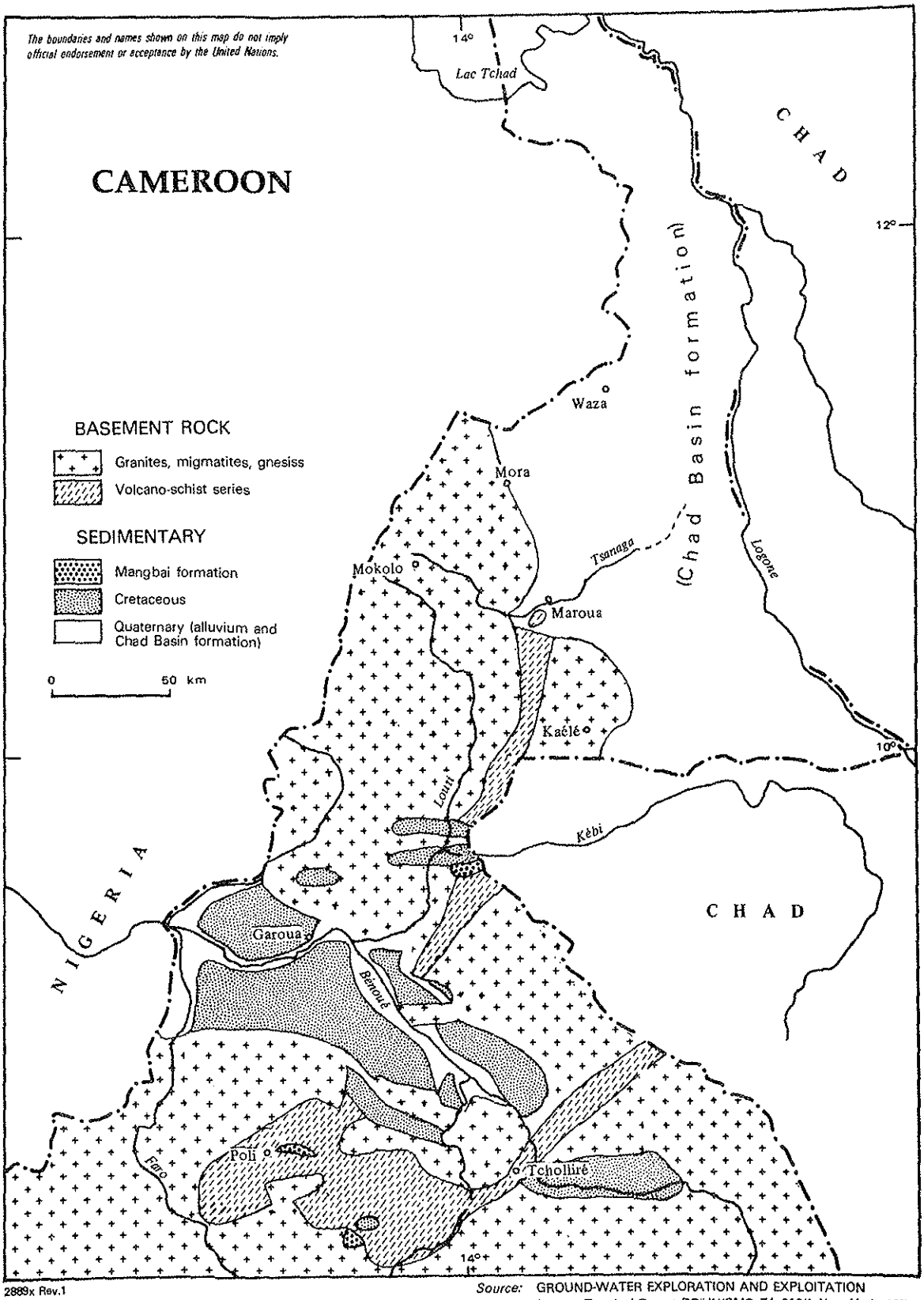

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Source: GROUND-WATER EXPLORATION AND EXPLOITATION Agency Terminal Report DP/UN/CMR-74-013/1 New York, 1979

CAMEROON

Area: 475,442 km^2

Population: 9.16 million (united Nations estimate, 1983)

I. BACKGROUND

Cameroon extends for more than 1,500 km from Lake Chad (far north) to Moloundou (far south) and it has a seaboard of 350 km on the Atlantic in the south-west.

