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Groundwater Governance: The Case of the Grootfontein Aquifer at Mahikeng, South Africa

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ABSTRACT: This research investigates the case of the Grootfontein Aquifer at Mahikeng. The main aim is to understand why, despite well-established capacity in hydrogeology and progressive groundwater governance rules and practices, groundwater management continues to be poor, with significant deleterious outcomes now and likely in the future. A combination of hydrogeological and institutional analysis reveals a complex set of institutional issues that has inhibited the outcomes anticipated in South African water legislation. The research identifies why conditions are unfavourable for the self-organisation anticipated in the groundwater governance approach that was adopted after 1994, and why actions by specific problem-solving actors are fundamental to the success of this approach. These findings illuminate approaches to economic development that have occurred within the larger public policy context in South Africa since 1994 and find that this has implications for the wider developmental agenda and the political-economic role of the modern African state.

KEYWORDS: Groundwater governance, hydrogeology, Grootfontein Aquifer, common-pool resource, South Africa

INTRODUCTION

After the African National Congress (ANC) won South Africa's first democratic election in April 1994, the new government focussed on the reconstruction and transformation of the South African economy. Authority over groundwater access and use was given particular attention. Water access, and the associated benefits of irrigation, recreation, and industrial use, had been linked to land ownership. As a result, these benefits accrued predominantly to white South Africans. The new legislative framework sought to address this inequity by vesting ownership of the nation's water resource in the state (Lazarus, 1998). A progressive, redistributive agenda was set out in the Constitution of South Africa, in the Water Services Act of 1997 (RSA, 1997), and in the National Water Act of 1998 (RSA, 1998). The purpose of the legislation was to both address equity issues and to promote sustainable use of the resource. However, the outcomes anticipated by the new policies have sometimes failed to materialise. One such instance concerns the water supply to the city of Mahikeng in North West Province, South Africa.

At the time of this political transition, one of the major sources of water supply for Mahikeng, the Grootfontein Aquifer, had been under pressure for some time. The purpose of this research is to examine why the situation with respect to this important component of Mahikeng's water supply has continued to deteriorate since 1994. This is an increasingly relevant policy concern, as in recent years there has been conflict and contestation about access and use of the resource in and around Mahikeng. Communities have engaged in service delivery protests, frequently over inadequate water supplies, and the business community in Mahikeng, many of whom have strong linkages to the agricultural sector,

are concerned about the implications of uncertain supply for the future of their businesses (Daily Maverick, 2014; News24, 2017; Mail and Guardian, 2017). Growing uncertainty related to climate change is likely to amplify these concerns.

This paper begins with a description of the water supply to Mahikeng and the long-standing trade-offs in the use of the aquifer. It provides an overview of what is known about the Grootfontein Aquifer, including its rate of recharge. Research undertaken between 2012 to 2015 considers three hypotheses put forward with respect to why the Grootfontein Aquifer continues to fail. The first of these is that the situation is a function of unknown (and possibly unknowable) characteristics of the resource. The second is that there is an absence of capacity or capabilities for hydrogeological analysis and policy-making to support sustainable use of the resource. The third hypothesis, which is that changes to organisational forms could support improved use, is given closer scrutiny. Given the contribution by Ostrom (2005) to the analysis of the governance of common pool resources, the research examines the case against Ostrom's theory of necessary conditions or attributes. A core finding is that the conditions or attributes necessary to underpin the groundwater management approach provided for in the legislation are absent in this case. This has implications for resource management policy and practice in South Africa.

THE WATER SUPPLY TO MAHIKENG

The city of Mahikeng (previously known as Mafikeng and historically as Mafeking) is the capital of North West Province and the seat of both Ngaka Modiri Molema District Municipality and Mahikeng Local Municipality (Figure 1). It has a population of about 70,000 people and the surrounding peri-urban areas are home to another 170,000 people. It is located close to South Africa's border with Botswana, and is approximately 1400 km northeast of Cape Town, and 260 km west of South Africa's capital city, Pretoria. First settled by the Barolong people, Mahikeng is a site of strategic importance and settlement. The Siege of Mafeking was a defining conflict of the second Anglo-Boer war (1899-1902), a war between Boer settlers and Britain over possession of land and control of the areas that would become modern South Africa after the creation of the Union of South Africa in 1910. Mahikeng was connected to South Africa's national rail infrastructure in the early twentieth century, and was the capital of the Bechuanaland Protectorate in the first half of the twentieth century. A significant part of the city, an area called Mmabatho, was designated the capital of the 'homeland' of Bophuthatswana a few years after the Bantustan was created in 1977. In 1994, Bophuthatswana was reincorporated into South Africa, and Mafikeng was made the capital of the new North-West Province. The city was renamed Mahikeng in 2010.

Today, urban Mahikeng requires about 18.3 Mm^3/y (million cubic metres per annum) of water. This water comes from three sources: a large spring about 40 km east of the city called the Molopo Eye (about 7.3 Mm^3/y or 40%); a well field in the Grootfontein Aquifer about 20 km to the south-east (about 3.7 Mm^3/y or 20%); and the Setumo Dam on the Molopo River to the west (another 7.3 Mm^3/y or 40%) (Figure 2).

Mahikeng is the most important South African city to rely so extensively on groundwater. Furthermore, the peri-urban areas surrounding Mahikeng are almost completely groundwater dependent, mainly from smaller stand-alone boreholes not connected to urban Mahikeng's supply.

The Molopo Eye spring and the Grootfontein Aquifer are located in the North-West dolomites, a series of extensive and prolific aquifers that are amongst South Africa's most important groundwater resources (Meyer, 2012). It is estimated that the North-West dolomites together contain a similar volume of water to South Africa's largest dam, the Gariep Dam (roughly 5000 Mm^3), and that the aquifers are currently recharged at a rate of around 300 Mm^3/y (Stephens and Bredenkamp, 2002).

Figure 1. Location of Mahikeng.

