Hydrogeology of Angola

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Angola is the seventh largest country in Africa. It became independent from Portuguese colonisation in 1975. Civil war in the country ended in 2002.

Angola has large petroleum and mineral resources, including diamonds, copper and gold. Since 1975, oil and diamonds have dominated the economy, which in recent years has been the fastest growing in Africa. Subsistence and commercial agriculture both reduced during the civil war, but began to recover after 2002.

Since the end of the civil war, Angola has been facing significant challenges in water and sanitation, including rebuilding infrastructure, developing institutional frameworks, and strengthening technical and professional skills as well as planning and coordination across different sectors. Large amounts of money have been invested in water supply infrastructure in recent years, but in 2015 only 28% of the rural population were classed as having access to safe water supplies, although the figure for urban areas was 75%.

□

Contents

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Please cite this page as: Upton, Ó Dochartaigh, Bellwood-Howard and González, 2018.

Bibliographic reference: Upton, K, Ó Dochartaigh, B É, Bellwood-Howard, I and González, M A. 2018. Africa Groundwater Atlas: Hydrogeology of Angola. British Geological Survey. Accessed [date you accessed the information]. http://earthwise.bgs.ac.uk/index.php/Hydrogeology_of_Angola

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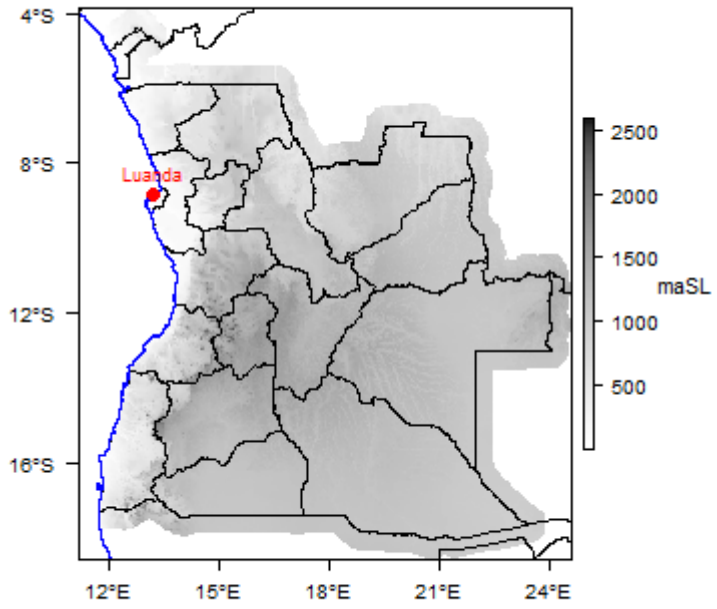
Geographical setting



Angola. Map developed from USGS GTOPOPO30; GADM global administrative areas; and UN Revision of World Urbanization Prospects. For more information on the datasets used to develop the map see the geography resource page

General

Angola is in central-southern Africa. There is a lowland coastal strip between 35 and 180 km wide that ranges from 300 to 500 m in elevation. Away from this, most of the country is formed of high plateaus from about 1000 to 1800 m in elevation, with the highest point at 2620 m. Hills and mountains rise inland from the coast into a major escarpment. Extending eastwards and south-eastwards from the escarpment is a large area of high plateau (planalto).

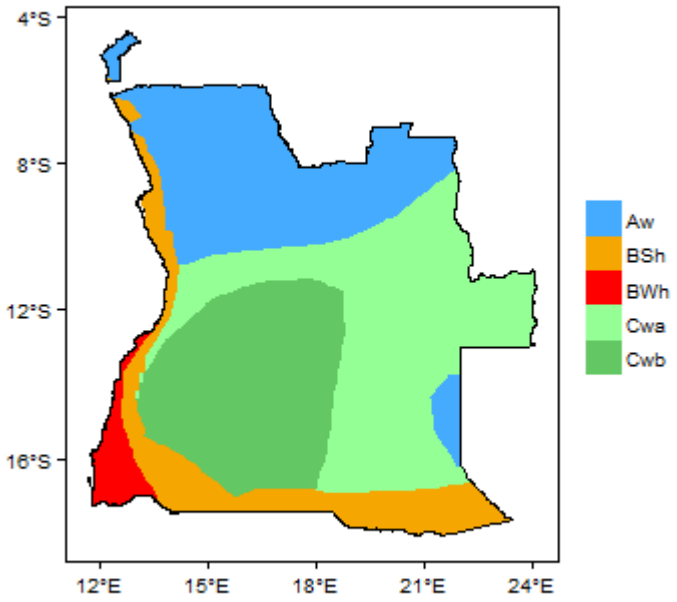
Capital city	Luanda
Region	Central Africa
Border countries	Namibia, the Democratic Republic of the Congo, Zambia
Total surface area *	1,246,620 (km^2) (12,467,000 ha)
Total population (2015)*	25,022,000
Rural population (2015)*	14,970,000
Urban population (2015)*	10,052,000
UN Human Development Index (HDI) [highest = 1] (2014)*	0.5316

