CAPACITY BUILDING FOR

GROUNDWATER DATA COLLECTION AND MANAGEMENT IN SADC MEMBER STATES

(SADC-GWdataCoM project)

CS2017/05

State of Groundwater Data Collection and Data Management in SADC Member States

FINAL REPORT - 31 January 2019

Presented by
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1. Introduction

The Southern African Development Community - Groundwater Management Institute (SADC GMI) has contracted the International Groundwater Resources Assessment Centre (IGRAC) to execute the project *Capacity building for groundwater data collection and management in SADC Member States* (SADC-GWdataCoM); SADC-GMI project no. P127086, contract CS2017/05 of 1 September 2017. IGRAC executed this project in close cooperation with the Institute for Groundwater Studies (IGS) from the University of the Free State (UFS) in South Africa. The project ran from September 2017 to April 2019.

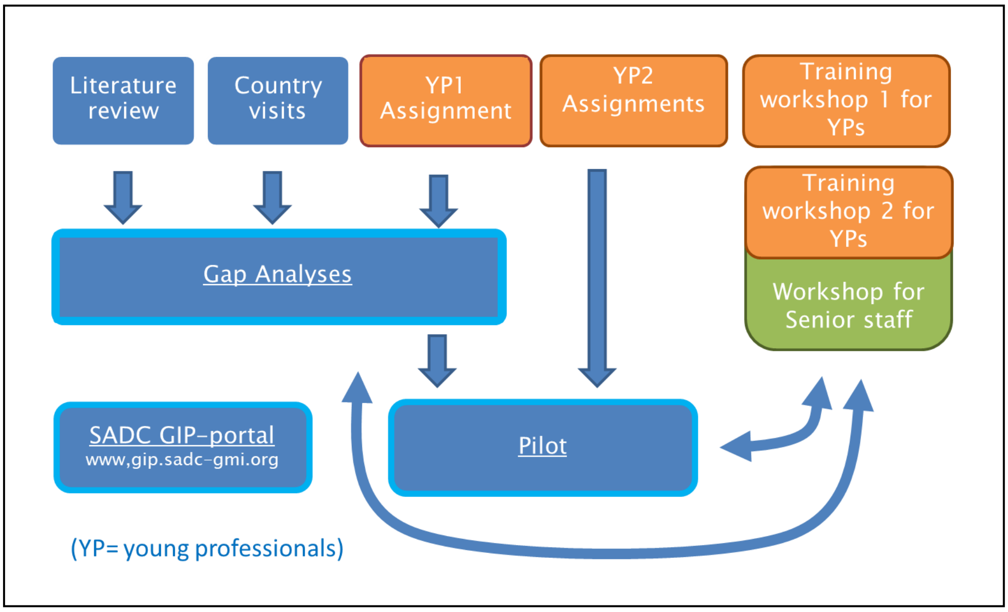

Figure 1: Overview of SADC-GWdataCoM project components

The project consisted of several components (see Figure 1):

1. Assessment of the current state of groundwater data collection and management in SADC Member States, including recommendations for improvements. This component included a literature review and interviews with professionals in the Member States who are working in groundwater.
2. Updating the SADC-Groundwater Information Portal with data which became available through the project
3. Capacity building component, which involved engaging young professionals from the Member States and students from IGS in the project. The Young Professionals were engaged through assignments and two training workshops (May and November 2018).
4. Pilot activity. In the course of the project it was decided to develop a Framework for Groundwater Data Collection and Management in SADC Member States. The framework aims to assist Member States, which are currently facing difficulties in groundwater data management, in developing adequate groundwater data collection and management procedures at the national level that match their current (financial and human) capacity. The framework also aims to facilitate transboundary cooperation on groundwater as well as regional groundwater analyses, by proposing

some form of harmonisation across Member States in terms of data collection relevant at the transboundary and regional scale and in terms of data-exchange.

The project team presented progress to the SADC GMI Steering Committee at several occasions (March and September 2018) and organised a workshop for senior officials from the Member States (November 2018). During these meetings the project team received feedback on draft products as well as additional inputs.

This report covers component 1: Assessment of the state of groundwater data collection and management in the SADC Member States. The other components are reported in separate documents:

component 2+3: IGRAC and IGS (January 2019): Capacity building for groundwater data collection and management in SADC Member States - Report on activities. Final report. (component 2+3).

component 4: IGRAC and IGS (in preparation for April 2019): Framework for Groundwater Data Collection and Management in SADC Member States.

To compile a comprehensive and up-to-date assessment of the state of groundwater data collection and data management in SADC, different activities have been carried out in the SADC-GWdataCoM project, the findings of which are presented in this report. The report starts with a brief description of the assessment activities or methodology (chapter 2). In chapter 3, the state of groundwater data collection and data management is described, for the individual Member States and in a SADC-wide synthesis. The report concludes with recommendations to improve the situation. Country specific recommendations are provided, as well as recommendations at the regional, SADC wide level (chapter 4).

"Groundwater data collection and management".
Terminology in the context of this project:
- Groundwater data collection: Collecting of field data related to borehole siting, drilling and testing as well as collecting on a regular basis groundwater monitoring data (=groundwater levels, groundwater quality analyses, groundwater abstraction / discharge data). The study has less of a focus on data related to hydrogeological mapping and assessment.

- Groundwater data management: quality assurance and quality control (QA/QC), storing of those data in archives and databases; sharing/access to data; analyses and interpretation of the data; dissemination of resulting groundwater information.

2. Methodology

2.1. Introduction

The assessment of the state of groundwater data collection and management in SADC Member States relies on information obtained from four project activities: a literature review, interviews with groundwater professionals in the Member States, assignments of young professionals engaged in the project and a workshop with senior officials from the Member States in November 2018. Most information is derived from the interviews undertaken during the country visits. The four activities are briefly described the next sections below:

2.2. Literature review

At the start of the project a brief literature review was conducted focussing on information regarding groundwater data collection and data management practices in the SADC region. This literature review was expected to provide initial insights for each SADC Member State into the nature of the collected groundwater data on how it is collected, stored, used, and managed. The review was initially limited to reports available in the public domain. An important source of information was the SADC Groundwater Grey Literature Archive (SADC et al., 2017), which contains many references on groundwater studies in SADC Member States. Another specific source of information is the online Africa Groundwater Atlas by BGS et al. (2018) with country specific descriptions in a Wikipedia style format. Some further documents where obtained during the visits to the countries and afterwards during the execution of the project. Information from the literature review has been used as a starting point for the project and contributed to the analyses in chapters 3 and 4. Documents are cited as appropriate in the current report. Furthermore all (references to) relevant documents, obtained through the project, have been uploaded into the SADC-Groundwater Information Portal (SADC, 2017)[1] and are listed in the project activity report[2].

The most relevant reports in the context of the current study are from SADC-wide studies such as the Southern African Development Community Regional Situation Analysis (SADC, 2003, republished as BGS, 2005), Groundwater monitoring in the SADC region (IGRAC, 2013) and Groundwater management in the Southern African Development Community (Pietersen and Beekman, 2016). SADC (2003) provides a comprehensive overview and analyses that focused on the role, availability and supply potential of groundwater as a component in drought management strategies. For this purpose, an assessment was made of the state of groundwater management in all SADC Member States (with the exception of Madagascar, which at the time was not yet a SADC Member). The assessment includes overviews of the state of groundwater-related data collection, data sharing and data interpretation, per country and SADC-wide. The report highlights a lot of shortcomings in groundwater monitoring and groundwater data in general, in storing and sharing of groundwater data. The authors relate these issues to some extend to institutional and capacity building issues. At the onset of the current project, it was assumed that the analyses, being more than 15 years old, was outdated. However, and quite sadly, a lot of the conclusions (and

[1] http://gip.sadc-gmi.org

[2] IGRAC and IGS (January 2019): Capacity building for groundwater data collection and management in SADC Member States - Report on activities. Final report. SADC-GMI.

consequently recommendations) of that study still stand. IGRAC (2013) provides a brief review of groundwater monitoring in 9 Member States (Angola, Botswana, Lesotho, Mozambique, Namibia, South Africa, Tanzania, Zambia and Zimbabwe). Pietersen and Beekman (2016) summarise the state of groundwater governance in SADC region. For each Member State, they described the relevance of groundwater, they identify relevant stakeholders in charge of groundwater management (including groundwater monitoring) and provide concise descriptions of the legal framework in Member States. As such this report provides important background information.

Apart from these 3 reports, the literature review did not yield that much more concrete and up-to-date information on the state of groundwater data collection and management in the SADC region or in specific countries. Hardly any official documents on groundwater resources management and groundwater data are available in the public domain, and only South Africa makes groundwater data available online. This situation makes it difficult to assess the state of groundwater data collection and management through a desk study / literature review only. For these reasons, visits to the Member States were foreseen in the project structure to interview persons engaged in groundwater data collection and management (see section 2.3).

2.3. Country visits

In addition to the literature review, country visits were conducted to obtain additional information. The scope of these country visits was to:

1) Obtain an overview of the full chain of data and information collection and management relevant for groundwater governance (including groundwater development, use, protection, management and policy development and implementation), through interviews with professionals working in groundwater.
2) Collect extensive meta data on relevant documents (e.g. reports, protocols, manuals, monitoring plans, policy plans), databases (including web-portals) and organizations/stakeholders who may be able to supply additional information.

From November 2017 to early March 2018, twelve countries were visited by IGRAC/IGS staff members: Angola, Botswana, DR Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, South Africa, eSwatini, Zambia and Zimbabwe. Unfortunately, it was not possible to arrange visits to Tanzania, Madagascar and Seychelles due to unresponsiveness of the liaisons at the local groundwater departments.

During the country visits, semi-structured interviews were conducted with professionals engaged in groundwater development, management, data collection and/or research. Entry point for the interviews were the SADC-GMI Focal Points, and interviews mostly started with professionals engaged in groundwater activities in the 'water departments' under the ministries responsible for water management. IGRAC/IGS conducted the interviews as much as possible with only one or two persons at a time, so that persons interviewed would all have equal chances to express themselves freely. Even though some of the interviews were conducted with larger groups, IGRAC/IGS has the impression that people expressed themselves quite freely and aimed to give as much as possible a critical but neutral view of current practices.

In total 145 persons from a wide range of organisations were interviewed in the 12 countries (Table 1). Information obtained from the interviews was recorded in individual country reports. These country reports where the major source of information for chapters 3 and 4.

Note: The country reports themselves are not included in this report as these may contain opinions of persons interviewed which do not necessarily reflect the official view of the organisation the person represents; neither was it always possible to verify if all details were always totally accurate. The country reports have been provided to SADC-GMI and are available upon request and at the discretion of SADC-GMI.

Table 1: Institutions visited and numbers of professionals interviewed during country visits.

	Angola	Botswana	DR Congo	eSwatini	Lesotho	Madagascar	Malawi	Mauritius	Mozambique	Namibia	Seychelles	South Africa	Tanzania	Zambia	Zimbabwe	**Total**
Water department	9	8	7	7	6	-	5	4	9	3	-	14	-	6	2	**80**
Other governmental*	-	-	2	2	3	-	1	4	-	-	-	3	-	6	5	**26**
Water company	-	1	-	-	-	-	-	-	2	3	-	-	-	-	-	**6**
University	-	1	-	-	1	-	-	-	1	-	-	-	-	4	1	**8**
Consultancy	-	3	-	-	-	-	-	-	-	1	-	2	-	-	-	**6**
Drillers	5	-	-	1	-	-	-	-	-	-	-	-	-	-	-	**6**
NGO	1	-	-	3	-	-	3	-	-	-	-	-	-	-	-	**7**
Other non-governmental**	-	-	-	-	2	-	-	-	-	4	-	-	-	1	-	**7**
Total	**15**	**13**	**8**	**13**	**12**	**-**	**9**	**8**	**12**	**11**	**-**	**19**	**-**	**17**	**8**	**145**

*Other governmental:

- DR Congo: Congo Atomic Energy Commission, Centre for Geological and Mineral Research
- eSwatini: Micro Projects Swaziland (semi-independent unit of the Ministry of Economic Planning and Development)
- Lesotho: Water Commission, Ministry of Health
- Malawi: National Water Resources Authority
- Mauritius: Central Water Authority (CWA, Ministry of Energy and Public Utilities), National Environmental Laboratory (Ministry of Environment, Sustainable Development, Disaster and Beach Management)
- South Africa: Water Research Council
- Zambia: Dept. of Agriculture, Water Resources Management Authority (WARMA), Environment Management Department
- Zimbabwe: Zimbabwe National Water Authority (ZINWA), National Action Committee (NAC) for Water and Sanitation, Nyagui Subcatchment Council

**Other non-governmental:

- Lesotho: EU delegate, Advisor Water sector reform
- Namibia: Namibian Hydrogeological Association
- Zambia: IWRM centre

2.4. Young professionals' assignment

As part of the capacity building component of the project, young professionals from the Member States have been engaged in the project; in principle 2 from each Member State. Not all Member States nominated young professionals and not all young professionals nominated were able to contribute to the project. In total 22 Young Professionals from 11 Member States (Angola, Botswana, eSwatini, Lesotho, Malawi, Mozambique, Namibia, South Africa, Tanzania, Zambia and Zimbabwe) participated in and contributed to the project. No contributions were received from DR Congo, Mauritius, Madagascar and the Seychelles. The young professionals took part in training workshops and worked on two assignments each. Full descriptions of the young professionals' capacity building component under the project are provided in the activity report (IGRAC and IGS, 2019).