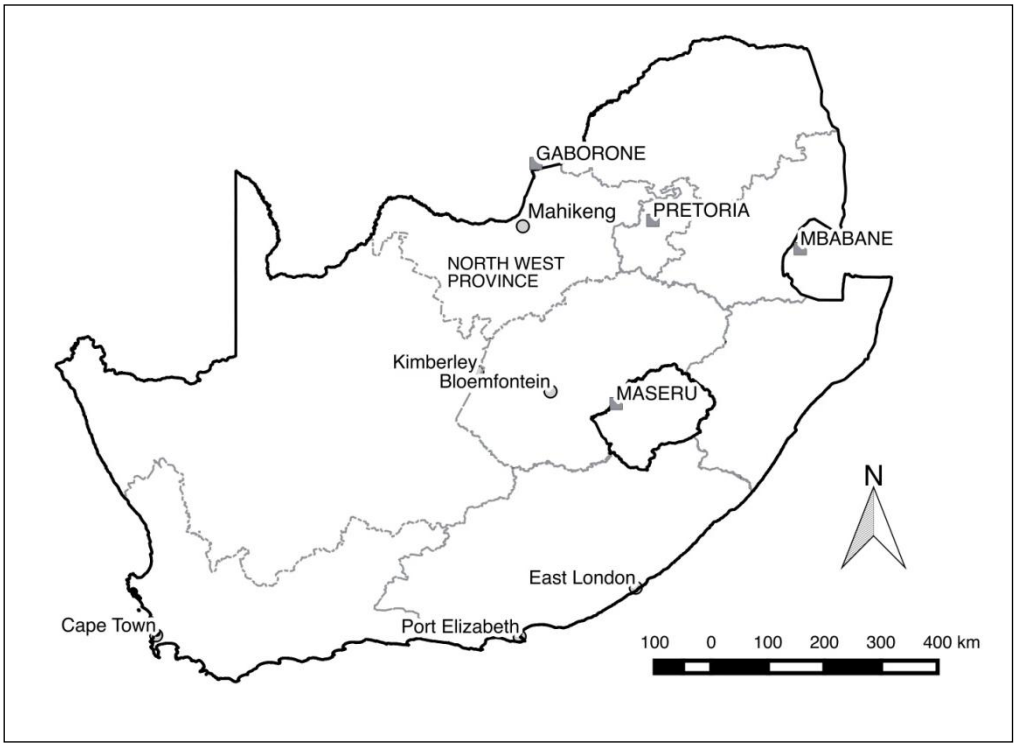
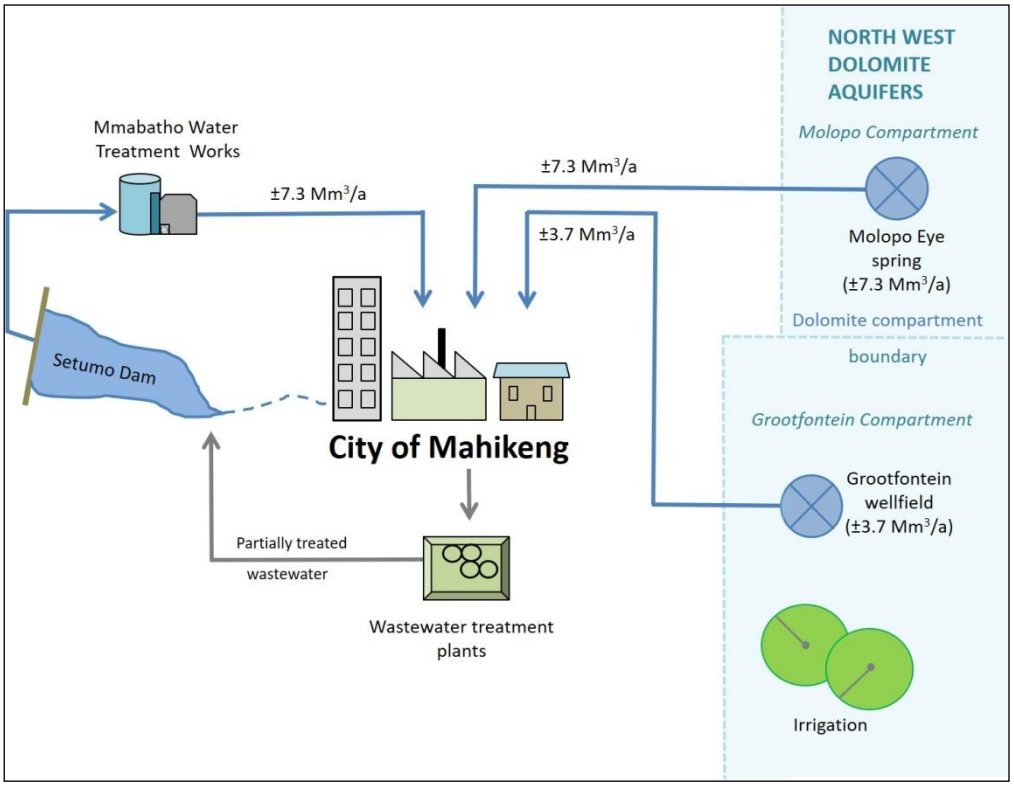


Figure 2. The water supply to Mahikeng.



The North-West dolomites cover about 5000 km^2 in total but are not a single continuous aquifer. They are divided into a patchwork quilt of semi-autonomous aquifers or 'compartments' by igneous dykes, contacts with adjacent rocks, and other relatively well-defined geological and geomorphological features (Meyer, 2012; Holland and Wiegmans, 2009). Under natural conditions, recharge into each compartment via rainfall is balanced by discharge to springs and wetlands, and by evapotranspiration. These compartments are a basis for groundwater assessment and management. Many of the compartments support extensive irrigated agriculture, depending on overlying soil conditions. This irrigation ranges from large tracts of maize to higher value vegetable and cut flower cultivation. The aquifers are also the mainstay of domestic water supply to numerous other towns in the region such as Itsoseng, Lichtenburg, Ottoshoop, Ventersdorp and Zeerust.

