ANTIGUA - BARBUDA

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PRELIMINARY SURVEY OF ANTIGUA AND BARBUDA WATER RESOURCES PROPOSAL FOR GROUNDWATER STUDY

B.R.G.M.
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B. R. G. M.

ANTIGUA - BARBUDA

Antilles Regional Geological
Survey

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PROPOSAL FOR GROUNDWATER STUDY

B.R.G.M. 84. ANT. 027

November 1984

FOREWORD

We would like to thank :

- Mr. H. SIMON

for the welcome he gave us and for the interest he personally took to see that our mission went well.

- Mr. P.S. VASUDEVA for his cooperation and for the assistance provided by the APUA departments

- Mr. M. VINCENT - Prefecture of Guadeloupe

for preliminary contacts with the autorities in Antigua and Barbuda.

* * * * * * *

SUMMARY

At the request of the authorities of Antigua and Barbuda, submitted to the Préfecture of Guadeloupe, the Antilles Regional Geological Survey of the Bureau de Recherches Géologiques et Minières (B.R.G.M.) carried out a hydro-geological reconnaissance to assess the possibilities for the development of water resources.

1 - PRESENT SITUATION

In Antigua 60% of the water-supply is provided by stored surface water and 40% by groundwater; Barbuda Island however is supplied entirely by groundwater.

The drought that have ravaged the Caribbean since 1983 has shown how fragile is the water-supply : In may and june 1984, Antigua and Barbuda have had to import water from other islands. It is the 1984 crisis which triggered the mission of B.R.G.M.

2 - ASSESSMENT OF WATER-SUPPLY POTENTIEL

2.1 - Surface water

Surface water reserves are directly related to the annual rain fall. Furthermore, the shape of the reservoirs - small depth and relatively large free surface - makes them sensitive to evaporation therefore. It is likely that it will be not easy to increase the surface water reserves.

2.2 - Groundwater

A rapid assessment of the water-balance of Antigua, also extended to Barbuda, shows that except during periods of drought the groundwater is regularly recharged. During droughts therefore, the important regulatory capacity of groundwater should be able to provide a solution to the problems of water-supply.

.../...

3 - PROGRAMME FOR THE STUDY AND DEVELOPMENT OF GROUNDWATER

In order to optimise the resource in already producing areas, and to seek new areas for production we recommend that a research programme, based essentially on geophysics, should be mounted to study the geometric and hydrogeologic characteristics of the geologic formations, and in particular the position of the salt/freshwater interface. By ensuring better siting of boreholes this would allow a reduction in the number of boreholes necessary. The proposed programme consists of the following stages:

1) Geophysical reconnaissance, using electrical soundings.
2) Geological reconnaissance by photointerpretation and field surveys. (simultaneously with 1))
3) Borehole drilling using diameters appropriate for future water-production, to refine geologic interpretations and test the aquifers.
4) Potentiometric survey and collection of climatic data.
5) Simulation, by mathematical modelling, of the behaviour of the aquifers to enable the groundwater to be properly managed.

The whole study can be divided in three main phases :

a - Prefeasibility study

This phases will be completed without borings and will include geological and geophysical survey as well as a study of the existing boreholes (water level survey). The prefeasibility study will allow to get an overall interpretation of the water reservoir geology and therefore to locate the new borehole to be carry out in the following phases. Carrying out this feasibility study demands about 5 mouths of expert. It should be started as soon as possible.

b - Exploration by boring

The number and the location, the cost of the drilling will be defined at the end of the prefeasibility study.

c - Numerical model

On the basis of the collected data a numerical model will be designed. This model will allow to optimise the withdrawal of water according to the rainfalls and the observed water table.

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I - INTRODUCTION

I.1 - BACKGROUND TO THE MISSION

This short mission by the BRGM's West Indies Geological Dept (Service géologique des Antilles) was carried out in response to a request for technical assistance from the authorities of Antigua and Barbuda to the Prefecture of Guadeloupe.

Due to the drought at present affecting the Caribbean, water has become crucially important. The aim of the visit was to analyse the possibilities of research into and development of water resources.

I.2 - SCHEDULE

The mission took place from Tuesday, 18th to Friday, 22nd June 1984, and includes bibliographic consultation, field trips and talks with the APUA authorities.

Tuesday 19th June : Talks with Mr. H. SIMON and Mr. P.S. VASUDEVA, visit to Potworks dam, Bristol Springs and Jennings, the main water producting centres in Antiga, with Mr. J. HUNT.

Wednesday 20th June : Talks with P.S. VASUDEVA, bibliographic consultation.

Thursday 21st June : Field trip on Barbuda, organized by Mr. SIMON, with Mr. FLEMING, geologist attached to the US Agency for International Development. Collection of water samples and measurements of salinity on Barbuda.

Friday 22nd June : Talks with Mr. H. SIMON and Mr. P.S. VASUDEVA fieldwork.

II - PHYSICAL ASPECTS

II.1 - ANTIGUA

II.1.1 - Geography

The Island of Antigua, with an area of 280 km^2 and a maximum altitude of 400 m, is located in the northern half of the Lesser Antilles at 17°N latitude. The islands nearest to it are Guadeloupe to the south, Montserrat to the west, and Saint Martin and Saint Barthelemy to the north (Fig. 1).

II.1.2 - Geomorphology and geology (A. Macle, D. Westercamp, 1981)

Antigua comprises three morphological and geological units are :

- In the southwest, steep hills, reaching 400 metres at Boggy Peak are parts of the basic volcanic complex within which a few lenses and beds of limestone are interstratified
- The central plain, crossing the island near sea level from north west to southeast, is a depression underlain by a variety of conglomerates, sandstone and shale with mary locally salicified limestone lenses, overlying the volcanic complex.
- A thick limestone sequence in the northeast, known as the Anti gua formation, overlies the clastic sediments of the central plain and forms low plateaus.

II.1.3 - Climatology

The tropical climate is characterised by permanent high temperatures, strong winds and relatively low seasonal rainfall. The average minimum and maximum temperatures are 24°C and 29°C. Relative humidity, varying between 70 % and 80 % throughout the year, is tempered by the prevailing northeasterly winds.

The average annual rainfall is about 1 100 mm, with a well-defined rainy season between August and November when half the annual precipitation falls, and also some heavy rainfall in May. Year to year variations are considerable (Fig. 3). Rainfall distribution are shown on the map (Fig. 4). The annual average increases from less than 890 mm on the northeast coast to over 1 200 mm in the first range of volcanic mountains facing the wind in the southwest of the island. The average annual rainfall in the limestone area is between 890 and 1 140 mm.

