ZAMBIA

Area: 753,000 km^2
Population: 6.5 million

I. BACKGROUND

Zambia is a landlocked State whose vast territory is almost cut in two at its centre by a kind of pincer movement of wedges of territory of Zaire in the north and Mozambique in the south.

Relief

The western part of the country is traversed by the Zambezi River which then forms the frontier with Zimbabwe. The Zambezi is interrupted here by the Kariba Dam, which has formed one of the world's largest artificial lakes - 250 km long and 40 km wide.

This western half of the country consists of a kind of regular plateau, 1,000-1,300 m above sea level, with a slightly higher area in the north rising to 1,600 m. This plateau is fairly well drained by major tributaries of the Zambezi, including the Kafue.

The eastern part of the country has more varied relief: it is cut in two by a ridge of high ground, the Muchinga mountains, running north-west to south-west. In the north there is a plateau 1,200-1,300 m high, the central lower part of which is occupied by the swampy area of Lake Bangweulu. In the south, the basin of the Luangwa, a tributary of the Zambezi, forms a vast depression between the Muchinga and Malawi mountains.

The highest ground is situated in the far north-east of the country: over 2,000 m above sea-level in the Mafinga hills (2,164 m).

The altitude declines steadily towards the Zambezi valley in the south-west and south. The lowest part of the country is situated at the confluence of the Luangwa and the Zambezi at Feira (329 m). To the west there are depressions occupied by numerous swamps, the largest of which is the Bangweulu swamp. Mention must also be made of the Mwere-Wantipa depression between Lake Mweru and Lake Tanganyika, the valley of the Chambeshi River, the broad plains along the Kafue, and the many swampy depressions in the west of the country.

Climate

Altitude has a moderating effect on the climate of the country, which is situated in the tropical zone. Broadly speaking, there is a cold dry season from May to August, a hot dry season from September to November, and a hot wet rainy season from October-November to the end of April. This rainy season can be interrupted by a "small dry season", for the maximum rainfall occurs in October-November and March-april. The average annual rainfall is highest in the north and north-west (1,400 m) and lowest along the southern frontier (620-759 mm). The average daily temperatures are about 18-20 °C during the cool dry season and 35 °C during the hot dry season, with an average of 30 °C in the rainy season.

Surface water

The river network is well distributed and well fed and it includes large and small watercourses.

The Zambezi, the largest river in Southern Africa, rises in the far north of the country. For most of its course it forms the frontier between Zambia and several neighbouring States (Namibia, Botswana and Zimbabwe).

Its total drainage basin, from source to mouth, occupies about 1.2 million km^2, 20 % of which is located in Zambia. The courses of two of its tributaries, the Kafue and the Luangwa, lie entirely within Zambia. The Chambeshi and the Luapula flow respectively into Lakes Bangweulu and Mweru, the latter forming part of the frontier between Zambia and Zaire.

The country has three large lakes. Lake Bangweulu is situated in the interior, while the other two form frontiers: Lake Mweru with Zaire, and Lake Tanganyika with Tanzania, Burundi and Zaire.

II. GEOLOGY

Zambia has the following large geological systems:

Precambrian basement, outcropping extensively in the north-east and east, and in the centre and south of the country. It consists of sediments, lavas and intrusive rocks, which have been affected by several episodes of metamorphism. This system is subdivided into two groups:

- The oldest basement formation as such, situated in the south-east along the Zambezi valley between Mazabuka and Livingstone, in the area between Lusaka and the Lunagwa, in the northern and north-eastern provinces, in the Copper Belt and in the central provinces. It consists mainly of gneiss, metamorphic schists, migmatites, amphibolites, granites and syenites;

- The most recent "Muva" group (Upper Precambrian) includes quartzites, quartz-schists, sandstones, conglomerates and phyllites. This group is in clear discontinuity with the preceding one: it occurs mainly to the south of the intrusion of Zaire into Zambia, in the Kapiri, Mposhi and Mkushi areas, north-east of Serenje in the area between Mpika and Chinsali, and in large areas of the northern parts of Luapula and Northern provinces.

The Katanga system is very well developed and of considerable interest from the economic standpoint, for it contains deposits of copper, lead, zinc and other minerals. The Katanga system dates to the Upper Precambrian/Lower Cambrian and includes the system of sedimentary rocks overlying the Muva group and underlying the Karroo group. This system is well developed in the north and north-west from Monga as far as the Zambia-Zaire frontier. It is divided into three subsystems:

- The Roan at the base (1,000-2,000 m) with conglomerates, dolomites, limestones, sedimentary schists and sandstones;

- The Mwashya (1,000 m) with tillites, sedimentary schists and coarse conglomerates;

- The Kundelungu at the top (1,500-3,000 m) with sedimentary schists, sandstones and stromatolithic limestones.

