GGRETA
GOVERNANCE OF GROUNDWATER RESOURCES IN TRANSBOUNDARY AQUIFERS

Online Course on Groundwater Management in African Lake and River Basin Organizations

Schweizerische Eidgenossenschaft
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Swiss Agency for Development and Cooperation SDC

Groundwater data management

Arnaud Sterckx, IGRAC

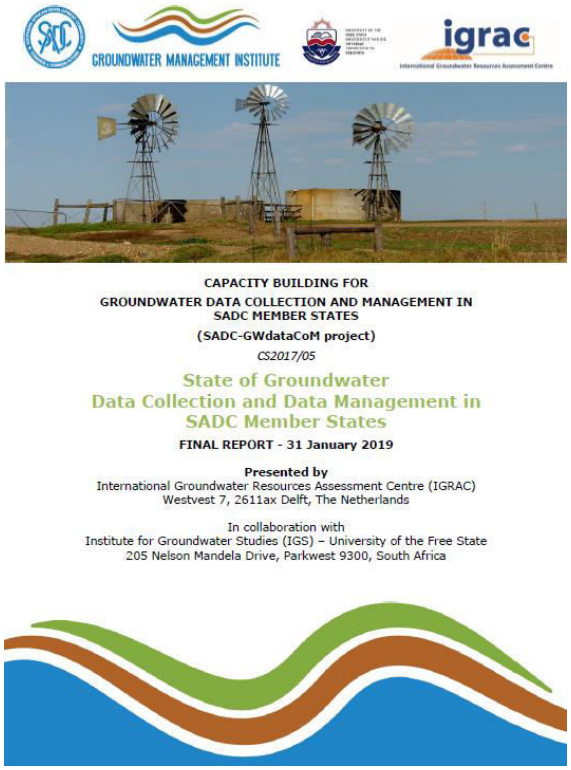
- After data is collected in the field (or in the lab), it needs to be properly managed.

Groundwater data management is the whole process of using groundwater data after their collection. It encompasses quality assurance and quality control (QA/QC) of those data, the storage of those data in archives and databases, sharing/providing access to data, analysis and interpretation of the data, and finally the dissemination of resulting groundwater information.

SADC-GMI, IGRAC, IGS (2019) SADC Framework for Groundwater Data Collection and Data Management. SADC-GMI report: Bloemfontein, South Africa.

Evaluating groundwater data collection and management

Country visits: 145 professionals interviewed in 12 Member States



2017-2018

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

https://sadc-gmi.org/wp-content/uploads/2020/03/State-of-GW-data-in-SADC_2019.pdf

+ inputs from 22 young professionals from 11 Member States

1. Overview of groundwater development in [COUNTRY NAME]

2. Data currently collected
- 2.1.Borehole siting
- 2.2.Borehole drilling
- 2.3.Borehole testing
- 2.4.Borehole equipping
- 2.5.Borehole monitoring
  - 2.5.1.Groundwater levels
  - 2.5.2.Groundwater quality
  - 2.5.3.Groundwater abstraction

3. Quality checks performed
- 3.1.Borehole siting
- 3.2.Borehole drilling
- 3.3.Borehole testing
- 3.4.Borehole equipping
- 3.5.Borehole monitoring
  - 3.5.1.Groundwater levels
  - 3.5.2.Groundwater quality
  - 3.5.3.Groundwater abstraction

