[illegible]

MINISTERIO DE AGRICULTURA
INSTITUTO NACIONAL
DE
AMPLIACION DE LA FRONTERA AGRICOLA
(INAF — PLANEAMIENTO)

FEASIBILITY STUDY
ON
CHANCAY-HUARAL VALLEY
REHABILITATION PROJECT
REPORT
(VOLUME I)

[illegible]

JAPAN INTERNATIONAL COOPERATION AGENCY

REPUBLICA DEL PERU

MINISTERIO DE AGRICULTURA
INSTITUTO NACIONAL
DE
AMPLIACION DE LA FRONTERA AGRICOLA
(INAF – PE-REHATIC)

FEASIBILITY STUDY
ON
CHANCAY-HUARAL VALLEY
REHABILITATION PROJECT

ANNEX
(VOLUME I)

MARCH 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

INTRODUCTION

The feasibility study on the Chancay - Huaral Valley Rehabilitation Project has been carried out by the study team, dispatched from the Japanese government (JICA), started on February 15, 1984. This report was prepared based on the result of field and home studies.

The report is compiled by the following four volumes.

- Main report	(English)
- Annex	(English)
- Drawings	(English)
- Summary	(Spanish)

The annex comprising two volumes are attached to the main report.

Volume I

Annex A	Meteorology and Hydrology
Annex B	Geology and Ground water
Annex C	Soil and land classification
Annex D	Salinity control
Annex E	Agriculture
Annex F	Agricultural economy

Volume II

Annex G	Irrigation and drainage
Annex H	Infrastracture
Annex I	Project Implementation and Cost estimation
Annex J	Operation and Maintenance
Annex K	Economic evaluation and financial analysis
Annex L	Others

CONTENTS

VOLUME I

ANNEX A

METEOROLOGY AND HYDROLOGY

CONTENTS

ANNEX A Meteorology and Hydrology

ANNEX A

List of Tables

ANNEX A

List of Figures

Page

ANNEX A. METEOROLOGY AND HYDROLOGY

1. General

1-1 Physical Condition

The Project area is situated in around 80 km. north-northwest of Lima City and is gently sloped toward the Pacific Ocean. Climate of the Project area is relatively mild regardless low latitude due to influence of the Humboldt Sea Current. However, flat area is mostly occupied by the desert and small area of farm land because of almost no precipitation year round.

Southern part of the Project area is penetrated by the Chancay River, which is principal water resource for this area and supplies irrigation water to the farm land extending in the Chancay Huaral Valley and distributes domestic water to the peoples living in the area along the River.

The Chancay River is originated from western part of the Andes Mountains range and flows down in steep river coarse of about 105 km. in length meandering among the deep mountaineous area. The drainage area of the Chancay River is estimated at approximately 3,454 square km. with 30 km. wide, of which 90% is extended in the mountaineous area. Area of more than 4,000 m in altitude is covered by mosses and Alpine trees due to high land area with heavy rainfall, and a little vegetation such as cactus variety can be seen among the rocks and gravels in the erosional valley.

1-2 Meteorology

The following meteorological and hydrological studies were conducted in order to clarify climatological and hydrological conditions for the formulation of the project.

Meteoro-hydrological data has been provided by el Servicio Nacional de Meteorologia e Hidrologia (SENAMHI) and Administracion Tecnica del Distrito de Riego Chancay - Huaral. The latter authority has established a number of observation station over the region mainly to observe runoff.

These studies were carried out based on the data collected in Peru.

The climatological analysis was conducted to understand the required characteristics such as temperature, humidity, wind, sunshine and evaporation. This study result is useful for formulation of the comprehensive irrigation works.

The runoff analysis was conducted to estimate probable discharge and utilizable discharge.

The location of observe station is shown in Fig. A-1-8.

A) Climatological Data

There exists one synoptic meteorological station at Huaral-Retes. As representing climate of the project area, climatological data at Huaral-Retes are adopted and is compiled in Table A-1-1 -- A-1-5.

Temperature

The mean annual temperature is about 19°C, fluctuating slightly throughout the year. The maximum and minimum monthly temperatures are 22.8°C and 15.8°C, respectively.

Fig. A-1-1 -- A-1-2 and Table A-1-1, A-1-6 -- 7 show the mean monthly and characteristic temperature at Huaral-Retes.

Humidity

The mean monthly relative humidity is about 94% within 2% range throughout the year.

The monthly relative humidity records are shown in Fig. A-1-3 and Table A-1-2.

Sunshine

The sunshine data is adapted to the approximate record at Alcantalla and Campo de Marte are located near the project area.

The sunshine hours fluctuates in accordance with the change of seasons. In the hot season from December to April, it is longer more than the cold months.

The mean monthly sunshine hours of each station are shown in Table A-1-3.

Wind

The mean velocity of the wind in this area is about 3.5 m/sec through out the year, and the maximum speed is 10 m/sec for the last twelve years. As regard to the direction of the wind, the northern or southern easterly wind dominates through out the year (Refer to Fig. A-1-5 and Table A-1-4).

Evaporation

The evaporation was measured by a pan evaporimeter at Huaral-Retes for about 13 years from 1964 to 1976.

According to these records, the mean daily evaporation ranges from 0.9 mm to 2.4 mm (Refer to Fig. A-1-6 -- 7 and Table A-1-5).

B) Rainfall in the Project Area

Alluvial fan area, the project area are situated, belongs to the coastal plain where rainfall hardly ever happened and that's invalied for irrigation water.

According to the precipitation records at Huaral-Retes station, the maximum annual rainfall shows only 40.8 mm for the last 15 years. In this connection, the characteristics of the rainfall is shown as follow:

The maximum daily rainfall record : 15.7 mm
The maximum monthly rainfall record : 19.2 mm
The mean annual rainfall over
a period of about 15 years : 10.0 mm
The non-rainfall year duaring 15 years
: 5 years

2. Present Conditions of Hydrology

2-1 River and River Basin

The Chancay River is originated from the Occidental Cordillera with a peak of 5,300 m above M.S.L., and empties into the Pacific Ocean with considerable steep slope in its full river course (the river course slope in mountainous area is ranged from 1/8 to 1/50 and 1/16 at average).

In the lower reaches of the Chancay River, the river course runs through southward of the project area and the river bed with a mean gradient of 1/70 meanders down more than 30 km to the estuary. The total length of the river is about 105 km and the catchment area is 3,454 km^2 of which shape is narrow and long.

The river basin can be divided roughly into six sub-areas as shown in Table A-2-1 and rainfall can be seen in the mountain side which is heigher than 2,000 m above M.S.L. where 48% of the entire river basin (equivalent to 1,654 km^2) is located. The sub-basin gradients in the upper and lower reaches of the confluence are about 1/15 and 1/8 respectively.

2-2 A Group of Lagoons

With regard to the water resource in upper area of the Chacay River basin, as many as 25 caldera lagoons of a large and small scale are scattered at a high altitude as shown in Table A-2-2.

As means of supplement water in the droughty season, seven lagoons of them have been utilized for irrigation and domestic water. They are under controlled by Administration Tecnica de Distrito Riego Chancay-Huaral. Their elements of available storage is shown in Table A-2-3.

2-3 Rainfall

Six rainfall gauges are located in and near the sub basin as shown in Fig. A-1-8 and Table A-2-4.

As mentioned before, the rainfall in the mountainous regions where are heigher than 2,000 m above M.S.L. has been available for water resouces of which about 80% concentrates in the period from December to April.

Each of such sub-basin have a particular characteristic in configuration and different rainfall patterns, whichever, the precipitation increases according to the altitude of river basin.

(1) Annual Rainfall

Annual rainfall in and near the sub-project basins is shown in Table A-2-4. On spatial distribution of regional rainfall, the annual precipitation in last several years has been fluctuated from 2 to 4 times due to the influence of the Humboldt sea current.

Herewith, the mean annual rainfall in the mountainous area can be estimated by the following equation with 98% correlation coefficient.

$$R_H = 1.138 \times 10^{-5} \times H^{2.181}$$

where, R_H : mean annual rainfall (mm)
H : mountainous altitude M.S.L. (m)

(2) Monthly Rainfall

The monthly distribution reflects the climatic characteristics of facing to the Pacific Ocean.

On average about 80 percent of the annual rainfall in the rainy season (from December to April) and then only a few falls in the transitional periods and dry season.

The maximum monthly rainfall of the year is usually recorded during in January to March.

(3) Daily Rainfall

The frequency analysis of the daily rainfall is normally required for the investigation of floods in designing the diversion weir.

A hyetal region of daily rainfall spreads over the whole basin. The correlations of daily rainfall was studied on the data at six stations. These correlations during the major floods of the last 10 years are not so clear and poor. The maximum daily rainfall records at these stations are about 30 mm to 47 mm.

(4) Rainfall-Runoff Relation

Regarding to the correlation between the annual rainfall and runoff in the river basin, both the observed records at Santa Cruz and Santo Domingo are connected with higher degree by plotting the double-mass curve as shown in Fig. A-2-2. According to the result of above study, the representative rainfall in the drainage basin would be based on the gauging records at Sta. Cruz.

Annual runoff coefficient with areal rainfall at Sta. Cruz station is evaluated as follow;

Drainage basin area	; 1,379 (km^2)
Average Annual Rainfall	; 551 (mm)
Average Annual Runoff	; 533.85 (MCM)
Observed Period	; 1963-1982
Average Annual Runoff Coefficient	; 70 (%)

(5) Probable Point Rainfall

The probable daily and two days continious point rainfall was analyzed by means of Gumbel method.

The probable point rainfall is shown in Fig. A-2-3 and Table A-2-5.

2-4 River Runoff

The upper reaches of the Chancay River shows topographically a mountainous land in which runoff congregates, and the lower reaches has an alluvial fan. As a whole, the Chancay River runs down rapidly along a primeval course wherein unstable guts passes.

The daily discharge of the Chancay River has been gauged at Santo Domingo for 64 years since 1920. According to the records well-arranged since 1963, the mean monthly and annual runoffs at Sto. Domingo with a catchment area of 1,860 km^2 are compiled in water year basis from August to July in Table A-2-6.

This Table indicates that maximum monthly runoff appears in March and minimum becomes from August to September.

3. Runoff Analysis

3-1 Purpose of Study

Standard project, design flood discharge and utilizable discharge were studied turning to account the existing runoff records and the results of rainfall analysis as mentioned in the foregoing.

The objectives of these study are of showing below.

1) Design flood discharge -

To determine the flood protection plan.

2) Standard project and utilizable discharge -

To facilitate the water resources development plan.

3-2 Design Flood Discharge

(1) Meteolology

In this study, water stage of the Chancay River has not been gauged, thence, the flood hydrograph is not clear to analyze the flood distribution.

Therefore, flood discharge is estimated for the formulation of a flood protection plan as follows:

1) Probable discharge
2) Flood traces
3) Specific discharge

(2) Probable Discharge

Daily discharge at Sto. Domingo has been recorded since 1963 (refer to Data book). The maximum discharge of the year is picked out of the daily data. But the value may not always be the maximum, for the daily records is observed at the time of 11:00 everydays. However, on a viewpoint of statistical observation, the probable discharge is calculated by means of Gumbel method adapting to logarithmic distribution.

Frequency curve of the flood discharge at Sto. Domingo is shown in Fig. A-3-1, estimated discharge is given in Table A-3-1.

(3) Flood Traces

The Chancay River sometimes inflicts flood damage in the project area. Regarding the data at Sto. Domingo, the first, second and third biggest floods of the Chancay River are recorded at 484 m^3/S in 1971, 401 m^3/S in 1967, and 180 m^3/S in 1965, respectively. Whenever the flood surprised, the left bank was overflowed in the upper reaches of the Palpa Bridge at 22.0 km upstream from the estuary, resulting in a big damage around the land side thereof and southern area of the Palpa area.

For judging floods of the Chancay River, flood traces at the Palpa or the San Jose Bridge, locating in 20.75 km or 13.8 km from the estuary respectively, serves to determine the flood discharge.

The largest discharge is presumed by applying Manning's formula to surveyed values at the each section (refer to Table A-3-2).

(4) Specific Discharge

As for flood runoff of the Chancay River, the specific discharge cannot be exactly clarified under the influence of the hydrological characteristics.

However, the comparative studies with neighboring or similar areas will make out approximate figures.

The specific discharge based on the design flood in Peru is collected as following Table.

River basin	Rio Chillon	Rio Canete	Rio Pisco
Catchment area A (km^2)	352	4,810	2,000
Flood discharge Q (m^3/S)	30.4	900	480
Specific discharge qr ($m^3/S/km^2$)	0.086	0.187	0.240

(5) Determination of Design Flood Discharge

Comparative studies on flood discharge have been made and the results provide various values. Derived values differ from one another, design flood discharge for overall plan is determined on the basis of the foregoing probable discharge as shown in Table A-3-3.

Table A-3-3 Probability on Flood Discharge

ReturnPeriod (year)	Flood discharge (m^3/S)	Specific discharge ($m^3/S/km^2$)	Remark
200	770	0.414	
100	580	0.312	
50	450	0.242	designed high-water
20	310	0.167	
10	240	0.129	
5	180	0.097	

Note : Catchnent are at gauging station (Sto. Domingo)
$A = 1{,}860\ km^2$

3-3 Flow Regime

In this study, daily discharge data at Sto. Domingo since 1963 had been used as the actual runoff.

The flow regime is calculated by arrangement in order of descending powers of daily discharge yearly.

The flow regime is shown in Table A-3-4.

On account of the fact that a record of a measured flow at gauging station has included some outflow from the lagoon in upper basin of the Chancay River, the natural flow may be obtained by decreasing the net flow from the lagoon.

4. Sedimentation

4-1 General

The field investigation and the observation of topographical map verified that the denuded areas (including small grassland) occupies about 80% of the Chancay River basin (1,654 km^2), and that the collapse area where now producing sediments is less than 50%.

The remaining 20% is the forest and farmland along the river channels.

4-2 Sediment Discharge

To estimate the annual sediment discharge, the following cases have been done.

1) Estimation by Tanaka's formula

2) Estimation by Ishito's formula

3) Estimation by Schoklitsch's formula

4) Comparative study of sedimentation with similar river basins.

Tanaka's formula

Dr. Tanaka proposed the formula by studying the topographic and geologic conditions on 36 reservoirs in Japan. The topographic condition is composed of relief energy and the average of heights. And according to the geological condition, the catchment area may be divided into three groupes. The formula to calculate the annual specific sediment discharge varies by each group.

The first group is the area consisting of plutonic and hypobyssal rocks and also their metamorphic rocks.

The secondary group is the area composed of paleozoic rocks. The feature of the remaining group, unlike the above groupes, is composed of crystaline schist, effusive rocks, Cenozoic sedimentary rocks and compound areas.

The relief energy (X_1) and the average of heights (X_2) must be measured on the topographic map of which has been fixed to square of 16 km^2 each. The weighed average $\bar{X}_1$ and $\bar{X}_2$ should be calculated as follows.

$$\bar{X}_1 = (\Sigma X_i)/n$$

where, X_i : relief energy in each square (expressed in unit of 100 m)

n : number of squares where same value of X_i is observed.

$$\bar{X}_2 = (\Sigma X_j)/n$$

where, X_j : average height in each square (expressed in unit of 100 m)

Then, the coefficient of topographical feature (X) should be calculated as below.

$$X = \bar{X}_1 \times \bar{X}_2$$

The annual specific sediment discharge (Y) is given by applying the X value to the following formulas.

Group I : $Y = 6.6X - 934 \pm 160$
or $= 4.5X + 150 \pm 49$

Group II : $Y = 10.1X - 254 \pm 107$

Group III : $Y = 13.0X - 6 \pm 189$

The project river basin is classified into I group. X and Y is calculated by the following equation.

$$X = \bar{X}_1 \times \bar{X}_2 = 11.7 \times 36.4 = 425.88$$

$$\begin{aligned} Y &= 6.6 \times 425.88 - 934 \pm 160 \\ \text{or } &= 4.5 \times 425.88 + 150 \pm 49 \\ &= 2{,}135 \text{ (max.) --- } 1{,}973 \text{ (average) --- } 1{,}711 \text{ (min.)} \end{aligned}$$

This formula which is adapted in Japan should be modified for application in Peru. The difference between Japan and Peru is the rainfall. Especially the intensity of rainfall in Japan is generally stronger than that in Peru. Therefore, the results, adapted to conditions in Japan, are considered to be to large. The value thus obtained may have to be modified by smaller values, taking the rainfall pattern and intensity in Peru into consideration.

Ishito's formula

Dr. Ishito gives the formula, expanding Tanaka's method, pon an annual sediment discharge, that is;

$$\text{Log } Y = 2.18 \text{ Log } X - 9.52 \pm 1.16\sqrt{0.05 + (\text{Log } X - 5.47)^2}$$

where, $X = \bar{X}_1 \cdot P$

P : precipitation of intensive rainfall (mm/year)

There are the last fourteen years' records which show the rainfall data at Sta. Cruz. Rainfall data, exceed 100 mm/month, should be picked up, because the intensity of continuous rainfall is put bounds to 100 mm and above.

Applying to the picked up data, the average annual rainfall of 391 mm/year is summed up.

