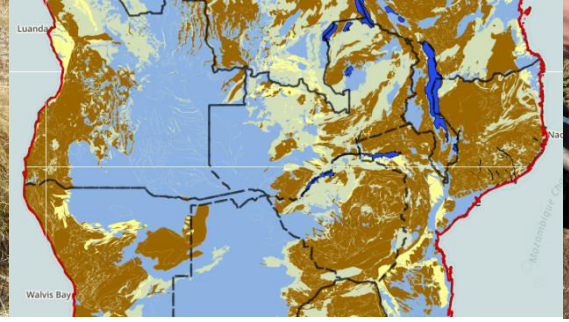




Training workshop on groundwater assessment and management for African L/RBOs

Groundwater Monitoring

Claudia Ruz Vargas
International Groundwater Resources Assessment Centre (IGRAC)

Groundwater Assessment and Monitoring

Assessment

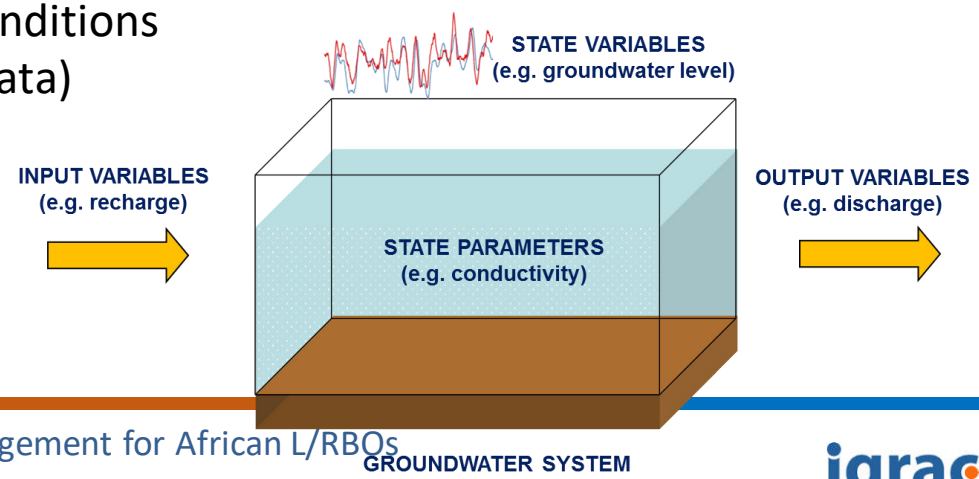
Use of monitoring data together with all other relevant information (static data, and cross-sectoral data / information), to evaluate the status of groundwater resource, the use, new opportunities as well as threats to the resource, generally with the purpose to support decision-making and planning processes.

Assessment:
Analysis of dynamic and static data to create a snapshot

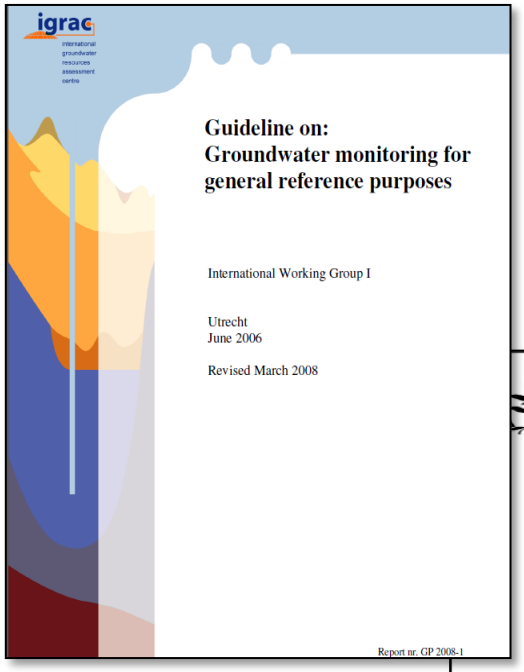
Monitoring

Systematic measurement / observation and recording of current and changing conditions of groundwater (collecting dynamic data)

Monitoring:
Collecting dynamic data
a continuous process

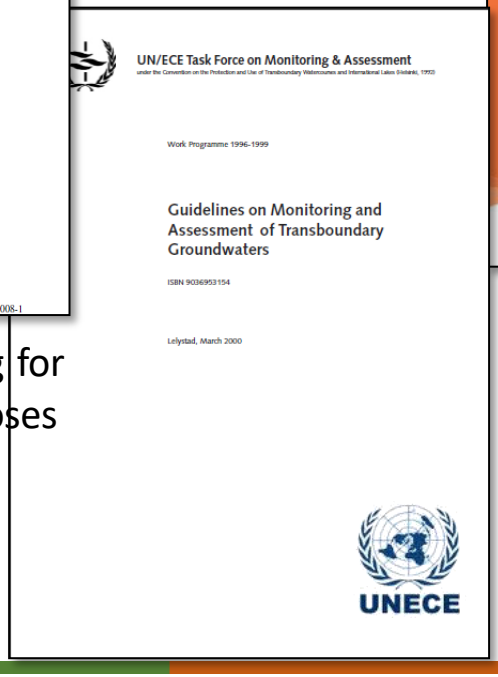


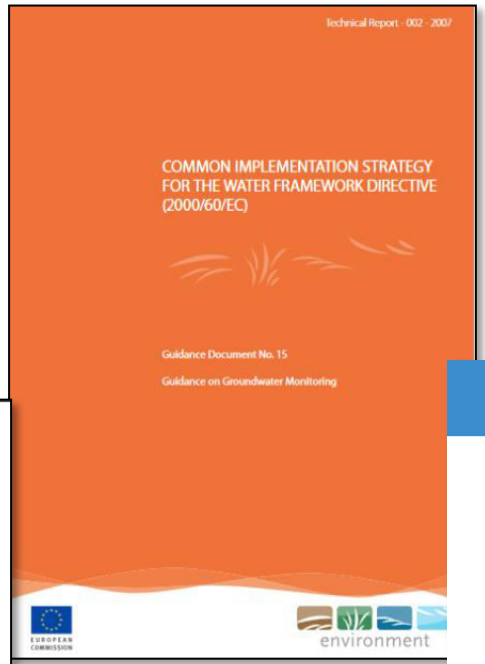
Available Monitoring Guidelines



Groundwater Monitoring for General Reference Purposes

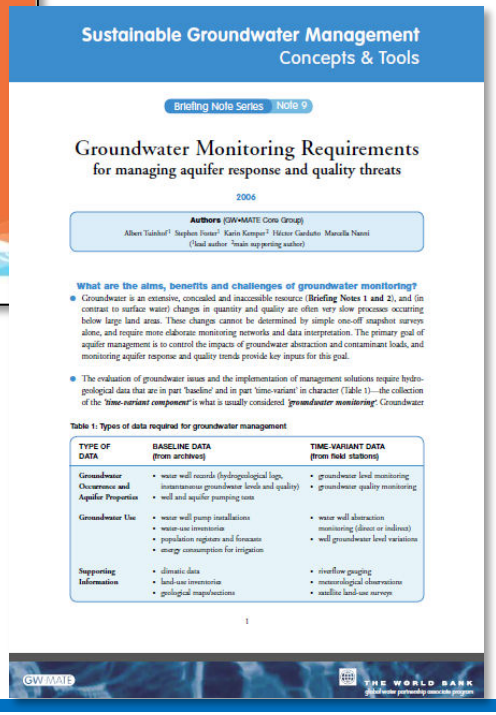
UNECE Guidelines on Monitoring and Assessment of Transboundary Groundwaters





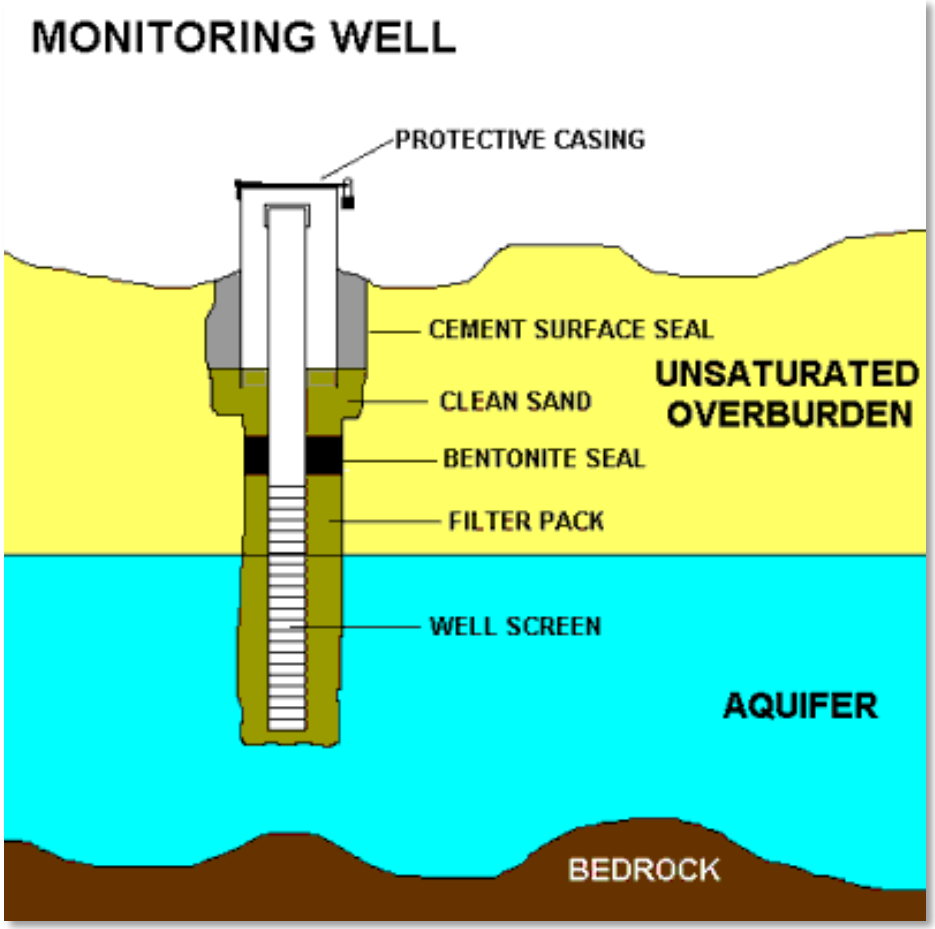
EU Water Framework Directive Guidance on Groundwater Monitoring

