humid areas and presenting similar topographic features. Obtained average value shows annually 50 mm is increased in each 100m of elevation.
The relation between altitude and rainfall can be theoretically estimated by the proposed statistic methods or by using mechanical or experimental methods, however, no calculation was made due to insufficient data on this Study.
In addition, annual rainfall varies with the size and course of hurricanes, consequently, more detailed information and time are required for a quantitative grasp of the relation ship between altitude and rainfall in the Project Area. As regards computation of the areal rainfall amount, the rainfall in the mountainous highlands was assumed by referring to Isohyetal Map shown in Fig 1.2.2.

3.1.2 Rainfall Distribution

1) Distribution pattern of the rainfall in 3 meteorological stations is shown in Fig 1.2.3. In the northern region of Monte Cristi influenced of the Atlantic Ocean brings relatively heavy rains in winter, almost 37% of the annual rainfall falls between December and March. When November data is added to the previous four months, the proportion will rise to about 52%. Except in July and August, rainfall is observed all year long, however, the annual rainfall in this area represents only 1/3 or 1/2 of the amount in the humid zones.

   In the other regions, the maximum rainfall generally occurs either in November or in April / May. Summer can be regarded as the rainy season and winter as the dry season. There is extremely little rain in July. Rainfall in the 4-month of winter does not exceed 10~15% of the annual rainfall.

   Rainfall days with a rain amount exceeding 25 mm/hr in Don Miguel represents about 20% of the annual rainfall days.

   As mentioned in the previous section, amount of rainfall intensity (mm/24hr, mm/hr) is very important because the amount of these heavy rainy days exceeds 50% of the amount of annual rainfall. Fig 1.3.2 shows noticeable annual fluctuations, in general, rainfall amount of a drought year accounts for 30% or so of a rainy year amount.

The longest draught continued days were collected at Pepillo Salcedo in 1976 with 120 days. 50 days of draught days are frequently observed.

Further, a maximum daily rainfall of 9.5 mm was recorded at Partido in 1985, with 60 draught days, and 312 draught days with rainfall amounting to less than 5 mm/day.

2) Daily rainfall in the 4 rainfall gauge stations of Don Miguel, La Antona, Partido and Quinigua in 1985-1990, were collected from INDRHI.

The specific character of rainfall, based on the measurements recorded in the stations are the following:

	Don Miguel (El. 45m)	Partido (El. 200m)	La Antona (El. 48m)	Quinigua (El. 138.0)
Mean annual rainfall, according to long-term records	1498.5 mm	1296.4 mm	740.6 mm	1004.7 mm
Mean annual rainfall (1985~1988)	1492.4 mm	448.6 mm	742.2 mm	1160 mm

Except for the Partido Station, long-term rainfall and short-term rainfall amounts are roughly the same. Annual rainfall observed from 1985 to 1987 (3 years) in the Partido Station shows a decrease of less than 200 mm, that is approximately 15% of the ordinary years. These small values were never observed during the past 30 years, and even ratio with other stations suggests any mis-measurement of these record.

Additionally, number of rainy days in 1988 (annual rainfall : 1310 mm) represents only 50% of the normal year. However, the 1985, 1986 and 1987 number of rainy days ranged between 85~106 days. Consequently, daily rainfall of three stations at Don Miguel, La Antona and Quinigua was analized.

Maximum rainfall per day for each year is as follows:

	Don Miguel	La Antona	Quinigua
1985	92.7 mm	60	183.6
1986	96.5	70.9	59.8
1987	146.0	91.1	100.3
1988	145.0	91.7	104.1

Duration of rainfall is usually only 1~2 hour a day. It is assumed that, in general, maximum rainfall intensity is approximately 80 mm/hr.

Rainy days classified according to the amount of rainfall is shown below:

	Don Miguel				La Antona				Quinigua			
mm	<5	<10	<25	>26	<5	<10	<25	>26	<5	<10	<25	>26
1985	35	23	21	22 (4)	26	23	12	7 (3)	63	25	15	9 (2)
1986	29	30	19	21 (8)	37	21	9	10 (3)	58	29	18	13 (1)
1987	28	35	35	19 (2)	45	24	17	13 (2)	53	26	15	18 (5)
1988	25	33	22	20 (8)	43	15	16	7 (1)	52	28	18	16 (8)

( ) indicates days with more than 45 mm/day rainfall.

Mean annual rainy days are 103 days at Don Miguel, 80 at La Antona, and 114 at Quinigua. Proportion of rainy days showing a rainfall exceeding 25 mm/day is 15~20%, which accounts for 50~58% of the annual rainfall, as presented below. Every year, this area is subjected to frequently localized torrential downpours.

3.1.3 Areal Rainfall

Based on the point rainfall records, the precipitation of each hydrological basin is estimated by to the simple Arithmetic Average Method, the Thiessen Method and the Isohyetal Method.

	Don Miguel		La Antona	Quinigua
1985	838.3 mm	(59.8%)	303.7 (45.4)	484.6 (49.0)
1986	937.7	(62.4)	333.5 (52.2)	481.1 (49.0)
1987	791.1	(51.0)	580.9 (60.2)	827.1 (64.5)
1988	914.1	(58.7)	257.1 (37.0)	835.9 (60.0)
Average		58%	49.7%	56.6%

<u>Arithmetic Average Method</u>

$$\overline{P} = \frac{1}{N}(P_1 + P_2 + \cdots\cdots + Pn)$$

where,

N = Number of points

Pn = Point Rainfall (Mean annual rainfall at the station)

<u>Thiessen Method</u>

$$\overline{P} = \frac{A_1P_1 + A_2P_2 \cdots\cdots + A_NP_N}{A_1 + A_2 + \cdots\cdots + A_N}$$

$$= \frac{1}{A}(A_1P_1 + A_2P_2 \cdots\cdots + A_NP_N)$$

<u>Isohyetal Method</u>

$$P = \frac{1}{A}\left(A_1\frac{P_1 + P_2}{2} + A_2\frac{P_2 + P_3}{2} + A_NP_N\right)$$

The areal rainfalls estimated by above methods are summerized as follows (See Table 1.3.2) :

	Arithmetic Average Method	Thiessen Method	Isohyetal Method
Areal Rainfall	10356.90 m3 1110 mm	9793.648 m3 1050 mm	11152.4 m3 1195 mm
Difference	100%	95%	107.7%

As precipitation is locally varing, the Isohyetal Method is considered most accurate, however, the simple Arithmetic Average Method was selected because of easily adoption on hydrological sub-basins.

3.2 Evaporation and Evapotranspiration

Long-term data on monthly and annual evaporation were collected from 11 observation stations. However, only 4 stations can provide A-Pan Type evapometers.

As shown in Table 1.2.7, All the annual evaporation by the evapometer exceeds the annual precipitation.

Evapotranspiration is composed of the evaporation from the soil surface and transpiration of plants growing on the ground. Evaporation varies in accordance with the climatic condition like wind, temperature, humidity, etc. Transpiration varies in accordance with the vegetation on the stage of the plant and the soil moisture content.

Potential evapotranspiration (PE) is defined as the evapotranspiration measured in a site where the soil moisture contatins the ordinary water holding capacity.

The PE is adopted to determine irrigation water requirement, however, when the water balance and the runoff discharge for a large area is considered, real evapotranspiration is assumed to be lower than PE because the surface soil can't keep the ordinary water holding capacity.

The potential evapotranspiration value, estimated in the Study Area in April 1979, by the IICA for the "Water Resource Development for the Agricultural Water in the Frontier Zone", are presented in Table 1.2.7.

Relative ratio of evaporation (E) and (ET) is considered as following formula:

$$\Sigma ET = a(\Sigma_E)^n$$

Many experimental values were proposed for the relative ratio of ET and E. Experimental coefficient was calculated by the Agricultural Technical Research Institute of Japan under the natural rainfall conditions:

$$\Sigma ET = 0.269(\Sigma_E)^{126}$$

However, according to this formula, $\Sigma_{ET}=1.05\Sigma_E$ and exceeds the annual point rainfall amount.

Further, according to Kaneko computations:

- In case of paddy fields, $\Sigma_{ET}=0.83\sim0.9\Sigma_E$
- In other cases, $\Sigma_{ET}=0.625\sim0.69\Sigma_E$

An American Survey stated that Σ_{ET} and Σ_E values of water surface was 67% in Denver and 70% in Colorado.

Kittredge's estimate of proportion of evaporation losses is 97% in case of saturated surface soil in open field, 36~39% for free water surface in forest, and 35% for saturated surface soil in forest.

According to the "Evaluation of National Resources" by OEA, the Project Area extends on about 6527 km^2, 54% of which are covered with the forests, waste land, lakes and rivers; 46% are arable land composed of the crop area (24%). Dry season irrigation system is implemented in 50% of the crop area. The main cultivated crops are coffee, rice, Ridney beans, corn, yucca, tobacco, peanut, banana, etc. Approximately 50% of the forest area are located on arid or waste lands. Forest vegetation is poor, and mainly composed of coppice (26%), brood leaf trees (16%), and pine trees (5%) (FAO Report, 1973).

After due consideration to various surveys, experimental formula, and present conditions of land use and forests, estimate of real evapotranspiration is 65-70% in humid forest areas, and 85-90% in arid areas.

3.3 River

3.3.1 Discharge

River discharge varies due to the rainfall distribution and recharging condition in the catchment area (land cover, geology, etc.).

Basic characteristics of the rivers in the Study area is summarized in Table 1.3.3.

Specific discharge is approximately 12~15 l/s/km^2 in Rio Guayubin and Maguaca; for Rio Amina and Cana about 30~33 l/s/km^2 23~25 l/s/km^2 in the upstream of Rio Yaque del Norte main stream ; 10~15 l/s/km^2 in Rio Chacuey; 25 l/s/km^2 in Rio Masacre. The specific discharge of Rio

Artibonito and its tributaries, excluding the Rio Macasia and Cana which lies in a range of 4~8 $l/s/km^2$, is about 11~20 $l/s/km^2$.

The coefficient of river regime is very small on the Table 1.3.3 because this calculation is made by monthly mean. Moreover, no discharge is obscured in many tributaries during dry season.

In general, discharge measurement in major rivers reveals a flood period in May, June, October and November, and a drought period in February or March as shown in Fig. 1.2.6. The monthly discharge rates to the total annual discharge are presented in Table 1.3.3.

Each river has been developed in order to utilize the river flow for agricultural irrigation water in the Project Area. Thus river discharge fluctuates by the controlled water like upstream dams, pumping and the return flow of irrigation water. The discharge in the downstream of the low dams is extremely decreased in the Chacuey, Maguaca, Guayubin, Cana and Masacre rivers.

The total discharge rates of the majors rivers from January to March, and from July to August, calculated from the annual discharge, are the following:

Rio Yaque del Norte System	Σ Jan., Feb., March (%)	Σ Jul., Aug. (%)	Σ Apr., May, June, Oct., Nov., Dec. (%)
Main Stream			
Jinamaguo	18.7	10.7	70.6
San Rafel	15.7	12.4	71.9
Ranchadero	14.9	13.2	72.0
Palo Verde	14.9	10.0	75.1
Rio Amina			
Iona	12.5	11.1	76.4
Potrero	14.5	12.8	72.7
Rio Mao			
Bulla	11.3	16.2	72.5
Chorrera	16.1	15.7	68.2
Rio Guay ubin			
La Rincon	14.8	13.8	71.4
La Antona	13.8	8.3	77.9
Rio Maguaca	13.0	12.5	74.5
Rio Chacuey			
La Pinta	17.5	22.5	60.0
La Espensa	5.1	7.2	87.7
Rio Masacre			
Don Miguel	13.0	12.5	74.5
Rio Artibonito			
Perdo Santana	9.8	19.0	71.2
Rio Tocino	17.9	18.8	63.3
Rio Joca	9.4	21.4	69.2
Rio Macasia			
Rinconcito	11.1	15.5	73.4
Renchitos	8.2	16.0	75.8
Rio Cana			
La Guinos	13.8	13.4	72.8
De Iuero	8.1	13.5	78.4

From the above Table, proportion of the total discharge for a 3-month period (January~March) is about 13% of the annual discharge amount in average, precisely 3.7% and 4.1% for February and March respectively.

During this period, the discharge of each tributary is extremely poor, therefore, the stream water is impossible to use.

The runoff percentage of each river was estimated based on the areal rainfall of each basin calculated in accordance with the Isohyetal Map (See Fig. 1.2.3).

Table 1.3.4 shows the results of upstream run-off percentage of Rio Yaque del Norte and its upstream tributaries. As for the Amin and Mao rivers, run-off measurement is considerably high, with 70 to 80% of the annual discharge. In the downstream tributaries (Cana, Gurabo and Guayubin rivers) runoff is less than 30%, while Masacre river is approximately 53%.

Runoff of the Artibonito river System (except Macasia and Cana rivers) is estimated 30 to 35%, while the Macasia and Cana rivers' runoff doesn't exceed a very low rate of 12%.

In order to analysis the river characteristics in the Study Area, the daily discharge records of Masacre and Guayubin rivers are selected because only these points have both discharge and rainfall records at same period is 1985 - 1988.

Summary of the discharge calculation of both rivers is the following:

Rio Guayubin

Station Name : Rincon EL. 57.0m Basin Area : 520 km2

Year	1985	1986	1987	1988
Daily Discharge				
Min. m^3/s	0.15	2.53	3.03	2.63
Max. m^3/s	194.26	219.56	302.25	171.08
Inst ant Max.	442.96	529.21	740.81	358.13
Inst. Min.	0.11	2.35	2.35	1.45
Annual Average				
Dischage	9.64	27.57	32.15	25.04
Specific Discharge $l/s/km^2$	18.54	53.02	61.83	48.15
Coefficient of River Regime	1295.0	87.0	100.0	65.0

Rio Masacre

Station Name : Don Miguel EL. 45.0m Basin Area : 162 km2

Year	1985	1986	1987	1988
Daily Discharge				
Min.	0.43	0.00	0.00	1.18
Max.	703.33	932.24	96.47	51.06
Inst. Max.	1776.27	932.24	282.03	398.01
Inst. Min.	0.13	0.0	0.0	1.18
Mean Annual				
Discharge	20.61	5.88	4.77	6.98
Specific Discharge	127.22	36.29	29.44	43.09
Coefficient of River Regime	1635	α	α	43.3

1) Masacre River

According to the collected discharge records from INDRHI, the mean annual discharge of 29 years (1954 ~ 1983) is $2.46 m^3/s$.

However, a long term period of 34 years up to 1988 shows a $4.09 m^3/s$ average, due to an extremely high mean annual discharge in 1984, 1985 and 1986: records were 3 to 4 times the quantity of a normal year.

In case the mean annual discharge is 4.09 m^3/s, runoff percentage is 53%, and mean annual discharge is 2.46 m^3/s, runoff percentage is 32%.

A maximum daily discharge of 932.24 m^3/s was recorded in April 22, 1986 ; the second maximum data was 703.33 m^3/s, previously recorded on November 17, 1985. Equivalent quantity in mm is respectively 497.8 and 375 mm.

Rainfall records observed above flooding day and 10 days before at 4 stations located in the catchment basin and its vicinity are shown below. Some rainfall data exceed the normal year records, however, rainfall data corresponding to the above mentioned discharge measurements were not recorded in any observation points.

Name	Longitude	Latitude	Elevation (m)	RAINFALL			
				7~16/11	17/11. '85	11~21/4	22/4. '86.
Don Miguel	71.40.40	19.30.10	45	15.4	92.7	19.5	0.0
(Partido)	71.33.20	19.33.20	200	3.5	0.0	6.7	0.1
La Antona	71.24.10	19.38.0	48	20.8	60.0	9.3	8.5
Quinigua	71.36.0	19.31.35	138	98.1	183.6	108.6	13.9

This flood is probably due to localized torrential downpours produced by a hurricane.

Following table shows monthly rainfall, equivalent river discharge and runoff percentages from 1985 to 1988.

	1985			1986			1987			1988		
	R	D	D/R	R	D	D/R	R	D	D/R	R	D	D/R
	mm	mm										
Jan.	16.2	258.25	15.9	63.1	No Data		28.2	0.661	0.023	47.7	104.98	2.2
Feb.	55.2	217.03	3.9	21.8	- do -		33.5	0.448	0.013	19.3	58,93	2.94
Mar.	93.2	211.29	2.3	173.9	- do -		62.5	1.653	0.0264	85.3	55.55	0.651
Apr.	59.1	216.48	3.7	89.1	(1544.15)	(1733)	296.7	15.04	0.050	17.1	31.52	1.84
May	254.1	286.48	1.1	490.2	151.94	0.31	160.1	127.63	0.797	210.1	133.75	0.64
Jun.	149.9	155.36	1.0	63.2	29.44	0.47	181.9	78.4	0.431	323.9	169.28	0.52
Jul.	221.1	100.19	0.45	104.9	14.22	0.14	77.5	68.117	0.879	199.1	161.7	0.81
Aug.	110.8	182.69	1.6	80.4	23.97	0.30	105.3	30.256	0.287	156.2	112.9	0.72
Sep.	195.9	803.84	4.1	90.5	3.36	0.04	244.2	152.64	0.625	234.9	179.52	0.76
Oct.	117.5	412.67	3.5	279.4	5.29	0.02	231.8	140.04	0.604	221.3	227.33	1.03
Nov.	127.2	827.52	6.5	44.3	5.12	0.11	89.7	164.16	1.83	196	83.84	4.28
Dec.	1.2	Non Data	-	0.0	1.98	α	-	149.67	-	21.6	43.15	2.00
Annual	1401.4	4012	2.86	1500.8	1144.6	0.762	1511.4	928	0.614	1556.1	1362.5	0.875

( ) : Maximum Discharge

The following runoff percentage is calculated on annual base, within a 12-year period from 1973 to 1984. Runoff rate clearly increases in rainy years.

1973	31.5 %	1979	50.6 %
1974	48.8	1980	51.7
1975	28.8	1981	57.6
1976	12.7	1982	36.2
1977	14.2	1983	28.8
1978	62.4	1984	215.4
		Average	49.1

Fig 1.3.3 and 1.3.4 shows the relation of rainfall and discharge. According to the results, this river is considered to take groundwater flow from other catchment area or rainfall in the upper part of the station is extremely high. Additionally, many intake weirs for drinking water and irrigation at upperstream make difficulty on any kind of equivalent analysis.

2) Guayubin River

The monthly runoff percentages of Guayubin river measured within a 4-year period (1985~1988) are as shown below:

	1985			1986			1987			1988		
	R <1	D	D/R	R <1	D	D/R	R <1	D	D/R	R <1	D	D/R
Jan.	11.5 (68) <2	13.13	1.14	70.1 (70.1)	51.35	0.73	17.4 (6.5)	29.51	1.69	84.5 (84.5)	85.66	1.01
Feb.	46.6 (38.0)	30.15	0.65	18.3 (14.7)	24.8	1.35	24.3 (15.1)	26.29	1.08	10.1 (0.9)	47.03	4.65
Mar.	69.7 (46.1)	25.45	0.36	124.2 (74.2)	57.2	0.46	77.3 (91.6)	32.81	0.42	42.0 (0.0)	33.68	0.80
Apr.	47.9 (36.5)	47.7	0.99	69.7 (50.2)	153.27	2.19	280.0 (263.6)	105.18	0.37	34.3 (34.3)	43.81	1,27
May	17.49 (95.7)	52.64	0.30	353.3 (216.4)	479.48	1.35	136.5 (112.8)	338.45	2.48	162.9 (115.7)	216.85	1.33
Jun.	110.0 (70.1)	32.50	0.29	38.8 (14.5)	241.16	6.21	173.6 (165.2)	274.9	1.58	269.5 (215.1)	232.93	0.86
Jul.	162.7 (104.3)	18.34	0.11	52.8 (0.7)	138.55	2.62	56.4 (35.2)	158.28	2.80	123.9 (48.6)	223.65	1.80
Aug.	107.3 (93.74)	28.23	0.26	53.2 (26.2)	113.0	2.12	67.2 (29.1)	87.3	1.299	82.3 (20.4)	123.79	1.50
Sep.	129.7 (53.3)	33.75	0.26	67.0 (35.4)	90.72	1.35	158.3 (72.4)	209.15	1.32	181.4 (127.9)	151.23	0.83
Oct.	122.9 (28.4)	67.11	0.55	198.6 (107.8)	226.07	1.13	157.2 (82.3)	291.94	1.85	130.9 (40.5)	280.30	2.14
Nov.	1111.2 (95.2)	164.34	1.48	36.4 (28.4)	57.62	1.58	93.0 (96.3)	205.81	2.21	12.6 (4.6)	58.22	4.62
Dec.	1.8 (1.2)	71.59	39.77	0.8 (0.4)	35.75	44.69	93.0 (91.2)	190.58	2.05	12.4 (3.3)	25.34	2.04

<1: Estimated rainfall based on the records of La Antona

<2: Estimated rainfall based on the Isohyetal Map of La Antona Station

According to this table, runoff percentage is very high, and the local rainfall in the upstream mountain zone could not be evaluated by the obtained rainfall data. Fig. 1.3.5 shows the relation of rainfall and dischange.

The monthly discharge rate of the 2 rivers, based on the mean annual discharge, is as follows:

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Guayubin River	%											
1985	2.2	5.4	4.4	8.2	9.0	5.6	3.1	4.8	5.8	11.5	28.1	12.2
1986	3.1	1.5	3.5	9.2	28.7	14.4	8.3	6.8	5.4	13.5	3.4	2.1
1987	1.5	1.3	1.7	5.4	17.4	14.1	8.1	4.5	10.7	15.0	10.5	9.8
1988	5.6	3.1	2.2	2.9	14.3	15.3	14.7	8.1	9.9	18.4	3.8	1.7
Average	3.1	2.8	3.0	6.5	17.4	12.4	8.5	6.0	7.9	14.5	11.5	6.5
Masacre River												
1985	7.0	5.9	5.5	5.8	7.8	4.0	2.7	5.0	21.8	11.0	22.0	1.5
1986	-	-	-	-	-	-	-	-	-	-	-	-
1987	0.07	0.05	0.18	1.6	13.7	8.4	9.3	3.4	16.4	15.1	17.7	16.1
1988	7.8	4.3	4.1	2.3	9.5	12.5	11.9	8.3	13.2	16.7	6.2	3.2
Average	5.0	3.4	3.3	3.3	10.3	83	7.3	5.6	17.1	14.3	15.3	6.9

Discharge volumes in January, February and March are extremely low, these 3-month accumulated discharge representing only about 10% of the annual discharge.

Results of the actual measurements in July and February, river is almost dry in the downstream of the intake weir for drinking water.

Observations of the flow regime of both rivers brings out its instability if used as a source for a water supply system. Particularly, even if abundant water resources are available in the rivers, important discharge volume is generally caused by the rainy season flood. Moreover, these water resources will be hardly effectively utilized without planning reservoir ponds.

3.3.2 Development Potential

The rivers of the Project Area have been highly developed in order to utilize water resources for irrigation and domestic water. Storage reservoirs are constructed on the Gurabo, Cana, Chacuey, Maguaca and Masacre rivers. Many barrages, intake weirs and pump stations are installed on other rivers, together with many temporary pump stations for private use of plantations.

Mountain streams are a particularly valuable source of domestic water, though allowing many other utilizations of water on various scales.

Rainfall in the northern hilly mountain area and coastal area of Monte Cristi, which belongs to the Atlantic Ocean meteorological zone, appears to be distributed in winter. The small rivers are almost dry all the year. They are functioning as only flood water diversion channels, and will not constitute valuable water sources for the population. In this area, each village has constructed small reservoirs with embankments in depression places to catch and store the surface run -off water for daily use.

