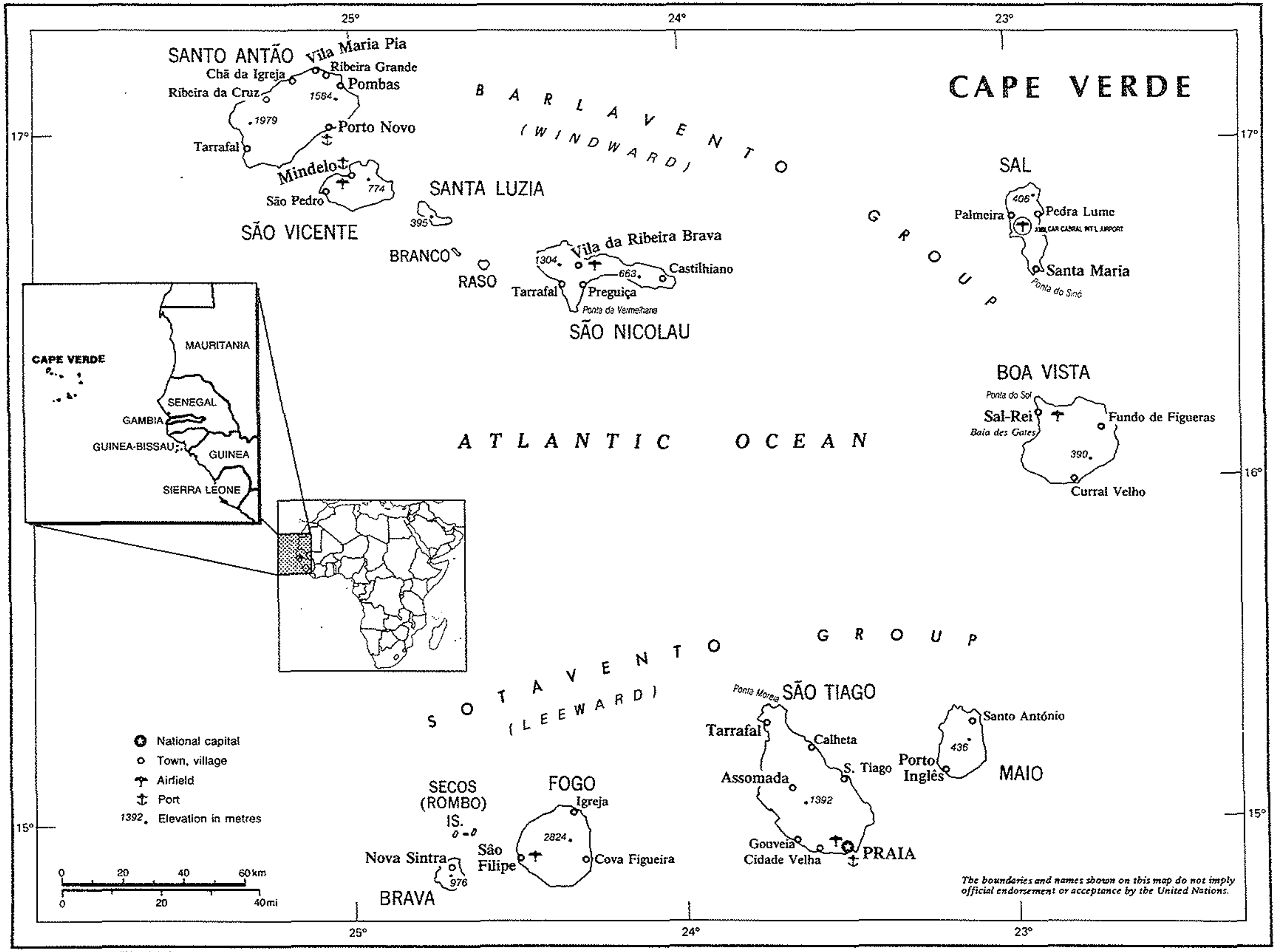


MAP NO. 2220 REV. 4 UNITED NATIONS
JULY 1984

CAPE VERDE

Area: 4,033 km^2

Population: 310,000 (United Nations estimate, 1983)

I. BACKGROUND

Physical geography

The Cape Verde Archipelago is located about 700 km off the coast of West Africa on the latitude of Dakar. It has 10 main islands and five smaller islands which form two groups:

- the Windward Islands, including Santo Antao, Sao Vicente, Santa Luzia, Sao Nicolau, Sal and Boa Vista;

- the Leeward Islands, including Maio, Sao Tiago, Fogo and Brava.

Sao Tiago is the biggest island, with an area of 991 km^2. It has the country's capital which is also the largest town: Praia.

From the geomorphological standpoint there are two types of island: the low flat islands of Maio, Boa Vista and Sal, and the high islands of Santo Antao, Sao Nicolau, Sao Tiago, Fogo and Brava, with elevated topography and pronounced relief with slopes of more than 45 degrees in many places. The maximum altitude (2,289 m) is reached at the peak of Fogo volcano only six kilometres from the sea. Here are found almost all the forms of landscape typical of the volcanic activity which produced the islands: basaltic mesas deeply gashed by river erosion, and sharp peaks and crests, all evidence of ancient volcanic formations, but also well preserved volcanic cones produced by more recent eruptions. Fogo is remarkable for its enormous "caldron" from which emerges the present 1,000-metre volcano. The steep coastlines of the high islands, with cliffs of 100 m and higher, contrast sharply with the broad sandy plains of the low islands.

