

SOUTH AFRICA

Area: 1,221,000 km²

Population: 31 million

I. BACKGROUND

South Africa occupies the southern part of the African continent; it has a long coastline on the Atlantic Ocean to the west and the Indian Ocean to the east. However, the most developed regions of the country with respect to agriculture, mining and industry - the Transvaal and Orange Free State - have their outlet on the Indian Ocean (at Maputo in Mozambique, which is more easily accessible).

The country is divided into four provinces: Transvaal, Orange Free State, Cape and Natal. It consists basically of a plateau at least 1,000 m high which terminates at the sea in fairly narrow coastal plains; in some places these plains rise sharply towards interior, i.e. towards the plateau.

The plateau itself is for the most part flat or slightly undulating. Lines of hills occur locally. The highest areas are in the south-east, and the north and west are generally lower. The highest part is called the "High Veld", and the others the Middle Veld and Low Veld. The Drakensberg, at the southern edge of the plateau, has several peaks over 3,000 m. The Orange River and its main tributary, the Vaal, rise here. The Orange flows westwards to the Atlantic Ocean. It forms the frontier with Namibia. The Limpopo River rises near the city of Johannesburg. It flows north and then east, forming the frontier with Botswana and Zimbabwe.

The climate is fairly gentle and dry throughout the country. It is hot and humid on the ocean coasts in the east and south. The rainfall decreases towards the west to a point at which the country becomes totally desert on the western coast. The rains fall in the summer except in the Cape Town region, which receives about 600 mm of rainfall a year, mainly in winter.

The amount of rainfall varies with altitude, proximity to the sea and latitude. At Durban, close to sea level, the average temperature in the warmest months of January and February is 22 °C. In the coldest months - June and July - it is 18 °C to 19 °C. In the interior at Johannesburg (altitude 1,800 m) the temperature in December and January, the hottest months of the southern summer, is likewise 18 °C to 19 °C, and 10 °C in June and July, the coldest months. At Cape Town, close to the sea on the west coast, the temperatures are lower than at Durban, for the latitude is higher and cold sea currents flow close to the coast. The average temperature in January and February, the warmest months, is 21 °C, with 11 °C in July, the coldest month.

To return to rainfall, most of the western half of the country receives less than 400 mm a year, with only 50 mm on the Atlantic coast south of the Orange River. This amount of rainfall is insufficient, for the annual evaporation from surface water exceeds 1,750 mm, typical of a semi-arid or arid region. The country's average rainfall is 475 mm, with the maximum on the coast in the south-east and south-west. Most of the rain falls in winter (April-September) on the west coast and in the south-west. In three-quarter of the country, 80 % of the rainfall occurs from October to March, i.e. in summer. Falls of snow are not sufficient to have any serious effect on surface runoff.

The rainfall pattern varies more as the amount of rainfall increases. In the areas with the highest rainfall, the divergence of the annual total from the average

can be from 20 to 300 %, with a 60 to 150 % range only in the areas with heavy rainfall in the east, south and south-west. The country has several thousand rain gauges which are read daily.

The average annual evaporation can vary from 1,250 mm in the south and east to 2,750 mm in the north-west near the Orange River. The annual evaporation varies less than the amount of rainfall.

Surface water

The country has more than 700 gauging stations, the majority of which have automatic measuring equipment. Flows are also measured at a number of dams. Rainfall/flow correlations have been established. The mean annual flow for the majority of the country has thus been estimated with reasonable accuracy.

For a rainfall of 125 mm, only 0.4 % of the water runs off, but for 2,500 mm (20 times greater) the proportion can be 80 % or higher (200 times).

As a general rule, 9 % of the rainwater reaches the rivers to provide surface flows, leaving 91 % for evaporation into the atmosphere and infiltration towards the aquifers.

About 75 % of the surface flow comes from only 32 % of the territory, an area 400 km wide extending north-east from East London. Only 15 % comes from the vast dry area in the north and west. Many of the watercourses have a large sediment charge: 0.8 % in the case of the Orange River.