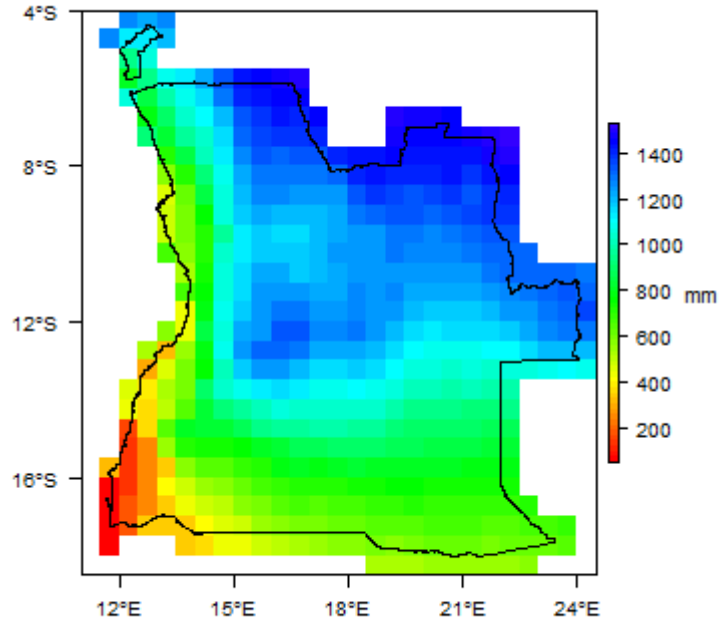
* Source: FAO Aquastat

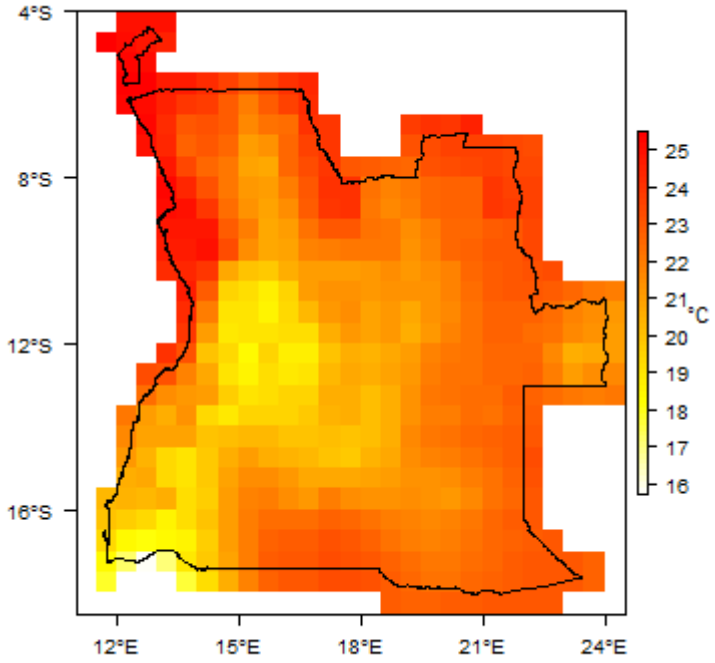
Climate

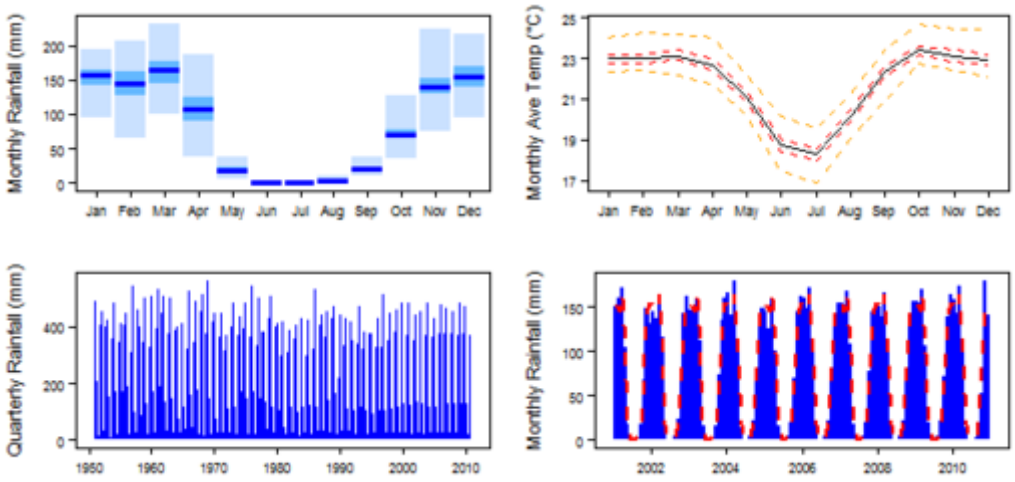
Most of Angola has a dry season from May to October and a rainy season from February to April,

with transitional rains from November to January. The south of the country, and along parts of the coastal strip, are semi-arid, with less than 400 mm/year of rain. The far north sees rainfall throughout much of the year, with more than 1400 mm/year of rain. The climate is greatly influenced by prevailing winds from the west and south-west.