Climate

Cape Verde's climate is of the dry subtropical type; it corresponds to the mainland climate in the Sahelian zone on the southern edge of the Sahara. Almost all the islands are subject to the trade winds blowing from the north-east and east which are usually dry and cool. The rainy season is short and lasts from July to October. The precipitation is caused by the northwards displacement of the zone of intertropical convergence, but the islands are usually affected only by the northern sub-zones with their low moisture content. This means that the rainfall is almost always torrential and irregularly distributed in space and time, delcining from south to north, as can be seen from the annual rainfall statistics (1950-1973) for the low islands:

Maio - 219 mm

Boa Vista - 128 mm

Sal - 84 mm

In the high islands these values are affected by the relief: they can double or even triple. The following average amounts of rainfall were measured on Sao Tiago (1949-1970):

Praia (altitude: 64 m) - 260 mm

Trindade (205 m) - 355 mm

Curralinho (950 m) - 906 mm

There can be some light rain in the dry season, more especially at high levels and on the windward slopes. This occurs when cold air from the north meets the high land.

The temperatures are moderated by the small size of the islands and the influence of the ocean. The monthly averages rarely reach 30°C. Praia has recorded a maximum daytime temperature of 36.2°C (1941-1960) and a minimum of 16.2°C. The average monthly temperatures range from 26.8°C in September to 22.2°C in February.

Owing to the hot sunshine and the strong winds, the average evaporation (Piche) is high, especially in the coastal areas:

Praia, Sao Tiago (1941-1960) - 2,730 mm/year

Mindelo, Sao Vicente (1931-1960) - 1,684 mm/year.

On the upper slopes the evaporation does not exceed 110 mm per month. The evaporation calculated for 1981 by the Penman method was high:

Praia (64 m above sea level), Sao Tiago - 2,226 mm

Trindade (205 m), Sao Tiago - 1,773 mm

Sao Jorge (3.9 m), Sao Tiago - 1,304 mm

Population

Nine of the 10 main islands are inhabited. In 1980 the total population was 296,093, distributed as follows:

Island	Total	Population Urban (percentage)	Rural (percentage)
Boa Vista	3,397	39	61
Brava	6,984	26	74
Fogo	31,115	13	87
Maio	4,103	35	65
Sal	6,006	70	30
Sao Tiago	145,923	33	67
Santo Antao	43,198	20	80
Sao Nicolau	13,575	15	85
Sao Vicente	41,792	88	12
Total	296,093	36	64

Thus the population is mainly rural, except on Sao Vicente and Sal where almost all the people live in the towns. The main towns are Praia (Sao Tiago) with 37,480 inhabitants and Mindelo (Sao Vicente) with 36,265 inhabitants. The average age is 25. Half the population is under 20.

One peculiar demographic feature is the lack of population in the 30-40 age group. If the annual growth rate (three per cent) and the emigration rate remain at their present levels the population will be 485,000 in 2000. However, according to the National Development Plan, it would be undesirable for it to exceed 420,000.

Surface water

Cape Verde has no lakes or permanent watercourses; the small size of the hydrographic basins, usually narrow and long, and the steepness of the slopes produce flash floods in the valleys and large quantities of solid matter in the water. A small amount of runoff can still occur some days after the rains.

There is hardly any means of measuring the rate of flow of the country's watercourses. But some estimates of surface runoff have been made (United Nations, 1980):

Island	mm/year	Rainfall (percentage)
Sao Tiago	108	34
Fogo	182	40
Brava	122	35
Maio	15	15
Boa Vista	10	13
Sal	10	13
Santo Antao	125	36
Sao Nicolau	37	25
Sao Vicente	10	13

Experiments are being carried out at present (1984) in two basins on Sao Tiago to measure, inter alia, the rates of flow and runoff. A first partial and approximate measurement has indicated a value of 14 per cent.

Geology

Although a considerable amount of geological work has been carried out in the Archipelago during the past 20 years, it has not advanced beyond the stage of a general survey.

Like most islands in the Atlantic, the Cape Verde Archipelago is of volcanic origin. Basaltic and pyroclastic rocks cover about 83 per cent of the surface, and phonolites and associated rocks about nine per cent. The petrographic sequence is as follows: 1) basaltic lavas; 2) phonolitic heavily alkaline lavas; 3) recent and contemporary basaltic lavas.

Sedimentary rocks are found on all the islands but over small areas and especially in the peripheral zones. Outcrops are found in notable quantity only on Boa Vista and Maio. They are usually thin, except on Maio where the outcrop of calcareous rocks attains a thickness of 435 m. Calcareous rocks are widespread (90 per cent). Oligocene-Miocene conglomerates are also found. The sedimentary rocks, although not extensive, are of major importance for study of the stratigraphy by virtue of the fossils which they contain.

Geological units

The oldest formations are the marine sediments, mainly limestones and neritic marls of the Lower Cretaceous (Neocomian) period and sometimes of the Upper Jurassic (Portlandian) period, which outcrop on Maio. Between the Cretaceous and Eocene periods complex and prolonged eruptive activity produced what has been called the "ancient internal irruptive complex". This complex forms the central core of the islands. With the exception of Fogo, Brava and Sal where the outcrops are small or non-existent, this complex is readily discernible. It is the formation with the most varied lithology with intrusive granular rocks such as gabbros, syenites, essexites and carbonatites, veins, breccias, basaltic tuffs and small intrusions of phonolites. Breccias and basaltic veins predominate, and sometimes the veins make up 50 per cent of the formation. These are compact rocks, heavily altered on the surface.

Following a long period of erosion, volcanic activity occurred at the beginning of the Miocene era with a very explosive phase which formed in particular the submarine breccias of the Flamengos formation on Sao Tiago with a small and variable proportion of pillow lavas, the breccial conglomerate (continental) of the dos Orgaos formation, also on Sao Tiago, and a few continental breccias on Maio.

