allocation is a mechanism available to ensure sustainable utilisation of the water resource, and not only to protect the natural riverine environment (fishes and bugs).

3.8 Institutional and governance processes

Institutional arrangements constitute a very important aspect of water resources management because successful implementation of the NWRS depends on existence of effective institutions and a strong regulatory framework. The National Water Act defines water management institutions as CMAs, WUAs and bodies responsible for international water management or any person who fulfills the functions of water management in terms of the NWA. However, the Department of Water Affairs (as water sector regulator) has also embarked on institutional realignment of its own operations both at head office and regional offices in order to make provision for a focused approach concerning water resource protection. To drive the process of implementing resource protection, the Resource Directed Measures Directorate (now Directorate: Reserve Determination.) was established in December 2002 and has since been confronted by many constraints and challenges: the finite nature of water resources; linking policy with research and development; applying scientific Reserve methods to surface and groundwater with highly variable characteristics, as well as various operational constraints. At the same time this realignment process also created an opportunity for the establishment of groundwater protection functions and activities within the policy, planning and regulatory branches of the Department.

3.9 National monitoring

This DWS has reviewed its conventional water quality monitoring programmes in order to make a deliberate shift from generic guidelines that are predominantly hazard base (where the emphasis in deriving the guideline is on the potential of what may go wrong) to a more realistic site-specific risk base approach (where the focus is on what may be expected to happen under real world circumstances). The national monitoring programmes operated and maintained by DWS have as their goal the assessment of status and trend in the determinants for which they are designed. These programmes thus form the basis of assessment, providing a means to focus realistically on site specific issues that need to be followed up with management actions in order to ensure effective protection of water resources.

The National Water Act, mandates the Minister to ‘ensure the continued and coordinated monitoring of water resources in its broadest sense. To give effect to this mandate, a 5-year Water Resource Quality Monitoring Plan was drawn up, which covered the following individual programmes:

- National aquatic ecosystems health (River Health) monitoring programme;
- National chemical monitoring programme;
- National eutrophication monitoring programme;
- National microbial monitoring programme;
- National radioactivity monitoring programme;
- National toxicity monitoring programme;
- Hydrological monitoring programme (flow);
- Geohydrological monitoring programme; and
- Green drop monitoring programme.

The various resource quality monitoring programmes make use of the Water Management System (WMS), the hydrological information & data base (HYDSTRA) and the National Groundwater Archive, aimed at providing information products related to water quality and quantity respectively. The Blue Drop and Green Drop Monitoring Programme were established more recently to monitor the performance of municipalities in the delivery of water supply and sanitation services respectively.

4. Progress with (G)RDM implementation

4.1 National Water Resource Strategy

In doing all the necessary forward strategic planning for the comprehensive management of our water resources, the DWS has revised the NWRS and subsequently prioritised its implementation. This 2nd edition NWRS, serves as a strategic guideline document for all water use stakeholders in the water sector, and it addresses various issues affecting the access to the resource and particular. Accordingly, the following NWRS sub-programmes have since received priority attention:

- The National Integrated Water Information System (NIWIS) to improve decision-making and improve access for the public
- Water allocation reform: the validation and verification of existing lawful users
- A structured water use license process with a maximum turnaround time of 30 days.

Protection is one of the fundamental principles of the National Water Resources Strategy and is prominent in Chapter 3 of the National Water Act, 1998.

4.2 RDM (Resource Directed Measures)

The NWA provides for the protection of water resources through 3 main measures namely:

- Classification of water resources;
- Determination of the Reserve and
- Setting the Resource Quality Objectives (RQOs) for the selected class.

The Water Resource Classification System (WRCS) was formally established in September 2010 whereby water resources are categorised according to specific Classes that represent a management vision of a particular catchment. The WRCS takes into account social, economic, ecological and environmental landscape in a catchment in order to assess the costs and benefits associated with utilization versus protection of a water resource defines three water resource classes, reflecting a gradual shift from resources that will be minimally used to resources that are heavily used. The classification of water resources represents the first stage in the protection of water resources and determines the quantity and quality of water required for ecosystem functioning as well as maintaining economic activity that relies on a particular water resource.

4.3 Planning mechanisms

Over the years, groundwater (quantity and quality) as a domain function has been well incorporated into the strategic planning function of DWS. However, operational plans at provincial and local levels are still lacking coherent implementation of groundwater protection measures, despite this function being an integral part of water resource planning. Planning attention should not only be focused on specific water supply issues, but on region-wide and national issues relating to vulnerable groundwater resources, for example the potential impact of shale gas exploitation on underground water resources and the pervasive impacts of acid mine drainage on the whole hydrological system, both ground- and surface water. Efforts to implement groundwater protection measures should therefore not only be considered within an IWRM context (Fig 3 in section 3.3), but also aim to advance a set of large-scale practical and effective science-based integrated scientific, engineering and technological (SET) solutions to counter groundwater problems evident at both source and resource throughout the physical water value chain (Figure 6). These interventions not only take into account resource protection measures at the resource but also considers water supply and sanitation issues at source, especially if the implementation of groundwater protection measures is to be realised at municipal level.

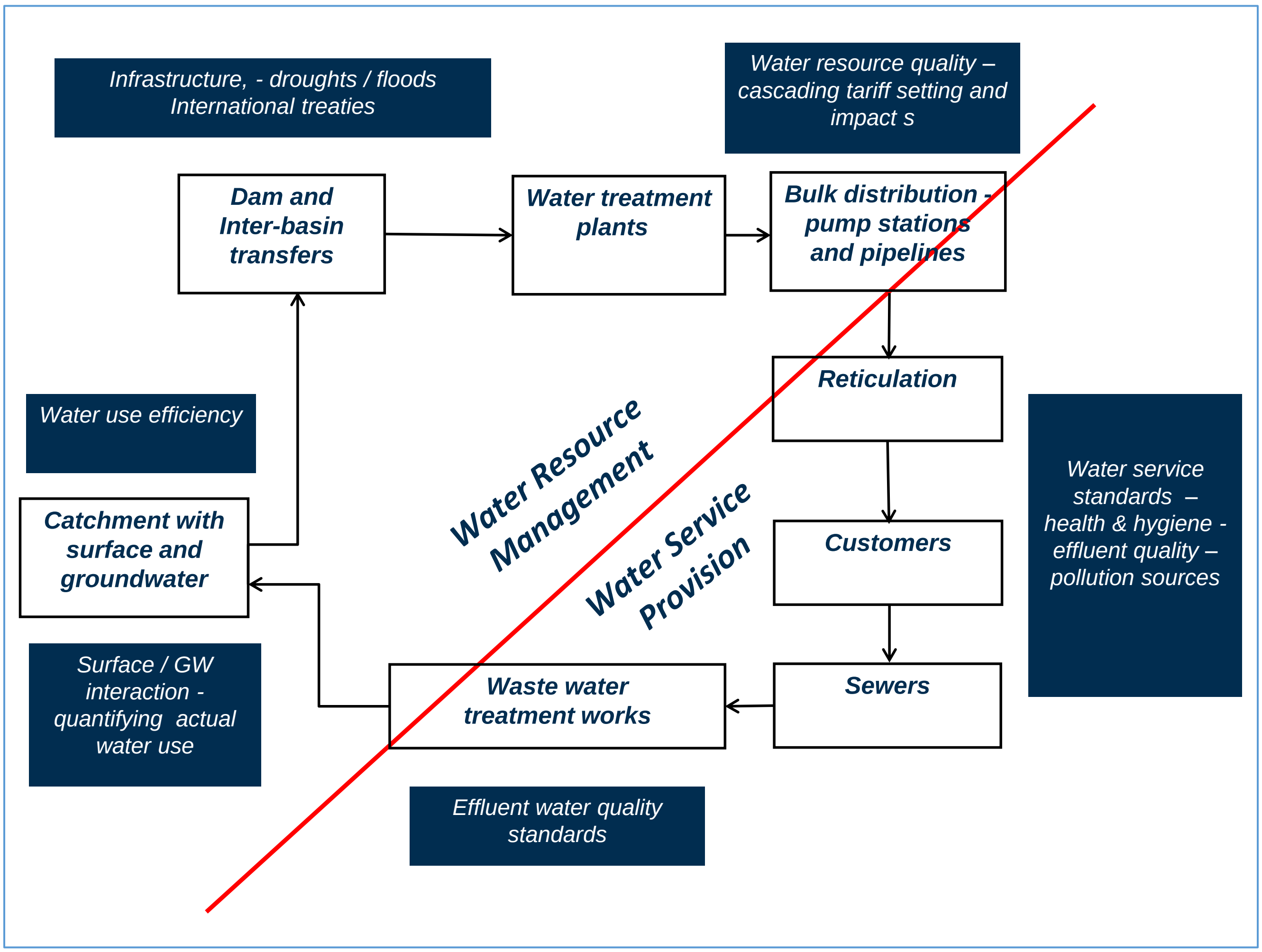

Figure 6: SET considerations throughout the water value chain to enhance the implementation of groundwater protection measures

4.4 Integration with Source Directed Controls (SDC)

To date, it would appear that, in general, decisions regarding water resource utilisation are not integrated and that RDM and SDC are being applied in isolation. The DWS has however established a function in its Regulations branch that is focused on environmental regulation, hence SDC could be concerned with implementing groundwater protection measures, while the determination and refinement of these protection measures are being determined by the RDM function that is performed within the Planning and Information Branch of the Department.

4.5 Financial measures

It was envisaged that the waste discharge charging system (WDCS) will be implemented in a phased manner in order to build capacity, where the WDCS will be applied to those catchments where resource quality objectives are threatened or exceeded. However, to date there is little evidence that suggest that this system (or elements thereof) has been implemented as initially envisaged, despite the following sound principles on which underpins this system:

- The WDCS is focused on reducing discharge load in order to achieve/maintain RQOs in a catchment.
- The WDCS applies to surface water and groundwater resources where RQOs have been defined and an adequate understanding of the resource supports the implementation of the system.
- The WDCS will be applied at a catchment/sub-catchment scale
- The WDCS will be applied to downstream/ upstream catchments if required
- The WDCS will be based on loads discharged.
- The WDCS is based on a linear relationship between load and charge (i.e. a flat charge rate is applied).
- Waste dischargers are liable only for their contribution to the water quality problem.
- A minimum discharge load may be identified, below which the charge is waived.

While the objective of the different water use charges mentioned in 3.4 is to contribute to achieving equitable and sustainable water use, they have to date played no role in practical measures to achieve groundwater security.

4.6 Implementation of GRDM

4.6.1 Initial focus on Reserve determination

Before classification of water resources was systematically introduced in various catchments, the key RDM process was Reserve determination in support of water use licensing. Table 3 below provides an indication of ‘Groundwater Reserves’ that have been assessed relative to the number of ‘Surface Water Reserves’ in a particular period up to 2013/14. The major effort this presents can be seen in Figure 7, which depicts the cumulative number of ‘Groundwater Reserves’ determined up to 2014 in each of the nine Water Management Areas (WMAs).

The figure also shows the different levels of detail to which the Reserve has been determined in each WMA, ie. Desktop, Rapid, Intermediate and Comprehensive. This breakdown of the different levels of detail in a particular year (2013/14) is shown for illustration purposes in Table 4.

Table 3 Summary of Reserves completed

Period	'Groundwater Reserves'	'Surface Water Reserves'
Up to May 2011	1306	1468
2011/12	94	1128
2012/13	1141	161
2013/14	21	53

*RDM Webpage and Motebe (2015)

Table 4: Summary of groundwater reserves completed between October 2012 and September 2013 (DWA, 2014b)

Drainage Region	Desktop	Rapid	Intermediate	Comprehensive	Total
A	13	53	68	-	134
B	3	23	114	-	140
C	18	20	149	-	187
D	31	14	-	-	45
E	5	10	-	-	15
F	8	-	-	-	8
G	27	6	-	-	33
H	13	-	-	-	13
J	7	3	-	-	10
K	10	19	-	-	29
L	7	-	-	-	7
M	6	-	-	-	6
N	9	-	-	-	9
P	7	-	-	-	7
Q	8	-	-	-	8
R	-	-	30	-	30
S	-	-	58	-	58
T	-	-	106	-	106
U	-	-	-	-	0
V	-	-	-	86	86
W	-	-	-	117	117
X	-	93	-	-	93
TOTAL	172	241	525	203	1141

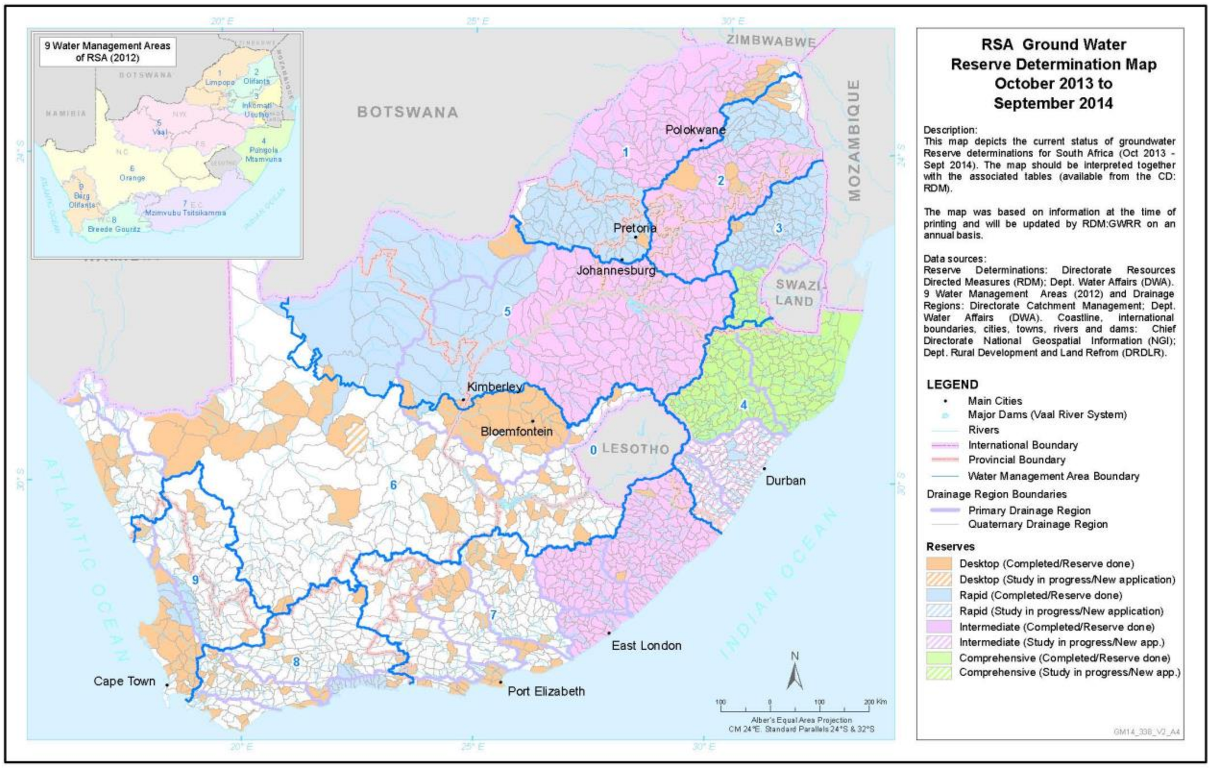

Figure 7: Status of Groundwater Reserve Determination – 2014 (Motebe, 2015)

According to Figure 7, Comprehensive 'Groundwater Reserves' have at this stage only been undertaken for the Pongola-Mtamvuna WMA and parts of the Inkomati-Usutu WMA. Intermediate determinations have been done for large parts the Limpopo, Olifants, Vaal WMA and Mzimvubu-Tsitsikamma WMAs. Large portions of the Orange, Breede-Gouritz and Berg-Olifants WMAs have at this stage only patches of Desktop determinations, with some Rapid and Intermediate Reserves along the coastal areas.

This highly relevant information could not yet be properly assessed, because it was only received at the time when the Position Paper was already due. A further important breakdown, already received previously, has not yet been discussed with DWS regarding its implications for groundwater resource protection, namely the focus of the 'Groundwater Reserve' determinations:

- 80% ad hoc water use license-related (protection of linked surface water);
- 20% protection of groundwater resources.

Critical background to the above information was provided in terms of the main aim of determining the "groundwater component of the Reserve, otherwise known as Groundwater Resource Directed Measures (GRDM) for the entire water management area":
"To ensure that water is available for current and future use. Protection involves the sustaining of a certain quantity and quality of water to maintain the overall ecological functioning of rivers, wetlands, groundwater and estuaries. An important outcome of the GRDM is the determination of the allocable groundwater portion (groundwater available after consideration of the Basic Human Needs and

Ecological Water Requirements and existing use) that will be used to address current as well as future water use license applications. These preliminary Reserves are presently used where the water resources have not been classified as yet. As further step, Ecological specifications are set and are used as surrogates for Resource Quality Objectives" (Motebe, 2015).

A conclusion that can be drawn at this stage of Reserve implementation is that groundwater resources per se are not yet protected by these extensive measures. The whole focus is on the ecological Reserve and its Ecological specifications, which are at this stage only defined for surface water resources. The Basic Human Needs Reserve for groundwater is a very small volume which can only be controlled if relevant Resource Quality Objectives are set.

4.6.2 Roll-out of Classification and Resource Quality Objectives

. There has been considerable progress in the catchment-wide roll-out of RDM since 2014 (see Table 5). It is further reported that the high confidence Reserves were conducted in the Gouritz, Mvoti and Usuthu catchments, with the groundwater component duly included (Atwaru, 2016). Significant also is the Water Research Commission's contribution to this initial period of establishing the groundwater component in Classification. All six groundwater studies mentioned below were undertaken with support from the WRC. All these reports were readily accessible and assisted in the assessment.

