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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS (INDRHI)
THE DOMINICAN REPUBLIC

THE FEASIBILITY STUDY
ON
THE LIMON DEL YUNA AREA AGRICULTURAL DEVELOPMENT PROJECT

FINAL REPORT

VOLUME III ; ANNEX II

NOVIEMBRE 1995

PACIFIC CONSULTANTS INTERNATIONAL
KOKUSAI KOGYO CO., LTD.

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ANNEX I: IRRIGATION AND DRAINAGE

I.1 General background

The irrigation system in the Study area is advanced in comparison with the Aguacate-Guayabo and the former El Poso in the AGLIPO. Almost all the Study area is covered with irrigation canal networks. Around 6,680 ha of paddy fields exist in the Study area and almost all of them can be irrigated using a gravity or pumping system. Some of the main springs in the Study area and the Yuna river and the Payabo river are the main water sources for irrigation water. Especially, the existence of springs has an important meaning for this area, which are placed along the mountain foot in the East-Southern part of the Study area. The irrigated areas of these water sources are as follows:

Water source	Ponton	Payabo	Guaraguao	La Cueva	Lagunita	Borojol	Total
Area (ha)	1,910	630	2,280	330	770	760	6,680

One of the characteristics of this area is that it is irrigated under many small pumping stations. Totally 2,470 ha of area is irrigated using small pumping system and this is equivalent as about 37 % of total irrigation area. Almost all the water for irrigation are drawn from the Yuna river.

The Payabo river and the Cascarilla drainage canal are the main drainage canals in the Study area and the area is flooded several times during the year due to their poor drainage capacity. Especially, several occurrences of inundation take place during the year in the area along Payabo river, between Payabo river and the mountain foot and at around downstream of the Cascarilla drainage canal. However, the inundation from the Yuna river has not been identified since the cyclone "David" in the Study area.

I.2 Irrigation System

I.2.1 Irrigation network

Irrigation system in the Study area can be classified into two sections which are located in Western and Eastern parts with the line connecting the Payabo river and the Guaraguao river. Totally around 6,680 ha of paddy field is irrigated using existing irrigation facilities and approximately 2,540 ha and 4,140 ha of them are in the Western and Eastern sections respectively. Mainly the irrigation water is taken from the some of main springs and Yuna river in the Eastern section, where the Payabo river is the main water source in the Western section. There are 6 irrigation networks and each of them use different intake site as shown in **Fig. I.2.1**. The area irrigated by each water source is shown in **Fig I.2.2**. The existing conditions in each irrigation network are as follows:

(1) Ponton irrigation area: 1,910 ha

Main water sources in this area are Payabo river and springs. Irrigated area is about 1,910 ha. Main irrigation canals are Ponton canal and Arrenquin canal. The Ponton canal run toward the Northeast along the Yuna river with more than seven branch canals. The length

of the main canal is about 9.8 km. The original route of Ponton canal was partially changed in 1980.
The Arrenquin canal run along Payabo river. The canal length is approximately 9.3 km. Water resources are the same as the Ponton canal, however, water from the Ponton canal flows into the Arrenquin canal at the initial point. The route of the original canal also had been partially changed since 1976. The canal had reached to Guaraguao area crossing over Guaraguao drainage canal, however the structure of pipeline does not exist now.

In this area, some pumps are installed and pumping station covers an area of about 980 ha. Main pumping irrigation area the area near Cano Ponton and the northern area. Especially, it is difficult to gain irrigation water at Cano Ponton and Arrenquin canal for its high land.

Main remained structure in this area is an aqueduct crossing over the Payabo river, with a discharge capacity of about 0.3 m^3/s. Temporary gates are established in Cano Ponton and Arrenquin canal, however function of the facilities are insufficient.

(2) Payabo irrigation area: 630 ha

This area is located in the south along Payabo river. Main water source is the Payabo river and the irrigated area is approximately 630 ha. The length of the canal is 5.0 km. This canal was designed for connection with the Guaraguao canal. However, the construction was not completed and this canal is not connected yet with the Guaraguao at present. The capacity of this canal is not sufficient compared with the discharge and some water often overflows. Pumping irrigation area in this area is about 240 ha; water source is Cano Azul.

(3) El Guaraguao irrigation area: 2,280 ha

This area is located in the middle of the Study area. Water source is spring named Guaraguao and this area has 2,280 ha which is the widest irrigated area in the study area. Out of 2,280 ha, 460 ha where are located at the northern part and the eastern part, is irrigated by pump. Therefore, the irrigation network system is complicated with a lot of branch canals. The length of the main canal is 4.75 km. Diversion works is the main structure working now and two main branch canals flow to the east from the west. Water level at the water source keeps around EL. 13.15 m, which goes down about 1 m within 1 km distance.

(4) La Cueva irrigation area: 330 ha

Water resource is the spring named La Cueva and the irrigated area is about 330 ha. The length of the main canal named La Cueva is 1.25 km. At the water sources, there are two pumping stations installed for the domestic water supply.
A part of this area is irrigated by pump; its area is 30 ha.

(5) Lagunita Cristal irrigation area: 770 ha

This area is located at the easternmost of the study area. Water source is the spring named Lagunita Cristal. Water directly flows over to the four main canals. Total irrigated area is about 770 ha. There is no pumping irrigation operated either, because the water level of water source keeps higher than the level of irrigated area and quantity of the spring water is sufficient. At present, the southeast of this area is under the farm land consolidation works.

(6) Borojol irrigation area: 760 ha

This area is located between the Yuna river and the Cascarilla drainage canal with about 760 ha. Water source is Yuna river, and all of the area is irrigated by many pumps. The number of pumping station are over 30 units. The diameters of suction bulbs are between 6" to 8", and some pumps of 10" are also installed in some places. All of the pumping stations are private. However, these pumps are too old to use, and there is a pump being used since 1968.

(7) Pumping irrigation area: 2,470 ha

Total pumping irrigation area is 2,470 ha, which occupies 37.0 % of the total area 6,680 ha. Pumping irrigation area of respective water sources is shown below. Total pump discharge capacity is estimated to be equivalent to Q = 2.5 m3/s. Pumping irrigation area is shown in **Fig I.2.2.**

Water Source	Ponton	Payabo	Guaraguao	La Cueva	Lagunita	Borojol	Total
Area (ha)	980	240	460	30	0	760	2,470
Capacity(m3/s)	0.98	0.25	0.46	0.03	0	0.76	2.47

Note: Pump discharge Q is estimated as follows:
Q (m3/s) = Area; A (ha) x Unit Water Requirement; q (l / s / ha) x 1,000
q = 1.0 (l / s / ha)

There are in total nine official pumping stations in the Study area. Seven of them are belonging to IAD and two of them are operated by INDRHI. These pumps are larger than the private pumps and two pumping stations are using 12" of suction bulb. These pumps are generally installed at the end of canal. However, these pumping station are also too old.

I.2.2 Irrigation Canals and Related Facilities

(1) Irrigation Canals

Irrigation canals are constructed to cover the great majority of the Study area and paddy fields within area are supplied water through this canal network. All of these canals are unlined canals and serve for both irrigation and drainage purposes except for the main canals. Lateral canals are not worked adequately due to thick growth of weeds and sand sedimentation. Paddy fields located at higher land elevation or near the end of canals take water from canals with aid of pumps. Features of major canals are as described hereinafter.

<u>Ponton Canal</u>

The Ponton canal (approximately 9.8 km in length-the main canal) runs toward the northeast along the Yuna river in the western part of the Study area and takes water from the Payabo river and springs. This canal benefits a total of 1,420 ha of paddy fields. The original route of the canal was modified partially in 1980. Paddy fields around the starting point of the canal have higher land elevation as well as those near the end of the canal are irrigated by means of pumps.

<u>Arrenquin Canal</u>

The Arrenquin canal (approximately 9.3 km in length-the main canal) is placed on the south of the Ponton canal and irrigates 490 ha of lands. Sources of water for this canal are same as the Ponton canal and some portion of the discharge through the Ponton canal deviates to the Arrenquin canal. The original route of this canal was also modified in 1979. Paddy fields around the end of the canal rely irrigation water on pumps because necessary water is distributed up to canal end. The major structure of this canal system is an aqueduct crossing over the Payabo river with discharge capacity of about 0.3 m^3/s.

<u>Payabo Canal</u>

This canal (approximately 5.0 km in length-the main canal) passes through southern part of the Study area for irrigating 630 ha of lands. Although this canal was designed to joint with the Guaraguao canal at the planning stage, the construction works have been suspended after completion of half of the designed length. Major source of water is the Payabo river. Without having sufficient cross section, overflow of water is frequently taken place.

<u>Guaraguao Canal</u>

Water flowing this canal (approximately 4.8 km in length-the main canal) is captured from the Guaraguao river and benefited lands by this canal reach 2,280 ha in total. Intake weir and diversion works installed at 3.2 km from the source of water are main structures of this canal system and from these structures two secondary canals are extended to the east and to the west. Structures are not working properly affected by physical deterioration, so rehabilitation works are required.

<u>La Cueva Canal</u>

Taking water from La Cueva spring this canal (approximately 2.5 km in length-the main canal) irrigates 330 ha of paddy fields through three lateral canals.

<u>Lagunita Cristal Canal</u>

This canal (approximately 3 km in length-the main canal) depends irrigation water on Lagnita Cristal. Irrigation water is supplied to 770 ha of lands through three canals.

(2) Related Structures

Major related structures of irrigation canal in the Study area are intake weir and diversion works. These facilities are concrete structure, but their physical deterioration together with inadequate O/M services has prevented rational distribution of water through canals.

(3) Constraints of the irrigation system in the Study area

The whole area of pumping irrigation in the Study area amounts to 2,470 ha or 37.0% of the total irrigated area. The fact that a lot of pumps are used for irrigation when there is sufficient water presents some relevant problems to the irrigation system as explained below:

1) Imbalance of water supply within area

Generally speaking, lands in the Study area slope down from west to east. Such irrigation blocks as Payabo, Ponton and Guaraguao located to the west of area with higher land elevation have irrigated paddy fields beyond potentials of water resource and are suffered from frequent shortage of water. Irrigation blocks of the eastern sector consists of La Cueva and Lagnita Cristal are supplied irrigation water satisfactorily.

2) Absence of necessary structures

It is observed that intake and diversion works are extremely insufficient and most of existing works are not functioning well. Under the circumstances, due to intake of major portion of discharge at upper stream of canal, paddy fields along the lower stream of canal are obliged to use pump in the face of insufficient distribution of water. On the other hand, spillway and stanching gate are not installed at Caño Ponton and Arrenquin canal, water is discharged without any control accelerating shortage of irrigation water within the area.

3) Inadequate provision of O/M services

O/M services for irrigation system are not adequately provided due to lower proportion for collection of water charge, insufficient allocation of INDRHI's budget and an absence of water users' association. In addition, major attention of O/M services is paid to excavation of canal by machinery expanding canal section larger than the optimum one. As a result of this unnecessary expansion of canal section, water level tends to lower to such level as make it infeasible to distribute water by gravity and excatated soils are forming small embankment.

I.2.3 Relation of the elevation between water sources and benefited area

The results of topographic survey on the water level at water resources are shown in **Fig. I.2.3.** These results show that it is possible to irrigate gravitationally to the whole area. For instance, as to the pumping irrigation area between the Yuna river and Cascarilla canal, the elevation of 3 to 6 m is fully lower than the water resources at Guaraguao or La Cueva.

I.3 Drainage System

Drainage network in the Study area is largely divided into two sections by the line connecting the Payabo river and the Guaraguao river just like the irrigation network. Approximate area and main drainage canal of each section are as follows:

Section	Area (km^2)	Main Drainage Canal
Western	47.7	Payabo river
Eastern	70.3	Cascarilla canal

The existing drainage system in the Study area is shown in **Fig I.3.1**.

I.3.1 Payabo river:

The Payabo river flows to the northeast from the southwest of the study area and flows out finally to Yuna river. The main tributary of the Payabo river in the Study area is only the Guaraguao. However, there are other small drainage canals which flow into the Payabo river. The Payabo river has the catchment area of about 340 km2 at the point where the river flows out to the plain from the mountain area and its average river bed slope is 1/3,000.

The river section at upstream is 4 to 5 m in width and 2 m in height and the discharge capacity is around 10 m3/s. That is, flood naturally overflows its river section. Although the river section grows larger and larger as the river shifts downstream, inundation often occurs at the area along river and the lower area between the Payabo river and the mountain. These inundation continue for 2 to 3 days and the maximum depth of inundation is about 1.0 to 1.5 meter. In this area, facilities for drainage do not exist.

I.3.2 Cascarilla Drainage Canal:

The Cascarilla canal flows from the west to the east along Yuna river and flows out to the Barracote river. Three main drainage canals; Los Caborices, El Cercado and El Vallecito flow into the Cascarilla canal. Its average canal slope is 1/2,000 and its catchment area is over 60 km2. As the canal has been excavated some times since the construction, in general, the canal has enough section for the larger runoff discharge. However, inundation often occurs at downstream of this canal.

I.3.3 Constraints of drainage system in the Study area

There are two problems on the drainage system in the Study area. The first is the inundation and the second is the ordinary drainage.

(1) Inundation

Inundation within the Study area is generally observed at upper stream zone and left margin plains of the Payabo river, at lower lands in the southern part of the area, and at the lower stream of the Cascarrilla drainage canal. left margin zone of the happens in the Study area on the upstream of Payabo river, left flat bank of Payabo river and downstream of Cascarilla canal. Among these areas, the most predominant inundation takes place at the upper stream of the Payabo river caused by small river section associated with backwater coming from the Yuna river.

(2) Poor land drainage

Lower lands at the foot of the mountain suffer from poor land drainage, which limits use of these land exclusively to grazing land.

I.3.4 Condition of the Facility

Most of the irrigation canals and the drainage canals in the Study area are unlined canals and dual-purpose canal except the main canals. Main irrigation canals are maintained comparatively better than the drainage canals. However, quickly growing weeds and sediments are reducing the capacity of the canals. And there are a lot of the eroded sections by the water dropped directly from the paddy fields, or by the provisional intake facilities installed optionally.

There are a lot of irrigation related facilities such as diversion works, division works and aqueduct, which function to some extent. However, important facilities such as the embankment of the Ponton lake are left as it is broken and almost all the facilities are too old to function well and need to be renewed.

I.4. Water Resources Development Potentials

Main water resources in the Study area are Payabo river in the western area and springs in the eastern area. In this section, the development available discharge of water resources is studied.

