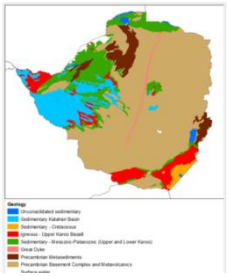
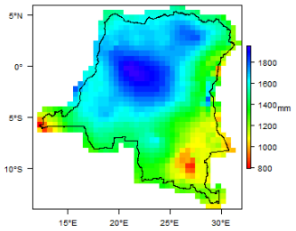
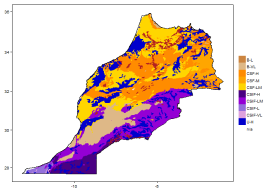
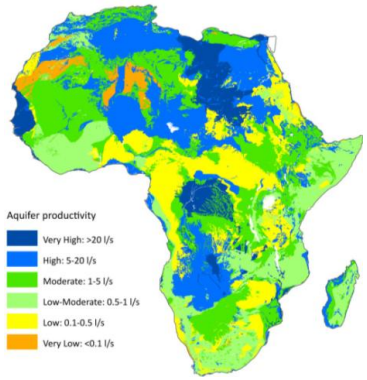








Africa Groundwater Atlas

Making African groundwater information more available

http://www.bgs.ac.uk/africagroundwateratlas/index.cfm

UP Gro — Unlocking the Potential of Groundwater for the Poor

BGS 1835 — British Geological Survey — NATURAL ENVIRONMENT RESEARCH COUNCIL

iah aih

NERC SCIENCE OF THE ENVIRONMENT

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

UKaid from the British people

What is the Africa Groundwater Atlas?

- A starting point for **understanding groundwater resources at a country-scale**
- Brings together groundwater information from many sources in a consistent way
- Makes Africa groundwater information more visible and accessible
- Allows comparison & learning between different countries

UPGro Unlocking the Potential of Groundwater for the Poor

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

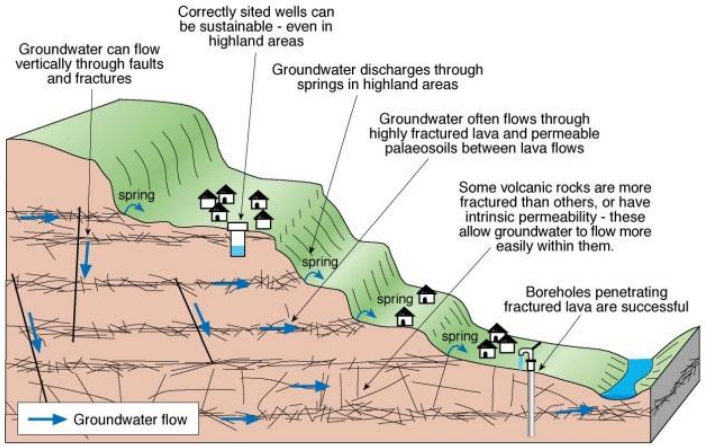
NERC SCIENCE OF THE ENVIRONMENT

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

UKaid from the British people

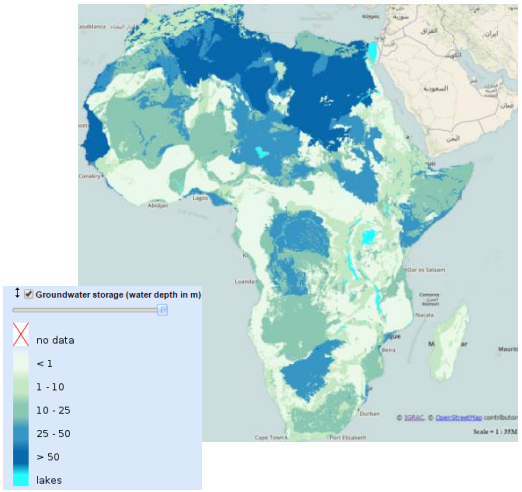
Why is the Atlas important?

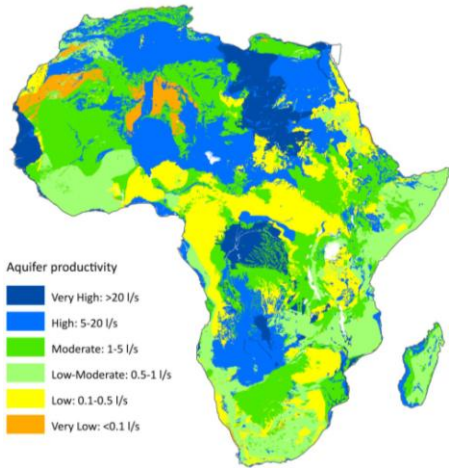
- For safe, sustainable groundwater development we need to **understand groundwater**
- To understand groundwater we need **good information** – which is hard to find!
- **BUT** there is lots of good information out there – it's just not always easily **visible** and **accessible**

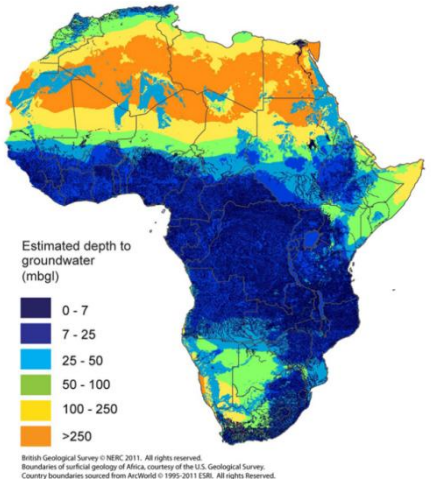


Background to the Atlas

- In 2012 – new maps of all-Africa **aquifer productivity**, **groundwater storage** and **depth to groundwater** – for a continental-scale overview







