3.2.2 Socio-economic Condition

In Monjas Basin, agriculture land accounts for 75% of the total area and agriculture population accounts for more than 80% of population of economic activities to the point where agriculture population is 99% of population of economical activities in agriculture villages. It may be said that this area is a pure agriculture zone.

Basic crops such as maize and kidney beans are cultivated mainly in the wet season, while, in the dry season, cash crops centered on vegetables are cultivated mainly in the Hoyo Irrigation Project area and ground water irrigation area. This suggests the trend of agriculture production after water resources have been developed.

Notwithstanding that the Study area is an agricultural zone, Monjas area is awarded few budgets for agriculture promotion by Monjas Community. Most of farmers are small-scale farmers, who depend on rainwater and are forced to be petty farmers. Excess labor in these farmers is absorbed by large-scale farmers in the form of the employee.

However, the excess labor power is released in the dry season, and employment opportunity is reduced, and potential unemployment increases. The excess labor scarcely flow out from the area. In addition, neither a cooperative for joint delivery nor agricultural joint utilization facilities are found in the Study area. Although this area has agricultural supporting organizations such as the test field of ICTA and the branch of INDECA and DIGESA, it may not be said that they fully exhibit their functions.

Development of this typical agricultural zone involves rapid establishment of agricultural facilities directed to irrigation which has long been cherished by local farmers. In addition, fulfilment of agricultural extension services will also be a keystone of the development.

3.2.3 Social Infrastructures

Paved National Highway No.19 runs from north to south at the center of Monjas Basin. The Monjas urban area is about 150 km from the Capital, and about 60 km from the border between Guatemala and El Salvador. Distances to Jalapa and Jutiapa, both of which are Department capitals, are 22 km and 30 km, respectively. Route has services are available for public use, and buses run to the Capital and between state capitals relatively frequently. Most of farm roads to the trunk road do not allow vehicle traffic, and some of them are not serviceable in the wet season. In most prefectures trunk roads have few bridges that allow vehicle traffic, and some rivers prevent crossing when river water reaches a high level during the wet season.

Electric power and water supply are available in the urban area and some villages. However, most rural area are not yet favored with electric light, and dependent for domestic water on well water and river water. No drainage is provided.

Monjas urban area, Llano Grande village, and El Ovejero village have clinics, where doctors and nurses are at services with insufficient facilities, supported by few staff. Objectionable living environments in the rural area increase the incidence of diseases of respiratory organs, digestion, and parasites.

Each village has its own elementary school while the ruban area has middle schools, high schools, a national higher normal school, a private higher commercial school, etc. More than 50% of children enter the elementary school, and about 10% the middle school. Especially, the rate of attendance in the rural area is low, where children of the school age are often engaged in household labor and agriculture employment labor. The incidence of illiteracy is about 54%.

In the urban area, there are a police station, a post office, a telephone station, the branch of governmental authorities such as INDECA and DIGESA, offices of a tobacco company, tomato wholesaler and carrier, etc.

3.3 Natural Conditions

3.3.1 Topography and Rivers

(1) Topography

The Study area is a mountain basin in the center of a volcanic belt width of 70 - 80 km almost from east to west on the south of the Republic. The basin covers the total area of about 90 km2.

Topographically, the Basin and surrounding area are divided into ① the mountain land, ② piedmont, and ③ plane land. The Study area is in the plane land. The mountain land has an altitude of 1,100 - 1,500 m A.S.L in the east and about 1,200 m A.s.L in the other sides, having relatively developed topography. Connected with the mountain land, the piedmont has an altitude of 990 - 1,050 m A.S.L and a gradient of 5 - 8%, and borders the plane land, with small undulations on the further developed slopes. The plane land is distributed in the vessel-bottom shape and extends from north to south, having an altitude of 940 - 990 m A.S.L and a gradient of 1 - 0.3% except for several monadnocks and small volcanoes. Terraces are found along rivers (Appendix 3.2.1).

(2) River

The Ostua River is the main river in the Study area, and is traced to a source with an altitude of about 2,400 m A.S.L near Astillero. The Ostua River flows down toward the southeast and into the Lake Guija located on the border with El Salvador, having a total distance of 103.5 km. The Ostua River joins many rapid streaming branches near the source, cutting the mountain land deep. After flowing down about 31.5 km, the Ostua River joins the Blanco River, a branch flowing on the west end of the Study area.

In the Basin, the Ostua River further joins with the Jutiapilla River, Guirila River (including the San Pedro River), Mojarritas River, Juan Cano River, etc. which flow from the west in due order. The Ostua River valley has catchment area of about 665 km^2 at the outlet from the Basin (Fig. 3.3.1-1).

The specific features of the main rivers are shown in Table 3.3.1-1.

Table 3.3.1-1 Specific Features of the Main Rivers

River name	Ostua	Blanco	Guirila	San Pedro	Majarritas
Bank	Main steam	Primary branch	Primary branch	Secondary branch	Primary branch
Catchment area (km^2)	665.0	39.0	80.4	101.0*	740
Altitude (m A.S.L)					
Source	EL+2500m	EL+2200m	EL+1600m	EL+1700m	EL+1500m
Plane land	EL+1000 to 940m	EL+1020m	EL+980 to 940m	EL+1000 to 950m	EL+1000 to 940m
Length (km)	47.5	10.0	22.0	16.7	16.0
Bed slope					
Mountain	1/5-1/20	1/5-1/10	1/8-1/10	1/4-1/15	1/5-1/15
Plane land	1/100-1/200	1/50-1/70	1/150-1/200	1/400-1/500	1/150-1/180

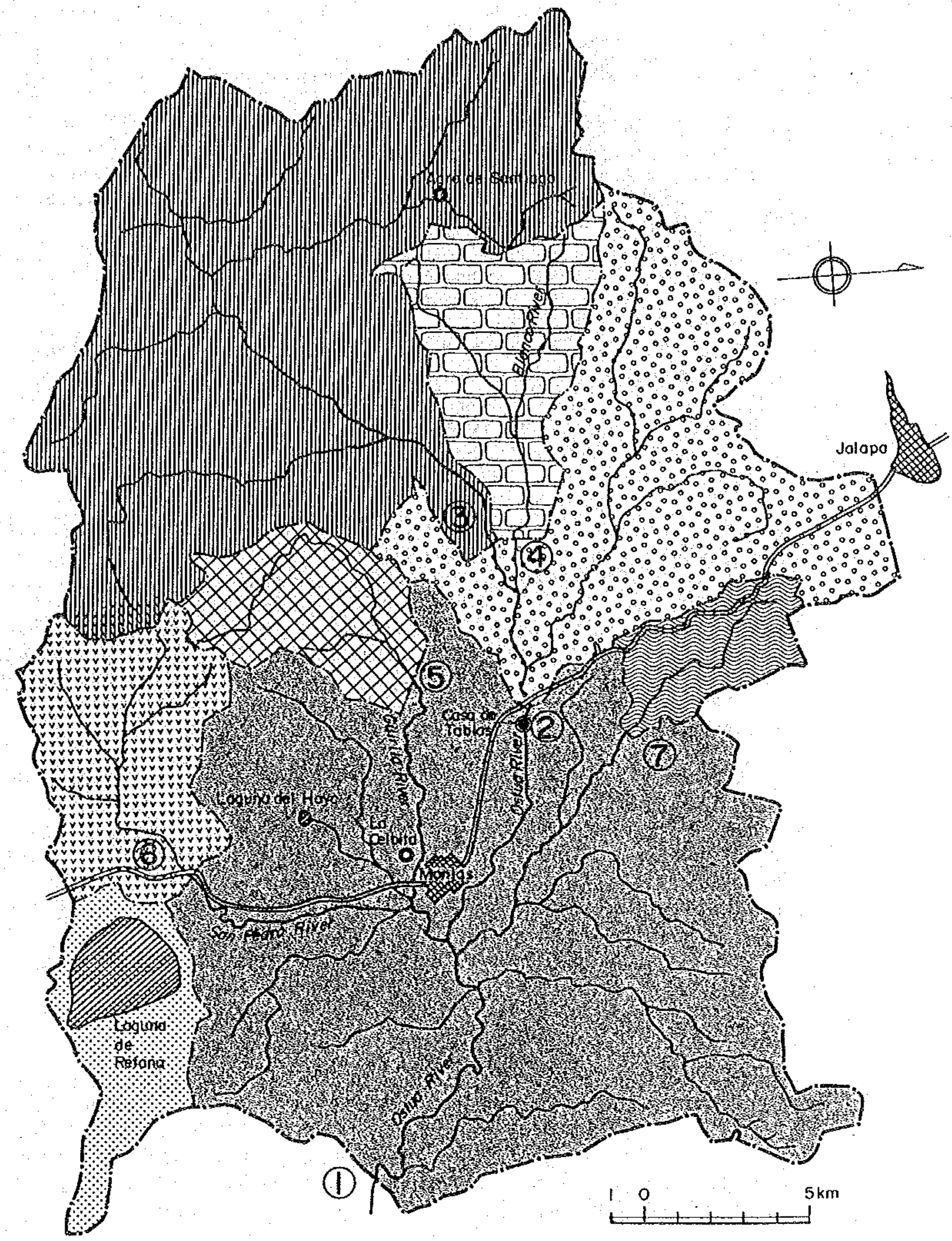
* including Retana Lake catchment area.

3.3.2 Meteorology

(1) Meteorological station and existing data

The are meteorological station at La Ceibita (961 m A.S.L) in the Study area and another station at Agro Santiago, in alzatate (1700 m A.S.L) in the upstream of the Ostua River. Established in 1963, La Ceibita Station observes evaporation, sunshine duration, relative humidity, mean daily temperature, wind speed, and precipitation. Agro Santiago Station keeps a daily precipitation record from 1958 to 1971.

In addition stations are located at Laguna del Hoyo and Jalapa, but are unable to furnish effective data because of a short observation period. Table 3.3.2-1 lists available meteorological data from the farmer 2 stations.



◎ Meteorological Station ◉ Gauging Station

NUMBER	RIVER	POINT	BASIN	REMARKS
①	Ostua	Monjas	665.0 km²	—
②	Ostua	Casa de Tablas	321.3 km²	Gauging Station
③	Ostua	Finca Jicaltepeque	177.0 km²	Ostua Dam
④	Blanco	Finca Esperanza	231.3 km²	Blanco Dam
⑤	Güirila	Piedra de Fuego	26.0 km²	Güirila Dam
⑥	San Pedro	San Pedro	40.0 km²	San Pedro Dam
⑦	Los Achiotes	Los Achiotes	13.0 km²	Los Achiotes Dam

Fig. 3.3.1-1 Catchment Area

(2) General meteorology

According to classification of Thorthwaite, climate of the Study area falls in subtropical climate. The wet season (from May to October) differs discriminatingly from the dry season (November to April) through the year. The Study area belongs to a region with fewest precipitations of the Republic (Fig. 3.3.2-1).

Temperature and humidity are less variation to a time-dependent change and a difference between places.

Fig. 3.3.2-2 shows the highest, lowest, and mean temperatures, relative humidity, evaporation, and precipitation by month.

(3) Meteorological characteristics

1) Precipitation

Precipitation data from La Ceibita and Agro Santiago station prove that annual precipitations increase corresponding to the altitude. The farmer registers an annual precipitation of about 900 mm while the latter about 1,400 mm. On the basis of yearly statistical data obtained, a precipitation correlation curve (Fig. 3.3.2-1) is obtainal for a quantitative relationship. The correlation curve proves that Agro Santiago in the mountain land has 1.35 times precipitations as big as those of La Ceibita in the plain land.

In addition, the mean catchment precipitation was obtained at Casa de Tablas on the Ostua River by the Thoisens method, and is 1.286 times bigger than the precipitation at La Ceibita and 0.95 times that at Agro Santiago. Listed below is the rate of precipitations in the wet season and the dry season, making up the total precipitation for each station.

	Wet season	Dry Season
La Ceibita	95	5
Agro Santiago	93	7

Precipitations in the wet season vary greatly with years. This is found from the fact that precipitations in the wet season has large standard deviations (Fig. 3.3.2-3). Data from La Ceibita station indicates that precipitations fall in a slump during the wet season. This shows that irrigation is necessary even in the wet season.

The feature of precipitation in the Area is the local heavy rain in a short period. Fig. 3.3.2-4 shows the result of probability analysis based on time-precipitation data of La Ceibita station.

2) Sunshine radiation and sunshine duration

Sunshine radiation was obtained from data of sunshine duration which means radiation is received by plant. Sunshine radiation is the sum of short wave radiation and long wave radiation. Mean daily sun radiation in the Area is within a range of 120 to 170 w/m^2, and sufficient for photosynthesis of plant (Fig. 3.3.2-5). Sunshine duration per day by month ranges from 5.8 to 8.6 hours, and sunshine duration becomes longer in the dry season (Fig. 3.3.2-5).

3) Wind

La Ceibita station registers a mean wind speed of 4.1 to 7.8 km/hr by month, which falls in a gentle wind (Fig. 3.3.2-5). Wind speed tends to increase in the dry season.

4) Temperature and humidity

La Ceibita station registers a mean daily temperature of 20 to 24°C (1968 to 1988) by month, making warm climate throughout the year (Fig. 3.3.2-6).

The same station registers a mean daily relative humidity of 58 to 78% (1966 to 1988), which is relatively high even in the dry season (Fig. 3.3.2-6).

5) Evaporation and evapotranspiration

According to measurements (1970 to 1988) by A-pan method in La Ceibita station, mean daily evaporation ranges from 3 mm to 7.8 mm, and becomes larger in March and April.

Potential evapotranspiration (ETo) was obtained using the Penman method (Fig. 3.3.2-7).

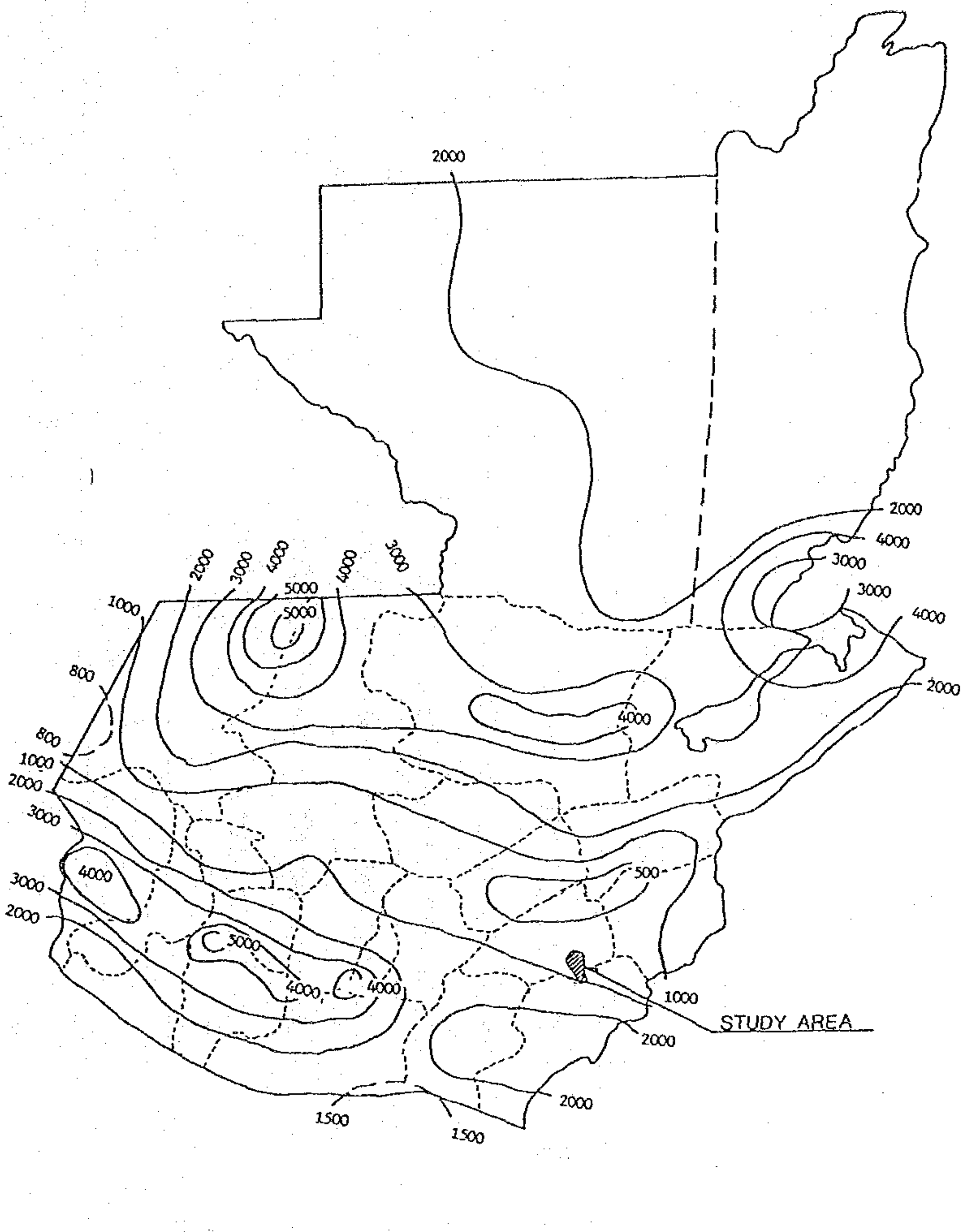
A relationship of ETo=0.81 Epan is obtained between pan evaporation and ETo by the Penman method. In addition, La Ceibita station registers observations with the Pinche atomometer together with Pan-evaporation. A relationship of potential evapotranspiration by the Penman method with these observations is ETo=1.00 Epiche.

The Penman method uses many meteorological elements as variables. Where lack of data prevents calculation, the above equations were used to obtain potential evapotranspiration.