Thence, $X = \bar{X}_1 \cdot P = 1{,}170 \times 391 = 457{,}470$

$$\text{Log } X = 5.6604$$

Therefore, the annual specific sediment discharge is;

$$\begin{aligned} \text{Log}Y &= 2.18 \times 5.6604 - 9.52 \\ &\quad \pm 1.16\sqrt{0.05 + (5.6604 - 5.47)^2} \\ &= 3{,}1603 \text{ or } 2.4790 \end{aligned}$$

$$Y = 1{,}446 \text{ or } 301 \text{ m}^3/\text{km}^2/\text{year}$$

Schoklitsch's Formula

Schoklitsch's formula is presented as follows.

$$G = \Delta (Q \times A)^{0.2}$$

where, G : annual sediment discharge (m^3)

Q : mean annual discharge of river (m^3)

A : Catchment area (km^2)

Δ : Coefficient varies with the following conditions.

600 --- 1,000	: for the large basin composed of various complex layers.
1,650 --- 4,500	: for wild devastated rivers in where erosion is prevalent.

The Chancay River has mean annual runoff of 534×10^6 m^3 and catchment area of 1,860 km^2 at Sto. Domingo.

Considering topographic and geologic conditions of the Chancay River basin, the value of coefficient "4" is assumed as approximately maximum 4,500.

Applying = 4,500,

$$G = (534 \times 10^6 \times 1,860)^{0.2} \times 4,500$$
$$= 1,128,800 \ (m^3/year)$$

Therefore, annual specific sediment discharge is;

$$Y = 1,128,800/1,826 = 607 \ (m^3/km^2/year)$$

Comparative Study of Sedimentation with Similar River Basins

A comparative study of sedimentation in Japan has been done and the results are as follows.

Shinano River : 22 -- 3,400 average 936 $m^3/km^2/year$

Tenrhu River : 300 -- 4,080 average 1,570 $m^3/km^2/year$

Ohi River : 525 -- 7,820 average 3,653 $m^3/km^2/year$

Yoshino River : 930 -- 2,698 average 1,430 $m^3/km^2/year$

4-3 Determination of the Annual Specific Sediment Discharge

The above mentioned studies provides various results by each method, such as followings.

1) Tanaka's formula : 1,711 -- 2,135 m^3/km^2/year

2) Ishito's formula : 301 -- 1,446 m^3/km^2/year

3) Schoklitsch's formula : 607 m^3/km^2/year

4) Existing example in Japan : 936 -- 3,653 m^3/km^2/year

The adaptable value in Peru may be selected either by Tanaka's formula or Ishito's formula.

Ishito's formula is said to be suitable with regard to rainfall. All the results are similar to one another.

Therefore, the annual sediment discharge should be proposed to be 1,500m^3/km^2/year in due consideration of the safety.

Table A-1-1 Monthly Mean Temperature

(Unit:℃)

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Min.	17.9	18.7	18.6	16.6	15.4	14.3	13.8	13.5	13.5	13.8	14.9	16.3
Ave.	21.9	22.8	22.6	20.8	18.7	17.0	16.4	15.8	16.0	17.0	18.4	20.2
Max.	26.6	27.8	27.7	25.8	22.5	20.2	19.3	19.0	19.6	20.9	22.6	24.5

Table A-1-2 Monthly Mean Humidity

(Unit:%)

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean	92.9	91.7	93.3	93.7	93.5	94.6	94.5	95.1	94.4	94.4	93.5	93.4

Table A-1-3 Monthly Mean Sunshine Hours

(Unit:hrs./day)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Huaura	5.8	6.7	7.0	6.9	4.8	2.9	2.7	2.9	3.7	4.6	5.2	6.1
Maria	5.9	7.7	7.8	7.2	3.9	1.6	1.3	1.2	1.3	2.5	3.7	5.8

Table A-1-4 Monthly Mean Wind Velocity

(Unit:m/sec)

Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
13 Hr.	3.9	3.8	4.1	4.1	3.0	2.8	2.3	2.4	3.0	4.6	3.6	3.9
Max.	5.8	5.4	5.8	6.3	5.7	5.4	5.7	5.0	5.8	5.7	5.4	5.7

Table A-1-5 Monthly Mean Evaporation

(Unit:mm)

Ite	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Month	64.4	66.5	66.6	54.4	41.4	35.5	32.9	28.2	31.1	38.3	47.9	60.2
Day	2.1	2.4	2.1	1.8	1.3	1.2	1.1	0.9	1.0	1.2	1.6	1.9

Characteristic Temperature of the Project Area

Observatory Name : Huaral-Retes
Altitude : 182 m
RecordingPeriod : 1965 ~ 1979

Table A-1-6 Characteristic Temperature

(Unit:℃)

Items	MostHotMonth February	MostColdMonth August	AnnualRange	AnnualMean
MonthlyMaximum	27.8	19.0	8.8	23.0
MonthlyMinimum	18.7	13.5	5.2	15.6
MonthlyAverage	22.8	15.8	6.4	19.0

Table A-1-7 Max. & Min. Temperature Records

ExtremeRecords	AirTemperature	Record Date
AbsoluteMaximum	33.0 ℃	1976-2-13
AbsoluteMinimum	7.0 ℃	1966-10-5

Table A-2-1

Distribution of Catchment Area with Altitude

Control Point : Santo Domingo Chico

Unit : km^2

Observatory	River System	Catchment Area	~2,000m	2,000~3,000	3,000~4,000m	4,000m~	(4,800m~)	Lagoon Basis	Note
Santa Cruz	Rio Vichaycocha	362.0	-	1.4	46.3	314.3	68.7	57.46	
Pirca	Rio Banos	247.3	-	1.0	18.0	228.3	14.0	72.22	
	Rio Chancay	259.0	6.0	44.5	73.7	134.8	3.6	9.45	
Carac	Rio Carac	343.0	4.3	33.9	100.7	204.1	27.0		
	Rio Huataya	265.0	62.8	103.9	43.7	54.6			
Pallac	Rio Anasmayo	257.0	31.4	62.6	77.4	85.6			
	Rio Chancay Down	126.5	101.6	24.9	-	-			
Total		1,859.8	206.1	272.2	359.8	1,021.7	113.3	139.13	

Table A-2-2

Main Lagoons List In The Chancay River Basin

Unit: ㎢

Tributary	SubTributary	Branch River	Number	SubBasin	Lagoon & Surface Area				Total
Rio Vichaycocha	Q.Rahuite		1	10.90	La Patococha	0.14	La Champahuasi	0.06	0.20
	Q.Escalon		2	7.58	La Rahuite	0.32	La Chancan	0.06	0.38
Rio Chicrin	Rio Chicrin		3	24.77	La Chungar	1.13	La Pampa	0.19	1.32
	〃		4	14.21	La Yuncan	0.41	La Cacray	0.47	0.88
			Sum	57.46					2.78
Rio Banos	Q.Tambo		5	4.72	La Huantash	0.32			0.32
	Rio Banos		6	12.58	La Ocruyoc	0.18	La Yanacocha	0.11	0.29
	〃		7	5.62	La Vilcacocha	0.34			0.34
	〃		8	10.00	La Hahuashauman	0.49			0.49
	Rio Ragrampi	Q.Curau	9	2.02	La Culacancha	0.22			0.22
	〃	Q.UchcoMachay	10	9.77	La Uchco-Machay	0.36	La Parcash	0.34	0.70
	〃	Rio Ragrampi	11	14.04	La Quisa	0.60	LaYanauyac0.32,LaIsco0.17		1.09
	〃	〃	12	3.03	Las Lichicocha	0.16			0.16
	〃	〃	13	5.67	La Sahuac	0.12	La Verdecocha	0.08	0.20
	〃	〃	14	4.77	La Patococha	0.06	La Acococha	0.06	0.12
			Sum	72.22					3.93
Q.Chuncurmayo			15	9.45	La Pacococha	0.18			0.18
			Sum	9.45					0.18
			Total	139.13					6.89

Table A-2-3 Hydrological Conditions of Administrative Lagoons

Administrative Lagoon	Catchment Area	High Water Level(msnm)	Full Water Area	Available Depth	Effective Capacity/ of Reservoir	Available Amount of Catchment Water	Remarks
La Quisa	14.04 km^2	4,430 m	0.90 km^2	14.0 m	13,690 *10^3 m^3	7,800~11,300 *10^3 m^3	
La Aguashauman	10.00	4,430	0.51	15.0	7,680 *10^3	8,300~11,900 *10^3	
La Yuncan	14.21	4,365	0.62	9.0	5,600 *10^3	11,800~16,800 *10^3	
La Cacray		4,293	0.47	8.0	3,800 *10^3		in need of repair
La Chungar	24.77	4,250	1.13	10.6	10,200 *10^3	20,600~29,400 *10^3	
La Rahuite	7.58	4,405	0.32	11.0	3,300 *10^3	6,300~9,000 *10^3	in need of repair
La Chancan		4,463	0.06	8.2	620 *10^3		
Total	70.60				44,890 *10^3	54,800~78,400 *10^3	
Total Active Storage						39,000~42,500 *10^3	

Table A-2-4

Monthly Mean Rainfall

(Unit:mm)

GaugingStation	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Annual	RecordTerm
RioPallanga	71.5	74.2	83.4	81.1	170.4	189.2	214.4	288.7	111.8	48.0	25.9	21.1	1,379.7	1968~1977
Yantac	18.8	65.4	77.7	60.8	113.7	153.7	160.7	153.4	90.1	64.1	11.9	12.7	983.0	1968~1977
SantaCruz	3.4	11.0	38.4	42.9	77.1	82.0	111.9	124.8	41.7	12.3	2.4	3.2	551.1	1963~1982
Pirca	0.3	1.4	12.3	20.9	50.1	97.7	108.4	141.0	36.7	5.4	1.1	0.1	475.4	1967~1980
Carac	0.4	2.7	17.4	12.6	34.4	69.9	90.8	103.2	17.8	1.5	0.4	0.1	351.2	1966~1980
Pallac	0.1	1.3	6.1	2.9	13.2	48.1	71.1	95.6	14.7	0.4	0.1	0.0	253.6	1963~1980

Note ; Altitude at Rainfall Station

RioPallanga : msnm. 4,633 m … out of Basin
Yantac : msnm. 4,600 m … 〃
SantaCruz : msnm. 3,500 m … in Basin
Pirca : msnm. 3,259 m … 〃
Carac : msnm. 2,600 m … 〃
PAllac : msnm. 2,333 m … 〃

Table A-2-5　Probable Point Rainfall*

(unit:mm)

Return Period (year)	Daily Rainfall	2 Days Continious Rainfall
300	55.8	108.5
200	53.3	99.9
100	48.9	86.3
70	46.6	79.7
50	44.6	74.2
20	38.8	60.2
10	34.2	51.0
2	23.3	33.2

* By Gumbel Method

Table A-2-6

Monthly Mean Discharge of The Chancay River
at Santo Domingo

Items	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Annual
MeanDischarge(m^3/s)	5.17	5.03	5.69	7.39	12.68	22.95	44.55	58.79	23.23	9.65	7.02	5.56	16.93
MonthlyVolume(MCM)	13.84	13.05	15.24	19.15	33.96	61.46	100.53	157.46	60.21	25.86	18.20	14.89	533.85

Note ; Located Conditions at Discharge Station

1): Altitude ··· 614 m M.S.L.

2): Distance from Estuary ··· 37.0 km

3): Catchment Area ··· 1,860 km^2

4): Observed Period ··· 1963 ~ 1982

Table A-3-1 Probable Discharge at Sto. Domingo

Return Period (year)	ProbableDischarge (m^3/s)	SpecificDischarge ($m^3/s/Km^2$)
200	731	0.393
100	581	0.312
50	456	0.245
20	321	0.173
10	240	0.129
2	107	0.058

Note : Catchment area at Sto. Domingo

$A = 1,860\ Km^2$

Table A-3-2 Flood Discharge by the Flood Traces

Item	Puente PALPA	Puente SanJOSE
Station Number	Sta.No.20+750	Sta.No.13+800
Width of River:B(m)	98.4	119.2
Area of Cross Section :A(m^2)	124.9	152.1
Hydraulic Radius :R(m)	1.149	1.090
Riverbed Gradient I	1/62	1/68
Roughness Coefficient :n	0.040	0.040
Velocity :V(m/s)	3.48	3.20
Discharge :Q(m^3/s)	435	487

Manning's formula ;

$$V = 1/n * I^{1/2} * R^{2/3}$$

$$Q = A * V$$

Table A-3-4 Chancay River Flow Regime

(at SantoDomingo Observatory)

Unit:cu.m/sec

Water Year	Annual Runoff	Droughty Wat.Dis.	LowWat. Dis.	Ordinary Wat.Dis.	95days Dis.	Annual Minimum	Annual Maximum	Annual Average	Remark
1963	7,159.2	4.94	5.65	9.90	25.89	4.52	97.86	19.56	
1964	6,708.0	5.16	5.86	7.17	10.48	5.01	180.21	18.38	
1965	3,324.9	3.81	4.94	5.91	9.61	3.64	61.00	9.11	
1966	11,056.6	3.03	5.95	10.98	20.59	2.96	400.60	30.29	
1967	3,170.1	3.97	4.57	5.58	9.00	3.75	37.50	8.66	
1968	4,284.1	3.72	3.94	5.86	8.68	3.51	88.79	11.74	
1969	7,049.9	2.81	4.23	9.32	18.85	2.60	158.83	19.31	
1970	5,970.8	4.54	5.59	8.10	18.42	4.24	83.20	16.36	
1971	12,012.1	4.73	5.64	9.60	20.24	4.22	484.19	32.82	
1972	8,644.1	5.25	6.60	9.93	31.36	4.67	172.08	23.68	
1973	8,211.4	6.09	8.07	10.63	30.05	6.09	143.20	22.50	
1974	4,929.9	4.85	5.49	7.14	13.39	4.21	86.33	13.51	
1975	5,679.5	5.21	5.80	7.25	18.79	5.11	125.43	15.52	
1976	5,273.8	4.49	5.56	6.30	11.37	4.14	115.51	14.45	
1977	3,821.6	3.96	4.78	5.98	12.72	3.61	64.85	10.47	
1978	4,320.6	4.00	4.82	5.86	8.54	3.63	90.05	11.84	
1979	3,078.9	3.42	4.08	5.49	7.24	2.91	76.25	8.41	
1980	6,967.4	3.27	5.11	7.31	19.28	2.82	142.53	19.09	
1981	4,822.4	4.84	5.70	7.91	15.07	4.26	76.69	13.21	
1982	7,065.3	4.80	5.40	8.00	25.00	4.59	120.00	19.36	
1983	6,202.1	4.20	4.85	8.12	17.10	4.06	116.62	16.95	
Mean	6,178.7	4.33	5.36	7.73	16.75	4.03	139.13	16.92	

Note: DroughtyWat.Dis.; The 355th largest discharge of the year
LowWat.Dis. ; The 275th 〃 〃 〃
OrdinaryWat.Dis.; The 185th 〃 〃 〃
95daysDis. ; The 95th 〃 〃 〃