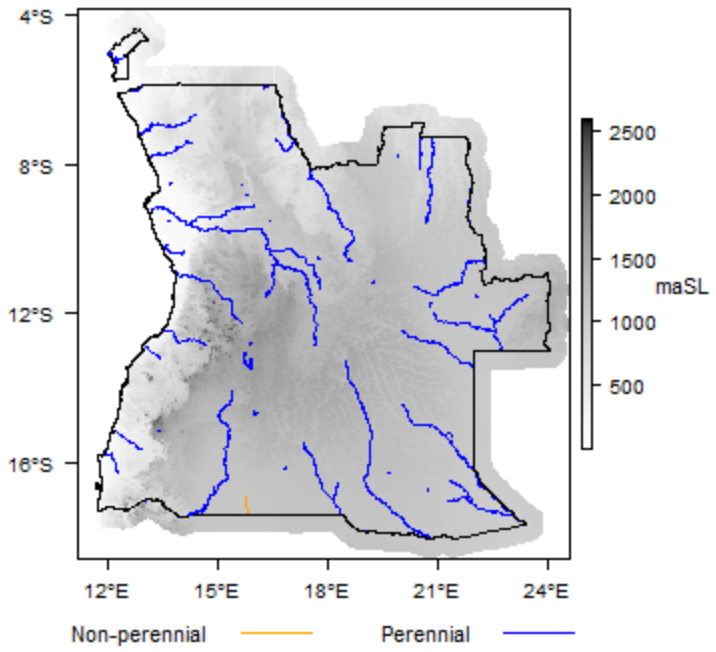


More information on average rainfall and temperature for each of the climate zones in Angola can be seen on the **Angola climate page**.

These maps and graphs were developed from the CRU TS 3.21 dataset produced by the Climatic Research Unit at the University of East Anglia, UK. For more information on the datasets used to develop these maps and graphs see the climate resource page.

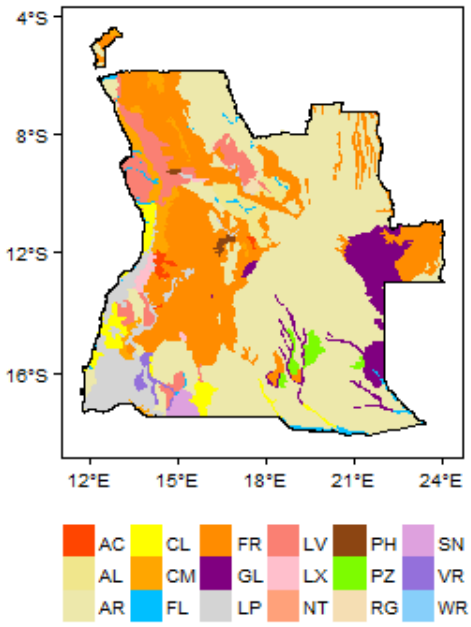
Surface water

The centre and north of Angola have many perennial rivers. In the south there are only three perennial rivers: the Cunene, Kuando and Cubango (which flows to the Okavango) rivers.
The Zambezi River and several tributaries of the Congo River have their sources in Angola. Many rivers originate in the central uplands, but take quite different flow paths. Some flow more or less due westerly to the Atlantic, providing water for irrigation and the potential for hydroelectric power in the dry coastal strip. Two of the largest rivers, the Cuanza and the Cunene, take a more indirect route to the Atlantic, the Cuanza flowing north and the Cunene flowing south before turning west. navigable. The Kwango and other rivers flow north from the high plateau to join the Kasai River (one of the largest tributaries of the Congo). Some rivers flow south into the Zambezi River system and from there to the Indian Ocean; others to the Okavango River (called the Cubango River in Angola) and thence to the Okavango Swamp in Botswana.