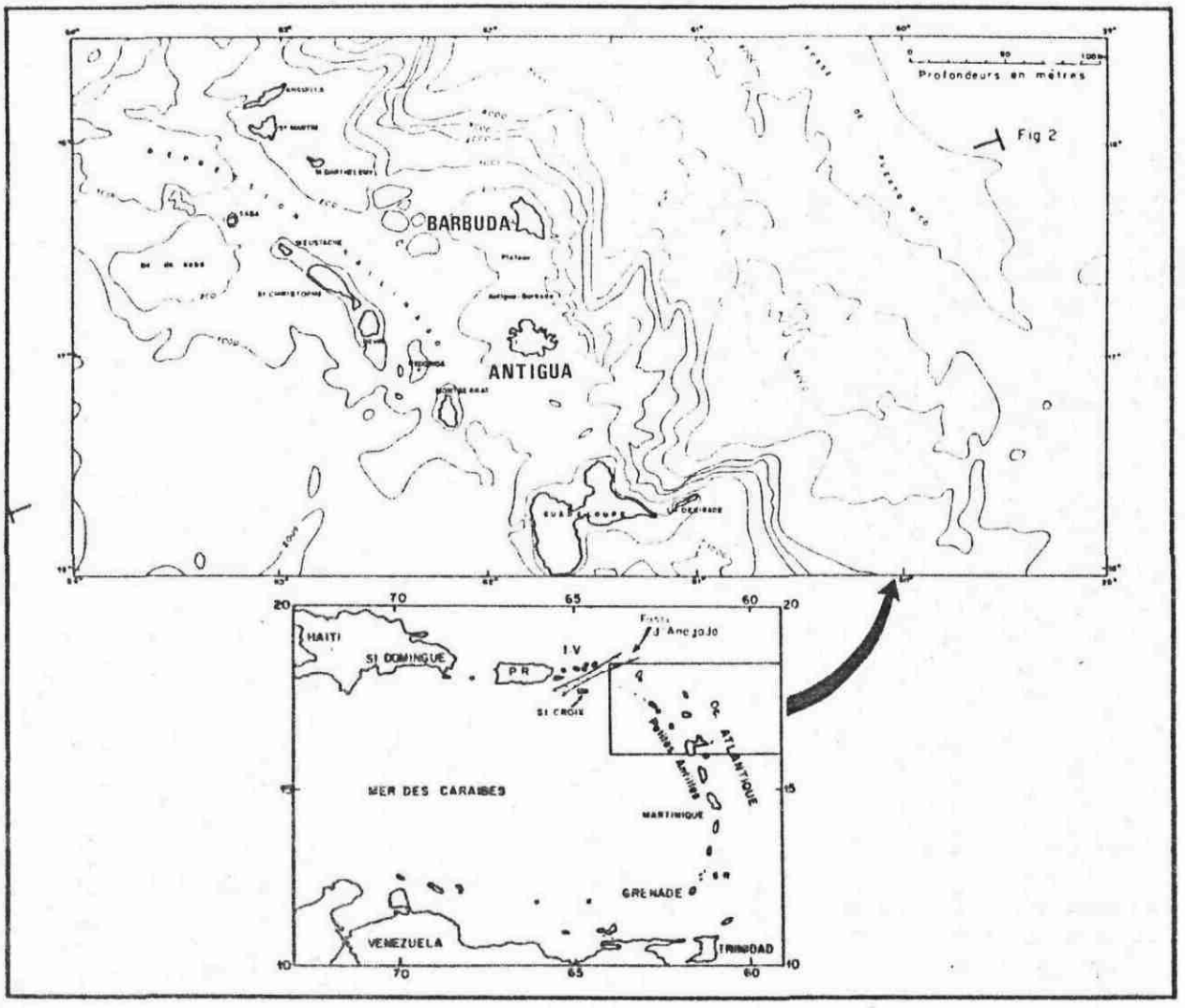


FIGURE 1 : Location of Antigua and Barbuda islands.

