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A4A – aqua for all
AGW-Net – Africa Groundwater Network
ANBO – African Network of Basin Organisations
BGR – Federal institute for geosciences and natural resources
UNDP-Cap-Net
BMZ – Federal Ministry for Economic Cooperation and Development
GWP – Global Water Partnership
IGRAC – International Groundwater Resources Assessment Centre
imawesa – Improved Management of Agricultural Water in Eastern and Southern Africa
IWMI - International Water Management Institute

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Picture: BGR – Bundesanstalt für Geowissenschaften und Rohstoffe
MANAGEMENT OF TRANSBOUNDARY AQUIFERS

LEARNING OBJECTIVES

■ To understand the concept of transboundary groundwater and its management issues
■ To become familiar with the location and extent of transboundary aquifers in Africa
■ To become familiar with the legal frameworks for the management of transboundary aquifers
■ To understand some of the current management issues and approaches applied to transboundary aquifers in Africa

4.1 Introduction
Water management is typically perceived and practically carried out within hydrological basins (river basins, lake basins). When such basins transcend national borders, the issues at hand become a matter of international concern. This is because the actions and perturbations to the water resources in one country potentially affect the other countries sharing that transboundary resource. International water cooperation is rising to become a very important topic in water resources management, as water resources become increasingly stressed from various factors such as climate change and human development. Most of the major and many of the smaller river basins in the world are shared between two or more countries and in total 263 river basins are transboundary. Tools for co-management, international law, and general theory of the best options for transboundary water management (TWM) are being steadily developed, and experience across the globe is increasing (INBO and GWP, 2012).

4.2 What is a transboundary aquifer (TBA)?
Groundwater, as well as surface water, inevitably flows across international borders. However the attention to this and possible implications and approaches for TWM related to groundwater have only recently been developed. Focus has hitherto been on surface water, for obvious reasons of visibility of the resource. However since surface water and groundwater are usually linked hydrologically, the groundwater component cannot be ignored if proper accounting for transboundary water interactions is to be achieved and possible associated conflicts are to be avoided.

Transboundary aquifers (TBAs) are those major groundwater systems that span across more than one country. The definition of a TBA is: ‘an aquifer or aquifer system, parts of which are situated in different States’ (Article 2c, Stephan 2009) (Fig. 4.1). Since groundwater is more or less ubiquitous, most borders will be underlain with shared groundwater. However the term TBA seems to be reserved for those larger contiguous and productive aquifers or aquifer systems that merit joint management due to their potential or current importance for water supply or other reasons, e.g. for important connected ecosystems. Currently more than 450 TBAs have been identified globally (IGRAC, 2012). As illustrated in Figure 4.1, transboundary groundwater systems may not have obvious upstream-downstream relations, as opposed to rivers, and they may even change flow direction as a result of changing abstraction patterns.
Even within the same overall system, heterogeneity in properties and layering can give rise to opposing flow between local shallow aquifers and deeper, regional aquifers. Such complexities specific to groundwater make the characterisation and co-management of TBAs more complex.

TBAs need to be characterized in terms of extent (horizontal and vertical), recharge (areas, mechanisms, rates), storage capacity, as well as flow patterns, relationship with surface water systems, vulnerability, current exploitation levels, potential for further development, and existing threats.

Historically such assessments would terminate at the border of each country, but for TWM these assessments need to be done jointly, in a harmonised way, and with balanced focus on all the shared parts of the aquifer systems. An important distinction is between renewable vs. non-renewable aquifers, i.e. aquifers that receive insignificant recharge during present climate and land use, as these will basically not be naturally replenished if exploited.

