Unpacking Groundwater Governance through the Lens of a Trialogue: A Southern African Case Study

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INTRODUCTION

Large portions of Southern Africa are arid or semi-arid, with most of the region having natural precipitation way below the global norm of 860mm/a. Groundwater resources are extremely important under these conditions, because a disproportionally large number of the very poor are totally reliant on this for the maintenance of basic livelihood flows. These resources are under risk from both anthropogenic and natural threats. Three basic threats are of particular importance – over-utilization, pollution resulting from the mismanagement of aquifers, and reduced recharge as a result of global climate change. This opens up the debate on how best to govern groundwater in semi-arid areas where there is a high reliance on the resource, specifically in the context of a developing country that has the need to sustain rural livelihoods as a core element of social stability. This paper consequently focuses on the governance issues arising from anthropogenic impacts only, because the sheer magnitude of the global climate change scenario is beyond the scope of such endeavours. The situation in the Southern African Development Community (SADC) region will be presented as a strategic background, because it illustrates these issues very well. Large areas of SADC occur in semi-arid locations, with many of the major aquifer systems being transboundary in nature. Work currently underway within the Natural Resource and Environment (NRE) group at the Council for Scientific and Industrial Research (CSIR) is developing a water resource governance model that is based on what is being called a Trialogue – an active dialogue between three distinct parties. This recognizes three core Actor-Clusters (Government, Science and Society) and focuses research on the interfaces between these entities. This paper presents core elements of the Trialogue Model, and then applies these to the Pomfret-Vergelegen Dolomitic Aquifer, which is a transboundary water resource shared by South Africa and Botswana.

GROUNDWATER IN SOUTHERN AFRICA

Southern Africa, defined in this case as being the mainland countries of the Southern African Development Community (SADC), has a mixture of both surface and groundwater resources. Official records at UNESCO-

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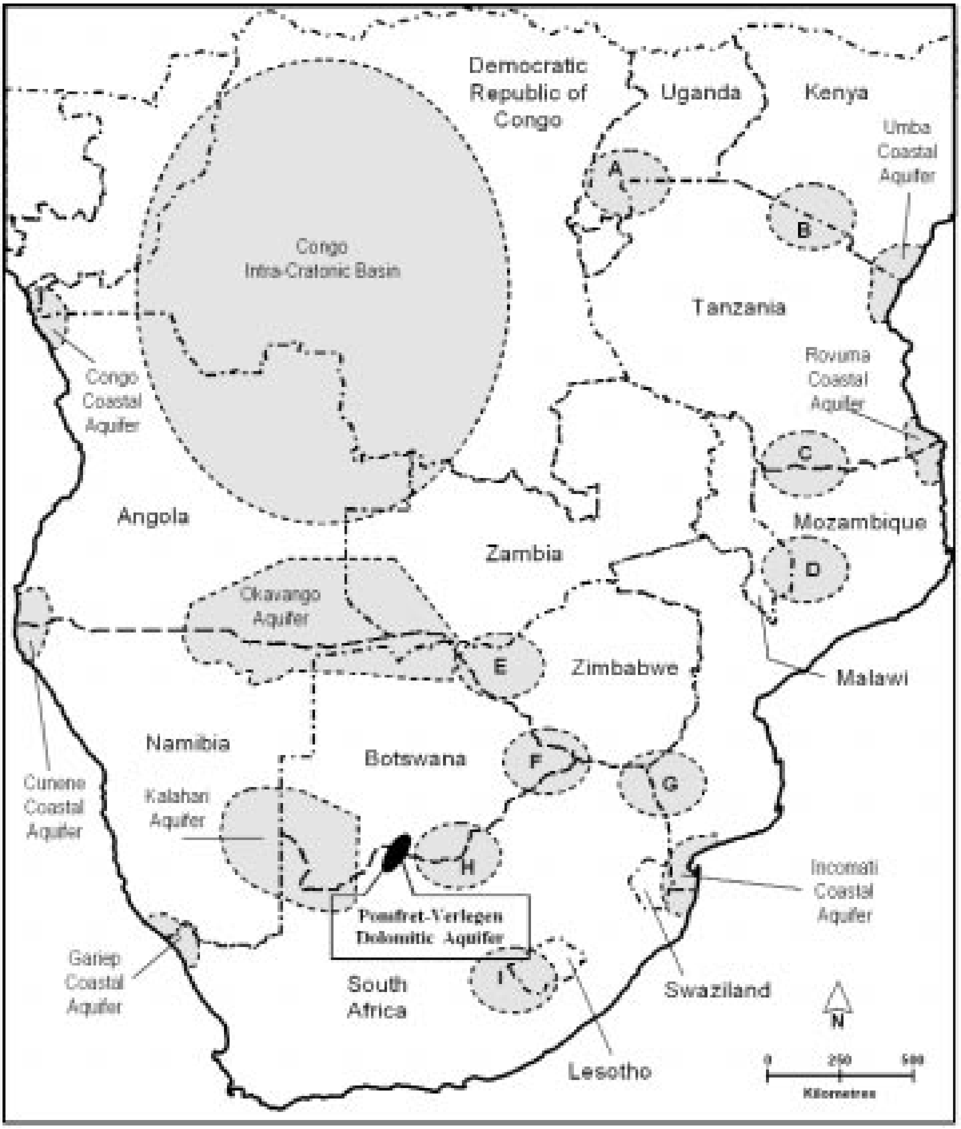
ISARM (2004) indicate the existence of eighteen transboundary aquifer systems in Southern Africa. These are shown geographically in Map 1 and are listed in Table 1.