Table 5: Roll-out of RDM in Catchments

Area	RDM Implementation[1]	Groundwater progress
Upper Vaal Middle Vaal Lower Vaal	Proposed classes of water resources were gazetted on 19 September 2014	WRC GRDM study WRC GRDM study
Crocodile (West) Marico		WRC Maloneys Eye study
Mokolo & Matlabas		WRC Case study for Manual
Mvoti Umzimkulu Classification Project	Water Resource Classes proposed for Mvoti and Umkhomazi catchmentsGroundwater, Wetlands, River and Estuary RQOs determination Public meeting planned for October 2015	
Olifants-Doorn	Water Resource Classes gazetted October 2014 Legal notices containing both classes and RQO were published for a further 60-day consultation RQOs are currently legally reviewed	GEOSS Technical Report
Olifants and Vaal RQO Project	Draft RQOs have been determined Now prepared for gazetting for 60-day public commenting period	

Incomati Classification and RQO project	Draft Water Resource Classes and RQOs have been determined Public Meeting March 2015 RQOs prepared for gazetting for 60 day public commenting period	
Letaba Classification and RQO project	Draft Water Resource Classes and RQOs have been determined Public Meeting June 2014 RQOs prepared for gazetting for 60 day public commenting period	WSM Leshieka Report

[1]Interdepartmental Inland Ecosystem Liaison Committee Meeting (April 2015)

Approximately R 380 million has been expanded on RDM implementation discussed in 4.6.1 and 4.6.2, of which we estimate that around a third had gone to groundwater protection measures. An assessment of the impact of this investment on the protection of groundwater resources is made in Chapter 5 and in the Case studies.

4.6.3 National monitoring

The Department of Water Affairs as a sole custodian of water resources of the country is mandated to monitor and manage these resources in a manner that supports socio-economic development without compromising the ecological integrity of natural systems. Chapter 14 of the National Water Act (NWA) calls for the establishment of monitoring and information systems to monitor, record, assess, and disseminate information on the quantity and quality of water resources.

In line with the progressive decentralization of water resources management as foreseen by the National Water Act, 1998, monitoring and assessment should also address these different levels of management.

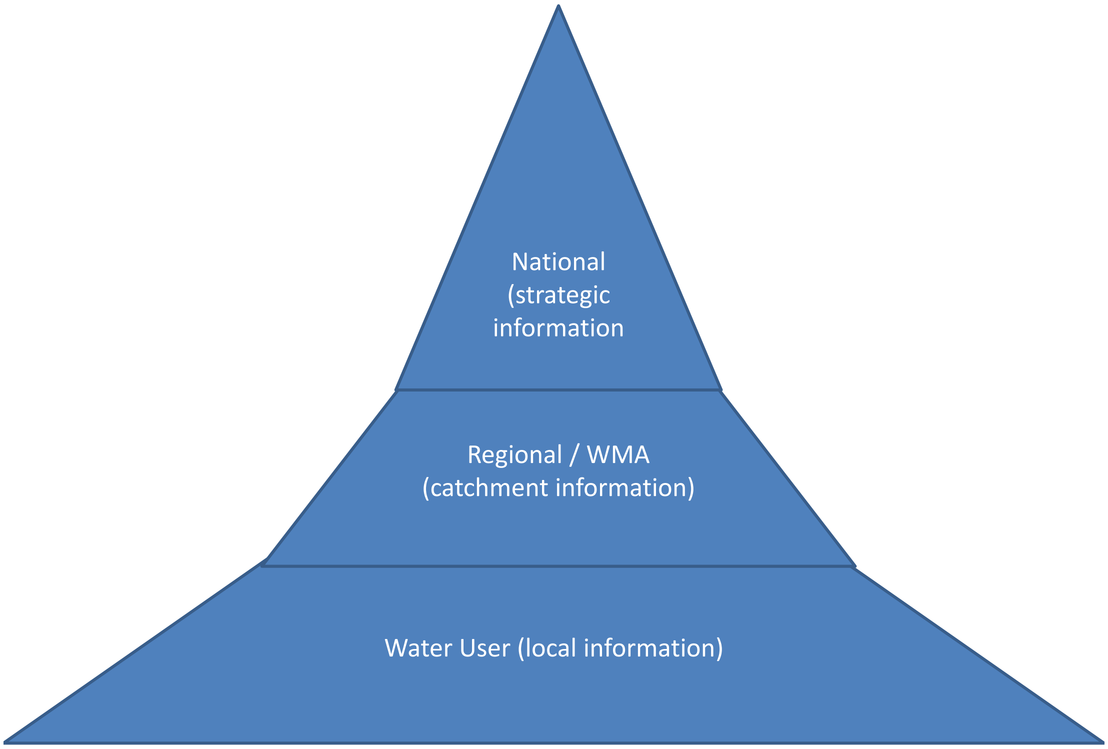

Figure 8: Hierarchy of information requirements for management of water resources

Besides data acquisition, good progress has been made with data management and storage, and information generation and dissemination. The relevant national information systems are fully in place. Quarterly reporting takes place in two of the regions and an annual National State of Water Resources Report was initiated in 2007 and has appeared regularly since 2011/12.

There are currently (2015) 1954 active groundwater monitoring stations (compared to 1631 for surface water). In 2008 there were 1836 active stations. While monitoring of rivers and dams has started around a hundred years ago, only a few groundwater level records are longer than forty years. The map of national groundwater level monitoring stations (see below), still shows large blank areas and investment into groundwater monitoring is about 15% of that for the surface water network (DWAF, 2004a).

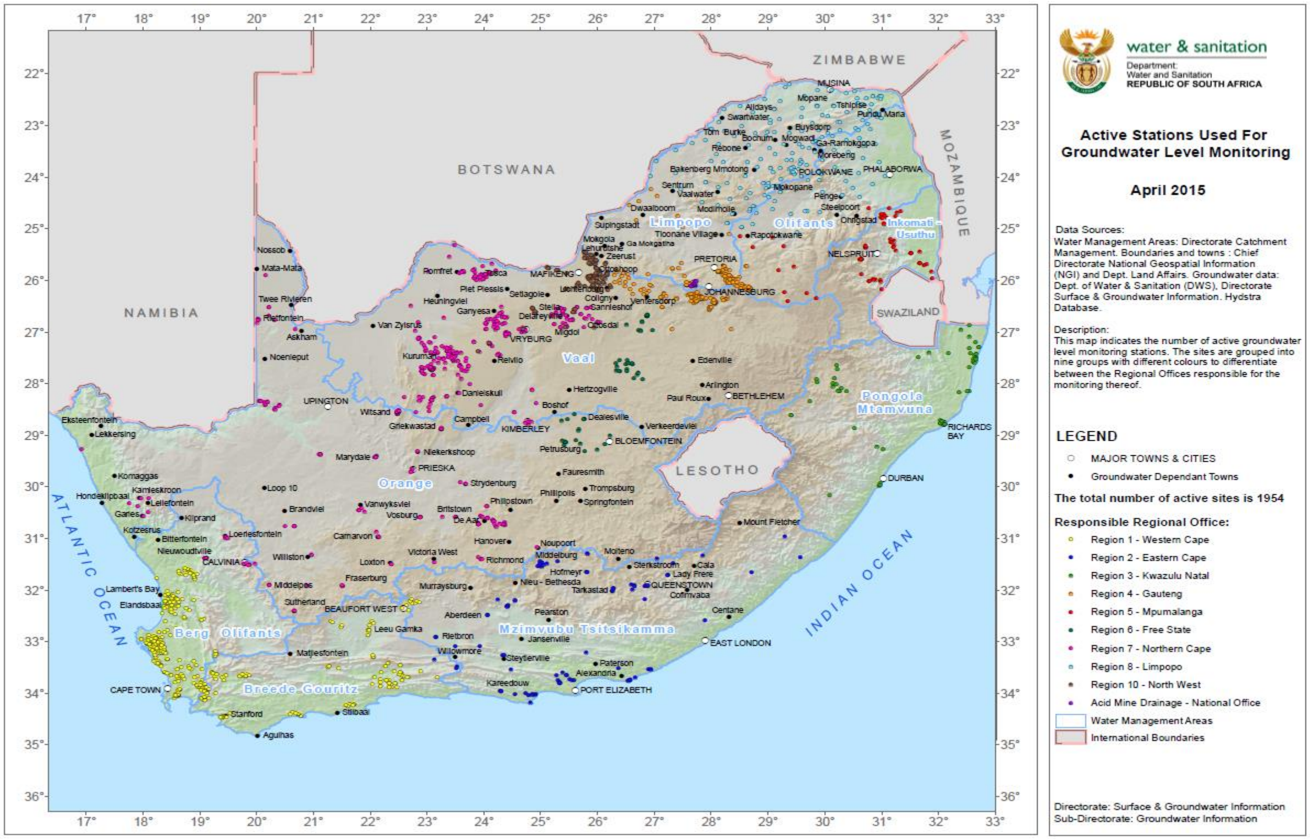

Figure 9: Active Groundwater Level Monitoring Sites – 2015

The groundwater quality monitoring programme started in 1994 to determine the time series and spatial trends in the groundwater quality on the national scale. Monitoring points are sampled twice a year, that is before and after rainfall season (October and April). In 2007 it had grown to 369 monitoring points; by 2011 there were 445 active monitoring points and by 2014 it was back to 311 monitoring points.

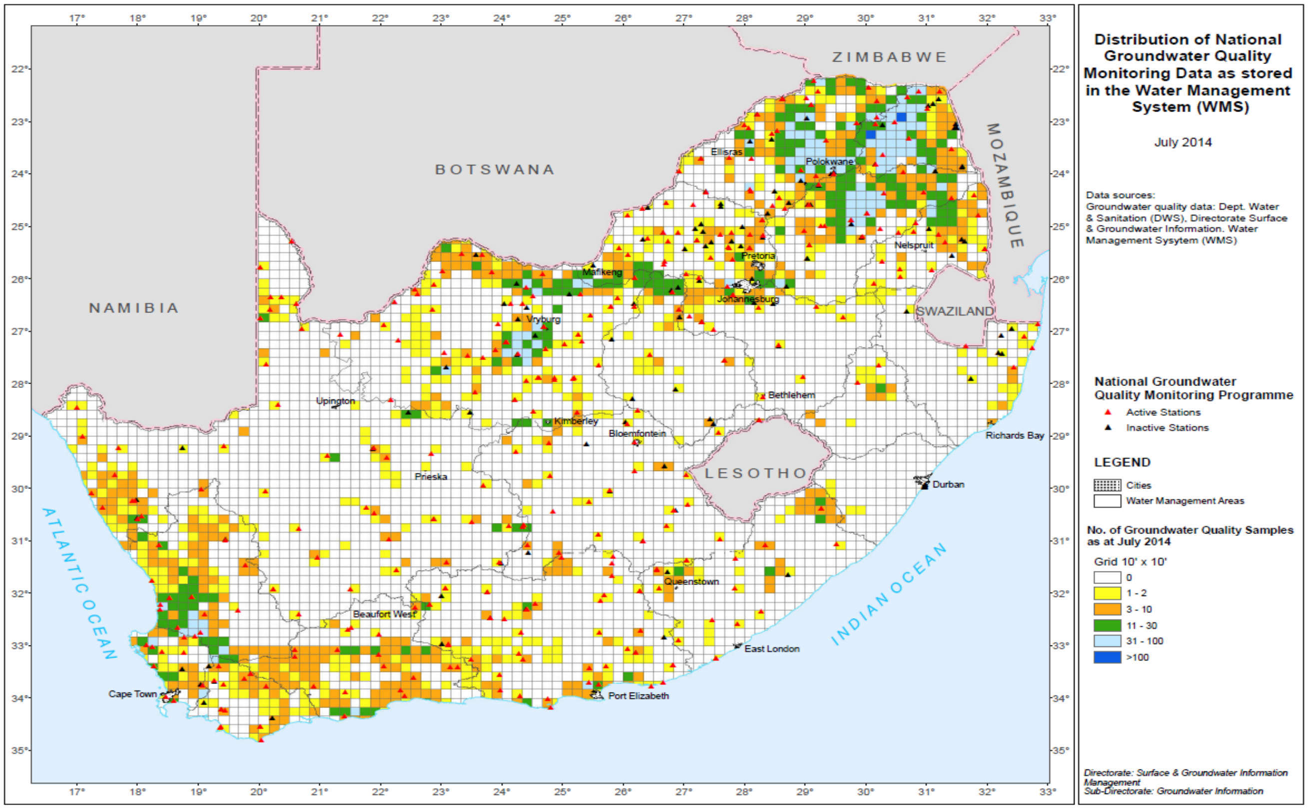

Figure 10: Active Groundwater Quality Monitoring Sites - 2013

Some of the strategic actions foreseen in terms of more systematic and integrated monitoring foreseen in the 5-year Monitoring Plan (DWAF, 2004a), namely an integrated monitoring plan for each Water Management Area and an overall monitoring governance model involving key stakeholders, are starting to be realized in some of the Regions.

In the Limpopo Region an Integrated Regional Monitoring Committee has been established. The purpose of the different networks has been spelled out. They are a mix of:

- National level (largely unimpacted areas)
- Regional level (protection and regulation focus)

The observation network is expanded every year by means of a special drilling programme (the Region has its own drills for this purpose).

In the Western Cape Region both baseline (unimpacted) and management support monitoring is undertaken. This includes, inter alia, focus on aquifers with large irrigation abstraction, with seawater intrusion potential and with contribution to river baseflow.

Both Regions undertake systematic reporting on a quarterly basis.

One special off-shoot from this monitor programme, which has now been completed in two-time slots (1999 - 2000 and 2007 - 2008), is the hydro-chemistry sampling/analysis of the National Dolomitic Eyes of South Africa.

The intention to monitor aquifer-dependent ecosystems has not been put into practice yet.

The integrated and user-focused monitoring of water resources, as foreseen in the 5-year monitoring plan, has not yet taken off, largely because integration was to take place at the catchment level, whereas the Catchment Management Agencies that were to lead this process are only just starting to be established. This is also the reason why the groundwater resources monitoring is poor in some Regional Offices of the Department of Water and Sanitation and strong in some others. A good development is the publication of an annual report on the State of Water Resources, based on the various monitoring programmes (DWA, 2012c). The Department is presently undertaking a project review and achieve optimisation of its the water resources monitoring networks, including the groundwater resources networks.

4.6.4 Local level monitoring

Groundwater governance

It is generally accepted that securing water for all, especially to vulnerable populations, is often not only a question of hydrology (water quantity, quality, supply, demand) and financing, but equally a matter of good governance. Effective governance approaches are particularly important for groundwater. Because of its ubiquitous nature and relative ease of local access, there are widely distributed and generally dispersed abstraction points and many stakeholders, who are involved in its development, use, as well as misuse. This complicates the traditional national approaches to resource regulation and requires a very high degree of participative management.

Establishment of Water User Associations

The National Water Act, 1998 provides for local level organization through the institution of a Water User Association (WUA). WUAs are defined in the NWA as water management institutions whose members voluntarily agree to undertake water related activities for their mutual benefit. Principal functions of the Association are concerned with management of the water resource or infrastructure. Typical examples (surface water related) in this category are preventing water wastage or unlawful use, regulating flow of the watercourse, protection of the water resource and monitoring flow quantity and quality.

Working cooperatively is new for groundwater users for whom the resource had been their ‘private water’ before the legislative changes of 1998. The few cases where it has been attempted in South Africa illustrate that cooperation is essential, but that there are many remaining challenges (Braune et al, 2014):

Dendron: The Dendron irrigation farming community in Limpopo Province had completely over-exploited their major aquifer system of deeply weathered granite rock. Through many years of intensive awareness-and capacity-building by Departmental geohydrologists, the initaitive became an example to the water user association establishment process under the new legislation. However, the enthusiasm was broken after long years of unsuccessful application to become a WUA (transformation from an irrigation board) and lack of continuing communication and support from DWAF. Monitoring and participatory management has ceased. Also pollution with elevated nitrates from fertilizer application and high concentration of pit latrines is widespread.

Tosca: The Tosca/Molopo Water User Association, concentrating on irrigation from groundwater in the arid Tosca / Vergelee area to the north of Mahikeng near the Botswana border, was established in 2004 by the Minister of Water Affairs, following the establishment of a pilot committee in January 2001 (Van

Dyk, 2005). Control of excessive irrigation volumes is critical in this arid area and was a significant issue in the early stages of the WUA, with DWA taking action against non-compliant users (Van Dyk, 2005). The current situation with respect to over-abstraction in that area is not known.

Steenkoppies: The Steenkoppies dolomitic compartment near Krugersdorp hosts one of the most valuable resources of groundwater in the country, key to an irrigated agricultural industry worth three quarters of a billion rand and employing thousands of people. Since the 90's the Department has been trying to control over-abstraction, which finally in 2007 led to a crisis downstream in the Magalies River, when eight of the nine springs constituting the compartment's outflow in the Maloney's Eye stopped flowing. Control has been hampered by a lack of an adequate assessment of the aquifer potential and of a verified groundwater use from the compartment. Since 2007 the irrigation farmers of the compartment have been trying to establish a Water User Association. It appears that to date the applications have been rejected, because the proposed WUA's governing board is not yet sufficiently representative of the area, and will need to be revised before final approval is granted. The responsible District Municipality, has up to now shown little attention to this economically important resource in its area, probably due to a lack of understanding of the issues (Holland et al, 2009).

Sandveld: The Sandveld is a very sensitive coastal aquifer system along the Cape West Coast. It has competing users, namely high value irrigated agriculture (seed potatoes), five towns virtually dependent on groundwater and sensitive groundwater-dependent ecosystems. Whatever management there is, is through foresight of Potatoes SA, an association serving the potato farmers. Potatoes SA employs a hydrogeologist to undertake monitoring and make annual management / operational recommendations. Through the active support of the then Department of Water Affairs (drilling and monitoring), a much better monitoring network was achieved. The big drawback is that Cederberg municipality draws from the same aquifer and has stopped all monitoring – this despite data loggers that were installed in 2005.

It is clear that local user participation and cooperation needs long-term support in terms of the institutional processes of WUA establishment, the proper assessment of the resource in terms of boundaries and potential and the establishment of monitoring and information systems for ongoing management (Braune et al, 2014).