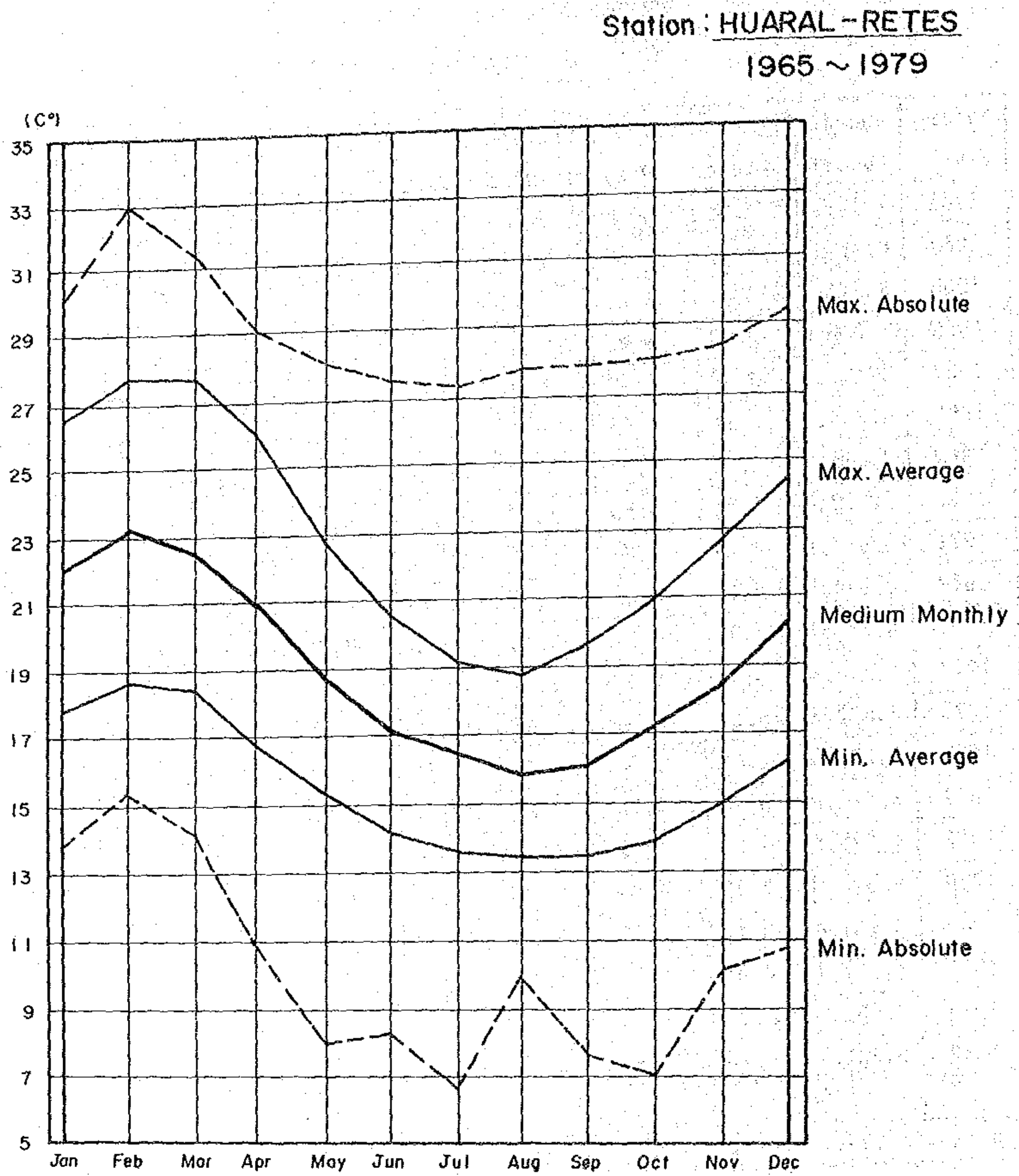


FIG. A-I-I MONTHLY ABSOLUTE AND MEAN TEMPERATURE

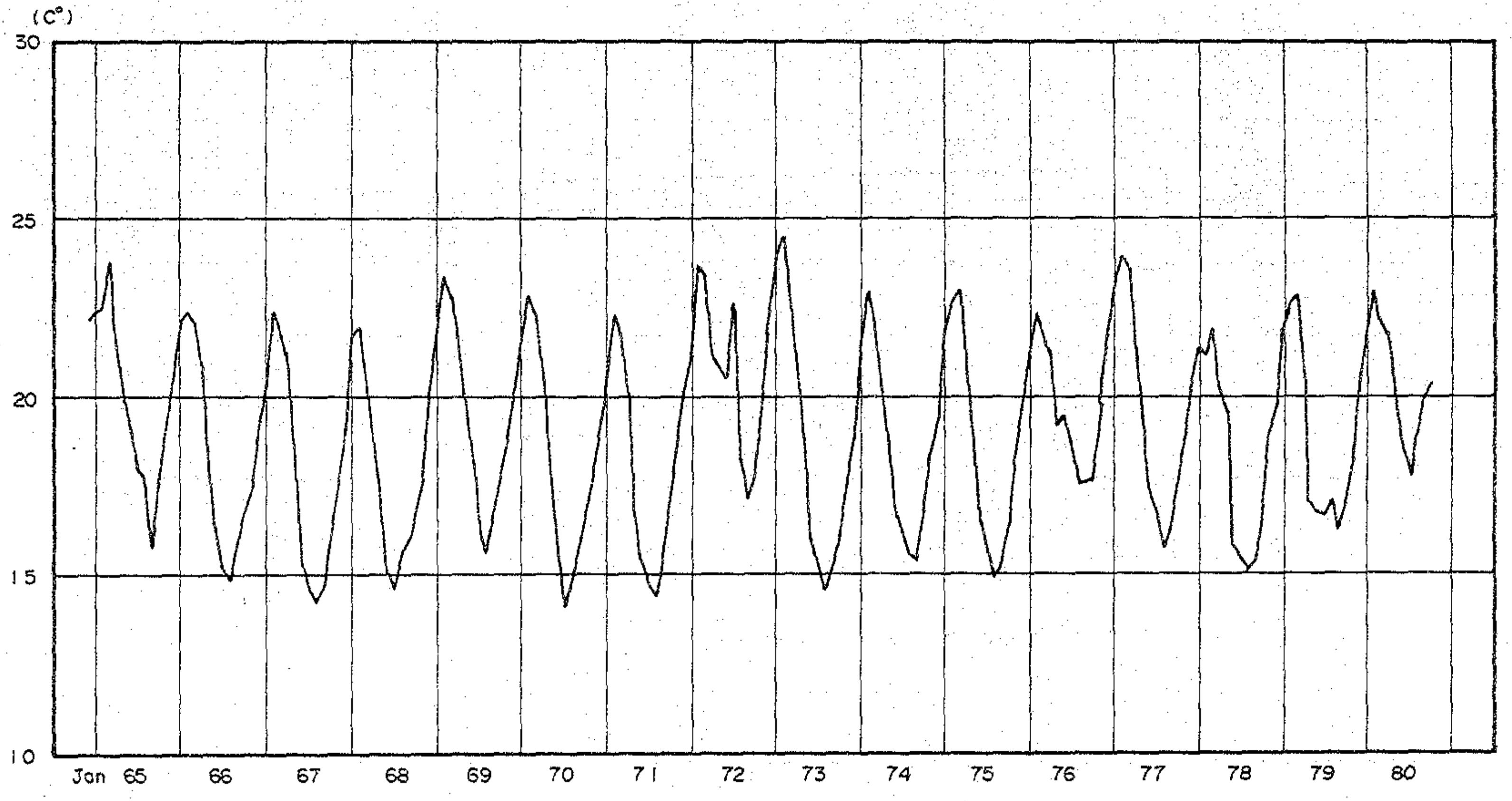


FIG. A-1-2 VARIATION OF THE MONTHLY MEAN TEMPERATURE

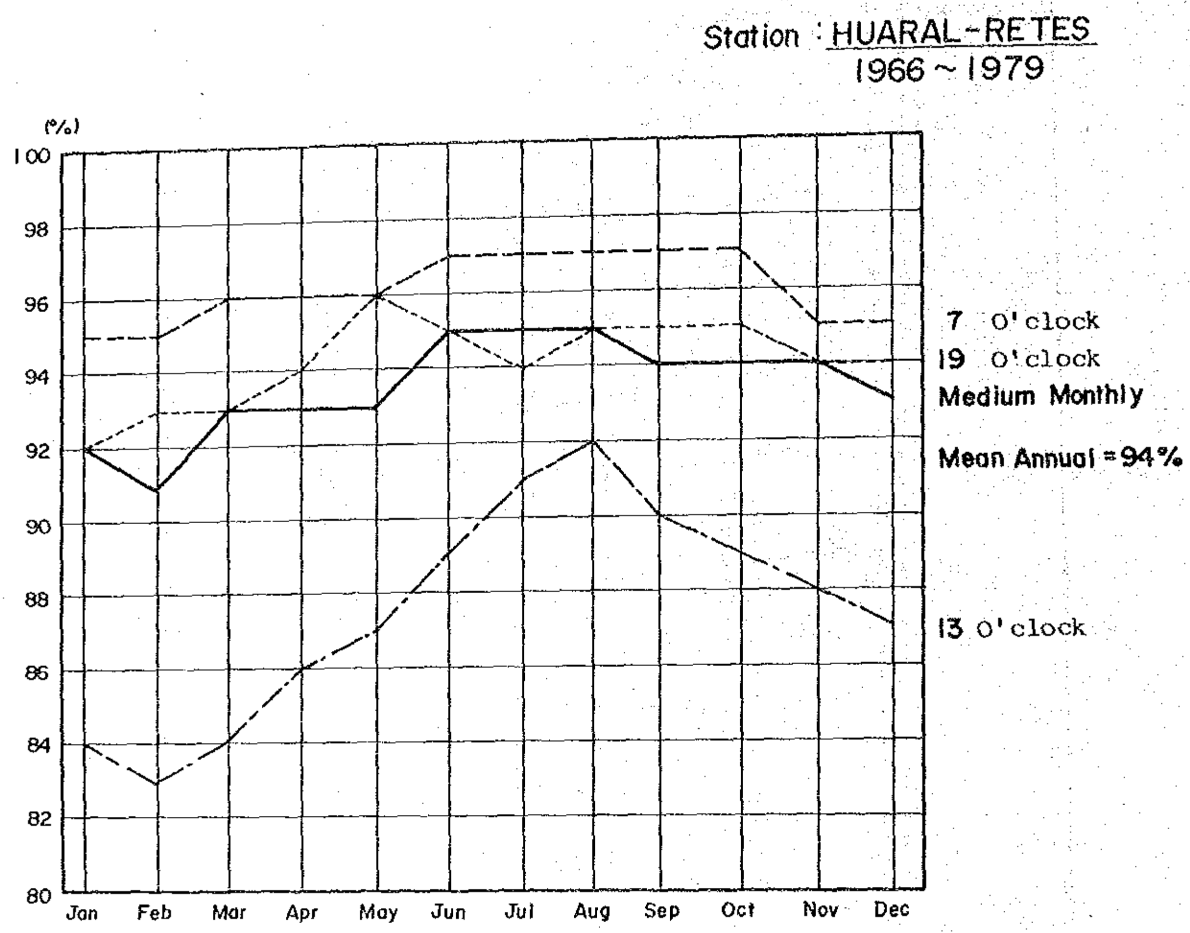
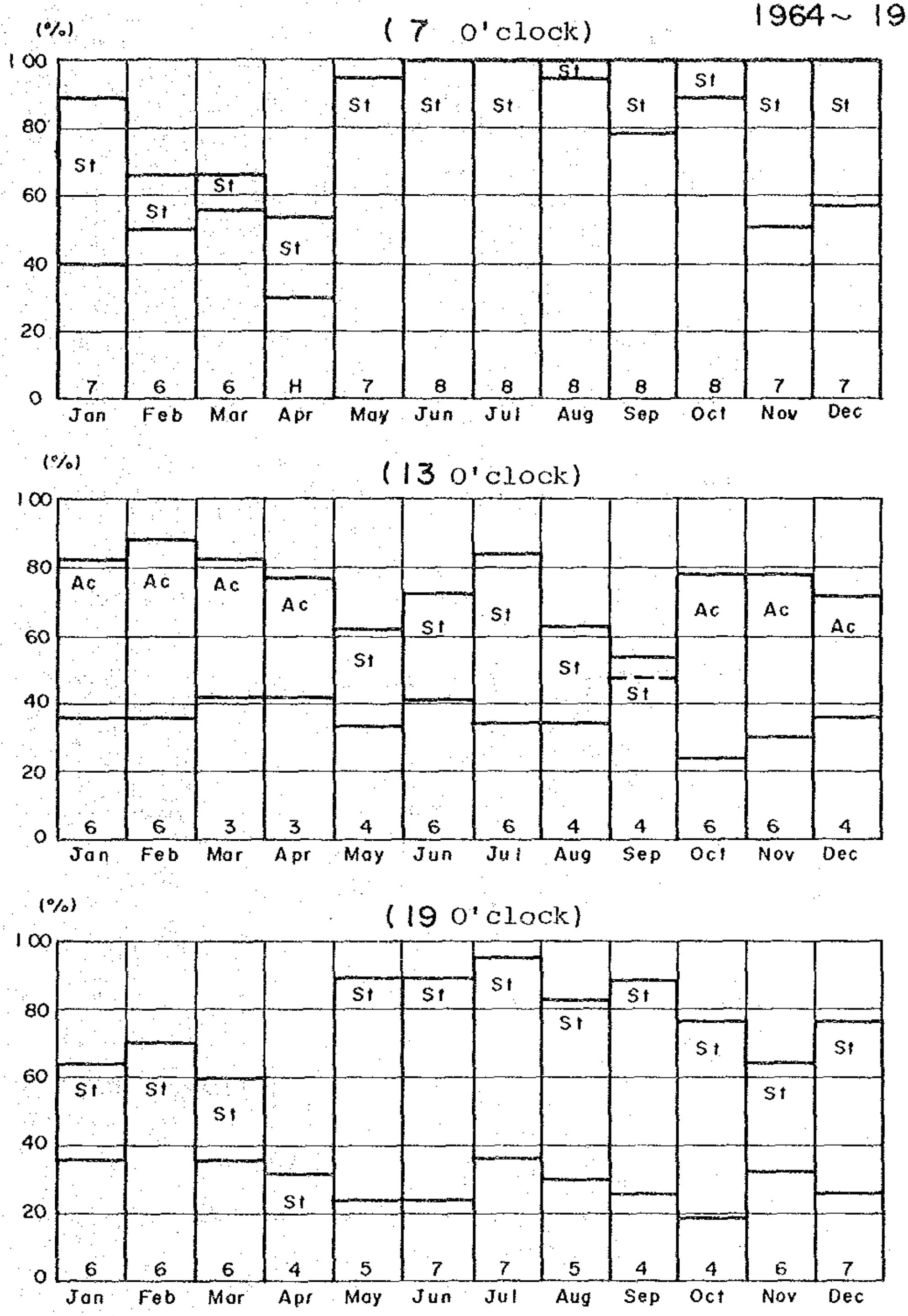


FIG. A-1-3 RELATIVE HUMIDITY (HOUR)

Station: HUARAL-RETES
1964～ 1980

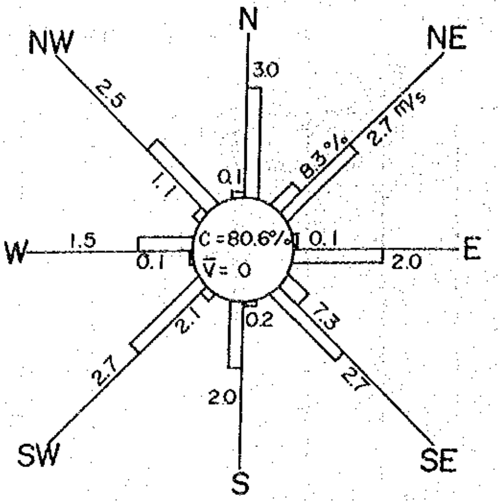


St : Stratus

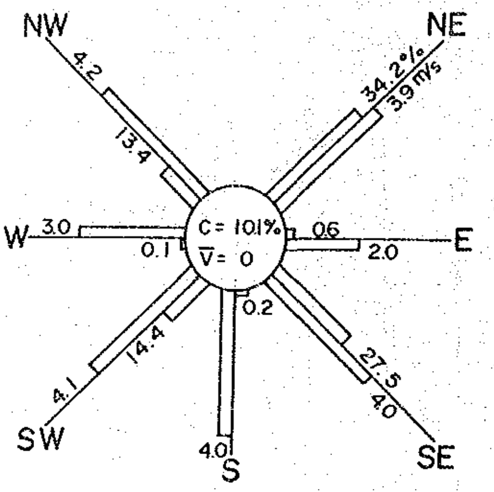
Ac : Atto Cumulus

FIG. A-I-4 MONTHLY MEAN CLOUD AMOUNT

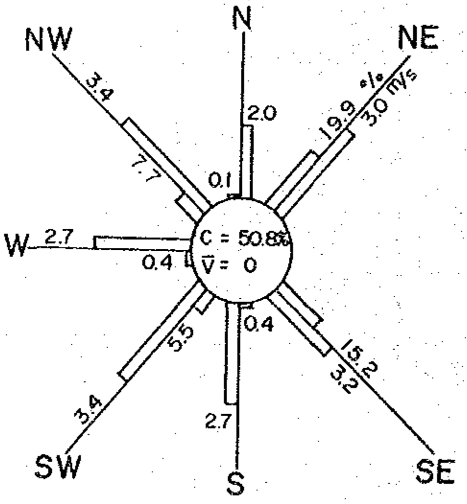
Station: HURAL-RETES
1969 ~ 1980



(7 o'clock)



(13 o'clock)



(19 o'clock)