Map 1. Map of southern Africa, showing the international (shared) aquifer systems used by the SADC states (Ashton & Turton, in press). (A = Kagera Aquifer; B = Kilimanjaro Aquifer; C = Upper Rovuma Aquifer; D = Shire Valley Alluvial Aquifer; E = Nata-Gwaai Aquifer; F = Tuli-Shashe Aquifer; G = Pafuri Alluvial Aquifer; H = Ramotswa Dolomite Aquifer; I = Karoo Sedimentary Aquifer. Map drawn from data in UNESCO-ISARM (2004: 7). The Pomfret-Verlegen Dolomitic Aquifer is not listed in UNESCO-ISARM (2004) and is shown in relation to the existing known transboundary aquifers (Godfrey & van Dyk, 2002).

While this is helpful, the information is incomplete in two critical areas. Firstly, the exact geographic extent of these transboundary aquifers is unknown. This means that the management of such systems is problematic, because existing governance structures tend to focus on surface waters, where knowledge is far greater and where the management unit is that of the river basin. Secondly, it is known from detailed work that has been done in the region that various transboundary aquifer systems are not yet on record with UNESCO-ISARM (2004). Details of one of these – the Pomfret-Vergelegen Dolomitic Aquifer that is shared between South Africa and Botswana – are presented in this paper as a separate case study.

In an attempt to move towards a future development condition in which sustainability is a key element, great emphasis has been placed in Southern Africa on governance. Epitomized at the regional level by the SADC Protocol on Shared Watercourse Systems (Ramoeli, 2002:105), the governance of water is framed in the context of the Integrated Water Resource Management (IWRM) paradigm. Given the fact that Southern Africa is water constrained, with the four most economically developed countries – South Africa, Botswana, Namibia and Zimbabwe – all approaching a situation where the majority of their readily available water resources have already been allocated to productive use (and in many cases over-allocated), water availability can become a factor limiting the future economic growth potential of the SADC region (Turton, 2005; Ashton & Turton, in press). It therefore becomes very instructive to analyse water resource management approaches in the region, because it is an excellent test case for the veracity of the once confidently predicted water and conflict scenario (Homer-Dixon, 1999; Irani, 1991; Starr, 1991). Ongoing research at the CSIR suggests that water is far too important to fight over in Southern Africa, so there is a rich and complex history of cooperative agreements as an empirically verifiable counter-argument (Turton, 2005). Significantly however, while there is a wealth of surface water agreements in Southern Africa, there is only one known international agreement involving the management of groundwater systems, focussed on the waters shared by Botswana and Namibia in the Chobe-Linyanti area of the Caprivi Strip (Ashton *et al.,* 2005; Turton, 2005). A research project currently being developed at the CSIR, seeks to verify this situation in greater detail. Available knowledge suggests that while groundwater is extremely important to many individuals in the region, the joint management of transboundary aquifers lags behind the management of surface water systems.

The Southern African region has a number of transboundary water resources, both surface and groundwater. These are listed in Table 1 as they are currently known to the CSIR, which shows significant resources only, merely for reasons of brevity.

Table 1. Significant Transboundary Water Resources within the SADC Region

Transboundary River Basin	Riparian States	Transboundary Aquifers within River Basin	Aquifer Riparians within River Basin
Orange	Botswana Lesotho Namibia South Africa	Gariep Coastal Aquifer	Namibia, South Africa
		Karoo Sedimentary Aquifer	Lesotho, South Africa
		Ramotswa Dolomite Aquifer	Botswana, South Africa
		Kalahari Aquifer	Botswana, Namibia, South Africa
		Pomfret-Vergelegen Dolomitic Aquifer	Botswana, South Africa
Okavango/Makgadikgadi	Angola Botswana Namibia Zimbabwe	Ramotswa Dolomite Aquifer	Botswana
		Okavango Aquifer	Angola, Botswana, Namibia
		Nata-Gwaai Aquifer	Botswana, Zimbabwe
		Okavango-Epukiro Basin	Namibia, Botswana
Limpopo	Botswana Mozambique South Africa Zimbabwe	Pafuri Alluvial Aquifer	Mozambique, South Africa, Zimbabwe
		Tuli-Shashe Aquifer	Botswana, South Africa, Zimbabwe
		Ramotswa Dolomite Aquifer	Botswana, South Africa
		Limpopo Granulite-Gneiss Belt	Botswana, South Africa, Zimbabwe
Incomati	Mozambique South Africa Swaziland	Incomati Coastal Aquifer	Mozambique, South Africa, Swaziland
Maputo	Mozambique South Africa Swaziland	Incomati Coastal Aquifer	Mozambique, South Africa, Swaziland
Umbeluzi	Mozambique Swaziland	Incomati Coastal Aquifer	Mozambique, Swaziland
Cuvelai	Angola Namibia	Okavango Aquifer	Angola, Namibia
		Cuvelai Basin	Angola, Namibia
Cunene	Angola Namibia	Cunene Coastal Aquifer	Angola, Namibia
			Angola, Namibia
Save-Runde	Mozambique Zimbabwe	None	None
Buzi	Mozambique Zimbabwe	None	None
Zambezi	Angola Botswana Malawi Mozambique Namibia Tanzania Zambia Zimbabwe	Congo Intra-Cratonic Basin	Angola, Zambia
		Nata-Gwaai Aquifer	Botswana, Zambia, Zimbabwe
		Okavango Aquifer	Angola, Botswana, Namibia, Zambia
		Shire Valley Alluvial Aquifer	Malawi, Mozambique
Rovuma	Malawi Mozambique Tanzania	Upper Rovuma Aquifer	Mozambique, Tanzania
		Shire Valley Alluvial Aquifer	Malawi, Mozambique
		Rovuma Coastal Aquifer	Mozambique, Tanzania

Table 1. Significant Transboundary Water Resources within the SADC Region (Cont.)