The first assignment, which all 22 young professionals worked on, was to create a *National overview of groundwater data collection and management* for their own countries. This first assignment can be seen as an extension of the country visits performed by the project team. Based on the country visits an initial assessment was made with regards to the groundwater data collection, data storage and dissemination of data in each country. The young professionals were provided with the draft report of their country, which served as a starting point for their work. They were requested to develop an overview of the state of groundwater data collection and management in their own country and to focus as much as possible on completing the knowledge gaps from the initial assessment by the project team. Objectives of the assignment were:

- For young professionals to gain a comprehensive insight into the state of groundwater data collection and management in their own country,
- For young professionals to gain an insight how the practice in their own country compares to that in other SADC Member States (through presentations one of the project training workshops),
- For young professionals to benchmark best practices in their respective countries,
- To complete the information gaps in the project team's initial assessment.

This last objective contributed to completing the information obtained from the country visits to describe the current state of groundwater data collection and management, and to analyse the gaps. Each national team of 2 young professionals provided a report. These reports were used for the analysis in chapters 3 and 3.4.2. The reports of the young professionals themselves are not included in this report. Like the country reports, all reports of the young professionals have been provided to SADC-GMI and are available upon request and at the discretion of SADC-GMI.

2.5. Workshop

In November 2018, a workshop was organised in Johannesburg (South Africa) for the young professionals engaged in the project assignments (see previous section 2.4) and senior officials from the Member States. One of the sessions of the workshop was dedicated to reviewing draft outcomes of this report. Based on the inputs from participants this report was corrected and amended as necessary.

3. Current state of groundwater data collection and data management in the SADC Member States

3.1. Introduction

This chapter describes the current state of groundwater data collection and data management in the SADC Member States, based on the information from the literature review, interviews during country visits, the 1st assignment of the young professionals and inputs from the project workshop in November 2018 (see previous chapter). Most information was derived from the 145 professionals interviewed during the country visits. To a lesser extent, the young professionals' assignments also contributed to provide additional information. The literature review provided limited additional insight, as few documents are available with concrete information relevant for this project. Review of the draft report by senior officials and young professionals during the November 2018 workshop resulted in some last (mostly minor) corrections and additions.

Table 2: Overview of per country contributions to the assessment

Member State	ISO code	Interviews during country visit	Young professionals' assignment	Review during Nov. 2018 workshop*	Country specific assessment possible
Angola	AGO	yes	yes	SO & YP	Yes
Botswana	BWA	yes	yes	YP	Yes
DR Congo	COD	yes	-	-	Yes
eSwatini	SWZ	yes	yes	SO & YP	Yes
Lesotho	LSO	yes	yes	SO & YP	Yes
Madagascar	MDG	-	-	-	-
Malawi	MWI	yes	yes	SO & YP	Yes
Mauritius	MUS	yes	-	-	Yes
Mozambique	MOZ	yes	yes	SO & YP	Yes
Namibia	NAM	yes	yes	SO & YP	Yes
Seychelles	SYC	-	-	-	-
South Africa	ZAF	yes	yes	SO & YP	Yes
Tanzania	TZA	-	yes	SO	Yes
Zambia	ZMB	yes	yes	YP	Yes
Zimbabwe	ZWE	yes	yes	SO & YP	Yes
Total		***12***	***11***	**9 SO & 10 YP**	***13***

*: SO= country represented by senior official(s); YP= country with young professionals engaged

Table 2 provides an overview of the countries which were visited, which ones participated in the young professionals' assignment and which ones participated in reviewing the draft in the workshop. The team was able to do a country specific assessment for 13 Member States. Unfortunately, it was not possible for Madagascar and Seychelles as they did not contribute to any of the assessment components. Country specific information for DR Congo and Mauritius is somewhat limited as no additional information was obtained through engagement of young professionals or senior officials. The same holds for Tanzania where it was not possible to conduct a country visit.

In the assessment process, some discrepancies were observed between different sources of information. Two reasons can explain these discrepancies. First, some of the documents reviewed are over 10 years old and the state of groundwater data collection and data management may have changed over the years. In some instances, the situation may have improved e.g. with installation of data loggers, adoption of new policies, implementation of guidelines or development of new databases. In other countries, the situation may in fact have deteriorated due to a lack of investments or organizational issues. Secondly and more important, significant gaps were observed between policy and practice. This came out at various stages during the project, and most significantly in some of the interviews and in discussions, where interviewees reported experiences which are sometimes in sharp contrast with the official version or policies. Examples may be that formally a country does have procedures in place to collect groundwater data on a regular basis and does have databases / archives to store that date, while in practice groundwater data collection and monitoring is rather haphazard, resulting in large data gaps and data of poor quality, while those data are also not properly archived for future retrieval and use.

In this chapter, the current state of groundwater data collection and data management is first presented per country (Section 3.2). For each country, a brief and general overview of groundwater use and institutional setting is given, followed by a description of the collection and the management of data related to the siting, the drilling and the testing of new boreholes, as well as groundwater monitoring data. In Section 3.3, a SADC-wide synthesis is presented, as many Member States face similar challenges and experience similar issues in terms of groundwater data collection and data management. These shared issues are more relevant at the regional level and can potentially be addressed jointly. The information is summarised at the end of this chapter in summary tables (tables 3 - 7). More detailed information is available in the unpublished reports of the country visits and the reports from the young professional's first assignment (all available via SADC-GMI on request).

Note of caution:
The information collected from the interviews and through the young professional's assignments must be used with some caution. Despite efforts of the authors to provide accurate information, and few discrepancies were found between the country visits, the young professional reports and feedback from the workshop, the authors cannot guarantee that the information provided is always completely accurate and complete. Opinions from interviewees and young professionals may not necessarily reflect the official view of the organizations these persons represent.

3.2. Synthesis per country

3.2.1. Angola (AGO)

➢ *General overview of groundwater use and institutional setting*

Angola has abundant surface water resources. Information on groundwater is limited. Pietersen and Beekman (2016) report that only 1.4% of total water use in Angola is from groundwater. This seems to be an under estimation. During the country visits it was stated that approximately 40% of population lives in rural areas and they are mostly depending on groundwater for water supply. Cowater (2015) as cited in Upton et al. (2018) also report higher estimates of 73% of water systems across Angola using groundwater and hand-pump operated boreholes make up for 36% of all water supply systems. They report groundwater use in urban areas to be concentrated in coastal and southern parts of the country where the climate is more arid and surface water availability is lower.

Since 2012 the National Institute of Water Resources (Instituto Nacional de Recursos Hídricos - INRH) under the Ministry of Energy and Water (Ministério da Energia e Águas - MINEA) is the responsible institute for water resource management and water data collection, including licensing of (ground)water abstractions. INRH is the successor of the former National Directorate on Water Resources [Direcção Nacional de Recursos Hídricos] (INRH, 2018). The National Directorate for Water (Direcção Nacional de Águas – DNA) is the authority responsible for drinking water quality.

➢ *Collection of borehole siting, drilling and testing data*

Boreholes with an abstraction rate of > 15 l/s are subject to licensing by the INRH. However, very little information is collected about the boreholes: geographic coordinates, static water level, borehole depth, abstraction rate, and whether or not a pump test has been done. Most of the data is collected and recorded by the driller for their own private records but is not reported to or stored in a national database.

➢ *Collection and management of monitoring data*

There is however no formal policy or plan specific to groundwater monitoring and no structural collection of data on groundwater levels or groundwater abstraction takes place in Angola. The only monitoring which takes place is on groundwater quality for water used for consumption. Every new borehole is supposed to be tested before it can be used for domestic purposes. Depending on the size of the community the water is also after drilling supposed to be sampled and tested. The supposed frequency of sampling depends on the size of the community which depends on the water source:

- Communities < 100 people: 2 samples per year
- Communities with 100 – 1000 people: 4 samples per year
- Communities > 1000 people: 4 samples per year + additional 3 samples for every 1000 m^3 abstracted.

Water used for consumption is supposed to be analysed and compared to the Angola standards which are based on World Health Organisation drinking water and Portugal's standards. The water samples are tested for: Alkalinity, NH_4, Ca, Cl, Fe, Mn, NO_2, NO_3, Na, SO_4. Data are kept by DNA.

IGRAC (2013) and Upton at al. (2018) report that the National Directorate for Water (Direcção Nacional de Águas – DNA) have carried out annual field surveys since 1996 to make inventories of the operational status of water supply systems, including boreholes and hand-dug wells including data such as depth and static water level. The information is archived by DNA (>3600 groundwater points in 2002; current status unknown). IGRAC (2013) acknowledges that a groundwater database and data management was lacking while inter-institutional relationships regarding data sharing and management did not exist. It was confirmed that this situation has not significantly changed by 2018.

- *Data management, analysis and dissemination*

As is clear from the above, currently little data on groundwater is collected on a structural basis in Angola and no formalised groundwater monitoring programme or national groundwater database exists. Therefore, further discussion on **data quality assurance and quality control**, **data storage**, **data sharing** and **analyses, interpretation and dissemination** are not applicable. DNA keeps some data on water quality for public water supply. INRH maintains a database on surface water data. During the November 2018 workshop it was made clear by the Angola representative that initiatives are underway to develop a database for groundwater (by INRH), and that Angola started issuing licenses for boreholes.

3.2.2. Botswana (BWA)

- *General overview of groundwater use and institutional setting*

Groundwater is the main source of water in Botswana. It is widely abstracted for rural water supply, and also used in other sectors: industry (including mining); energy (by power plants); irrigation; and urban water supply (Upton, Dochartaigh, Key, Farr and Bellwood-Howard, 2018). Rural populations rely almost entirely on groundwater due to the scarcity of (permanent) surface water and Botswana Government (2016) reports that 56% of all water supplied to towns and cities is groundwater.

The Department of Water Affairs (DWA), under the Ministry of Minerals, Energy and Water Resources (MMEWR) (after announced reforms the Department of Water and Sanitation under the Ministry of Land Management, Water and Sanitation Services) is responsible for resource management, including the protection and the baseline monitoring of groundwater resources. Water Utilities Corporation (WUC), which is a parastatal, is the water supply authority responsible for abstraction and distribution, including the monitoring of production boreholes / wellfields. Production boreholes and wellfields are developed by DWA. Granting of water rights to private parties (licensing), including groundwater abstractions, falls under the responsibility of the Water Apportionment Board.

- *Collection and management of borehole siting, drilling and testing data*

Boreholes in Botswana need to be registered at DWA and receive a national identification number (z-number for private boreholes and bh-number for government boreholes). In practice, not all private boreholes are being registered. Data about siting (geophysical surveys), drilling and testing are supposed to be recorded and supplied to DWA for storage in central databases. The data collected during drilling include borehole lithological logs, borehole depth, depth of water strikes, penetration rates, casing installed in the borehole, and the position of the screened sections. Records from private boreholes are often incomplete. DWA performs pumping tests (step-test and constant rate) on public boreholes, and in some cases on public boreholes.

- *Collection and management of groundwater monitoring data*

It was reported by several interviewees that groundwater monitoring faces organizational, logistical and technical issues since the restructuring of the water sector in 2008, with responsibilities shifting from the Department of Geological Survey (DGS) to the DWA, and from DWA to WUC. This has seriously affected the quality of data collection and storage in databases. No official groundwater monitoring plan is available, but DWA staff reported two objectives for groundwater monitoring: resource monitoring and control of groundwater abstractions reported by large groundwater users (compliance monitoring). WUC reported monitoring of the performance of individual production boreholes as an objective for monitoring.

Via regional offices, DWA performs monitoring of boreholes around wellfields operated by WUC (WUC manages approx. 850 production boreholes in approx. 40 wellfields) and other big groundwater users (e.g. mines). The monitoring network comprises around 1100 boreholes, of which around 100 are out of service. Also, around 100 boreholes are equipped with data loggers. In the others, groundwater levels are measured with manual dip meters every month. Outside the wellfields, groundwater is not monitored at the aquifer level like it used to be at the time of the DGS (prior to 2008). There are several data gaps, especially from boreholes that are not equipped with data loggers. However, use of data loggers is also not without problems and for several locations data have been lost because of malfunctioning dataloggers and/or vandalism.

Groundwater quality monitoring, much alike groundwater level monitoring, is mostly focussed around wellfields and big groundwater users. Intended sampling frequency is every 3 months. DWA does not monitor ambient groundwater quality throughout the country.

In practice DWA does not monitor groundwater abstraction. There are no data available on abstraction volumes related to for example rural water supply schemes, stand pipes in villages, the use of groundwater for watering livestock or for irrigation. WUC and other (licensed) water users are meant to report on groundwater use on an annual basis.

