The Stampriet Artesian Aquifer Basin

A case study for the research project
”Transboundary groundwater management in Africa”

Marianne Alker

Preface

I would like to thank Mr. Piet Heyns (Heyns International Water Consultancy, formerly Under Secretary and Head of the Department of Water Affairs and Forestry Namibia) for contributing all technical information on the Namibian part of the Stampriet Artesian Basin and for his valuable input into the present study; furthermore, many thanks to Dr. Gideon Tredoux (DTEC/CSIR South Africa) and Dr. W. Struckmeier (BGR) for sharing their knowledge with me.

After the work on this desk studie was already acomplished I learnt during the World Water Week in Stockholm, that the riparian countries of the Stampriet Artesian Basin / Western Kalahari Karoo Aquifer agreed upon a joint assessment of this shared aquifer. The fact that research cannot keep pace with the political developments in this case raises hopes for future successful transboundary cooperation over groundwater in this arid part of the world.

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1 Introduction

The Stampriet Artesian[30] Basin (SAB),[31] which is shared by Namibia, Botswana and South Africa, was selected for one of five illustrative studies within the research project "Transboundary Groundwater Management in Africa" for the following reasons: First, the presence of fresh water is of special value in the very arid environment at the border between Namibia, Botswana and South Africa, where brackish and saline groundwater is frequent. Second, the SAB lies within the Orange River Basin, where a river basin commission exists. This means that an institution for transboundary cooperation concerning shared water resources is already in place and could also serve for joint management of the shared groundwaters. Third, the SAB has been well studied, at least on the Namibian side,[32] and thus provides a basis for analysis.

2 General characteristics of the Stampriet Artesian Basin

The name "Stampriet Artesian Basin" refers to a transboundary groundwater system that has been identified and investigated thus far only in Namibia (Christelis / Struckmeier 2001), where it encompasses the Nossob and Auob sandstones of the Ecca subgroup in the Karoo and Kalahari Sequences. Although no studies have yet been undertaken to investigate the basin as a whole and to confirm the extent of its eastern perimeter (Tredoux

30 Artesian water is confined in an aquifer between impermeable beds and is under pressure, like water in a pipe. When a well or fracture intersects the aquifer, water rises in the opening, producing a flowing well or an artesian spring (Hamblin / Christiansen 1995).

31 The basin was named after the town of Stampriet that was established by missionaries who saw a potential for using free-flowing groundwater from the Auob aquifer for gardening purposes.

32 The Internationally Shared Aquifer Resources Management (ISARM) Programme has also chosen the SAB under the name "Kalahari / Karoo Multi-Layered Aquifer" for a case study. This study has not yet been commenced. The present paper draws upon the problem analysis presented in Puri (2001).

email 3.4.2007), it is assumed that the aquifers extend into parts of Botswana and to a lesser extent into South Africa.

2.1 Geographical characteristics

The SAB lies within the Orange River Basin and covers 7.1 % of its total area in Southern Africa (DWAF [Namibia] 2000; Christelis / Struckmeier 2001).

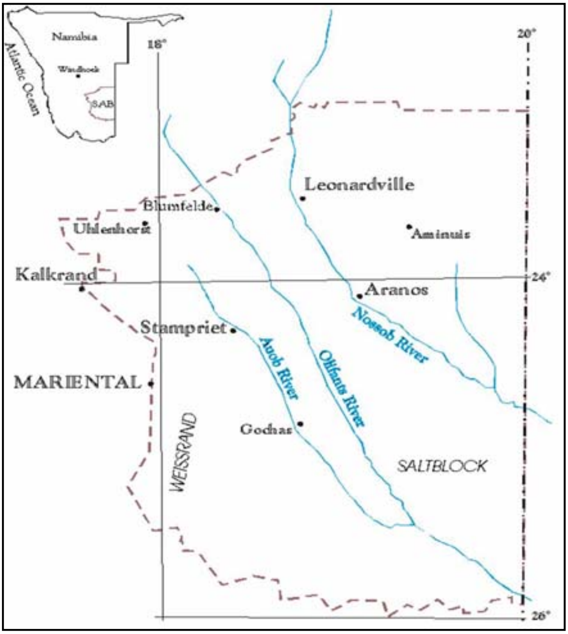
The boundaries of the SAB are well known in Namibia. The northern boundary is visible in the form of sub-outcrops of Karoo strata. In the northwest, the boundary follows an arbitrary margin that delineates where sandstone with artesian groundwater may still be encountered under the Kalkrand Basalt. In the west, the boundary is formed by the escarpment of the Weissrand Plateau above Nama Group sediments along the watershed between the Orange River Basins's Fish River sub-catchment to the west and Auob River sub-catchment to the east. In the south, the boundary of the SAB runs along a line south of which no artesian conditions exist. On the east, the basin stretches into Botswana and South Africa across the Namibian border, which runs along the 20° east longitude line.

In Namibia, the SAB covers an area of about 71,000 km², or about 8.6 % of the country's total surface area (cf. fig. 1). The north of the basin is characterized by a transition from quartzite ridges in the far north to monotonous flat plains of sand and calcrete in the northeast. On the western edge of the basin, the Weissrand, a surface limestone plateau, rises about 80 m above the Fish River plain and is predominantly covered by calcrete and dune sand. A dune field comprising stationary, longitudinal dunes roughly follows the upper part of the Auob River in a NNW-SSE direction and continues eastward toward and across the border with Botswana. The dunes are 10 to 15 m high. It is assumed that these linear dunes were formed during the last glacial period when a persistent high pressure cell circulated over the subcontinent, resulting in strong, dry windstorms.

As mentioned above, little is known about the southeastern, eastern and northeastern boundaries of the SAB.[33] Puri have estimated that the basin

33 A geological map of Botswana demarcates the Nossob Basin from the Namibian border at about 21.5 ° east (ORASECOM 2007, 32), and it is known that the Ecca sandstone is found in large areas of Botswana's part of the Orange River Basin (ORASECOM 2007,

Figure 1: Location of the Stampriet Artesian Basin in Namibia



Source: DWAF (Namibia) / JICA (2000)

occupies 70,000 km² within the territory of Botswana, but no such estimates exist for the SAB in South Africa (Puri 2001, 54–55).

Interestingly, available data indicate that 90 % of the SAB's aquifers lie within Namibia. The contrast between this and the figures presented by Puri suggests that the terms "Stampriet Artesian Basin" (used in Namibia) and "Kalahari/Karoo Multi-layer Aquifer" (used by the Internationally Shared Aquifer Resources Management [ISARM] Programme) are not necessarily congruent.