Transboundary River Basin	Riparian States	Transboundary Aquifers within River Basin	Aquifer Riparians within River Basin
Congo	Angola Burundi Cameroon Central African Republic Congo (DRC) Congo-Brazzaville Rwanda Tanzania Zambia	Congo Intra-Cratonic Basin	Angola, Congo (DRC), Congo-Brazzaville, Zambia
		Congo Coastal Aquifer	Angola, Congo (DRC)
		Chad Basin	Central African Republic, Cameroon, Chad, Niger, Nigeria
Chiloango	Angola (Cabinda) Congo (DRC) Congo-Brazzaville	Congo Coastal Aquifer	Angola (Cabinda), Congo (DRC)
Lake Natron	Kenya Tanzania	Kilimanjaro Aquifer	Kenya, Tanzania
Umba	Kenya Tanzania	Kenya-Tanzania Coastal Aquifer	Kenya, Tanzania
Nile	Burundi Congo (DRC) Egypt Eritrea Ethiopia Kenya Rwanda Sudan Tanzania Uganda	Nubian Sandstone Basin	Egypt, Sudan
		Awash-Djibouti Basin	Ethiopia
		Upper Nile Basin	Ethiopia, Sudan
		Rift Valley Secondary Aquifers	Ethiopia, Kenya, Sudan, Uganda
		Mount Elgon Aquifer	Kenya, Uganda
		Kilimanjaro Aquifer	Kenya, Tanzania
		Kagera Aquifer	Uganda, Tanzania, Rwanda
Pagani	Kenya Tanzania	Kilimanjaro Aquifer Kenya-Tanzania Coastal Aquifer	Kenya, Tanzania Kenya, Tanzania
Pungué	Mozambique Zimbabwe	None	None
Thukela	Lesotho South Africa	None	None

Sources: Ashton, 2005; Ashton & Turton, in press; Godfrey & van Dyk, 2002; Ndengu, 2004; UNEP, 2002; UNESCO-ISARM, 2004; Vegter, 2001; Wolf *et al.,* 1999.

The distribution of transboundary aquifer systems as currently known to the CSIR is presented in Figure 1, which lists the different countries in relation to various aquifer systems.

Riparian \ Aquifer	Cunene Coastal	Cuvelai	Congo Coastal	Congo Intra-Cratonic	Gariep Coastal	Incomati Coastal	Kagera	Kalahari	Karoo Sedimentary	Kenya-Tanzania Coastal	Kilimanjaro	Limpopo Granulite-Gneiss Belt	Nata-Gwaai	Okavango	Okavango-Epukiro	Pafuri Alluvial	Pomfret-Vergelegen Dolomite	Ramotswa Dolomite	Rovuma Coastal	Shire Valley Alluvial	Tuli-Shashe	Upper Rovuma	*Shared aquifers*
Angola	X	X	X	X										X									5
Botswana								X				X	X	X	X		X	X			X		8
Congo (DRC)			X	X																			2
Lesotho									X														1
Madagascar																							0
Malawi																				X			1
Mauritius																							0
Mozambique						X										X			X	X		X	5
Namibia	X	X			X			X						X	X								6
South Africa					X	X		X	X			X				X	X	X			X		9
Swaziland						X																	1
Tanzania							X			X	X								X			X	5
Zambia				X									X	X									3
Zimbabwe												X	X			X					X		4
Countries sharing	2	2	2	3	2	3	1	3	2	1	1	3	3	4	2	3	2	2	2	2	3	2	

Figure 1. Transboundary Aquifers in the SADC Region
Cross-reference between SADC Member States Sharing Individual Aquifers Systems

From this it is evident that there are more transboundary aquifer systems in Southern Africa than there are transboundary river basins, with South Africa and Botswana both having the greatest number of known shared groundwater systems. This serves to contextualize the specific case study presented below.

The Trialogue Model of Governance

Within the Water Competency Area of the Natural Resource and Environment (NRE) group of the CSIR, governance is being defined as the process of informed decision-making that enables trade-off's between competing users of a given resource so as to balance protection and use in such a way as to mitigate conflict, enhance security, ensure sustainability and hold government officials accountable for their actions (Turton *et al.,* forthcoming). More specifically, what are being called Actor-Clusters, are considered to be extremely important, of which there are three main sets (Turton *et al.,* 2005).

The first is what we can generically call Government, but in reality, this cluster consists of three distinct elements:

- Rule making structures, processes and procedures that resides in the Legislature.
- Rule application structures, processes and procedures that occurs *via* the Executive.
- Rule adjudication structures, processes and procedures that are performed by the Judiciary.

The Government Actor-Cluster is similar in most modern states, with the three arms of government being reflected in different forms, but always in existence. This is known technically as the *trias politicas* in political science literature, reflecting the three core elements of the sovereign authority in any country. The relationship between these three arms of government is normally defined in the constitution of the country concerned. A core element of the Government Actor-Cluster is the capacity to generate incentives for the Science Actor-Cluster to continue developing solutions to increasingly complex problems. In this regard there are two major schools of thought. The Malthusian School views social collapse as being inevitable as the result of population growth, which is seen to inevitably outstrip the capacity of society to adapt. This argument is sometimes reflected in the explanation of the brain drain phenomenon from the Developing South to the Industrialised North. The Cornucopian School essentially sees human ingenuity as being boundless, arguing that any problem that arises can be solved. Both of these schools are reflected in the sustainable development discourse. Central to these two schools is the role of the Government Actor-Cluster as a generator of incentives and a developer of institutions that are conducive to the continued solution of social problems.