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

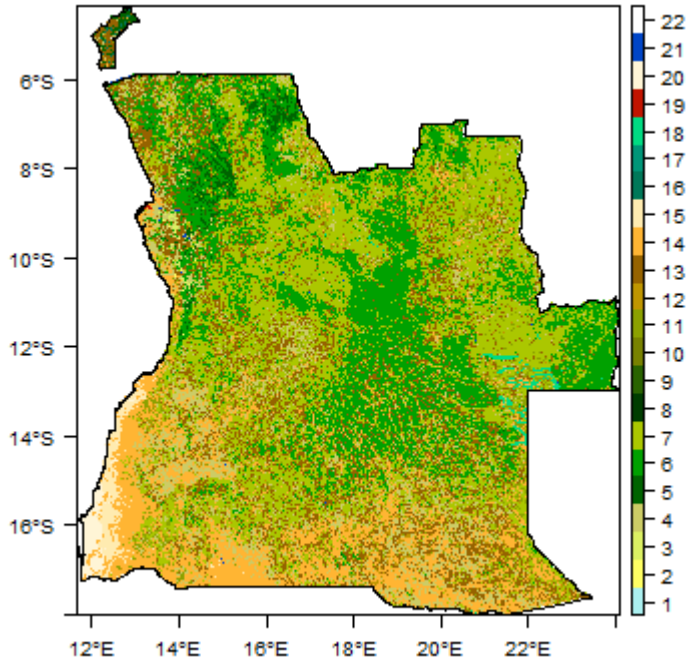
Soil



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

Land cover

In the far south and south-west of Angola, land cover is dominated by desert or sparse savannah or grassland vegetation. This gives way northwards to shrubland and then to a mix of shrubland then to deciduous forest, which covers much of the rest of the country.



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

Water statistics

	2005	2014	2015
Rural population with access to safe drinking water (%)			28.2
Urban population with access to safe drinking water (%)			75.4
Population affected by water related disease	No data	No data	No data
Total internal renewable water resources (cubic metres/inhabitant/year)		5,915	
Total exploitable water resources (Million cubic metres/year)	No data	No data	No data
Freshwater withdrawal as % of total renewable water resources	0.476		
Total renewable groundwater (Million cubic metres/year)			58,000
Exploitable: Regular renewable groundwater (Million cubic metres/year)	No data	No data	No data
Groundwater produced internally (Million cubic metres/year)		58,000	
Fresh groundwater withdrawal (primary and secondary) (Million cubic metres/year)	No data	No data	No data
Groundwater: entering the country (total) (Million cubic metres/year)			
Groundwater: leaving the country to other countries (total) (Million cubic metres/year)			
Industrial water withdrawal (all water sources) (Million cubic metres/year)	240		
Municipal water withdrawal (all water sources) (Million cubic metres/year)	302		
Agricultural water withdrawal (all water sources) (Million cubic metres/year)	147		

Irrigation water withdrawal (all water sources) (Million cubic metres/year)	147		
Irrigation water requirement (all water sources) (Million cubic metres/year)	40		
Area of permanent crops (ha)		290	
Cultivated land (arable and permanent crops) (ha)		5,190	
Total area of country cultivated (%)		4.163	
Area equipped for irrigation by groundwater (ha)	17,000		
Area equipped for irrigation by mixed surface water and groundwater (ha)	No data	No data	No data

Source and more statistics at: FAO Aquastat.