The issue of local monitoring and management is discussed further in the Olifants-Doring case study.

4.7 Groundwater quality protection strategy

The comprehensive groundwater quality protection strategy of the Department (DWAF, 2000) had been virtually forgotten in the GRDM methodology development. However, the quality protection strategy has been strongly brought back into the Departmental Groundwater Strategy (DWA, 2010). It stresses that an integrated approach to the management of groundwater and surface water is required in order to provide for adequate protection and efficient management of the total resource. However, the value and vulnerability of groundwater represents a strategic component of the water resources of South Africa. Groundwater occurs widely and, geographically, almost two thirds of South Africa's population depends on it for their domestic water needs. Security of groundwater supplies is thus essential and protection of groundwater has become a national priority. In this regard, the need for pro-active establishment of protection zones around groundwater abstraction points (and sometimes well fields and even whole aquifers) within which activities that may pollute groundwater are controlled, is stressed (DWA, 2010).

4.8 Groundwater scientific methods and information

The Water Research Commission (WRC) funds approximately 50% of water related research in South Africa. Research has been structured according to four key strategic research areas: (i) water resource management; (ii) water-linked ecosystems; (iii) domestic, industrial and mining water use and (iv) waste management; and, water utilisation in agriculture. Outside of these four key research areas, but closely connected to them and forming an integral part of the water-related research and innovation system, is a fifth key focus area, dedicated to knowledge management to ensure that the water sector is able to gain the greatest possible advantage from the WRC's investment in research, development and innovation. The Department of Science and Technology also fulfils a national facilitating and coordinating role for all R&D and thereby serves to link water-centred research and innovation to all other relevant R&D initiatives in South Africa. It has, through its Innovation Fund, funded the development and commercialisation of a limited number of new, water-centred technologies. Despite all these investment efforts and noticeable progress, a clear lack of integrated scientifically-robust methodologies that adequately supports the coherent approaches for groundwater protection implementation still remains evident.

4.9 Decision-support tools (NIWIS, WARMS update, EWULA, WULAACs, etc.)

To date, the Department has managed to integrate its data and information (WARMS, WMS, EWULA, ArcGIS, etc.) to one coherent system that was recently launched (July 2015), called NIWIS (national integrated water information system), thereby linking all data across all branches of the department (i.e. both water services and water resources functions).

4.10 Institutional and governance processes

The Department of Water and Sanitation has obtained a Cabinet approval for the reviewed water policy positions and is currently revising legislation in order to align the policy and legislation. The policy reaffirms the 1997 White Paper's policy position on the establishment of Catchment Management Agencies (CMAs) to manage water resource in South Africa. Institutional arrangements constitute a very important aspect of water resources management because successful implementation of the NWRS depends on existence of effective institutions and a strong regulatory framework. The National Water Act defines water management institutions as CMAs, WUAs and bodies responsible for international water management or any person who fulfils the functions of water management in terms of the NWA. Previously, there has been no clear separation of the regulatory functions from policy development and operational activities within the then DWA. This changed only recently with the establishment on proto-CMAs. These proto-CMAs also serve to counter the rather slow process of CMA establishment as experienced previously. Therefore, decentralization of responsibilities for water resource management to the lowest appropriate level will soon be realized, with ongoing high-level water sector coordination efforts to enforce the implementation of the NWRS by all sector departments and other partners. The situation analysis of the institutional realignment process has led to the reduction of the number of CMAs and WMAs to established (Figure 11).

However, there is a need to simplify the regulatory requirements for WUAs for emerging farmers, as proto-CMAs or regional DWS could become the regulator for this category. Moreover, WUAs managing government water schemes and transformed Irrigation Boards could be regulated more stringently by the custodian of water resources. The effectiveness of WUAs requires support of several government departments at all levels to be able to achieve the policy objectives, especially the WUAs established to support emerging black farmers. Whilst proto-CMAs are now in place, a structured process is still required for identifying functions that CMAs can delegate to WUAs with capacity. This governance role of WUAs at local level is of utmost importance to realise local level groundwater management and the implementation of groundwater protection measures, especially in groundwater dependent areas serving rural communities. In addition, expanding the role of water boards (with capacity to manage effectively) could be a considered option in order for these entities to perform certain functions on behalf of DWS and CMAs.

Research has shown groundwater governance at the local scale in in South Africa to be weak to non-existent (Pietersen et al., 2011; Knüppe, 2011). The WRC has commissioned a groundwater governance project K5-2238 with the purpose of identifying and prioritizing key interventions that can improve local groundwater governance in South Africa. An extensive report has been compiled detailing the results of that investigation (Seward and Xu, 2015). The following is to highlight and unpack the interventions, so as to provide insight into their practical implementation.

In order for local groundwater governance to improve, there needs to be a shift from the perception that groundwater governance can be 'fixed' by a once-off intervention, to the understanding that it is an ongoing and organic process. The proposed interventions require a change of attitude to local groundwater governance, or a change of mental and conceptual models of local groundwater governance, more than they require changes to laws, science and institutions.

One of the key conceptual underpinnings to good groundwater governance appears to be social capital. Regarding the current drive to abolish WUAs in South Africa, it is suggested that the key question is what is the best way to improve the net social capital in the overall governance system - local, CMA, national. It is suggested that a move to polycentric governance might increase social capital more effectively than abolishing WUAs.

The requirements and commitment needed to realise good groundwater governance are daunting. There is a very strong case for only attempting to improve local groundwater governance when there is a very strong need to do so, and essentially treating the remainder of the country's groundwater as a de facto private good.

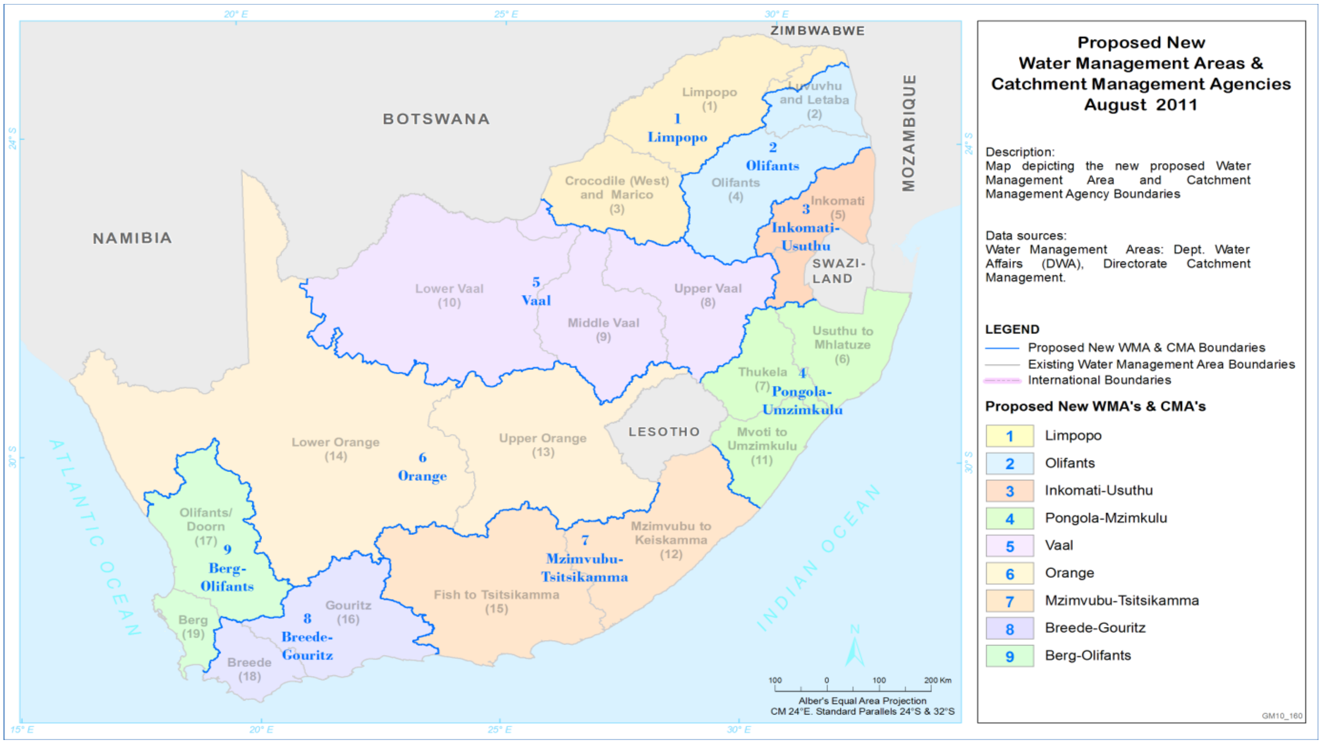

Figure 11: Map of 9 amended WMAs

An important institutional development was the handing over to local government the responsibility for providing and sustaining water services, following the local government elections of 2000. This followed the tremendous progress South Africa had made in providing safe drinking water to its citizens since 1994. In the process, thousands of groundwater schemes were transferred from DWAF and community management structures to new municipal administrations. Since then there have been many reports of scheme failure, of which the most publicized was the cholera outbreak in Delmas in 2005. The available evidence suggests that the reasons for failure have largely to do with the operational requirements of sound groundwater management, a challenge that has not yet been appropriately addressed.

5. Assessment of protection measures

5.1 State of groundwater resources

The protection state of groundwater in South Africa can best be viewed in relation to vulnerability of its aquifers (Figure 12).

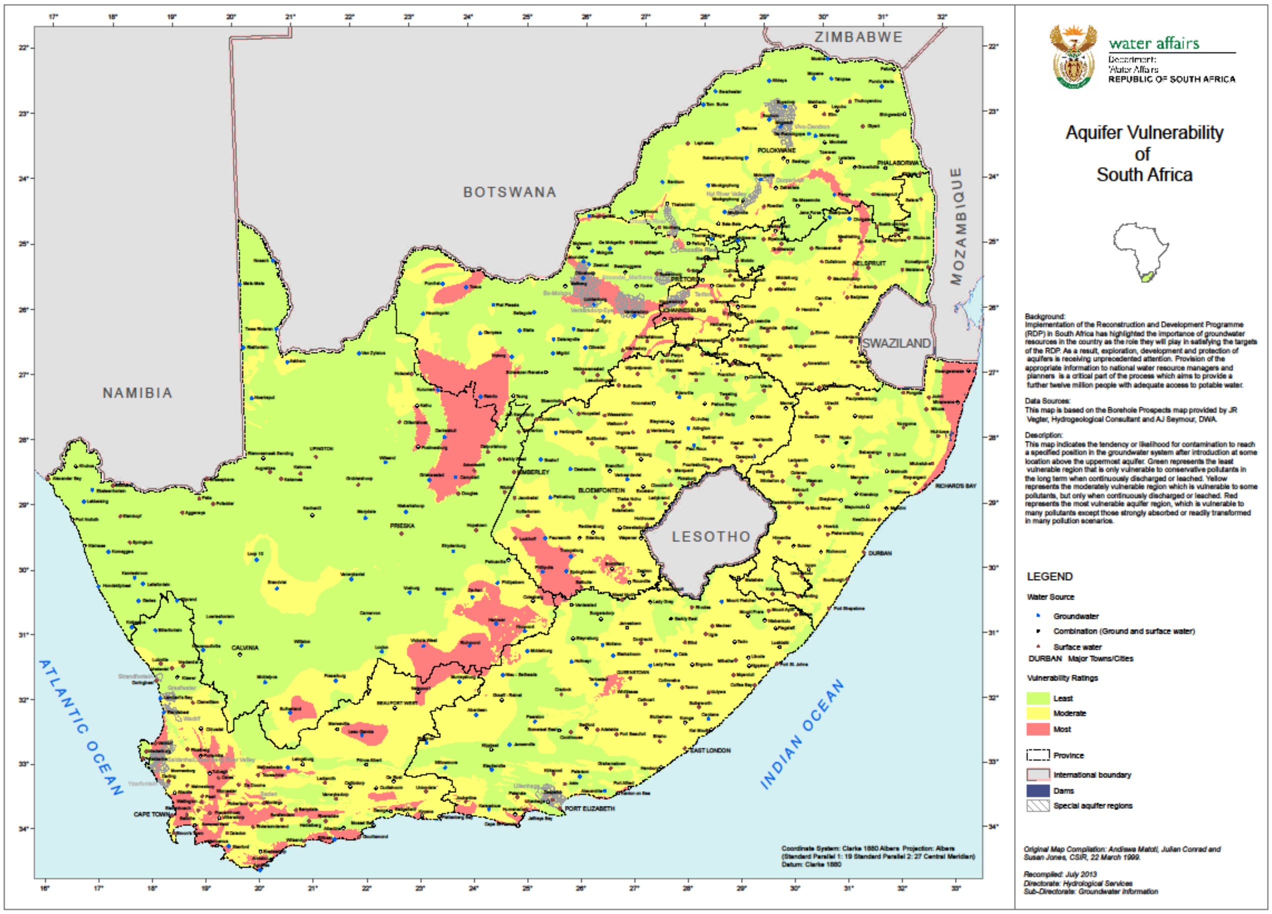

Figure 12: Aquifer vulnerability in South Africa

Highest vulnerability to pollution is found in the highly transmissive and often shallow dolomitic and coastal aquifers. Most of the Karoo falls into the moderate vulnerability category. Vulnerability to supply failure as a result of lack of monitoring and of poor management is particularly high in the generally low-yielding fractured aquifers.

Some observed trends are described in the 2013/14 State of Water Resources Report:

- In KwaZulu-Natal Province a gradual declining trend in groundwater levels is observed (as a result of extensive plantation of Eucalyptus mainly in the coastal regions);
- In Limpopo Province groundwater levels are well above historical levels as a result of good recharge in 2013; however, local deviations from the general trend are present in some places due to over-abstraction and/or a combination of factors;
- Groundwater in Karst aquifers in South Africa is under pressure. Groundwater levels in the North West, specifically the Mafikeng's Grootfontein wellfield, have dropped due to over-abstraction mainly for irrigation. The same applies to the Steenkoppies Dolomite Compartment where the very high groundwater use for irrigation has resulted in flow reduction discharging from the Maloney's Eye and the groundwater levels dropping. Also, in the Western Cape Province, the Vanrhynsdorp Karst Aquifer shows a decline in groundwater levels as a result of over-abstraction.

Groundwater quality that have been observed are:

- Groundwater quality, based on the salinity is reasonably stable with slight seasonal variations. Water quality impacts in areas affected by mining and industrial activities, are not visible in the national scale monitoring points.
- The Fish to Tsitsikamma WMA has consistently shown high salinity levels in some areas. In coastal aquifers this could be attributed to sea water intrusion and in other cases to agricultural activities;
- Increasing Nitrate levels are observed in parts of Limpopo, Northwest and Free State (along the Vaal River) Provinces and may be as a result of human activities, such as agriculture, industry and domestic effluents.

There is little connection between national monitoring and RDM processes. However, the Regions, which are strong in monitoring, actively address regulation and protection needs. This is evident from their quarterly monitoring reports.

Western Cape (February 2015):

- Over-abstraction in parts of the Sandveld and Klein Karoo only have local impact. Establishment of monitoring committees to collect data and source management solutions for these localities recommended.
- The aquifer in the general area of Vanrhynsdorp is over- exploited for agriculture. The users are supported by Geohydrology in the monitoring and provision of management advice. It is recommended that no further groundwater use licenses are issued in the stressed parts of this aquifer.
- The groundwater levels in the primary aquifers of the Berg Water management area near Langebaan are on a declining trend. This may be a result of climatic changes and /or increasing abstraction. Better management of this aquifer is needed to ensure that the aquifer is optimally used. The verification and validation of groundwater use in this area, and termination of any illegal groundwater use is recommended. Comprehensive Reserve determination, classification and development of a management plan for this aquifer is recommended to ensure that the aquifer is optimally used taking into account the societal and ecosystem needs.
- Expansion of monitoring networks into new areas where groundwater development is expanding (e.g Kalbaskraal and in the Berg WMA) and where Reserve studies indicate aquifers may be stressed (e.g. Gouritz WMA). More attention needs to be given to improving an understanding of groundwater –surface water interaction in monitoring network design. Expansion in the Karoo may be required depending on the Departmental needs associated with Shale Gas development.
- In general, the groundwater hydrochemical character is stable. Unexplained long-term Sodium Chloride decline is observed at the coastal monitoring sites at Gansbaai, Bredasdorp, Stilbaai and George. This trend is opposite to that observed on the west coast, and further work would be required to determine the cause (e.g. weather pattern / sea spray changes).

Limpopo (June 2012):
This region has a strong focus on drought management. Below is one of its information products addressed to regional drought management (Figure 13).