The second Actor-Cluster can be generically called Society that is constituted of three major sub-elements:

- Civil society that represents people, which collectively have interests that they seek to articulate in one form or another.
- The economy that employs these people, which has interests of its own, many of which are articulated through both formal and informal channels.
- The environment in which society and the economy is embedded, both as a source of primary resources and as a sink for waste products arising from the manufacturing and consumption process.

The Society Actor-Cluster has the environment included, because in the Developing South, there is a more intimate link between livelihood flows from direct access to natural resources, than in the Industrialised North. This is not exclusive to the South however, because the Industrialised North was the home of the environmental movement, which successfully placed ecological concerns onto the international agenda to the extent that triple bottom line accounting is now an internationally accepted form of corporate governance applicable to large multi-national firms. Largely for this reason, the sustainable development discourse is firmly embedded in this Actor-Cluster, consisting of a dynamic interaction between society, the economy and the environment, each of which have now become separate indicators of sustainability that are reflected in the notion of triple bottom-line accounting. It is through this process of corporate governance that large multi-national companies are being held accountable by their shareholders.

The third Actor-Cluster can be generically called Science, but in reality it consists of three distinct sub-components:

- The natural sciences when practiced in an applied sense.
- The social sciences when practiced in an applied sense.

- Tertiary educational institutions that provide the human capital for the applied sciences as categorized.

It is the structure and function of the Science Actor-Cluster that forms the core logic in Homer-Dixon's argument about the role of ingenuity in sustaining society in a socially and politically stable manner (Homer-Dixon, 1994; 1995; 1996; 1999; 2000).

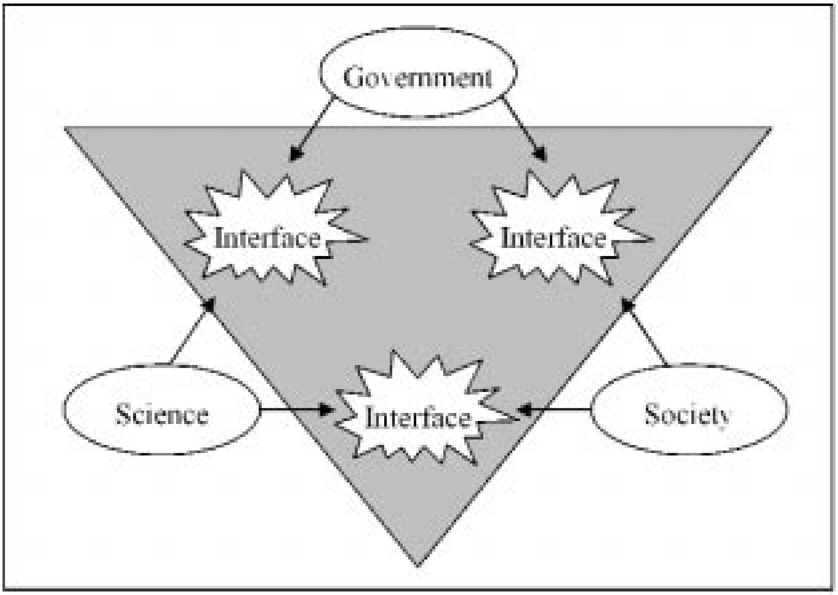


Figure 2. Opening up the Black Box of Governance: A Schematic Representation of the Trialogue Model as Envisaged by the CSIR (Turton et al., 2005).

Closer examination of these three Actor-Clusters therefore shows that while they are all structured in some way with one another, in a configuration that can best be called a Trialogue, each cluster is a form of triangle in its own right. This raises an important conceptual element within the model of governance being developed at the CSIR. If these three Actor-Clusters are all individually important within a given society, then they are all locked into some form of relationship with one another at more than one level, and in more than one place. That relationship is based on communication and feedback loops, so the effectiveness of the relationship is clearly a function of the interface between each of these three Actor-Clusters. In this regard, there are consequently three important Interfaces:

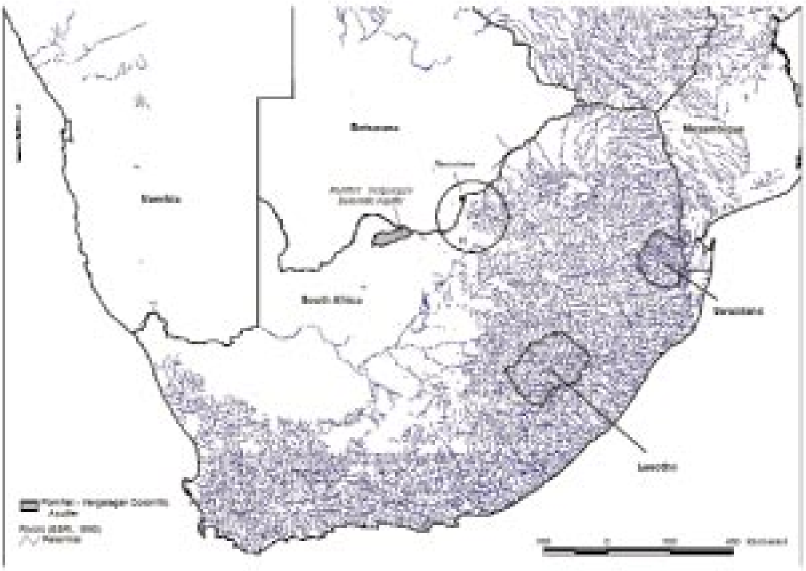
- The Government/Society Interface determines both the legitimacy of the political process, and the permeability of government to new ideas from civil society and the corporate world.
- The Government/Science Interface determines the extent to which science and technology forms the basis of the political economy, and the extent to which scientific knowledge informs the decision-making processes that are a core output of the Government Actor-Cluster. This interface is critical to any Cornucopian view on the future of society, and as such has major implications for social stability and economic growth, making it a key issue for effective governance in the Developing South.