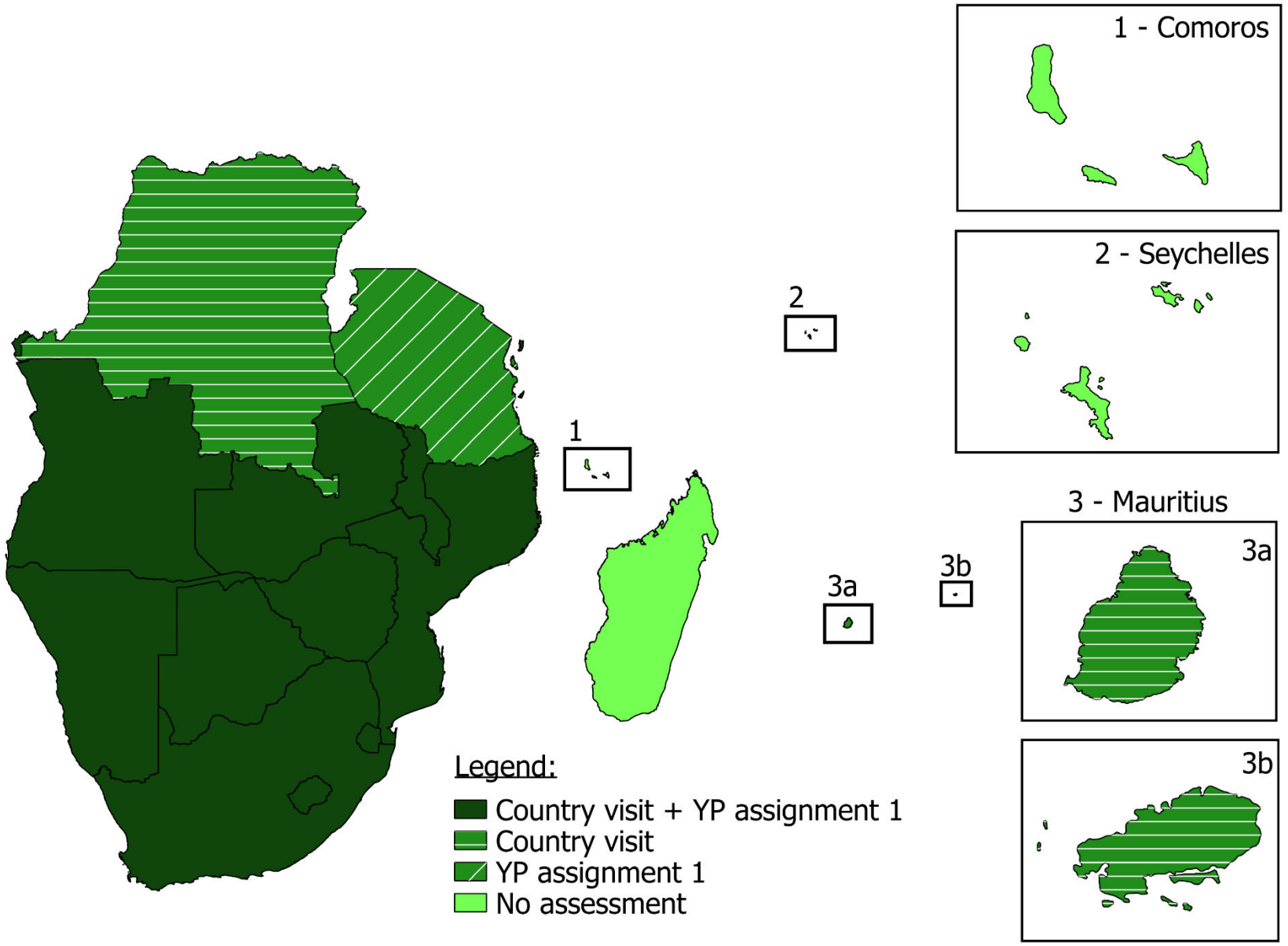
4. Short comings identified
- 4.1.Borehole siting
- 4.2.Borehole drilling
- 4.3.Borehole testing
- 4.4.Borehole equipping
- 4.5.Borehole monitoring
  - 4.5.1.Groundwater levels
  - 4.5.2.Groundwater quality
  - 4.5.3.Groundwater abstraction

5. Proposed improvements
- 5.1.Borehole siting
- 5.2.Borehole drilling
- 5.3.Borehole testing
- 5.4.Borehole equipping
- 5.5.Borehole monitoring
  - 5.5.1.Groundwater levels
  - 5.5.2.Groundwater quality
  - 5.5.3.Groundwater abstraction

6. Analysis
- 6.1.Borehole siting
- 6.2.Borehole drilling
- 6.3.Borehole testing
- 6.4.Borehole equipping
- 6.5.Borehole monitoring
  - 6.5.1.Groundwater levels
  - 6.5.2.Groundwater quality
  - 6.5.3.Groundwater abstraction