GW MATE Briefing Note on Groundwater Monitoring Requirements



Groundwater Monitoring: Main Considerations

- Monitoring purpose
  - General
  - Specific
- Monitoring variables
  - Quantity (level, abstraction, springs)
  - Quality
- Monitoring network design
  - Network density
  - Frequency of observations
- Data management (including quality control)
- Institutional arrangements



GW Monitoring: Purpose

Monitoring purpose (WFD)

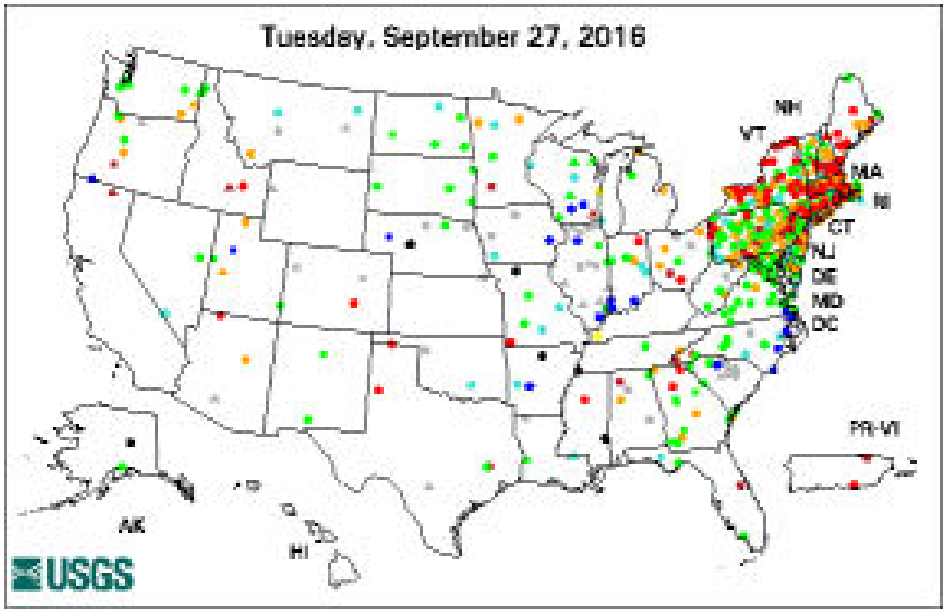
- Surveillance monitoring (quantity quality, validate risk, assess trend) ***- resource***
- Operational monitoring (quality, already at risk) ***– compliance***
- Drinking water protected areas - ***- protection***

Monitoring purpose (UNECE)

- Basic/reference monitoring ***- resource***
- Monitoring linked to functions and uses (***compliance*** with regulation or standards)
- Monitoring for specific purposes (development of special protection areas; implementation of remediation measures, etc.) - ***protection***
- Early-warning and surveillance (accidental spills, illegal land disposal sites, etc.). ***- protection***

GW Monitoring: Purpose

Example: Climate Response Network



USGS
science for a changing world

U.S. Geological Survey Ground-Water Climate Response Network

The U.S. Geological Survey serves the Nation by providing reliable hydrologic information used by others to manage the Nation's water resources.

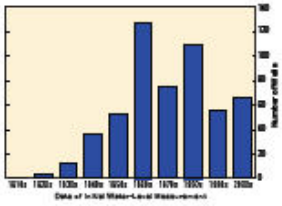
The U.S. Geological Survey (USGS) measures more than 20,000 wells each year for a variety of objectives as part of Federal programs and in cooperation with State and local agencies. Water-level data are collected using consistent data-collection and quality-control methods. A small subset of these wells meets the criteria necessary to be included in a "Climate Response Network" of wells designed to illustrate the response of the ground-water system to climate variations nationwide.

The primary purpose of the Climate Response Network is to portray the effect of climate on ground-water levels in unconfined aquifers or near-surface confined aquifers that are minimally affected by pumping or other anthropogenic stresses. The Climate Response Network Web site (*http://groundwaterwatch.usgs.gov/*) is the official USGS Web site for illustrating current ground-water conditions in the United States and Puerto Rico.

The Climate Response Network Web pages provide information on ground-water conditions at a variety of scales. A national map provides a broad overview of water-table conditions across the Nation. State maps provide a more local picture of ground-water conditions. Site pages provide the details about a specific well.

In 2006, the Climate Response Network contained more than 500 wells. About 140 of the wells are supported by the USGS Ground-Water Resources Program. The remaining wells are managed under a partnership among the USGS and State and local agencies through the Cooperative Water Program. Ideally, wells in the network have many years of measurements. The longest available record in the network is from a Nevada well with measurements collected since 1918. The median measurement starting date for a well in the network is 1983; however, some wells have been measured for only a few years. The value of water-level measurements increases with length of record and frequency of measurement.

As of 2006, the Climate Response Network contains 280 wells instrumented



Distribution of wells in the Climate Response Network, based on initial measurement data.

Types of Data

There are three types of water-level data available from wells measured by the USGS:

- Periodic data are ground-water levels measured by hand at selected intervals, usually with a steel or electric tape. These measurements typically are made monthly to quarterly. Thus periodic data displayed in the Climate Response Network may be the most recently measured, but still several months old.

Field measurement with electric tape. (Photograph by Bill Cunningham, USGS)

- Continuous data are ground-water levels measured by an automatic sensing device, recorded by a data logger, and periodically retrieved from the well. The availability of continuous data may lag current conditions by one to several months because they must be retrieved from the field, processed, and loaded into the USGS database.

Real-time well. (Photograph by Jason M. Sey, USGS)

Sutron 9400 recorder installation with laptop for data download. (Photograph by Bill Cunningham, USGS)

- Real-time data are continuous data that are transmitted from the well to the USGS by satellite or telephone at least once per day. Real-time data reflect current ground-water conditions at the well.

U.S. Department of the Interior
U.S. Geological Survey

Printed on recycled paper

Fact Sheet 2007–3069
February 2007

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International Groundwater Resources Assessment Centre

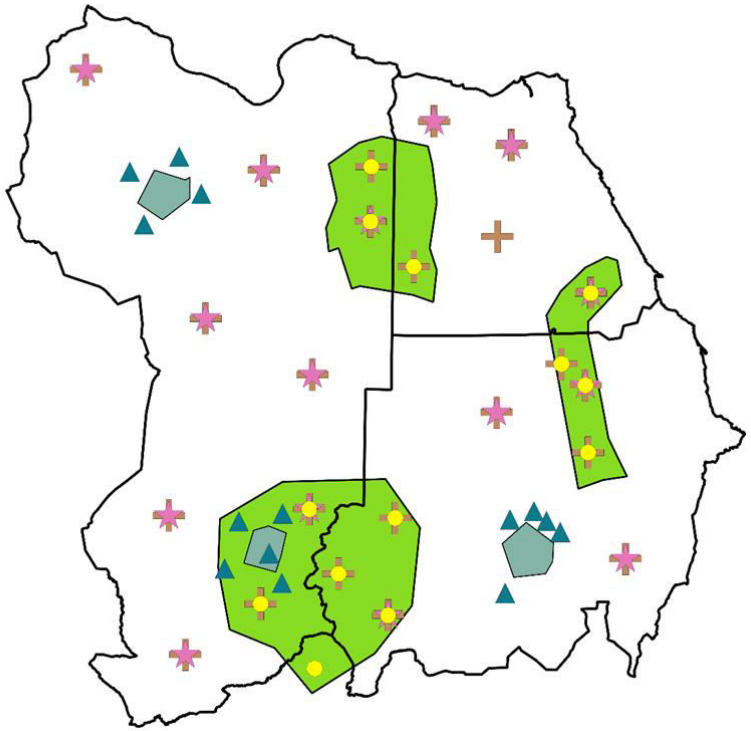
GW Monitoring: Purpose

TBA: combining networks

Differentiate between different monitoring purposes, e.g.

- **General reference monitoring**
- **Protection monitoring**
- **Pollution control/containment monitoring**

but be efficient: one observation point can serve multiple monitoring networks



GW Monitoring: Variables

Quantity

- groundwater levels in boreholes or wells,
- spring flows,
- groundwater abstraction,
- stage levels of surface water courses during drought periods,
- stage levels in significant groundwater dependent wetlands and lakes.