Download maps from BGS as GIS files

or

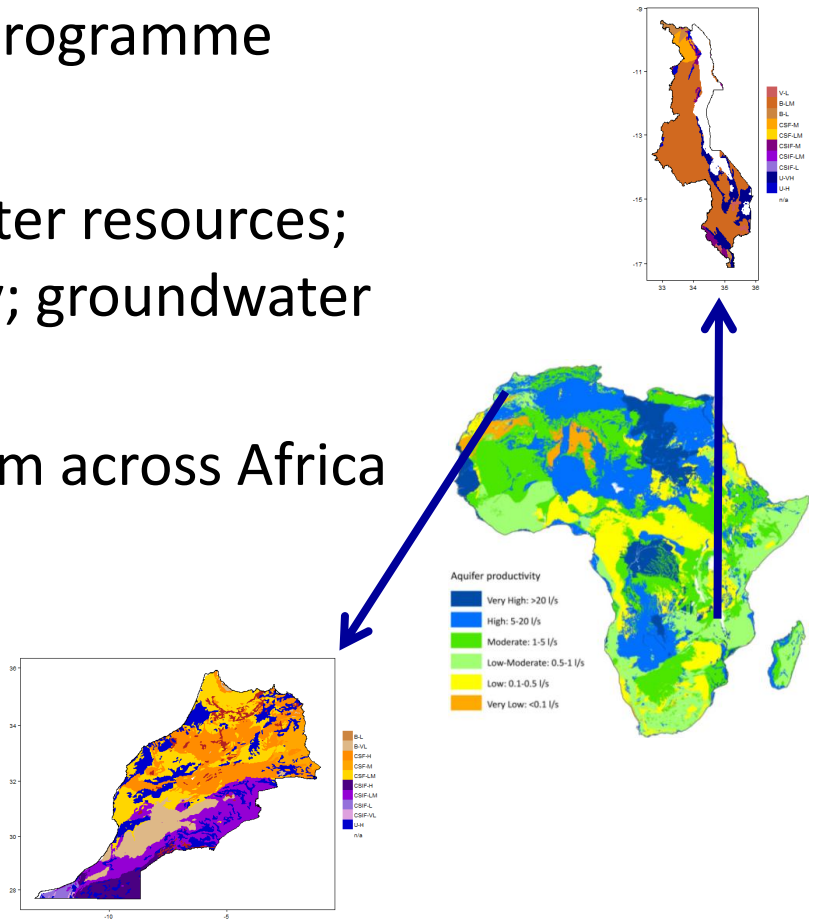
View IGRAC's ***Groundwater Resources in Africa*** *webpage*

http://www.bgs.ac.uk/research/groundwater/international/africanGroundwater/maps.html

https://ggis.un-igrac.org/ggis-viewer/viewer/groundwaterafrica/public/default

Developing the Africa Groundwater Atlas

- To meet demand for country-scale information
- Funded by UK government UPGro programme
- For 51 countries
- A consistent overview of groundwater resources; key aquifers and their hydrogeology; groundwater status and management
- Co-written with hydrogeologists from across Africa
- Online and free
- Offline version available



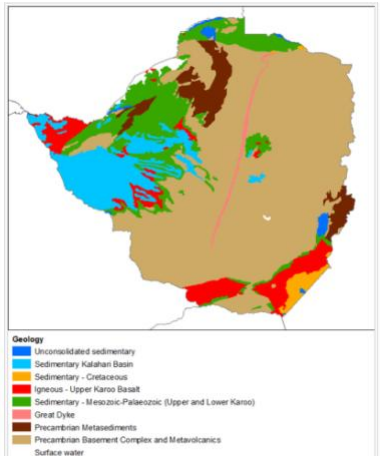
UP Gro Unlocking the Potential of Groundwater for the Poor

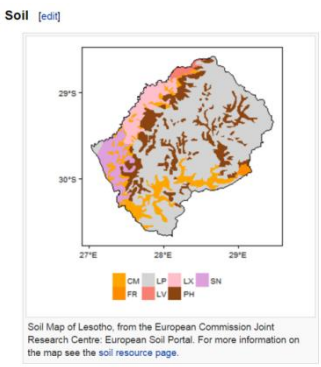
www.upgro.org

What's inside the Atlas?

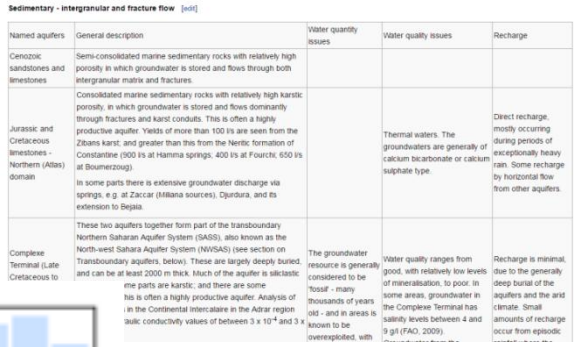
Information on:

- How geology, hydrogeology and groundwater resources vary across each country
- Climate – rainfall and temperature
- Soil, land cover and surface water
- Groundwater status – quality and quantity
- How groundwater resources are managed