FIG. A-1-5 VELOCITY AND DIRECTION OF THE WIND

Station : HUARAL-RETES
1964~1976

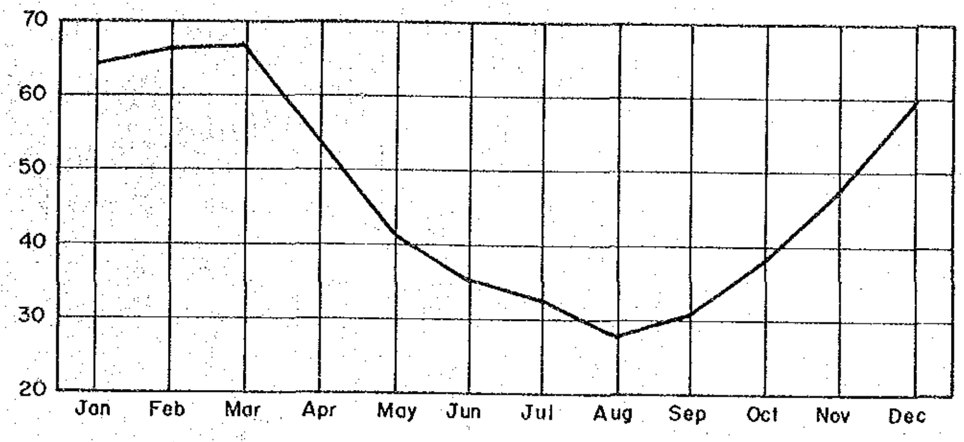


FIG. A-1-6 MEAN MONTHLY EVAPORATION

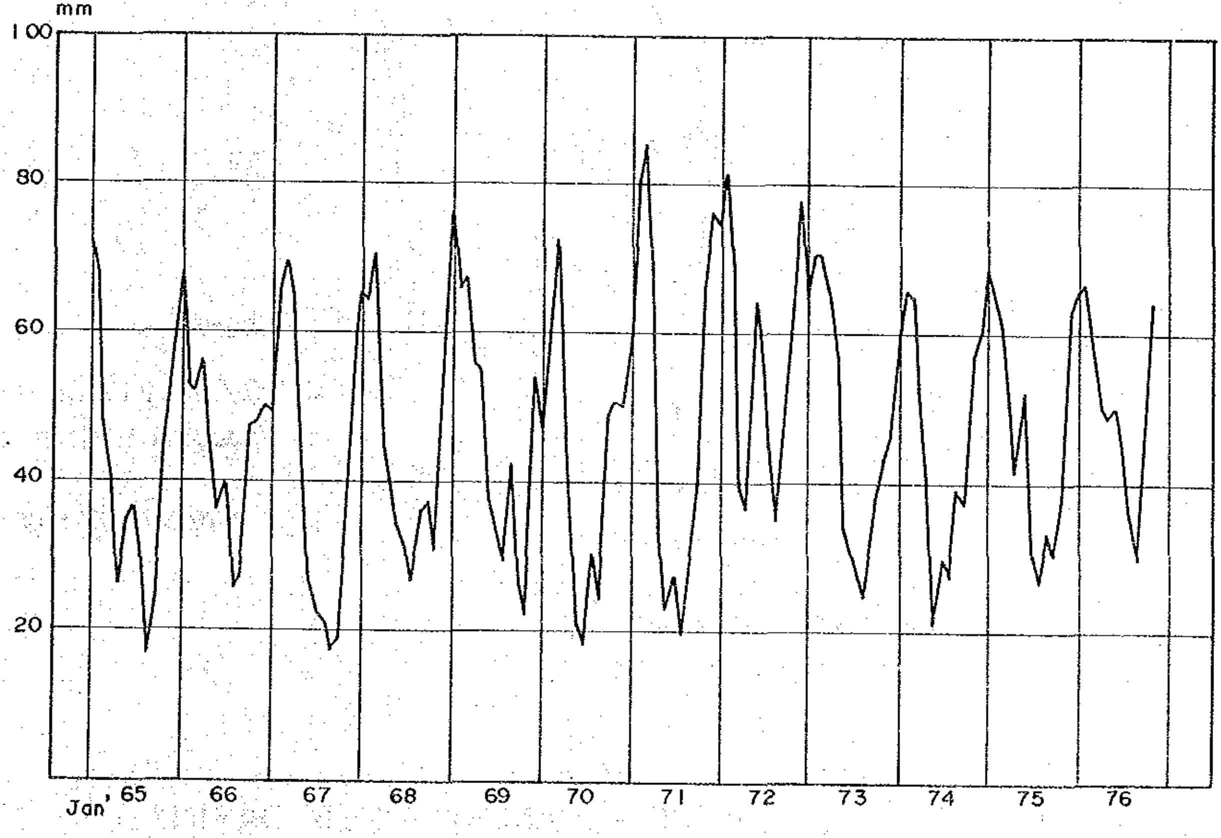


FIG. A-1-7 MONTHLY EVAPORTION

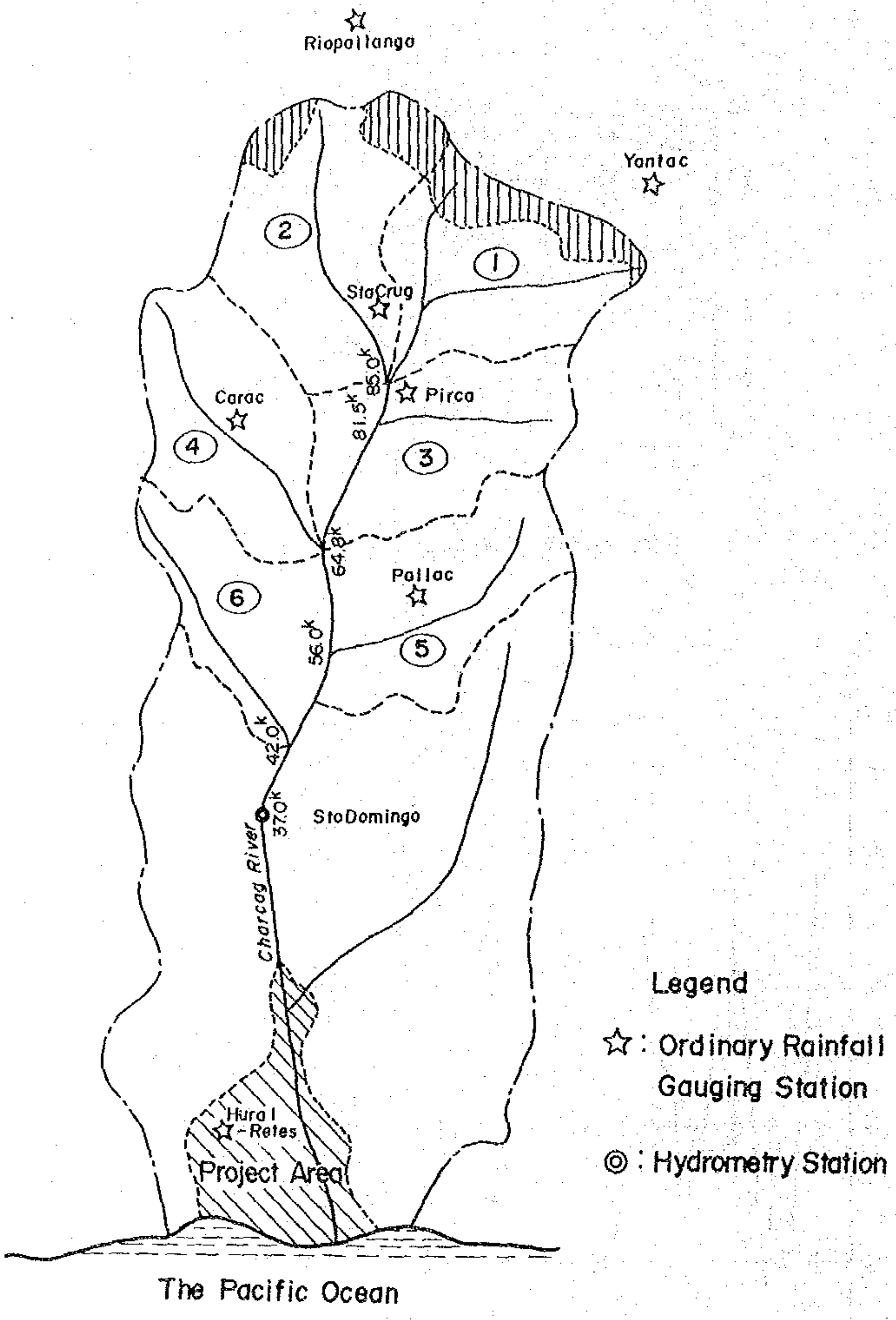


FIG. A-1-8 LOCATION MAP OF CHANCAY RIVER BASIN

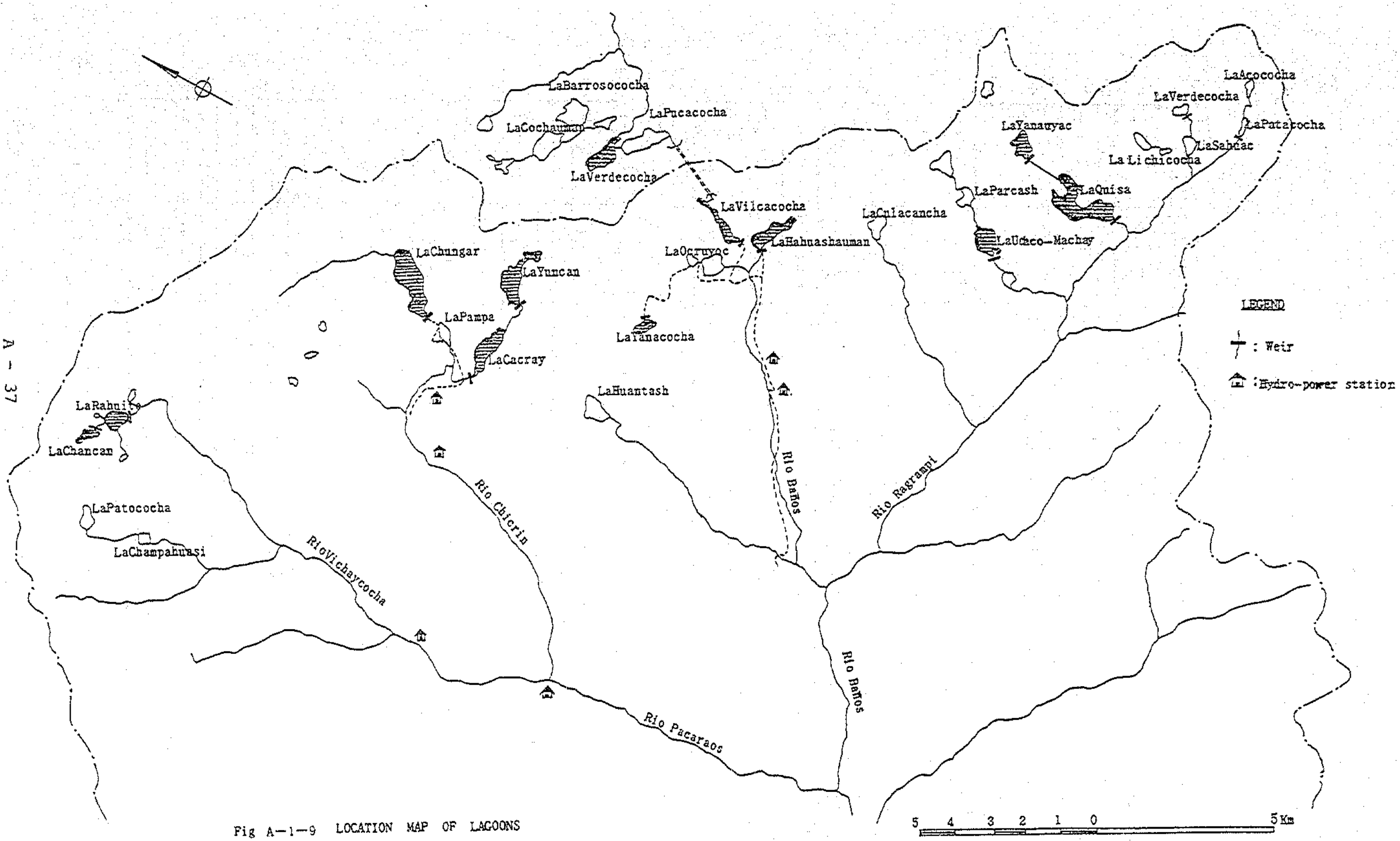


Fig A-1-9 LOCATION MAP OF LAGOONS

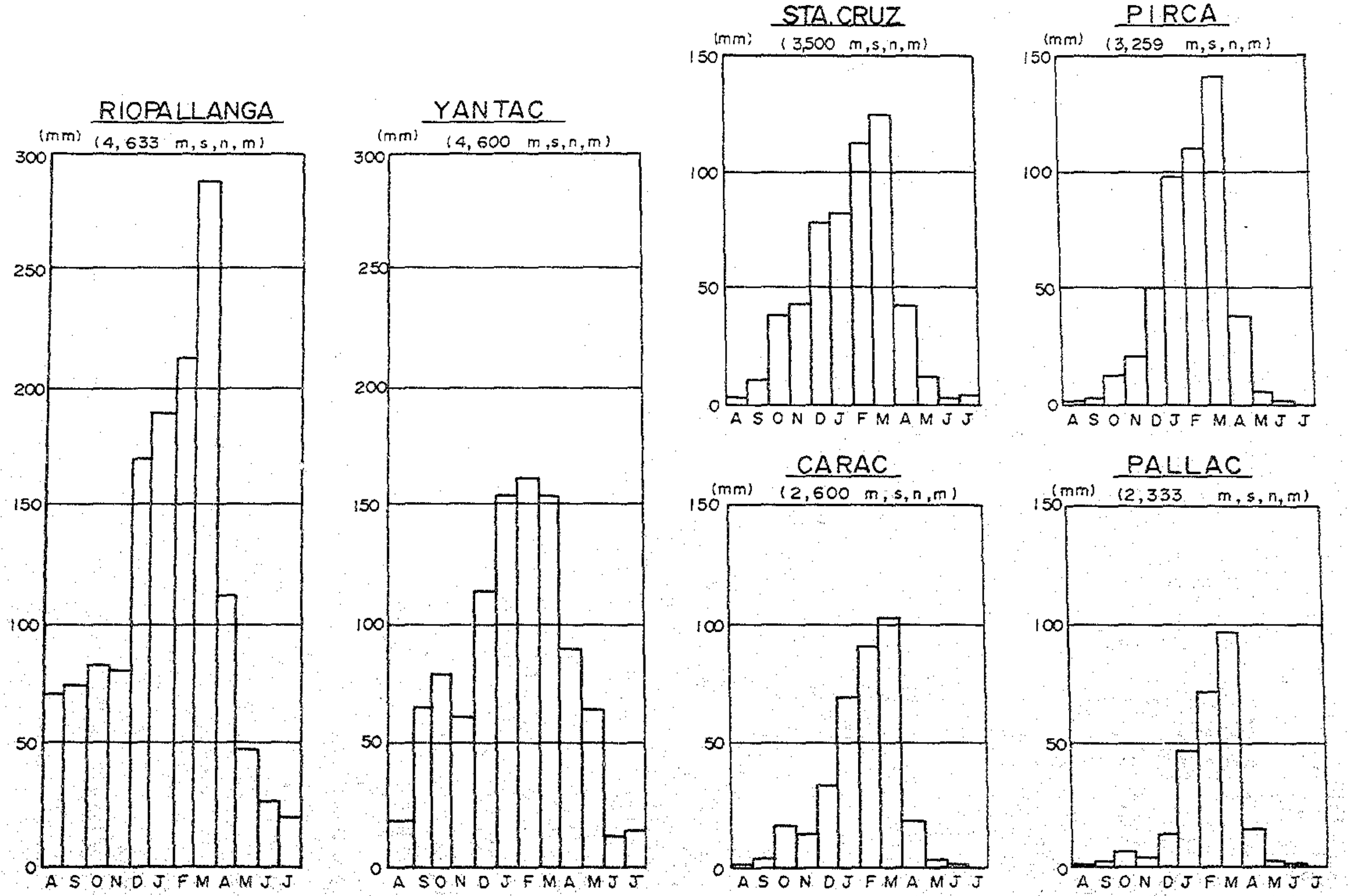


FIG. A-2-1 HISTOGRAM OF MONTHLY MEAN RAINFALL

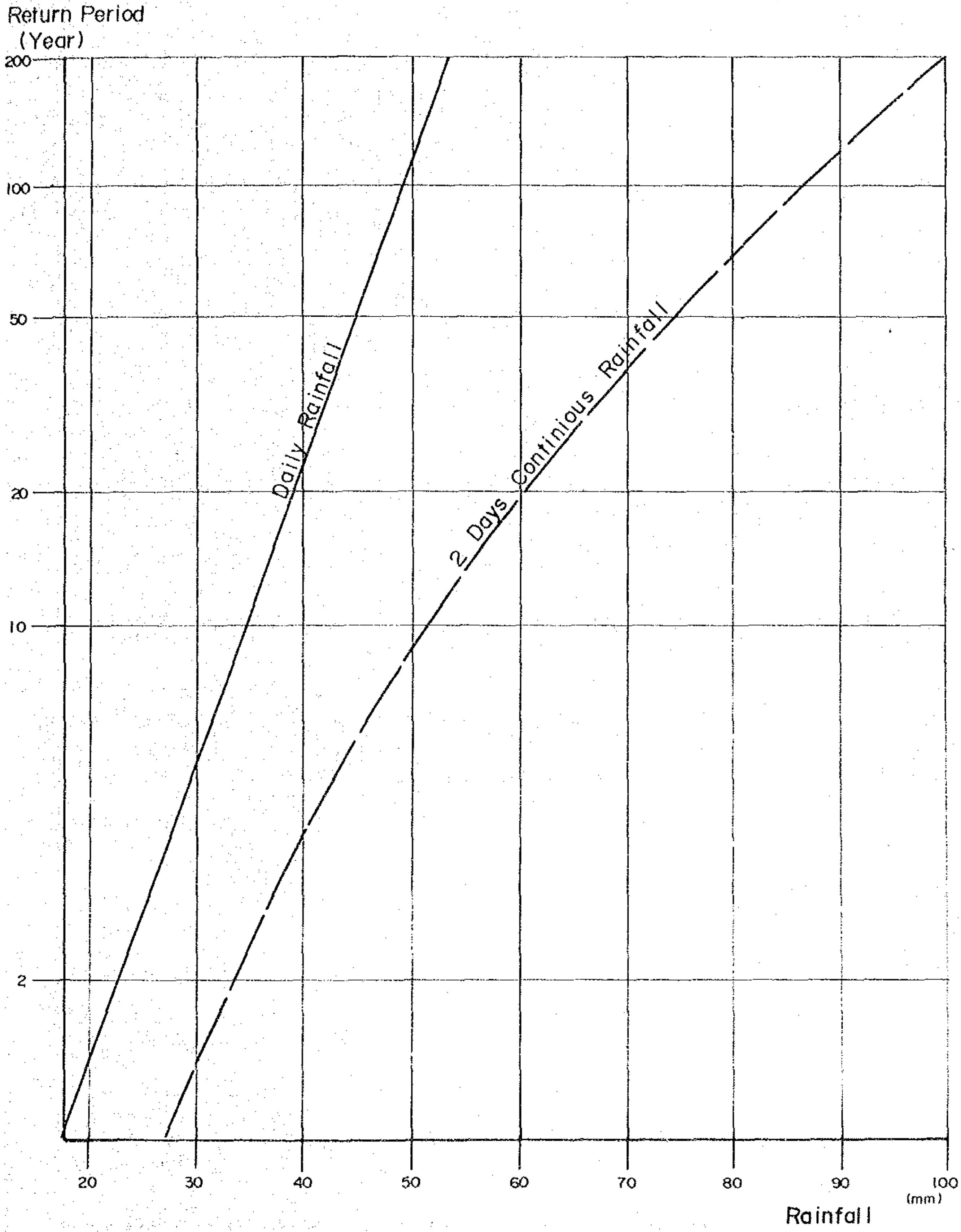
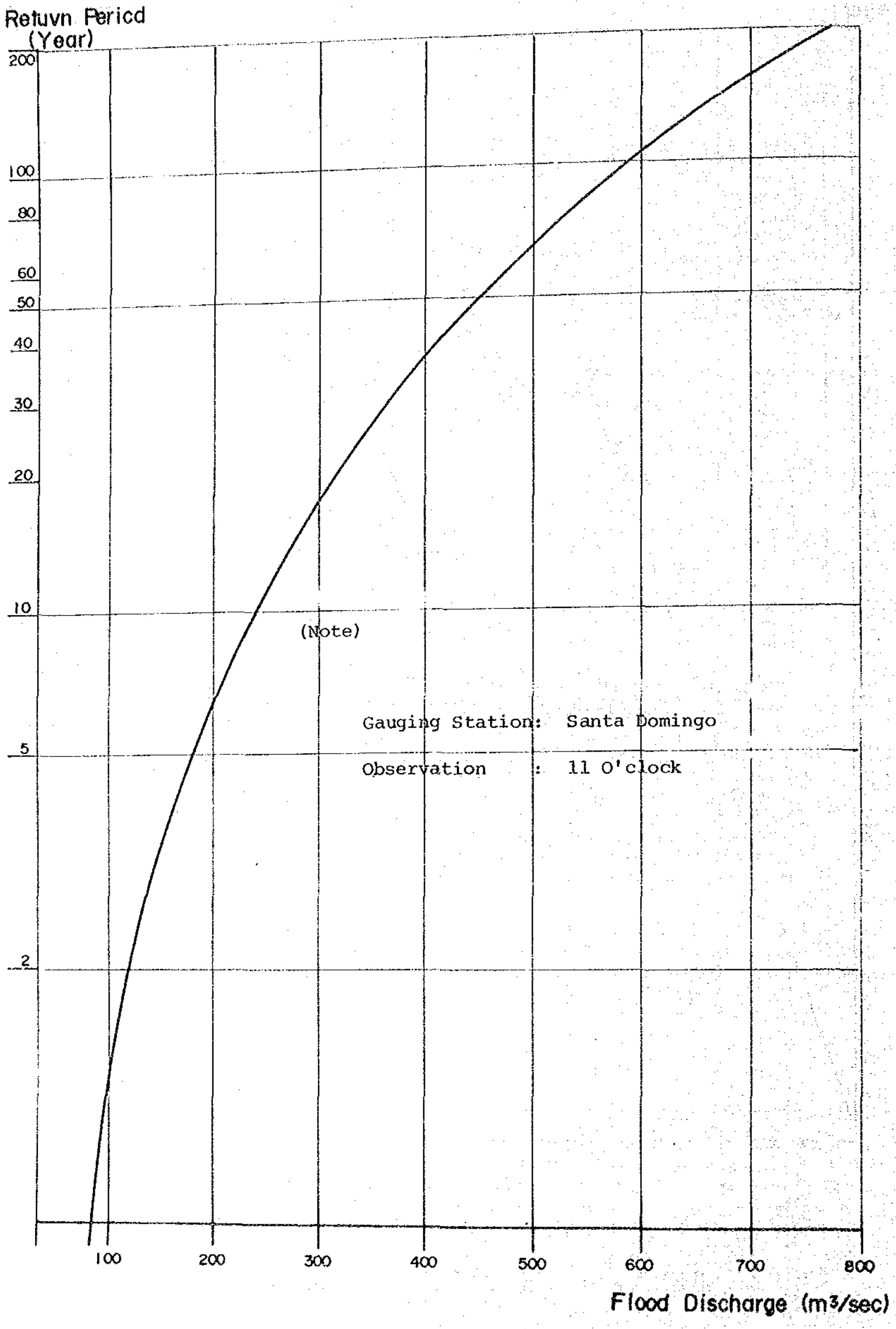


FIG. A-2-2 PROBABLE RAINFALL

(Santa Cruz Gauging Station)



(Note)

Gauging Station: Santa Domingo

Observation : 11 O'clock

FIG. A-3-1 PROBABLE FLOOD DISCHARGE CURVE

ANNEX B

GEOLOGY AND GROUND WATER

CONTENTS

ANNEX B Georogy and Groundwater

Page

ANNEX B

List of Tables

ANNEX B

List of Figures

ANNEX B GEOLOGY AND GROUNDWATER

1 Geology and Topography

1-1 Topography

The Project area is at the west end of the river basin of the Chancay-Huaral Valley where the Chancay river flows rapidly down the steep slope of the west side of the Andes mountains, forming an erosional valley.

The valley opens out into a fluvial plain at Palpa, the boundary of the Project area. Three hills, Macaton, La Minas and La Calera governed formation of the fluvial plain on the right bank and deposits transported from the same resulted in a plane-like slope of diminishing gradient in the Huaral. On the left bank, the Tinchera, Atalaya and Huando hills resulted in the Palpa planation surface while the Pasamayo and Lunavilca hills resulted in the Aucallama-Boza planation surface. Along with deposits transported from hills surrounding the Huaral plain.

On the Chancay river bank, a fluvial terrace and a terrace scarp have developed from the vicissitudes of the river stream while on the coast, a marine terrace has arisen from changes in sea level and cruatal movement.

Topography of the Project area, is principally classified into the north and northeastern hills with elevations of more than 400m, scattered hills the along the coast, 4--8km from the coastlines with elevations of more than 400m, fluvial terraces and planation surface which are distributed along the Chancay river, the Huaral slope of diminishing gradient, marine terraces and the coastal plain.

Hills having elevations of 400--1000m are located in the north and northeastern areas of the Huaral district, on both banks of the Chancay river from the Huando to the upper stream and east of the Palpa and Aucallama area.

Hills having elevations of 400--800m are scattered 4--8km from the coastline and governed the planation working of the Chancay river, supplying sand materials for dunes in the coastal zone.

River terraces are classified into lower, middle and upper. The lower terraces are inundated in the flood season on part of the Palpa and the Aucallama areas and in Granada the some become marsh. The middle terraces are not flooded, forming a plain on the Palpa, Boza, Huaral and Pasamayo areas, and are generally distinguished by terrace scarp from the lower. The upper terraces are situated at the foothills, forming a gentle slope which is contenuous with the middle terraces.

The slope of the Huaral which diminish in gradient were formed from soils transported from the north and northeastern hills of the Huaral and the Chancay river creating a planation surface with a relative height of about 100m. The transported fluvial soils of the Chancay river, however, formed a highland which is now the site of Huaral town. The Huaral plan generally inclines to the northwest with a slope of 1--2° and fluvial transported soils formed planes via Jecuan to Chancayllo and via Quepe Pampa to Chancay town between Calera hill and Macaton hill.

Marine terraces are observed along the coast with a relative height of about 20m. The coastal plane is located along the narrow and long coastal strip, about 8km in length from Chancay town to the south with a width of 500--1000m.

1-2 Geology

Geology in the Project area consists of batholith, coastal bed rock and deposits, as shown in Table B-1-1 and Fig. B-1-1. The batholith of the Chancay basin is plutonic rock denominated by Coastl Batholith which consists of diorite, tonalite and granodiorite. A diverget portion of batholith intruded into old igneous rocks, in the Cretaceous to Tertiary Periods forming batholith and distributing lamprophyre and pegmatite as dikes and sills. Diorite and granodiorite are observed in the Project area, and distributed on the northeastern hills of Huaral and Aucallama districts.

Bedrocks in the coastal zone of Chancay district are volcanic sedimentary rocks of the Puente Piedro formation, compounded by volcanic fluids, andesitic flows, mudstones and tuffaceous sandstones formed in the Jurassic to Cretaceous, and are distributed along the coastal zone with a width of 8km. Deposits in the Project area are clasified into fluvial, eolian, compound and marine deposits (cf. Fig. B-1-1).

Distribution of fluvial deposits depends on geological structure, shape of rock mass and distribution of bedrocks: diorite and volcanic sedimentary rocks (Puente Piedro formation) and deposits are observed on existing plains, alluvial areas and terraces. These deposits are composed of materials transported from the Chancay river, its branches and dried up rivers in the hills and mountains surrounding the fluvial planes.

Dried up rivers refer to those which have no flow at present but which may occasionally be filled by sudden, heavy precipitation. A flood in 1925 occuring in formerly dry rivers on the hills surrounding the Huaral district submerged the latter in 3m of water. The deposits consist of clays, sands, gravels, boulders and broken stones principally from diorite.

Eolian deposits are sediments transported on the wind from weathered rocks, observed on slopes, foothills and mountains, and distributed along the coastal zone with a width of 20km. The deposits formed in the currents of intermittent flood, consist of alternate deposits of fluvial and eolian soils and may be observed in the dried riverbeds of the area distributed with batholith. These deposits consist of sand, gravel, eolian sand with gravel, angular fragments and residual fine sand.

Marine deposits are observed on the coast near the Chancay river's estuary, consisting of sand layers with a shell and forming a long limited plain along the Chancay coast, 500 to 1000m in width.

1-3 Seismic Exploration

In August, 1984 a seismic exploration was carried out at 3 diversion weirs, Palpa, Esperanza and Huando, for geophysical investigations of structure under construction foundation. The traverse line length of seismic exploration at each diversion weir are as follows:

(a)	Palpa diversion weir	1 line	420m