I. GEOLOGY

South Africa has five large geological units:

(1) The Precambrian basement rock which outcrops in the north-west along the frontier with Namibia, in the north in two masses close to the Botswana frontier, and in the north-east along the frontiers with Mozambique and Zimbabwe; it includes:

- The Lower Precambrian of the eastern zone (the Swaziland system). Age: 3,300 million years. An intensely metamorphized system of granitogneiss, schists and quartzites invaded by Ancient granite (G_1);
- The Middle Precambrian: lavas, schists and quartzites invaded by granites (G_2);
- The Upper Precambrian with the Witwatersrand and Ventersdorp series, which includes 7,000 m of sediments: schists and sandstones, with gold-bearing conglomerates in many places, up to 600 m thick. This is a vast syncline 180 km long from east to west and 70 km wide. Several hundred gold mines are located here. South of Johannesburg the Witwatersrand is covered by lava to a depth of 4,000 m.
- The Terminal Precambrian with:
 - The Transvaal system (6,000 m thick), including:
 - The Black Reef series: conglomerates, sandstones and quartzites 800 m thick. It rests in discontinuity on the Precambrian basement;

- The Dolomites series: cherts and some banks of schists and quartzites (2,500 m thick, decreasing towards the north);
- The Pretoria series: 3,000 m of schists and quartzites and locally up to 1,000 m of lavas. With a trench 400 x 240 km in area filled with eruptive rocks: dolerites, red granites;
- . The Waterburg system: 2,000 m of coarse sandstones.

(2) The pre-Karoo Paleozoic formation (Cambrian-Lower Carboniferous), 6,000 m thick with, from bottom to top:

- The Nama system:
 - Tillite quartz sandstones of Kuibis (200 m);
 - Schwartzkalk black dolomitic limestones (300 m);
 - Schwartzrand black limestone (350 m);
 - Fish River sandstones and quartzites (800 m);
- The Cape system:
 - Table Mountain sandstones and quartzites (1,700 m);
 - Bokkeveld schists and sandstones (800 m);
 - Witteberg schists and sandstones (800 m).

(3) The Karroo formations which cover 600,000 km² or more than half of the country; 7,000 m thick in the south. They contain coal strata. The Karroo basin is 1,300 km long from south-west to north-east and has a maximum width of 600 km. It contains from bottom to top:

- Dwyka series (Upper Carboniferous) with schists and tillites: 800 to 1,000 m.
- Ecca series (Lower Permian) around the perimeter of the basin: maximum thickness 1,800 m;
 - With Lower Ecca (300 m): schists;
 - Middle Ecca (up to 500 m): sandstones and schists;
 - Upper Ecca (200 m): argillaceous schists;
- Beaufort series (Permian-Triassic): 3,000 m of continental sandstones and argillaceous schists;
- Stormberg series (Upper Triassic) with, from bottom to top:
 - Molteno beds (600 m): sandstones and argillaceous schists;
 - Red beds (50 to 500 m): sandstones and argillaceous schists;
 - Cave sandstone: massive white sandstones;

Drakensberg volcanic formations (Upper Triassic): 1,000 to 2,000 m of basaltic lavas;

(4) The intercalated continental (Triassic-Jurassic) of the coastal zone of the Cape: thick conglomerates, limestone lenses, diamond-bearing Kimberlite chimneys.

(5) The Cretaceous sedimentary coastal basins of marine origin: conglomerates, calcareous sandstones.

II. GROUND-WATER RESOURCES

The following are the main aquifers:

1. The fractured veins in the Karroo sediments and their hardened contact zones in these sediments. These dolerite veins constitute an intrusion system in the Carboniferous and Triassic sediments: sub-horizontal sedimentary schists and sandstones of low permeability and therefore unproductive. However, large yields are available from the dolerite veins of the contact-hardened sedimentary zones, which can be from a few centimetres to about 15 centimetres thick.

The dolerite veins can be detected by magnetometer. Down-the-hole hammers can penetrate these veins but the bits of percussion cable rigs cannot.

2. The fairly thick zones of alteration and fracturation of the igneous rocks such as granites and diabases, which can be up to about 100 m thick. This type of formation covers 20 % of the territory, and half of the country's water boreholes are located here. The decision to install a borehole is taken on the basis of geophysical prospecting to measure resistivity.

3. The sands and alluviums of the beds of dry watercourses or flood plains. These plains are usually small in extent and traversed by dolerites veins forming natural dams behind which are deposited the sands and silts carried down by the flood waters.