1) Discharge Record

As previously stated, discharge of each river in the subject area fluctuates remarkably by month and year.

The average monthly and annual discharge of each river are shown in Table A3.10 of the Appendix.

Since the observation period is short and variable, the average discharge record may not correlate with the average discharge f the same river system. Therefore, the annual average flow at each gauging station was estimated based on the existing discharge records with 80% and 50% return probability, as shown in Table 1.3.5 (1) and (2).

In order to assess the development potential of the surface water, 80% return probability (1.25 year of flow return period) is estimated to be the design discharge for each river, so as to ensure stable water supply.

2) Available Streamflow (D_P)

The available streamflow was estimated by using the following equation:

$$D_P = D_T - D_E - D_M$$

Where,

D_P : Available Streamflow
D_T : Average Annual Streamflow
D_E : Existing Water Use
D_M : Maintenance Flow

(1) Average Annual streamflow (D_T)

The average annual streamflow of each river was estimated as the flow with 80% return probability. The designed average annual runoff of each hydrological basin is shown below:

River Basin	Gauge Station	Annual Streamflow (m^3)
Yaque del Norte	Ranchadero	1,064 million
Chacuey	La Espensa	150
Guajabo <1 (incl. Laguna Saladilla	(Confluence)	650
Dajabon	Don Miguel	360
Artibonito		1,000

<1: INDRHI data are used for Guajabo river basin including Laguna Saladilla.

The average annual streamflow of the Artibonito river basin is estimated as follows.

(i) Total annual flow of sub-river basins

Sub-River Basin	Gauge Station	Annual Streamflow (m^3)
Artibonito	Pedro Santana	373,355,000
Joca	El Corte	126,176,000
Tocino	Cojuilitos	9,997,000
Macasia	Ranchitos	107,286,000
Total		616,814,000

(ii) Streamflow from the remaining catchment area is estimated as 70% of the discharge at Pedro Santara because of the contribution from Haiti;

$$520,000,000 \times 0.70 = 364,000,000$$

(iii) Streamflow at Dos Bocas station is estimated as 70% of 1,630 million m^3

$$1,630,000,000 \times 0.70 = 1,141,000,000$$

(iv) Annual streamflow of Artibonito river basin is total of (i) and (ii), on (iii). Therefore, the amount finally adopted is 1,000 million m^3.

(2) Presenty used streamflow (D_E)

Basin	Irrigation ($10^6 m^3$)	Drinking Water ($10^6 m^3$)	Total ($10^6 m^3$)
Yaque del Norte, Gurabo Dajabon, Chacuey River	700	30	730
Artibonito River	80	3.54	84.0
Enriquillo Lake Basin	(82)	(5.0)*	(87.0)*

* The development potential of the surface water in the Lake Enriquillo Basin is excluded because most of its water resources come from springs.

(3) Maintenance Flow (D_M)

In order to maintain the river-course and the supply of domestic water to the inhabitants downstream, 30% of the discharge is estimated to be the Maintenance Flow.

(4) Available Streamflow (D_P)

The results of the calculation of the available streamflow are as follows:

Basin Name	D_T $10^6 m^3$	D_E $10^6 m^3$	D_M $10^6 m^3$	D_P $10^6 m^3$
Yaque del Norte, Gurabo Dajabon, Chacuey River	1,639.0	730	491.7	417.3
Artibonito River	1,000.0	84	300.0	616
Lake Enriquillo	-	-	-	-
Total	2,639	814	791.7	1033.3

If 10% of the total available streamflow shown above is assumed to be usable as domestic water of the area residents, the surface water development potential for drinking water will be around 103 million m^3 per year.

3) Development potentiality estimated by ONAPLAN

Development Potentiality of the water resources were estimated for the "Development Project of the Frontier Zone" by ONAPLAN. Development potential of the major rivers in the Project Area is as follows:

River Name	Point	Potential Volume (million m^3 per year)
Masacre	Don Miguel	60
Guajabo	Lag. Saladilla	55
Yaque del Norte		
Amina	Inoa	137
Mao	Moncion	400
Gurabo	Sin Nombre	19
Cana	Angostura	43
Guayubin	Rincon	155
Artibonito		
Neita	Restauracion	84
Libon	Villa Anacaona	115
Joca	Los Corogos	28
Tocino	Cajuilito	260
Artibonito	Los Algodones	390
Artibonito	El Corte	420
Artibonito	Pedro Santana	1570
Macasia		
Yacahueque	Puzo Hondo	25
Yacahueque	Palme Sola	8
Yabonico	Loma de la Cabezuda	8
Yabon	Seco Babor	4
Macasia	Puertecito	10
Macasia	Los Jobes	52
Cana	Los Mesas	57
Arroyo Alonso Olivero	Guanito	18
Arroyo Alonso Olivero	Naranjo	20
Lago Enriquillo Basin	Guayabal	25
Total		3963

The above estimated potential is based on the available discharge obtained from the annual data. However, it seems that the construction of dams is required to guarantee stable water resources for the water supply system .

The total discharge of the 3-month low water season represents 10% of the annual discharge. Discharge of downstreams of existing water facilities is extremely small, and it will be thus extremely difficult to intake such a negligible quantity of surplus water even with facilities such as intake weir, collecting gallery or water absorbtion conducts.

According to the discharge measurment in the downstream of the existing water intake facilities implemented in the tributaries of Yaque del Norte and Artibonito Rivers on July - August and January - February, it is considered there is little potentiality for additional development.

Consequently, due to the actual conditions of the discharge pattern, it can be stated that, except for the headspring area of the mountain streams, the tributaries of the Yaque del Norte and Artibonos rivers (except both rivers mainstreams) show an extremely low potential for a systematic development of domestic water supply if a suitable plan for dam construction is not devised.

4) Development Potentiality of Mountain Streams

The river headsprings are located in the mountainous area with an altitude ranging 400 - 2000 meters, where annual rainfall is 1500 2000mm in the high-rain areas.

Compared with the flatlands and hilly areas, mountains are characterized by rich vegetation and by the rainfall interception and the surface water storage capacities.

Additionally, there is a sub-surface and ground flow, like in the Neiba Mountains sector, where mountain streams are numberless. Although many of them dry out or discharge becomes extremely poor in the dry season, the stream water is being used systematically or not by the residents.

In the isolated mountain villages behind in the development of social infrastructure, mountain stream is very important water source used by the residents. However, information on mountain stream discharge and its stability needed to evaluate the development potentiality are not available. It is therefore difficult to assess the quantity of development potential and availability of domestic water for the local inhabitants.

CHAPTER Ⅳ

SURFACE WATER DEVELOPMENT PLAN

4.1 General

According to the water supply plan, the surface water development plan will be devised as an alternative to groundwater development.

The water supply development plan proposes surface water as a main water resource for the Northern villages of the Monte Cristi Province, because there is no potentiality of groundwater development due to the detailed hydrogeological study in this area.

Existing water supply system in this area is based on the small reservoir. All villages have two or three reservoirs constructed by INDRHI, and village people convey water by themselves. However, reservoir's capacity is not sufficient to satisfy water needs year round, especially in dry season, and its specification makes problem on water quality for drinking. Most of the reservoirs are constructed in the depression sites of the dry streams to receive and store water flush in the rainy season. This flush contains garbage and soil erosion of the upper reach and flows into reservoir directly. Therefore, the reservoir water is easily contaminated and worsened by high rated evaporation. Additionally, livestocks of the village people can walk into the reservoir freely and contaminate water easily.

Considering the above conditions, the surface water development plan will be practical and feasible.

4.2 Proposed Villages

4.2.1 Location

The number and name of the proposed villages are as follows:

- Coastal Area
  No. 2 Esabel de Torres No. 33Loma Atravezada
  No. 30Buen Hombre No. 17Estro Balsa

- Plateaus Area
  No. 11Los Conucos No. 21Cayal
  No. 4 Las Aguitas No. 32La Brigada No. 34Sabana Cruz
  No. 31Las Canas No. 37El Manantial

These villages are scattered along rural roads each 2-6 km.

Village elevation is less than 10m in the coastal area, while the altitude of plateau villages lies in the range between 160 and 190 meters.

4.3 Climate

4.3.1 Precipitation

The proposed area faces the Atlantic Ocean extending 25 km in the east-west direction, and 10 km in the south-north direction.

There is no rainfall gauge station as well as any observation records to assess the local climate conditions.

During the study period, in order to evaluate the rainfall, the team installed a rain recorder at Papajo located at the eastern tip of the plateaus. The observation records are presented in the Data Book. According to the measurement from December 15, 1990 to November 3, 1991 (323 days), the rainy days numbered less were 38. Rainfall amounted to 838 mm (however, no data recorded in April), 62% (524 mm) of which represented the rain volume of 11 rain-days and a total of about 20 hours of rainfall. In addition, during the 11 rain-days recorded in May 1991, rainfall amounted to 277 mm owing to the hurricanes. In the same period, rainfall at the Monte Cristi Station was about 700 mm.

Consequently, the design precipitation to estimate the potentiality of the surface water development in the proposed area were estimated based on the isohyetal maps of the national monthly rainfall distribution provided by the "National Meteorological Department" and the historical records of the Monte Cristi and Villa Vasque Stations.

In the estimation, the probable rainfall was evaluated in accordance with the records of the Monte Cristi Station.

Thus, the designed annual and monthly rainfall were estimated as follows:

Annual Rainfall 740 mm
Monthly Rainfall:

unit : mm

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
62	39	40	69	75	44	20	37	44	80	125	115

Effective rainfall for the project shall be assumed from the amount of rainfall of Oct., Nov., Dec., Jan. , Apr. and May by the lower limitation of monthly 45mm because of low runoff percentage.

4.3.2 Evapotranspiration

The proposed village are located in a semi-arid zone, where upland crops area and the whole farm lands are left as it is without any weeds during the dry season. It is assumed that the soil moisture is below the wilting point, and the grass completely dries in this season.

The farm lands consist of ordinary water holding capacity in the begining. However, when evaporation from the soil surface will be made rapidly, soil moisture will be decreased, and evaporation ration will be scanty in the end.

The transpiration is also varied due to the amount of the soil moisture.

In consideration of the rainfall intensity and distribution pattern, transpiration in the rainy season decreases due to heavy downpours, where as evaporation from the soil surface is rapidly increasing.

On the other hand, evaporation from the water surface of the reservoirs, which supply domestic water to the local inhabitants is very large and make water level of the reservoir rapidly fall down during the dry season.

About 75% of the Project Area consists of shrubbery land surface without grass on the land surface.

The following estimation of the design evaporation for the Project refers to the potential evapotranspiration estimated by the records of Monte Cristi meteorological station and to existing information of the national climate, and takes the various correlated regional characteristics into consideration.

Annual evapotranspiration for the farm/forest lands is estimated 522 mm. It is equivalent to 83% of the annual rainfall, but 60% of the rainfall within the definite period of the rainy season. Evapotranspiration from the reservoirs is estimated at 1307 mm/year.

4.4 Surface Runoff

The runoff of a catchment in any specified period is the total quantity of water draining into a reservoir.

In different areas, rainfall is distributed according to the following:

Absorption :
- In sustaining the plan life
- In maintaining the moisture in the soil
- In replenishing the sub-soil water level
- By evaporation

The factors affecting the flow from a catchment are the following:

- Precipitation Characteristics	: areal distribution, duration and intensity of rainfall
- Geological features of the catchment	: type of surface soil and sub-soil and their permeability
- Size and Shape of the catchment	: Rainfall intensity is higher in small areas
- Topography	: Inclination of the surface
	: Fluctuation

	:	Wind direction to the mountain slope
- Meteorological Conditions	:	Annual/seasonal temperature, Barometric/atmospheric movements, etc.
- Character of the catchment Surface	:	Drainage of the area, Cultivation in the area, natural bare lands or lands covered with vegetation crops, grass or forests
- Storage characteristics	:	Reservoir capacity, nature of the ground storage

Runoff is assessed by various methods. According to the "Recomendaciones Provisionales Parael Diseno Y Construccion De Sistemas de Dreneja en carresteras" published by the "Secretarria de Estado De Dbrrs Publicas Y Comunicaciones", Rational Method is recommended for the runoff estimation in each area.

In this method the runoff is correlated with the rainfall. However, the rainfall is assumed uniform and constant all over the catchment. Additionally, the formula also assumes that the slopes of the catchment are uniform. All these conditions are difficult to meet and this method can not be used for large basins.

Although the proposed areas are not so large, the catchment areas are rugged and surrounded by hillocks and mountains. The catchment area of the reservoirs is considerably limited, their area ranging between 2.2 and 3.5 km^2.

The runoff of each catchment area is simply estimated with reference to the runoff coefficients.

1) Runoff coefficient

The runoff R and rainfall P can be correlated as follows:

$$R=KP$$

The runoff coefficient K depends on factors affecting the runoff. The Empirical Formula is applicable only for small areas. The values of K given by the said formula are:

Forests	0.05~0.2
Farm/pasture	0.05~0.3

T. G. Barrlow gave the following value of K:

(i)	Flat, partly cultivated various soils	0.15
(ii)	Average	0.20
(iii)	Hills and plains with little cultivation	0.35
(iv)	Very hilly and steep zones with very few cultivation	0.45

The above coefficient values are to be modified by the application of the following coefficients, according to the nature of the season

	i)	ii)	ii)	iv)
① Light rain	0.8	0.8	0.8	0.8
② Average or varying rainfall, no continuous downpours	1.0	1.0	1.0	1.0
③ Continuous downpours	1.5	1.6	1.7	1.8

The value of K according to the Rational formula is given by M. Bernard as follows:

Soil type	Cultivated	Pasture	Forest
Above the average infiltration rate, usually sand or gravel	0.2	0.15	0.15
Average infiltration rate, no clay pans larm and similar soils	0.4	0.35	0.3
Below the average infiltration rate, heavy clay soils, or soil with a clay pan near the surface : shallow soils above impervious rock	0.5	0.45	0.4

2) Designed Runoff Coefficient

In consideration of the following regional characteristics, the runoff coefficient was estimated as follows:

- Runoff percentage of the rainfall fluctuates very much seasonally due to the maldistribution of rainfall; duration and intensity of rainfall varies with each rainfall; rainfall intensity is high.
- Effective soil depth is considerably shallow; soil erosion is important due to heavy downpours; permeability of the soil comparatively low.
- Vegetation is poor; many waste lands and bare lands.
- The village is surrounded with hilly or mountainous areas; altitude between the farm land and the mountains lies in a range of 50~150 meters generally.
- The whole farm lands are cultivated only during the wet season.
- Storage capacity of flood water is low.

Given the preceding indications, the volume of effective rainfall planned for the reservoir proposed in the Project is accumulated rainfall of the rainy season, which presents a rainfall amount exceeding 40 mm/month.

Farmland cultivation is undertaken as soon as the rainy season begins. Tobacco and other crops are cultivated on most of the farmlands.

Taking these points into consideration, the designed runoff coefficient is assumed to be 40% of the mean annual rainfall, on the base of the different runoff coefficients abovementioned.

4.5 Available Water

Within the framework of the Water Supply Plan, a Storage Reservoir Plan is formulated as a Water Resources Development Plan intended for seven (7) of the eleven (11) villages located in the Project Area.

According to the proposed Plan, the surface runoff water will be stored in 2 places and will supply the population of adjacent villages with domestic water. Catchment area of the reservoirs and the designed demand water of the planned villages, will be follows:

Village name	Catchment Area (km^2)	Designed Demand Water (m^3)
Sabana Cruz		11038
El Cayal	3.1	7358
La Conucos	3.5	8410
Las Canas	2.2	4205
La Brigada *	2.7	1577
Las Aguitas *	3.7	12089
Buen Hombre *	3.0	2102

* Reservoir for La Brigada, Las Aguitas and Buen Hombre: three small ones each or combined for all will be constructed.

Amount of surface runoff (R)

$$P = KP$$

where

R : Runoff per km^2

K : Coefficient of runoff 0.40

P : Rainfall Σ 52.5 mm/year

$$R = 0.40 \times 0.525 \times 1000000$$
$$= 210000 \ m^3/km^2$$

In consideration of the collecting efficiency for the runoff discharge as 70% and the water loss by evaporation from the water surface of the reservoirs, the total amount of the possible water catchment to be flowed into each reservoirs, and the total amount to be collected in each reservoir, in order to provide a stable water supply which will meet the demand all year round, are estimated below. The surface area of the proposed reservoirs in full water level is assumed to be 20,000 m^2.

Reservoir Name	Catchment Area (km^2)	Possible Water Catchment (m^3)	Design Water Demand (m^3)	Design Water Evaporation Loss (m^3)	Total (m^3)
Sabana Cruz El Cayal	3.1	455,700	18,396	26,140	44,536
Los Conucos	3.5	514,500	8,410	26,140	34,550
Las Canas	2.2	323,400	4,205	26,140	30,345
La Brigada	2.7	396,900	1,577	26,140	27,717
Las Aguitas	3.7	543,900	12,089	26,140	38,229
Buen Hombre	3.0	441,000	2,102	26,140	28,242

According to this rough estimation, reservable potentiality can satisfy the water supply demand of proposed villages.

CHAPTER V

CONCLUSION

Estimated amount of the available river water resources exceeds 1,000 millions m^3 per annum. However, the development potential of the designed water resources assessed to supply the local population with domestic water will remain extremely low in absence of reservoir system.

Consequently, the future surface water development must be devised as an integrated water resources one, which combines with irrigation water development.

Furthermore, it was not possible to evaluate quantitatively the development potentiality, however, the possibilities of utilization are presently very high. In conclusion, water resources for the mountains village residents must be promoted, from a practical and realistical standpoint, by means of continuous measurements of annual runoff and assessment of development potential and possible amount.

TABLES

Table 1.2.1 List of Meteorological Stations

STATION		PROVINCE	NUMBER OF YEAR	UBICATION		
No.	NAME			ALTITUDE	LATITUDE	LONGITUDE
0102	Don Miguel	Dajabón	46	45	19° 30′	71° 40′
5401	Matayaya	San Juan	9	430	18° 53′	71° 35′
0405	Quinigua	Dajabón	17	148	19° 31′	71° 36′
0406	Mao	Valverde	21	90	19° 33′	71° 03′
0407	Sto. Rodríguez	Sto. Rodríguez	10	120	19° 28′	71° 20′
0408	La Anton	Monte Cristi	21	48	19° 38′	71° 24′
0622	Mao	Valverde	29	78	19° 33′	71° 04′
0626	Polo	Barahona	22	703	18° 04′	71° 17′
0655	Cabral	Barahona	45	19	18° 15′	71° 13′
0659	V. Vásquez	Monte Cristi	26	24	19° 44′	71° 26′
0681	Tamayo	Bahoruco	5	21	18° 23′	71° 13′
0693	Monción	Sto. Rodríguez	39	366	19° 24′	71° 09′
0698	Neiba	Bahoruco	21	10	18° 28′	71° 25′
0714	Bánica	Elías Piña	26	271	19° 05′	71° 42′
0715	La Descubierta	Independencia	35	9	18° 34′	71° 44′
0745	Pepillo Salcedo	Monte Cristi	30	5	19° 42′	71° 45′
0750	El Cercado	San juan	27	720	18° 43′	71° 31′
0754	Hondo Valle	Elías Piña	36	890	18° 43′	71° 41′
0759	L.M. de Farfán	San Juan	23	430	18° 52′	71° 31′
0773	Restauración	Dajabón	50	594	19° 19′	71° 41′
0783	Monte Cristi	Monte Cristi	56	7	19° 51′	71° 38′
0784	Elías Piña	Elías Piña	50	384	18° 52′	71° 42′
0715	Pedernales	Pedernales	28	11	18° 02′	71° 44′
0797	Jimaní	Independencia	40	31	18° 30′	71° 51′
4903	San Juan	San Juan	9	378	18° 45′	71° 09′
4904	El peñón	Barahona	9	4	18° 17′	71° 11′
4905	Barahona	Barahona	9	23	18° 13′	71° 05′
5301	Neyba	Bahoruco	9	100	18° 30′	71° 26′
5302	Puerto Escondido	Independencia	9	400	18° 19′	71° 34′
0001	Duverge	Independencia	34	9	18° 23′	71° 31′

Source : INDRHI

Table 1.2.2 List of Collected Data

STATION		PROVINCE	Avalaible Data				
No.	NAME		Rainfall	Temperature	Wind	Evaporation (2	Humidity
0102	Don Miguel	Dajabón	○	○	○	(○)	–
5401	Matayaya	San Juan	○	–	–	–	–
0405	Quinigua	Dajabón	○	–	○	(○)	–
0406	Mao	Valverde	○	–	○	(○)	–
0407	Sto. Rodríguez	Sto. Rodríguez	○	–	–	(○)	–
0408	La Anton	Monte Cristi	○	–	–	–	–
0622	Mao	Valverde	○	–	–	–	–
0655	Cabral	Barahona	○	–	–	–	–
0659	V. Vasquez	Monte Cristi	○	–	–	–	–
0693	Monción	Sto. Rodríguez	○	–	–	–	–
0698	Neyba	Bahoruco	○	–	○	(○)	–
0714	Bánica	Elías Piña	○	○	–	–	–
0715	La Descubierta	Independencia	○	○	–	○	○
0745	Pepillo Salcedo	Monte Cristi	○	○	–	○	○
0750	El Cercado	San juan	○	–	–	–	–
0754	Hondo Valle	Elías Piña	○	○	–	○	○
0759	L.M. de Farfán	San Juan	○	–	–	–	–
0773	Restauración	Dajabón	○	○	–	○	○
0783	Monte Cristi	Monte Cristi	○	○	○	○	○
0784	Elías Piña	Elías Piña	○	○	–	○	○
0797	Jimaní	Independencia	○	○	○	○	○
5301	Neyba	Bahoruco	○	–	–	–	–
5302	Puerto Escondido	Independencia	○	–	–	–	–
0001	Duverge	Independencia	○	○	–	–	–

(2 : O Evapotranspiration (O) Evaporation

Table 1.2.3 Mean Monthly Rainfall (Unit mm)