WUC monitor groundwater levels, quality (4x year) and abstraction rates (monthly water meter readings) in the wellfields they operate. In reality, measuring of water levels in the pumped boreholes often doesn't happen as many boreholes are not equipped with dipper access tubes. The division of roles, responsibilities and objectives between DWA and WUC in terms of groundwater monitoring don't seem to be very clearly defined / are not clear at the operational level.

- *Data management, analysis and dissemination*

There are no formal procedures for ***data quality assurance and quality*** *control* (data QA/QC). DWA staff indicated that technical officers are meant to plot measurements in graphs for visual inspection of the data, but in practices this doesn't happen because they have insufficient training and computer skills to do so. Interviewees both from DWA and WUC indicate that there are concerns over the quality of the data being collected, as technicians / technical officers are often insufficiently trained in their tasks. Additionally, concerns are expressed over data gaps resulting from logistical issues. In general procedures to assign unique identification numbers to boreholes work well, although it does occur that the same borehole identification numbers have been handed out for different locations, which causes problems with data integrity in databases; there is no procedure in place to resolve such issues.

Data storage: It is the intention that all borehole completion certificates, data from borehole siting surveys (geophysics) and from pumping tests are archived, digitised and uploaded into DWA's digital data bases. In reality, there is a large back-log in digitising these data and most data are only available in hardcopies in DWA archives. Data from private boreholes are often incomplete or altogether missing. Groundwater level and quality data are supposed to be stored in the DWA database (Wellmon). Also, for groundwater monitoring data, which are collected through the DWA regional offices, there is a large backlog in entering the data into the central database. As a result, DWA regional offices use their own spreadsheets as an alternative to the national database.

Data collected by WUC and other large (private sector) groundwater users is not submitted to DWA for inclusion into the national groundwater database. WUC has no centralised database for their data; data are stored in spreadsheets per district.

In terms of groundwater abstraction data, only a limited number of users submit their annual water monitoring reports to the Water Apportionment Board (Setlhogile and Harvey, 2015). There appears to be no centralised database for groundwater quality data collected by DWA or WUC.

Data access and data sharing: Apart from the back-log in data entry, regional offices also do not have direct / easy access to the national database. Therefore, they have reverted to using their own spreadsheets rather than data from the official database(s). At DWA headquarters efforts are made to connect the different groundwater relevant databases into one user interface, but this is currently only operable by one person. Private sector or universities do not have insights into or direct access to available data, although upon request data are provided.

Groundwater data are not widely used for ***analyses, interpretation and dissemination***: Neither DWA nor WUC report on a structural basis on trends or analyses from the groundwater monitoring data (no regular analyses or reporting). Use of monitoring data seems very limited and ad-hoc. WUC does report on an annual basis to DWA for compliance monitoring, but the analyses in these reports is limited. The fact that data are not analysed and interpreted in a structured manner and are not presented in a way that appeals to users is reported as a serious shortcoming: Data are not turned into information.

3.2.3. Democratic Republic of the Congo (COD)

- *General overview of groundwater use and institutional setting*

In general surface water is abundant in Democratic Republic of the Congo and groundwater is little used at large scale. Pietersen and Beekman (2017) report that the domestic sector is the largest water user with 53% followed by the agricultural sector (incl. irrigation: 30 per cent) and industry (incl. mining: 17 percent) sectors. They report that about 13 percent of total water use is from groundwater. Interviewees reported that as a result of this limited (need to) use groundwater, there has also been limited focus on groundwater. Currently however, efforts are being made by the Water Resources Directorate, in the Ministry of

Environment, to develop a policy on the conjunctive use and management of surface and groundwater resources.

The Water Resource Directorate under the Ministry of Environment oversees / directs the management of all water resources in the country. The department of Water and Hydrology under the Ministry of Energy and Hydraulic Resources is responsible for the issuing of drilling and water permits; is also supposed to monitor the resource and to monitor compliance for groundwater use. In practice this does not happen. The National Service of Rural Hydraulics (Service National d'Hydraulique Rural - SNHR) under the Ministry of Agricultural and Rural Development is responsible for siting and drilling of boreholes, and collecting of associated data.

Two main department has the responsibility of collecting data related to groundwater monitoring, although it's not happening as expected:

- *Collection and management of borehole siting, drilling and testing data*

SNHR is responsible for siting and drilling of boreholes and for related data. New boreholes must be registered at the SNHR. If boreholes are drilled by private parties, they must communicate the information to the SNHR. Data are mostly stored as hardcopies (fieldnotes), sometimes in softcopy spreadsheets. The records include information about the siting (magnetic and electrical resistivity surveys are usually performed), the borehole number, location, depth, (static) groundwater level, lithology, borehole construction data, and information about the pumping test (constant rate test). A sample of groundwater is also supposed to be analysed at the end of the borehole construction. Degree of compliance is unclear. It seems that in reality little data are collected.

- *Collection and management of monitoring data*

The department of Water and Hydrology, Ministry of Energy and Hydraulic Resources is responsible for drilling permits and water use permits as well as groundwater quality and level monitoring. However, there is currently no national groundwater monitoring plan nor does any coordinated monitoring of groundwater take place and there is no centralised database. It was reported that boreholes for public water supply are being monitored for groundwater quality. It is however not clear which data is being collected and how it is stored.

Monitoring of abstraction rates are obviously not monitored either. Interviewees indicated there is more concern over contamination of groundwater than over abstracted volumes.

- *Data management, analysis and dissemination*

As is clear from the above, currently hardly any data on groundwater is collected on a structural basis in DR Congo and no groundwater monitoring programme or national groundwater database exists. Therefore, further discussion on **data quality assurance and quality control**, **data storage**, **data sharing** and **analyses, interpretation and dissemination** are not applicable. SNHR is said to store data and borehole owners are expected to submit data; it is unclear if in practice this happens.

3.2.4. eSwatini (SWZ)

➢ *General overview of groundwater use and institutional setting*

The agricultural sector is reported to be the largest water user (98% of total water use, and mostly from surface water), domestic and industrial water use both account for only about 1%. Groundwater accounts only for about 2% of the total water use in eSwantini. Nevertheless, groundwater is of crucial importance to the rural population as an estimated 90% of the population in rural areas fully depends on groundwater for potable water supply (Pietersen and Beekman, 2016). There are an estimated 6000 boreholes in eSwatini. Groundwater resources are currently governed by the eSwatini Water Act of 2003, which outlines a set of criteria regarding the proper management and utilization of groundwater. Most of the hydrogeological knowledge dates from a groundwater mapping project in the early 90's carried out by the eSwatini Department of Geological Surveys and Mines, in collaboration with the Canadian International Development Agency (source: Swaziland MNRLE and Canada IDA, 1992).

The *Ministry of Natural Resources and Energy's* is responsible for the monitoring and management of groundwater resources in Swaziland. The ministry is also responsible for water supply water in the rural areas. The Swaziland water Service Corporation is responsible for urban water supply. Rural water supply depends largely on groundwater from boreholes. It was remarked that groundwater assessment, resource monitoring and management is getting insufficient attention. Reason for this the limited capacity in combination with a high workload related to rural water supply activities: Everybody in eSwatini has the right of access to drinking water. This is seen as the right to a borehole, resulting in small settlements, schools, public organisations and even private persons requesting to have boreholes drilled. This situation has resulted in a huge waiting list for boreholes (some 3000 at time of interviews) and the limited staff members not having any time or resources for activities related to monitoring or management of groundwater.

➢ *Collection and management of borehole siting, drilling and testing data*

The siting of new boreholes usually includes a geophysical survey (magnetic or electrical resistivity survey). Once the borehole drilled, a constant rate or a step pumping test is performed. Usually, pumping tests last less than 2h (instead of recommended 24h). Additional data about the boreholes include the lithology, the water strike and the borehole construction. These data are collected directly by the different units at the Ministry of Natural Resources and Energy or by private drilling companies who must communicate the data to the Ministry. In addition, a sample of groundwater is analysed after the completion of the borehole. EC, pH, turbidity, TDS and temperature are the parameters that are usually measured on the field. It is not clear what further analyses are made when the samples are brought to the lab, although WHO standards are said to be followed.

➢ *Collection and management of monitoring data*

There was mentioning of a national groundwater monitoring plan, but the status remained somewhat unclear. Groundwater monitoring is centrally organised and performed from HQ in Mbabane, while surface water monitoring has been delegated to districts offices. Due to the high workload with regards to water supply there is insufficient time and capacity to perform all necessary groundwater monitoring. It was also reported that significant numbers of monitoring boreholes have been equipped as production boreholes for water supply during drought periods. This process was never reversed, and the monitoring network was seriously affected by this. Groundwater level and quality are measured only directly after the completion of boreholes. Private well owners are supposed to monitor groundwater levels themselves and communicate data to the ministry, but it is not enforced. Additional groundwater samples can be analysed if problems are reported (e.g. people getting ill).

Groundwater abstraction is not monitored.

The few data that are collected are mostly stored as spreadsheets, often in different places, which makes access to data more difficult.

- *Data management, analysis and dissemination*

In terms of ***data quality assurance and quality control*** very little is formalised. It was reported that training on groundwater level monitoring is required. ***Data storage*** in eSwatini is mostly hardcopies or softcopies of report (data on borehole siting, drilling records, pumping tests, etc.). Groundwater level data are stored in excel files. There was an Access relational database, but this is no longer maintained or operational. Even though ***data sharing*** may technically be somewhat hampered because of the lack of relational digital databases, it was reported by many that generally the sharing of data between organisations is easy. There is an open-data culture. In terms of ***Analyses, interpretation and dissemination*** of results, very little is happening.

3.2.5. Lesotho (LSO)

- *General overview of groundwater use and institutional setting*

An estimated 41% of the total water use in Lesotho originates from groundwater (Pietersen and Beekman, 2016). Groundwater is the predominant source of water for rural areas: In the mountainous parts of Lesotho, groundwater emanating from springs is captured and used for rural water supply. In the western lowlands, including the capital Maseru, boreholes are more frequent.

- *Collection and management of borehole siting, drilling and testing data*

All boreholes drilled for non-domestic purposes are supposed to be registered / licensed. However, law enforcement is weak, resulting in low compliance, and available borehole data mainly concern public boreholes. Data collected include lithology, water strike, static water level, borehole depth and penetration rates. When a geophysical survey is done, data are reported. Pumping tests are mandatory for public water supply wells (step test and/or constant rate test).

- *Collection and management of monitoring data*

National groundwater monitoring is conducted by the Department of Water Affairs (DWA) under the Ministry of Energy, Meteorology and Water Affairs (MEMWA). Borehole and springs in the lowlands are being monitored by DWA staff from the central unit, while mountain springs are monitored by staff from regional offices. Lesotho is in a process reforming the water sector, and this entails among other things also decentralisation of groundwater monitoring to local communities, especially in rural and mountainous areas, whereas the work of DWA is being reduced to an advisory role. The national monitoring network consist of springs and boreholes. Groundwater data is routinely collected on groundwater levels (for boreholes), quality (for boreholes and springs), and spring discharge.

There appears to be no official groundwater monitoring plan and the objectives for groundwater monitoring are not clearly formulated.

The current groundwater monitoring network was the outcome of an Italian funded project from the early 1990's. Under this project boreholes were drilled for the development of the Lesotho Hydrogeological Map. These boreholes became the national groundwater monitoring network. Staff members interviewed did not know if the locations of these boreholes related to a purposefully designed monitoring network, or how these locations where chosen. Neither are the objectives of this monitoring programme clear. From the initial 72 observation boreholes, only 48 are currently operational as monitoring points. Reasons which were mentioned is that under pressure from local communities and in recent drought (2015) some of the observation boreholes have been equipped with pumps and have been turned into production boreholes, while some other boreholes have been vandalised and can no longer be used either. The Department of Water Affairs (DWA), in charge with the monitoring, no longer has any records on the borehole construction data (e.g. depth, lithological logs, water strikes), which means that analyses and interpretation of the monitoring data is seriously hampered.

Groundwater levels are supposed to be measured every 3 months (4x/year), but many gaps are noted due to insufficient capacity and logistical issues. Data are collected by regional offices of DWA, using dip meters, and sent by email to the central office, where they are recorded in spreadsheets.

Groundwater quality is supposed to be measured at about 30 springs and 20 monitoring boreholes, which have been prioritized based on the population depending on the source (data from the Department of Rural Water Supply), the age of the source (data from the Department of Rural Water Supply) and disease trends in the population using the source (data from the Ministry of Health). TDS, temperature and pH are measured on the field. Major ions and fluoride are measured subsequently in the lab. Microbiology is not being analysed. Because of limited resources, monitoring of groundwater quality is in practice quite limited.

There is no monitoring of groundwater abstraction from boreholes. The volumes pumped in the boreholes owned by the Department of Rural Water Supply and the Water and Sewage Company are supposed to be recorded but there is no evidence of that. Flow rates for springs captured for public water supply are measured at regular intervals.