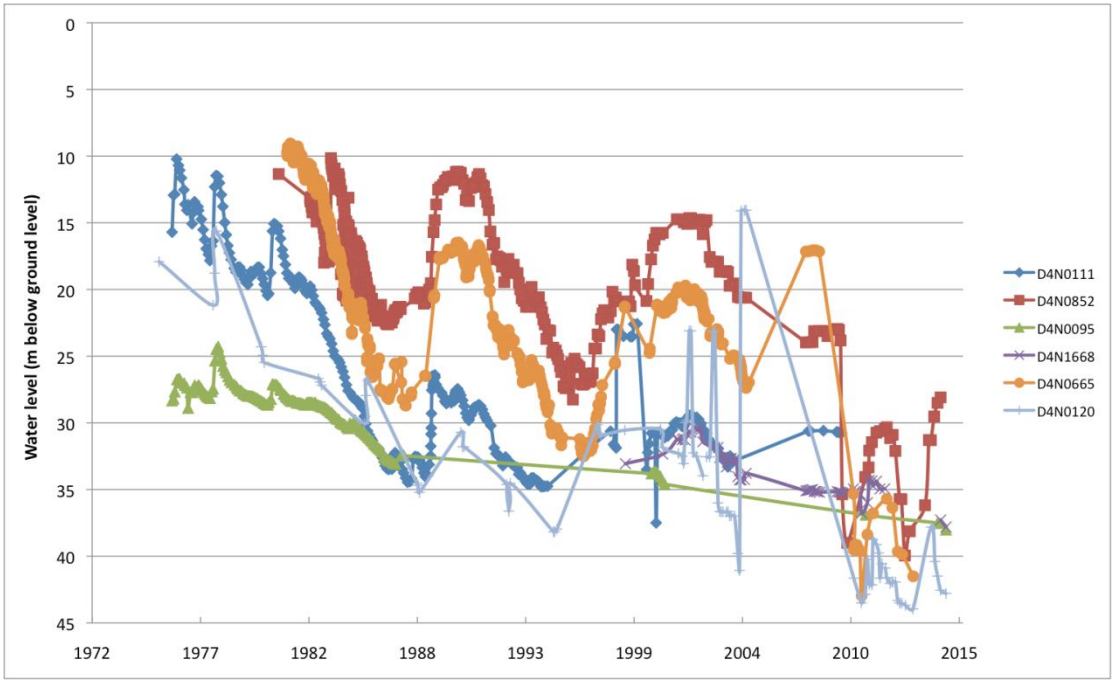
The Molopo Eye and the Grootfontein Aquifer are in separate compartments, and are not thought to be hydraulically linked (Holland and Wiegmans, 2009). The Molopo Eye spring drains the Molopo Compartment, which has poor soils and is characterised by low irrigation demand. This has helped to preserve the Molopo Eye spring from the effects of over-abstraction, and as a result, it continues to flow and yield a significant part of Mahikeng's water. The Grootfontein well field is situated in the Grootfontein compartment which has fertile soils and numerous centre-pivot irrigation systems pumping groundwater. In general, the Molopo Eye and the Grootfontein well field supply excellent quality water, needing only precautionary chlorination before being put into public supply (Cobbing, 2017). In marked contrast, the Setumo Dam is polluted (it is eutrophic, with algal blooms), as it relies partly on semi-treated wastewater return flows from the town. Water from this dam requires a relatively complex series of treatment steps at the Mmabatho Water Treatment Works to treat it to South African drinking water standards (DWS, 2014b).

The Grootfontein Aquifer covers an area of about 240 km^2, has an average thickness of about 50 m, and is recharged at a rate of between about 4% and 8% of the average annual rainfall of 560 mm – roughly equivalent to between 5 and 10 Mm^3/y (Cobbing, 2018). Transmissivities in this karstic dolomite aquifer are as high as 23,000 m^2/d, and specific yields vary from about 1% to 14% across the aquifer (van Tonder et al., 1986).

The Grootfontein Aquifer used to be naturally drained by a large spring, known as the Grootfontein ('great spring'), and by evaporation from areas of wetland, since groundwater levels were originally at the surface in the northern parts of the aquifer. The availability of this resource was a major reason for settlement in this area from the late 19th century. In the 1960s, rural electrification and the availability of affordable pumps and centre-pivot systems, together with growing hydrogeological knowledge, led to a boom in groundwater irrigation through the 1970s and 1980s. At the same time, increasing demand for water from the growing town of Mahikeng led to a series of boreholes for public water supply being drilled around the spring (the well field). These activities together led to a fall in the water table, diminishing the spring's flow. Finally, in 1981, the spring stopped flowing altogether. Nearby wetlands also dried up, for the same reason. Until the mid-1980s, the Grootfontein Aquifer was the city's main water source, supplying more than twice the volume water it does today (DWS, 2014b).

Average groundwater levels in the Grootfontein compartment continued to fall as both irrigating farmers and the city of Mahikeng continued to pump water from the aquifer. The groundwater level is now more than 28 m below ground level near the old spring (Cobbing, 2017). Episodic recharge and the heterogeneity of the Grootfontein Aquifer complicate the picture, but analysis of records dating from the 1970s show that water levels in the Grootfontein Aquifer have fallen by about 0.4 m/y on average across the compartment (Figure 3, and Cobbing, 2018). One reason why the well field delivers less water today than it did in the past, is that the groundwater level is now too deep for several of the boreholes to reach.

Figure 3. Hydrographs of six groundwater monitoring stations from across the Grootfontein Aquifer (DWS data).



At present, irrigating farmers abstract about 13.6 Mm^3/y, whilst the Grootfontein well field supplying Mahikeng abstracts about 3.7 Mm^3/y (Cobbing, 2018). Other smaller users abstract about another 1.5 Mm^3/a. Since average recharge is a maximum of about 10 Mm^3/y, these figures imply a significant continuing deficit of about 8.8 Mm^3/y (Cobbing, 2018). If a substantial reduction in abstractions (particularly irrigation abstractions) could be agreed, and the water level decline arrested and stabilised, then appropriators would all have greater long-term water supply certainty. This would in turn make the water supply to Mahikeng more reliable, lowering risk and increasing confidence. A stable water level that was closer to ground level would also lower pumping costs, and wear and tear on equipment.