35). The only information found for the South African side is that the main known productive aquifers are along the Molopo and Nossob Rivers (ORASECOM 2007, 39).

A surface drainage system runs from the northwest to the southeast across the basin. The Auob, Olifants and Nossob Rivers are ephemeral water-courses that are part of the larger Orange River Basin in Southern Africa. These rivers flow only when above-average rainfall occurs, but they are endoreic within the Orange River Basin. This means that their runoff never reaches the Orange River but rather dissipates into the Kalahari Desert about 130 km to the north of the Orange River in South Africa.

Mean annual rainfall across the basin varies between 120 mm (Stampriet) and 240 mm (Leonardsville). It is highly variable and therefore cannot be reflected accurately in a figure for average precipitation. Rarely, extreme rainfall can even reach 500 mm. The mean annual potential evaporation varies between 3,000 mm in the north and 3,500 mm in the south.

The northwestern part of the SAB in Namibia lies at an elevation of 1,350 m above mean sea level; this drops 500 m over a distance of 400 km to 850 m ase in the southwest.

The landscape of the SAB is characterized by two distinct biomes. A tree and shrub savanna occurs in the north and southeast, while dwarf shrub-land of the Nama Karoo covers the west and southwest of the SAB. The valleys between the dunes of the Kalahari sandveld may be up to several hundred metres wide and are covered with grass and acacia trees (mostly Camelthorn). The grass and pods from the Camelthorn trees form the basis of the biomass on which extensive stock farming activities in the area rely. The presence of the trees indicates shallow groundwater.

The density and quality of the vegetation depend on seasonal rainfall conditions. The carrying capacity is in the range of 12 to 15 hectares per large stock unit[34] (ha/LSU) in the Kalahari sandveld and 18 to 24 ha/LSU in the Nama Karoo biome.

The Kalahari sandveld is covered by (windblown) ferralic arenosols which have a high content of iron and aluminium oxides, resulting in the red colour of the sand. In the northwest and southwest areas, petric calcisols predominate. These soils have the potential to be fertile, but have a solid layer at shallow depth and contain accumulations of calcium carbonate. In the Stampriet area there are fertile eutric leptosols (caused by erosion) and

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34 A large stock unit is one head of cattle; this is considered equivalent to five small stock units such as goats and sheep.

fluvisols (flood deposits) with a low base saturation. Irrigation is common on these soils.

2.2 Information about the Stampriet Artesian Basin

2.2.1 Studies carried out in Namibia

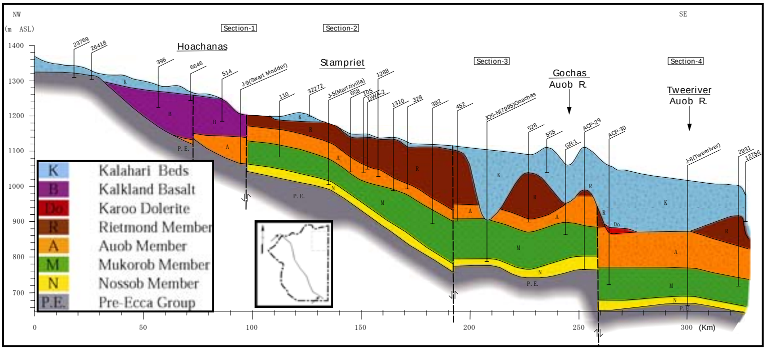
The geology, hydrology and hydrogeology of the Stampriet Artesian Basin are relatively well known because of well-documented meteorological data and borehole information. The first results of hydrogeological investigations were published by Range (1915). After World War One, the Irrigation Department of the newly created South West Administration undertook an extensive drilling program with the aim of finding water for the development of new stock farms in previously undeveloped areas. This process was repeated after World War Two.

The quality of groundwater in the basin has also been investigated. In 1965, the Committee for Water Research of the South West Africa Administration employed the Council for Scientific and Industrial Research in South Africa to investigate the quality of the groundwater in an area west of the town of Kalkrand. This led to the Water Quality Map Project, which included a hydrochemical analysis of more than 30,000 water samples from boreholes, wells and springs across Namibia between 1969 and 1981. Four maps showing total concentrations of dissolved solids, sulphate, nitrate and fluoride in the groundwater of Namibia were prepared, and a similar map is available for the SAB.

In the 1980s, further work was done in the north and northwestern parts of the SAB by the Geohydrology Division of the Namibian Department of Water Affairs (DWAF [Namibia]). A major improvement in aquifer management resulted from the collection of extraction data, which led to a better understanding of the impact of extraction on recharge and the implications of this for sustainable use.

The last round of investigation started at the turn of the present century, when the Japanese Government, through the Japanese International Cooperation Agency (JICA), provided funds for a hydrogeological investigation of the so-called Southeast Kalahari Basin (JICA 2002). The aim of this was to develop an integrated Groundwater Management Plan. This work provided a better conceptual model of the basin, as reflected in Figure 2.

Figure 2: Geological Cross-Section of the Stampriet Artesian Basin



Source: DWAF (Namibia) / JICA (2000)

At the same time, the International Atomic Energy Agency funded an isotope-based study project to investigate the recharge of the aquifers in the SAB.

2.2.2 Studies carried out in Botswana

No integrated investigation of the SAB on the Botswana side has been undertaken. The main problem for studies in this regard is that lithological units have different names in the two countries and that the terms used to describe stratigraphy have also been amended from time to time (Tredoux email 3.4.2007).

Nevertheless, some information from local studies does exist. The Department of Water Affairs for Botswana has undertaken studies in the areas of Matsheng and Kang-Phuduhudu, tapping Ecca Sandstone Aquifers that may lie within the SAB or be connected with it. This latest investigation of the deep Ecca aquifer of the Kalahari in southwestern Botswana concluded that the high-yield Ecca aquifer horizons contain highly saline groundwater which is unsuitable for agricultural purposes (Cheney et al. 2006, 311).

Other investigations currently being carried out in Botswana are the Groundwater Recharge Estimation Study, implemented by the University of Botswana and the Botswana government's Department for Geoscience in association with the University of the Netherlands, and the ongoing Kalahari Research Program of the International Institute of Aerospace Survey and Earth Science (ORASECOM 2007, 39-40). In Botswana, data on groundwater levels and extraction are being collected by the Department of Water Affairs and the Department of Geoscience. Unfortunately, the information gathered by these two departments is not mutually complementary and is also unsatisfactory in terms of quality and quantity (ORASECOM 2007, 39–45).