**Figure 4.1 Transboundary groundwater**

Different classification methods for TBAs have been developed in an attempt to systematically group the TBAs and as a tool to provide coherent management according to different characteristics of the TBAs. One such example is given in Figure 4.2. UNESCO’s Internationally Shared Aquifer Resources Management (ISARM) initiative, the Worldwide Hydrogeological Mapping and Assessment Programme (WHYMAP), the International Groundwater Resources Assessment Centre (IGRAC), the UN World Water Assessment Programme (WWAP), the Food and Agriculture Organisation of the United Nations (FAO) and many other partner organizations over the last decade, and the recent TWAP Assessment of Transboundary Aquifers have been compiling and complementing the available information at the global scale related to TBAs.
4.3 Transboundary aquifers in Africa

Africa is known for its large proportion of water systems that are shared between nations. Approximately 64% of the continent’s landmass occurs in transboundary international river basins. River basins such as the Nile, Congo, Niger, Volta, Orange-Senqu, and Zambezi are the major ones. A large number of TBAs have also been identified for Africa, presently about 80, but more and smaller ones are likely to be added as more information and knowledge becomes available. Figure 4.3 shows a map of the presently identified TBAs in Africa overlain on the international river basins, and Table 4.1 gives key data for the TBAs. It is clear from this that groundwater and surface water resources do not necessarily coincide geographically.

The TBAs encompass a wide variety of characteristics, in size as well as geological setting, recharge and population density. Presently identified TBAs represent approximately 42% of continental land area and 30% of the population. There is a huge difference between the aquifers in terms of population living within individual TBAs, reaching approximately 63 million in the case of the Nubian Sandstone Aquifer System (AFNE12) to less than hundred inhabitants (Medium Zambezi Aquifer, AFS17; and L’Air Cristalline Aquifer, AFWC21) (Altchenko and Vilholth, 2013). The same heterogeneity exists in terms of areal extent, ranging from smaller than 1500 km² (Jbel El Hamra Aquifer, AFNE22 and Fighug Aquifer, AFNE18) to larger than 2.6 million km² (Nubian Sandstone Aquifer System, AFNE12). The latter is comparable to the size of the Lake Chad River Basin (2.4 million km²). TBAs are shared between two and up to eight states, the latter being the case for the Lake Chad Aquifer Basin (AFWC14).
**Type A:**
An unconfined aquifer that is linked hydraulically with a river, both of which flow along an international border (i.e., the river forms the border between two states)

**Type B:**
An unconfined aquifer intersected by an international border and linked hydraulically with a river that is also intersected by the same international border

**Type C:**
An unconfined aquifer that flows across an international border and that is hydraulically linked to a river that flows completely within the territory of one state

**Type D:**
An unconfined aquifer that is completely within the territory of one state but that is linked hydraulically to a river flowing across an international border (in such cases, the aquifer is always located in the “downstream” state)

**Type E:**
A confined aquifer, unconnected hydraulically with any surface body of water, with a zone of recharge (possibly in an unconfined portion of the aquifer) that traverses an international boundary or that is located completely in another state

**Type F:**
A transboundary aquifer unrelated to any surface body of water and devoid of any recharge

Figure 4.2. Different types of TBA systems, based on flow characteristics and interactions with surface water. Source: Eckstein and Eckstein (2003)
INTEGRATION OF GROUNDWATER MANAGEMENT INTO TRANSBOUNDARY BASIN ORGANIZATIONS IN AFRICA