The country is divided into two very different geographical regions by the Adamaoua Mountains which range in altitude from 1,500 to 2,500 m:

- The north, from Ngaoundéré to Lake Chad (altitude ranging from 300 to 750 m) has plains covered with savannah and some mountainous areas;

- The south and the centre have plateaus covered with equatorial forest. The coastal plain is dominated by Mt. Cameroon (4,070 m).

Climate

South of the Adamaoua Mountains the low-lying densely forested areas have an equatorial climate with two separate seasons: heavy rainfall from April to October, and a less wet season from November to the end of March.

The rainfall is very heavy from June to September. It reaches 3,963 mm at Douala and even as high as 10,500 mm at Bibundi on the southern and western flanks of Mt. Cameroon.

The average annual temperature is 26°C and there is little variation between a monthly minimum of 23°C and a maximum of 30°C.

The climate evolves towards the tropical type in the direction of the high plateaus of the west and of Bamenda, i.e. on high land. The rainfall is less heavy than in the forest zone, and the temperatures are more moderate with wider seasonal ranges (average annual temperature 20°C, monthly minimum 15°C, and monthly maximum 25°C).

North of the Adamaoua plateau the climate is of the normal tropical type with a very dry season from November to May and a rainy season from June to September.

The rainfall declines towards the north. It is 1,420 mm at Poli, only 977 mm at Garoua and 500-600 mm at Kousséri. At Garoua the climate is of the Sudanese type; it becomes Sahelian-Sudanese from latitute 9°N.

The temperatures are high with large seasonal variations. Maroua, for example, has recorded 11.2°C in December and 44.9°C in May.

Surface water

As a direct effect of the relief and the climate, the perennial rivers and streams are numerous south of the Adamaoua, whereas most of the streams in the north, called "mayos", are seasonal.

The following are the main watercourses in the south:

Watercourse	Flow	Length
Wouri	-	250 km
Moungo	-	Navigable for 110 km
Dibamba		
Sanaga	The average flow is 2,300 m^3/S; 6,500 m^3/s in October; it drops to 400-500 m^3/s at its lowest level	
Ntem	-	400 km
Mbam	-	400 km

The north has only two important perennial watercourses:

- The Logone, the main tributary of the Chari which flows into Lake Chad;

- The Bénoué, with 350 km of its course in Cameroon, flows into the Niger after having received Mayo Kebi as its main tributary, with an average flow of 400 m^3 s, which can decline in April to 2 m^3/s and increase at flood crests to 6,000 m^3/s at Garoua.

From September to October these two rivers flood vast areas; these flood waters act as reserve stocks during the low-water season.

Geology

Crystalline and metamorphic formations outcrop over 90 per cent of the territory of Cameroon. The sedimentary areas occupy the remaining 10 per cent, i.e. about 45,000 km^2.

The following are the main geological units:

The Precambrian basement rock (subdivided into three systems): the Lower Precambrian, a complex of granites, micaschists and migmatites; the Middle Precambrian (south-east, north of the Adamaoua around Poli), made up of a series of schists-amphibolites with intercalations of quartzitic sandstones and phyllites; the generally non-metamorphized Upper Precambrian, made up of tillites of sandstone and schist intersected by granitic intrusions (Lower Dja series).

The sedimentary formations are of Mesozoic and Cenozoic age.

Several clearly delimited sedimentary basins are found in the north and west of the country.

The coastal basin of Douala is composed mainly of marine sandstones and limestones of Cretaceous age which in places achieve thicknesses of 1,000 to 2,000 m. The base sandstone is overlain by Paleocene, Miocene and even Quaternary sands.