A second advantage of stabilising the water level at Grootfontein relates to the large storage potential of the aquifer. Using a (conservative) average specific yield of 2%, a 1 m average change in the water table of the Grootfontein Aquifer equates to a volume of groundwater of about 50 Mm^3. This is more than double Mahikeng's annual water demand. A stable water level in the aquifer, well above the intakes of pumping boreholes (say within 5 m of the ground surface), would allow a temporary drop in the water table to yield a substantial volume of water during an emergency situation such as a long-term drought or the failure of one of Mahikeng's other water sources. This temporary deficit could be recovered during wetter years, as part of an integrated aquifer management plan. More sophisticated management could use managed aquifer recharge (MAR) to store excess surface water in the aquifer during times of plenty (Murray, 2004).[1] Such an 'insurance policy' is possibly the most valuable of the several advantages of a well-managed Grootfontein Aquifer.

[1] The Molopo Eye spring, or another nearby dolomite compartment, could potentially provide a source of surplus groundwater during wetter years for a MAR system. Use of grey water for MAR would be more complicated since Grootfontein is about 30 km from the water treatment plants at Mahikeng, and there would be concerns about polluting the aquifer.

However, reducing irrigation abstractions from the Grootfontein Aquifer may have considerable implications over the short term. Agriculture continues to be of great importance to the North-West Province, and the provincial government identifies that it contributes 19% of formal employment. It identifies that some 6% of the South African GDP in agriculture are based on the output of North West Province. Maize produced in North-West Province supports South Africa's national food security and exchange rate exposure in trade. Production of sunflowers in the North-West Province accounts for approximately 60% of all oilseeds produced locally. There are also linkages with other sectors because primary by-products of these two commodities support the animal feed manufacturing sector in the form of edible oil and protein meal. Nevertheless, current patterns of water use and agricultural production at Grootfontein are not sustainable.

In addition, the continued over-abstraction situation at Grootfontein is imposing significant and increasing direct costs. There are the immediate and real costs of pumping from greater depths, and of sourcing the town's water increasingly from the polluted Setumo Dam. Falling groundwater levels, a perception that groundwater is inherently limited and unsustainable, and the intractable governance problems have led the city of Mahikeng to invest in upgrades to the Mmabatho treatment works at the Setumo Dam (DWA, 2014a), and to investigate other water supply options (Cobbing, 2017). The upgrades cost more than ZAR33M (about US$2.8M) between 2012 and 2015 (DWS, 2014b), and the recurrent costs of staffing and operating the treatment works are also high. These costs associated with the surface water supply should be set against the much lower costs in terms of infrastructure and operation that characterise the town's groundwater sources, and the relatively small amounts that have been allocated to solving the over-abstraction problems.

Water supply uncertainty is also lowering expectations and increasing costs in the local economy, and further eroding social cohesion. Without assurance of a steady and reliable water supply further investment is less likely, and the value of existing business is reduced. Inequity is deepened as wealthier residents self-insure with their own boreholes, on-site storage, or household reverse-osmosis systems. As a result, they become more detached from the municipal affairs of the city. There are also ecological and amenity costs: declining water tables destroy springs and wetlands and reduce river flows, with difficult to quantify costs related to long-term ecological functioning, tourism, and recreational value. For example, apart from the demise of the Grootfontein spring and wetlands in the early 1980s, springs draining adjacent dolomite compartments (near the towns of Lichtenburg and Polfontein) have also failed following over-abstraction in those compartments. This has led to loss of amenity and other difficult-to-quantify impacts on regional social, economic and ecological systems (Cobbing and de Wit, 2018).

ANALYSIS OF THE CASE

Some combination of the following three hypotheses is often advanced to explain water governance shortcomings South Africa. They are:

1. The *Technical Hypothesis* explains groundwater governance problems as a function of a lack of hydrogeological data and technical expertise. The remedy is further hydrogeological studies to provide information necessary to support governance and decision-making. It is rooted in the notion of water governance as essentially a set of supply-side technical challenges. In the case of the Grootfontein Aquifer there have been calls for better technical knowledge of the dolomites (e.g. Stephens and Bredenkamp, 2002).
2. The *Lack of Capacity Hypothesis* holds that DWS or other organisations mandated to govern groundwater in South Africa do not have the skills, financial resources or staff numbers to tackle groundwater governance problems (e.g. Seward et al., 2015). The remedy is more resources, better training, workshops, and other forms of 'capacity building'. International

development partners as well as state organisations themselves commonly advance this hypothesis (e.g. Xu, 2008).

3. The *Organisation Hypothesis* asserts that the underlying reason for poor groundwater governance is inappropriate formal organisation to support equity and sustainability. This hypothesis partly underpins important water governance paradigms such as IWRM and decentralisation, in which new organisations, or changes in the relationships between organisations, are emphasised. It has driven the periodic restructuring of South African water management organisations (both within and between organisations) in the last quarter century (van Koppen and Schreiner, 2014).

Regarding the first hypothesis, the semi-arid nature of South Africa and resulting reliance on groundwater by many communities, towns and agricultural areas has resulted in a wide awareness of groundwater in South Africa. There has been a long standing economic and strategic interest in ensuring that the water from the dolomites is adequately understood given their importance to farming and urban supply (e.g. RSA, 1977). Regarding Grootfontein, technical questions remain, but in general the aquifer is hydrogeologically adequately understood because it was important as the source of water to the city and to irrigating farmers in the rural areas surrounding Mahikeng. At least 16 of DWS' technical groundwater reports focus on Grootfontein, showing a comparatively high level of technical understanding, and there are several scientific papers, conference proceedings and numerical models that focus on the aquifer (Cobbing, 2018).

