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CRITICAL REFLECTIONS ON 20 YEARS OF GROUNDWATER RESEARCH, DEVELOPMENT AND IMPLEMENTATION IN SOUTH AFRICA

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ABSTRACT

The aim of this paper is to highlight the changes that have taken place in terms of groundwater resource development and management in South Africa in the 20 years since the political transformation of the country in 1994. Groundwater, the previously neglected resource, received a strategic role in the monumental programme to bring basic water infrastructure coverage to more than 95% of the population during this period. The post-1994 water policy reforms have also had a very positive impact on groundwater; its legal status changed from "private water" to a "significant resource" and it became an integral part of integrated water resource management in terms of the National Water Act, 1998. A systematic assessment of changes, undertaken within a framework of groundwater governance, indicates that significant advances have been made in the groundwater field at the enabling environment/policy level as well as at the strategic/national level in terms of institutional and management instrument development. Thus groundwater has become an integral part of water resource planning, with appropriate groundwater data and information systems to back this up. Groundwater management at the national level can still be significantly improved by way of appropriate regulations that address the unique requirements of groundwater resources in terms of protection, information management and human resources. The present challenge lies at the local level, where the management of thousands of groundwater schemes was transferred from national government and from community management structures to newly established municipal administrations. Urgent attention will need to be given to building the institutional capacity for groundwater resource management at this local level. It will require the coordinated effort of the entire groundwater sector, led by the national Department of Water and Sanitation (DWS) and founded in ongoing research and development through the Water Research Commission (WRC).

Introduction

South Africa is celebrating 20 years of democracy. The new constitution of 1996 clearly expressed the overarching national goal of eradication of poverty and the building of race and gender equality. Every sector of South African society has been touched and transformed by the creative energy released following the watershed elections of 1994. While the emphasis of past governments had been on commercial agriculture and the urban/industrial sectors, the new political dispensation focused on meeting the basic needs of the poorest of the poor of society, including their water and sanitation needs.

The immediate priority for the water sector was therefore to address the massive backlog in the provision of basic water and sanitation services, which presented both grassroots and national scale challenges that the sector and national department had never

The report is Braune E., Adams S. and Fourie F., 2014. 20 Years of groundwater research, development and implementation in South Africa. Water Research Commission Report SP78/14. Water Research Commision, Pretoria, South Africa. 77pp.

experienced before. The ultimate achievement for the water sector in the 20-year period under discussion has been to bring basic water infrastructure coverage to more than 95% of the population in less than two decades, and providing access to an improved water supply to approximately 27 million people (Cobbing et al., 2013).

Previously often neglected groundwater resources played a major role in this achievement, becoming the primary source of water for between 50% and 90% of those unserved communities, depending on province. Its strategic importance also brought about a major shift in its valuation, from a past status in law as "private water" to a "significant resource" and an integral part of integrated water resource management (IWRM), the vision of the National Water Act, 1998.

This paper highlights the changes that have taken place in terms of groundwater resource development and management in South Africa, given its new role and policy environment. To allow for a more systematic assessment of these changes, the further discussion of 20 years of groundwater research, development and implementation in South Africa will be undertaken within a framework of groundwater governance, including the policy level, the institutions and instruments at national level and the local level institutions and actions (Riemann and Eaton, 2014; Braune and Adams, 2013).

Governance as an organising framework

A key message from the 2012 Marseille World Water Forum was that the "water crisis" the world community faces today is largely a governance crisis. Securing water for all, especially for vulnerable populations, is often not only a question of hydrology (water quantity, quality, supply, demand) and financing, but equally a matter of good governance – requiring resilience, institutions, collaborative efforts and sound capacity at all levels (WWF 2012:5 in Harris et al., 2013).

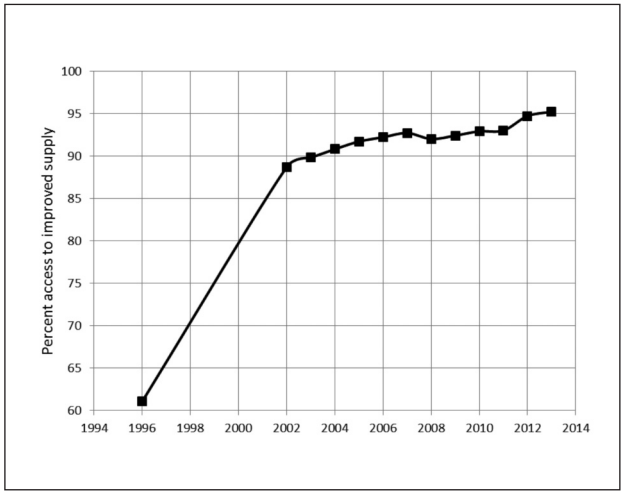

Figure 1. *Water supply improvements in South Africa since 1996 (Cobbing, 2013).*

Worldwide, a similar trend to focus on the broader concept of resource governance is also being observed in the case of groundwater resources. The good governance of this vital resource continues to be bedevilled due to the fact that it is unseen, it exists in nature as a common property resource, and its functioning within the hydrological environment is still poorly understood. In view of the global concern that the state of groundwater and groundwater governance is not "good" and needs improvement, an international partnership initiative "Groundwater Governance – A Global Framework for Action (2011-2014)" was recently launched (FAO/GEF, 2010). The project, in which Africa is an active participant, is designed to raise awareness of the importance of groundwater resources for many regions of the world, and to identify and promote best practices in groundwater governance as a way to achieve the sustainable management of groundwater resources.