The Karroo system was formed between the Upper Carboniferous and the Jurassic. It is found in the basement depressions which follow the valleys of the Luangwa and the Zambezi and the Lusefua, Lusakashi and Rufunsa. Karroo strata are also found in a number of western zones near the Angolan frontier, where most of them are covered by Kalahari sands. The stratigraphic series includes sandstones and conglomerates, as well as carbonate strata with coal seams in places.

The Kalahari system of Cenozoic age occurs only in the west and south-west of the country, where it overlies the older formations over vast areas. It is relatively thin at its eastern edges and tends to thicken towards the west. The formation consist mainly of unconsolidated or consolidated eolian sands, gravels, clays and marls. Very few data are available from earlier hydrogeological studies. The most extensive research was carried out at Mongu in 1980 and 1982 when 10 boreholes were drilled at the edges of the Zambezi's flood plain. The first borehole was 134 m and the others 80 m deep.

III. GROUND WATER

Ground water is present in the fractured and altered zones of the basement formations. The alteration formations can be up to 30 m thick but most of them are only 10-15 m thick. The fracturation affects the upper part of the substratum of solid rock to a depth of 60-70 m. The ground water yields are generally large and depends on the degree of alteration and fracturation.

Lower group (crystalline basement): This group includes schists, migmatites, gneiss, granites and syenites. The following statistics refer to 106 boreholes:

Average depth (m)	Average drawdown (m)	Average yield (l/s)
53.5	24.2	1.4

Yield (l/s)	Number of boreholes	Percentage
Under 1	47	44
1-3	57	18
3-5	5	5
5-6	3	3

Upper group (Muva): This group consists of quartzites, schists, conglomerates and phyllites. The following statistics refer to 22 boreholes:

Average depth (m)	Average drawdown (m)	Average yield (l/s)
59	26	3

Yield (l/s)	Number of boreholes	Percentage
Under 1	5	23
1-3	11	50
3-5	5	13.5
5-6	3	13.5

This demonstrates clearly that the Muva group is generally more productive than the older basement formations. This is because its fractured and altered zones have better permeability and porosity. The smallest yields come from the phyllites, the joints and fractures of which are closed beyond a shallow depth.

Katanga system. This system includes Zambia's best aquifers: limestones, dolomites and dolomitic limestones, various distributed and with different hydrogeological properties. The transmissivity coefficient for the dolomitic limestones is about 800-1,000 m^3/day.

Sandstones, conglomerates, schists, quartzites:

Number of boreholes considered: 157

Average depth (m)	Average drawdown (m)	Average yield (l/s)
60	31	1.5

Yield (l/s)	Number of boreholes	Percentage
Under 1	72	46
1-3	66	42
3-5	15	10
5-76	4	2.5

This seems to indicate that the aquifers are only average.

Schists, dolomites, quartzites, limestones:

Number of boreholes: 84

Average depth (m)	Average drawdown (m)	Average yield (l/s)
52	20	3

Yield (l/s)	Number of boreholes	Percentage
Under 1	7	8
1-3	29	35
3-5	32	38
5-10	16	19

This system is more productive. The ground-water flow occurs in the fractures and fissures.

Limestones, dolomites, dolomitic limestones:

The rocks are traversed by a network of fissures and caves. The ground-water flow usually occurs in the upper part of the stratum, i.e. down to 30 m below the piezometric level. The aquifers have high transmissivity coefficients and hydraulic potential.

Number of boreholes studied: 190

Average depth (m)	Average drawdown (m)	Average yield (l/s)
	11	6

Yield (l/s)	Number of boreholes	Percentage
Under 1	11	6
1-3	29	15
3-5	52	27
5-10	83	44
10-20	13	7
	2	1

These boreholes were drilled mainly for co-operatives, farmers and landowners. Those with the highest yields were drilled to supply water to the municipalities of Lusaka, Kabwe and Ndole and to irrigate a State farm near Mpongwe. Unit yields of 35-50 l/s have been recorded from boreholes in the zones of limestone and dolomitic rocks. The transmissivity coefficient is about 800-1,000 m^2/day.