Table 3.3.2-1 Available Meteorological Data

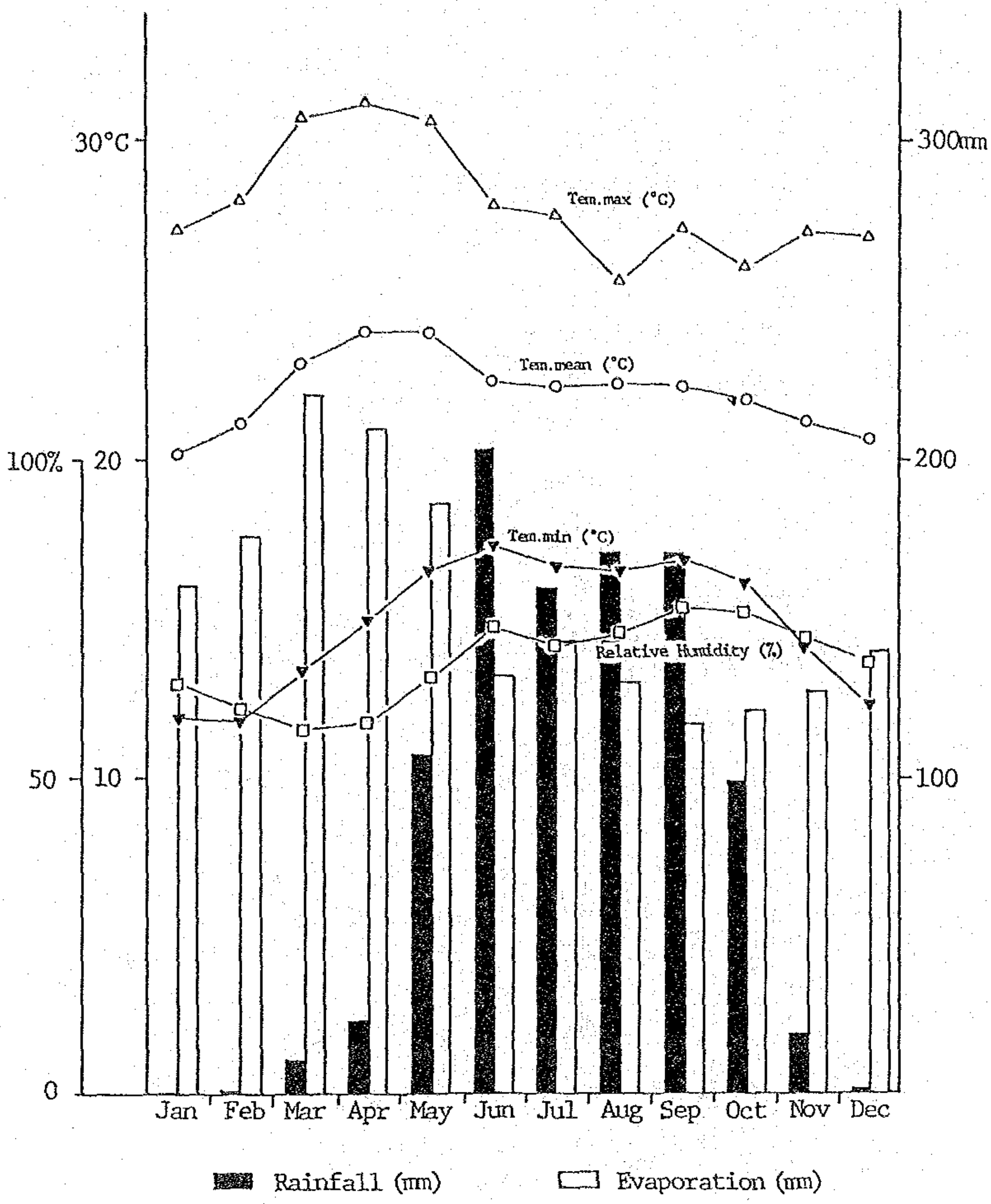
	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87
PAN EVAPORATION AT LA CEIBITA	×	×	×	×	×	×	×	×	×	×	×	×	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	×
SUNSHINE HOUR AT LA CEIBITA	×	×	×	×	×	×	×	×	×	×	×	×	△	△	△	○	○	○	○	○	○	△	○	△	○	△	△	△	○	×
RELATIVE HUMIDITY AT LA CEIBITA	×	×	×	×	×	×	×	×	×	×	×	△	△	△	△	△	△	△	△	△	△	△	△	△	△	○	○	△	○	×
DAILY AVERAGE TEMPERATURE AT LA CEIBITA	×	×	×	×	×	×	×	×	×	×	×	○	△	△	△	△	△	△	△	△	△	○	△	△	△	△	△	△	×	×
WIND VELOCITY AT LA CEIBITA													△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	×
RAINFALL AT LA CEIBITA	×	×	×	×	×	△	△	△	○	○	○	○	○	△	○	△	○	△	○	○	○	○	○	○	○	○	○	○	○	×
RAINFALL AT AGRO SANTIAGO	○	○	○	○	○	○	○	○	○	○	○	○	○	○	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87

Note ×: non data
△: incomplete
○: complete



Unit ;mm

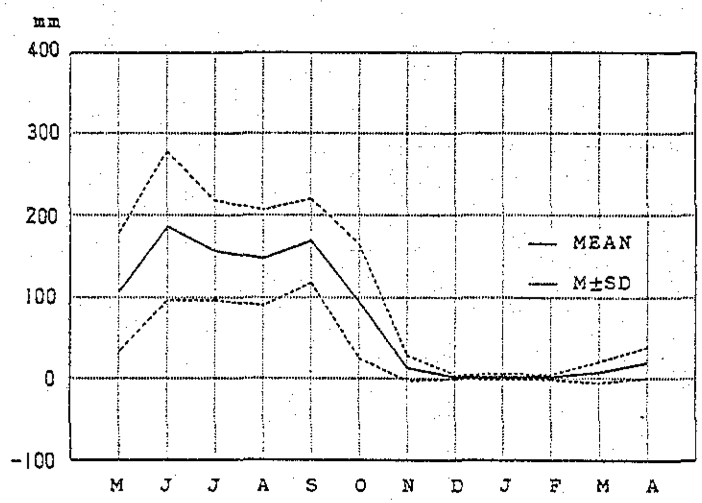
Fig. 3.3.2-1 Isohyet Map



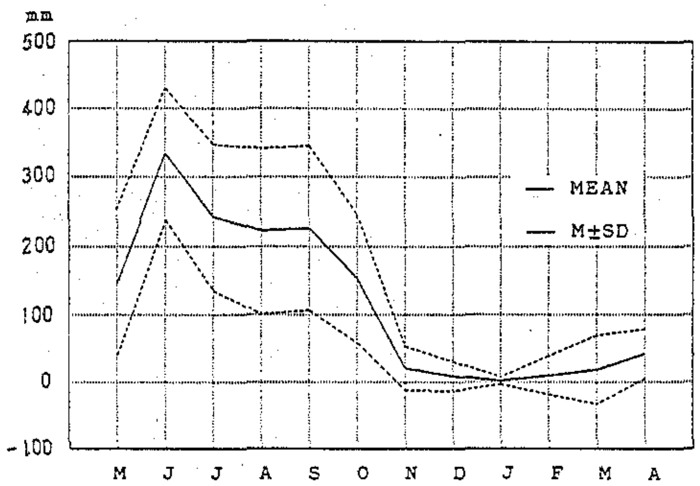
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tem.mean (°C)	20.2	21.1	23.0	24.0	24.0	22.5	22.3	22.4	22.3	21.9	21.2	20.6
Tem.max (°C)	27.2	28.1	30.7	31.2	30.6	28.0	27.7	25.6	27.2	26.0	27.1	27.0
Tem.min (°C)	11.9	11.8	13.4	15.0	16.5	17.3	16.6	16.5	16.8	16.1	14.1	12.3
Relative Humidity (%)	65	61	58	59	66	74	71	73	77	76	72	68
Rainfall (mm)	0.67	1.04	10.96	23.88	107.05	203.38	159.52	171.81	170.38	98.32	18.29	0.96
Evaporation (mm)	161.2	176.4	220.1	210.0	186.0	132.0	142.6	130.2	117.0	120.9	126.0	139.5