2.2.3 Studies carried out in South Africa

Generally, little is known about groundwater in the Orange Basin in South Africa (ORASECOM 2007, 104). Although South Africa is currently undertaking some groundwater resource assessment activities, no specific information for the SAB there is available. DWAF (South Africa) and the Water Research Commission (WRC) have prepared a number of groundwater maps (e.g. the Groundwater Harvest Potential Maps) which provide quantitative information on sustainable rates of groundwater extraction. The maps are prepared by the Department of Water Affairs and Forestry's Directorate of Geohydrology (http://www.dwaf.gov.za/Geohydrology/Maps/harvpot.asp).

2.3 Hydrogeological features

2.3.1 Groundwater occurrence

It is assumed that groundwater occurs in all three riparian countries in the upper Kalahari Group and in the underlying Karoo Sequences. The three main aquifers in the SAB in Namibia are in the Kalahari Beds, the Auob Sandstone and the Nossob Sandstone. The average thickness of the Kalahari Aquifer is 100 m, that of the Auob 80 m, and that of the Nossob 25 m (JICA 2002). In the southeastern part of the Namibian SAB, the Kalahari sediments are considerably thicker, reaching about 250 m in the ‘Pre-Kalahari Valley’.

The Auob Sandstone Aquifer and the Nossob Sandstone Aquifer lie in the Ecca Group of the lower Karoo Sequence and are separated by shale layers of the Mukorob Member, which is overlaid by Rietmond Shale and Sandstone. The Auob and Nossob Aquifers are confined and free flowing in the Auob Valley from Stampriet and further downstream, as well as in the Nossob Valley around Leonardville. Water levels elsewhere in boreholes in the artesian aquifers are subartesian. Several springs are located in the eastern outcrop of the Kalkrand Basalt in the northwest. Groundwater also occurs in the Kalahari layers across the basin and in the Prince Albert Formation of the Karoo Sequence.

As stated earlier, little is known about groundwater occurrence on the Botswana and South African side. For Botswana the most significant water-bearing layers are believed to be in the Lebung and Ecca Group (within the Karoo Supergroup). The Ecca Group is divided into two formations: the lower Kobe Formation and the Otshe Formation. The Otshe Formation is equivalent to the Auob Sandstone in Namibia. A conglomerate at the base of the Kobe Formation is classified as the Nossob Sandstone in Namibia and also occurs in Botswana (ORASECOM 2007, 28). Groundwater stored in the Kalahari Group is an important water source for settlements in southwestern Botswana (ORASECOM 2007, 35–36).

In South Africa, the aquifer in the Kalahari Group is known to be the most productive. Additionally, the underlying bedrock Karoo Sediments may contain important waterbearing strata. This, however, has not yet been investigated in detail for the whole region (Puri 2001, 52).

Estimates of groundwater storage volumes exist for the different aquifers in Namibia. It is estimated that the total quantity of water stored in the SAB's aquifers is 357 BCM, of which 120 BCM (33.6 %) is thought to be present in the Kalahari Aquifer, 180 BCM (50.4 %) in the Auob, and 57 BCM (16,0 %) in the Nossob.

These estimates, shown here in Table 1, assume an average porosity of 5 % of the Auob and Nossob Sandstones. However, this assumption has been called into question by various experts who believe that the actual figure is lower (A. Margane, personal communication 2007). The total stored volume in that case would also be smaller. Data available for the Namibian SAB therefore reflects uncertainties while at the same time showing gaps where further investigation is required.

Villages in southwestern Botswana's Matsheng area extract their water mainly from the shallow Kalahari Group, whose thickness ranges from 8

Table 1: Namibian aquifer data (unavailable for Botswana and South Africa)			
Aquifer	**Average depth (m)**	**Stored volume BCM**	**Percentage of total (%)**
Kalahari	0-250	120	33.6
Auob	0-150	180	50.4
Nossob	0-60	57	16.0
Total	-	357	100.0
Source: JICA (2002)			

to 108 m, and from the Lebung Group, which ranges from 17 to 120 m in thickness (Cheney et al. 2007, 303–04).

2.3.2 Geological origins and implications for water quality

Sedimentary succession in the SAB was basically created by a river system that enters Namibia at a point about 20°E and 24°S and flows in a southwesterly direction. This river system cuts deeply into the Karoo Sequence, which rests on the Kamtsas Formation in the north and northwest and on the Nama Group of rocks in the remainder of the basin. The Karoo Formations dip about 3 degrees to the southeast, and groundwater flow generally follows that direction. Sediments that created the sandstone layers were transported from higher-lying mountains in the northeast and were deposited in a deltaic environment in the basin. The subsequently deposited Kalahari layers are relatively thin along their northern and western boundaries, with calcrete and dune sand at the surface; in the southeast, however, the layers may be up to 150 m thick and are about 250 m thick in the pre-Kalahari River.

Groundwater quality deteriorates in a south-southeasterly direction[35] because the Kalahari in the central parts of the basin consists mainly of fine sand, silt and clayey deposits which have accumulated mineral salts due to

35 The quality of artesian water in the upper part of the basin is in the order of 1,000 to 2,000 mg dissolved solids/l, but this deteriorates to more than 5,000 mg dissolved solids/l in the southeastern parts of the basin.

low rainfall and runoff as well as high evaporation. The confining layer of the Auob Aquifer has also been largely carried away in the southeastern parts of the pre-Kalahari River, resulting in saline groundwater. In fact, the southeastern area of the SAB is referred to as the "Salt Block" because of the brackish to saline water in the Kalahari, Auob and Nossob Aquifers.

Regarding the border region between Namibia and Botswana, it is assumed that groundwater with good quality is found for 100-150 km into Botswana. The water is characterized by a relatively high sodium bicarbonate content, but salinity is low enough in most of the area to make it suitable for livestock consumption (and generally also for human consumption). Nevertheless, it is not necessarily usable for irrigation (Tredoux email 3.4.2007). Recent investigation of the Ecca aquifer in the Matsheng area of Botswana has shown that the water stored there is too saline for human or animal use.

Nitrates present in large areas of the SAB also limit groundwater use. Most of these nitrates are of natural origin. They extend to the artesian part of the aquifers via the overlying Kalahari Beds. Nitrate concentrations within artesian aquifers are naturally lower due to the presence of coal and carbonaceous shale (Tredoux email from 4.4.2007; WRC 2005).