After a period of erosion in the Miocene and Pliocene eras, a system of volcanic, mostly basaltic rocks came to occupy a vast area of the islands and form the main reliefs. Sometimes called the "intermediate series", these rocks are known on Sao Tiago as the "eruptive complex of Pic d'Antonia". It is possible to distinguish in this system:

i) A lower explosive part where brecceas and pyroclastic material predominate; it achieves its maximum development in the lower vein complex of Santo Antao and Sao Vicente; there is also a submarine phase of abundant pillow lavas associated with tuffs; it appears mainly on Sao Tiago but also on Sao Nicolau;

ii) The relatively thick upper part can attain several hundred metres; it is composed mainly of basaltic beds alternating with ancient alluviums, pyroclastic deposits and base breccias.

The last great upheavals of the Pliocene era produced the Assomada formation (Sao Tiago) which includes thick basaltic strata in unconformity with the previous series.

With the exception of Fogo, the Archipelago's only active volcano, the volcanic activity ended with the eruptions which produced the recent series of Pliocene-Quaternary age in which uncompacted pyroclastic elements predominate, forming in the majority of cases well preserved volcanic cones with some associated flows. The latter are commoner on Santo Antao.

Owing to the morphological factors (narrow, deep and steeply-sided valleys), alluviums are rare, except on Santo Antao, Sao Tiago and Sao Vicente where they are fairly widespread. In most cases they are poorly sorted and coarse, especially in the lower part, and the sand and limestone content increases in an upward direction.

Tectonic structures

Little is known about these structures; the majority of those which have been studied are pseudo-tectonic or volcano-tectonic. Only three main faults have been identified (Mitchell-Thomé, 1972): a) an incurved north-south fault on the western edge of Campo da Preguiça, Sao Nicolau; b) an inverse fault parallel to the north coast on Santo Antao, responsible for the lifting and northwards tilt of the block between Ribeira Grande and the coast; c) lastly, a large fault running north-north-west/south-south-east in the south-east of Maio, with a displacement of 450 m; this would be part of a deep-lying diapiric structure. The results of gravimetric measurements seem to confirm the existence of a rift caused by the intrusion of essexites under Maio. This is the only island where aerial photography has revealed a dense fault system running in four main directions: north-south and east-west and diagonally. The present work (1984) on Sao Tiago indicates the same main directions and points to the existence of a minor fault running north-east/south-west in the south-east of the island.

The basalts are intensely jointed but there are no detailed studies on this topic. Very few noteworthy unconformities have been identified. The main one is the 75° angular unconformity between the horizontal Tertiary limestones and the Mesozoic limestones. Erosional and sometimes angular unconformities are found in the various volcanic units. They can be regional, such as the one between the ancient internal eruptive complex and the intermediate series/Pic d'Antonia formation, or local such as those found in the latter formation.

The steep slopes of the Mesozoic strata on Maio are exceptional. These slopes are usually gentle throughout the Archipelago: 20° to 30° and even less on Sao Tiago.

The generation of these volcanic rocks in the Pic d'Antonia formation, which constitutes a stratified volcanic complex, and the major or minor erosional unconformities have produced intense lithological heterogeneity.

II. GROUND WATER

Organization of the water sector (1984)

As the table below shows, many bodies play a part in the development and management of water resources, but the main responsibility rests by governmental decree with the Ministry of Rural Development. The activities are distributed within this Ministry as follows:

- The Studies and Planning Office co-ordinates the activities of the various technical services and the many foreign aid programmes;

- The Department of Ground-Water Exploitation and Management is responsible for the prospecting, exploitation and control of ground water resources.

- The Department of Agricultural Engineering is responsible for the construction of reservoirs, public water-supply systems, irrigation channels, small dams, etc.;

- The Department of Soil and Water Conservation Services is concerned with works to protect water sources and control erosion, as well as with artificial recharge;

- The Centre for Agronomic Studies carried out physical, chemical and bacteriological analyses of the water;

- The Centre for Equipment and Workshop Maintenance is responsible for the maintenance of all the Ministry's equipment and vehicles, including drilling rigs and pumps.

In 1985 the Government was considering the creation of a single service for water resources, in conjunction with the preparation of new water legislation.

Ground water research

With the exception of some earlier work, the systematic study of ground water really began in Cape Verde in 1971 under a contract between the Portuguese Government and the BURGEAP study company (Paris). A ground-water unit was set up at the same time, equipped with two drilling rigs. The study lasted two years from 1971 to 1973. The first field operations were carried out in 1972 on Sao Tiago: more than 100 exploitation and observation boreholes were drilled. In addition, an inventory of water points was drawn up and a summary general hydrogeological presentation was prepared, together with a preliminary water balance.

When Cape Verde became independent in 1975 these activities were continued under the Department of Ground-Water Exploitation and Management Services (DSEGAS) of the Ministry of Rural Development, as part of several. bilateral, ultilateral and international co-operation projects financed by the European Economic Community (EDF) on Sao Tiago, by the Fonds d'aide et de coopération (France) on Sao Nicolau and Sao Tiago, by the Netherlands on Santo Antao, by UNDP on all the islands (except Sao Nicolau), by UNICEF on Sao Tiago, Maio and Boa Vista, by the United States on Sao Tiago, etc. The prospecting and exploitation operations have been extended in varying degrees to almost all the islands, with the exception of Fogo and Brava. The first detailed studies of hydrographic basins and other zones have been made on Sao Tiago in order to determine the ground-water potential. The digging of the country's first deep gallery has begun on Sao Nicolao.