Quality

- (mandatory) oxygen content , pH-value, electrical conductivity, nitrate and ammonium.
- Standards drinking water supply (WHO), EU WFD groundwater threshold values/trend guidance

Monitoring Objectives and Variables

	Monitoring objectives	Groundwater observation wells			Groundwater pumping wells			Springs			Surface water observation points		
		levels	discharge	quality	level	discharge	quality	level	discharge	quality	level	base flow	quality
	Groundwater development												
1	GW system characterisation	xx	n.a.		x			x			x		
2	GW potential for development (quantity and quality)	xx	n.a.	xx		xx	xx		xx	xx		xx	x
3	Best locations for well fields	xx		xx			xx			x			(x)
	Control and protection												
4	Trends of over-exploitation	xx	n.a.		x	xx			xx			xx	
5	Nature conservation	xx	n.a.			xx		x	xx			xx	
6	Saline water intrusion	x	n.a.	xx*	x	xx	xx*				x	x	(x)
7	Land subsidence	x	n.a.			xx							
8	Contamination of aquifers		n.a.	xx			xx			xx			xx

x = desirable data; xx = necessary data; xx* = mainly Chloride; n.a. = not applicable.

Source: IGRAC (2008)

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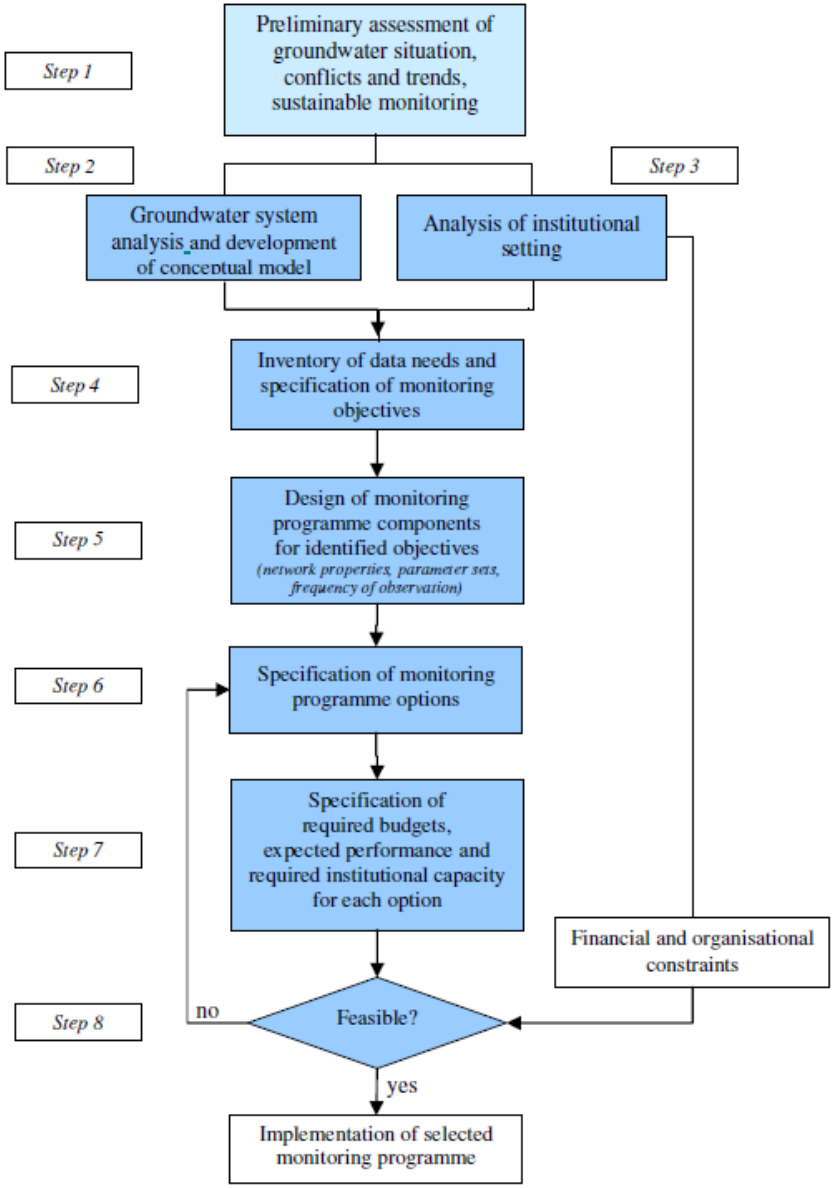
Network Design & Optimisation

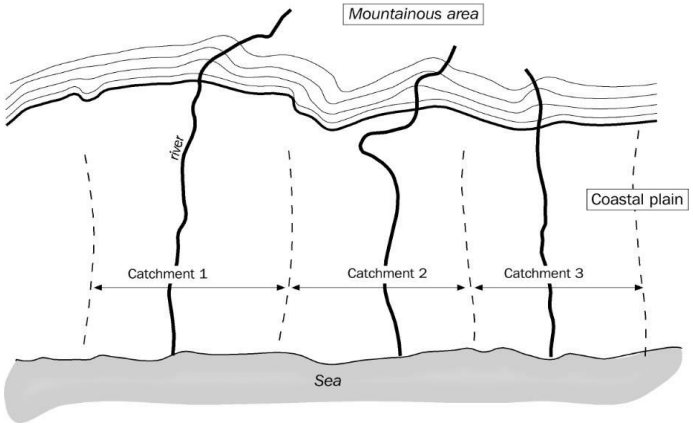
Basic requirements:

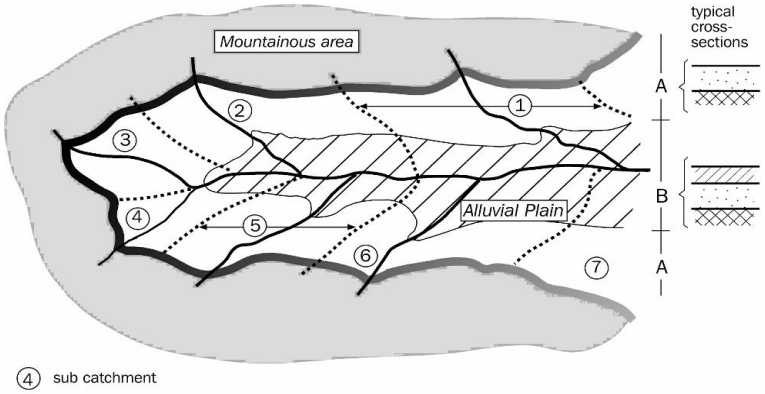
- understanding of the hydro(geo)logical setting
- long-term planning and commitment of staff and budget
- securing uninterrupted access to observation/sampling points