Fig. 3.3.2-2 Meteorological Characteristics

MONTHLY PRECIPITATION AT LA CEIBITA



MONTHLY PRECIPITATION AT AGRO DE SANTIAGO



MONTHLY PRECIPITATION OVER RIO OSTUA CATCHMENT
AT CASA DE TABLAS

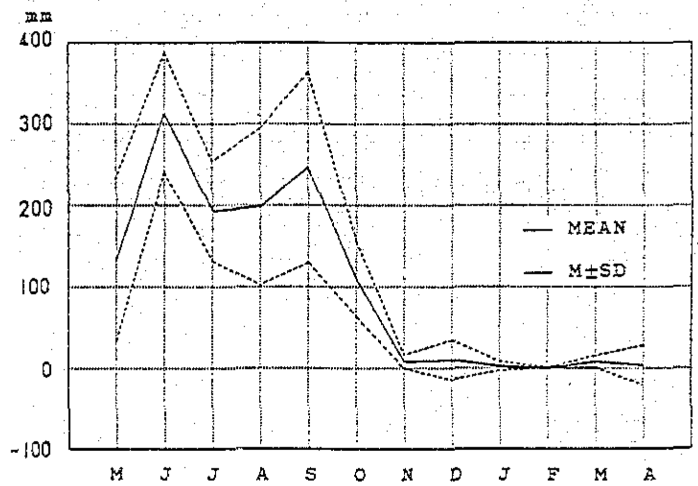


Fig. 3.3.2-3 Monthly Precipitation

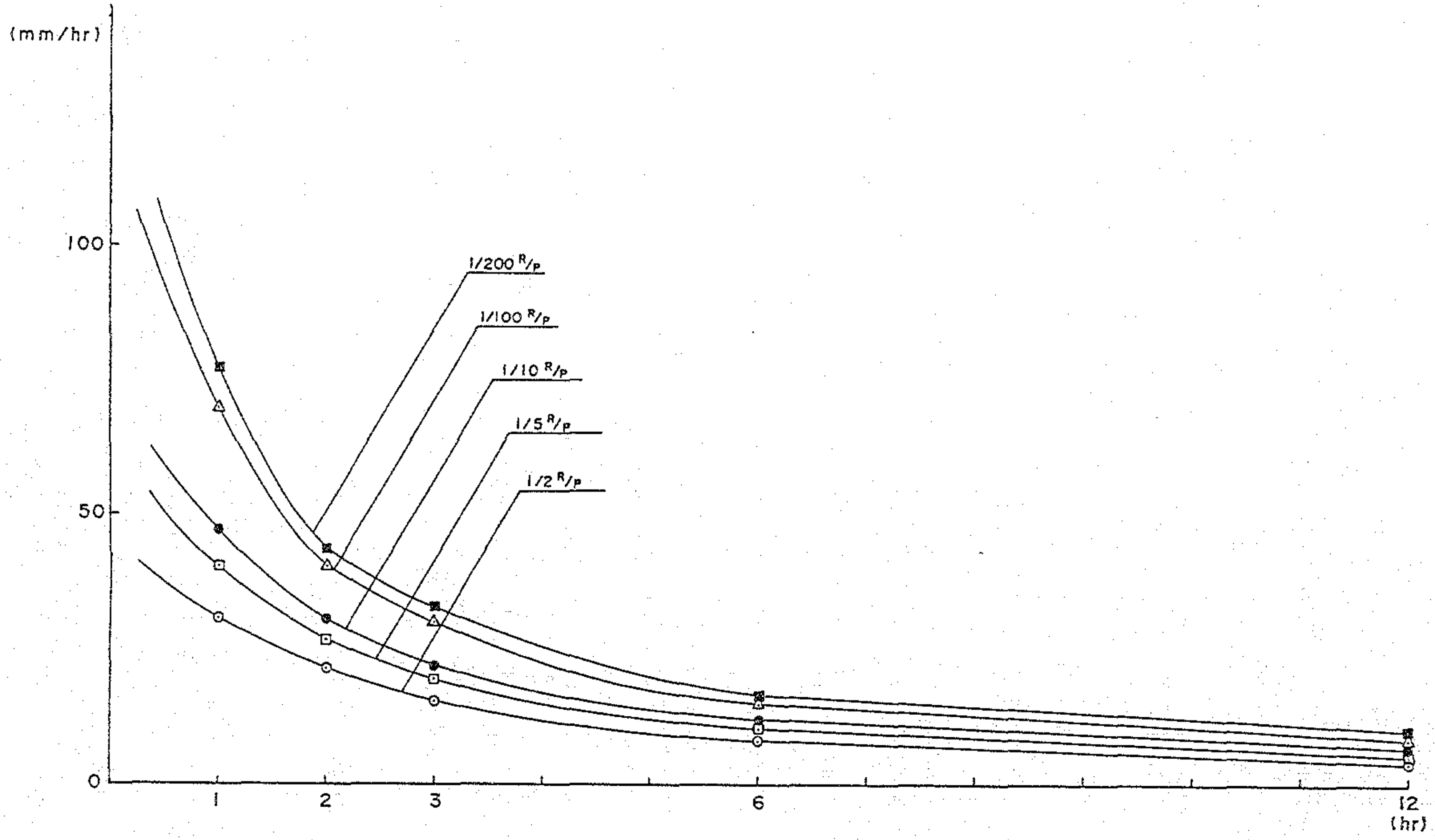


Fig. 3.3.2-4 Intensity - Hour Curve

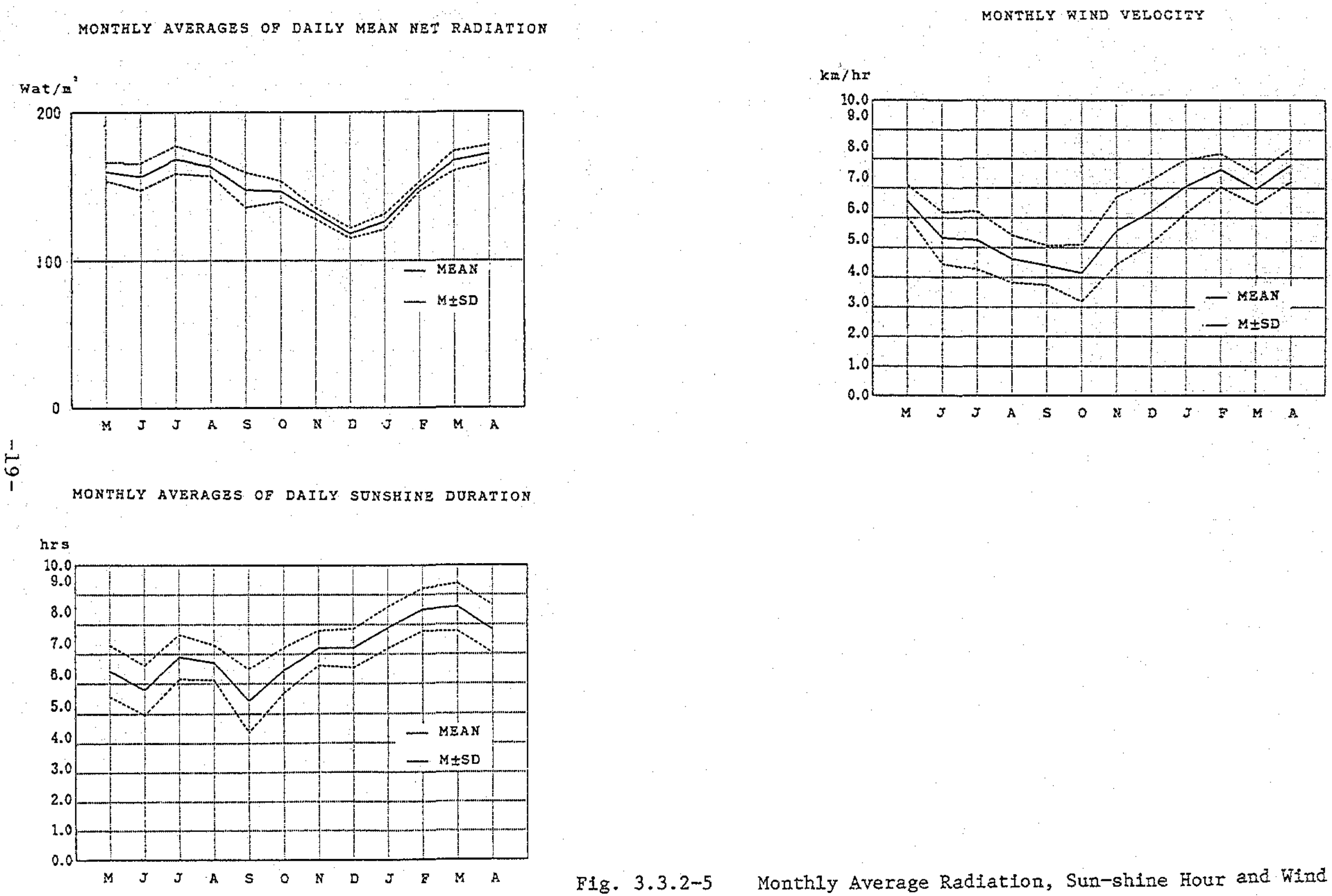


Fig. 3.3.2-5 Monthly Average Radiation, Sun-shine Hour and Wind Velociy

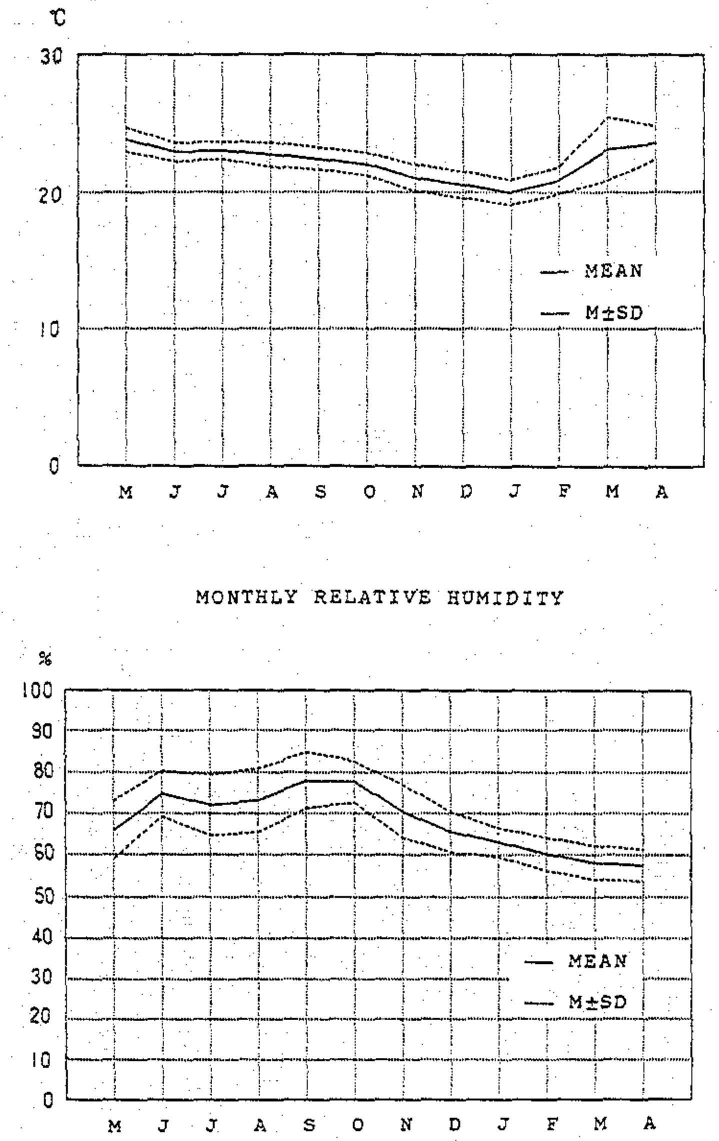


Fig. 3.3.2-6 Monthly Average Temperature and Relative Humidity

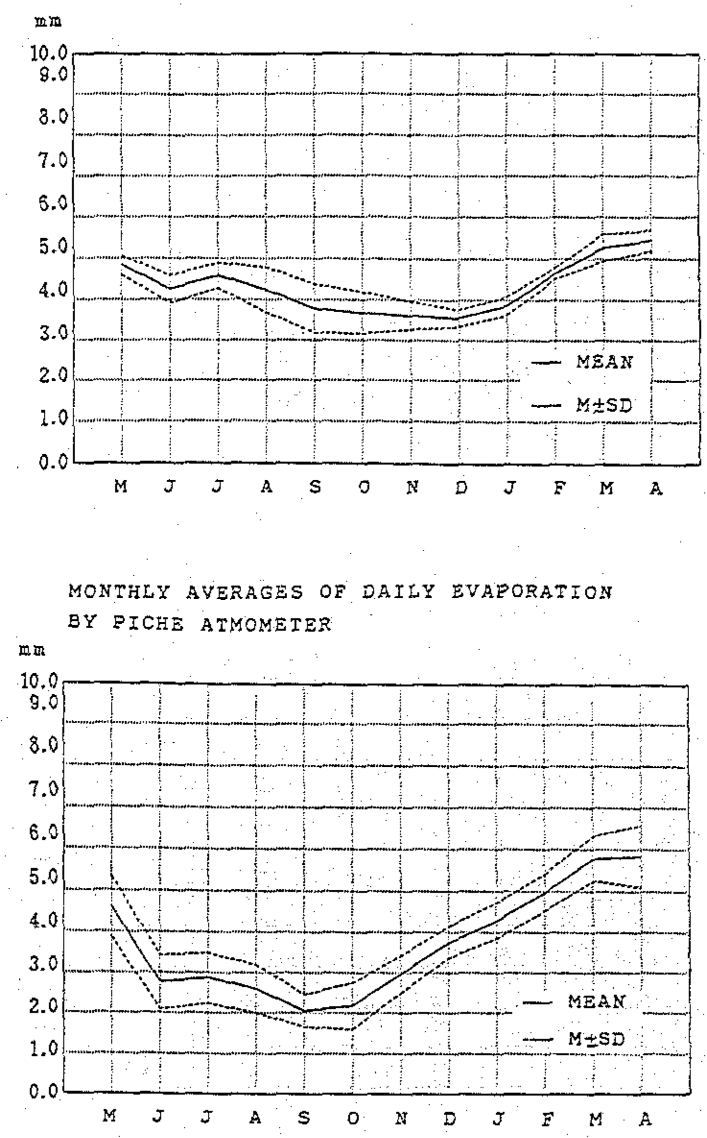


Fig. 3.3.2-7 Monthly Average Evaporation and Evapotranspiration

3.3.3 Hydrology

(1) Hydrological station and existing data

The Study area has only one hydrological station at Casa de Tablas on the Ostua River. The station is located to the west-northwest of Monjas urban area, and continued observations until large flood between 1970 and 1982. Casa de Tablas station keeps many data of discharge at low level since 1970.

Table 3.3.3-1 shows the available hydrological data.

(2) Runoff characteristics

In the Study area runoff analysis is oriented to the upstream area of Casa de Tablas where the station is located. A relation between annual runoff and annual catchment precipitation was studied and led to the assumption that years before 1970 falls in the wet year and years after 1970 in the dry year. Annual mean runoff discharge is estimated at 170 x 10^6 m^3 at the point of the station, with a great standard deviation of 88 x 10^6, and indicates significant changes by years (Fig. 3.3.3-1). The maximum discharge in the past was studied and led to the assumption that the maximum discharge registered in 1982 is interpreted into the runoff discharge in a probability year of 200 years or more (Fig. 3.3.3-2).

(3) Runoff analysis

Runoff analysis uses the following rational formula.

$$Q = \frac{1}{3.6} f \cdot r \cdot A$$

where Q: runoff discharge (m^3/sec)
A: catchment area (km^2)
f: runoff coefficient
r: precipitation intensity in flood reach time (mm/hr)

No hourly precipitation data at Agro Santiago is available that has significant influence on runoff discharge at Casa de Tablas. Therefore, hourly precipitation intensity was obtained from hourly precipitation at La Ceibita using the above correlation, and was subjected to probability calculation (Appendix 3.2.3). The runoff coefficient of 0.72 was obtained at Casa de Tablas on the Ostua River, and used. Table 3.3.3-2 shows the assumption of flood discharge at Casa de Tablas in each probability year.

Table 3.3.3-1 Available Hydrological Data

	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87
DAILY AVERAGE WATER LEVEL AT CASA DE TABLAS	×	×	×	×	×	×	×	×	×	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	×	×	×	×	×	×
DAILY AVERAGE DISCHARGE AT CASA DE TABLAS	×	×	×	×	×	×	×	×	×	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	×	×	×	×	×	×
	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87

×: non data

Δ: incomplete

○: complete

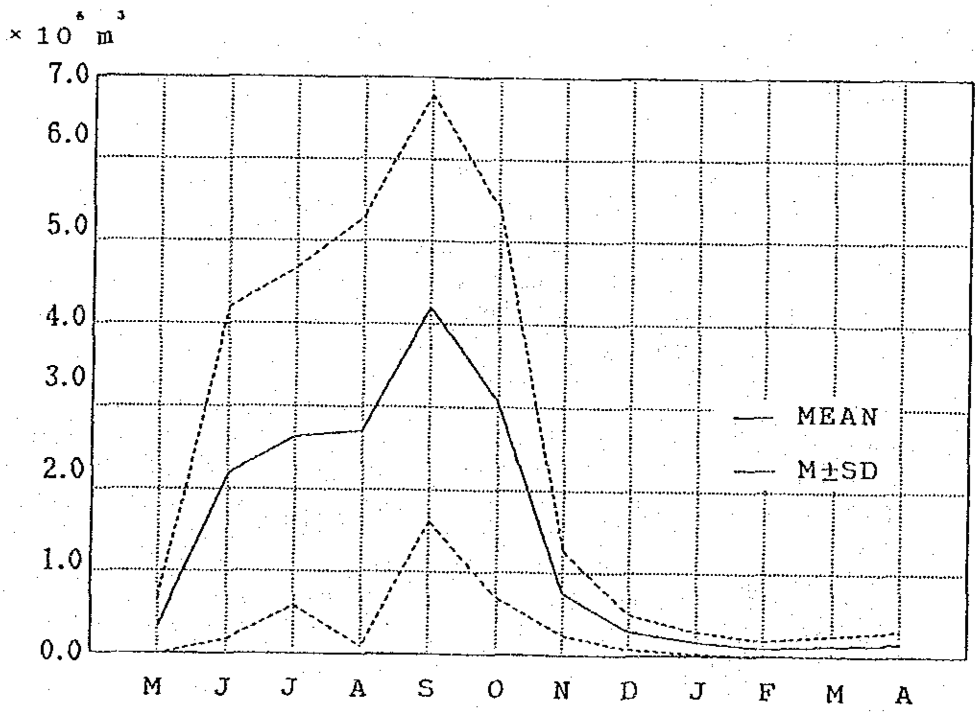
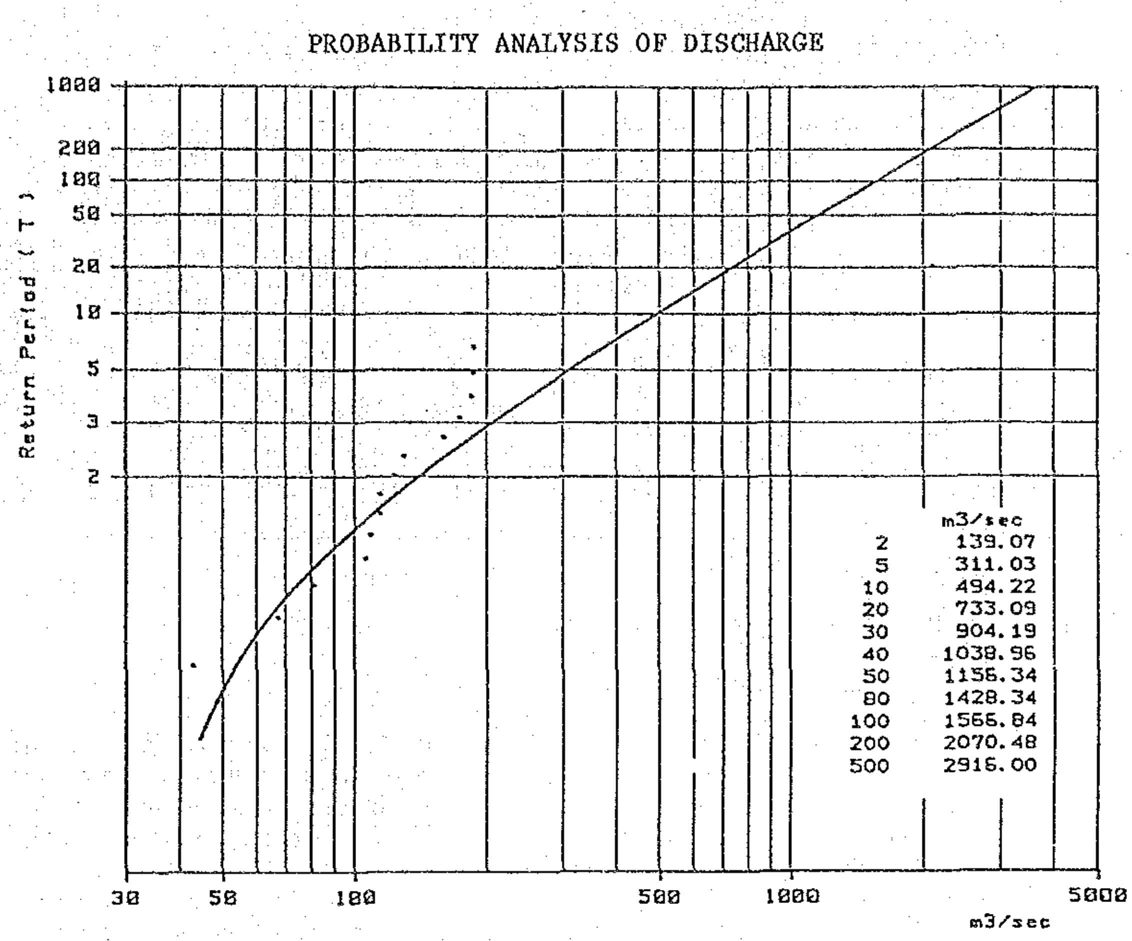


Fig. 3.3.3-1 Monthly Average Discharge



Yearly Maximum Water Level and Discharge at Casa de Tablas

Year	Data	Water Level (m)	Discharge (m^3/s)
1967	6, Oct.	2.024	123.27
1968	25, Oct.	2.340	173.98
1969	2, Jul.	2.400	184.76
1970	2, Sep.	2.410	186.60
1971	2, Oct.	3.500	452.66
1972	25, Jul.	2.260	160.18
1973	14, Oct.	2.410	186.60
1974	28, May	1.960	114.21
1975	7, Oct.	2.070	130.03
1976	4, Sep.	1.920	108.83
1977	26, Sep.	1.960	114.21
1978	16, Jul.	1.900	106.08
1979	3, Jun.	1.700	81.45
1980	28, Jul.	1.300	43.08
1981	16, Sep.	1.570	67.43
1982	19, Sep.	6.700	2116.90

Fig. 3.3.3-2 Probability Analysis of Flood

Table 3.3.3-2 Estimation of Flood Discharge at Dam Sites

Dam Site	Catchment Area (km2)	Lag time (hrs)	Precipitation (mm)				Peak Discharge (m^3/sec)			
			5 year	10 year	100 year	200 year	5 year	10 year	100 year	200 year
Ostua	177.0	1.9	29	31	42	48	1027	1097	1487	1700
Blanco	36.0	0.9	42	49	72	81	302	352	518	583
Guirila	26.0	1.1	38	44	65	74	198	229	338	384
S. Pedro	40.0	0.6	48	56	86	96	384	448	688	768
Achiotes	13.0	0.5	50	59	91	101	130	153	237	263

3.3.4 Geology and Seismology

(1) Outline of geology

The mountain area surrounding the Basin is composed of volcanic rocks while the basin river deposit and pyroclastic flow deposits (pumice flow, welded tuff), pyroclastic materials. More particularly, widely distributed in the mountain area are pyroclastic rocks (volcanic breccia, tuff breccia, and tuff), pyroclastic materials (volcanic ash, pumice, and scoria), and volcanic rocks, all of which were erupted and deposited from the end of the Tertiary to the Quaternary, forming the basement of the Basin. Covering the basement rock, pyroclastic materials and sediments (sand, gravels, silt, clay, etc.) are interbedded to compose the Basin. Fig. 3.2.4-1 shows the general geological map, and Appendix 3.2.4 shows distribution and features of each geological unit.

(2) Hydrogeology

1) Distribution and properties of aquifer

In the Study area, there are two hydrogeological units: impermeable bedrocks and alluvial sediments. At present, groundwater pumping sectors correspond to the area where alluvial sediments are predominant near rivers, and the end of fans.

Judging from the hydrogeological profile obtained from the existing boring logs and the result of electric prospection, several layers of clay, sandy clay, volcanic ash, and pumice are interbedded between gravel, sand, and silt layers 5 - 20 m below the surfaces. This sandy gravel layer is the aquifer targeted by shallow wells. Under this layer there are two sand and gravel layers with relatively large thickness; the upper layer has a thickness of 30 - 40 m while the lower layer 30 - 90 m. These layers are overlayed and underlayed by clay layers containing slight fine sands (Fig. A.3.2.4-4). From layer distribution for each sector, it is assumed that many sand and gravel layers are discontinually distributed at the center of the Basin while the sand and gravel layer with relative continuity is distributed in the area with a small gradient.

The outline of hydrogeology for each sector and the result of electric prospection are discussed in Appendix 3.2.4.

As to properties of the aquifer, the following results are obtained from the simplified continuous pumping test during well digging and the pumping test conducted in the present Study (Tables A.3.2.4-1 to 3, Figs. A.3.2.4-8 to 10).

	Specific capacity (m^3/day/m)	Transmissivity (m^2/sec)	Storativity
Mojarritas Sector	125 - 623	7.3×10^{-5} (4.3×10^{-4})*1	3.6×10^{-1}
San Pedro Sector	890*2	1.2×10^{-3}	9.7×10^{-1}
Other Sector (surroundings of the Guirila and the Ostua Rivers)	38 - 190		

*1 Measurement: recovery method
*2 Measured values of only one well

2) Flow of groundwater

Basically, groundwater distributed in the Study area is furnished by rainfall in the wet season. However, groundwater is differently accumulated depending on locations of distribution. Groundwater in the shallow layer is supplemented by precipitation penetrated in the Basin while groundwater in the deep layer by precipitation in the mountain area.

Flow of groundwater is affected by river distribution, topographical gradients, geological characteristics of the aquifer. In the Area, the whole Basin seems to form a natural underground reservoir with a water barrier, and groundwater flows down toward rivers, which are "drainage canal". Flow of groundwater may be summarized as shown below.

- Groundwater table in the gentle slope at the piedmont is inclined toward the plain land at a gradient of 1/3 to 1/240.
- In the alluvial fan, groundwater table is shallow at the fan top, deep at the fan center, and again shallow at the fan end.
- In the plain area with a gentle gradient of about 1/100, flow is gentle because of a hydraulic gradient of 1/600.
- Finally, groundwater flows into the Ostua River. The Study area may be divided into north and south blocks (Fig. 3.2.4-11).

3) Groundwater balance

Groundwater balance in whole Monjas Basin may be found in the following equation assuming that soil moisture remains unchanged.

$$P = D + E + G$$

where, P = Precipitation
D = Surface runoff
E = Evapotranspiration
G = Groundwater penetration

The annual average precipitation in the mountain area (Agro Santiago, A: 400.3 km^2) and in the flat area (La Ceibita, A: 264.7 km^2) are 1,387 mm and 955 mm, respectively according to data for past ten years. Therefore, the annual average precipitation in the Basin is obtained from the following calculation.

$$1,387 \text{ mm} \times 400.3 \text{ km}^2 + 955 \text{ mm} \times 264.7 \text{ km}^2 \doteqdot 808,000,000 \text{ m}^3$$

In the second, the runoff discharge of the Ostua River at Casa de Tablas is 174,000,000 m^3 according to discharge data at Casa de Tablas for 15 years (1967-1981). Where runoff coefficient in the mountain area of Tertiary formation is 0.75(:f1) and runoff coefficient in the plain land is 0.5(:f2) in the downstream area, the runoff discharge at the exit of the Monjas Basin is obtained in the following equation.

$$Qct = R1 \times A1 \times f1$$
$$Qout = R2 \times A2 \times f2$$
$$Qoutt = Qct + Qout$$

where, Qct : annual runoff discharge at Casa de Tablas
Qout : annual runoff discharge at the exit of the Basin
Qoutt: total annual runoff discharge at the exit of the Basin
R_1 : annual average precipitation at Agro Santiago
R_2 : annnual average precipitation at La Ceibita
A_1 : 400.3 km^2, A_2 = 264.7 km^2
R_1 : 1.35 R_2, f_1 = 0.75, f_2 = 0.5

$$\text{where, } \frac{Qct}{Qout} = \frac{R1 \times A1 \times f1}{R2 \times A2 \times f2} = \frac{R1 \times A1 \times 0.75}{\frac{R1}{1.35} \times A2 \times 0.5}$$

$$= \frac{0.75\ R1 \times A1}{0.370\ R1 \times A2} = 2.027 \cdot \frac{A1}{A2}$$

$$Qout = \frac{Qct\ .\ A2}{2.027\ A1}$$

$$Qoutt = \frac{Qct\ .\ A2}{2.027\ A1} + Qct$$

The above constants are calculated as follows:

Qoutt = 0.326 . Qct + Qct = 1.326 Qct
= 1.326 x 174,000,000 m^3 = 231,000,000 m^3

The annual penetration quantity in mountain area composing of welded tuff and hard volcanic ash is estimated at 50 mm. Therefore, if this penetration quantity is deposit quantity, the deposit quantity is estimated as follows:

50 mm x 400.3 km^2 = 20,000,000 m^3

Therefor, the water balance is calculated as follows:

808,000,000m^3 - 231,000,000m^3 - 20,000,000m^3 = 557,000,000m^3

Assuming that this balance is annual evapotranspiration, it is interpreted at about 838mm. On the other hand, if rainfall days in the Area are 180 days, or 6 months from May to October, annual average evapotranspiration by Penman method is 1,838 mm, and evapotranspiration in this period is 799mm.