- *Data management, analysis and dissemination*

There was no clear evidence of any formalised or implemented procedures for d***ata quality assurance and quality control***. Issues were reported with boreholes having different coordinates and coordinates are even reported in different coordinate systems depending on the age of the borehole. A nationwide system for identifying boreholes and springs has been developed but has not yet been implemented, resulting in further inconsistency issues. Borehole data are kept in hardcopy or in spreadsheets, but not in a searchable database. ***Data storage*** is in spreadsheets and those are not publicly available online but can be given out on request. The spreadsheets are not structured in a consistent way, and there is no back-up procedure to prevent loss of the national groundwater monitoring data in the event of loss of the specific laptop which is used to store the data. Neither are there any procedures in place to ensure that copies of the spreadsheet are only made from one centrally stored master file. This means there is a serious risk that parallel versions of the database evolve over time which compromises data integrity. Based on the lengthy procedure and the experiences of some interviewees outside government ***data sharing*** is in practice not common practice in Lesotho. Some interviewee reported it was impossible to get access to data.

No structural / regular ***analyses, interpretation and dissemination*** of groundwater data and information takes place in Lesotho. One of the interviewees pointed out that the low frequency of monitoring (4x/yr.) in combination with the many data gaps, seriously limits the use of the groundwater monitoring data.

3.2.6. Malawi (MWI)

- *General overview of groundwater use and institutional setting*

Groundwater is used by most of the rural population. Over 46,000 boreholes are counted across the country. A National Water Resources Master Plan including groundwater resources was issued in 2017, which addresses groundwater monitoring. The collection and management of groundwater data is under the responsibility of the Groundwater Division, within the Department of Water Resources, but it will be taken over by the National Water Resources Authority.

- *Collection and management of borehole siting, drilling and testing data*

Every new borehole, private or public, must be registered at the Department of Water Resources, including data relevant to siting, drilling and testing. However, private drillers often submit incomplete forms or simply don't submit anything. Most of registered boreholes are public ones or boreholes drilled by NGOs. Records are archived as hardcopies and spreadsheets.

The data include location, date of drilling, construction data, lithology and information about testing (step tests, constant rate and recovery tests). In addition, a sample of groundwater is taken when the borehole is completed

- *Collection and management of monitoring data*

The monitoring network comprises 75 boreholes equipped with automatic data loggers. Data are cross-checked with manual measurements. There are gaps in observations but those are substantially reduced in last several years, with the installation of data loggers. Some construction failures are recorded, such as inflow of surface water into the piezometer which may affect water quality data. Some wells are vandalised.

Groundwater samples are also analysed. After borehole completion, groundwater quality checks should be made every 6 months, but many gaps are reported. pH, EC and TDS are measured directly on the field. Major ions are measured in the lab, with a bacteriological analysis when requested.

Monitoring data are first processed in and checked in spreadsheets, then entered into WISH and Hydstra databases.

Groundwater abstraction is not monitored.

Data are usually firstly stored into Excel which allows easy processing and visualisation. The Ministry is using WISH database (Windows Interpretation System for Hydro-geologists) developed by the Institute for Groundwater Studies (IGS) at the University of the Free State and the Water Research Commission (WRC) in South Africa. There is an easy link from Microsoft Excel/Access format to the WISH database. Processing/analysis of data in general is insufficient, in many cases dissemination/information sharing as well.

3.2.7. Madagascar

No information available through this project

3.2.8. Mauritius (MUS)

- *General overview of groundwater use and institutional setting*

Groundwater resources are managed by the Water Resources Unit (WRU), within the Ministry of Energy and Public Utilities. Within the same ministry, the Central Water Authority (CWA) is responsible for providing a sustainable water supply to the people. Several policy documents have been issued that concern groundwater, such as the Groundwater Acts (1969and 1973) and The Ground Water Act Regulations (1973, 1989, 1998, 2006, 2002 and 2011)[3], the National Water Policy (2014)[4], and the National Integrated Water Resource Management Plan (2017).

- *Collection and management of borehole siting, drilling and testing data*

Data about the siting, drilling and testing of boreholes are saved in hardcopies and spreadsheets. Considering that the areas size of country is small (2 040 km²), they can thoroughly collect this data, thus the quality and consistency is good.

- *Collection and management of monitoring data*

The Ministry of Energy and Public Utilities (MEPU) supported by Central Water Authority (CWA) and Water Resources Unit (WRU) are responsible for the water resource assessment of aquifers in Mauritius. They undertake establishment of groundwater monitoring networks; yield assessment and pollution risk assessment. In 2002, groundwater data that was being collected includes groundwater levels, quality, demand and abstraction (Wellfield Consulting Services 2011).

The WRU is in charge with monitoring groundwater levels. Groundwater levels are monitored at over 300 locations, which represents a good density of monitoring point given the small area of the country. However, the frequency of monitoring is variable, depending on the budget available. Measurements are mostly manual (dip meter) but 13 boreholes are equipped with data loggers.

Groundwater abstraction and quality are monitored only in abstraction wells (over 400 in total). It is the responsibility of CWA.

[3] http://publicutilities.govmu.org/English/Pages/Legislation.aspx
[4] http://publicutilities.govmu.org/English/publications/Documents/National%20Water%20Policy.PDF
[3] http://publicutilities.govmu.org/English/Documents/Hydrology/chapter%204.pdf

In addition, 29 boreholes are meant to monitor the seawater/fresh water interface along the coast. Fluid Electrical Conductivity (EC) profiles are made for these boreholes every month. The monitoring of seawater/fresh water interface is informed by formal policy and planned accordingly. It is important considering that the contribution of groundwater to potable water supply is about 51 %[3] in this island state. There are always concerns that mining of the resource might occur and could generate sea water intrusion. Groundwater quality data is regarded as sensitive for public access, but the persons interviewed indicated that their experts routinely analyse the data and produce reports for informed decision making and protection of the groundwater in line with governmental department protocols.

Interviewees reported a need for a clear groundwater monitoring plan.

3.2.9. Mozambique (MOZ)

- *General overview of groundwater use and institutional setting*

80% of the rural population is supplied by groundwater, such as some cities. Water Resources Management is supervised by the Ministry of Public Works, Housing and Water Resources (MPWHWR), through the National Directorate of Water Resources Management (DNGRH) at the central level and by the Regional Water Administrations (ARAs) at regional/local level. The National Directorate for Water (Direcção Nacional de Águas - DNA) under the Ministry of public works, housing and water resources (Ministério das Obras Públicas, Habitação e Recursos Hidricos – MOPH) is responsible for integrated water resources management, water supply and sanitation.

Maputo has a quite a unique water distribution system, where FIPAG (Fundo de Investimento e Património do Abastecimento de Água) supplies water to the Central Business District of the city, while surrounding areas are supplied by many little water supply companies delivering water only to the houses in the direct vicinity of the borehole – 8 or 10 dwellings.

- *Collection and management of borehole siting, drilling and testing data*

Every potential borehole needs to be registered before it is drilled, although it is not always the case. ARAs oversee the borehole registration. Information such as the type of geophysics employed for siting the borehole, lithological profile and pumping test information is also stored in the registration databases. Latitude and longitude are recorded but not the elevation. Pumping tests consist mostly on 24 to 72h constant rate tests, during which the groundwater quality (usually EC) is also measured. Records also include construction data (depth, filters, casing, diameter, etc.). Boreholes are given an identification number but there are inconsistencies.

- *Collection and management of monitoring data*

ARAs are in charge of groundwater monitoring. Groundwater levels are supposed to be measured every month, while groundwater chemistry should be analysed every 6 months, but several gaps are noted. Groundwater levels are measured automatically by data loggers or manually with dip meters. Groundwater analyses include all major ions, pH, EC, temperature, TDS and bacteriological analysis.

Abstracted groundwater volumes are supposed to be monitored if not for personal or domestic purposes, but installation of flow meters is not enforced.

Data are currently stored as spreadsheets in ARAs databases, but a national database is under development at DNGRH.

As of 2002, there was no national routine groundwater monitoring to collect and manage groundwater data (Wellfield Consulting Services 2011). However according to IGRAC (2013), ARA-Sul was at that time undertaking a pilot project on groundwater monitoring to collect hydrogeological data of a complete aquifer system (~5000 km2) in the metropolitan area of Maputo. The groundwater data which were collected includes monthly groundwater levels, electrical conductivity (EC) and basic chemistry (all the major ions) on a six-monthly basis. Mozambique uses the WHO water quality guidelines. When the water abstracted is not for personal use, the owner needs to indicate the average volume abstracted on which he/she will be levied. The installation of flow meters is encouraged but not enforced and abstracted volumes are not recorded and reported.

3.2.10.Namibia (NAM)

➢ *General overview of groundwater use and institutional setting*

Namibia is an arid country that highly depends on groundwater. There are more than 54000 boreholes in the country, among which 630 are national monitoring boreholes.

➢ *Collection and management of borehole siting, drilling and testing data*

Boreholes are managed by different organizations. The Department of Water Affairs and Forestry is responsible for public boreholes. City councils are responsible for the water supply in the cities. NAMWATER is a parastatal institution responsible for rural water supply, although it also supplies industry and some cities, like Windhoek. All boreholes are stored in the national groundwater database, GROWAS2. Records include data about the siting methods, drilling and testing. Siting methods usually include an electrical conductivity survey. After drilling, a pumping test is performed (step test, constant-rate test and recovery test). EC/TDS and pH are measured during the pumping test. The borehole drilling data include penetration rates, water strikes, apparent water quality, borehole depth, borehole diameter, blow yield, rest water level, lithological logs, casing diameter, volume of gravel and sanitary seals installed, and borehole collar height. Elevation is missing for many boreholes, so that only relative groundwater levels are known.

➢ *Collection and management of monitoring data*

The Directorate of Water Resources Management (DWRM) is responsible for groundwater monitoring. There is no official national groundwater monitoring plan. Annual plans are made, depending on the needs and the available resources. There are 630 groundwater monitoring boreholes in Namibia, of which 196 are equipped with digital data loggers, the other 434 are monitored manually with a dip meter. Groundwater levels are collected every 3 months. Monitoring boreholes are strategically located. Most of them are in the region of Windhoek. Some other are located within transboundary aquifers. Loggers data are compared with manual data whenever the loggers are checked (every 3 months) to make sure that the data are consistent.

Groundwater is sampled to analyse its quality (standard water quality parameter set). It is not clear what the distribution (50 boreholes? all monitoring boreholes?) and the frequency (every 3 months? every year?) of groundwater sampling are. Ion balance is calculated, together with other checks, to make sure that the groundwater quality data are reliable. Double samples are often taken.

NAMWATER monitors the abstraction in the boreholes it oversees, and receives groundwater abstraction data from other users, mostly from the industry. Every licensed user must forward the abstracted volumes to NAMWATER read from a flowmeter. Field visits are conducted to collect data from non-compliant users.

Monitoring data are stored in the National Groundwater Database (GROWAS) under the Department of Water Affairs and Forestry, within the Ministry of Agriculture, Water and Forestry. Data are first recorded in spreadsheets, then in GROWAS2. The database is not readily accessible online to the public, but data are available on request. GROWAS provides data visualisation and basic processing (trend analysis and correlation). The City of Windhoek is using the data in a groundwater model. In 2018, DWRM will prepare the first Annual Groundwater Status Report, to improve the analysis and dissemination of groundwater monitoring data.

3.2.11.Seychelles (SYC)

No information available through this project

3.2.12.South Africa (ZAF)

➢ *General overview of groundwater use and institutional setting*

According to Pietersen and Beekman (2016) groundwater accounts for about 15% of South Africa's total water use. In 2013, the Department of Water Affairs (now the Department of Water and Sanitation, DWS) reported that about 65% of groundwater was used for agriculture (about 60% for irrigation and about 5% for watering livestock). Most of the remainder of groundwater was used is the mining sector (about 13%), domestic water supply services in towns and cities (about 13%) and industry (3%). The rural water supply makes up the remaining ~6% of groundwater use. In rural areas, groundwater is generally the only source of water. Since the National Water Act of 1998 came into force, DWS is responsible for monitoring, managing and protecting all water resources in the country, this includes groundwater[5]. DWS developed the National Groundwater Archive (NGA)[6]. The NGA contains about 252 800 registered boreholes (privately owned and public boreholes). This database can be accessed online by any registered user to consult and download data. Still many of the privately-owned boreholes are not registered on the NGA.

➢ *Collection and management of borehole siting, drilling and testing data*

A nationwide system for coding boreholes has been developed and is implemented. When available, the National Groundwater Archive provides information about the siting, the drilling/construction and the testing of the boreholes. Siting methods usually include geophysics (magnetic, resistivity, seismic, electromagnetic and gravity surveys), performed by DWS or by local groundwater companies. Data collected during the construction of the borehole include the lithology, penetration rate, water strike, borehole depth and construction data. Pumping test parameters and results are also stored in the database.