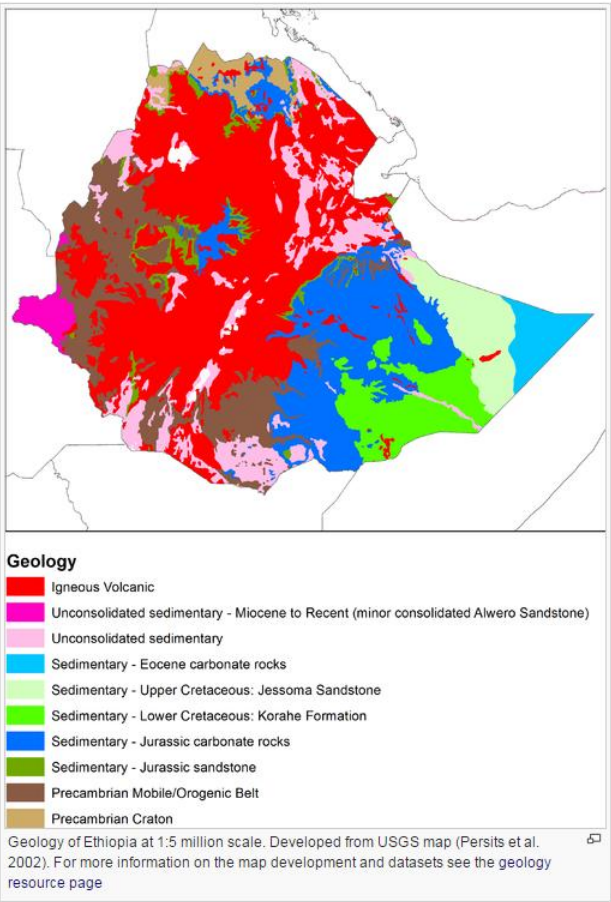
Maps



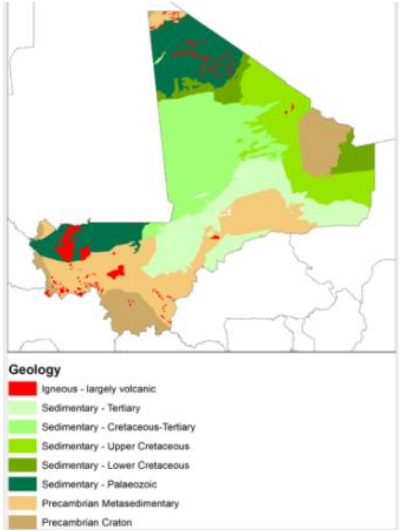
Descriptions

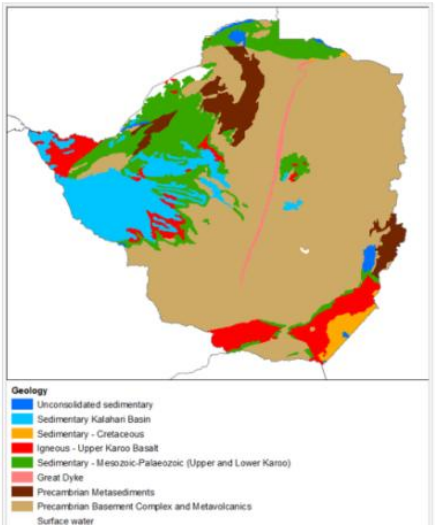
Graphs

National geological map



Geology of Ethiopia at 1:5 million scale. Developed from USGS map (Persits et al. 2002). For more information on the map development and datasets see the geology resource page