Regarding the second, the Department of Water and Sanitation, Ngaka Modiri Molema District Municipality, and Sedibeng Water Board all employ Mahikeng-based engineers and hydrogeologists, and all parties can call on experienced private-sector partners and consultants if necessary. More generally, six or more South African universities provide training in hydrogeology to post-graduate level. South Africa publishes an above-average number of peer-reviewed journal papers in hydrological science, relative to its population. South African achievements in groundwater science include pioneering work in the geophysical siting of boreholes and acclaimed international work in isotope hydrology (Nel, 2013; Braune et al., 2014), and the most comprehensive groundwater databases and groundwater maps on the continent (e.g. the 'General Series' of hydrogeology maps which cover South Africa in a series of 21 map sheets at a scale of 1:500,000, using the standard UNESCO legend).

Regarding the third, several organizational structures (de jure) have been attempted at Grootfontein, including different legal and organisational regimes either side of the 1998 National Water Act. At a national level, the post-1994 system of groundwater governance requires that groundwater abstractions larger than those required for domestic use or basic stock and garden watering (known as 'Schedule 1' use) require licenses, administered by the Department of Water and Sanitation (DWS). This is because groundwater is legally a part of the national water resource and can no longer be 'owned' in the manner that prevailed prior to 1994. Under previous water legislation (the Water Act of 1956), groundwater was deemed private property of the landowner, except for certain designated Groundwater Control Areas, generally areas of unusually high groundwater potential, and with extensive commercial groundwater irrigation. Under the new governance arrangements, the management of bulk and environmental water resources, such as rivers, dams and aquifers, is primarily the responsibility of the Department of Water and Sanitation (DWS), via its national, regional and local offices. The National Water Act also specifies the creation of separate and independent Catchment Management Agencies (CMAs), based on South Africa's 19 river basins, and cutting across provincial and municipal boundaries. The intention of this provision was that groups of interests would form CMAs which would be self-funding and would take over many of the responsibilities of DWS' regional (i.e. provincial) offices.

The legislation also provides for the emergence of Water User Associations (WUAs) – cooperative bodies of local water users who jointly manage a local water resource for their mutual benefit (DWAF,

n.d.). WUAs are empowered to borrow money and enter legal proceedings. They can cover a single sector (e.g. irrigation), or bridge several sectors (e.g. farming, mining, urban water supply). The Minister of Water and Sanitation must formally approve WUA constitutions and boards. Participation and wide consultation are emphasised, with WUA boards ideally representative in race and gender terms of their constituencies. However, changes were made in the late 1990s/early 2000s, and very few groundwater-based WUAs were constituted. The national Department anticipated that the functions of WUAs would be fulfilled by the CMAs, when these latter organisations are established (DWS, 2014a). However, the process of CMA formation has been very slow and a smaller total number of CMAs is envisaged (DWA, 2013). Mahikeng and surrounding areas do not presently have a Catchment Management Agency, nor have any Water User Associations been formed.

Responsibility for domestic water supply in South Africa lies with the local sphere of government. A local municipality (or its overarching district municipality) is designated as a Water Services Authority (WSA), with the duty to ensure "progressively ensure efficient, affordable, economical and sustainable access to water services" (RSA, 1997: 18). Minimum amounts of water are set aside for basic human requirements, and for environmental functioning (collectively known as 'the Reserve'), to which other uses of water are legally subordinate. Basic amounts (the amount varies depending on local policy and context) of safe drinking water are provided free of charge to those who cannot afford to pay (Muller, 2008). WSAs have the power to appoint water services providers and other intermediaries to carry out these duties. In many cases, WSAs enter into contracts with Water Boards to manage bulk water supply, water treatment and other functions. Water Boards are financially self-contained body corporate entities (although they are publicly owned), often with the in-house technical expertise to manage large and complex water supply operations.

APPLICATION OF OSTROM'S ATTRIBUTE APPROACH TO THE CASE

As described, South African legislation requires groundwater abstraction licenses for quantities of water in excess of 'Schedule 1' use (essentially domestic or subsistence agricultural use). Currently, combined irrigation abstraction licenses at Grootfontein significantly exceed the available annual groundwater resource (Cobbing, 2018). To date DWS has been unable or unwilling to verify existing abstractions at Grootfontein,[2] a key step in revising abstractions or enforcing new abstraction regimes in a legally consistent or defensible way. This shortcoming is often attributed to 'capacity' at DWS, but the problem is likely to lie more in operational procedures and chains of accountability within the organization, rather than in more accessible metrics such as budgets or staff qualifications (Cobbing, 2017). However, a second issue is also important to the scope and reach of DWS' authority at Grootfontein, and DWS' failure so far to intervene. This is the implicit legal duty of local-level cooperative organisations to undertake the day-to-day management of water resources, including resolving overdraft. Without detracting from the Minister of Water Affairs' overall responsibility, WUAs were clearly intended to deal with local level issues of over-abstraction and protection. For example, according to DWS the functions of a WUA include "To prevent water from any water resource being wasted", "To protect water resources", and "To prevent any unlawful water use" (DWS, n.d.). These specific tasks are part of the overarching goal of more equitable and representative water governance (i.e. redistribution and restitution).

Combined with the broader decentralisation focus of South African water legislation (Lazarus, 1998), the legal responsibility vested in local level organisations for issues such as over-abstraction has

[2] Verification and validation ('V&V') of water use licenses is said to be a priority at DWS but remains elusive, even for large and potentially polluting uses of water such as mine water abstraction licenses. It is a potentially complex process (particularly if legal action is anticipated), and ideally requires the cooperation of water users.

complicated the division of responsibility between the various tiers of government. Is the enforcement of water licenses primarily DWS' responsibility, or should it be left to local structures? The organisational provisions in the legislation require (and arguably anticipate) cooperation and synergy between local organizations such as WUAs and municipalities, and the district and national offices of DWS. The legislation anticipates, for water, the gains in efficiency and reductions in information asymmetries that are commonly asserted for decentralisation more generally. But the failure of local-level actors to self-organise (exacerbated by DWS' reluctance to approve WUAs, amongst other factors), has meant this key local force for better water governance is absent.