I.4.1 Western area

Main water resource in the western area is Payabo river. Cano Ponton, where is located at upstream of the area, reserve discharge water from Payabo river and springs at upstream of this pond. Although Cevicos river located at the west side of Cano Ponton do not flow directly into the Study area, available discharge is studied.

a. Payabo River

The Payabo River is principal water source that supplies irrigation water to the Study area. The low flow with the return period 1/5 for 24-year observation period 1971-1994 is calculated to be Q = 1.05 m^3/s and multiplying this low flow by the monthly minimum discharge, an available discharge of the Payabo river is obtained as given in the following table.

Unit: m^3/s

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
A.M.D.	2.36	2.07	1.70	1.58	2.46	3.96	3.83	4.22	4.56	4.43	3.78	2.96
L.F.	1.60	1.37	1.13	1.05	1.61	2.65	2.57	2.81	3.05	3.01	2.57	1.97

Note: A.M.D. - Average Minimum Discharge, L.F. - Low Flow

b. Springs at Cano Ponton and Cevicos river

Spring discharge at Cano Ponton and discharge of Cevicos river were calculated with hydrometry survey and its analysis. These available irrigation water becomes to the lowest level in April and discharge in April are as follows:

Cano Ponton: 0.500 m3/s; (See **Table I.4.1**)
Cevicos river: 0.600 m3/s

c. Total water source in the western section

Water sources of Cano Ponton and Cevicos river are springs same as the El Guaraguao. Therefore, other monthly discharge of Cano Ponton and Cevicos river is calculated with the comparison between the discharge of the El Guaraguao. Monthly discharge of water sources in the western area is shown as follows:

Unit: m^3/s

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Payabo	1.600	1.370	1.130	1.050	1.610	2.650	2.570	2.810	3.050	3.010	2.570	1.970
Ponton	0.636	0.513	0.470	0.500	0.750	1.051	0.910	0.937	0.812	0.728	0.816	0.783
Cevicos	0.764	0.615	0.563	0.600	0.900	1.261	1.092	1.124	0.975	0.873	0.980	0.939
Total	3.000	2.498	2.163	2.150	3.260	4.962	4.572	4.871	4.837	4.611	4.366	3.692

I.4.2 Eastern area

Water source in the eastern area is springs mainly. Principal springs are El Guaraguao, Lagunita Cristal and La Cueva. The most complete data regarding spring discharge within the Study area coincide with the El. Guaraguao where a total of 110 pieces of record observed for the period of 1975-94 are available, although they are not daily data but are of specific date/period. Other springs have fewer observation records. These existing data give information on seasonal variation of spring discharge, but not available discharge to be used for irrigation purpose is very hard. Facing with this difficulty, the available spring discharge to be taken for irrigation purpose has been calculated processing spring data of the El Guaraguao and rainfall data of the Barraquito station by multiple regressive analysis method.

a. Spring discharge at El. Guaraguao

Guaraguao spring has two canals of main canal I and secondary canal II as irrigation canal. The multiple regressive analysis is calculated with using actual discharge of Canal. General formula is as follows:

$$Y = a + b_1 * X_1 + b_2 * X_2 + b_3 * X_3 + \text{-----} + b_n * X_n \quad \text{-----------} \quad \text{(Formula 4.2.1)}$$

where, Y: Guaraguao spring discharge (Canal I) (m^3/s)
a, b_n: coefficient
X_n: Barraquito rainfall (mm)

Through trial and error with respect to X_n the following formula was presented as technically reliable and highly correlated one. (Correlated coefficient: 0.78)

$$Y = 0.7756 + 0.0028*X_1 + 0.0074*X_2 + 0.0035*X_3 + 0.0014*X_4 + 0.0040*X_5 + 0.0024*X_6 + 0.0062*X_7 + 0.0071*X_8 + 0.0038*X_9 + 0..0066*X_{10}$$ (Formula 4.2.2)

Input data and the result of calculation of this formula are shown in **Table I.4.2**, **Table I.4.3** and **Fig I.4.1**.

In accordance with the following steps, the volume of spring discharge has been estimated subject to the return period 1/5.

i) To calculate rainfall at the Barraquito station subject to the return period 1/5 (R=1,773mm; See **Table I.4.4**)

ii) To select a year which is featured by the representative rainfall pattern among 19 years (the selected year: 1983, R = 2,136.7 mm, Correlated coefficient: 0.906)

iii) To convert the rainfall of the year 1983 into that of the return period 1/5

iv) To fix the amount of rainfall calculated in above item iii) into the Formula 4.2.2 to get the volume of the spring discharge of Canal I(See **Table I.4.5**).

v) To calculate total discharge of Guaraguao with the comparison of actual discharge between Canal I and Canal II
(Discharge of Canal I+Canal II / Discharge of Canal I = 1.213; See Table **I.4.6**)

The volume of the spring water calculated above is as given below.

Unit: m^3/s

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Canal I	1.464	1.179	1.080	1.150	1.726	2.417	2.094	2.154	1.869	1.674	1.878	1.800
Canal II	0.312	0.251	0.230	0.245	0.368	0.515	0.446	0.459	0.398	0.357	0.400	0.383
Total	1.776	1.430	1.310	1.395	2.094	2.932	2.540	2.613	2.267	2.031	2.278	2.183

b. Monthly discharge in other springs

There are 5 principal springs of Guaraguao, La Cueva, Lagunita Cristal, El Celcado and Laguna Cristal in the eastern area.
Data of hydrometry survey of other springs except Guaraguao are shortage and it is difficult to calculate monthly available discharge with these data. Therefore, monthly discharge of these springs was calculated with the comparison between Guaraguao spring discharge. The result of calculation is as follows:

Unit: m^3/s

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
La Cueva	0.519	0.418	0.383	0.407	0.611	0.856	0.742	0.763	0.662	0.593	0.665	0.638
Lagunita	1.341	1.080	0.989	1.053	1.581	2.214	1.918	1.973	1.712	1.533	1.720	1.648
Laguna	0.584	0.471	0.431	0.459	0.689	0.965	0.836	0.860	0.746	0.668	0.749	0.718
Cercado	0.838	0.675	0.618	0.658	0.988	1.384	1.199	1.233	1.070	0.958	1.075	1.031

Note: The detailed data of comparison between Guaraguao and other springs is shown in **Table I.4.7**.

I.4.3 Other Water Resources

In the dry season, constant shortage of irrigation water is foreseen, so development of new water resources would be essential to offset the shortage.

New Water resources will be as follows:

a. Return flow

Farmlands located between the Yuna River and the Cascarrilla canal are actually irrigated pumping water from the Yuna river. For these farmlands, diversion of water from the Guaraguao spring is the most economical proposal, but water volume of the spring is not sufficient enough to supply water to farmlands in question. Therefore, follows way will be used.

- To distribute the return flow drained to the Payabo River; to realize this proposal by gravity it is required to elevate intake point of the dam.

- To plot an irrigation canal network for each small farmland bloke in view of making use of the return flow and saving water for irrigation.

b. Construction of a reservoir

There is a suitable spot at the confluence of Laguna Guaraguao and the Payabo river for construction of a reservoir. The construction of a reservoir pretend to store excess water of Laguna Guaraguao at the time of high water period or at the time when less irrigation water is distributed to paddy fields, and to discharge stored water in the dry season. The relation among irrigable area, storage volume and reservoir area is given in the following table. Reservoir with water level higher than 13 meters is not technically recommended.

Irrigable area (ha)	300	400	500	600	700	800
Storage volume (m^3 x 000)	1,344	1,880	2,417	2,950	3,660	4,400
Water level (m)	10.9	11.3	11.6	12.0	12.5	12.9
Reservoir area (ha)	120	140	145	152	160	170

Relationship between new irrigation area and required storage water is shown in **Table I.4.8.** Relationship between water level and active storage is shown in **Fig I.4.2.**

c. Control for unnecessary discharge of water

This plan pretends to use unnecessary discharge of the Cevisco River which comes from the Ponton spring and flows into the Yuna river for irrigating farmlands within the Study area.

I.5. Water Intake Plan

As explained in I.4. Development Potentials of the Water Resources, the following water resources can be used as sources of irrigation water.

Water Resource	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1. Wetern Sector	3.000	2.498	2.163	2.150	3.260	4.962	4.572	4.871	4.837	4.611	4.366	3.692
- Payabo River	1.600	1.370	1.130	1.050	1.610	2.650	2.570	2.810	3.050	3.010	2.570	1.970
- Cano Ponton	0.636	0.513	0.470	0.500	0.750	1.051	0.910	0.937	0.812	0.728	0.816	0.783
- Cevicos River	0.764	0.615	0.563	0.600	0.900	1.261	1.092	1.124	0.975	0.873	0.980	0.939
2. Easter Sector	5.058	4.074	3.731	3.972	5.963	8.351	7.235	7.442	6.457	5.783	6.487	6.218
- Guaraguao	1.776	1.430	1.310	1.395	2.094	2.932	2.540	2.613	2.267	2.031	2.278	2.183
- La Cueva	0.519	0.418	0.383	0.407	0.611	0.856	0.742	0.763	0.662	0.593	0.665	0.638
- Lagnita Cristal	1.341	1.080	0.989	1.053	1.581	2.214	1.918	1.973	1.712	1.533	1.720	1.648
- Laguna Cristal	0.584	0.471	0.431	0.459	0.689	0.965	0.836	0.860	0.746	0.668	0.749	0.718
- El Cercado	0.838	0.675	0.618	0.658	0.988	1.384	1.199	1.233	1.070	0.958	1.075	1.031

In addition, the following water resources may be taken to use for irrigation purpose.

1. Reservoir: About 800 ha of land will be irrigated with the maximum storage volume of 4 million m^3

2. Yuna River: A maximum of 2 m^3/s of water is available

3. Return flow: Reuse of discharged water into drainage canals

The total amount of available water to be taken form the above sources is not abundant on average, so the irrigation planning will be formulated taken the whole resources cited above into account.

I.6. Irrigation Plan

I.6.1 Meteorological data

The meteorological data used for irrigation planning are those recorded at the Barraquito station, where liable meteorological data such as temperature, humidity, wind velocity, amount of cloud are compiled. Data collected for the period 1975-92 were processed for this purpose.

I.6.2 Cropping calendar

The cropping calendar proposed in the Crop Production and Farming System Plan is as follows:

Farming Work	1st Cropping	2nd Cropping
Seeding on nursery bed	Early Dec. - Mid Jan	Early Jun - Mid Jul
Farming Works	Early Jan - Mid Feb	Early Jul - Mid Aug
Harvesting	Early May - End Jun	End Oct - Mid Dec

I.6.3 Unit water requirement

(1) Applied criterion

FAO's "guideline for predicting crop water requirements" was refered for the calculation.

The unit water requirement is calculated using the following formula:

UWR = {Eto x kc + WRLP + DP - ER} x IR

where: Eto = reference crop evapotranspiration
kc = crop coefficient
WRLP = water requirement L.P.
DP = deep percolation
ER = effective rainfall
IR = irrigation efficiency

(2) Reference Crop Evapotranspiration

Reference crop Evapotranspiration was computed with applying the Penman Method.

Eto = c x [W x Rn + (1-W) x f(u) x (ea-ed)

where, Eto: Reference crop evapotranspiration (mm/day)
W: Temperature-related weighting factor
Rn: Net radiation in equivalent evaporation (mm/day)
f(u): Wind-related function
(ea-ed): Difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in mbar
c: Adjustment factor to compensate for the effect of day and night weather condition

The calculation of Eto is summarized in **Table I.6.1**.

(3) Effective rainfall

The effective rainfall was estimated processing rainfall data with the return period 1/5 of the Barraquito station. (See **Table I.4.4**)

(4) Irrigation Efficiency

Irrigation efficiency employed to predict the unit water requirement was calculate as follows:

E = Ec x Eb x Ea = 0.9 x 0.8 x 0.8 = 0.58

where, E: Irrigation Efficiency
Ec: Conveyance efficiency = 0.9
Eb: Field canal efficiency = 0.8
Ea: Field application efficiency = 0.8

(5) Water requirement for land preparation and nursery

Water requirements for land preparation and nursery are calculated to be 100 mm for both first and second harvests.

(6) Unit water requirement

The calculation of unit water requirement is shown in **Table I.6.2**.

The peak unit water requirement falls on April, while less water is required for three months from November to January.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Unit Water Requirement	0.402	0.746	0.942	1.061	0.743	0.420	0.512	0.953	0.908	0.688	0.311	0.244

I.6.4 Irrigation network

(1) Basic concept on planning canal system

a. Minimum block

The minimum block for convenience of operation and maintenance of irrigation water is established as around 40 ha (400 m x 1,000 m). This block corresponds to the tertiary unit, in which the "Nucleos de Regantes" formed by 10 or so water users will take charge of operation and maintenance of related gate.

b. Canal system for operation and maintenance (O/M)

Irrigation water is to be distributed to paddy fields in the order of: main canals, secondary canal and tertiary canals, thus irrigation system to deviate water directly from main canals or secondary canals to paddy fields is avoided. Diversion works equipped with water gate which regulates distribution of water will be installed at the crossing part of canals so that the minimum unit of the water users' association (Junta de Regantes) might be in charge of the tertiary gates.

(2) Irrigation block

Taking into consideration of the actual irrigation network as well as available water resources, the irrigation network for the project is proposed as illustrated in **Fig. I.6.1** and **Fig. I.6.2**. This proposed irrigation network is summarized in the table below.

2-1) Alternative Plan A (See Fig 1.6.1)

Irrigable Blocks	Source of Water	Irrigable Area (ha)		Intake Volume (m3/s)	Available Return flow (m3/s)
		Total	Return Flow		
Payabo	Payabo River	730	59	0.712	0.170
Ponton	Payabo River Cevicos River Springs	1630	275	1.438	0.227
Guaraguao-1	Springs	1632	327	1.385	0.227
Guaraguao-2	Reservoir	258	-	0.274	0.082
La Cueva	Springs	380	-	0.403	
El Cercado	Springs	270	-	0.286	
Lagnita Cristal	Springs	880	-	0.934	
Borojol	Return flow Reservoir	870	870	-	0.923
Total		6650	1531	5.432	1.629

a. Payabo block

A headworks will be installed at the Payabo river to take 1.05 m^3/s of water; of which 0.719 m^3/s will be distributed to the Payabo block and the remaining 0.331 m^3/s will de deviated to the Ponton block. Irrigation water through the main canal will flow to the east along the Los Haitises to benefit 730 ha of paddy fields located up to the confluence with the Guaraguao canal. Drained water from this block can be used to irrigate the Borojol block.

b. Ponton block

Irrigation water to this block will be taken from the Payabo river (0.331 m^3/s), the Cevicos river (0.60 m^3/s), and springs (0.50 m^3/s). Some paddy fields (82 ha) situated at higher land elevation will be irrigated by pumping to comply with their actual situation. Water taken from the Caño Ponton will be regulated by the gate to be installed at the intake point of the Ponton Canal. Irrigation water to flow this Ponton Canal will be diverted to the Arrenquin Canal at 2.5 km downstream from the start of the Ponton Canal. Drained water from this block will irrigate the Borojol block.