In probably one of the most insightful groundwater resource management books, entitled *Groundwater and Society – Resources, Tensions and Opportunities*, Burke and Moench (2000) make a plea for the development of effective governance approaches for groundwater, a very complex common pool (open access) resource. 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. It also requires novel approaches to the systematic planning, financing and implementation of hundreds and even thousands of small, locally dispersed groundwater schemes (Burke and Moench, 2000).

The management approach advocated under these unique circumstances has been coined as "top-down facilitation of local actions" (Foster, 2006). This approach has been incorporated into a very useful groundwater-specific analytical framework (Wijnen et al., 2012) that also formed part of the African regional consultation for the global "Groundwater Governance" initiative (Braune and Adams, 2013). Their definition of governance and their framework (below) include both the top-down and local part.

- **Definition**
  "Governance is the operation of rules, instruments and organizations that can align stakeholder behaviour and actual outcomes with policy objectives."

- **Strategic Framework for Groundwater Governance**
  Enabling environment/policy level
  Processes by which a nation establishes its objectives for groundwater, integrates those policies with water, land and environmental policies, and aligns and

harmonizes them with other related policies affecting groundwater.

Strategic/national level
Institutions and instruments designed by a nation to align stakeholder behaviour and actual outcomes with policy objectives. These include planning, regulation, economic instruments, institutional development and information management.

Local level
Organizations and institutions that control actual outcomes on the ground and respond (in varying degrees) to the rules and incentives from strategic level governance. This level includes the individual groundwater users, local collective management institutions and relevant public agencies.

Strategic Framework for Groundwater Governance (Wijnen et al., 2012)

After a brief sketch, as context, of the overall water resource management environment in South Africa and the changing role of groundwater, the further discussion of the highlights of groundwater research, development and implementation in South Africa over the past 20 years will broadly follow the above governance framework.

The changing water resource management environment

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 on the promotion of basic human rights and the democratic values of human dignity, equality and freedom throughout the society.

With the promulgation of the National Water Act, 1998 (Act 36 of 1998), groundwater lost its previous status of private water and became public water. The Act, with its vision of IWRM, 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 in which the water resource is protected, used, developed, conserved, managed and controlled in an integrated manner. Thus, for the first time, groundwater had to be managed according to the instruments for national water resource management, including a number of key instruments and concepts that were introduced with the water sector transformation initiated in 1994 (Muller, 2000):

- The concept of the Reserve, through which water requirements to meet basic human needs and sustain the environment are given priority;
- A system to classify water resources in terms of desired environmental protection levels which will guide the technical determination of the environmental Reserve;
- A flexible allocation system that allows changes of use to achieve equity and meet changing social and economic priorities by regulation rather than administration or expropriation, but limits the duration of use rights to a maximum of forty years;
- Institutional arrangements to manage water at a catchment level within a national framework "in such a manner as to enable interested parties to participate."; and
- Separate legislation for water resources and water services, distinguishing between the regulation and management of water in rivers and water in pipes.

Water supply was dealt with separately in policy and legislation. Already in November 1994 a White Paper on Water and Sanitation was released which emphasised the political importance of a speedy delivery of water and sanitation services, ensuring that all South Africans can have access to basic water supply and sanitation services. This was to have a major impact on the role of groundwater in South Africa.

Changing role of groundwater in South Africa

Many parts of South Africa 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 resources in terms of management and allocation. Following water conservation and demand management, further utilisation of groundwater has become the first supply option to address water imbalances (DWA, 2013).

The dramatic shift in the role of groundwater came about as a result of changing political priorities. The massive backlog with regard to an improved water supply to all the country's citizens was addressed through the Reconstruction and Development Programme (RDP) of 1994 and subsequent plans and strategies. This was achieved, taking coverage with an improved drinking water source from 61% to 95% between 1996 and 2013 (DWA, 2013).

The majority of these supplies (50% to 90% of communities served depending on province) have been served from groundwater sources. In terms of volumes, this represents a very small portion of the overall water supplied, but in terms of the national objective of development and the elimination of poverty and inequality, it represents major progress. In general, these local groundwater sources would also be adequate for village subsistence level cropping, critical to the improvement of food security at local scale, for stock watering, and other local productive needs, should there be a policy priority to step up basic water services.

Groundwater is also becoming increasingly important for urban water supply; 22% of towns use groundwater as sole source and another 34% in combination with surface water. Water sources for domestic water supply are shown on the map (Figure 2).

In terms of volumes, commercial irrigation is still by far the largest user of groundwater in South Africa. Like in many other parts of the world, this has mainly happened as a result of private development.