(b)	Esperanza diversion weir	1 line	840m
(c)	Huando diversion weir	1 line	420m
	Total	3 lines	1,620m

Positions of the traverse line and sectional velocity layers at each diversion weir are shown in Fig. B-1-2 and B-1-4 from the results of the exploration. Based on the figures, the foundation of the diversion weir consists of 3 layers, overburden, fluvial deposit and bedrock. Primary wave velocity (Vp) of the overburden is in the range of 0.3--1.3km/s, Vp of fluvial deposit in the range of 1.5--2.4km/s, and Vp of bedrock in the range of 3.7--5.9km/s. Mean primary wave velocity of each layer at each diversion weir is as follows (Vp:km/s):

Location name	Overburden	Fluvial Deposit	Bedrock
Palpa	0.59	2.26	4.29
Esperanza	0.43	2.51	4.69
Huando	0.73	2.21	5.24

Thickness of the overburden is generally in the 2--4m range, but at the buried old river channel it is more than 7m. The overburden consists of coarse grained materials with abundont cohesive soils, and, at Experanza the Vp is slower than at other locations because most of the traverse line is on arable land and cohesive soil content in the overburden is hight.

Thickness of the fluvial deposit is in the 20--60m range and someplaces exceeds 100m. The deposit mainly consists of coarse materials (pebbles and cobbles) with fine soils, is very dense and becomes saturated with water.

Depth of the bedrock is generally from 20m to more than 100m. In the figures, the depth at 2 intakes, Palpa and Huando, is about 20m, but the traverse lines were about 10--20m distant from the weir body, and the weirs are on actually sited bedrock outcrops. The bedrock is diorite, solid and hard rock, and classified into hard to moderately hard by Vp. The velocity of secondary wave (Vs) and Poisson's ratio (Nu), which is evaluated from Vp are as follows:

Vs = 2.14--3.78km/s
Nu = 0.23--0.30

1-4 Recommendations for Foundation

Based on the results of geological investigations and seismic exploration, planning of foundation engineering for repair and reconstruction of some diversion weirs and regulating reservoirs.

The foundations of 2 existing diversion weirs, Palpa and Huand, are on hard diorite, and presumably present no problems. From seismic exploration, depth of the bedrock at both diversion weirs is about 20m from the position of the existing weir to a point about 90m distant, and from the latter point to the river center the bedrock surface has an incline of about 6° on the Palpa and at about 12° on the Huando side.

Under the overburden, there is fluxial deposit having a primary wave velocity of more than 2.2km/s and the deposit presents no problems for bearing capacity of construction foundation. On the earthwork, the overburden can be easily removed with mechanical excavation devices. Devices used for excavation work on the fluvial deposit however, should be carefully considered as the same is mainly composed of pebbles and cobbles.

The existing Esperanza diversion weir was damaged by flood in February, 1984 and presently is taking water from temporal diversion. The bedrock under the said weir is hard diorite with a surface incline to the river center of about 7° and a depth at the existing diversion weir of more than 100m. The same cannot directly bear the load of the weir foundation; however the bearing capacity of the fluvial deposit which has a 2.5km/s P wave velocity will be sufficient for the foundation. On the overburden, earthwork will be easier than that for other diversion weirs because of the higher content of cohesive soils; however, careful selection of mechanical excavating devices for the fluvial deposit in this weir will be necessary due to the high content of cobbles.

The bank of the Palpa regulating reservoir has a plan height 3m greader than the actual height. Bedrocks in this area is diorite and the foundation of the existing bank is located on terrace deposits. Increasing the height by 3m represents no problem to bearing capacity, but bank materials which were formed of soils of the bank body should therefore take into consideration methods to compensate for the same, such as designing the gradient of bank slope at 1:2--1:3 and increasing the depth of watertight concrete wall.

2 Groundwater

In the Project area groundwater is uded to supply water for shortages in irrigation and stock farming supply. According to existing data, there are 33 irrigation wells providing a supply of 5,600,000--20,200,000m^3/year (0.18--0.64m^3/s). Permissive mining yield of the same, however, may be only 11,600,000m^3/year (0.37m^3/s).

As the cost of using groundwater is often higher than that for surface water, use of groundwater for irrigation will be limited to supplementary supply in the dry season.

Features and problems concerning the sue of groundwater in the Project area are as presented below.

2-1 Distribution of Aquifer

Groundwater in the Project area is saturated with fluvial deposits transported mainly by the Chancay river, its branches and dried up rivers in the hills surrounding the Project area. The geologic map, Fig. B-2-1 shows the distribution of fluvial deposits.

Fluvial deposits principally consist of coarse grained materials: boulders, cobbles, gravels and sands, but the variable river flow also deposits some fine and cohesive materials, resulting in a complex geological profile.

A compound deposit at a piedmont will form an effective aquifer, if it is located over a groundwater artery. An eolian deposit may form a small aquifer at the depth of the clayey layer.

According to previous studies of the hydrogeology and groundwater of the Project area, the depth of the aquifer is about 1--2m with a thickness of about 10-40m and very good permeability. The depth, thickness and stratified condition of the aquifer, however, are different in various places. For instance, stratum of a well near Huayan is gravel from ground surface to 60m in depth, while strata of a well near Huand is sand with gravel from the ground surface to 30m in depth with cohesive soil to 60m. Both wells are located near the right bank of the same river at upper and lower points, but the strata are not the same.

Geological profiles based on existing well logs and topographical charts are shown in Fig. B-2-2 and B-2-6. It is evident from the same that on the left bank of the Chancay river layers are rich in cohesive soils and on the right bank layers are rich in sand-gravels. On the profiles from La Huaca to Esperanza Baja (Fig. B-2-4, E-E), however, two traces of buried erosion caused by the river stream at La Huaca and north of Huaral can be seen. Water from Boza's spring has been infiltrating through volcanic sedimentary rocks and from Chancay coastal spring has been infiltrating through a border under the coastal terraces situated on impermeable layers.