The Lake Chad basin is composed of a succession of mainly sandy-argillaceous formations from very old to very recent in age:

- The sandstone-clay interbedded continental;
- The terminal continental - 200 to 400 m of sands with interbedded sandstones;
- The Lower Pliocene represented by sands;
- The Upper Pliocene including multicoloured clays;
- The Early Quaternary with clays and sands, sometimes in lenses;
- The clay-sand alluviums of the Lake Quaternary and recent alluviums.

The Garoua basin includes Cretaceous formations with the following main subdivisions:

- Lower series of clays and sandstones in the south-east;
- Upper series of sandstones in the west of the basin.

Mention must also be made of the smaller sedimentary basins of Koum, Babouri-Figuil, Mayo Oulo, Mayo Sorawel, Mamfé, Bamusso and Djerem.

A series of parallel fractures running north-east/south-west, with faults whose displacements sometimes reach 1,000 m in the axis of the trench, throw up large volcanic massifs of various ages and compositions from the Adamaoua to the Atlantic. Many thermal springs emerge from these volcanoes.

II. GROUND-WATER RESEARCH

The Hydrogeological Service, a national service in the Department of Mines and Geology, is responsible for the inventory of ground-water resources throughout the country, the monitoring of aquifer fluctuations, the collection of the results of all water-drilling operations and, where necessary, the issue of drilling or pumping permits.

It also acts as adviser to the users of ground water, the final goal being the rational and planned exploitation of ground water.

In 1972 the ground-water project financed largely by UNDP strengthened the Hydrogeological Service by training local drillers and furnishing drilling equipment (drills, compressors, etc.).

Background

The Agricultural Engineering Service was set up in 1952 to take charge of livestock and village water supply in the northern part of Cameroon.

In 1953 the Department of Mines and Geology put Mr. P. Schwoerer, a geological engineer, in charge of the "Hydro-North" mission, which was designed to study hydrogeological problems and offer advice to executing agencies such as the Agricultural Engineering Service.

This mission was replaced in 1961 by the hydrogeological research mission and 1962 saw the establishment at Garoua of the "Water Office", which subsequently became the Hydrogeological Service.

From 1962 to 1964 the Fonds d'aide et de coopération (FAC) financed the study of three hydrogeological systems:

- The big flats, the spreading zone of seasonal rivers or mayos;
- The isolated and discontinuous surface aquifers;
- The dune system (from Limani to Yagoua).

A number of ad hoc studies were carried out from 1965 to 1969, including in particular some regional studies such as those on:

- The Mandara Mountains (C. Dassibat, BRGM), which led to the sinking of wells and construction of a number of dams in the Mandara Mountains;
- The Cretaceous basins (Wakuti Co.). The Middle and Upper Cretaceous basin of the Bénoué and the Lower Cretaceous basins of Hama Koussou, Babouri-Figuil and Mayo Oulo;
- The artesian aquifer of the Chad plain (geophysical prospecting) carried out by Lerici Co.;
- The Logone aquifer (M. Biscaldi, BRGM).

From 1972 to 1975, as part of the ground-water research and exploitation project financed by UNDP and executed by the United Nations, the Office for Hydrogeological Studies (Pisa, Italy) studied a number of priority areas (about 30 sites) for the installation of wells and boreholes with a view to the exploitation of the ground water, with a training sector for national drillers.

This project was extended until 1977 with a second phase consisting mainly of a borehole programme.

From 1978 to 1983 the FSAR project (Special Fund for Rural Actions) took over the UNDP project and implemented a programme of 430 boreholes.

Activities

The Hydrogeological Service sinks wells and boreholes after interpretation of the photo-geological documents and field surveys. It also monitors the

drilling works and prepares water-chemistry maps on the basis of several chemical analyses.

It must be made clear that all the hydrogeological work in connection with ground-water research undertaken by the National Service has been concentrated almost exclusively in the northern part of the country, which has a sub-Sahelian climate. Studies have just begun (1985) in other regions, especially in Mbam (Arlab Studies Office) and were to be extended to the rest of the territory (1985).