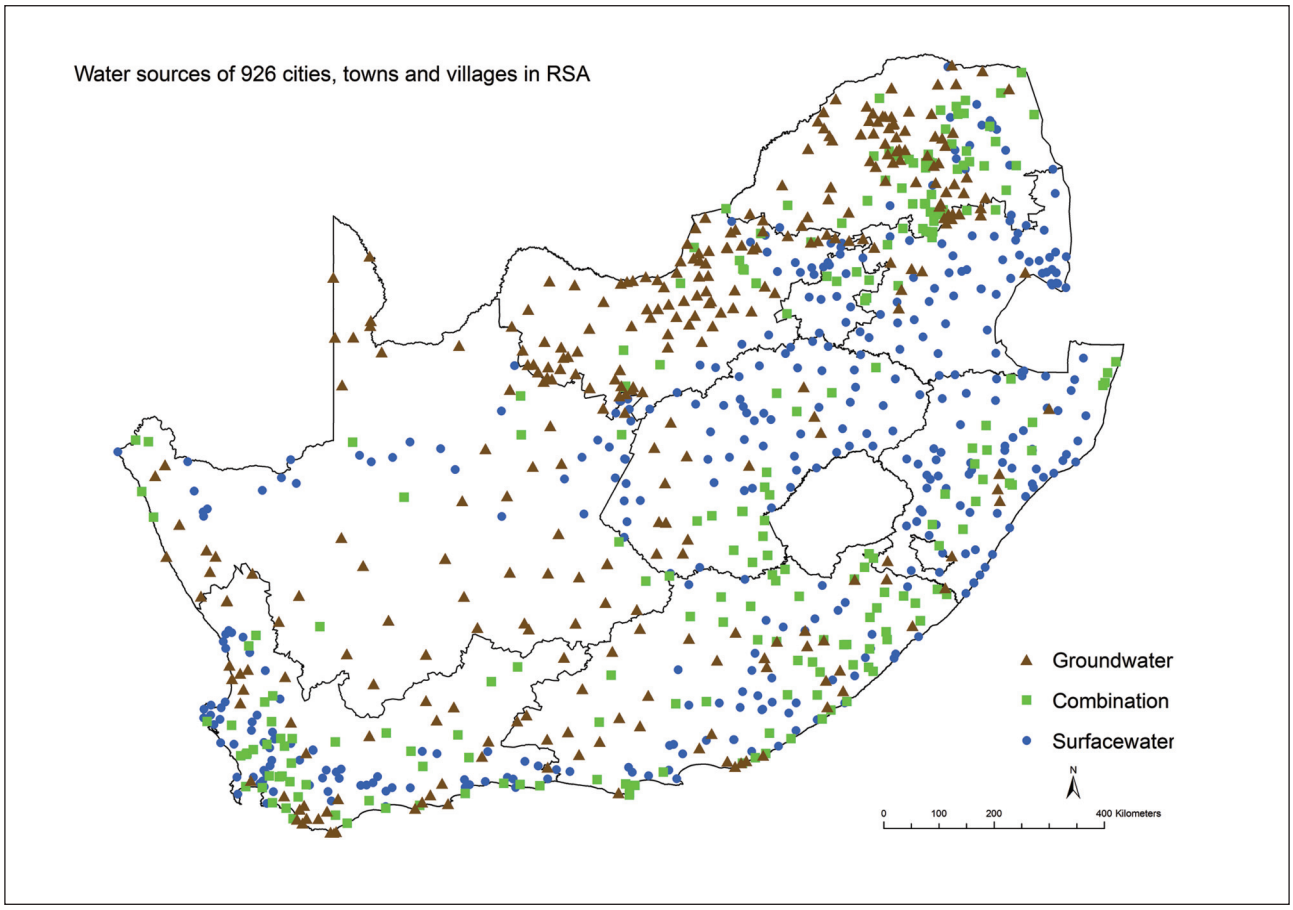

Figure 2. *Water sources for domestic water supply (DWA, 2012).*

The total volume of available, renewable groundwater in South Africa (the utilisable groundwater exploitation potential) is 10 300 million m³/a (or 7 500 million m³/a under drought conditions). Current groundwater use is between 2 000 million m³/a and 4 000 million m³/a. 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, more than 80% of which has already been allocated (DWA, 2010a).

Enabling environment of policies and strategies

The law pertaining to 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. Today, in terms of the National Water Act, 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.

Professor Kader Asmal, who took over as Minister of Water Affairs and Forestry in 1994, initially commissioned an environmental lawyer to help draft a separate chapter on groundwater for the National Water Act, but this approach was not pursued in order to maintain the focus on integrated water resource management in the intended framework legislation. Instead, the Department focused on the development of an appropriate groundwater strategy. The aims of the National Groundwater Strategy, published in 2010 (DWA, 2010), were decided on, following a detailed consultation process with public and private sector stakeholders:

- Groundwater is recognised as an important strategic water resource in South Africa, within an integrated water resource management approach.
- The knowledge and use of groundwater are increased along with the capacity to ensure sustainable management.
- Better groundwater management programmes are developed and implemented at required water resource management levels, tailored to local quantity and quality requirements.

For a strategy to be effective, it needs to be officially linked to the National Water Resource Strategy. This has not yet formally happened. Even though the key groundwater message in the second edition of the National Water Resource Strategy (NWRS 2) (DWA, 2013)

is that "groundwater is important, currently undervalued and under-used", this has not yet resulted in a programmatic roll-out of the Groundwater Strategy. Thus there is presently a bottleneck at the policy and strategy level, which needs to be overcome in order to address some of the unique challenges of groundwater governance in South Africa, to be highlighted in the rest of the paper.

Water resource planning and development

The vision of the National Water Act, 1998 is integrated water resource management. Following the major restructuring of the Department in 2003, groundwater became fully integrated into the water resource planning functions and there are two groundwater specialists in the planning team. This has had tremendous benefits for groundwater resource development and management, including:

- Development of a Departmental Groundwater Strategy and the regular reference to groundwater in the second edition of the National Water Resource Strategy.
- Groundwater is part of the nationwide programme to develop water reconciliation strategies for all towns, villages and clusters of villages across the country since 2008 - the All Town Reconciliation Strategies provided the groundwater potential for each municipality at a local scale and identified possible target aquifers (e.g. DWA, 2011).
- Groundwater staff with opportunity to comment on major municipal projects to be undertaken with government grant funding, e.g. the Municipal Infrastructure Grant (MIG).
- Departmental guidelines prepared, addressing various aspects of sustainable development and management of groundwater resources (e.g. DWAF, 2008 and DWA, 2010b).