South Africa's groundwater quality has been investigated for the Lower Orange Water Management Area.[36] It is very poor near the borders with Namibia and Botswana (Western Highveld), where the highest concentration of groundwater nutrients is found with a median of 15.1/mg/l in 2003. This value is above the threshold for human consumption (DTEC/CSIR 2004, 11).

2.3.3 Groundwater recharge

Most aquifer recharge is thought to occur on Namibian territory (Puri 2001, 52). Recent studies in Namibia have provided more details on recharge from surface runoff into the different aquifer layers. Estimates based on these studies are that recharge to the artesian aquifers in normal rainfall years is relatively low but that considerable recharge may occur during wet years, i.e. about once every fifty years. Recharge to all aquifers

36 The Lower Orange Water Management Area contains 13 groundwater regions (DTEC/CSIR 2004, 11).

in the basin during years with average rainfall is estimated at 105 MCM/year, or 0.5 % of rainfall (JICA 2002). However, recharge in wet years may be as much as 3 %, or around 1.5 BCM.

A recent study has led to a better understanding of these recharge mechanisms (JICA 2002). According to this study, small, shallow depressions caused by calcrete dissolution become karstic sinkholes where local runoff concentrates and sinks into permeable layers or structures below. In addition, fractures are also a major source of groundwater recharge. These geological features exist in the west, northwest and southwest of the basin. It has been confirmed that water tables begin to rise in artesian aquifers some 50 km from these recharge areas a few weeks after heavy rainfall has occurred. In addition, isotopic evaporation of the water in these artesian aquifers is very low or nonexistent.

In contrast to this, the water in the Kalahari layers in the central part of the basin has a very definite isotopic evaporation signal, indicating that a substantial proportion of rainfall evaporates and consequently does not recharge the aquifer.

2.3.4 Groundwater extraction in Namibia

A hydrocensus conducted as part of the most recent study[37] covered 1,269 commercial farms and collected information at boreholes (including wells and springs). It was found that of a total number of 6,280 boreholes in the SAB, 4,915 are currently in use, of which 3,915 tap the Kalahari Aquifer and 1,000 the artesian aquifers.

Extraction from the Kalahari Aquifer is estimated to be 9.8 MCM/year. This comprises about 65 % of all water extracted in the SAB in Namibia. Of the 1,000 boreholes drilled into artesian aquifers, 200 (20 %) yield artesian flow while 800 (80 %) tap subartesian water levels. 4.97 MCM/year are extracted from the Nossob Aquifer and only 0.2 BCM/year from the Nossob Aquifer (see table 2).

The depth of the boreholes ranges from 250 to 380 m. The age of the water is less than 40,000 years, and the water temperature is around 30 °C.

37 See DWAF (Namibia) / JICA (2000).

The artesian pressure is normally around 11 m, but drops in some places to between 5 and 6 m. Different factors may be responsible for this phenomenon: overextraction from the artesian aquifers, leakage into the upper aquifers, or a possible compression of confined layers, thus reducing storage capacity.

Table 2: Extraction data for Namibia

Aquifer	Stored volume (BCM)	Extraction (MCM/year)	Percentage of total (%)
Kalahari	120	9.80	65.50
Auob	180	4.97	33.20
Nossob	57	0.20	1.30
Total	357	14.97	100.00

Source: DWAF (Namibia) / JICA (2000)

3 Groundwater use patterns

The following is an attempt to shed light on patterns of groundwater use in the three countries which share the SAB's aquifers. All countries are highly dependent on groundwater resources, since climatic conditions are arid and surface water is unavailable during most of the year, especially at the joint borders.

3.1 Groundwater use patterns in Namibia

Approximately 35,000 people live in the SAB in Namibia. They extract groundwater from aquifers in the SAB for their domestic water supply, their livestock production, and for irrigation. Almost no groundwater is used for industrial purposes (see table 3).

Groundwater for domestic purposes in larger towns in the area is extracted from the Auob Aquifer. Only the town of Koës in the south uses water from the Nossob Aquifer. The subartesian aquifers at Aminuis have maintained their yields over many years, but other boreholes in the same aquifer have lower yields. At Leonardville, over-extraction has caused a large local drop in the water table, but at Aranos in the northwest the aquifer continues to supply sufficient water of good quality (although fine sand entering the boreholes causes operational problems). The town of Gochas formerly obtained water from the Auob Aquifer, but this groundwater gradually became contaminated with salt water from the overlying 150-m-thick Kalahari Aquifer, and it proved necessary to move the boreholes to a more suitable well field some 10 km to the north.

The great majority of the local population is dependent on farming for its livelihood. Groundwater is supplied to about 2,000 commercial farms in the SAB; these have now diversified from the production primarily of karakul pelts to stock farming with cattle, sheep, goat and ostriches. Groundwater is also used by 160 farms for irrigation, and the total area under irrigation is about 550 ha (all information by Piet Heynes).

The extension of the national electricity supply network to this area has increased the economic viability of irrigation farming, and further expansion will be limited only by the availability of water. It can be assumed that a major challenge for stakeholders in the area will be to determine the ecological and social sustainability of available water.

Table 3: Water consumption in the Stampriet Artesian Basin in Namibia

Sector	Consumption (MCM/year)	Percentage of total (%)
Domestic	2.37	15.80
Stock	5.70	38.10
Irrigation	6.90	46.10
Total	14.97	100.00

Source: DWAF (Namibia) / JICA (2000)

Almost no groundwater is used for industrial production. Although it is known that high-quality coal deposits are present, there is as yet no mining activity.[38] The small service industries in the towns are not major water consumers. The value of economic activities in the basin is estimated at roughly 1.33 million US$/a (N$1.0 billion/year, 1 US$ = 7.5 N$).

A study carried out by the DWAF (Namibia) and JICA in 2000 came to the conclusion that present groundwater extraction exceeds recharge in SAB, and that the groundwater supply is therefore unsustainable at present extraction rates. However, the assumptions used by this study to create a model of the water balance and for deriving rates of water use and sustainable extraction were not fully agreed upon by all stakeholders in Namibia. Consequently, monitoring has been further improved in order to keep track of these quantities and, if necessary, to arrive at results on the basis of which reasonable allocation decisions can be made.