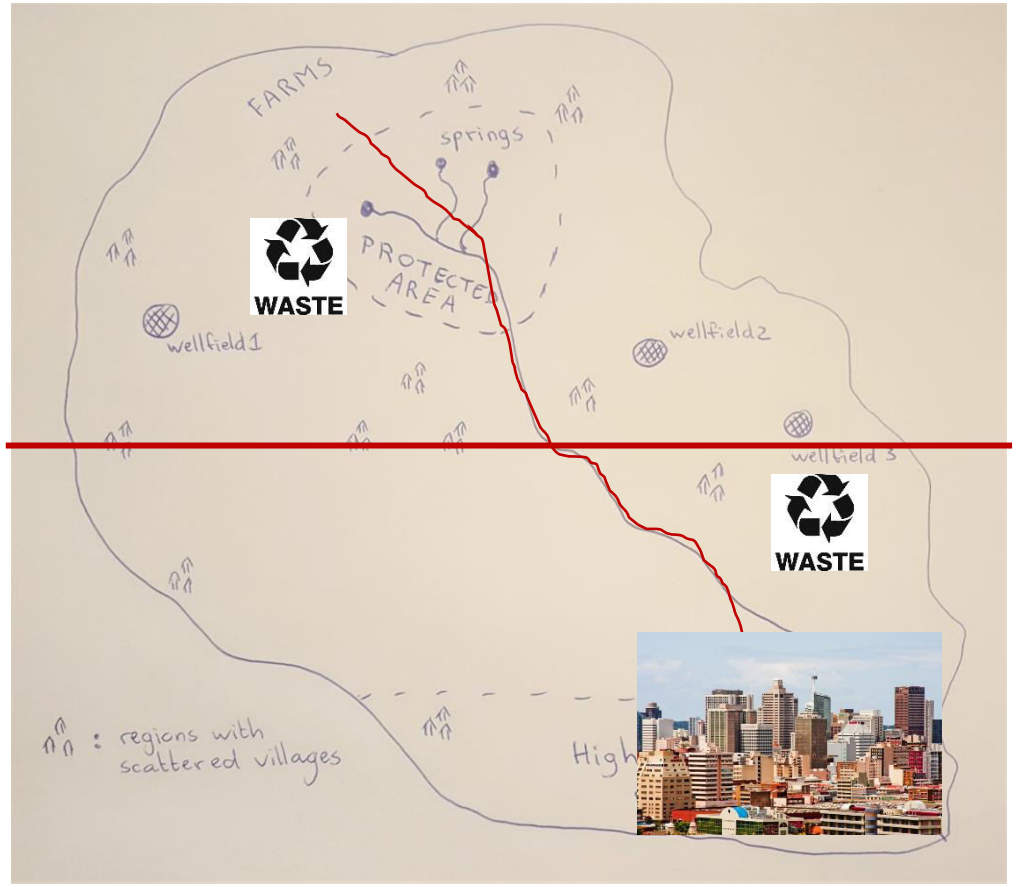


International Groundwater Resources Assessment Centre

Network Density and Frequency



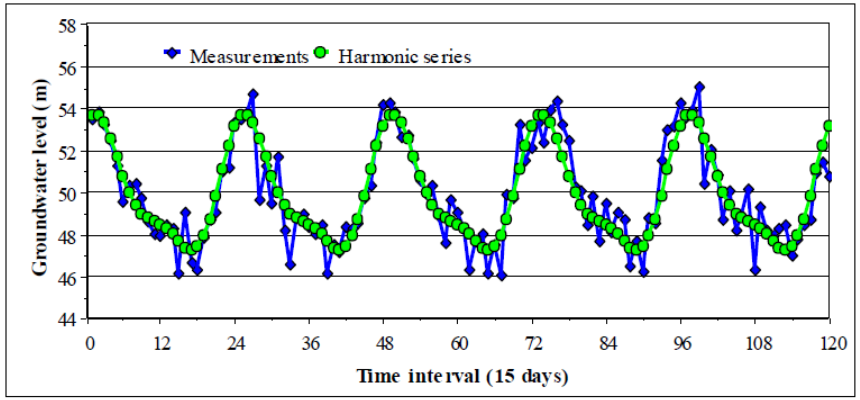


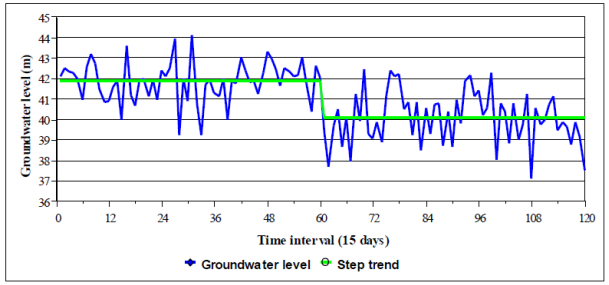


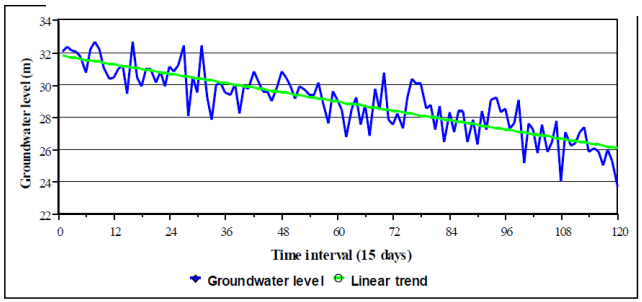
Network Density and Frequency

Frequency:

- Fluctuations (short term, seasonal, long term)
- Trends may be sudden (block trends) or gradual

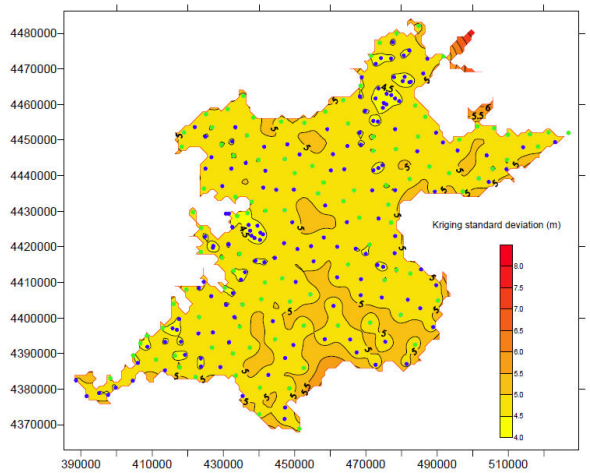


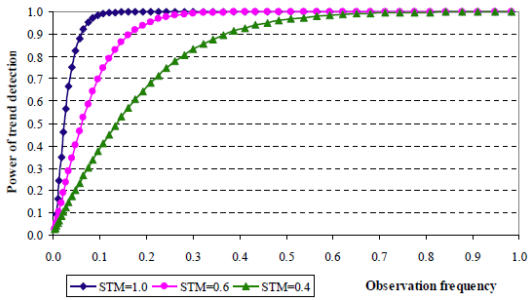




Density:

- kriging,
- spatial interpolation
- /correlation method





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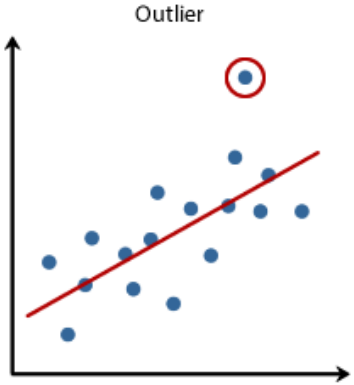
Network Density and Frequency

Possible differentiation of the network density and frequency of observation in relation to depth and degree of confinement of the aquifers

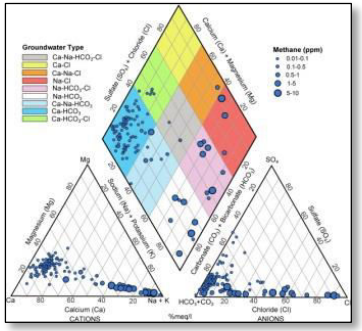
Aquifer type	Details	Spatial variation (response to recharge)	Required network density for spatial image	Temporal variation (response to recharge)	Required frequency of observation for temporal image
Shallow (< 20 m)	Unconfined				
	- Dense drainage system	Highly variable	OOOO	Fast	OOOO
	- Limited drainage system	Modestly variable	OOO	Fast	OOO
	(Semi)-Confined	Modestly variable	OOO	Restrained	OO
Medium deep (20 – 100 m)	Unconfined				
	- Shallow water table	Highly variable	OOOO	Restrained	OOO
	- Deep water table	Modestly variable	OOO	Calm	OO
	(Semi)-Confined	Weakly variable	OO	Calm	OO
Deep (100 - >500 m)	Unconfined				
	- Shallow water table	Much shallow variation	OOO or (O)	Fast	OOO
	- Deep water table	Very low	O	Calm	OO
	(Semi)-Confined	Extremely low	O	Very calm	O

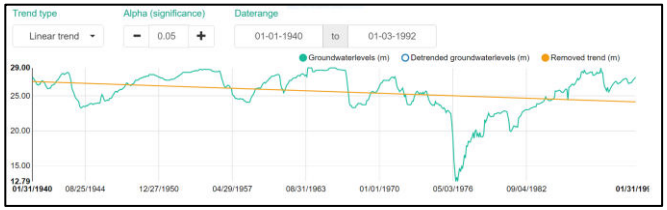
oooo, ooo, oo, o: indicators of the network density or frequency of observation, ranging from high to low

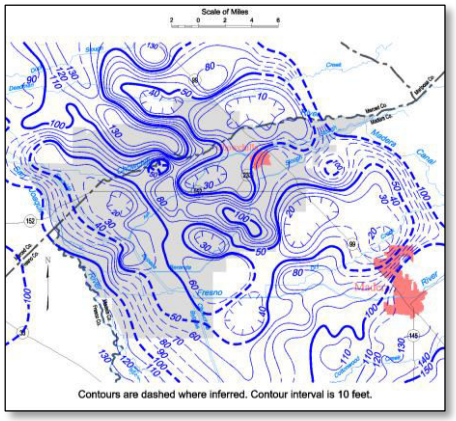
Data Processing



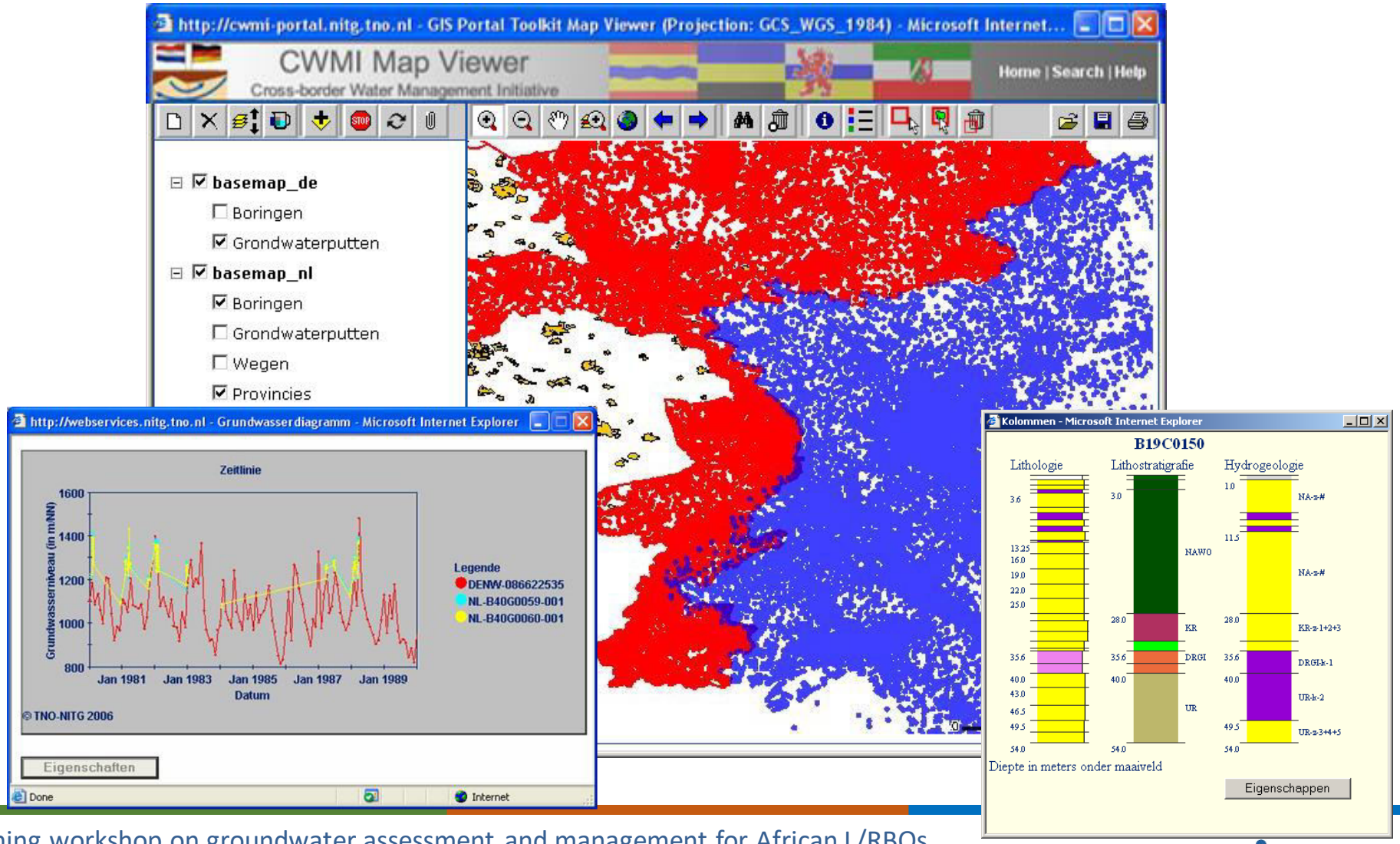
- Collection/selection and storage (ideally in aquifer/river basin information systems)
- Standardisation and harmonisation (language, classifications, reference systems , formats, etc.)
- Data validation (detection of outliers, missing values and other obvious mistakes (mg/l versus µ/l), etc.)
- Analysis and interpretation (temporal, spatial) according to a common Data Analysis Protocol
- Reporting and presentation (contour maps, hydrographs, Piper, Stiff diagrams, etc.
- Data exchange/sharing (international standards)