STATION		MONTHLY RAINFALL												TOTAL
No.	NAME	J	F	M	A	M	J	J	A	S	O	N	D	
0102	Don Miguel	31.3	49.5	55.1	128.5	222.6	180.6	132.6	135.7	194.6	224.2	97.6	46.5	1498.8
5401	Matataya	8.3	8.6	31.0	114.4	185.8	113.2	83.8	139.6	152.1	158.2	44.7	10.6	1050.3
0405	Quinigua	52.4	32.5	57.4	99.5	136.0	92.1	58.4	64.3	94.6	107.7	116.1	86.8	997.8
0406	**Mao Valverdo**	24.2	37.7	35.8	70.2	116.4	72.0	25.5	39.9	66.1	82.4	65.8	41.8	677.8
0407	Stgo. Rodríguez	30.6	47.3	32.2	80.8	143.9	153.9	94.2	90.2	157.0	154.3	117.4	52.3	1154.1
0408	La Antona	30.2	28.4	40.8	66.1	120.9	112.3	46.4	54.8	86.3	76.5	51.1	38.2	752.0
0622	Mao	23.0	31.0	38.0	71.0	122.0	88.0	28.0	46.0	88.0	97.0	67.0	52.0	751.0
0655	Cabral	19.2	18.0	22.8	30.0	134.3	124.7	42.9	116.3	108.2	136.7	50.0	20.8	823.9
0659	V. Vásquez	38.0	31.0	39.0	55.0	89.0	82.0	37.0	34.0	57.0	72.0	94.0	71.0	699.0
0681	Tamayo	14.0	9.0	9.0	21.0	71.0	49.0	24.0	91.0	53.0	88.0	34.0	18.0	481.0
0693	Monción	42.0	51.0	71.0	125.0	225.0	138.0	55.0	83.0	140.0	161.0	109.0	67.0	1267.0
0698	Neiba	8.0	17.0	22.0	36.0	106.0	51.0	36.0	61.0	74.0	99.0	50.0	21.0	581.0
0714	Bánica	16.4	23.0	40.1	137.4	257.8	161.6	151.2	190.1	207.5	187.7	56.6	28.6	1458.0
0715	La Descubierta	19.7	15.5	35.9	73.0	117.3	45.8	41.3	81.8	84.1	111.9	49.7	18.8	694.8
0745	Pepillo Salcedo	47.2	36.4	49.0	59.6	89.4	90.7	59.0	66.0	79.7	88.0	73.1	57.6	795.7
0750	El Cercado	11.0	17.0	30.0	112.0	175.0	83.0	82.0	145.0	177.0	140.0	83.0	33.0	1088.0
0754	Hondo Valle	16.7	35.9	70.8	166.4	265.8	127.7	138.8	226.5	244.9	230.6	96.9	28.5	1649.5
0759	L.M. de Farfán	11.0	19.0	27.0	99.0	150.0	111.0	87.0	142.0	139.0	146.0	54.0	19.0	1004.0
0773	Restauración	53.5	52.7	67.6	121.7	231.1	198.3	146.5	192.4	239.6	221.6	107.2	87.6	1719.8
0783	Monte Cristi	62.6	46.5	42.6	54.9	62.7	42.8	21.0	28.7	38.5	73.2	99.3	94.9	667.7
0784	Elías Piña	15.5	34.8	73.2	161.1	331.5	188.5	159.4	220.8	258.0	220.1	83.8	29.3	1776.0
0715	Pedernales	14.0	17.0	24.0	43.0	91.0	45.0	34.0	95.0	112.0	143.0	68.0	23.0	709.0
0797	Jimaní	15.2	26.8	38.1	88.2	137.8	46.0	28.1	67.3	90.6	133.0	54.8	24.5	750.4
4903	San Juan	3.0	16.0	35.0	41.0	69.0	74.0	51.0	74.0	111.0	113.0	54.0	18.0	659.0
4904	El peñón	19.0	24.0	15.0	43.0	73.0	143.0	26.0	49.0	122.0	95.0	30.0	18.0	657.0
5301	Neyba	8.0	15.0	29.0	46.0	68.0	51.0	24.0	26.0	93.0	70.0	29.0	20.0	479.0
5302	Puerto Escondido	16.0	12.0	12.0	35.0	103.0	72.0	33.0	55.0	76.0	86.0	34.0	17.0	551.0
0001	Duverge	8.4	13.8	21.4	27.6	87.0	51.6	20.1	70.0	70.1	77.1	36.9	11.1	495.1

Source : INDRHI

Recording Period Refer to Table 1.21

Table 1.2.4 **Rainfall Records Observed by Installed Gauge**

La Jaguita Station (Elias Pina)

	'90 12	'91 1	2	3	4	5	6	7	8	9	10	11	12
1.									3	18			
2.						1			26				
3.					8	1							
4.					1	37		9	51		53		
5.		3		4		32		2					
6.													
7.													
8.									14				
9.						12							
10.						15			24	2	9		
11.									1	1			
12.									1				
13.													
14.					15					40			
15.					4				6				
16.										55			
17.										7	1		
18.					106					1			
19.					3					1			
20.									56	2	67		
21.					7				9				
22.					9				23		12		
23.								2			23		
24.								33		1	6		
25.								7	1	25			
26.				3			41	8	2				
27.								4					
28.													
29.									1				
30.					118			11					
31.					3								
Total		(3)	–	7	274	(98)	(41)	76	218	153	171		
Rainy day		1	–	2	10	6	–	8	14	11	7		

Table Rainfall

<u>Villa Elisa Station (Montecristi)</u>

	'90 12	'91 1	2	3	4	5	6	7	8	9	10	11	12
1.							43	4					
2.						6							
3.						11						14	
4.													
5.												91	1
6.													
7.			4										
8.			8									54	
9.			2									1	
10.											27		
11.											79		
12.					3								
13.													
14.													
15.						3							
16.		61				1							
17.		1			20					5			
18.		31	6										
19.		69	1					7			16		
20.					3							2	
21.					19	1				23			
22.						86							
23.						1							
24.						1							
25.						39							
26.						1							
27.										1			
28.													
29.		9			9								
30.		10											
31.													
Total		179	21	-	54	150	(43)	11	-	29	122	162	1
Rainy day		6	5	-	5	10	1	2	-	3	3	5	

Table Rainfall

Loma de Cabrera Station (Dajabon)

	'91 12	'92 1	2	3	4	5	6	7	8	9	10	11	12
1.									56		10		
2.						76		11		15			1
3.			5		57					28			
4.									62				
5.									2				
6.				71									
7.							7			1			
8.							13	5		48		52	
9.						83				8	36	1	
10.						25				3	22		
11.				41						9	12		
12.		3		2									
13.		1					1		175		5		
14.										6			
15.						16	4	34	1				
16.						17			39		1		
17.									21				
18.					63	38							
19.					27	12			10	5	13		
20.		6							8				
21.		3			15		26		11				
22.		7			71	21			1		1		
23.					42	74	38						
24.						2			2				
25.						39		6	18				
26.					12	24			48				
27.					87			7			2		
28.					53		31						
29.					9			68	49		3		
30.					35		16			37			
31.						4							
Total		(20)	(5)	114	471	431	141	131	493	160	105	53	1
Rainy day		5	1	3	11	13	8	6	15	10	10	2	

Table Rainfall

Castanuelas Station (Montecristi)

	'90	'91											
	12	1	2	3	4	5	6	7	8	9	10	11	12
1.								38	6		17		
2.					3							25	
3.										24	1		
4.													
5.													
6.													
7.													
8.													
9.										3			
10.													
11.						62			1	31			
12.							54				99		
13.										2			
14.													
15.						2							
16.						1							
17.						1							
18.						1	15		5				
19.						1							
20.													
21.					4	9	4		16				
22.					39	7			1				
23.						1							
24.						18							
25.						8							
26.									2				
27.													
28.									31				
29.													
30.								7	6				
31.								1			1		
Total					46	111	73	46	68	60	118	25	
Rainy day					3	11	3	3	8	4	4		

Table Rainfall

Postrer Rio Gaging Station (Independencia)

	'90 12	'91 1	2	3	4	5	6	7	8	9	10	11	12
1.						1						11	
2.												3	
3.						4							
4.						6							
5.					5				119		3		
6.						33			12			10	
7.						1		8	6			1	
8.							3	5					
9.							1	14					
10.						5					2		
11.					31	34						9	
12.					5	13						1	
13.						6							
14.													
15.													
16.								1		1			
17.						5	5		33	11	11		
18.							11		42	3			
19.						11					1		
20.								19				11	
21.									15			2	
22.					16	1	1	3					
23.					23	18	18		29	3	1	8	
24.						5	5						
25.									1				
26.					7			1					
27.													
28.				4						25			
29.					8					2			
30.													
31.											4		
Total				4	95	143	44	51	257	45	22	56	
Rainy day					7	14	7	7	8	6	6	9	

Table Rainfall

Papayo Station (Montecristi)

	'90 12	'91 1	2	3	4	5	6	7	8	9	10	11	12
1.		18										6	
2.		1					35					11	
3.						27						1	
4.						13					2		
5.						46							
6.				32		16							
7.										74			
8.													
9.						7				1			
10.				5		4					28		
11.											45		
12.													
13.													
14.													
15.	1					6							
16.													
17.													
18.						5		24					
19.							10				39		
20.	5			4									
21.			37	19		17							
22.	5						34						
23.													
24.	21									6			
25.				2							3		
26.	9			56		91							
27.	1					35							
28.													
29.													
30.	1												
31.								25					
Total	43	19	37	118	–	277	79	49	–	81	117	18	
Rainy day	7	2	1	6	–	11	3	2	–	3			

Table 1.2.5 Mean Monthly Temperature (Unit °C)

STATION		MEAN MONTHLY TEMPERATURE												MEAN ANNUAL TEMPERATURE
No.	NAME	J	F	M	A	M	J	J	A	S	O	N	D	
0102	Don Miguel	23.4	23.6	24.4	25.4	26.2	26.9	27.0	27.2	26.8	26.5	25.2	23.7	25.6
5401	Matayaya	22.5	23.5	23.8	24.0	23.9	24.3	24.6	24.3	24.8	23.9	23.4	21.6	23.7
0405	Quinigua	21.9	22.8	23.7	23.8	23.7	24.4	25.1	24.5	24.8	24.2	23.4	22.1	23.2
0446	**Mao Valverd**	23.5	24.0	25.2	26.0	27.2	27.7	28.2	28.3	28.0	27.1	25.5	23.8	26.2
0407	Stgo. Rodríguez	25.1	26.2	26.6	27.9	27.9	28.4	29.1	29.3	25.7	28.2	26.3	25.1	27.1
0408	La Antona	22.9	23.5	24.0	25.5	27.0	27.6	28.0	28.1	27.6	27.1	25.3	23.3	25.9
0622	Mao	24.4	25.1	26.2	27.3	28.0	28.6	29.0	29.5	29.1	28.4	26.8	25.1	27.3
0626	Polo	20.0	20.2	20.8	21.7	22.2	22.4	27.7	23.0	22.4	22.5	21.9	20.8	22.1
0655	Cabral	25.3	25.7	26.5	27.0	27.3	27.2	27.6	28.0	27.8	27.4	26.5	25.6	26.8
0659	V. Vasquez	24.4	25.1	26.6	27.1	28.0	28.8	29.2	29.3	29.1	28.6	26.7	25.0	50.7
0684	Tamayo	25.1	24.7	25.8	26.3	27.0	27.3	27.7	27.9	27.9	27.7	27.1	25.8	26.7
0693	Monción	21.3	21.8	22.8	23.9	24.4	24.8	25.3	25.8	25.5	24.7	42.3	22.1	25.4
0698	Neiba	25.9	26.6	27.4	28.7	28.3	28.4	28.9	29.1	28.9	28.3	27.5	26.4	27.9
0714	Bánica	23.4	24.1	25.2	25.8	25.8	26.2	26.1	26.3	26.1	25.8	24.9	23.6	25.3
0715	La Descubierta	26.6	27.1	27.8	28.3	28.9	29.8	29.5	29.4	29.2	28.7	27.9	26.8	28.3
0745	Pepillo Salcedo	24.7	25.0	26.0	26.6	27.5	28.3	29.0	29.0	28.4	27.7	26.4	25.0	27.0
0750	El Cercado	20.7	21.8	22.7	23.4	23.6	24.7	24.9	24.5	24.4	23.6	22.1	20.7	23.1
0754	Hondo Valle	19.0	19.8	20.8	21.7	22.1	22.5	22.6	22.5	22.4	22.3	20.8	19.3	21.3
0759	L.M. de Farfán	24.0	25.1	25.9	26.5	27.0	26.6	27.1	27.1	26.7	26.1	24.9	23.5	25.9
0773	Restauración	22.8	23.3	24.0	24.5	25.5	25.6	25.7	25.9	25.4	25.6	24.6	23.3	24.7
0783	Monte Cristi	23.9	24.2	25.1	25.9	27.0	28.1	28.4	28.5	28.3	27.5	26.0	24.5	26.4
0784	Elías Piña	24.4	25.0	25.6	25.8	26.1	26.3	26.5	26.4	26.2	25.8	25.1	24.3	25.6
0715	Pedernales	25.5	25.9	26.9	27.8	28.6	29.1	29.5	29.6	29.2	28.6	27.4	26.2	27.9
0797	Jimaní	25.6	26.0	26.8	27.3	27.6	28.4	29.1	29.2	28.6	27.8	27.0	25.9	27.4
4903	San Juan	22.8	23.4	24.2	24.9	25.4	25.6	25.7	25.7	25.7	25.3	24.8	23.5	24.7
4904	El peñón	23.7	24.2	21.8	25.8	26.5	27.0	27.4	27.3	27.0	26.6	26.0	24.6	25.9
5301	Neyba	25:0	25.4	26.1	26.8	27.2	27.5	27.9	27.9	27.6	27.2	26.5	25.5	26.7
5302	Puerto Escondido	19.9	20.5	21.6	22.8	23.8	24.2	24.3	24.4	24.2	23.1	22.0	20.4	22.6
	Duverge	26.0	26.4	27.4	28.4	28.6	28.9	29.6	29.6	29.4	28.7	27.6	26.5	28.1

Source : INDRHI

Recording Period Refer to Table 1.21

Table 1.2.6 Mean Monthly Relative Humidity (Unit %)

STATION		MEAN MONTHLY RELATIVE HUMIDITY												MEAN ANNUAL
No.	NAME	J	F	M	A	M	J	J	A	S	O	N	D	
0102	Don Miguel	76.1	74.5	73.8	73.4	77	77.2	75.0	75.3	76.3	77.3	79.5	77.5	76.3
5401	Matayaya	77.6	75.1	74.1	78.8	81.0	76.6	74.8	76.8	79.5	87.8	78	79 7	85.2
0405	Quinigua	82	81	79	74	74	74	72	72	77	80	83	85	78
0406	Mao	74	73	68	66	69	68	66	67	69	74	77	78	71
0407	Sto. Rodríguez	71	70	66	64	68	70	66	67	72	73	76	76	70
0408	La Antona	71	69	66	63	65	66	62	62	68	70	72	74	67
0622	Mao	72	72	71	74	79	75	69	71	75	77	75	75	74
0626	Polo	79	78	76	77	96	95	91	93	98	95	84	77	87
0655	Cabral	72	70	69	70	81	80	73	81	79	84	73	70	75
0659	V. Vasquez	73	72	71	73	75	75	70	70	72	74	77	54	71
0684	Tamayo	71	70	69	69	74	72	69	76	72	76	71	71	72
0693	Monción	76	76	76	80	89	81	72	75	81	84	70	78	78
0698	Neiba	70	70	69	70	77	72	70	75	74	77	73	71	72
0714	Bánica	72	72	72	81	92	83	81	86	88	86	75	73	80
0715	La Descubierta	70	69	69	72	77	70	71	72	74	79	70	70	72
0745	Pepillo Salcedo	75	71	73	73	75	79	72	73	74	74	78	76	74
0750	El Cercado	73	73	72	79	84	76	75	81	85	82	79	75	78
0754	Hondo Valle	74	76	76	84	93	81	81	91	95	92	82	76	83
0759	L.M. de Farfán	71	71	70	77	81	78	75	81	81	82	75	72	76
0773	Restauración	77	75	75	81	93	89	83	89	92	90	81	81	84
0783	Monte Cristi	76	74	72	72	74	71	69	70	71	75	80	80	74
0784	Elías Piña	71	73	69	80	96	84	83	87	90	89	77	71	81
0715	Pedernales	70	70	70	71	76	71	70	76	78	81	75	71	73
0797	Jimaní	70	72	71	76	82	71	70	74	76	83	74	72	74
4903	San Juan	73	71	72	70	71	70	70	71	72	73	73	73	72
4904	El peñón	69	69	68	67	67	69	66	68	71	72	70	69	69
5301	Neyba	70	74	73	69	72	72	70	69	72	73	71	63	71
5302	Puerto Escondido	73	72	69	68	73	72	67	69	75	79	78	75	73

Source : INDRHI

Recording Period Refer to Table 1.21

Table 1.2.7 (1) Mean Monthly Evaporation and Evapotranspiration

Nº	STATION NAME	PERIOD	EVAPORIMETER OF TYPE	MEAN MONTHLY EVAPORATION J	F	M	A	M	J	J	A	S	O	N	D	ANNUAL TOTAL
4904	El Peñón	68.82		137.80	146.30	200.40	214.10	192.20	182.90	210.00	198.00	164.60	148.30	131.50	127.30	2053.40
0102	Don Miguel	81.90		139.67	146.71	168.75	182.21	178.80	190.20	179.80	200.90	176.40	157.00	126.90	106.20	1953.50
0407	Santiago Rodríguez	68.77	TANK "A"	136.40	131.70	170.30	168.10	157.30	151.90	189.00	180.40	151.80	145.10	126.60	118.00	1826.60
0408	La Antona	68.82	TANK "A"	140.30	152.20	213.00	221.00	204.00	198.50	246.10	241.80	190.00	163.20	131.00	122.00	2223.30
0405	Stgo. Quinigua	71.82	TANK "A"	118.00	128.40	179.10	206.50	210.00	214.40	234.40	224.30	191.60	179.10	129.10	111.40	2126.30
4903	San Juan de la Maguana	68.82		115.40	109.60	136.30	148.60	106.00	117.00	132.70	118.20	110.80	121.10	100.90	105.90	1422.50
0698	Neiba	68.80		173.20	177.20	222.50	224.40	222.50	206.60	239.50	223.40	196.20	170.30	159.00	161.90	2379.70
0406	Valverde Mao	68.82	TANK "A"	130.20	136.30	189.90	209.40	199.60	294.00	232.60	223.80	183.60	172.50	119.10	112.10	2113.10
05410	Narantito	80.90	TANK "A"	108.5	94.8	112.9	113.8	117.4	121.2	125.2	116.3	110.5	116.5	117.5	107.8	1362.4
05410	Matayaya	68.90	TANK "A"	194.1	196.3	234.6	217.3	215.8	229.9	225.3	219.4	187.1	170.7	174.7	182.7	2448.1

SOURCE : INDRHI

EVAPOTRANSPIRACION

Nº	STATION NAME	MEAN MONTHLY EVAPOTRANSPIRATION J	F	M	A	M	J	J	A	S	O	N	D	ANNUAL TOTAL
0784	Elias Piña	96.35	99.22	123.18	128.98	144.42	145.63	153.51	147.54	132.09	122.83	103.94	94.00	1491.70
0783	Monte Cristi	86.30	85.63	112.22	128.53	161.41	183.88	196.44	193.78	173.47	152.90	115.48	93.60	1683.60
0001	Duverge	118.04	126.10	148.11	172.96	178.29	186.53	206.80	206.88	200.90	181.00	152.84	128.18	2006.60
0715	La Descubierta	123.07	126.55	162.02	178.64	210.83	210.27	232.82	223.33	199.15	180.96	148.62	125.86	2122.10
0797	Jimani	107.85	108.82	140.87	154.82	174.19	192.19	217.94	215.18	181.72	158.75	131.10	111.89	1895.30

SOURCE : INDRHI

Table 1.2.7 (2) Mean Monthly Evapotranspiration

No.	STATION NAME	J	F	M	A	M	J	J	A	S	O	N	D	ANNUAL TOTAL
		MEAN MONTHLY EVAPOTRANSPIRATION												
0102	Don Miguel	87	96	121	151	159	159	176	168	139	104	86	79	1525
5401	Matayaya	102	100	149	159	156	157	161	152	138	106	92	81	1561
0405	Quinigua	82	88	125	160	184	180	199	187	146	117	86	72	1633
0406	Mao	97	106	155	181	197	202	215	201	168	133	97	86	1838
0407	Santiago Rodríguez	107	118	166	194	204	198	219	206	152	139	102	93	1896
0408	La Antona	103	113	159	184	207	205	219	209	170	144	109	98	1919
0622	Mao	103	110	151	163	167	181	207	193	154	130	105	95	1759
0655	Cabral	107	117	158	173	153	154	187	452	137	107	110	108	1664
0659	Villa Vásquez	100	110	152	166	179	184	206	196	163	137	99	227	1918
0693	Monción	89	94	128	131	110	146	180	164	123	98	156	83	1504
0698	Neiba	115	121	161	179	173	190	202	186	158	131	114	109	1838
0714	Bánica	102	100	147	135	98	141	151	127	99	96	101	96	1402
0715	La Descubierta	116	124	165	177	178	196	202	190	161	126	121	112	1867
0745	Pepillo Salcedo	97	112	146	165	178	168	200	186	158	135	97	93	1736
0750	El Cercado	94	102	138	134	128	163	169	138	107	101	87	86	1447
0754	Hondo Valle	106	114	153	151	151	162	177	149	129	108	103	97	1600
0759	Las Matas de Farfán	87	80	122	111	80	135	138	91	60	66	78	82	1139
0773	Restauración	92	102	137	133	90	113	145	111	79	82	88	80	1251
0783	Monte Cristi	94	104	145	164	181	193	207	195	164	130	92	82	1752
0784	Elías Piña	108	112	160	142	72	140	151	126	96	89	101	110	1408
0797	Jimaní	112	115	155	155	151	191	205	182	152	109	109	102	1739
5301	Neiba	111	109	147	176	186	186	199	192	159	137	115	118	1835
5302	Puerto Escondido	93	100	141	162	168	171	191	177	139	110	90	86	1628

Source : ONAPLAN

Table 1.2.8 Mean Monthly Wind Velocity (Unit m/S)

Mean Monthly Wind Velocity

(Unit m/s)

STATION			MEAN MONTHLY WIND VELOCITY										A[1m] of HEIGHT (UNIT m/s)		
No	NAME	PERIOD	J	F	M	A	M	J	J	A	S	O	N	D	MEAN ANNUAL m/s
4904	El Peñón	71-82	1.6	1.8	2.3	1.9	2.1	1.7	1.7	1.9	1.7	1.4	1.2	1.3	1.7
0405	Santiago Quinigua	71-80	2.1	1.5	2.1	2.3	2.9	3.1	3.5	3.2	4.1	2.3	1.8	1.7	2.6
0406	Valverde Mao	68-74	5.9	5.3	5.9	5.7	3.8	4.9	8.1	6.9	5.6	3.3	3.5	4.8	5.3
0698	Neiba	73-76	1.7	1.7	2.0	2.0	2.0	2.2	2.0	1.8	1.7	1.4	1.3	1.4	1.8
4903	San Juan	73-77	0.6	0.8	1.1	1.1	1.1	1.0	1.0	0.8	0.8	0.5	0.5	0.6	0.8
0783	Monte Cristi (1	76-80	9.1	10.2	11.2	12.4	10.5	10.2	11.8	11.8	11.9	9.9	9.0	9.3	10.6
0102	Dajabon (1	**77-87**	**1.1**	**1.4**	**1.5**	**1.5**	**0.9**	**0.8**	**1.4**	**1.4**	**0.8**	**1.1**	**0.8**	**1.0**	**1.5**
0797	Jimani (1	80-87	9.1	10.4	10.4	10.4	9.3	11.8	12.3	11.3	10.7	8.2	7.3	7.9	9.9
5401	**Matayaya**	**76-90**	**1.9**	**2.4**	**2.3**	**2.2**	**2.2**	**2.5**	**2.2**	**2.1**	**2.1**	**1.8**	**1.5**	**1.7**	**2.1**

SOURCE : INDRHI

(1 : Velocity Unit km/hr

Table 1.2.9 Mean Monthly solar Radiation (Unit Cal. /km^2/DAY)

STATION		MONTHLY SOLAR RADIATION												MEAN ANNUAL
No.	NAME	J	F	M	A	M	J	J	A	S	O	N	D	
0407	Stgo. Rodríguez	350	402	454	454	468	478	499	499	355	391	356	317	418
4903	San Juan	381	400	450	491	478	446	479	443	412	401	372	345	425
5302	P. Escondido	385	419	467	496	482	482	507	472	480	429	411	401	452