Some sections within this block are unable to be irrigated by gravity, which enforces to employ pumping system. These sections are:

Section A: 51 ha (0.054 m^3/s)
Section B: 127 ha (0.135 m^3/s)

c. Guaraguao block-1

The Guaraguao Spring offers the most abundant water resource within the Study area, so irrigable area by this spring can be extended to the paddy fields near the Yuna river, which are located to the opposite side of the spring. The main canal will be placed along the river bank which constitutes the western limit of the Study area.

d. Guaraguao block-2

Although the Guaraguao has an abundant available water to irrigate 1,890 ha of paddy fields, some of these paddy fields are not benefited by water of the spring in March and April if they are planted paddy twice a year. For breaking this bottleneck, it is proposed to construct a reservoir and to arrange the existing irrigation block.

To irrigate 600 ha of paddy fields consist of 258 ha in the Guaraguao block and 342 ha in the Borojol block, a total of 290 million m^3 of water (110 m^3 for the Guaraguao block and 180 m^3 for the Borojol block) should be stored at the reservoir, and to attain this storage the effective minimum and the maximum water levels of the reservoir are designed to be each 9 m.a.s.l. and 12 m.a.s.l. Irrigation water will be supplied from the reservoir through the canal designed exclusively for this system.

e. La Cueva block and El Cercado block

Spring water taken from La Cueva and El Cercado will be used to compensate shortage of irrigation water at the Guaraguao block-1. Due to lower water level, water of the El Cercado Spring has not been used for irrigation purpose up to date; in this irrigation planning it is proposed to distribute this water to the paddy fields located to lands with lower elevation.

f. Lagunita Cristal block

This block corresponds to the irrigable area from the Lagunita Cristal. Lagunita Cristal has such sufficient water resource as to benefit irrigable area of this block without relying on other sources, so this block will be the same as the actual situation.

g. Borojol block

For rational use of irrigation water, this block is divided into two sub-blocks; one is a sub-block which is to be benefited by taking drained water from the Payabo and Ponton blocks by means of the headworks to be installed at the Payabo river and complementing is with water distributed from the reservoir and the other sub-block will be irrigated by return water discharged in the Cascarrilla Canal. The main canal will be placed along the Yuna river.

2-2) Alternative Plan B (See Fig 1.6.2)

Irrigation Blocks	Source of Water	Irrigable Area (ha)		Intake Volume (m3/s)	Available Return flow (m3/s)
		Total	Return Flow		
Payabo	Payabo River Springs	1180	60	1.188	0.064
Ponton	Yuna River Cevicos River	1890	287	1.702	0.304
Guaraguao	Springs Yuna River	2350	336	2.137	0.356
La Cueva	Springs	380	-	0.403	
El Cercado	Springs	270	-	0.286	
Lagnita Cristal	Springs	880	-	0.934	
Borojol	Return flow Yuna River	910	768	-	0.966
Total		7860	1451	6.650	1.690

The Alternative A envisages the following aspects which are different from the alternative A.

a. Intake of water from the Yuna river by means of pumping system is considered. Irrigable area and intake volume proposed for this pumping system are:

Blocks	Irrigable Area (ha)	Intake Volume (m^3/s)
Ponton	697	0.740
Guaraguao	709	0.752
Borojol	142	0.151
Total	1,548	1.643

b. Construction of a reservoir is not included; this alternative pretends to cover proposed land for this infrastructure into paddy field (approximately ha).

c. Diversion of spring water flowing into Caño Ponton to the Payabo block is proposed.

I.6.5 Irrigation Canal

Irrigation canal is divided in 3 routes of main irrigation canal, second irrigation canal and tertiary irrigation canal. These canals are also proposed with two construction style as follows:

New construction: Canal proposed in new route
Rehabilitation: Canal reconstructed existing canal

Total length of canal are as follows:

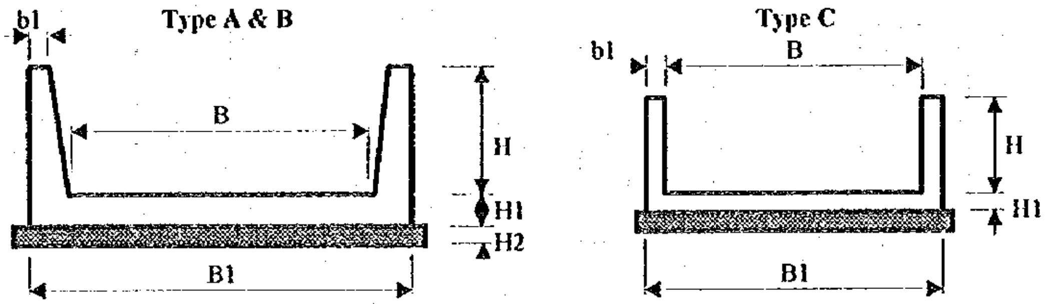
Unit: m

Canal	Alternative: A			Alternative: B		
	New Const.	Rehabili.	Total	New Const.	Rehabili.	Total
Main	63,080	31,510	94,590	67,020	32,190	99,210
Secondary	60,500	8,360	68,860	63,280	7,200	70,480
Tertiary	183,570	33,660	217,230	226,730	33,870	260,600
Total	307,150	73,530	380,680	357,030	73,260	430,290

(1) Canal Section

a. Main Irrigation canal

In relation to the section of main irrigation canals, concrete lining structure is proposed. Structure of canal are divided in 3 types under design discharge as below.



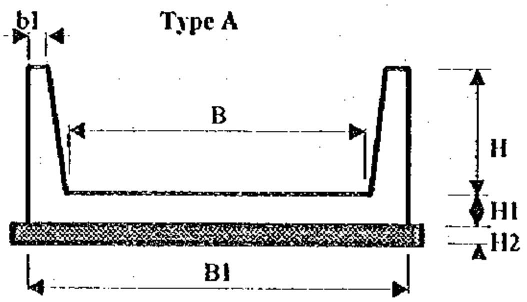
Length and dimension of each type are presented as follows:

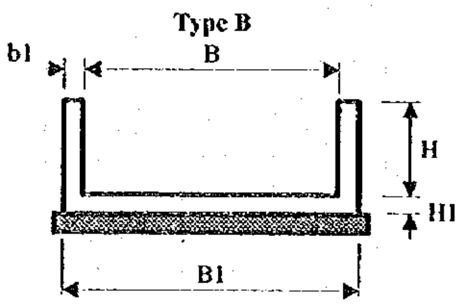
Alternative: A									
New Construction					Rehabilitation				
Type	B (m)	H (m)	H1 (m)	Length (m)	Type	B (m)	H (m)	H1 (m)	Length (m)
MC-A-1	3.00	1.10	0.20	-	MC-A-1	3.00	1.10	0.20	2,560
MC-A-2	2.50	1.05	0.20	7,280	MC-A-2	2.50	1.05	0.20	1,860
MC-A-3	2.25	1.00	0.20	-	MC-A-3	2.25	1.00	0.20	3,240
MC-A-4	2.00	1.00	0.20	4,000	MC-A-4	2.00	1.00	0.20	-
MC-A-5	1.75	1.00	0.20	990	MC-A-5	1.75	1.00	0.20	-
MC-A-6	1.50	1.00	0.20	1,030	MC-A-6	1.50	1.00	0.20	1,780
MC-A-7	1.25	1.00	0.20	7,150	MC-A-7	1.25	1.00	0.20	6,910
MC-A-8	1.00	1.00	0.20	5,350	MC-A-8	1.00	1.00	0.20	1,650
MC-B-1	1.50	0.65	0.15	2,520	MC-B-1	1.50	0.65	0.15	960
MC-B-2	1.25	0.70	0.15	4,610	MC-B-2	1.25	0.70	0.15	3,170
MC-B-3	1.00	0.70	0.15	7,850	MC-B-3	1.00	0.70	0.15	1,060
MC-B-4	0.75	0.70	0.15	11,270	MC-B-4	0.75	0.70	0.15	5,330
MC-B-5	0.50	0.70	0.15	5,150	MC-B-5	0.50	0.70	0.15	1,080
MC-C-1	1.00	0.45	0.15	-	MC-C-1	1.00	0.45	0.15	690
MC-C-2	0.75	0.45	0.15	1,280	MC-C-2	0.75	0.45	0.15	1,220
MC-C-3	0.50	0.45	0.15	4,600	MC-C-3	0.50	0.45	0.15	-
Total				63,080	Total				31,510

Alternative: B									
New Construction					Rehabilitation				
Type	B (m)	H (m)	H1 (m)	Length (m)	Type	B (m)	H (m)	H1 (m)	Length (m)
MC-A-1	4.25	1.00	0.20	-	MC-A-1	4.25	1.00	0.20	2,560
MC-A-2	3.00	1.10	0.20	1,380	MC-A-2	3.00	1.10	0.20	810
MC-A-3	2.50	1.05	0.20	7,260	MC-A-3	2.50	1.05	0.20	3,240
MC-A-4	2.25	1.00	0.20	-	MC-A-4	2.25	1.00	0.20	-
MC-A-5	2.00	1.00	0.20	4,830	MC-A-5	2.00	1.00	0.20	6,940
MC-A-6	1.75	1.00	0.20	610	MC-A-6	1.75	1.00	0.20	200
MC-A-7	1.50	1.00	0.20	3,760	MC-A-7	1.50	1.00	0.20	1,780
MC-A-8	1.25	1.00	0.20	8,200	MC-A-8	1.25	1.00	0.20	2,910
MC-A-9	1.00	1.00	0.20	2,350	MC-A-9	1.00	1.00	0.20	730
MC-B-1	1.50	0.65	0.15	3,620	MC-B-1	1.50	0.65	0.15	2,940
MC-B-2	1.25	0.70	0.15	10,470	MC-B-2	1.25	0.70	0.15	660
MC-B-3	1.00	0.70	0.15	4,780	MC-B-3	1.00	0.70	0.15	150
MC-B-4	0.75	0.70	0.15	5,680	MC-B-4	0.75	0.70	0.15	4,950
MC-B-5	0.50	0.70	0.15	3,810	MC-B-5	0.50	0.70	0.15	1,630
MC-C-1	1.00	0.45	0.15	2,890	MC-C-1	1.00	0.45	0.15	330
MC-C-2	0.75	0.45	0.15	2,500	MC-C-2	0.75	0.45	0.15	2,010
MC-C-3	0.50	0.45	0.15	4,880	MC-C-3	0.50	0.45	0.15	350
Total				67,020	Total				32,190

b. Secondary irrigation canal

In relation to the section of secondary irrigation canals, concrete lining structure is proposed. Structure of canal are divided in 2 types under design discharge as below.





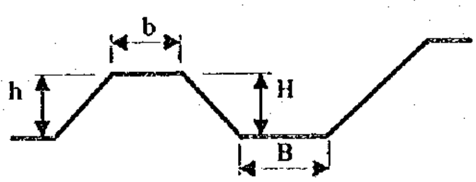
Length and dimension of each type are presented as follows

Alternative: A									
New Construction					Rehabilitation				
Type	B (m)	H (m)	Hl (m)	Length (m)	Type	B (m)	H (m)	Hl (m)	Length (m)
SC-A-1	0.75	0.70	0.15	900	SC-A-1	0.75	0.70	0.15	-
SC-A-2	0.75	0.65	0.15	1,770	SC-A-2	0.75	0.65	0.15	-
SC-A-3	0.50	0.70	0.15	450	SC-A-3	0.50	0.70	0.15	-
SC-A-4	0.50	0.65	0.15	510	SC-A-4	0.50	0.65	0.15	990
SC-B-1	0.90	0.45	0.15	1,350	SC-B-1	0.90	0.45	0.15	810
SC-B-2	0.80	0.45	0.15	1,350	SC-B-2	0.80	0.45	0.15	-
SC-B-3	0.70	0.45	0.15	4,950	SC-B-3	0.70	0.45	0.15	2,000
SC-B-4	0.60	0.45	0.15	4,570	SC-B-4	0.60	0.45	0.15	580
SC-B-5	0.50	0.45	0.15	14,990	SC-B-5	0.50	0.45	0.15	1,470
SC-B-6	0.40	0.45	0.15	16,540	SC-B-6	0.40	0.45	0.15	2,140
SC-B-7	0.30	0.45	0.15	13,120	SC-B-7	0.30	0.45	0.15	370
Total				60,500	Total				8,360

Alternative: B									
New Construction					Rehabilitation				
Type	B (m)	H (m)	Hl (m)	Length (m)	Type	B (m)	H (m)	Hl (m)	Length (m)
SC-A-1	1.50	0.65	0.15	450	SC-A-1	1.50	0.65	0.15	-
SC-A-2	1.25	0.65	0.15	900	SC-A-2	1.25	0.65	0.15	-
SC-A-3	1.00	0.65	0.15	10	SC-A-3	1.00	0.65	0.15	-
SC-A-4	1.00	0.70	0.15	630	SC-A-4	1.00	0.70	0.15	810
SC-A-5	0.75	0.70	0.15	2,450	SC-A-5	0.75	0.70	0.15	-
SC-A-6	0.75	0.65	0.15	1,710	SC-A-6	0.75	0.65	0.15	-
SC-A-7	0.50	0.70	0.15	3,080	SC-A-7	0.50	0.70	0.15	-
SC-A-8	0.50	0.65	0.15	510	SC-A-8	0.50	0.65	0.15	990
SC-B-1	0.90	0.45	0.15	430	SC-B-1	0.90	0.45	0.15	-
SC-B-2	0.80	0.45	0.15	1,350	SC-B-2	0.80	0.45	0.15	-
SC-B-3	0.70	0.45	0.15	5,040	SC-B-3	0.70	0.45	0.15	-
SC-B-4	0.60	0.45	0.15	3,710	SC-B-4	0.60	0.45	0.15	900
SC-B-5	0.50	0.45	0.15	10,570	SC-B-5	0.50	0.45	0.15	1,800
SC-B-6	0.40	0.45	0.15	24,750	SC-B-6	0.40	0.45	0.15	2,240
SC-B-7	0.30	0.45	0.15	7,690	SC-B-7	0.30	0.45	0.15	460
Total				63,280	Total				7,200

c. Tertiary irrigation canal

In relation to the section of tertiary irrigation canals, unlined canal structure is proposed. Structure of canal are proposed under to design discharge as below.