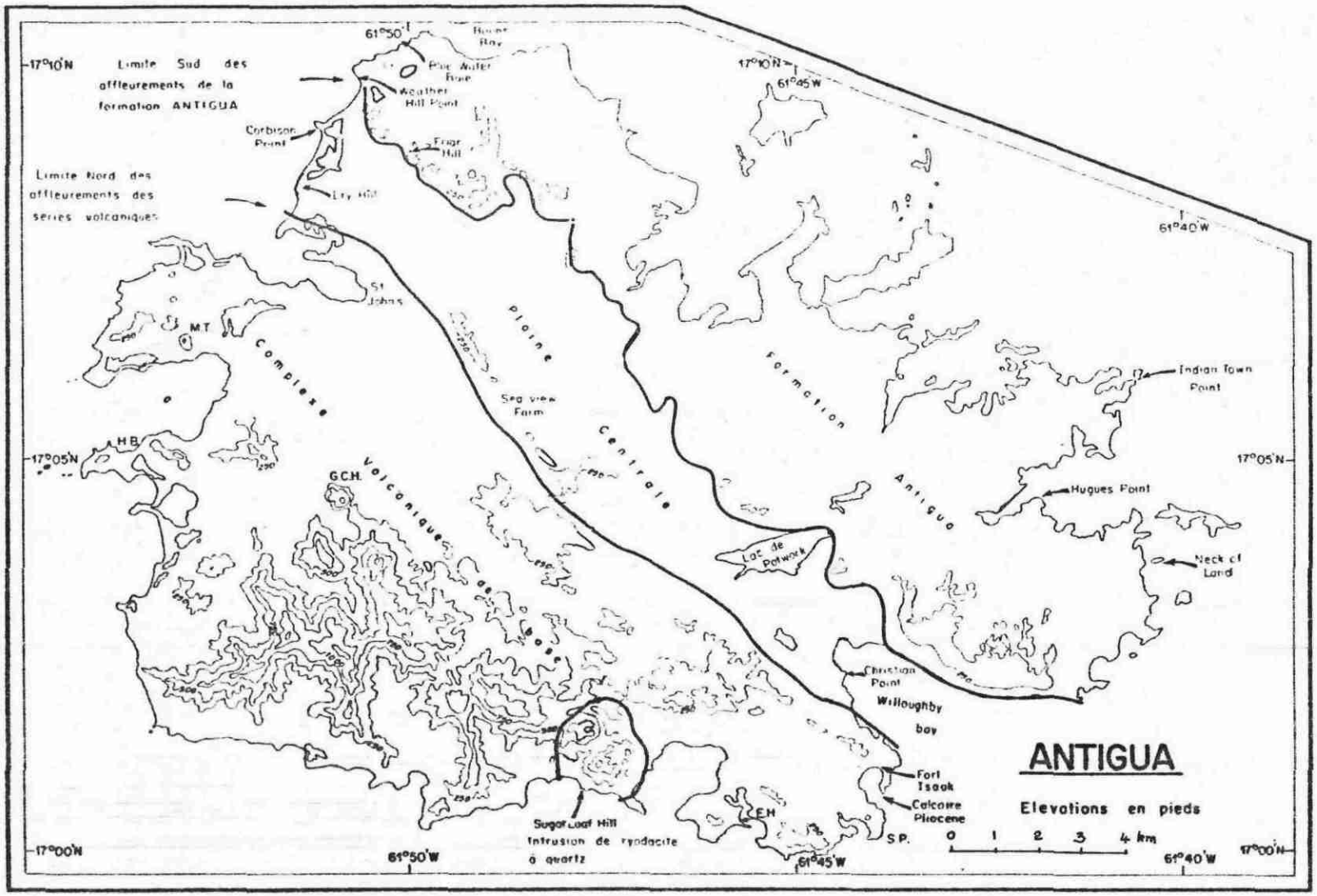


FIGURE 2 : Geological sketch map of Antigua.

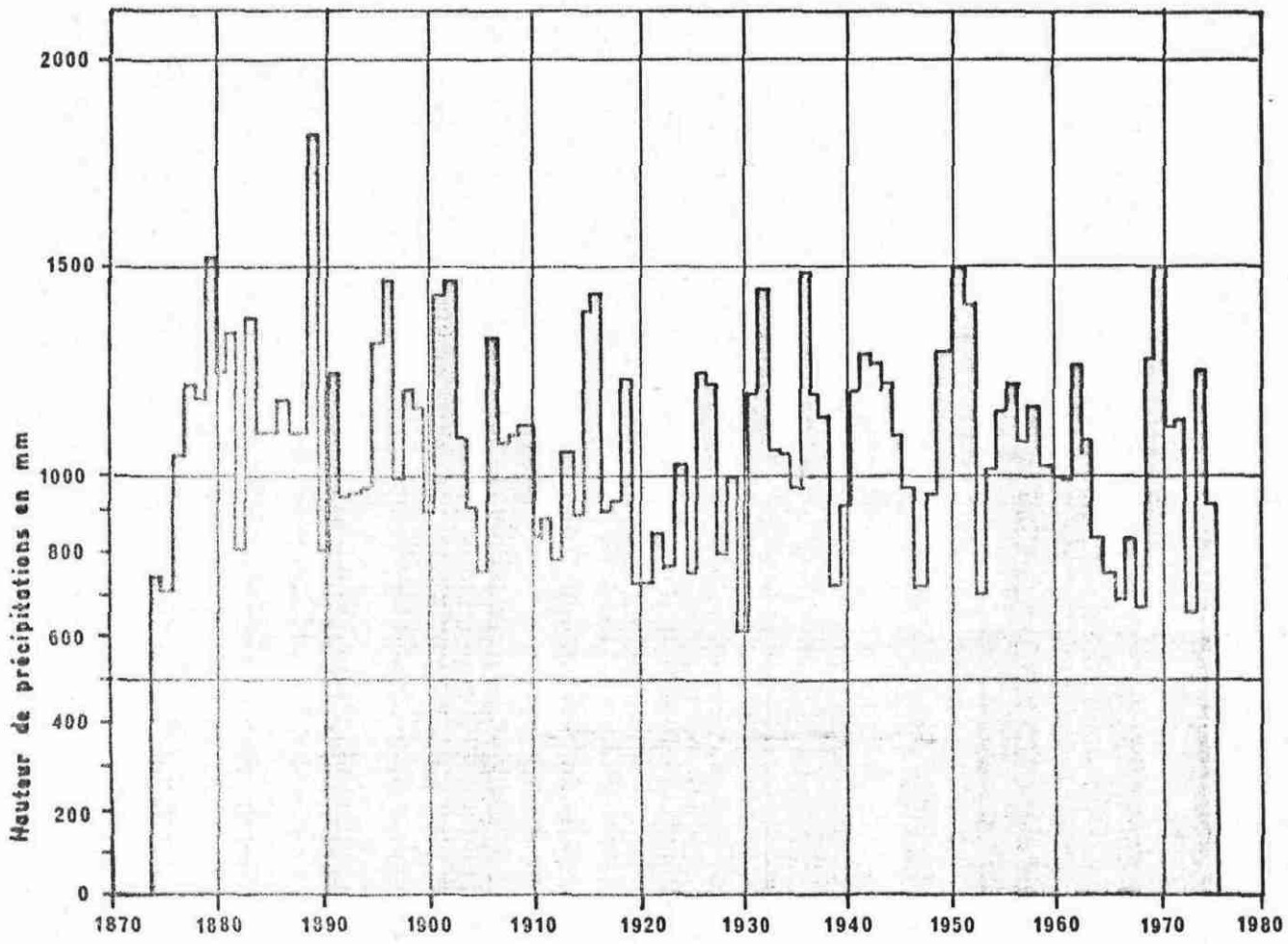
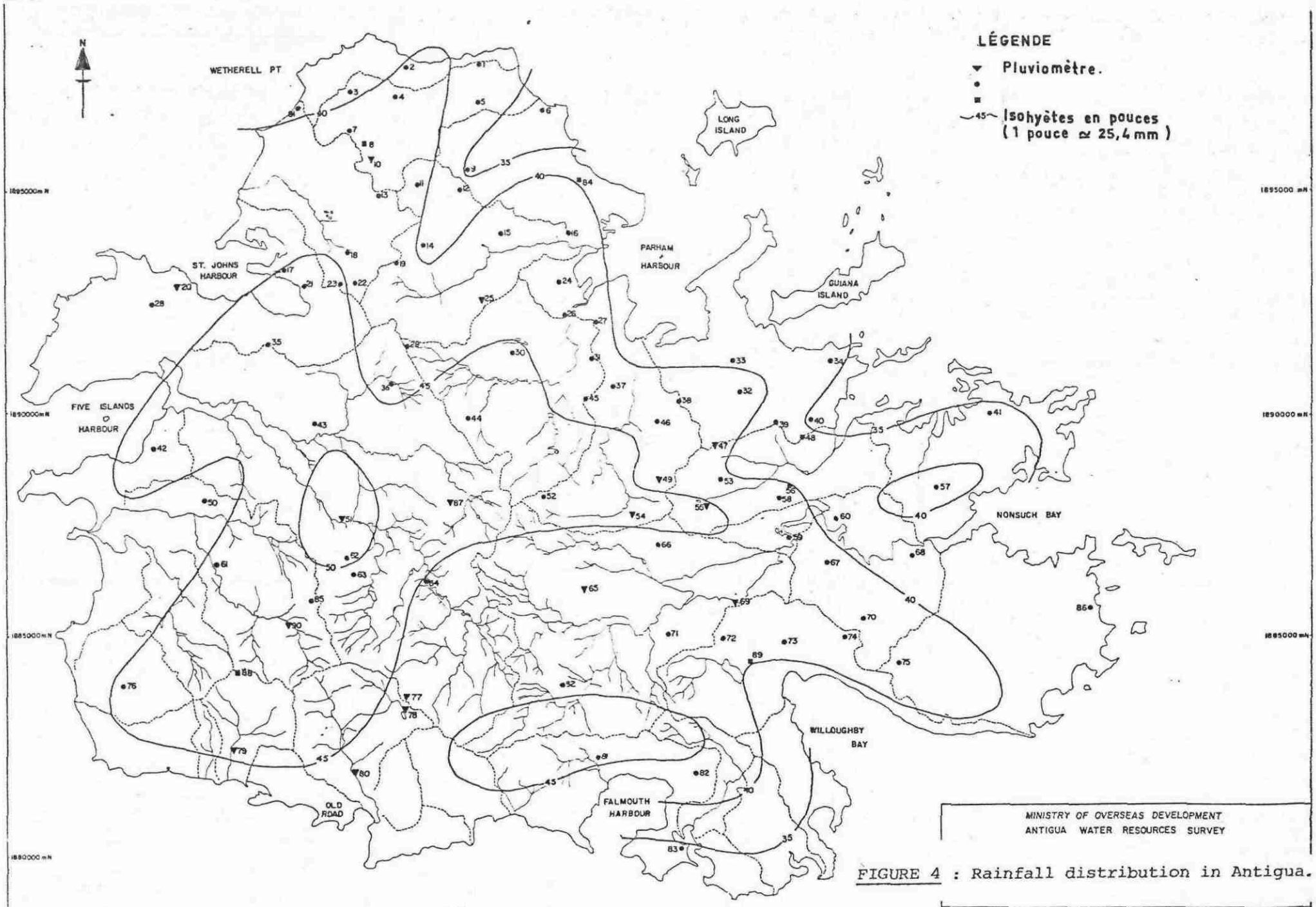