SOURCE : INDRHI

Table 2.10 (1) List of Discharge Gauge Stations

CATCHIMENT RIVER	STATION		RIVER	UBICATION			CATCHM-ENT AREA (km²)	DAY OF RECORD	QUANTITY OF WATER RECORD (m³/S)	MAXIMUM INSTANTANEOUS QUANTITY OF WATER RECORD (m³/S)
	NUMBER	NAME		LATITUDE	LONGITUDE	ALTITUDE (m)				
Yaque del Norte	040007	Jinamagao	Yaque del Norte	19° 32′ 46″	70° 59′ 39″	65	2653	60-75	31.99	974
	040008	Puente San Rafael	Yaque del Norte	19° 35′ 25″	71° 03′ 33″	50	4254	58-84	67.15	1080
	040010	Palo Verde	Yaque del Norte	19° 45′ 29″	71° 33′ 48″	11	6718	59-75	59.27	1156
	040020	Ranchadero	Yaque del Norte	19° 39′ 09″	71° 20′ 48″	28	5230	77-83	65.21	384
	043001	Inoa	Amina	19° 21′ 10″	70° 58′ 52″	322	330	67-86	10.08	1412
	043002	Potrero (2)	Amina	19° 28′ 10″	70° 57′ 36″	115	1	56-67	6.82	135
	044001	Bulla	Mao	19° 25′ 11″	71° 04′ 43″	145	625	67-85	20.81	732
	044002	Chorrera	Mao	19° 27′ 50″	71° 05′ 05″	108	672	58-67	20.27	242
	045001	Rincón	Guayubín	19° 31′ 18″	71° 23′ 21″	57	520	64-88	10.54	741
	045002	La Antona	Guayubín	19° 37′ 48″	71° 24′ 10″	38	739	55-66	9.68	473
	047002	Paso de la Palma	Maguaca	19° 35′ 17″	71° 30′ 56″	60	89	79-85	1.28	181
Chacuey	020001	La Espensa	Chacuey	19° 34′ 40″	71° 33′ 15″	80	81	77-84	1.27	335
	020002	La Pinta	Chacuey	19° 38′ 38″	71° 33′ 05″	35	123	65-77	1.21	51
Dajabón	010001	Don Miguel	Masacre	19° 30′ 10″	71° 40′ 42″	45	162	55-88	4.09	1776
Artibonito	540001	El Corte (1)	Artibonito	19° 08′ 27″	71° 38′ 05″	279	707	56-72	11.2	200
	540002	Pedro Santana	Artibonito	19° 06′ 10″	71° 41′ 30″	253	1029	56-86	16.8	798
	540003	Las dos Bocas	Artibonito	18° 56′ 45″	71° 53′ 00″	155	4143	61-64	51.6	978

Table 2.10 (2) List of Discharge Gauge Stations

CATCHIMENT RIVER	STATION		RIVER	UBICATION			CATCHM-ENT AREA (km²)	DAY OF RECORD	QUANTITY OF WATER RECORD (m³/S)	MAXIMUM INSTANTANEOUS QUANTITY OF WATER RECORD (m³/S)
	NUMBER	NAME		LATITUDE	LONGITUDE	ALTITUDE (m)				
Artibonito	541002	El Corte	Joca	19°08′24″	71°38′02″	281	257	55-84	5.7	140
	542001	Cajuilitos	Tocino	19°04′15″	71°36′00″	430	56.5	78-88	1.00	81
	543001	Puertecito	Macasía	18°48′00″	71°30′40″	574	44	55-83	0.35	30
	543002	Ranchitos	Macasía	18°55′50″	71°36′44″	328	1231	56-86	5.86	1046
	543003	Las dos Bocas	Macasía	18°58′38″	71°52′05″	156	1542	61-65	5.75	72
	543004	Rinconcito	Macasía	18°57′28″	71°46′03″	268	1506	55-65	5.83	144
	543201	Guineos	Caña	18°43′00″	71°38′21″	780	73	55-64	1.81	65
	543202	Olivero	Caña	18°53′42″	71°36′03″	371	414	55-65	2.09	27
	543101	Pozo Hondo	Yacahueque	18°59′30″	71°29′45″	484	77	64-83	1.23	527
	543401	Sonador	Sonador	18°41′55″	71°34′50″	760	10	73-83	0.57	10
	543501	Olivero	Arroyo Alonzo	18°52′22″	71°38′03″	400	66	64-67	1.14	34
Nizaito	510001	Villa Nizao	Nizaíto	18°01′22″	71°11′23″	122	116	55-81	3.55	66
Lago Enriquillo	531001	Cerro del Medio	Don Juan	18°28′34″	71°23′57″	-8	N/d	N/d	N/d	N/d
	532001	Puerto Escondido	Las Damas	18°19′15″	71°34′20″	400	117	N/d	N/d	N/d
	533001	Olivero	Barrero	18°31′46″	71°35′10″	60	N/d	N/d	N/d	N/d
	534001	Conuquitos	Guayabal	18°34′26″	71°37′49″	118	N/d	N/d	N/d	N/d

Table 2.11 Mean Annual / Monthly Discharge

STATION			Period of inspection	MEAN MONTHLY WATER VOLUME												MEAN ANNUAL
NUMBER	NAME	RIVER		J	F	M	A	M	J	J	A	S	O	N	D	m^3/S
040007	Jinamagao	Yaque del Norte	64-75	27.20	23.36	21.97	31.75	48.59	42.24	23.15	16.98	25.90	36.65	43.30	42.53	31.99
040008	Puente San Rafael	Yaque del Norte	58-84	43.37	40.39	41.83	53.03	91.12	93.86	57.19	40.37	59.09	91.71	87.76	80.20	67.15
040010	Palo Verde	Yaque del Norte	59-76	42.14	37.03	44.06	50.52	114.85	105.21	49.56	30.65	57.41	95.06	97.00	86.85	59.27
040020	Ranchadero	Yaque del Norte	77-83	37.40	30.57	30.79	45.69	137.90	100.14	53.24	40.96	87.46	75.78	75.07	34.02	65.21
043001	Inoa	Amina	67-85	4.71	4.80	5.93	11.38	22.33	16.88	7.49	5.88	9.58	13.24	10.81	7.57	10.08
043002	Potrero (2)	Amina	56-67	3.57	3.56	4.97	9.78	9.44	10.73	5.65	4.51	4.71	10.80	8.87	6.15	5.82
044001	Bulla	Mao	67-85	9.53	9.17	8.64	11.40	30.89	33.54	21.16	17.48	25.21	34.54	25.94	13.96	20.81
044002	Chorrera	Mao	57-67	13.38	12.06	13.44	15.94	23.45	29.89	20.30	17.38	23.76	28.54	25.73	20.95	20.27
045001	Rincón	Guayubín	64-88	5.72	5.41	4.32	7.96	19.13	18.52	9.40	6.62	10.43	13.57	12.89	8.66	10.54
045002	La Antona	Guayubín	55-66	4.93	4.38	6.48	9.88	15.37	15.76	8.02	8.14	8.67	14.49	12.44	8.58	9.68
047002	Paso de la Palma	Maguaca	79-85	0.41	0.30	0.50	2.55	2.72	2.03	0.77	0.54	0.84	2.46	1.61	0.51	1.28
020001	La Espensa	Chacuey	77-84	0.35	0.37	0.17	0.60	4.34	5.42	0.57	0.51	1.50	1.77	0.73	0.38	1.27
020002	La Pinta	Chacuey	64-77	0.96	0.66	0.45	0.58	1.35	1.01	0.94	1.85	1.20	1.00	1.05	1.44	1.21
010001	Don Miguel	Masacre	55-88	2.39	2.12	2.08	5.73	4.61	5.07	2.78	3.22	5.19	7.01	6.28	3.20	4.09
540001	El Corte (1)	Artibonito	56-72	5.48	4.83	5.69	7.89	12.24	17.07	12.60	12.42	15.28	16.83	12.94	11.16	11.20(1)
540002	Pedro Santana	Artibonito	56-86	7.09	6.82	7.03	8.18	19.22	25.07	18.77	19.59	27.87	31.76	20.25	12.83	16.80
540003	Las dos Bocas	Artibonito	61-64	15.32	10.91	9.67	19.51	60.60	118.50	59.40	61.50	80.50	87.40	59.20	36.40	51.60
541002	El Corte	Joca	56-84	2.60	2.14	1.93	2.38	5.39	7.60	7.27	7.47	10.65	11.05	7.66	4.13	5.70
542001	Cajuilitos	Tocino	78-86	0.85	0.59	0.60	0.60	1.19	1.14	1.14	0.94	0.92	1.26	0.96	0.76	1.00
543001	Puertecito	Macasía	55-83	0.26	0.23	0.20	0.25	0.40	0.42	0.31	0.32	0.44	0.55	0.47	0.36	0.35
543002	Ranchitos	Macasía	55-86	2.09	1.93	1.71	3.19	9.81	7.95	3.85	5.04	9.52	12.11	8.65	3.68	5.86
543003	Las dos Bocas	Macasía	61-65	2.98	1.28	1.11	2.53	5.26	5.93	4.34	5.37	8.34	14.85	11.52	5.25	5.75
543004	Rinconcito	Macasía	55-65	2.38	1.97	1.94	3.51	6.21	6.24	3.99	5.44	8.99	9.81	6.17	4.43	5.83
543201	Guineos	Caña	55-64	1.18	1.01	1.02	1.31	2.14	1.86	1.56	1.99	2.63	3.59	2.25	1.59	1.81
543202	Olivero	Caña	55-65	1.16	0.59	0.57	1.03	2.78	2.29	1.37	2.10	2.03	4.96	3.91	2.33	2.09
543101	Pozo Hondo	Yacahueque	64-83	0.61	0.40	0.40	0.73	1.86	1.34	1.18	1.40	2.04	2.79	1.46	0.70	1.23
543401	Sonador	Sonador	73-83	0.44	0.36	0.34	0.40	0.63	0.70	0.56	0.62	0.63	0.77	0.72	0.62	0.57
543501	Olivero	Arroyo Alonzo	64-67	0.89	0.72	0.62	0.64	1.10	1.17	1.21	1.24	1.23	2.16	1.54	1.13	1.14
531001	Cerro del Medio	Don Juan	N/D													N/D
532001	Puerto Escondido	Las Damas	N/D													N/D
533002	Olivero	Barrero	N/D													N/D
534001	Conuquitos	Guayabal	N/D													N/D

SOURCE : INDRHI

Table 1.3.1 Seasonal Rainfall Distribution Rate

Station Name	Average Annual Rainfall (mm)	Dec., Jan., Feb., Mar. 4-Month Average (mm)	(%)	July, Aug. %	Apr., May, June, Sept., Oct., Nov. (%)
Monte Cristi	667.7	246.6	37.0	9.6	53.4
Papillo Salcedo	795.6	190.2	24.0	15.7	60.3
Quinigua	755.0	210.0	27.8	11.4	60.8
Mao	612.0	145.0	23.7	9.6	66.7
La Antona	713.0	139.0	19.5	12.3	68.2
V. Vasqueg	699.0	148.0	21.1	10.2	68.7
Stgo. Rodrigues	1371.0	208.0	15.2	13.7	71.1
Don Miguel	1365.0	133.0	9.7	19.8	70.5
Moncion	1265.0	231.0	18.3	10.9	70.8
Restauracion	1921.0	307.0	15.9	20.0	64.1
Banica	1458.1	108.0	7.4	23.4	69.2
Elias Pina	1776.0	152.8	8.6	21.4	70.0
Hondo Vallo	1649.3	151.9	9.2	22.0	68.8
Matataya	998.0	68.0	6.8	26.1	67.1
Cercado	1088.0	91.0	8.4	20.9	70.8
Las Matas de Farful	1033.0	76.0	7.6	22.2	70.2
Jimani	750.6	104.6	13.9	12.7	73.9
Cabral	823.9	80.8	9.8	19.3	70.9
Duverge	494.9	54.7	11.1	18.2	70.7
La Descubierte	582.0	68.0	11.7	18.2	70.1
Neiba	581.0	68.0	11.0	16.7	72.3
Neiba (2)	482.0	63.0	13.1	17.0	69.9

Table 1.3.2 (1) Estimated Areal Rainfall (1)
Arithmetic Average Method

Hydrological Basin	Area (km^2)	Mean Rainfall (mm/year)	Areal Rainfall (mil. m^3)
Rio Dajabon	230	1405.0	323.150
Rio Guagabo /Lag. Saladilla	172	1040.0	178.88
Rio Chacuey	397	1007.7	400.06
Rio Yaque del Norte	(2366)		
Mao	891	1104.1	983.753
Gurabo	102	1219.5	124.389
Cana	199	1242.2	247.198
Guaybin	786	1055.8	829.859
Maguaca	146	980.1	143.095
Yaque del Norte	242	694.5	168.069
Rio Artibonito	(2614)		
Joca	260	1587.5	412.75
Tocino	170	1455.0	247.35
Macasia	1540	1278.3	1968.58
Artibonito	644	1607.8	1035.423
Lag. Enriquillo	(3193)		
North	656	1149.0	753.744
West	342.5	702.5	240.606
East	768.0	519.0	398.592
South	1426.5	1114.0	1589.121
Atlantic coast	356.9	875.0	312.288
Total	9328.9		10356.90

Estimated Areal Rainfall in the Study Area = 1,110.2 mm

Table 1.3.2 (2) Estimated Areal Rainfall (2)
Thiessen Method

Station No.	Point Rainfall	Area (km^2)	Areal Rainfall (mil./m^3)
0783	690.0	257.3	177.537
0659	699.0	321.6	224.798
0408	740.6	460.9	341.342
0406	713.0	130.1	92.8
0745	795.6	164.6	130.956
0405	826.0	329.9	272.497
0407	1371.0	858.0	1176.318
0693	1265.0	284.2	359.513
0102	1498.5	496.2	743.556
0773	1921.0	699.8	1344.316
0714	1458.1	567.1	826.889
0784	1776.0	238.1	422.866
5401	998.0	264.4	263.871
0759	1003.0	505.1	506.615
Atlantic Coaster	875.0	312.3	273.263
0754	1717.0	271.6	466.337
0750	1088.0	362.9	394.835
0715	694.9	334.0	232.097
0698	581.0	651.0	378.231
0797	823.0	379.8	312.575
5302	549.0	708.2	388.802
0684	480.0	374.9	179.952
0655	910.0	356.9	293.729
Total		9328.9	9793.648

Estimated Areal Rainfall in the Study Area = 1049.8 mm

Table 1.3.2 (3) Estimated Areal Rainfall (3)

Isohyet Method

Hydrological Basin	Average Rainfall (mm)	Area (km^2)	Areal Rainfall (mil. m^3)
Yaque del Norte	875	23	20.125
	1,875	104	195.000
	700	943	660.100
	875	212.8	186.200
	1,125	246.9	277.763
	1,375	441.0	606.375
	1,625	291.6	473.850
	2,000	103.8	207.600
Chacuey	700	20.5	14.350
	875	200.6	175.525
	1,125	126.9	142.762
	1375	49.4	67.925
Guarabo Lg. Saladillo	875	58.5	.51.167
	1,125	95.5	107.437
	1,375	18.0	24.750
Atlantic coaster	1,125	28.7	32.287
	875	104.2	91.175
	700	155.2	108.640
	700	68.6	48.020
Dajabon	1,125	34.3	38.587
	1,375	78.4	107.800
	1,375	46.3	63.662
	1,875	36.75	68.906
	2000	34.3	68.600
Artibonito	2000	313.4	626.800
	1,750	353.8	619.150
	1,875	44.7	83.812
	1,625	98.9	160.712
	1,375	251.8	346.225
	1,250	39.2	49.000
	1,125	1,034.0	1,163.250
	2,000	51.5	103.000
	1,625	175.0	284.375
	1,375	252.3	346.912

Table 1.3.2 (4) Estimated Areal Rainfall (3)
Isohyet Method

Hydrological Basin	Average Rainfall (mm)	Area (km²)	Areal Rainfall (mil. m³)
Lug. Enviquillo	2,000	132.0	264.000
	1,875	82.0	153.750
	1,625	62.0	100.250
	1,625	386.0	627.250
	1,375	33.0	45.512
	1375	55.1	75.762
	1,125	70.6	79.425
	1,125	61.7	69.412
	875	221.1	193.900
	625	137.7	86.062
	500	884.5	442.250
	875	263.5	230.562
	1,125	155.4	174.825
	1,825	191.077	191.077
	1,375	142.45	142.450
	2,000	46.3	92.600
	1,625	180.075	263.250
	1,375	257.25	318.312
Total		9,328.9	11,152.400

Estimated Areal Rainfall in the Study Area = 1195.5 mm

Table 1.3.3 Percentage of Monthly Discharge

Station \ Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Rio Yaque del Norte Jinamaguo	7.2	5.7	5.8	8.2	12.9	10.8	6.2	4.5	6.7	9.7	11.0	11.3	100
Puenta San Rafael	5.2	5.0	5.3	7.0	12.0	12.3	7.3	5.1	7.4	12.0	11.0	10.1	100
Ranchadero	5.0	3.7	4.2	6.6	18.0	12.7	7.6	5.6	12.0	10.1	9.6	4.9	100
Palo Verdo	5.1	4.4	5.4	6.0	14.0	13.0	6.0	4.0	7.0	12.0	12.0	11.0	100
Iona/R-Amina	4.0	3.6	4.9	9.2	19.2	13.8	6.2	4.9	7.8	11.2	8.8	6.4	100
Putrere/R-Amina	4.5	4.0	6.0	11.5	11.3	13.2	7.0	5.8	5.5	12.8	10.7	7.7	100
Bulla/R-Mao	4.1	3.6	3.6	4.6	13.1	13.7	8.9	7.3	10.2	14.4	10.5	6.0	100
Chorrera/R-Mao	5.5	4.5	5.6	6.5	9.7	12.0	8.4	7.3	9.5	11.9	10.4	8.8	100
Rincon/Guaybin	4.6	3.9	3.4	6.1	15.3	14.3	7.5	5.3	8.0	14.8	10.0	6.9	100
La Antona/Guaybin	4.0	3.8	6.0	8.0	14.0	13.0	6.8	7.0	7.2	12.7	10.5	7.0	100
La Palma/Maguaca	2.6	1.8	3.4	17.4	18.0	13.3	4.8	3.5	5.3	16.2	10.2	3.4	100
Rio Chacuey La Pinta	7.6	6.4	3.5	4.4	10.9	7.7	7.5	15.0	9.4	7.9	8.1	11.6	100
La Espensa	2.1	2.0	1.0	3.5	26.3	31.8	3.5	3.7	8.8	10.7	4.2	2.3	100
Rio Masacne Don Miguel	4.9	3.9	4.2	11.4	9.6	8.0	5.8	6.7	12.3	14.4	12.5	6.4	100
Rio Artibonito Pedro Santana	3.4	3.0	3.4	4.0	9.6	12.0	9.4	9.6	13.6	16.0	9.6	6.4	100
Cajuilitos/Tocino	7.7	4.8	5.4	5.3	10.6	12.7	10.3	8.5	8.0	11.4	8.4	6.9	100
El Corte/Joca	3.8	2.8	2.8	3.4	7.8	10.7	10.6	10.8	14.7	15.8	10.8	6.0	100
Rinconcite/Macasia	4.8	3.1	3.2	5.7	10.2	10.0	6.5	9.0	14.4	16.0	9.9	7.3	100
Ranchitos/Macasia	3.0	2.5	2.6	4.6	14.2	11.2	5.7	7.4	13.5	17.7	12.1	5.4	100
Los Guinos/Cana	5.3	4.0	4.5	6.0	10.0	8.5	7.0	9.0	11.9	16.5	10.0	7.3	100
De luero/Cana	4.1	2.0	2.0	4.0	11.0	9.0	5.2	8.5	10.0	20.0	15.0	9.5	100

Table 1.3.4 Coefficient of River Regime and Specific Discharge

Hydrological Basin	River	Station	Area of Basin (km^2)	Average Annual Discharge (m^3/s)	Average Annual Discharge (mil. m^3)	Standard Deviation (m^3/s)	Coefficient of River Regime	Specific Discharge ($\ell/s/km^2$)	Estimated Annual Rainfall (mm)	Run of Percentage (%)
Yaque del Norte	Yaque del Norte	Jinamaguo	2,653	31.99	1,009	13.58	–	12.06	1,011	37.6
		Puerta San Rafael	4,254	65.42	2,063	44.52	2.4	15.38	989	49.0
		Ranchadero	5,230	65.96	2,080	22.72	4.5	12.61	956	41.6
		Palo Verde	6,718	69.27	2,184	42.74	3.1	10.31	896	36.3
	Amina	Iona	322	10.03	316	4.50	4.7	31.15	1,180	83.2
		Potrero	207	6.82	215	3.45	3.0	32.95	1,270	81.8
	Mao	Bulla	625	20.31	640	6.73	4.0	32.50	1,471	59.7
		Chorrera	672	20.27	639	9.80	2.5	30.16	1,329	71.6
	Gurabo	Gurabo	92	1.02	32	–	–	11.01	1,202	29.1
	Cana	Cana	164	1.97	62	–	–	12.00	1,378	27.5
	Guaybin	Rincon	520	10.64	336	7.38	4.4	20.46	1,474	43.8
		La Antona	739	9.68	305	4.80	3.6	13.10	1,440	28.7
	Maguaca	Paso de la Palma	89	1.28	40	0.88	9.0	14.18	1,329	34.1
Chacuey	Chacuey	La Pinta	123	1.21	38	1.26	4.1	9.84	1,440	21.7
		La Espensa	81	1.27	40	0.76	31.9	15.68	1,450	34.1
Dajabon	Masacre	Don Miguel	162	4.09	129	4.26	3.4	25.25	1,499	53.1
Artibonito	Arti Domito	El Corte	707	11.2	354	–	3.5	10.90	1,900	26.3
		Pedro Santana	1,029	16.8	530	5.48	4.6	16.30	1,900	27.1
		Dos Bocas	4,143	51.6	1,630	–	7.4	12.40	1,162	33.8
	Joca	El Corte	257	5.7	179	2.04	5.7	22.20	1,820	38.4
	Tocino	Cajuilitos	665	1.0	32	0.65	2.4	15.00	1,625	29.2
	Yachaeque	Pozo Hunds	77	1.23	39	0.53	7.0	16.00	1,460	34.5
	Macasia	Puertecito	44	0.35	11	0.19	3.0	8.00	1,230	20.4
	Macasia	Ranchites	1,231	5.06	160	3.20	7.1	4.10	1,110	11.7
	Cana	Guineos	78	1.81	57	0.55	3.5	23.20	1,700	43.0
		Olivero	414	2.09	66	1.30	8.7	5.00	1,350	11.8
	Alonso	Olivero	66	1.14	36	0.65	13.5	17.30	1,600	34.0
	Macasia	Rinconate	1,506	5.84	183	2.40	5.0	3.90	1,160	10.5
		Dos Bacao	1,542	5.75	181	3.38	13.4	3.70	1,162	10.1