2-2 Groundwater System

The river net map in the Project area is shown in Fig. B 2-7. Most of the rivers in the Project area are "dried up rivers", except the Chancay river. Water flows expected from the river net are indicated in the said figure. Expected groundwater systems are shown in Fig. B-2-8 and B-2-9 from existing well logs, geological profiles, river net and topographical chart. From the figure, the main source of groundwater in the Project area appears to be the Chancay river stream and influent flow in the riverbed. Groundwater is classified into infiltration water from irrigation water and groundwater current from the upstream on the right bank, and into groundwater from Orcon ravine, infiltration water from irrigation water, groundwater current from the upstream and infiltration water from the east hill area onthe left bank of the river.

As shown in the Fig. B-2-8 a groundwater artery is observed from Experanza Alta via Retes to Calera hill. Fig. B-2-4, E-E shows a geological profile from San Jose (Aucallama Dist.) via La Huaca and Retes to Esperanza Baja. In the figure traces of erosional valleys are observed forming perpendicular arteries. The groundwater artery through La Huaca is from influent water of the Chancay river, while an artery through Retes is from irrigation water.

In the said figure a profile near Boza is shown and the source of Boza's spring is water infiltrated through southeastern volcanic sedimentary rocks and the influent flow of the Chancay river is partially to the right bank of the river.

a) Miraflores via San Jose and Boza to Pasamayo (in Aucallama Dist.)

b) Jesus via the west foot of the Macaton hill to Chancay city (in Huaral and Chancay Dist.)

c) Esperanza Alta via Retes to the Calera hill (in Huaral Dist.)

d) Esperanza Baja via Jecuan to Chancayllo (in Huaral and Chancay Dist.)

Irrigation water in poor drainage zones such as Cuincha and Donoso cannot infiltrate into the deep zone very well due to the existence of the calcareous or clayey layer and flows as semi-perched water under the surface, some of it seeping out into the deep zone. Ahere a zone having no aquiclude blocking infiltration, irrigated water flows directly into aquifer (cf. Fig. B-2-10).

2-3 Direction of Groundwater Flow and Displacement of Groundwater Level

Dynamic groundwater trend in the Project area is controlled by hydrogeologic structure, the Chancay river flow and its utilization rate. Occasionally heavy precipitation in the hills surrounding the area causes accumulation of large amounts of groundwater; however this phenomenon is periodic, occuring every eight to ten years.

Fig. B-2-11 and B-2-13 show contours of groundwater levels reported at different times; 1968, 1976 and 1982. Arrows indicate groundwater flow directions, from which two main flow directions are noticeable. The first direction indicates influent flow along the riverbed of the Chancay river. The second is from Esperanza Alta via Retes to Casa Amarilla branching off in to directions on the east side of La Calera foothills; north-west and south-east. Those directions are the same as the directions expected for groundwater arteries in Fig. B-2-8 from different data.

Fig. B-2-14 shows contour lines of ground level in the limit of the aquifer which are very similar in comparison to those for groundwater levels. Differences in contour suggest the presence of artificial variation of groundwater level or a former valley now buried by erosion debris.

As is evident from Fig. B-2-11 and B-2-13, the groundwater level rose during the ten years from 1966 to 1975, and dropped during the six years from 1975 to 1981. Measurement of each level was carried out in June. The groundwater level in the Huaral district is considered to correspond directly with increase and decreases in the amount of water supplied from irrigation canals and reservoirs along the Chancay river. In the Chancay district and soth-west part of the Aucallama district where the aquifer has a lower flow area, the influence of irrigation water use is greater than in the upper area.

When annual rainfall is scarce, use of groundwater increases as groundwater is used to compensate for irrigation water shortages. During such period groundwater level drops.

2-4 Index Properties of the Aquifer

According to existing data, the index properties of the aquifer (transmissivity, coefficient of permeability, coefficient of storage and hydraulic gradient) are as follows:

Transmissivity T, coefficient of permeability k and coefficient of storage S are evaluated from recuperation anyalysis based on results of a pump up test on one well.

$T = 0.013 -- 0.056$ (m^2/s)
$k = 0.0004 -- 0.005$ (m/s)
$S = 2.4$ (%)

where: the value of coefficient of storage is considered as a rough estimate because hydraulic gradient in the area surrounding the test well during the test is unclear.

Hydraulic gradients of groundwater where estimated from contours of groundwater level in 1981, and if the hydraulic gradient of the artery along the Chancay river is expressed by the symbol I1 and the artery through Retes by I2, the gradients are as follows:

$I1 = 1 -- 1.5$ (%)
$I2 = 0.6 -- 0.7$ (%)

So the longitudinal gradient of the Chancay river in the Project area is 1.4% on the average.

2-5 Use of Groundwater

Groundwater reserve in the Project area can be calculated from inflow, runoff and recharge in a certain profile of aquifer where they are equal to each other and inflowing and recharging quantities are the same. If the sectional area of the aquifer A and apparent velocity of groundwater are known, groundwater flow Q can be calculated by the following equation:

$$Q = VA$$

Where V is calculated V=KI. K is the coefficient of permeability, and I is the hydraulic gradient. I should be corrected by Theta which is the angle made by the flow line and sectional line as the flow line is not usually perpendicular to the sectional line.

Based on contours of groundwater level in 1981, groundwater flow is calculated on the profile from San Jose in Aucallama Dist. to Esperanza Baja (Fig. B-2-4, E-E). Groundwater flow in the profile is 5.96m^3/s and total annual reserve is 189,900,000m^3. This total quantity is about half of total irrigation water quantity in 1981 (cf. Table B-2-1).

According to existing data in the INAF and PLANREHATIC III reports, utilizable groundwater yield in the Project area is 24,900,000m^3/year estimated from water-table depression. In this case the water-table depression must have been calculated at about 2.5--3.7m. If available range of the depression is made hydrodynamically 1.0--2.0m, utilizable quantity is 11,600,000m^3/year. Thus total utilized quantity in 1981, 9,400,000m^3 is 81% of the utilizable quantity and quantity utilized for irrigation, 20,200,000m^3 in 1979--1980, is 174% (cf. Table B-2-2 and B-2-3).

Maximum groundwater quantity used for irrigation, as shown in Table 2-4-3, was 20,200,000m^3 in the term of one year, 1979--1980, while no minimum was reported for the year 1982--1983, or in the last fiver year.

The ratio of utilized groundwater to the sum total of irrigation water in the Project area is 0.06 for a poor discharge year, 1982--1983. The maximum quantity, however, is equal to the lift rate taken by water-table depression of about 3m in all aquifers of the Project area. Maximum quantitty appears to be the maximum quantity of permissive mining yield, because the Chancay river is the only groundwater resource in the Project area.

Taking the quantity of used groundwater and discharge of the Chancay river at Santo Domingo as criterion, the ratios of the annual quantity and discharge to the same are plotted in Fig. B-2-15. On the basis of the said figure, groundwater used in irrigation is in inverse proportion to discharge of the Chancay river. However, Fig. B-2-16, which shows the relationship between each ratio indicates that if the Chancay river receives more than double the discharge of the poor discharge year, 1979--1980, 530,000,000m^3, use of groundwater for irrigation will be almost totally unnecessary.

As a general rule, wells are used for irrigation for a 2--3 month period which peaks in November. This is unclear in Fig. B-2-17 which was plotted monthly using the rate of groundwater from each year in the last five years (cf. Table B-2-3).

2-6 Possibility of Use of Groundwater in Areas of Water Shortage

In the Project area irrigation water shortages occur from limited water flow in the driving canal. Possibility of use of groundwater for those areas generally do not meet to the expected of project requirements in the Project area, due to insufficiency of the permissive mining yield. However, the costs of drilling new wells, withdrawal, maintenance and management for use of groundwater for irrigation are often higher than that for surface water. Possibility of use of groundwater for those areas is studied as discussed below.

It seems that there is no possibility of use of groundwater for irrigation in the northwest part of La Esperanza Baja due to lack of effective aquifer and groundwater resources. Wells in Los Laureles Sur and Torre Blanca south-west of Quepe Pampa are generally shallow in depth (7--8m) and employ 38--50mm caliber pumps which continuously pump a small quantity of water for domestic and liverstock use. These pumps are an adequate for lifting water from deep wells and it seems that construction and operation of wells for irrigation use will be difficult. However, groundwater arteries are presummed at the north-west foot of the Macaton hill and the east foot of the Calera hill. It would be possible to drill several wells at the latter locations to obtain groundwater for the west area.

Groundwater at Casa Blanca in the Aucallama district is derived from infiltration water from the northern area and at Granada a spring recharges the lower zone of the southeastern hills. The spring at Granada is fed by water infiltrating through volcanic sedimentary rocks and the weathered zone of the same, and is rich in salinity, sulfate and boron. Only flowing surface water is used in this area as standing water quickly becomes stagnant and there are no bored wells. Use of groundwater for irrigation is therefore difficult in this area.

As for the proposal to supply lift water from drilled wells from Boza Alta to Boza Baja, the same seems less suitable as the layers of the left bank of the Chancay river are generally rich in cohesive soils in contrast with the right bank and thus withdrawal capacity of the aquifer is poor. Instead installation of an infiltration gallery in the riverbed is planned in which influent water or infiltration water will caught and used for to supply downstream areas. This alternative appears more appropriate than the former proposal.

2-7 Recommendation for Maintenance and Management of Wells

According to existing data, 33 wells are in use for irrigation 26 of which have reported pumping rates. There are, however, many tubular wells which requir repairs. The wells were filled with sand due to boiling of sand by over withdrawal, abandonment of well with too little withdrawal, or drying up and consequently pumping equipment was superannuated and damaged. Most of them are belong to individuals or associations. The management of public and company wells is generally good.

Wells are frequently abandoned by due to lack of funds for repair and increased cost of driving, maintenance and management. Some abandoned wells are also abandoned due to low cost performance arising from lack of effective aquifer or excessive distance from a groundwater artery.

Based on actual conditions of well operation, recommendations are as follows:

a) Renovation of pumping equipment on 26 wells which are actually driving is recommended as most of them are superannuated (cf. Table B-2-4);

b) Frequently used pumping equipment should be electrified (pumping equipment used 2--3 months in a year usually have a diesel engine);

c) As determination of the appropriate pumping rate for each well is very difficult due to limitation of rate by depth, thickness, texture, aquifer, pipe, capacity of pumping equipment, pumping rate, frequency, period of withdrawal, etc, it is recommended that sand content of water at the withdrawal point be checked to avoid over pumping. The simblest method is to sample water at the discharge pipe, determine the sand content and control the pumping rate.

d) At present, wells on groundwater arteries which fill up with sand and decrease the mining yield should be recovered by bailing.

e) In future, new wells should be located on groundwater arteries in accordance with the figure of groundwater system (Fig. B-2-8) and water from the same should be run off to existing canal.

f) According to the figure of groundwater contour level in 1968 (Fig. B-2-11), a contour 0m in altitude intrudes into the inland area about 2.3km from the coastline. This fact indicates that the mining yield discharge is greater than groundwater recharge. If the groundwater level draws down below sea level, a saline-water intrusion develops, changing groundwater into brine. About 40--50 years is required to revert from brine water back to fresh water if the groundwater level is restored to its original level. The use of groundwater in the Project area therefore, should be limited to within certain permissive range to prevent the drawdown lelel of groundwater from sinking lower than sea level.

The groundwater level seems to vary at the same ratio as the Chancay river discharge to mining yield. Groundwater level should be controled by limiting pump caliber and managing of the mining yield at a permissive groundwater level.

3 Water Quality

Fourty-two water samplings were carried out for chemical analysis at elevent points of existing wells and underdainage in the first then days of March, 1984, and at fifteen points twice in the first ten day and at the end of July, 1984. Sample numbers, dates, well numbers and location names are shown in Table B-3-1 and B-3-3. The results of the water analysis are shown on Table B-3-4 and B-3-10 and the results of the analysis of 17 surface water samples taken from irrigation canals (principally infiltration water) and the Chancay river during the above mentioned periods in the Project area are also shown.

According to the results of water analysis, both groundwater and surface water are classified as having medium to high salinity hazard and low to medium sodium hazard (C2S1--C3S2). The same are classified from criterion of U.D. Dept. of Agriculture (Agriculture Handbook, '60) based on sodium (alkali) hazard of SAR (SAR: sodium Absorption Ratio) and salinity hazard of electrical conductance. All are suitable for irrigation use, except Granada spring in Boza. The spring is classified as having high salinity and high sodium hazard (C4S4) and is rich in boron (3.0--6.2p.p.m), which is unsuitable for irrigation despite the fact that it is presently used for the same.

A guideline for interpretation of water quality for irrigation by adjusted SAR, electrical conductance and chemical elements is shown in Table B-3-11. Based on this guideline, results of detailed interpretation of the water quality of the 42 water samples are shown in Table B-3-12 and B-3-18. Groundwater and surface water are generally suitabile for irrigation ase according to the criterion of the U.S. Dept. of Agriculture.

During the water sampling period, in July, infiltration water quantity increased in comparison to that in March without changing in water quality for irrigation. The PH of groundwater creased in range from 8.1--8.5 in March to 7.2--8.1, generally increasing electrical conductance. PH of surface water in canals remained almost constant (8.0--8.3) while electrical conductance doubled.

Fig. B-3-1 and B-3-6 show key diagrams of percentage of anion and cation content for each sampling period and ground and surface water. The figures indicate that groundwater and surface water mainly contain Calcium-Magnesium Bicarbonate while the spring contains Alkali-Chloride Alkali-Sulfate. Groundwater and surface water have the properties of shallow groundwater, infiltration water and river water, while spring water has properties similar to a spa. Fig. B-3-7 and B-3-8 show groupings of the same in both sampling periods, March and July. Chloride and sulfate content of groundwater, surface water and spring water increased during the 4 month period.

4 Future Investigation

4-1 Geology and Topography

Geological structural foundation at the diversion weirs investigated in this study, namely, Palpa, Esperanza and Huand, have been clarified. The geological foundation structures are complex and vary with location necessitating drill exploration at the actual site of construction in the stage of detail design.

The depth of exploratory drilling should be 10m and the diameter of the hole should be 50--100cm because drilling is very difficult with a generaly drill diameter 66m due to the large cobbles. The contents of exploration will be limited to confirming geological overburden and fluvial deposit as sounding in the hole will be impossible and visual determination of grain-size distribution sufficient. Drill holes should be spaced at intervals of about 50m.

For the regulating reservoir it is necessary to determine the foundation condition to drill for exploration at 2 points, one in the bank and one in the reservoir bottom. The depth of exploratory drilling with 66mm diameter drill should be 10m. Driling will be carried out at the some time as the Standard Penetration Test (ASTM D 1586-67, 1974) at intervals of 1m in depth, except in layers of cobble, pebble and bedrock.

A mechanical analysis of soil for each stratum should also be undertaken. Laboratory tests should be performed on bank materials, including sieving, Atterberg'limits, compaction and permeability, to determine index properties, optimum water content, compaction density and permeability of the same.

4-2 Groundwater

A detailed report of groundwater in the Project area was submitted by INAF in 1982. A similar study should be made every 5 years or less.

It is very important to measure the groundwater level in the Project area in order to make a contour of the groundwater level and to determine variations in the water table. It is necessary however to strictly control lifting of groundwater to prevent excessive water-table depression. As for measurement of the groundwater level, it is necessary to distinguish the water level of semi-perched water in the poor drainage area to the water level of the aquifer and to establish the depth of the observation well for semi-perched water about 1--2m under the surface for water table measurement. Existing wells may be easily used for water-table measurement of the aquifer.

It is necessary to know the shape of the groundwater basin, strata and permeability for determination of basin reserve of groundwater and effective use of the same. The profiles of hydro-geological structure were partially clarified in this study, but further study is required. An exploratory drilling will be necessary for determining the hydro-geological profile. The depth of the drilling will be 100-150m for depth confirmation of the bedrock. It is better to make the diameter of the drill hole 66mm, to obtain information on strata, thickness and permeability and to drill in conjunction with electrical well logging. Suitable points of exploratory drilling are 100-200m southwestward from Puento Libero, Huaral town, Retes, the center of the narrow section at Jecuan, Quepe Pampa and Pasamayo. Detailed exploratory drillings should be reconsidered after clarification of the hydro-geological profile.

Groundwater and surface water were sampled in March and July and quality tests were carried out in the study. Groundwater and surface water were more abundant in March and July than in November. For comparison water of quality in abundant periods to that in scarcer periods, water samplings and quality tests should be carried out in November at the same points which were sampled in March and July.