Whilst there is a clear need for DWS to play its part in convening water governance at Grootfontein, the failure of local governance initiatives to coalesce 'naturally' at Grootfontein is also important, since it appears to undermine the expectation of automatic efficiency gains often linked to decentralisation. A measure of local, self-directed cooperative resolution of water disputes is essential – no state in the world has the resources to monitor and enforce every groundwater abstraction license without the broad cooperation of local users. A set of institutional norms that discourages free-riding and other collective action problems, and orients water use in the long-term collective best interest, is implicitly required. Such institutional norms should be nurtured and supported by over-arching laws, and include sanctions for transgressors where necessary. This support exists in South African water law, which vests final responsibility for water governance in the Minister of Water Affairs.

This research has therefore concentrated not only on the formal organisations (those already existing, and those not yet formed such as WUAs and CMAs) governing water, but more importantly on the institutional relationships between them, and within them. In South Africa (as in most other jurisdictions), the institutional norms shared by local water users must mesh with more formal structures, laws and organisations to produce acceptable water governance outcomes. These are two sides of the same coin, and a deficit in either harms water governance.

As the Grootfontein case shows, de jure organisational changes alone do not automatically assure better water governance – indeed, the situation at Grootfontein has worsened since the 1990s. The research revealed that the actual norms and behaviour of the various stakeholders (i.e. their shared institutions) has a pivotal impact on the successful functioning of the organisational forms set out in the legislation. Establishing new organisations is in effect partly a commitment to create new institutions – the new organisations do not in themselves constitute those institutions. In some cases, institutions persist long after the formal organisations designed to curate or promote them have been dissolved.[3] Conversely, new institutions may be propagated within existing organisational structures. In South Africa much debate has focused on organisational forms (and more recently on anticipated new legislative changes), without a similar emphasis on the institutional forms that are present, those that are required, and those that are possible.

Analysis of formal and informal institutions, particularly in a complex governance situation with multiple stakeholders and various tiers of formal organisations, requires an organising conceptual framework. Without a framework the risk of internal bias and other errors rises (Yin, 2009). The political economist Elinor Ostrom (1933-2012) produced a body of influential work on water governance. Her research interests included issues of collective action, equity and trust as these applied to 'common pool' resources such as groundwater (Ostrom, 2002). She gave attention to human institutions, which she defined as "the prescriptions that humans use to organise all forms of repetitive and structured interactions" (Ostrom, 2005: 3).

Ostrom (2005) defined six variables or 'attributes' of the appropriators of common pool resources, which she argued should be present for successful governance. These attributes together "enhance the

[3] Arguably the case at Grootfontein, where abstractions are still dominated by a small number of large irrigators, and norms of behaviour developed under previous legislation persist.

likelihood of appropriators organizing themselves to try to avoid the social losses associated with open access rules that are not yet working well" (Ostrom, 2005: 244). Whilst Ostrom emphasises the institutional attributes of appropriators and the consequent likelihood of self-organisation, the over-arching legal and organisational framework under which such collaboration takes place is also vital.

The six appropriator attributes advanced are (Ostrom, 2005: 244):

1. Salience: Appropriators depend on the resource system for a major portion of their livelihood or the achievement of important social or religious values.
2. Common understanding: Appropriators have a shared image of how the resource system operates and how their actions affect each other and the resource system.
3. Low discount rate: Appropriators use a sufficiently low discount rate in relation to future benefits to be achieved from the resource.
4. Trust and reciprocity: Appropriators trust one another to keep promises and relate to one another with reciprocity.
5. Autonomy: Appropriators are able to determine access and harvesting rules without external authorities countermanding them.
6. Prior organisational experience and local leadership: Appropriators have learned at least minimal skills of organisation and leadership through participation in other local associations or learning about ways that neighbouring groups have organised.

The appropriators at Grootfontein include several groups and organisations with different roles and positions, and varying control and information on the outcomes there. They include:

The *Department of Water and Sanitation (DWS)* operates and manages the well field at Grootfontein, providing the raw bulk water to Sedibeng Water Board. DWS, as legal custodian of the nation's water, is also ultimately responsible for managing the groundwater resource at Grootfontein, addressing poor wastewater treatment in Mahikeng, and monitoring groundwater levels and quality. DWS has a regional office in Mahikeng, a satellite office at the Grootfontein well field, and its main office in Pretoria. DWS also organises local forums designed to facilitate local cooperation between stakeholders, such as Catchment Management Forums and Stakeholder Operating Forums. During the research, DWS was focusing on the establishment of a new Catchment Management Agency (CMA), including practical issues such as which DWS staff would be transferred to the CMA and their anticipated conditions of employment.

Sedibeng Water Board is a large regional water board (more than 700 employees) with considerable technical and financial capacity. It is contracted by the municipalities to supply water in Mahikeng and surrounds, and it has absorbed other smaller water boards in the recent past (including the former Botshelo Water Board in Mahikeng). Sedibeng treats and pumps the water from Mahikeng's two groundwater sources (the Molopo Eye spring and the Grootfontein well field) to bulk storage reservoirs, and it manages the water reticulation system in Mahikeng. It also operates the Mmabatho water treatment works at the Setumo Dam, including a series of upgrades and expansions to this facility (DWS, 2014a). Sedibeng has diverse other responsibilities, including the operation, maintenance and upgrading of numerous rural stand-alone groundwater schemes in the greater Mahikeng area.

Ngaka Modiri Molema District Municipality (NMMDM) and Mahikeng Local Municipality (MLM) are responsible for the billing of consumers and the operation of the town's two wastewater treatment plants (major sources of water for the Setumo Dam). NMMDM is the Water Services Authority (WSA) and contracts with Sedibeng, DWS and others to provide water services. Both municipalities face financial, staffing and planning challenges, and struggle to meet their full responsibilities regarding water supply.