Source: INDRHI

Tabla 1.3.5 (1) Probable Discharge

River	Station			Mean Annual Discharge	Probable Discharge		50 % Probability		80 % Probability	
	No.	Name	Area		50 %	80 %	Annual Discharge	ℓ/s/km²	Annual Discharge	ℓ/s/km²
Yaque del Norte River System			(km²)		(m³/s)	(m³/s)	(10 m³)		(10 m³)	
Yaque del Norte	040007	Jinamagao	2653	31.99	28.673	18.000	904,232	10.81	567,648	6.79
	040008	Puente San Rafael	4254	67.15	60.155	24.850	1,897,048	14.14	783,670	5.84
	040010	Palo Verde	6718	59.27	56.302	30.943	1,775,540	8.38	975,818	4.61
	040020	Ranchadero	5230	65.21	60.273	33.732	1,900,769	11.53	1,063,772	6.45
Amina	043001	Inoa	322	10.08	9.412	5.815	296,817	28.52	183,382	17.62
	043002	Potrero	207	6.82	5.007	2.361	157,901	24.19	74,457	11.45
Mao	044001	bulla	625	20.81	19.290	14.093	608,330	30.87	444,437	22.55
	044002	Chorrera	672	20.27	12.823	7.876	404,386	19.08	248,378	11.72
Guayubin	045001	Rincon	520	10.54	9.500	5.681	299,592	18.27	179,156	10.93
	045002	La Antona	739	9.68	9.694	4.033	305,710	13.12	127,185	5.46
Maguaca	047002	Paso de laPalma	89	1.28	0.775	0.607	244,404	8.71	19,143	6.82
(Gurabo)		(Confluence)	102	(1.06)						(10.4)
(Cana)		(Confluence)	199	(2.31)						(11.6)
(Guayubin)		(Confluence)	786	(13.38)						(17.0)
(Maguaca)		(Confluence)	146	(1.00)						(6.9)
Chauey River System										
Cahuey	020001	La Expense	81	1.27	1.172	0.477	369,602	14.47	150,427	5.89
	020002	La Pinta	123	1.21	0.832	0.433	262,380	6.77	136,551	3.52
Dajabon River System	010001	Don Miguel	162	4.09	2.902	1.141	915,175	17.92	359,826	7.05
	(010002)	(Dam Site)	322							

Tabla 1.3.5 (2) Probable Discharge

River	Station			Mean Annual Discharge	Probable Discharge		50 % Probability		80 % Probability	
	No.	Name	Area		50 %	80 %	Annual Discharge	ℓ/s/km^2	Annual Discharge	ℓ/s/km^2
Artibonito River System			(km^2)		(m^3/s)	(m^3/s)	(10 m^3)		(10 m^3)	
Artibonito	540001	El Corte	707	(11.2)						
	540002	Pedro Santana	1029	16.8	15.981	11.839	503.977	15.53	373,355	11.51
	540003	Las Dos Bocas	4143	(51.6)						
Joca	541002	El Corte	257	5.7	5.574	4.001	175,782	21.69	126,176	15.57
Tocino	542001	Cojuilitos	66.5	1.0	0.909	0.317	28,666	13.67	9,997	4.77
Macasia	543001	Puertecito	44	(0.35)	–	–				
-do-	543002	Ranchitos	1231	5.86	5.72	3.535	180,286	4.55	111,480	2.95
-do-	543002	Las Dos Bocas	1542	(5.75)	–	–	–			
-do-	543004	Rinconcito	1506	5.83	5.429	3.402	171,209	3.61	107,286	2.26
Cana	543201	Guines	73	1.81	1.737	1.248	54,778	23.80	39,357	17.10
-do-	543202	Olivero	414	2.09	1.917	0.775	62,126	4.63	24,441	1.88
Yacahueque	543101	Pozo Hondo	77	(1.23)						
Sonador	401	Sonador	10	(0.57)						
Arroyo Alonzo	501	Olivero	66	(1.14)						

FIGURES

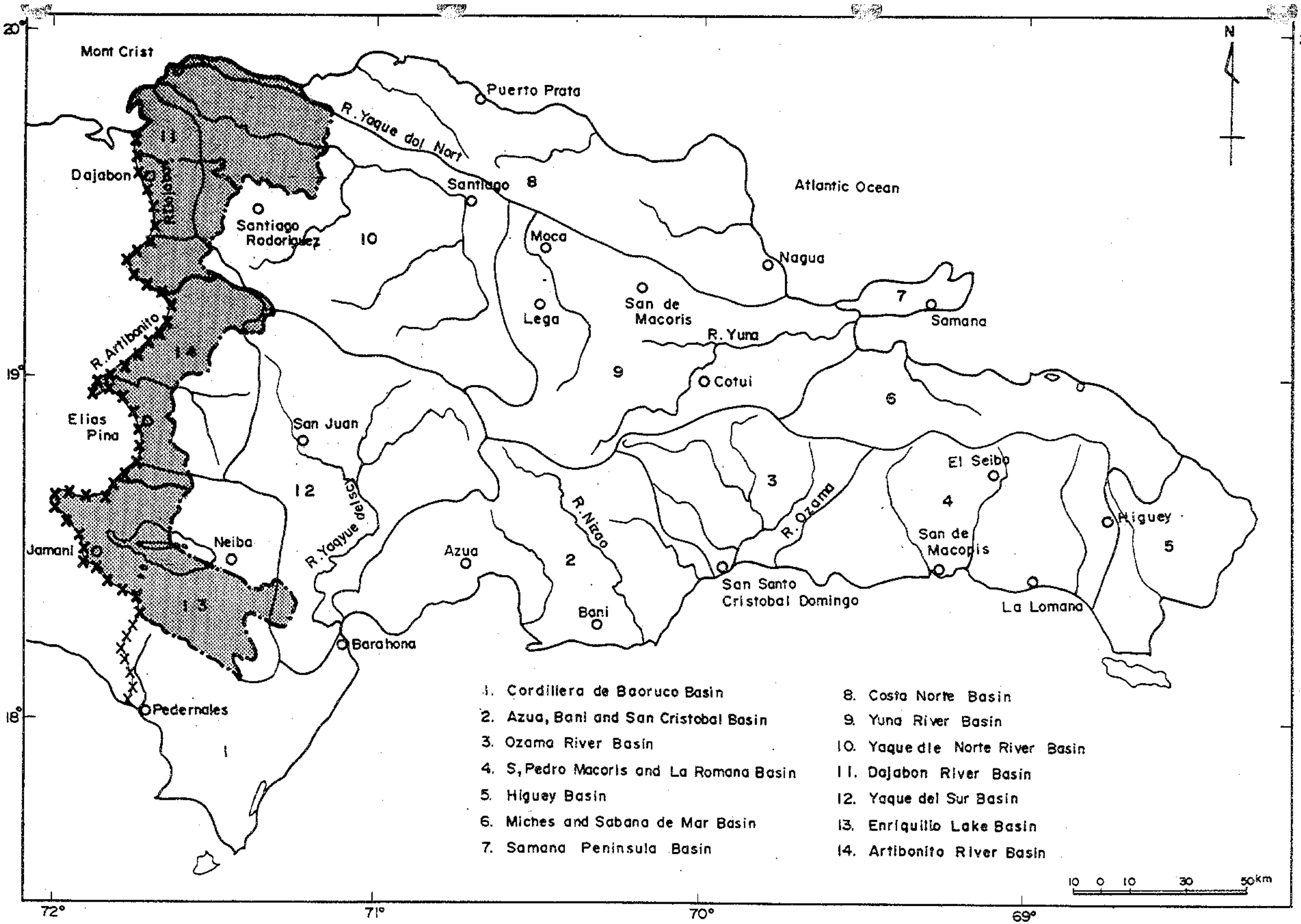


Fig. 1.1.1 **Hydrological Basin of Dominican Republic**

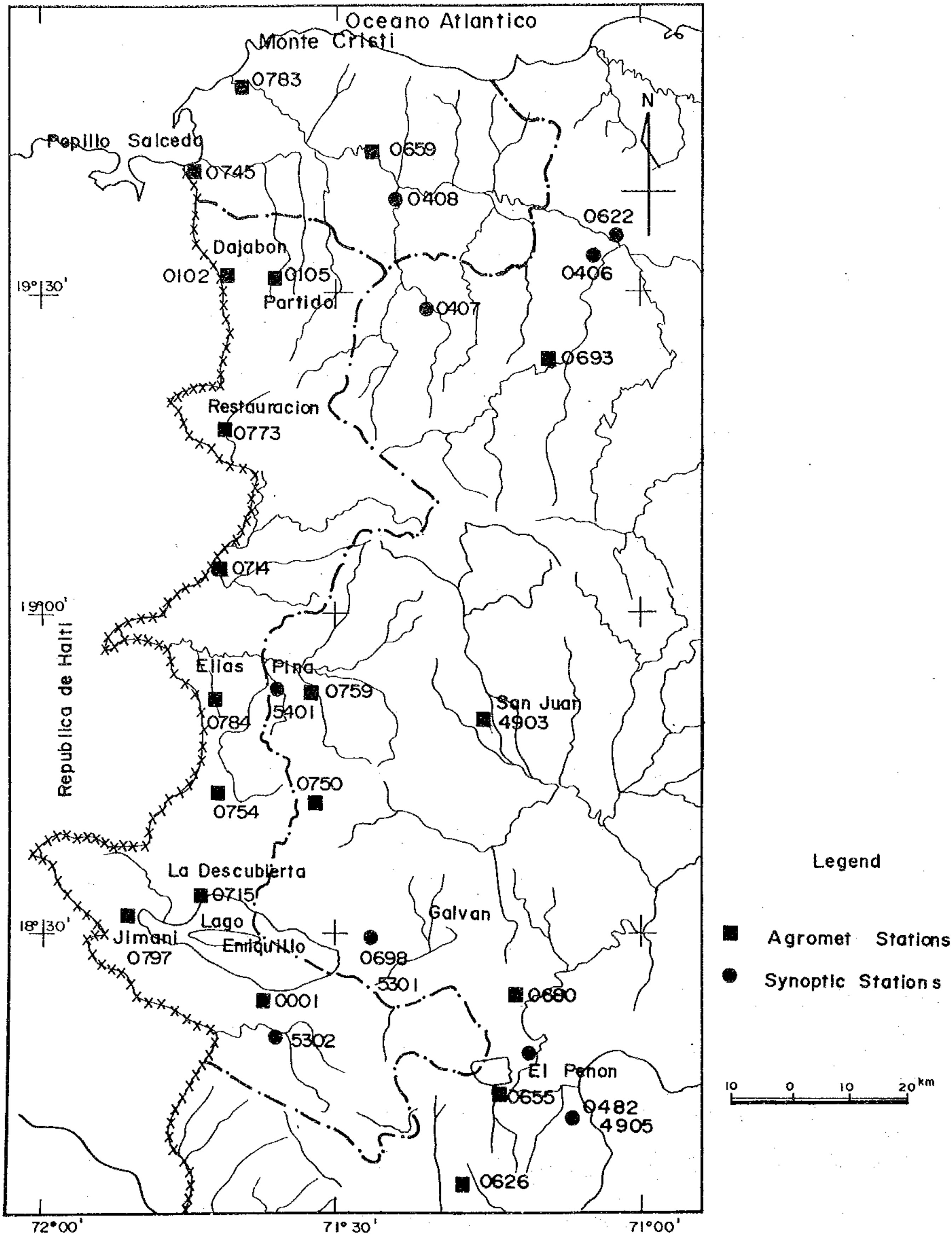


Fig.1.2.1 Location of Meteorological Observation Station

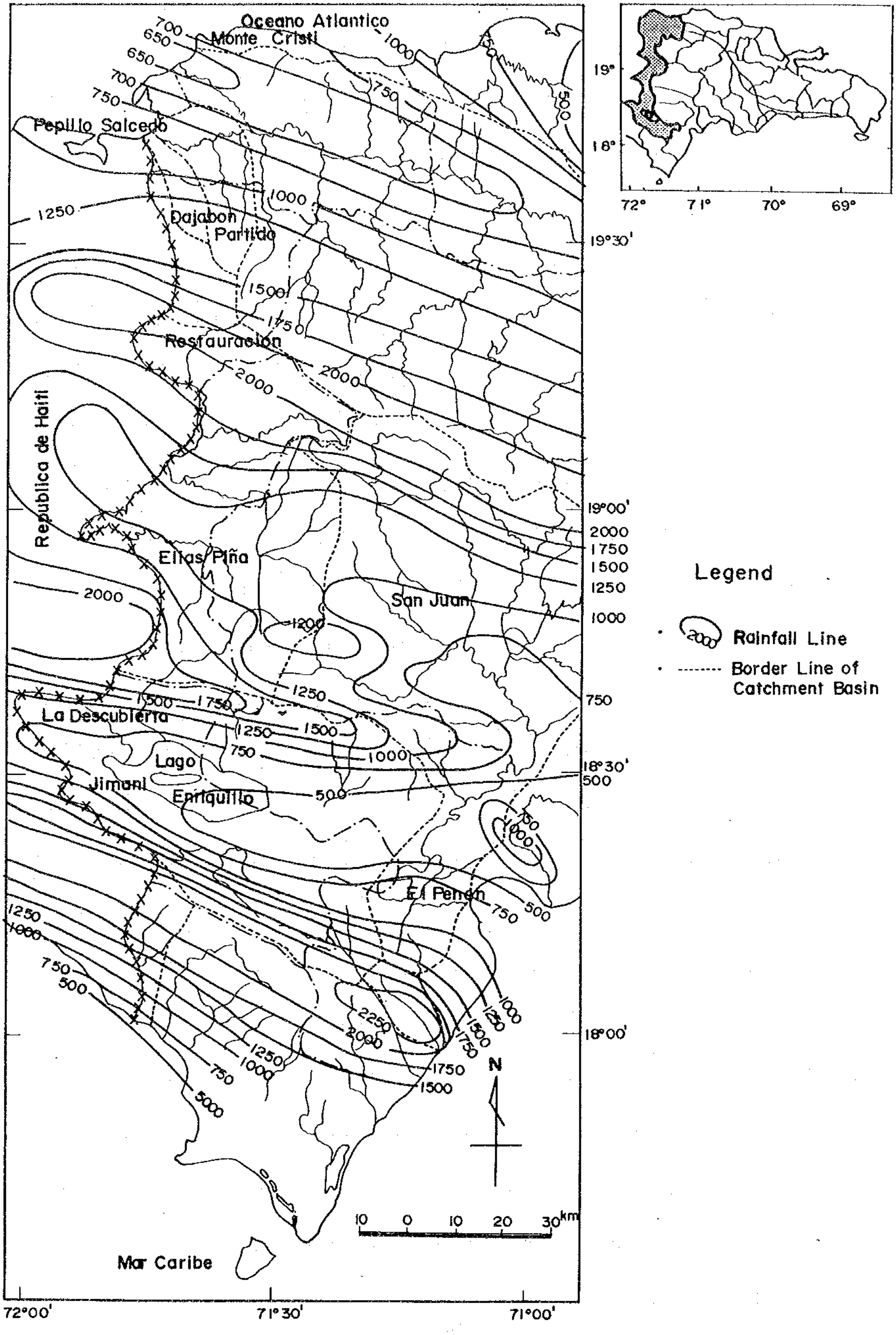


Fig.I.2.2 Annual Isohyetal (Unit mm/year)

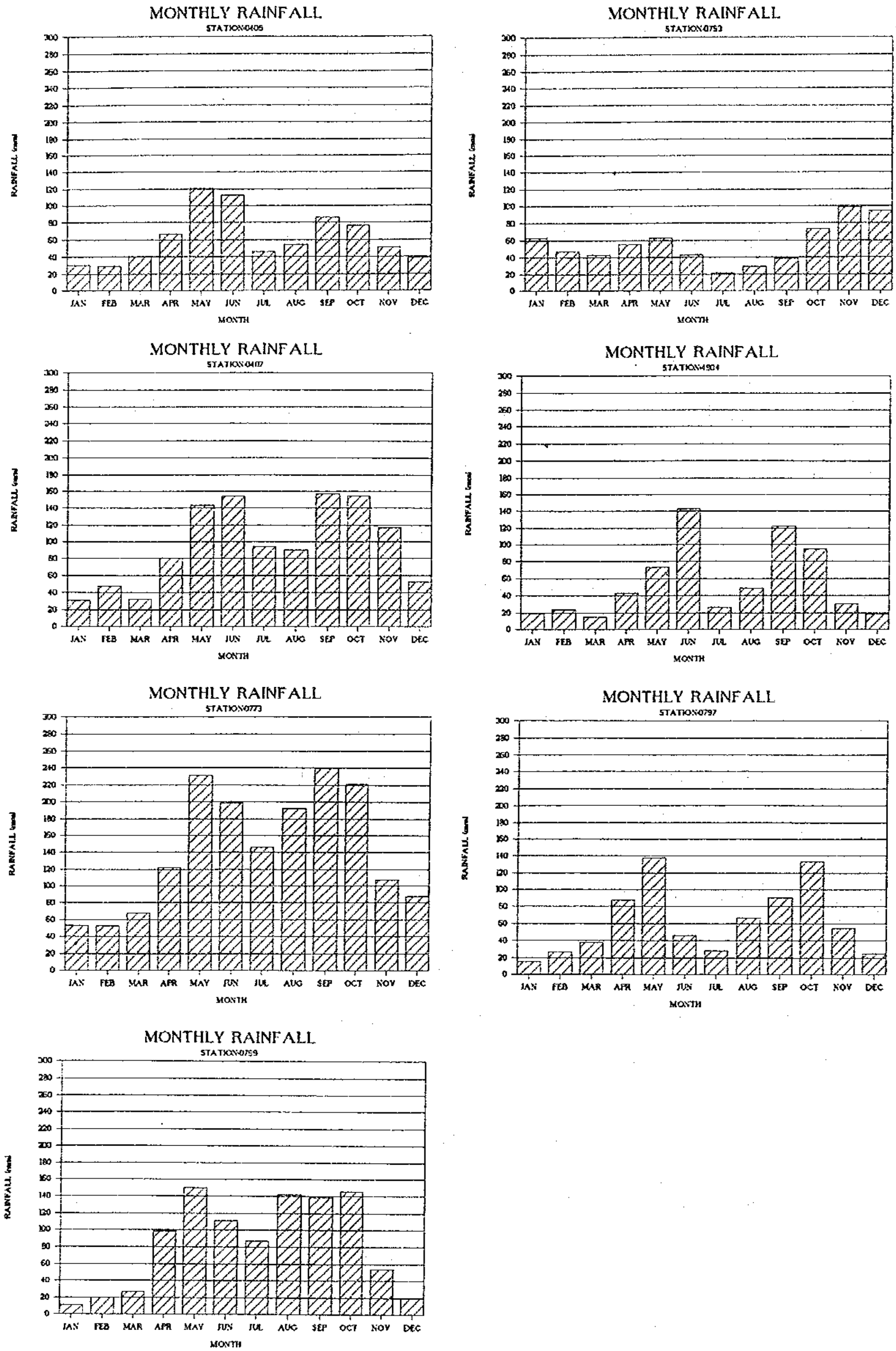
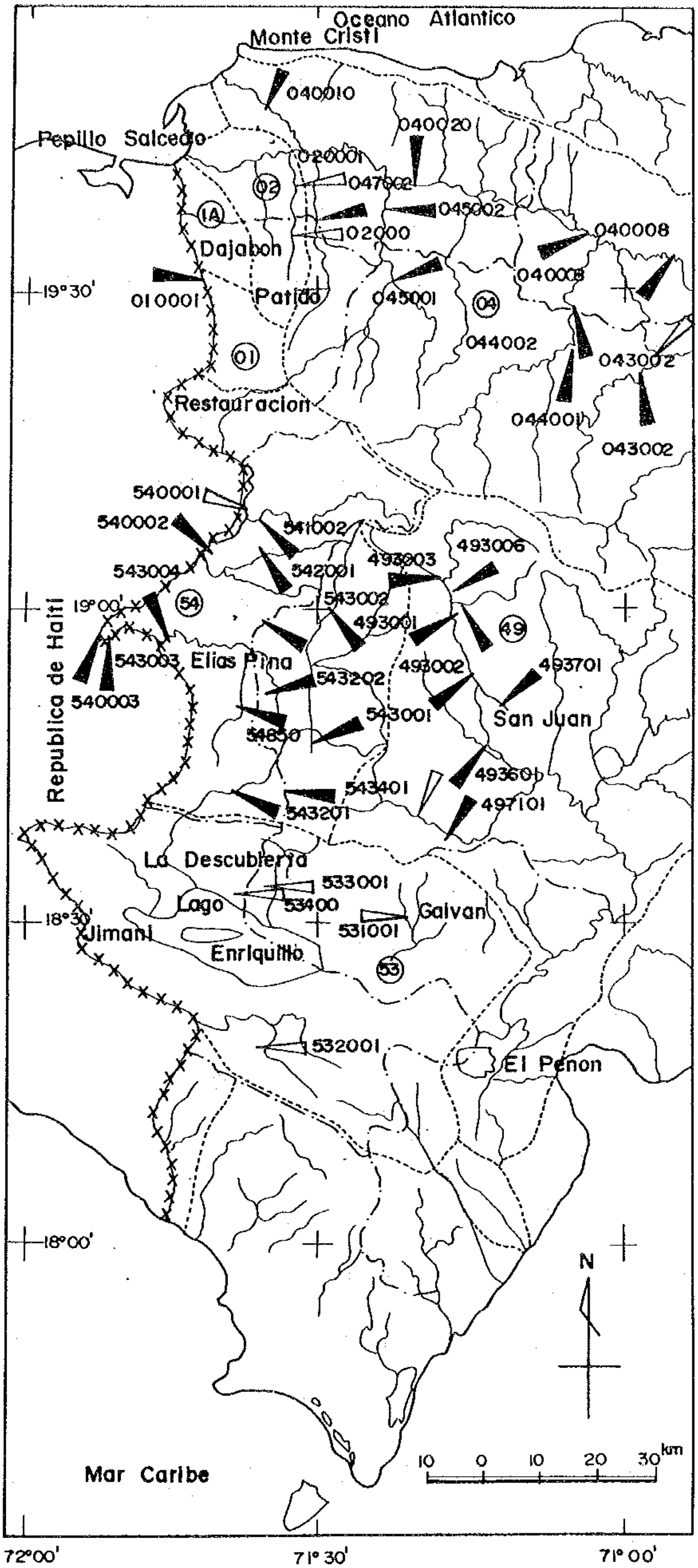
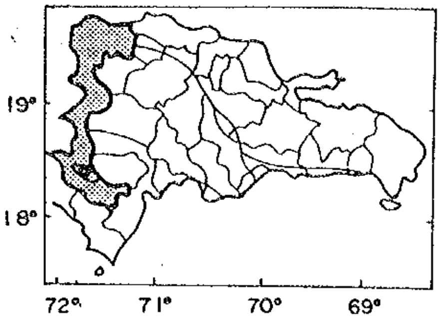


Fig. 1.2.3 Monthly Rainfall





LEGEND

DISCHARGE MEASUREMENT STATION

DISCHARGE MEASUREMENT STATION

(54) NUMBER OF CATCHMENT BASIN

541002 NUMBER OF STACION

CATCHMENT BASIN OF APPROXIMATE AREA (Unit km²)

No.	NAME OF CATCHMENT BASIN	AREA (Unit km²)
01	Rio DAJABON	351
01A	Rio GUAYABO/LAKE SALADILLA	172
02	Rio CHACUEY	397
04	Rio YAQUE DEL NORTE (1)	7,044
05	Rio ARTIBONITO (4)	2,614 (9,000)
06	RAGO ENRIQUILLO (3)	3,193