Type	b(m)	h(m)	B(m)	H(m)
TC-1	0.30	0.30	0.30	0.30
TC-2	0.30	0.30	0.40	0.30
TC-3	0.30	0.30	0.50	0.30

(2) Hydraulic calculation

Manning formula was applied to calculate the canal velocity as follows:

$V = 1/n \times R^{2/3} \times I^{1/2}$ (m/sec)

$Q = A \times V$ (m/sec)

where, V: mean velocity (m/sec)
n: coefficient of roughness
concrete lining canal: n= 0.015
nonlining canal: n= 0.035
R: hydraulic mean depth (m)
A: cross sectional area of flow (m2)
P: wetted perimeter (m)
I: hydraulic gradient
Q: discharge (m3/s)

I.7 Drainage Plan

The great majority of excess water within the Study area is drained into the Payabo river and the Cascarrilla Canal. These two systems function as a main drainage canal which connects with the remainder of the drainage systems within the Study area. Improvement proposal on the Payabo river and the Cascarrilla Canal will be discussed in the "Flood Mitigation Plan".

The submergence analysis quoted in the section I.2.2 and I.2.3 of this report has disclosed that even intensive rainfall is taken place no serious damage would be brought about over agricultural production due to flooding of paddy fields. This means that flooding caused by intensive rainfall is within limit of allowable submergence. Nevertheless, in view of the fact that some drainage systems pass through populated area, the drainage canals will be designed with a cross-section which enables to drain 24-hour-rainfall within 24 hours under 5-year-return period.

I.7.1 Drainage network

The principle of drainage planning is to drain excess water to the main drainage canal after passing through small and secondary drainage canals. The existing main drainage system which connect with the Payabo river and the Cascarrilla canal will be improved to function adequately as secondary canal system and, to complete the drainage network throughout the development area, small drainage system will be jointed with these secondary system. On the other hand, a drainage system which makes it possible to function drainage of excess water constantly will be provided at poor drainage lands located at the foot of the Los Haitises National Park.

Drainage canal is divided in 3 routes of main canal, secondary canal and tertiary canal. These canals are also proposed with two construction style as follows:

New construction: Canal proposed in new route

Rehabilitation: Canal reconstructed existing canal

Total length of canal are as follows:

Unit: m

Canal	Alternative: A			Alternative: B		
	New Const.	Rehabili.	Total	New Const.	Rehabili.	Total
Main	5,090	3,850	8,940	6,310	3,850	10,160
Secondary	60,320	11,640	71,960	67,350	11,340	78,690
Tertiary	148,330	32,480	180,810	188,760	26,720	215,480
Total	213,740	47,970	261,710	262,420	41,910	304,330

I.7.2 Canal section

(1) Hydraulic calculation

The design runoff is predicted according with the following formula:

$$Q = f \times R \times A/3.6$$

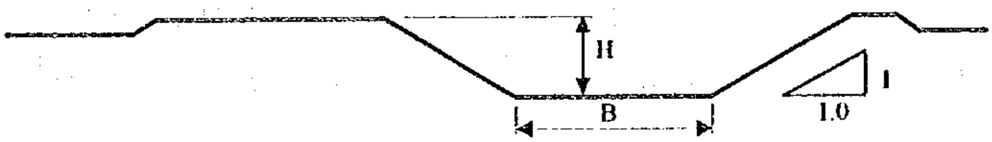
where, Q = design runoff (m^3/s)
f = runoff coefficient (0.75)
R = average rainfall intensity (5.57 mm/hr., 133.7 mm/day)
A = catchment area (km^2)

The catchment area of the secondary drainage canal system is estimated to be around 6 km^2, so the relation between the catchment area and the design runoff becomes as shown below.

Catchment area (km^2)	1	2	3	4	5	6
Design runoff (m^3/s)	1.2	2.3	3.5	4.6	5.8	7.0

(2) Canal section

In relation to the section of drainage canal, unlining canal structure is applied.
Structure of canal are proposed under design discharge as below.



Alternative:A

	Type	Dimension		Length L(m)		
		B (m)	H (m)	New Const.	Rehabili.	Total
Main Canal	MC-1	10.00	2.00	1,270	2,650	3,920
	MC-2	5.00	2.00	2,540	1,200	3,740
	MC-3	3.00	2.00	1,280	-	1,280
	MC-4	1.50	2.00	-	-	-
	MC-5	0.50	2.00	-	-	-
	Sub-total	20.00		5,090	3,850	8,940
Secondary Canal	SC-1	3.00	1.50	3,960	530	4,490
	SC-2	1.50	1.50	1,030	900	1,930
	SC-3	1.00	1.50	2,880	-	2,880
	SC-4	0.50	1.50	52,450	10,210	62,660
	Sub-total			60,320	11,640	71,960
Tertiary Canal	TC-1	4.00	1.00	-	2,000	2,000
	TC-2	2.50	1.00	3,100	6,570	9,670
	TC-3	2.00	1.00	2,760	1,000	3,760
	TC-4	1.50	1.00	12,430	5,880	18,310
	TC-5	1.00	1.00	21,050	4,860	25,910
	TC-6	0.50	1.00	108,990	12,170	121,160
	Sub-total			148,330	32,480	180,810
Total				213,740	47,970	261,710

Alternative:B

	Type	Dimension		Length L(m)		
		B (m)	H (m)	New Const.	Rehabili.	Total
Main Canal	MC-1	10.00	2.00	1,270	2,650	3,920
	MC-2	5.00	2.00	3,760	1,200	4,960
	MC-3	3.00	2.00	1,280	-	1,280
	MC-4	1.50	2.00	-	-	-
	MC-5	0.50	2.00	-	-	-
	Sub-total	20.00		6,310	3,850	10,160
Secondary Canal	SC-1	3.00	1.50	9,820	530	10,350
	SC-2	1.50	1.50	7,790	1,930	9,720
	SC-3	1.00	1.50	45,190	4,880	50,070
	SC-4	0.50	1.50	4,550	4,000	8,550
	Sub-total			67,350	11,340	78,690
Tertiary Canal	TC-1	4.00	1.00	2,970	1,490	4,460
	TC-2	2.50	1.00	-	1,930	1,930
	TC-3	2.00	1.00	10,870	1,330	12,200
	TC-4	1.50	1.00	8,910	5,730	14,640
	TC-5	1.00	1.00	34,590	5,010	39,600
	TC-6	0.50	1.00	131,420	11,230	142,650
	Sub-total			188,760	26,720	215,480
Total				262,420	41,910	304,330

ANNEX I :TABLES

[illegible]

Table I.4.1 Hydrometry of Spring Water at Cano PONTON

Observation (1) / Date; Feb 7, 1995

	Location	Discharge Area A (m2)	Mean Velocity V (m/s)	Discharge (m3/s)	Total (Qin,Qo) (m3/s)	Qx = Qo-Qin (m3/s)
Qin	Payabo River	5.503	0.202	1.112	1.112	0.641
Qo1	Canal A	0.000	0.000	0.000	1.753	
Qo2	Arrenquin Canal	1.128	0.272	0.307		
Qo3	Arrenquin Canal	1.817	0.482	0.875		
Qo4	Ponton Canal	1.927	0.296	0.570		
Qo5	Canal B	*	*	0.001		

Observation (2) / Date; Feb 17, 1995

	Location	Discharge Area A (m2)	Mean Velocity V (m/s)	Discharge (m3/s)	Total (Qin,Qo) (m3/s)	Qx = Qo-Qin (m3/s)
Qin	Payabo River	6.175	0.164	1.015	1.015	0.164
Qo1	Canal A				1.179	
Qo2	Arrenquin Canal	0.414	0.297	0.123		
Qo3	Arrenquin Canal	0.637	0.474	0.302		
	Pump	0.260	0.169	0.044		
Qo4	Ponton Canal	2.400	0.296	0.710		
Qo5	Canal B	*	*	0.000		

Observation (3) /Date; Feb 28, 1995

	Location	Discharge Area A (m2)	Mean Velocity V (m/s)	Discharge (m3/s)	Total (Qin,Qo) (m3/s)	Qx = Qo-Qin (m3/s)
Qin	Payabo River	6.364	0.188	1.195	1.195	1.145
Qo1	Canal A				2.340	
Qo2	Arrenquin Canal	0.769	0.384	0.295		
Qo3	Arrenquin Canal	2.313	0.510	1.179		
Qo4	Ponton Canal	3.007	0.288	0.866		
Qo5	Canal B	*	*	0.000		

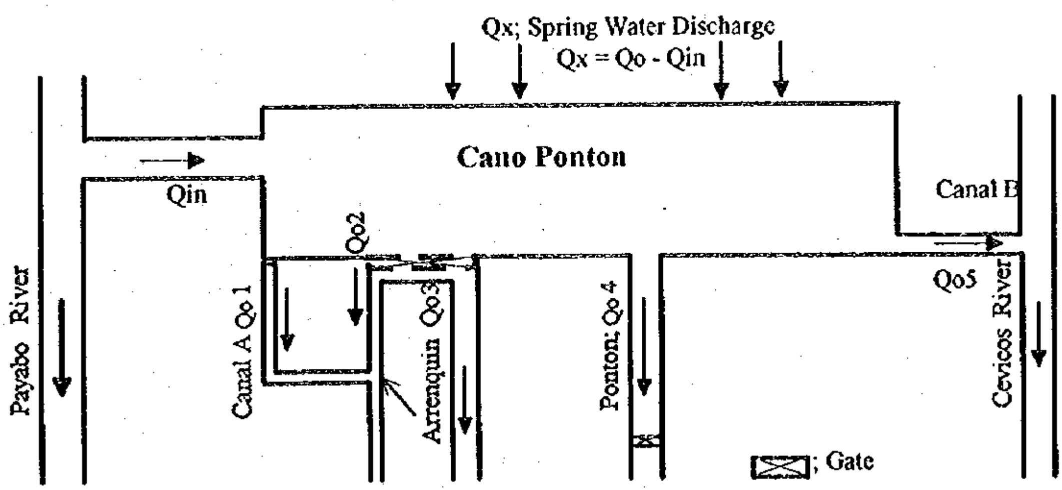


Table I.4.2 The Calculation of Multiple Regression Equation (Input Data: 1/2)

Unit: mm

Year	Month	Date	Guaraguao Discharge Q (m3/s)	Daily Rainfall at Barraquito Station X1 1 days	X2 3 days	X3 3 days	X4 5 days	X5 5 days	X6 5 days	X7 5 days	X8 5 days	X9 5 days	X10 5 days
1977	Jan	7	1.163	0	3.1	0	1	5.4	0	5.2	28.7	38.7	50.6
	Feb	9	0.874	10	2.8	0	0	0.1	18.6	3.3	0.7	3.1	0
	Mar	4	0.823	7	1.5	0.5	0	6.3	0	13.1	0	0	18.3
	Apr	6	0.884	13	0.7	0	6.8	1.1	0	0.8	11.7	19.7	0.5
	Jun	10	1.261	0	0	9.8	0	54.8	65.1	83.1	0	0	12.4
	Jul	8	1.217	10.9	2.7	68.5	29	14.9	10.9	8	0	9.8	11
	Aug	5	1.191	8.8	26.9	18.1	141.5	0	18.5	31.1	14.3	81.9	27.3
	Sep	7	1.945	1.1	1.2	43.7	15	97	16.2	63.8	17.7	73.8	128.1
	Nov	15	1.874	1.1	10.2	4.3	13.2	84.3	27.8	6.2	8.2	62.8	65.4
1978	Jan	17	2.397	6	0	0	1.9	3.5	212.6	8.7	4.1	47.3	11.6
	Feb	7	2.238	27.6	3.2	7.1	106.2	3.9	6.7	0	1.9	2.9	213.2
	Mar	6	1.869	19.5	0.8	1.1	2.4	0	0	29.9	31.5	93.5	22.8
	Jun	14	3.015	0.6	40	3.4	6.4	12.8	81.3	114.9	10.6	21.2	42.6
	Jul	13	2.86	1.2	18.1	1.8	60.7	65.1	18.7	8.5	27.6	16.8	8.5
	Oct	24	1.909	26.5	1.9	0	24.1	4.5	0	43.7	114.8	52.5	1.1
	Nov	25	2.763	19.5	2.7	40.1	13.2	1.1	7	6.4	29	28.4	6.4
	Dec	19	1.513	13.9	0	0	0	50.8	71.7	22.2	40.1	14.1	0.2
1979	Jan	12	1.502	1.5	4.1	60.2	16.7	0	0.5	23	0	0	52.2
	Feb	10	1.266	0	0	0	0	0	0	21.6	5.2	61.3	16.3
	Mar	13	1.162	0	0	0	2.5	0.8	17.7	0.9	28.9	0	0
	May	29	5.019	70.6	37.1	3	213	83.8	94.1	89.3	68.2	33.4	186.8
	Oct	18	3.336	0	0	12.9	17.2	125.2	13.5	13.5	23.7	22	74.2
	Nov	14	3.359	0.2	104.5	57.5	44.7	45.2	40.2	11.8	2.3	25.4	115.1
	Dec	19	3.286	0	0	20.1	9.3	101.4	36.9	54.5	84.8	4.3	157.9
1980	Mar	18	1.728	0	1.2	1.4	5.7	49.3	38.4	35.8	0	0.3	10.5
	Apr	8	1.503	0	0	0	0	0	2.8	2.6	2.7	52.3	38.4
	May	14	1.467	33.4	36.9	59.2	25.1	0	27	20.3	31.7	42.5	0
	Jun	3	2.32	0	0	69.7	127	69.7	73.1	59.2	25.1	0	27
	Jul	1	3.087	1	12.3	48.8	8.2	37	31.6	50.9	0	72	128.9
	Jul	22	3.156	11	25.3	2.2	16.3	45.5	19.9	61.1	8.2	37	31.4
	Aug	4	2.591	3	1.6	27.6	53.1	36.8	6.5	22.1	38.3	22.2	55.9
	Sep	4	2.626	0	3.2	8.1	90.2	30.7	11.5	63.8	91.1	26	51.6
	Nov	13	2.108	0	0	5.7	14.3	12.3	19.4	27.6	2.6	0	58
	Dec	11	1.736	0	18.1	125.6	17.4	1.9	10.1	0.5	0	17.7	9.6
1981	Jan	20	1.658	0	25.2	0.3	19	53.1	35.3	0.6	18.8	6.1	10.7
	Feb	17	1.895	69.2	7.9	36.2	45.6	165.8	14.1	0.3	25.2	6.4	25.7
	Mar	16	1.279	16	3.9	0	23.3	41.3	0	6.9	81.9	64.8	12.2
	Apr	10	1.93	11.6	52.2	36.8	12.5	64.8	0	21.3	0	23.3	41.3
	May	9	1.914	1.5	58.3	15.4	110.5	0	3.3	4.9	62.5	39.8	13.3
	Sep	21	2.323	0	21.7	51.9	21.3	9.6	2.5	7.2	91.7	4	80.2
	Oct	19	1.944	23.2	0.4	12.3	6.7	29.5	0.2	0	22.1	71.7	11.1
	Nov	23	1.566	0	11	0	3.7	55.2	26.5	26.4	6.4	58.3	12.3
	Dec	15	1.478	7.8	0	27.7	100.6	23.8	18.1	11	3.2	36.3	22.3
1982	Feb	4	1.103	15.6	55.1	12.4	5.8	23	2.5	4.2	8.9	26.4	44.9
	Mar	18	1.114	1.2	1.8	1.6	15.4	7.1	9.6	0	10.5	6.2	64.1
	Apr	21	0.79	0	0	24.7	0	0.5	17.1	1.3	1.2	2.5	10.9
	Jun	16	3.828	49.4	1.6	59	120.3	11.9	36.5	71	95.7	98.6	97.5
	Aug	20	2.156	1	23	2	25.8	10.4	17.1	37.4	48.8	27.1	35.3
	Nov	5	1.31	0.9	18.8	27.4	19.5	25.7	22.8	4.1	0	0	50