7. Reporting
- 7.1.Borehole siting
- 7.2.Borehole drilling
- 7.3.Borehole testing
- 7.4.Borehole equipping
- 7.5.Borehole monitoring
  - 7.5.1.Groundwater levels
  - 7.5.2.Groundwater quality
  - 7.5.3.Groundwater abstraction

8. Conclusions


1 - Comoros
2 - Seychelles
3 - Mauritius
1
2
3a
3b
3a
3b
Legend:
Country visit + YP assignment 1
Country visit
YP assignment 1
No assessment

Country overviews + summary tables

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 Regio regional/local level. The National Directorate under the Ministry of public works, housing a Públicas, Habitação e Recursos Hidricos – MO resources management, water supply and sar

Maputo has a quite a unique water distributio Investimento e Património do Abastecimento Business District of the city, while surrounding supply companies delivering water only to the 8 or 10 dwellings.

➢ *Collection and management of borehole s*

Every potential borehole needs to be register the case. ARAs oversee the borehole registrat geophysics employed for siting the borehole, information is also stored in the registration c but not the elevation. Pumping tests consist r which the groundwater quality (usually EC) is construction data (depth, filters, casing, diam identification number but there are inconsiste

➢ *Collection and management of monitoring*

ARAs are in charge of groundwater monitorin measured every month, while groundwater c but several gaps are noted. Groundwater leve or manually with dip meters. Groundwater ar temperature, TDS and bacteriological analysis

Abstracted groundwater volumes are suppose domestic purposes, but installation of flow m

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

Frequent shortcomings

- **Budget**
- **Insufficient staff**
- **Insufficient equipment (e.g. piezometers, sampling sets, transport, computers, lab analyses, IT)**

- **Monitoring objectives and strategy**
- **Few official groundwater data collection plans with dedicated budgets and numbered objectives**
- **Absence of clear groundwater monitoring purposes**

GW-MATE, 2006

Effective groundwater monitoring is characterized by two key requirements:

- it should be driven by a specific objective—***monitoring for its own sake often leads to inefficient use of manpower and budgets***
- the data collected should be systematically stored for future use—***there are far too many cases of monitoring data being 'lost along the way'.***

- **Related issues: access to monitoring boreholes, irregular sampling, etc.**

https://www.un-igrac.org/special-project/gw-mate

- **Interpretation of groundwater data**
- Lack of interpretation of groundwater data: No interpretation because no data? Or no data because no interpretation?
- Lack of training
- Lack of software programs

- **QA/QC procedures**
- The data collected are sometimes (often?) of poor quality
- Lack of protocols and guidelines (for monitoring, siting, drilling and testing, for lab analyses, data check)
- Lack of field forms/templates
- Lack of data interpretation

- **Data storage and sharing**
- **Few countries rely on relational databases and software programs. Spreadsheets and hardcopies are still frequently used.**
- **Data are stored in different locations**
- **Lack of reliable data backup strategies**

GW-MATE, 2006

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- it should be driven by a specific objective—***monitoring for its own sake often leads to inefficient use of manpower and budgets***
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- **Barrier to data sharing**