Figure 4.3. Map of transboundary aquifers in Africa. Source: Altchenko and Villholth (2013)
<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Countries sharing the aquifer</th>
<th>Population (inhabitants)</th>
<th>Area (km²)</th>
<th>Aquifer type</th>
<th>Rainfed (mm/year)</th>
<th>Annual recharge (MM/MPA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFS1</td>
<td>Karoo sedimentary aquifer</td>
<td>Lesotho/South Africa</td>
<td>5,569,000</td>
<td>166,000</td>
<td>Consolidated sedimentic rocks</td>
<td>350 – 1,200</td>
<td>VS to M</td>
</tr>
<tr>
<td>AFS2</td>
<td>Coastal sedimentary basin 1</td>
<td>Mozambique/South Africa/Kenya</td>
<td>7,300</td>
<td>11,700</td>
<td>Quaternary and consolidated sedimentic rocks</td>
<td>700 – 1,200</td>
<td>M to H</td>
</tr>
<tr>
<td>AFS3</td>
<td>Coastal sedimentary basin 2</td>
<td>Mozambique/South Africa/Thailand</td>
<td>306,000</td>
<td>5,500</td>
<td>Volcanic/Quaternary</td>
<td>800 – 830</td>
<td>VS to VL</td>
</tr>
<tr>
<td>AFS4</td>
<td>Coastal sedimentary basin 3</td>
<td>Botswana/Namibia/South Africa</td>
<td>19,500</td>
<td>11,700</td>
<td>Karoo groups aquifer and Karoo supergroup aquifer</td>
<td>300 – 350</td>
<td>VL to IS</td>
</tr>
<tr>
<td>AFS5</td>
<td>Ngoro aquifer</td>
<td>Botswana/Namibia</td>
<td>2,300</td>
<td>10,300</td>
<td>Consolidated sedimentic rocks</td>
<td>300 – 350</td>
<td>VL to IS</td>
</tr>
<tr>
<td>AFS6</td>
<td>Ngoro sedimentary basin</td>
<td>Botswana/Namibia</td>
<td>377,000</td>
<td>5,200</td>
<td>Quaternary and consolidated sedimentic rocks</td>
<td>300 – 350</td>
<td>VL to IS</td>
</tr>
<tr>
<td>AFS7</td>
<td>Loulo groundwater basin</td>
<td>Botswana/Namibia</td>
<td>135,000</td>
<td>3,200</td>
<td>Molinia subgroup of the Tanaese supergroup</td>
<td>300 – 350</td>
<td>VL to IS</td>
</tr>
<tr>
<td>AFS8</td>
<td>Loulo groundwater basin</td>
<td>Botswana/South Africa</td>
<td>313,800</td>
<td>20,000</td>
<td>Volcanic and basement rocks</td>
<td>400 – 700</td>
<td>VL to GS</td>
</tr>
<tr>
<td>AFS9</td>
<td>Tull Kano subsurface basin</td>
<td>Botswana/South Africa/Zimbabwe</td>
<td>70,600</td>
<td>14,330</td>
<td>Volcanic and basement rocks</td>
<td>300 – 400</td>
<td>VL to IS</td>
</tr>
<tr>
<td>AFS10</td>
<td>Northern Kaban/Karno basin</td>
<td>Angola/Botswana/Namibia/Zambia</td>
<td>35,900</td>
<td>144,000</td>
<td>Consolidated sedimentic rocks</td>
<td>380 – 200</td>
<td>LS to IS</td>
</tr>
<tr>
<td>AFS11</td>
<td>Eastern Kaban/Karno basin</td>
<td>Angola/Botswana/Zimbabwe</td>
<td>54,300</td>
<td>38,600</td>
<td>Unconsolidated intergranular aquifer and weathered basement complex</td>
<td>400 – 600</td>
<td>VS to LS</td>
</tr>
<tr>
<td>AFS12</td>
<td>Eastern Kaban/Karno basin</td>
<td>Angola/Botswana/Zimbabwe</td>
<td>30,300</td>
<td>10,700</td>
<td>Unconsolidated intergranular aquifer and weathered basement complex</td>