- The Science/Society Interface can be thought of as science in the service of society, consisting of a number of elements, including the way that scientific knowledge is diffused into that society. In the Industrialised North this is manifest as the technology-base of the economy, eventually manifesting as comparative advantage in the global economy. In the Developing South this is manifest as the effectiveness with which the science and technology-base is harmonised with the overall needs of society, and becomes a key determining factor in the success of the emerging economy as it overcomes its historic and structural comparative disadvantage.

These three Actor-Clusters therefore act in dynamic equilibrium with one another, each being connected by means of a two-way interface. It seems reasonable to conclude that the quality of those Interfaces is a key determining factor, to the extent that any serious study of governance is likely to benefit by treating these as independent variables in their own right. This is a core assertion of the Trialogue Model of Governance being developed by the CSIR. This is presented schematically in Figure 2, which shows the triangular relationship between the three Actor-Clusters along with their respective Interfaces. The shaded area in the diagram covers the three Interfaces, and it is this area that can be thought of as the space in which governance as process functions. The quality of these three Interfaces determines the extent to which Government can generate the incentives needed to develop Society by allowing Science to inform the decision-making process. It can therefore be said that the quality of these three Interfaces is an independent variable in determining the outcome of governance as product.

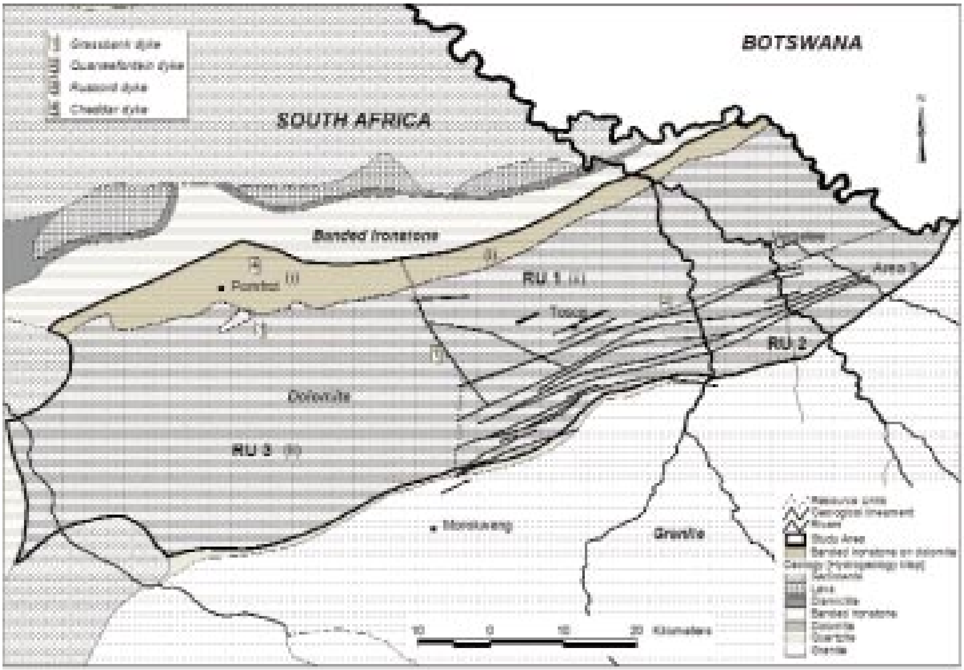
Case Study: Pomfret – Vergelegen Dolomitic Aquifer, South Africa

With this background of theory we can now ask how this is applicable to the practise of managing a real-world transboundary aquifer system?



Map 2. Location of the Pomfret-Vergelegen Dolomitic Aquifer straddling the border of South Africa and Botswana (ESRI, 1993; Godfrey & van Dyk, 2002).

The management of transboundary aquifers, particularly secondary fractured rock aquifers, pose an interesting challenge to Government, Society and Science as they are configured in the Trialogue Model of Governance (Hattingh *et al.,* 2005). Work being done at the CSIR provides an excellent repository of data against which these new ideas can be tested. To this end work that has been done on the Pomfret–Vergelegen Dolomitic Aquifer (PVDA) (Map 3) provides excellent case study material. The PVDA is a high-yielding karstic aquifer in the North-West Province of South Africa, straddling the boundary with Botswana (Map 2), but not yet listed in UNESCO-ISARM (2005). The PVDA, although in proximity to the Ramotswa Dolomitic Aquifer (Map 1, Table 1), named after the town of Ramotswa on the Botswana/South Africa border and listed in UNESCO-ISARM (2005), comprises a different geological formation. The PVDA is contained within the dolomites of the Campbell Group of the Griqualand West Sequence, while the Ramotswa Aquifer consists of dolomites of the Malmani Subgroup of the Transvaal Sequence, so they comprise two distinctly separate systems.



Map 3. Pomfret-Vergelegen Dolomitic Aquifer and sub-outcrop geology with Kalahari sands removed (Godfrey & van Dyk, 2002).

The PVDA is located in an area of little to no perennial flow (Map 2) due to the low annual rainfall, which is an average of 385 ± 153 mm/a (Godfrey & van Dyk, 2002) and high evaporation, which is between 2050–2250 mm/a (Midgley *et al.,* 1994). As such only a small percentage of rainwater is available to recharge aquifers, with an actual recorded value of less than 4% (Smit, 1977). The Molopo River, forming the boundary between South African and Botswana, is a non-perennial river characterized by episodic hydrological events. Flow in the river used to occur after heavy rainfall events, but the building of dams

(Disaneng and Modimola) upstream has impeded natural stream-flow, with only five recorded occurrences of flow in this reach of the Molopo since 1980 (Godfrey & van Dyk, 2002). Local inhabitants in this area are therefore completely dependant on groundwater as their only source of water for livelihood maintenance, which consists primarily of irrigation and stock farming, with domestic abstraction playing an important role in maintaining social stability.