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

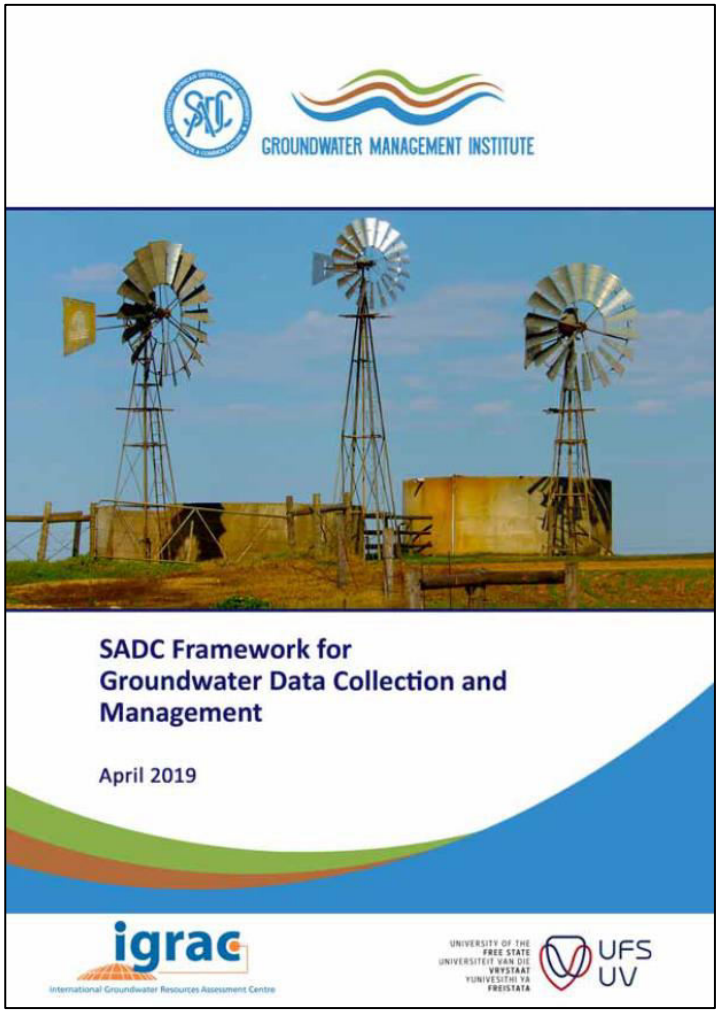
IGRAC (2020) Expansion of the SADC Groundwater Information Portal (SADC-GIP), SITUATIONAL ANALYSIS REPORT

Table 3-3 Database software programs in use in SADC member states.

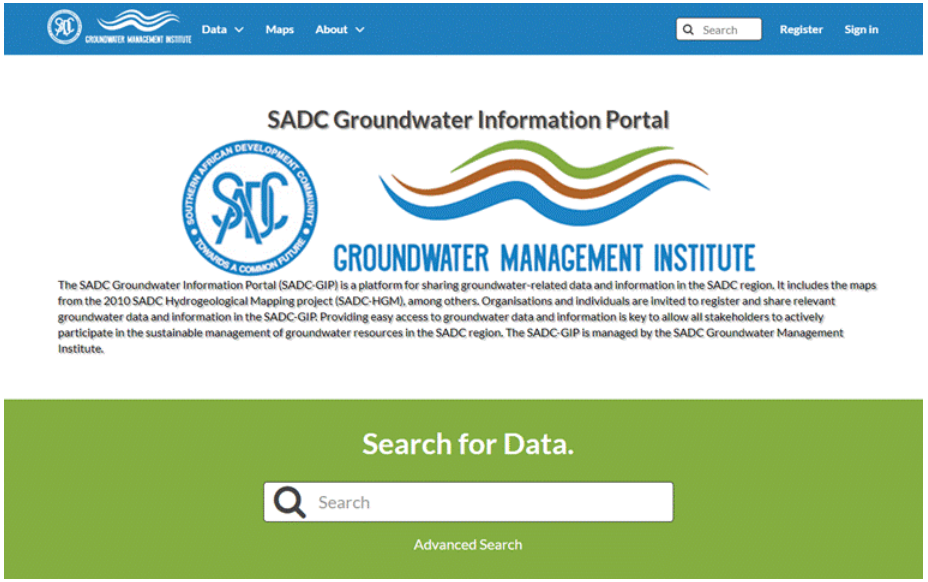
	Member State	Borehole database	Groundwater level monitoring database	GW quality monitoring database	Groundwater data sharing platform
1	Angola	Excel			
2	Botswana	NBA	Wellmon		
3	Comoros		KoBoToolbox		
4	DRC	very few data, no database			
5	eSwatini	Excel/Access			
6	Lesotho	Excel	Excel	?	
7	Madagascar	no information available			
8	Malawi	Excel*	Hydstra / WISH?	dBase3	
9	Mauritius	Excel	Excel	Excel	
10	Mozambique	Excel	Excel	?	
11	Namibia	GROWAS II			
12	Seychelles	no information available			
13	South Africa	NGA			
			Hydstra		
				WMS/CHART	
14	Tanzania	Excel			
15	Zambia	Geodin			
16	Zimbabwe	Excel	Excel	?	

