

**Ministry of Agriculture
Republic of Peru**

**THE PREPARATORY STUDY
ON
PROJECT OF THE PROTECTION OF
FLOOD PLAIN AND VULNERABLE RURAL
POPULATION AGAINST FLOOD IN THE
REPUBLIC OF PERU**

**FINAL REPORT
I-6 SUPPORTING REPORT
ANNEX-1 METEOROLOGY /
HYDROLOGY/RUN-OFF STUDY**

March 2013

**JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)**

**YACHIYO ENGINEERING CO., LTD.
NIPPON KOEI CO., LTD.
NIPPON KOEI LATIN AMERICA –
CARIBBEAN Co., LTD.**

GE
CR(4)
13 - 096



**THE PREPARATORY STUDY ON PROJECT OF THE PROTECTION
OF
FLOOD PLAIN AND VULNERABLE RURAL POPULATION AGAINST FLOOD
IN THE REPUBLIC OF PERU
FEASIBILITY STUDY REPORT
SUPPORTING REPORT**

**Annex-1
Meteorology/Hydrology/Run-off Study**

TABLE OF CONTENTS

STUDY AREA

CHAPTER 1 PREFACE	1-1
1.1 Background of Project.....	1-1
1.2 Objectives of Project.....	1-1
CHAPTER 2 METEOROLOGY AND HYDROLOGY DATA.....	2-1
2.1 Temperature	2-1
2.1.1 Chira River	2-1
2.1.2 Cañete River	2-2
2.1.3 Chincha River	2-3
2.1.4 Pisco River.....	2-5
2.1.5 Yauca River.....	2-6
2.1.6 Majes-Camana River	2-7
2.2 Rainfall.....	2-10
2.2.1 Chira River	2-10
2.2.2 Cañete River	2-15
2.2.3 Chincha River	2-19
2.2.4 Pisco River.....	2-24
2.2.5 Yauca River.....	2-30
2.2.6 Majes-Camana River	2-35
2.3 Discharge	2-42
2.3.1 Chira River	2-44
2.3.2 Cañete River	2-46
2.3.3 Chincha River	2-48
2.3.4 Pisco River.....	2-50
2.3.5 Yauca River.....	2-51
2.3.6 Majes-Camana River	2-53

CHAPTER 3 RUN-OFF STUDY	3-1
3.1 Probable Flood Discharge Based on Observation Data	3-1
3.2 Run-off Analysis Based on Rainfall Data (HEC-HMS Method)	3-5
3.2.1 HEC-HMS	3-5
3.2.2 Preparation of Basin Model	3-6
3.2.3 Rainfall Analysis.....	3-7
3.2.4 Excess Rainfall by SSC Method.....	3-13
3.2.5 Probable Flood Discharge and Hydrograph.....	3-22
3.3 Consideration on Results of Analysis.....	3-26
3.3.1 Verification of Peak Discharge	3-26
3.3.2 Flood Discharge with Return Period of 50-year in Cañete Basin	3-28

Appendix-1 Hydrologic Study of Majes-Camana River Basin

Appendix-2 Hydrologic Study of Cañete River Basin

Appendix-3 Hydrologic Study of Chincha River Basin

Appendix-4 Hydrologic Study of Pisco River Basin

Appendix-5 Hydrologic Study of Chira River Basin

Appendix-6 Hydrologic Study of Yauca River Basin

LIST OF TABLES

Table 2.1	Average Monthly Temperature in Cañete basin and Adjacent Area.....	2-3
Table 2.2	Average Monthly Temperature in Chincha basin and Adjacent Area(C°).....	2-4
Table 2.3	Average Monthly Temperature in Pisco basin and Adjacent Area(C°)	2-5
Table 2.4	Average Monthly Temperature in Yauca(C°)	2-6
Table 2.5	Relation between Elevation and Mean Annual Temperature of Stations	2-8
Table 2.6	Rainfall Observation Station (Chira River).....	2-10
Table 2.7	Observation Period of Rainfall Data (Chira River).....	2-11
Table 2.8	Average Monthly Rainfall in Chira Basin and Adjacent Basin (mm)	2-12
Table 2.9	Yearly Maximum of 24-hour Rainfall (Daily Rainfall) in Chira Basin (mm).....	2-13
Table 2.10	Rainfall Observation Station (Cañete river).....	2-15
Table 2.11	Observation Period of Rainfall Data (Cañete river).....	2-15
Table 2.12	Average Monthly Rainfall in Cañete Basin and Adjacent Basin (mm).....	2-17
Table 2.13	Yearly Maximum of 24-hour Rainfall (Daily Rainfall) in Cañete Basin (mm)	2-18
Table 2.14	Rainfall Observation Station (Chincha river).....	2-20
Table 2.15	Observation Period of Rainfall Data (Chincha river).....	2-20
Table 2.16	Average Monthly Rainfall in Chincha Basin and Adjacent Basin (mm).....	2-21
Table 2.17	Yearly Maximum of 24-hour Rainfall (Daily Rainfall) in Chincha Basin (mm) ...	2-23
Table 2.18	Rainfall Observation Station (Pisco river)	2-25
Table 2.19	Observation Period of Rainfall Data (Pisco river)	2-25
Table 2.20	Average Monthly Rainfall in Chincha Basin and Adjacent Basin (mm).....	2-26
Table 2.21	Yearly Maximum of 24-hour Rainfall (Daily Rainfall) in Pisco Basin (mm).....	2-28
Table 2.22	Rainfall Observation Station (Yauca river)	2-30
Table 2.23	Observation Period of Rainfall Data (Yauca river)	2-30
Table 2.24	Average Monthly Rainfall in Yauca Basin and Adjacent Basin (mm)	2-32
Table 2.25	Yearly Maximum of 24-hour Rainfall (Daily Rainfall) in Yauca Basin (mm).....	2-33
Table 2.26	Rainfall Observation Station (Majes-Camana river).....	2-36
Table 2.27	Observation Period of Rainfall Data (Majes-Camana river).....	2-37
Table 2.28	Monthly Rainfall in TISCO	2-39
Table 2.29	Yearly Maximum of 24-hour Rainfall (Daily Rainfall) in Majes-Camana Basin (1/2) (mm).....	2-40
Table 2.29	Yearly Maximum of 24-hour Rainfall (Daily Rainfall) in Majes-Camana Basin (2/2) (mm).....	2-40
Table 2.30	Location and Recording Period of Each Discharge Gauging Station of Each	

Catchment	2-44
Table 2.31 Discharge Observation Stations (Chira river)	2-45
Table 2.33 Discharge Observation station (Cañete river)	2-46
Table 2.34 Yearly Maximum Daily Discharge (Cañete river) (m ³ /s).....	2-46
Table 2.35 Discharge Observation station (Chincha river)	2-48
Table 2.36 Yearly Maximum Daily Discharge (Chincha river) (m ³ /s).....	2-48
Table 2.37 Discharge Observation Station (Pisco river)	2-50
Table 2.38 Yearly Maximum Daily Discharge (Pisco river) (m ³ /s)	2-50
Table 2.39 Discharge Observation station (Yauca River)	2-51
Table 2.40 Yearly Maximum Daily Discharge (Yauca river) (m ³ /s)	2-52
Table 2.41 Discharge Observation station (Majes-Camana river)	2-53
Table 3.1 Probable Discharge at Reference Point.....	3-1
Table 3.2 Probable 24-hour Daily Rainfall (m ³ /s) for each Return Period	3-8
Table 3.3 Probabilistic Rainfall for each Sub-basin Calculated Using 24-hour Maximum Rainfall (Majes-Camaná)	3-10
Table 3.4 Accumulated Curve of 24-hour Rainfall in SCS Hypothetical Storm	3-11
Table 3.15 Used Values of CN	3-15
Table 3.16(1) CN Value Depending on Land Use and Soil Conditions (1/3).....	3-16
Table 3.16(2) CN Value Depending on Land Use and Soil Conditions (2/3).....	3-17
Table 3.16(3) CN Value Depending on Land Use and Soil Conditions (3/3).....	3-18
Table 3.17 CN Values for Ica River Basin	3-21
Table 3.18 CN Values for Grande River Basin	3-21
Table 3.19 Probable Flood Discharge	3-22
Table 3.20 Probable Specific Flood Discharge	3-22
Table 3.21 Comparison of Historical Maximum Discharge and the Peak Discharge Calculated (t=50).....	3-23
Table 3.22 Run-off Characteristics of Each Basin	3-29
Table 3.23 Comparison of Probable Flood Discharge and Specific Discharge	3-30
Table 3.24 Probable 24-hour Rainfall at Reference Point (mm).....	3-30
Table 3.25 Probable Total 24-hour Rainfall Amount at Reference Point (1,000m ³).....	3-31
Table 3.26 Probable Specific Discharge at Reference Point (m ³ /sec/km ²)	3-31
Table 3.27 Ratio between Probable Observation Discharge and Total Rainfall Amount	3-32
Table 3.28 Estimation of Probable Discharges in Cañete Basin based on Data of Other Basin	3-32
Table 3.29 Comparison of Probable Discharge in Cañete Basin	3-33

LIST OF FIGURES

Figure 2.1	Monthly Average Temperature in La Esperanza, Chilaco and Mallares	2-1
Figure 2.2	Monthly Average Temperature in La Toma Catamayo, Vilcabamba, Malactos and Quinara	2-2
Figure 2.3	Monthly Average Temperature in Zapoltillo, Macara and Sausal de Culucan	2-2
Figure 2.4	Distribution of Average Monthly Temperature in Cañete basin and Adjacent Area.....	2-3
Figure 2.5	Distribution of Average Monthly Temperature in Chincha basin.....	2-4
Figure 2.6	Distribution of Average Monthly Temperature in Pisco basin	2-6
Figure 2.7	Relation between Elevation and Mean Annual Temperature of Station.....	2-9
Figure 2.8	Relation between Elevation and Mean Annual Temperature of Station (over 2,000m)	2-9
Figure 2.9	Location of Rainfall and Discharge Observation Station (Chira River)	2-11
Figure 2.10	Distribution of Average Monthly Rainfall in Chira Basin and Adjacent Basin (mm)	2-12
Figure 2.11	Isohyetal Map of Yearly Rainfall (Chira Basin).....	2-14
Figure 2.12	Location of Rainfall and Discharge Observation Station (Cañete river).....	2-16
Figure 2.13	Distribution of Average Monthly Rainfall in Cañete Basin and Adjacent Basin (mm)	2-17
Figure 2.14	Isohyetal Map of Yearly Rainfall (Cañete Basin)	2-19
Figure 2.15	Location of Rainfall and Discharge Observation Station (Chincha river)	2-21
Figure 2.16	Distribution of Average Monthly Rainfall in Chincha Basin and Adjacent Basin (mm)	2-22
Figure 2.17	Isohyetal Map of Yearly Rainfall (Chincha Basin)	2-24
Figure 2.18	Location of Rainfall and Discharge Observation Station (Pisco river).....	2-26
Figure 2.19	Distribution of Average Monthly Rainfall in Pisco Basin and Adjacent Basin (mm)	2-27
Figure 2.20	Isohyetal Map of Yearly Rainfall (Pisco Basin)	2-29
Figure 2.21	Location of Rainfall and Discharge Observation Station (Yauca river).....	2-31
Figure 2.22	Distribution of Average Monthly Rainfall in Yauca Basin and Adjacent Basin (mm)	2-32
Figure 2.23	Isohyetal Map of Yearly Rainfall (Yauca Basin)	2-34
Figure 2.24	Location of Rainfall and Discharge Observation Station (Majes-Camana river) ...	2-38

Figure 2.25	Isohyetal Map of Yearly Rainfall (Majes-Camana Basin)	2-41
Figure 2.26	Storm Duration (Majes-Camana Basin).....	2-42
Figure 3.1	Location of the base station at Chira River Basin.....	3-2
Figure 3.2	Location of the base station at Cañete River Basin	3-2
Figure 3.3	Location of the base station at Chincha River Basin	3-3
Figure 3.4	Location of the Base Station at Pisco River Basin.....	3-3
Figure 3.5	Location of the Base Station at Yauca River Basin.....	3-4
Figure 3.6	Location of the Base Station at Majes-Camaná River Basin	3-4
Figure 3.7	Majes-Camaná Basin´s Sub-division into Secondary Basins.	3-6
Figure 3.8	Majes-Camaná Basin HEC-HMS Model.....	3-7
Figure 3.9	Isohyetal Map of 24h-hour Rainfall with Return Period of 50-year (Majes-Camaná)	3-9
Figure 3.10	Thiessen Polygons and Distribution of Rainfall Stations	3-10
Figure 3.11	Distribution of 24hour Rainfall in Each Type.....	3-12
Figure 3.12	Division of 24-hour Rainfall.....	3-12
Figure 3.13	Type of 24-hour Rainfall and Applied Area.....	3-13
Figure 3.14	Relation among CN, P and P_e	3-14
Figure 3.5	Value of CN selected for Majes-Camana Basin.....	3-15
Figure 3.6	Location of Nearby Catchments	3-20
Figure 3.7	Flood Hydrograph in Chira Basin.....	3-23
Figure 3.8	Flood Hydrograph in Cañete Basin.....	3-24
Figure 3.9	Flood Hydrograph in Chincha Basin	3-24
Figure 3.10	Flood Hydrograph in Pisco Basin	3-25
Figure 3.11	Flood Hydrograph in Yauca Basin	3-25
Figure 3.12	Flood Hydrograph in Majes-Camana Basin	3-25
Figure 3.13	Probabilistic Specific Discharges and Calculated Peak Discharges ($t=1/10$)	3-26
Figure 3.14	Probabilistic Specific Discharges and Calculated Peak Discharges ($t=1/20$)	3-27
Figure 3.15	Probabilistic Specific Discharges and Calculated Peak Discharges ($t=1/50$)	3-27
Figure 3.16	Probabilistic Specific Discharges and Calculated Peak Discharges ($t=1/100$)	3-28
Figure 3.17	Cross section at Sosci Station	3-29

CHAPTER 1 PREFACE

1.1 Background of Project

The Republic of Peru (hereinafter “Peru”) is a country with high risk of natural disasters such as earthquakes, Tsunamis, etc. Among these natural disasters there are also floods. In particular, El Niño takes place with an interval of several years and has caused major flood of rivers and landslides in different parts of the country. The most serious disaster in recent years due to El Niño occurred in the rainy season of 1982-1983 and 1997-1998. In particular, the period of 1997-1998, the floods, landslides, among others left loss of 3,500 million of dollars nationwide. The latest floods in late January 2010, nearby Machupicchu World Heritage Site, due to heavy rains interrupted railway and roads traffic, leaving almost 2,000 people isolated.