Changes in groundwater availability on the Namibian side due to overuse make the question of future development of the aquifer a complicated and politically sensitive issue. Both the supply of potable water and the economic activities of the population in the basin depend on groundwater. What is certain is that artesian pressure on the Namibian side has decreased in some places from 11 m to 5 or 6 m in other places. Three possibilities have been advanced for this: over-extraction from the artesian aquifers, major leakage into the upper aquifers, and/or a compression of the confined layers which may have reduced storage capacity. Stakeholders in Namibia have reacted to these changes with further improvements in groundwater management in order to avoid further losses. Moreover, groundwater monitoring has been intensified in order to acquire reliable data as a basis for development decisions.

38 An investigation by the Coal Commission has shown that the coal deposits probably cannot be mined profitably, especially in view of the depth and the artesian water environment.

3.2 Groundwater use patterns in Botswana

Population density is low in Botswana's Molopo Basin, that part of Botswana into which the SAB extends. This is particularly true of the Kgalgadi District next to the Namibian border (ORASECOM 2007, 13–14). Extraction from the SAB in Botswana is therefore estimated to be limited. Groundwater is the only available water source most of the time in this region. It is drunk by game and is used for stock watering, human consumption, agriculture, and tourism.

Current plans to develop commercial ranching in the Kgalagadi District would overstrain the available supply of fresh groundwater (Cheney et al. 2006). Moreover, recent studies of the hydrogeological potential of the Kalahari's deep Ecca Aquifer in southwestern Botswana have shown that groundwater in the high-yield Ecca Aquifer is suitable neither for human nor for animal consumption due to its high salinity.

One third of the Kgalagadi District is in the Kgalagadi Transfrontier National Park, where water is used for tourism and by wild animals. The park is shared by Botswana and South Africa and unites the Kalahari Gemsbok National Park in South Africa with the Gemsbok National Park in Botswana. It can be assumed that further development of tourism in the region will (modestly) increase water demand.

3.3 Groundwater use patterns in South Africa

In South Africa, the Kgalagadi Transfrontier National Park is part of the Gordonia District in Northern Cape Province. The area belongs to the Lower Orange Water Management Area. The DWAF (South Africa) has underscored the importance of careful groundwater utilisation in this water management area, since groundwater is the only source of water in many parts of the WMA. However, groundwater availability and quality is low in the northern, sparsely populated parts of the bordering Namibia and Botswana[39] (DTEC/CSIR 2004, 15).

39 Since the borders of the SAB have not yet been clearly identified, it should be noted that the Molopo groundwater region can count on a much higher availability of groundwater (Molopo: 31 MCM/year, Lower Orange – Orange Sub-Water Management Area: 9 MCM/year) (DTEC/CSIR 2004, 15).

Both surface and groundwater extraction facilities in the area are so fully developed and utilised that no significant potential for further development exists (DWAF [South Africa] s. a.). In particular, aquifers in the Karoo sediments have only limited potential for further development because, apart from their water quality, their permeability and storativity is low. Consequently, it would be possible to derive significant further quantities of water only through a high number of boreholes (ORASECOM 2007, 108).

4 Transboundary implications

The following chapter elaborates on transboundry impacts in the SAB and analyses the cooperation problem which is mainly characterized by highly asymmetric development of the groundwater resources in the SAB.

Although accurate information on the extent and composition of the hydrogeological environment is almost entirely limited to the Namibian side, it is certain that aquifers in the SAB there continue further southeastwards into Namibia's neighbouring countries. The SAB must therefore be regarded as a transboundary aquifer system. Thus, transboundary impacts can occur.

At the time of writing, no information was available that point towards manifest negative transboundary impact from this use. Nor is information available which might indicate a reduction of extractable volumes on the part of downstream riparians due to (over-)use in the (Namibian) upstream area. Nor is the decline in water quality along the groundwater flow from northwest to southeast caused by groundwater use in the upstream riparian area; it is assumingly due to natural processes which limit the usable volume of groundwater (information from DWAR).

Therefore, even if Botswana and South Africa were to aim at further development of the SAB's aquifers in their territories, the low quality of the water in these aquifers and their respective hydrogeological conditions would probably limit possibilities for usage. However, an accurate assessment of transboundary implications will be possible only after the boundaries and interrelationships of the aquifer basin as a whole become known.

The transboundary cooperation problem at the SAB is characterized by two facts: First, demand and use by the riparian countries is asymmetrical, as the previous chapter has shown. Although three countries share the groundwater basin, only Namibia makes significant uses of its groundwater. This is presumably due to the more favorable natural conditions, i.e. groundwater occurrence and quality, on the Namibian side.

Secondly, transboundary cooperation in use of SAB groundwater must take into account the upstream-downstream constellation between Namibia as the upstream riparian and Botswana and South Africa downstream. This can be illustrated by using the types of Eckstein and Eckstein already described (Eckstein / Eckstein 2005). As mentioned, these six types were developed as paradigms for the application of international law in relation to groundwater. They show the potential implications of transboundary groundwater by two riparian countries which share one aquifer.

Although three countries share the SAB, and in spite of the fact that little is known about the aquifers underlying Botswana and South Africa, the Eckstein Models B and E seem to apply best to the situation in the SAB the upper Kalahari Aquifer is unconfined, the lower Auob and Nossob Aquifers appear to be partially both confined and unconfined, and recharge is present in one country. The aquifers are hydraulically connected to rivers and are intersected by international borders, and there is a water flow from one state to the other (in this case Namibia would be State A, Botswana and South Africa would be State B/State C).

Following this analysis South Africa and Botswana are likely to be only moderately interested in using the SAB's groundwater because of its poor quality and because population density in the border regions is low. For their part, Namibian farmers, who are in an upstream position, will likewise have only a limited interest in cooperating with their neighbours for fear that this might limit their use of groundwater from the SAB, on which they are very dependent.

Apart from the transboundary groundwater cooperation problems, groundwater management problems exist within Namibia (compare 3.1), and conflicts between Namibia and Botswana over available surface water have occurred. Future water-related conflicts could also arise due to dam building projects and to growing water demands on all sides as a result of population growth and climatic changes.[40]

5 Institutional arrangements for groundwater management and transboundary cooperation

The following is a brief overview of national and interriparian institutional arrangements for groundwater management in the SAB. A detailed analysis of these arrangements, including water legislation and policies, would far exceed the scope of this paper and is therefore not given here.