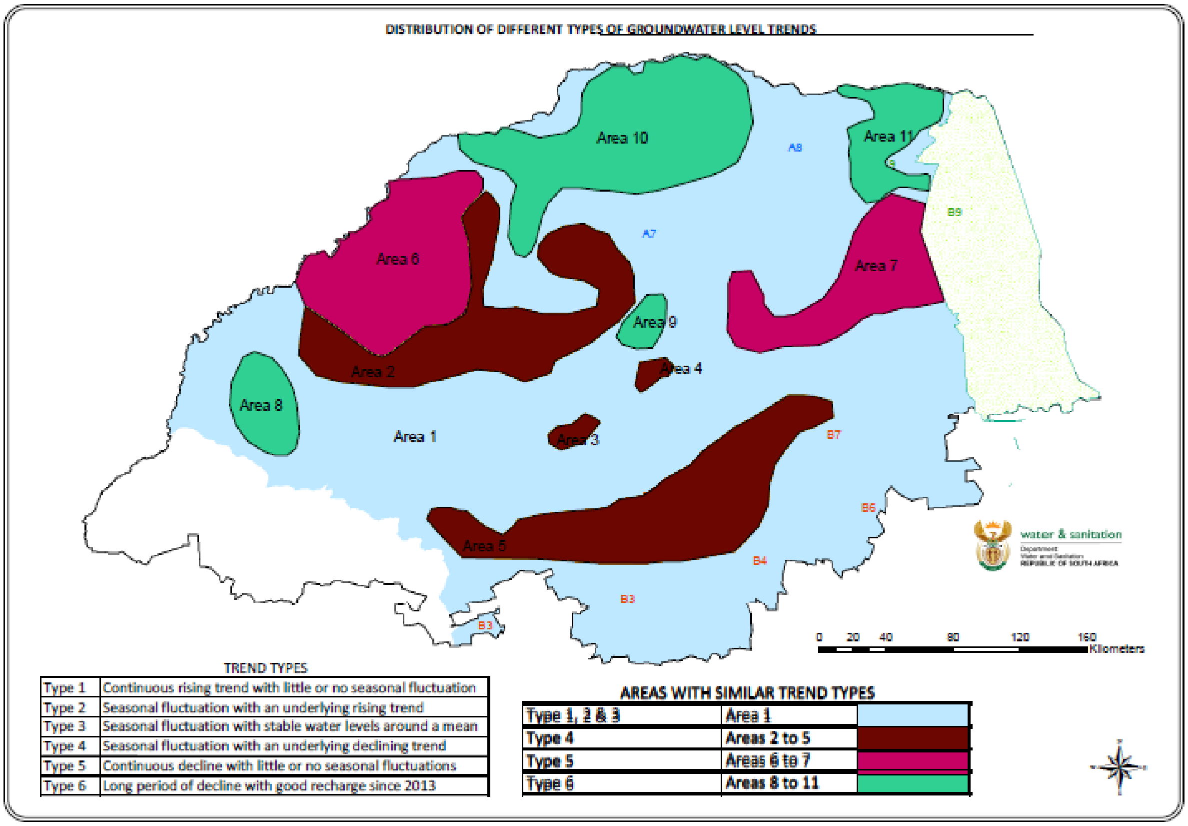

Figure 13: Areas with different groundwater level trends in Limpopo Region (DWS, 2012d)

The situation in Areas 6 and 7 will have to be monitored closely. A further dry spell of 3-4 years could bring a situation of serious concern.

Warning is also provided in areas of local overuse, pointing out the lack of local monitoring (see Figure 14).

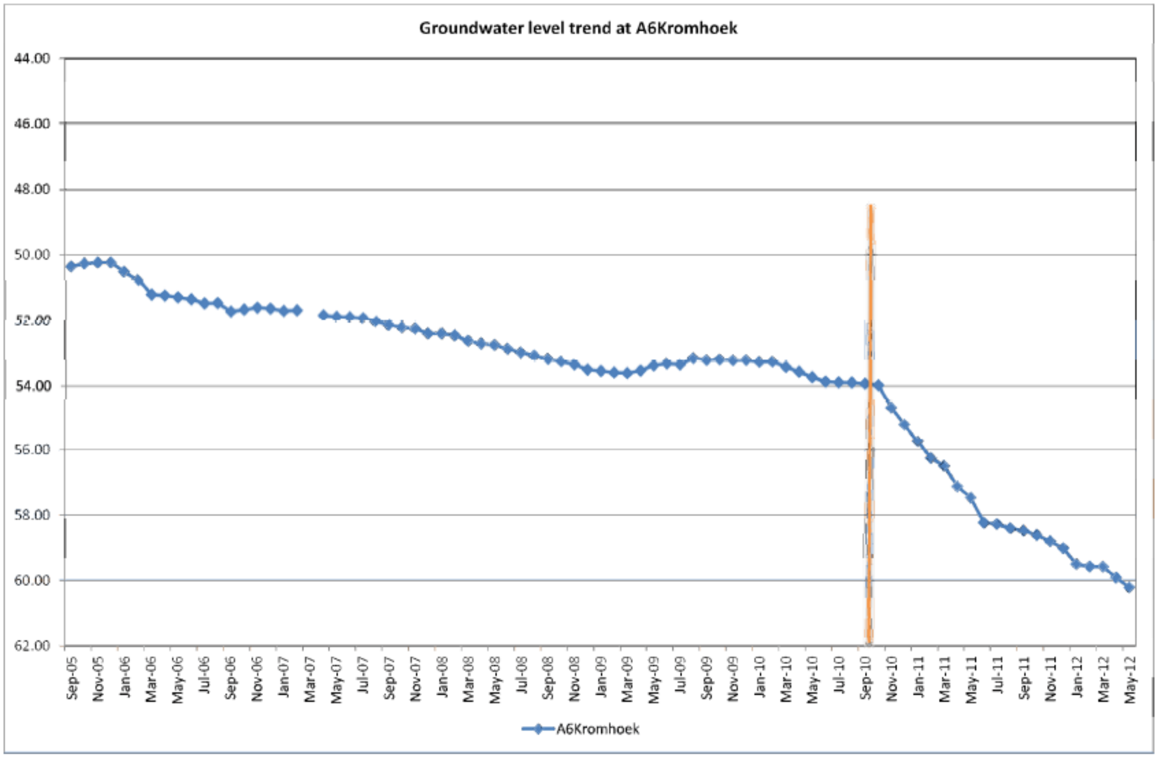

Figure 14: Potential failure of Kromhoek aquifer for small town supply (DWS, 2012d)

Since characteristics of natural flow systems, such as water levels, are dynamic and may fluctuate significantly over time, especially in the predominantly occurring hard-rock aquifer systems, follow up monitoring is critical to the Reserve determination process. Monitoring is required to verify and improve the baseline conditions and the assessment of groundwater resources. Such monitoring has not been undertaken at a regional scale in South Africa and will only be meaningful if it is based on an understanding of the flow system (Xu et al, 2000, Parsons and MacKay, 2000).

One of the least understood and least quantified aspects of the hydrological balance needed for a comprehensive Reserve determination is the groundwater-vegetation interaction. This may not be revealed until systems are stressed for some time. There thus has to be monitoring following groundwater development where such impacts can be expected.

5.2 Institutional processes

The introduction of the NWA (Act 36 of 1998) resulted in the legislative requirement to address the protection of the aquatic ecosystems formally through institutional and governance arrangements, structures and functions, in particularly the chief directorate of Water Ecosystems, in the Department of Water and Sanitation, within the Planning and Information branch of the Department. However, the importance of effective water management institutions at operational levels (i.e. provincial and local level) cannot be over-emphasised. In this instance, the DWS has fast-tracked the establishment of proto-CMAs in all nine provinces across the country, as a means to effectively implement the operational requirements of water management (including groundwater resource protection) as prescribed in the NWA. At the same time, the NWA identifies the Minister of Water and Sanitation as the public trustee of the nation's water resources on behalf of the national government, hence DWS is responsible for the regulatory and institutional oversight functions of operational activities that are being performed directly by proto-CMAs.

Moreover, DWS' Policy and Planning branch (including its Water Resource Infrastructure branch) still has a direct responsibility for planning, developing, operating and maintaining State-owned water resource management infrastructure. Each of the newly established proto-CMAs have jurisdiction over a defined Water Management Area (WMA), in order to enable water users and other key stakeholders to participate more meaningfully in the effective management of water resources, water service provision and all water related sanitation aspects. At present, proto-CMAs and DWS staff jointly share the responsibility for managing the water resources in the WMAs, with additional responsibilities being delegated or assigned to the proto-CMAs as it progressively builds its own capacity and capabilities to effectively perform water management function in accordance with its mandate.

However, during this exciting transition period in which all role-players are anxious to effectively fulfil their respective roles and responsibilities, to date, there is little evidence (if any) that suggest that groundwater protection measures are being effectively implemented in practice, despite the complementary nature of the following summary of functions to be performed by these proto-CMAs:

- Providing specialist inputs to water-use authorisation processes
- Managing hydrological and hydrogeological studies
- Responses to water-related disasters such as floods, droughts and spills
- Ensuring integration of water quantity and quality issues in planning processes
- Involvement in developing a catchment management strategy
- Coordination of RDM and other integrated initiatives
- Strategic water resource planning for the Upper Vaal WMA
- Involvement in water-related national and regional plans

Interpretation of relevant monitoring data.

5.3 Scientific methodology

5.3.1 Resource Directed Measures

Groundwater resource protection can take place pro-actively through the classification of an area or it can take place as a requirement of the processing of a water use licence application. The NWA requires that both source- and resource directed measures (resource classification, Reserve - ecological and basic human needs, and relevant Resource Quality Objectives) must be taken into consideration during the issuing of a water use licence. As shown in Fig 15, every one of above measures has its place in resource protection and should be used as such for groundwater protection.

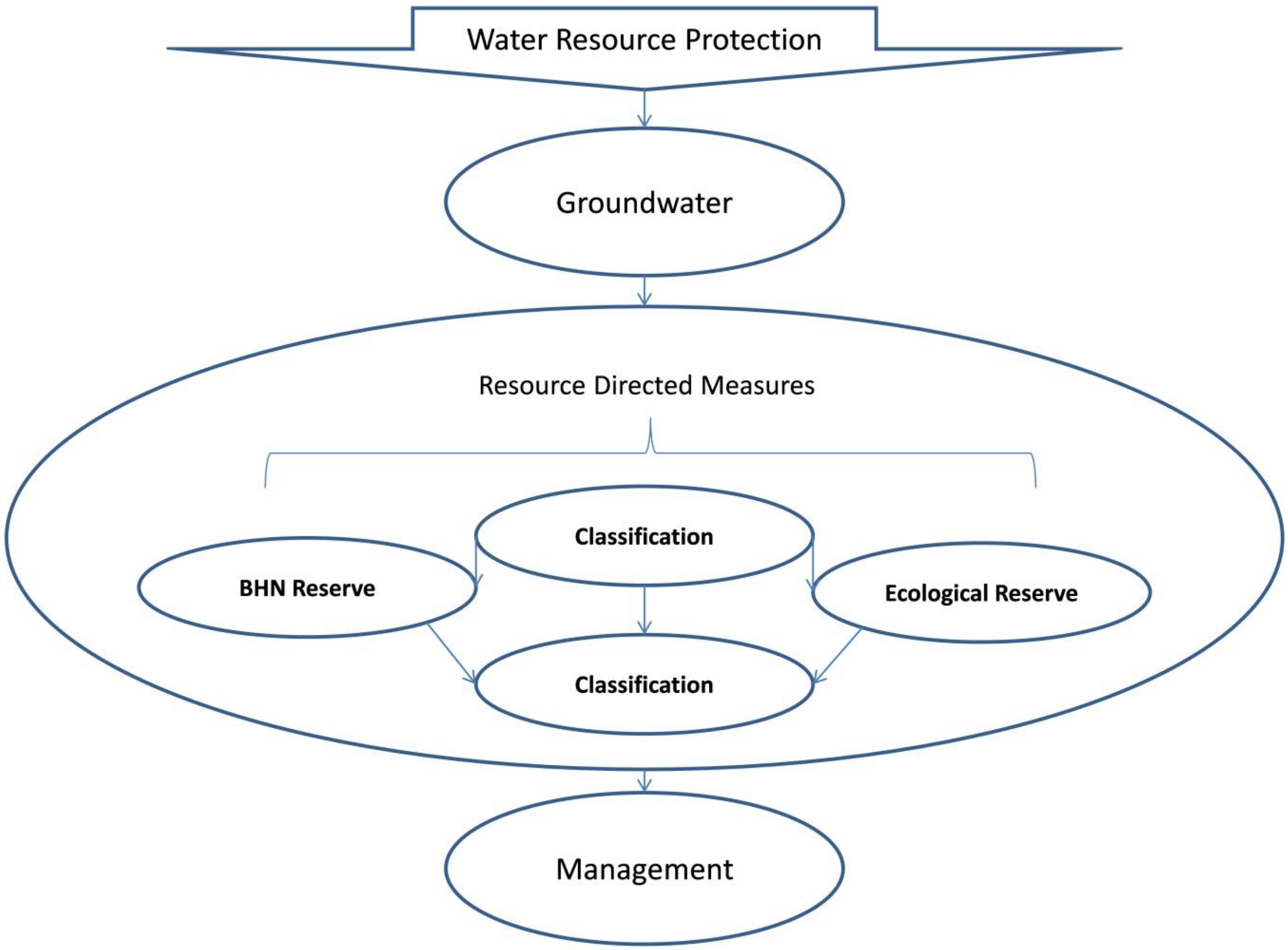

Figure 15: Diagram indicating groundwater protection measures

- Ecological Reserve: A groundwater contribution is determined, where there is a linked aquatic ecosystem that requires protection.
- Basic Human Needs Reserve: A Reserve is determined where people take water from or are being supplied from the groundwater resource. This process is not dependent on whether the groundwater contributes to an Ecological Reserve.
- Classification: Classification should be used in combination with the determination of both Reserve components, as well as for the protection of groundwater resources where neither of the Reserve components is relevant.
- Reserve Quality Objectives: These should be set for each of the three above measures to express the management requirements for the groundwater resource in more specific and executable terms.

5.3.2 Classification

DWA has developed a risk-based approach to classification which attempts to balance the need to protect with the importance of the resource. The different classes assigned to water resources represent different levels of acceptable risk of modification from natural conditions. The following classes are used, namely Protected, Good, Fair and Severely Modified.

The objective is to break down a catchment / aquifer into resource units and to classify each of these in terms of the desired management class. In essence, the classification process aims to define a resource in its natural state, assess its current state and levels of its development and use, and define the future desired state of the resource. For each class of water resource there should then be procedures to determine the Reserve, management procedures to satisfy the water quality requirements of water users (as far as possible) and regulations to protect the resource from the impacts of land-based and in-stream activities.

This requires a sound understanding of the overall character and use of aquifers in an area, including:
• Uses of groundwater and their importance;
• Links to other water resources;
• The reference conditions and present state of impact of the resource;
• The risks posed to groundwater resource quality;
• The degree of modification of the resource acceptable to stakeholders.

The original intention was to link the management classification to an aquifer type classification as shown in Table1. This would, in practice, be implemented for groundwater in order to prevent impacts on major aquifers and on those which provide a sole source of water for domestic supply. Impacts on minor aquifers will be controlled by impact assessments and impact consents where appropriate. In order to be pro-active in the protection of priority aquifers, the Department would establish maps indicating the boundaries of the different classes (DWAF, 2000).

At this stage the classification system for groundwater is still generically similar to that for surface water, even though there is a recognition that a different approach to groundwater protection is required (Dennis, 2013).

5.3.3 Reserve

The Reserve is defined as the quantity and quality of water (including groundwater) required to satisfy basic human needs and to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource. Where groundwater contributes to supports basic human needs or aquatic ecosystems, groundwater forms a component of the Reserve and hence has to be considered. However, groundwater also occurs in areas away from aquatic ecosystems and supports other components of the environment that may not form part of the Reserve. In such instances, groundwater protection is mainly affected through classification and resource quality objectives (RQOs).

A key surface water expression of the Reserve in the case of rivers is Instream Flow Requirements (IFR), also called Ecological Water Requirements. The present approach to determining the groundwater contribution to the Reserve, ie to the IFR, is a volumetric one.

The volume of groundwater that could be abstracted without impacting the ability of the groundwater to sustain or contribute to the surface water Reserve, is estimated by determining the recharge to a particular groundwater resource, assessing the contribution to baseflow or a surface water resource and calculating the basic needs to be met from groundwater. It is also necessary to control the amount of water abstracted to protect the structural integrity of the aquifer and to protect the terrestrial ecosystems dependent on the groundwater supplies. The Reserve includes the quality of water required and this must also be determined (Dennis, 2013).

These requirements impose constraints on the aquifer in the vicinity of the aquatic ecosystems. Such constraints should be translated into groundwater terms like spatially referenced water levels, gradient and flux towards a surface water body. Due to the fact that all aquifers are heterogeneous and that critical ecosystem linkages mostly occur in specific parts of the landscape; distributed models are required to determine the best strategy for the allocation and protection component. Modelling in support of the comprehensive determination must treat, often simultaneously, all components of the hydrological cycle, in particular the recharge and discharge.

Depending upon significance and sensitivity of the resource in question, the Reserve determination required may be a desktop, a rapid, an intermediate or comprehensive evaluation. Table 6 provides the guidance (Dennis et al, 2013).

Table 6: Guide for setting the LEVEL of GRDM Assessment

INDICATOR (ECOSYSTEMS AND BASIC HUMAN NEEDS)	AQUIFER Type		
	LOW YIELDING	**MODERATE YIELDING**	**HIGH YIELDING**
Sole Source Dependency	Intermediate	Comprehensive	Comprehensive
Highly impacted	Intermediate	Comprehensive	Comprehensive
High Risk of Contamination/ over-abstraction	Rapid	Intermediate	Comprehensive
Moderately Impacted	Rapid	Intermediate	Intermediate
Moderate risk of contamination/ over-abstraction	Rapid	Intermediate	Intermediate
No sole source dependancy	Rapid	Rapid	Intermediate
Low level of impact	Rapid	Rapid	Intermediate
Low risk of contamination/over-abstraction	Rapid	Rapid	Intermediate

5.3.4 Resource Quality Objectives

Through setting the Resource Quality Objectives (RQOs), any requirements or conditions that may be needed to ensure that the water resource is maintained in a desired state or condition can be achieved. While the focus of the Reserve is on the protection of aquatic ecosystems, the RQOs can also address additional considerations relating to the physical and chemical degradation of the aquifer itself. To set appropriate RQOs will require a good understanding of the critical system relationships, e.g. between abstraction rates and changes in water quality, between groundwater level and physical integrity of the aquifers and between hydraulic gradients in the aquifers and spring flow and river baseflow discharge.

In the drier two thirds of the country, where groundwater does not support aquatic ecosystems, the Basic Human Needs Reserve as a right must be safeguarded. While the norm of 25 l/p/d is minimal, to locally guarantee its quantity and quality may require strict proactive protection measures. These measures can be regarded as sets of RQOs and include delineation of borehole protection areas, if necessary (DWAF, 2008; Rajkumar and Xu, 2010). It should be remembered here the provision of basic human needs to communities who had never been served had been the highest national objective since 1994. By 2010, 95% of the basic needs backlog had been addressed, 50-90% from groundwater sources, depending on province. The protection of these water sources should therefore also be accorded the same priority as their original development.