In this context, the central government has implemented 「El Niño phenomenon I and II contingency plans」 in 1997-1998, throughout the Ministry of Agriculture (MINAG) in order to rebuild water infrastructures devastated by this phenomenon. Next, the Hydraulic Infrastructure General Direction (DGIH) of MINAG began in 1999 the River Channeling and Intake Structures Protection Program (PERPEC) in order to protect villages, farmlands, agricultural infrastructure, etc. located within flood risk areas. The program consisted of financial support for regional government to carry out works of bank protection. In the multiyear PERPEC plan between 2007-2009 it had been intended to execute a total of 206 bank protection works nationwide. These projects were designed to withstand floods with a return period of 50 years, but all the works have been small and limited, without giving a full and integral solution to control floods. So, every time floods occur in different places, damages are still happening.

MINAG planned a “Valley and Rural Populations Vulnerable to Floods Protection Project” for nine watersheds of the five regions. However, due to the limited availability of experiences, technical and financial resources to implement a pre-investment study for a flood control project of such magnitude, MINAG requested JICA’s assistance to implementation this study. In response to this request, JICA and MINAG held discussions under the premise of implementing it in the preparatory study scheme to formulate a loan from JICA, about the content and scope of the study, the implementation’s schedule, obligations and commitments of both parties, etc. expressing the conclusions in the Minutes of Meeting (hereinafter “M/M”) that were signed on January 21 and April 16, 2010. This study has been implemented in accordance with this M/M.

1.2 Objectives of Project

➤ Ultimate Target

The ultimate target of the Project is to alleviate the vulnerability of valleys (Valles) and local

community to flooding and promote local economic development.

➤ **Components of Project**

The Project is composed of the following components and by implementation of which the purpose of the Project will be attained.

➤ **Structural Measures**

➤ **Non-structural Measures (Afforestation, Sediment Control)**

➤ **Technical Assistance (Disaster Prevention Education and Capacity Building)**

This Annex-1 describes Meteorological and Hydrological conditions of six basins (Chira, Cañete, Chincha, Pisco, Yauca, Majes' Camana) and Run-off study of six basins.

CHAPTER 2 METEOROLOGY AND HYDROLOGY DATA

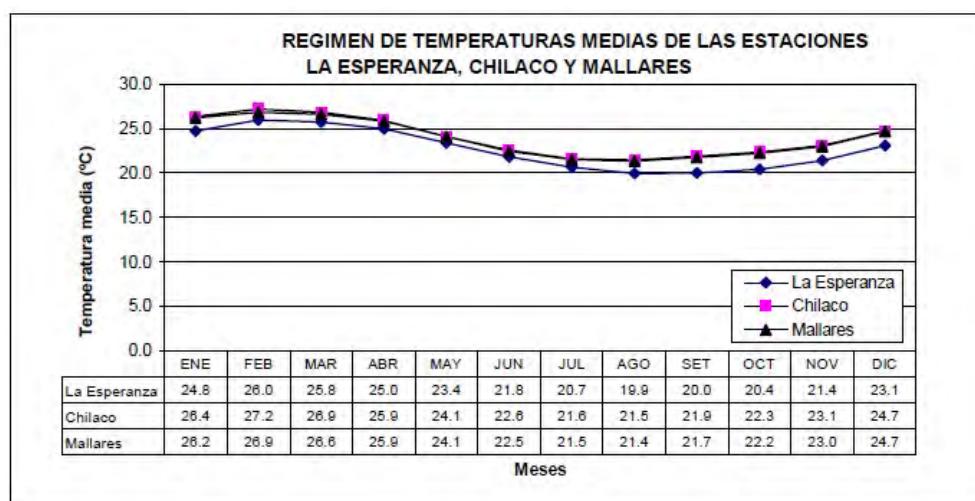
2.1 Temperature

The summary of the temperature conditions of each basin is as shown below. The observation of temperature is performed in the Meteorological and Hydrological stations described later clause.

2.1.1 Chira River

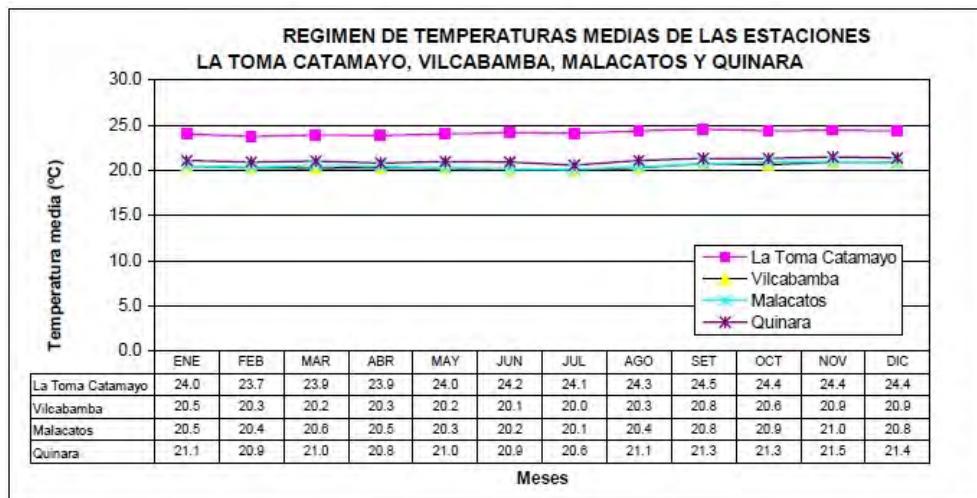
The average monthly temperature in each observation station in Chira basin is as shown in the *Figure 2.1- Figure 2.3*.

The average temperature is 24 ° C which is almost same in the downstream area and the middle stream area, however it goes down to 13 ° C toward the upstream area. The maximum temperature occurs between 13:00 to 15:00 reaching to 38 ° C in the low altitude area in February or March, and 27 ° C in the high altitude area. The minimum temperature occurs from June to September reaching to 15 ° C in the coastal area, and 8 ° C from June to September in the highland.



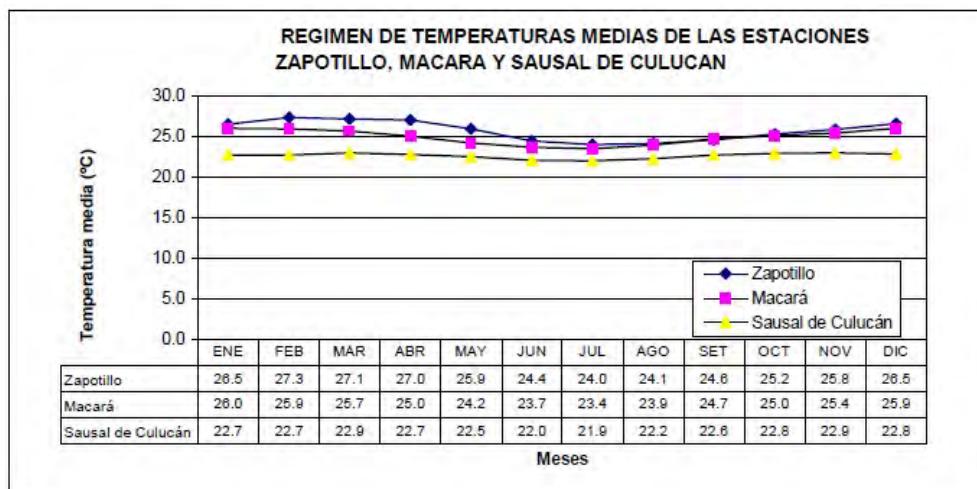
Source: Proyecto Binacional Catamayo – Chira

Figure 2.1 Monthly Average Temperature in La Esperanza, Chilaco and Mallares



Source: Proyecto Binacional Catamayo – Chira

Figure 2.2 Monthly Average Temperature in La Toma Catamayo, Vilcabamba, Malactos and Quinara



Source: Proyecto Binacional Catamayo – Chira

Figure 2.3 Monthly Average Temperature in Zapotillo, Macara and Sausal de Culucan

2.1.2 Cañete River

The average monthly temperature in Cañete, Pacarán and Yauyos observation stations in Cañete basin is as shown in the **Table 2.1** and **Figure 2.4**.

The yearly average of monthly average temperature in Pacarán and Cañete is almost same, and 20.7 and 20.0 °C respectively. It is 17.6° C in Yauyos which is little bit lower since located in 2,290 a.m.s.l

As shown in the figure, the tendency of temperature is almost same in Pacarán and Cañete, shows high temperature from January to April, however shows almost no change through year in Yauyos with higher elevation, but a little bit high from September to

November

In Cañete valley, the maximum monthly average temperature occurs in January and April reaching to about 28 °C and the minimum monthly average temperature occurs from June to September reaching to 14 °C. The maximum and minimum temperatures in the past are 33 °C in January and 11.6 °C in September respectively.

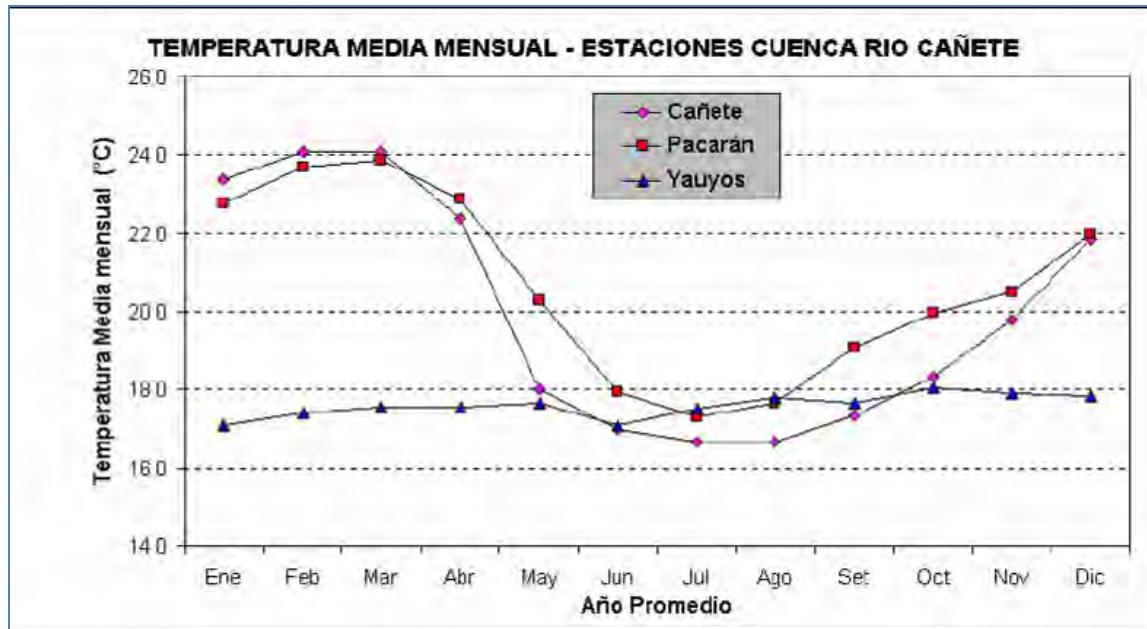
Table 2.1 Average Monthly Temperature in Cañete basin and Adjacent Area

ESTACION : YAUYOS													ALTITUD : 2,290 msnm	
Año	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Set	Oct	Nov	Dic	MEDIA	
Máx	18.6	18.9	18.3	18.7	18.6	17.9	18.7	18.3	17.9	18.6	18.8	18.8	18.2	
Min	15.6	16.5	16.6	16.9	17.1	16.6	16.9	17.5	17.3	17.1	17.1	17.3	17.1	
Prom.Mes	17.1	17.4	17.5	17.5	17.7	17.1	17.5	17.8	17.7	18.1	17.9	17.8	17.6	

ESTACION : PACARAN													ALTITUD : 700 msnm	
Año	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Set	Oct	Nov	Dic	MEDIA	
Máx	24.2	25.0	25.0	23.8	20.9	19.5	19.2	19.0	20.0	20.5	20.9	22.8	21.2	
Min	21.8	22.9	23.2	22.2	19.9	16.5	16.0	17.0	18.6	19.5	19.7	21.5	20.2	
Prom.Mes	22.8	23.7	23.9	22.9	20.3	17.9	17.3	17.6	19.1	20.0	20.5	22.0	20.7	

ESTACION : CAÑETE													ALTITUD : 150 msnm	
Año	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Set	Oct	Nov	Dic	MEDIA	
Máx	23.4	24.1	24.0	22.8	21.9	22.1	21.4	21.0	21.0	20.7	22.0	24.7	22.3	
Min	22.6	23.6	23.4	21.2	18.4	15.8	15.6	16.2	16.6	17.6	18.3	21.1	19.2	
Prom.Mes	23.4	24.1	24.1	22.4	18.0	17.0	16.7	16.7	17.3	18.3	19.8	21.8	20.0	

Source: Assessment and Management of Water Resources of the Cañete River Basin. IRH-INRENA-MINAG, 2003



Source: Assessment and Management of Water Resources of the Cañete River Basin. IRH-INRENA-MINAG, 2003

Figure 2.4 Distribution of Average Monthly Temperature in Cañete basin and Adjacent Area

2.1.3 Chincha River

The average monthly temperatures in Fonagro, Chincha de Castrovirreyna, Chincha de Yanac, Villa