Distribution of responsibilities in the water sector

Functions	Zone	Ministry
Agro-climatological studies and research	Whole country	
Drilling and tapping - equipment and maintenance	Whole country	Rural Development
Exploitation and distribution of drinking water and irrigation	Rural areas	
Construction of distribution networds and reservoirs	Urban centres	Public Works
Distribution and sale - network maintenance	All population centres	Interior
Desalination of sea water - distribution and administration	Mindelo and Sal	Economy and Finance
Quality control	Whole country	Health
National meteorology	Whole country	Transport and Communications

The following are the main items of research under way at present (1984):

- Feasibility study of the galleries on Sao Tiago and prefeasibility study on Fogo (EDF(BURGEAP);

- Evaluation of ground-water resources in two pilot basins on Sao Tiago (UNDP/TCD).

DESGAS, whose present organigramme is set out below, employs about 250 persons, six of them relatively young and with university education. Most of the technical and site staff have received practical training "on the job" without adequate prior theoretical training.

DSEGAS has the following prospecting equipment:

- Eight drilling units with equipment;

- Seven compressors;

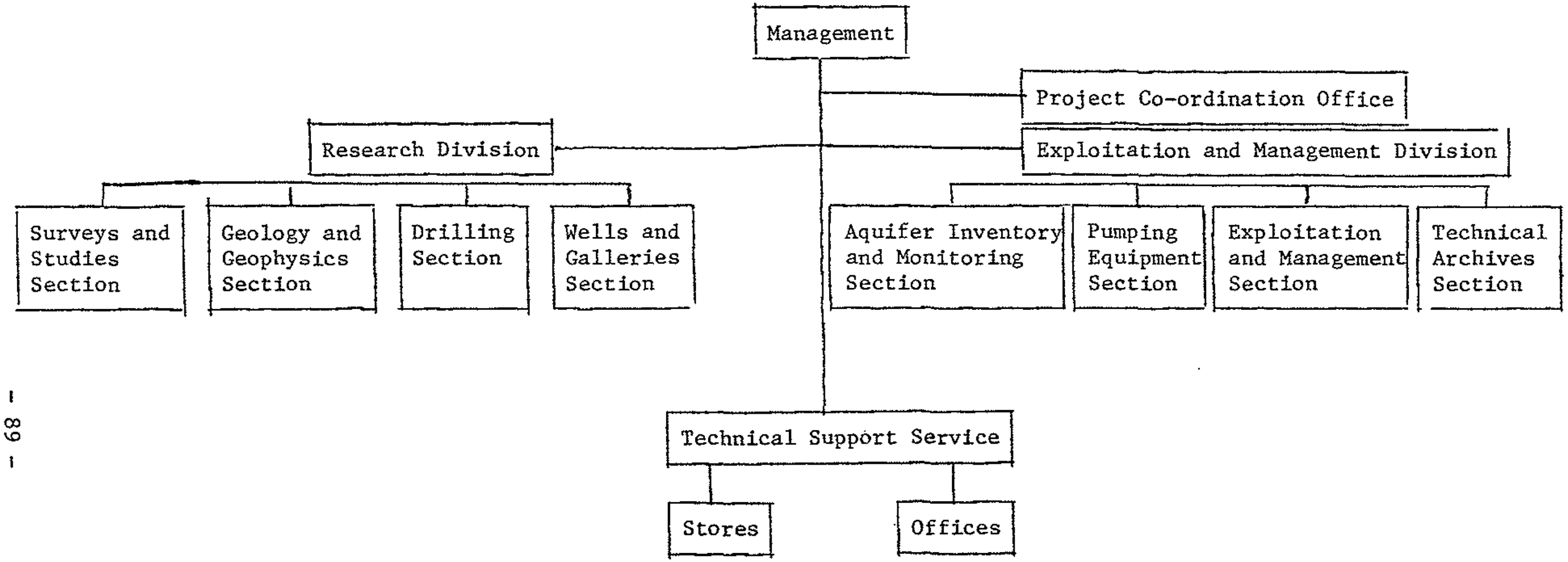
- Six lorries;

- Nine light vehicles;

- Three test pumps (submersible);

- Miscellaneous equipment (piezometric probes, conductimeters, chronometers, etc.).

Department of Ground-Water Exploitation and Management Services



Prospecting Methods

The prospecting methods have always been diverse, but everything depends on the availability of specialized technical staff (hydrogeologists) and the necessary surveying materials (instruments, maps, drilling rigs). As far as possible, the following operations are carried out:

- Preparation or updating of hydrological inventory. Geological field surveys to prepare a geological map and a structural map of the aquifer. It should be noted that the interpretation of aerial photographs helps very little in the determination of the morphological characteristics;

- Preparation of a hydrogeological plan and drilling of boreholes;

- Test drilling with the assistance of a hydrogeologist;

- Exploitation wells;

- Test pumping at constant discharge for 24 hours in the exploitation well;

- Piezometric drilling to monitor the aquifer when the exploitation is fairly intensive or the aquifer is close to the sea.

As indicated above, not all these operations are carried out in all cases. The boreholes are usually drilled without hydrogeological supervision and on the basis of practical criteria (access, proximity of users, etc.).

During the BURGEAP study (1971-1973) a number of electro-geophysical soundings were carried out with fairly satisfactory results, but only recently has this method been used in specific projects. The positive results of the drillings based on this method demonstrate its effectiveness. An experiment with seismic refraction has shown that this method is not suitable, owing both to the geological characteristics and the practical difficulties of implementation.

Description of the main aquifers

Although the study of ground water has been extended to all the islands since Independence, most of the work has been concentrated on São Tiago, and knowledge of the other islands remains very incomplete. Consequently, most of the characteristics described below, in particular the numerical values, relate in fact to São Tiago. However, it is thought that they are equally valid for the other islands, given their geological similarity to São Tiago.