Artificial recharge of groundwater, also referred to as managed aquifer recharge, is one of the areas that has received special attention in the form of Departmental strategy and guidelines. However, despite excellent guidance material, a programmatic approach to the implementation of this important strategy is still lacking.

Regulatory measures

The foundation of water management in the National Water Act, 1998 is to regulate water use, which includes both the abstraction and discharge of water, which can make it less useful through pollution.

Water use registration, the first step in the authorisation process, provided the first overall assessment of groundwater use in South Africa. More than 20 000 users were registered, following the registration requirement set for uses of 10 m³/day and more. The total registered volume on the DWS WARMS database was 2 300 million m³/a (DWS, 2014a).

The data given in Table 1 still largely reflect the pre-1994 situation, with private agriculture being by far the largest groundwater user. The true state of groundwater use will only be known when the second step in the authorisation process, namely verification, has taken place. This has progressed slowly in the case of widely distributed groundwater sources and only a few parts of the country have been covered as yet. Importantly, it has led to illegal irrigation being stopped at Tosca (Northern Cape) and Maloney's eye (Gauteng). This had been long overdue and signifies that the Government has made clear its intentions to regulate groundwater use in terms of the National Water Act

Table 1. Registered groundwater users (DWS WARMS database, 2014).

Use sector	Percentage of registered users
Agriculture	79.5
Water services	8.3
Industry	5.2
Other (mainly Schedule 1)	4.2
Mining	2.6
Urban	0.2
Total: 20 269 users	100.0

A general concern is that the issuing of groundwater abstraction licences is taking prohibitively long (5 to 6 years in the case of the small coastal town of Hermanus) and is one of the reasons why municipalities shy away from groundwater. This has partly to do with the scientific processes underlying resource protection, which are largely surface water-focused, and with the lack of groundwater specialist capacity in the regulatory arm of DWS. Groundwater practitioners, recognising the resilience available in groundwater systems, have suggested an adaptive management approach in which a conditional abstraction licence is granted, based on best understanding and a model of the aquifer, which will be reviewed after a specified time of monitoring (Riemann, 2013).

A unique groundwater aspect still requiring regulation is the drilling of boreholes. Much of the success and sustainability of groundwater schemes rests with the groundwater infrastructure, in particular the borehole itself, the installed casing, screens and pump equipment, as well as the finish around the borehole (sealing, water runoff, etc.) An estimated 80 000 to 100 000 boreholes are drilled annually. It would also be of great benefit to have this information generally available on a national database. Such regulation of drillers had already been proposed at the time of writing the National Water Act, 1998, but it was felt at the time that the critically important registration of water use was a major task and should receive priority, whereas the more detailed aspect of borehole registration should only follow afterwards. Significantly, the Borehole Water Association of Southern Africa (BWA) already in 1996 followed up their general guidelines "A Minimum Code of Practice for Borehole Construction and Pump Installation" with a project to have SABS Standards for

borehole construction, based on their guidelines (SABS, 2003).

Resource protection

Resource degradation through pollution of underlying groundwater is widespread in Africa in both urban and rural areas (Xu and Usher, 2006). This is because of its invisible nature - it takes a long time to notice when it has become polluted and, unlike surface water, it has limited ability to purify itself. Thus, already in 2000, the Department published a groundwater quality protection strategy, focusing on three main functional areas, namely source-directed measures, resource-directed measures and remediation measures (DWAF, 2000).

This widely consulted strategy has been lying dormant since then. The scientifically challenging and information-intensive resource-directed measures, introduced in the National Water Act, have been the regulator's resource protection focus to date, and in particular the requirement of a Reserve determination as part of any water-use licence application. While this is obviously crucial for the long-term protection of the water environment, the more than 1 000 Groundwater Reserves that have been determined to date, have served little purpose towards the protection of the groundwater resource itself. The process of resource classification and the setting of resource quality objectives, which are seen as the foundation for systematic groundwater resource protection, has only just started, e.g. in the Olifants/ Doring and Komati Catchments.

Fortunately, some source-directed actions have come about through legislation other than the National Water Act. The National Environmental Management Act, 1998 (NEMA) has been a crucial instrument for preventing or minimising various forms of high impact on groundwater, e.g. from coal mining and from petrol filling stations.

Still completely missing in South Africa's groundwater quality protection initiatives and strongly stressed in the Departmental strategy of 2000, is a programme of special protection of vulnerable groundwater sources supplying domestic water to communities. Proactive protection of groundwater sources has become a standard practice in many parts of the world. It is also essential in South Africa in order to safeguard human health and to maintain the major groundwater infrastructure benefit that has been created. The approach was first suggested in South Africa in the 1990s (Jolly and Reynders, 1993), followed by unique work to develop appropriate zoning methodology for South Africa's predominantly hard-rock aquifers with tracer experiments at the Campus Test Site of the University of the Free State in Bloemfontein (Xu, 1998) and more recently in the Western Cape (Nel et al., 2014).

Water resource information management

Already in 1998, a new era of groundwater resource information was foreseen, with the emphasis changing from a groundwater exploration and resource assessment focus to a sustainable development focus, requiring a much improved understanding of the hydrological systems, especially at the interface with terrestrial ecosystems, with the hydrologist becoming the manager of the hydrological cycle and the educator and supporter of hundreds of local groundwater stakeholders (Braune and Reynders, 1998).