Monitoring: Groundwater in the Changing World



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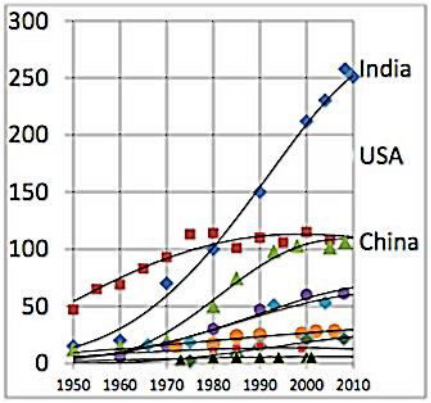
Groundwater in the Changing World

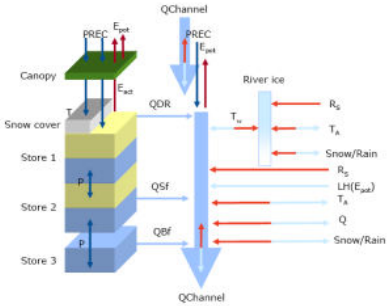
What about groundwater monitoring on a global scale?

- State of aquifers (both quality and quantity of groundwater) is **changing in time** due to change of various **environmental processes** (e.g. change of precipitation pattern) and **human impacts** (i.e. change of land cover, groundwater abstraction).
- Groundwater assessment is not complete- and no predictions can be made without an analysis of historical data.

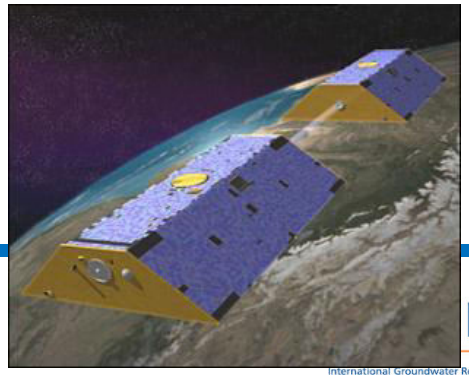


We can't manage,

what we don't measure.



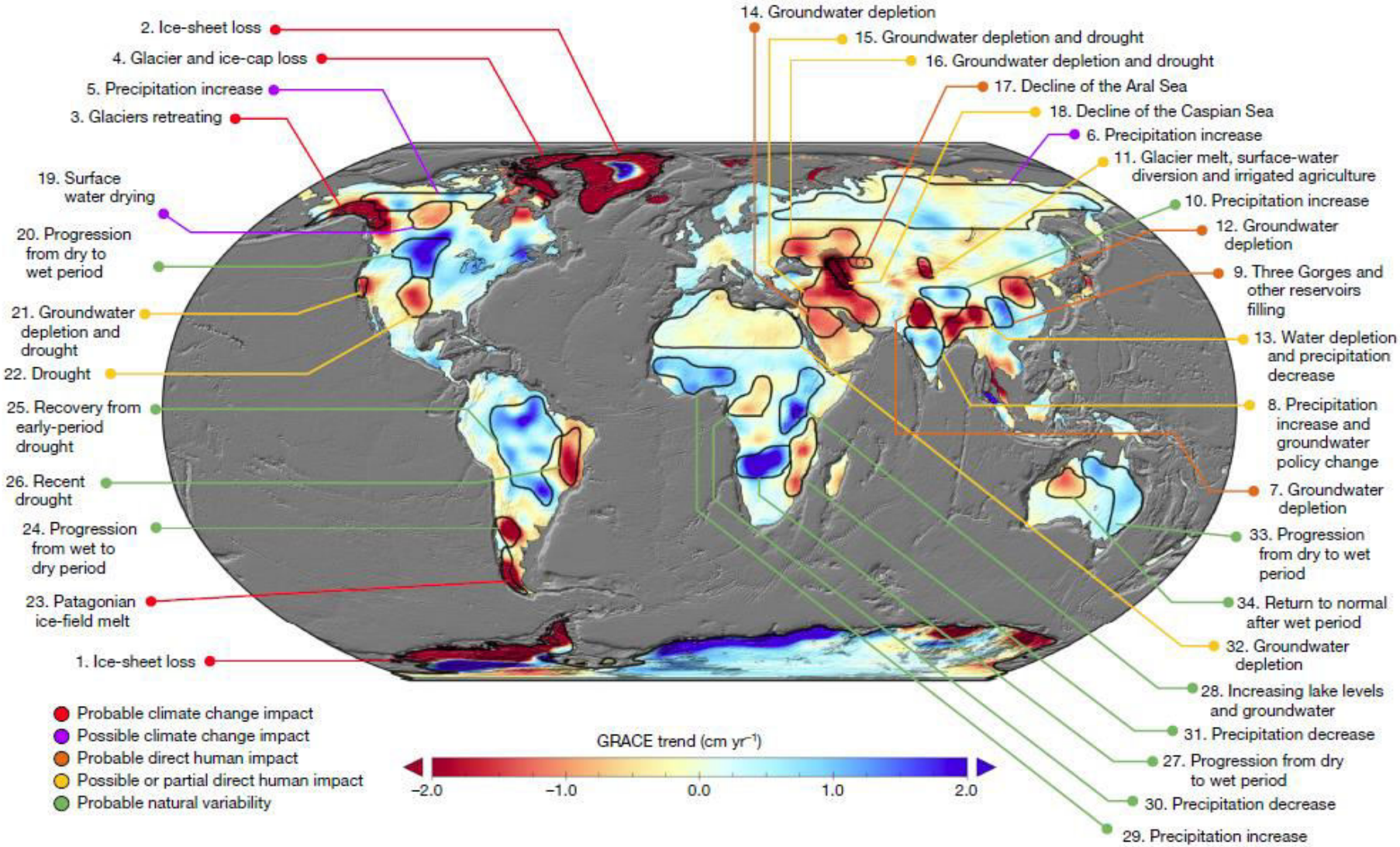
- There is **no sufficient information** about the state and trends of groundwater resources globally.