<td>700 – 750</td>
<td>VS to IS</td>
</tr>
<tr>
<td>AFS13</td>
<td>Shire Valley aquifer</td>
<td>Malawi/Zambia</td>
<td>827,000</td>
<td>8,200</td>
<td>Terminal Continental</td>
<td>780 – 950</td>
<td>M to VS</td>
</tr>
<tr>
<td>AFS14</td>
<td>Aruanga Alluvial</td>
<td>Malawi/Zambia</td>
<td>12,500</td>
<td>21,000</td>
<td>Alluvial</td>
<td>780 – 1,200</td>
<td>VS to LS</td>
</tr>
<tr>
<td>AFS15</td>
<td>Aruanga Alluvial</td>
<td>Malawi/Zambia</td>
<td>2,103,000</td>
<td>20,300</td>
<td>Unconsolidated intergranular aquifer and weathered basement complex</td>
<td>800 – 1,300</td>
<td>VS to LS</td>
</tr>
<tr>
<td>AFS16</td>
<td>Coastal sedimentary basin 1</td>
<td>Mozambique/South Africa</td>
<td>1,700</td>
<td>19,600</td>
<td>NI</td>
<td>1,600 – 1,750</td>
<td>H to VH</td>
</tr>
<tr>
<td>AFS17</td>
<td>Coastal sedimentary basin 2</td>
<td>Mozambique/South Africa</td>
<td>13,300</td>
<td>23,000</td>
<td>NI</td>
<td>1,400 – 1,750</td>
<td>M to VL</td>
</tr>
<tr>
<td>AFS18</td>
<td>Coastal sedimentary basin 3</td>
<td>Mozambique/South Africa</td>
<td>7,900</td>
<td>1,700</td>
<td>NI</td>
<td>1,400 – 1,750</td>
<td>M to VH</td>
</tr>
<tr>
<td>AFS19</td>
<td>Coastal sedimentary basin 4</td>
<td>Mozambique/South Africa</td>
<td>20,600</td>
<td>4,400</td>
<td>NI</td>
<td>1,250 – 1,650</td>
<td>VL to M</td>
</tr>
<tr>
<td>AFS20</td>
<td>Coastal sedimentary basin 5</td>
<td>Mozambique/South Africa</td>
<td>4,740,000</td>
<td>24,000</td>
<td>NI</td>
<td>1,300 – 1,930</td>
<td>H to VH</td>
</tr>
<tr>
<td>AFS21</td>
<td>Coastal sedimentary basin 6</td>
<td>Mozambique/South Africa</td>
<td>6,300</td>
<td>1,200</td>
<td>NI</td>
<td>1,000 – 1,500</td>
<td>M to H</td>
</tr>
<tr>
<td>AFS22</td>
<td>Coastal sedimentary basin 7</td>
<td>Mozambique/South Africa</td>
<td>2,300</td>
<td>410</td>
<td>NI</td>
<td>950 – 1,400</td>
<td>H to M</td>
</tr>
<tr>
<td>AFS23</td>
<td>Coastal sedimentary basin 8</td>
<td>Mozambique/South Africa</td>
<td>1,827,900</td>
<td>22,800</td>
<td>NI</td>
<td>450 – 550</td>
<td>VL to M</td>
</tr>
<tr>
<td>AFS24</td>
<td>Coastal sedimentary basin 9</td>
<td>Mozambique/South Africa</td>
<td>1,870,000</td>
<td>38,400</td>
<td>Karstic</td>
<td>440 – 500</td>
<td>VL to L</td>
</tr>
<tr>
<td>AFS25</td>
<td>Coastal sedimentary basin 10</td>
<td>Mozambique/South Africa</td>
<td>716,000</td>
<td>74,300</td>
<td>Sedimentary</td>
<td>740 – 750</td>
<td>VS to IS</td>
</tr>
<tr>
<td>AFS26</td>
<td>Coastal sedimentary basin 11</td>
<td>Mozambique/South Africa</td>
<td>716,000</td>
<td>74,300</td>
<td>Sedimentary</td>
<td>740 – 750</td>
<td>VS to IS</td>
</tr>
<tr>
<td>AFS27</td>
<td>Coastal sedimentary basin 12</td>
<td>Mozambique/South Africa</td>
<td>716,000</td>
<td>74,300</td>
<td>Sedimentary</td>
<td>740 – 750</td>
<td>VS to IS</td>
</tr>
</tbody>
</table>
4.4 Approach and mechanisms for TBA management