Irrigating farmers are the heaviest users of the Grootfontein groundwater, using it to irrigate crop areas of varying sizes (from about 2 Ha up to about 50 Ha per centre pivot irrigation system). Whilst most commercial farmers are white, and most irrigated farms are relatively sophisticated operations, this appropriator group includes emerging black farmers, tenant farmers, and part-time farmers with a diverse range of commercial and livelihood strategies. In this particular case, it was not always easy to establish who owns land, who farms it, and who makes decisions regarding crop types and irrigation schedules. In some cases, farmers have expanded their choices and managed their risk by ensuring that they have significant off-farm income (e.g. a family member with a job in town). Kinship ties bind some farmers together, facilitating sharing of equipment or consolidation of land parcels. In other cases, adjacent farmers rarely cooperate. Not all of the larger commercial farmers belong to the same agricultural union. Nevertheless, irrigating farmers of all backgrounds share common interests such as crop and electricity prices, government agricultural policy, rainfall, transport, security, labour, and other issues.

It can be shown (see Cobbing, 2017 for a full discussion) that these appropriator groups with a stake in Grootfontein groundwater have none of the 'appropriator attributes' described by Ostrom (2005). For example, not all stakeholders depend on the resource to the same extent (*salience*) and some are more dependent on it than others (*discount rate*).

Stakeholders do not share the same conceptual view of the fractured and hydrogeologically complex dolomite Grootfontein Aquifer (*shared understanding*) – some stakeholders have geological training, others see the aquifer is an essentially finite resource that will inevitably be exhausted. This is exacerbated by the complex karst hydrogeology, episodic recharge, lack of easily accessible water level information, obscure compartment boundaries, and other hydrogeological factors (Cobbing, 2018).

Although the enforcement of existing licences and laws is weak, appropriators cannot act independently of each other (*autonomy*) – for example, Sedibeng Water Board cannot increase its pumping rate because water levels are low, due mainly to pumping by irrigating farmers. Lack of past collaboration contributes to a shortage of *organisational experience and leadership*.

Finally, *trust and reciprocity* were at low levels and falling when fieldwork was conducted in 2015. For example, the division of responsibilities between the two municipalities and DWS is contested. In May 2015 a former DWS employee stated:

> Ngaka Modiri and us was in a big, big, big, big fight, until the management or the board or the council, and the top management, was dissolved by the Minister of, of Local Government. They were fired, all of them, new councillors were there, um, were elected, and up til now there's only administrators for more than a year now, about one year (Source: DWS former employee, June 2015).

A farmer in the area, referring to the relationship between farmers and DWS, said:

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

Yet officials at DWS do not feel they have a clear legal mandate to constrain irrigation abstractions, a situation exacerbated by lack of clarity on when or how new organisations such as the CMAs or WUAs will emerge, and on where the responsibility for reducing abstractions should fall. For example, a DWS groundwater specialist stated:

> Ja, it would be easy if you confront the guy and say but your water use [is] unauthorised please stop, and they do stop… But most of them turn to legal aid and it turns into legal battles, which can last for years… (Source: DWS employee, May 2015).

Interviews conducted in 2015 made it clear that the various appropriators at Grootfontein were not discussing their mutual problem, far less resolving it. The law provides for the creation of WUAs as a

local meeting, forum or grouping attended by stakeholders to advance progress on resolving over-abstraction at Grootfontein. There was no evidence of a forum for such discussions attended by representatives of all the appropriator groups, and addressing over-abstraction at Grootfontein.

In the late 1990s some of the farmers at Grootfontein collaborated towards forming a Grootfontein WUA. This WUA, like other proto-WUAs in the North-West dolomites (e.g. at Groot Marico, at Steenkoppies, and at Lichtenburg), was ultimately not approved by the Minister for Water Affairs. In some cases, this decision followed months or years of preparatory work. Farmer interviewees stated that the reason provided by the Minister was the inadequate attention to race and gender disparities on the proposed WUA boards. Informal discussions with DWS staff confirm that DWS was concerned that the proposed WUAs would replicate the previous race and power structures of the Irrigation Boards, something that the National Water Act of 1998 was specifically designed to address. Today, few if any groundwater WUAs exist in South Africa.

Formal reasons for the de facto cancellation of the WUAs have not been articulated by DWS or in the literature, although the decision is defensible on the grounds that the emerging WUAs might have only consolidated previous power hierarchies. Harder to defend is that no credible local-level alternative to the WUAs has been advanced so far. Interim local organisations (Stakeholder Operating Forums or SOFs, and Catchment Management Forums or CMFs) were established, but these have not attracted wide support in the Grootfontein area, and they are not attended by key stakeholders such as commercial farmers, emerging farmers, farm workers, technical consultants, or town business representatives. They are also administered by relatively junior DWS staff who do not feel they have the mandate to effect substantial changes, and they are not supported by existing hydrogeological expertise at DWS (Cobbing, 2017). The SOFs and CMSs may even inadvertently retard other local water governance initiatives, since they superficially appear to be a credible forum for local participation. Any future attempt to constitute a local users' association would have to overcome this failure.

Thus, the situation at Grootfontein can be described as a kind of stalemate, one in which none of the appropriators holds a clear advantage. DWS and the municipalities, despite having a legal mandate, cannot or will not address the over-abstraction problem, and instead invest in other sources of water such as the expansion of the treatment works at the Setumo Dam. The irrigating farmers, despite abstracting the lion's share of the groundwater at Grootfontein, are concerned about ever-falling water levels but take an increasingly short-term view, continuing to abstract the groundwater while it is there.

The appropriators see no advantage in changing their current behaviour, even though the situation is in no-one's best interest. Such a situation can be described as a sub-optimal or Nash equilibrium (Cobbing and de Wit, 2018). As the water table falls, abstraction becomes more expensive and continued access becomes less certain. Both DWS and the farmers therefore incur real costs in the present, as well as the costs and missed opportunities contingent on future uncertainty. Longer term, all of the users of groundwater at Grootfontein are 'losers' in the current equilibrium.