The mission of the Department's groundwater mapping strategy – "to achieve confidence in the use of groundwater and for groundwater to be an integral and correctly managed part of the water resources of the country" – reflects this changed focus (DWAF, 1992).

The foundation for the groundwater mapping work was already laid in 1986, with the help of the Water Research Commission, through the establishment of the National Groundwater Database at the Department of Water Affairs and Forestry. By the time the National Water Act of 1998 explicitly required the establishment of a water resource information system and regular monitoring and assessment of resources, a national assessment (aspects like borehole prospects, mean annual groundwater recharge, water quality and groundwater component of river flow) had already been completed (Vegter, 1995) and work was underway on a new generation National Groundwater Information System, GIS-based and with stand-alone capability, in each of the nine regions. In parallel, the Department completed their part of the national assessment in 2003 through the publication of a series of 21 hydrogeological maps covering the country at a scale of 1:500 000.

This information was immediately incorporated in a major revision of the Water Resources of South Africa, 2005 study (WR2005), which in the past had played a major role in providing key hydrological information to water resource managers, planners, designers, researchers and decision-makers throughout South Africa and had never included groundwater.

Apart from improved static information on the resource, the country now also needs much more widespread dynamic resource information, in particular groundwater abstraction, groundwater level and quality changes, and a much greater integration of groundwater and surface water monitoring. The map of national groundwater level monitoring stations still shows large blank areas, while investment in groundwater monitoring is about 15% of that for the surface water network (DWAF, 2004a).

Information management will become a strategic requirement to transform water management in South Africa from a highly centralised to a strongly devolved and participative approach. This is particularly important for groundwater governance – "national facilitation of local actions". A rapidly increasing number of stakeholders at all levels will have to provide groundwater data and will need information support. A groundwater information system must lead and maintain this entire process, created and sustained by vision and commitment and anchored in legislation. Some critical success factors of the system will be:

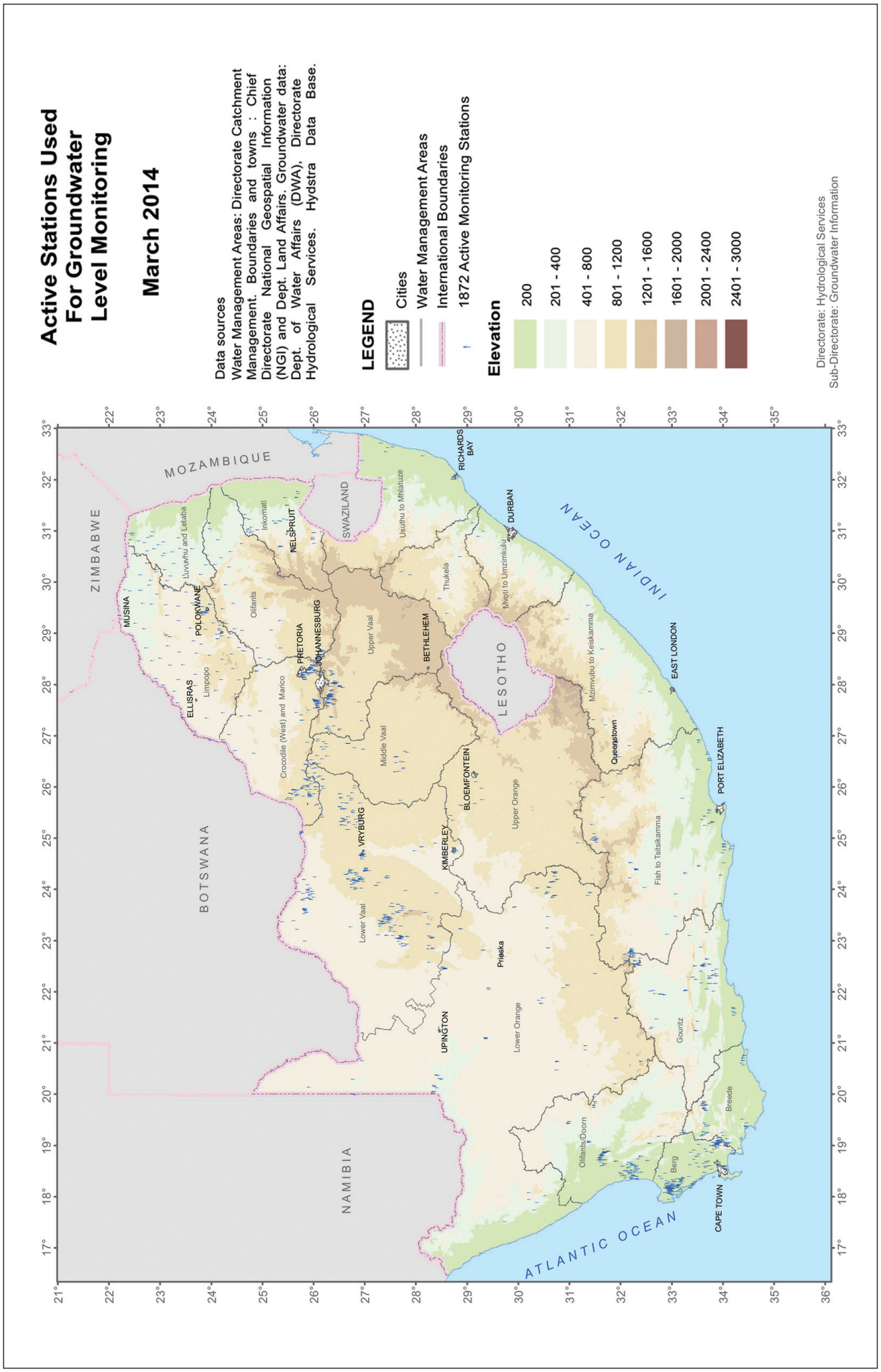

Figure 3. *National groundwater monitoring stations (DWS, 2014b).*

- Dynamic system (continuously updated and adapted)
- Participative and client-driven
- Appropriate technology to achieve participation and effectiveness
- Central direction, coordination and maintenance; and
- Openness to all.