The PVDA is a high-yielding system, with recorded borehole yields of up to 126 l/s. This dolomitic aquifer is overlain by porous, unconsolidated to semi-consolidated sediments of the Kalahari Group, which vary in thickness from approximately 15 m south-west of the town of Tosca, to up to 120 m north-east of the town of Vergelee, on the Botswana border. The exact nature of the PVDA inside Botswana is not fully known at present, but it is unlikely to stop at the political border, so a reasonable assumption is that it is a transboundary system. The increasing thickness of the overlying sediments in the direction of Botswana makes the accessibility of groundwater from the dolomites difficult and increasingly costly as one moves in a north-easterly direction. As a result deep boreholes are often required to abstract groundwater from the dolomites, which introduces a specific new management factor. The deeper one needs to drill, the more costly the exercise so it can only be practised by a smaller group of users, mostly from wealthier social strata. This has particular relevance in post-Apartheid South Africa, where historic redress is a key constitutional imperative that is deeply entrenched in the National Water Act of 1998. The presence of regional dolerite dykes, divides the PVDA into three major compartments (Map 3), with the Tosca Compartment, known as Resource Unit 1 (RU 1 in Map 3) being the highest yielding, with average borehole yields of 6.32 l/s on record.

The area has seen a considerable increase in groundwater usage over the past 15 years. A census conducted in 1990, showed that groundwater use within the Tosca Compartment of the PVDA was limited to human consumption and stock watering, with a total groundwater use in the area of approximately 1.8 Mm^3 per annum. Since 1990 however, more high-yielding boreholes have been drilled, as the irrigation potential has been realized, and a steady increase in groundwater use has been detected (Table 2). In 2002, the use of groundwater for the irrigation of wheat, corn, paprika, peanuts and alfalfa amounted to nearly 92% of the groundwater use (Godfrey & van Dyk, 2002).

Table 2
Groundwater usage within the Tosca Compartment (Godfrey & van Dyk, 2002).

Year	**1990**	**1996**	**2001**	**2002**
Irrigation systems	2	22	32	40
Irrigation area (ha)	100	600	1182	1495
Irrigation (Mm^3) *	0.77	4.6	9.1	11.1
Stock watering ($Mm^{3)}$	0.5	0.5	0.5	0.5
Human consumption (Mm^3)	0.5	0.5	0.5	0.5
Total (Mm^3)	1.8	5.6	10.1	12.1

The calculated available groundwater resource for the PVDA (as at 2002) was 19.57 Mm^3/a, of which 6.90 Mm^3/a was available within the Tosca Compartment. From the figures of groundwater abstraction given in Table 2, it is evident that the Tosca Compartment was being over-abstracted by 5.2 Mm^3/a in 2002 (Godfrey & van Dyk, 2002). This over-abstraction led to an alarming decline in the groundwater levels between 1990 and 2002, with values of between 10 - 20 m being recorded regionally, and up to 60 m over the central part of the PVDA in close proximity to large-scale abstraction (van Dyk & Vermaak, 2002). This increasing usage of groundwater from the PVDA is believed to be causing a dewatering of the overlying unconfined upper Kalahari Aquifer, of up to 20 m (Godfrey & van Dyk, 2002). As such, irrigation farming has placed a considerable strain on the PVDA, and subsequently the Kalahari Group Aquifer. Wealthier irrigation farmers could afford to drill deeper boreholes in order to chase the declining groundwater levels. The result of this over-abstraction has a direct negative impact on poorer communities, whose basic survival depends on their access to shallower, low-yielding groundwater in the Kalahari Group Aquifer.

This makes the management of the system very sensitive, because it opens the whole issue of historic redress that is central to the South African Constitution and the National Water Act of 1998. Van Dyk & Vermaak (2002) noted that, "*By 2001 the situation has led to major competition for water with competing factions the irrigators [sic] with investment in abstraction infrastructure and further profit in crops and the stock farmers with the long-term goal of sustainable farming [sic]*". The inequitable use of groundwater is evident in the water-use figures, with an estimated 95% of the groundwater being used on just 0.5 % of the land-use area (van Dyk & Vermaak, 2002). As a result of this mining of the PVDA, the government was obliged to intervene in terms of their Constitutional mandate, to manage the growing conflict between the irrigation and stock farmers in the area, and to facilitate the remediation of the aquifer to one of sustainable groundwater use. This was a complex process with many political sensitivities being confronted, not least of which was the possibility of increased tension along historically defined racial lines.

The Trialogue Model, presented earlier in this paper, provides a theoretical mechanism with which to unpack the dynamics of this potentially volatile situation, by assessing the potential roles of the various actors in more detail. It was recognised by both groundwater users and the South African Department of Water Affairs and Forestry (DWAF), that the rate of abstraction of groundwater was unsustainable, and was resulting in unintended impacts on other groundwater users within the area. The national-level DWAF was requested by the provincial-level DWAF to assist with the quantification of groundwater in the area by means of a Reserve Determination Study, aimed at assisting the discussions with the newly-formed Water User Association (WUA). The WUA consisted of the whole range of groundwater users that were dependent on the PVDA, making it an interesting case study in groundwater governance, because this is the only significant resource in that specific area. It was believed at the time that the volumetric quantification of the groundwater resource would assist DWAF in engaging with a series of informed consultations with the newly-established WUA.