* Only permits are stored at the National Water Resources Authority. mWater contains water points data, including borehole data.

A basis for capacity-building…



… and for transboundary data sharing



Summer 2020 – Senegalo-Mauritanian Aquifer Basin (BASM)

Table 1-1 Numbers of professionals consulted.

Organisation type	Gambia	Guinea-Bissau	Mauritania	Senegal	Total
Water department	2	5	2	2	11
Other governmental*	1	1	-	-	2
Water utility company	-	1	-	2	3
University	-	-	-	1	1
Consultants, drillers	1	-	1	2	4
NGOs, international agencies and donors	3	2	-	-	5
OMVS/OMVG	-	-	-	3	3
Total	**7**	**9**	**3**	**10**	**29**

*Other governmental:

- Gambia: Public Utilities Regulatory Authority (PURA)
- Guinea-Bissau: SERVIAGUAS – Public company for Hydrogeological Studies and supervision of borehole construction

- Similar methodology but virtual meetings, less interviewees

Table 3-2 Status of groundwater monitoring in the countries

Type of monitoring	Status	Gambia	Guinea-Bissau	Mauritania	Senegal
Nation-wide monitoring	Responsible organisation	DWR	DGRH	CNRE	DGPRE
	Ongoing?	yes	no	no	yes
Wellfield monitoring	Responsible organisation	NAWEC	various city-based public water suppliers	SNDE	SONES
	Ongoing?	no	not in Bissau, maybe in other cities	yes	yes

IGRAC (2020) Deliverable number 4: Report on the assessment of available groundwater data in the SMAB.

Table 3-1 Overview of data availability and accessibility.

	Gambia	Guinea-Bissau	Mauritania	Senegal	Regional scale
Geological map	At BRGM.	Obtained online	Obtained online	Obtained from Division des Mines	Obtained online
	Hardcopy	Georeferenced image	Shapefile	Pdf (shapefile must be available)	Image
Hydro-geological map	Obtained from DWR (contour map) in pdf. Shapefile available at DWR	Obtained from DGRH	Obtained online	Probably available at Division des Mines	There are several maps available (with consistency issues)
	Shapefile	Image/Shapefile	Shapefile	Shapefile	Image/Shapefile
Borehole data	Available at DWR. Currently being updated.	Obtained online (mWater).	Obtained from MHA but no data since 2007	Obtained from DGPRE in pdf. Excel copy available at DGPRE	
Monitoring data	Available at DWR	There is no systematic monitoring	Available at SNDE	Available at DGPRE	

3. Management issues and recommendations
   - i. Groundwater governance
   - ii. Borehole licensing
   - iii. Groundwater monitoring
   - iv. Research and knowledge gaps
   - v. Data storage
   - vi. Data sharing
   - vii. Engagement of drinking water supply companies
   - viii. Translating data into information
   - ix. Awareness-raising in communities
   - x. Improvement of drinking water supply
   - xi. Education in hydrogeology
   - xii. Professional training
   - xiii. Sustainable financing

What are the key questions to answer?

Responsibilities

- In most countries, groundwater monitoring and the collection of borehole data is in the hands of a public authority, e.g. ministry of water, water authority, geological survey, etc.
- In some countries, water management is decentralized (e.g. Mozambique). Groundwater data might be collected and managed by subnational authorities.
- Additional data might be held by other ministries or departments (e.g. environment), water companies, universities, NGOs, private companies, etc.

→ It is sometimes challenging to identify who collects and manages groundwater data

What data are available?

- In low-income countries, it is often the case that groundwater monitoring programs are insufficient and borehole licensing is not effective.

→ Identify what data are actually being collected.

- In case of monitoring:
- groundwater level?
- groundwater quality? If yes, what parameters
- groundwater abstraction?
- How many data point are monitored? What is the frequency of monitoring?