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40 Conflicts between Namibia and Botswana over available surface water runoff are reported stemming from a number of dams that have been built in the upper reaches of the Auob and the Nossob rivers in Namibia. The downstream impacts of these dams have been regarded as negligible by Namibia. The reason for this approach is firstly the fact that the flow in the Oanob River, which is a tributary of the Auob River, is basically blocked off by sand dunes and the runoff would therefore not have been available to augment flow further downstream in the Auob. The effect of the Oanob Dam at Rehoboth in Namibia on the flow Oanob River and indirectly in the Auob River could therefore be regarded as negligible. Secondly, the same argument applies to the Otjivero Dam at Omitara on the White Nossob River and the Daan Viljoen Dam at Gobabis on the Black Nossob River. The Otjivero Dam commands a relatively small portion of the total catchment and the Daan Viljoen Dam has a very small basin that can only impound a small portion of the runoff. Downstream of the confluence of these two tributaries the river is known as the Nossob River.

It is also known that the farmers along the Nossob river construct low cost embankments comprising the *situ* river alluvium, about 1,000 mm high, across the river to retard the flow during runoff events in order to give the water time to recharge the alluvium in the river bed with groundwater for future extraction. These embankments are normally washed away during a runoff event. However, this practice raised concern by Botswana because it is perceived that there is a reduction in the surface runoff in the Nossob River where it forms the border between Botswana and South Africa in the Kgalagadi Transfrontier National Park (Information from DWAF [Namibia]).

A conflict has also arisen because farmers along the Nossob river regularly construct low-cost embankments of *in situ* river alluvium about 1 m high across the river to retard its runoff in order to recharge the alluvium in the river bed with groundwater for future extraction. These embankments normally wash away during runoff. This has caused concern in Botswana that surface runoff may be reduced in the Nossob River between Botswana and South Africa in the Kgalagadi Transfrontier National Park (Information from DWAF [Namibia]).

5.1 National institutional arrangements

5.1.1 Institutional arrangements in Namibia

The Department of Water Affairs and Forestry for Namibia (DWAF [Namibia]) within the Namibian Ministry of Agriculture, Water and Forestry has a Geohydrology Division which is responsible for all water resource development projects in the country, including irrigation planning and development.

Groundwater extraction in Namibia is controlled through a permit system. After Namibia came under South African administration in 1921, the Artesian Water Control Proclamation (Proclamation 49, 1921) for the control of drilling activities in artesian aquifers in the country was issued in 1921 in order to ensure correct drilling techniques and prevent leakage from the confined artesian aquifers into the surrounding unconfined aquifers.

A licence had to be obtained before any drilling work was carried out, and all boreholes had to be licensed for purposes of supervision. This Proclamation was followed by two more in 1949 and 1950 in an attempt to improve the control over the drilling and extraction of water. In 1955, the existing laws governing use of artesian water were consolidated in the Water Ordinance No 35 of 1955, and the SAB was formally declared a Subterranean Water Control Area. The Ordinance also required that information about the actual quantity of water extracted must be provided by the permit holder. After the Articles of the South African Water Act of 1956 (Act No 54 of 1956) were made applicable in Namibia, Regulation R1278 was promulgated to regulate the sustainable use and management of artesian water sources, including those of the SAB.

At present, existing laws and regulations are enforced in the form of cooperation with water users. Groundwater management is controlled by means of both the permit system and the activities of local water user committees.

User participation is institutionalized in Namibia through Basin Management Committees. These organizations are created for surface water basins. In view of concerns on the part of both local water users and the government about possible overextraction of water in the SAB in Namibia, an aquifer management committee, the so-called Stampriet Basin Water

Committee, was formed to assist the Department of Water Affairs and Forestry in monitoring water utilization in the basin.

The Department consults with the Committee about new applications for water development, and the Committee provides information about the extraction of water, the management of water resources, the illegal drilling of boreholes, leakage of boreholes, and any wasteful use of water. The Department also monitors water levels and gives technical advice to the drilling industry about the development of boreholes under artesian conditions. The technical capacity of the Committee is limited, however, by the fact that its members are mostly farmers who have not been trained in water-related disciplines.

5.1.2 Institutional arrangements in Botswana

A number of institutions are responsible for water management in Botswana, including the Department of Water Affairs (DWA), the Department of Geological Surveys, and the Water Utilities Corporation in the Ministry of Minerals, Energy and Water Affairs, which is responsible for national water policy. The Water Utilities Cooperation is responsible for supplying water to all urban and mining centres. The Ministry of Agriculture supervises water provision to livestock and agriculture. In the rural areas, district councils under the supervision of the Ministry of Local Government, Lands and Housing oversee the supply of water to rural villages (FAO Country Profile Botswana).

This organizational setup has been criticised as lacking a clear and simple structure for water administration and for poor performance as a result (Swatuk / Kgomotso 2006, 4).

In Botswana, the National Water Master Plan being revised with the aim of providing an analysis of development potential of all available water resources. Given Botswana's high dependency on groundwater, this is of special concern: the Botswana Government currently estimates that groundwater supplies will be exhausted by the year 2020 due to increasing demand (NWMP 1992, cited in Swatuk / Kgomotso 2006, 3). Options currently under consideration are infrastructure developments such as dam construction, more boreholes, intrabasin and inter-basin transfer schemes, and technological intervention for better detection and utilisation of groundwater resources (Swatuk / Rahm 2004; Allan 2003 both cited in Swatuk / Kgomotso 2006, 3).

Against this background, Botswana has recognized the use of internationally shared water supplies (border rivers and perhaps transboundary aquifers) as a very important challenge for the future. It has therefore established an International Water Unit within the Ministry of Natural Resources to provide technical support for the management of shared river basins (Kranz / Interwies / Vidaurre 2005, 4, 5).

In the area of the SAB, however, no user-based organisation or institutionalized participation mechanism are known in Botswana. At most, an institutionalised mechanism of participation for the Okavango region has been mentioned by Swatuk and Kgomotso, who also describe a countrywide Community-Based Natural Resources Management Program; both rely on stakeholder participation (Swatuk / Kgomotso 2006, 3). It can therefore be assumed that at least a few user participation mechanisms do exist, at least formally, in the Botswanian part of the SAB.

5.1.3 Institutional arrangements in South Africa

In South Africa, the Water Act of 1998 specifies that all water use, with the exception of reasonable domestic use, home garden use, and stock water requirements, must be licensed. The issue of shared water basins is also integrated into this act (compare Heyns 2005, 60).[41] The Geohydrology Division in South Africa's Department of Water Affairs and Forestry (DWAF [South Africa]) is in charge of for groundwater-related issues in that country. The DWAF (South Africa) monitors surface and groundwater resources, supports the formulation of national water strategy, and is responsible for implementation of the Water Act. For its part, the Water Research Commission is responsible for most of the research conducted on the various aspects of water use in South Africa.