[5] http://www.dwa.gov.za/iwqs/eutrophication/NEMP/AppendixAWaterAct.pdf
[6] http://www3.dwa.gov.za/nganet/

- *Collection and management of monitoring data*

DWS monitors groundwater levels and quality across the country. The total number of registered groundwater level monitoring points is 6033, but about 2/3 are inactive. This proportion varies, depending on the capacity of DWS regional offices in charge of the monitoring. Not all regional offices have sufficient resources to perform this task. Piezometric levels are measured manually with dip meters, no data loggers are used. Groundwater levels are supposed to be monitored every month. Groundwater level data are stored in the NGA if monitoring frequency doesn't exceed one data per month. Larger time series are stored in a separate data base called Hydstra. Hydstra and the NGA are not linked.

There are currently 535 groundwater quality monitoring points across the country, including boreholes and springs. As for groundwater level monitoring boreholes, only 378 of those are active. Groundwater is sampled twice in a year, before and after the rainy seasons. Major ions are analysed (Ca, Mg, K, Na, Cl, NO_3, SO_4, HCO_3, CO_2), as well as and EC and pH. The interpretation of groundwater quality data is done using CHART[7]. Groundwater quality data are stored in the Water Management System (WMS). WMS and NGA are linked using a unique numbering system.

The NGA is accessible for every registered user. The DWS also manages an experimental dashboard called National Integrated Water Information System (NIWIS)[8]. NIWIS gives an overview of groundwater related data on a map, where the user can zoom in and interrogate individual data points.

In addition, DWS hosts an online library called the Groundwater Geohydrological Report System[9], where reports from the DWS or related projects are made available in pdf format. Maps like the Hydrogeological map are also available in shapefile format. Documents can be searched by Title, Author and Keywords.

Groundwater abstraction is not monitored.

DWS has developed its own network of rainfall gauges, to avoid paying to access meteorological data from the department of meteorology. Apparently, it is current for governmental organizations to charge other governmental organizations for data.

3.2.13. Tanzania (TZA)

- *General overview of groundwater use and institutional setting*

The development and management of water resources in Tanzania is guided by the National Water Policy (NAWAPO, 2002), and the Water Resources Management Act, No. 11 of 2009. The policy accounts for sustainable management of groundwater resources. Groundwater is an important resource, especially in rural areas, although some big cities also depend on it. Groundwater and surface water are managed through nine River and Lake Basins Organizations (RLBO).

[7] http://www.dwa.gov.za/Groundwater/chart.aspx
[8] http://niwis.dws.gov.za/niwis2
[9] http://www.dwa.gov.za/ghreport

- *Collection and management of borehole siting, drilling and testing data*

Every new borehole must be approved by the relevant RLBO before drilling, based on a borehole siting report. Groundwater exploration shall be carried out by using at least two geophysical and hydrogeological methods, one of them must be Vertical Electrical Sounding (VES) method. After completion, additional data must be reported to the RLBO, such as the location of the borehole (Region, District, Ward and Street and coordinates), rig type, drilling depth, drilling diameter, lithology (performed on the field), pump type, pump capacity, aquifer type and pumping test results. The pumping test is performed for every borehole before installing the pump, to determine the static water level, drawdown and yield. It lasts from 8 to 72h, depending on the use of the borehole (boreholes for public supply require 72h pumping tests). These operations are supervised by a hydrogeologist. Despite the obligation to submit new borehole information to RLBOs, many boreholes are not registered. As of today, is impossible to know how many boreholes exist in Tanzania. Many borehole completion reports are also incomplete or incorrect.

- *Collection and management of monitoring data*

Groundwater monitoring is done by the Ministry of Water. Groundwater data collection includes; groundwater levels, quality, abstraction and demand (Wellfield Consulting Services 2011). The Ministry of Water is also responsible for storing groundwater data.

Groundwater levels are monitored by 23 monitoring wells located in five RLBOs. Monitoring boreholes are equipped with automatic data loggers that send the data to the servers of the respective RLBOs. Data are recorded every 30 minutes. An officer is responsible for daily maintenance of the servers. Data are stored in spreadsheets and are not available for downloads, but when needed a formal letter should be submitted to the RLBOs or to the Ministry of Water and Irrigation. It has been reported that some monitoring boreholes cannot be visited in time to replace the batteries, leading to monitoring gaps.

Groundwater quality data are sampled depending on the availability of funds. Physical, chemical and biological parameters are then tested. Some are measured on the field with a Portable Water Quality Kit (pH, Temperature, total alkalinity, Dissolved Oxygen and Electrical Conductivity), while other parameters are analysed in the lab (TDS, Hardness, Carbonate, Non-Carbonate, Sulphate, Chloride, Fluoride and Nitrate).

Groundwater abstraction is said to be monitored by public water supply authorities.

3.2.14.Zambia (ZMB)

- *General overview of groundwater use and institutional setting*

Groundwater is a major source of safe drinking water in many parts of Zambia, especially in rural areas. Much of Zambia’s population relies on groundwater for domestic water supplies, but groundwater is also used for irrigation and livestock. There are 3 types of aquifers in the country: medium to high yield fractured/fissured formations (including karstic aquifers in the Lusaka province), primary porosity aquifers (e.g. alluvial soils and Tertiary sand deposits), and low yielding weathered basement. The Water Resources Management Act (2011) rules the management of groundwater. Since 2018, groundwater is considered a public resource.

➢ *Collection and management of borehole siting, drilling and testing data*

The Water Resources Management Authority (WARMA) manages public boreholes development. Data about private boreholes must be communicated to WARMA. Data about boreholes are stored in WARMA's database (GeoDin). It contains around 16 000 boreholes, of which ~4000 have no coordinates. The following data are reported: coordinates, depth, diameter type of borehole, type of casing, type of pump, lithology. Borehole data usually include information about the siting method (e.g. resistivity) and the pumping test. Commercial water supply boreholes are pumped for 72h, domestic boreholes for 4 hours (in general).

➢ *Collection and management of monitoring data*

The Revised National Water Policy from 2010 includes the assessment, planning and development of surface water and groundwater. However, there is no apart stipulated groundwater monitoring plan. There was an attempt at developing a national managed groundwater development programme, including a plan for groundwater monitoring, but it didn't concretize. Groundwater monitoring is managed by the Department of Water Resources Development (DWRD), within the Ministry of Water Development, Sanitation and Environmental Protection. It manages around 100 monitoring boreholes across the country. 44 are around Lusaka, 11 in the upper Kafue catchment. Some monitoring boreholes are equipped with data loggers, the others are monitored manually with a dip meter. According to IGRAC (2013), most of the monitoring and assessments on both quantity and quality are not carried out by governmental organizations due to a lack of financial resources and poorly maintained monitoring stations. Groundwater monitoring is rather mostly done by other stakeholders, mainly on a project basis.

There is no monitoring of groundwater quality, although some data have been collected from specific projects, locations (e.g. around Lusaka) or mining companies.

There is no monitoring of abstraction.

Interviewees reported a lack of resources to monitor groundwater resources properly.

WARMA uses a Ground Water Management Information System (GRIMS), an application for groundwater data analyses and visualisation, e.g. GIS maps. BGR supports this application within WARMA through the upgrading the technical components, training courses and intensive on-the-job training.

3.2.15.Zimbabwe (ZWE)

➢ *General overview of groundwater use and institutional setting*

Groundwater is considered as the most reliable and safest source of drinking water in Zimbabwe, mainly in rural areas. With 67% of Zimbabwe's population living in the rural areas (National Population Census, 2012), most of the people rely on groundwater for drinking and other purposes. Recently, groundwater has been increasingly relied upon by urban populations due to erratic water supplies from local authorities. Most urban local authorities are facing challenges of contamination of surface water sources by industrial effluent and sewage. There are more than 50 000 boreholes in Zimbabwe. In six of the country's 10 provinces, there are 26 074 boreholes (RWIMS Database) and in Harare

Metropolitan Province alone there are more than 20 000 boreholes (Upper Manyame Sub-Catchment Council Database).

- *Collection and management of borehole siting, drilling and testing data*

The development of public boreholes is managed by the Zimbabwe National Water Authority (ZINWA) and the District Development Fund (DDF). Private boreholes must be registered, and relevant information communicated to ZINWA. Borehole data consist in borehole siting data (using electrical resistivity and magnetic geophysical methods), location, depth, diameter, lithology logs, water strikes and any other relevant information. Each borehole is given a unique identification number. Pumping test data are also saved. A pumping test is performed for every public borehole and for private boreholes whose owners can afford one. Groundwater is sampled after completion of the borehole for analysing the quality in line ISO/TC 147 Water Quality specifications. The data about boreholes are stored in hardcopy in ZINWA and DDF offices, sometimes as softcopy.

In addition, there is a Rural WASH (Water Sanitation and Hygiene) Information Management System (RWIMS), where borehole data are stored and shared digitally. There is no linkage between RWIMS, DDF and ZINWA databases.

- *Collection and management of monitoring data*

ZINWA is in charge of groundwater monitoring. ZINWA is a parastatal under the Ministry of Environment, Water and Climate (formerly the Ministry of Water Resources Development and Management) and is responsible for groundwater monitoring and therefore data collection and management of data. There is no official national groundwater monitoring plan. Groundwater is monitored only in the 3 major aquifers well fields of the country, namely Nyamandlovu (161 boreholes, started in 1989), Middle Sabi (168 boreholes, started in 1997) and Lomagundi (198 boreholes, started in 2017). Monitoring of the Gokwe water supply started in 2017. Currently only groundwater levels are being monitored. Groundwater levels are measured manually, with dip meters. The Environmental Management Agents & Ministry of Health and Child Care are carrying out routine water quality monitoring but information is not shared widely.

Routine quality checks on groundwater level data are supposed to be performed for detecting irregularities but there are no standard protocols employed and little dedicated time for it. Besides, the Environmental Management Agency and the Ministry of Health and Child Care are carrying out water quality monitoring, although the information is not shared widely.

Due to limited capacity and resources, ZINWA has implemented community-based groundwater monitoring near the well fields to measure the monthly water levels for them.

Besides, licensed groundwater users have the responsibility to measure water levels, quality and abstraction, which are the only sources of groundwater quality data. No clear data quality control procedures are defined for these data, except that groundwater samples must be analysed by accredited laboratories. Licensed groundwater users are also supposed to measure groundwater abstraction with flowmeters and to communicate the abstracted volumes monthly. However, due to limited resources and capacity this is loosely enforced Groundwater abstraction is also monitored by ZINWA in the Nyamandlovu aquifer well field.

Data are stored in hardcopy or spreadsheets. Groundwater quantity and quality data are stored within different departments and organizations. There is therefore a need to create and develop a national database to compile data from different sources.

3.3. SADC-wide synthesis

3.3.1. Collection of borehole siting, drilling and testing data

An overview of borehole siting, drilling and siting data collection in the SADC Member States is given in Table 3. Most countries use a geohydrological investigations to determine the position of a new public water supply borehole (borehole siting) if this is drilled under the responsibility of a government agency. The geohydrological investigations tend to include a desktop study and a geophysical survey (mostly resistivity and electromagnetic surveys). The data produced tend to be stored in project archives in hard copies. Data gathered during drilling is archived in hard copies and in some instances also in spreadsheets or even in a relational database. Most countries will perform pumping tests to recommend a sustainable yield. A 2-hour pumping test, as is the case in one country, is regarded as too short as it is questionable if the borehole is really stressed during such short time period. At the other end of the spectrum, some countries report 72-hour pumping tests, but is unclear how often such tests are performed in reality. Most of the countries keep records of the static water level and the safe yield estimated by the pumping test. Most countries also take a sample of groundwater after the borehole completion to analyse the quality of the groundwater.

In almost all countries, private boreholes are supposed to be registered (and require licensing in many cases) and siting, drilling and testing data must be forwarded to the responsible government agency/department. However, many countries report that many private boreholes are not registered or that incomplete forms are submitted.

Boreholes tend to be registered in one centralised database or in some cases in different regional databases (spreadsheets in most cases, rarely a relational database). Siting, drilling and testing data tend to be stored as hardcopies or as softcopies of reports (not softcopies of the raw data). In addition, not all countries have a system enforced for identifying the boreholes with a single identification number. As a result, those data are barely accessible in most countries.

The management of the boreholes is almost always delegated to the end-user, a water company, a community or a city council. Most of the time, they are also responsible to monitor abstraction (volumes and pumping hours), groundwater level and groundwater quality but there is little evidence that they do so (exceptions being some water utilities companies). Most countries reported that monitoring of abstraction boreholes is in practice very limited or non-existent. In some instances, this also has a technical cause whenever boreholes are not equipped with access tubes to safely measure the water level. Data on abstracted volumes are hardly available.

- Boreholes are mostly sited based on a desktop study and/or geophysics (magnetic or electric methods on the ground) and/or visual site inspection.
- Sets of drilling and construction data are recorded that usually include the location of the borehole, the depth and the lithology.

- Pumping tests tend to be conducted to advise on safe yields. The type of tests varies greatly among and within the countries, as it probably depends on the geological setting and final use of the borehole.
- Siting, drilling and testing data related to public boreholes are most often stored in hardcopies or in spreadsheets, rarely in a searchable database.
- Private boreholes must normally be registered but many are not, or incomplete registration forms are submitted.
- Single identification numbering is promoted but not always enforced, with obvious issues of cross-references.
- Big groundwater users (public or private companies) are supposed to monitor groundwater levels, quality and abstraction. However, very few countries report the monitoring of groundwater abstraction, with no evidence of being enforced. Groundwater abstraction is mostly estimated based on the recommended yield/pumping capacity.