- In case of borehole data:
- What data are collected? Is the inventory of boreholes up-to-date?

What is the quality of the data?

- When data are available, it happens that they are of poor/dubious quality.
- What are the protocols followed in the field or in the lab?
- What are the QA/QC procedures to ensure a good quality of the data?
- Are metadata stored with the data?

In what format the data are stored?

Hard copy?
Excel?
Access?
Server-based database?

SADC-GMI, IGRAC, IGS (2019) SADC Framework for Groundwater Data Collection and Data Management. SADC-GMI report: Bloemfontein, South Africa.

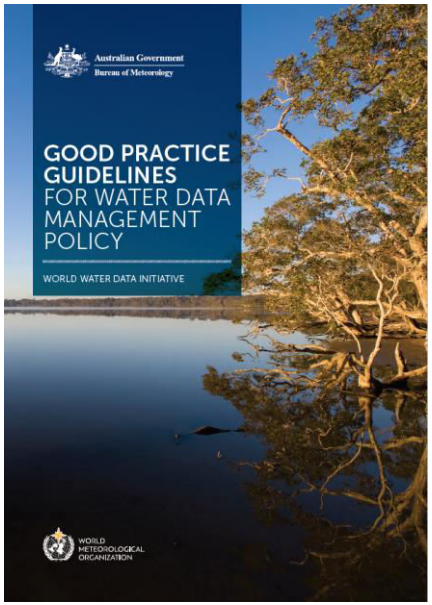
Table 6.1: Overview of database functionalities and organisational requirements for different database options

Database Type	Spreadsheet database	Desktop relational database	Server based database
Maximum number concurrent users	1	255 (theoretically, MS Access)	32676 (MS SQL-Server)
Maximum database size	2 GB (MS Excel)	2 GB (MS Access)	524272 TB
Primary database model	Flat	Relational	Relational
Query/filtering functionality	Basic	Advanced	Advanced
Indexing of data	No	Yes	Yes
Logical checks on data entry	Basic	Advanced	Advanced
Data quality control process	Very basic / impractical	Possible	Advanced
Audit trail	No	No	Possible (must be part of the database architecture)
Backup	External hard-drive or in the cloud.	External hard-drive or in the cloud.	Dedicated backup procedures are required.
User roles and authorisations	Only 2 roles can be defined using a password for the spreadsheet	Different user roles and authorisation levels can be set	Advanced management of user roles and authorisation levels possible (and required)
User interface	Generally, not required but possible (e.g. data input forms)	Not required, but practical; relatively easy to develop	Required and custom-made
Integration of various tools (processing, analysis, visualisation, reporting)	Basic	Moderate (self-made/ custom made)	Advanced (custom made)
Human capacity needed	• End-users require only basic understanding of spreadsheet software • Person setting up and maintaining the spreadsheet requires additional basic understanding of relational database concepts and (optional) programming in Visual Basic.	• End-users may need basic training in the use of the database. • Development and maintenance may be done by staff with more advanced experience/training in the use of desktop databases and concepts of relational databases	• End-users will require training in the use of the database interface and the specific tools they will be authorised to use (differentiated training) • Database developer(s) and administrator(s) needed with specialised knowledge on database management and server-maintenance etc.
Financial implication	• Software: little to none (most people already have the software) • Training: very little • Hardware: no additional hardware required apart from backup drives	• Software: limited • Training: limited for users • Hardware: no additional hardware required apart from backup drives	• Software: Costly • Training: extensive • Hardware: additional hardware required (server, server room) and related infrastructure, which all require maintenance (recurring costs)

How are data shared?

- What are the conditions under which data are shared?
- Is there a data sharing platform?
- Is it necessary to request the data?
- Is it necessary to pay a fee?
- What is the waiting time before receiving the data?