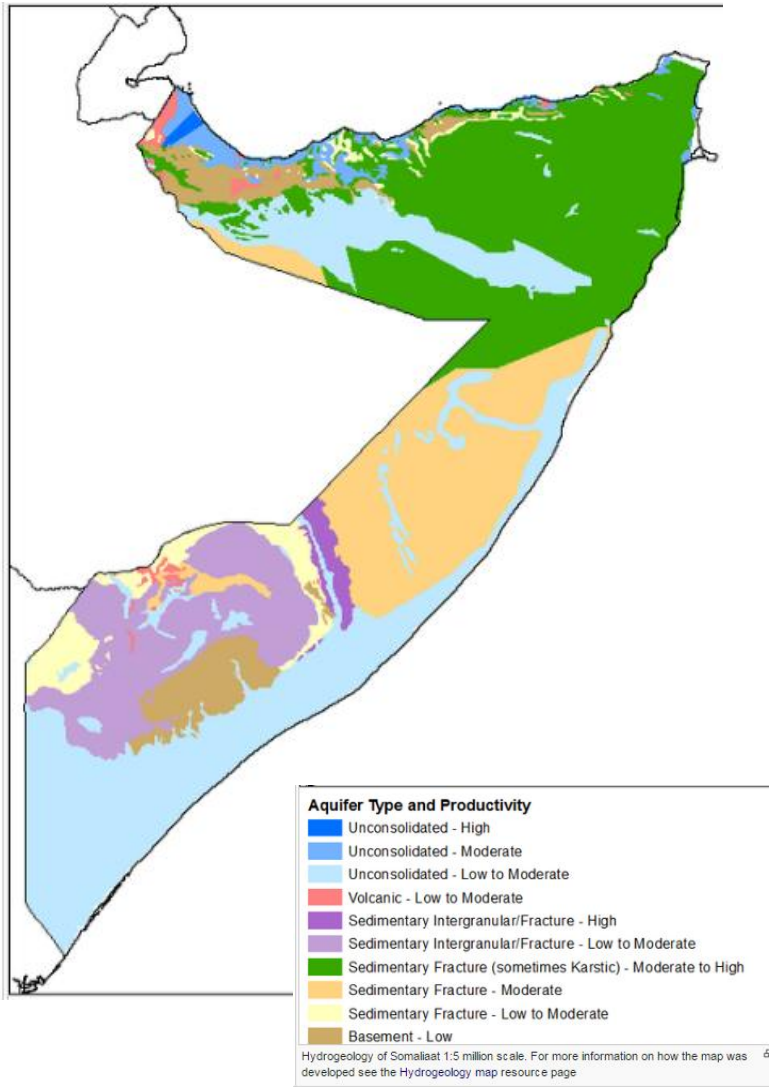


Geological Environments

Key Formations	Period	Lithology	Structure
		Igneous - volcanic	
Lesotho Formation (Drakensberg Group)	Jurassic	Massive basalts which overlie the sedimentary rocks of the Karoo Group.	Reaches thickness of 1600m at Mount-aux-Sources in the north of Lesotho (Schmitz and Rooyani 1987).
		Igneous - intrusive	
Dolerite intrusions	Jurassic	Numerous dykes cross the country in two dominant directions: NW-SE and NNE-SSW. Most dykes are near vertical, plate-like bodies, but some dip as shallowly as60° (Schmitz and Rooyani 1987). Some dykes cut across all geological formations and others die out within the basalts. Sills (plate-like, near-horizontal intrusions) occur in older Karoo sedimentary strata, especially in the southwest of Lesotho.	
		Sedimentary – Karoo	
Clarens Formation (Cave Sandstone) (Stormberg Group)	Late Triassic to Early Jurassic	This is the youngest sedimentary formation underlying the basalts of the Jurassic Lesotho Formation. It occurs across the central and eastern parts of Lesotho, but crops out only in central Lesotho and in major valleys within the Lesotho Formation. The sandstones are of aeolian origin. Generally pale white and cream coloured, although darker beds occur. The formation can be subdivided into three zones: 1. Zone I: thickly to very thickly bedded, light brown and light red, very fine grained sandstone, silty sandstone and sandy siltstone. 2. Zone II: alternating beds of massive and cross-bedded sandstone. 3. Zone III: massive to very thickly bedded, very fine grained sandstone to massive silty sandstone, sandy siltstone and siltstone.	Thickness from 15 to 250m. Outcrops in the form of plateaux in the lower foothills and as cliffs overlooking the lowlands.
Elliot Formation (Red Beds) (Stormberg Group)	Late Triassic to Early Jurassic	Underlies the Clarens Formation and characterised dominantly by red and purple mudstones and shales and medium to fine grained sandstones. The strong red and purplish coloration differentiates it from the underlying Molteno Formation and from the white and cream coloured overlying Clarens Formation. The transition from the underlying Molteno Formation to the Elliot Formation is gradual, indicating continuous sedimentation.	Thins from a maximum of 250m in the south to 15m in the north.
Molteno Formation (Stormberg Group)	Late Triassic to Early Jurassic	White arkosic grits and gritty sandstones, mainly pebbly, with occasional thin shaly sandstones and bluish mudstone (Schmitz and Rooyani 1987). The Molteno Formation underlies the whole of Lesotho and outcrops in the lowlands, where it comprises up to 50m of massive, coarse sandstone.	Thins out northwards (Schmitz 1984): from 35m in the north to 150m in the south.
Burgersdorp Formation (Beufort Group)	Mid Permian to Lower Triassic	Green, purple and red shales and mudstones with some buff sandstone; occasional carbonaceous shales with thin coal seams; some ferruginous concretion beds. Only the uppermost part of this formation is exposed in Lesotho, with its maximum exposed thickness in the Mohokare (Caledon) River Valley in the extreme western part of Lesotho (UNDP 1984).	Maximum exposed thickness of 200 to 250m

Summary of main geological formations

National hydrogeological map



Hydrogeology of Somaliaat 1:5 million scale. For more information on how the map was developed see the Hydrogeology map resource page

Igneous [edit]

Named aquifers	General description	Water quantity issues	Water quality issues	Recharge
	Igneous aquifers exist in Zaccae, Djudjura, Collo and l'Edough in the east, and in Hoggar. Groundwater flows through fractures and altered horizons, and discharges naturally through springs. In Hoggar, borehole drilling has shown that groundwater is encountered at between 20 and 50 m depth. The aquifers generally have low productivity.		Average total dissolved solids in Hoggar are 500 mg/l	Important recharge occurs in northern igneous aquifers.*

Sedimentary - intergranular and fracture flow [edit]

Named aquifers	General description	Water quantity issues	Water quality issues	Recharge
Cenozoic sandstones and limestones	Semi-consolidated marine sedimentary rocks with relatively high porosity in which groundwater is stored and flows through both intergranular matrix and fractures.			
Jurassic and Cretaceous limestones - Northern (Atlas) domain	Consolidated marine sedimentary rocks with relatively high karstic porosity, in which groundwater is stored and flows dominantly through fractures and karst conduits. This is often a highly productive aquifer. Yields of more than 100 l/s are seen from the Zibans karst; and greater than this from the Neritic formation of Constantine (900 l/s at Hamma springs; 400 l/s at Fourchi; 650 l/s at Boumerzoug). In some parts there is extensive groundwater discharge via springs, e.g. at Zaccar (Miliana sources), Djurdura, and its extension to Bejaia.		Thermal waters. The groundwaters are generally of calcium bicarbonate or calcium sulphate type.	Direct recharge, mostly occurring during periods of exceptionally heavy rain. Some recharge by horizontal flow from other aquifers.
Complexe Terminal (Late Cretaceous to Cenozoic) and Continental Intercalaire (Palaeozoic to Late Cretaceous)	These two aquifers together form part of the transboundary Northern Saharan Aquifer System (SASS), also known as the North-west Sahara Aquifer System (NWSAS) (see section on Transboundary aquifers, below). These are largely deeply buried, and can be at least 2000 m thick. Much of the aquifer is siliclastic sandstone; some parts are karstic; and there are some evaporates. This is often a highly productive aquifer. Analysis of pumping tests in the Continental Intercalaire in the Adrar region suggests hydraulic conductivity values of between 3 x 10^{-4} and 3 x 10^{-5} m/s.	The groundwater resource is generally considered to be 'fossil' - many thousands of years old - and in areas is known to be overexploited, with	Water quality ranges from good, with relatively low levels of mineralisation, to poor. In some areas, groundwater in the Complexe Terminal has salinity levels between 4 and 9 g/l (FAO, 2009).	Recharge is minimal, due to the generally deep burial of the aquifers and the arid climate. Small amounts of recharge occur from episodic