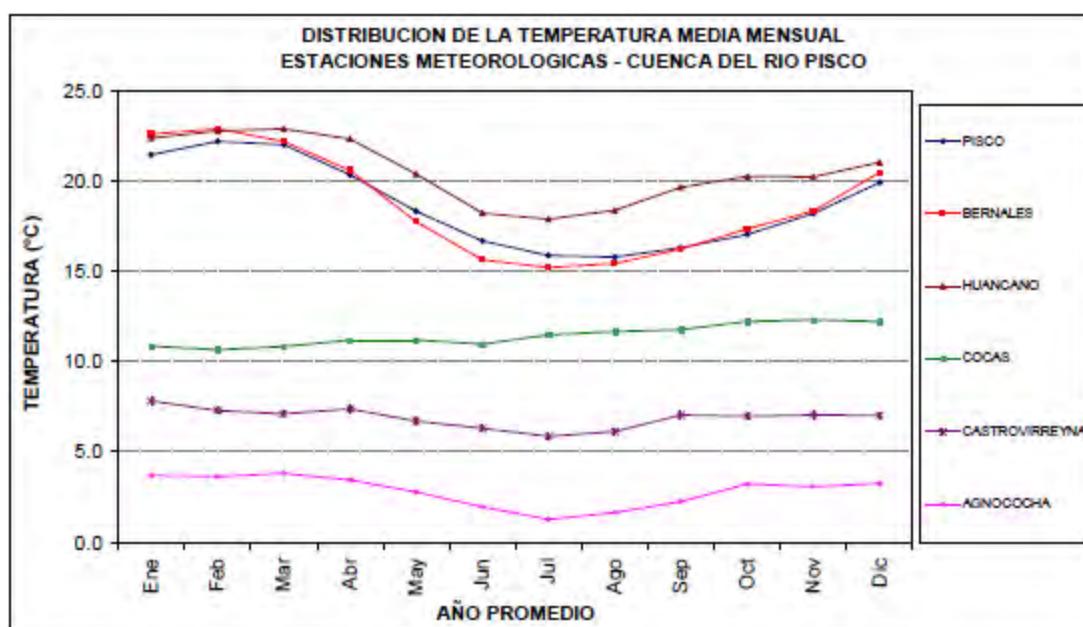
de Arma, San Pedro de Huacarpiana in Chincha basin and in Huáncano, Agnocoche in adjacent Pisco basin are as shown in the **Table 2.2** and **Figure 2.5**.

As shown in the **Table 2.3** there is reverse relationship between temperature and elevation. The average of monthly average temperature is high in Fonagro(20.3°C) and Huancano (20.6°C) and minimum in Acnocoche(2.8°C) . The distribution of monthly average temperature is high in San Juan and minimum in Acnocoche as shown in the **Figure 2.5**.

Table 2.2 Average Monthly Temperature in Chincha basin and Adjacent Area(C°)

ESTACION METEOROLOGICA	ALTITUD msnm	AÑO PROMEDIO												MEDIA ANUAL
		Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Set	Oct	Nov	Dic	
FONAGRO	50	23.6	24.3	23.8	22.3	19.9	17.9	17.4	17.4	17.5	18.4	19.4	21.6	20.3
HUANCANO (*)	1006	22.4	22.8	22.9	22.4	20.4	18.3	17.9	18.4	19.7	20.3	20.3	21.1	20.6
SAN JUAN DE CASTROVIRREYNA	2150	19.7	19.3	19.9	19.4	19.8	18.9	19.5	19.3	19.6	19.4	19.2	19.4	19.4
SAN JUAN DE YANAC	2400	14.8	14.9	15.0	14.9	15.9	15.5	15.5	16.1	15.8	15.8	15.4	16.1	15.5
HUACHOS	2680	15.1	14.7	14.7	14.7	15.2	15.2	14.9	15.9	15.8	15.8	15.1	16.0	15.2
VILLA DE ARMA	3280	11.8	10.4	11.3	12.0	12.6	12.3	13.0	12.6	13.2	12.8	11.7	11.4	12.1
S.P.HUACARPANA	3680	9.1	8.6	9.5	9.4	9.8	9.3	9.6	9.2	9.5	10.2	9.6	10.1	9.5
AGNOCOCHA (*)	4650	3.7	3.6	3.8	3.4	2.8	2.0	1.3	1.6	2.2	3.2	3.1	3.3	2.8

Source: Assessment and Management of Water Resources of the Chincha River Basin. IRH-INRENA-MINAG. 2003



Source: Assessment and Management of Water Resources of the Chincha River Basin. IRH-INRENA-MINAG. 2003

Figure 2.5 Distribution of Average Monthly Temperature in Chincha basin

2.1.4 Pisco River

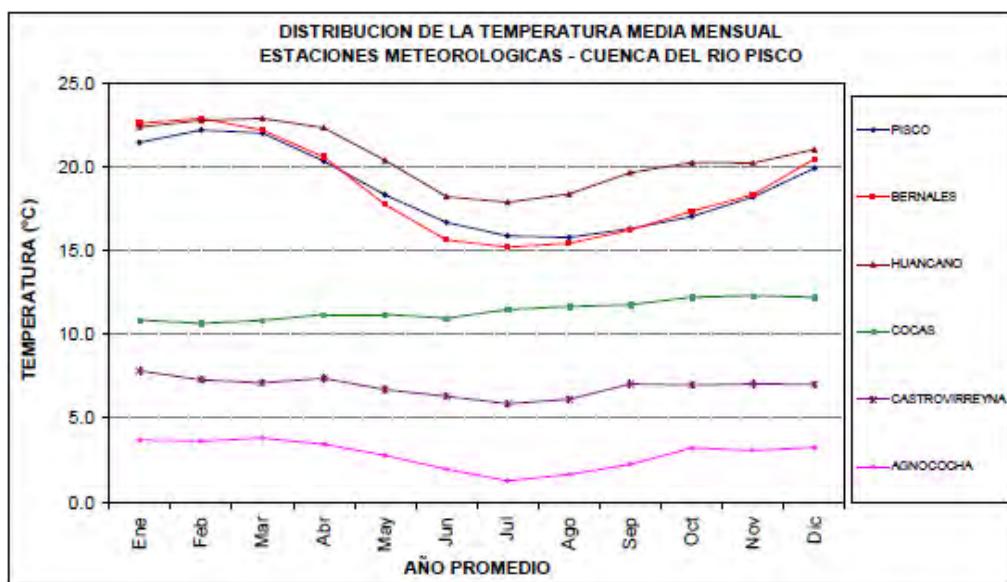
The average monthly temperatures in Pisco, Bernales, Huáncano, Cokes, Acnocoche Castrovirreyna in Pisco basin and in Huamaní, Acora, Tunnel Zero, San Pedro de Huacarpiana in adjacent Ica basin are as shown in the **Table 2.3** and **Figure 2.6**.

As shown in the **Table 2.3** there is reverse relationship between temperature and elevation. The average of monthly average temperature is high in Huamani stations (20.5°C) and Huancano (20.6°C) and minimum in Tunel Cero (3.7°C) and Acnocoche (2.8°C). The distribution of monthly average temperature is high in Pisco and Hancano Bernales and minimum in Acnocoche as shown in the **Figure 2.6**.

Table 2.3 Average Monthly Temperature in Pisco basin and Adjacent Area(C°)

Nº	ESTACION METEOROLOGICA	ALTITUD msnm	AÑO PROMEDIO												MEDIA ANUAL
			Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Set	Oct	Nov	Dic	
1	PISCO	7	21.5	22.2	22.0	20.4	18.3	16.7	15.9	15.8	16.3	17.1	18.2	20.0	18.7
2	BERNALES	250	22.6	22.9	22.2	20.6	17.8	15.7	15.2	15.5	16.3	17.4	18.5	20.6	18.8
3	HUAMANI	800	23.0	23.8	23.7	22.0	20.1	17.5	16.6	17.5	18.8	19.9	20.7	22.0	20.5
4	HUANCANO	1006	22.4	22.8	22.9	22.4	20.4	18.3	17.9	18.4	19.7	20.3	20.3	21.1	20.6
5	ACORA	1800	17.2	17.4	17.8	17.3	16.7	16.2	16.5	16.6	16.8	17.3	17.2	17.5	17.0
6	COCAS	3246	10.9	11.0	10.8	11.2	11.2	11.0	11.5	11.7	11.9	12.2	12.3	12.2	11.5
7	S.P.HUACARPANA	3680	9.1	8.6	9.5	9.4	9.8	9.3	9.6	9.2	9.5	10.2	9.6	10.1	9.5
8	CASTROVIRREYNA	3956	7.8	7.3	7.1	7.4	6.7	6.3	5.9	6.1	7.1	7.0	7.1	7.0	6.9
9	TUNEL CERO	4425	4.3	4.4	4.5	4.1	3.5	2.5	2.3	2.9	3.5	4.1	4.5	4.4	3.7
10	AGNOCOCHA	4850	3.7	3.6	3.8	3.4	2.8	2.0	1.3	1.6	2.2	3.2	3.1	3.3	2.8

Source: Assessment and Management of Water Resources of the Pisco River basin. IRH-INRENA-MINAG, 2003



Source: Assessment and Management of Water Resources of the Pisco River basin. IRH-INRENA-MINAG, 2003

Figure 2.6 Distribution of Average Monthly Temperature in Pisco basin

2.1.5 Yauca River

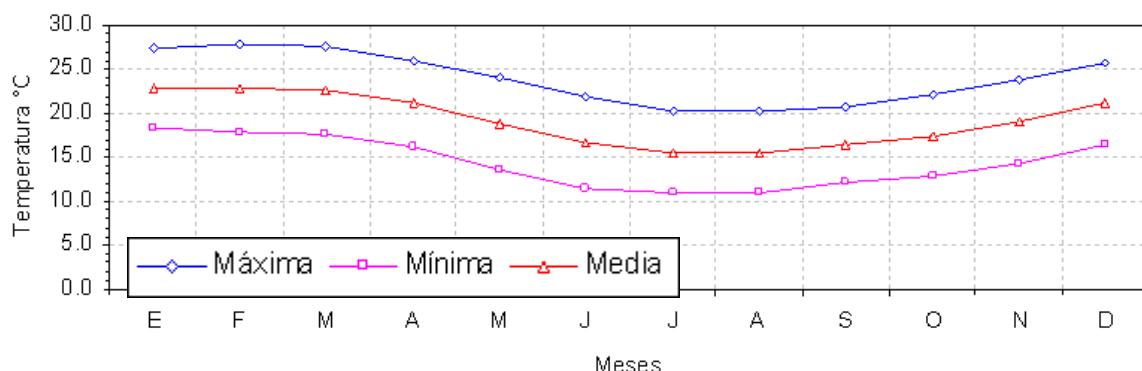
The temperature is the factor most linked to their altitudinal variations. In the basin, it has been seen that varies from semi-warm (19 °C approximately) in the area of coast to the frigid type (5 °C approximately) in the area of puna.

The existing meteorological network, only have reliable statistical data on temperature at 4 stations. Three are located in Coracora, Chavín and Sancos respectively (Sierra or mountain side), and one is in Yauca (coast side). The former 3 observation station is located far from the objective study area so that the average monthly temperature in Yauca is shown in the **Table 2.4** and the **Figure 2.7**.

Table 2.4 Average Monthly Temperature in Yauca(°C)

Temperature	Month												Average
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Maximum	27.40	27.90	27.60	26.00	24.00	21.90	20.30	20.10	20.70	22.10	23.90	25.80	23.98
Minimum	18.30	17.80	17.70	16.30	13.60	11.30	10.90	11.00	12.20	12.80	14.40	16.40	14.39

Source: Asignación de Agua en Bloque en el Valle Yauca, ATDR Acari-Yauca-Puquio, 2006



Source: Asignación de Agua en Bloque en el Valle Yauca, ATDR Acari-Yauca-Puquio, 2006

Figure 2.7 Distribution of Monthly Average Temperature(C°)

2.1.6 Majes-Camana River

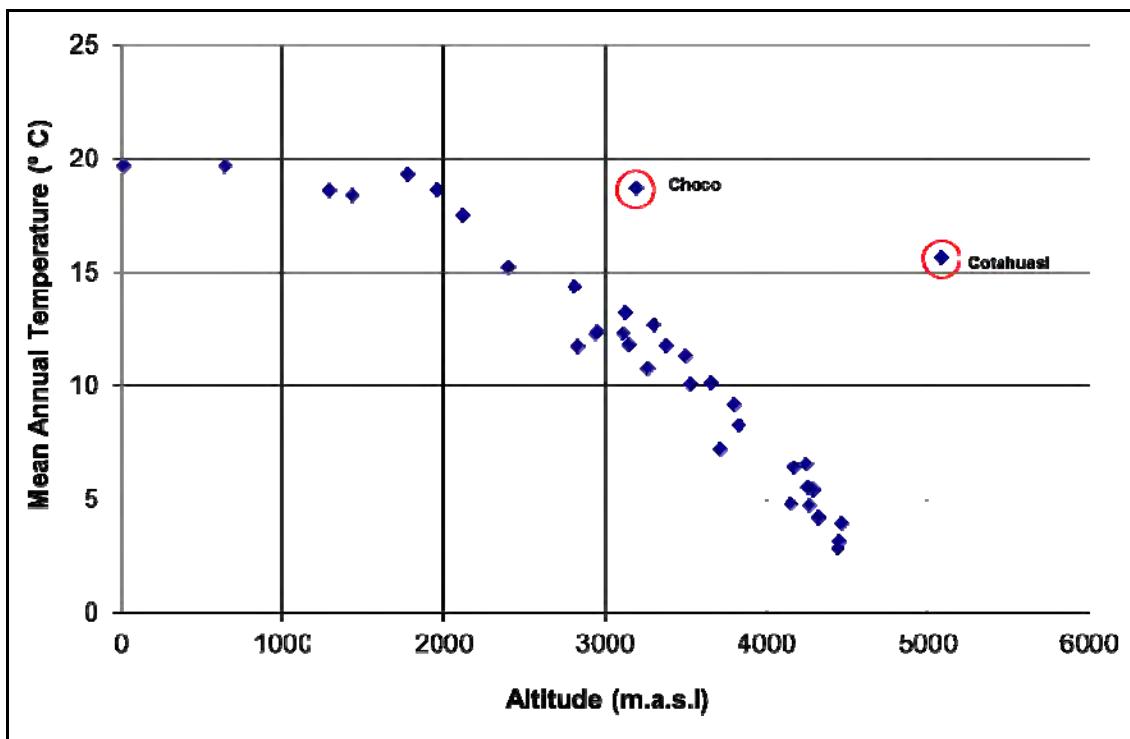
In Majes-Camana basin the annual average temperatures are semi temperate in the lower reaches, between 0 and 800 m.a.s.l. with an average annual temperature of 19°C. Temperature descends above 800 m. Between 2,200 m and 3,100, stations Pampacolca and Chuquibamba register average temperature ranges between 10.8 ° C and 12.9 °C. Between elevations 3,100 m and 3,900, the Sibayo station (3,800 m.a.s.l.) has registered annual temperatures of 7.8 ° C. However, higher temperatures reach 20 ° C and the lower temperatures are around -6.8 °C. Between 3,900 and 4,800 m.a.s.l., temperatures have been registered at Pañé, with an annual average temperature of 3.1°C.