FIGURE 3 : Annual rainfall in Antigua.



MINISTRY OF OVERSEAS DEVELOPMENT
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FIGURE 4 : Rainfall distribution in Antigua.

DRAWING No. 5	
DATE :- MAY 1977	Sir William Halcrow & Partners Consulting Engineers

A study of thunderstorm frequency shows their important contribution to the volume of rainfall especially in May (Sir W. Halcrow and Partners, 1977). These heavy rainfalls cannot be absorbed by evaporation and contribute significantly to surface runoff and aquifer recharge.

The most complete evaporation data, measured on a US CLASS A evaporation tank, come from the Cotton Research Station, at Friars Hill in the north of the island. According to these the annual evaporation is about 2 000 mm, with the highest values occurring between March and August (table 1).

Table 1 - Evaporation - Cotton Research Station
(Class A evaporation tank)

Measurements in inches 1" = 25.4 mm

	1969	1970	1971	1972	1973	Average
January	5,47	6,11	5,02	5,96	5,31	5,57
February	5,86	6,22	5,90	5,13	5,30	5,68
March	9,25	8,77	8,01	7,07	7,04	5,57
April	7,48	7,66	5,91	5,05	7,85	6,79
May	6,95	5,44	7,45	7,36	7,13	6,87
June	8,23	5,58	7,56	7,19	7,85	7,28
July	7,59	8,37	6,35	7,52	8,35	7,64
August	7,27	7,80	5,26	8,03	7,18	7,11
September	5,73	6,42	7,15	6,69	5,57	6,31
October	4,96	4,74	5,51	4,90	6,71	5,36
November	4,55	4,19	5,17	5,01	5,85	4,95
December	5,29	4,34	4,67	5,31	5,36	4,99
Total	78,63	75,64	73,96	75,22	79,20	76,59

(Sir W. Halcrow and Partners 1977).

It should be borne in mind that these evaporation values relate to free water surfaces (surface reservoirs). To obtain an approximate value of potential evapotranspiration these results must be multiplied by a coefficient of about 0.8. The corrected values can then be used for a first assessment of the water balance.

II.2 - BARBUDA

II.2.1 - Geography

The island of Barbuda, covering a surface of about 150 km^2, is 45 km north of Antigua (Fig. 1).

II.2.2 - Geomorphology and geology

Barbuda is a limestone island must of which is less than ten metres above sea level, though the Highlands in the east are 30 metres high. On the western edge of the island, the limestone gives way to sandy deposits (Palmetto Sands) bordering the lagoons (Fig. 5).

II.2.3 - Climatology

The climate is similar to that of Antigua. Annual rainfall is less than 1 000 mm. about the same as that recorded in the limestone area of Antigua. Because of the absence of data for Barbuda and the similarities in rainfall, vegetation and type of soil between Barbuda and the limestone region of Antigua, we shall apply the evaporation values for the latter to Barbuda (para II.1.3).