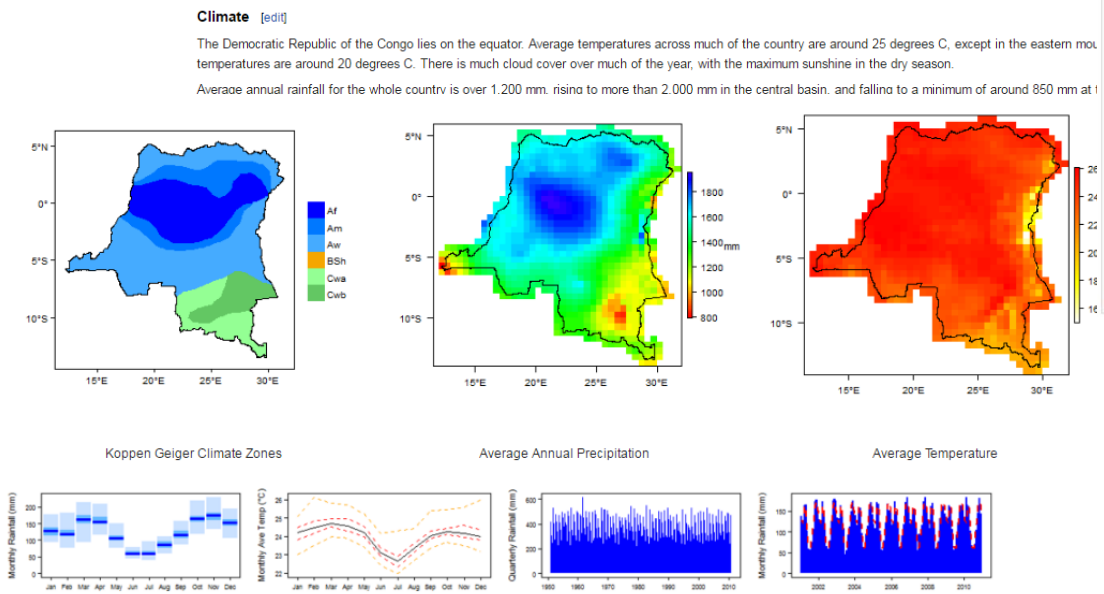
Summary of key aquifers

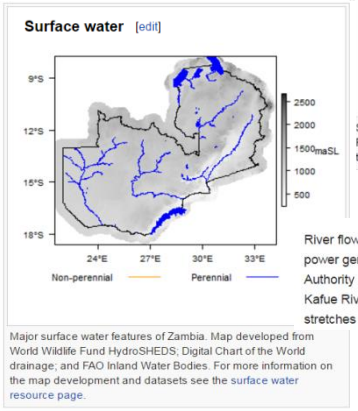
Answers to questions like:

- Where are the high yielding aquifers?
- Is groundwater storage and flow in pores or weathered zones or fractures?
- What are typical borehole yields from an aquifer?
- What is the groundwater quality?

Summaries of climate, surface water, topography, soil and land cover

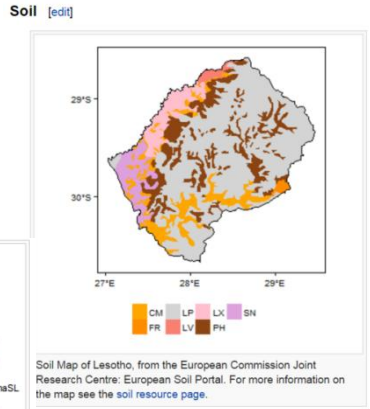
- Derived from 3rd party data
- Easily compare from one country to another



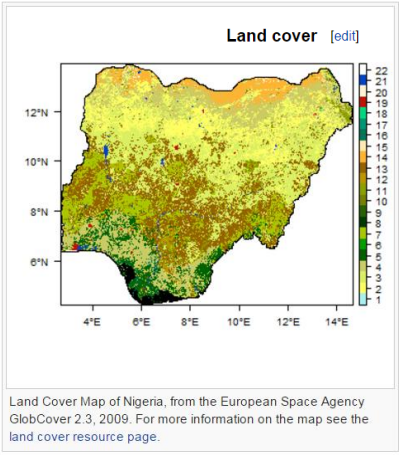


Major surface water features of Zambia. Map developed from World Wildlife Fund HydroSHEDS; Digital Chart of the World drainage; and FAO Inland Water Bodies. For more information on the map development and datasets see the surface water resource page.

River flow gauging is undertaken by Zesco, Zambia's power generating company, and the Zambezi River Authority (ZRA). Zesco's gauging stations are mainly on the Kafue River, while the ZRA gauges the Zambezi and stretches of the Kafue.



Soil Map of Lesotho, from the European Commission Joint Research Centre: European Soil Portal. For more information on the map see the soil resource page.



Land Cover Map of Nigeria, from the European Space Agency GlobCover 2.3, 2009. For more information on the map see the land cover resource page.

Answers to questions like:

- When is the recharge season?
- Have there been droughts in recent years?
- Are there areas with no surface water resources?

Groundwater status, use & management

Groundwater Status [edit]

Groundwater quantity [edit]

The recent FAO/SWALIM study (2012) considered that in the northern provinces of Somaliland and Puntland, where there is no perennial surface water, "total annu groundwater (although not necessarily available for abstraction) in the major aquifer systems is theoretically equal to some 4.3 x 10^9 m³. Although this amount of w of 139 m³/s looks very promising, the large area of these two regions - more than than 289 000 km² - means that groundwater water is still scarce. Estimated specif less than 0.5 l/s/km², which classifies northern Somalia as having extremely poor groundwater reserves.

Most drilled boreholes provide yields in the range 1 to 5 l/s, but there are many with lower or higher yields. In some cases, boreholes can't sustain high pumping rat aquifer could yield more groundwater if higher capacity pumps or pipe diameters were installed to increase borehole capacity.

The highest known aquifer potential is illustrated by the most productive well known in northern Somalia, in the Auradu karstic limestone aquifer in Ceerigabo, whic had a test yield of 50 l/s for a drawdown of only 2.43 m (Faillace and Faillace 1986). Another known high productivity aquifer is the terrace and alluvial sediments c are used for the water supply of Hargeysa (the capital of Somaliland). Average boreholes yields are 15 l/s with drawdown not larger than 5-10 m.

Groundwater quality [edit]

Groundwater quality is a major issue in many parts of Somalia. The natural quality of groundwater depends in part on aquifer lithology and the soluble products of aspects such as seasonal recharge, so that groundwater quality can vary from season to season. Many boreholes are abandoned because of poor water quality. Th in individual aquifers is summarised in the relevant tables above.