The relation between mean annual temperature and elevation in each station is as shown in the **Table 2.5**. And the relation between elevation and mean annual temperature is as shown in the **Figure 2.7**, in addition that the same relation in the elevation more than 2,000 m is also as shown in the **Figure 2.8**, which shows strong relation between two factors.

Table 2.5 Relation between Elevation and Mean Annual Temperature of Stations

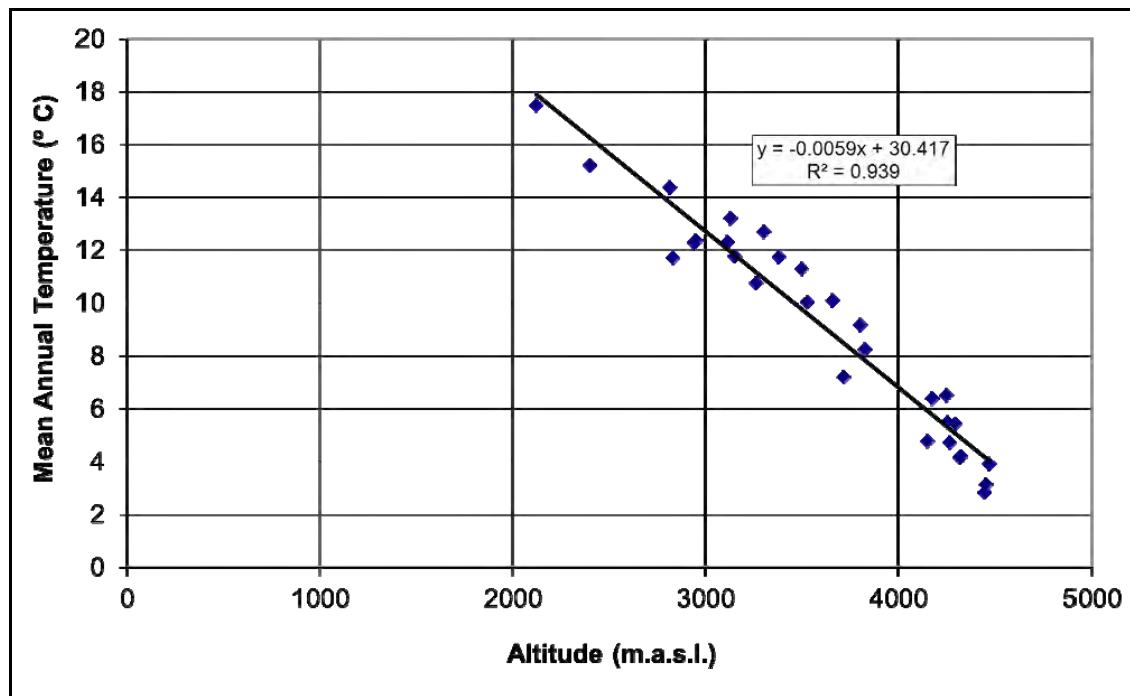
Weather Station	Altitude (m.a.s.l.)	Mean Annual Temperature (° C)
Andahua	3528	10.05
Aplao	645	19.67
Ayo	1956	18.64
Cabanaconde	3379	11.74
Camaná	15	19.67
Caravelí	1779	19.29
Chachas	3130	13.20
Chichas	2120	17.47
Chiguata	2943	12.27
Chivay	3661	10.09
Choco	3192	18.70
Chuquibamba	2832	11.71
Cotahuasi	5088	15.62
Crucero Alto	4470	3.91
El Frayle	4267	4.72
Huambo	3500	11.30
Imata	4445	2.83
La Angostura	4256	5.50
La Joya	1292	18.59
La Pampilla	2400	15.20
Lagunillas	4250	6.52
Las Salinas	4322	4.20
Machahuay	3150	11.76
Madrigal	3262	10.75
Orcopampa	3801	9.16
Pampa de Arrieros	3715	7.18
Pampa de Majes	1434	18.40
Pampacolca	2950	12.37
Pampahuta	4320	4.16
Pillones	4455	3.13
Porpera	4152	4.79
Pullhuay	3113	12.30
Salamanca	3303	12.68
Sibayo	3827	8.23
Sumbay	4294	5.42
Tisco	4175	6.39
Yanaquihua	2815	14.38

Source: SERVICIO NACIONAL DE METEOROLOGIA E HIDROLOGIA DEL PERU (SENAMHI)



Source: SERVICIO NACIONAL DE METEOROLOGIA E HIDROLOGIA DEL PERU (SENAMHI)

Figure 2.7 Relation between Elevation and Mean Annual Temperature of Station



Source: SERVICIO NACIONAL DE METEOROLOGIA E HIDROLOGIA DEL PERU (SENAMHI)

Figure 2.8 Relation between Elevation and Mean Annual Temperature of Station (over 2,000m)

2.2 Rainfall

The rainfall data is collected and processed in order to obtain the observation conditions of rainfall data in the study area, which are to be used in the run-off study. The rainfall data is collected mainly from SENAMHI which is the observation agency of the most of the stations. The observation method is not automatic but manual at regular time of a day for all of the stations in the study area so that there is no hourly data but only daily data (24 hour -rainfall data).

2.2.1 Chira River

(1) Conditions of Rainfall Observation

The rainfall observation stations and their observation period in Chira basin are as shown in the **Table 2.6 – Table 2.7** and the **Figure 2.9**.

In Chira basin, the rainfall has been observed in 14 stations including the station in which the observation is stopped at present, and the longest observation period is 47 years from 1964 to 2010.

Table 2.6 Rainfall Observation Station (Chira River)

Code No.	Observation Station	Region	Longitude	Latitude	Responsible Agency
152202	ARDILLA (SOLANA BAJA)	PIURA	80° 26'1	04° 31'1	SENAMHI
150003	EL CIRUELO	PIURA	80° 09'1	04° 18'1	
152108	FRIAS	PIURA	79° 51'1	04° 56'1	
230	LA ESPERANZA	PIURA	81° 04'4	04° 55'55	
152125	LAGUNA SECA	PIURA	79° 29'1	04° 53'1	
152104	LAS LOMAS 1	PIURA	80° 15'1	04° 38'1	
140	LAS LOMAS 2	PIURA	80° 15'1	04° 38'1	
208	MALLARES	PIURA	80° 44'44	04° 51'51	
152144	MONTERO	PIURA	79° 50'1	04° 38'1	
152101	PANANGA	PIURA	80° 53'53	04° 33'33	
152135	SAN JUAN DE LOS ALISOS	PIURA	79° 32'1	04° 58'1	
203	SALALA	PIURA	79° 27'27	05° 06'6	
152110	SANTO DOMINGO	PIURA	79° 53'1	05° 02'1	

Table 2.7 Observation Period of Rainfall Data (Chira River)

Observation Station	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
ALAMOR																																																			
ARDILLA																																																			
EL CIRUELO																																																			
FRÍAS																																																			
LA ESPERANZA																																																			
LAGUNA SECA																																																			
LAS LOMAS 1																																																			
LAS LOMAS 2																																																			
MALLARES																																																			
MONTERO																																																			
PANANGA																																																			
SAN JUAN DE LOS ALIOSOS																																																			
SALALA																																																			
SANTO DOMINGO																																																			

■ : year of El niño

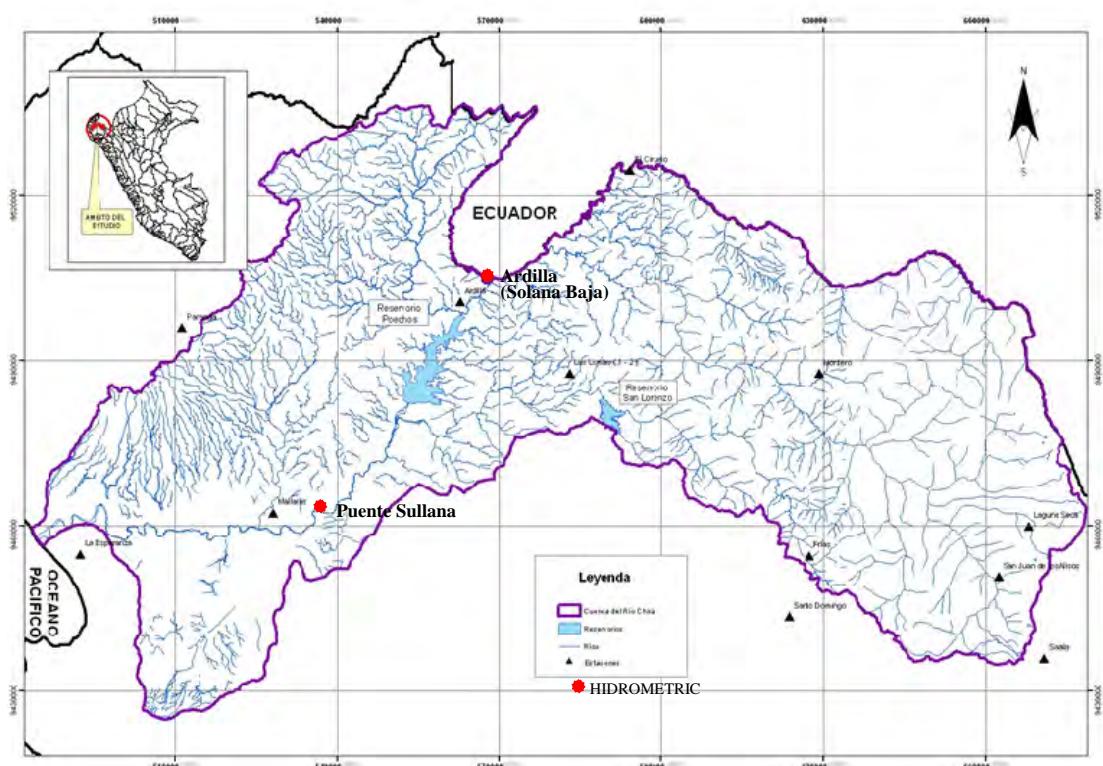


Figure 2.9 Location of Rainfall and Discharge Observation Station (Chira River)

(2) Monthly Rainfall

The average monthly rainfall and its distribution of each station in Chira basin are as shown in **Table 2.8** and the **Figure 2.10**.

According to the Table and the Figure, the monthly rainfall is large from October to April and extremely small from May to September. And the yearly rainfall varies from 100 mm in La Esperanza to 1,584mm in Laguna Seca.

Table 2.8 Average Monthly Rainfall in Chira Basin and Adjacent Basin (mm)

ESTACION	Mes												Total
	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic	
ARDILLA	58.0	114.2	184.1	92.4	26.8	21.5	0.0	0.4	0.1	2.6	1.5	6.9	594.1
EL CIRUELO	102.2	161.0	231.1	141.0	22.1	8.1	1.3	0.2	0.6	2.6	4.4	30.3	680.3
FRIAS	180.3	251.8	308.4	155.7	54.1	12.6	4.0	5.3	10.3	19.2	19.2	74.1	1145.9
LA ESPERANZA	14.7	17.7	28.1	17.3	12.8	7.2	0.1	0.1	0.2	0.4	0.3	3.1	100.8
LAGUNA SECA	240.2	278.2	261.0	236.0	124.1	45.0	39.7	33.8	33.8	104.7	99.2	195.5	1584.1
LAS LOMAS 1	36.8	59.7	136.9	70.6	48.9	11.0	0.1	0.1	0.5	2.5	1.5	10.1	380.0
LAS LOMAS 2	8.3	86.9	123.0	53.0	5.7	0.6	0.1	0.1	0.0	0.2	2.2	5.9	287.6
MALLARES	30.2	46.3	69.6	37.5	15.0	0.4	0.2	0.2	0.3	1.0	0.9	8.2	221.5
MONTERO	123.7	181.2	296.1	191.1	79.9	29.3	5.5	5.8	7.8	17.6	15.1	45.7	987.4
PANANGA	39.3	59.9	95.2	43.8	14.3	3.9	0.1	0.0	0.2	0.8	0.9	11.4	272.5
SAN JUAN DE LOS ALISOS	186.7	222.7	229.5	184.7	68.9	33.9	18.3	18.8	22.1	67.2	72.7	145.4	1291.0
SALALA	104.4	138.9	128.0	114.7	82.4	58.4	51.4	27.1	33.3	81.1	84.0	104.0	1029.3
SANTO DOMINGO	169.0	263.7	370.6	217.4	74.5	12.7	2.8	4.3	10.7	16.6	28.6	76.7	1233.1

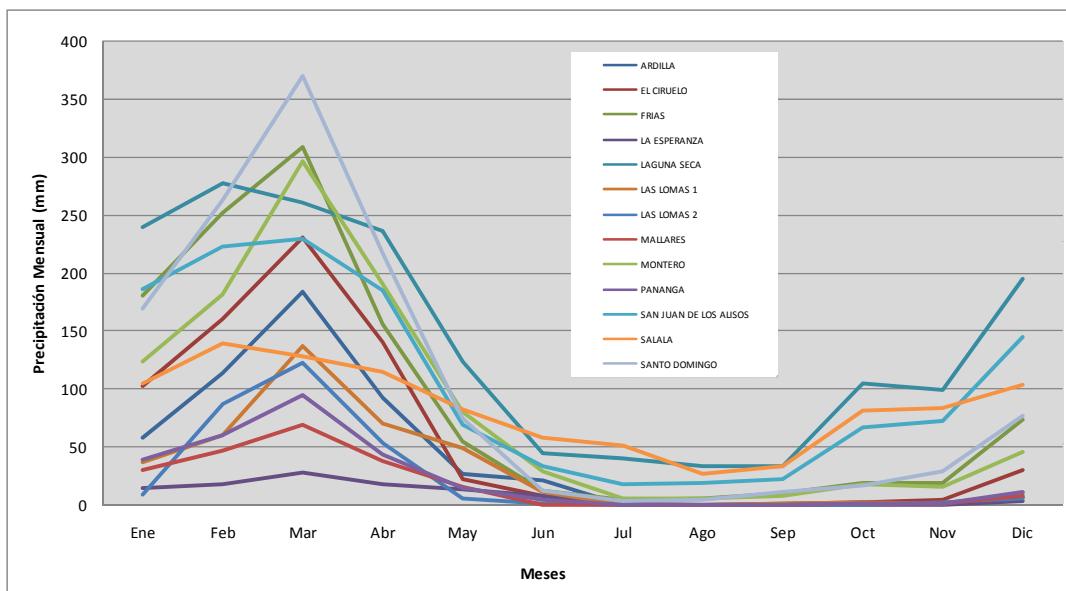


Figure 2.10 Distribution of Average Monthly Rainfall in Chira Basin and Adjacent Basin (mm)

(3) Yearly Maximum of 24-hour Rainfall

The yearly maximum of 24-hour rainfall of each observation station in Chira basin is as shown in the **Table 2.9**.