Groundwater management is a complex endeavour as it requires coordination across many sectors and users (e.g. water supply, agriculture, energy, industry, and environment) and it needs to integrate with surface water management. Trying to do this at the international level poses another dimension of challenges in terms of coordination and integration. Groundwater traditionally has been considered a national matter, but the need for international cooperation on groundwater is increasingly recognised. This is particularly the case where:

- Groundwater resources evidently flow across borders, as in the case where groundwater is primarily recharged in one country but discharges in another (like Type E in Figure 4.2)
- Groundwater development in one country has (or could have) significant implications and adverse impact in the other country
- Significant ecosystems in one country depend on groundwater influx from another country
- Significant groundwater development or land-use changes with implications for groundwater resources (quantity or quality) in neighbouring countries is planned in one country
- Groundwater is a significant resource in drought management and generally for human development for one or more of the sharing countries

The principles of international law for cooperation on transboundary aquifers build on the general principles of cooperation on surface water. Some of these principles relate to:

- Cooperation on the basis of sovereign equality, territorial integrity, mutual benefit and good faith
- The concept of ‘equitable and reasonable use’
- The concept of ‘no-harm’, i.e. that all resource development and management is done with no prior intention of harming the other part
- Prior notification, i.e. that states have an obligation to inform each other before implementing major investments and interventions that may affect the resource in a transboundary sense. Notification also refers to immediately informing other states of emergency conditions related to the watercourse that may affect them, such as flooding
Table 4.2 Particular characteristics of aquifers and implications for management of TBAs

<table>
<thead>
<tr>
<th>Groundwater distinct characteristic</th>
<th>Special considerations/provisions needed in TBA management</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Joint use/registration, regulation, monitoring and enforcement</td>
</tr>
<tr>
<td>Open source</td>
<td>xx</td>
</tr>
<tr>
<td>Invisible and heterogeneous</td>
<td>x</td>
</tr>
<tr>
<td>Vulnerable to land use impacts</td>
<td></td>
</tr>
<tr>
<td>Slow reacting/delay in response/slowly renewable</td>
<td>x</td>
</tr>
<tr>
<td>Recharge/discharge is distributed and uneven</td>
<td></td>
</tr>
<tr>
<td>Boundaries uncertain</td>
<td>x</td>
</tr>
<tr>
<td>Climate change impacts uncertain</td>
<td>xx</td>
</tr>
<tr>
<td>Blurred up and downstream relations</td>
<td>x</td>
</tr>
</tbody>
</table>

- Sharing of data, i.e. institutionalised mechanisms for regular sharing of new data and knowledge related to the TBAs
- The precautionary principle, i.e. that development is not done if insufficient knowledge exists to show that environmental and socio-economic impacts will be low. These protections can be relaxed only if further scientific findings emerge that provide sound evidence that no significant harm will result
- Stakeholder involvement, i.e. that stakeholders are involved and have a say in decisions related to the development of the resource
- Dispute settlement
However, it is important to bear in mind that groundwater has some particular inherent characteristics that necessitate strong emphasis on certain of these principles, i.e. the precautionary principle, long-term monitoring of the resource, joint monitoring/registration of users, prior notification, and prioritized protection (Table 4.2). Because groundwater generally moves very slowly, the precautionary principle, the long-term monitoring and the prioritized protection, e.g. of significant recharge zones, are critical. For the prior notification, development may relate to significant land use change plans or widespread development of the groundwater resource, rather than large infrastructure dams that typically affect surface water sharing. Prior notification could also relate to the spill of chemicals or detection of groundwater contamination in the border region. In order to achieve full and efficient cooperation on TBAs, states need to formulate joint (or separate but coordinated) plans and programmes for groundwater development, use and protection, to implement common/harmonised groundwater management policies, the joint training of technical personnel and the joint undertaking of environmental studies.

In principle, groundwater as part of the unified hydrological system falls under the provisions of international water law. However, the mechanisms for managing international waters traditionally have focused on surface water, and groundwater was either ignored or simply assumed to be covered. Due to recognition of the importance of groundwater as well as its inherent characteristics, there has been an increase in work dedicated to developing separate and integrated frameworks for international law on groundwater.

Four most important pieces of international water legislation, with each their strong and weak aspects, are included in Table 4.3. These conventions are meant as guidelines and encourage states to draft specific binding agreements (treaties) between nations related to their specific shared (ground)water resources and establish permanent transboundary organizational setups for their management.

Since aquifers and river/lake basins seldom coincide (Fig 4.3), the most appropriate body to oversee management of TBAs may not necessarily be the basin organisation specific to the river/lake (if existent). Cooperation among several basin organisations may be necessary. Similarly, separate aquifer basin organisations may be a relevant solution where there is no effective surface water-based transboundary basin organization.