SOURCE : INDRHI

Fig. 1.2.4 Location of Existing Discharge Measurement Station

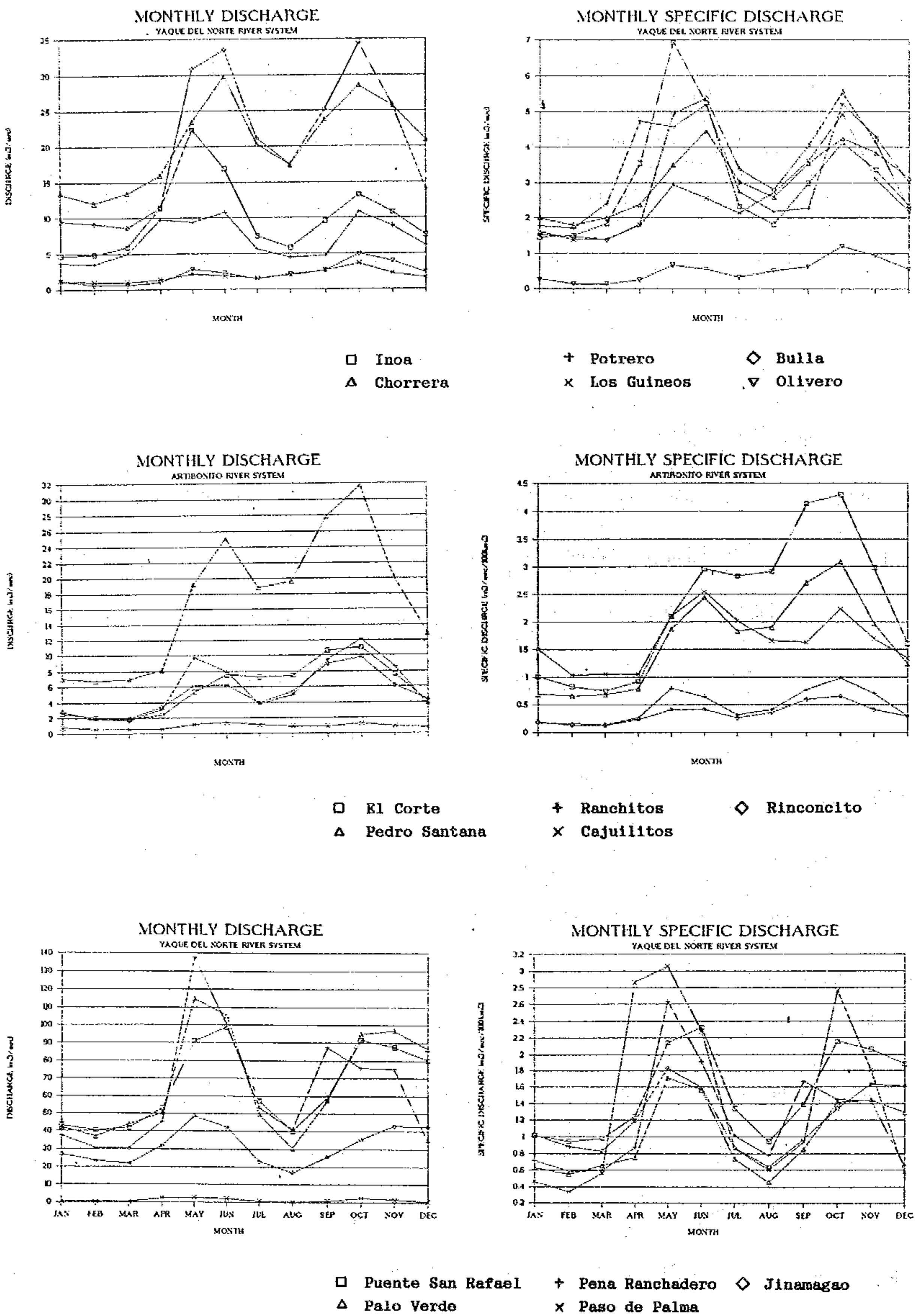


Fig. 1.2.5 Monthly Dsicharge

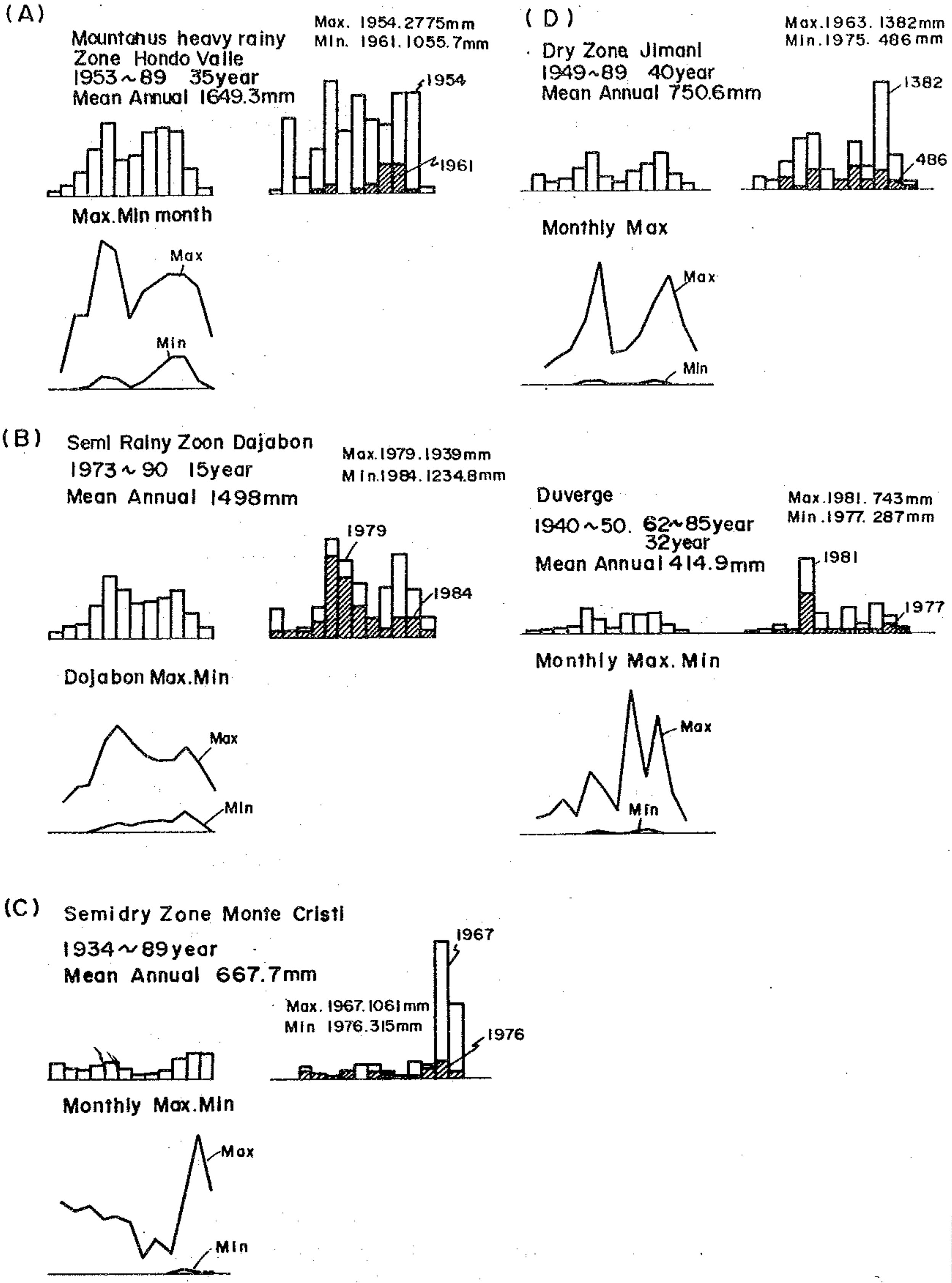


Fig 1.2.6 Monthly Max/Min Rainfoll

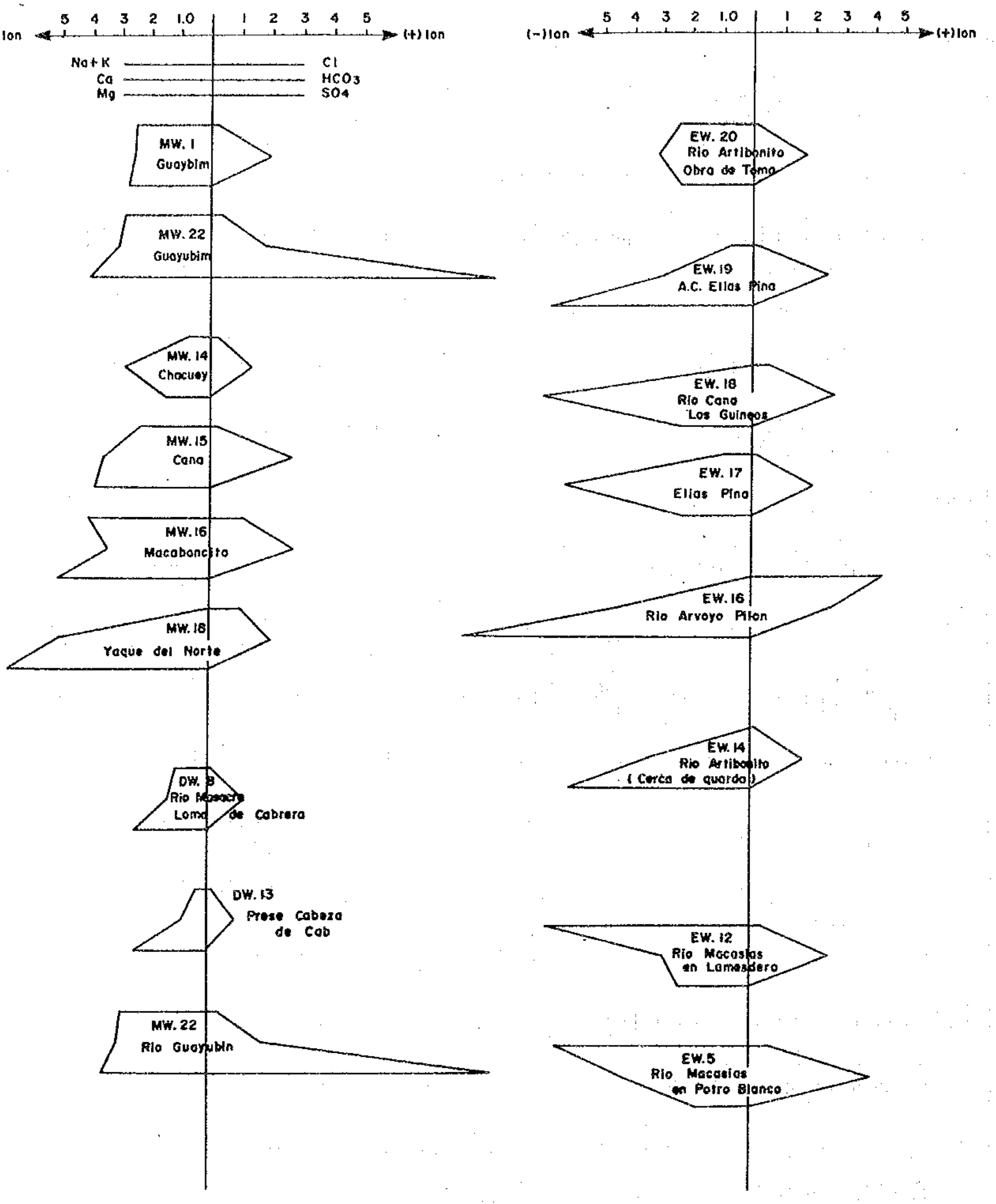


Fig. 1.2.7 (1) Pattern Diagram of River Water Quality

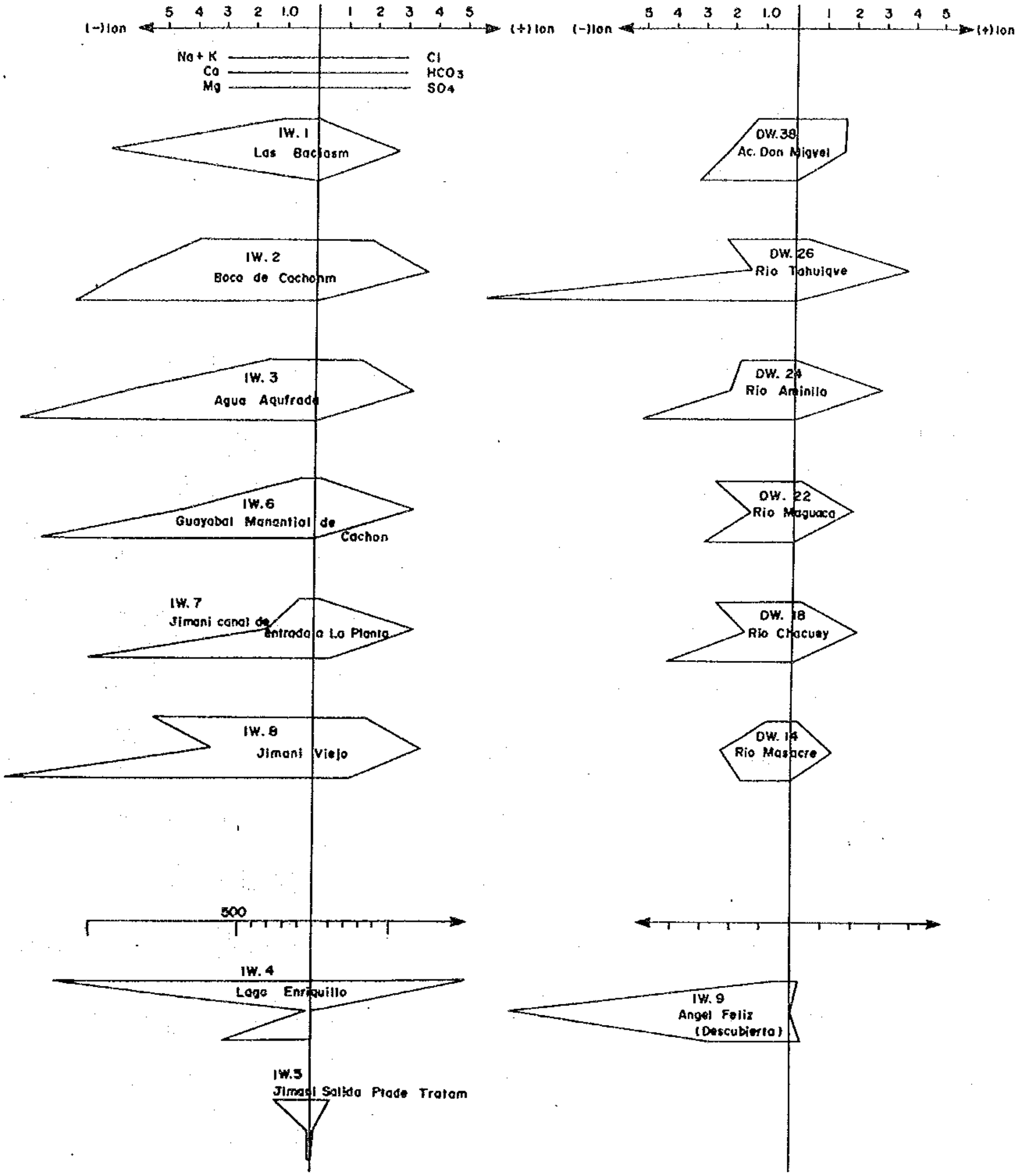


Fig. 1.2.7 (2) Pattern Diagram of River Water Quality

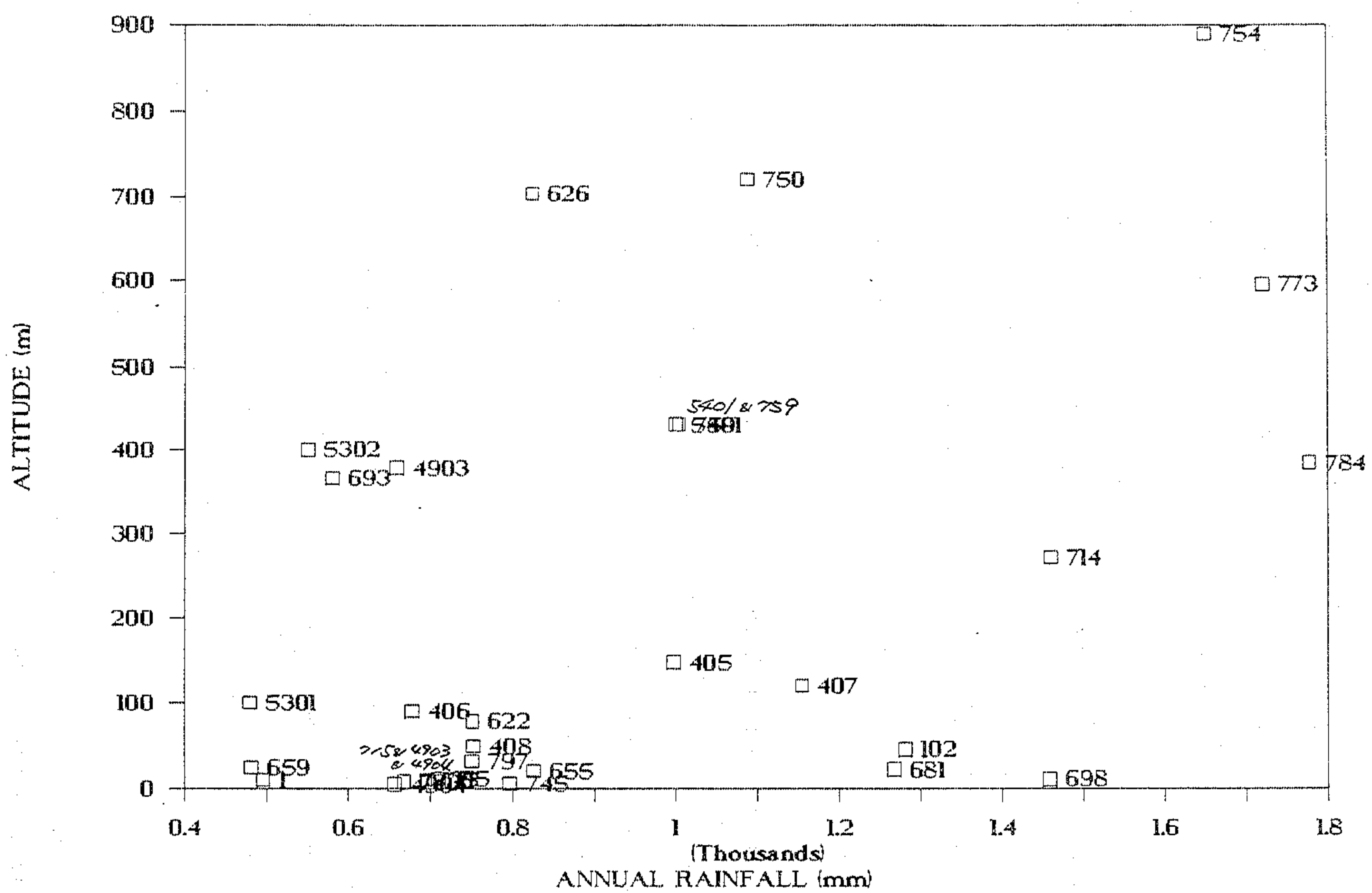


Fig. 1.3.1 Annual Rainfall and Altitude

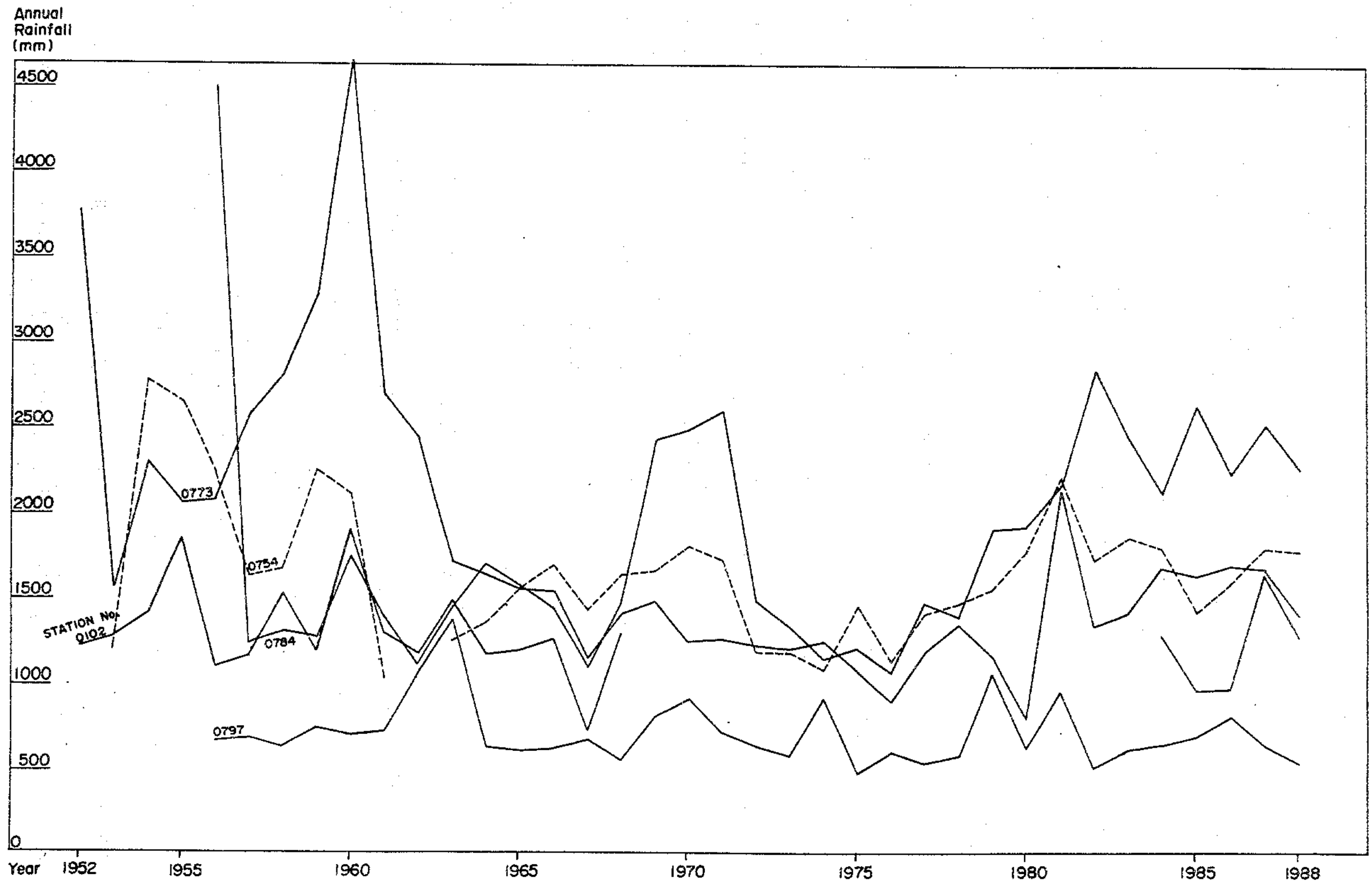


Fig. I.3.2(1) Annual Rainfall

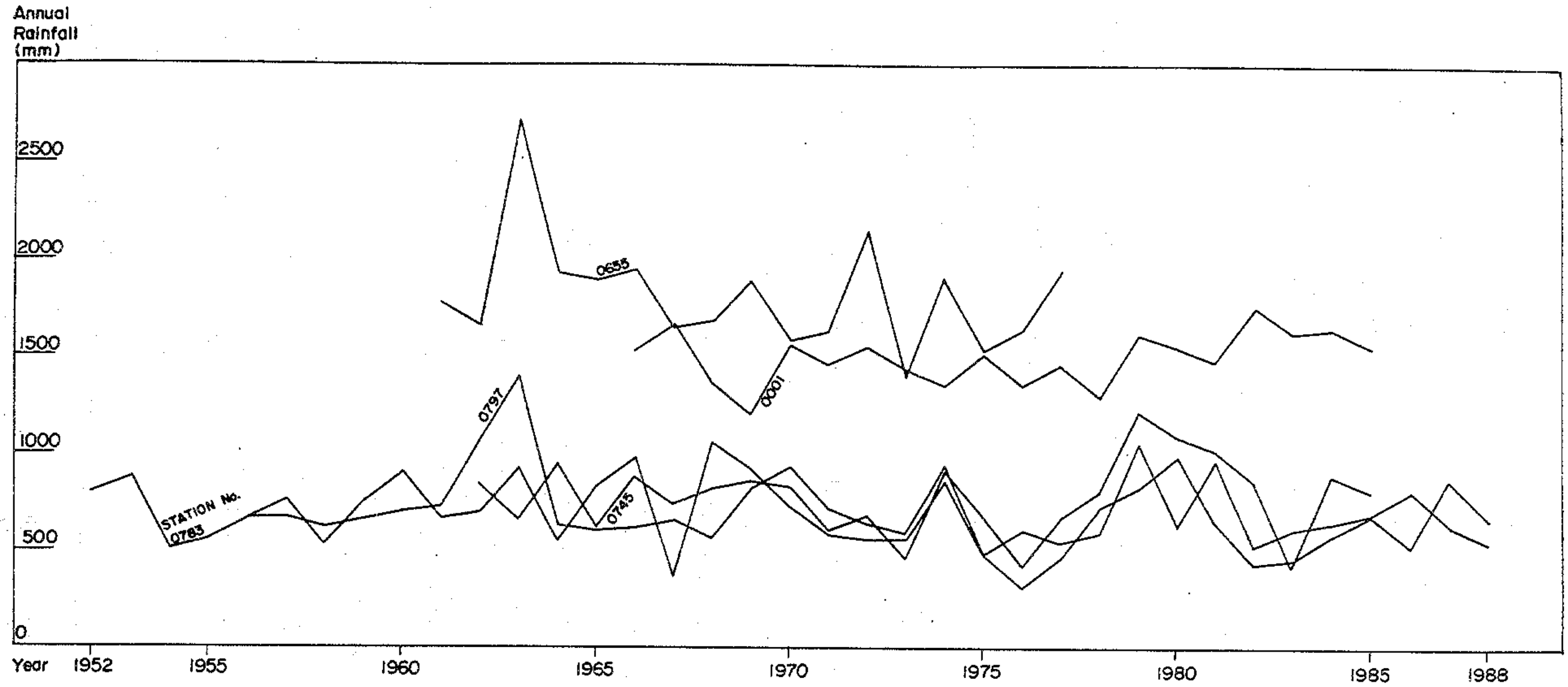


Fig. 1.3.2 (2) Annual Rainfall

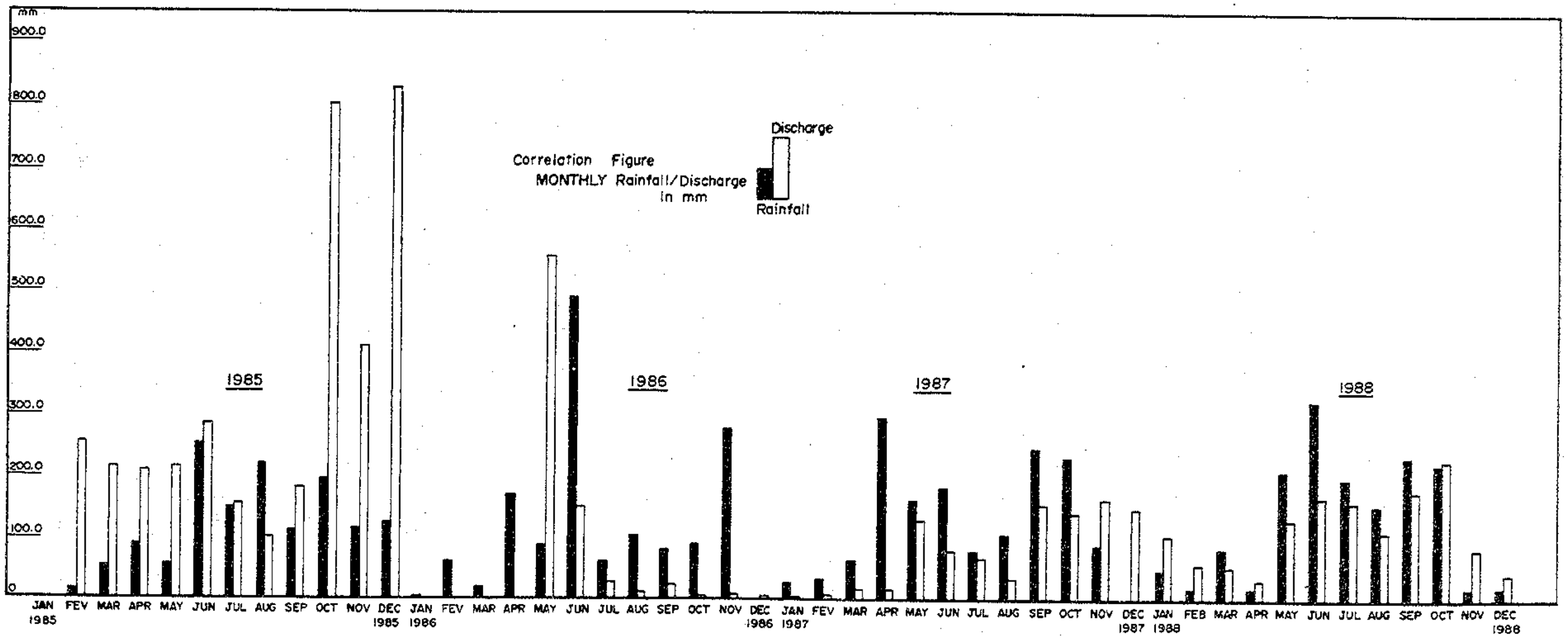


Fig. 1.3.3 Monthly Discharge and Rainfall of Rio Masacre

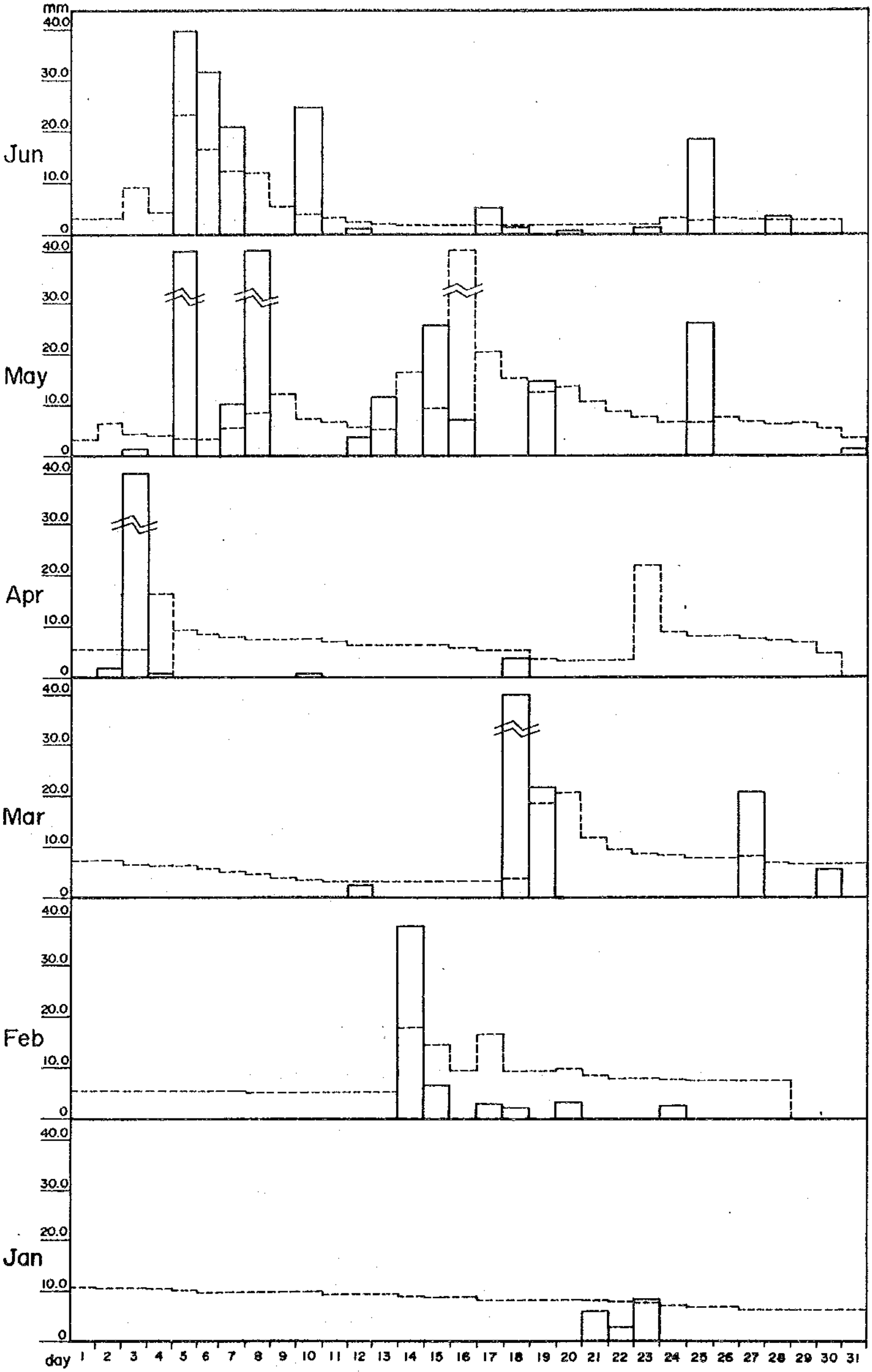


Fig. 1.3.4.(1) Daily Dischage/Rainfall Rio MASACRE

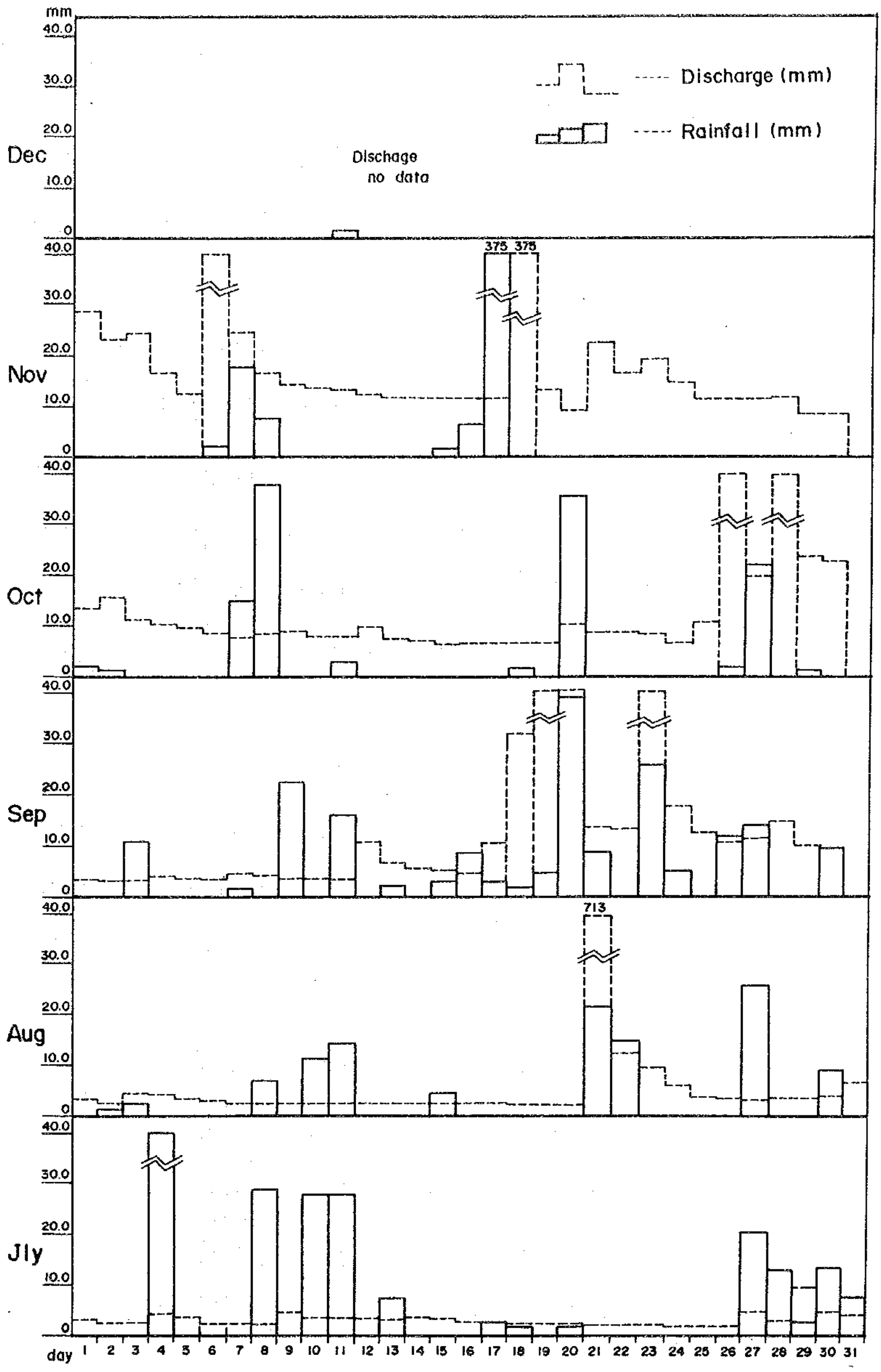


Fig. I.3.4. (2) Daily Dischage / Rainfall Rio MASACRE

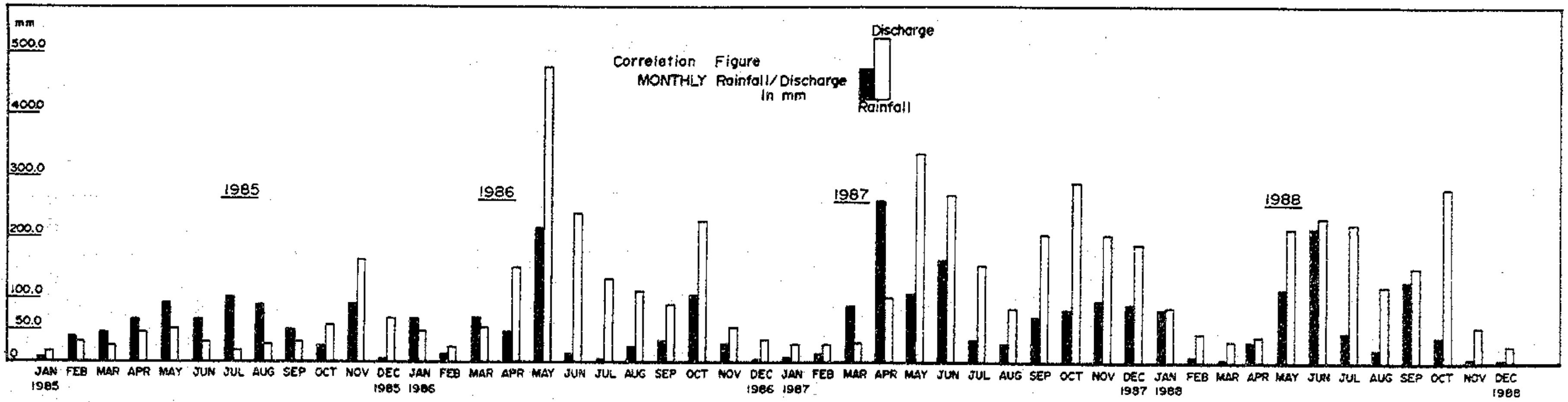


Fig. 1.3.5 **Monthly Discharge and Rainfall of Rio Guayubin**

SUPPORTING REPORT C

WATER SUPPLY PLAN

VOLUME Ⅲ SUPPORTING REPORT C

WATER SUPPLY PLAN

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CHAPTER I

OUTLINE

1.1 Background of the Project

Water supply projects in the Dominican Republic are supervised by INAPA, with the exclusion of Santo Domingo and San Diego cities. INAPA is responsible for the development, repair and improvement, operation and maintenance of the water supply equipment. INAPA is also undertaking water production projects.

At present, with the exclusion of the two big cities of Santo Domingo and Santiago, 128 cities out of 130 urban areas (81% of the population) are covered with water supply services. On the other hand, 1,507 out of 8,615 rural areas (22% of the population) are covered with water supply services. About 45% of the overall population benefits from water supply services.

The water supply service rate under the INAPA Jurisdiction is shown in Table 1.1.

Water service coverage in the four western provinces of Monte Cristi, Dajabon, Elias Piña and Independencia is shown in Table 1.2.
Water service coverage in rural area of Monte Cristi and Elias Piña provinces amounted to less than 5%, and is particularly way behind.

In 1987, the Government of the Dominican Republic formulated the "Border Area Development Plan", as a supplement to the National Development Plan. Then, in 1988, INAPA requested the Government of Japan for technical cooperation for the study on groundwater potential and the preparation of a rural Water Supply Plan for the four western provinces. Survey activities started in October 1990.

Number of villages for the Water Supply Plan is 154 (4 villages were subsequently added.) (See Table 1.3)

Development of groundwater resources will be difficult in this region, because almost 80% of the villages are located in mountains and hilly areas with little rainfall during the dry season, and because of the high salinity content of groundwater in many places. Surface water development will be difficult, too, due to poor runoff during the dry season, except for the Yaque del Norte and Rio Masacre rivers.

The Study Team conducted a field survey in the 158 proposed villages. Development potentialities of the groundwater and surface water resources were evaluated, and the water resources development plan to be implemented was formulated in accordance with the water demand.

1.2 Basic Policy of the Water Supply Plan

The aim of this Project is to devise the most suitable water supply plan for the 158 villages in the four western provinces of the Dominican Republic. The 158 villages, each having a population of between 200 and 400 people (according to the 1981 Census), were selected by INAPA.

Up until the present, INAPA water supply systems have been classified into three different types, as indicated in Table 1.4. The villages included in this particular plan fall into the windmill pump supply system category.

To make optimum water supply plans on the basis of the above classification, field surveys were conducted in the proposed 158 villages in accordance with the following items.

1) Present population and number of households
2) The dispersion pattern of the beneficiary villages
3) The present water supply condition
4) Environmental and sanitary conditions
5) Village public needs and cooperative system status

In villages where groundwater development potential is very low, a water supply plan with surface water as the source, will be formulated.

1.3 Outline of the Field Survey

A two-phase survey consisting of personal interviews and field surveys was conducted on the 158 villages. Local counterparts assisted the INAPA with the survey. The basic results of the survey are listed below.

1) Present Population and Household Number

   The population and household number of the various villages differed greatly from the 1981 census owing to village desertion and the merging of two or more villages. A new survey to determine the present population and household number was, therefore made.

2) Dispersion rate

Most of the villages are located near the road and are spread over several kilometers, resulting in an extremely low population density. Consequently, the dispersion rate was roughly estimated based on household groups considered as the village nucleus.
Dispersion Rate = (total household number-grouped household number)/Total household number.
If more than 50% of the village has dispersed, the water supply efficiency rating is very low.

3) Present water supply Status