Table 2.9 Yearly Maximum of 24-hour Rainfall (Daily Rainfall) in Chira Basin (mm)

Year	ARDILLA (SOLANA BAJA)	EL CIRUELO	FRIAS	LA ESPERANZA	LAGUNA SECA	LAS LOMAS 1	LAS LOMAS 2	MALLARES	MONTERO	PANANGA	SAN JUAN DE LOS ALISOS	SALALA	SANTO DOMINGO
1964						5.8				3.2			20.0
1965			13.8			102.0				154.0			65.6
1966			14.7			30.1				25.3			49.9
1967			12.2			59.3				11.6			64.6
1968			18.6	2.8		4.0				2.7			18.4
1969			75.2	20.0		40.0				40.0			58.4
1970				0.9		44.0				1.9			36.9
1971			69.0	0.0		57.2			93.7	21.5			82.6
1972	68.4		80.2			73.0		50.5	113.5	64.4			98.4
1973	95.8		90.7	22.0	162.3	56.0		31.0	48.4	34.6	79.2		91.2
1974	14.4			2.0	48.9	6.5		3.5	35.3	7.0	55.0		44.0
1975	47.5		53.4	18.9	90.0			10.9	57.8	62.0	64.5		51.5
1976				73.2					67.3	106.1	19.4	54.5	75.4
1977	107.1	135.9	88.4	13.9	106.0				10.8	69.1		91.4	85.9
1978		28.0	49.1	8.7	80.0	46.0		25.6	46.3	27.7	65.8		51.5
1979	24.1	30.0	88.5	2.0	50.0	12.2		2.7	43.3	4.5	55.4		41.9
1980	38.7	72.9	70.3	10.7	60.1	20.8			51.3	7.8	51.7		54.1
1981		93.2	66.7	3.2	65.0	84.9		9.6	55.5	14.0	63.8		90.9
1982		100.8	68.0	1.8	70.0	60.7		11.5	40.7	15.3	98.4		62.4
1983	151.9	209.1	120.6	134.8	77.0	165.0		148.1	74.0	85.5	65.8		119.5
1984	102.1	82.5	52.3	4.6	55.0	37.4		47.3	53.8	53.0	56.3		73.9
1985	35.1	49.7	66.6	11.3		8.5			25.9	10.0	43.2		42.3
1986	18.3	100.5	40.8	3.8	44.7	21.5		4.7	81.2	24.3	55.4		39.5
1987	152.4	152.3	78.4	32.8	41.3			64.0	80.4	82.2	90.0		55.1
1988	126.3	16.1	37.9	3.2	50.0		24.2	15.7	29.9	22.7	46.4		29.8
1989	152.5	91.0	66.8	9.3			117.3		55.5	37.8	79.1		68.0
1990		18.3	41.4	2.1			11.5	2.6	40.2	4.3			28.5
1991	105.3	164.0		1.5			21.8	15.4	36.9	11.4	60.1		60.3
1992							138.3			8.3			85.3
1993							51.3			67.2			60.4
1994		116.5	122.0		59.9		58.2	11.7	58.3	15.4	57.4		60.4
1995		85.0		8.8	65.7		37.0	1.8	59.0	23.7			76.4
1996				2.9						10.0			60.3
1997				24.7				85.8		71.4			59.8
1998				96.6				201.0		150.1		40.8	118.1
1999				22.8						55.0			71.1
2000				6.2				19.7		26.7		33.9	86.5
2001				14.5				62.5		60.2		34.2	49.0
2002				22.4				47.1		60.5		37.3	60.9
2003				8.6				12.9		41.8		34.4	46.2
2004				5.3				7.3		46.1		40.5	63.3
2005				1.5				6.1		28.3		29.5	80.8
2006				10.0				25.8		29.9			103.0
2007				3.7				8.4		36.4		44.2	61.1
2008				72.0				79.0		96.3		56.0	
2009				8.7						34.0		34.9	127.9
2010													

(4) Isohyetal Map of Yearly Average Rainfall

The isohyetal map of yearly average rainfall which was prepared by SENAMHI based on the observed rainfall data for 10 years in Chira basin.

There is big difference in the yearly rainfall data by areas in Chira basin, for instance yearly rainfall is 50mm in the minimum, on the other hand 1,000mm in the maximum, and the amount is small in the downstream area and becomes large toward the upstream.

In the objective section for flood protection, the yearly rainfall is not so much from 50~200 mm, however the amount is largest among the objective 6 basins in this study.

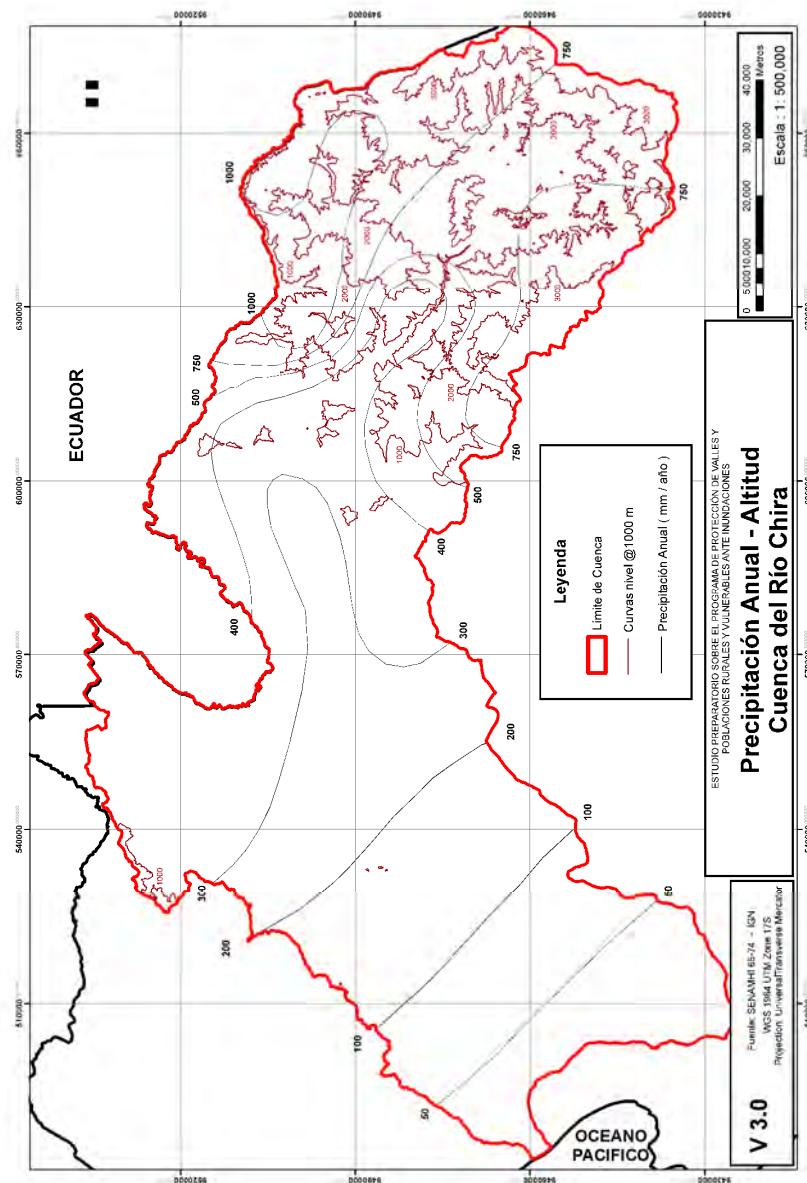


Figure 2.11 Isohyetal Map of Yearly Rainfall (Chira Basin)

2.2.2 Cañete River

(1) Conditions of Rainfall Observation

The rainfall observation stations and their observation period in Cañete basin are as shown in the **Table 2.10** and the **Figure 2.12**.

In Cañete basin, the rainfall has been observed in 13 stations, and the longest observation period is 47 years from 1964 to 2010.

Table 2.10 Rainfall Observation Station (Cañete river)

Code No.	Observation Station	Region	Longitude	Latitude	Responsible Agency
636	YAUYOS	LIMA	75° 54'38.2	12° 29'31.4	SENAMHI
155450	YAURICOCHA	LIMA	75° 43'22.5	12° 19'0	
155169	TOMAS	LIMA	75° 45'1	12° 14'1	
156106	TANTA	LIMA	76° 01'1	12° 07'1	
6230	SOSCI CAÑETE	LIMA	76° 11'40	13° 01'42	
638	PACARAN	LIMA	76° 03'18.3	12° 51'43.4	
6641	NICOLAS FRANCO SILVERA	LIMA	76° 05'17	12° 53'57	
156112	HUANTAN	LIMA	75° 49'1	12° 27'1	
156110	HUANGASCAR	LIMA	75° 50'2.2	12° 53'55.8	
156107	COLONIA	LIMA	75° 53'1	12° 38'1	
156109	CARANIA	LIMA	75° 52'20.7	12° 20'40.8	
156104	AYAVIRI	LIMA	76° 08'1	12° 23'1	
489	COSMOS	JUNIN	75° 34'1	12° 09'1	

Table 2.11 Observation Period of Rainfall Data (Cañete river)

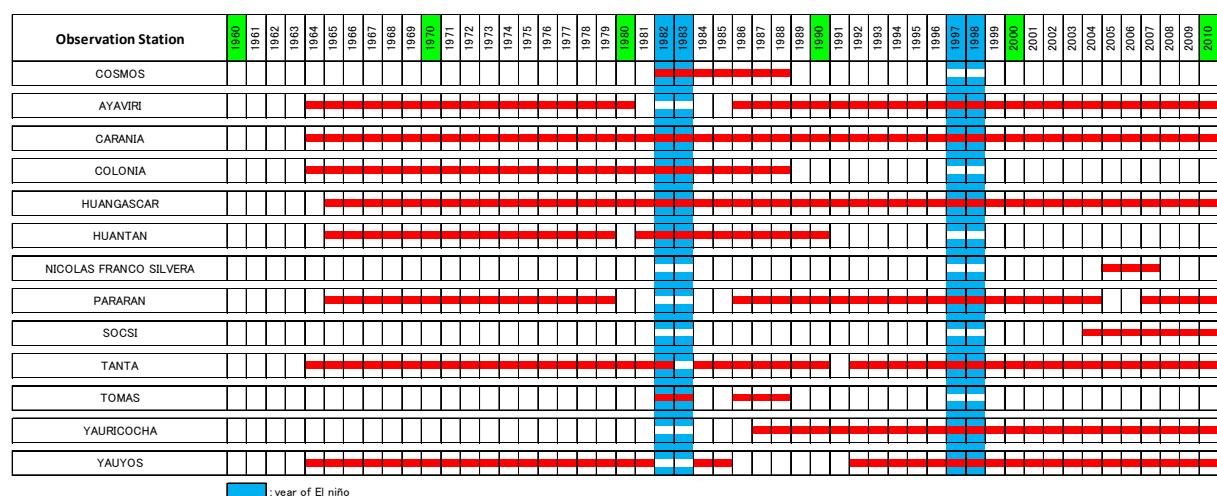




Figure 2.12 Location of Rainfall and Discharge Observation Station (Cañete river)

(2) Monthly Rainfall

The average monthly rainfall and its distribution of each station in Cañete basin are as shown in **Table 2.12** and the **Figure 2.13**.

According to the Table and the Figure, the monthly rainfall is large from October to April and extremely small from May to September. And the yearly rainfall varies from 1.47 mm in Socsi to 1,016mm in Yauricocha.