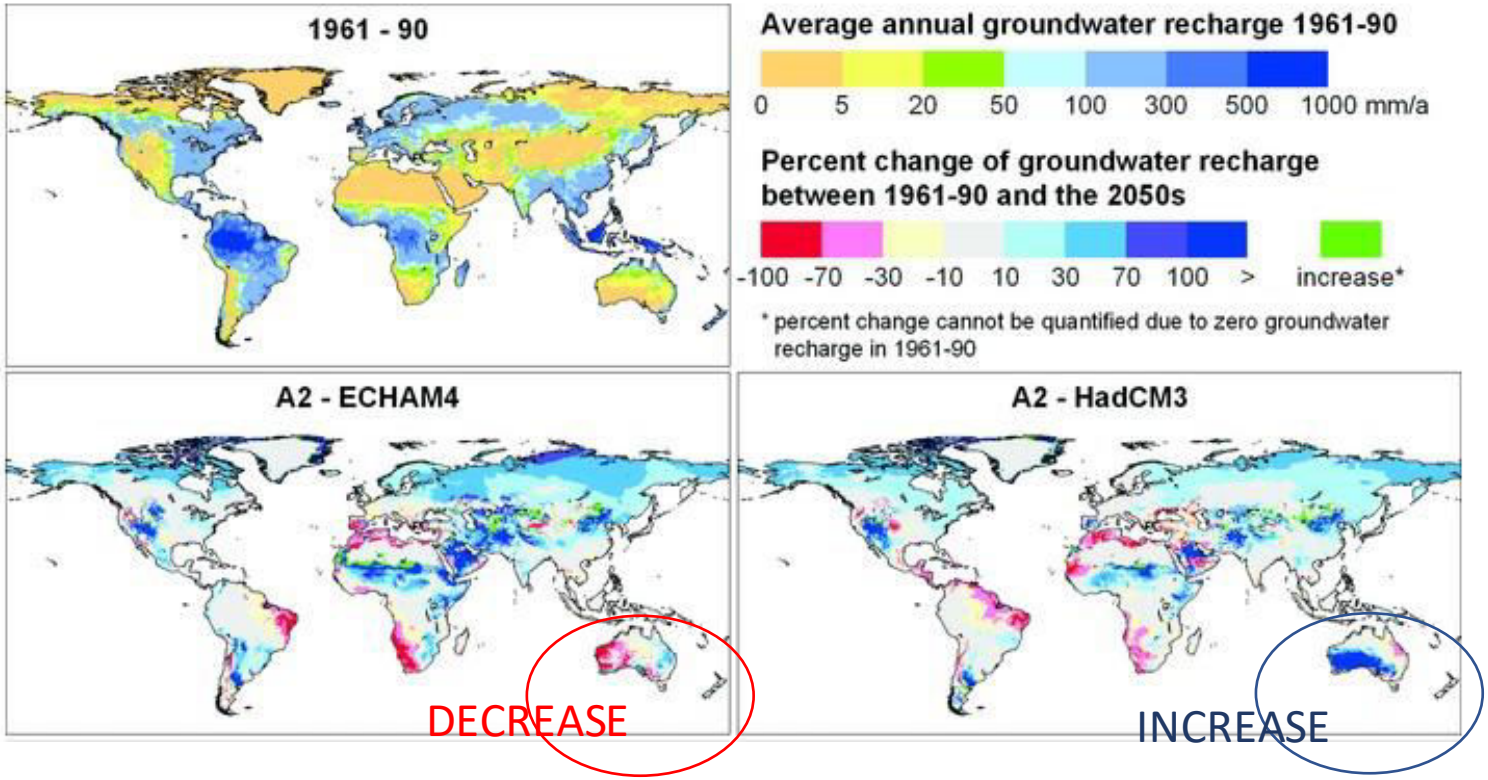
Future of Groundwater Resources

Emerging Trends in Terrestrial Water Storage

M. Rodell et all, 2018



Future of Groundwater Resources



Climate change impacts on long-term average groundwater recharge (Döll and Flörke, 2005)

High uncertainly of the impact associated with: choice of General Circulation Models (GCMs), climate projections derived from GCMs, applied emission scenarios, downscaling of GCM projections….

GGMN - Global Groundwater Monitoring Network

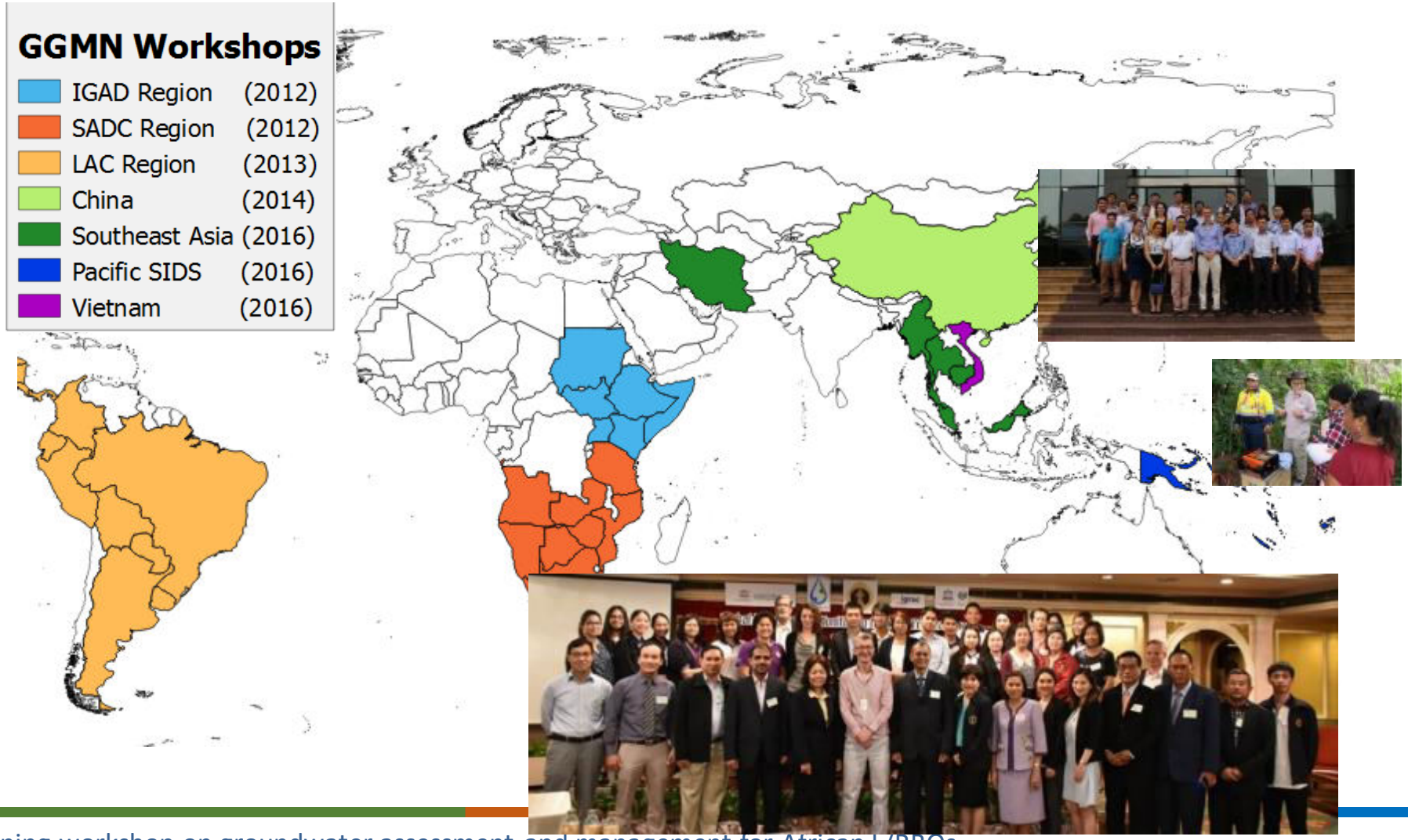
Global Groundwater Monitoring Network programme is initiated to **improve quality and accessibility** of groundwater monitoring information.

GGMN People Network

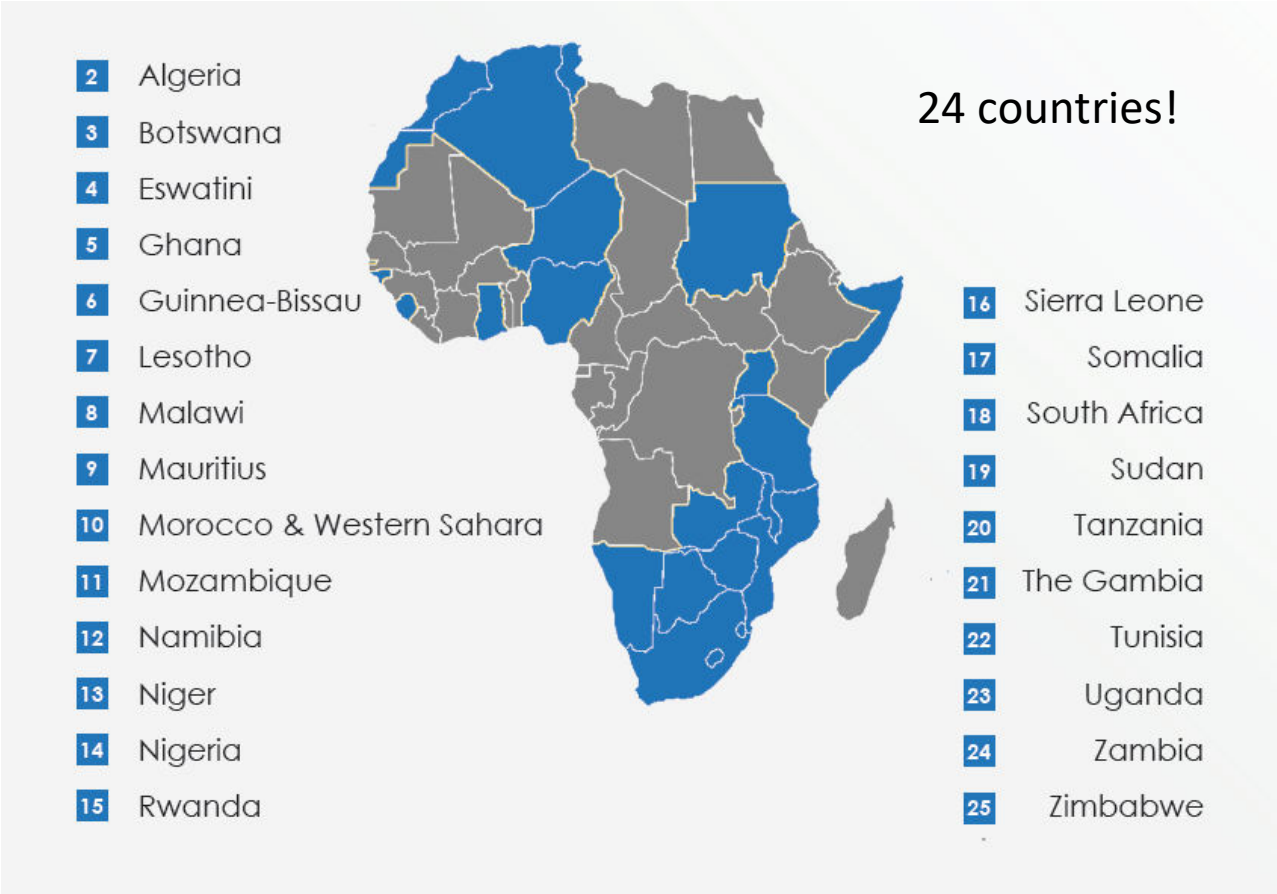
GGMN Portal

igrac
International Groundwater Resources Assessment Centre

GGMN People Network



National groundwater monitoring programmes – A global overview



https://www.un-igrac.org/resource/regional-monitoring-overview-africa

South Africa (RSA)

Capital city: Cape Town (legislative) / Pretoria (administrative) / Bloemfontein (judicial)
Inhabitants: 57.8 Million

INSTITUTIONAL SETTING AND PURPOSE

The institution in charge of groundwater management in Republic of South Africa (RSA) is the Department of Water Affairs and Forestry (DWA). The DWA has delegated most of the monitoring tasks to its regional offices. Regional offices are set up in all the provinces of RSA, but some of them lack capacity to complete all the delegated tasks.