Therefore, evapotranspiration obtained from water balance is considered almost realistic in that rainfall is concertrated on the above period and evaporation and evapotranspiration take place in the Area. This leads to the assumption that annual average accumulation in the Area is about 20,000,000m^3. When this volume is subtracted by about 1,000,000m^3, flow-out of a spring (near Agua Tibia), the present groundwater pumping discharge 6,350,000m^3 is equal to about 34% of the accumulated volume.

4) Groundwater quality

Table 3.2.4-4 shows the groundwater quality results of shallow and deep wells in the Study area. Fig. A.3.2.4-13 shows a key diagram which plots the above resutls. Studies indicate that almost all groundwater belongs to carbonic-calcium type. Irrigation water is classified into S1 (low alkali) in alkalinity, and into C1 (low salt water) and C2 (middle salt water) in Electric Conductivity. This tells that all groundwater is suitable for irrigation and useable without treatment.

5) Utilization of groundwater

Groundwater is used for irrigation and domestic use in the Study area by means of machine dug deep wells and shallow wells, respectively. Potable groundwater is supplied in Monjas by spring water. Thus groundwater is one of important water resources in the Area.

More than 1,000 shallow wells are widely scattered in the Area. All shallow wells are manually dug, and most of them are 70-90cm in diameter and 6-20m in depth. Of which 10m in depth is predominant. Generally, water layer thickness is 1-3m, and water is lifted by hand. This type of groundwater shows some troubles such as reduction in water table, an increase in salinity, and pollution in the dry season, and is not useable in some areas.

Groundwater irrigation by deep wells have been practiced for 15 years among large-and middle scale farmers. Main development sectors are ① Mojarritas sector, ② San Pedro sector, and ③ others (around the Guirila River and Ostua River) (Fig. A.3.2.4-3 and Table A.3.2.4-5).

There are 37 deep wells in total in the Study area, and 31 wells are in operation. Total pumping discharge is estimated at about 6.5 MCM. The deep well has a depth of 55 - 90 m from ground surface, a casing diamater of about 200 mm, and a well diameter of about 100 mm is predominant. All screens are of slot type, and incompletely gravel packing often clogged. In some wells, intial water lift potential is greatly reduced. Some screen positions do not agree with aquifer thickness. In addition, well digging techniques have some problems, and several deep wells require repairs. All wells but one are provided with electric submergeble pumps.

Some deep wells adjacent to one another at a distance of 300 m suffer from a including sand due to a rapid fall of water table.

Groundwater development requires an initial cost per well of about Q70,000 (such as digging cost and pump cost) and annual operation and maintenance cost of Q200-Q330 per hectar-year (such as electric charges and maintenance expenses). Operation and maintenance cost are expensive as compared with initial investment cost (Table A.3.2.4-7). This causes only large- and middle-scale farmers to be able to employ groundwater irrigations. They are engaged in intensive cultivation of vegetables with higher potential profitability.

As the end of 1987 the Government announced an increase in electric charges by 40%, which seems to cause many problems with future utilization of groundwater resources from the view point of farm household management.

(3) Seismology

The Republic experienced about 10,240 sensible earthquakes for 42 years from 1941 to 1982 according to the annual seismology reports of INSIVUMEH for 5 years from 1978 to 1982. These earthquakes are principally traced to the following 2 zones.

- Pacific Ocean coast
- Northwest line connecting Santa Rosa - Totonicapan - Chimaltenango - Guatemala

The past earthquakes were within a magnitude range from 3 to 6. However, Jalapa Department to which the Study area belongs has experienced few earthquakes.

An earthquake registered the greatest magnitude of 5 within a range of 100km in radius from the center of the Study area.

The seismic intensity for the design of dams should be decided in consideration of the maximum acceleration experienced at dam site.

Acceleration at the dam site was calculated by the Okamoto's formula. There are formulas published by Gutenberg - Pichter, and Esteva - Posenblueth, however the Okamoto's formula provides values larger than the others.

$$\text{Log}_{10} \frac{Ac}{640} = \frac{(D + 40)}{100} \times (-7.604 + 1.7244M - 0.1036M^2)$$

Where, Ac = acceleration, (Gal)
M = magnitude
D = distance from dam site to epicentre (km)

The maximum acceleration observed at the dam site is 38.43 Gal in representative values obtained from data measured between 1978 and 1982, and the ratio of seismological acceleration to gravity acceleration is 0.04. This value is extremely small to effect the dam site. On the other hand, a paper on the seismology in the Republic on architechture was published by Stanford University. A seismic intensity map is quated from the paper. According to the paper the Study area belongs to the major damage zone, and in the case of essential facilities, the seismic intensity for the design applies 0.45. This consideration is for the design of buildings. On the case of a fill dam, a considerable allowance is made for phisical property values and stability calculations of fill materials because of many uncertain factors for safety.

From the above view point, the seismic intensity for the design of the dam applies 0.12 in consideration of the acceleration obtained from the data, the paper of Stanford University and the seismic intensity of Japan.

3.3.5 Soil and Land Classification

(1) Soil

Soil distributed in the Study area is classified according to Soil Taxonomy and shown in Table 3.3.5-1, and a soil map shown in Fig. 3.3.5-1 indicates distribution for each soil category.

Table 3.3.5-1 Soil Classification and Distribution Area

Order	Sub-order	Great-group	Sub-group	Area (ha)	%
Vertisol	Usterts	Chohusterts	Typic-Cromusterts	4,279	60
Vertisol	Usterts	Pellusterts	Typic-Pellusterts	143	2
Inceptisol	Tropepts	Ustropepts	Vertic-Ustropepts	2,139	30
Inceptisol	Ochrepts	Durochrepts	Vetric-Curochrepts	71	1
Alfisol	Ustalfs	Durustalf	Vertic-Durustalf	71	1
Alfisol	Ustalfs	Haplustalfs	Vertic-Haplustalfs	71	1
Sub-total				6,774	
Others*				356	5
Total				7,130	100

* Urban area, road, river, forest, etc.

Soil for each order is as outlined below.

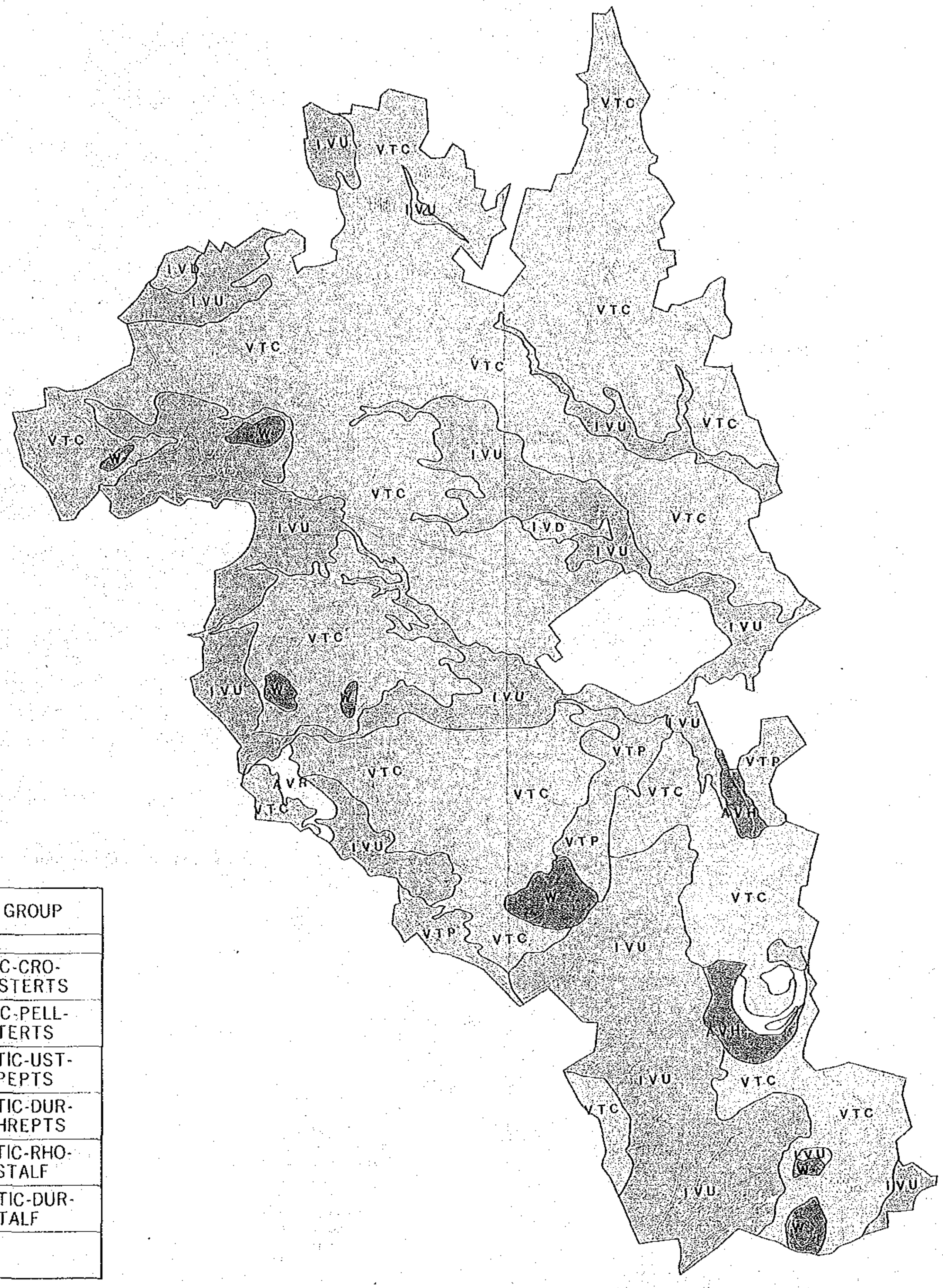
1) Vertisol

Vertisol is widely distrubuted in the Study area, and covers an area of about 4,420 ha (62%). Most of the Area is occupied by bright Chromusterts with soil color intensity of 1.5 or more. On the other hand, darkish Pullusterts is only distributed to the southwest of Monjas and a limited area near the mountain.

This type of soil looks darkish, and fertile irrespective of less leaf mold. The darkish soil layer is deep, but some lower layers (50 cm or less) exhibit the duripan.

This soil has high clay content, and consitituent clay mineral consists of 2:1 type. This soil markedly swells and shrinks according to dry and wet conditions, and develops cracks in the dry season while it turns muddy in the wet season. As a result, this soil has an angulated block structure or semi-blocky structure, having inverse influence on agriculture work. Some lower layers show the concretion of grayish white calcium carbonate of 0.5 - 1.0 cm in large.

Fig. 3.3.5-1 Soil Map
Mapa de Suelos



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UNIT	ORDER	SUB ORDER	GREAT GROUP	SUB GROUP
V T C	VERTISOL	USTERTS	CROMUSTERTS	TYPIC-CRO-MUSTERTS
V T P	〃	〃	PELLUSTERTS	TYPIC-PELL-USTERTS
I V U	INCEP-TISOL	TROPEPTS	USTROPEPTS	VERTIC-UST-ROPEPTS
I V D	〃	OCHREPTS	DUROCHREPTS	VERTIC-DUR-OCHREPTS
A V R	ALFISOL	USTALF	RHODUSTALFS	VERTIC-RHO-DUSTALF
A V H	〃	〃	DURUSTALFS	VERTIC-DUR-USTALF
W	HILL			

The pH of soil is generally 5.5 or more, and sub-soil shows the lower the acidity. Most soil has relatively much exchangeable calcium and magnesium, and base saturation of 70% or more. Most top-soil has a cation exchangeable capacity of 25 meq or more while the rather coarse surface layer a smaller capacity. Exchangeable sodium accounts for only 5% or less of the total exchangeable cation, therefore sodium accumulation of the soil is not serious.

2) Inceptisol

Inceptisol is widely distributed in the Study area second to Vertisol, and covers an area of 2,210 ha (31%). This soil is distributed near El Ovejero, along large and small rivers, and the west area near the mountain. This soil has insufficiently developed stratification, and has a bright Ochric surface layer.

The soil color is blackish brown, dark brown, or grayish yellow brown, and consists of loam or sandy loam with less clay content. Neither a remarkeable blocky structure nor cracks are found. As to this type of soil, the under layer 1 m or less in depth contains Durockrept which forms duripan and those distribution area is estimated about 1%.

The pH of soil shows acidity of 5.5 or less. Most of this soil has less exchangeable calcium and magnesium. Generally, this soil has a cation exchangeable capacity smaller than Vertisol.

3) Alfisol

This soil has the least distribution area (142 ha) among the 3 types of soil order, and is distributed in the higher area around San Pedro Lake and in a limited area near mountains in the southwest.

Durustalfs exhibiting the duripan is found in the Alfisol underlayer 1m or less in depth, but is distributed only in a limited area. This soil looks blackish brown or dark brown, and most sub-soil is brown or light yellow brown. The top-soil is a little coarse and, the lower the underlayer, the higher the clay content.

The pH is 6.1 or less, with rather high exchangeable calcium and magnesium content. Generally, this soil has a cation exchangeable capacity lower than Vertisol and higher than Inceptisol.

These three soil orders have a cation exchangeable capacity of 2 meq or less, excluding very few exceptions. With most soil, the lower the underlayer, the higher the value. Exchangeable sodium accounts for 3% or less of the exchangeable capacity; this ratio is an index of soil salinification. In terms of pH and exchangeable sodium content, no saline soil is found.

The profile of each soil order is shown in Fig. A.3.2.5-3.

(2) Problems with crop cultivation

Highly fertile Vertisol is principally distributed in the Study area, but has high clay content enough to cause problems because of physical properties. Careful consideration should, therefore, be given to the following points for the purpose of soil control.

- Proper water control is required because moisture content of soil governs soil hardness.
- This type of soil requires more water at the initial stage of irrigation than any other soil orders.
- Organic materials manured to this soil prove very effective in improving physical properties of the soil.
- For the purpose of preventing salt injury of soil, irrigation water should be controlled in order not to inhibit excess water in the ground.

As to Inceptisol, most soil is acidic with rather low base content and a lower cation exchangeable capacity. For this reason, correction of acidity, supplement of base, and manuring of organic matter should be required.

(3) Land capability classification

Land is classified according to the standard of USDA through review of the existing land calssification map. Table 3.3.5-2 shows the area of classified land and Fig. 3.3.5-2 shows a land classification map.

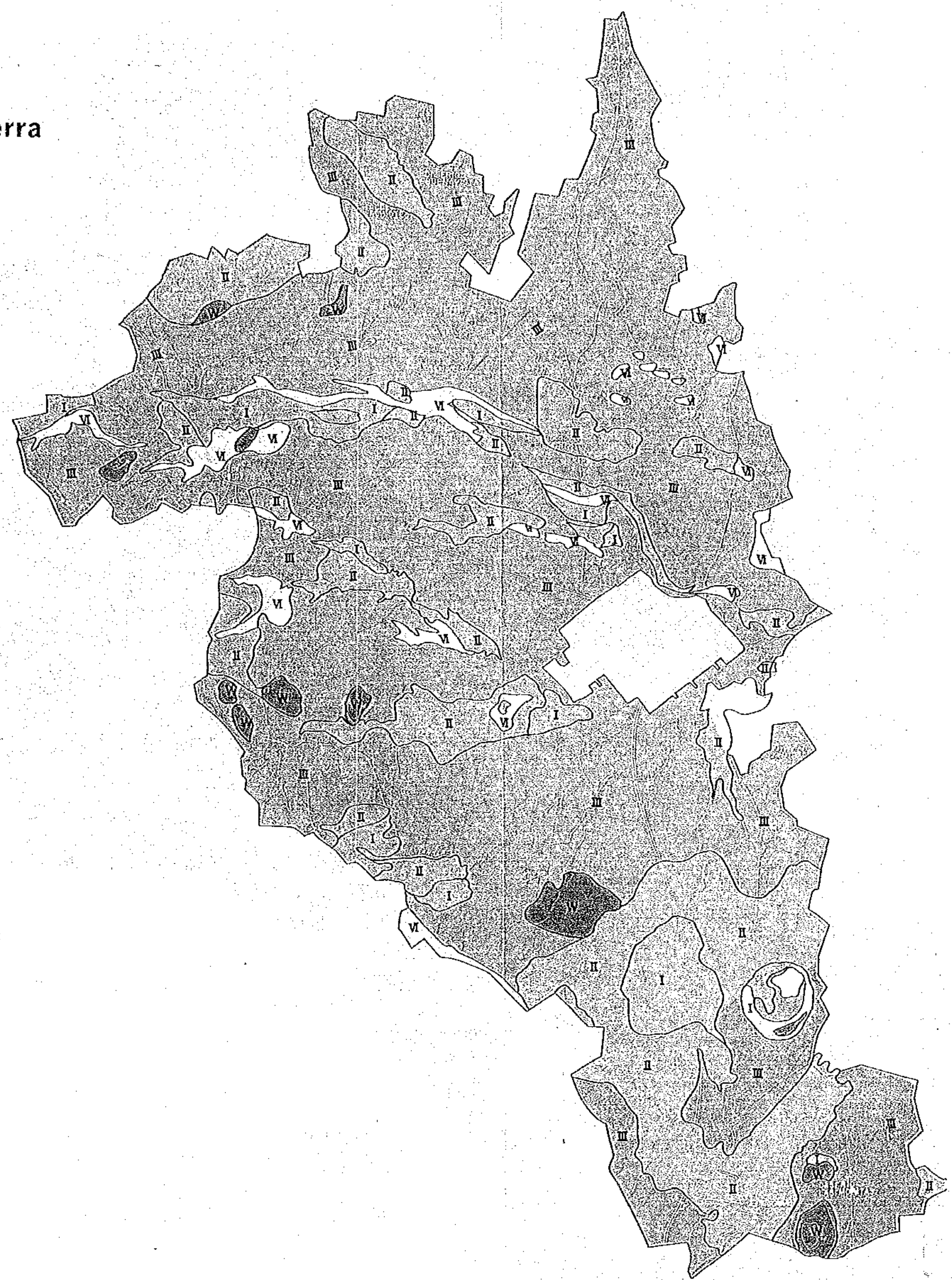
Table 3.3.5-2 Land Capability Classification

Class	Area (ha)	Ratio (%)
Land suitable for agriculture		
Class I,	342	4.8
Class II,	1,427	20.0
Class III,	4,763	66.8
Total	6,532	91.6
Land unsuitable for agriculture		
Class IV,	242	3.4
Class W	121	1.7
Urban land, etc.	235	3.3
Grand total	7,130	100

Table 3.3.5-2 proves that the class I to class III accounts for about 92% in the Study area and is regarded as suitable for agriculture. In terms of soil, class III consists of Vertisol and Alfisol while class II consists mainly of Inceptisol.