A strategic assessment was made, which revealed a number of possible engagement scenarios. In particular, the engagement by Government with the WUA presented three possible routes by which a viable solution could be negotiated, each of which could potentially result in the sustainable utilisation of groundwater in the region:

- A co-operative approach in which Government and users jointly addressed the issue, engaging in a series of interactions aimed at negotiating a solution that was agreeable to both parties. Central to this approach is the allowing of farmers to voluntarily reduce abstraction within the set allocation plan for the aquifer, while ensuring continuous monitoring of water levels. This was the most-preferred option and is represented as Option (a) in Figure 3.

- Legal action could be considered by Government to force users to reduce groundwater abstraction. Central to this approach is a range of management options, including a compulsory licensing process of all groundwater users, or the prosecution and closure of all illegal groundwater users. This is represented as Option (b) in Figure 3.
- Recognising that if conflict occurred between Government and Society when trying to reach an agreeable solution, mediation might need to be sought in order to bring the process back within the parameters of viable co-operation. This was the least-preferred option and is represented as Option (c) in Figure 3.

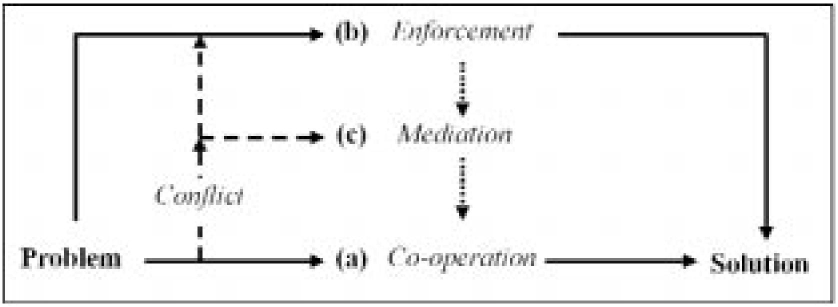


Figure 3. Possible options adopted to resolve the situation of unsustainable groundwater abstraction from the Pomfret-Vergelegen Dolomitic Aquifer.

The role of the Trialogue partners, and the strength of engagement between the three Actor-Clusters, is seen to differ for each of the proposed Options (a-c). Each of the scenarios is analysed below using the Trialogue Model as an analytical tool.

Option (a) is based on voluntary co-operation between Government and Society in the sincere quest to find a viable solution that is agreeable to both parties. This is seen as being an option based on sustainable utilisation of the resource over time, with the lowest level of conflict potential; the highest level of self-regulation; the lowest level of direct Government intervention; and therefore the preferred option. Here the rate of engagement between the two parties is strong and equitable. Science is seen to play a supporting role to both Society and Government by providing unbiased technical information to support neutral decision-making. This is shown schematically in Figure 4.

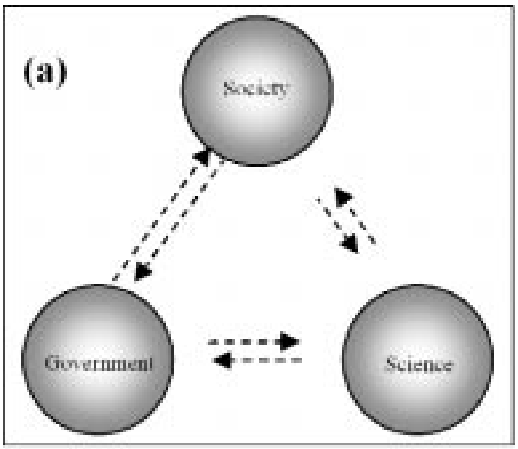


Figure 4. Schematic representation of Option (a), which is based on cooperative self-regulation.

Option (b) takes the route of legal enforcement by Government. This may be seen by the currently disadvantaged users as being the preferred route to follow, because it would ensure a suitable and timeous response by a numerically larger portion of Society, but it would also involve maximum levels of intervention, regulation and enforcement by Government. Conversely it may be seen as a last resort by Government, to be considered only when failure to reach a cooperative solution seems inevitable. In such a situation, the rate of engagement between Government and Society is one-sided, driven by Government to ensure legal compliance by Society as a whole. Here Government often relies heavily on the input of Science to provide sound scientific information to inform legal action, but this also brings Science into a possible conflict with Society if the final solutions are perceived to be contrary to the strategic interests of powerful sub-groups. This is shown schematically in Figure 5.

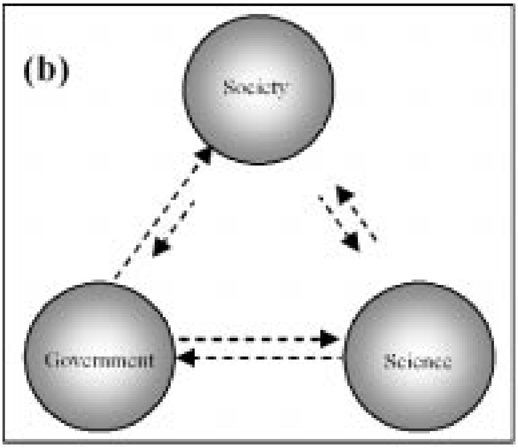


Figure 5. Schematic representation of Option (b), which is based on enforcement.

Option (c) can be considered where the logical solution as viewed through the lens of sustainability would involve financial losses for some, as in the case of the PVDA, where reduced abstraction means reduced irrigation and production, and hence reduced income for those in the formal economy. Under these circumstances, communication can break down completely between Government and Society. In such a situation, Science may be forced to play the role of mediator, providing technical information to both Society and Government in order to facilitate co-operation between otherwise intransigent actors. This may either assist (where information provided to Government and Society corresponds) or further antagonise Government and Society (where differing scientific opinions are provided to the antagonistic parties). This is shown schematically in Figure 6.