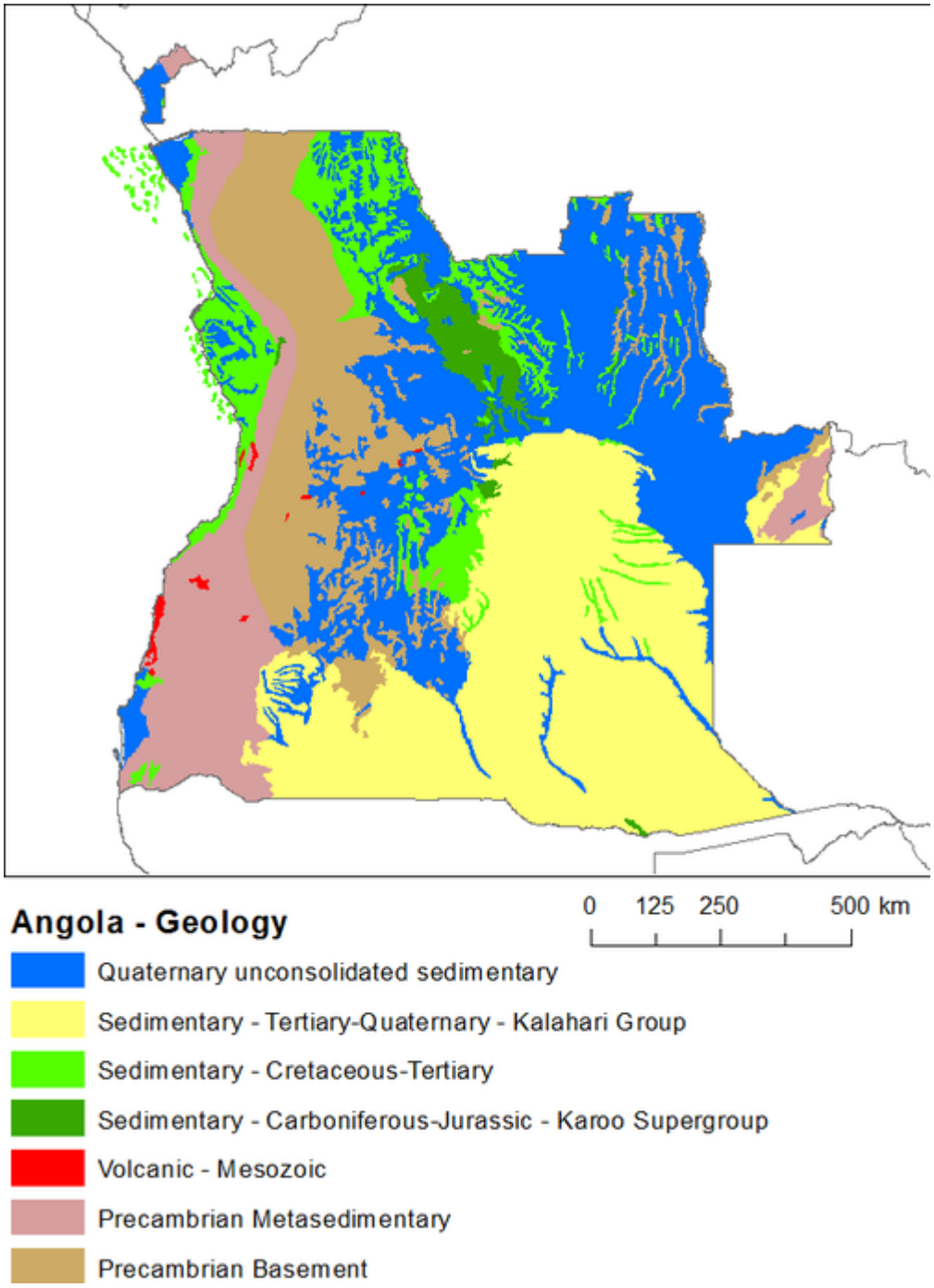
Geology

This section provides a summary of the geology of Angola. More information is available in the report 'Groundwater in Eastern, Central and Southern Africa' (UN 1989) (see References section, below).

The geology map shows a simplified version of the geology at a national scale (see the Geology resources page for more details).

Download a GIS shapefile of the Angola geology and hydrogeology map.

The geology of the west of Angola is reasonably well known, but less detail is known of the geology of the east of the country (DNA 2005). The geology can be generally divided into sedimentary rocks (generally easily weathered and 'soft), and Precambrian metamorphic rocks (generally hard).



Geology of Angola at 1:5 million scale. Based on map described by Persits et al. 2002 / Furon and Lombard 1964. For more information on the map development and datasets see the geology resource page. Download a GIS shapefile of the Angola geology and hydrogeology map.

		Geological environments
Key formations	Period	Lithology
		Unconsolidated/Semi-consolidated
Alluvium	Quaternary	Unconsolidated alluvial sediments infilling valleys. These are thickest below the floodplains and near-coast deltas of the large rivers - the Cuanza, Zaire and Cunene.

Kalahari Group	Tertiary–Quaternary	Loosely consolidated sandstones and unconsolidated sands and silts, which cover much of the eastern part of Angola to a maximum depth of 600 m. They overlie ancient basement rocks, and were deposited within the Kalahari Basin, which began subsiding in Jurassic times. Today, the Kalahari Basin covers a surface area of 2.5 million km^2 across central-southern Africa, but there is considerable regional and local variation in Kalahari Group sediments across the basin (Hipondoka 2005). A detailed description of the lithology and structure of the Kalahari Group in the Owombo Basin in neighbouring Namibia is given in Hipondoka (2005) (see Reference list, below).
	Cretaceous–Tertiary	Up to 150 m thickness of Aptian-Maastrichtian age sedimentary rocks, often argillaceous sandstones with marine and evaporitic deposits. Overlain by up to 1200 m thickness of Paleocene to Pliocene age sedimentary rocks.
	Consolidated sedimentary	
Karoo Supergroup	Carboniferous–Jurassic	Argillaceous limestones, sandstones and shales at the edge of Congo Basin. Up to 500 m thick. Intruded by dolerites.
	Volcanic rocks	
	Mesozoic	
	Precambrian	
Bembé System	Late Precambrian–Lower Cambrian	Metasedimentary rocks: schist-limestones overlain by metasandstones, metaconglomerates and quartzites
Oendolongo System	Precambrian	Metasedimentary rocks: quartzitic metasandstones
Crystalline basement	Archaean	Crystalline igneous and metamorphic rocks, largely granites, gneisses and gabbros, part of the African craton. Often with quartz veins. Except for the coastal area, Precambrian basement rocks are exposed in large parts of Angola (DNA, 2005).