3.3.2. Collection of groundwater monitoring data

An overview of groundwater level, quality and abstraction monitoring is given in tables 3 - 7. Most countries have a monitoring plan either official or non-official, although IGRAC/IGS has not been able to obtain copies of any such plans. Most countries do monitor groundwater levels, some also monitor groundwater quality, very few monitor groundwater abstractions. The objectives of monitoring are unclear in most countries.

Groundwater monitoring is the least developed in humid/tropical countries of the SADC region, where surface water is abundant (Angola and DRC).

The responsible departments in most countries are hampered by organizational and financial problems resulting in a relatively small number of boreholes being monitored. Logistical problems (also due to finances and organization) lead to irregular monitoring resulting in many data gaps. Many organizations have reported transport issues to access remote boreholes. Vandalism of boreholes and equipment is another widespread issue.

Groundwater levels are mostly measured manually with dip meters and in some instances automatically with data loggers, sometime also equipped with telemetric communication for data transfer. Data loggers are often seen as a cost-effective solution to monitoring groundwater in remote areas, but issues with data logger failing are ample, often resulting in loss of data. Therefore, data loggers can be used to increase monitoring frequency (e.g. from 6/year to 1/day) but sites still need to be visited on a regular basis to check on equipment and to safeguard data by downloading them from the data loggers.

Country visits and young professional reports provided little concrete numbers on sampling points and frequency in relation to groundwater quality. As a result, the distribution of groundwater quality monitoring boreholes and frequency of sampling is unclear. It seems that groundwater quality analysis is performed irregularly, whenever budget allows. The most frequent groundwater quality parameters recorded are those that can be measured in the field (EC, pH, temperature, TDS). Lab analyses include major ions, fluoride or arsenic in regions affected by these contaminants. Some countries also do microbiological analyses. Only one country reported a network of boreholes dedicate to seawater intrusion monitoring.

Monitoring of groundwater abstraction is almost non-existing. Depending on national legislation monitoring of abstraction volumes is the responsibility of the end-user (owner of the borehole) and tends to be regulated via water use licensing, but enforcement / compliance is very limited to non-existing.

- Most countries collect data on groundwater levels, albeit that quality of the data is poor (data gaps and often poor geographical coverage)
- Many countries collect data on groundwater quality, but this seems to be on a very irregular basis
- Monitoring of abstraction volumes is almost non-existing. Groundwater users are responsible for monitoring of groundwater use through provisions in water use licences, but compliance and enforcement are limited.
- Data sets in all countries suffer from data gaps, albeit to varying degrees
- Most countries lack clear objectives for monitoring (objectives are defined in very general terms)
- Some boreholes are inaccessible
- Vandalism is common

3.3.3. Data quality assurance and quality control (QA/QC)

The quality of the monitoring data varies greatly from one country to another, depending on the capacity of the departments in charge. Some countries lack field forms, which would assist in collecting consistent data. More generally, procedures and guidelines are missing.

In countries where monitoring boreholes are equipped with data loggers, cross-checks can be made with manual measurements performed whenever the loggers are inspected (e.g. for replacing the battery). Once in the computer, data are usually checked to detect any possible outlier.

Some countries reported the absence of licensed labs and the non-reliability of the groundwater quality analyses. Some make double analyses (e.g. with double samples or with one sample and the set of parameters (EC, pH) measured on the field).

When it comes to data quality control, many countries simply reported that the data are checked by a hydrogeologist, without further precision.

Many countries reported the need to train or re-train the staff in charge of field data collection, which would be beneficial for the quality of the data reported.

The country visits and young professional reports give the impression that the focus is not much on the quality of the data collected but rather on the collection of data itself.

- Quality of the collected data is uneven
- Countries lack staff, budget and tools to check (and interpret) monitoring data
- Protocols for quality control of collected data are not well developed, and quality control procedures are not implemented.

3.3.4. Data storage

The method of data storage differs greatly among the countries. Only 3 countries use a relational database. Zambia uses GEODIN, Malawi Hydstra and WISH, Namibia uses GROWAS2, a purpose-built database still under development, and South Africa has a

National Groundwater Archive, and used Hydstra[10] to store time series data. The Botswana database administrator has developed a relational database in Oracle, but in practice this is not accessible for general use because of the lack of a user-friendly interface.
Some other countries are using spreadsheets as a database and some have a mixture of paper files and spreadsheets. There is a SADC-wide agreement with respect to Hydstra software, which includes licensing to use Hydstra software in all SADC countries. However, only some countries such as South Africa and Malawi seem to be using Hydstra. In South Africa, the connections between Hydstra and the National Groundwater Archive are not always clear and in practice it can be difficult to combine data from these 2 databases. Angola uses Hydstra but only for surface water, since groundwater is not monitored in this country. In the other countries, spreadsheets and sometimes even hardcopies are used for storing data.

In theory, only the databases of Botswana, Namibia, South Africa and Zambia seem to include monitoring data and public/private borehole data. In many other countries, the monitoring of groundwater levels, quality, abstraction and the registration of public and private boreholes is managed by different organizations, with different databases.

A point of concern is the lack of back-up capabilities in some countries.

- In all countries there are major issues with the continuity of data collection and storing in databases, resulting in many data gaps.
- Most countries store monitoring data in spreadsheets.
- Only few countries have a relational database to store monitoring data and public/private boreholes data.
- Lack of back-up facilities in some countries is a serious concern.

3.3.5. Data sharing

In theory, all countries share data to people/organisation requesting such data. In practice there are large differences between the countries in dealing with such requests. Only South Africa shares monitoring data online through a web enabled interface that allows querying the full database. For time series, the users need to send in a request (online) for a person to manually collate the data and make it available to the requester. In all other countries, a manual request must be sent. Some users reported long bureaucratic procedures and poor quality of the data (e.g. lack of relevant meta data) as limitations in using the data. In some countries, it is reported to be practically impossible to obtain data. In some instances, this may be due to the absence of (accessible) data, which is obscured by bureaucratic procedures. In most cases there seem to be no costs or only nominal costs associated with obtaining groundwater data. Digitally available data appears to be provided free of charge, while hardcopies of maps tend to be given out at a nominal fee (intended for cost recovery).

Incomplete or inconsistent databases are seen as the major obstacle to data sharing. The absence of relational databases in most countries also impedes the sharing of data, e.g. time series of groundwater levels cannot easily be connected to basic information like borehole location, surface elevation and depth of filter. In some countries, a lack of 'open-data culture' was observed, although it is hard to determine if data are not shared because they can't technically be shared or because someone doesn't want to share them. The fact is that

[10] Hydstra software see: http://kisters.com.au/hydstra.html

all countries but one, do not provide the possibility to browse data online and to download them independently.

- In theory, groundwater data are available for users upon request in all countries.
- In practice groundwater data in several countries are not easily available to potential users outside the government department responsible for those data. There are obvious technical reasons for that (absence of data, lack of user-friendly databases / interfaces), but in some countries data sharing is hampered by bureaucratic procedures.

3.3.6. Cross sectoral integration

Meteorological data is collected in all countries, as is data on land-use and relevant statistical data on population etc. In some countries the data is readily available to hydrogeologists upon request. But in other countries issues were reported related to high costs and/or tedious procedures of obtaining such data, even to the extend where water departments and university revert to set up their own meteorological stations. The sharing of meteorological doesn't seem more developed than the sharing of groundwater data.

During the country visits few examples of cross-sectoral cooperation were given. An interesting example was cooperation with a Ministry of Health in relation to the quality of drinking water (monthly reports of occurrences of water borne diseases are used as a measure to prioritise groundwater quality monitoring). None of the persons interviewed gave concrete examples of cooperation in policy development or implementation with sectors like agriculture, industry or mining (apart from compliance monitoring for groundwater use licenses) or even environmental management.

- Collaboration with other sectors to develop an integrated vision of groundwater resources is pretty much non-existent.

3.3.7. Analyses, interpretation and dissemination

The little use of data from other sectors (e.g. industry and mining, agriculture, forestry, socio-economic data) can be related to the general lack of interpretation of groundwater data by the professionals in groundwater departments. In most countries, the lack of analyses of groundwater monitoring data was reported, for purposes of resource management or for wellfield or even borehole management. It was commonly stated that groundwater management is very much on an ad-hoc and incident-based basis, rather than being strategically planned based on analyses and a clear understanding of the long-term behaviour of the (ground)water system(s). Reasons which were mentioned were lack of time, lack of capacity, lack of sufficient data, lack of (software) tools and lack of experience in doing such analyses. An evidence is the absence of reports on groundwater resources in many countries; in writing their reports, many young professionals used data of the Africa Groundwater Atlas[11], not data from their own department.

- There is very little use (interpretation) of the groundwater data collected in SADC Member States

[11] http://earthwise.bgs.ac.uk/index.php/Africa_Groundwater_Atlas_Home

3.4. Summary tables

3.4.1. Summary tables of groundwater data collection and data management in the SADC Member States

The information described in the previous sections was summarized in a few tables, which are presented below.

Note of caution:

Summarizing all information into tables is challenging and a lot of nuance has to be left out in the process. As a result, these tables don't reflect all uncertainties pertaining the information that was collected. The tables could give a false impression of confidence. Nevertheless, they offer to the readers a quick overview of the situation in SADC.

Table 3: Overview of borehole siting, drilling and testing data. BH = borehole.

	Borehole siting, drilling and testing		
Country	**Data collection**	**Data storage**	**Shared online?**
AGO	no*	no (plan to develop a database in 2019)	Not applicable
BWA	in principle for all boreholes (public and private)	hardcopies + spreadsheets	no
COD	in principle for all boreholes (public and private)	hardcopies + spreadsheets	no
SWZ	in principle for all boreholes (public and private)	hardcopies + spreadsheets	no
LSO	public boreholes only	hardcopies + spreadsheets	no
MWI	in principle for all boreholes (public and private)	hardcopies + spreadsheets	no
MUS	in principle for all boreholes (public and private)	hardcopies + spreadsheets	no
MOZ	in principle for all boreholes (public and private)	spreadsheets	no
NAM	in principle for all boreholes (public and private)	GROWAS2	no
ZAF	in principle for all boreholes (public and private)	NGA	yes
TZA	in principle for all boreholes (public and private)	?	no
ZMB	in principle for all boreholes (public and private)	GEODIN	no
ZWE	in principle for all boreholes (public and private)	hardcopies + spreadsheets	no

*: DNA has made inventories of water points for public supply. Data are not collected in a structural manner.

Table 4: Overview of groundwater monitoring.

ISO code	Monitoring of groundwater			Monitoring objectives	Overarching institution
	levels	quality	abstraction		
AGO	no	no	no	Not formulated / available	National Institute for Water Resources (INRH) under Ministry of Energy and Water
BWA	yes	Yes	yes	- Assessment of wellfields and large groundwater users	Ministry of Minerals, Energy and Water Resources
COD	no	no	no	Not formulated / available	Ministry of Environment, Conservation of Nature and Tourism
SWZ	no	no	no	Not formulated / available	Ministry of Natural Resources and Energy
LSO	yes	no	no	General assessment of groundwater resources	Department of Water Affairs
MWI	yes	yes	no	General assessment of groundwater resources	Ministry of Agriculture, Irrigation and Water Development
MUS	yes	yes	no	- General assessment of groundwater resources - Assessment of seawater intrusion	Ministry of Energy and Public Utilities
MOZ	yes	yes	no	General assessment of groundwater resources	Ministry of Public Works, Housing and Water Resources
NAM	yes	yes	yes	General assessment of groundwater resources	Ministry of Agriculture, Water and Forestry
ZAF	yes	yes	no	General assessment of groundwater resources	Department of Water and Sanitation
TZA	yes	yes	yes	General assessment of groundwater resources	Ministry of Water and Irrigation
ZMB	yes	no	no	General assessment of groundwater resources	Ministry of Water Development, Sanitation and Environmental Protection
ZWE	yes	no	no	Assessment of wellfields	Ministry of Environment, Water and Climate

Table 5: Overview of groundwater level monitoring in SADC Member States.