Table I.4.2 The Calculation of Multiple Regression Equation (Input Data: 2/2)

Unit: mm

Year	Month	Date	Guaraguao Discharge Q (m3/s)	X1 1 days	X2 3 days	X3 3 days	X4 5 days	X5 5 days	X6 5 days	X7 5 days	X8 5 days	X9 5 days	X10 5 days
				Daily Rainfall at Barraquito Station									
1983	Feb	1	1.399	0	1	0	0	10.6	50.1	0	23.2	19.3	39.5
	Mar	7	1.151	1.7	15.2	1.7	0.7	24.4	0	22.2	0.4	4.6	0
	Aug	22	2.303	10.7	3.3	66.7	7.2	36.8	53.4	86.4	27.8	60.3	6.8
	Oct	13	1.275	14	30	1.7	14.2	45.9	22.5	42.9	44.9	9.4	3.8
	Nov	18	2.087	127.2	0	0	47.7	23.5	68.9	9.1	49.3	22.1	31.7
	Dec	1	1.265	1.5	6.3	10.1	4	127.2	0	48.2	63.5	28.4	9.1
1984	Apr	10	0.893	0	0.8	2.1	27.9	0	74.7	2.8	7.6	4.9	2.1
	Jun	8	3.001	0	138.1	64	60.1	99.1	79	15.7	1.6	19.5	1.6
	Jul	25	1.558	13	8.1	7.6	6.4	17.3	8.4	20.8	0.5	21.6	50.5
	Oct	30	3.422	0.8	18.7	37.1	25.2	9.4	1.2	76.5	51	24.6	16.8
	Dec	4	2.095	0.6	1.9	2.4	50.9	29.6	14.3	75.5	46.6	19.2	39.8
1988	Jun	6	1.308	0	0	0	3	21.7	13.4	9.7	39.9	1	6.9
1989	Feb	7	1.259	7	33.9	24.9	18.9	2.6	6.1	0	0	0.4	39.1
	Mar	7	1.952	0	3.8	10.9	30.1	48.7	39.5	3.1	41.9	30.1	14
	Apr	12	2.432	7	6.1	0	13.7	15.1	7.1	71.8	40.6	17.3	14.3
	Jul	10	1.43	0	22.2	9.2	2.6	0.4	0.7	8.5	17.4	20.1	38.5
	Aug	10	1.18	0	2.6	0	39.6	16.6	69	8.4	33	27.3	6.7
	Oct	9	2.476	0	0	4	5	34.8	16.9	21.8	46.7	27.7	27.2
	Oct	24	1.909	0	1.9	2.8	17.3	0	4	5	34.8	16.9	21.8
	Nov	6	1.669	8	4.8	0.5	28.6	1.9	2.8	17.3	0	4	19.9
	Dec	6	1.28	0.7	11.9	0	3.4	0.7	6.7	7.1	33.7	1.7	28.6
1990	Feb	7	0.821	1	5.3	24.4	19.2	15	181.8	7.7	1.4	3.7	0.6
	Mar	8	0.869	1	2	2.7	14.1	3.4	12.8	8.4	17.6	32.3	16.6
	Apr	9	0.949	0	1.3	0	17.4	1	0	18.3	58.4	3	16.8
	May	7	0.701	0	2	1	1.6	5	10.3	43.9	1.3	0	18.4
1991	Apr	3	1.311	0	0	37.9	5.5	8.1	0.2	10.7	0	5	23.4
	Jun	7	1.863	20	0.7	0	50.1	28.2	9.7	13.4	5.7	28.8	21.7
	Nov	12	0.875	0	14.2	16.3	60.1	1.5	80.8	69.3	2.3	11.2	38.6
1992	Mar	6	1.067	0	6.5	0	0.4	15	4.8	9.6	2.2	0	5.8
	May	12	2.154	3.6	17.1	19.8	50.5	40.7	3.9	69.9	74.1	38.2	0.6
	Sep	8	2.135	3.8	24.1	49.5	40.3	11.9	0.4	60.1	64	21.2	42
	Nov	19	1.675	0.2	5.7	0.7	2.4	18.9	0	0	69.6	1.5	0
1993	Mar	9	1.115	0	0	0	9.2	5.7	19.6	61	0.2	7.5	93.4

Source: Guaraguao Discharge; Q(m3/s): INDRHI
Rainfall (mm): Barraquito Station

Table I.4.3 The Calculation of Multiple Regression Equation

Y= a + b1 x X1 + b2 x X2 + ------- + bn x Xn

where, Y; Guaroguao Discharge (m3/s)
b1,b2,---,bn; Coefficient
X1,X2,---,Xn; Baraquito Rainfall (mm)

b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	a
0.00655538	0.00384172	0.00713282	0.00623847	0.00242199	0.00395546	0.0013636	0.00353242	0.00739598	0.00278092	0.77561032
0.00164185	0.00267719	0.00246653	0.0024771	0.00176823	0.00190758	0.00200614	0.00269783	0.00301334	0.00362291	0.12669226
0.77921234	0.54560647	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
10.9740619	71	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
32.6682922	21.1357358	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

Remark: 0.77921234 : Correlation Coefficient

Table I.4.4 Rainfall and Effective Rainfall

Return Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (mm)													
1/2	112.26	95.07	115.42	164.08	307.79	180.93	192.77	204.58	158.88	174.34	188.25	126.71	2021.08
1/5	96.26	81.52	98.96	140.69	263.91	155.13	165.29	175.42	136.23	149.49	161.42	108.64	1732.96
1/10	88.82	75.22	91.32	129.82	243.52	143.15	152.52	161.86	125.71	137.94	148.95	100.25	1599.08
1/20	83.12	70.39	85.45	121.48	227.89	133.96	142.73	151.47	117.64	129.08	139.38	93.81	1496.39
1/50	77.13	65.32	79.30	112.74	211.48	124.32	132.45	140.57	109.17	119.79	129.35	87.06	1388.70
1/100	73.38	62.14	75.45	107.26	201.19	118.27	126.01	133.73	103.86	113.96	123.06	82.82	1321.13
1/200	70.11	59.37	72.08	102.47	192.22	112.99	120.39	127.77	99.23	108.88	117.57	79.13	1262.22
Effective Rainfall (mm)													
1/2	89.34	80.08	90.82	102.69	107.00	103.53	104.13	104.72	102.43	103.21	103.90	96.13	1187.98
1/5	80.86	71.28	82.61	99.41	107.00	102.24	102.75	103.26	98.39	101.44	102.56	87.64	1139.44
1/10	76.02	67.01	77.65	96.91	106.66	99.98	102.11	102.58	95.66	98.78	101.31	83.45	1108.14
1/20	72.32	63.05	73.83	93.67	105.88	97.87	99.88	101.89	91.87	96.74	99.11	79.26	1075.39
1/50	68.42	58.90	69.83	89.56	105.06	95.01	97.52	99.39	87.89	92.88	96.81	74.88	1036.14
1/100	65.51	56.29	67.20	86.99	104.55	92.16	95.80	97.81	85.39	90.14	94.41	72.12	1008.37
1/200	62.82	54.02	64.44	84.74	104.10	89.68	93.16	96.44	82.79	87.75	91.83	69.72	981.49

Table I.4.5 Calculation of Guaraguao Spring Discharge

Unit: m3/s

Date	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	1.908	1.318	0.936	1.207	1.272	1.866	2.314	2.208	2.244	1.610	1.805	2.007
2	1.882	1.278	0.906	1.204	1.298	2.092	2.161	2.178	2.032	1.691	1.852	1.936
3	1.769	1.197	0.883	1.142	1.332	2.139	2.186	2.091	2.033	1.601	1.761	1.919
4	1.616	1.155	0.991	1.077	1.346	2.331	2.132	2.234	1.985	1.567	1.765	1.953
5	1.545	1.157	1.032	1.051	1.314	2.591	2.190	2.026	1.939	1.605	1.848	1.782
6	1.686	1.237	1.082	1.035	1.296	2.731	2.122	2.078	1.934	1.636	1.782	1.749
7	1.700	1.275	1.084	1.078	1.249	2.881	2.093	2.040	2.135	1.564	1.791	1.829
8	1.637	1.242	1.107	1.104	1.207	2.915	1.947	2.150	2.116	1.535	1.786	1.876
9	1.612	1.201	1.086	1.151	1.055	2.954	1.940	2.098	1.989	1.574	1.819	1.806
10	1.613	1.272	1.075	1.159	1.213	2.884	2.076	2.256	1.870	1.435	1.758	2.079
11	1.270	1.381	1.075	1.174	1.558	2.663	2.046	2.083	1.871	1.583	1.759	2.030
12	1.229	1.284	1.046	1.176	1.865	2.592	2.052	2.091	1.841	1.675	1.750	1.890
13	1.252	1.259	1.081	1.149	2.027	2.558	2.153	2.042	1.946	1.725	1.683	1.822
14	1.268	1.197	1.074	1.116	2.212	2.399	2.247	2.006	1.810	1.803	1.595	1.902
15	1.430	1.158	1.081	1.128	2.238	2.186	2.211	1.868	1.882	1.739	1.587	2.049
16	1.553	1.069	1.045	1.050	2.230	2.320	2.239	1.940	1.875	1.641	1.630	2.000
17	1.555	1.030	1.070	1.041	2.016	2.618	2.211	2.194	1.810	1.619	1.629	2.077
18	1.419	1.031	1.073	1.116	1.615	2.904	1.983	2.199	1.632	1.568	1.896	2.050
19	1.346	1.028	1.149	1.252	1.599	3.228	1.905	2.206	1.693	1.579	2.460	1.927
20	1.369	1.092	1.213	1.211	1.521	3.347	1.852	2.037	1.790	1.634	2.534	1.561
21	1.360	1.230	1.217	1.237	1.549	3.044	1.864	2.117	1.731	1.944	2.438	1.462
22	1.314	1.301	1.196	1.230	1.878	2.365	1.985	2.057	1.880	1.909	1.962	1.467
23	1.362	1.306	1.152	1.169	2.088	2.276	1.928	2.040	1.893	1.964	2.015	1.415
24	1.313	1.262	1.002	1.167	2.152	1.989	1.983	1.952	1.908	1.831	1.914	1.449
25	1.308	1.174	0.989	1.142	2.122	1.530	2.118	2.168	1.876	1.924	1.664	1.783
26	1.299	0.998	0.962	1.137	2.253	1.555	2.248	2.172	1.906	1.789	1.841	1.798
27	1.354	0.943	1.008	1.161	2.195	1.651	2.273	2.319	1.613	1.713	1.863	1.791
28	1.350	0.937	1.083	1.222	2.079	1.786	2.102	2.473	1.553	1.621	1.898	1.848
29	1.375		1.233	1.194	2.039	1.929	2.068	2.644	1.621	1.619	2.007	1.921
30	1.341		1.264	1.228	1.906	2.182	2.026	2.457	1.656	1.613	2.255	1.298
31	1.349		1.295		1.780		2.265	2.358		1.594		1.321
Ave	1.464	1.179	1.080	1.150	1.726	2.417	2.094	2.154	1.869	1.674	1.878	1.800
Rank	9	10	12	11	7	1	3	2	5	8	4	6

Table I.4.6 Result of Hydrometry at Guaraguao (1/4)

unit: m3/s

Date	Month	Year	Time	Main Canal	Sub Canal	Total
18	Aug.	94	15:47	1.349	0.277	1.626
19	Aug.	94	7:01	1.263	0.318	1.581
19	Aug.	94	16:53	1.458	0.161	1.619
20	Aug.	94	7:00	1.739	0.234	1.973
20	Aug.	94	16:52	1.564	0.486	2.050
21	Aug.	94	7:10	1.289	0.391	1.680
21	Aug.	94	15:41	1.320	0.298	1.618
22	Aug.	94	7:24	1.284	0.392	1.676
22	Aug.	94	16:59	1.209	0.386	1.595
23	Aug.	94	17:52	1.302	0.260	1.561
25	Aug.	94	7:03	1.351	0.324	1.675
26	Aug.	94	19:31	1.401	0.316	1.717
27	Aug.	94	17:26	1.218	0.332	1.550
28	Aug.	94	7:00	1.526	0.246	1.772
28	Aug.	94	17:00	1.364	0.275	1.639
29	Aug.	94	7:00	1.424	0.307	1.731
31	Aug.	94	7:00	1.238	0.266	1.504
1	Sep.	94	7:00	1.327	0.242	1.569
1	Sep.	94	17:06	1.118	0.275	1.393
2	Sep.	94	7:00	1.260	0.317	1.577
2	Sep.	94	17:00	1.133	0.463	1.596
3	Sep.	94	7:00	1.198	0.406	1.604
3	Sep.	94	17:00	1.172	0.249	1.421
4	Sep.	94	7:00	1.210	0.291	1.501
4	Sep.	94	17:00	1.224	0.266	1.491
5	Sep.	94	7:00	1.666	0.362	2.028
6	Sep.	94	17:10	1.272	0.232	1.504
7	Sep.	94	7:05	1.414	0.217	1.631
7	Sep.	94	17:00	1.302	0.250	1.552
8	Sep.	94	7:01	1.372	0.210	1.582
14	Sep.	94	7:00	1.812	0.645	2.457
14	Sep.	94	17:00	1.602	0.393	1.995
15	Sep.	94	7:09	1.717	0.436	2.153
15	Sep.	94	17:00	1.572	0.439	2.011
16	Sep.	94	7:09	1.493	0.385	1.878
16	Sep.	94	17:00	1.364	0.388	1.752
17	Sep.	94	7:23	1.534	0.366	1.900
17	Sep.	94	17:10	1.260	0.247	1.507
18	Sep.	94	7:19	1.402	0.270	1.672
18	Sep.	94	17:00	1.193	0.348	1.541
19	Sep.	94	7:07	1.309	0.353	1.662
19	Sep.	94	17:00	1.443	0.213	1.656
20	Sep.	94	7:14	1.328	0.190	1.518
20	Sep.	94	17:00	1.306	0.226	1.532
21	Sep.	94	17:00	1.213	0.354	1.567
23	Sep.	94	17:00	1.424	0.029	1.453
24	Sep.	94	17:00	1.346	0.253	1.599
25	Sep.	94	17:00	1.641	0.426	2.067
26	Sep.	94	17:00	1.494	0.448	1.942
27	Sep.	94	17:00	1.752	0.652	2.404
28	Sep.	94	17:00	1.481	0.429	1.910
29	Sep.	94	17:00	1.295	0.418	1.713
30	Sep.	94	17:00	1.284	0.344	1.628