5.3.5 Available geohydrological data and information

Implementation of Resource Directed Measures in South Africa is constrained by the available geohydrological data and information. The Table 7 provides a summary of the present situation.

Table 7: Available Information Systems / Groundwater Datasets in South Africa

Information System	Held by	Data Type
NGA	DWS	Borehole point data from (260 000 Sites)
HYDSTRA	DWS	Groundwater Level monitoring data
WMS	DWS	Groundwater quality monitoring data
WRMS	DWS	Groundwater use information
GRIP	DWS(only in some Regional offices	Borehole Infrastructure Information
ARCGIS GEODATA	DWS	Spatial data, largely based on a 1:500 000 Hydrogeological Map series covering the country and produced from the above data sources
Private Sector	Various Companies	Data sets from a large number of groundwater-related projects

Data and information has become much more readily available since the Phase 1 Groundwater Resource Assessment (GRA1) in 2003. However, a large amount of data held by the private sector and more recently also by local government, is not yet available for general use.

In an outline of a future improved Groundwater Resource Assessment (GRA3), the authors recommend a greater focus on representing and analyzing groundwater data as part of IWRM, aimed at raising the profile of groundwater in South Africa and ensuring wider and more sustainable groundwater use, as well as making recommendations for increasing the quantity and availability of groundwater data in South Africa. Increasing the submission of data by the private sector to public databases is a vital issue that can be carried out relatively easily and cheaply by requiring drilling contractors to routinely supply details of boreholes drilled to DWA in line with common practice in many other countries. Specific recommendations were also made to improve the monitoring of groundwater systems, both in terms of spatial coverage and for improved estimation of aquifer properties (Witthueser et al., 2009).

There is recognition that the key geohydrological parameters in any license application, groundwater recharge and groundwater contribution to baseflow (as well as to other groundwater-dependent ecosystems) have a very high uncertainty (Dennis et al, 2013). Abstraction information, which was non-existent in the past, has improved through the water use registration process, now needs to be systematically monitored and made available on the WARMS information system. Thus, the impacts of groundwater abstraction cannot be calculated with certainty before at least some development takes place – i.e. there is an element of "adaptive management" inherent in all groundwater schemes. The management monitoring requirements stipulated in Resource Quality Objectives cannot be seen apart from the Resource Directed Measures and Reserve Determination.

5.3.6 Limitations of scientific methodology

The following general shortcomings could be gleaned from available GRDM reports.

- Before catchment-wide Reserve determinations were initiated in 2012, Groundwater Reserves have been mostly determined as part of a groundwater use license applications and not as part of an integrated water resource Reserve determination;
- The Reserve, Classification and Resource Quality Objectives are defined with a surface water environment focus and this has determined the practical outcome of the RDM process to date. Groundwater resources are seen as a contributor to surface water systems and all the protection focus is on these and not on the protection of the groundwater resource itself and is various direct uses.
- The Basic Human Needs Reserve, which is to protect the strategic groundwater sources for communities has to date only been expressed as a number (relatively small) and has had no practical outcome in Resource Quality Objectives.
- The scientific approach clearly lacks much greater hydrogeological understanding of the aquifer than the present volumetric approach assuming a uniform groundwater bucket over the whole catchment (unit of study). This is not only a failing of the methodology but also of the much-neglected hydrogeological information. For at least 10 years no more systematic groundwater resource exploration has been undertaken and the investment into groundwater monitoring is completely inadequate.
- The Groundwater Reserves are reported on a quaternary scale insofar as licensing is concerned. The relevant scale differences between surface water bodies and groundwater need to be better considered during the Reserve determination process, and even more so for the classification and the development of RQOs, eg.;
    - Aquifer boundaries mostly do not coincide with surface water catchment boundaries, especially for fractured aquifers, dolomite aquifers and confined aquifers;
    - Groundwater discharge occurs at distinct areas, such as river reaches or springs, and is not homogenously distributed across the catchment or aquifer;

- Groundwater variability is partly lost when classification is undertaken in surface water units (quaternary catchments);
- Groundwater flow is significantly slower than surface water flow, which impacts on the seasonal pattern of groundwater discharge as well as water availability for users;

- There are still difficulties with quantifying groundwater contributions to wetlands, springs and GDEs, and thus the ecological reserve is still mainly based on the groundwater contribution to baseflow.
- Recharge and contribution to baseflow estimates come from different datasets – results do not match; so much so that often the baseflow contribution requirement is higher than the recharge and no more groundwater is available for allocation (in 20 out of 90 quaternaries in the case of Olifants/Doorn).
- National water level and water quality data is short and unevenly distributed and provide challenges for assessment in many areas, for example Vaal WMA, Olifants/Doorn and Olifants WMA.

As shown in Figure 5, the volumetric concepts of the methodology have to be implemented through waterlevel monitoring, which is rendered inefficient in practice. As groundwater is always fluctuating dynamically, there is need to consider the frequency and amplitude of the water level fluctuation in a meaningful monitoring design to reflect various status of groundwater flow regime. Otherwise the various terms of water levels proposed in Fig 5 would likely be misused including those such as *base of aquifer, management water level restriction*, *base zone of natural dynamic water level fluctuation*, *current water level* and *average water level*. It is strongly advised to have a monitoring guideline in place to collect, interpret and apply such water level parameters correctly (IGRAC, 2006). This situation is exacerbated by the fact that the National Groundwater Data Base still has a poor spatial and temporal coverage in its groundwater level monitoring programmes. The volumetric method heavily relies on a problematic determination of the status of dynamic water levels, which renders the water balance an unrealistic approach. To get around this problem, it is proposed that the water balance method be guided by a space-based approach as proposed by Seward et al (2015).

Seward et al (2015) investigated whether a simple, spatially-based approach to groundwater sustainability using radius of influence should be used to replace the pervasive, yet deprecated, 'natural recharge water balance' volumetric method. Using South Africa as a case study, the radius of influence methodology was shown to be scientifically practical, to provide plausible results, and to be permissible under the country's water laws. The approach also provides better indicators for institutions involved in groundwater management, and remains conceptually correct at all scales. However, further research is recommended on more robust alternatives to the Cooper-Jacob equation for determining radius of influence.

One of key issues in dealing with groundwater / surface-water interaction is the recharge and its contribution to baseflow. Used methods and datasets must be reconciled with each other to obtain realistic and consistent recommendations (Xu and Beekman, 2003; Levy and Xu, 2012).

5.4 Implementation of protection measures

In implementing the protection measures of the NWA realistic time frames should be specified. While it is well understood that the development of a water resource takes more than 50 years, it does not mean the realization of implementing groundwater protection measures should take as long. Water resource practitioners should allow themselves time to learn from the initial implementation lessons and improve the implementation of the provisions of protecting water resources. There is a significant difference between the determination of the Reserve and giving effect to the requirements of the Reserve through a process of water use licensing and other implementation initiatives. Rigorous conditions for an integrated approach are provided by the Integrated Water Use Licence Application (IWULA). Further integration opportunities are provided through DWS's recently established Integrated Water Quality Management Strategy. To even suggest that the specific teething problems that are experienced with the implementation of the Reserve automatically imply failure of the entire concept is quite misleading. The implementation of the protection provisions, and specifically the Reserve, cannot be viewed in isolation from the broader framework of implementation of the NWA. Correcting misunderstandings and preventing negative sentiments in terms of the Reserve must be addressed. The Reserve includes both the ecological and basic human needs components. As such the Reserve should ensure the sustainable utilisation of the goods and services (in its broadest context) that are provided by aquatic ecosystems. This includes protecting terrestrial and aquatic ecosystems at such a level as to provide for the sustainable availability of products directly derived from these ecosystems and used by rural communities for daily subsistence and economic survival.

5.4.1 Compliance monitoring

A proper process and actual implementation of compliance monitoring is not available yet in the case of groundwater.

5.4.2 Protection measures

Due to South Africa's widespread and highly localised groundwater occurrence and use, it is not possible to protect all groundwater resources to the same degree. For this reason, a differentiated protection approach has been to taken, based on the vulnerability and regional/local importance of aquifers. Aquifers are assigned management classes based on the potential yield, as well as the level of dependence that communities have on that water source. Aquifers that are a sole source of water for communities enjoy the highest level of protection. A differentiated approach is also to be taken to control the disposal of water and wastewater, where land needs to be zoned according to its suitability for waste disposal. No waste disposal activities must be allowed near the recharge zones of major aquifers or sole-source aquifers. Monitoring of the performance of waste disposal facilities and their associated pollution prevention measures is therefore deemed mandatory. Despite being departmental policy (DWAF, 2000), this type of protection zoning has not yet been put into practice. A fresh opportunity is becoming available through the delineation of strategic water source areas country-wide under a Water Research Commission project (Seyler et al, 2016). Managing and protecting such water source areas is a cost-effective means of keeping contaminants out of drinking water and delivering a continued supply of good quality water to downstream users. Further strategic level guidance for freshwater ecosystem protection can be obtained from the National Freshwater Ecosystem Priority Areas (NFEPA) map products. They provide a single, nationally consistent information source for incorporating freshwater ecosystem and biodiversity goals into planning and decision-making processes. (2011).

5.4.3 Participation

The whole RDM process is a participative process that must take into account inputs by stakeholders. The final setting of a class should therefore represent the needs of stakeholders in a catchment. Various preliminary Reserve determination studies have been completed with some form of stakeholder engagements as part of these studies. However, stakeholders have not been informed of the potential socio-economic consequences of their considerations and choices for selecting preliminary Reserve scenarios, and this process are now being addressed as part of the ongoing formal classification process.

6. Case studies

6.1 Objective

Two case studies – in one Western Cape and one in Limpopo are covered in South Africa. The purpose of the case studies is to make a more specific assessment of groundwater protection processes and outcomes, in terms of their effectiveness, practicality and cost-effectiveness under different aquifer physical and socio-economic conditions. It should also allow consideration of potential alternative measures.

6.2 Olifants-Doorn groundwater situation

The area was chosen because it had recently completed a resource classification and has set Resource Quality Objectives for the catchment. A visit to the DWS Western Cape Regional Office greatly helped to understand roles, responsibilities and progress in area of regional / local management of groundwater resources. The study visit was coordinated by Mr. Mashudu Murovhi, heading the Berg-Olifants proto-CMA. The insights provided by the Regional Office team informed the assessment below (Murovhi, 2015).

The Olifants-Doring catchments and Water Management Area (WMA) is situated in the South-Western Cape. The Olifants River is the main river within the WMA. It flows to the north-west, through a deep, narrow valley that widens and flattens into a wide floodplain below Clanwilliam. The Doring and Sout rivers are major tributaries. The Sandveld comprises the seasonal Verlorenvlei, Langvlei and Jakkals rivers which flow westwards of the Olifants River towards the Atlantic Ocean (see Figure 16).

The WMA has a total catchment area of some 54 000 km² and an estimated mean annual runoff of 1065 million m3/a. The WMA lies within the winter rainfall region of South Africa and mean annual precipitation varies from 900 mm/a in the south-west to less than 100 mm/a in the north-west.

Land-use in the area consists largely of livestock farming (sheep and goats), with small areas being used for dryland farming. Citrus, grapes, deciduous fruit and potato farming is intensive in the south-west. Urban and rural areas are small, with the main towns being Citrusdal, Clanwilliam, Vredendal, Vanrhynsdorp, Niewoudtville, Calvinia and Lamberts Bay.

Water abstractions from surface and groundwater throughout the Water Management Area (WMA) have modified flow, particularly reducing low flows in summer. The perennial Olifants River which is heavily impacted due to the catchment's suitability to agriculture and is therefore more developed and more populated, while the Doring River valley is sparsely populated and relatively unimpacted. The Sandveld rivers and the lower Olifants River are also heavily impacted.

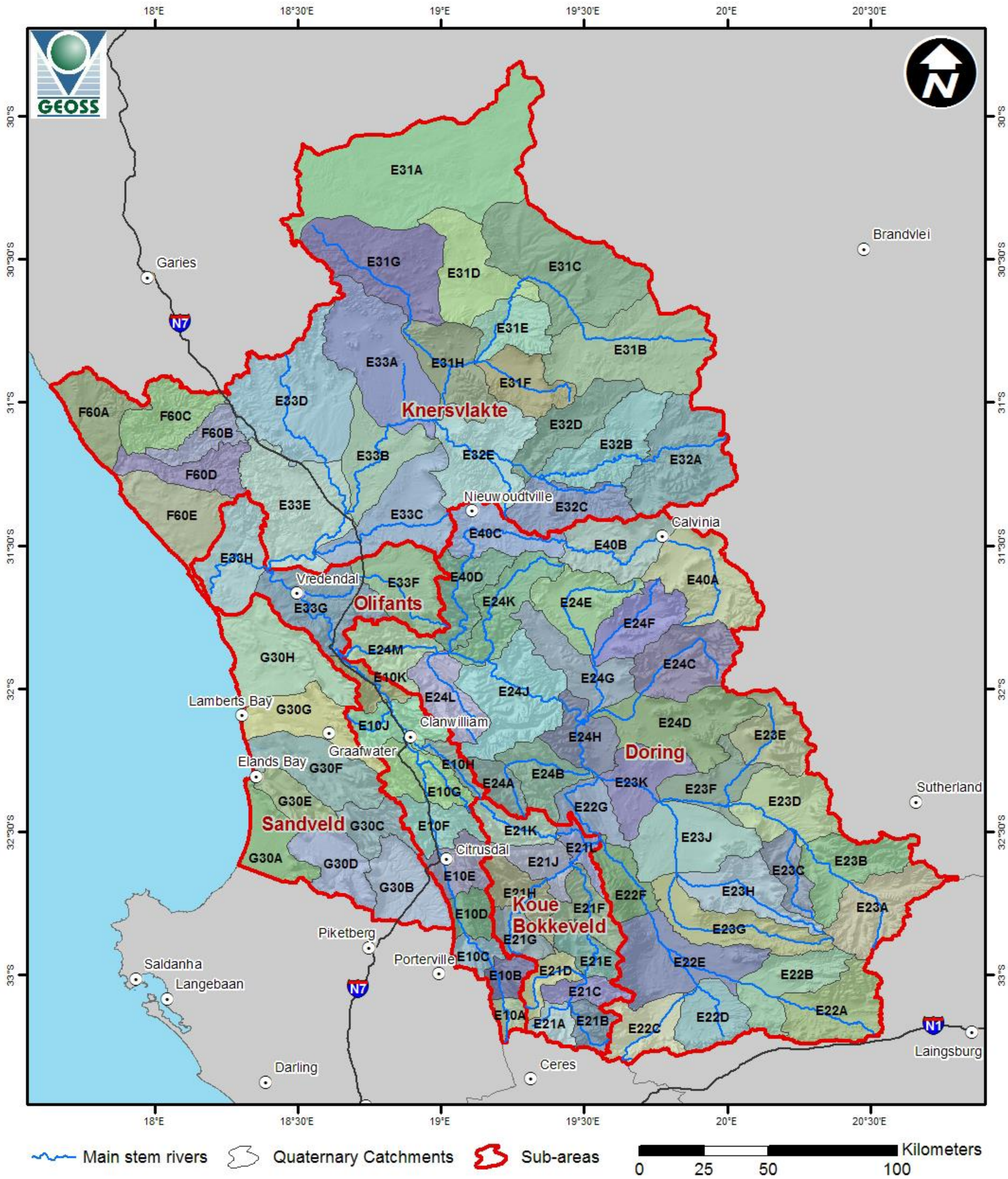

Figure 16: Major catchment and quaternary catchments of the Olifants-Doorn WMA

The four aquifer types within the Olifants-Doorn WMA are:

- Fractured (78 %)
- Intergranular and fractured (20 %)
- Intergranular (1 %)
- Karst (1 %).

Across the Olifants-Doorn WMA groundwater recharge ranges from 0 - 245 mm/a. The highest groundwater recharge occurs in the Upper Olifants sub-area, especially in the Winterhoek mountain area. Significant recharge also occurs in the Koue Bokkeveld, eastern Doring, and eastern Sandveld sub-areas. For the remaining areas groundwater recharge is quite limited.

The highest baseflow contribution areas are the same as areas of highest groundwater recharge. It must be noted, however, that in the other areas groundwater still plays a significant role in maintaining river baseflow, although on a much smaller scale, i.e. smaller volumes and more limited in extent.

Groundwater quality varies greatly across the WMA and this is a function of many factors but mainly geology and recharge. The groundwater quality is good in the Koue Bokkeveld, Olifants, eastern Sandveld and western Doring sub-areas. Groundwater quality (as indicated by Electrical Conductivity (EC)) is very poor in the western part of the Knersvlakte sub-area.

Groundwater importance varies across the WMA, the use being by the private, commercial and municipal sectors. All three river systems in the Sandveld consist largely of a series of wetlands, connected by poorly defined river channels. These systems are largely groundwater driven or groundwater dependent ecosystems. Multiple freshwater springs or ‘eyes’, occur along the length of all three systems. There are also many river riparian zones throughout the WMA where the probability of Groundwater Dependent Ecosystems occurring is high.

6.2.1 Institutional development

Western Cape Regional Office of DWS

The Western Cape Regional Office is the implementation arm of the Department of Water and Sanitation in the Western Cape Province, responsible for implementing Water Services Act 108 of 1997 and National Water Act 36 of 1998.

All three of its core functions have a bearing on sustainable groundwater resource development and management:

- Contribution to a responsive, effective, efficient and accountable Local Government System (Municipalities) by supporting the Water Sector to improve access to Water and Sanitation Services.
- Building capacity in Municipalities through its water infrastructure development programmes in cooperation with Western Cape Provincial Government.
- Regulating water use and water management institutions, with primary responsibility for Compliance Monitoring and Enforcement and ensuring equitable allocation of water.