In the Republic, class W is assigned to special soil where rocks are exposed such as volcanic bodies and monadnocks and not suitable for agriculture.

Fig. 3.3.5-2 Land Capability Map
Mapa de Capacidad de la Tierra



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NO.	Class Clase	Area (ha) Area (ha)
1	I	342
2	II	1,427
3	III	4,763
4	VI	242
5	W	121
TOTAL		6,895 ha

3.4 Agriculture

3.4.1 Land Use and Land Ownership

(1) Land Use

The Study area is 7,310 ha in total, of which 5,350 ha (75%) is utilized as agricultural land. About 4,350 ha (80%) of agricultural land are ordinary upland fields while the rest 1,000 ha (20%) are in use as pasture land.

Land except agriculture land are classified such as 1,750 ha (15%) of forest, 370 ha (5%) of urban land and village, 35 ha of the lakes, and 300 ha of roads, rivers, etc.

The present land use is shown in Table 3.4.1-1 and Fig. 3.4.1-1.

Table 3.4.1-1 Present Land Use

Item		Area Jutiapa Dept.	Area Jalapa Dept.	Total	%
Agricultural land	Upland field	715	3,635	4,350	61
	Pasture	70	930	1,000	14
	Total	785	4,566	5,350	75
Forest		235	840	1,075	15
Urgan land and village		5	365	370	5
Lake		35	-	35	1
Road, river, etc.		65	235	300	4
Grand total		1,125	6,005	7,130	100

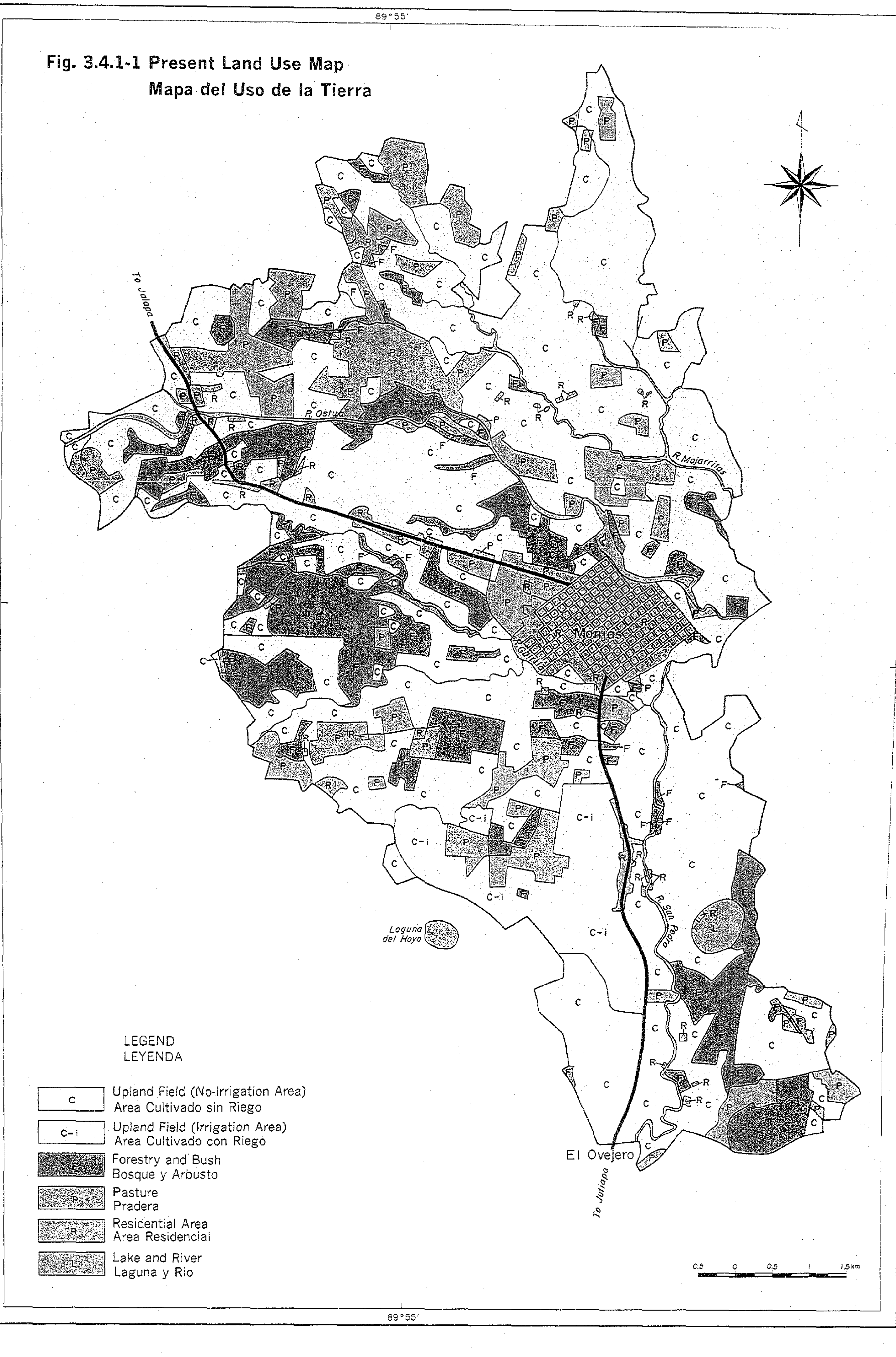
(2) Land ownership

The Republic classifies farm by scale of owned land : Microfamilies own 0.7 ha or less, Sub-families 0.7-7.0 ha, Families 7-44.8 ha, and Multi-families 44.8 ha or more.

Sub-families own about 25% of the total area, families about 30%, and multifamilies about 44%. Evidently, most land is owned by Families and multifamilies .

In terms of land distributed and owned by scale, land is divided into small sections in the Area between El Ovejero and Monjas, where many sub-families live. On the other hand, the north area has many families and multifamilies, who utilize a part of their own land as pasture, etc.

Fig. 3.4.1-1 Present Land Use Map
Mapa del Uso de la Tierra



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C	Upland Field (No-Irrigation Area) Area Cultivado sin Riego
C-i	Upland Field (Irrigation Area) Area Cultivado con Riego
F	Forestry and Bush Bosque y Arbusto
P	Pasture Pradera
R	Residential Area Area Residencial
L	Lake and River Laguna y Rio

3.4.2 Present Feature of Agriculture

In the Study area, agricultural land is classified into the upland field (4,350 ha) and pasture (1,000 ha); the former is the ordinary upland field for grain produced as the basic crop, vegetables for export, and crops for food processings, while the latter is subdivided into pasture and natural grassland.

Crops are mainly cultivated in the wet season, when maize and kidney beans are planted in more than half of the all cultivated land. Grain tends to increase both in the cropping area and in output (Table A.3.3.2-1, 2). In the dry season, broccoli, tomatoes, onions, etc. are mainly produced in some areas with irrigation facilities, but the other areas are left unused that accout for 80% of agricultufal land and are not irrigated.

Livestock production in the Study area is mainly dairy dependent on dairy and beef cattle, while other small livestock such as swine and chickens are intended for self-consumption, with the least contribution to farmers' househole economy.

3.4.3 Agricultural Production

Main crops in the Study area are outlined as below.

(1) Maize

The cultivated area is about 3,100 ha. The unit yield is 2.7-2.9 t/ha in the wet season cropping and about 3.2 t/ha in the dry season cropping, exceeding the average yield 1.6 t/ha in Jalapa Department. Production volume is about 8,400 tons and the rest of self-consumption is sold to brokers at the farm gate. Varieties recommended by ICTA are principally cropped.

(2) Kidney beans

The cultivated area is about 660ha. The unit yield is 1.1 to 1.5 t/ha in the wet season and 1.4-1.5 t/ha in the dry season, exceeding the average yield of 0.8 t/ha in Jalapa Department. Production volume is about 740 tons. The rest of self-consumption is sold to brokers at the farm gate. Varieties recommended by ICTA are mainly Cultivated.

(3) Tobacco

Tobacco is cultivated according to a contract between 2 tabacco processors and farmers. The cropping area is assigned to farmers by the processor. Tabacco is cropped mainly in the wet season. The cultivated area is about 480ha, and the unit yield is 1.4-1.8 t/ha. Production volume is about 670 tons of which about 80% are exported to the U.S.A. Processor furnish farmers with seeds, fertilizer, and agricultureal chemicals. Only the variety of "Virginia" is cultivated by about 50% of all tobacco producers.

(4) Tomatoes

The cultivated area is about 610 ha in the wet season and about 260 ha in the dry season. The unit yield is 17-24 t/ha in the wet season and 19-26 t/ha in the dry season. Production volume is about 15,000 tons of which 99% are exported to El Salvador. Variety of UC.82.B recommended by ICTA is used by about 80% of all tomato producers.

(5) Broccoli

Broccolis are cultivated on the contract basis between 4 exporters and farmers. The cultivation area is about 340ha, and the unit yield is 8-10 t/ha. Production volume is about 2,800 tons of which about 80% is exported to the U.S.A. and 14% to El Salvador. Contract conditions such as supplied materials and purchase price vary with exporters. Only the variety of "Green Valiant" is cultivated.

(6) Onion

The cultivation area is about 130 ha. The unit yield is about 8 t/ha. Production volume is about 1,100 tons and products are sold to brokers at the farm gate. About 80% of production volume are exported to El Salvador and about 12% to the U.S.A. The variety of "Chata Mexicana" is mostly cultivated.

Where crops are cultivated on the contract basis, purchasers give technical instructions to contract farmers, whose cultivating techniques are standardized. Any crop is dependent on chemical fertilizer (compound fertilizer and urea), with no organic fertilizer in use.

The present cropping pattern is shown in Fig. 3.4.3-1 and cropping area in Table 3.4.3-1

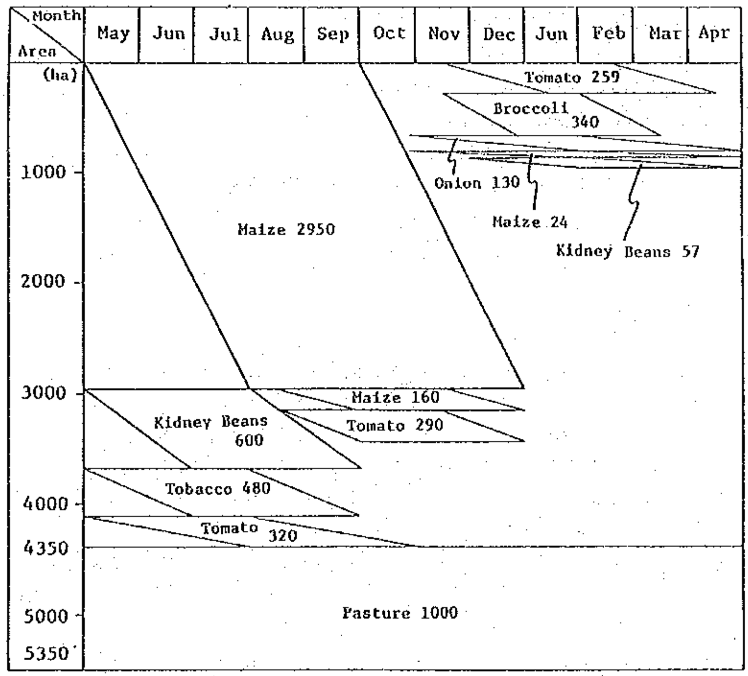


Fig. 3.4.3-1 Present Cropping Pattern

Table 3.4.3-1 Cropping Area, Yield and Production Volume of Principal Crops

Crop		Cropping area				Unit yield 3)		Productions		
		Area 1)		Ratio 2)						
		Wet (ha)	Dry (ha)	Wet (%)	Dry (%)	Wet (t/ha)	Dry (t/ha)	Wet (t)	Dry (t)	Total (t)
Maize	F.	2,950	–	67.8	–	–	–	–	–	–
	S.	160	–	3.7	–	–	–	–	–	–
Sub-total		3,110	24	71.5	0.6	2.7	3.2	8,397	77	8,474
Kidney beans		600	57	13.8	1.3	1.1	1.4	660	80	740
Tobacco		480	–	11.0	–	1.4	–	672	–	672
Tomato	F.	320	–	7.4	–	–	–	–	–	–
	S.	290	–	6.7	–	–	–	–	–	–
Sub-total		610	259	14.1	6.0	17.0	18.5	10,370	4,792	15,162
Broccoli		–	340	–	7.8	–	8.3		2,822	2,822
Onion		–	130	–	3.0	–	8.5		1,105	1,105
Grand total		4,800	810	110.4	18.7					

Note: 1) Oficina de Unida de Riego "Laguna de Hoyo" 1987 and Field Survey Datas

2) $\frac{\text{Cropping Area}}{\text{Upland Field Area}} \times 100$

3) Table A.3.3.2-4, -5
Dry: Dry Season, Wet: Wet season
F.: First Cropping, S.: Second Cropping

3.4.4 Livestock Breeding

Farm household survey shows that there are about 100 large-scale cattle breeding farmers.

A farmer breeds about 6.5 milking cows (including 3.5 dry-up cows), 0.4 stud cattle, about 13 raising cattle, and about 2.0 draft cattle in an average. The main stream is dairy dependent on dairy beef cattle. Small livestock such as swine and chicken is bred only for self-consumption, far from cattle breeding.

In the Study area, most farmers breed milking cows of a cross blood between the Brown Swiss and Cebu systems while a small number of farmers breed the Holstein. Only pasturage is employed. In the dry season, grass and pasture fade out and most farmers remove their cattle to the mountain area in Jalapa Department or pasture land along the Pacific Ocean Coast, except for some large-scale farmers. The dairy season is mainly 6 months of the wet season milkings per cow are about 3 l/day in the dry season and 5 day in the wet season. Dairy cattle serves about 8 years before being disposed of as beef cattle.

3.4.5 Agricultural Management

(1) Management scale

As to the area of cultivated land per farmer, sub-families, families, and multi-families have 2.2 ha, 14.9 ha, and 53.1 ha, respectively. The ratio of pasture land to upland field in the Area is about 2% with the sub-families, about 6% with the families, and about 37% with the multi-families (Table A.3.3.4-2). Micro-families own small land and do not play importance role in the agricultural activity.

(2) Number of farm labor

Number of families per farm household is 6.5 in the sub-families, 7.1 in the families, and 8.4 in the multi-families. Working labor per farmer of the sub-families, the families and the multi-families is 2.4, 2.8 and 3.8, respectively (Table A.3.3.4-1).

(3) Agricultural labor

Given the present cropping pattern, about 501,000 man.day are required per year (Table A.3.3.4-10). Number of agricultural laborers in the Study area is estimated at 4,180 (about 80% of population of economic activities). This means that 104,000 man.day in total are ready for employment per month. However, about 77,000 man.day in total (rate of employment : 74%) are employed even in August, when the most laborers are required. The rate of annual average employment is 40% only.

(4) Production cost and Production Value

Of main agricultural products, grain requires less production cost than vegetables. The ratio of labor cost to production cost ranges from 30% to 65%. In particular, the ratio of tobacco and onions is as high as 65% and 51%, respectively. On the other hand, the ratio of material cost ranges from 19% to 37%. The ratio of vegetables is higher than that of grain and tobacco (Table A.3.3.4-11).

In terms of net production value per unit area, tomatoes harvested in the dry season register the highest value of about Q2,400/ha, followed by vegetable in the wet season such as tomatoes, onions, and broccoli. Grain and tobacco register relatively low value (Table A.3.3.4-13, 14).

Pasture marks a net production value of about Q100/ha, which is a little higher than that of maize.

3.4.6 Marketing and Proccessing of Agricultural Products

(1) Marketing of Agricultural Products

1) Marketing Channel of Agricultural Products

Agricultural products are marketed and distributed through sales channels as shown in Fig. A.3.3.5-1.

Grain such as maize and kidney beans is sold to intermediate broker at farm gate and shipped to Guatemala, Jalapa, and Jutiapa markets. To inhibit excess price fluctuations of the grain, which is the main food of the nation, INDECA is authorized to intervene in the grain market. More particularly, INDECA purchases grain when wholesale price reduces, and discharges grain when wholesale price rises.

Tobacco is cultivated under contract concluded between farmers and tobacco processors, according to the production plan of the processor. Harvested tobacco flows through a channel which connects the farmer directly with the processor. For the purpose of quality control, the processor furnishes the farmer with onerous seeds, fertilizer, agricultural chemicals, and extension services of cultivation techniques.

Broccoli is cultivated under contract between farmers and exporters. In the Study area 4 exporters act in transaction. Each exporter provides the farmer with production materials and cultivation techniques, as in the case of tobacco.

Tomato and onions are sold at farm gate to intermediate broker and shipped to markets. Tomatoes for processing are sold to tomato processors through intermediate brokers.

2) Main Exports Countries of Vegetables

Broccoli: More than 50% of broccoli is exported to the U.S.A. by air or sea line through Guatemala city. Also partly broccoli is exported to Panama, England, and Mexico. About 12% of production volume of broccoli is exported to El Salvador by land.

Tomato: About 60% of production volume of tomato is for fresh vegetable and the rest for processing. About 33% of fresh vegetable is exported to El Salvador directly. The rest of fresh vegetable is shipped to Guatemala market, however large parts of them are exported to El Salvador.

Onion: About 28% of production volume of onion is exported to El Salvador directly. The rest is shipped to Guatemala market, however, as case of tomato, onion shipped to Guatemala market is exported to El Salvador and partly is exported to Mexico, Belice, and Honduras.