The Water Act divides South Africa into 19 Water Management Areas. It provides for a phased establishment of catchment management agencies which will gradually take over water resource management functions currently performed by the DWAF (South Africa). These catchment mana-

41 For an assessment of South African Water Policy see for example Turton et al. (2003).

gement agencies will be responsible for planning, implementing and managing water resources and will also coordinate all water-related activities and ensure public participation in water management (Mvula Trust 2005).

Where water user associations and catchment management agencies have not yet been finalized or are still being set up, the DWAF (South Africa) will continue to carry out these functions. Establishment of a catchment management agency for the Lower Orange WMA has only low priority, and it will therefore be years before this catchment management agency can take over the tasks of DWAF (South Africa) in this area (Herrfahrdt-Pähle, personal communication 2007).[42]

5.2 Interriparian agreements on water

Numerous bilateral and multilateral agreements exist concerning water use among the riparian countries. For the SAB, however, no special institution for joint management is in place, and consequently no formal interriparian cooperation in use of the SAB exists. Due to the fact that the riparian countries already cooperate in the form of numerous agencies and therefore share close contact and experiences regarding transboundary water management, formal and operational collaboration on groundwater issues will probably intensify as the need becomes more pressing. Since the SAB lies within the Orange River Basin, the River Basin Commission would be the most likely candidate in that case to assume responsibility for transboundary groundwater management.

5.2.1 Bilateral agreements

In 1992, the governments of Botswana and Namibia established a Joint Permanent Water Commission (JPWC) to deal with water matters of common interest (i.e. the Okavango River, various transboundary groundwater sources, and the Kwando-Linyanti-Chobe System (Heyns 2005, 71). According to Turton et al., this agreement is the only known international

42 Turton et al. discuss successful cooperation between the Water User Associations and the DWAF (South Africa) for managing the transboundary Pomfret-Vergelegen Dolomitic Aquifer, which is shared by South Africa and Botswana (Turton et al. 2006b, 377–384).

agreement in the SADC region that includes groundwater systems (WRC 2007, 25).

South Africa and Namibia established a Permanent Water Commission (PWC) in 1992, particularly in order to deal with issues involving management of the Lower Orange River along the common border between the two countries. The Commission's responsibilities were also to extend to ephemeral rivers along the boundaries of the Walvis Bay enclave in Namibia, which was South African territory until 1994. Although management of internationally shared groundwater sources was not specifically mentioned at that time, both States implicitly understood that it falls within the Commission's area of jurisdiction (information from DWAF [Namibia]).

5.2.2 Multilateral agreements

As members of the Southern African Development Community (SADC), all riparian countries of the SAB support the SADC Protocol on Shared Water Resources. They are also members of various other river basin commissions. The SADC has given increasing attention to groundwater issues in recent years (box 1).

The riparian countries of the SAB also share the Orange River Basin with Lesotho. In November 2000, they established the Orange-Senqu River Basin Commission (ORASECOM) in order to deal with water matters of common interest[43] and agreed to share information on a regular basis. In order to improve joint efforts to protect the basin, the parties also agreed to notify each other of any activities affecting the river system which might have a negative impact on the other riparians.

ORASECOM is intended to be a mediatory as well as an advisory body to the members. It conducts feasibility studies and can, in case of disputes or disapproval, transfer the issues in question to the political level, where the SADC's dispute settlement mechanisms come into play (Wirkus / Böge 2006). ORASECOM is funded both by the water ministries of the member states and by international donors. Together with other international donors, Germany is providing support for the development of ORASECOM.

43 Botswana and Namibia also cooperate in the Permanent Okavango River Basin Water Commission (OKACOM) and the Zambezi Watercourse Commission (ZAMCOM).

The institutional structure of ORASECOM was modified in 2005[44] to provide a small secretariat in South Africa and a Technical Task Team for the management of ORASECOM projects.

Currently, ORASECOM has put together a groundwater overview as a prelude to the development of the Integrated Water Resources Management (IWRM) Plan for the Orange Basin (see ORASECOM 2007). This clearly shows the importance of groundwater issues for ORASECOM. Another hint in this direction is, for example, the fact that in 2004 ORASECOM presented a project portfolio to the EU in which numerous legislative issues and studies of transboundary aquifers were listed as priorities (Heyns 2004, 9, in Wirkus / Böge 2005). The need for further investigation of the shared aquifers was again underscored in the preparatory paper for the IWRM plan concerning groundwater (ORASECOM 2007).

It should also be noted that the member governments instructed ORASECOM at its inception to conduct a joint study of the Molopo and Nossob watercourse system. Terms of reference for a formal study have already been drafted, and donor interest has been mobilized to fund the project. Since the lower Nossob River may lie within the SAB, an inventory of water resources in the study area will probably also yield information on the SAB.

Since ORASECOM's head offices are manned by only a small staff, the capacities of ORASECOM for transboundary groundwater management in the SAB depend heavily on the capacities of the member states themselves, i.e. on their political willingness to cooperate in use of the SAB.

44 The importance and strategic interests of all riparian countries in the Orange-Senqu-Basin are analysed in Wirkus / Böge (2006) and Kranz / Interwies / Vidaurre (2005).

Box 1: Groundwater in the SADC

All riparian countries of the SAB are members of the SADC and are therefore committed to support the SADC Protocol on Shared Water Resources (a revised version of which came into force in 2003). This Protocol defines watercourses in accordance with the UN Convention on Use of International Watercourses, which are defined in that Convention as systems in which surface and ground waters flow into a common terminus. The SADC Protocol lays down principles for the coordinated, cooperative and equitable use of water by the riparian countries. It takes issues of social development and environmental protection into account, and mandates an exchange of information among the riparian states about plans and projects pertaining to shared water resources. The SADC protocol provides for the development of joint management mechanisms (e.g. at the river basin level) and supports the IWRM concept, which implicitly includes groundwater.

Given the importance of transboundary aquifers in the SADC region, experts have called for an SADC agreement that specifically focuses on groundwater. To this end, accurate groundwater maps, groundwater classification in terms of hydrogeological characteristics and future demands, and adequate management regimes are deemed necessary (Turton et al. 2006, 3).