A FAO/SWALIM survey in 2012 showed that in the northern Somaliland and Puntland regions, across all aquifers, only 30% of groundwater samples were below the limit of 1500 microS/cm, with 29 % of the samples in the range 1500 to 3000 microS/cm and 41 % of the samples above 3000 microS/cm.

Recharge [edit]

Recharge occurs only if the rainfall regime is favourable. In areas with scarce and uneven rainfall, infiltration may occur only along stream beds and floodable depre thunderstorms covering small areas usually occur in the northern regions and generate spate flows in *toggas* (wadis or seasonally dry streambeds), which lasti from couple of days (Faillace and Faillace 1986).

Groundwater dependent ecosystems [edit]

There are numerous springs in the north of Somalia in the study area of the FAO/SWALIM programme. A total of 287 springs were registered, which tend to be mor and/or karstic aquifers. They are of crucial for local ecosystems.

Groundwater use and management [edit]

Groundwater use [edit]

Given the lack of perennial streams and the arid climate in much of Somalia, groundwater is the sole water resource in most of the coun Juba and Shabelle. Approximately 95% of the population use groundwater for drinking water. Most groundwater is used for drinking, anc also a significant groundwater use. Irrigation is not widely developed, except along the two major perennial rivers. There are no large gr industrial sector.

The most productive groundwater sources are boreholes drilling into unconsolidated alluvial terrace aquifers and karstic aquifers. Boreho alluvium in *toggas* (wadis), to a few hundred meters in Eocene karstic aquifers or the Nubian (Yessoma) sandstone aquifer. Submersible hand pumps are used to tap water from shallow aquifers.

Due to limited reserves related to very low effective rainfall; a very deep groundwater table in many areas; and/or increased water salinit limited access to it in most of the country. The water supply situation in many parts of Somalia is therefore exceptionally severe. A large access to safe, sufficient groundwater. Several deep drilling projects have been undertaken with the aim of developing groundwater resc hydrogeological knowledge, the success rate of groundwater development has been very low.

Fourteen water utilities serve major towns and settlements in the Somaliland and Puntland regions, with a total around 2,544,000 inhab Somalia. However, not more than 25% of this population is connected to water distribution systems and pipelines (FAO/SWALIM 2012). is in Sheikh, at 4%, but most problematic is Hargeysa where over 750,000 of residents, mostly in suburban areas, have no proper acces

Groundwater management [edit]

Key groundwater institutions include:

The Ministry of Water Resources in Mogadishu

The Ministry of Water Resources in Somaliland

The Puntland State Agency for Water, Energy and Natural Resources

After the end of the former government of Somalia there was no legal framewo Somaliland and Puntland have made significant steps towards re-establishment 2013, and put into use, with the Ministry of Water Resources issuing permits fo strengthened for the laws and policies to be fully implemented.

Groundwater monitoring [edit]

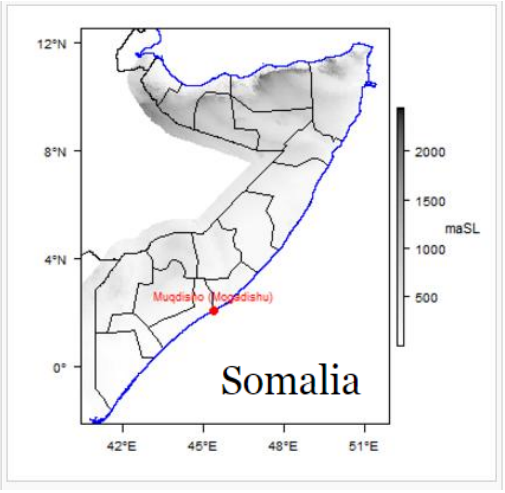
Groundwater level monitoring [edit]

FAO/SWALIM established an initial groundwater monitoring network in the nortl 8 groundwater level loggers are installed in Hargeisa, Borama, Berbera and Bur

Data from this network will help to prevent future depletion of aquifers due to th water for domestic use and watering livestock.

Groundwater quality monitoring [edit]

No systematic groundwater quality monitoring is done. Local water utilities spor

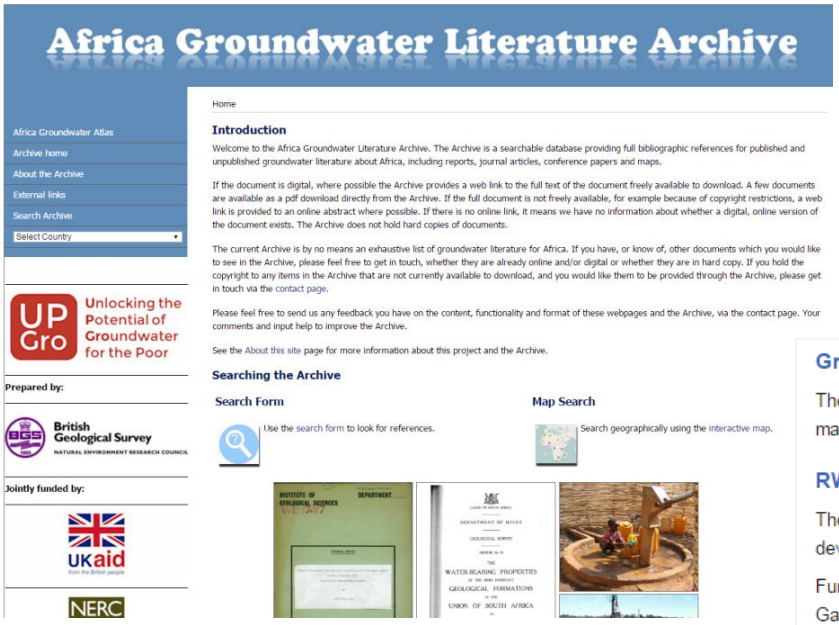


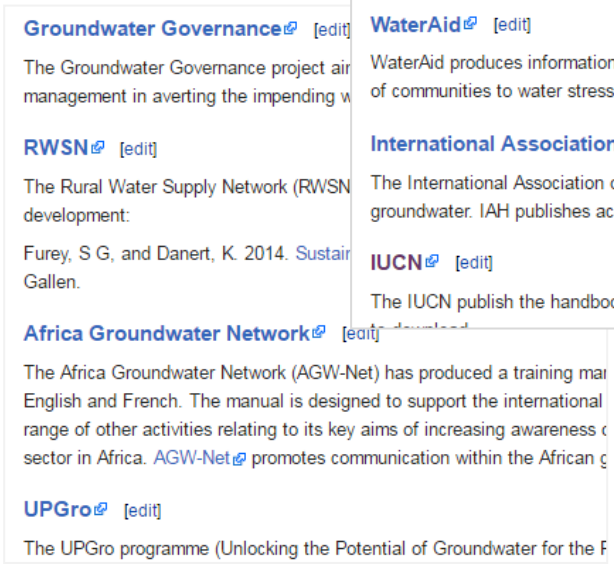
Answers to questions like:

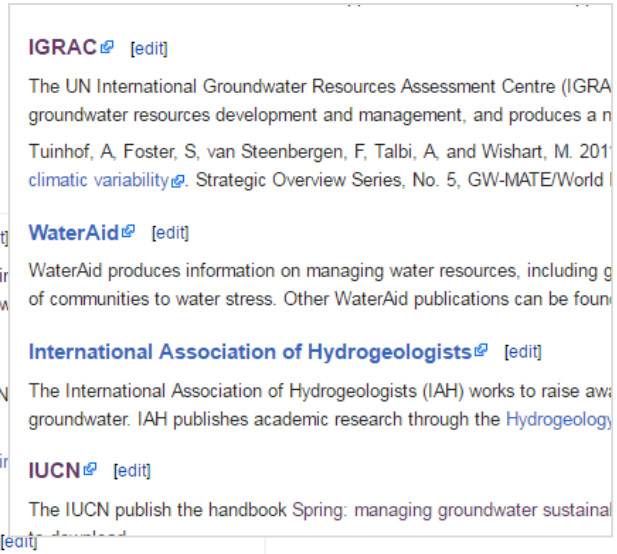
- What are the main uses of groundwater?
- Are there any big groundwater problems? (water quality? over-abstraction?)
- Which institutions are involved with groundwater management?
- Is there groundwater monitoring?
- Are there national groundwater databases?

Where to find more information

- Key geological & hydrogeological references
- Links to other websites



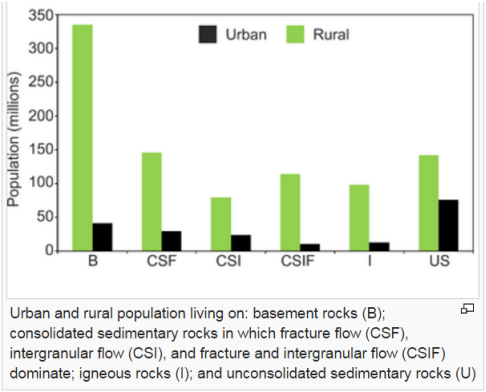




Resource Pages

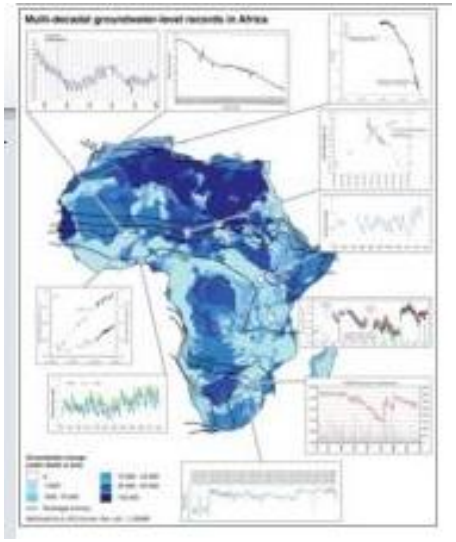
Background information and technical explanations on key issues, e.g.:

Groundwater use

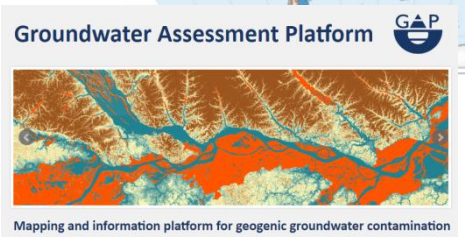


Urban and rural population living on: basement rocks (B); consolidated sedimentary rocks in which fracture flow (CSF), intergranular flow (CSI), and fracture and intergranular flow (CSIF) dominate; igneous rocks (I); and unconsolidated sedimentary rocks (U)