(2) Agricultural Product Precessing

No agricultural product processing facility on a large scale is found in the Study area. Small-scale facilities are managed by local farmers, for example, the tobacco primary curing house (dry oven), milk processing station, butchery, and fresh vegetable processing station (not in operation).

3.4.7 Agricultural Supporting System

(1) Agricultural Supporting Organization

Ministry of Agriculture, Cattle and Food Resources divides the whole nation into 8 regions, and establishes agricultural supporting organization for each region. The Study area belongs to the Region VI. Main agricultural supporting organizations are as shown in Table 3.4.7-1.

(2) Agricultural Test and Research Institutions

ICTA takes charge of agricultural test and research in the Area.

ICTA has a test farm of about 5.6 ha in Jutiapa, and is engaged in the seed test, origin seed production, and distribution of grain such as maize, kidney beans, and sorghum. In addition, ICTA has many display fields and test fields. In the Study area, ICTA has display fields at 14 farmhouses as well as test fields. Moreover, ICTA started test and research of vegetables (tomatoes) in 1987.

Table 3.4.7-1 Agricultural Supporting Organizations

Name of Agency	Works
Direction General de Servicios Agricolas (DIGESA)	* Control and statistics of national agricultural production. * Crop diversification. * Extension and technology transfer. * Export and import control of agricultural materials. * Certification, distribution and control of seed.
Direction General de Servicios Pecuarios (DIGESEPE)	Divided into Liverstock and Fishery <u>Livestock</u> * Control of national livestock production. * Prevention of epidemic and investigation of formula feed. * Extension and technology transfer. * Quality and hygiene control for livestock and meat productions on export and import. <u>Fishery</u> * Preservation of fishery resources, and control of fishery production, etc.
Direction Technica de Riego y Avenamiento (DIRYA)	Sub-structure of DIGESA. * Planning and study of irrigation project. * O/M of irrigation project. * Calculation of water charge. * Production control and technology transfer to water users in the irrigation area. * Organization Chart of DIRYA is shown in Fig. A.3.3.6-5
Instituto Nacional de Transformacion Agrario (INTA)	* Land reclamation and settlement planning of state land. * Transfer control of state land. * Technology transfer for land use.
Instituto de Ciencia y Tecnologia Agricola (IGTA)	* Research and test for improvement of seed, and crop diversification. * Improvement grain seed and production of foundation seed, and control of extension seed. * Improvement of cropping technology and the technology transfer.

Table 3.4.7-1 - continued

Name of Agency	Works
Instituto Nacional Forestal (INAFOR)	* Planning and execution of national development of forestry. * Research and test of forestry; seedling; re-forestation. * Control of tree diseases and conservation for natural resource. * Technology transfer to the users of tree and forestland.
Banco de Desarrollo Agricola (BANDESA)	* Financial Funds, mainly supply of credit for small and medium-scale farm.
Instituto Nacional de Comercializacion Agricola (INDECA)	* Price control, storage and marketing of cereals (maize, kidney beans, sorghum and rice, etc.) * Purchase and release of products for price fluctuation control.
Planta Procesadora de Productos Lateos de Asuncion Mita (PROLAC)	(milk powder, cheese, butter), for the purpose of price stabilization and stable supply of the products.

Farmers are supplied with seeds as follows: first, seed producing farmers purchase origin seeds from ICTA or DIGESA, breed seeds for distribution, and sell them to seed traders who in turn sell the seeds to farmers in demand. At present, 6 farmers produce such seeds, most of them breed grain (maize) seeds. Most vegetable seeds depend on import.

Fig. A.3.3.6-3 shows the chart of service of ICTA.

(3) Agricultural Extension Organization

Agricultural extension services are provided according to the plan formulated by DIGESA headquarter and DIGESA Region VI Branch.

DIGESA has agriculture extension branch in Monjas, in which one agriculutral adviser and two local instructors are at service

DIGESA formulates the extension activities plan. In accordance with DIGESA plan, the extension adviser gives instructions about new cultivation techniques to representative farmers from 10 villiages in the Study area. Finally, these techniques are transferred to farmers together with test results obtained from field test.

The extension organization has been established, but the personnel and materials of the organization are too insufficient to expect enough effect.

Agriculture extension activities are outlined in Fig. A.3.3.6-4.

(4) Agriculture Financial Organization

BANDESA is responsible for agricultural finance. BANDESA has a branch office in Jalapa, which takes charge of financing in the Study area.

Farmers are financed almost in the form of short-term loans, and borrow Q5,000 or less per loan. Loans for more amount are seldom utilized by farmers because of the taxation required.

Finance is used as summarized below.

1) Short-term loan
- . Finance is used for production materials
- . The amount of loan is decided after BANDESA in consideration of the intended crop and cultivated area.
- . Annual interest rate is 10%.
- . Finance term is about 6 months.

2) Middle-term loan
- . Finance is made for improvement of facilities of cattle breeding and agriculture.
- . Annual interest rate is 14%.
- . The finance term is 5-8 years.

(5) Other Supporting Organizations

1) INAFOR

INAFOR is engaged in forestation for the purpose of preserving forest. Ten officers take charge of overall forest in Jalapa Department.

2) DIGESEPE

The office is located at Jalapa, and 4 officers serve mainly for preventing epidemic, but provide no activities in the Study area.

3) DIRYA

The purpose of DIRYA is to promote irrigation agriculture. In the Study area, DIRYA has been directly responsible for planning, implementation, and management of Hoyo Lake Irrigation Project since 1960s. The Hoyo Lake Irrigation Project office belongs in the competence of DIGESA, while DIRYA takes charge of the technical issue.

This Office performs the following services:

- Application of irrigation water,
- Guidance for irrigation techniques,
- Control of water resource facilities, and
- Operation and maintenance of irrigation facilities.

Fig. A.3.3.6-6 shows the control system of Hoyo Lake Irrigation Project.

3.4.8 Farmers' Organization

INACOP takes charge of services for upbringing, guidance and approval of the farmers' organization. There are 449 farmers' organizations all over the Republic. Only 11 small-scale organizations are established in each Jutiapa and Jalapa Departmemt (Fig. A.3.3.6-3).

In the Study area, no advance was found in the organization of farmer's cooperative. In 1982 the Monjas Farmer's Cooperative (28 members) was established to produce tomatoes under contract with a tomato processor but stopped union activities because both parties failed to reach agreement on price in 1984.

No farmers' cooperative was established for Hoyo Lake Irrigaition Project. DIRYA takes direct charge of maintenence of facilities, and the local office of Ministry of Finance levies irrigation charge. A few organization for the improvement of living condition are found in the Study area.

3.5 Existing Facilities

3.5.1 Condition of Irrigation and Drainage

(1) Outline of Irrigation and Drainage

Distribution of precipitaition in the Study area proves that the dry season is differeciated from the wet season, as tabulated below.

		Precipitation (mm)	
		Whole year	Monthly average
Dry season	Nov. - Apr.	56	10 mm or less
Wet season	May - Oct.	911	150 mm
Total		967	

In general, the wet season has a precipitation of about 150 mm per month enough to grow crops, but the dry season has only less than 10 mm per month to prevent any crop from growing. In addition, the wet season may have insufficient precipitation. For this reason, the following irrigation works have been progressed so that crops may be cultivated even during the dry season, and the area of about 910 ha has been irrigated (Table 3.5.1-1 and Fig. 3.5.1-1).

- Hoyo Lake Irrigation Project (1968 - present)
- Small-scale irrigation by wells (1970 - present)
- Smalle-scale irrigation by river water (unknow)

The irrigation area in the dry season accounts only for about 20% of all upland fields (4,350 ha) in the Area. Therefore, local farmers are desirous of irrigation for the rest 80%.

Table 3.5.1-1 Irrigation Area

Water Resources	Irrigation Area (ha)		
	Gravity	Sprinkler	Total
Hoyo Lake Irrigation Project (*1)	319.7	33.2	352.9
(%)	(91)	(9)	(100)
Groundwater Irrigation	278.4	186.3	464.7
(%)	(60)	(40)	(100)
River Water Irrigation	90.0	0	90.0
(%)	(100)	(0)	(100)
Total	688.1	291.5	907.6
(%)	(76)	(24)	(100)

(*1) Source: Hoyo Lake Irrigation project office
(Average between 1982 and 86)

(2) Hoyo Lake Irrigation Project

This Project was put into practice at the cost of about Q 290,000 between 1968 and 1970 in order to irrigate a planned irrigation area of 450 ha. The main facilities and irrigation condition are as shown below.

1) Main facilities

a. Division weir (Dam length: 26.5 m and 68 m) 2 places
b. Driving canal (Capacity: 2.5 m^3/s, Total length L = 3.7 km)
c. Driving tunnel (Total length L = 3.7 km)
d. Reservoir (Hoyo Lake, 3,000,000 m^3)
e. Water pumping volume 120 l/s x 18 m) 3 pumps
f. Main canal (Capacity 200 to 350 l/s)

2) Irrigation condition

Fig. 3.5.1-2 shows the irrigation system of Hoyo Lake Irrigation Project while Table A.3.4-1 shows the result of water utilization.

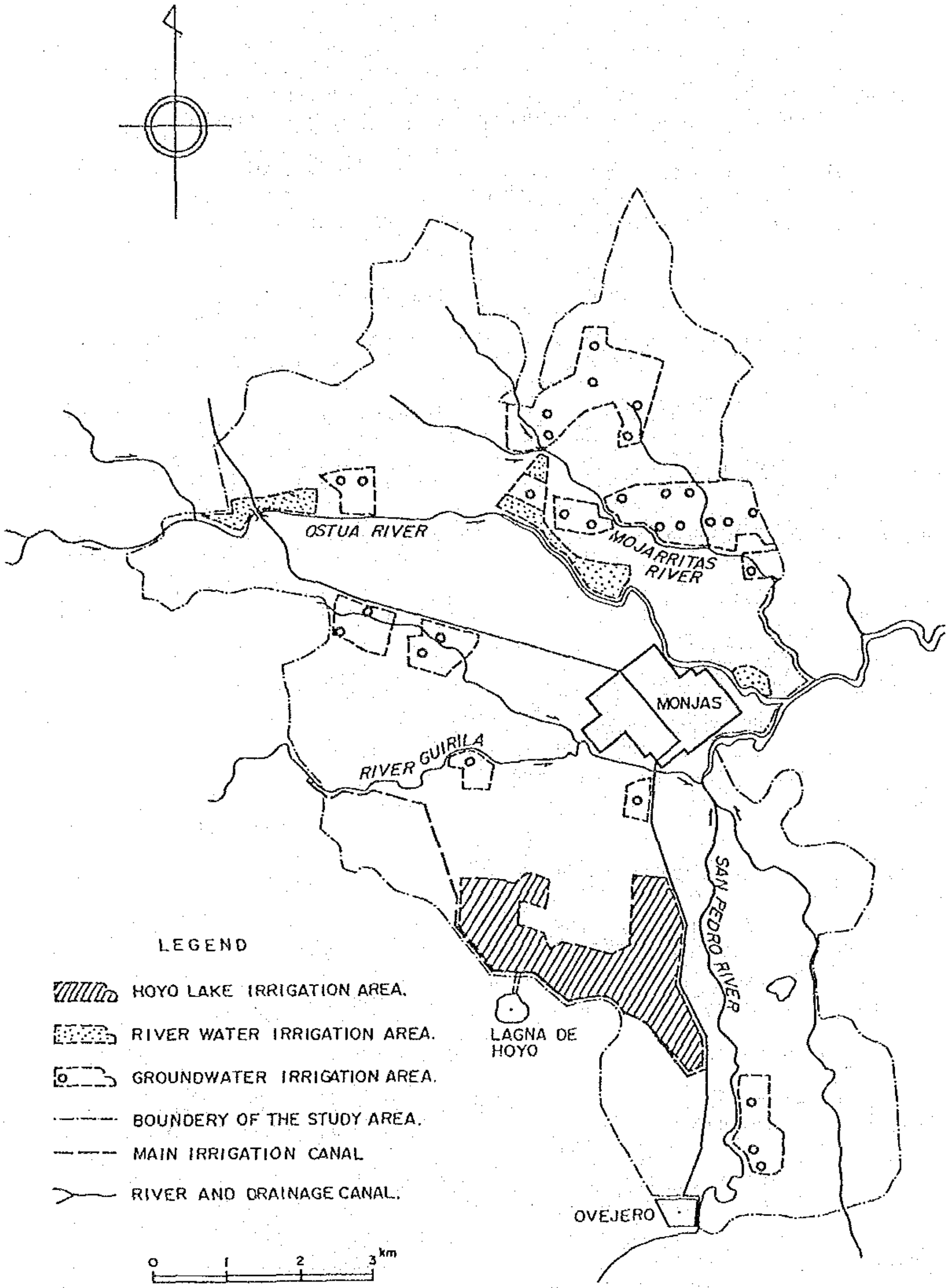
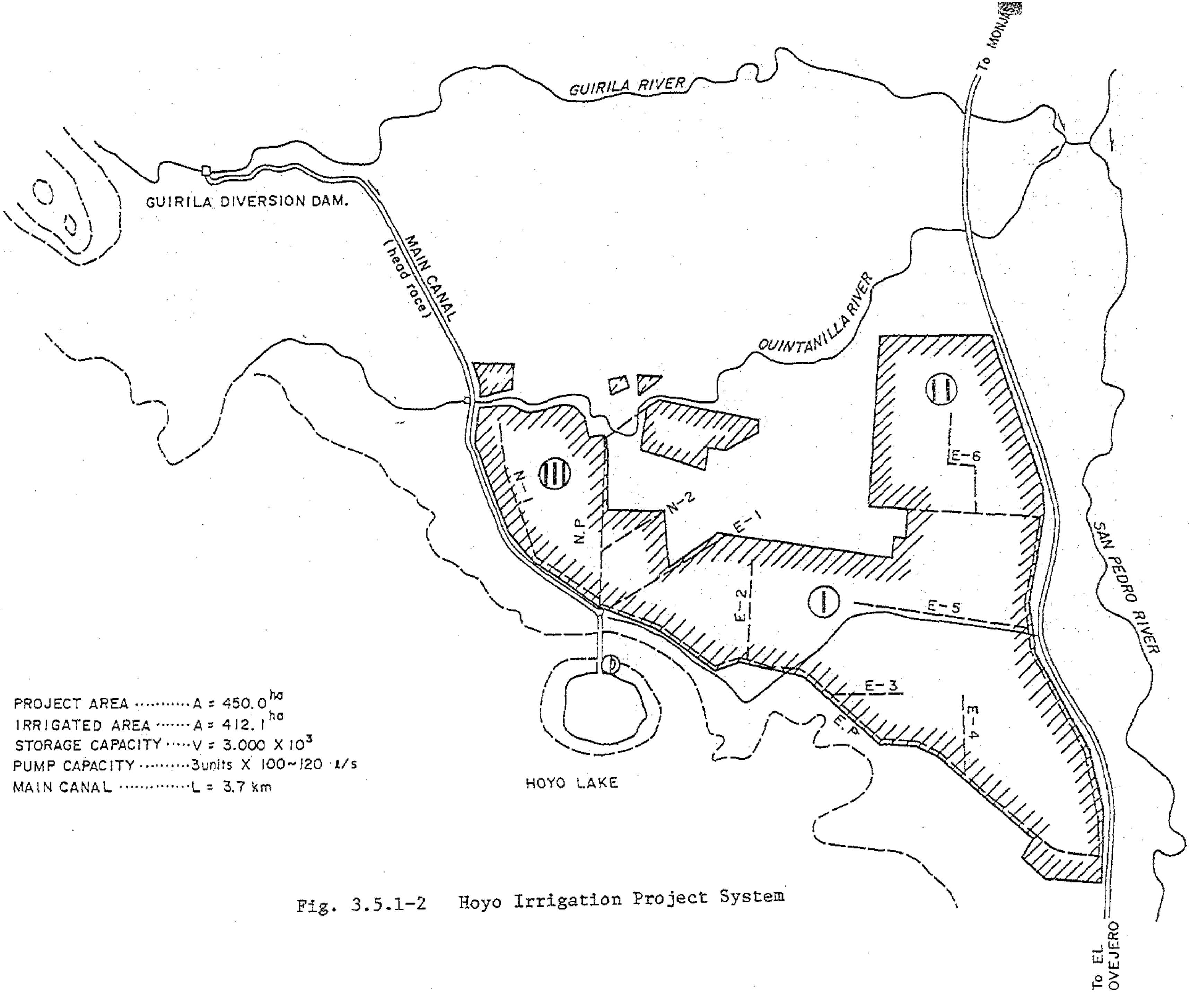


Fig. 3.5.1-1 Existing Irrigation and Drainage System



PROJECT AREA ………… A = 450.0 ha
IRRIGATED AREA …… A = 412.1 ha
STORAGE CAPACITY …… V = 3.000 X 10^3
PUMP CAPACITY ………… 3units X 100~120 l/s
MAIN CANAL …………… L = 3.7 km

Fig. 3.5.1-2 Hoyo Irrigation Project System

The result of irrigation leads to the following summary of water utilization volume and irrigation condition.

a. Utilization of lake water

- Lake water was utilized for about 6 months from the middle of December to the middle of May.
- The Hoyo Lake is supplied with water by the Guirila and Quintanilla River, and stores water in a period from June to September. However, the Lake was not filled full in 1972 abnormal drought year (Fig. A.3.4-1).

- Pump capacity : 160 l/s (daily average)
- Irrigation time: 13 hr/day, average
- Irrigation day : 22 day/month, average

In the dry season of 1985 and 1986, pumping water volume was about 2,000,000 m^3, which are less than 2,400,000 m^3 necessary for irrigating 350 ha. In May 1986, at the end of the dry season, the lake water level lowered down to - 18 m, the lower limit of pumping. Therefore, this volume (2,000,000 m^3) seems to be the maximum value of water supply potential of Hoyo Lake. In other words, the present Hoyo Lake Irrigation system has a capacity of irrigating an area of about 350 ha or less and will be unable to irrigate 450 ha as expected at the initial phase. Presumably, this causes a difference of about 1,000,000 m^3 between a storage capacity of 3,000,000 m^3 and actual pumping volume of 2,000,000 m^3 different is considered water leakage, evaporation, etc.

b. Irrigation condition

Irrigation in the Hoyo Lake Project area is as shown below:

- Start of irrigation	15, October	
- Irrigation time	24 hours maximum 13 hours average	
- Irrigation method	farrow irrigation	379 ha (92%)
	sprinkler irrigation	33 ha (8%)
- Water distribution Initial irrigation	The water distribution schedule is prepared according to cultivation area.	
Irrigation stage	The total area is divided into 3 blocks, which are irrigated in the following order.	