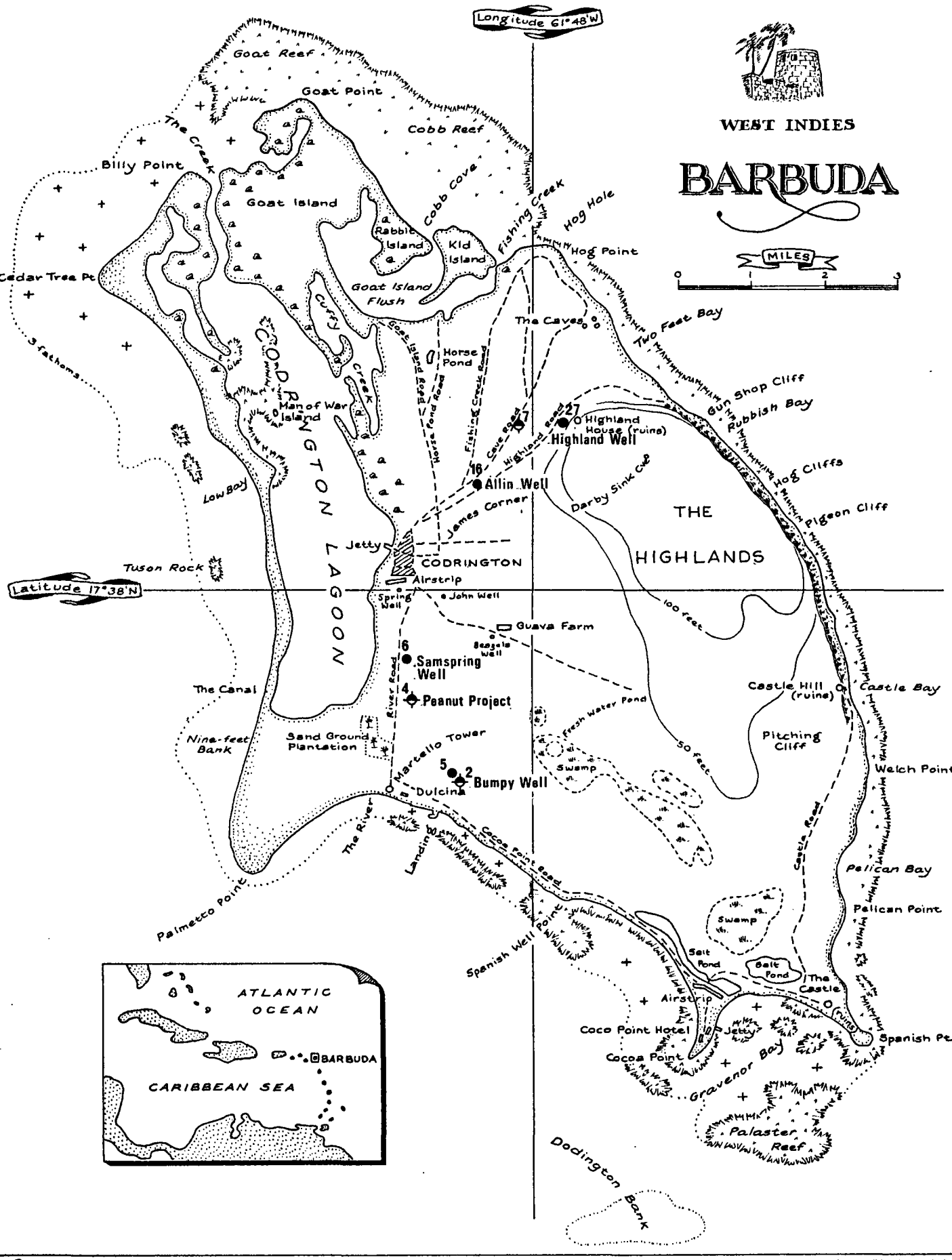


FIGURE 5 : Map of Barbuda - Location of water points sampled on 21st June 1984.

III - PRESENT SITUATION

III.1 - ANTIGUA

III.1.1 - Distribution of water production

This is summarised in the following table :

Table 2 - Distribution of water production in 1980

Source	1980 production, m3/day	
Surface water		
. Upper Creekside Catchment	1044	
. Potworks/Delaps	4086	5130
Groundwater		
. Bendals	636	
. Christian Valley	636	
. Cades Bay	590	
. Claremont	590	
. Follies	785	
. Long Lane Bristol	981	4218
Total average daily production		9348

The figures for 1980 hold good, as an average, for the following years, although a production peak in August 1982 (11,800 m3/day) should be noted.

Antigua has been badly affected by the present drought in the Caribbean and the shortage of rainfall recorded in 1983 (564 mm instead of 1 074 mm at Coolidge Airport) has brought about a regular fall in water production since the beginning of 1984. In March 1984, water production did not exceed 6,700 m^3 per day.

III.1.2 - Surface water

Surface water provides about 60 % of the island's supply and is stored on the upstream side of the numerous dam that have been built in the volcanic area and the central plain. The largest of these reservoir, Potworks Dam, is in the central plain on the edge of the limestone outcrops.

Surface water is at present the best developed water resource on the island. However, the effects of evaporation are very noticeable during extended periods of drought, especially as the free surface of some of these reservoirs, such as Potworks Dam and Collins Dam, is very extensive compared with the volume of water stored. In this type of shallow, extensive reservoir, the water is subject to heavy loss by evaporation.

.../...

III.1.3 - Groundwater

Groundwater accounts for an average of 40 % of the total water production. Most of the production comes from wells in the alluvium of the valleys in the volcanic area at Bendals, Christian Valley, Claremont, Cades Bay, and Follies. The rest of the production is from the Bristol Springs region in the limestone area not far from Potworks Dam.

The most acute problem seems to be the excessive salinity of some water points particularly in the central plain and the limestone region, a feature that Sir W. Halcrow an Partners (1977) attributed partly to the leaching of the rocks. In the absence of data on the geometry of the aquifer systems, this question cannot be answered.

III.1.4 - Distribution system

The treatment stations for surface water and the wells are linked by pipelines to the various reservoirs in the settlements (Fig. 6).

III.2 - BARBUDA

There are about 50 water points on the island comprising natural holes converted into wells, dug wells and boreholes. In the past, electrical conductivity and salinity measurements have been made at all the water points. During our stay in Barbuda some of these water points, whose locations are shown on figure 5, were sampled by the members of APUA to measure chloride content. The first results are given in table 3.

Table 3 - Salinity measurements in the Barbuda wells 21.6.84

Name	N°	Cl. in mg/litre
Peanut Project	Borehole 4	409
Samspring Well	Well 6	807
Bumpy Well	Well 5	1035
(Near Bumpy Well)	Borehole 2	1093
Highland Well	Well 27	629
(Near Baker Cave)	Borehole 7	280
Allin Well	Well 16	1106

As in Antigua, there is considerable spatial variation in groundwater salinity. Significant differences occur between wells, that in some cases are less than 1 500 m apart. The salinity values given verbally by M.H. Simon (documentation not retained) for the sandy area of Palmetto Sands are among the lowest in the island. Time Variations in salinity are also sometimes very high with a ratio of 1 to 10 for Samspring Well, for example.