ISO code	Groundwater levels monitoring	Number of monitoring boreholes	Scale	Method	Frequency	Organization in charge	Storage	Shared online?
AGO	no	Not applicable						
BWA	yes	~ 1000	local	dip meter + data logger	1 month	Department of Water Affairs	spreadsheets	no
COD	no	Not applicable						
SWZ	no	Not applicable						
LSO	yes	48	national	dip meter	3 months	Department of Water Affairs	spreadsheets	no
MWI	yes	75	regional	data logger	15 minutes	Department of Water Resources	HYDSTRA + WISH	no
MUS	yes	300	national	dip meter + data logger	4 months	Water Resources Unit	spreadsheets	no
MOZ	yes	?	regional	dip meter + data logger	1 month	ARAs	spreadsheets	no
NAM	yes	630	national	dip meter + data logger	1 day - 3 months	Directorate of Water Resources Management	GROWAS2	no
ZAF	yes	1800	national	dip meter	1 - 6 months	Department of Water and Sanitation	NGA	yes
TZA	yes	23	regional	data logger	0,5 h	River Basin Organizations	spreadsheets	no
ZMB	yes	~ 100	regional	dip meter	3 months	Department of Water Resources Development	GEODIN	no
ZWE	yes	527	local	dip meter	1 month	Zimbabwe Water Authority, Groundwater Division	hardcopies + spreadsheets	no

Table 6: Overview of groundwater quality monitoring in SADC Member States.

ISO code	Quality monitoring	No. monitoring boreholes	Scale	Frequency	pH, T, EC	Major ions	Micro-biology	Organization(s) in charge	Storage	Shared online?
AGO	no	Not applicable								
BWA	yes	?	local	?	?	?	?	Department of Water Affairs / Water Utilities Corporation	?	no
COD	no	Not applicable								
SWZ	no	Not applicable								
LSO	no	Not applicable								
MWI	yes	?	?	variable	yes	yes	yes	Department of Water Resources	HYDSTRA	no
MUS	yes	?	?	?	?	?	?	Central Water Authority	spreadsheets	no
		29	regional	1 month	yes	no	no	Water Resources Unit	spreadsheets	no
MOZ	yes	?	regional	variable	yes	yes	yes	ARAs	spreadsheets	no
NAM	yes	?	national	?	yes	yes	yes	Directorate of Water Resources Management	GROWAS2	no
ZAF	yes	378	national	6 months	yes	yes	?	Department of Water and Sanitation	NGA + WMS	yes
TZA	yes	variable	local	variable	yes	yes	no	River Basin Organizations	spreadsheets	no
ZMB	no									
ZWE	yes	?	?	?	?	?	?	Environmental Management Agency / Ministry of Health and Child Care	?	no

Table 7: Overview of groundwater abstraction monitoring in SADC Member States.

ISO code	Groundwater abstraction monitoring	Organization(s) in charge
AGO	no	INRH through licencing
BWA	large wellfields	- Water Utilities Corporation - Large groundwater users
COD	no	
SWZ	no	
LSO	no	
MWI	no	
MUS	400 boreholes	Central Water Authority
MOZ	no	
NAM	licensed groundwater users	Directorate of Water Resources Management (DWRM)
ZAF	no	
TZA	yes	Public water supply authorities
ZMB	no	
ZWE	no	

3.4.2. Reported issues

The issues reported by the interviewees during the country visits are listed below. They are also summarized in Table 8, with the countries where they have been reported. Again, this table may not be exhaustive or accurate, but it gives a general idea of the main challenges that need to be addressed in the Member States.

➢ *Issues related to data collection*

- Insufficient number of BH being monitored: There are insufficient monitoring boreholes to fulfil the monitoring objectives; e.g. they don't cover the entire territory of the Member States or the monitoring network is not dense enough to provide significant insight on groundwater resources.
- Issues in the design of monitoring network or monitoring boreholes: The monitoring network is not efficient because the monitoring boreholes have not been located in the right places, they don't always tap into the right aquifers, or information on the construction of the boreholes is missing, etc.
- Damaged observation boreholes or observation boreholes turned into production wells: Monitoring boreholes are not repaired when damaged or have been equipped with pumps. This reduces the size of the monitoring network.
- Vandalism: Monitoring boreholes and infrastructure are damaged by locals.
- No data or incomplete data from private groundwater users: In many Member States, private groundwater users must report to the authority in order to get a license, but they don't.
- Gaps in monitoring data series: The monitoring boreholes are not monitored as often as desired; the frequency of monitoring is variable.
- Issues with data quality and data quality check: The quality of the data collected is poor or is not checked.
- Problems of data loggers maintenance: Data loggers collect data automatically but they need to be visited regularly to be recharged and to save the data. If this is not done on a regular basis this may result in loss of data (data gaps).
- Need for automatic data loggers: Collecting data with data loggers requires less efforts than collecting data manually. Or for the same effort, they allow collecting more data than manually.

➢ *Issues related to data storage*

- No centralized database / use of spreadsheets
- Use of hardcopies
- No national coding system of BH or issues with BH numbering
- Use of different coordinate systems
- No backup system

➢ *Issues related to data sharing*

- Data sharing can be difficult

➢ *Issues related to data interpretation*

- Lack of interpretation, resulting in ad-hoc interventions and lack of interest (= lack of budget) from decision makers.

➢ *Issues related to all components of data collection and data management*

- Limited resources (e.g. budget, staff, equipment)
- Logistics/organizational issues
- No official monitoring plans
- No clear objectives of groundwater monitoring
- Lack of training

Table 8: List of issues reported during the country visits.

	AGO	BWA	COD	SWZ	LSO	MDG	MWI	MUS	MOZ	NAM	SYC	ZAF	TZA	ZMB	ZWE	count
Issues related to data collection																
insufficient number of BH being monitored					X					X		X		X	X	**5**
issues in the design of monitoring network or monitoring BH							X			X						**2**
damaged BH or BH turned into production wells					X					X						**2**
vandalism	X	X			X		X									**4**
no data or incomplete data from private groundwater users		X	X		X		X		X			X			X	**7**
gaps in monitoring data series		X			X		X		X			X				**5**
issues with data quality and data quality check		X			X										X	**3**
problems of data loggers maintenance		X														**1**
need for automatic data loggers								X								**1**
Issues related to data storage																
no centralized database / use of spreadsheets	X	X	X	X	X		X	X	X				X		X	**9**
use of hardcopies		X	X	X	X		X	X	X				X		X	**8**

	AGO	BWA	COD	SWZ	LSO	MDG	MWI	MUS	MOZ	NAM	SYC	ZAF	TZA	ZMB	ZWE	count
no national coding system of BH or issues with BH numbering	X	X			X		X									**4**
use of different coordinate systems					X											**1**
no backup system					X											**1**
Issues related to data sharing																
data sharing can be difficult		X	X		X		X						X		X	**6**
Issues related to data interpretation																
lack of interpretation		X					X			X						**3**
Issues related to all components of data collection and data management																
limited resources (e.g. budget, staff, equipment)		X	X	X			X		X	X		X	X	X	X	**9**
logistics/organizational issues		X		X	X							X	X			**4**
no official monitoring plan	X	X			X			X		X					X	**6**
no clear objectives of groundwater monitoring					X											**1**
lack of training		X		X	X							X	X			**4**

4. Recommendations

4.1. Introduction

The assessment of the current state of groundwater data collection and management in the SADC Member States has highlighted several gaps that need to be addressed. This section lists these gaps and provides recommendations.

The gap analysis was performed across the entire SADC region, not on a country basis. One reason is that many/most Member States face the same gaps. It is true that the SADC encompasses very different socioeconomic and environmental situations: there are obviously differences in terms of groundwater management between economically stronger developed and more arid countries such as South Africa and less developed and more humid countries like DR Congo; between island states like Mauritius and inland countries like Botswana; between large countries like Tanzania and small countries like eSwatini; etc. However, almost all countries have reported insufficient budget and capacity, resulting in monitoring gaps; a need for training staff and monitoring procedures; a lack of interpretation; issues with data storage and sharing; etc.

4.2. Recommendations per country

4.2.1. Angola (AGO)

It is vital, from a geohydrological perspective, to start collecting data on groundwater on a regular basis. Development and implementation of a (national) groundwater monitoring programme should have priority, and it should include monitoring of groundwater levels, groundwater quality and data on groundwater abstraction (volumes and user categories). Angola has already a database for surface water and is in the process of developing a database for groundwater data. This database should be developed in such a way that it can accommodate all relevant groundwater data such as: data on borehole siting, data from drilling, pumping tests, time series of groundwater levels, groundwater quality data, abstraction data and other data related to the licensing of groundwater use. Depending on budget and available human capacity a comprehensive database can be developed at once, or if budget or in particular human capacity is limited then it may be better to develop the national groundwater database in a modular way: starting simple and gradually expanding the database over time.

Staff must be (re)trained to enable Angola to collect reliable groundwater data and to interpret the data together with other relevant hydrogeological data.

4.2.2. Botswana (BWA)

- Botswana has several different groundwater related databases and most of its data can only be accessed by one person. To make sure that the databases reach their full potential, a program must be started to integrate the databases so that they can be accessed from one central platform/user interface and give access to the all potential users, also in the regional offices.

- Develop and implement a nation-wide monitoring programme: Most respondents reported issues with groundwater monitoring in terms of data gaps, data handling, data storage and access to data. Monitoring objectives don't seem to be clearly defined. DWA is advised to develop a nationwide groundwater monitoring programme, in consultation with WUC. The monitoring programme should describe the monitoring efforts related to the protection and management of the wellfields for public water supply (location of observation points and frequency of observations/sampling) and could also include a nation-wide general reference monitoring network to evaluate general trends. The monitoring programme has to match (realistically) available budgets for monitoring and should also include regular analysis and reporting on monitoring data as well as evaluation of the monitoring programme (regular optimisation of monitoring programmes) as to better be able to inform for example on the licensing for groundwater abstractions (advice role to Water Apportionment Board).
- Efforts should be made to monitor groundwater abstractions as this information is key to analysing and understanding trends in resource development.
- Improve cooperation between DWA and WUC: Notwithstanding the different responsibilities and mandates of DWA and WUC, groundwater management in the country can benefit from improved cooperation and data sharing between these two major players. Monitoring efforts of both organisations can and should be harmonised, and all data should be made available to the national groundwater database with full direct access to the database for both organisations. It should be considered to 'force' large water users who have to monitor groundwater for compliance monitoring to not just report on their water use, but to also share the underlying data for inclusion into the national groundwater database.
- To resolve the serious backlog in processing of paper forms (such as borehole completion certificates, groundwater monitoring data, water quality analyses and water use rights) DWA is advised to temporarily increase efforts to resolve this back-log and in the mean-time improve and simplify procedures (e.g. by making use of digital forms or apps rather than paper forms) to avoid the build-up of new backlogs.
- Human capacity: there seems to be a lack of trained and qualified staff, especially in WUC throughout all levels. Increase numbers qualified staff, with dedicated training on groundwater from operational and technical to the level of senior hydrogeologists. This requires more on the job training at all levels, (certified) vocational training programmes for borehole / wellfield operators and for groundwater technicians, and more attention to dedicated hydrogeology courses at academic levels.
- Data sharing / access to data can be made easier by developing comprehensive national data portals, integrating data overviews irrespective of which department keeps the data, such as to guide researchers on where the specific data are available.

4.2.3. Democratic Republic of the Congo (COD)

Groundwater development is in an early stage in Democratic Republic of the Congo. It is recommended to:

- develop a groundwater strategy to organize the sustainable development of the resource.
- Develop and implement a national groundwater monitoring program
- develop a national groundwater, which would involve consolidation of existing data into one form of storage.
- develop capacity on theoretical and practical applications of methods for groundwater data collection.
- improve awareness about the value of groundwater in the country.

4.2.4. eSwatini (SWZ)

In order to monitor groundwater in eSwatini a monitoring network is required. Boreholes that were diverted from monitoring to water supply must be reversed or if that's not possible additional monitoring boreholes must be drilled. Data collected must be stored in one central database (or for starters in a spreadsheet) and make sure that proper backup copies are available. In the meantime, progress must be made with the development of a central relational database. Staff must be (re-)trained or increased to enable eSwatini to collect and interpret the geohydrological data.

4.2.5. Lesotho (LSO)

For the immediate future Improve your excel spreadsheet and make sure you have a backup in the cloud (OneDrive/Dropbox etc). Also, for the immediate future make sure that the IT-budget is controlled by the department. Once this is in place the department can start establishing their own (relational) database. Staff must be (re-)trained or increased to enable Lesotho to collect and interpret the geohydrological data.

- There is a need to develop a clear and realistic nationwide groundwater monitoring programme (for the specific situation of Lesotho this includes monitoring of boreholes and mountain springs) covering groundwater level monitoring, a strategy / monitoring plan for groundwater quality monitoring and for monitoring of abstraction rates and spring discharges. As funds and human capacity are limited, it is advisable to develop such a programme in a modular way and to start with modest ambitions and expand if future opportunities arise, rather than developing an ambitious programme which cannot be implemented or maintained. The monitoring programme should consider both incidental and structural costs related to monitoring as well as regular analyses and interpretation of data.
- In terms of data management Lesotho needs to improve its data storage. Ideally a centralised relational database is set-up which allows access for multiple users. However, if / as long as budget and IT-infrastructure are limited, Lesotho should develop and use on standard template for storing and visualising all groundwater monitoring data in spreadsheets. Furthermore, a procedure should be developed and implemented ensuring version management to avoid that parallel versions of the excel databases develop, and to secure some form of back-up system of the excel databases. Even the simplest solutions of freely available cloud storage such as dropbox, google-cloud or onedrive can be considered for the time being.