1 International water law is a system of norms and rules governing relations between and among sovereign States and plays an important role in the peaceful management of transboundary water resources.
Table 4.3. Four most important pieces of international water legislation for groundwater

<table>
<thead>
<tr>
<th>Focusing on groundwater or surface water?</th>
<th>Regional scope</th>
<th>In force</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>UN Draft Articles on Transboundary Aquifers</td>
<td>Groundwater</td>
<td>Global</td>
<td>No</td>
</tr>
</tbody>
</table>

* Only one more country needs to ratify it for it to enter into force, as of 27 Feb. 2014.

b Enters into force if all 33 states originally parties to the convention approve. So far 23 have approved.

4.5 Specific challenges and cases of TBA management in Africa

The need for transboundary groundwater management in Africa is at present most acute in semi-arid and arid regions where the surface water resources may be limited or seasonally or inter-annually very variable or located far away from significant populations. These are typically also the regions where significant transboundary groundwater reserves are non- or less renewable, increasing the challenges of sustainable TWM.

One of the most important decisions that joint management committees have to make in such conditions is the maximum allowed annual drawdown of the aquifer. This is the case in much of northern Africa and in southern Africa. Transboundary management could also be of concern in areas where surface waters are declining or affected by contamination, e.g. the Lake Chad Basin in western Africa.

Significant conflicts over shared aquifers are not apparent or are still not fully documented in terms of extent and underlying causes. The ‘needs assessment’ (BGR / IWMI 2013) identified alluvial groundwater abstraction for irrigation alongside international water courses (Fig 4.2 Type A and Type B) in some of the surveyed TBOs (LIMCOM, OMVS) as the activity with the most immediate “suspected” transboundary impact. These TBOs expressed concern at the impacts of alluvial groundwater abstraction on transboundary surface water flows, but indicated that no conflicts have yet been experienced.

Reflecting these needs, greater efforts have been pursued in the arid regions in terms of managing the shared groundwater resources. At present, formal agreements exist between countries sharing the Nubian Sandstone Aquifer System (NSAS, AFNE12),
the Northwestern Sahara Aquifer System (AFNE16), while significant work is ongoing in the Lake Chad aquifer (AFWC14) and the Iullemeden/Taudeni Aquifer Systems (AFWC20+15). Such efforts are typically supported by international organizations (e.g. UNESCO, FAO) and technical institutions with expertise in groundwater characterization (e.g. IAEA, IGRAC, BGR, and BRGM).

The agreements relate mostly to the setting up of consultative mechanisms to coordinate, promote and facilitate the rational management of the aquifers and the collection, sharing and interpretation of data as part of so-called transboundary diagnostic analyses. The TBA in Africa that counts on the most advanced level of joint management is the Nubian Sandstone Aquifer System (NSAS, AFNE12), which constituted a Joint Authority in 1989 for the study and development of the aquifer and with quite broad responsibilities. The aquifer-sharing states (Egypt, Libya, Sudan, and Chad) and the Joint Authority also agreed on a strategic action plan in 2013 for the shared vision and future cooperative management of the NSAS.
4.6 References

*Transboundary aquifer mapping and management in Africa: a harmonised approach.*

BGR and IWMI, 2013.

*A hydrogeological approach to transboundary ground water resources and international law.*

IGRAC (International Groundwater Resources Assessment Centre), 2012.

INBO and GWP, 2012.

SADC (Southern African Development Community), 2000.
*Revised protocol on shared watercourses in the Southern African Development Community.*


*Convention on the Protection and Use of Transboundary Watercourses and International Lakes.*

4.7 Exercise
This exercise provides an example guideline of the manner in which TBOs may approach the management of TBAs in the first instance.

**Step 1.**
For your country, list the transboundary aquifers or groundwater resources with potential or apparent transboundary issues in terms of development, use, and management.

**Step 2.**
Categorize and rank the resources in terms of problems or possible solutions to human and environmental needs.

**Step 3.**
Compare your list with the lists for your neighboring countries and identify the areas of joint priority for transboundary and cooperative management.

**Step 4.**
Identify technical and management interventions that could be best dealt with jointly to address the issues identified in Step 1-3.

**Step 5.**
Assess the interventions in terms of the benefits and trade-offs for the countries, in terms of addressing equity, sustainability and efficiency.

**Step 6.**
Indicate where the institutional responsibility lies to carry out the proposed management interventions. Highlight in particular the role / interventions that can be best carried out by the TBO.