Table 2.12 Average Monthly Rainfall in Cañete Basin and Adjacent Basin (mm)

STATION	Month												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
YAYOS	71.36	83.70	83.26	20.35	3.36	0.52	0.15	0.92	3.10	12.94	19.68	44.46	343.80
YAURICOCHA	178.17	168.19	169.94	92.76	20.76	9.40	10.52	20.85	37.28	88.02	81.24	138.64	1,015.78
TOMAS	128.45	119.02	100.86	67.50	21.93	17.36	11.13	14.36	35.34	44.19	55.36	86.90	702.39
TANTA	151.80	157.83	162.22	91.07	25.07	7.23	5.52	11.23	29.59	60.70	78.74	110.98	891.99
SOCSI CAÑETE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.47	0.00	0.00	0.00	0.00	1.47
PACARAN	4.21	4.70	3.83	0.29	0.10	0.04	0.01	0.07	0.09	0.41	0.41	1.93	16.09
NICOLAS FRANCO SILVERA	1.80	4.57	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	2.33	11.50
HUANTAN	195.68	236.82	196.02	72.60	7.82	1.09	1.77	2.17	2.61	50.73	62.07	98.77	928.15
HUANGASCAR	59.94	72.77	85.06	9.93	0.63	0.20	0.03	0.25	0.43	2.23	6.45	24.95	262.87
COLONIA	84.62	109.69	127.22	27.47	3.15	0.35	0.79	0.56	3.81	15.23	21.41	64.96	459.25
CARANIA	118.12	118.97	126.34	43.37	12.69	3.80	3.19	4.98	11.01	27.60	32.47	79.56	582.10
AYAVIRI	119.80	137.90	151.32	46.06	5.25	0.02	0.28	0.83	1.93	10.36	17.37	56.67	547.80
COSMOS	110.38	99.85	110.09	53.48	24.93	4.10	7.03	13.01	32.87	49.44	52.59	95.53	653.29

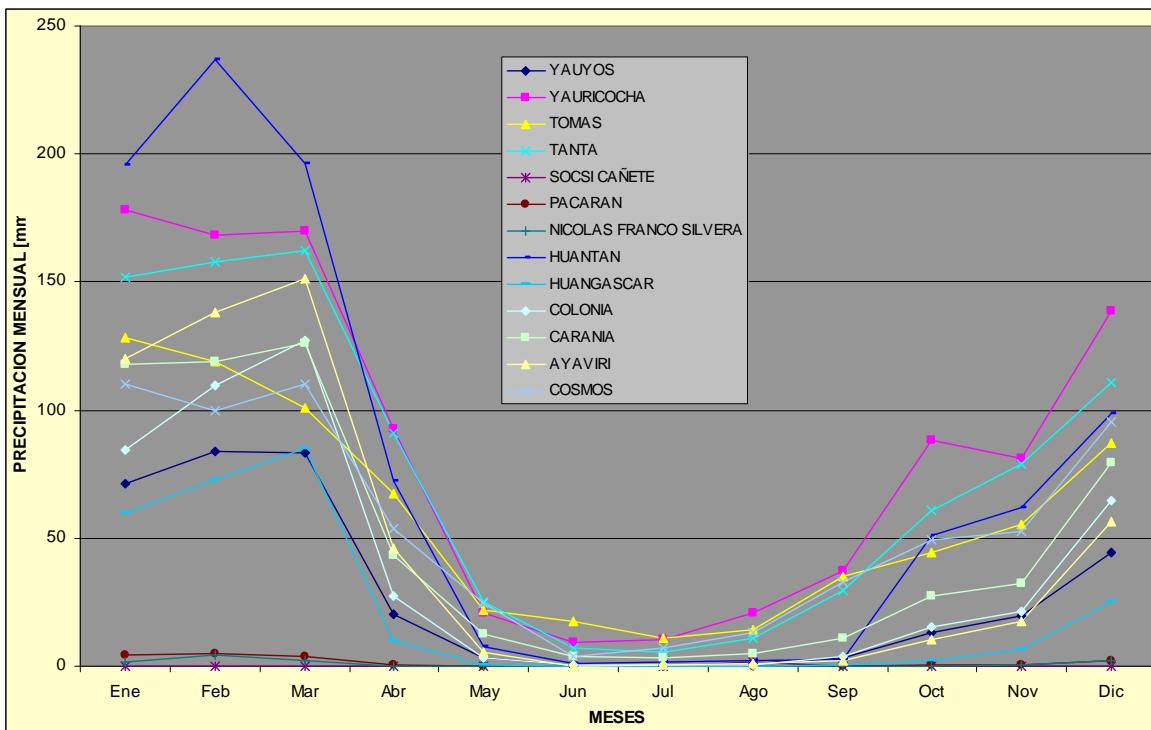


Figure 2.13 Distribution of Average Monthly Rainfall in Cañete Basin and Adjacent Basin (mm)

(3) Yearly Maximum of 24-hour Rainfall

The yearly maximum of 24-hour rainfall (daily rainfall) of each observation station in Cañete basin

is as shown in the **Table 2.13**.

Table 2.13 Yearly Maximum of 24-hour Rainfall (Daily Rainfall) in Cañete Basin (mm)

Year	YAUYOS	YAURICOC HA	TOMAS	TANTA	SOCSI CA ÑETE	PACARAN	NICOLAS FRANCO SILVERA	HUANTAN	HUANGAS CAR	COLONIA	CARANIA	AYAVIRI	COSMOS
1964	19.5			25.4						14.2	28.4	12.0	
1965	31.4			34.5		2.1		41.6	15.0	43.5	44.3	13.0	
1966	23.3			26.6		2.5		20.0	25.1	34.4	25.0	28.5	
1967	23.6			28.0		8.8			35.3	62.8	18.6		
1968				23.7				17.7	12.9	18.1		19.7	
1969	17.4			33.0					21.3	17.2	29.3	33.5	
1970	26.8			37.9		20.3		21.2	28.0	24.2	16.6	29.9	
1971	33.0			24.5		6.3		18.5	19.6	31.5	18.0	22.7	
1972				26.1		4.8		29.3	70.5	16.3	20.1	33.0	
1973	28.2			18.2		6.0		30.2	27.2	15.8	22.6	37.6	
1974	21.5			19.3		2.4		20.0	12.7	15.7	16.8	30.5	
1975	19.0			15.1		3.3		40.1	34.6	14.1	16.0	34.8	
1976	20.0			17.5		0.4		32.4		23.2	19.3	16.1	
1977	14.8			16.4		0.8			29.4	24.9	17.4	34.4	
1978	20.1			16.3		0.2		22.0	49.8	25.2	16.1	33.4	
1979	16.9			11.7					18.1		15.1	11.2	
1980	15.5			14.4					8.5		17.1		
1981	22.8			13.1					21.0	17.6	17.5		
1982				16.8	13.3			61.2	17.2		15.6	19.3	
1983				9.8				33.6	9.7	21.5	16.6	15.5	
1984	10.0			11.3				53.4	14.9		14.2	27.0	
1985				12.4					13.8	8.0	12.9		
1986				17.5	18.0	3.5		36.2	19.0	26.5	20.0	32.7	33.7
1987				37.6	13.1	16.8		35.5	13.1	12.5	20.9	31.9	29.3
1988				28.8	13.6	13.8			20.4		33.1	23.8	
1989				26.1		13.9		6.0	27.7	20.0	24.4	39.4	
1990				30.8		15.8		1.2		20.0	26.0	25.6	
1991				24.0		11.5		1.5		19.0	12.4	27.4	
1992	6.3			21.5		16.0		1.2		5.0	15.1	29.9	
1993	17.3			40.5		41.6		3.0		20.0	16.0	29.7	
1994	31.5			21.8		26.4		9.0		24.0	14.1	30.2	
1995	12.2	20.2			27.0		6.2			30.0		13.5	30.2
1996	24.3	16.6		31.7		2.6			23.0		16.1	24.6	
1997	18.8	28.2		27.4		3.6			25.3		14.6	46.2	
1998	14.7	27.6		41.8		5.5			33.8		14.1	32.4	
1999	19.9	24.4			24.5		11.2			24.3		15.6	23.1
2000	12.9	58.6		28.9		3.8			30.6		27.0	35.4	
2001	13.3	20.6		22.7		5.6			12.8		14.9	24.0	
2002	11.6	25.8		28.2					24.8		17.7	28.7	
2003	14.4	60.4		28.0		4.4			15.0		18.9	18.2	
2004	14.2	41.3		32.9					17.7		21.4	29.2	
2005	13.6	30.4		22.0	0.0			6.4	13.0		20.5	21.0	
2006	20.6	26.2		29.5	0.0			3.0		25.1		30.1	26.5
2007	19.8	29.0		33.6	0.0	2.3			14.6		23.4	34.2	
2008	19.9	15.4			0.0	2.6			24.0		21.9	30.4	
2009	15.1	26.9		69.2	8.0	6.0			14.8		20.5	27.3	
2010													

(4) Isohyetal Map of Yearly Average Rainfall

The isohyetal map of yearly average rainfall in Cañete basin is as shown in the **Figure 2.14**.

There is big difference in the yearly rainfall data by areas in Cañete basin, for instance yearly rainfall is less than 25mm in the minimum, on the other hand 750mm in the maximum, and the amount is small in the downstream area and becomes large toward the upstream with higher elevation.

In the objective section for flood protection, the yearly rainfall is not so much from 25~50mm.

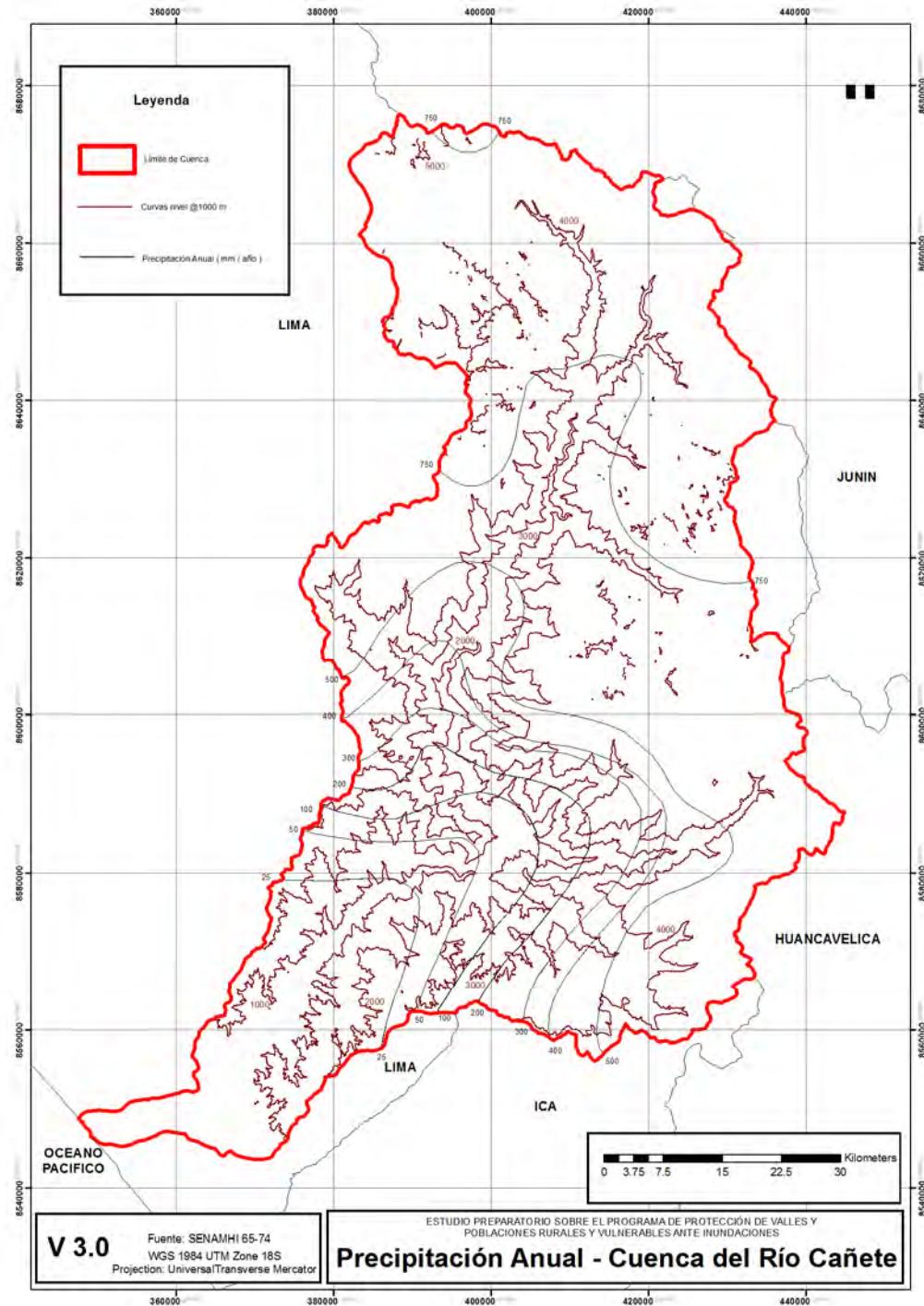


Figure 2.14 Isohyetal Map of Yearly Rainfall (Cañete Basin)

2.2.3 Chincha River

(1) Conditions of Rainfall Observation

The rainfall observation stations and their observation period in Chincha basin are as shown in the **Table 2.14 ~ Table 2.15** and the **Figure 2.15**.

In Chincha basin, the rainfall has been observed in 14 stations, and the longest observation period is 31 years from 1980 to 2010.