The overall hydrogeological system has not yet been studied in detail.

The general opinion is that there exists a vast single aquifer involving all the formations, with the intermediate series constituting the main reservoir. However, the presence of one or several perched aquifers is not excluded, possibly in part of the intermediate series and, at a greater depth, in the main aquifer or the saturation zone located mainly in the base series.

The aquifers vary greatly in depth, depending on the distance from the edge and the altitude of the soil cover. Difference of more than 100 m can be observed between points only a little distance apart.

It must be noted that the values given in the table below, which summarizes the characteristics of the aquifers, are not entirely representative, for the following reasons:

- They refer only to productive wells;

- In most cases they do not refer to the whole thickness of the aquifer in question;

- The wells have usually been drilled in the valleys. Few are located in level ground ("achadas") where the aquifers are covered by a considerable thickness of volcanic rocks.

Limestones and eruptive limestone complex of Borde (Jurassic-Cretaceous)

These are found only on Maio, surrounding the island's central massif. These fissured limestones, with heavy intrusions of basaltic veins in the eruptive limestone complex constitute the island's main aquifer with stocks evaluated at 55 million m^3 for a saturated depth of 20-30 m below sea level. The great thickness of the formations, their steep slope and their degree of fissuration indicate water circulation at a great depth. The water is fairly saline, with conductivity values of between 1,200 and 3,400 micromhos/cm. The Cl^-/HCO_3- ratio varies from 1.2 to 1.8.

The geological formations have been grouped into three series according to their hydrogeological behaviour: base series, intermediate series and recent series.

Base series. This is made up of tuffaceous breccia formations of the ancient internal irruptive complex (AC) and the Flamengos (Fl.) and Orgaos (CB) formations. They are fairly compact and impermeable in comparison with more recent formations and act as a substratum. However, they are not totally barren and do constitute a low yield aquifer, with greater porosity in the Flamengos and Orgaos formations. The aquifer studied so far is generally limited to the more fractured upper part, which is some 10 to 30 metres thick. The conditions at greater depth are not known, and it is possible that the islands' true - saturated - aquifer may be found there (see above).

The productivity increases, sometimes attaining very high values, in the veins and especially in those caused by the most recent eruptions. This fact is particularly important in the CA where there are many of these intrusions. The same phenomenon occurs in the Flamengos formation in the few places where pillow lavas are abundant. The recharge in these formations is adversely affected by a thick argillaceous surface alteration, especially in the CA where it can attain five to 10 metres.

Description of the aquifers 1/

Formation and geological age	Island 2/	Production limits (Q) m^3/hour	Transmissivity (T) m^2/day	Storage (S) 3/
Limestones (Jurassic-Cretaceous)	Maio	1-12	70-5,900	0.07
Calco-eruptive complex (Jurassic-Cretaceous)	Maio	4-35	60-190	0.02
Ancient internal eruptive complex (Cretaceous-Eocene)	São Tiago São Nicolau	0-10	1-10	0.03
Flamengos formation (Miocene)	São Tiago São Nicolau	0-45	1-120	6×10^{-4} to 3.6×10^{-3} 0.15
Orgãos formation (Miocene)	São Tiago	0-10	1-4	-
Intermediate series (Miocene-Pliocene)				
- submarine phase	São Tiago	20-100	50-9,000	5×10^{-4} to 10^{-3}
- aerial phase	São Tiago, São Nicolau, Maio, Santo Antao	5-60	5-160	4×10^{-4} 0.05
Alluviums (Holocene)	São Tiago	20-100	800-8,600	-

1/ According to test pumping.

2/ Where the aquifer has been studied and exploited.

3/ Values obtained from very few tests (sometimes only one).

Intermediate series. A number of factors help to make this aquifer the most important:

- Relatively good permeability and porosity owing to the abundance of well-fractured basalts and uncompacted intercalations of alluviums and pyroclastic sandstone;

- Great size in the majority of the islands;

- Favourable recharge conditions in the hilly regions where the rainfall is heaviest;

- Lower section of breccias and tuffs which can act as an impermeable base similar to the CA, giving rise to many springs, as occurs on Santo Antão in the lower complex and on São Tiago in the lower Pic d'Antonia formation.

Apart from the pillow lavas, the most productive zones are usually found in pyroclastic deposits, sandstones and alluviums, with the ancient valleys of erosional unconformity at the base of the series playing an important role.

With their very high permeability and porosity, the pillow lavas of the submarine phase occupy an important position. However, the extreme transmissivity values given in the table above are subject to serious reservation, for they come from tests which recorded downdraws of only a few centimetres and very rapid stabilization. The order of magnitude of the transmissivity coefficient may be 400-1,000 m^2/day.

The irregular distribution of the various products of the subaerial volcanic phase mean a high degree of heterogeneity in the aquifer, with transmissivities ranging up to a factor of 10 over distances of a few hundred metres.

Except in the lower section where they are more abundant and can act as drains, the veins play a secondary role. In the few cases when the boreholes have reached the base of the series, the total depth of the aquifer has attained or exceeded 50 m. An important factor is the position of the base of the series (or even the erosion surface of the base series) in relation to sea level, for this can mean a fairly incurved and probably perched aquifer or indeed a deep aquifer.

At the top of the main aquifer there may be one or several perched aquifers resting on relatively impermeable strata, some of them situated at a high altitude and offering many tapping points and springs.