The Regional Strategic Action Plan for IWRM of 1998 includes a Regional Groundwater Management Program as one of 31 strategic projects. This Groundwater Management Program for the SADC Region aims at promoting sustainable use of water resources by assessing groundwater and groundwater management programs, integrating groundwater issues into regional water resource development programmes, and linking up national and regional initiatives in this respect.

The SADC has established a Sub-Committee for Hydrogeology in which each member state is represented. This committee supervises and guides national hydrogeological projects of regional magnitude. The Sub-Committee has undertaken an analysis of groundwater management in the Member Countries and has prepared a Regional Code of Good Practice for Groundwater Development. Joint management of river basins and their underlying groundwater resources is encouraged by the Sub-Committee in order to ensure efficient use of the RBO's institutional and personnel capacities.

Box 1 continued
International donors are active in the groundwater sector of the SADC. With support from United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Kingdom has provided grants, and International Groundwater Resources Assessment Centre (IGRAC), a web-based database for information on transboundary aquifers in Southern Africa, has been developed to facilitate information sharing and joint transboundary groundwater management. Nevertheless water experts from the region agree that information on the transboundary implications of groundwater use in the region is lacking in many cases and mostly concerns only one riparian country. Difficulties in reaching a regional consensus on groundwater information requirements reflect the lack of a functioning regional monitoring network (WRC 2007, 24). The World Bank, the Global Environment Facility (GEF) and the Swedish International Development Cooperation Agency (SIDA) are currently supporting a SADC Drought Management Project. One of the project's objectives is the establishment of a regional Groundwater Institute of Southern Africa (GISA). Moreover, the German and French governments are funding hydro-geological mapping activities as part of this international project (WRC 2007, 24).

6 Prospects for transboundary cooperation and recommendations for German development cooperation

Access to information and conclusions

Namibia can rely on detailed information concerning the SAB. (This information has kindly also been made available to the author of the present study by Piet Heyns).

Only limited information is available concerning aquifers in Botswana and South Africa, presumably because precise data on SAB aquifers underlying the two countries is still lacking. It would certainly be worthwhile to investigate these aquifers in more detail as part of a full-scale investigation of groundwater occurrence in the SAB. Among other benefits, this would permit an investigation of potential downstream impacts in the basin.

The fact that the SAB has not yet been fully investigated in the very groundwater-dependent countries of Botswana and South Africa suggests that these two riparian countries have limited interest in making use of the SAB.

Transboundary implications and conclusions for transboundary cooperation

Aquifers in the SAB are heavily used in Namibia, where water occurrence and water quality are favourable. However, there are also signs of overuse of the aquifers in the SAB there. In Botswana and South Africa, on the other hand, groundwater use in the area assumed to lie within the SAB, that is, in the triangle between the three countries and near the border between Botswana and Namibia, is rather limited. This seems to be due to the rather poor quality of the groundwater, which in Botswana and South Africa is apparently similar to the low water quality of Namibia's so-called “Salt-Block”. Both population density and demand in these areas of Botswana and South Africa are low.

The cooperation problem in the SAB shows two characteristics: First, a highly asymmetric demand and development of the groundwater in the three riparian countries, with Namibia as the only significant user the aquifers, and second, an upstream-downstream constellation between the upstream-user Namibia and the downstream riparians Botswana and South Africa.

However, from the information available rather similarly low incentives for cooperation can be concluded for Namibia as the upstream, main user of the groundwater and Botswana and South Africa with low water quality and/or limited groundwater occurence in the area. As for the South African side no possible further development of the groundwater resources in the (Lower) Orange Basin is stated, the interst to specificall cooperate over the SAB might also be limited. But, further information on potential transboundary impacts might modify this preliminary conclusion and reveal driving forces for cooperation.

Institutions already in place have created a promising environment for the riparian countries of the SAB to expand their cooperation (e.g. for carrying out joint studies on the hydrogeological environment of the aquifers) if needed:

— National institutions and policies for groundwater management are in place in all three riparian countries. This provides a basis for transboundary cooperation. In Namibia, where the SAB is used most, groundwater management is carried out in close cooperation with water users in order to ensure ecological and socially sustainable groundwater management.

— Botswana, Namibia and South Africa have all ratified the United Nations Convention on the law of non-Navigational Uses of International Watercourses, and all three states are party to the Protocol on Shared Watercourses drafted in accordance with the Treaty that established the SADC.

— In view of existing bilateral and multilateral water institutions (e.g. the JPWC, the Pricewaterhouse Coopers, and ORASECOM), there seems to be a considerable degree of understanding and mutual trust on both the technical and political levels between the basin states.

— Since no mechanism exists for transboundary consultation on the part of local authorities, the Water Committee in Namibia, and other riparian institutions, ORASECOM is destined to play a key role in supporting transboundary groundwater investigations and studies and in monitoring initiatives in the SAB. ORASECOM is aware of the importance of this role for basinwide groundwater management and is integrating its tasks into the development of the Orange Basin IWRM Plan.

— The capacity of ORASECOM to carry out projects for transboundary groundwater management in the SAB will depend on the personnel and financial capacities made available by the member states; this in turn will depend on the priorities of the member states. At present, the riparian countries appear to assign only low priority to transboundary groundwater management of the SAB.

Role of external factors and recommendations for German development cooperation

External factors play a role mainly in the development of technical capacities and advisory services for water policies at national and regional levels and in providing support for hydrogeological and socio-economic investigations.

In this regard, German development cooperation can be applied effectively at both the national and regional levels:

— At the regional level, German DC should support the riparian countries through the ISARM initiative in a basin-wide groundwater investigation in order to clarify potential transboundary implications and to find possibilities for the improvement of groundwater use and development in the riparian countries. In the process, German development cooperation can contribute to the SADC Regional Groundwater Assessment Project, which lists development of the Karoo aquifers as one of 10 high-priority projects. In this regard, German expertise could be brought in by the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR).

— At the regional level, German DC should support transboundary groundwater management as a task of ORASECOM. Currently, German DC is already bilaterally supporting ORASECOM by supporting the SADC water management as implemented through Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). Here, a "groundwater component" could be added.

— At the national level, only Namibia has found signs of overuse of the SAB aquifers. Support for ecologically and socially sustainable groundwater management should therefore be provided by German DC. Water, however, is not a priority of German development cooperation in the three riparian countries. In Namibia, on the other hand, water-related activities are being carried out in the priority areas of environmental policy, conservation and sustainable use of natural resources.

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