REFERENCES

1. Hidrogeologia vallle Chancay-Huaral, Dpto. Lima, Provs. Chancay y Huaral, Cuenca del Rio Chancay-Huaral, INAF, 1982
2. Ing. Migel Ventura Napa: Diagnostio del la Explotacion e Infraestructura de las Augas Subterranas en el Valle de Chancay-Huaral. Tomas I y II, (Tesis), 1976
3. Geological invectigation of structure foundation sites, Palpa, La Esperanza and Huand, Jose e. Arce Helberg, Exploration Gelogist, Aug., 1984
4. Sinopsis de la geologia del Peru, vol. no.22, Instituto geologio minero y metalurgico, 1982

Table and Figures

Table B-1-1 GLOLOGIC ASPECT IN THE PROJECT AREA (CHANCAY-HUARAL VALLEY)

Epoch	System	Formation	Lithology	Formation of Soils	Symbol
CENOZOIC	Deposits and Sedimentary Rocks				
	QUATERNARY	Eolian Deposit Under cover of sand (Dunes, barchans, monadnocks)	Beach and Piedmont sand of several composition; medium grade to fine	Transported: sandy; variavle thickness, controlled by the pendent, high permeable	Q_e
		Marine Deposit Small marine terraces and beach hillocks	Semi-consolidated sand, lens of conglomerate and marine shells	Sandy; deep, permeable; saltish, limited areal extension	Q_e
		Fluvial Deposit Recent plains and alluvial areas; include a system of four terraces	Clays, sands, gravels and boulder, brocken stone, diorite, principally	Alluvial; deep, the periodical floods introduce new materials	Q_{Al}
		Compound Deposit (fluvial and eolian) In the current of intermitent water; include deposits of piedmont	Sand, gravel, clay and eolian sand. The piedment consisted of gravel, anguler fragment and residual fine sand	Alluvials and cover by eolian sand in alternating form; medium deep, permeable	Q_a
MESOZOIC	JURASSIC TO CRETACE-OUS	Peunte Piedro Formation (coastal zone)	Volcanic fluid stratified of andesitic composition; grayey green color mud-stone in the base	Sandy, considerable thickness; dark colors	J_s
	Intrusive Rocks				
	CREATACE-OUS TO TERTIARY	Andean Batholith (Igneous rock of composition intermediate to basic)	Diorite, tonalite and grano-diorite. Lamprophyre and Pegmatite in form from dikes and sills	Sandy, little deep; by influence of climate has weathered in grain thick, the plagio-clases itself encounter strongly altered	K_{Ti}

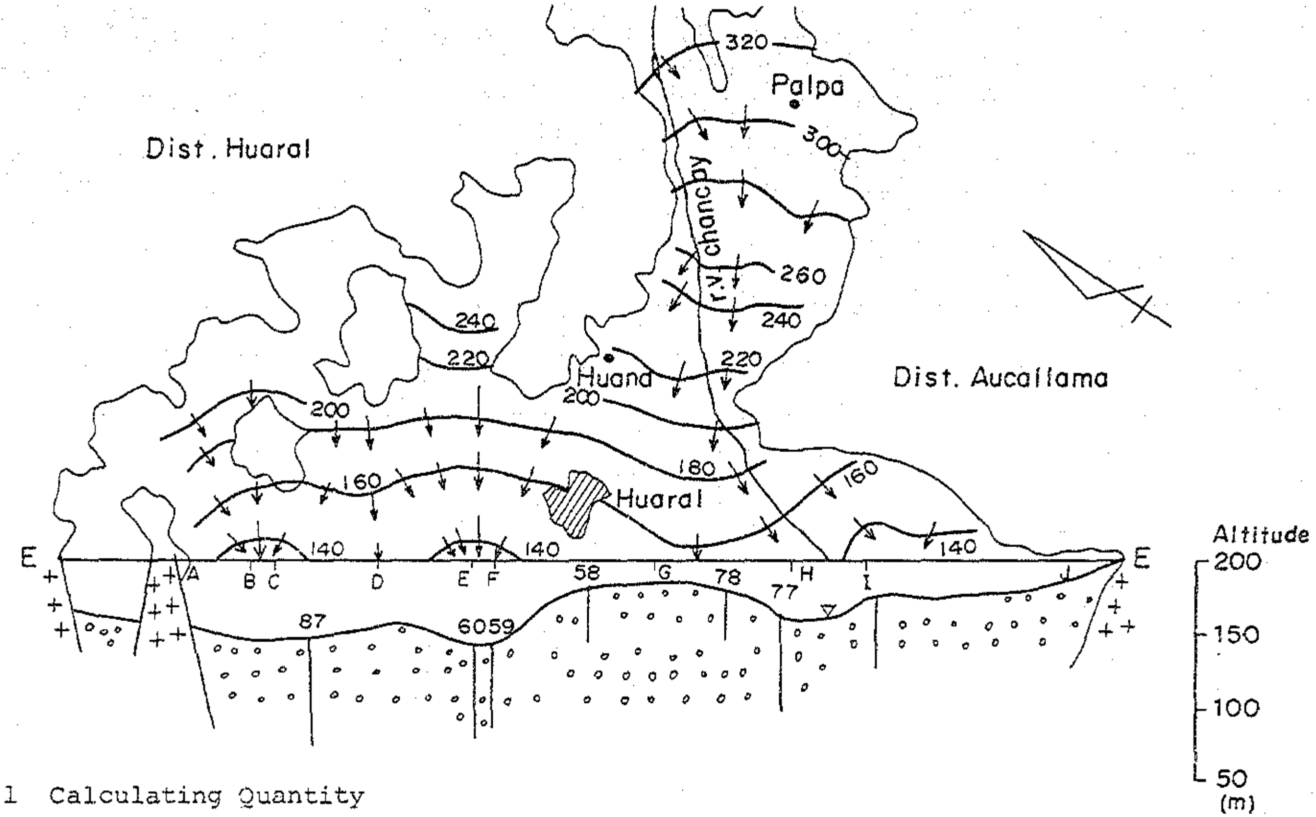


Table B-2-1 Calculating Quantity

Range	Length(m)	Thickness(m)	Area (m^2)	K (m/s)	I	θ	V=KIsinθ	Q (m^3/s)
AB	1,000	50	50,000	1.0×10^{-3}	0.01	45°	7.07×10^{-6}	0.354
BC	500	50	25,000	1.0×10^{-3}	0.01	90°	1.0×10^{-5}	0.25
CD	2,500	50	125,000	1.0×10^{-3}	0.01	45°	7.07×10^{-6}	0.884
DE	2,000	50	100,000	1.0×10^{-3}	0.01	45°	7.07×10^{-6}	0.707
EF	500	80	40,000	1.0×10^{-3}	0.01	90°	1.0×10^{-5}	0.4
FG	4,000	70	280,000	5.0×10^{-4}	0.01	45°	3.5×10^{-6}	0.98
GH	3,200	70	224,000	5.0×10^{-4}	0.008	45°	2.8×10^{-6}	0.627
HI	2,000	70	140,000	1.0×10^{-3}	0.01	30°	5.0×10^{-6}	0.7
IJ	5,000	30	150,000	1.0×10^{-3}	0.01	50°	7.7×10^{-6}	1.061
Total			1,134,000					5.96

Table B-2-2 ESTIMATE OF EXPLOITABLE RESERVE OF CHANCAY-HUARAL VALLEY

District	Area of Aquifer A ($\times 10^{-6}$ m^2)	Coefficient of Storage S (%)	Water-table Depression H (m)		Exploitable reserve (Re) ($\times 10^{-6}$ m^3)	
Chancay	169.8	2.4	2.5	1.0	10.2	4.1
Huaral	74.5	2.4	3.2	1.5	5.7	2.7
Aucallama	100.4	2.4	3.7	2.0	9.0	4.8
The total	344.7				24.9	11.6

Note: $Re = A \times S \times H$ (m^3)

Table B-2-3 USE OF GROUNDWATER FOR IRRIGATION $(\times 10^3\ m^3)$

Year / Month	1977	1978	1979	1980	1981	1982	1983
Aug.	723	917	1,824	1,296	638	-	-
Sep.	517	990	2,272	1,375	304	-	-
Oct.	551	1,152	2,489	-	324	-	-
Nov.	843	1,146	2,763	-	726	-	-
Dec.	764	1,056	2,743	-	713	-	-
Jan.	837	1,067	1,893	184	771	-	-
Feb.	653	958	1,189	350	207	-	-
Mar.	619	1,025	819	402	259	-	-
Apr.	677	881	977	433	259	-	-
May	700	1,063	762	401	363	-	-
Jun.	782	1,036	1,212	402	518	-	-
Jul.	857	1,084	1,267	573	538	-	301
Total	8,523	12,373	20,210	more 5,416	5,620	-	301
Month / Year	1978	1979	1980	1981	1982	1983	1984

FROM WATER ADMINISTRATION OFFICE IN HUARAL.

Table B-2-4 LIST OF 26 ADMINISTRATED WELLS

Location	Well	With drawal	Well			Pump			Cost for renewal (U.S.$)		
	number	(ℓ/s)	Type	diameter (m)	depth (m)	Type	Power	HP	Pump	Power	Accessories
Huaral											
Cap. Huando	5.8.1 - 69	40	Tubular	0.39	25.0	T.V.	Electric	10	4,540	350	489
- do -	5.8.1 - 70	60	- do -	0.39	30.0	T.V.	- do -	30	5,620	785	641
- do -	5.8.1 - 71	80	- do -	0.39	18.0	T.V.	- do -	30	4,265	785	505
- do -	5.8.1 - 72	40	- do -	0.39	20.0	T.V.	- do -	20	3,724	600	432
- do -	5.8.1 - 73	40	- do -	0.39	28.5	T.V.	- do -	10	5,620	350	597
Cap. Candalaria	5.8.1 - 74	68	- do -	-	36.0	T.V.	- do -	30	6,980	785	777
- do -	5.8.1 - 77	61	- do -	-	36.0	T.V.	- do -	30	6,980	785	777
Cap Jesus del Valle	5.8.1 - 78	60	- do -	-	23.2	T.V.	Diesel	70	4,810	10,320	1,513
- do -	5.8.1 - 79	65	- do -	0.39	16.5	T.V.	- do -	71	3,320	10,320	1,364
- do -	5.8.1 - 82	61	- do -	0.39	27.0	T.V.	- do -	67	3,320	8,480	1,180
Cap. Esquivel	5.8.1 - 58	45	- do -	-	30.0	T.V.	- do -	45	5,410	7,560	1,297
- do -	5.8.1 - 59	40	- do -	-	50.0	T.V.	Electric	30	9,680	785	1,046
Asoc. de Reganfus Esq.	5.8.1 - 60	90	mixed	0.39	60.2	T.V.	- do -	40	12,660	1,600	1,426
Hda. Esquivel	5.8.1 - 61	30	open	1.20	14.0	centrifugal	- do -	10	933	350	128
- do -	5.8.1 - 62	40	- do -	-	13.4	- do -	- do -	10	958	350	131
- do -	5.8.1 - 65	25	- do -	1.40	15.3	- do -	- do -	10	840	350	119
Chancay											
Cap. Torre Blanca	15.8.5 - 75	90	Tubular	0.47	50.0	T.V.	Diesel	110	10,500	12,150	2,265
Aucallama											
Cap. Boza	15.8.4 - 7	30	Tubular	0.47	50.0	T.V.	Diesel	110	9,410	12,150	2,156
Pablo Vazques	15.8.4 - 10	40	- do -	0.47	27.0	T.V.	- do -	70	4,540	10,320	1,486
Cap. San Jose	15.8.4 - 17	40	- do -	0.47	47.0	T.V.	- do -	45	8,330	7,560	1,589
Cap. Caqui	15.8.4 - 23	33	- do -	0.39	50.0	T.V.	- do -	45	9,410	7,560	1,697
Cap. Palpa	15.8.4 - 25	25	- do -	0.39	46.0	T.V.	- do -	100	8,060	10,320	1,838
- do -	15.8.4 - 27	100	- do -	0.47	40.5	T.V.	- do -	100	8,600	10,320	1,892
- do -	15.8.4 - 41	27	- do -	0.47	63.6	T.V.	- do -	45	11,850	7,560	1,941
Cap Boza	15.8.4 - 55	41	- do -	0.39	75.0	T.V.	- do -	45	14,020	7,560	2,158
Eusebie Diaz	51.5.4 -102	31	open	1.80	5.7	centrifugal	Electric	10	612	350	96
Subtotal		1,302						1,193	164,992	130,405	29,540
									TOTAL 324,947 U.S.$		

Remark: T.V.: Vertical Turbine Pump
Costs of Pump and Power are FOB cost at Pt. KOBE.
Cost of accessories is 10 percent of sum of costs of Pump and Power.

Table B-3-1 LIST OF GROUNDWATER SAMPLES

SAMPLE NUMBER	DATE	NUMBER OF WELL	SAMPLING LOCATION	REMARKS
1	3/8	-	Border of Esperanze	Underdrainage
2	3/8	15.8.5-61	Chancayllo	Water of a well
3	3/9	15.8.1-77	La Huaca	Water of a well
4	3/9	-	Bonos de Boza	Water of a mineral spring
5	3/9	-	Bonos de Granada	Water of a mineral spring
6	3/10	15.8.4-69	Palpa	Water of a well
7	3/10	15.8.1-76	Cuincha	Water of a well
8	3/10	-	Torre Blanca	Water of a well
9	3/10	15.8.1-55	Atauanpa (Huaral)	Water of a well
10	3/10	15.8.1-68	Esquivel	Water of a well
11	3/11	-	Chancay	Town water
12	3/11	15.8.5-26	Chancay	Water of a well

Table B-3-2 LIST OF GROUNDWATER SAMPLES

SAMPLE NUMBER	DATE	NUMBER OF WELL	SAMPLING LOCATION	REMARKS
1-2	7/6	-	Border of Esperanza	Underdrainage
2-2	7/6	15.8.5-61	Chancayllo	Water of a well
3-2	7/7	15.8.1-77	La Huaca	Water of a well
4-1	7/6	-	Jecuan	Water of a well
5-2	7/7	-	Banos de Granada	Water of a mineral spring
6-2	7/7	15.8.4-69	Palpa	Water of a well
7-2	7/6	15.8.1-176	Quincha	Water of a well
8-2	7/6	-	Torre Blanca	Water of a well
9-2	7/6	15.8.1-55	Atahuanpa (Huaral)	Water of a well
10-2	7/6	15.8.1-68	Esquivel	Water of a well
11-2	7/6	-	Chancay	City water
12-2	7/6	15.8.5-26	Chancay	Water of a well
13-1	7/7	15.8.4-14	Aucallama	Water of a well
14-1	7/7	-	Case Blanca (Aucallama)	Water of a well
15-1	7/7	15.8.1-107	Esperanza Baja	Water of a well

Table B-3-3 LIST OF GROUNDWATER SAMPLES

SAMPLE NUMBER	DATE	NUMBER OF WELL	SAMPLING LOCATION	REMARKS
1-3	7/30	-	Border of Esperanza	Underdrainage
2-3	7/30	15.8.5-61	Chancayllo	Water of a well
3-3	7/30	15.8.1-77	La Huaca	Water of a well
4-2	7/30	-	Jecuan	Water of a well
5-3	7/30	-	Banos de Granada	Water of a mineral spring
6-3	7/31	15.8.4-69	Palpa	Water of a well
7-3	7/30	15.8.1-176	Quincha	Water of a well
8-3	7/31	-	Torre Blanca	Water of a well
9-3	7/30	15.8.1-55	Atahuampa (Huaral)	Water of a well
10-3	7/31	15.8.1-68	Esquivel	Water of a well
11-3	7/30	-	Chancay	City water
12-3	7/30	15.8.5-26	Chancay	Water of a well
13-2	7/30	15.8.4-14	Aucallama	Water of a well
14-2	7/30	-	Case Blanca (Aucallama)	Water of a well
15-2	7/30	15.8.2-107	Esperanza Baja	Water of a well

Table B-3-4　CHEMICAL ANALYSIS OF WATER (FROM GROUNDWATER)

Location Name	Esperanza Baja underdrainage			Chancayllo			La Huaca			Bonos de Boza
Sample Number	1	1-2	1-3	2	2-2	2-3	3	3-2	3-3	4
Sampling date	3/8	7/6	7/30	3/8	7/6	7/30	3/9	7/7	7/30	3/9
E.C. x 10^6 on 25°C	996	879.8	940	1,261.6	1,162	1,034	506.3	664.0	625.4	6,640.0
PH	8.3	7.7	8.2	8.1	7.7	8.3	8.1	7.3	8.1	8.7
Ca^{++} Meq/lt	1.58	1.91	1.70	4.24	4.24	4.45	3.49	4.82	3.70	2.57
Mg^{++} Meq/lt	0.66	0.91	0.79	1.49	1.54	1.24	0.99	1.41	1.16	63.99
Na^+ Meq/lt	6.30	7.00	6.80	7.9	6.50	6.80	0.90	0.90	0.90	720.
K^+ Meq/lt	0.23	0.11	0.27	0.17	0.16	0.18	0.07	0.55	0.07	0.70
Sum of Cation	8.77	9.92	9.56	13.8	12.48	12.67	5.45	7.68	5.83	787.26
$C\ell^-$ Meq/lt	2.33	2.20	2.45	2.96	2.96	3.21	0.69	0.81	0.69	662.76
SO_4^{--} Meq/lt	2.65	5.01	3.08	3.87	3.94	4.61	1.49	2.41	2.11	135.76
CO_3^{--} Meq/lt	0.41	0.0	0.0	0.	0.	0.0	0.	0.	0.0	2.29
HCO_3^- Meq/lt	3.62	3.69	3.64	6.64	4.75	4.70	3.00	4.10	2.91	16.97
NO_3^- Meq/lt	0.20	0.00	0.10	0.10	0.00	0.10	0.00	0.00	0.00	0.30
Sum of Anion	9.21	10.90	9.27	13.57	11.65	12.62	5.18	7.32	5.71	818.08
Boron p.p.m.	0.10	0.30	0.80	0.	0.50	0.70	0.	0.30	0.20	31.0
SAR	5.95	5.91	6.09	4.58	2.10	4.06	0.6	0.51	0.50	124.0
Adj. SAR	10.71	11.20	10.97	11.66	9.14	9.27	1.20	1.17	1.21	472.76
Sodium Carbonate res.	2.79	0.89	1.15	0.91	0.	0.0	0.	0.	0.0	0.
Sodium Percentage	73.	70.	72.	58	52	54	17	12	13	92
Classification	C_3S_1	C_3S_2	C_3S_2	C_3S_1	C_3S_1	C_3S_1	C_2S_1	C_2S_1	C_2S_1	-