Karroo system

Few data are available on this aquifer system. The water resources depend mainly on the degree of development of the formations which have become compacted over time. The boreholes yield about 0.5 to 0.6 l/s. The sandstones and conglomerates have the best permeability and are therefore the most productive formations. The average yield is about 1.5 l/s. The average depth of the boreholes is 50 m.

Kalahari system

Hydrogeological research has shown that this system is a multilayer aquifer. The best aquifer horizons are those which contain fine or medium grained sands and gravels; the horizons containing silty sands have poor permeability with very slow ground-water flow. The marl and clay layers are impermeable aquicludes.

The studies carried out in 1980 and 1982 at Mongu verified that the unit yields of the boreholes were 15-22 l/s. The aquifer is of the widespread homogeneous and isotopic type. The average transmissivity coefficient is 100 m^2/day.

Water quality

The results of chemical analyses indicate that the ground water is generally fit for human and animal consumption. However, the water can be contaminated in the vicinity of the towns.

It must be pointed out that water analyses have not been made in all cases, and more detailed studies of water quality will have to be carried out in the future.

Some data on Zambia's ground water

Localities and districts	Formations	Observations
South province		
Livingstone	Basalts, Kalahari sands	Low yields, water sometimes saline
Kalomo-Choma	Alteration zone of granito-gneiss, quartz dykes and pegmatites	Well depth: 35 m Yield: 0.9-1.5 l/s (for 6-inch borehole); the water is under slight pressure in the quartz dykes (yield: up to 2-3 l/s)
Mazabuka	Lower Katanga: sandstone-schist	Well depth: 35 m Yield: 1 l/s (0.4 l/s in phyllades)
"	Middle Katanga: limestones, dolomitic schist-limestones, argillites	Low yield in argillites, 1-3 l/s in dolomites, 12 l/s on the Mazabuka fault
"	Upper Katanga: calcareous-siliceous rocks	
Munalipass	Biotitic schists	0.3 l/s
Kafue	Schist-limestones	1 l/s
	Upper Karroo sandstones	1-2 l/s (depth: 45-50 m)
Gwenbe valley	Karroo in a Rift Valley: schists, sandstones	0.2-0.5 l/s 1 l/s (water sometimes fluorine)
Central province	Synclinals of Katanga system isolated in basement depressions:	
	Dolomites	1-5 l/s (at 45 m)
	Fractured dolomites at Lusaka	2,000 m^3/day from 10-inch tubes
	Quartz dykes in the basement schists	1-2 l/s
	Granitogneiss north of Broken Hill	Insignificant yields
Western province (Copper Belt)	Katanga limestones and dolomites (pumping for copper mines)	Large yields (see above)
	Basement schists	0.5 l/s (35-45 m holes)

Exploitation of the ground water

The Water Service, which was established in 1943, now has five teams of hydrogeologists and geophysicists: three based at Lusaka, one at Monze and one at

Chipata. As a rule, the drilled wells have a diameter of 6 inches and an average depth of 50-70 m. At present (1986) the Service has 14 drilling rigs in operating order: 10 percussion and 4 rotary. Zambia also has two private drilling firms: Waterwell Ltd. and Geomin Ltd.

Water-drilling operations are carried out mainly for government bodies, municipalities, villages, para-State bodies, farmers and small landowners. The scope of the drilling works is restricted by a number of constraints such as lack of means of transport, geophysical prospecting equipment and personnel.

IV. CONCLUSION

Ground-water resources are of great importance in Zambia, a country where the network of permanent flows is sparse and most of the watercourses run dry in the dry season. The supply of water to towns, villages and industries and for irrigation has been improved in recent years by means of increased exploitation of ground water.

The most productive aquifers are the limestones and dolomites of the Katanga system. The boreholes in the areas of Lusaka, Ndola, Kobwe and Mpongwe yield up to 35-50 l/s. There are many boreholes in the dolomitic limestone formations which are used for irrigation, with yields of 10-20 l/s in some cases.

Second in importance are the sandy strata of the Kalahari system, which can yield 10-20 l/s per borehole for long periods. The aquifers of the crystalline basement and the Karroo system furnish smaller yields but sufficient to supply villages and small rural centres.

The exploitation of ground water in Zambia can only increase in the years to come owing to the growing demand and the relative abundance of ground-water resources. The conditions of ground-water deposits are more favourable in Zambia than in the surrounding countries with respect to the depths to be drilled, the useful porosity and the available unit yields.

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