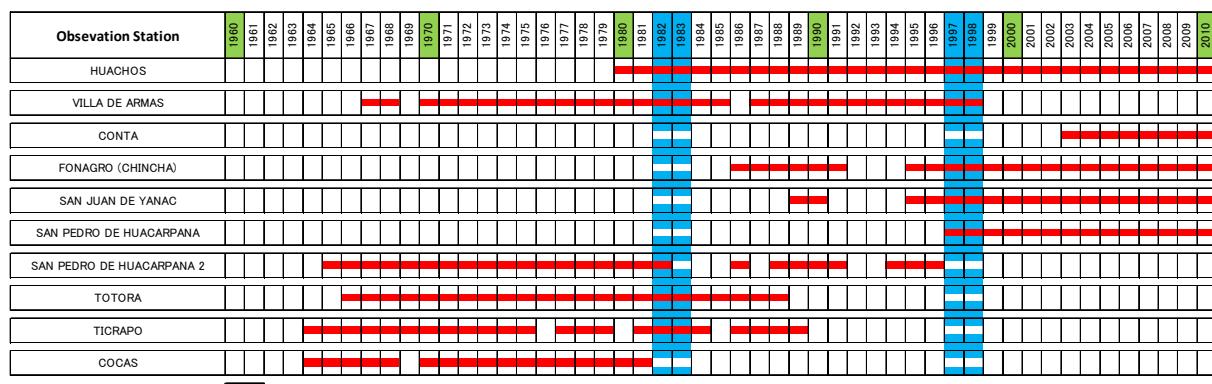
Table 2.14 Rainfall Observation Station (Chincha river)

NOMBRE DE ESTACION	CODIGO ESTACION	Cuenca	Tipo Estac.	Inicio Func.	Años de Observ.	UBICACION POLITICA			UBIC. GEOGRAFICA			Instituc.	Observacion
						Dpto	Prov	Dist	Lat	Long	Alt		
CONTA	203501	San Juan	H-Lm	1922	80	Ica	Chincha	Chincha Alta	13°27'	75°58'	320	JUNTA USUARIOS	OPERATIVA
FONAGRO	130791	San Juan	MAP	1986	17	Ica	Chincha	Chincha Baja	13°28'	76°08'	50	SENAMHI	OPERATIVA
SAN JUAN DE CASTROVIRREYNA	156114	San Juan	PLU	1966	37	Huancavelica	Castrovirreyna	San Juan	13°12'	75°38'	2150	SENAMHI	OPERATIVA
SAN JUAN DE YANAC	156113	San Juan	PLU	1964	37	Ica	Chincha	Chavín	13°13'	75°47'	2400	SENAMHI	OPERATIVA
HUACHOS	151503	San Juan	PLU	1980	23	Huancavelica	Castrovirreyna	Huachos	13°14'	75°32'	2680	SENAMHI	OPERATIVA
VILLA DE ARMAS	110641	San Juan	CO	1964	27	Huancavelica	Castrovirreyna	Arma	13°08'	75°32'	3600	SENAMHI	OPERATIVA
SAN PEDRO DE HUACARPANA	156115	San Juan	CO	1964	34	Ica	Chincha	S.P.Huacarpana	13°03'	75°39'	3680	SENAMHI	OPERATIVA
LAGUNA HUICHINGA	110632	San Juan	PLU	1980	18	Huancavelica	Castrovirreyna	Aurahua	13°02"	75°34"	3480	SENAMHI	PARALIZADA
TANTARA	110633	San Juan	PLU	1980	18	Huancavelica	Castrovirreyna	Tantará	13°14"	75°37"	2690	SENAMHI	PARALIZADA
CHUNCHO	110631	Mantaro	PLU	1945	23	Lima	Yauyos	Tupe	12°45'	75°31'	4695	IRRIG-SAN JNUAN	PARALIZADA
BERNALES	110650	Pisco	CO	1964	39	Ica	Pisco	Humay	13°45'	75°57'	250	SENAMHI	OPERATIVA
HUANCANO	110639	Pisco	CO	1964	39	Ica	Pisco	Huancano	13°36'	75°37'	1006	SENAMHI	OPERATIVA
TICRAPO	110643	Pisco	PLU	1964	39	Huancavelica	Castrovirreyna	Ticrapo	13°23'	75°26'	2174	SENAMHI	PARALIZADA
TOTORA	110644	Pisco	PLU	1964	39	Huancavelica	Castrovirreyna	Totorap	13°08'	75°19'	3900	SENAMHI	PARALIZADA

H-lm: Aforo automático MAP: Monitoreo meteorológico para la agricultura

PLU: Monitoreo pluviométrico CO: Monitoreo meteorológico

Table 2.15 Observation Period of Rainfall Data (Chincha river)



: year of El Niño

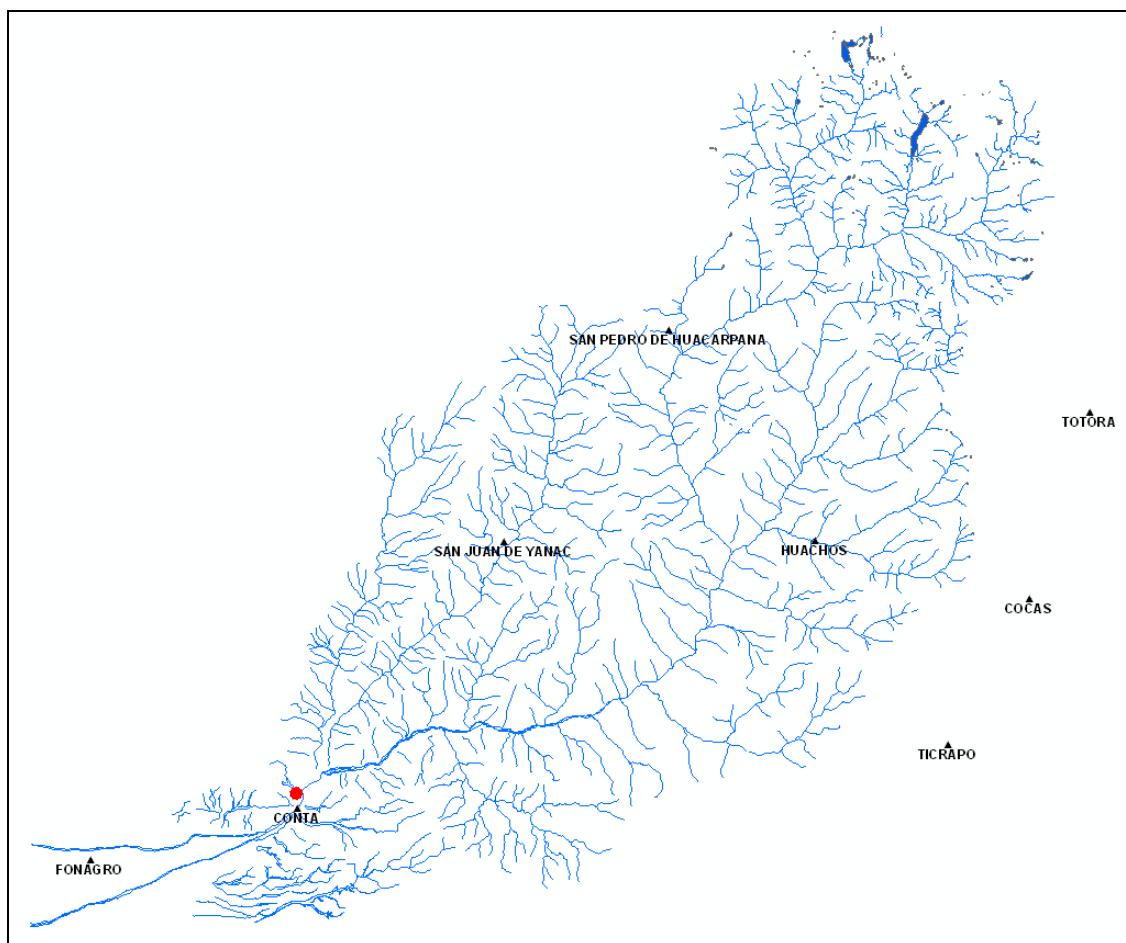


Figure 2.15 Location of Rainfall and Discharge Observation Station (Chincha river)

(2) Monthly Rainfall

The average monthly rainfall and its distribution of each station in Chincha basin are as shown in **Table 2.16** and the **Figure 2.16**.

According to the Table and the Figure, the monthly rainfall is large from October to April and extremely small from May to September. And the yearly rainfall varies from 6.95mm in Conta to 625.95mm in Totora .

Table 2.16 Average Monthly Rainfall in Chincha Basin and Adjacent Basin (mm)

Observation Station	Month												Total
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	
TOTORA	125.39	133.76	104.56	46.33	18.20	4.07	4.90	7.76	24.24	32.59	41.47	81.67	624.95
TICRAPO	54.24	75.45	73.35	14.10	0.44	0.20	0.03	0.45	0.98	3.99	5.05	24.32	252.60
COCAS	94.93	111.50	138.93	29.87	5.31	0.26	0.36	1.54	6.70	11.83	16.61	40.73	458.57
SAN PEDRO DE HUACARPANA 2	114.93	137.80	161.96	50.64	5.30	0.38	0.23	2.25	5.51	17.68	30.93	58.94	586.56

SAN PEDRO DE HUACARPANA	121.19	136.68	139.80	34.99	2.64	0.00	0.04	2.53	7.24	12.94	27.45	64.52	550.02
CHINCHA DE YANAC	27.03	37.28	39.98	6.97	0.27	0.00	0.10	0.02	0.76	2.81	2.11	14.08	131.41
FONAGRO (CHINCHA)	0.42	1.08	0.34	0.07	0.48	1.23	1.34	0.83	0.68	0.38	0.21	0.56	7.60
CONTA	1.84	3.24	0.81	0.31	0.01	0.03	0.06	0.04	0.05	0.18	0.14	0.24	6.95
VILLA DE ARMAS	133.69	136.26	148.26	39.55	2.82	0.00	0.01	1.57	8.52	10.84	22.17	59.92	563.61
HUACHOS	98.45	120.27	119.57	29.42	1.90	0.23	0.25	1.01	1.73	6.74	15.33	57.08	451.98

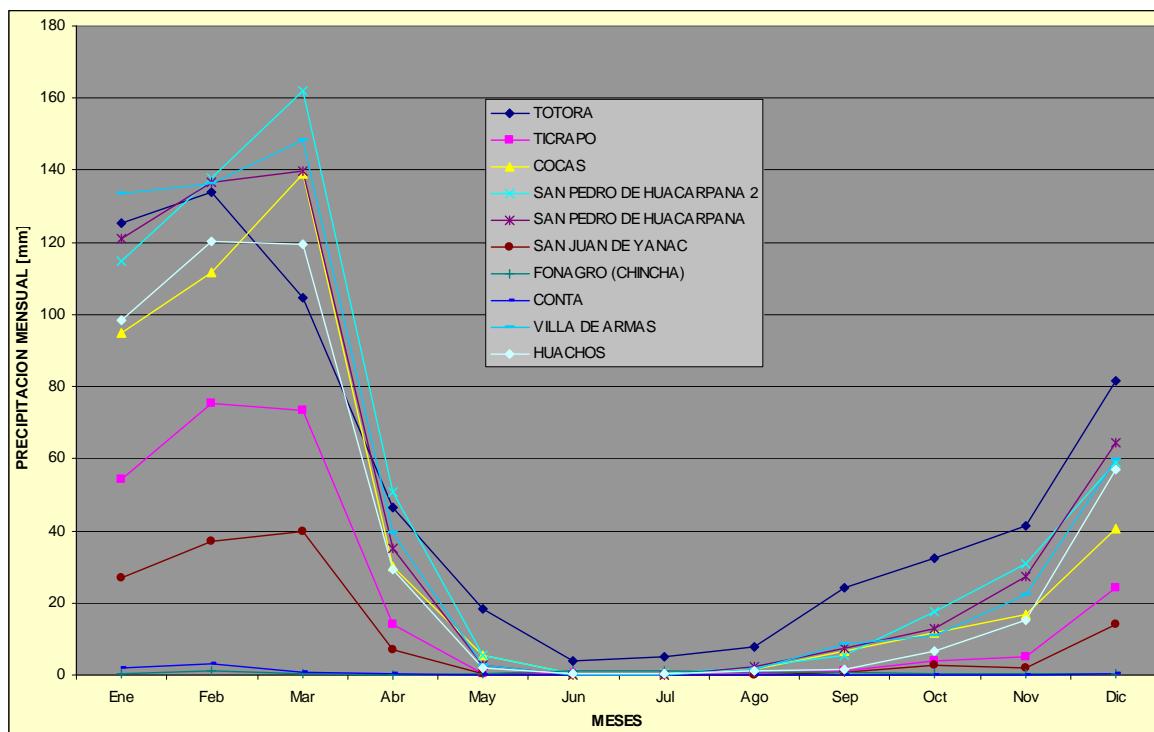


Figure 2.16 Distribution of Average Monthly Rainfall in Chincha Basin and Adjacent Basin (mm)

(3) Yearly Maximum of 24-hour Rainfall

The yearly maximum of 24-hour rainfall (daily rainfall) of each observation station in Chincha basin is as shown in the **Table 2.17**.

Table 2.17 Yearly Maximum of 24-hour Rainfall (Daily Rainfall) in Chincha Basin (mm)

Year	TOTORA	TICRAPO	COCAS	SAN PEDRO DE HUACARPANA 2	SAN PEDRO DE HUACARPANA	SAN JUAN DE YANAC	FONAGRO (CHINCHA)	CONTA	VILLA DE ARMAS	HUACHOS
1964		21.5	19.8							
1965	24.0	20.7	21.6	15.0						
1966	15.0	12.6	20.2	5.2						
1967	24.0	24.4	36.0	31.0						59.6
1968	20.0	10.0		16.0						
1969	22.0	35.8		24.5						
1970	23.0	40.2	22.1	24.5						24.9
1971	21.0	28.4	29.4	20.0						31.0
1972	27.0	32.0	30.8	26.0		12.8				29.6
1973	25.0	44.3	36.8	21.1						42.4
1974	22.0	14.0	20.6	14.5		8.2				36.0
1975	19.0	19.5	22.4	22.5		10.3				35.8
1976	20.0	25.5	21.4	17.0						38.0
1977	25.0	24.0	20.6	15.0						36.2
1978	20.0	5.4	14.4	26.0						61.8
1979	25.0	18.0	27.4	32.0						27.4
1980	35.0	24.1		19.5						43.0
1981	29.0	33.0	0.0	32.0						35.2
1982	29.0	10.9		18.0						30.0
1983	24.0	30.0								11.8
1984	37.0	20.8								11.8
1985	30.0	18.0								20.8
1986	27.0	26.8		24.0			0.3			20.0
1987	13.0						0.2			19.0
1988	25.0			32.0			0.7			20.0
1989				27.0		6.8	3.0			10.8
1990				24.0		5.5	2.0			20.0
1991				33.0						28.0
1992										
1993				23.0						26.0
1994				30.0						21.4
1995				25.0		10.3	2.3			28.4
1996						0.4	0.9			48.6
1997					23.6	2.5	0.8			25.4
1998					25.0	11.3	1.5			38.5
1999					28.0	15.9	6.0			41.6
2000					24.2	14.0	1.5			20.5
2001					24.2	9.7	1.1			23.8
2002					30.0	14.6	1.1			37.0
2003					20.6	9.5	0.5	0.6		15.2
2004					28.7	7.2	1.2	0.4		44.2
2005					16.0	16.5	0.9	1.0		28.6
2006					27.8	37.4	3.2	6.0		25.6
2007					16.0	14.2	1.0	4.0		20.5
2008					22.6	14.7	1.9	0.8		23.8
2009					16.4	15.9	2.2	0.3		
2010						23.8				

(4) Isohyetal Map of Yearly Average Rainfall

The isohyetal map of yearly average rainfall in Chincha basin is as shown in the **Figure 2.17**.