Catchment Management Agencies

The National Water Act, 1998 has mandated the Minister of Water and Environmental Affairs to establish catchment management agencies (CMAs) for the management of water resources at the catchment level. In 2012 the Minister finally gave the go-ahead for the establishment of 9 CMAs for the country. A reduction from the originally foreseen 19 CMAs to 9 is due to a number of reasons including the technical capacity required to staff CMAs, and the challenges such a large number of institutions poses to the Department of Water and Sanitation (DWS) in regulating their performance. The CMAs will play a critical role in managing the country's scarce water resources, including facilitating stakeholder input into the management of water resources. This is particularly important for the management highly localized and common pool groundwater resources.

The CMA for the Olifants-Doring WMA is to be established in 2016. While its delegated functions have been published by the Minister, actual water resource management is only expected to start in about two years to allow administrative processes to roll out. Its initial role will be an investigative, monitoring and advisory role and the promotion of community participation. A key responsibility during this period will be the development of a catchment management strategy together with stakeholders. Following legitimization and the development of capacity, a final phase with the assignment of responsible authority functions will follow. At this stage, national government will continue to undertake RDM and water use licensing. The Regional Office will audit what the CMA monitors.

Catchment forums

The process for the establishment of the Olifants-Doorn CMA was already initiated in 2000. At the time Catchment Forums were established for 11 sub-catchments. Only two of these are at this stage still functional. Despite lack of formal status in the absence of a CMA, these forums are playing a significant role in stakeholder participation and holding national government accountable.

Water User Associations

Local management is critical for localized, common property groundwater resources. Local level governance involves the organizations and institutions that control actual outcomes on the ground and respond (in varying degrees) to the rules and incentives from strategic level governance (Braune and Adams, 2013). Water User Associations (WUAs), which are established in terms of the National Water Act, 1998, offer this opportunity. Priority as part of the current water sector transformation in South Africa is at this stage a strong political responsibility – enhancing empowerment, democracy, equity and representativity at local level. As part of this process, DWS is converting existing Irrigation Boards into becoming Water User Associations. There are already nine water user associations established in the Olifants-Doorn WMA, but their functionality is not clear at this stage. None have taken on a groundwater management/monitoring responsibility so far or have been created specifically for that purpose.

Monitoring committees

Monitoring committees can be required for bigger abstractions as part of abstraction licence conditions. This gives different stakeholders – users and those who are impacted/potentially impacted – a chance to participate in management through the monitoring information provided and to propose adjustments, within limits, to the scheme operation.

Three monitoring committees have existed in the Olifants-Doorn WMA, of which none are functioning anymore. A general problem is that municipalities do not comply with their monitoring requirements and thus set a poor example for private sector users.

Another reason for the failure is that there is little government support to create capacity for groundwater monitoring. Regional Office geohydrologists have demonstrated that it is possible to achieve local monitoring (van Rhynsdorp WUA) with a major support effort, but this stopped completely again when no financial support for instrumentation and payment of dedicated monitoring person could be provided from CMA funds) and support could not be maintained.

6.2.2 Classification and Resource Quality Objectives

A Classification has been undertaken (DWA, 2012) and Resource Quality Objectives (RQOs) have been determined (DWA, 2014) for this WMA. Determining the RQOs is seen as a unique study, because catchment-wide Resource Quality Objectives have been established for the first time. The RQO determination process was done for all significant water resources, including wetlands, lakes, rivers, and groundwater.

The groundwater analysis was also being completed on a Quaternary Catchment basis, defined according to topographical variation and features, as this facilitates and simplifies the integration of the classification process with the other disciplines.

It is acknowledged that the groundwater flow is controlled to a large extent by the geological and hydrogeological conditions and not by the surface topography, in particular as for 78% of the WMA the groundwater occurs within a fractured rock aquifer setting. A lot of the spatial variability inherent in this type of groundwater setting may thus be missed in the analysis units adopted. This was partly overcome by the RQO process which broke each unit of analysis up into its main aquifer types and provided separate RQOs for each.

Classification provided the following Present Status for the 90 RUs making up the Olifants-Doring (DWA, 2012a), shown in Table 8.

Table 8: Water resources present status in the Olifants-Doring

Category	Present Status Category	Number of units
A	Unmodified natural	50
B	Largely natural	12
C	Moderately modified	12
D	Largely modified	6
E	Seriously modified	-
F	Critically modified	10

RQOs were determined (DWA, 2014) at different levels of detail depending on importance to and threats posed to users as well as available information. The information criterium was seen as necessary, because even though Reserve data may be available for a site, if it cannot be monitored at that site then implementation of the Reserve cannot be assessed.

The outcome was a set of pragmatic and implementable RQOs for priority RUs.

Of the total of 90 RUs, 16 were classified ‘Largely modified’ / ‘Critically modified’ and of these, 8 RUs were provided with detailed RQOs. It is important to note that aquifer-specific RQOs were specified not for groundwater resource protection per se, but to ensure that the minimum requirements for groundwater contribution to the surface water bodies are met. These RQOs are tabled in Appendix 1.

6.2.3 Reserves

Ecological Reserve

A first rapid Reserve determination for groundwater in the Olifants-Doring Catchment was undertaken by Parsons and Associates (2000). More comprehensive Groundwater Reserve determinations were undertaken by SRK (2006). The level of determinations undertaken were based on the importance, sensitivity and the demand for groundwater, where higher confidence Reserves were undertaken for catchments E21A – K; E22C, D; E24M; E33E – H and E40A and B; and low confidence determinations were done for most of the remaining catchments. The G30 catchments in the Sandveld were later addressed at the high confidence level in a separate study (Conrad, 2006). Parsons and Associates also determined the Reserve for the E10 catchments in a project funded by the Water Research Commission (Flanagan et al., 2006).

Based on the groundwater priority units later identified in the Resource Quality Study, it is these later undertaken Reserves in the G30 and E10 catchments that warranted the higher confidence determinations.

The Reserve methodology, discussed under 5.3, still has considerable shortcomings as discussed in Section 5.3.6. In the Olifants-Doring Catchment Reserve estimation, groundwater discharge (groundwater contribution to baseflow) was estimated higher than groundwater recharge in 20 of the 90 units. This meant that no further groundwater could be allocated for use in these units. In the recent case of a planned major wellfield in a very complex hydrological environment in another catchment in the Region, an overall catchment Reserve determination with a very high uncertainty also indicated that no more water could be allocated. A practical decision here would be to grant a licence to abstract in stages, each abstraction increase dependent on systematic monitoring, reassessment and authorization.

Basic Human Needs Reserve

While the norm of 25 l/p/d for the BHN Reserve is minimal, to locally guarantee its quantity and quality may require strict proactive protection measures. No sets of RQOs, including delineation of borehole protection areas, were put forward in the 2014 catchment RQOs, despite the considerable number of small towns relying on groundwater sources.

6.2.4 Licensing and compliance

Licensing

Not too many new abstraction licenses have been granted by the Regional Office. Most of the practical licence conditions are provided by the Regional Geohydrologist and are not yet part of the Reserve determination. A recent example of such conditions is summarized in Table 9.

Table 9: Groundwater abstraction licence conditions - Example

Abstraction	1.6 Mm^3/a groundwater
Use	Domestic, urban, commercial or industrial

Source	Wellfield with 3 boreholes
Capacity	Combined maximum capacity of 5200 m^3/day or 60l/s
Changes	Quantity may not be exceeded without prior authorization by the Minister Any new production holes to be approved by the Regional Office
Measurement	Installation of appropriate volume measuring devices; daily measurement, record of measurement; 6 monthly submission to Regional Office
Monitoring	Implementation of the Monitoring Programme as approved by the Monitoring Committee Monitoring to be automated
Water User Association	If a WUA is established in the area to manage the resource, membership of the Licensee is compulsory
Record-keeping	Keeping of records as specified by the Monitoring Committee and making these available to the Regional Office
Numerical model	Wellfield numerical model to simulate different scenarios as basis for operation of wellfield
Thresholds	Automated shut down of pumping if water level in a production borehole drops down to a threshold level specified in the Monitoring Programme; Abstraction rate reduction considered when observing deteriorating water quality in production boreholes – termination if quality reaches Basic Human Needs Reserve (150 mS/m)
Impact	Implementation of mitigation/compensation measures if existing lawful water user is unacceptably impacted by this development
Review	Valid for 20 years, review after 2 years and thereafter every 5 years

Compulsory licensing

Compulsory licensing in terms of the National Water Act, 1998 of all water users in a specified area is important to control over-use of groundwater. There are a number of different objectives for the use of this measure:

- Achieve a fair allocation of water from a resource that is under stress or to achieve equity in allocation;
- Promote beneficial use of water in the public interest;
- Facilitate efficient management of the water resource;
- Protect water resource quality

Because groundwater was only declared a public water source with the coming of the 1998 Act, it is still widely under-registered or non-registered. The can only be rectified where a verification of registered use takes place, followed by a compulsory licensing of a new allocation schedule for the area.

This measure has however not yet been implemented to alleviate groundwater stress, eg in the E10 and G30 (Sandveld) catchments, despite the threat to ecosystems of national importance and small towns entirely relying on these groundwater sources. The Jan Dissel River catchment, where the first compulsory licensing took place in 2012, has no groundwater priority. The proposed allocation schedule was (DWS, 2012b):

Surface water (34 users):	3.9 Mm^3/a
Groundwater (6 users):	3.0 Mm^3/a
Reserve:	35.2 Mm^3/a

In general, it is important to note that the registration of water use by the national Department of Water and Sanitation did not yet achieve adequate groundwater use information on the national water use data base, WARMS. To achieve groundwater information on which long term management of the resource can be based, will be a major undertaking. For example, it took a Regional Office staff a year to unofficially verify the use from widely distributed boreholes in the van Rhynsdorp area (E33F).

Impact licensing

At this stage the most important protection tool still appears to be the control of impacts through licences (mining, radioactivity, waste disposal etc). This is a major responsibility of the regional geohydrologists. Because of the variety of issues requiring a wide range of scientific knowledge, regional geohydrologists are often in need of professional support.

Compliance

The achieving of compliance with licence conditions has become a major new priority for the National Department and Regional Offices. Monitoring information must be checked and guidance given, licences must be regularly reviewed based on compliance information, and where necessary, compliance must be enforced. For the enforcement purpose a special 'Blue Scorpions' group has been created in the Regional Office.

Despite serious over-use, no groundwater compliance has been enforced yet. The main reason is that the legal situation of groundwater authorizations is often not 100% clear, particularly in the groundwater control areas that had been established in terms of the previous act (Water Act, 1956), eg in the West Coast aquifers like the Sandveld (G30).

Poor compliance in terms of sustainable groundwater use is at this stage still by municipalities. This is a serious concern, because domestic water supply to communities represents the most strategically important use of groundwater in South Africa.

The best groundwater use compliance, according to officials of the Regional Office, is achieved by the Overberg Municipality groundwater scheme for Hermanus. An adaptive groundwater management process has been followed here, together with local stakeholders, based on ongoing monitoring and evaluation of the groundwater sources, with the ongoing involvement of consultant groundwater professional expertise since the development of the scheme more than 10 years ago.

6.2.5 RDM Methodology

The main focus of RDM, as illustrated in the case study, remains to ensure that the minimum requirements for groundwater contribution to the surface water bodies are met and not the sustaining of direct uses from the groundwater resource itself.

Most of the Groundwater Reserve determinations, especially rapid/intermediate ones, have just remained numbers, without any practical consequences.

The Integrated Water Use License Application (IWULA) process offers opportunities for an integrated Reserve determination. However, most of the Groundwater Reserve determinations are undertaken separately, as part of license applications and not as part of the ecological Reserve determination; There is not yet an integrated RDM methodology which, at the same time, makes adequate provision for unique aspects of groundwater resources. It should be noted that in an outline of a future improved Groundwater Resource Assessment (GRA3), the authors recommend a greater focus on representing and analyzing groundwater data as part of IWRM, aimed at raising the profile of groundwater in South Africa and ensuring wider and more sustainable groundwater use.

The present approach to determining the groundwater contribution to the Reserve is a volumetric one. Groundwater recharge and groundwater contribution to baseflow estimates, the determinants of the Groundwater Reserve, are derived through unrelated methodologies, both with a high degree of uncertainty. This results in the doubtful outcomes discussed under ecological Reserve.

Many geohydrologists are critical of the Groundwater Reserve methodology, because it assumes that an average volumetric restriction over the quaternary catchment can achieve, even in very non-homogeneous aquifer conditions, the impacts on groundwater levels and flow, there where they are required (next to the river, wetland, spring or borehole). In practice this can only be achieved through appropriate restrictions on groundwater development or restrictions in where (area) groundwater development can take place (distance from river, wetland or other boreholes) as well as the setting of minimum water level gradients. It is interesting to note that these types of practical measures have been recommended in the RQOs used in the Olifants-Doring Catchment.

A major shortcoming is that RDM is not yet a participative process. Weaknesses in the science remain unchallenged by users and those that could be impacted by the groundwater use and mis-use.

6.3 Olifants WMA – Letaba Catchment

6.3.1 Resource classification focus

This case study is based on an evaluation of the resource classification that had been undertaken in the Letaba Catchment. Various reports and supporting information were kindly provided by the Regional Geohydrologist, Mr. W. du Toit. A more detailed evaluation of groundwater resource protection in the Water Management Area was not possible, because of lack of time.

The description is taken for the entire Luvuvhu and Letaba Water Management Area for which a recent reconciliation study had been undertaken by the Department of Water and Sanitation (DWS, 2015). The main rivers in the WMA are the Luvuvhu, Shingwedzi and Letaba rivers, which all flow in an easterly direction. The two main tributaries of the Letaba River, the Klein and Groot Letaba, have their confluence on the western boundary of the Kruger National Park, whilst the Letaba River flows into the

Olifants River just upstream of the border with Mozambique. Rainfall is strongly seasonal and occurs mainly during the summer months. The mean annual precipitation varies from less than 450mm on the low lying plains (northern and eastern part of the WMA) to more than 2 300 mm at Entambeni in the Soutpansberg in the mountainous areas (south western and north western parts of the WMA).

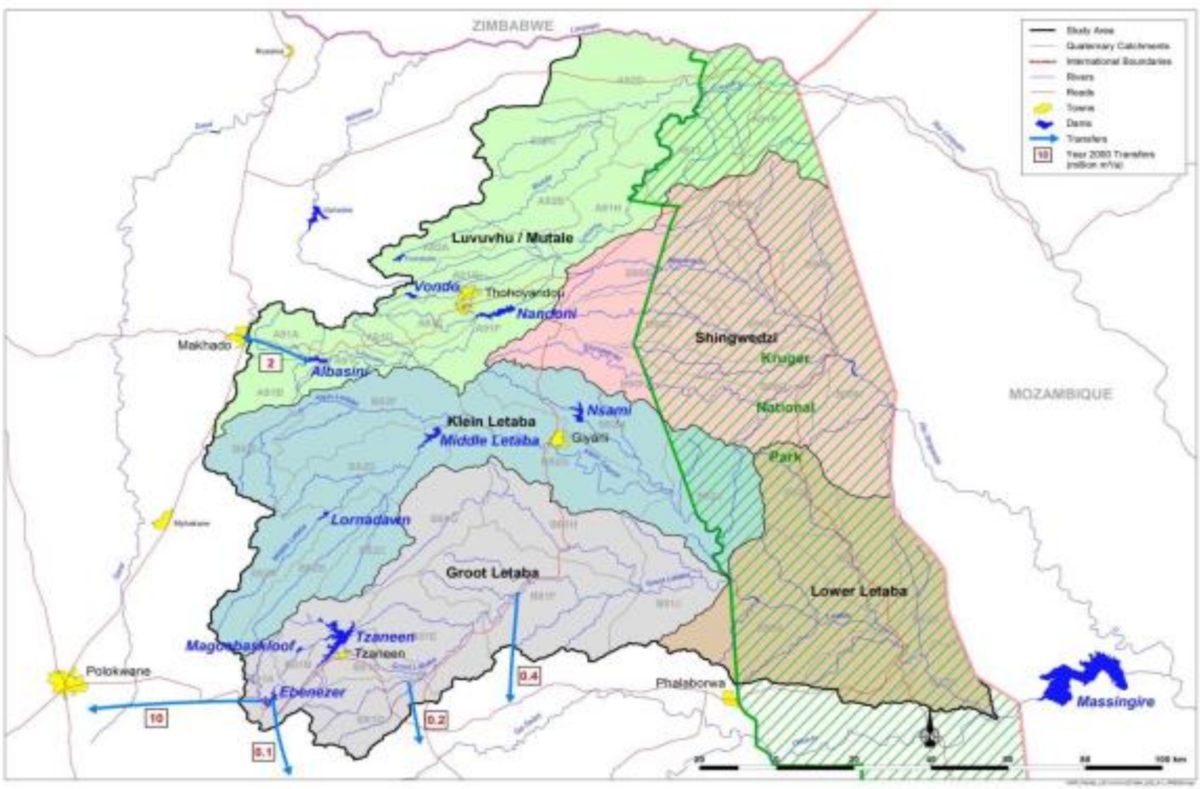

Figure 17: Study Area of Reconciliation Study for Luvuvhu/Letaba (DWA, 2012)

The geology is varied and complex and consists mainly of sedimentary rocks in the north and metamorphic and igneous rocks in the south. High quality coal deposits are found near Tshikondeni and in the northern part of the Kruger National Park, whilst the eastern limb of the mineral rich Bushveld Igneous Complex touches on the southern parts of the water management area. With the exception of sandy aquifers in the Limpopo River Valley, the formation is of relatively low water-bearing capacity. The total population for the study area is around 1.8 million people. Approximately 80-90% of the population can be described as rural. A large proportion of the population depends on subsistence farming and this makes availability of water a vital subject for consideration.

Downstream of the Middle Letaba Dam, and particularly along the Groot Letaba and Letsitele Rivers, as well as in the upper Luvuvhu River catchment, vegetables (including the largest tomato production area in the country), citrus and a variety of fruits such as bananas, mangoes, avocados and nuts are grown. Large areas have been planted with commercial forests in the high rainfall parts of the Drakensberg escarpment and on the Soutpansberg.