In some places similar accumulations of sand have been produced by the construction of an overflow dam across the bed of the watercourse which is gradually raised as the sand builds up. The sands constitute aquifers which are exploited for domestic use or for livestock.

4. The Transvaal dolomitic series which probably constitute the country's largest aquifer, for they contain major water resources in the interconnected dissolution channels in the rocks. These dolomitic masses are broken up into a number of separate compartments by impermeable veins of syenite. These compartments vary in size up to 100 km². The storage capacity of the two main compartments, Oberholzer and Venterpost, has been estimated at 600 and 400 m³ respectively.

The existence of a large number of these big water-bearing dolomitic compartments in the Far West Rand close to the industrial-mining-urban complex of Witwatersrand-Pretoria-Vereeniging fed by the Vaal River offers the possibility of exploiting these water resources as a reserve stock, for the losses through evaporation are very small in periods of drought, i.e. when the surface water resources are insufficient.

Complex studies have been carried out in order to decide the location of large-diameter boreholes or wells capable of delivering 400 m³/h in periods of drought. An effort has been made to investigate the fractured zones located at considerable depth below the water table.

The fractured zones are fault systems filled in many cases with porous, permeable and unconsolidated sediments. The "geological valleys" which form the main ground-water reservoirs are being investigated by means of geophysical gravimetric studies. The borehole locations are chosen so as to connect with a large concentration of dissolution channels and fractures deep below the unconsolidated deposits of the valleys. However, it is possible that the water resources tapped in this manner will be exhausted, for the drawoffs are far in excess of the natural recharge of the aquifer.

IV. EXPLOITATION OF THE GROUND WATER

Ground water is the only water resource of the vast arid expanses of South Africa. It supplies almost 15 % of all water consumed in the country, which has about one million water boreholes. Some 20,000 to 30,000 installations are constructed every year. The country has manufacturers of water-drilling equipment, in particular down-the-hole hammers, and pumps.

The consumption of ground water was as follows in 1980:

	<u>Million of m³</u>
- Urban areas (with industries and mines supplied from urban networks)	73
- Urban areas supplied from private boreholes	10
- Rural areas	120
- Watering of livestock (50 million heads)	100
- Irrigation	1,400
- Mines and quarries	<u>100</u>
Total rounded to	1,800

This total represents 15 % of a total consumption of water assessed at 12,200 million m³ in 1980. (Owing to the drought in 1983/84 the urban consumption from private boreholes was probably 40 million m³).

This proportion (15 %) should be compared with the figures for other countries: Netherlands (65 %), Israel (80 %), Denmark and Austria (98 %).

The reason why more use is not made of ground water in South Africa is that the hydrogeological conditions are not very favourable, for the Cretaceous, Cenozoic and Quaternary strata which usually contain the best aquifers occupy only a small part of the territory in small thin "pockets": narrow alluvial deposits, sandy deposits along the coasts, and lenses of sandstone and conglomerate of Cenozoic age in the Kalahari and at Bredasdorp-Stilbaai and Alexandria. Moreover, most of the Cenozoic and Quaternary formations in the Kalahari and on the west coast are located at a higher altitude than the surface of the ground-water aquifer.

The older formations of hard rocks of the Jurassic to Precambrian periods occupy 90 % of the country. These formations contain hardly any porous rocks. The water is held mainly in fractures caused by tectonic deformation and the "decompression" of surface rocks, at average depths of 10 to 50 m.

The primary porosity and permeability of the sandstones are as follows:

Age	Stratigraphy (group)	Porosity %	Permeability (m/s)
Upper Proterozoic		1.8 to 2.4	1×10^{-9}
Ordovician-Devocian	Table Mountain	1.1	Under 10^{-9}
Devonian	Bokkeveld	2.7 to 7	2×10^{-9} to 6×10^{-9}
Ancient Carboniferous- Devocian	-	1.4	Under 10^{-9}
Permian	Ecca	1.6 to 25	10^{-9} to 6×10^{-6}
Permian-Triassic	Beaufort	1.2 to 11	Under 10^{-9} to 10^{-8}
Triassic	Molteno	5 to 10	1.5×10^{-9} to 3×10^{-8}
Upper Triassic	Clarens	4.7 to 21	10^{-8} to 7.2×10^{-7}
Cretaceous	Vitenhage and Zululand	6.5 to 30	8×10^{-9} to 1.9×10^{-5}

With the exception of the Precambrian karstic dolomitic strata, the transmissivity of the hard rocks tends to be low and laterally very variable. The storage capacity is also low in comparison with other formations, especially karstified ones.