Equipment and Specialized Personnel

From 1954 to 1955 the "Hydro-North" mission had three light drilling rigs which could reach a depth of 15 m in soft terrain and one Rotary Caly which could reach 80 m, also in soft terrain.

From 1960 to 1964 the hydrogeological research mission and subsequently the Water Office gradually acquired:

- Three Boilot winches mounted on trailers and driven by Bernard diesel motors; this equipment could operate down to a depth of 50 m in soft terrain;

- Four portable Platy and Banka hand drills for shallow alluviums;

- One APEC OK Bonne Esperance drilling rig, convertible from rotary to percussion, down to 200 m;

- Two small Toy and Explorer continuous coring rigs.

With the exception of one Boilot winch, this equipment is not in use.

The Ground-Water Project

Three drilling units supplied under UNDP and World Bank projects are at present being used in a national project: the Ground-Water Project (GWP); the equipment includes:

One Failing 250 rig which can reach 80 to 100 m in soft terrain; this is a rotary rig but used with a compressor it can also operate as a down-the-hole hammer;

- One Stenuick rig which operates only as a down-the-hole hammer with five-inch diameter; it can reach 80 m in crystalline formations;

- One Ingersoll Rand TH 60 convertible rig (rotary and down-the-hole hammer); this is the most recent acquisition and it can exceed 400 m with three-inch diameter in any formation.

Well-digging equipment has been furnished under the UNDP project. It includes compressors, pneumatic hammers and motor winches.

The Hydrogeological Service has a well equipped laboratory with research and testing equipment such as limnimetric probes to measure the water levels in the holes, screens for granulometric studies, submersible pumps for pumping tests, and a number of pH-meters, conductivity meters, etc. It also uses Johnson electro-geophysical and diagraphy equipment.

The personnel includes two engineers, two geologists, four technicians and a number of drillers.

The ground-water project is directed by a geologist assisted by an administrator.

Prospecting methods

At the beginning of the implementation of the FSAR project a geophysical prospecting campaign was carried out in the most difficult areas (bedrock, thin alterite stratum under zones of basement uplift, dune zone) by a BRGM geophysicist working in collaboration with two Cameroon senior geophysical technicians. This campaign added to the electro-geophysical data produced by the Lerici, Hydrogéo and Hydro-plan campaigns.

A BRGM hydrogeologist then worked with the team of geologists on the aerial photographs, the results of the geophysical campaign and the data collected in the course of field surveys for installations in areas of discontinuous aquifers (dune zone, Mandara Mountains) and in crystalline formations (syenite of Mindif, Kaélé, etc.).

In Cameroon geomorphological observations and structural geology form the basis of hydrogeological prospecting. The available aerial photographs do not cover all the villages concerned. The most frequently used research tools are the inventory of water points and the structural map showing faults, discontinuities, fractures and vegetation. They generally give fairly satisfactory results.

III. GROUND-WATER RESOURCES

Cameroon has three hydrogeological systems:

- The crystalline basement rock;
- The small sedimentary basins;
- The areas of widespread aquifers, mainly Logone-Chari-Chad.

Precambrian and metamorphic crystalline basement rock

Crystalline rocks cover nine-tenths of the total area of Cameroon. There are also many more areas with outcrops of bedrock (Mindif, Guider) and areas in which the rocks are covered with a more or less thick layer of alluviums and alterities.

In these regions the aquifers are usually small and limited to favourable sites where the rock is fractured and faulted. The best yields are obtained in areas where the fissured rocks are overlain with a thick stratum of alteration or alluvium (big flats of the mayos).

The yields are usually 1-3 m^3/h in the region of the Mandara Mountains and can attain 30 m^3/h in places in the Kribi region (Hévéacam drilling on a covered fault).

Small Cretaceous sedimentary basins

The sedimentary basins of Hama Kossou, Babouri-Figuil, Sorawel and Mayo Oulo contain aquifers from which wells and boreholes can draw a maximum of 5 m^3éh per unit.