Table I.4.6 Result of Hydrometry at Guaraguao (2/4)

unit: m3/s

Date	Month	Year	Time	Main Canal	Sub Canal	Total
1	Oct.	94	17:00	1.114	0.316	1.430
2	Oct.	94	17:00	1.255	0.256	1.511
3	Oct.	94	17:00	1.043	0.305	1.348
4	Oct.	94	17:00	1.092	0.321	1.413
5	Oct.	94	17:00	1.135	0.271	1.406
6	Oct.	94	17:00	1.083	0.304	1.387
7	Oct.	94	17:00	1.285	0.311	1.596
8	Oct.	94	17:00	1.304	0.305	1.609
9	Oct.	94	17:00	1.204	0.237	1.441
11	Oct.	94	17:00	1.540	0.322	1.862
14	Oct.	94	17:08	1.363	0.320	1.683
15	Oct.	94	17:00	1.456	0.275	1.731
17	Oct.	94	17:00	1.446	0.315	1.761
18	Oct.	94	17:00	1.951	0.000	1.951
19	Oct.	94	17:00	1.226	0.412	1.638
20	Oct.	94	17:00	1.675	0.321	1.996
21	Oct.	94	17:00	1.397	0.265	1.662
22	Oct.	94	17:00	1.459	0.260	1.719
23	Oct.	94	17:00	1.398	0.229	1.627
25	Oct.	94	17:00	1.777	0.123	1.900
28	Oct.	94	17:00	1.614	0.222	1.836
29	Oct.	94	17:00	1.290	0.233	1.523
30	Oct.	94	17:00	1.423	0.271	1.694
31	Oct.	94	17:00	1.507	0.129	1.636
1	Nov.	94	17:00	1.465	0.268	1.733
2	Nov.	94	17:00	1.324	0.323	1.647
3	Nov.	94	17:00	1.286	0.200	1.486
4	Nov.	94	17:00	1.321	0.124	1.445
5	Nov.	94	17:00	1.282	0.197	1.479
6	Nov.	94	17:00	1.341	0.189	1.530
7	Nov.	94	17:00	1.663	0.164	1.827
9	Nov.	94	17:00	1.450	0.106	1.556
13	Nov.	94	17:00	1.581	0.375	1.956
14	Nov.	94	17:00	1.569	0.286	1.855
15	Nov.	94	17:00	1.350	0.257	1.607
16	Nov.	94	17:00	1.299	0.299	1.598
17	Nov.	94	17:00	1.577	0.309	1.886
18	Nov.	94	17:00	1.304	0.242	1.546
19	Nov.	94	17:00	1.344	0.290	1.634
20	Nov.	94	17:00	1.387	0.233	1.620
21	Nov.	94	17:00	1.577	0.243	1.820
23	Nov.	94	17:00	1.298	0.250	1.548
28	Nov.	94	17:00	1.276	0.280	1.556
29	Nov.	94	17:00	1.188	0.298	1.486
30	Nov.	94	17:00	1.295	0.269	1.564

Table I.4.6 Result of Hydrometry at Guaraguao (3/4)

unit: m3/s

Date	Month	Year	Time	Main Canal	Sub Canal	Total
1	Dec	94	17:00	1.289	0.276	1.565
2	Dec	94	17:00	1.597	0.304	1.901
3	Dec	94	17:00	1.105	0.292	1.397
4	Dec	94	17:00	1.429	0.257	1.686
5	Dec	94	17:00	1.445	0.283	1.728
6	Dec	94	17:00	2.059	0.306	2.365
7	Dec	94	17:00	1.966	0.229	2.195
8	Dec	94	17:00	1.404	0.242	1.646
9	Dec	94	17:00	1.380	0.288	1.668
11	Dec	94	17:00	1.074	0.304	1.378
14	Dec	94	17:00	1.482	0.332	1.814
15	Dec	94	17:00	1.381	0.261	1.642
16	Dec	94	17:00	1.414	0.274	1.688
17	Dec	94	17:00	1.159	0.190	1.349
18	Dec	94	17:00	1.130	0.318	1.448
19	Dec	94	17:00	1.323	0.262	1.585
20	Dec	94	17:00	1.371	0.250	1.621
21	Dec	94	17:00	1.383	0.298	1.681
22	Dec	94	17:00	1.466	0.292	1.758
23	Dec	94	17:00	1.398	0.280	1.678
25	Dec	94	17:00	1.395	0.376	1.771
28	Dec	94	17:00	1.608	0.000	1.608
29	Dec	94	17:00	1.338	0.194	1.532
30	Dec	94	17:00	1.311	0.284	1.595
31	Dec	94	17:00	1.256	0.263	1.519
2	Jan.	95	17:00	1.181	0.347	1.528
3	Jan.	95	17:00	1.117	0.210	1.327
4	Jan.	95	17:00	1.258	0.330	1.588
5	Jan.	95	17:00	1.114	0.283	1.397
6	Jan.	95	17:00	1.252	0.262	1.514
7	Jan.	95	17:00	1.503	0.254	1.757
8	Jan.	95	17:00	1.288	0.258	1.546
9	Jan.	95	17:00	1.433	0.215	1.648
10	Jan.	95	17:00	1.017	0.380	1.397
14	Jan.	95	17:00	1.235	0.292	1.527
15	Jan.	95	17:00	1.332	0.344	1.676
16	Jan.	95	17:00	1.226	0.201	1.427
18	Jan.	95	17:00	1.263	0.214	1.477
19	Jan.	95	17:00	1.262	0.456	1.718
20	Jan.	95	17:00	1.281	0.356	1.637
21	Jan.	95	17:00	1.193	0.362	1.555
22	Jan.	95	17:00	1.439	0.143	1.582
23	Jan.	95	17:00	1.205	0.328	1.533
24	Jan.	95	17:00	1.354	0.379	1.733
25	Jan.	95	17:00	1.385	0.371	1.756
26	Jan.	95	17:00	1.458	0.221	1.679
30	Jan.	95	17:00	1.204	0.300	1.504

Table I.4.6 Result of Hydrometry at Guaraguao (4/4)

unit: m3/s

Date	Month	Year	Time	Main Canal	Sub Canal	Total
1	Feb	95	17:00	0.986	0.109	1.095
2	Feb	95	17:00	1.285	0.205	1.490
3	Feb	95	17:00	1.209	0.216	1.425
4	Feb	95	17:00	1.229	0.261	1.490
5	Feb	95	17:00	1.371	0.240	1.611
6	Feb	95	17:00	1.167	0.251	1.418
7	Feb	95	17:00	1.079	0.296	1.375
8	Feb	95	17:00	0.804	0.386	1.190
9	Feb	95	17:00	0.943	0.259	1.202
10	Feb	95	17:00	0.805	0.254	1.059
14	Feb	95	17:00	1.402	0.250	1.652
15	Feb	95	17:00	1.161	0.211	1.372
16	Feb	95	17:00	1.103	0.330	1.433
22	Feb	95	17:00	1.356	0.344	1.700
23	Feb	95	17:00	1.112	0.327	1.439
24	Feb	95	17:00	1.094	0.213	1.307
25	Feb	95	17:00	1.119	0.295	1.414
26	Feb	95	17:00	1.142	0.223	1.365
27	Feb	95	17:00	1.238	0.278	1.516
	Average			1.343	0.286	1.629
	Portion = Total Average / Main Canal Average =					1.213

Table I.4.7 Result of Hydrometry at Springs

Unit: m3/s

Year	Month	Date	GUARAGUAO	LA CUEVA	LAGUNITA	LAGUNA	CERCADO	Source
1994	Aug	19	2.128	0.382	1.481	0.428	0.624	INDRHI
	Sep	7	1.485	0.511	*	*	*	INDRHI
		16	1.429	0.654	1.156	0.446	0.538	INDRHI
		28	1.268	0.936	1.449	0.684	0.547	INDRHI
	Oct	11	1.808	0.913	1.567	0.435	0.495	INDRHI
	Nov	17	1.51	0.678	2.062	0.541	0.67	INDRHI
	Dec	6	2.246	0.598	2.353	0.756	1.048	INDRHI
1995	Jan	10	1.138	0.373	1.75	0.499	0.639	INDRHI
	Feb	7	1.496	0.4	0.82	0.473	0.895	JICA team
		10	1.236	0.323	0.633	0.547	0.871	JICA team
		13	1.694	0.314	0.821	0.519	0.969	JICA team
		16	1.629	0.323	0.654	0.546	0.831	JICA team
		20	*	0.279	0.76	0.501	0.739	JICA team
		23	1.626	0.309	*	0.536	0.952	JICA team
		27	1.688	0.356	*	0.51	0.766	JICA team
	Mar	2	1.533	0.355	0.777	0.506	0.838	JICA team
		6	1.863	0.286	0.742	0.528	0.752	JICA team
		9	*	*	*	0.551	*	JICA team
	Average		1.611	0.470	1.216	0.530	0.761	
	Portion		1.000	0.292	0.755	0.329	0.472	

Remark: (*) Non Observation

Table I.4.8 Relationship between new irrigated area and required storage water

A:New irrigated area (ha) =	300											
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
(1):Spring water(m3/s)	1.774	1.429	1.309	1.394	2.092	2.929	2.538	2.611	2.265	2.029	2.276	2.182
(2):Unit water(m3/s/ha)	0.402	0.746	0.942	1.061	0.743	0.42	0.512	0.953	0.908	0.688	0.311	0.244
(3):Irrigable area(ha)	4412.9	1915.5	1389.6	1313.9	2815.6	6973.8	4957	2739.8	2491.5	2949.1	7318.3	8912.6
	Irrigated area (ha)=			1300								
(4):Water req. for 1300 ha(m3/s)	0.523	0.970	1.225	1.379	0.966	0.546	0.666	1.239	1.180	0.894	0.404	0.317
(5):Excess water ;(1)-(4)(m3/s)	1.251	0.459	0.084	0.015	1.126	2.383	1.872	1.372	1.085	1.135	1.872	1.865
(6):Monthly storage water(1000m3)	3351.7	1110.9	226.06	38.102	3016.1	6176.7	5015	3675	2811.3	3038.9	4851.4	4994.7
(7):Accum. storage water(1000m3)					3016.1	9192.9	14208	17883	20694	23733	28585	33579
(8):New water req. for 200ha(m3/s)	0.121	0.224	0.283	0.318	0.223	0.126	0.154	0.286	0.272	0.206	0.093	0.073
(9)=(4)+(8) (m3/s)	0.643	1.194	1.507	1.698	1.189	0.672	0.819	1.525	1.453	1.101	0.498	0.390
(10):Lack of water; (1)-(9)(m3/s)	1.131	0.235	-0.198	-0.304	0.903	2.257	1.719	1.086	0.812	0.928	1.778	1.792
(11):Req. manthly storage water			530.86	786.93								
(12):Accum. storage water(1000m3)			530.86	1317.8								
A:New irrigated area (ha) =	258											
(8):New water req. for A (m3/s)	0.104	0.192	0.243	0.274	0.192	0.108	0.132	0.246	0.234	0.178	0.080	0.063
(9)=(4)+(8) (m3/s)	0.626	1.162	1.468	1.653	1.158	0.654	0.798	1.485	1.415	1.072	0.485	0.380
(10):Lack of water; (1)-(9)(m3/s)	1.148	0.267	-0.159	-0.259	0.934	2.275	1.740	1.126	0.850	0.957	1.791	1.802
(11):Req. manthly storage water			424.89	671.43								
(12):Accum. storage water(1000m3)			424.89	1096.3								
A:New irrigated area (ha) =	400											
(8):New water req. for A (m3/s)	0.161	0.298	0.377	0.424	0.297	0.168	0.205	0.381	0.363	0.275	0.124	0.098
(9)=(4)+(8) (m3/s)	0.683	1.268	1.601	1.804	1.263	0.714	0.870	1.620	1.544	1.170	0.529	0.415
(10):Lack of water; (1)-(9)(m3/s)	1.091	0.161	-0.292	-0.410	0.829	2.215	1.668	0.991	0.721	0.859	1.747	1.767
(11):Req. manthly storage water			783.16	1061.9								
(12):Accum. storage water(1000m3)			783.16	1845.1								
A:New irrigated area (ha) =	500											
(8):New water req. for A (m3/s)	0.201	0.373	0.471	0.531	0.372	0.210	0.256	0.477	0.454	0.344	0.156	0.122
(9)=(4)+(8) (m3/s)	0.724	1.343	1.696	1.910	1.337	0.756	0.922	1.715	1.634	1.238	0.560	0.439
(10):Lack of water; (1)-(9)(m3/s)	1.050	0.086	-0.387	-0.516	0.755	2.173	1.616	0.896	0.631	0.791	1.716	1.743
(11):Req. manthly storage water			1035.5	1337								
(12):Accum. storage water(1000m3)			1035.5	2372.4								
A:New irrigated area (ha) =	600											
(8):New water req. for A (m3/s)	0.241	0.448	0.565	0.637	0.446	0.252	0.307	0.572	0.545	0.413	0.187	0.146
(9)=(4)+(8) (m3/s)	0.764	1.417	1.790	2.016	1.412	0.798	0.973	1.811	1.725	1.307	0.591	0.464
(10):Lack of water; (1)-(9)(m3/s)	1.010	0.012	-0.481	-0.622	0.680	2.131	1.565	0.800	0.540	0.722	1.685	1.718
(11):Req. manthly storage water			1287.8	1612								
(12):Accum. storage water(1000m3)			1287.8	2899.7								
A:New irrigated area (ha) =	700											
(8):New water req. for A (m3/s)	0.281	0.522	0.659	0.743	0.520	0.294	0.358	0.667	0.636	0.482	0.218	0.171
(9)=(4)+(8) (m3/s)	0.804	1.492	1.884	2.122	1.486	0.840	1.024	1.906	1.816	1.376	0.622	0.488
(10):Lack of water; (1)-(9)(m3/s)	0.970	-0.063	-0.575	-0.728	0.606	2.089	1.514	0.705	0.449	0.653	1.654	1.694
(11):Req. manthly storage water		152.41	1540.1	1887								
(12):Accum. storage water(1000m3)			1692.5	3579.5								
A:New irrigated area (ha) =	800											
(8):New water req. for A (m3/s)	0.322	0.597	0.754	0.849	0.594	0.336	0.410	0.762	0.726	0.550	0.249	0.195
(9)=(4)+(8) (m3/s)	0.844	1.567	1.978	2.228	1.560	0.882	1.075	2.001	1.907	1.445	0.653	0.512
(10):Lack of water; (1)-(9)(m3/s)	0.930	-0.138	-0.669	-0.834	0.532	2.017	1.463	0.610	0.358	0.584	1.623	1.670
(11):Req. manthly storage water		332.88	1792.4	2162								
(12):Accum. storage water(1000m3)			2125.3	4287.3								