A research project could be considered in which the expected flow of data and information from and to different stakeholders and levels is analysed to arrive at a streamlined flow of information and appropriate processes/systems to manage it.

Local level management

Groundwater governance requires local action and a high degree of participative management. This was certainly the intention of the National Water Act, 1998 in its principle of "devolution of management as far down as possible, so that everyone can participate". This is in keeping with the ideas of integrated water resource management (IWRM). Local level water management must also be integrated with local, regional and national spatial and environmental planning more generally – although too often various issues such as water supply, housing, transport and economic opportunity are still being considered in isolation.

Appropriate local action has become crucially important at this time in South Africa, because the most strategically important groundwater service, that of domestic water supply, is being very poorly managed at the local level. A key reason for this problem is that the intended devolution of water resource management to catchment management agencies (CMAs) and supporting management institutions, in particular water user associations (WUAs), has not yet taken place in any significant way. Inexperienced and non-capacitated municipalities, already struggling with their supply function, also have to develop and manage their local groundwater resources, without comprehensive direction,control and support from national government.

South Africa has made tremendous progress in providing safe drinking water to its citizens since 1994. The White Paper on Water and Sanitation, released in November 1994, had emphasised the political importance of a speedy delivery of water and sanitation services, ensuring that all South Africans can have access to basic water supply and sanitation services (DWAF, 2004b). Once wall-to-wall local government came into being in 2000, the responsibility for managing thousands of groundwater schemes was transferred from DWA and from community management structures, in the case of the former homelands, to newly established municipal administrations.

Since then there have been many reports of scheme failure, starting with the much publicised Dinokana in 2004 and Delmas in 2005. Overall figures of the performance of groundwater schemes are not available, because as yet not enough attention is being paid to compliance monitoring. Most of the smaller groundwater supply systems are not covered by the Blue Drop reporting system.

The available evidence suggests that the reasons for this situation have less to do with hydrogeology and aquifer yields than with the operational requirements of sound groundwater management. Operational management requirements are comparatively straightforward, but they do require attention to logistical detail, and this requirement exposes vulnerabilities in the institutional capacity of many water services providers.

Still completely missing at local level is some form of regulation and organisation of local users of a shared groundwater resource, which is generally seen as essential for the sustainable development of the resource. The Act now provides for local level organisation through the institution of a WUA. This could lead to mutual support in monitoring, assessing, conserving and optimally using the shared resource. Own experience in a few instances in South Africa, e.g. Dendron, Steenkoppies and Sandveld, has shown that this needs long-term support in terms of the institutional processes required to establish a WUA, the proper assessment of the resource in terms of boundaries and potential, and the establishment of monitoring and information systems for ongoing management (Pietersen et al., 2011). The national department has not been able to sustain such support in most instances. WUAs have proved arduous to set up, with a variety of requirements that only the best motivated local groups have been able to meet. In other cases, such as Dendron, groundwater management is de facto carried out privately, with little involvement from local or national government.

In the case of remote rural areas, the logistical challenges of groundwater services far outweigh the technical challenges. Here international experience has shown that a sustainable water service cannot be obtained without some form of community-based operation. This approach has never taken off in South Africa, despite having been successfully piloted in two Eastern Cape Districts, namely the Alfred Nzo District Municipality with 144 villages and 27 000 households served, and the Chris Hani District Municipality with almost double the number of households served (Gibson, 2010). Again, the experience of developing countries has also shown that this type of operation will fail unless it is appropriately supported from outside.

Thus, despite the raised profile at a national planning level, experience on the ground indicates that many municipalities only turn to groundwater as a last resort. It is perceived by many (if not most) municipal role-players and communities as an unreliable and difficult source to manage, and they have a marked preference for surface water sources – ideally with bulk potable water supplied by a water board. Vital operation and maintenance continues to be neglected in planning and budgeting at municipal level. Also, there is a lack of skilled technicians and other O&M specialists, particularly in small towns and remote rural areas where

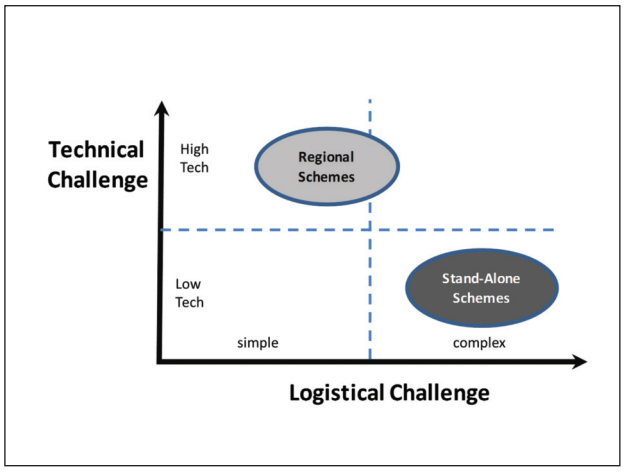

Figure 4. *Technical vs. logistical challenges (Gibson, 2011).*

many groundwater schemes are located (Cobbing et al., 2013).