The basin of Mayo Oulo has an area of 120 km^2; it contains two aquifers: one phreatic and one artesian, tapped by a GWP borehole in 1982 at Sorawel between 120 and 148 m and giving a yield of 500 l/h.

The Koum basin has an area of 1,200 km^2; water is found in the sandstones at Gouga, but its characteristics are not known.

Widespread aquifers

In the Bénoué basin, which has Lower and Upper Cretaceous formations, the permeability coefficient (K) is between 10^{-5} and 10^{-4}m/s (Garoua sandstone). The transmissivity coefficient (T) is between 3×10^{-3} and 2×10^{-2} m^2/s.

The storage coefficient (S) is 2.5×10^{-2}.

The sub-outcrop aquifer of the Quaternary basin of Chad is fed deep underground by the watercourses (Chari, Logone, Serbewel). The transmissivity (T) ranges from 4×10^{-5} m^2/s to 7×10^{-4} m^2/s.

In the Douala basin there are four aquifers located in:

- The base sandstones exploited by shallow boreholes in outcrop zones;
- The Paleocene sands which cover 80 km^2;
- The Post-Eocene and Oligocene formations;
- The Quaternary formations exploited by industries at Bassa to the extent of 1,400 m^3/day.

In the area of Mayos Tsanaga and Kalia the piedmont aquifers have variable yields of 40 to 80 m^3/h; they are exploited to supply Maroua. T = 8×10^{-3} to 4×10^{-2} S = 2.5×10^{-2}.

The depth of the aquifers and the installations (in order of magnitude) is as follows:

Geological period; aquifer depth	Geographical location	Depth of wells and boreholes (m)
Cretaceous Bénoué sandstones - 30 m in the west, rising almost to the surface near the Bénoué	Northern Cameroon	40 to 200
Paleocene sand aquifer, 20-37 m	Douala Basin	60 to 200
Quaternary terminal continental and intercalated, 7-36 m	Chad Plain	30 to 600
Small Cretaceous basins	Hama Kossou, Babouri-Figuil, Mayo Oulo	120 to 180
Piedmont aquifer - Quaternary alluviums on crystalline bedrock	Northern Cameroon	12 to 39

IV. CHEMICAL COMPOSITION OF THE GROUND WATER

The chemistry of the water varies throughout the country. In the Bénoué basin the water has a very low mineral content and a low pH content (5.1) and it is therefore very acid.

The basic composition is as follows (mg/1):

Dry residue	= 50	HCO_3	= 24.4
Ca	= 2.4	Cl	= 1.2
Mg	= 0.9	SO_4	= 9
Na	= 1.3	NO_3	= 2.1

In the Chad basin (Logone, Chari, Chad) the salt content varies greatly from south to north near Lake Chad. The water generally has a low mineral content.

Hôpital de Yagoua pH = 6.2 Composition in mg/1

Calculated dry residue	= 102		
Total salinity	= 129		
Ca	= 16	HCO_3	= 44.6
Mg	= 4.4	NO_3	= 0.2
Fe	= 0.004	PO_4	= 0.2

Tildé

pH	= 6.5		
CaO	= 53	Cl	= 3
MgO	= 17	SO_3	= 14
K_2O	= 57	SiO_2	= 54
Na_2O	= 27	NO_3	= 20

Douala Basin (Paleocene)

Water with very low mineral content (dry residue below 170 mg/1)

pH = 4 to 6

CO_2 = 40 mg/1

Fe = 0.7 to 3.5 mg/1

In the crystalline rocks the water is usually more mineralized than in the other areas, as can be seen in from the following three examples:

	Boula-Ibi (granites)	Mindif (syenites)	Badjengo (embrechites)
pH	7.6	7.4	7.1
Cl	40	68	8
P_2O_5	-	-	3
SO_3	14	24	8
SiO_2	50	50	74
CaO	184	202	85
MgO	66	35	29
K_2O	20	-	8
Na_2O	77	78	25

The water in the sedimentary formations, although of good chemical quality, usually has a high iron content, for example 1.4 mg/l in the Akassou Yagoua borehole and 3.7 mg/l at Douala.