The objectives of the groundwater monitoring plan are to identify spatial and temporal trends, and to understand the causes and effects of groundwater changes in affected areas. The plan includes the monitoring of groundwater levels and its quality.

CHARACTERISTICS OF THE NETWORK

Groundwater levels are monitored monthly at approximately 1,800 monitoring points. Piezometric levels are measured manually with water level dippers. The Department of Water and Sanitation (DWS) makes use of (detailed) field forms developed by an in-house Groundwater Field Monitoring Committee.

Standard operation procedures (SOP) are applied as a data quality control to ensure proper data collection. Two main procedures are: standard for Geosite description, and standards for capturing groundwater data.

PROCESSING AND DISSEMINATION

DWS produces annual Groundwater Level Maps, Figure 1. Currently three maps are available on the website of the DWS indicating the difference of groundwater levels between Septembers of 2017 to 2018, of 2018 to 2019 and of 2017 to 2019.

Data are stored in the National Groundwater Archive (NGA), which is a centralized database with a web interface. Everyone with an interest in groundwater can register to search, capture and store data. Only one value of water level per month is stored in the NGA; larger time-series are stored separately in a Hydstra database.

The databases can be accessed from inside and outside the department and are accessible for registered users. However, not all data are online and detailed water level time series must be requested.

Figure 1 - Difference in groundwater levels September 2018 to September 2019. Source: DWA

Sources

- Department of Water and Sanitation (DWS). Groundwater level maps 2017-2019 - http://www.dwa.gov.za/Groundwater/maps/gwlevelmaps.aspx;
- DWS. The National Groundwater Archive (NGA) - http://www.dwa.gov.za/groundwater/nga.aspx;
- Feedback from the Department of Water Affairs and Forestry - received on 05-10-2020;
- IGRAC, 2013. Groundwater Monitoring in the SADC Region, 2013. Overview prepared for the Stockholm World Water Week - https://www.un-igrac.org/sites/default/files/resources/files/Report_Groundwater%20Monitoring%20in%20SADC%20region.pdf; and
- SADC Country visits - 2017.

Institution in charge of national groundwater monitoring programme (if any).

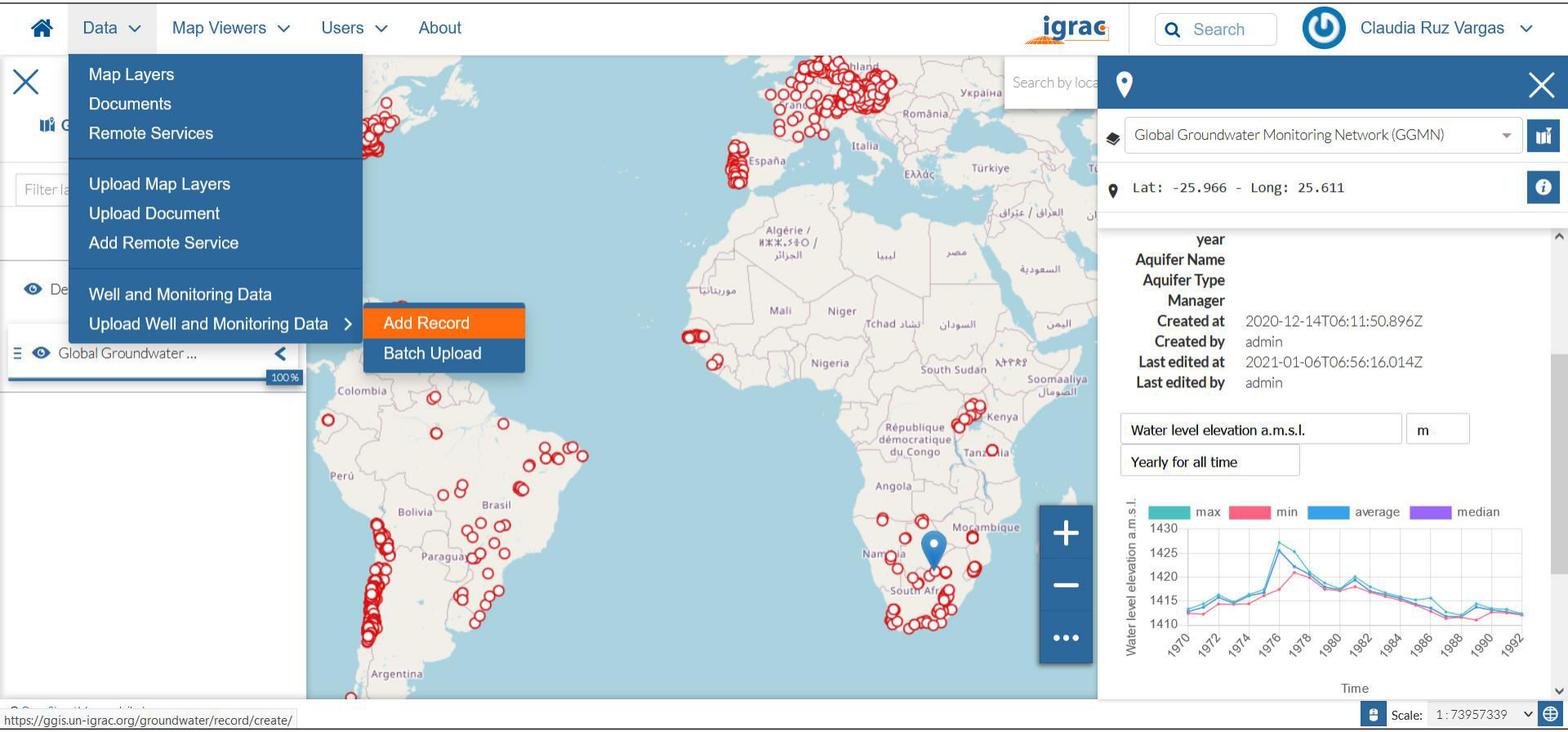
Number of monitoring stations, frequency of observations, automatic vs manual, etc.

Processing: data processing methods to interpret data.

Dissemination: website, database or web portal where data and information (raw data, reports, graphs, indicators, etc.) are stored/shared.

GGMN Portal

Upload, store, visualize, download data



GGMN Portal: basic functionalities

Dedicated database

Data | Map Viewers | Users | About

Well and Monitoring Data Record

- General Information
- Drilling and Construction
- Hydrogeology
- Management
- Monitoring Data ▾
  - Groundwater Level
  - Groundwater Quality
  - Abstraction / Discharge
- Metadata

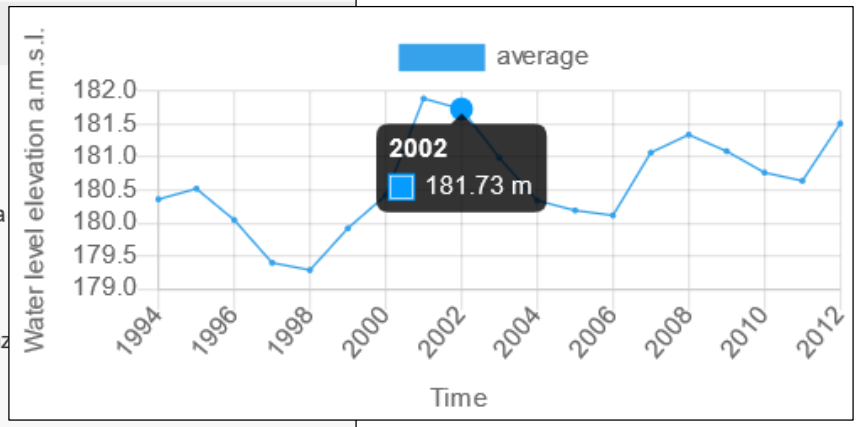
GENERAL INFORMATION

Identification

GGIS UID	RWFA Rwanda (Rwanda)-P5
Original ID	P5
Name	Musanze_Rwaz
Feature type	Water well
Purpose	Observation / monitoring
Status	Active
Photo	
Description	