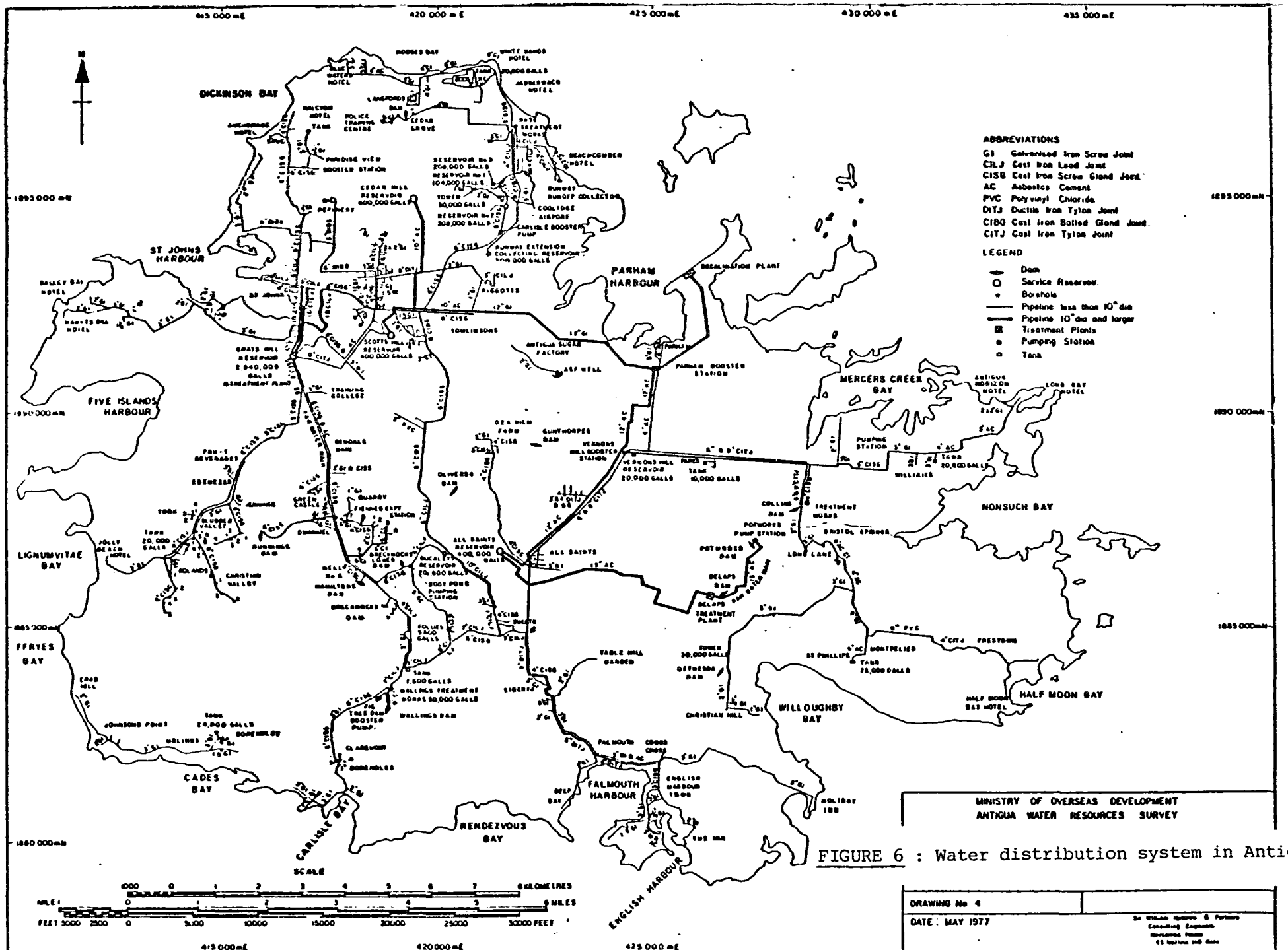


FIGURE 6 : Water distribution system in Antigua.

In order to understand and control the salinity, these results point out the need to explore the respective geometries of fresh and salt water aquifers.

IV - PROSPECTS

IV.1 - ANTIGUA

IV.1.1 - Surface water

We have commented upon the problem of significant water loss by evaporation when the ratio free surface/volume of stored water is too high. The best surface water storage sites will, therefore, be found in isolated regions where relief is sufficient to reduce the free surface of the water compared with the usable volume and give shelter from the wind, features that occur in the volcanic part of the island.

IV.1.2 - Groundwater

IV.1.2.1 - Reservoir formations

In the southwestern part of the island the boreholes that are being exploited traverse the products of erosion of the volcanic rocks, accumulated in the valleys. The rocks of the volcanic complex are fissured at outcrop. A fissured aquifer, protected from evaporation and with high recharge through seepage, almost certainly exists in this area and should be searched for.

In the central plain, conglomerate and bioclastic limestone will constitute the reservoir formations. In the northern part of the island, reservoir rocks are provides by the limestones of the Antigua formation, which at outcrop, show a network of fissures trending N. 80° and N.160° with traces of oxidation due to the cirulation of water. Shaly intercalations less than a metre thick occur locally in the carbonate sequence.

IV.1.2.2 - Water balance

It has been possible to assess the monthly variation in the water balance from the evaporation and rainfall data provided by the Cotten Research Station for the years 1969 to 1973. the main results are summarised in table 4.

In the absence of soil data two Available Water Reserve values, 50 mm and 100 mm, were selected.

Table 4 - Water balance from 1969 to 1973
Cotton Research Station Antigua

	1969	1970	1971	1972	1973
Annual rainfall (mm)	1232	1636	1217	1027	643
Annual surplus (mm) AWR = 50:	230	600	200	60	0
AWR = 100:	180	500	150	10	0
Month of surplus	May	May June November December	December	October	-

It can be seen that even when the AWR is taken at 100 mm, which is the most unfavourable case, there is generally surplus rainfall during May (storm rains) and the last three months of the year.

Surface runoff is negligible in limestone areas, where the surplus is absorbed by seepage. The same important seepage is lekely to occur in that part of the volcanic area, unaffected by alteration.

In the central plain and the lower valleys of the volcanic area, the situation is different as the shaly mantle decreases seepage and increases surface runoff.

In 1983 aquifer recharge was unusually low due to the shortage of rainfall but groundwater exploitation nevertheless continued well, which shows the regulating effect of this type of environment. This capacity of being able to undergo temporary overexploitation should be measured as this would provide a working tool for scheduling exploitation under conditions of inadequate recharge.

IV.2 - BARBUDA

As conditions here are identical to those prevailing in the limestone region of Antigua, it can be assumed that seepage values with be comparable. The sandy surface of Palmetto is undoubtedly the area with the highest seepage in the island, which would account for the presence of a fairly significant fresh water lens of the Ghyben Hertzberg type.