The water resources in this WMA can be described as fully developed. To date the Middle Letaba is in a serious water supply crisis, which has been, aggravated by a series of droughts, coupled by poor water management practices in the operation of the system. To ameliorate the situation the Department

together with the local authorities and water users are implementing a series of actions, ranging from water restrictions, groundwater development to the implementation of Water Conservation and Water Demand Management measures. These actions are mainly to address the short term crisis.
The reconciliation strategy study aims at consolidating these actions together with long term strategies, putting emphasis into detailed investigation of the water resources, particularly groundwater.

6.3.2 Resource classification

Proposed classes of water resources for the Letaba Catchment were published by the Department of Water Affairs in 2014 for public comment (DWA, 2014a). For each Integrated Units of Analysis (12 for the whole catchment), broken down into biophysical nodes representing river reaches or resource units, a target ecological category (Management Class) is provided. This class solely relates to the management requirements of the river itself.

As a follow-on study, Resource Quality Objectives were established for each of the resource units that had previously been classified (DWA, 2014a). The level of detail of the RQOs depended on a prioritization of resource units based on ecological hotspots in the river.

Resource Quality Objectives (RQOs) were defined as numerical and/or descriptive statements about the biological, chemical and physical attributes that characterise a resource for the level of protection defined by its Class. These Resource Quality Objectives might describe, among other things, the quantity, pattern and timing of instream flow; water quality; the character and condition of riparian habitat, and the characteristics and condition of the aquatic biota.

RQOs were established for the following water resource components:

- River flow
- Habitat and Biota
- Fish EcoSpecs and TPCs
- Macro-invertebrate EcoSpecs and TPCs
- Riparian vegetation EcoSpecs and TPCs
- Water quality (river)
- Groundwater

The prioritization of resource units did not affect the RQOs for groundwater, which all had the same level of detail - per quaternary catchment in each IUA:

- Existing groundwater use and stress index (total use/aquifer recharge);
- The Harvest and economic Exploitation Potentials;
- Recharge and aquifer recharge (which excludes the component of recharge lost as interflow and not available to groundwater users);
- Groundwater contribution to baseflow, interflow and total baseflow;
- The Natural MAR, and the present MAR resulting only from present day groundwater abstraction;
- The reduced baseflow that would occur if groundwater abstraction would be increased to the harvest potential;
- Significance of baseflow to the catchment;
- Groundwater numerical RQO for the protection of baseflow.

An example table for one of the IUAs is shown in Table 10 (DWA, 2014a).

Table 10: IUA 2 - Letsitele and Thabina: Summary of Groundwater Balance (DWA, 2014a)

	Natural MAR	Irriga-tion	Water Supply	Total Use	Stress index	Harvest Potential	Exploita-tion Potential	Recharge	Aquifer recharge	Interflow	Baseflow	G'water baseflow	Present baseflow	Present MAR reduct-ion	Reduced baseflow due to increased abstraction
	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a		Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a	
	107.85	1.13	3.00	4.13[1]	0.32	7.77[1]	5.44	90.25	12.84	77.41	79.00	1.59[1]	77.18	1.83	75.58
Percent contribution to total baseflow of the Letaba								28.86%							

[1]The resulting numerical RQO: Groundwater abstraction can be increased from 4.13 Mm3/a to 7.77 Mm3/a, with a 1.60 Mm3/a reduction in baseflow.

The Groundwater Narrative and Groundwater Numerical RQOs are presented for a few of the resource units, together with the Management Class for the unit and the key groundwater users and issues that were identified, to illustrate the focus and outcome of classification (Table 11)

Table 11: Groundwater RQOs for selected in Resource Units in Letaba Catchment

Resource Unit	Manage ment Classes	Key user	Key issue	Groundwater Narrative RQO	Groundwater Numerical RQO
IU1 B81A B81B	C, D B, C, D	Forestry and some irrigation	Groundwater abstraction and afforestation impacts significantly on baseflow in this IUA. This IUA provides nearly 45% of baseflow in the Letaba. Only 15% of baseflow is from the regional aquifer, consequently afforestation can have a greater impact than abstraction by diminishing interflow from high lying areas	Groundwater is underutilised. Abstraction impacts significantly on baseflow and this region is one of the most significant sources of baseflow in the Letaba system. Hence further investigations as to the impact of abstraction and SFR activities are required before any significant increase takes place	Groundwater abstraction can be increased from 2.79 Mm3/a to 10.44 Mm3/a, with a 4.76 Mm3 reduction in baseflow.
IU2 B 81D	B	Agriculture	Groundwater abstraction and afforestation impacts significantly on baseflow in this IUA. This IUA provides nearly 29% of baseflow in the Letaba, of which only 2% is from the regional aquifer.		
IU7 B82A, B82D	D C, D	Agricultural activities, including commercial tomato producers ZZ2 at Mooketsi, water supply.	Groundwater abstraction has significant impact on baseflow in this IUA. This IUA was a significant source of baseflow in the Letaba, contributing 14% of baseflow, however, its contribution has been diminished by more than 50% due to groundwater abstraction	Groundwater is moderately utilised. Abstraction impacts signifcantly on baseflow locally and on inflows into the middle Letaba dam. Increases in abstraction should consider the impacts on the yield of the middle Letaba dam.	Groundwater abstraction can be increased from 7.45 Mm^3/a to 17.47 Mm^3/a, with a 5.27 Mm^3/a reduction in baseflow. An investigation of the baseflow reduction on the yield of the middle Letaba dam is required
IU7	D	do	do	Groundwater is over exploited and has resulted in	Groundwater abstraction

B82B, B82C	E			significant reduction in inflows into the Middle letaba dam. No further groundwater abstraction should be permitted.	exceeds the Harvest Potential and the simulated aquifer recharge. No further abstraction should take place.
IU9 B82G	C/D	Dense urban settlements (e.g. Giyani) and informal settlements (i.e. limited subsistence and cultivated agriculture, with livestock).	Groundwater abstraction has a minor impact on baseflow in this IUA. This IUA is a very minor source of baseflow to the Letaba	Groundwater use is low and can be utilised up to the Harvest Potential with little to no impact on baseflow	Groundwater abstraction can be increased from 0.6 Mm3/a to 11.02 Mm3/a, with a 0.05 Mm3/a reduction in baseflow.
IU12 83A-E	Mainly A	Land-use is protected land or conservation area, i.e. the Kruger National Park.	Groundwater abstraction has a minor impact on baseflow in this IUA. This IUA is a very minor source of baseflow to the Letaba.	Groundwater is underutilised and can be utilised up to the Harvest Potential with little to no impact on baseflow	Groundwater abstraction can be increased to 29.44 Mm3/a, with a 0.02 Mm3/a reduction in baseflow.

Mr. du Toit kindly supplied information on the groundwater utilization issues in the catchment: "There are a large number of rural communities in the Levuvhu/Letaba WMA that depend on groundwater and it is thus an import source. Challenges are more on water quality side but the biggest problem is maintenance and theft of pumps, cables, etc. There is also no groundwater management done by municipalities. This catchment in particular is experiencing drought conditions with several supply dams down to 30% to 70% of their capacity. There are initiatives in the pipeline to supplement supply to communities from 4 dams in the catchment from groundwater. We have some monitoring stations showing a declining trend in the area over some time now but the impact of the drought has not really yet manifested itself in groundwater"(du Toit, 2015).

6.3.3 Evaluation in terms of outcomes for groundwater resource protection

A number of observations can be made with respect to the outcome of catchment classification for groundwater resource protection and sustainable utilization.

- Classification of the Letaba Catchment has been done with a surface water focus (target ecological categories);
- There was no prioritization of RQOs in the case of groundwater – all resource units have the same type of narrative and numerical RQOs;
- There is no hydrogeological description of the units and the groundwater issues mentioned only relate to the units' contribution to baseflow;
- None of the groundwater utilization issues mentioned by the Regional Geohydrologist are addressed in the RQOs, despite community water supply being a priority groundwater use in the area;

- The resulting RQOs for groundwater are nothing more than Ecological Reserves (volumetric restrictions) for each resource unit;
- The elaborate groundwater balance calculations (Table 9) bear no relation to the uncertainty related to these estimates;
- No effort has been made to provide objectives that can be measured and can thus be put as licence conditions, ie. abstraction exclusion zones near sensitive river reaches, groundwater level gradients, and groundwater quality targets that should be maintained;
- No attention has been paid to protect the critical role that groundwater already plays in sustaining community rural livelihoods as well as the future role assigned to it in the DWS Reconciliation Strategy.

Despite this lack of focus on the sustainable utilization on the groundwater resource itself, these RQOs will place a major new workload on the groundwater staff of the Regional Office. Already, implementation questions are asked of the Regional Office for each of the resource units (du Toit, 2015):
- Can the regional office monitor this?
- How possible is it to keep track of the quantity of water allocated in the IUA?
- Can these be gazetted as numerical and narrative RQOs? How can they be report on?

In conclusion it can be stated that the recent Classification and setting of Resource Quality Objectives the Letaba River, once gazette, are not going to contribute to the protection and sustainable utilization of groundwater resources in this catchment, because the present methodology has a surface water focus. This should be of major concern, because resource classification, together with RQOs for implementing a Basic Human Needs Reserve, had been seen as the prime protection measures for groundwater resources in terms of the National Water Act, 1998.

7. A Groundwater Thrust within South Africa / Africa (AMCOW) / China Water Cooperation

7.1 Introduction

A review assignment commissioned by the WRC and presently being concluded, is deemed cooperative and strategic in nature. It aims to draw comparisons at desktop level, focusing on the implementation of groundwater resource protection measures in South Africa and The People's Republic of China., and intends to:

1. both unlock new areas of cooperation while enhancing ongoing collaborative initiatives between China and Africa in the water field.
2. create momentum for the Africa Groundwater Commission under the African Ministerial Council on Water (AMCOW).
3. achieve strategic review outcomes that further contribute to an adaptive management approach for promoting coherent and integrated implementation of groundwater resource protection measures.

The Position Paper 'A review of the implementation of groundwater protection measures in South Africa', already submitted, was strictly focused on objective 1 (Xu et al., 2015). A similar paper was produced and presented by China. In the note below an attempt is made to jointly address objectives 1. – 3., by providing our understanding of the need for a cooperative roll-out of AMCOW's Africa

Groundwater Initiative and the contribution that South Africa and the ChinAfrica cooperation could make in this regard.

The findings of the Position Paper were presented and discussed at the ChinAfrica Water Forum Resources Dialogue No. 3 held at the University of the Western Cape, 17-19 August 2015. Recommendations from the Conference (Conference Statement, 2015) have been incorporated into this note to provide a sketch of a cooperative project based on the above review, which could serve as a major trigger for long-term cooperation towards sustainable utilization of groundwater resources in Africa.

The Conference stated: 'The objective of cooperation is to work towards a lasting partnership between the two regions in the area of sustainable utilisation of water resources in developing countries. Both China and Africa face massive challenges of human development in a changing environment, and have very similar water resources management priorities, particularly from a research, development and implementation perspective. Special focus would be given to the neglected resource, groundwater, in line with a policy direction which AMCOW has already been looking to implement for a number of years now. For this purpose, every effort will be made to make AMCOW's Africa Groundwater Commission fully functional.'

7.2 Groundwater in Africa

An authoritative statement on groundwater in Africa was made in 2008 at the Groundwater & Climate in Africa Conference. Here the stress of a partnership approach:

'Recognising that groundwater resources in Africa are broadly distributed, of generally good quality and resilient to climate variability including extreme climate events; that rainfall and freshwater from rivers and lakes will become more variable and thus less reliable as a result of climate change; that groundwater is the daily source of drinking water for more than 75% of the population across Africa; and that rapid population growth and economic development will place considerable reliance upon groundwater in Africa to meet the Millennium Development Goal of halving the number of people without access to safe water and sanitation by 2015; we stress that dependence upon groundwater in Africa to meet domestic, agricultural and industrial water demands will intensify substantially over the next few decades and call upon the international community to support the African Groundwater Commission (AGWC) and allied initiatives for coordinating research and advisory activities related to African groundwater' (Kampala Statement, 2008).

In response to calls from a variety of stakeholders, AMCOW, at its 6th Ordinary Session in Brazzaville in May 2007, adopted key groundwater resolutions, in particular that AMCOW would become the custodian of a continent-wide strategic groundwater initiative. This led to the decision to establish a commission on groundwater management in Africa that will operate as an autonomous body reporting to the AMCOW EXCO on a regular basis. A roadmap to the constitution and functioning of an AGWC was launched at the First African Water Week in Tunis, 26-28 March 2008. Finally, the African Groundwater Commission was approved by the Heads of State of African Union in 2008 in Sharmh El Sheikh (Egypt) and forms part of the Sharmh El Sheikh Commitment.

The Road Map of the AGWC sketches the vision (AMCOW, 2008):

‘To turn around the present ineffective and unsustainable use of Africa groundwater is an immense challenge, which will require regional, national, and international action on a number of fronts. These are highlighted in the vision and three major thrusts for action (below), all underpinning the African Water Vision.’

Vision
An Africa where groundwater resources are valued and utilized sustainably by empowered stakeholders.

Thrusts for action

Awareness
This thrust must result in a widespread awareness of groundwater, its developmental role, its hydrological and ecosystem function, its vulnerability to human impact and approaches to its sustainable utilization by key stakeholders at all levels.

Capacity
This thrust must result in appropriate capacity, including policy and legislation, and institutional and human resources, to plan and implement sustainable groundwater utilization at all levels.

Knowledge
This thrust must result in a knowledge base, including monitoring networks, resource assessment, best practice database, information systems and fundamental sciences, to enable the optimal utilization of groundwater within an Integrated Water Resources Management (IWRM) framework.

7.3 Institutionalizing the Africa Groundwater Commission

Recognising the need for a cooperative approach, the groundwater sector in Africa called for an urgent strengthening of institutional structures at continental (e.g. AGWC) and regional scales, and the development of legal and institutional frameworks to enable sound governance and equitable sharing of transboundary groundwater resources (Kampala Statement, 2008).

The Road Map for the AGWC had highlighted that to be aligned with regional conditions, policies, approaches and programmes, the performance of the AGWC should be at the level of the Regional Economic Communities (RECs), and ultimately River and Lake Basin Organizations (R/LBOs), as well as local government, civil society and the private sector. Financing of the AGWC operations would be the responsibility of the AMCOW EXCO. Core funding should come from the ADB. Various budgets of different African institutions, e.g. part of NEPAD’s funds for establishing centres of excellence and the ADB funds for the Rural Water Supply and Sanitation Initiative (RWSSI), should be prioritized for a common Africa Groundwater Initiative, coordinated by the AGWC. International development cooperation partners should be attracted through the strategic nature of the initiative and the coordinated and long-term approach achieved through the AGWC. Both monetary and in-kind support will be essential to achieve empowered groundwater stakeholders in Africa. For continuity, the AGWC will have to be supported by an adequately staffed professional secretariat from AMCOW, with support from partner institutions as required.

In a bridging action in 2009, the Interim Chair of the AGWC was held by Kenya and UNESCO and UNEP in Nairobi, supported by the UNESCO Chair in Groundwater at the University of the Western

Cape (UWC), acted as the Interim Secretariat. A period of inaction followed when the Chair was held by Libya since 2010.

Importantly, SADC immediately took the initiative when the AMCOW groundwater resolutions had been passed. Already in 2007, a report on 'Status of Sustainable Utilization and Management of Groundwater Resources in Southern Africa (2007)' commissioned by AMCOW-TAC members for Southern Africa and funded through a WRC consultancy. In 2008, a SADC / AMCOW Workshop on 'Groundwater within the SADC IWRM Initiative', based on the above assessment, in November 2008, funded by GIZ, had a major impact on SADC groundwater policy. As a direct outcome, the 3rd SADC Multi-Stakeholder Water Dialogue in May 2009, for the first time had a theme of 'Groundwater'.

At a meeting of the AGWC, coinciding with the AMCOW Exco meeting in Sharm el Sheikh, June 2013 it was suggested to move the AGWC Secretariat, presently with the AMCOW Secretariat, to the Faculty of Natural Sciences at the University of the Western Cape, South Africa, conditional on support from the South African government. As a follow-up, the Dean of Natural Sciences, Prof. Davies-Coleman in August 2013 wrote a letter to the DG of DWS, agreeing to a partnership with DWS in this regard. Since then there has only been informal feedback that DWS was still trying to find a budget. It is not clear what diplomatic steps would still be required to make this arrangement functional.

To see the potential South African and ChinAfrica contributions in context, some of the early actions that were outlined in the Road Map to reach a fully functional and visible AGWC are shown below:

- Secure initial funding for the operation of the AGWC and secretariat;
- Develop a strategic framework and proposal for action in consultation with AMCOW, AU Commission, NEPAD, development cooperation partners and others;
- Establish communication and consultative fora at the sub-regional level;
- Secure sustainable financing to promote Africa's groundwater agenda;
- Participate, with AMCOW and others, in relevant international and regional meetings and
- deliberations on groundwater in Africa.

The very poor funding commitment to groundwater resources assessment and management relative to the strategic importance of the resources for a number key development sectors in the region was touched on in the Africa Report of the Global Groundwater Governance Initiative (Braune and Adams, 2013). Particular investment is required in groundwater institutional development. To rectify the situation, a strategic effort at regional (AMCOW), the RECs, countries and their international development partners will be necessary. This should lead to long-term commitments and new ways of financing, e.g. funding of resource management as a portion of the investment of groundwater infrastructure, through basket funding in which groundwater receives its equitable share, through focus on funding for climate change adaptation, through public-private partnerships and through achieving an income from regulating those who have groundwater use benefits, ie abstraction, drought security and pollution.'