Hydrogeology

This section provides a summary of the hydrogeology of the main aquifers in Angola. More information is available in the report 'Groundwater in Eastern, Central and Southern Africa' (UN, 1989) (see References section, below).

The hydrogeology map on this page shows a simplified version of the type and productivity of the main aquifers at a national scale (see the Hydrogeology Map resource page for more details).

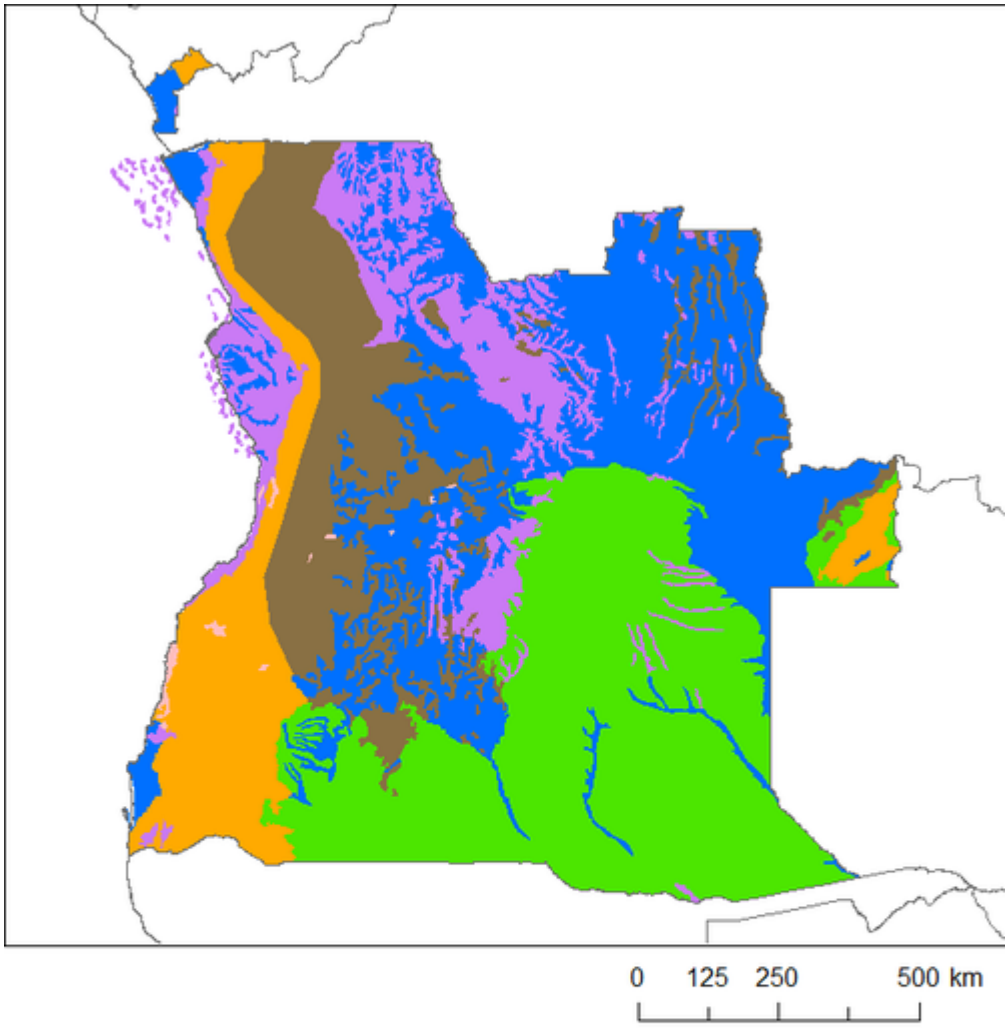
Download a GIS shapefile of the Angola geology and hydrogeology map.

Other hydrogeological maps of Angola exist:

- Angola is covered by the SADC hydrogeological map and atlas (2010), available through the SADC Groundwater Information Portal.
- A hydrogeological map of Angola at 1:1,500,000 scale was published by Hidroprojecto

Consultores de Hidraulica e Salubridade SA (1990) (see Reference section, below).
- A hydrogeological map of Angola at 1:250,000 scale was published by the World Bank United Nations Development Program.

There are limited data on the hydrogeological characteristics and groundwater potential of Angolan aquifers. Most information is available for the southwestern provinces of Huíla, Namibe and Cunene, where many boreholes have been drilled and registered. But for some aquifers there is very little data from water boreholes (DNA 2005).



Hydrogeology of Angola at 1:5 million scale. For more information on how the map was developed see the hydrogeology map resource page.
Download a GIS shapefile of the Angola geology and hydrogeology map.