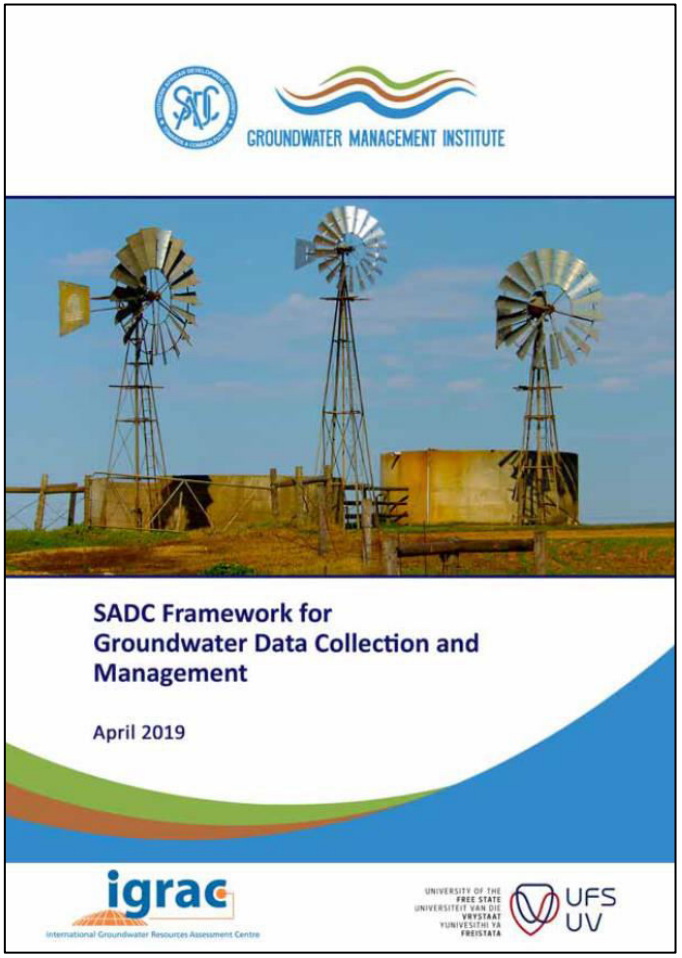
- Is there a data management strategy?



Bureau of Meteorology, 2017. Good practice guidelines for water data management policy: World Water Data Initiative. Bureau of Meteorology, Melbourne

! There is often a gap between policy documents and practice

! The situation can change rapidly, depending on e.g. political changes, budgets, etc



SADC-GMI, IGRAC, IGS (2019) SADC Framework for Groundwater Data Collection and Data Management. SADC-GMI report: Bloemfontein, South Africa.

- UNECE Task Force on Monitoring and Assessment (2000). **Guidelines on Monitoring and Assessment of Transboundary Groundwater.** Lelystad. https://www.unece.org/fileadmin/DAM/env/documents/2018/WAT/05May_28-30_IWRM_WGMA/Transboudary_Groundwaters.pdf
- Bureau of Meteorology, 2017. **Good practice guidelines for water data management policy: World Water Data Initiative**. Bureau of Meteorology, Melbourne http://www.bom.gov.au/water/about/publications/document/Good-Practice-Guidelines-for-Water-Data-Management-Policy.pdf
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- INBO, UNESCO (2018) **The Handbook On Water Information Systems Administration, Processing And Exploitation Of Water-related Data** https://www.riob.org/sites/default/files/_HB-2018-SIE-BAT_web.pdf

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- Fitch P., Brodaric B., Stenson M., Booth N. (2016). **Integrated Groundwater DataManagement.**In: Jakeman A.J., Barreteau O., Hunt R.J., Rinaudo JD., Ross A. (eds) (2016)Integrated Groundwater Management. Springer, Cham. DOI: https://doi.org/10.1007/978-3-319-23576-9_26

And many more!

Recommendation

- L/RBOs should have insight on groundwater data collection and management in the riparian states.
- There is a value in transboundary cooperation for capacity building in groundwater assessment and management, e.g. for attracting funding, sharing of experiences and good practices, economies of scale. See for instance:

GROUNDWATER MANAGEMENT INSTITUTE

https://sadc-gmi.org/

L/RBOs can be instrumental in fostering such cooperation between countries.

Thank you for your attention

International Groundwater Resources Assessment Centre

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United Nations Educational, Scientific and Cultural Organization

International Hydrological Programme

World Meteorological Organization

Government of The Netherlands