South Africa has done well in the provision of groundwater infrastructure. Now it needs to invest equally into its operation and maintenance. A recent cost-benefit study of groundwater supplies for rural areas in developing countries found that (Whinnery, 2012):

- Almost 40 times more benefit, than cost, is provided with a properly constructed, operated and maintained well-system.
- A 3- to 5-fold increase in net value is realised with the implementation of an operation and maintenance (O&M) programme.

What can be achieved has been demonstrated in a few cases through persistence of the private sector in a support role to local government. The coastal town of Hermanus has employed professional groundwater expertise from the private sector since 2002 to support the planning, development and operation of its three well fields. Systematic monitoring of groundwater quantity and quality is undertaken, which is providing input to an aquifer management model as well as to a widely representative monitoring committee. This thorough and transparent approach has created trust in the hidden resource among residents and other stakeholders and can serve as an example to other municipalities (Water Wheel, 2013). It remains to be seen whether the successes associated with a relatively well resourced and responsive municipality, close to centres of groundwater expertise, can be replicated elsewhere.

National government, including the Department of Water and Sanitation, have responded to some of the challenges inherent in local water governance and the roll-out of local and regional organisations for water management in several ways. For example, the original 19 proposed WMAs have been reduced and consolidated into nine. New funding structures (such as MWIG) promise higher levels of DWS expertise and involvement in local government water schemes. DWS is also currently reviewing all of its water monitoring networks (including groundwater) in order to streamline and optimise these.

There is a great need to build the capacity of local government for this important task through appropriate guidelines, planning and financing procedures, local institution building, performance monitoring and above all, professional support as long as required, from national government and through an appropriately empowered private sector.

Research and capacity development

Overall, the country has an excellent capacity in the groundwater resource field. Many new groundwater consulting firms have been established throughout South Africa during the past 20 years. There is a strong core of professionals with hydrogeology and technical expertise, well-coordinated and represented by the Ground Water Division of the Geological Society of South Africa. Appropriate academic institutions have been established and wide-ranging research has been undertaken for 40 years and more. The then Geological Survey (now Council for Geosciences), the Department of Water Affairs (now Water and Sanitation), the Water Research Commission and the CSIR, among others, have all been major role-players at different points in time.

The scope and depth of groundwater research was highlighted recently in a glossy document for a wide range of stakeholders under the headings (WRC, 2013):

- Groundwater management
- Pollution and the environment
- Exploration, characterisation and development.

The initial research focus was on resource characterisation and groundwater technology. Since 2000 a greater resource management focus within an integrated water resource management framework was added to the WRC research portfolio. The WRC's investment in groundwater research has, in all probability, been the most significant contribution to the building of capacity for the sustainable utilisation and management of groundwater resources in South Africa. Funding for groundwater projects has varied between 6% and 16% of the WRC's annual research spending. In 2012, more than R5 million was invested in groundwater projects, with another R2.8 million in 2013 (Adams, 2013).

On the academic front, first negotiations between the University of the Free State and the then Minister of Water Affairs and Forestry on the establishment of an Institute for Groundwater Studies (IGS) already started in 1973. Almost 20 years later, with the re-opening of the global science world to South Africa, a UNESCO Chair in Groundwater was created at the University of the Western Cape to serve the southern African region with groundwater expertise.

Approximately 600 students graduated in the past ten years from these two institutions alone, 127 with a Masters or Ph.D. (Braune et al., 2010). Approximately

70% of these post-graduate qualifications were achieved through a WRC-funded research project. The WRC also supports several other universities (e.g. Fort Hare, Venda, Pretoria, KwaZulu-Natal, Nelson Mandela Metropolitan, North West and Witwatersrand), science councils, NGOs and consulting firms. Through the academic institutions that have developed and that have had the benefit of this research investment, a significant human resource development impact has been achieved nationally, in the southern African region and on the continent as a whole.

The CSIR has been active in groundwater research and development since the 1970s. They were able to undertake significant multidisciplinary work, because of the many different technical competencies and excellent laboratory infrastructure within the organisation. The Council for Geoscience is in a unique position through its huge geological knowledge base and expertise and the established branch offices of the organisation to support the increasingly decentralised water management and be a partner in specialised groundwater research.

This overall groundwater research and development capacity also plays a major regional role in southern Africa and wider. At this stage, there are only about three other institutions in SADC outside South Africa, which have groundwater R&D and teaching capacity. The newly established SADC Groundwater Management Institute will be hosted at the Institute of Groundwater Studies on the University of the Free State campus.

At this point in time, the capacity challenge in South Africa lies at the institutional level. Lack of appropriate capacity in critical stakeholders, in particular national and local government, is regarded by many as the most important factor holding back sustainable development and management of groundwater resources in South Africa. The public sector in general has great difficulty in retaining skilled experienced specialists and technical managers. Most of the professional capacity in South Africa is located outside the public sector and will remain so.

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. It is clear that local government, which has the devolved water services responsibility, is presently unable to meet its objectives, including the achievement of the Millennium Development goals (MDGs) with respect to water and sanitation delivery, because of a complete lack of capacity for the sustainable utilisation and management of local groundwater resources.