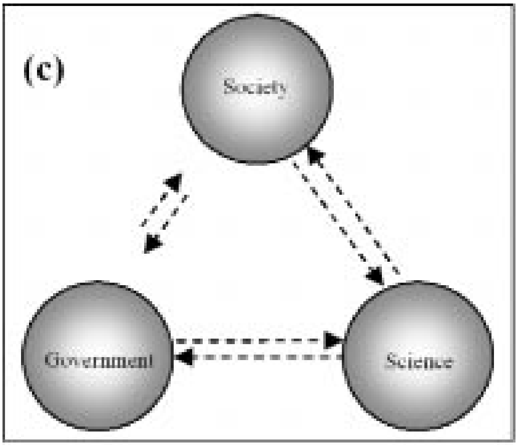


Figure 6. Schematic representation of Option (c), which is based on mediation.

It is recognised that the interaction between the three Trialogue Actor-Clusters is a dynamic and complex one, typically oversimplified in the diagrams of the Trialogue Model. This dynamic relationship is fuelled by challenges facing each of the three Actor-Clusters.

Government is faced with the task of enforcing rules of sustainable abstraction, in an area of economic growth and emerging farmers, of legal and illegal water users and of potentially conflicting water use between high-demand, high-scale abstraction for irrigation and basic human needs. In so doing, both Government and Society must embrace the guiding principles of the South African National Water Act (1998: Chapter 1).

> "*Sustainability and equity are identified as central guiding principles in the protection, use, development, conservation, management and control of water resources. These guiding principles recognise the basic human needs of present and future generations, the need to protect water resources, the need to share some water resources with other countries, the need to promote social and economic development through the use of water and the need to establish suitable institutions in order to achieve the purpose of the Act.*" (National Water Act, 1998: Chapter 1).

Society, on the other hand, is faced with both competing and conflicting groundwater uses, exemplified by resulting inequality of access to groundwater between a society of '*haves*' and '*have nots*', exacerbated by the historic legacy of Apartheid. This is a complex set of issues, often reflected as differing societal opinions around equitable water rights, the need for groundwater security to ensure sustainable livelihoods (whether it be for agriculture, stock watering or basic subsistence), and notions of historic redress that are enshrined in the South African Constitution. This occurs in the face of a lack of trust in the intentions of Government and of information provided to them by Science, and a growing risk of loss of groundwater rights, capital investment, land value and potentially land rights arising from post-Apartheid legal reforms.

Science is faced with the difficulty of a quantification of aquifer potential, recharge calculations, defining compartment boundaries, determining recharge 'episodes', defining recharge zones, all required to confidently determine the available groundwater resource to be used as the basis for setting the allocation plan for the aquifer and the resulting water rights of farmers. There is consequently a very high demand being placed on the capacity of the scientific community to provide the type of data and information.

The situation is further aggravated by the nature of the aquifer. Being a transboundary aquifer shared between South Africa and Botswana, this introduces an added dimension to the overall problem. High groundwater abstraction on the South African side has the potential to unknowingly impact upon groundwater users in Botswana, because of the inherent transmissivity of the karstic system. Similarly, enforcement by Government to reduce groundwater abstraction on the South African side may result in farmers moving over to Botswana to exploit groundwater there from the same aquifer, which has the potential to impact upon the improved management of groundwater in South Africa. Differing legislation in the two neighbouring countries (South African and Botswana) and the differing approach to groundwater management and water resource protection in the two countries, can also support the migration of farmers from South Africa to Botswana to 'escape' stringent water management practices being enforced by DWAF. The existence of strong enabling legislation, in the form of the SADC Water Protocol, provides a robust framework on which improved cooperation in the joint management of transboundary groundwater can be practiced.

The Pomfret-Vergelegen Dolomitic Aquifer is therefore an example of inequitable, conflicting groundwater use from a SADC transboundary aquifer, exacerbated by the lack of knowledge of groundwater rights, particularly those of poorer communities; the blatant exploitation of groundwater rights by some; the differing legislation and groundwater management practices in the two sharing countries; technical difficulties in scientifically quantifying the groundwater resource; and understanding the resulting impacts to enable sound groundwater management and inform planning and decision-making by both Government and Society. This is particularly relevant in the context of possible future changes to aquifer recharge patterns, arising from future Global Climate Change scenarios, as predicted by some scientists (Scholes and Biggs, 2004).

CONCLUSION

The Trialogue Model of Governance currently under development by the CSIR in South Africa, provides a conceptual and analytical tool with which to understand the dynamics of integrated water resource management. One particularly useful aspect of this model is its possible deployment in assessing potential roles that can be played by the various Actor-Clusters (Government, Science and Society). This provides Government decision-makers with a wider range of management options than they previously thought were available, as shown in the case study. The Pomfret-Vergelegen Dolomitic Aquifer, which is a transboundary water resource shared between South Africa and Botswana, provides an excellent example of the use of this analytical approach. Of particular value, this specific case study serves to illustrate the potential of the Trialogue Model of Governance in the management of transboundary groundwater systems, because there are no other significant water resources in the area. Finally, the SADC Water Protocol provides an excellent example of enabling legislation at a regional level, because it establishes a robust structure for the evolution of joint governance structures for the management of transboundary aquifer systems. There is a history of peaceful cooperation in the management of transboundary river basins within the SADC Region, so while the governance of groundwater is clearly lagging behind, the prognosis for the future evolution of sound governance structures is reasonably good.

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