Table I.6.1 Calculation of Reference Crop Evapotranspiration

No.	Abbr.	Unit	Description	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Reference
(1)	Tmean	C	Mean Air Temperature	23.6	23.6	24.2	25.4	26.1	26.9	26.9	26.9	27.0	26.5	25.5	24.1	Table3.4.4
(2)	RHmean	(%)	Mean Relative Humidity	83.6	83.3	80.4	79.4	82.5	76.8	83.7	83.7	83.8	84.4	85.2	84.8	Table3.4.4
(3)	ea	mbar	Saturation Vapour Pressure	29.1	29.1	30.2	32.5	33.8	35.5	35.5	35.5	35.7	34.7	32.7	30.0	App. 3
(4)	ed	mbar	Vapour Pressure; ed = (2)x(3)	24.3	24.3	24.3	25.8	27.9	27.3	29.7	29.7	29.9	29.2	27.8	25.4	
(5)	ea-ed	mbar	Vapour Pressure; ea-ed=(3)-(4)	4.8	4.9	5.9	6.7	5.9	8.2	5.8	5.8	5.8	5.4	4.8	4.6	
(6)	U	km/day	Wind Speed	120	120	127	144	115	104	95	85	156	92	90	98	App. 1
(7)	f(u)		Wind Function; f(u)=0.27(1+U/100)	0.59	0.59	0.61	0.66	0.58	0.55	0.53	0.50	0.69	0.52	0.51	0.53	
(8)	1-W		Weighting Factor	0.27	0.27	0.27	0.26	0.25	0.24	0.24	0.24	0.24	0.25	0.26	0.27	App. 5
(9)	W		Weighting Factor	0.73	0.73	0.73	0.74	0.75	0.76	0.76	0.76	0.76	0.76	0.75	0.73	App. 6
(10)	Ra	mm/day	Extra Terrestrial Radiation	11.2	12.7	14.4	15.6	16.3	16.4	16.3	15.9	14.8	13.3	11.6	10.7	App. 7
(11)	n/N		n/N Racio	0.65	0.67	0.69	0.66	0.61	0.64	0.64	0.64	0.64	0.65	0.64	0.64	App. 2
(12)			Maximum Sunshine Hours; (0.25+0.5n/N)	0.58	0.59	0.60	0.58	0.56	0.57	0.57	0.57	0.57	0.58	0.57	0.57	
(13)	Rs	mm/day	Solar Radiation; Rs=(0.25+0.50n/N)xRa	6.4	7.4	8.6	9.0	9.0	9.3	9.3	9.1	8.4	7.6	6.6	6.1	
(14)	Rns	mm/day	Net Solar Radiation; Rns=(1-ƒ¿)xRs	4.8	5.6	6.4	6.8	6.8	7.0	7.0	6.8	6.3	5.7	5.0	4.6	ƒ¿=0.25
(15)	f(T)		Effect of Temperature	15.3	15.3	15.5	15.8	15.9	16.1	16.1	16.1	16.1	16.0	15.8	15.4	App. 9
(16)	f(ed)		Effect of Vapour Pressure	0.12	0.12	0.12	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.11	0.12	App.10
(17)	f(n/N)		Effect of the Ratio Actual and Maximum Bright Sunshine Hours; f(n/N)=0.1+0.9n/N	0.69	0.70	0.72	0.69	0.65	0.68	0.68	0.68	0.68	0.69	0.68	0.68	App.11
(18)	Rnl	mm/day	Longwave Radiation; Rnl=f(T)xf(ed)xf(n/N)	1.3	1.3	1.4	1.3	1.1	1.2	1.1	1.1	1.1	1.1	1.2	1.2	
(19)	Rn	mm/day	Net Radiation in Equivalent Evaporation; Rn=Rns-Rnl	3.5	4.2	5.1	5.5	5.7	5.8	5.9	5.7	5.2	4.6	3.8	3.3	
(20)	c		Adjustment factor	1.05	1.07	1.08	1.13	1.14	1.14	1.14	1.12	1.08	1.07	1.05	1.05	App.12
(21)		mm/day	Radiation Term; Wx(Rns-Rnl)	2.57	3.08	3.70	4.10	4.26	4.41	4.46	4.33	3.99	3.49	2.84	2.44	
(22)		mm/day	Aerodynamic Term; (1-W)xf(u)x(ea-ed)	0.78	0.79	0.97	1.13	0.86	1.09	0.73	0.70	0.96	0.69	0.63	0.66	
(23)		mm/day	W(Rns-Rnl)+(1-W)f(u)(ea-ed)=(21)+(22)	3.35	3.87	4.67	5.23	5.12	5.50	5.20	5.03	4.95	4.17	3.47	3.10	
(24)	ETo	mm/day	Reference Crop Evapotranspiration; ETo=(20)x(23)	3.5	4.1	5.0	5.9	5.8	6.3	5.9	5.6	5.3	4.5	3.6	3.3	
(25)			Adjustment for Project	1.10	1.12	1.13	1.15	1.15	1.15	1.15	1.15	1.13	1.12	1.11	1.10	
(26)	ETo	mm/day	ETo=(24)x(25)	3.9	4.6	5.7	6.8	6.7	7.2	6.8	6.5	6.0	5.0	4.0	3.6	
(27)	ETo	mm/month		119.9	130.0	176.7	203.8	207.9	216.5	211.2	200.8	181.1	155.0	121.3	111.0	
*	ETo	mm/month	Elpozo	112	129	177	192	198	192	198	192	171	146	117	109	
**	ETo	mm/month	Aguacate Guayabo	115	129	174	204	211	207	211	195	168	152	117	105	

Table I.6.1 Calculation of Reference Crop Evapotranspiration

Appendix 1 Monthly Mean Wind Velocity at Barraquito

Unit: m/s

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975												1.1
1976		1.7		1.9	2.1	1.6	1.4	1.3		1.2		
1977											1.1	1.1
1978	1.3	1.4		1.7	1.4	1.2					1.0	
1979												
1980						1.8	1.8	0.2	1.4	1.5	1.3	1.4
1981	1.6	1.7	2.3	2.3	1.6	1.0	0.2	1.6	1.7	1.3	1.2	1.2
1982	2.1	2.2	2.0	2.5	1.7	1.7	1.5	1.3	1.3			
1983												
1984			1.5	1.8			2.0		1.5		1.6	1.9
1985	1.4	1.4		1.5	1.4	1.4	1.1	1.4	1.2			
1986	1.3		1.2			1.3	1.1	1.0			0.9	1.0
1987	1.2		1.3		1.2	0.9			1.0	0.9		0.9
1988		1.0			1.2		0.9	0.9	1.0	0.7	0.8	
1989		1.1	1.9	1.3	1.0		1.0			0.8		
1990		1.2		1.1		0.9	1.0		0.7			
1991	0.8		1.0	0.9		0.8	0.7	0.6				
1992		0.8	0.6		0.4	0.6	0.5	0.6	6.4		0.4	
1993												0.5
Mean (m/s)	1.4	1.4	1.5	1.7	1.3	1.2	1.1	1.0	1.8	1.1	1.0	1.1
Mean (km/day)	120	120	127	144	115	104	95	85	156	92	90	98

Appendix 2 Monthly Mean Cloudiness Oktas at Barraquito

Unit: m / s

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975			2	1	2	2	2	2	3	3	3	4
1976	2	3	3	3	3	4	3	3	3	4	4	4
1977	4	3	3	4	4	4	4	4	4		4	4
1978	4	4		4	4	4	4	4	4	4	4	3
1979	3	2	3	3	4	4		4	4	4	3	3
1980	3	3	2	3	3	3	3	3	3	3	2	3
1981	4	3	3	3	4	3	3	3	3	3	3	3
1982	3		2	3	4	4	4	3	3	3	3	4
1983	3	3	3	3	4	3	4	3	3	3	3	3
1984	3	3	3	3			3	3	3	3		3
1985	3	3	3	3	3	3	3	3	3	3	3	3
1986	3	2			4	3	3	3	3	3	3	2
1987	2	2		2	4	3	2	2		3	3	3
1988	3	3	2	3	3	2		3	3	2	3	3
1989		3	3	3	3	2	3	3	3	2	3	2
1990		3	3	2	2	3	3		2	3	3	
1991	2	2	2	3	3	2	3	3	3	3	3	3
1992	3	2	2	3	3		3	3	3		3	3
1993	3				4	3		3	3	2		
Mean	3.0	2.8	2.6	2.9	3.4	3.1	3.1	3.1	3.1	3.0	3.1	3.1
n / N	0.65	0.67	0.69	0.66	0.61	0.64	0.64	0.64	0.64	0.65	0.64	0.64

Appendix 3 Saturation Vapour Pressure (ea) in mbar as Function of Mean Air Temperature (T) in °C

Temperature °C	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
ea mbar	6.1	6.6	7.1	7.6	8.1	8.7	9.3	10.0	10.7	11.5	12.3	13.1	14.0	15.0	16.1	17.0	18.2	19.4	20.6*	22.0
Temperature °C	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**
ea mbar	23.4	24.9	26.4	28.1	29.8	31.7	33.6	35.7	37.8*	40.1	42.4	44.9	47.6	50.3	53.2	56.2	59.4	62.8	66.3	69.9

1/ Also actual vapour pressure (ed) can be obtained from this table using available Tdewpoint data. (Example: Tdewpoint is 18°C; ed is 20.6 mbar)

Appendix 4 Vapour Pressure (ed) in mbar from Dry and Wet Bulb Temperature Data in °C (Aspirated Psychrometer)

drybulb T°C	Depression wet bulb T°C altitude 0-1 000 m: 0	2	4	6	8	10	12	14	16	18	20	22
40	73.8	64.9	56.8	49.2	42.2	35.8	29.8	24.3	19.2	14.4	10.1	6.0
38	66.3	58.1	50.5	43.6	37.1	31.1	25.6	20.5	15.8	11.4	7.3	
36	59.4	51.9	44.9	38.4	32.5	26.9	21.8	17.1	12.7	8.6	4.9	
34	53.2	46.2	39.8	33.8	28.3	23.2	18.4	14.0	10.0	6.2		
32	47.5	41.1	35.1	29.6	24.5	19.8	15.4	11.3	7.5	4.0		
30	42.4	36.5	30.9	25.8	21.1	16.7	12.6	8.8	5.3			
28	37.8	32.3	27.2	22.4	18.0	14.0	10.2	6.7	3.4			
26	33.6	28.5	23.8	19.4	15.3	11.5	8.0	4.7	1.6			
24	29.8	25.1	20.7*	16.6	12.8	9.3	6.0	2.9				
22	26.4	22.0	18.0	14.2	10.6	7.4	4.3	1.4				
20	23.4	19.3	15.5	12.0	8.7	5.6	2.7					
18	20.6	16.8	13.3	10.0	6.9	4.1	1.4					
16	18.2	14.6	11.4	8.3	5.4	2.7						
14	16.0	12.7	9.6	6.7	4.0	1.5						
12	14.0	10.9	8.1	5.3	2.8							
10	12.3	9.4	6.7	4.1	1.7							
8	10.7	8.0	5.5	3.1	0.8							
6	9.3	6.8	4.4	2.1								
4	8.1	5.7	3.4	1.6								
2	7.1	4.8	2.8	0.8								
0	6.1	4.0	2.0									

drybulb T°C	Depression wet bulb T°C altitude 1 000-2 000 m: 0	2	4	6	8	10	12	14	16	18	20	22
40	73.8	65.2	57.1	49.8	43.0	41.8	31.0	25.6	20.7	16.2	12.0	8.1
38	66.3	58.2	50.9	44.1	37.9	36.7	26.8	21.8	17.3	13.2	9.2	5.7
36	59.4	52.1	45.2	39.0	33.3	32.1	23.0	18.4	14.3	10.4	6.8	3.5
34	53.2	46.4	40.1	34.4	29.1	24.1	19.6	15.4	11.5	8.0	4.6	1.5
32	47.5	41.3	35.5	30.2	25.3	20.7	16.6	12.6	9.1	5.8	2.6	
30	42.4	36.7	31.3	26.4	21.9	17.7	13.8	10.2	6.9	3.8	0.9	
28	37.8	32.5	27.5	23.0	18.9	14.9	11.4	8.0	4.9	2.1		
26	33.6	28.7	24.1	20.0	16.1	12.5	9.2	6.0	3.2	0.5		
24	29.8	25.3	21.1	17.2	13.9	10.3	7.2	4.3	1.6			
22	26.4	22.3	18.3	14.3	11.5	8.3	5.5	2.7	0.2			
20	23.4	19.5	15.9	12.6	9.5	6.6	3.9	1.3				
18	20.6	17.1	13.7	10.6	7.8	5.0	2.5	0.1				
16	18.2	14.9	11.7	8.9	6.2	3.6	1.3					
14	16.0	12.9	10.0	7.3	4.8	2.4	0.3					
12	14.0	11.2	8.4	5.9	3.6	1.4						
10	12.3	9.6	7.0	4.7	2.6	0.4						
8	10.7	8.2	5.8	3.7	1.6							
6	9.3	7.0	4.8	2.7	0.7							
4	8.1	6.0	3.8	1.8								
2	7.1	5.0	2.9	1.0								
0	6.1	4.1	2.1									