In these circumstances, there are few boreholes in hard rocks capable of delivering at least several litres a second.

The water resources of the various formations expressed as height of free (surface) water are as follows (metres);

	<u>Metres</u>
- Karstic dolomite and residuary cover in the Far West Rand before drainage	4.9 to 8.3
- <u>Idem</u> in the Grootfontein compartment in the Western Transvaal	1.9
- Sandy deposits on the Atlantic coast	2.5 to 5

	<u>Metres</u>
- Alluviums	2
- Decomposed granite	0.5 to 1
- Sedimentary Karroo	0.1 to 0.5

The recharge of the aquifers by rainwater infiltration has been estimated at between 16 and 37 billion m³. Only part of this total volume can be exploited at a sustained rate, owing to the losses of ground water through drainage of the watercourses and borehole pumping. In view of the small yield of some boreholes and the low transmissivity of the formations, in many cases it is not possible to exploit the ground water of the non-porous aquifers to meet large concentrated needs (towns, industries). Lastly, the ground water may be available in areas too far distant from the consumption centres (the case of the Karroo). In view of these constraints, it is probable that only 5 billion m³ of ground water can usefully be exploited in the whole country.

At the present rate of growth of ground-water installations, it is possible that this exploitation level of 5 billion m³ will be reached by about 2010-2020. In fact, the effective exploitation level will be determined to a large extent by the cost-benefit ration of irrigation and by the demand in urban areas, especially in view of the trend towards urbanization of the large African villages.

In some urban areas there was a remarkable increase in the number of private boreholes as a result of the 1983-1984 drought, particularly in the Pretoria-Witwatersrand-Vereeniging area, but this may be a merely temporary phenomenon.

Generally speaking, the quantity and quality of the ground water are acceptable to supply rural areas and livestock throughout the country. However, in some parts of the Kalahari the ground water is too saline to be used. Where the urban areas are concerned, about a hundred towns and bourgs are supplied exclusively from ground water, and 15 others partially so. In some cases the water is brought from a considerable distance away (for example, 40 km for the town of Aaar, which consumes about 2.5 million m³/day).

The dolomitic limestones of the Southern and Western Transvaal furnish large yields. Some studies have indicated that several tens of thousands of cubic metres a day could be drawn off from the upper strata of the dolomites and ribbed sandstones which overlie them in the Sishen-Kathu area.

The small towns in rural areas have various kinds of water-supply problems: lack of funds, difficulty of obtaining water for public use from private property; lack of knowledge about ground water, its exploitation and management; and preference for surface water.

Ground water from wells and boreholes was used to irrigate 178,000 hectares in 1976 (not counting 25,000 hectares irrigated from springs). In previous years, the irrigated area had increased by an average of 5 % a year. In 1976, 90,000 hectares were irrigated with ground water in the Transvaal; the figure for the Cape was 67,000 hectares.

The country's best aquifers are the karstic dolomites of Malami (Precambrian) or Southern and Western Transvaal, with their residual cover of Karroo sediments and

Quaternary deposits which can be over 150 m thick. The Malami dolomites are traversed by veins of dolerites and syenites which divide them into independent water-bearing compartments with considerable stocks of water: 730 million m³ for the Oberholzer compartment (area 154 km²); and 450 million m³ for the Venterpost compartment (54 km²).

The dry residue of the water is 100 to 400 mg/l. As a rule, the higher the rainfall, the better the water quality.

To sum up, it seems that ground-water exploitation could increase threefold over its present level from the standpoint of exploitable potential, but it is probable that only 15 to at most 20 % of the country's future water needs will be met from ground water.

The country's ground-water resources tend to be overexploited, for the needs have increased considerably in recent years owing to the population increase, the larger numbers of livestock, and the drought which has affected Southern Africa. This threat to the availability of ground water in the country is aggravated by impairment of the water quality by increasing use of fertilizers and pesticides in agriculture and by industrial development (chemical and mining industries).