IV.3 - CONCLUSIONS

- groundwater reservoirs seem to have adequate recharge with an important surplus in normal years,
- The regulating capacity of the groundwater reservoir has already been used, for the last years, but not as much as possible,
- Therefore the surest way of dealing with the problems of drought is undoubtedly to continue with the present exploitation of ground water and to extend it to other areas. But an overall management of this resource is yet to be studied in order to :
  - . increase the production of water by optimizing the exploitation of existing borehole and by carring out others borehole in selected sites,
  - . avoid overexploitation in order to safeguard the quality of water.

V - WORK PROGRAMME

Following the data collected and presented hereabove, the B.R.G.M. suggests to undertake a comprehensive study of the groundwater resource of Antigua and Barbuda.

This study should have three main phases :

a - Prefeasability study

This phases would be completed without borings and would include geological survey, geophysical survey and a study of the existing borehole (Water leve survey). The prefeasibility report would give an overall interpretation of the geology of the water reservoirs and would locate the borehole to be carry out in the following phases.

b - Exploration by drilling.

c - Construction of a numerical model.

V.1 - GEOPHYSICAL PROGRAMME

We suggest to undertake a programme of geophysical exploration by electrical prospecting. This method has already been used in Guadeloupe under similar conditions and has given excellent results especially in areas where fresh water overlie salt water aquifers. The further advantage of this method is that it can be employed quickly and at moderate cost.

V.1.1 - Antigua

The location of the proposed electrical soundings along profiles is given on Figure 7. The areas to be investigated are in the volcanic area, the central plain and the limestone region. Some profiles, trending SW - NE, cover all three areas for a broad reconnaissance of the various aquifers. In some cases the profiles are laid out in areas that are already exploited, such as the valleys of the volcanic area and Bristol Springs in the limestone area, to collect the data necessary for the overall management of all the aquifers. For the central plain and the rest of the limestone a region however, they are for reconnaissance for the drilling of production borehores.

V.1.2 - Barbuda

As shown on Figure 8 the proposed electrical soundings explore the lower part of the island and are confined to the area of Palmetto Sands to provide the data required for the management and exploitation of the sandy aquifer.

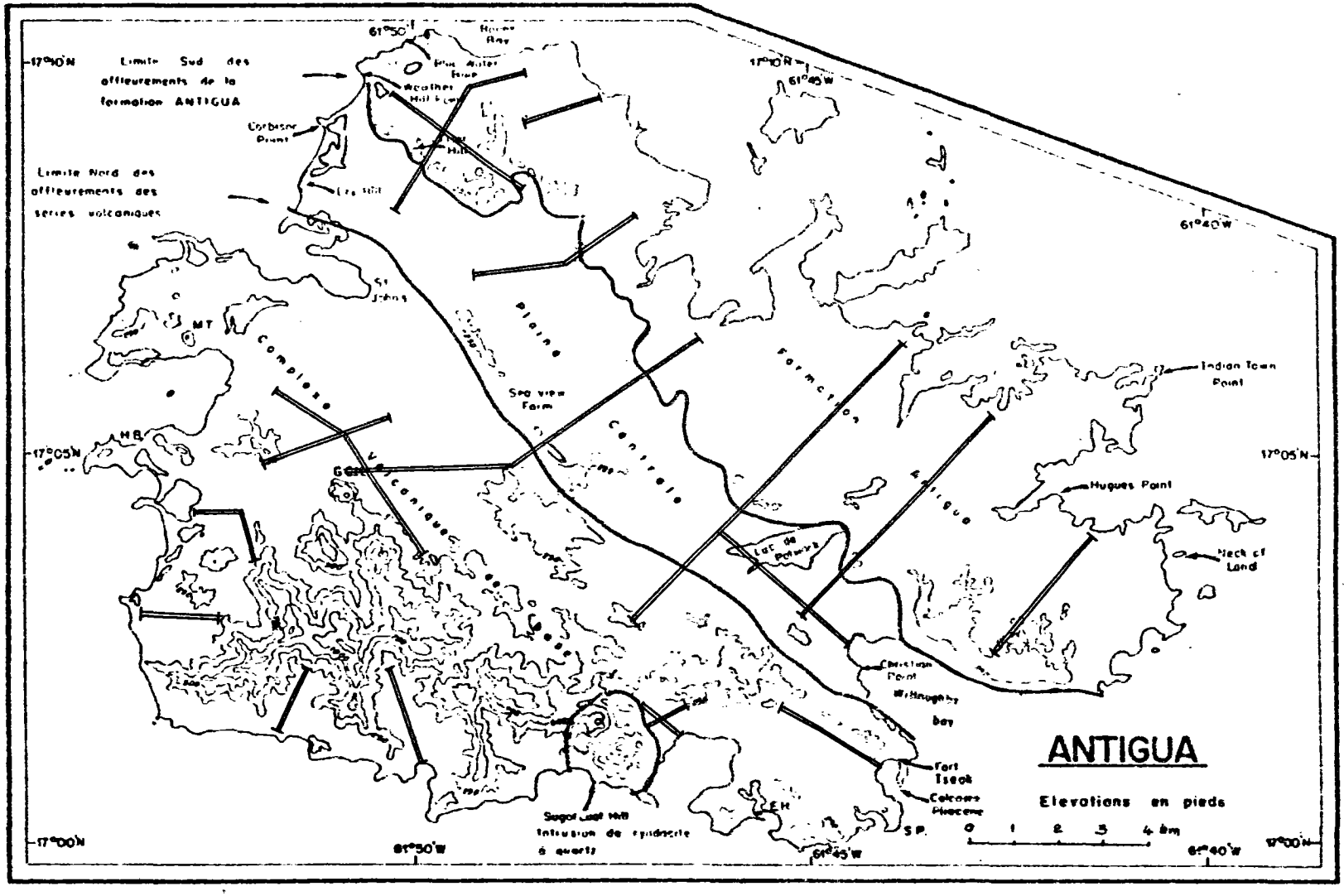


FIGURE 7 : Proposed geophysical profiles - Antigua.