Although many local studies have been carried out, it is still not possible to evaluate the ground-water resources of Cameroon or to draw up a water balance. The periods of drought in recent years, which have caused wells to dry up, have underlined the importance of making observations of the fluctuations in aquifers and studying the measures to be taken for their recharge.

The dune zone, i.e. the vast and wide belt of dunes from Limani to Yagoua, poses serious problems for ground-water research. The drilling operations in this zone have so far all produced very disappointing results, despite the joint use of aerial photography and geophysical techniques. The intention is therefore to extend the prospecting into the underlying crystalline formations between 30 and 45 m deep.

V. EXPLOITATION OF GROUND WATER

Bodies concerned

Ground-water exploitation is the responsibility on the one hand of the Department of Agricultural Engineering and Village Hydraulics, which digs the wells and waterholes to supply the villagers and their livestock, and on the other hand of the National Water Company of Cameroon (SNEC) which has a monopoly of water distribution in the urban centres. SNEC is a semi-public company represented in each province by a regional office. It commissions and finances the exploitation boreholes to supply towns such as Douala, Garoua, Maroua and Kousséri. The Department of Agricultural Engineering is also represented in each province.

Cameroon has two private drilling companies:

- FORACO (Forage rationnel construction)

- SOTRAHY (Société de travaux hydrauliques)

and also a drilling service which operates mainly in rural areas: the Ground-Water Project (GWP).

This project is an offshoot of UNDP project CMR 74/013. It has the three drilling rigs mentioned above, namely a Failing 250, a Stenuick and an Ingersoll-Rand.

In several months of field operations per year GWP has drilled 84 to 120 boreholes 40 m in depth, i.e. a total of 3,500-5,000 m.

The personnel includes four drillers and three assistant drillers trained on the site. The technical qualifications of the drilling personnel needs to be somewhat improved, especially with respect to the use of muds, the installation of filter blocks and the repair of the machinery.

SOTRAHY is a small drilling company which has been operating in Cameroon since 1979. Depending on the year and the number of orders, it has drilled between 800 and 2,000 m a year (exceptionally, 5,000 m).

FORACO is a French drilling company operating in several African countries. The metrage drilled in Cameroon is very variable and depends on orders: from 600 to more than 3,600 m/year.

Users

The main users of ground water are SNEC to supply certain urban centres, the Ministry of Livestock for the watering of animals and the Department of Agricultural Engineering and the National Rural Development Fund (FONADER) for village water supplies.

The main towns supplied with ground water are:

Garoua: with 10 boreholes the town of Garoua consumes 15,000 m^3/day, to which must be added the production of a number of private boreholes for industrial use such as those of Cameroon Breweries (1,000 m^3/day), SOCAPROD, the Veterinary Laboratory and the Office of Scientific Research. A total amount of 1,700 m^3/day is drawn off from the Garoua aquifer.

Maroua: 3,500 m^3/day are exploited by SNEC with four boreholes, to which must be added a number of private boreholes, making a total of 5,000 to 6,000 m^3/day;

Guider: a drain in Mayo Guider gives a variable yield of 500-750 m^3/day in high-water periods, decreasing at low water (April-May) to 250 m^3/day, which is quite inadequate for the town's needs;

Kousséri: two artesian boreholes producing 500 m^3/day feed part of the town; six shallower borehoes with yields of 6-10 m^3/h installed by GWP and equipped with hand pumps with a capacity of 700 l/h supply the peripheral districts; the total extraction is about 640-700 m^3/day;

Waza: to meet the hotel requirements in the National Park, two boreholes operating alternately each delivers 10 m^3/h, a total of 240 m^3/day;

Douala: at present 12 SNEC boreholes produce 60,000 m^3/day. In addition to these major exploitations, mineralized water is drawn off from the Adamaoua mainly to water livestock, and ground water is drawn off for bottling; for example, at the northern tip of the Douala sedimentary basin Cameroon Breweries market water drawn from a borehole. Water from the Muyuka basalts will also be exploited by borehole in the near future and sold as table water.