Recent series. The pyroclastic deposits and the occasional scoriaceous lavas which make up this unit are extremely permeable and porous. Even if they are not aquifers, they do at least constitute excellent recharge zones for the underlying formations. However, this behaviour appears to be due more to the disposition and extent of the outcrops. On Santo Antão where this series is better developed, recent drilling has revealed ground water in the basalts and pyroclastic breccias attributable to this series which have high specific yields (similar to those of the pillow lavas).

Alluviums. Owing to their coarse granulometry they form very permeable aquifers but only in the lower part of valleys where they are sufficiently extensive and thick to permit substantial exploitation. Here they can attain a width of several hundred metres and a depth of 40 metres. A little distance away from the sea, perhaps five kilometres, these values decline rapidly, but the aquifer can still be exploited by dug wells.

Quality of ground water

In order of magnitude the specific hydraulic conductivity indicative of total mineralization ranges between 200 and 5,000 micromhos/cm (± 150 to 4,300 mg/l). It increases naturally in the direction of flow (downstream) but also towards contact with the formations of the base series where it attains values of 1,000 to 3,000 micromhos/cm. The change is quite sudden. The high values are typical of the coastal zones and those above 3,000 micromhos/cm are found on contact with the wedge of salt water. Very high values (9,000-150,000 micromhos/cm) can sometimes be observed in the formations of marine origin as a result of contamination by salt or polluted water. The commonest type is sodium bicarbonate (bicarbonate/chloride according to the most recent analyses). Alkaline-earth ions are also common, especially in the base series, but sulphate is fairly rare.

Few bacteriological analyses have been made so far. They have indicated the contamination of springs and wells by faecal matter, also revealed by the frequent presence of NO_2-, NO_3-, and NH_4+.

Although the salt content is in many cases higher than the drinking-water standards established by WHO, the water can be used for human supply. However, it must be used with care for irrigation, if not by reason of its total salinity, then at least owing to its high sodium content.

Water balance and ground water resources

Of the various headings in the water balance, only the precipitation has been measured directly, but even these measurements have not been made regularly over long periods. This is why various indirect methods of estimation have been used to calculate an approximate value of the balance and/or recharge. In 1974 BURGEAP produced for the recharge the formula $I = 0.25\ (P - 300)$ mm, P being the annual precipitation in mm; this formula has been used to estimate the total ground water resources indicated in the table "Ground water resources" (see below).

In 1980 the United Nations project CVI/75/001 established a first provisional balance for the Archipelago, the results of which are given in the table "Trial water balance" (see below).

In 1982 , M. I. Dittrich produced the following values for São Tiago:

	Reception	Interception	Surface runoff	Infiltration	Actual evaporation
mm	360	40	38	50	232
percentages	100	11	11	14	64

The ratio of recharge to average annual rainfall is given by I = 0.21 (P - 142 mm).

For the intermediate series on Santo Antão A. Bosscher (1983) found the recharge/rainfall ratio: I = 0.1 (P - 50 mm).

Lastly, in 1983 BURGEAP established a new balance for the massif of Pico d'Antonia (São Tiago) with a new approach based on infiltration co-efficients ranging between 15 and 50 per cent of rainfall depending on the steepness of the mountain slopes.

In order to give an idea of the order of magnitude, the table "Ground water resources" gives the 1974 BURGEAP estimates and those made by the United Nations in 1980 (project CVI/75/001) (see below).

Trial water balance

Island	Area	Rainfall		Actual evapo-transpiration	Surface runoff		Infiltration	
	km^2	mm/year	hm^3/year	mm/year	mm/year	hm^3/year	mm/year	hm^3/year
São Tiago	991.0	320	317	157	108	108	55	55
Fogo	476.0	450	214	180	182	87	88	42
Brava	67.4	350	24	160	122	8	68	5
Maio	269.0	100	27	75	15	4	10	3
Boa Vista	620.0	75	46	60	10	6	5	3
Sal	216.0	75	16	60	10	2	5	1
Santo Antão	779.0	350	273	157	125	97	69	54
São Nicolau	388.0	150	58	90	37	14	23	9
São Vicente	227.0	75	17	60	10	2	5	1
Total	4,033.4	-	992	-	-	328	-	173
Average	-	246.4	-	122.3	81.2	-	42.9	-
Percentage of precipitation		100		49.6	33.0		17.4	

Data from United Nations project CVI/75/001 (1980).

Ground water resources

m³/day	United Nations - 1980		BURGEAP 1974
	Available	Exploitable	Total
Boa Vista	8,000	1,600	1,200
Brava	14,000	7,000	4,500
Fogo	120,000	60,000	60,000
Maio	8,000	2,000	3,000
Sal	3,000	300	300
São Tiago	150,000	85,000	60,000
Santo Antão	145,000	71,000	80,000
São Nicolau	25,000	8,000	12,000
São Vicente	3,000	500	800
Total	476,000	235,400	221,800

III. EXPLOITATION OF GROUND WATER

Governmental Bodies

Although many bodies are involved in the exploitation and use of ground water (see above), only the Department of Ground Water Exploitation and Management Services is concerned with the construction of tapping and drawoff installations up to the wellhead. The Drilling Section employs 23 persons, including seven drillers. Their training is mainly practical; some of them have more than 10 years work experience, but none of them has more than four years of primary education.

The Section has eight drilling units with the following equipment:

Equipment model	Type	Capacity
1 Koehring-Speedstar SS-15-III	Normal rotary and air with compressed air hammer (down-the-hole)	300 m - 6" 150 m - 10"
1 Bonne Esperance FBE 2 N GC	Idem	300 m - 6" 150 m - 8.5"
1 Stenuick HS66D (modified)	Air rotary with compressed air hammer	120 m - 8" 20 m - 6"
1 Stenuick HS66D	Idem	90 m - 8"
2 Schott-Dubon	Cable-tool percussion	150 m - 8" 70 m - 17" 1/
2 Longyear	Coring 2/	250 m - 2"

1/ Actual capacity much lower owing to the lack of test tubing and difficulties in hard rocks.