Table B-3-5 CHEMICAL ANALYSIS OF WATER (FROM GROUNDWATER)

Location Name	Jecuan		Bonos de Granada			Palpa			Cuincha	
Sample Number	4-1	4-2	5	5-2	5-3	6	6-2	6-3	7	7-2
Sampling date	7/6	7/30	3/9	7/7	7/30	3/10	7/7	7/31	3/10	7/7
E.C. x 10^6 on 25°C	1,228.	1,316.0	4,897	4,316	4,906.8	647.4	605.9	729.4	730.4	697.2
PH	7.9	8.3	8.7	8.4	8.6	8.2	7.8	8.0	8.4	7.5
Ca^{++} Meq/lt	3.16	2.70	0.91	3.41	3.86	4.07	4.65	3.12	3.66	4.32
Mg^{++} Meq/lt	1.33	1.45	7.73	9.06	8.94	1.74	1.91	3.36	1.42	1.41
Na^+ Meq/lt	7.20	10.20	37.50	35.00	31.60	1.80	0.90	0.91	2.45	2.25
K^+ Meq/lt	0.13	0.10	0.75	0.31	1.75	0.80	0.06	0.09	0.09	0.10
Sum of Cation	11.82	14.45	46.89	47.78	46.15	7.69	7.46	7.48	7.62	8.08
$C\ell^-$ Meq/lt	3.27	3.46	15.49	14.67	15.24	0.75	0.75	1.00	0.88	0.75
SO_4^{--} Meq/lt	3.76	3.88	10.29	13.33	13.94	1.64	2.21	2.62	1.78	2.38
CO_3^{--} Meq/lt	0.	0.08	4.20	2.63	1.86	0.	0.	0.	4.80	0.
HCO_3^- Meq/lt	5.90	5.74	20.0	21.56	22.8	5.11	3.97	3.95	0.41	4.92
NO_3^- Meq/lt	0.	0.10	0.3	0.	0.70	0.	0.	0.	0.	0.
Sum of Anion	12.93	13.26	50.28	52.18	54.54	7.5	6.93	7.57	7.46	8.05
Boron p.p.m.	1.00	1.00	6.20	4.70	3.00	3.70	0.70	0.20	0.40	0.70
SAR	4.85	7.12	18.	14.0	12.53	1.06	0.50	0.50	1.54	1.33
Adj. SAR	11.05	15.58	50.51	42.05	37.47	2.42	1.09	1.11	3.38	3.06
Sodium Carbonate res.	1.50	1.67	15.56	9.72	11.86	0.	0.	0.	0.12	0.
Sodium Percentage	61.	71.	81.	73.	68.	23.	12.	13.	33.	28.
Classification	C_3S_1	C_3S_2	C_4S_4	C_4S_4	C_4S_4	C_2S_2	C_2S_1	C_2S_1	C_2S_1	C_2S_1

Table B-3-6 CHEMICAL ANALYSIS OF WATER (FROM GROUNDWATER)

Location Name	Cuincha	Torre Blanca			Atauampa (Huaral)			Esquivel		
Sample Number	7-3	8	8-2	8-3	9	9-2	9-3	10	10-2	10-3
Sampling date	7/30	3/10	7/6	7/31	3/10	7/6	7/30	3/10	7/6	7/31
E.C. x 10^6 on 25°C	752.	946.2	1,037.5	1,071.6	655.7	664.0	752.	946.2	1,162.	1,047.1
PH	8.1	8.2	7.8	8.1	8.1	7.6	8.1	8.3	7.5	8.1
Ca^{++} Meq/lt	4.25	6.15	7.73	8.15	4.57	5.65	5.53	6.73	9.65	9.52
Mg^{++} Meq/lt	1.11	2.49	3.49	3.12	1.16	1.42	1.33	1.66	2.24	1.62
Na^+ Meq/lt	2.24	1.20	1.20	1.30	0.90	0.85	0.70	1.5	1.60	1.60
K^+ Meq/lt	0.10	0.10	0.10	0.15	0.07	0.07	0.07	0.15	0.15	0.15
Sum of Cation	7.70	9.94	12.52	12.72	6.70	7.99	7.63	10.04	13.64	12.89
$C\ell^-$ Meq/lt	0.94	1.32	1.51	1.38	0.81	0.81	-.94	1.26	1.51	1.70
SO_4^{--} Meq/lt	2.42	3.11	5.67	7.88	2.02	2.30	2.39	3.76	6.15	6.30
CO_3^{--} Meq/lt	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
HCO_3^- Meq/lt	4.67	6.5	4.63	4.57	3.69	4.01	3.93	4.78	4.05	4.10
NO_3^- Meq/lt	0.	0.1	0.	0.1	0.	0.	0.	0.1	0.	0.10
Sum of Anion	8.03	11.03	11.81	13.93	6.52	7.12	7.26	11.9	11.71	12.20
Boron p.p.m.	0.30	0.00	0.50	0.20	0.00	0.00	0.30	0.49	0.40	0.10
SAR	1.37	0.58	0.50	0.549	0.53	0.46	0.37	0.73	0.65	0.67
Adj. SAR	3.01	1.44	1.27	1.37	1.22	0.99	0.83	1.83	1.64	1.69
Sodium Carbonate res.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Sodium Percentage	29	12	9	10	14	11	9	15	12	12
Classification	C_3S_1	C_3S_1	C_3S_1	C_3S_1	C_2S_1	C_2S_1	C_3S_1	C_3S_1	C_3S_1	C_3S_1

Table B-3-7 CHEMICAL ANALYSIS OF WATER (FROM GROUNDWATER)

Location Name	Chancay city water			Chancay			Aucallama		Casa Blanca	
Sample Number	11	11-2	11-3	12	12-2	12-3	13-1	13-2	14-1	14-2
Sampling date	3/11	7/6	7/30	3/12	7/6	7/30	7/7	7/30	7/7	7/30
E.C. x 10^6 on 25°C	713.8	564.4	639	755.3	581.0	620	796.0	864.8	730.4	752.0
PH	8.4	7.9	8.2	8.3	8.0	8.2	7.7	8.2	7.7	7.0
Ca^{++} Meq/lt	5.24	4.57	4.45	3.99	4.32	4.53	5.40	5.44	5.15	5.00
Mg^{++} Meq/lt	1.49	1.41	1.20	2.28	1.83	1.12	1.49	1.53	1.91	1.62
Na^+ Meq/lt	0.77	0.70	0.66	2.16	0.75	0.96	1.70	1.84	1.20	1.12
K^+ Meq/lt	0.07	0.06	0.08	0.14	0.06	0.05	0.16	0.18	0.14	0.15
Sum of Cation	7.57	6.74	6.39	8.37	6.96	6.66	8.69	8.99	8.40	7.89
$C\ell^-$ Meq/lt	0.75	0.69	0.88	1.26	0.75	1.00	1.28	1.38	1.13	1.38
SO_4^{--} Meq/lt	3.65	2.25	2.53	3.26	2.00	2.61	2.82	3.66	2.67	3.15
CO_3^{--} Meq/lt	1.02	0.	0.0	0.81	0.	0.0	0.	0.	0.	0.
HCO_3^- Meq/lt	3.17	3.07	2.93	3.5	3.03	2.95	3.62	3.58	3.54	3.64
NO_3^- Meq/lt	0.	0.	0.	0.1	0.	0.	0.	0.1	0.	0.
Sum of Anion	8.59	6.01	6.34	8.93	5.78	6.56	7.72	8.72	7.34	8.17
Boron p.p.m.	0.	0.50	0.20	5.40	0.30	0.0	0.30	0.	0.80	0.30
SAR	0.42	0.376	0.39	1.24	0.42	0.57	0.92	0.99	0.64	2.26
Adj. SAR	0.92	0.89	0.86	2.72	0.94	1.26	2.01	2.17	1.41	1.35
Sodium Carbonate res.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Sodium Percentage	10.	10.	10.	26.	11.	14.	19.	20.	14.	40.6
Classification	C_2S_1	C_2S_1	C_2S_1	C_3S_1	C_2S_1	C_2S_1	C_3S_1	C_3S_1	C_2S_2	C_3S_1

Table B-3-8 CHEMICAL ANALYSIS OF WATER (FROM GROUNDWATER)

Location Name	Esperanza Baja		
Sample Number	15-1	15-2	
Sampling date	7/7	7/30	
E.C. x 10^6 on 25°C	763.6	827.	
PH	7.3	8.0	
Ca^{++} Meq/lt	3.24	3.28	
Mg^{++} Meq/lt	1.24	1.20	
Na^+ Meq/lt	3.36	3.36	
K^+ Meq/lt	0.42	0.43	
Sum of Cation	8.26	8.27	
$C\ell^-$ Meq/lt	1.95	2.20	
SO_4^{--} Meq/lt	2.33	2.27	
CO_3^{--} Meq/lt	0.	0.	
HCO_3^- Meq/lt	3.64	3.54	
NO_3^- Meq/lt	0.	0.2	
Sum of Anion	7.92	8.19	
Boron p.p.m.	0.30	0.30	
SAR	2.26	2.26	
Adj. SAR	4.71	4.71	
Sodium Carbonate res.	0.	0.	
Sodium Percentage	41.	40.6	
Classification	C_3S_1	C_3S_1	

Table B-3-9 CHEMICAL ANALYSIS OF WATER (FROM CANAL AND RIVER)

Location Name	Palpa Orcon		Quincha-Jecuan			Chancay river Pte Huaral			Chancay riv.Pt.Libe
Sample Number	-	A-13	-	A-14	-	-	A-15-1		A-15-2
Sampling date	3/8	7/7	3/8	7/7	7/28	3/8	7/7	7/28	7/7
E.C. x 10^6 on 25°C	273.9	630.0	946.2	879.8	789.6	268.9	564.4	639.2	365.0
PH	8.0	8.3	8.3	8.0	8.0	8.1	8.2	8.0	8.3
Ca^{++} Meq/lt	1.91	4.40	3.99	1.91	3.02	1.91	4.40	3.74	2.74
Mg^{++} Meq/lt	0.83	1.91	1.16	0.83	0.83	0.58	1.49	1.83	1.41
Na^+ Meq/lt	0.32	1.15	4.80	6.10	4.32	0.35	2.25	0.96	0.57
K^+ Meq/lt	0.09	0.07	0.12	0.15	0.14	0.07	0.07	0.07	0.06
Sum of Cation	3.15	7.53	10.07	8.99	8.31	2.91	8.14	6.60	4.78
$C\ell^-$ Meq/lt	0.50	0.88	1.95	2.26	1.71	0.37	0.64	0.88	0.44
SO_4^{--} Meq/lt	0.63	2.94	3.01	3.36	2.33	0.58	2.70	2.80	1.96
CO_3^{--} Meq/lt	-	0.24	4.5	0.	0.	1.80	0.	0.	0.16
HCO_3^- Meq/lt	1.5	3.64	0.80	3.77	3.48	-	2.99	2.89	2.05
NO_3^- Meq/lt	0.	0.	0.1	0.	0.	0.	0.	0.	0.
Sum of Anion	2.63	7.70	9.46	9.39	7.51	2.75	6.38	6.57	4.61
Boron p.p.m.	0.00	4.90	0.25	1.00	0.80	0.30	0.40	0.40	0.00
SAR	0.27	0.64	3.0	5.25	3.13	0.31	0.31	0.58	0.40
Adj. SAR	0.44	1.42	6.58	9.90	5.92	0.51	2.75	1.21	0.71
Sodium Carbonate res.	0.	0.	0.15	1.0	0.	0.	0.	0.	0.
Sodium Percentage	10	15	48	68	52	12	27	15	12
Classification	C_2S_1	C_2S_1	C_3S_1	C_3S_1	C_3S_1	C_2S_1	C_2S_1	C_2S_1	C_2S_1

Table B-3-10 CHEMICAL ANALYSIS OF WATER (FROM CANAL AND RIVER)

Location Name	Los Laureles (canal)			Los Laureles Donoso			Donoso		
Sample Number	-	A-16	-	-	A-17	-	A-18	-	
Sampling date	3/8	7/7	7/28	3/8	7/7	7/28	7/7	7/28	
E.C. x 10^6 on 25°C	268.9	614.6	770.8	307.1	597.6	601.6	763.6	808.4	
PH	8.1	8.2	8.0	8.1	8.2	8.0	7.8	8.0	
Ca^{++} Meq/lt	1.91	4.82	5.14	2.24	4.74	4.32	6.32	5.69	
Mg^{++} Meq/lt	0.66	1.49	1.58	0.74	1.49	1.12	1.74	1.62	
Na^+ Meq/lt	0.29	0.80	0.91	0.37	0.75	0.84	0.98	0.96	
K^+ Meq/lt	0.05	0.07	0.28	0.06	0.07	0.08	0.13	0.09	
Sum of Cation	2.91	7.18	8.26	3.41	7.05	6.36	9.17	8.36	
$C\ell^-$ Meq/lt	0.37	0.75	0.50	0.37	0.69	0.88	0.88	1.13	
SO_4^{--} Meq/lt	0.58	3.14	3.56	0.69	3.31	2.47	3.91	3.03	
CO_3^{--} Meq/lt	1.75	0.	0.	2.0	0.	0.	0.	0.	
HCO_3^- Meq/lt	-	3.23	3.87	-	3.19	3.65	3.97	3.83	
NO_3^- Meq/lt	0.	0.	0.1	0.	0.	0.	0.	0.	
Sum of Anion	2.70	7.12	8.03	3.06	7.19	7.00	8.76	8.01	
Boron p.p.m.	0.30	0.50	0.10	0.70	0.30	0.20	0.30	0.60	
SAR	0.25	0.45	0.48	0.30	0.42	0.51	0.50	0.50	
Adj. SAR	0.41	0.99	1.06	0.51	0.94	1.12	1.12	1.15	
Sodium Carbonate res.	0.	0.	0.	0.	0.	0.	0.	0.	
Sodium Percentage	10.	10.	11.	11.	11.	13.	11.	12.	
Classification	C_2S_1	C_2S_1	C_3S_1	C_2S_1	C_2S_1	C_2S_1	C_3S_1	C_3S_1	

Table B-3-11 GUIDELINES FOR INTERPRETATION OF WATER QUALITY FOR IRRIGATION

IRRIGATION PROBLEM	DEGREE OF PROBLEM		
	No Problem	Increasing Problem	Severe Problem
SALINITY (affects crop water availability)			
ECw (mmhos/cm)	< 0.75	0.75-3.0	> 3.0
PERMEABILITY (affects infiltration rate into soil)			
ECw (mmhos/cm)	> 0.5	0.5-0.2	< 0.2
adj. SAR 1/ 2/			
Montmorillonite (2:1 crystal lattice)	< 6	6-9 3/	> 9
Illite-Vermiculite (2:1 crystal lattice)	< 8	8-16 3/	> 16
Kaolinite-sesquioxides (1:1 crystal lattice)	< 16	16-24 3/	> 24
SPECIFIC ION TOXICITY (affects sensitive crops)			
Sodium 4/ 5/ (adj. SAR)	< 3	3-9	> 9
Chloride 4/ 5/ (meq/l)	< 4	4-10	> 10
Boron (mg/l)	< 0.75	0.75-2.0	> 2.0
MISCELLANEOUS EFFECTS (affects susceptible crops)			
NO_3-N (or) NH_4-N (mg/l)	< 5	5-30	> 30
HCO_3 (meq/l) [overhead sprinkling]	< 1.5	1.5-8.5	> 8.5
pH		[Normal Range 6.5-8.4]	

1/ adj. SAR means adjusted Sodium Adsorption Ratio and can be calculated using the procedure given in a equation by contents of Na, Ca, Mg, CO_3 and HCO_3.

2/ Values presented are for the dominant type of clay mineral in the soil since structural stability varies between the various clay types (Rallings, 1966, and Rhoades, 1975). Problems are less likely to develop if water salinity is high; more likely to develop if water salinity is low.

3/ Use the lower range if ECw < .4 mmhos/cm;
Use the intermediate range if ECw = 0.4 - 1.6 mmhos/cm;
Use upper limit if ECw > 1.6 mmhos/cm

4/ Most tree crops and woody ornamentals are sensitive to sodium and chloride (use values shown). Most annual crops are not sensitive.

5/ With sprinkler irrigation on sensitive crops, sodium or chloride in excess of 3 meq/l under certain conditions has resulted in excessive leaf absorption and crop damage.

< means less than
> means more than