Block	Name of Canal	Irrigation Day	Frequency of Canal Usage
I	Upper reach of East Main Canal	Mon., Wed., Fri.	3 days/week
II	Low reach of East Main Canal	Tur., Thu., Sat.	3 days/week
III	North Main Canal	Daily	Daily

- Irrigation Interval: 8 to 12 days
- Electric charge necessary for pumping (1986)
  Total area (350 ha) 41,600Q/year
  per ha 119 Q/ha/year

(3) Groundwater irrigation by well

The groundwater irrigation system using wells was constructed between 1970 and 1980. This system now uses 31 wells of which 60% are located along the Mojarritas River, and the rest 40% in the upstream area of the Ostua, Guirila, and San Pedro Rivers. The total irrigation area with wells is about 460 ha of which 190ha (40%) depend on sprinkler irrigation using sprinklers. Sprinkler irrigation is more common than Hoyo Lake irrigation area. This is because the sprinkler uses the head of the pump which lifts water from the well. At present, many wells and pumps require renewal or repairs.

Groundwater irrigation is outlined as below.

Number of wells and pumps: 31
Average irrigation area per well: 13 ha average
Irrigation hours: 12 to 24 hr/day
Irrigation hours (average): 16 hr/day

Pumping volume:	
per well	14.8 l/s
total	519.2 l/s
daily average	346.1 l/s
Diameter of well	4 inches
Depth of well	54 to 120 m (70 m average)
Annual Electric charge	270 Q/ha/season

(4) River water irrigation

Small scale irrigation systems take water from the Ostua River. Typical examples are the intake weir (18 ha) of the Orchoj River, a tributary of the Ostua River, and the intake weir at Casa de Tablas (36 ha) in the downstream of the Ostua River. River water irrigation systems do not serve as stable irrigation source because they have only temporary weir which are lost in the wet season, and river water is subject to a great variation of discharge in the dry season. They intake water at the rate of 20-40 l/s and use earth canals. Some upland fields are irrigated by use of portable pumps. River water is supplied to a total irrigation area of about 90 ha.

3.5.2 Existing Road Network

Land traffic is the only one traffic mean in the Study area plays an important role. The road network in the Study area is shown in Fig. 3.5.2-1 and Table 3.5.2-1

(1) Trunk road

One of the main trunk roads in the Study area is Route 19 which is a national road, leading to Jalapa in the north and to El Progreso in the south. Route 19 connects with Interamerican Route at the suburbs of El Progreso, leading Guatemala city and El Salvador.

People and agricultural products in the Study area are conveyed to Jalapa, El Progreso, and other neighbor urban areas through Route 19, and to Guatemala city and El Salvador through Interamerican Route. Route 19 and Interamerican Route are asphalt paved. However, the asphalt pavement has heavily damaged throughout the route, causing reduction in transport efficiency.

Aside from Route 19, Department Route 1 is considered the trunk road in the Study area. Department Route 1 starts the 153 km post on Route 19 to the north of Casa de Tablas where Route 19 crosses the Ostua River, and runs eastward along the Ostua River and reaches San Manuel Chaparron, where Route 1 turns northward and reachs San Luis Jilotepeque. Route 1 has a total length of about 40 km and is gravel paved. Route 1 is a very important road for inhabitants in the north of the Ostua River to have communication with those in Monjas and Jalapa.

(2) Other roads

Roads other than trunk road, i.e. other Department Roads and road between villiages, are mostly left insufficienely maintained. Few farm road is available in the Study area.

(3) Road density

Road density is low, and 1.0-2.2 m/ha in the trunk road and 1.2-3.4 m/ha in other roads (Table 3.5.2-2).

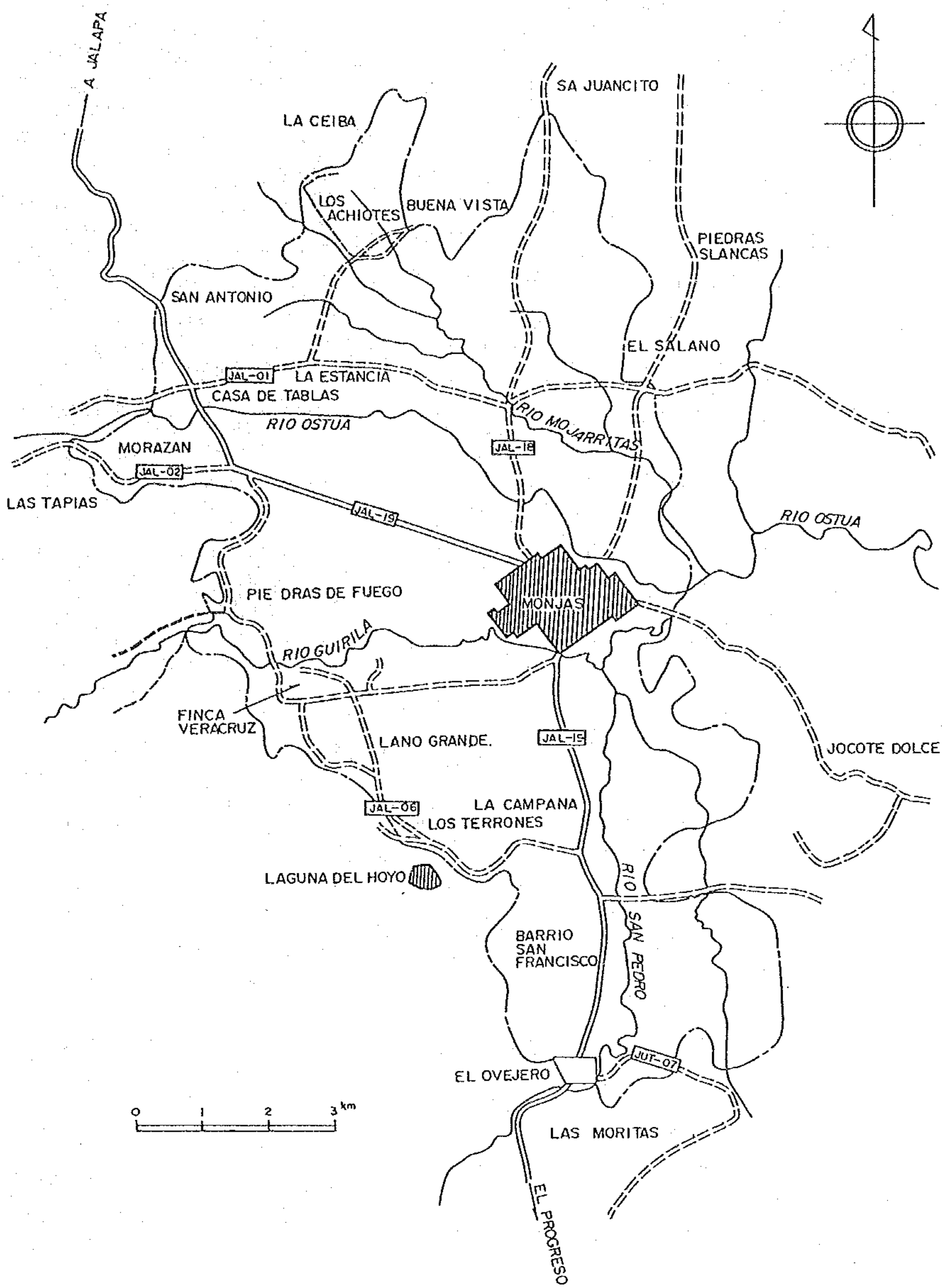


Fig. 3.5.2-1 Road Network

Table 3.5.2-1 Road Length in the Study Area

Route	Classification	Start	End	Length
Route 19	National	El Ovejero	San Antonio	16 Km
JAL01	Departmental	Casa de Tablas	El Salamo	7
JAL02	Departmental	Morazan	Las Tapias	2.5
JAL03	Departmental	Route 19	Achiotes	2
JAL04	Departmental	Morazan	Piedras de Fuego	2.5
JAL06	Departmental	La Campana-Los Terrones - Llano Grande-Piedras de Fuego		7.7
JAL18	Departmental	Monjas	San Juancito	7
JAL19	Departmental	Monjas	Cemetary	0.4
JUT07	Departmental	El Ovejero	Las Moritas	1.6
JUT08	Departmental	Barrio San Francisco	Rio Ovejero	0.5
-	Other	Llano Grande	Finca Vercurz	2.5
-	Other	Monjas	El Salamo	2.7
-	Other	Achiotes	Buena Vista	1.0
-	Other	Casa de Tablas	Las Tapias	2.0
Total				55.6

Table 3.5.2-2 Road Density

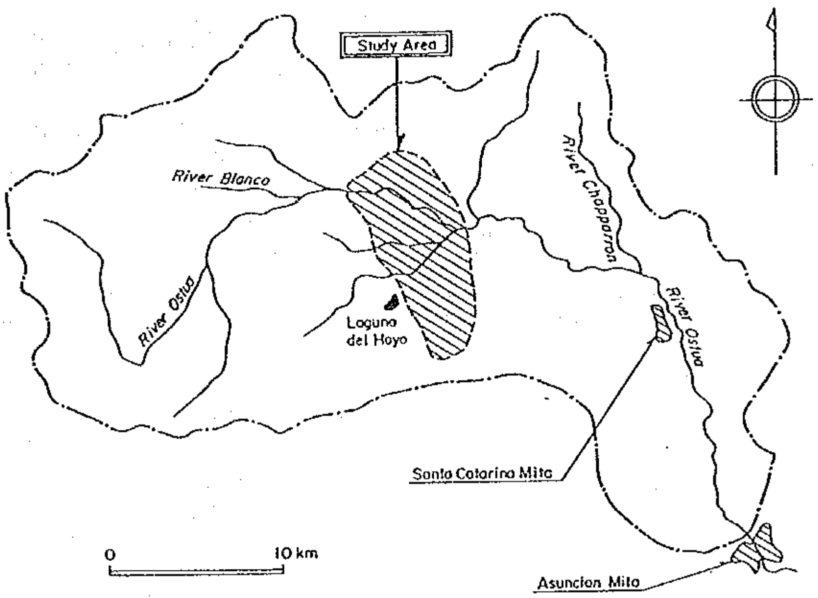
	Classification	Pavement	Total length	Road Density
Trunk road	Route 19 National	Asphalt	16 km	2.2 m/ha
	JAL01 Departmental	Gravel	7 km	1.0 m/ha
Others	Departmental		24.2 km	3.4 m/ha
	Others		8.4 km	1.2 m/ha
Total				7.8 m/ha

3.6 Relevant Project

Two irrigation areas utilize water of the Ostua River on the downstream side from the Study area, and are outlined below.

Relevant Projects

Description	Asuncion Mita	Santa Catarina Mita
Area	1,000 ha	100 ha
Irrigation Area	535 ha (1986 - 1987)	90 ha
Intake (Plan) Intake (Actual)	1.0 m^3/s 0.44 m^3/s	0.10 m^3/s -
Irrigation Period	Nov. - May	Nov. - May
Main Facilities		
Diversion Weir	1	
Pump Station	-	10" x 40 HP x 120 l/s x 2 units
Main Canal	Q = 1.0 m^3/s L = 8.4 km	 L = 2.7 km
Secondary	L = 18.6 km	-
Construction Cost	Q 123,400	Q 500,000
Design and Constructed by	DIRYA	DIRYA
Construction Period	1962 to 1964	1987 to 1988 (under construction)
Irrigation Method	Furrow	Furrow



Project	Project Area	Catchment Area
Asuncion Mita	1,000.0 ha	841.0 km^2
Santa Catarina Mita	100.0 ha	718.0 km^2

Fig. 3.6-1 Relevant Project Areas

3.7 Point at Issue and Task

Point at issue and task of the Study area are shown in the following table.

	Present Condition	Point at Issue	Task
Topography and river	- Altitude: 940-1,000 m - Topography: Almost plain - The Ostua River passes through the center of the Basin from west to east - Tributaries of the Ostua River have the discharge dried up excessively in the dry season.	- Least availability of river water in the dry season.	- Storage of surface water in the wet season
Meteorology and Hydrology	- Warm climate, suitable for cropping - Annual Precipitation of about 1,000 mm; 95% concentrated in the wet season (May - October)	- Serious water shortage in the dry season	- Necessity of irrigation water in the dry season
Soils	- Vertisol with high fertility and good chemical properties	- High clay content; trouble with physical properties - Solidification due to water content	- Supplement of organic matter - Appropriate water management - Necessity of desalinization water
Agricultural Production	- Non-irrigation farmers: cropping limited only in the wet season - Irrigation farmers: cropping vegetables even in the dry season	- Impossible to crop without irrigation - Vegetable cropping restricted by cropping oriented to self-consumption in the dry season - Low rate of cultivated land use	- Improvement of cropping rate and diversification of crops through ensured water in the dry season - Improvement of productivity
Agricultural Management	- Self-supply agriculture oriented to maize and kidney beans	- Few cash income - Over labour fources in the dry season	- Increase in cropping area of cash crops (vegetable) and employment opportunity

	Present Condition	Point at Issue	Task
Marketing	- Cultivation under contact with brokers, wholesalers and processors	- Inavailability of farmer-oriented purchase and sales	- Upbringing of farmers' organization
Agricultural Supporting System	- Instructions given by only one adviser	- Insufficient communication of test/ research results and improper technical guidance	- Consolidation of extension service system
Irrigation Facilities	- Hoyo Lake Irrigation Project (about 350 ha)	- Hoyo Lake: Great water leakage and deterioration of water pump	- New water resource development
	- Groundwater Irrigation (31 wells, about 460 ha)	- Groundwater: Deterioration of well and pump, high cost of operation and maintenance	
	- River water Irrigation (about 90 ha)	- Unstable of river discharge, loss of weir in flood moment	

CHAPTER 4 PROJECT PLAN

CHAPTER 4 PROJECT PLAN

4.1 Objectives and Basic Policy of the Project

4.1.1 Objectives

Monjas Basin is an area suitable for crop cultivation due to natural conditions such as topography, climate and soils, etc., however cropping is restricted due to shortage of water required for growth of crops. This is because about 95% of annual precipitation is concentrated to the wet season. For this reason, about 80% of the total upland field (4,350 ha) is irrigable only in the wet season depending on rain water and is left unused in the dry season, except for a part of the irrigated area.

In the light of the background mentioned above, the present project is to accomplish the following objectives by effective utilization of water resources to a maximum through introduction of irrigation facilities enough to cover water shortage in the dry season.

① Agricultural production throughout the year.
② Enlargement in upland field.
③ Increase in cropping ratio.
④ Increase in agricultural production.
⑤ Increase of income
⑥ Increase in employment opportunities, etc.

Fulfilment of objectives mentioned above will contribute to vitalization of regional economy, rising up of living standard and stabilization of civil administration.

4.1.2 Basic Policy

The basic policy of the project is as summarized below in establishing the project plan.

- The expansion benefited area i.e.: changing of pasture land to upland field.
- Including existing irrigation area to the Project.
- Secure of water resources.
- Effective utilization of Hoyo Lake Irrigation project facilities.
- Minimization of the operation and maintenance cost borne to beneficiaries.
- Selection of crops which farmers can cultivate by their present techniques.
- Absorbing excess labor in the dry season and creating job opportunities.

4.2 Basic Development Concept

4.2.1 Water Resource Plan

(1) Surface water

The catchment in mountain area has an annual average precipitation of 1,384.7mm of which about 95% are concentrated in the wet season (May to October) to make only one surface water resource. At present, surface water in the dry season is utilized only in two areas : one is Hoyo Lake Irrigation Project area dependent on the Guirila and the Quintanilla Rivers, and the other is an area along the Ostua River, which takes river water with simplified weirs. The rest surface water is not utilized. The proposed irrigation area is the agricultural land with high production potential, but absence of irrigation facilities restricts cropping in the dry season, leaving many fields unused. Therefore,surface water stored in dams in the wet season enables agricultural production even in the dry season.

1) Study of proposed dam sites

Five (5) candidate dam sites were selected and compared. They are located in the upstream of the Guirila, Ostua, Blanco, San Pedro, and Achiotes Rivers, all of which were selected among rivers in the Study area through field survey, review of topographic map, etc. and were made comparative study (Fig. 4.2.1-1)

Hydrological analysis has proved the following annual mean runoff discharge at each dam site.

Dam site	Catchment area	Annual mean discharge
Ostua dam	177.0 km^2	96.7 MCM
Guirila dam	26.0 km^2	11.9 MCM
Blanco dam	36.0 km^2	18.9 MCM
San Pedro dam	40.0 km^2	17.7 MCM
Achiotes dam	13.6 km^2	5.6 MCM

Topographic and geological feature and outline of each dam site are summerized in Table 4.2.1-1.

Detailed study of each dam site is described in Appendix 4.1.1, (1).