2/ Mainly for geological surveying (galleries, foundations, etc.)

The yield of the rigs is very irregular; it is not unusual for equipment to be out of commission for a year or more, almost always as a result of mechanical difficulties. From 1980 to 1984 a total of 223 boreholes was drilled with a total depth of 17,784 m, i.e. an average of 45 per year or 2,957 m. Of this total, 24 per cent has proved productive, 26 per cent was drilled for observation and/or study purposes, 25 per cent was drilled for the laying of foundations or mineral prospecting, and 25 per cent was abandoned.

There is also a Wells and Galleries Section with a staff of 28, which is concerned with the digging of wells and construction of installations to tap springs or the building of small galleries. This work is generally done by hand, with the help of a compressed-air drill in the case of galleries.

Tapping and use of ground water

Tapping methods. As was stated above, the first drilling for water was carried out in 1972. Up till then the ground water had been taken from springs, filtration galleries and dug wells.

At present the springs are tapped by different types of installation, either small accumulation basins or actual small galleries no more than a few metres in length, or a few dozen metres in exceptional cases. However, there are longer galleries: the one at São Martinho Pequeno (São Tiago) is probably the longest at 710 m. The first long gallery (2,200 m) of recent times was constructed on São Nicolau with technical assistance and supervision by BURGEAP. From 1950 to 1960 many filtration galleries were built, first in the longitudinal and then in the transversal alluviums along underground dams. They still produce large quantities on Santo Antão, but on São Tiago and São Nicolau where they are located in alluviums of little depth or close to the surface, many have dried up or reduced their yield. The system of springs and filtration galleries continues to be the most important means of exploitation, supplying about 50 per cent of all the ground water extracted in the country. On Brava, Fogo and Santo Antão it is virtually the only means of exploiting ground water.

As might be expected, the dug wells are located mainly in alluviums, but many of them also exploit the underlying volcanic rocks which usually belong to the base series. Only rarely do they penetrate more than one or two metres into the aquifer; their productivity is therefore very low. In thick alluviums their yield rarely exceeds 100 m^3/day; they are built with diameters of two to five metres and depths of four to 20 m; their exploitation by motorized surface pumps for irrigation is relatively recent, and drinking water is usually drawn off in buckets. Wells are particularly numerous on São Tiago, accounting for about 50 per cent of the supply.

Drilling for water is usually carried out by means of compressed-air drills with diameters of 200 to 250 mm. The installations are furnished with 150-160 mm PVC tubing. Their depth has been pushed beyond 100 m in recent years, and as far as 170 m. In June 1984 there were 142 exploitation boreholes producing some 20,000 m^3/day. They are very unevenly distributed: most of them are on São Tiago and there are none on Brava, Fogo or Santo Antão. The commonest drawoff method is by vertical-spindle turbine pump driven by a diesel motor. About 50 per cent of the boreholes have this equipment; the next commonest method is wind power - 20 per cent; the remaining 30 per cent is produced by submerged electrical pumps, surface turbine pumps with diesel motors, and a few hand pumps and pumps driven by aerogenerators.

The table below (Exploitation of ground water) gives the daily yields for each island by these various methods. Although the figures relate to different periods, they do give a fairly accurate idea of the present situation.

Exploitation of ground water

(m^3/day)

Island	Springs and galleries	Dug wells	Boreholes No.	Boreholes 1/	Total
Boa Vista	22 1/	480 5/	6	210	712
Brava	-	-	-	-	2,500* 6/
Fogo	-	-	-	-	1,500* 3/
Maio	10 5/	1,160 5/	11	1,730	2,900
Sal	-	270 3/	2	40	310
São Tiago	10,200 2/	19,600 2/	94	15,836	45,636
Santo Antão	-	-	-	-	28,000* 3/
São Nicolau	1,200 4/	200 4/	26	1,532	2,932
São Vicente	-	1,500 2/	3	650	2,150
TOTAL	-	-	142	19,998	86,640

* Almost exclusively from springs and galleries.

Data produced by:

1/ Livramento, D.R. and Pieterse, N., 1984.

2/ Fernandopulle, D., 1979.

3/ United Nations project CVI/75/001, 1980.

4/ BURGEAP, 1981.

5/ Beurskens, H.J.M., 1981.

6/ BURGEAP, 1974.

Utilization. For various reasons, in particular because the water is drawn off for many different uses, it is difficult to obtain reliable values for the amounts of water consumed by each use.

The larger part - if not all - of the water is used for irrigation and as drinking water. The BURGEAP estimates for 1980 are reproduced in the table "Ground-water utilization in 1980 (according to BURGEAP estimates, 1981)" (see below).

The value for drinking water seems to be consistent with the existing delivery systems which supply about 170,000 people, or some 58 per cent of the population, usually in an inadequate manner. The remaining 42 per cent of the population take their supplies themselves from springs and dug wells in a total amount estimated at 2,500 m^3/day. The total production of water for human supply is in the order of 4,600 m^3/day.

Most of the 68,000 m^3/day used for irrigation is consumed on São Tiago and Santo Antão, which have 94 per cent of the irrigated land - a total area of 1,790 ha. According to the Central Corporation for Land and Rural Development, Investment and Resource Management (SCETAGRI) (1981), sugar cane is grown on 1,029 ha (57 per cent), potatoes on 355 ha (20 per cent) and bananas on 181 ha (10 per cent). The remaining 13 per cent of the land is used for the production of vegetables, maize, manioc, etc.