The villagers obtain their domestic water from a number of sources, some of which are polluted, thereby causing health and sanitary problems. Some households are located up to three kilometers away from the water sources, resulting in daily laborious task of water transportation by man or animals. During the survey, the study team came across about 20 or so windmill pumps that had been built in the 60's, but only one of these was still working. The team also came across 50 or so hand pumps built by the Ministry of Welfare in the 70's of which less than one-third were still being used.
The water in mountainous areas is mainly supplied from valley springs or from mountain streams. Apart from those provided by the INAPA, many of these water supply facilities have been provided by Fudeco or Christian religious organizations. Some of the villages located near the cities are supplied with water through the city facilities, but many of these supplies have dried up in recent years. The overall water supply efficiency rating (population divided by the length of the village) of the villages is extremely low.

4) Environmental and Sanitary Condition

The doctors of 40 or so medical clinics within the survey area were interviewed on the sanitation and common sicknesses within the villages. The most common patients, the team was told, were infants with diarrhea.

5) Village Needs and Cooperation

A survey on the needs of the villages was conducted through a series of interviews. Special attention was paid to the villagers intended level of cooperation with regard to system supervision and the collection of water charges. The survey indicated that although no charges were presently being made for the use of hand water pumps or for road transported water supplies at any of the villages, households connected to water supplies were paying service charges of 7RD$ per month.

6) Village topographical Survey/Outline of Mapping

Rough maps of the villages were sketched and collected to clarify village dispersion.

CHAPTER II

BASIC APPROACH

2.1 Planning Criteria

2.1.1. Target Year

The planned target year is 2000, in consideration of the future expansion of water demand.

2.1.2. Service Population

The 1990 population of some areas of the regions surveyed had more than doubled (203%) since the 1991 census, while other areas had decreased or even dispersed altogether (-100%). In order to accommodate these changes, the project will, therefore, be based on the following standards.

– Present population:	The population as of the 1990 survey
– Population Growth Rate:	This will be based on the 1981 - 1990 growth rate. Service population of villages where population decrease is evident will be based on the 1981 census.
– Standard Year:	The year 2000 is to be the target year for completion of water supply facilities construction

2.1.3. Water Consumption

Proposed water consumption per capita is a realistic quantity evaluation on the basis of INAPA's norms. Designed water consumption for each proposed supply system is indicated in Table 1.5.

2.1.4. Water Quality Standard

The INAPA water quality is applicable to all INAPA operated water supply facilities and is similar to the WHO norms (see Table 1.6).

2.1.5. Water Supply System

1) Manual pump (Handpump) and Electric Engine Pump (Motorized Pump)

i) Hand Pump - Covers over 20 households
- Groundwater level in the basehole is less than (-) 40 m below ground level

ii) Motorized Pump
- Covers over 50 households

2) Selection of the power sources for the motorized pump

i) Diesel Engine Generator
- The most suitable system in the project area

ii) Windmill Pump
- Future studies will be carried out after completion of data

iii) Solar Pump System
- Not to be used because of high construction and maintenance cost

3) Water Treatment

i) Slow Sand Filtration System
- The most suitable treatment process for this Project, because operation is easier than rapid sand filter and O/M cost is low

ii) Rapid Sand Filtration System
- Not to be used

CHAPTER III

FORMULATION OF THE WATER SUPPLY DEVELOPMENT PLAN

The proposed villages were classified into 2 categories, in consideration of their hydrological and geological conditions and selected water supply system.

3.1 Hydrological and Geological Classification

The Project target areas were classified into eight different types according to the results of hydrological and geological surveys.

1) Cordillera Septentrional

a. Low groundwater potential; low groundwater reserves and high amount of salt.

b. Low annual rainfall; almost no rain during the dry season; surface water sources extremely poor due to a yearly evaporation rate exceeding the precipitation rate.

c. Springs can be found within the project area, but most of them cannot be relied on during the dry season.

d. Villages in these areas rely on rainwater (collected from roofs and stored in a tank or in a reservoir pond) or water transported by tank lorries.

2) Llano de Yaque del Norte

a. The development potential in these areas is high because of large reserves of groundwater with low salinity content. However, water may have to be filtered in some areas due to a high content of suspension solids as a result of the sedimentary geological beds in the surrounding area.

b. A stable supply of surface water may be obtained from the Yaque del Norte River. A rapid water filtering system will have to be employed if this source is developed, in order to cope with the seasonal change in river water quality.

c. Although water from irrigation networks may be a source for domestic use, it is not suitable for drinking due to contamination from fertilizers and pesticides.

