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

Groundwater Monitoring

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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.

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

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

**Monitoring:**
Collecting dynamic data a continuous process
Available Monitoring Guidelines

UNECE Guidelines on Monitoring and Assessment of Transboundary Groundwaters

Groundwater Monitoring for General Reference Purposes

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

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 stress. 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 page provides 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 1/40 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 1963; 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

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 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.

- **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 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.

Field measurement with electric tape (Periodic measurement, USGS)

Siren MWK recorder installation with laptop for Data-logging (Periodic measurement, USGS)

Real-time well, phone calls to USGS

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GGRETA3 project
30 June 2021
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

TBA: combining 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

Source: IGRAC (2008)

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

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

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

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

GGMN - Global Groundwater Monitoring Network

GGMN People Network

GGMN Portal

Training workshop on groundwater assessment and management for African L/RBOs
GGRETA3 project
30 June 2021
GGMN People Network
National groundwater monitoring programmes – A global overview

24 countries!

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

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.

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 September 2017 to 2018, 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 ground water level time series must be requested.

Sources

- Feedback from the Department of Water Affairs and Forestry - received on 05-10-2020

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

**Well and Monitoring Data Record**

**General Information**

**Identification**
- GGIS UID
- Original ID: P5
- Name: Musanze_Rwanda
- Feature type: Water well

**Purpose**
- Observation / monitoring

**Status**
- Active

**Photo**

**Location**
- Latitude: -1.529629
- Longitude: 29.662915

**Groundwater Quality**

**Measurement**

<table>
<thead>
<tr>
<th>Date and Time</th>
<th>Parameter</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021-12-31 12:00:00</td>
<td>T (Temperature)</td>
<td>Measured by pressure sensor in bottom of well</td>
</tr>
<tr>
<td>2021-12-30 12:00:00</td>
<td>T (Temperature)</td>
<td>Measured by pressure sensor in bottom of well</td>
</tr>
<tr>
<td>2021-12-29 12:00:00</td>
<td>T (Temperature)</td>
<td>Measured by pressure sensor in bottom of well</td>
</tr>
<tr>
<td>2021-12-28 12:00:00</td>
<td>T (Temperature)</td>
<td>Measured by pressure sensor in bottom of well</td>
</tr>
<tr>
<td>2021-12-27 12:00:00</td>
<td>T (Temperature)</td>
<td>Measured by pressure sensor in bottom of well</td>
</tr>
<tr>
<td>2021-12-26 12:00:00</td>
<td>T (Temperature)</td>
<td>Measured by pressure sensor in bottom of well</td>
</tr>
</tbody>
</table>

**Water level elevation a.m.s.l.**

- Average: 181.73 m
- Year 2002
GGMN Portal: Overlay Maps

- Transboundary Aquifers
- Hydrogeological Map
- Estimated depth to groundwater
- Digital Elevation Models and more
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