Quaternary Unconsolidated Aquifers

Named aquifers	Aquifer Productivity	Aquifer properties and groundwater quality
Alluvium - Quaternary	Variable: Low to High	Aquifer productivity depends on the aquifer lithology (whether dominated by permeable sands and gravels or low permeability fine-grained deposits), thickness and lateral (areal) extent. At their most productive, alluvial sediments in river valleys form the best aquifers in Angola, with recorded borehole yields of 15 to 50 l/s (DNA, 2005). The largest alluvial aquifers are found in the provinces of Huíla, Benguela, Cuanza Sul, Bengo and Zaire (DNA, 2005). Some groundwater in alluvial aquifers is reported to have high iron and sulphate concentrations, probably linked to the low precipitation and high potential evapotranspiration. In some deltas and low parts of alluvial plains the quality of groundwater is influenced by salt water (DNA, 2005).

Sedimentary Aquifers - Intergranular flow

Named aquifers	Aquifer Productivity	Aquifer properties and groundwater quality
Kalahari Group - Tertiary–Quaternary	Moderate to High	Thought to form a moderate to high productivity aquifer. The water table in the Kalahari Group is shallower in the north, and becomes deeper towards the south, where the Kalahari Group is typically completely dry (Groundwater Consultants Bee Pee (Pty) Ltd, SRK Consulting (Pty) Ltd, 2002).

Sedimentary Aquifers - Intergranular and Fracture flow

Named aquifers	Aquifer Productivity	Aquifer properties and groundwater quality
Unnamed small aquifers along the coast - Cretaceous–Tertiary	Moderate	Argillaceous sandstones along the coast have proved to be moderately productive aquifers. Groundwater can be relatively highly mineralised, sometimes associated with salt-bearing formations.
Karoo Supergroup (inland) - Carboniferous–Jurassic	Moderate	Groundwater can be relatively highly mineralised

Sedimentary Aquifers - Fracture flow

Named aquifers	Aquifer Productivity	Aquifer properties and groundwater quality

Metasedimentary rocks - Precambrian (locally Lower Cambrian)	Usually Moderate; sometimes High	Some quartzites, sandstones and conglomerates may form useful aquifers. These are scattered throughout most of the areas with Precambrian rocks in southwest Angola. Average borehole yields are thought to be around 3 l/s (DNA, 2005). Metamorphosed sandstones, limestones, dolomites, greywackes and volcanic rocks of the Pan-African orogen, which occur in various parts of the country, may form the highest productivity Precambrian aquifers, with average borehole yields of 3 to 6 l/s or even greater (DNA, 2005).

Basement Aquifers

Named aquifers	Aquifer Productivity	Aquifer properties and groundwater quality
Crystalline basement - Precambrian	Usually Low, sometimes Moderate	Basement rocks form local aquifers, generally with low productivity but sometimes up to moderate productivity. Groundwater is only found where the rocks are fractured and/or weathered. Different lithologies within the basement have different hydrogeological properties. In general, the most common yields of boreholes in granites and gneisses is less than 1 l/s, especially where boreholes are less than approximately 50 m deep (DNA, 2005). The basic rocks in Angola such as gabbros and norites are probably the best aquifers, and in the hydrogeological map of Angola their productivities are often indicated as being 3-5 l / s with a drill success rate of 70-80% (DNA, 2005). Basic intrusive rocks are found both in the north and south of the country. One study showed that borehole yield was directly related to the direction of tectonic structures (fracture orientation). For example, where fractures are in a NE-SW direction, yields are less than 3 m^3/hour; and where fractures are in a N-S direction, yields are more than 8.5 m^3/hour (United Nations, 1989). The best groundwater potential may be in zones of quartz veins and basic rocks; contact zones between crystalline rocks of different texture and composition; zones of fractured granitogneiss; and contact zones between metavolcanic and quartz-schist rocks.

Groundwater status

Only limited research has been conducted concerning groundwater and no national resource estimates have been completed. However, based on the presently identified potential and the limited level of existing development, it is safe to assume that only a very small portion of national groundwater resources are being used (Groundwater Consultants Bee Pee (Pty) Ltd, SRK Consulting (Pty) Ltd, 2002).

Although groundwater quality it not presently monitored, it has been reported that water quality has declined in the coastal part of Namibe Province (Groundwater Consultants Bee Pee (Pty) Ltd, SRK Consulting (Pty) Ltd, 2002). This is most likely to be because of seawater intrusion, which may be a problem along the whole coast where boreholes are being pumped at high capacity for long periods

(DNA, 2005). However, other urban and rural water supply schemes using groundwater in the coastal belt have not reported seawater intrusion (Groundwater Consultants Bee Pee (Pty) Ltd, SRK Consulting (Pty) Ltd, 2002). Mineralised groundwater is reported along the south coast of Benguela and parts of the interior of southwest Angola, where both borehole yields and groundwater mineral content often increase with depth (DNA, 2005). There are also reports that mining activities have caused groundwater pollution (Schlüter 2006).