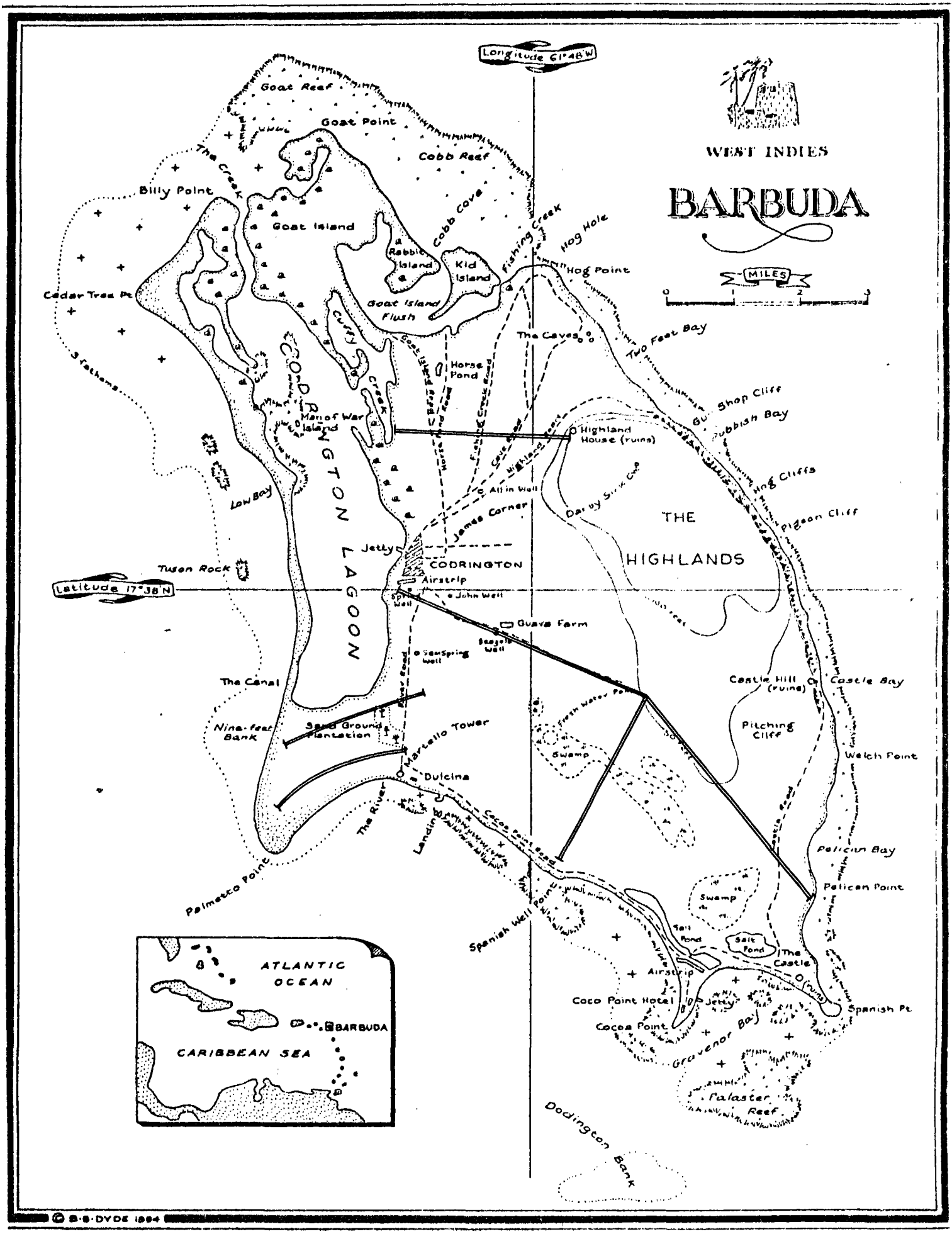


FIGURE 8 : Proposed geophysical profiles - Barbuda.

V.1.3 - Execution

The geological and geomorphological studies are the first stage of the operation. The number of electrical soundings is estimated at about 160 -(125 in Antigua, 35 in Barbuda) which means about two months field work with a team consisting of a geophysicist and four unskilled workers. For climatic reasons and the sake of speed the campaign must be conducted during the dry eason.

V.2 - GEOLOGICAL AND GEOMORPHOLOGICAL EXPLORATION

This should start with the stereoscopic examination of the airphotos for geomorphologic and tectonic features. This should be done before the beginning of the geophysical campaing so as to guide or modify, if necessary, the location of the proposed electrical soundings. The geological study with comprise an examination of the literature, a lithologic description of the formations and examination of drill cores.

V.3 - EXPLORATION BY DRILLING

The drilling of cored holes of a diameter suitable for future exploitation (12", 300 mm) will have several purposes. It will be possible to calibrate the geophysical interpretation of the aquifers and impervious formations against the observed geology in the borehores. It will be possible to test the hydrodynamic characteristics of the aquifers. Once the borehores have been equipped it will be possible to follow the fluctuations of water level in the aquifer, and accurate information on the aquifer will allow the most favourable sites to be developed for exploitation.

The exact number of drill holes and their location will be fixed according to the results obtained at the end of the geophysical campaign. There will probably about 10 to 15, the deepest being about 80 m deep.

V.4 - POTENTIOMETRIC SURVEY AND COLLECTION OF CLIMATOLOGICAL DATA

During the first stage, the wells that are not at present in use will be used to make bi-monthly readings of the static levels. The levels of the wells themselves should also be surveyed. the recording of this information should start at once so as to have data covering as long a period as possible available when necessary thereby increasing, the accuracy of calibration of the groundwater management model. The collection of climatological data (temperature, rainfall, and evaporation) with, of course, continue during the same period.

V.5 - CONSTRUCTION OF A NUMERICAL MODEL

The combined data will define both the extention and depth of the aquifers and their hydrodynamic characteristics and working conditions natural recharge and exploitation. On the basis of these data, a model with a two-fold purpose will be designed.

1) Defining the flow regime totally and evaluating the water balance inputs and outputs. This would be the analytical aspect of the model.

2) Simulating different conditions of exploitation on the model, and, in particular, optimazing withdrawals for years of low recharge and testing the possibilities of development of new wells. The model would in this way be used as a means of management.

The model with be designed for unsteady state operation in order to be able to simulate planning of groundwater withdrawal on yearly cycles under varying conditions od severity.

REFERENCES

William HALCROW and PARTNERS - "An engineering of the water resources of Antigua - Vol. I, II, III, IV prepared under assignment from the Ministry of Overseas Development for the Government of Antigua, September 1977.

James M. MONTGOMERY - consulting engineers, INC, "Antigua water supply project" prepared under the assignment from the Agency for International Development of USA for the APUA. March 1983.

PHA MARTIN KAYE - "Report on Antigua water supply" British Guiana Geological Georgetown - February 1965.

William HALCROW and PARTNERS - "A preliminary report on the conservation of water in Antigua - Department of Agriculture, Ministry of Trade, Production and Labour - St John's Antigua Leeward Islands.

A. MASCLE - D. WESTERCAMP - La géologie d'Antigua, Petites Antilles - Rapport IFP, 1983.