In the rural areas and especially in north Cameroon all the villages have at least one well dug by the Department of Agricultural Engineering. The yields are very variable: from a few m^3/h to nil in the dry season.

At present the region has about 340 boreholes equipped with hand pumps discharging 700-800 l/h distributed among the Departments of Bénoué, Mayo Danai, Margui Wandala, Logone et Chari, and Diamaré.

Ground water is not yet used for irrigation purposes. This is planned at Afade (Kousséri region) for rice growing. The medium-term requirements (1990-1995) are estimated as follows: 30,000 m^3/day for Garoua, 100,000-200,000 m^3/day for Douala (100 litres per day per inhabitant), 5,000-10,000 m^3/day for Maroua, and 1,500-2,000 m^3/day for Yagoua.

The exploitation of ground water is not envisaged for other towns.

Problems

At Douala the problem of salt-water invasion exists above a certain level of exploitation and over a fairly well defined area.

At Garoua where the stocks are limited (45,000-50,000 m^3/day) and at Maroua uncontrolled exploitation may lead to the rapid exhaustion of the aquifer. Already at Garoua there has been a significant decline in the aquifer (10 m) in the area exploited by the oldest boreholes.

Water-balance studies must therefore be carried out immediately (recharge, exploitation) to determine the protected areas reserved exclusively for urban supply. It might even be decided that certain aquifers could be exploited only for this purpose.

VI. CONCLUSION

Importance of ground water

In Cameroon the importance of ground water varies from region to region. In the provinces of the north and the far north (Guider, Poli, Tcholliré) ground water is the only resource available during the long dry season, i.e. from October to June, for the mayos (seasonal rivers) and the waterholes are then dry. On the other hand, south of the Adamaoua the water is more abundant: most of the villages are supplied from surface water (springs, rivers, etc.). Only the risk of pollution during the low-water period threaten the supply to Douala, which already has integrated use of ground and surface water.

Ground water is vital for the northern part of Cameroon. The establishment of permanent water points close to concentrations of population enables the people to give more time to agricultural or domestic tasks by reducing the distances they have to go to obtain water. It must be realized that when the water point is 10 km from the village, the walk there and back to fetch water takes between five and seven hours for buckets or containers of 15 to 30 litres. It takes less than an hour when the wells or boreholes are close to home. Furthermore, the installation of modern water points reduces the incidence of water-borne diseases such as bilharziosis. The improvement of sanitation standards promotes increased productivity and can lead eventually to better living conditions.

Cost of ground water

The cost of the water is very variable. It depends on the cost price of the water point (borehole or well), its capacity and the means of drawoff (foot or hand pump or bucket and rope). The unit cost per cubic metre is calculated on the basis of the cost price of the installation, its probable life and the various costs of maintenance and drawoff. For the existing 400 or so water points (usually boreholes equipped with foot or hand pumps) a distinction must be made between satisfactory water points and boreholes which are used for about 10 hours a day and those with low yields which are used almost 24 hours a day.

On the basis of an amortization period of five years, the average cost of the water is about CFAF 150 per cubic metre (about US $0.40 in April 1986).

The cost is roughly the same for the 20-metre wells dug by Agricultural Engineering.

Given the increasingly severe drought, especially in the north of the country, it is becoming ever more necessary to extend the search for and development of ground water to meet human and livestock requirements.

Operation FSAR II (Special Fund for Rural Actions) initiated in 1984 envisages the installation of 1,000 village boreholes equipped with hand pumps, the creation of maintenance facilities at village and department level and the installation of piezometers in the far-north province.

The Hydrogeological Service is to be strengthened in staff and equipment and it will be responsible at the national level for the inventory, protection, exploration and exploitation of ground water, for which operations it has its own drilling equipment furnished under the Ground-Water Project.

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