Serious capacity shortcomings in the then national Department of Water Affairs (DWA) were pointed out in a submission by the groundwater sector, represented by the Groundwater Division of the Geological Society to the Parliamentary Portfolio Committee on Water Affairs and Forestry during their Review of the National Water Act (Groundwater Division, 2008). "An inability to implement the National Water Act, as a result of a lack of sufficient skilled and experienced staff, prevents groundwater from being used productively and sustainably to promote economic growth and social upliftment." The national leadership and internal championing role of a Directorate Geohydrology was lost during a major Departmental restructuring in 2003 to achieve integration of groundwater into all water resource management functions.

Excellent guidelines already exist, virtually for all areas of groundwater resource management, either developed through the national department or with the support of the WRC; for example, for the proper valuation of groundwater resources, for groundwater infrastructure development, for borehole field operation and maintenance, for groundwater quality management and for groundwater institutional development. The Water Research Commission has now helped design a Groundwater Management Framework (GMF) to become an overarching guideline for this existing guidance material in order to guide and improve management of groundwater resources at local level (Riemann et al., 2011).

Outlook for groundwater governance in South Africa

There have been dramatic changes for groundwater resource development and management since South Africa's transition to democracy in 1994 and landmark water sector reforms. Groundwater became the main source of supply in the major community water supply drive in which approximately 27 million people in South Africa had gained access to an improved water supply by 2013.

The strategic role of groundwater was also recognised in policy and strategy. With the promulgation of the National Water Act, 1998, groundwater lost its previous status of private water and became public water. The Act sees water as an indivisible national resource (rivers, streams, dams, and groundwater) and all the rules about the way in which the water resource is protected, used, developed, conserved, managed and controlled in an integrated manner, now also apply to groundwater.

Registration of all water uses in terms of the National Water Act, including groundwater, has for the first time provided a country-wide picture of groundwater use per economic sector. At the same time national hydrogeological mapping and assessment programmes have provided readily available and understandable country-wide information about groundwater occurrence and development potential.

Understanding of the role of groundwater has improved greatly by bringing hydrogeological expertise into the national planning function and introducing groundwater into planning at all levels from national/strategic level to local feasibility studies. The second edition of the National Water Resource Strategy sees development of local groundwater resources as the water supply option of choice,

following water conservation and demand management measures.

Progress with the new regulation of groundwater resources has, however, been slow and not focused on priority groundwater issues. This is largely because the unique characteristics of groundwater are not adequately addressed in the surface water-focused management instruments for protection of the resource.

Continuity in groundwater research has played a major role in creating the knowledge base, the management instruments and the human capacity required to address the challenges resulting from the changed role and the integrated resource management environment for groundwater in South Africa.

A major concern is that, despite the raised profile of groundwater at a national planning level, the management of local groundwater schemes by municipalities is generally poor and many municipalities only turn to groundwater as a last resort. The problem is one of lack of capacity in municipalities as well as lack of systematic support and regulation, where necessary, from national government. A key reason for this situation is that the devolution of water resource management, foreseen in the National Water Act, to CMAs and WUAs, has for all practical purposes not yet happened. This is serious because the major achievements of infrastructure development are at risk of being undone and the image of strategically important groundwater resources could be tarnished.

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. Already in 2008 it had been reported to the Parliamentary Portfolio Committee on Water Affairs and Forestry that a lack of sufficiently skilled and experienced staff in the Department had led to an inability to implement the National Water Act. The national leadership and internal championing role of a Directorate Geohydrology had been lost during a major Departmental restructuring in 2003 to achieve integration of groundwater into all water resource management functions. This is in addition to the general problem the public sector has in retaining skilled experienced specialists and technical managers.

The turn-around of this situation needs to be addressed strategically and at many different fronts. It cannot wait for the establishment of catchment management agencies. The geohydrological capacity and leadership function within the Department of Water and Sanitation will have to be recreated, both nationally and in the regions, in order to lead the various thrusts.

Systematic implementation of the Groundwater Strategy, anchored in national strategy, could form the basis for the roll-out of the various thrusts. Much more attention would have to be given to human and institutional capacity development at the strategic and water resource planning levels.

Improved technical management of groundwater will need to be anchored in appropriate regulations to address the unique protection, information management and human resource requirements for good governance of groundwater resources.

Urgent attention will need to be given to building the institutional capacity for local level groundwater resource management and the municipal groundwater supply services. The establishment of WUAs will need to be promoted and facilitated to achieve sustainable institutions, wherever significant groundwater resources are shared by potentially competing users.

Groundwater governance requirements can be expected to become more and more stringent. Many factors point to a growing reliance on groundwater sources; planners are increasingly relying on groundwater to meet the rising demand. Groundwater is likely to play an even greater role for human survival and economic development under changing climatic conditions, as it provides a cushion against drought and uncertainty in surface water availability. With issues like unconventional gas mining, including hydraulic fracturing, managing of mine closures throughout the country, development of deep groundwater sources, and protection of groundwater sources from increasing surface development pressures, groundwater governance will move from the local into the national arena.

Future research will focus more on improving and quantifying uncertainty in groundwater resource assessments as well as quantifying the risks associated with land-based activities on known and unknown aquifer systems. The integration of groundwater hydrology with other disciplines will be key in meeting the sustainable development goals and in mitigating climate change and variability.

Overall, adequate groundwater capacity is available in the country in terms of guidelines, education and training, research and development and groundwater human resources. This needs to be focused on in the roll-out of a national groundwater strategy and at the local level of management, in synergy with IWRM institutions and processes already in place. New partnership ways will have to be found to harness the capacity of the private sector and the academic sector in this turn-around towards the national objective of good groundwater governance.

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