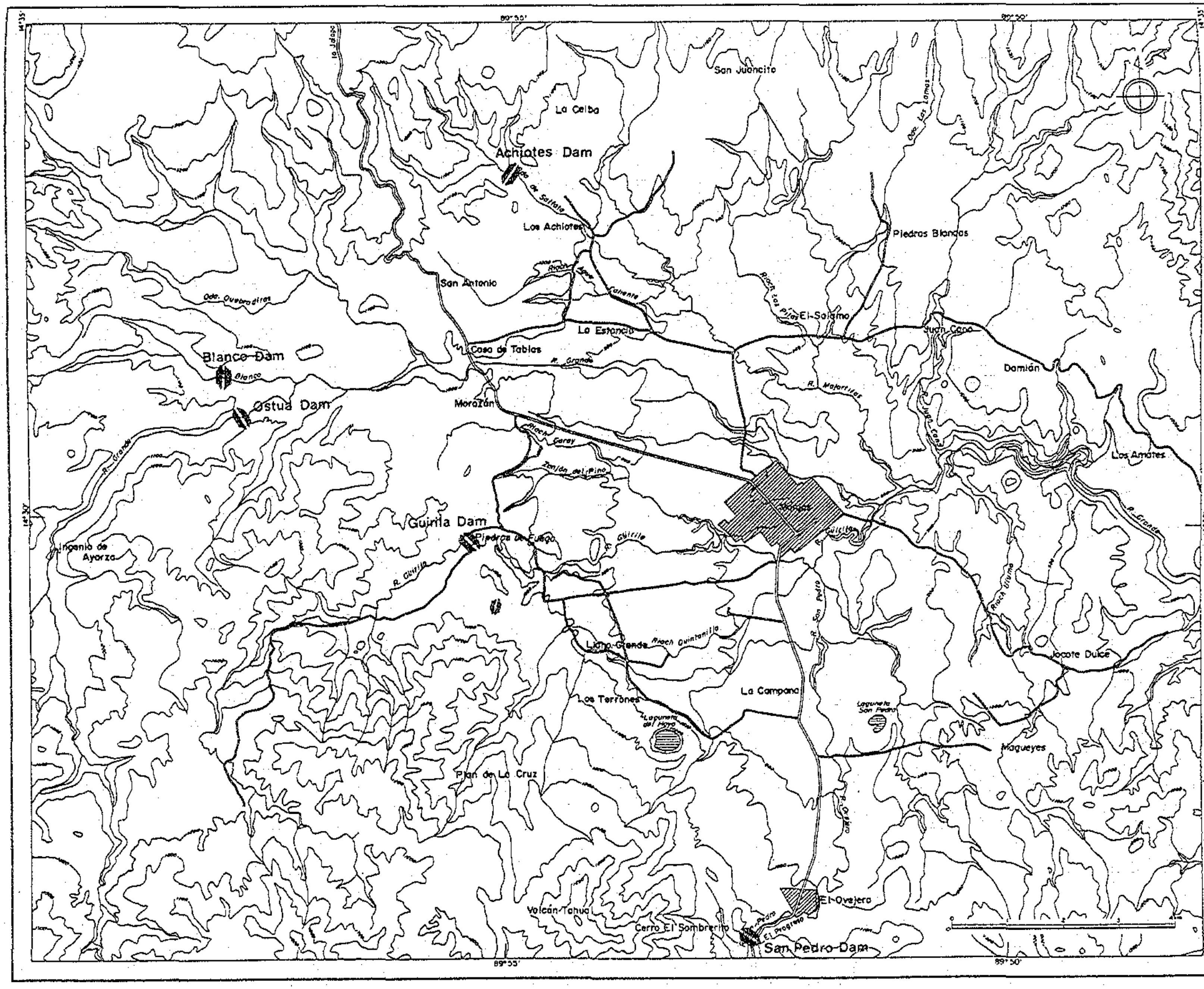


Fig. 4.2.1-1 Studied Dam Sites

Table 4.2.1-1 Comparison of Studied Dam

Items	Guirila Dam	Ostua Dam	Blanco Dam	San Pedro Dam	Achiotes Dam
Location	About 4km south from Case de Tablas.	About 1.5km upstream from the confluence of the Ostua river and the Blanco river.	About 1.5km upstream from the confluence of the Ostua river and the Blanco river.	About 700m southeast from El Ovejero.	About 3km north northeastern from Casa de Tablas.
Topography and Geology of Dam Site	Topography: Gentle slope is formed to a large extent due to wide erosion. In both banks, terrace show copicuous flat plains. A sub-dam is needed due to the suddle of right bank. Right abutment 1:2.5 Left abutment 1:4.0 Span-height ratio 23 Geology: Base rock is welded tuff and sand-gravel covers in a few in thickness on the base rock. Welded tuff is weak, but it is massive and low permeability.	Topography: Dam site is U-shape valley. Steep lidge rise at both banks. The right bank forms a flat plain like terrace composed of basalt lava. Right abutment 1:1.5 Left abutment 1:2.0 Span-height ratio 4.7 Geology: Base rock is welded tuff. Basalt covers on the base rock. Welded tuff is a low welding and weak rock. But it is massive and low permeability. Basalt is hard and has developed open joints.	Topography: Dam site has the topography of converse tropezoid, and right abutment uses in common the left abutment of Ostua dam. Right abutment 1:3.0 Left abutment 1:2.5 Span-height ratio 10 Geology: Same as Ostua dam site. River deposit layer is very thick.	Topography: Dam site is V-shape valley. Right and left abutment form very steep topography. Right abutment 1:2.0 Left abutment 1:1.5 Span-height ratio 4.6 Geology: Composed of porous basalt, basalt lava and andesite. Porous basalt: loose high permeability. Basalt Lava: fine, compact and hard rock, but high permeability due to open joints. Andesite: fine to medium grain and hard rock, but matrix is loose and high permeability due to open joints.	Topography: Dam site is a gentle V-shape valley. Right abutment 1:7.0 Left abutment 1:3.0 Span-height ratio 7.3 Geology: Base rock is welded tuff. Very loose in welding and solidifying. Low permeability due to massive.
Basin — Catchment Area km²	26.0	177.0	36.0	40.0	13.6
Inflow discharge MCM	11.9	96.7	18.9	17.7	5.6
High water level m	HWL 1041.00	HWL 1071.50	HWL 1067.00	HWL 1082.00	HWL 1033.00
Full water level m	FWL 1039.50	FWL 1068.50	FWL 1065.50	FWL 1080.00	FWL 1032.00
Dead water level m	DWL 1008.00	DWL 1063.00	DWL 1046.30	DWL 1068.00	DWL 1015.50
Gross capacity of reservoir MCM	40.9	14.00	13.00	7.50	5.00
Live capacity of reservoir MCM	39.6	5.15	11.20	5.50	4.32
Sediment capacity MCM	1.3	8.85	1.8	2.0	0.68
Usable water depth m	39.5	5.5	19.2	12.00	16.50
Reservoir area in FWL km²	2.05	0.90	0.85	0.60	0.43
Dam height m	49.0 (31.0)	50.00	50.00	39.50	35.50
EL of top of dam m	EL 1044.00	EL 1075.00	EL 1070.00	EL 1084.50	EL 1035.50
EL of Min. trench m	EL 995.00 (EL 1015.00)	EL 1025.00	EL 1020.00	EL 1045.00	EL 1000.00
Width of dam crest m	8.0 (6.0)	8.0	8.0	8.0	8.0
Crest length m	1072.0 (397.0)	410.0	500.0	160.0	290.0
Dam volume MCM	2.63 (0.40)	1.53	2.80	0.45	0.56
Dam slope Upstream	1:2.8	1:2.8	1:2.8	1:2.8	1:2.8
Downstream	1:2.3	1:2.3	1:2.3	1:2.3	1:2.3

(Notes) (1) Reservoir Loss (evaporation, seepage) estimate 5% of Live Reservoir Capacity.
(2) Figures of ( ) show dimension of saddle dam.

2) Study of dam scale

Table 4.2.1-1 shows the reservoir and dam scale of each proposed dam site. The dam scale is caluculated on the basis of the following conditions.

- An irrigaition area of 4,000 - 4,800 ha requires a reservoir capacity of 32 - 40 MCM.

- The dam height is desired to be as low as possible as a result of topographical and geological review.

Specification of the reservoir determined from the Height-Volume curve (prepared from a topographic map of scale of 1:12,500) is shown in Fig. A.4.1.1-1.

3) Study of optimal dam site

Five dam sites are synthetically evaluated as indicated below.

- Topographically, the San Pedro and Achiotes dam sites are limited to a live capacity of reservoir of 4-6 MCM.

- Except for the Ostua dam site, the Guirila and Blanco dam sites have a catchment area of 26 km^2 and 36 km^2, respectively, whereby they are unable to maintain the effective reservoir capacity of 30 MCM or more from their own catchment areas. This means that they have to depend on water introduced from the Ostua River. Topographically, the Ostua and Blanco dam sites require a dam with a height of 70 m or more to ensure an effective capacity of 30 MCM or more. On the other hand, the Guirila dam site has an effective capacity of 30 MCM or more with a dam less than 50 m in height, with the least dam volume of all, however saddle dam is required in view of topographic feature at site.

- It is difficult to construct a dam 70 m high in the Ostua and Blanco dam sites, and the dam height is limited to 50 m, as shown in outlined of geology of proposed dam Table 4.2.1-1. A dam less than 50 m high never attains the live capacity of reservoir of 30 MCM.

- The coefficient of reservoir storage places the best at Guirila dam site over any other dam sites.

- The Guirila dam site has a small catchment area of 26 km^2 whereby it requires only a small-scale spillway.

- Assuming that the Guirila and Ostua dam sites have a dam constructed with the live capacity of reservoir of 39.6 MCM, water cost is estimated as shown below.

Item	Guirila dam	Ostua dam
Gross capacity of reservoir (MCM)	40.9	40.9
Live capacity of reservoir (MCM)	39.6	32.0
Dam cost (10^6Q) (*1)	37.8	41.6
Water costs (Q/m^3) (*2)	0.097	0.107

*1 Dam cost not including land acquisition and compensation cost.
*2 Water cost is estimated by the following equation.

$$\text{Water cost} = \frac{C \times (1 + 0.4 \times i \times P) \cdot (A + i) + O/M}{D}$$

Where, C = Construction cost
i = Annual interest rate 6.5%
P = Construction period: 5 years (estimated)
A = Amoritization ratio 1/60 = 0.0167
O/M = Operation and Maintenance cost: C x 0.5%
D = Water demand: 37.7 MCM

The most optimum dam site canditate is the Guirila dam site as shown above.

4) Embankment material

The final borrow area, quarry and random area are located in right margin of the proposed reservoir at about 2.0 to 3.0 km on the upstream from the dam site.

It is possible for filter material to use sand-gravel distributed on the Ostua River located at about 4.0 km north from the dam site.

The following materials are applied to the dam embankment.

Heavily weathered tuff : Imprevious material
Fine rock of tuff and weathered soil: Randam material
Basalt : Pervious material
Sand and Gravel : Filter material

It will be able to obtain more than 2 times the required quantity of each embankment materials. The embankment volume of each zone is shown on the below.

Material	Required volume *
Imprevious material	777,000 m^3
Randam material	970,000
Pervious material	936,000
Filter material	357,000
Total	3,040,000 m^3

(*) including embankment volume of saddle dam.

The impervious material tests of borrow area selected by the Work I field survey were carried out at the laboratory of the San Carlos University. However, the impervious material tests of final borrow area have not been done. The material of final borrow area is classified in ML by the unified soil classification based on the field observation. And it is possible to obtain sufficient strength by means of mixing because gravels are considerably included in the material. Andestic tuff 20 to 50 cm diameter which distribute widely and in large quantitites at the quarry site are gathered and used for the pervious material. Andestic tuff is very hard, and CM - CH class judging from rock classification.

The sand-gravel for filter material distributes widely on the Ostua River bed and the property has good grading and hardness. And also, this material is suitable for concrete aggregate.

(2) Groundwater

The basic concept is that a groundwater resource is one supplementary resource of surface water. This subparagraph deals with the outline of the groundwater development plan through review of the potential development area and potential groundwater development volume.

The simplified continuous pumping test report was first reviewed that was made when existing wells were dug. The test proves that high specific capacity places Mojarritas sector (125 -623 $m^3/d/m$) and San Pedro sector (890 $m^3/d/m$) over any other sector. In addition, an electrical prospecting survey suggests that 2 or 3 aquifers are distributed in the above 2 sectors, and detects no continuous distribution of identifiable aquifers any other sector (Fig. A.3.2.4-7). For this reason, Mojarritas and San Pedro sectors are proposed for groundwater development.

Groundwater volumes are estimated considering the above two sectors to be an underground reservoir, as shown below. Development area for each sector was determined from the present land use and hydrogelogical survey.

<u>Mojarritas sector</u>

5.14 km^2 x 13.6 m (*1) x 0.36 (*2) (Storativity) ≈ 25 MCM

<u>San Pedro sector</u>

2.88 km^2 x 15 m (*1) x 0.97 (*2) (Strativity) = 42 MCM

*1 average thickness of aquifer obtained from electrical propecting survey
*2 obtained from pumping test results

The two sectors have aquifers composed of sand mixed with silt, and gravel (as shown in boring log). Assuming that ratio of specific yield is 20%, Mojarritas sector has potential pumping output of about 5 MCM and San Pedro sector about 8.4 MCM. At present, Mojarritas sector and San Pedro sector pump 4.1 MCM and 0.9 MCM, respectively. If potential pumping discharges are subtracted by these present pumping volume, potentials of net pumping volume may be estimated : 0.9 MCM in Mojarritas sector and 7.5 MCM in San Pedro sector.

On the other hand, water requirements are estimated at about 7,900 m^3/ha from the proposed cropping pattern. It is assumed that these water requirements for about 800 ha are fully met, allowing for a water conduction loss, etc. A proper irrigation area per well is 15 ha considering field distribution and customary scale of groundwater utilization. The present plan is to newly construct 55 wells and repair existing in both sectors. Proposed pumping volume is to be 7.6 liter/sec considering safety pumping volume proven in the past. Well water is pumped 18 hours per day (max), and is kept at rest for recovery for 6 hours. New wells will be equipped with the same equipment as existing wells, and electric submergeble pumps are instolled.

New well construction cost is estimated at about Q 2,850,000 for 33 wells (Table A.4.1.1-5) and repair cost about Q 190,000 for existing 22 wells. Electric charges and maintenance expenses are estimated at Q 353 (Table A.4.1.1-8) and Q 83 (Q 436 in total) per well per year, respectively. On the basis of the above estimation, groundwater pumping cost is estimated at about Q 0.12/m^3 (where i = 5%) and Q 0.15/m^3 (where i = 10%) for a new well dug in San Pedro sector.

4.2.2 Benefited Area

(1) Present agricultural land

Of the Study ara, 7,130 ha, there exists agricultural land of 5,350 ha, which comprises the ordinary upland field of 4,350 ha and pasture of 1,000 ha. The agricultural land is situated at an elevation of 1,010 m or less in the Basin.

The ordinary upland field depends for the water resource in the wet season on rain water, and about 900 ha of the ordinary upland field is irrigated with water from the Hoyo Lake, river water, and groundwater. Some of pasture is positively managed for the purpose of breeding cattle, while some others are left as natural grassland because of shortage of irrigation water.

(2) Treatment of Present irrigation area

The present irrigation area in the Study area is described as below.

Hoyo Lake irrigation project area	:	353 ha
Groundwater irrigation area	:	465 ha
River water irrigation area	:	90 ha
Total	:	908 ha

The Monjas Irrigation Project is planned including the existing irrigation area, mainly for reasons shown below as a result of study on the available water volume, and operation and maintenance.

1) *Hoyo Lake irrigation project area*

- Hoyo Lake is incapable of supplying water requirements of the initial plan area of 450 ha.
- Hoyo Lake depends for the main water resource on the Guirila River, which is also targeted by the Plan. The proposed Guirila dam stores water from the Guirila River (conversion of water source).
- Water requirements are supplied to the irrigation area with the pump at Hoyo Lake, which requires expensive electric charges and causes a burden to maintenance. Dependence on the dam reduces operation and maintenance cost.
- The existing irrigation canal may be utilized by the Plan.

2) *Groundwater irrigation area*

- Most of farmers using groundwater are desirous of irrigation by the dam. This is because household economy is pressed by electric charges for pumping.
- Some wells have capacities insufficient to supply water required by intended irrigation fields

3) River water irrigation area

- Weirs are temporary structures which require renewal every year.
- Necessary water is not available because of insufficient and unstable discharge.

(3) Extention of benefited area

- Elevation of water resource and benefited area

The lowest intake level of the Guirila dam is EL 1,008 m in elevation and areas lower in elevation are benefited, as a rule, except the agricultural land around El Ovejero about 1,010 m in elevation. The cultivated land has excellent agricultural capacity, therefore this land is targeted depending on pumps.

- Land utilization and benefited area

The benefited area is the present upland field and newly upland field converted from pasture scattered in the Area.

- Soil and benefited area

The upland field and pasture spotted in the former field have soil composed of Vertisol and Inceptisol, both of which are suitable for agriculture. Soil condition does not create any limitation.

- Irrigable area

The irrigable area is closely related to the water resource plan. Optimizing calculations were made for several water resources for different irrigation areas, as shown otherwise, and have led to a conclusion that a benefited area of 4,800 ha is maximum and economical.

(4) Proposed irrigation area

From the above study, this Plan sets the area of 4,800 ha to an irrigable area to be benefited. This area consists of the existing upland field (4,350 ha) and the intended cultivated land converted from pasture spotted in the upland field.

The benefited area is positioned in a extention shown in the proposed land use map (Fig. 4.3.1-1).

4.2.3 Cropping Pattern

The production plan aiming an increase in productions and income is established considering expansion of cropping area in the dry season, increase of cropping ratio, and introducton of more profitable crops by means of irrigation in the dry season.

Consideration such as maintenance of soil fertility, avoidance of trouble by continuous cropping, and smoothed demand in labor with no excessive peak are given to the plan of cropping pattern.

(1) Selection of crops

Main crops are intended for the Plan as shown below.

Wet season: maize, kidney beans, tomatoes and tobacco.
Dry season: maize, kidney beans, tomatoes, broccoli and onions.

These main crops are selected for the following reasons.

1) Maize

Maize is self-supply food and one of the most important basic crops. In the Study area maize is harvested in the largest area, and the present average unit yield exceeds the national average, therefore maize is suitable for this Area.

Maize is less profitable than other crops but should be emphasized as self-supply food, forage for livestock and organic matter resources.

2) Kidney beans

Like maize, kidney beans are one of basic food. Kidney beans are second to maize in cropping area in the Study area, and the present average unit yield exceeds the national average, therefore kidney beans is suitable for this Area.

Kidney beans are less profitable than vegetables but should be emphasized as self-supply food. In addition, kidney bean is a legume and should be emphasized to keep soil ferfility.

3) Vegetables

In the Study area vegetables cultivation have increased its importance in recent years. Vegetable cultivation techniques of farmers are comparatively high, and vegetables are valuable cash crops.

Should irrigation facifites be furnished, cropping in the dry season, and expansion of cropping area are possible. Generally, vegetables are highly profitable while they require much labor. Expansion of cropping area is expected to increase an employment opportunity, not limited to an increase in profit.

At present, irrigation farmers crop tomatoes in the wet season, and tomatoes, broccoli, and onions in the dry season. In view of natural conditions in the Area, water melons, melons, cucumbers, gumbos, etc. may be introduced positively for the diversification of crops. However, this Plan is oriented to expanded cropping of tomatoes, broccoli, and onions, for which cultivation techniques have been established and mastered by farmers.

In the Study area most of tomatoes, broccoli, and onions are exported to North America and El Salvador and those exportation are expected to increase in the future. Production of exporting vegetable wide acquisit foreign exchange and contribute to the improvement of international trade balance of Guatemala.

4) Tobacco

Tobacco cropping is specified in accordance with the production plan of the tobacco manufacturer. Technical guidance given by the manufacturer has leveled cultivation techniques to the extent that tobacco is evaluated as an important cash product.

Tobacco is inevitably subject to the production control of the manufacturer and is not expected to be in rising demand enough to expand the present cropping area, although the present average unit yield exceeds that of Jalapa Department and may be said to be suitable for the Area.