- Data quality control can simply be improved by making use of graphs in excel to visualise all groundwater monitoring data, immediately after collecting the data, so there is an opportunity to filter out and/or resample extreme and suspicious outliers.
- As vandalism of monitoring sites was reported as a serious issue, measures to avoid this should be undertaken. On one hand this can be in developing or purchasing vandal-proof hardware, but in the long term it may be more efficient and more effective to develop and implement campaigns to inform and create awareness under the local (often rural) population on the importance of groundwater resource management and monitoring. Ideally the local population becomes involved in the management of their groundwater infrastructure and the monitoring of the resource (community-based approaches).

4.2.6. Malawi (MWI)

- Implement the new groundwater management plan and operate the migration of the groundwater division
- Secure a sufficient budget for groundwater monitoring
- Include siting, drilling and testing data in the database
- Estimate groundwater abstraction using proxy data.
- Improve the sharing of data

4.2.7. Madagascar

No information available through this project

4.2.8. Mauritius (MUS)

- Develop a groundwater monitoring plan, which should include clarification of the responsibilities of the different stakeholders collecting groundwater data, to avoid having different departments collecting their own data.
- Develop a centralized database.
- Consider expanding the use of data loggers for groundwater levels and Electric Conductivity (EC) profiling, in addition to the currently quite successful manual measurements of water levels and Electric Conductivity (EC) profiling for sea water intrusion early warning systems.
- Consider monitoring groundwater quality in other groundwater points, don't limit it to abstraction boreholes only.
- Scheduled evaluation and review of monitoring networks to improve the effectiveness and efficient. This will help to establish appropriate distribution of monitoring resources and monitoring frequency to suit aquifer responses,
- Development of capacity of young professional in the groundwater departments. This can involve recruiting young professionals in the relevant groundwater departments who can be trained and mentored by experienced hydrogeologists. This is important to ensure that there can be knowledgeable and experience experts sustain the systems when the older generation has retired.

4.2.9. Mozambique (MOZ)
Although it can be beneficial to delegate task from the department to the ARA's, some control must be maintained to make sure that the required data is actually collected in the field and stored in a database. Staff must be (re-)trained or increased to enable Mozambique to collect and interpret the geohydrological data.

4.2.10.Namibia (NAM)
- Retrieve the elevation of the boreholes in the database, with a GPS or a Digital Elevation Model (DEM)
- Improve the sharing of data, e.g. ease the access of groundwater data online

4.2.11.Seychelles (SYC)
No information available through this project

4.2.12.South Africa (ZAF)
Securing sufficient budget for groundwater monitoring or adapt groundwater monitoring to the available budget, prioritizing the boreholes that must be monitored first. resulting in a reduced operational budget for fieldwork and chemical analysis. Rectifying this problem must have the highest priority. The DWA allows external users to access their geohydrological data stored on the National Groundwater Archive. But not all data is stored on the NGA (think water quality and detailed time series data) Building one overarching portal from where all geohydrological data can be accessed must be considered.

4.2.13.Tanzania (TZA)
- A central database should be developed.
- Efforts should be made to turn the data collected into valuable information for decision-makers.

4.2.14.Zambia (ZMB)
- Develop a groundwater monitoring plan.
- Secure a sufficient budget for groundwater monitoring.
- Collect the GPS coordinates of the boreholes that are missing coordinates. This can be done on the long term or in one shot with a dedicated campaign.
- Collect the monitoring data from the different stakeholders.
- Estimate groundwater abstraction using proxy data.

4.2.15.Zimbabwe (ZWE)
- Develop a groundwater monitoring plan and provide clarity on the responsibilities of different stakeholders/department to avoid having different departments collecting their own data. This should also be linked to the development of a centralised data base,
- Development of a centralised groundwater data base. Such activity will have to consolidate all the currently existing data sets from different departments,
- Improve capacity of professionals to analyse and interpret groundwater data,

- Utilisation of affordable home-made dip meters. Home-made dip meters are cheaper and thus bridge the gap of limited funds which have been reported.
- Expand the use of citizen science to other groundwater monitoring sites. Lessons can be drawn from the monitoring on well fields and Rural WASH (Water Sanitation and Hygiene) Information Management System (RWIMS) community-based data collection.

4.3. SADC-wide recommendations

4.3.1. General observations

Most rural communities in SADC are served from groundwater; multiple large cities throughout SADC rely on groundwater for their urban water supply; groundwater irrigation is important for food production in the region (although its application is not as widespread as might be expected in some of the drought prone areas); and groundwater is important in supporting important (wetland) ecosystems in the region (Pietersen and Beekman, 2016). The importance of groundwater for the socio-economic development in the SADC region and to sustain important ecosystems, is not reflected in the current state of groundwater management in general or groundwater data collection management in particular. Pietersen and Beekman (2016) already reported an alarming situation describing issues related to groundwater pollution, groundwater depletion and lack of access to / year round availability of water, while investments in operation and maintenance of groundwater infrastructure are limited, implementation of (ground) water policies and enforcement of regulations are lacking (e.g. instruments such as groundwater protection zones are hardly used; water use licences are not enforced and fines are neve imposed), explicit agencies responsible for groundwater management don't really exist, and coordination between the groundwater sector and other sectors such as the agricultural sector, urban planning and industrial development are lacking. They also report that groundwater information management and monitoring are weak throughout most of the SADC Member States; a finding which is confirmed in the current assessment. Issues already reported by IGRAC (2013) have not really improved in recent years since the current assessment. Gaps in data records, the need for training of staff in monitoring practices and data management, lack of standardisation, the need to increase the number of groundwater monitoring stations and associated human and capital resource and the regular interpretation of groundwater monitoring data, lack of / inadequate data quality and data control standards and of (accessible) database, are all issues which were reported in previous studies and which also come out of the current assessment, with very little evidence of improvements in the years since previous inventories.

Many of the staff members interviewed or otherwise engaged in the project (e.g. the young professionals, senior staff members contributing to the workshop and SADC GMI focal persons) are quite passionate about their work, but organisational issues such as lack of budget for (adequately trained) personnel, equipment and logistics and lack of priorities to conduct structural groundwater data collection and management activities seem to be at the core of the problem.

In many cases there appears to be a significant gap between policy and practice. The project team often experienced that there is a discrepancy between the official version and reality. The official version may be that groundwater levels and groundwater quality are monitored on a regular basis and that these groundwater monitoring data are available. In practice however, it turns out the data are collected at irregular intervals due to budgetary or logistical issue, that observation boreholes have been vandalised or have been equipped as production boreholes, and that groundwater monitoring data are difficult to obtain because the data are stored in many different places and in some instances bureaucratic procedures delay or in the worst case prevent access to data.

Recommendations - ABC

Allocate staff and budget Lack of sufficient (and adequately trained) staff and insufficient budget for equipment and logistics are obvious obstacles in improving groundwater data collection and management, and these issues have to be resolved at managerial and the political level (budget allocation).

Be realistic: It is equally important to develop / evaluate groundwater monitoring programmes and groundwater databases to match available budgets and capacity. A simple monitoring programme and database that are fully operational, is more valuable than a highly ambitious monitoring programme and complex database that are dysfunctional.

Convert data into policy relevant information: Groundwater professionals themselves, should on a regular basis process and analyse groundwater monitoring data and develop policy relevant advice and interventions based on such information. Leveraging groundwater data in this way can gain more attention (and budget) for adequate groundwater monitoring and data management. To obtain this groundwater professionals also need to be trained / capacitated in this type of analyses.

4.3.2. Monitoring objectives and strategy

While almost all countries do monitor groundwater, it was very difficult to get hold of **official groundwater data collection plans with dedicated budgets and numbered objectives.** It may be that these plans exist but are not shared, but it is likely that they don't exist, and that monitoring is performed on an incidental basis, depending on the budget available. Such plans are crucial in order to have an efficient collection of groundwater data. It is recommended that each organization in charge with groundwater data collection and management define clear objectives, even if small, that are realistic, i.e. that can be met with their current capacity (budget, staff, material). What matters most is that the collection of data is consistent, and that monitoring is regular. It may be preferable to have less monitoring points with regular time series than more monitoring points affected by several gaps. Clear monitoring objectives are crucial in defining which data must be collected and at which frequency (and not the other way around). As reported in the GW-MATE briefing notes, monitoring "should be driven by a specific objective - monitoring for its own sake often leads to inefficient". For instance, groundwater levels are monitored by almost all countries, but it is unclear why and on which basis the monitoring network was designed. Is the objective a number of wells/area (e.g. South Africa)? A number of wells/capita? Is a certain region targeted (e.g. Zimbabwe)? The same holds for groundwater quality and abstraction.

Scheduled evaluation and review of monitoring networks to optimise groundwater monitoring (modify frequency and or geographical distribution). This will help to establish appropriate distribution of monitoring resources and monitoring frequency to suite aquifer responses and available budgets and human capacity.

4.3.3. QA/QC procedures

Most countries reported that the quality of the data collected is generally poor. This can be related to several factors. A major cause for this is lack of continued data collection and data not ending up in accessible databases. Other reasons include the absence / lack of implementation of **procedures for field data collection, including templates and field forms.** This has been reported in several countries. Clear and simple forms are not difficult to develop and can greatly improve the quality of the data collected. Simple procedures can greatly improve the quality of the data collected and can also help maintaining equipment in good order. Procedures can also be developed for guiding pumping tests, since some countries have reported that pumping tests are not performed correctly (e.g. they are too short).

Trained staff are key to obtaining reliable data. Almost all countries report a need for training on field techniques, such as calibrating common field equipment, basic field trouble shooting, installation of equipment, pumping tests and data measurements. Some countries have developed strategies for **data checks**; such procedures do not need to be complicated and those need to be widely implemented (e.g. double-checking groundwater levels and quality measurements, data plotting for detecting outliers). In addition, regular analysis and interpretation of data can help detecting suspicious data and improve / optimise data collection strategies / monitoring programmes.

Easy to implement recommendations are to improve data quality control by making use of graphs in excel for visual inspection of groundwater monitoring data, immediately after collecting the data, so there is an opportunity to filter out and/or resample extreme and suspicious outliers.

More advanced methods, but not beyond reach with current technologies and readily available **mobile phone apps**: To avoid mistakes during digitising of field forms and to simplify / speed up procedures to upload / enter field data into databases Member States should consider making use of software / mobile phone apps to replace paper field forms. There are several apps available for these purposes. Some required the data to be downloaded manually from the mobile phone to a computer (for upload into the centralised national database), while there are also more advanced applications which can connect directly to a data server so that it is no longer necessary to manually upload the data to a database.

4.3.4. Data storage and sharing

Data storage is an issue. Very few countries rely on dedicated software for storing and interpreting groundwater monitoring data. Some use spreadsheets, which can be a solution when few data are involved. Hardcopies should be avoided (other than for archiving / backup purposes). When data are stored in different locations and in different formats, **access to data** becomes an issue.
Some countries even lack sound **data backup** strategies. Databases centralized on one server with automatic backups are recommended, but simple alternatives are the use of cloud

storage or even regular backing up through separate hard drives, although the latter tends to have the risk of being forgotten after some time.

Issues with data storage directly result in issues with **data sharing**. Access to groundwater data is difficult in many Member States. Besides disorganized data storage, in some countries there also appear to cultural or other barriers to providing access to data / data sharing.

4.3.5. Processing, interpretation and dissemination of policy relevant information

Many countries reported the lack of **interpretation of groundwater data,** for whatever purpose (e.g. resource management, wellfield or even borehole management, contamination assessment, protection). The general impression is that data are collected to be stored in a database (in the best case), while no clear examples of analysis and evaluation could be given.

Throughout the whole project not one example was provided of groundwater monitoring data being used in relation to groundwater resource evaluation or management. When questioned during the interviews about processing and interpreting groundwater monitoring data it became apparent that this does not take place at a regular basis or worse: not at all in some countries. This means that management interventions and development of policies are not being based on long term data and trend analyses, elements which are of paramount importance to be able to manage the resource sustainably. Explanations provided for this hiatus included lack of priority, lack of sufficient capacity, lack of technical capacity or lack of experience, lack of software tools and lack of data of sufficient quality.

The lack of software programs doesn't appear to be a big obstacle, since several free (and sometimes open-source) programs are available nowadays. However, the staff may need training on the use of these programs and in groundwater data interpretation in general.

An often-heard complaint was lack of funds for monitoring. However, to break the vicious circle of lack of data and lack of information from data, it is equally important to start making use of existing data and to turn this into policy relevant and practical information. Without this, non-groundwater specialists and decisions makers will not understand the importance of long-term groundwater monitoring, and are not likely to provide additional budgets.

Such level of interpretation requires technical skills of data processing and analyses, but it also requires an understanding of the issues and position of groundwater users and developments therein (e.g. developments in agriculture). It is recommended to build capacity on this level of interpretation of groundwater data either through tertiary (university) education and/or through dedicated training programmes.

It is equally important to develop clear and realistic (i.e. feasible within available budget and human capacity) groundwater monitoring programmes with clearly defined objectives. This avoids collecting data for the sake of collecting.

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