Yet it is possible to imagine a situation in which abstractions (particularly irrigation) were significantly reduced, leading to a recovery of water levels, lower pumping costs and higher assurances of supply for Mahikeng. As discussed, there is even the possibility of temporarily over-pumping Grootfontein during very dry years (i.e. exploiting some of the storage in the aquifer) in the anticipation of managed recovery during wetter years. If the situation at Grootfontein could be resolved, all would benefit to some extent. In this aspect, it has much in common with other collective action problems in South Africa involving appropriators of common-pool resources and diverse stakeholders.

The current sub-optimal equilibrium is persistent, and unlikely to resolve itself. It is possible that eventual near-exhaustion of the resource (initially in the area of the well field since this is where abstraction from the aquifer is concentrated) would lead to the exit of DWS as an appropriator

(because the well field no longer functioned).[4] This would in turn leave the partially depleted aquifer largely to the irrigating farmers who might cooperate more closely and self-regulate to ensure water level recovery. However, the irrigating farmers are not a homogeneous group and have never formed a groundwater user group (although some did contribute to the ill-fated attempt at a Grootfontein WUA in the late 1990s). Like most other appropriators, their conceptual understanding of the aquifer is also poor. Irrigators might also be deterred from collaborating to rescue water levels, since a recovering resource might incentivise DWS to restart abstractions at the well field, reconstituting the status quo ante.

LESSONS FROM THE CASE

In the mid-2000s, the ANC began to respond to growing concerns about lower than expected outcomes in the promotion of equity, growth and development through political and governance arrangements put in place over the preceding decade. The ANC's National General Council of 2005, policy conference of 2007, and the national election manifesto of 2009 stressed that the party intended to build a more developmental state that would play a more direct role in addressing the problems of high unemployment, poverty and inequality. Pursuit of a 'developmental state' is thus currently official policy of the South African Government and is embedded in a new National Development Plan 2030: Our Future – Make it work (RSA, 2012).

The National Development Plan (NDP) aims to:

> eliminate poverty and reduce inequality by 2030. South Africa can realize these goals by drawing on the energies of its people, growing an inclusive economy, building capabilities, enhancing the capacity of the state, and promoting leadership and partnerships throughout society (RSA, 2012: 14).

The NDP emphasises the importance of capabilities, and the 'lack of capacity' hypothesis features prominently throughout. The NDP recognises that more needs to be done to use the existing endowments of a funded bureaucracy, a strong private sector and vibrant civil society voice, to deliver better outcomes, but does not set out what that might be.

The core implication of this research is that if government intends to pursue its equity objectives and trigger stronger, more sustained and inclusive growth, then as highlighted by Netshitenzhe (2015), the state should focus on breaking logjams in the interactions among various sectors of society in order to prevent narrow sectoral interests from paralyzing the broader public interest. There are legal means and political structures that have been set up to resolve critical issues of public policy. However, they often fail because each constituency pursues frozen mandates, representation has been juniorised, and interactions are either technocratic or do not occur in the manner provided for in the policy and legislative framework (Netshitenzhe, 2015). The Grootfontein case suggests that nurturing the institutions necessary for positive appropriator attributes suggests the need for a convening body or organisation with the funds, skills, democratic mandate and legal authority to cultivate: salience; common understanding; low discount rate; trust and reciprocity; autonomy; and to embed prior organisational experience and local leadership.

South African water legislation and policy envisages this role for DWS. No other organisation has either the resources or the legal and political mandate to convene different interests. However, the case reveals that this is not DWS's understanding of the role, and is among the appropriators frustrating the approach envisaged by the legislation. It is likely that institutional deficits that characterise the

[4] The DWS boreholes at Grootfontein are close to the base of the aquifer already, making deeper drilling impractical. It is also likely that DWS shares the common conviction that the Grootfontein aquifer is finite and bound to fail. Rather than invest at Grootfontein, DWS has investigated other sources of water such as upgrading the water treatment plant at the Setumo Dam.

appropriators at Grootfontein also apply to other similar shared resource contexts within South Africa. Furthermore, since the water supply to Mahikeng is an issue with ramifications well beyond the local aquifer and local users, it is necessary to assess the trade-offs between local interests and regional and national priorities, beyond the short term.

Efforts to promote equity, and increase economic development require that the drivers of stalemates such as at Grootfontein are properly specified. If they are not, it is likely that the first two hypotheses described here, neither of which involve difficult choices and investment in relationships, are likely to continue to be identified as the reason for failure and the more straightforward remedies they suggest will continue to be prescribed.

CONCLUSIONS

It has been twenty years since the National Water Act was signed, without more effective governance at Grootfontein coalescing. In the interim, regressive behaviours leading to falling water levels and based on a limited understanding of hydrogeology or on outdated policies and laws appear to have become more firmly entrenched (Cobbing, 2017).

In the absence of the necessary local conditions and institutions (formalised here as Ostrom's appropriator attributes) spontaneous local self-regulation is unlikely to emerge at Grootfontein. The longer the situation persists, the less likely it is that these attributes will materialise (e.g. trust and reciprocity, or a low discount rate applied to the resource). As described, there is likely to be a critical role for a legally mandated convening organisation that is able to balance local, regional and national interests, able to draw on existing technical expertise, and able to define and promote both the progressive organisations and bundled institutions that are required. Doing so would help to overcome the stalemate linked to power asymmetries that were deliberately developed during the years of apartheid, as well as morbid institutions that have arisen since.

At present, an equilibrium persists at Grootfontein which imposes costs on all appropriators, and in which the likely outcome is further decline in water levels. This has significant real and opportunity costs, harming economic dynamism and social cohesion, and acting against the nation building ethos. A Department of Water and Sanitation that can break sub-optimal equilibria that characterise the failure to resolve collective action problems could play a part in virtuous circles of development in South Africa, and fulfil the contemporary South African emphasis on an activist or technocratic state. If this is not possible, then a more pragmatic approach to groundwater governance in South Africa may need to be pursued.

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