Cost of ground water

The ex-well production costs of ground water 1/ are given below on the basis of BURGEAP data (1981). They do not include the costs related to the distribution networks.

	Tapping	Drawoff	Total
Boreholes			
- São Nicolau	2.5	3 to 27	5.5 to 29.5
- São Tiago (J. Varela)	1	16	17
Private dug wells	3	2 to 5	5 to 8
Springs	2	0	2
Galleries	3.5 to 7.5	0	3.5 to 7.5

1/ Cape Verdian escudos per m^3 (US $1 = 50 Cape Verdian escudos).

These figures have been obtained by different methods of calculation and thus they are not fully comparable; they do however indicate the order of magnitude of the values. It can be seen that the drawoff, which includes the costs of equipment and operation, has a strong influence on the total cost.

Deterioration of the aquifers

The main difficulties encountered in the exploitation of ground water are connected with the intense drought which has affected the country since 1970. It has caused a considerable decline in piezometric levels, and many springs and galleries and many dug wells have dried up or had their yields reduced. In addition, some boreholes drilled since 1970 to combat the effects of the drought have been affected by declines in piezometric levels sometimes in excess of 10 m. The overexploitation of the aquifers has also contributed to these declines, but it is difficult to quantify the relative effects of these various causes.

The most seriously affected aquifers are those located at altitude which are small in size and/or perched, especially alluvial aquifers. Most of the filtration galleries constructed in these aquifers have now dried up. The large aquifers found in favourable recharge conditions, for example the aquifer in the Pic d'Antonia formation, have not suffered so much. On São Tiago, for example, the discharge of the tapped springs of Aguas Verdes which supply Praia has hardly declined at all. In contrast, on São Nicolau where there are hardly any springs in contact with the substratum, the number of springs declined by 60 per cent between 1969 and 1980 and by 80 per cent between 1956 and 1980.

Sea-water intrusion has occurred in some coastal zones, in particular in the alluvial aquifers and pillow lavas. This intrusion has not usually been very extensive. However, in places it has caused the abandonment of a number of dug wells used for irrigation. It has probably been more extensive on the low islands; for example, on Maio in the area of Calheta sea water had penetrated in 1980 up to 2 to 3 km inland, apparently under the combined influence of the decline of the already low piezometric level, exploitation, drought and perhaps reforestation. In order to improve the aquifers by artificial recharge, many small dams have been built in the valleys. These are not really artificial recharge installations but rather installations designed for multiple purposes, such as erosion control, control of the torrential runoffs, and the creation of additional arable land. This last objective involves rapid filling with fine and coarse sediments, which casts doubt on the effectiveness of these installations for artificial recharge.

Ground-water utilization in 1980

(according to BURGEAP estimates, 1981)

Island		Drinking water (m^3/day)	Irrigation (m^3/day)
São Tiago total		1,340	33,800
Town of Praia	900		
Towns of Assomada, Tarafal and Porto de Pedra Badejo	240		
Rest of the island	200		
Santo		145	30,500
São Nicolau		112	1,500
Brava		-	1,400
Maio		14	680
Fogo		300	280
Boa Vista		70	80
São Vicente		100	400
Total		2,081 (+2,500) 1/	68,640

1/ About 2,500 m^3/day should probably be added for personal supplies not taken from the water-supply networks.

Requirements and future development

According to the first National Development Plan, the long-term goals (year 2000) require the following water resources:

Drinking water

Rural population (260,000):	11,200 m^3/day		
Urban population (160,000):	5,200 m^3/day		
		Total:	16,400 m^3/day
Irrigation			
(3,600 ha)			137,000 m^3/day
Industry			900 m^3/day
		Total (year 2000):	154,300 m^3/day

The available ground-water resources, estimated at 220,000 to 235,000 m^3/day (see above), are generally sufficient to meet these requirements. However, not all the resources are easy to exploit. In the light of the various technical and economic difficulties which must be overcome in mobilizing the resources, a number of estimates have been made of the production increase (m^3):

	BURGEAP 1974	United Nations 1980	BURGEAP 1981
Boa Vista	600 x 2	600	1,200 - 1,700
Brava	1,000 x 2	2,300	1,800 - 2,200
Fogo	5,000 x 2	58,500	15,800 - 27,000
Maio	1,500 x 2	1,500	2,200 - 2,600
Sal	300	-	150 - 250
São Tiago	15,000 x 2	54,000	15,500 - 20,500 (+ 5,000)
Santo Antão	10,000 x 2	43,000	17,000 - 23,000
São Nicolau	3,000 x 2	5,600	3,400 - 4,600 (+ 1,800)
São Vicente	200	-	1,100 - 2,100
Total	72,700	165,500	58,150 - 83,950 (+6,800)

With a very small increase of 65,000 m^3/day, the total exploitation would be approximately 150,000 m^3/day, which would meet the requirement for 2000. However, it must be remembered that this general situation does not apply to all the islands or to each individual sector; in some places the resources/exploitation balance can show a deficit. In any event, very intensive and effective artificial recharge is highly advisable, especially for the solution of local problems. According to BURGEAP (1981), most of the future exploitation should be by means of extensive galleries, in the long if not in the short term.

For future borehole exploitation, account must be taken of the production cost elements described above. Given the relatively high drawoff cost, it would seem preferable to use the cheapest techniques - wind power for example - even though in this case the number of boreholes would have to be increased to compensate for their low discharge.

Since the only existing fresh-water resource is ground water and since little is konwn about the actual available flows, any exploitation will have to be strictly monitored and regulated in the light of the aquifer's behaviour.

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