Appendix 5 Values of Weighting Factor (1-W) for the Effect of Wind and Humidity on ETo at Different Temperatures and Altitudes

Temperature °C	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
(1-W) at altitude m																				
0	0.57	.54	.51	.48	.45	.42	.39	.36	.34	.32	.29	.27	.25	.23*	.22	.20	.19	.17	.16	.15
500	.56	.52	.49	.46	.43	.40	.38	.35	.33	.30	.28	.26	.24	.22	.21	.19	.18	.16	.15	.14
1 000	.54	.51	.48	.45	.42	.39	.36	.34	.31	.29	.27	.25	.23	.21	.20	.18	.17	.15	.14	.13
2 000	.51	.48	.45	.42	.39	.36	.34	.31	.29	.27	.25	.23	.21	.19	.18	.16	.15	.14	.13	.12
3 000	.48	.45	.42	.39	.36	.34	.31	.29	.27	.25	.23	.21	.19	.18	.16	.15	.14	.13	.12	.11
4 000	.46	.42	.39	.36	.34	.31	.29	.27	.25	.23	.21	.19	.18	.16	.15	.14	.13	.12	.11	.10

Appendix 6 Values of Weighting Factor (W) for the Effect of Radiation on ETo at Different Temperatures and Altitudes

Temperature °C	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
W at altitude m																				
0	0.43	.46	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77*	.78	.80	.82	.83	.84	.85
500	.44	.48	.51	.54	.57	.60	.62	.65	.67	.70	.72	.74	.76	.78	.79	.81	.82	.84	.85	.86
1 000	.46	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.80	.82	.83	.85	.86	.87
2 000	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.81	.82	.84	.85	.86	.87	.88
3 000	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.81	.82	.84	.85	.86	.87	.88	.89
4 000	.54	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.81	.82	.84	.85	.86	.87	.89	.90	.90

Appendix 7 Extra Terrestrial Radiation (Ra) Expressed in Equivalent Evaporation in mm/day

Northern Hemisphere													Southern Hemisphere											
Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Lat	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
3.8	6.1	9.4	12.7	15.8	17.1	16.4	14.1	10.9	7.4	4.5	3.2	50°	17.5	14.7	10.9	7.0	4.2	3.1	3.5	5.5	8.9	12.9	16.5	18.2
4.3	6.6	9.8	13.0	15.9	17.2	16.5	14.3	11.2	7.8	5.0	3.7	48	17.6	14.9	11.2	7.5	4.7	3.5	4.0	6.0	9.3	13.2	16.6	18.2
4.9	7.1	10.2	13.3	16.0	17.2	16.6	14.5	11.5	8.3	5.5	4.3	46	17.7	15.1	11.5	7.9	5.2	4.0	4.4	6.5	9.7	13.4	16.7	18.3
5.3	7.6	10.6	13.7	16.1	17.2	16.6	14.7	11.9	8.7	6.0	4.7	44	17.8	15.3	11.9	8.4	5.7	4.4	4.9	6.9	10.2	13.7	16.7	18.3
5.9	8.1	11.0	14.0	16.2	17.3	16.7	15.0	12.2	9.1	6.5	5.2	42	17.8	15.5	12.2	8.8	6.1	4.9	5.4	7.4	10.6	14.0	16.8	18.3
6.4	8.6	11.4	14.3	16.4	17.3	16.7	15.2	12.5	9.6	7.0	5.7	40	17.9	15.7	12.5	9.2	6.6	5.3	5.9	7.9	11.0	14.2	16.9	18.3
6.9	9.0	11.8	14.5	16.4	17.2	16.7	15.3	12.8	10.0	7.5	6.1	38	17.9	15.8	12.8	9.6	7.1	5.8	6.3	8.3	11.4	14.4	17.0	18.3
7.4	9.4	12.1	14.7	16.4	17.2	16.7	15.4	13.1	10.6	8.0	6.6	36	17.9	16.0	13.2	10.1	7.5	6.3	6.8	8.8	11.7	14.6	17.0	18.2
7.9	9.8	12.4	14.8	16.5	17.1	16.8	15.5	13.4	10.8	8.5	7.2	34	17.8	16.1	13.5	10.5	8.0	6.8	7.2	9.2	12.0	14.9	17.1	18.2
8.3	10.2	12.8	15.0	16.5	17.0	16.8	15.6	13.6	11.2	9.0	7.8	32	17.8	16.2	13.8	10.9	8.5	7.3	7.7	9.6	12.4	15.1	17.2	18.1
8.8	10.7	13.1	15.2	16.5	17.0	16.8	15.7	13.9	11.6	9.5	8.3	30	17.8	16.4	14.0	11.3	8.9	7.8	8.1	10.1	12.7	15.3	17.3	18.1
9.3	11.1	13.4	15.3	16.5	16.8	16.7	15.7	14.1	12.0	9.9	8.8	28	17.7	16.4	14.3	11.6	9.3	8.2	8.6	10.4	13.0	15.4	17.2	17.9
9.8	11.5	13.7	15.3	16.4	16.7	16.6	15.7	14.3	12.3	10.3	9.3	26	17.6	16.4	14.4	12.0	9.7	8.7	9.1	10.9	13.2	15.5	17.2	17.8
10.2	11.9	13.9	15.4	16.4	16.6	16.5	15.8	14.5	12.6	10.7	9.7	24	17.5	16.5	14.6	12.3	10.2	9.1	9.5	11.2	13.4	15.6	17.1	17.7
10.7	12.3	14.2	15.5	16.3	16.4	16.4	15.8	14.6	13.0	11.1	10.2	22	17.4	16.5	14.8	12.6	10.6	9.6	10.0	11.6	13.7	15.7	17.0	17.5
11.2	12.7	14.4	15.6	16.3	16.4	16.3	15.9	14.8	13.3	11.6	10.7	20	17.3	16.5	15.0	13.0	11.0	10.0	10.4	12.0	13.9	15.8	17.0	17.4
11.6	13.0	14.6	15.6	16.1	16.1	16.1	15.8	14.9	13.6	12.0	11.1	18	17.1	16.5	15.1	13.2	11.4	10.4	10.8	12.3	14.1	15.8	16.8	17.1
12.0	13.3	14.7	15.6	16.0	15.9	15.9	15.7	15.0	13.9	12.4	11.6	16	16.9	16.4	15.2	13.5	11.7	10.8	11.2	12.6	14.3	15.8	16.7	16.8
12.4	13.6	14.9	15.7	15.8	15.7	15.7	15.7	15.1	14.1	12.8	12.0	14	16.7	16.4	15.3	13.7	12.1	11.2	11.6	12.9	14.5	15.8	16.5	16.6
12.8	13.9	15.1	15.7	15.7	15.5	15.5	15.6	15.2	14.4	13.3	12.5	12	16.6	16.3	15.4	14.0	12.5	11.6	12.0	13.2	14.7	15.8	16.4	16.5
13.2	14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9	10	16.4	16.3	15.5	14.2	12.8	12.0	12.4	13.5	14.8	15.9	16.2	16.2
13.6	14.5	15.3	15.6	15.3	15.0	15.1	15.4	15.3	14.8	13.9	13.3	8	16.1	16.1	15.5	14.4	13.1	12.4	12.7	13.7	14.9	15.8	16.0	16.0
13.9	14.8	15.4	15.4	15.1	14.7	14.9	15.2	15.3	15.0	14.2	13.7	6	15.8	16.0	15.6	14.7	13.4	12.8	13.1	14.0	15.0	15.7	15.8	15.7
14.3	15.0	15.5	15.5	14.9	14.4	14.6	15.1	15.3	15.1	14.5	14.1	4	15.5	15.8	15.6	14.9	13.8	13.2	13.4	14.3	15.1	15.6	15.5	15.4
14.7	15.3	15.6	15.3	14.6	14.2	14.3	14.9	15.3	15.3	14.8	14.4	2	15.3	15.7	15.7	15.1	14.1	13.5	13.7	14.5	15.2	15.5	15.3	15.1
15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8	0	15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8

Appendix 8 Conversion Factor for Extra-Terrestrial Radiation (Ra) to Net Solar Radiation (Rns) for a Given Reflection α of 0.25 and Different Ratios of Actual to Maximum Sunshine Hours $(1-\alpha)(0.25 + 0.50\ n/N)$

n/N	0.0	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0
$(1-\alpha)(0.25 + 0.50 n/N)$	0.19	.21	.22	.24	.26	.28	.30	.32	.34	.36	.37	.39	.41	.43	.45	.47	.49*	.51	.52	.54	.56

Appendix 9 Effect of Temperature f(T) on Longwave Radiation (Rnl)

T°C	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
$f(T) = \sigma Tk^4$	11.0	11.4	11.7	12.0	12.4	12.7	13.1	13.5	13.8	14.2	14.6	15.0	15.4	15.9	16.3*	16.7	17.2	17.7	18.1

Appendix 10 Effect of Vapour Pressure f(ed) on Longwave Radiation (Rnl)

ed mbar	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
$f(ed) = 0.34 - 0.044\sqrt{ed}$	0.23	.22	.20	.19	.18	.16	.15	.14	.13*	.12	.12	.11	.10	.09	.08	.08	.07	.06

Appendix 11 Effect of the Ratio Actual and Maximum Bright Sunshine Hours f(n/N) on Longwave Radiation (Rnl)

n/N	0	.05	.1	.15	.2	.25	.3	.35	.4	.45	.5	.55	.6	.65	.7	.75	.8	.85	.9	.95	1.0
$f(n/N) = 0.1 + 0.9\ n/N$	0.10	.15	.19	.24	.28	.33	.37	.42	.46	.51	.55	.60	.64	.69	.73	.78	.82*	.87	.91	.96	1.0

Appendix 12 Adjustment Factor (c) in Presented Penman Equation

	RHmax = 30%				RHmax = 60%				RHmax = 90%			
Rs mm/day	3	6	9	12	3	6	9	12	3	6	9	12
Uday m/sec	Uday/Unight = 4.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.79	.84	.92	.97	.92	1.00	1.11	1.19	.99	1.10	1.27	1.32
6	.68	.77	.87	.93	.85	.96	1.11	1.19	.94	1.10	1.26	1.33
9	.55	.65	.78	.90	.76	.88	1.02	1.14	.88	1.01	1.16	1.27
	Uday/Unight = 3.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.76	.81	.88	.94	.87	.96	1.06	1.12	.94	1.04	1.18	1.28
6	.61	.68	.81	.88	.77	.88	1.02	1.10	.86	1.01	1.15	1.22
9	.46	.56	.72	.82	.67	.79	.88	1.05	.78	.92	1.06	1.18
	Uday/Unight = 2.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.69	.76	.85	.92	.83	.91	.99*	1.05*	.89	.98	1.10*	1.14*
6	.53	.61	.74	.84	.70	.80	.94	1.02	.79	.92	1.05	1.12
9	.37	.48	.65	.76	.59	.70	.84	.95	.71	.81	.96	1.06
	Uday/Unight = 1.0											
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.64	.71	.82	.89	.78	.86	.94*	.99*	.85	.92	1.01*	1.05*
6	.43	.53	.68	.79	.62	.70	.84	.93	.72	.82	.95	1.00
9	.27	.41	.59	.70	.50	.60	.75	.87	.62	.72	.87	.95

Table I.6.2 Calculation of Unit Water Requirement

No.	Description		DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Reference
(1)	Cropping Pattern Note: Sowing Land Preparation Transplanting Growing Period Harvesting		10 20	10	First Crop	115		15	10 20	10	Second Crop	105	15		10 20	
																
(2)	ETo:Reference Crop Evapotranspiration	(mm/month)	111.0	119.9	130.0	176.7	203.8	207.9	216.5	211.2	200.8	181.1	155.0	121.3	111.0	Table I.6.1(27)
(3)	Kc:Crop Coefficient		1.10	1.10	1.10	1.05	1.05	0.95	1.10	1.10	1.10	1.05	1.05	0.95	1.10	
(4)	Crop Water Requirement (C.W.R)	(mm/month)	122.1	131.9	143.0	185.5	214.0	197.5	238.2	232.3	220.9	190.2	162.8	115.2	122.1	(2)x(3)
(5)	Area Factor of C.W.R		0.075	0.300	0.867	1.000	1.000	0.792	0.208	0.300	0.867	1.000	0.992	0.600	0.075	(1):Figure
(6)	Weighted C.W.R	(mm/month)	9.2	39.6	124.0	185.5	214.0	156.4	49.5	69.7	191.5	190.2	161.4	69.1	9.2	(4)x(5)
(7)	Area Factor of Land Preparation		0.133	0.400	0.133	0.000	0.000	0.000	0.133	0.400	0.133	0.000	0.000	0.000	0.133	(1):Figure
(8)	Water Requirement Land Preparation	(mm/month)	13.3	40.0	13.3	0.0	0.0	0.0	13.3	40.0	13.3	0.0	0.0	0.0	13.3	(7)x100mm/M
(9)	Deep Percolation (1.0 mm/day)	(mm/month)	31.0	31.0	28.0	31.0	30.0	31.0	30.0	31.0	31.0	30.0	31.0	30.0	31.0	
(10)	Field Water Requirement	(mm/month)	53.5	110.6	165.3	216.5	244.0	187.4	92.8	140.7	235.8	220.2	192.4	99.1	53.5	(6)+(8)+(9)
(11)	Effective Rainfall	(mm/month)	74.5	68.7	60.6	70.2	84.5	91.0	86.9	87.3	87.8	83.6	86.2	87.2	74.5	Table 4.4.2
(12)	Area Factor of Effective Rainfall		0.208	0.700	1.000	1.000	1.000	0.792	0.341	0.700	1.000	1.000	0.992	0.600	0.208	(1):Figure
(13)	Weighted Effective Rainfall	(mm/month)	15.5	48.1	60.6	70.2	84.5	72.1	29.6	61.1	87.8	83.6	85.5	52.3	15.5	(11)x(12)
(14)	Net Irrigation Requirement	(mm/month)	38.0	62.5	104.7	146.3	159.5	115.4	63.2	79.6	148.0	136.6	106.9	46.8	38.0	(10) - (13)
(15)	Irrigation Efficiency		0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	
(16)	Irrigation Requirement	(mm/month)	65.5	107.7	180.5	252.3	275.0	198.9	109.0	137.2	255.2	235.4	184.4	80.7	65.5	(14)/(15)
(17)	"	(mm/day)	2.111	3.475	6.446	8.139	9.166	6.416	3.632	4.426	8.232	7.848	5.948	2.691	2.111	(16)/days
(18)	"	(l/s/ha)	0.244	0.402	0.746	0.942	1.061	0.743	0.420	0.512	0.953	0.908	0.688	0.311	0.244	(17)/8.64