Location

Latitude	-1.529629
Longitude	29.662918

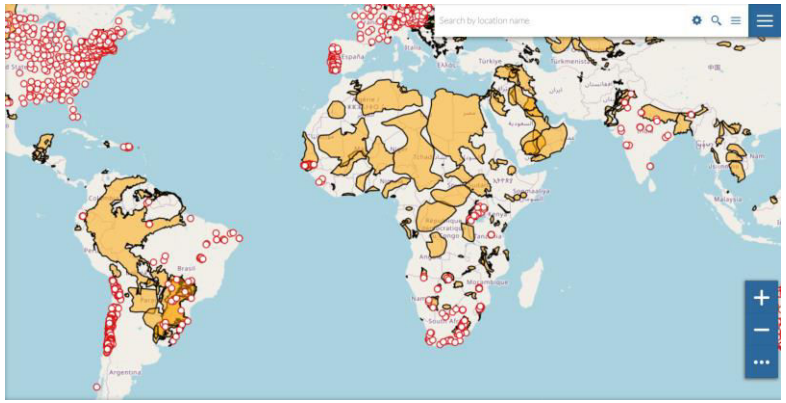


GROUNDWATER QUALITY

Measurement

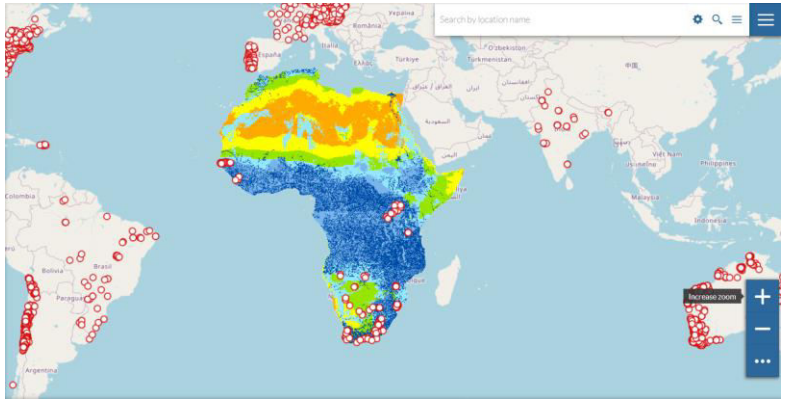
Date and Time	Parameter	Methodology
2021-12-31 12:00:00	T (Temperature)	Measured by pressure sensor in bottom of well
2021-12-30 12:00:00	T (Temperature)	Measured by pressure sensor in bottom of well
2021-12-29 12:00:00	T (Temperature)	Measured by pressure sensor in bottom of well
2021-12-28 12:00:00	T (Temperature)	Measured by pressure sensor in bottom of well
2021-12-27 12:00:00	T (Temperature)	Measured by pressure sensor in bottom of well
2021-12-26 12:00:00	T (Temperature)	Measured by pressure sensor in bottom of well

GGMN Portal: Overlay Maps

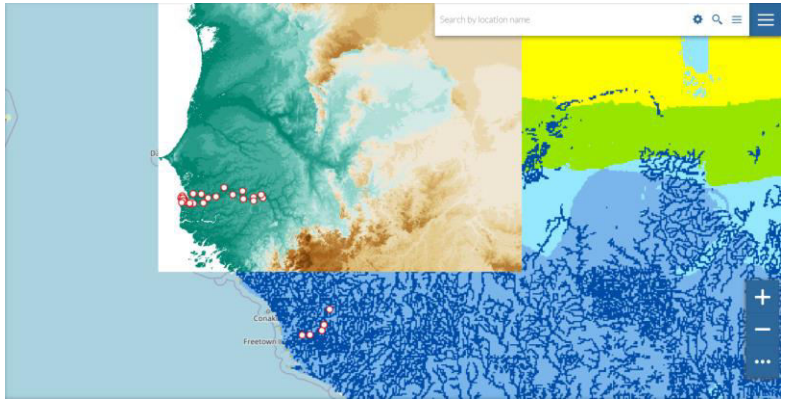


Transboundary Aquifers

Hydrogeological Map

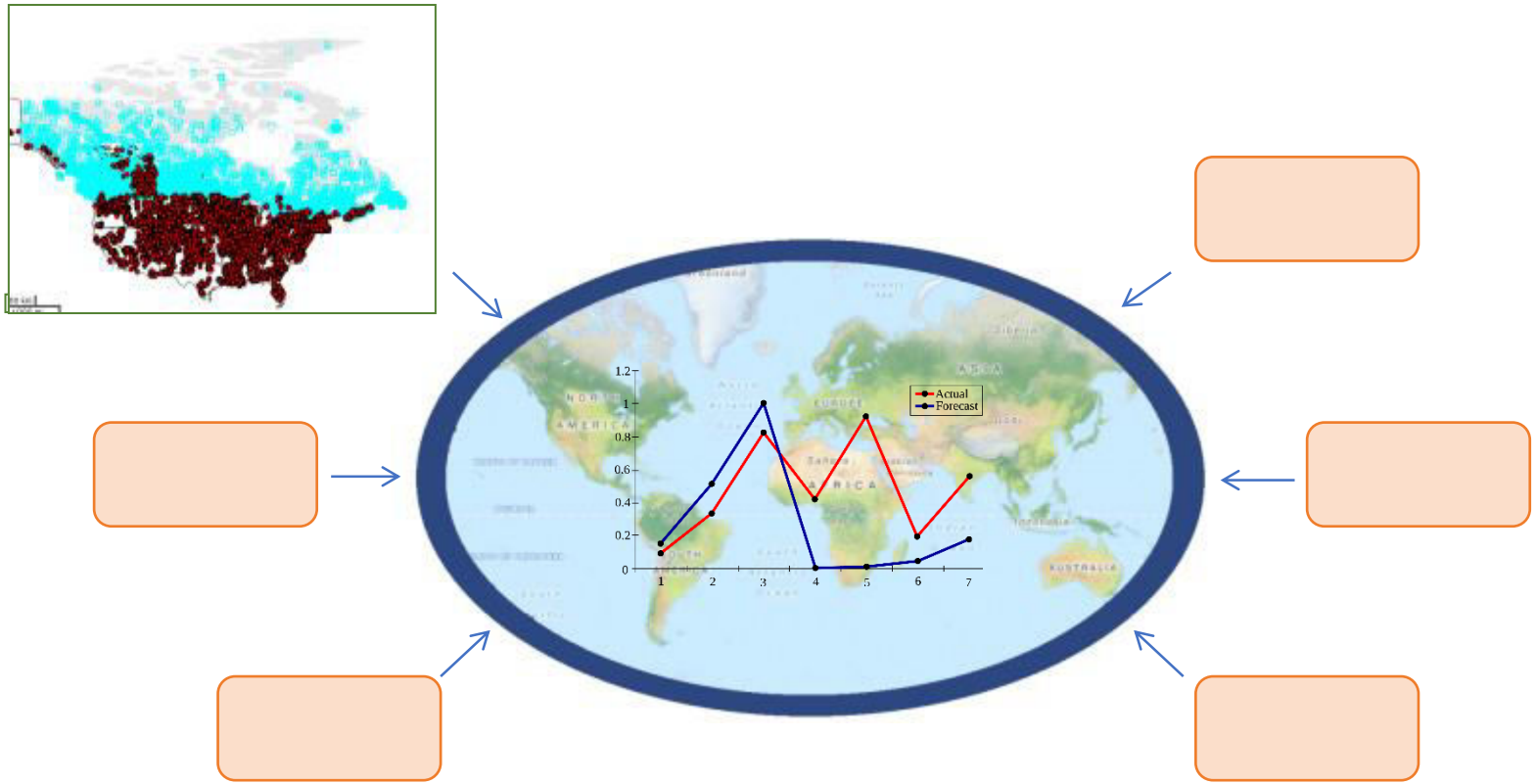


Estimated depth to groundwater



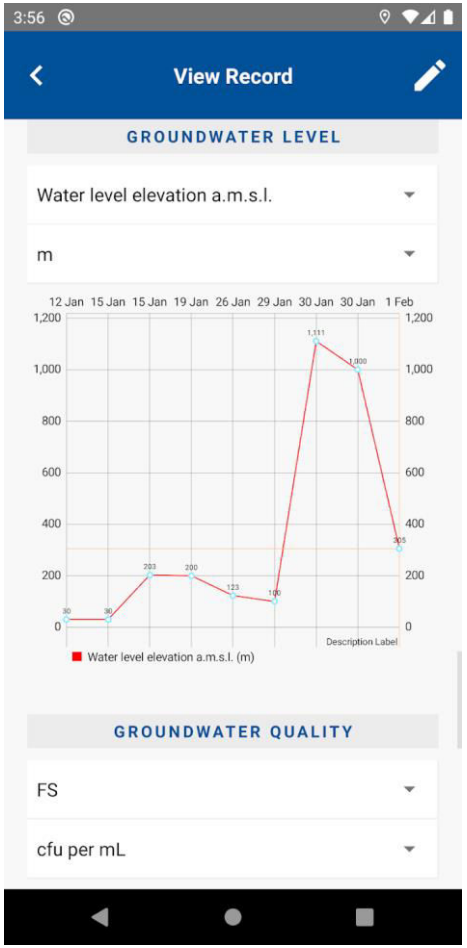
Digital Elevation Models and more

GGMN Portal: Sharing (not exchange)



Connecting National Monitoring Networks in one system using Sensor Observation Service (SOS), Application Programming Interface (API) and other technologies

GGMN App



- A smartphone application specially made to register groundwater monitoring stations and monitoring data in the GGMN
- The app works also without internet, allowing the user to upload the data when internet is available

Concluding Remarks

- Groundwater assessment and monitoring are key elements to achieve proper groundwater management
- Groundwater monitoring networks must be designed considering purpose, variables, network design, and data management.
- There is no sufficient information about the state and trends of groundwater resources globally
- The role of GGMN programme is to create awareness, share knowledge and improve quality and accessibility to groundwater monitoring data through workshops and the portal (storage, processing, analysis, dissemination).

Thank you for your attention

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