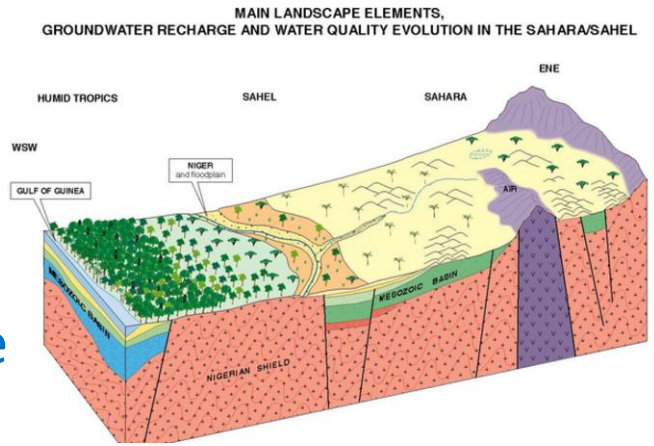
Groundwater monitoring



Groundwater quality

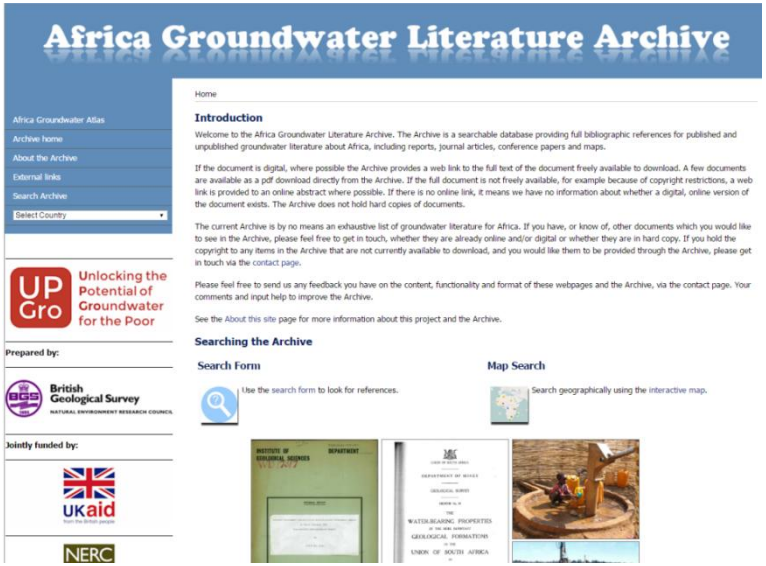


Recharge



Africa Groundwater Literature Archive

- The most comprehensive yet index of African groundwater literature
- ~7000 entries (so far!)
- Full text download if available; or for copyrighted documents, link to online abstract if available
- Full bibliographic references
- Complements other literature archives: e.g. WRC; IRD; SADC Grey Literature Archive



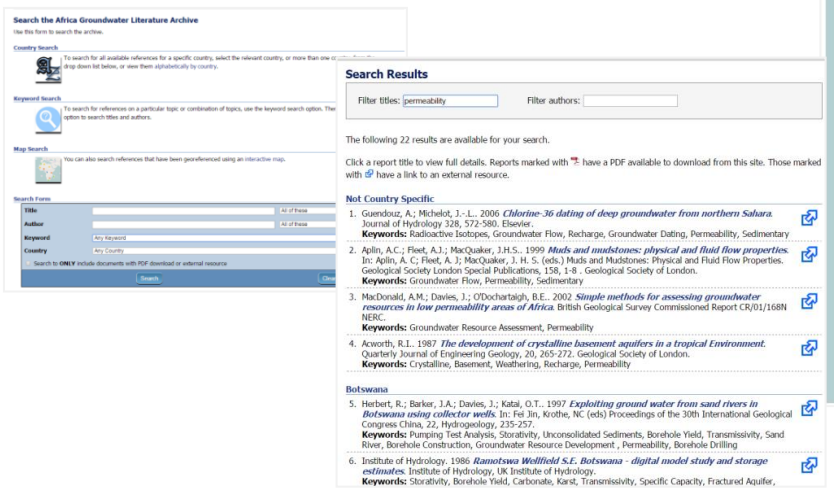
What's in the Archive?

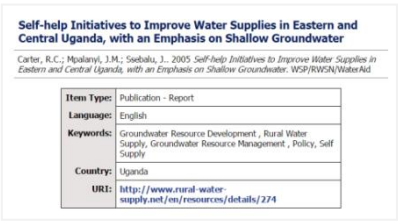
- **Reports** (e.g. by geological surveys, governments, development organisations); **journal articles**; **conference papers**; **academic theses**; **books**; **hydrogeological maps** (mostly pdf or image files)
- Documents from 1897 to today

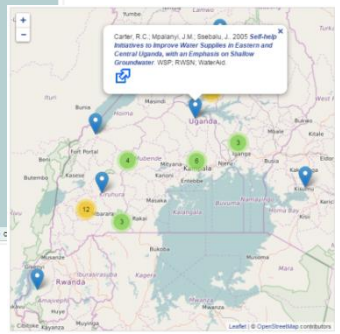
Using the Archive

Powerful search options:

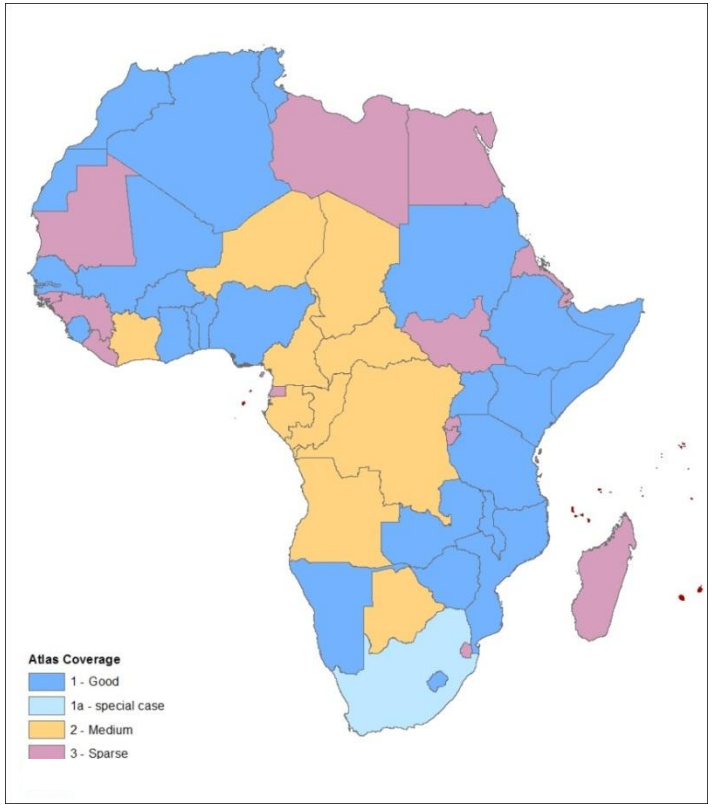
- **Keyword**: >200 hydrogeological keywords
- **Free text**: search or filter results by Title and Authors
- **Geographically**:
  - Every relevant reference is tagged by country
  - As many as possible are georeferenced – searchable on interactive map







What's next? Future developments



- Add more information for countries that so far have only sparse information
- GIS downloads of hydrogeology and geology maps
- Add more hard-to-access references in Literature Archive
- Add more socio-economic information

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