7.4 Partnerships towards a sustainable AGWC

The Africa Report of the Global Groundwater Governance Initiative (Braune and Adams, 2013) stresses the need for a cooperative approach:

'The importance of groundwater in this region, the cooperative regional IWRM structures and institutions that already exist, the understanding there is already for groundwater at the highest decision-making levels, plus the desire of key international cooperation partners to help turn the situation around and join forces to make an impact, offers a major opportunity to initiate a systematic, region-wide, programme and approach, as envisioned by AMCOW for building the capacity required to ensure that groundwater resources are utilized and managed sustainably in Africa. AMCOW already has a Roadmap for the way forward and has created the Africa Groundwater Commission (AGWC) to take the process forward.'

Some potential partnerships for groundwater in Africa were put forward at a significant meeting of Africa groundwater stakeholders and its international partners at the Africa Regional Consultation of the Global Groundwater Governance Initiative in Nairobi in May 2012:

The Africa Groundwater Commission presents a major opportunity for groundwater in Africa. It now needs to be fully operational and thus also become the focal point in Africa for the GEF Global Groundwater Governance initiative.

- IAH and partners could help with communication, awareness creation and an Africa Groundwater website to help kick-start the initiative.
- Ultimately countries must be mobilized to take the lead with programmes, because funders like the World Bank, the African Water Facility and the African Development Bank only fund country programmes. Seed money could be used to jointly develop proposals and access funding.
- Country/region partners should draw the UNESCO Chair in Groundwater at UWC into big projects, initially with just some travel funds and once it was on site, deeper modalities for participation could be worked out.
- Country mobilization could be triggered by GEF Transboundary Aquifer projects as a follow-on to the Global Groundwater Governance project, but until then a continent-wide momentum needs to be maintained.
- A more immediate funding support could come from Japan, which has an interest in Transboundary Aquifers and in the implementation of the Draft Articles on the Law on Transboundary Aquifers (DG of UNESCO to meet Ambassador of Japan).
- The UNESCO Chair is to prepare a Masterplan for a 2 year period to highlight priorities, possible projects, and ways in which UNESCO could facilitate actions.

Through the Chin-Africa Water Dialogue a fresh momentum has been created to move the Africa Groundwater Initiative of AMCOW forward.

- Both the South African Water Research Commission and the Council for Scientific and Industrial Research (CSIR) of South Africa have entered into a Memorandum of Understanding with the International Research Center on Karst (IRCK) in China.
- A desktop study has been launched in both countries as foundation for a joint pilot project in the area of groundwater governance. This is to serve as a forerunner of ongoing joint research, development, innovation and implementation in the area of water and development.
- AMCOW together with its development partners would help to create mobility of water experts from across the continent to participate in the Water Forum initiatives and related events and projects.
- The UNESCO IHP in sub-Saharan Africa (Office in Nairobi) would support associated capacity development through short courses and networking through its International Hydrology Program (IHP) Water Family. UNESCO can also assist to draw in the growing networks of the NEPAD Water Centers of Excellence being established across the continent.
- The International Research Center on Karst (IRCK) is linked to the China Geological Survey and is a well-established UNESCO Center. This creates opportunities for strengthening science excellence and further promoting regional cooperation.

7.5 First cooperative project

As a trigger for the above developments, both the Water Research Commission and CSIR are already planning first cooperation actions with the IRCK and a number of possible topics were highlighted at the Conference that could become pilot projects. Particular strengths in South Africa are its IWRM approaches and its continuity and excellence in water research. Particular strengths in China are its long earth science tradition, a holistic approach to environmental management and integrated monitoring, often using latest technology advances. Both countries see decentralized management of water resources as strategic in their overall management approach.

A cooperative groundwater project, which was considered a priority by the Conference, could look broadly as follows.

Trigger Project	A cooperative project providing a framework thrust on appropriate groundwater governance
Objective	Coordinated learning and action towards sustainable utilization and management of widespread local groundwater resources for local, national and regional development.
Focus	Regulatory and institutional bottlenecks and the supporting resource assessment and information management requirements.
Approach	Framework thrust with an increasing number of country-supported initiatives in response to identified needs in terms of regulation, institutional development, and resource monitoring and assessment. This could be supported by China with similar actions in China and with financial and appropriate in-kind support to the Africa thrust.
Africa Cooperation	Functioning of AMCOW's Africa Groundwater Commission needs to be safeguarded for a period of 3-5 years in order to empower it to lead a groundwater networking and advocacy role for the continent as a whole through which the trigger project could be rolled out and grown in the continent as a whole. AMCOW, the RECs and individual countries would use the window of opportunity to bring other development partners on board.

To enable the international Africa-China cooperation project, the diplomatic efforts towards making the Africa Groundwater Commission fully functional, will require dedicated and coordinated efforts on a number of fronts, eg WRC-DWS-DST-Foreign Affairs-SADC-AMCOW-NEPAD-UNESCO.

The authors see the above outline as their response to the request by the Water Research Commission and as a way to unlock areas of cooperation between China and Africa in the water field and they look forward to further involvement in this critical venture for water and development in Africa.

8. Conclusions and Recommendations

Review

A significant catchment-wide implementation of GRDM has taken place since 2012 and was preceded by a large, often catchment-wide, coverage with preliminary ‘Groundwater Reserves’. Groundwater has been fully integrated in this process, helped greatly by a substantial Water Research Commission investment into methodology development for the groundwater component of RDM.

Progress

Very little integrated Reserve determinations have been undertaken before the catchment-wide implementation of GRDM started in 2012. The Integrated Water Use License Application (IWULA) process offers opportunities for an integrated Reserve determination. However, most of the Groundwater Reserve determinations up to that time were undertaken as part of a groundwater use license applications and not as part of an integrated water resource Reserve determination.

The outcomes of the catchment-wide implementation of GRDM do not yet have practical consequences for groundwater resource protection, because the key RDM measures of Classification and RQOs have only just kicked in (2014) and have not yet been officially gazetted.

However, the RDM process itself and its groundwater-related findings and recommendations could be evaluated nationally and in two case studies, locally.

It is clear, and of major concern, that the multi-million Rand investment into RDM, and as part of it, into Groundwater RDM, will not make a significant contribution to the security of groundwater sources, and this despite that fact that the Groundwater Strategy of the Department of Water and Sanitation has declared the protection of groundwater a national priority.

Assessment

Groundwater RDM is being systematically implemented as part of catchment-wide RDM implementation since 2012. It is clear that such an integrated approach to the management of groundwater and surface water is essential in order to provide for adequate protection and efficient management of the total resource.

The main finding has been that the RDM process is still completely surface water-focused. The Reserve, Classification and Resource Quality Objectives are defined with a surface water environment focus.
The process does not yet cater for the unique characteristics and role of groundwater resources in the South African water resources environment. Groundwater’s hydrogeological characteristics, its specific management needs and its challenging resource information requirements are not yet addressed. Groundwater resources are just seen as a contributor to surface water systems and all the protection focus is on these and not on the groundwater resource itself.

Resource Quality Objectives, which provide the opportunity to address the protection of important groundwater sources, have to date only addressed the Ecological Reserve, except in the Olifants-Doring Catchment, where a local groundwater expert introduced a practical groundwater focus. The Basic Human Needs Reserve, which is to protect the strategic groundwater sources for communities, has to date only been expressed as a number (a very small volume) which can only be controlled if relevant

Resource Quality Objectives are set. This has not happened yet and thus the Basic Human Needs Reserve has had no practical outcome for groundwater source protection.

Nowhere has groundwater source protection zoning for domestic water supplies from groundwater been implemented to date, despite the fact that almost two thirds of South Africa's population depend on it for their domestic water need and the highest protection priority had originally been assigned by DWA to this measure.

The scientific approach clearly lacks much greater hydrogeological understanding of the aquifer than the present volumetric approach, assuming a uniform groundwater bucket over the whole catchment (unit of study). Experience has shown that specific protection objectives can only be achieved through specifications more detailed than average volumetric restriction over the quaternary catchment, i.e. restrictions regarding where (area) groundwater development can take place (distance from river, wetland or other boreholes) as well as the setting of minimum water level gradients. A more integrated understanding of aquifers as hydrological systems in terms of recharge, discharge and ecosystem linkages in both space and time is crucial for such an approach. Simpler, spatially-based approaches are available to enable practical protection, which have not been applied to date.

Integrated and user-focused monitoring of water resources, which is an essential prerequisite for the implementation of groundwater resource protection, is only happening in a few of the DWS Regions. Country-wide implementation can only be expected when all Catchment Management Agencies are fully functional. An excellent national development is the publication of an annual report on the State of Water Resources, based on the various monitoring programmes.

It is of concern that ongoing groundwater use authorization process has not contributed significantly to groundwater resource protection. The existing tools of compulsory licensing, capacity building and compliance enforcement have not been utilized, even where domestic water supply to small towns and ecosystems of national interest are threatened.

Besides the lacking information capacity, there is a lack in human capacity. Overall, the country has an excellent capacity in the groundwater resources field, on par with the best in the world. The critical shortcomings at this stage are in government, both national and local. Lack of capacity in municipalities where groundwater has, in many instances, become the sole source of domestic water supply, is regarded by many as the most important factor holding back sustainable development and management of groundwater resources in South Africa. The weakness in the groundwater function in national government is of particular concern at a time when new groundwater capacity has to be built in CMAs and in local government.

Once the Classification and RQO requirements have been established in all catchments, CMAs and Regional Offices will be overloaded with work. This is already the case, following the recent priority the national Department has set on compliance with licensed conditions. It can be expected that the capacity of DWS Regional Offices and Catchment Management Agencies will grow with the increasing work load and with greater clarity with regard to respective roles and interaction. Specific groundwater capacity is intended to be addressed with the establishment of a groundwater governance unit within DWS (DWS, 2016).

A generally recognized factor that must drive sustainable groundwater utilization, is participation of local water users and other stakeholders. Despite the good intent of the National Water Act, 1998, this critical requirement is still virtually completely missing for groundwater resources. There are no Water User Associations for groundwater and very few local monitoring committees are functional. Besides the challenges of a complex and poorly understood resource, its previous ‘private water’ nature still play a major role in groundwater’s lagging far behind the institutional development for surface water resources.

Recommendations

1. Groundwater resource focus

Groundwater resource protection as part of RDM should remain clearly anchored within the IWRM approach, integrated with surface water resources and water-dependent ecosystems. Various, more recently established integration strategies and tools need to be considered in any GRDM revision, eg the National Freshwater Ecosystem Priority Areas (NFEPAs), the Integrated Water Use Licence Application (IWULA), the Integrated Water Quality Management Strategy and the Strategic Water Source Areas. Practical cooperative governance can be achieved through the Interdepartmental Inland Water Ecosystems Liaison Meetings which deal with matters related to ecosystem sustainability and protection across the departments.

GRDM methodology will need a completely fresh focus on the unique hydrogeological characteristics and vulnerability of groundwater systems, supported by groundwater-specific methodologies, appropriate exploration drilling, pumping tests and distributed numerical models. Attention will also have to be paid to the inclusion of unique groundwater-dependent ecosystems into RDM. The role that various aquifers will have to play in the country’s development will also need consideration in the methodology and prioritization of RDM. Such methodology revision will have to be accompanied by a groundwater resource information strategy with emphasis on resource exploration, assessment and monitoring and, in particular the sharing of data held by different economic sectors like government, consultants and mining companies, in the national interest.

2. Capacity at all levels

Groundwater resources assessment and management is a specialized field. Such specialists will increasingly be required in national government, in local government and in the CMAs. Experience has shown that it will be essential for groundwater professionals to stay involved in the management of wellfields they have developed to ensure that they are properly operated, and that recommendations for sustainable pumping are followed. This needs to be regulated to achieve the desired effect. The present serious shortcomings in water service delivery from groundwater sources will need to be overcome as a highest priority. This will only be possible if the professional resources of the whole groundwater sector, including consultants and academic sectors, are drawn in partnership ways to master the situation.

3. Groundwater governance

One of the critical success factors for groundwater resource protection will be groundwater user / stakeholder participation. Establishment of new local user associations which are essential for sustainable groundwater resource utilization, will require long-term hydrogeological support, in particular with the assessment of the resource and with the establishment of monitoring networks and information management systems. This technical support has to go hand in hand with support towards the institutional processes of WUA establishment and effective water use regulation.

A review assignment, which is commissioned by the WRC is deemed cooperative and strategic in nature, has a far-reaching implication in the following aspects, namely to:

1. unlock new areas of cooperation while enhancing ongoing collaborative initiatives between China and Africa in the water field.
2. create momentum for the Africa Groundwater Commission under the African Ministerial Council on Water (AMCOW).
3. achieve strategic review outcomes that further contribute to an adaptive management approach for promoting coherent and integrated implementation of groundwater resource protection measures.

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Appendix 1: Olifants-Doring WMA Classification (2012) and RQO (2014) Studies

Quat with GW action	Aquifer	Groundwater Risk	Desired Management Category (2012)	Class Implications for groundwater management (2012)	Priority RQOs for groundwater action (2014)
E10A	TMG	Irrigation from groundwater; Groundwater role for baseflow	B	Groundwater monitoring network necessary	
E10B	TMG	Intensive agriculture, mainly from groundwater	B	Groundwater monitoring network necessary	
E10D	Quaternary 15% TMG 85%	Intensive agriculture, mainly from groundwater; contribution to baseflow very important	C → B	Assess status of groundwater monitoring; Agricultural activities must not impact groundwater contribution to baseflow	GW stress index: 2% GW Reserve: 24% Extreme drought flow should not drop below a threshold <u>For Alluvium aquifers</u> Annual licence audit by DWA; Proposed new monitoring points Buffer zones around wetland and river Compliance with water quality standards for domestic use Extension of WMS network <u>For TMG Aquifers</u> Similar
E10F	TMG Alluvium - narrow strip along river	Significant groundwater abstraction; Crucial role for baseflow	C → B	Possible groundwater abstraction revision; Monitoring essential	GW Stress index: 9% GW Reserve: 18% Annual licence audit by DWA Proposed new level and water quality monitoring points
E10H	Jan Dissels River	Only a surface water priority	B → A	**Compulsory licensing** which did not come out of the Classification process	
E10J	TMG	Groundwater used extensively; Risk of overabstraction	C	Possible groundwater abstraction revision; Extension of normal monitoring network if necessary.	
E21A	TMG	Lots of agriculture; Groundwater use not certain	D → C	Verify groundwater abstraction;	

				Introduce a few dedicated monitoring sites	
E21D	Witteberg 12% Bokkeveld 47% TMG 41%	Extensive agriculture; Extensive groundwater use in summer	D → C	Groundwater monitoring by landowners and DWA is necessary	
E21E	Witteberg 67% Bokkeveld 9% TMG 24%	Extensive groundwater use in summer	D → C	Groundwater monitoring by landowners and DWA is necessary	
E21G	Quaternary 24% Bokkeveld 39% TMG 37%	Extensive agriculture; Groundwater use exceeds recharge and levels are dropping.	F → D	Groundwater use needs to be assessed; Monitoring network needs to be established; If necessary, compulsory licensing of groundwater use	GW Stress index: 21% GW Reserve: 11% For alluvium aquifer Annual licence audit by DWA Water level and quality extension of monitoring network required; Extension of water quality parameters required; Bufferzone of 250m around river and wetland; Low flow limit in river For TMG Aquifer Similar
E32E	van Rynsdorp Group 48% TMG 17% Dwyka Group 27%	Lots of agriculture; Significant groundwater use and dropping groundwater levels	F → D	Groundwater monitoring needs to be carried out by land owners and DWA	
E33E	Quaternary 38% van Rynsdorp Group 41%	Lutzville in this catchment Groundwater could be overabstracted	C → B	No recommendations	
E33F	TMG aquifer contributes to baseflow by discharging as springs or by interaction with the rivers through the weathered zone.	Essentially no groundwater use in catchment; Contradiction: RQO study found that groundwater recharge was virtually fully used; Contains Van Rhynsdorp WUA.	A	No recommendations	GW Stress index: 91% GW Reserve: 0% Annual licence audit by DWA Existing water level and quality monitoring network by DWA and Vanrhynsdorp WUA
E33G	Quaternary 42% van Rynsdorp Group 39% TMG 19%	Vredendal in this catchment Groundwater levels could be dropping	D → C	Excellent monitoring by DWA	

E40B	Karoo Dolorite suite 32% Ecca Group 68%	Calvinia in this catchment Possibly groundwater levels dropping	C → B	No recommendations	
G30C	Sandveld TMG	Groundwater over-abstraction can occur. An important recharge area	C	Monitoring is important.	
G30D	Sandveld Verlorevlei Quaternary 59% TMG 23% Malmesbury Group 18%	Groundwater is used extensively, however the aquifers are high yielding. The risk is quite high that over-abstraction can occur. Groundwater quality can also deteriorate as a result of irrigation return flow	C → B	Needs to be monitored carefully	GW Stress index: 58% GW Reserve: 10% Revised allocation schedule Otherwise very much as above
G30E	Sandveld Verlorevlei Quaternary 42% TMG 55% Wetland area 8%	Groundwater is used extensively; however, the aquifers are high yielding. The risk is quite high that over-abstraction can occur. Groundwater quality can also deteriorate – saline intrusion. Groundwater only source for 2 small towns. Groundwater sustains Verlorevlei (a RAMSAR site).	D → C	Needs to be monitored carefully, especially in area of Verlorenvlei	**GW Stress index: 165%** GW Reserve: 13% As above Bufferzone of 500m around wetland WARMS registration, licensing (**compulsory licensing??)**
G30F	Sandveld Langvlei Quaternary 35% TMG 65% Wetland area 5%	Groundwater is being over-abstracted; Ecosystems impacted; Groundwater quality worsening in places.	F → D	Needs to be monitored	**GW Stress index 141%** GW Reserve 7% As G30E
G30G	Sandveld Jakkalsvlei Quaternary 58% TMG 42%	Groundwater levels are dropping and water quality worsening in places; Risk of saline intrusion;	D → C	Needs to be monitored	GW Stress index 64% GW Reserve 4% As G30E Monitoring by local municipality

		2 small towns solely dependent on groundwater			