3) Sur del Yaque del Norte

a. Located in the upper reaches of the Yaque del Norte tributary, the development of mountain streams as drinking water supply sources is highly possibly in this area, although a plain filter treatment will be necessary.
b. Groundwater sources may be able to provide water to villages with 1,000 population. This has not yet been confirmed through. Nevertheless, it is an area with high groundwater development potentials.
c. As some of the pre-existing deep wells are increasingly contaminated with bacteria, it is necessary to boil water before drinking.

4) Cordillera Central

a. Access is difficult in these regions (elevated over 500 meters above sea level) especially for the boring truck. Therefore, well drilling is not very possible.
b. The development of surface water of mountain streams that run between the valleys is highly possible.
c. The development of spring water sources located between mountain valleys is also highly possible.

5) Valle de San Juan

a. This area is composed of hills, of 300~400 m in elevation. The development of mountain streams is highly possible in this area.
b. The development of groundwaters is highly possible through hand pumps. The water is of high quality and can be found in abundance.

6) Sierrade Neiba

a. The area, ranging from 200 to 1900 m in elevation, has poor access road, thereby making the transportation of boring machines to the site, for groundwater development difficult.
b. Mountain streams in the site are not contaminated and are suitable domestic water sources. Rainfall is abundant , perennial mountain streams can be found. Stream water is being used by the villagers.

7) Cuenca de Enriquillo

8) Sierra de Baoruco

a. Rainfall in the Neiba Mountain Range (over 2000 mm) supplements the spring waters at the piedmont of the mountain of north Enriquillo Lake. The spring waters are abundant and are sufficient for domestic water sources.
b. South area of the Enriquillo Lake is endowed with sufficient groundwater of suitable quality. Therefore, the area has high groundwater development potential.

3.2 Water Supply System Classification

Classified into either underground or surface systems, the type of supply system to be constructed is chosen according to this development potential of the source. The basic concept of these systems are indicated in Table 2.1. The facility plans are described below.

3.2.1 Ground water sources

1) Hand Pump System (system type G- I -1)

The most common of all existing systems. This type of system has been installed in approximately 250 locations in the four western provinces. Only about 30% of these are still operating. The causes for disuse include, in order of frequency: mechanical breakdown of the pump, deterioration of water quality, and depletion.
The depth of the wells to be bored for hand pump use varies depending on the geological conditions of the region. At present, plans call for wells of between 60 and 150 meters, with a diameter of approximately 10 inches. The amount of water obtainable through hand pumps decreases largely for wells of more than 40 meters.
The average number of households covered by one pump can be calculated by the amount of water the hand pump is able to pump per minute. For example, if:

Average pumping rate:	15ℓ/min
Daily operation:	8 hours
Operating Ratio:	70%
Av. daily per capita consumption:	40ℓ/c/d
Average household size:	6 persons

Then, the number of service households can be calculated as:

15ℓ/min × 8 × 60 × 0.7/40 × 6 = 20 (households)

This means that the 20 households per pump are efficiently supplied with water.
The area covered by one pump will also be set at a one kilometer radius due to the close proximity of villages just outside the target regions.

2) Motorized pump systems (system type G- I -2)
This kind of system is intended for villages with relatively large populations. As opposed to the one point well source of the hand pump system, this system conveys water pumped from the well to several different faucets throughout the village.
The well for the motor pump will be basically the same as that of the hand pumps, although there will be no depth limitations. The settings of pump operating depth and pumping volume limits will have to be settled, however, due to the pump operating below the normal water surface level. The exact values for each of these cases will have to be determined through the boring and test pump data.
The following will be the basic structure of the system:
Submersible Motor Pump (with own power generator)
Elevated Water Tank Distribution Pipe Communal Faucet.

3) Windmill Pump System (system type G- I -3)
It has been estimated that windmill pumps are only effective in areas with an average monthly wind velocity of more than three meters per second (source: World Bank Wind Pumping, A Hand Book). Although normally considered highly efficient in pumping up groundwater, even windmill pumps would probably not produce favorable yield in some of the target areas due to the depth of the wellss (over 50 meters). The following equation illustrates this fact.

$E \alpha V^3 A$ --- (1) E = Energy necessary to pump up the water
V = Wind Velocity
A = Effective Windmill Operating Service Area

The lower the wind Velocity, the greater the surface area of the windmill becomes. Maintenance cost and breakdown must be also considered if a large windmill is to be used (see Fig. 2.1). (Assuming that wind velocity is 3.0 m/s and the rotor diameter is 6 m, the pumping volume of a water lifting head at 5 m will be 1 ℓ/S.)

Due to lack of information on wind speed, the development of windmill pump systems will be studied in the future.

3.2.2 Surface Water Sources

1) Rain Water (system type S-1)

(1) Storage tank
Used in dry areas throughout the ages. This system entails the collection and storage of rainwater from the roofs of the villagers' houses, and it is still widely used in Monte Cristi. The storage tanks in use at present were apparently donated by a Christian organization. The volume of water collected in the tanks varies depending on monthly and seasonal (almost none in the dry season) as well as the private consumption rate of each household. Due to the limitations of the system, villagers in Monte Cristi almost never rely on rain water storage tanks alone for domestic water supply.

(2) Reservoir
Under this system, rain water collected in artificial or natural ponds is supplied to one or several villages after treatment. The volume and water balance of a reservoir can be calculated using the following equation:

V= I - W - IR - L
V= Reservoir Storage Capacity
W= Intended Monthly Water Pipe Supply
IR= Intended Monthly Supply for Agricultural and Other uses
L= Evaporation, Seepage and other Water Volume Loss.

The Monte Cristi northern mountainous areas has an average annual rainfall of 750 mm. At present, the average annual evaporation is estimated to be 1400 mm. A long-term field survey will be necessary to calculate the potential storage capacity and the runoff in the catchment area, as well. Development plans are presently being made for storage ponds that remain filled throughout the year. Anti pollution measures from domestic sewerage, horses, cows and other domestic livestock will have to be incorporated in the mattersupply plan. Many of the ponds that remain filled throughout the year have been used up until a few years ago as domestic water source, but have fallen into disuse recently due to increased state of pollution. An adequate water maintenance will be, therefore, necessary before such sources can be utilizedfor domestic use.

2) Spring Water (system type S-Ⅱ)

Spring water is the most effective domestic water sources, provided it is of drinkable quality. If the volume is large, spring water may sufficiently provide water to several villages at once. Some plans call for the use of pumpless spring water sources that take advantage of high-altitude locations of many springs in the target areas. Special caution will have to be exercised in the selection of sites, however, since fact that such springs often run dry during the dry season.

3) River Water (system type S-Ⅲ)

Hydrological surveys showed that up to 10% (1.1 million tons) of the estimated 11 million tons annual flow capacity of the Yaque del Norte, Chacuey,Dajabón and Artibonito Rivers, can be tapped for the supply of domestic water. As a result, the development plan of river resources may be devised in accordance with topographical survey results.

If developed as a domestic water resource, river water will have to be treated and sterilized before use, due to year round variation in water quality as well as contamination from fertilizers and pesticides.

(1) Slow Sand Filtration Systems (system type S-Ⅲ-2)

One of the oldest filtration methods in existence, this system is used for water sources with an annual turbidity rate of less than 30 N.T.U. It makes use of gravity to convey water through a relatively fine sand filter. This organic filtration system is mainly used for filtering out turbid. Substances Sand filter alone can not kill colon bacilli or other bacteria, thus making further treatment, such as sterilization, necessary.

Although several water treatment plants exist within the areas surveyed, all of the plants were not operative when water is highly turbid. Some of the plants had been abandoned altogether, while others did not have any facilities for sterilization. Although water treatment facilities of this type would be unsuitable for flat lands within the survey area, they would be effective in the upper reaches of mountain streams where degree of turbidity varies slightly. Such facilities are also cheap as they require no treatment chemicals and only very little maintenance during operation. Sand filter beds usually operate at a low speed of 4.0-5.0 meters per day. When the filter gets clogged (usually after about 30 days) 1.5-2.0 cm of the surface is scraped off and replaced. Two filters are usually used alternately.

(2) Rapid Filtration Systems (system type S-Ⅲ-3)

Under this system, a rapid filter (120-200 m/d on average) is used for treatment. Rapid filtration is made possible by the use of chemical additives which flocculate impurities in the water and aid sedimentation. Once flocculated, the microbes and other impurities are then filtered out.

This kind of system is commonly used for sources with high or rapidly changing degrees of turbidity. Such systems can be quite costly however, as they require skilled labour for chemical application as well as daily filter sand cleaning requirements. The system also requires the same kind of sterilization measure the slow sand filtration system requires.

Many of the cities within the target areas use similar systems for water treatment. The system is not appropriate for many of the target rural villages however, due to high construction and operation costs.

4) Mountain Stream Water (system type S-Ⅳ)

Under this system, water taken from mountain streams passes through a simple filter and then sterilized. This long established system is still presently used in many mountainous areas. Mountain stream water is free from contamination and water treatment plants in the areas surveyed all employed a simple sand filtration system for water turbidity due to rainfall, discontinuing pumping operations during this period.

A stream water treatment will be employed in big villages in the Project area, while water will be boiled before drinking in small villages.

5) Irrigation Canal (system type S-Ⅴ)

Irrigation canal development is in progress in many of the areas surveyed. This was particularly remarkable in the province of Monte Cristi where a number of large plantations are being developed. In spite of this, measures for the provision of drinking water have been falling behind and many areas are relying on irrigation water for their domestic water supplies. In treating irrigation water for human use, pollutants from nitrogen, potassium and calcium based fertilizer also have to be extracted. This will also require constant testing due to varying seasonal concentrations.

6) Reservoir Pond Water (system type S-VI)

A large number of farm reservoir ponds (many constructed by the Ministry of Agriculture) can be seen within the survey area. Under this system, domestic use water is obtained from treated farm reservoir pond water. The type of water treatment used for this system is the same as that for rain water storage reservoirs.

CHAPTER IV

ASSESSMENT OF THE TARGETED VILLAGES

4.1 General

Assessment of the targeted villages were formulated based on the result of the field survey and boring tests which were carried out in 27 selected sites. Groundwater development potential has been carefully examined.

In this case, groundwater development is the first priority of the water supply project. The existing water supply systems are classified in Table 3.2.

The assessment was studied according to the Flow chart of the water supply development plan shown in Table 3.1.

If the groundwater development plan is considered unfeasible, a surface water development plan will be examined

The overall planning are shown in Table 3.3.1.~3.3.4., and the targeted villages were assessed according to the following:

4.2 Criteria

Priority A: Villages which require the most urgent water supply plan based on the result of the following field survey on:

- Socio economic condition;
- Health of the inhabitants and water related diseases;
- Needs of the population;
- Existing water supply condition;
- Possibility of groundwater development

Priority B: Villages with conditions similar to A but with less urgent needs

Priority C: Villages with existing water supply facilities and favorable supply condition.

- water supply facilities have not been developed or improved in the villages. This is highly possible in the near future though, through INAPA, FUDECO and other agencies
- Poor and impassable road conditions
- Groundwater development is impossible but surface water easy to intake from stream, spring, and rivers.

Priority D: Dispersed villages with less than 20 households left or non at all.

4.3 Village Classification

All of the villages were classified as follows:

G: Groundwater resources
S: Surface water resources

G-A
G-B } Groundwater resources ranked under A, B and C
G-C

S-A
S-B } Surface water resources ranked under A, B and C
S-C

In Monte Cristi Northern Area, Groundwater development is very difficult and surface water sources is very poor. In the case

G-B: Supply of drinking water through tha tank lorry
S-B: Surface water is treated in the existing reservoir improved during the project

4.4 Non Urgent Plan

The reason why some villages are not in need of any urgent plan are as follows and as shown in the above C rank.

- Due to existing water supply facilities
- Groundwater development plan is impossible but water supply conditions are remarkably good owing to water sources located nearby
- Where water supply services by INAPA, FUDECO or other agencies can be expected in the near future.

Table 3.4.1 (1/4~4/4) shows the non urgent plan for 82 villages, and the summary of these villages are shown in Table 3.5.

4.5 Summary of the assessment

Summary of the assessment is shown in Table 3.5 and are as follows.

The location of these villages was mapped out and is shown in Fig. 3.1.1, 3.1.2

Urgent Plan	Groundwater Source	47 villages
	Surface Water Source	11
	Sub-total	58
Non Urgent Plan	Groundwater Source	5
	Surface Water Source	77
	Sub-total	82
Dispersed Villages		18
	Total	158

CHAPTER V

FACILITY PLANNING

5.1 Basic Approach

Water supply facility plan was formulated based on the proposed Water Supply Plan for the 58 villages.
The basic approach for the planning of the proposed facilities is as follows:

1) Classification of the facilities

The required facilities in the proposed water production/supply systems are classified into four types as shown in Fig.5.1.1.

2) Basic planning standard

(1) Type I system ·····Hand pump

a) Wells

i) Standard drilling method and diameter
The drilling method shall either be Rotary Rigs drilling or Percussion Rigs drilling depending on the results of the test drillings which were carried out in this study period. The drilling diameter will be 10-5/8 inches.

ii) Standard tubewell
The standard design of the hand pumped well is shown in Fig. 5.1.2.
The design depth is 70 to 150 m and the diameter is 6". The depth shall differ according to the hydrogeological conditions of each province.

iii) Casing and Screen
FRP (Fiberglass Reinforced Plastic) pipe will be used for well casing to prevent corrosion from groundwater containing with high salinity and SO_4 contents. FRP slot pipe is to be used for well screen too, and the opening ratio shall be more than 3%.
The casing length, opening ratio, and screen length will differ according to the hydrogeological conditions of the area.

b) Hand pumps

i) Hand pumps are to be used for deep wells the cylinder shall be 3⅝" diameter steel pipes.

ii) The base of the hand pump facilities shall be made of concrete for the shower and waste water drain.

2) Type Ⅱ system ····· Motorized pump

(1) Wells

The wells shall be constructed in the same way as those for the hand pump system.
The standard design of the motorized pump well is shown in Fig. 5.1.3.

(2) Motorized pumps

i) Submersible motor pumps suitable for pumping large volume of groundwater shall be used. It shall be made from stainless steel to ensure long use.
ii) An engine generator, a generator house, and an electrical panel shall be attached to the motorized pump.

(3) Elevated tank

i) In order to cope with the maximum hourly demand, a tank with a capacity to cover 10 hours of daily maximum demand shall be designed.
ii) The elevated tank is to be made of concrete and is estimated to be 7.0 m above the ground.

(4) Distribution pipeline

i) Pipes are to be made of galvanised steel to cope with the external pressure of geological erosion.
ii) The pipeline head loss calculation shall be according to the Williams & Hazen equation the friction coefficient is to be $C=130$.
iii) A communal faucet shall cover 20-30 households, and their distance from the houses shall be 500 m.

3) Type Ⅲ system ····· Surface water treatment

The proposed system consists of reservoir intake, water treatment facilities, and water conveyance/distribution facilities.
To curtail construction and operation/maintenance costs, the reservoir and clean water production system shall have to be in

accordance the water demand of the 7 villages. The preliminary design is shown in Fig. 5.1.4. and 5.1.5.

(1)) Reservoir

The location of the reservoir was decided by conducting a parallel study on the technical soundness and economical viability of the existing reservoirs, based on geographical conditions, collectability of surface runoff water, safety in the discharge of surplus water, and required length for the water supply.

It was decided that the existing reservoirs located at El Cayal and Las Brigada are to be improved.
Both reservoirs are constructed in the natural catchment canal line of the Arroyo Borrance Blanca and Cañada Los Corbanos headstreams.

The proposed dam is a homogeneous earth dam with an enbankment-excavation structure, compounded and the preminarly design of the reservoir is shown in the Supporting Report.

(2) Water treatment plant

The water treatment system shall adopt the slow sand filtration process, as annual raw water turbidity is less than 30 NTU units, and it is easier than the rapid sand filtration process for operation & maintenance. Furthermore, this process is a log easier to operate and maintain than the rapid sand filtration process.

(3) Distribution facilities

Drinking Water shall be conveyed to the elevated water tank installed in each village through booster pumps and pipelines.

4) Type Ⅳ system ····· Tank Lorry Water Distribution

(1) Tank lorry

Drinking water is transported from the water treatment plant by a tank lorry which will be provided by INAPA.

(2) Clear water tank

A clear water tank designed to meet a 4 day demand constructed in the villages.
Water will be sterilized after distribution by introducing solid chlorine in each water distribution tank.

5) Access road

The following are the improvements needed by the access roads for the passage of boring trucks:

- repair works
- the need to construct a river crossing
- the need for a new small road

6) Windmill pumps

The following equation illustrates this fact
$E = \alpha V^3 A$,
where: E: Energy necessary to pump up water
V: Wind Velocity
A: Effective Windmill Operating Area

The lower the wind speed, the greater the windmill's surface area has to be. Maintenance cost and breakdowns should also be considered if a large windmill will be used.
The study team was not able to collect the wind velocity data in the project area. Further studies will be performed after data completion.

7) Solar Pump System

The mean annual duration of sunshine is 8 hours, and solar radiation averages 425 cal/km^2/day in the Dominican Republic. The development of the solar pump system has wide possibilities.
At the project area's borehole wells, the duration of sunshine and value radiation values is 80% less in December.
The solar pump system has to be waterproof due to an average humidity of 74% in the Project Area, and has to be protected from damages caused by wild birds living in great numbers.
The most significant problem is the high construction and maintenance cost. The submersible motor pump uses 1.5 kw and 2.2 kw, considered which is economically impractical.

The facility plan was formulated based on the norms of the project. The facilities planned for each village are shown in Table 5.2.1-1 to 5.2.1-2, and are summarized in Table 5.2.1.

5.2 Formulation of the Facilities Plan

1) Type I

Province	Number of Villages	Total Borehole length	Number of Hand pumps
		m	unit
Monte Cristi	2	350	5
Dajabon	20	6,340	72
Elias Piña	18	3,880	54
Total	40	10,570	131

2) Type II

Province	Number of Villages	Total Borehole length	Number of Motor pumps	Number of Elevated tank	Number of Faucet units
		m			
Monte Cristi	6	480	6	6	23
Dajabon	1	80	1	1	2
Total	7	560	7	7	25

3) Type III

The existing reservoirs in La Brigada and El Cayal shall be used.

Treatment plant	Service population (and villages)	Treatment Capacity	Intake pumps	Sand Filter Area	Distribution Pumps
		m^3/d	kw	m^2	kw
Las Aguitas	1,455 (4)	69.0	0.4×2	25.6×2	3.7×2
El Cayal	1,554 (3)	73.0	0.4×2	25.6×2	5.5×2
Total	3,009 (7)	142	0.4×4		

4) Type IV

Province	Number of Villages	Total Demand	Clear Water Tank Total volume	Tank Lorry
		m^3/d	m^3	unit
Monte Cristi	4	20.0	73	$8m^3 \times 2$

5) Access Road

Repair Work 4 villages × 6.5 km
River Crossing 14 villages
New road 5 villages × 145 km

5.3 Operation and Maintenance Facilities

1) O&M Office

Monte Cristi office 1 office
Elias Piña office 1 office

2) O&M Equipment

a) Equipment

i) Water Wagon 2 sets
ii) Crane Truck 2 sets
iii) Pick up 1 set
iv) Motor Bicycle 2 sets

b) Spare parts

Hand pump 13 units 10% for 131 unit
Submersible pump 2 units 1.5 kw × 1 2.2
Pipes and valves 1 set 10% of the equipment

5.4 Summary of the Major Project Facilities

Features of the Major Project Facilities

Items	Unit	Nos/ Quantity	Remarks
1. Preliminary	Lum	1	
2. Land Acquisition	ha	14.33	
3. Water Production/supply Facilities			
Hand Pump Systems		131	40 villages
Well	No	131	D=6'
Drilling	M	10.570	D=18-5/8 inches
Hand Pum	Set	131	
Motor Pump Systems	No	7	7-villages
Well	No	7	D=6'
Drilling	M	560	D=10-5/8
Submersible Motor Pump	Set	7	1.5 kw - 5 nos. 2.2 kw - 2 nos.
Engine Generator	Set	7	7.7 kva - 6 nos 6.3 kva - 1 nos
Engine room	No	7	
Water Tank	Set		2.5×2.5×2.0H (rainforce concrete) H:7 Rainforced concrete
Faucet	Set	16	25 mm × 2
Pipe-line	M	7,100	ϕ50~ϕ100
Reservoir/Treatment System	No	2	7-villages
Reservoir	No	2	A-20,000 m^2
Treatment Plant	Set	2	69 m^3/day, 73m^3/day
Booster Pump	Set	2	3.7kw-2, 5.5kw-2
Water Pipe	M	13,100	ϕ50~ϕ100
Water Distribution Tank	No	4	Rainforced concrete C:6~24m^3
Tank Lorry System	Unit	2	4-villages
Water Wagon	No	2	C:8m^3
Water Distribution Tank	No	4	4.0×4.0×1.01-1 4.0×4.5×1.5-2 4.0×5.0×1.5-1

4. O/M Facilities			
Office Building	No	2	60 m^2
Work Shop	Lum	1	
Patrol Service Car	Lum	1	4t-truck crane-2 etc.
5. Access Road			
Improvement	km	6.5	
New Construction	km	14.5	
River Crossing	No	14	
6. Monitoring Facilities			
Well	No	6	Dia. 150 mm
Groundwater Level Meter	Set	6	Depth 100~150 m

CHAPTER VI

COST ESTIMATION

6.1 General

The implementation of this project shall entail direct construction expenses, management expenses, land acquisition expenses, technical management expenses and contingencies with respect to work load and price fluctuations. The financial cost estimation of the project was, therefore, performed based on the following.

1) Financial evaluation was based on the December 1991 price rate.

2) The following exchange rate was used:
US$1 = 12.45 Dominican Republic Pesos

3) The construction works are to be implemented on the basis of competivite bidding between international and domestic contractors.

4) The expenses of the material for the construction work are to be directly purchased by INAPA, the implementing body, and are to be procured and supplied to the contractors.

5) The construction cost comprises foreign and local currency portions. The classification of foreign and local costs is shown below.

(1) Foreign Costs

- Galvanized steel pipe
- Hand pump and submersible pump with accessories
- Chlorinator and accessories
- Generator and operation board
- Casing pipes, strainer
- Drilling work for the wells
- Engineering service cost of foreign consultants

(2) Local Costs

- Labour forces
- Reinforcement bars
- Cement, sand and gravel
- Fuel, oil etc.
- Inland transportation costs
- Engineering service costs for local consultants

6) Fiscal contingencies are regarded as 10% of the direct works expenses, land acquisition,O/M facilities/equipment, engineering services/ administration.

7) Price contingencies are estimated as 30% of the grand total expenses.

6.2 Project Cost Estimate

Accordingly, the project cost for draft final facility plan is estimated for the urgent water supply plan for the 58 villages.
Details are shown in Supporting Report C and summarized in the Table below.

Unit RD$×1000

Item	Foreign Cost	Local Cost	Total
Direct Construction Costs	64,649	25,556	90,205
Spare Parts	1,705	–	1,705
Land Acquisition Costs	–	143	143
Administration and Engineering Costs	10,818	4,524	15,342
Sub total	77,172	30,223	107,395
Physical Contingencies	7,717	3,022	10,739
Total	84,889	42,312	127,201