Groundwater use and management

Groundwater use

A report in 2105 stated that 73% of known water systems across Angola use groundwater sources, and that drilled boreholes equipped with hand pumps represented 36% of all water supply systems (Cowater 2015). The use of groundwater varies across the country, with some provinces obtaining over 90% of their water supplies from groundwater, but most obtaining between 40% and 80% of water supplies from groundwater. Only three provinces obtain less than 20% of water supplies from groundwater (Cowater 2015).

The provincial capitals of Malange, Bengucia, Lubango and Namibe, and the urban centres of Tobwa and Lobito, rely on groundwater to a greater or lesser extent. In general, groundwater use in urban areas is concentrated in southern and coastal areas, where the climate is more arid and surface water is less available. Additionally, groundwater is being increasingly developed for local systems to augment water supplies in rapidly growing peri-urban areas, particularly Luanda (Groundwater Consultants Bee Pee (Pty) Ltd, SRK Consulting (Pty) Ltd, 2002).

Rural areas rely almost entirely on groundwater - from drilled boreholes, hand-dug wells and springs. However, in areas where existing groundwater supply systems are no longer working or have not been developed, surface water is used (Groundwater Consultants Bee Pee (Pty) Ltd, SRK Consulting (Pty) Ltd, 2002).

Another major use of groundwater is for livestock in the southern provinces. Water supply for livestock watering is coordinated by the Ministry of Agriculture, and groundwater is supplied through boreholes and wells equipped with either manual or powered submersible pumps. In a 1973 survey there were 943 boreholes and 319 wells supporting such systems. The present number is not available, but based on recent figures available from Cunene Province, where 125 out of 607 systems are functioning, the current number of operable systems is likely to be less than in 1973. However, individual farmers and ranchers also commonly construct boreholes and wells in these southern areas (Groundwater Consultants Bee Pee (Pty) Ltd, SRK Consulting (Pty) Ltd, 2002).

Groundwater management and monitoring

The National Directorate for Water (DNA) are responsible for aspects of water supply and water resources.

In 2002 there was no formal institution responsible for data collection related to groundwater. However, since 1996, DNA have carried out annual field surveys of the operational status of water supply systems, including boreholes and hand-dug wells, to assess the level of water supply coverage. During these field campaigns, data collected includes the location of boreholes and hand-dug wells; the number of users of each borehole or well; the borehole/well depth; the rest water level; the type and mark of pump; the name of a responsible person; and the maintenance record over the previous year. This field information is kept in paper form in the DNA archive for future

use, and used to compile annual reports summarising the total number of water point sources by province and a summary of their operational status. In 2002 there were records of over 3600 groundwater points (Groundwater Consultants Bee Pee (Pty) Ltd, SRK Consulting (Pty) Ltd, 2002).

Another institution collecting data related to groundwater is the company Hidromina, which maintains a digital database with basic information generated by boreholes they have drilled. In 2002, this database held records of over 2500 boreholes (Groundwater Consultants Bee Pee (Pty) Ltd, SRK Consulting (Pty) Ltd, 2002).

General information on groundwater management in Angola may be available via the SADC Groundwater Management Institute.

Groundwater development and drilling

Despite a high reliance on groundwater, the drilling sector in Angola is not well developed. A training workshop was held in November 2017 to address this, by UNICEF and the Skat Foundation in partnership with the Ministry of Energy And Water. The 'Professional Borehole Drilling Management Training Course' introduced ideas on how to develop the drilling sector to key actors from government departments, private drilling companies, NGOs and academia. Participants learnt about hydrogeology, contract procurement and management, monitoring and costing, and reviewed a 'Preliminary Study of the Drilling Sector in Angola'. More information is available in the workshop report.

Transboundary aquifers

Angola shares a number of aquifers with other countries. These include (Altchenko and Vilholth, 2013):

- the Northern Kalahari/Karoo Basin, shared with Botswana, Namibia and Zambia
- Cuvelai–Etosha Basin, shared with Namibia
- the Coastal Sedimentary Basin (Cunene River) aquifer, shared with Namibia
- the Lower Congo Precambrian Dolomite aquifer and the Congo River Coastal Sedimentary aquifer, both shared with the Democratic Republic of the Congo.

For further general information about transboundary aquifers, see the Transboundary aquifers resources page.

References

The following provide more information on the geology and hydrogeology of Angola. Many of these, and others, can be accessed through the Africa Groundwater Literature Archive

Online resources

SADC Groundwater Information Portal

General information on surface water and groundwater resources in SADC

Water Resources in Angola Portal

Documents

Adekile D, Matabire B, Gonzalez Alonso MA and Danert K. 2017. Striving for Professionalism in Cost Effective Boreholes Angola - Professional Borehole Drilling Management Training Course - Understanding groundwater, cost-effective boreholes, procurement, contract management and costing and pricing of boreholes. Workshop report.

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