There is big difference in the yearly rainfall data by areas in Chincha basin, for instance yearly rainfall is less than 25mm in the minimum, on the other hand 900 mm in the maximum, and the amount is small in the downstream area and becomes large toward the upstream with higher elevation.

In the objective section for flood protection, the yearly rainfall is almost nil, only 25mm.

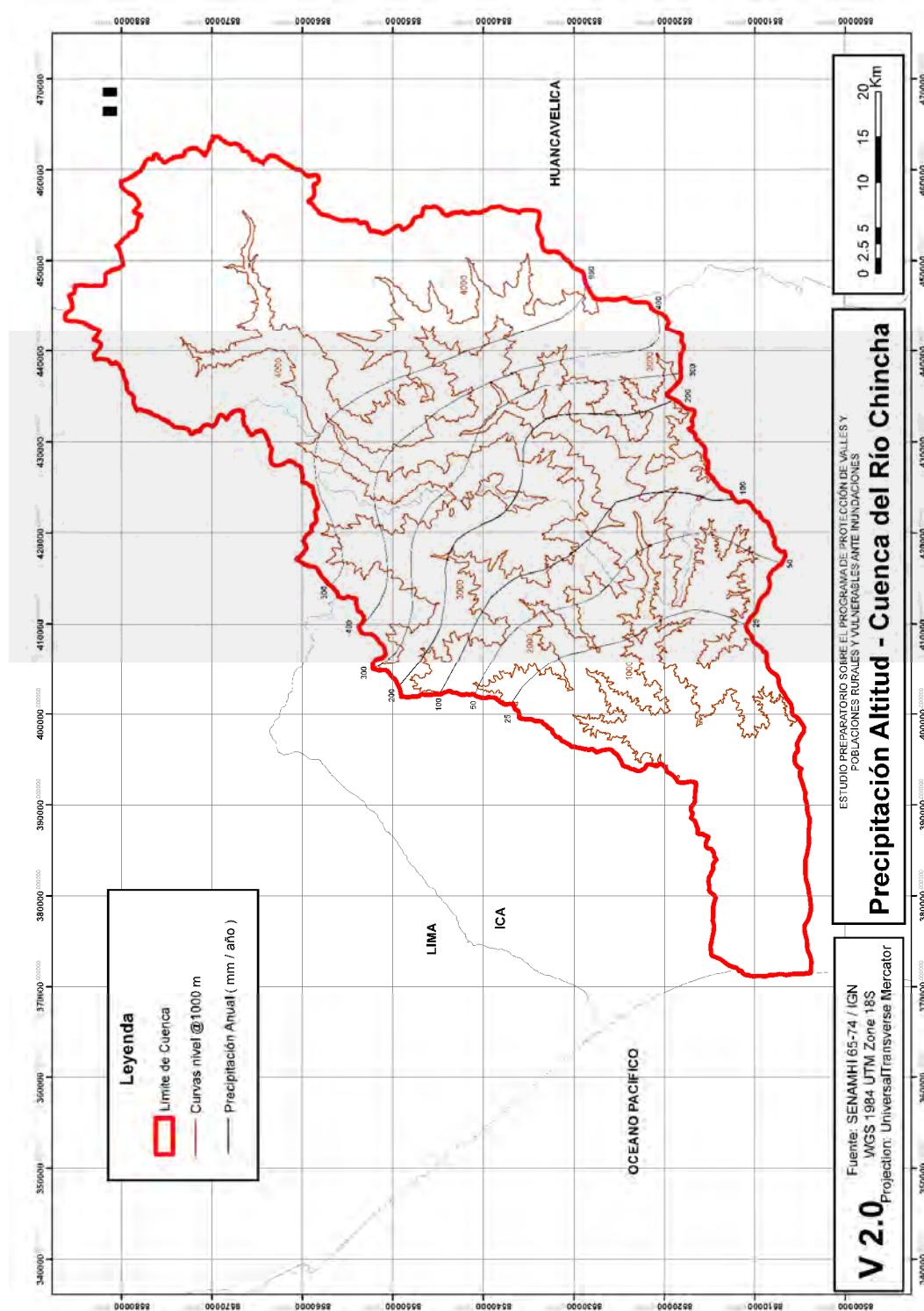


Figure 2.17 Isohyetal Map of Yearly Rainfall (Chincha Basin)

2.2.4 Pisco River

(1) Conditions of Rainfall Observation

The rainfall observation stations and their observation period in Pisco basin are as shown in the **Table 2.18 – Table 2.19** and the **Figure 2.18**.

In Pisco basin, the rainfall has been observed in 20 stations, and the longest observation period is 39 years from 1964 to 2002.

Table 2.18 Rainfall Observation Station (Pisco river)

STATIONS	DEPARTMENT	LONGITUD	LATITUD	IN-CHARGE
観測所	県	経度	緯度	担当機関
ACNOCOCHA	HUANCAVELICA	75° 05'1	13° 13'1	SENAMHI
CHOCLOCOCHA	HUANCAVELICA	75° 02'1	13° 06'1	SENAMHI
COCAS	HUANCAVELICA	75° 22'1	13° 16'1	SENAMHI
CUSICANCHA	HUANCAVELICA	75° 18'18	13° 29'29	SENAMHI
PARIONA	HUANCAVELICA	75° 04'1	13° 32'1	SENAMHI
SAN JUAN DE CASTROVIRREYNA	HUANCAVELICA	75° 38'38	13° 12'12	SENAMHI
TAMBO	HUANCAVELICA	75° 16'16	13° 41'41	SENAMHI
TICRAPO	HUANCAVELICA	75° 26'1	13° 23'1	SENAMHI
TOTORA	HUANCAVELICA	75° 19'1	13° 07'1	SENAMHI
TUNEL CERO	HUANCAVELICA	75° 05'5	13° 15'15	SENAMHI
HACIENDA BERNALES	ICA	75° 57'57	13° 45'45	SENAMHI
HUAMANI	ICA	75° 35'35	13° 50'50	SENAMHI

Table 2.19 Observation Period of Rainfall Data (Pisco river)

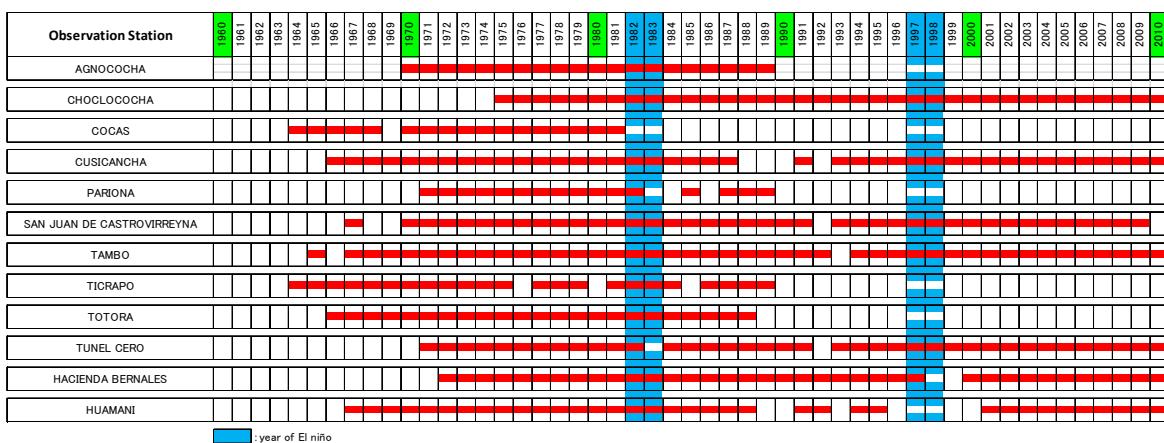




Figure 2.18 Location of Rainfall and Discharge Observation Station (Pisco river)

(2) Monthly Rainfall

The average monthly rainfall and its distribution of each station in Pisco basin are as shown in **Table 2.20** and the **Figure 2.19**.

According to the Table and the Figure, the monthly rainfall is large from October to April and extremely small from May to September. And the yearly rainfall varies from 2.93mm in Hacienda Bernales to 884mm in Choclococha .

Table 2.20 Average Monthly Rainfall in Chincha Basin and Adjacent Basin (mm)

Observation Station	Month												Total
	Jan.	Feb	Mar	Apr	May	June	Juyl	Aug.	Sep	Oct	Nov	Dec	
ACNOCOCHA	139.08	145.04	129.35	56.57	17.74	8.18	5.65	13.73	21.69	40.59	52.30	83.59	713.51
CHOCLOCOCHA	147.66	161.73	156.09	80.13	26.52	14.25	8.03	22.18	35.24	59.48	68.69	103.97	883.97
COCAS	94.93	111.50	138.93	29.87	5.31	0.26	0.36	1.54	6.70	11.83	15.36	40.73	457.31
CUSICANCHA	74.40	88.26	104.57	33.77	1.74	0.00	0.01	0.71	3.48	4.85	12.38	36.37	360.55
PARIONA	161.82	155.42	174.45	68.15	13.61	3.06	3.12	4.02	16.39	32.52	54.23	90.91	777.70
SAN JUAN DE CASTROVIRREYNA	49.69	54.27	46.95	8.78	0.96	0.09	0.17	0.67	0.95	3.50	7.06	19.24	192.34
TAMBO	82.19	120.28	130.42	32.03	3.95	0.00	0.12	0.51	0.88	9.53	11.48	40.40	431.78

TICRAPO	54.24	75.45	73.35	14.10	0.44	0.20	0.03	0.45	0.98	3.99	5.05	24.32	252.60
TOTORA	125.39	133.76	104.56	46.33	18.20	4.07	4.90	7.76	24.24	32.59	41.47	81.67	624.95
TUNEL CERO	163.61	162.53	150.68	72.29	20.96	7.59	6.98	14.51	29.20	56.12	72.29	121.55	878.32
HACIENDA BERNALES	0.84	1.50	0.05	0.03	0.07	0.14	0.08	0.08	0.02	0.01	0.03	0.09	2.93
HUAMANI	3.08	3.75	3.45	0.05	0.00	0.00	0.01	0.00	0.08	0.00	0.00	0.17	10.60

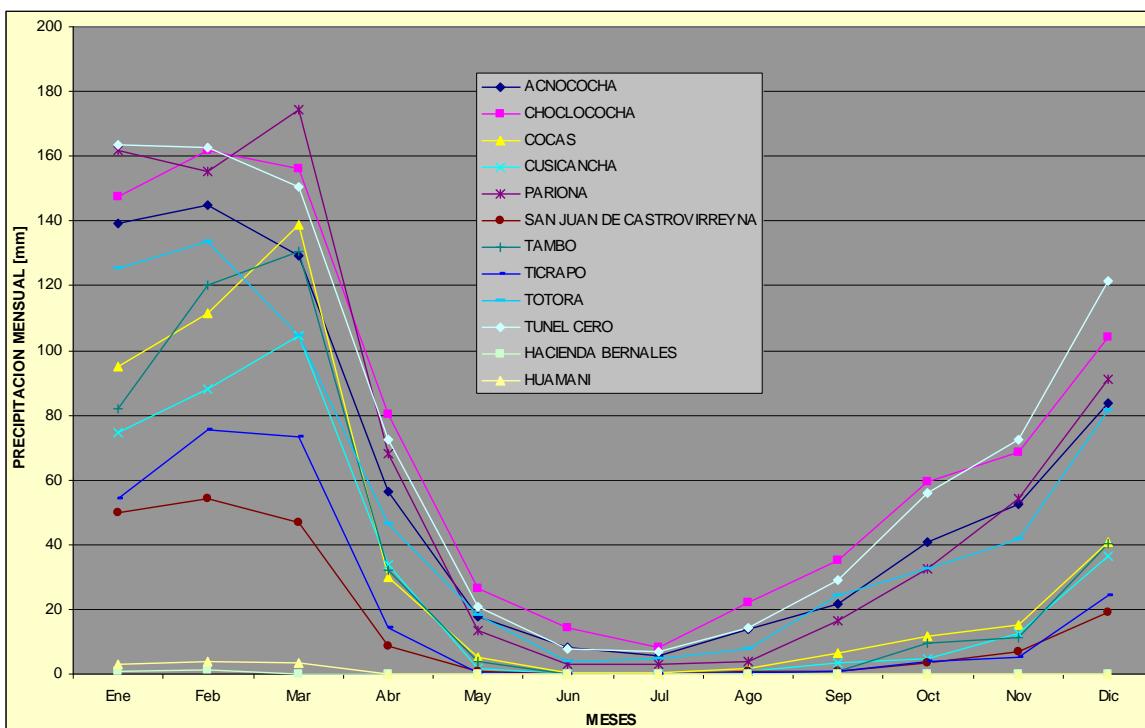


Figure 2.19 Distribution of Average Monthly Rainfall in Pisco Basin and Adjacent Basin (mm)

(3) Yearly Maximum of 24-hour Rainfall

The yearly maximum of 24-hour rainfall (daily rainfall) of each observation station in Pisco basin is as shown in the **Table 2.21**.

Table 2.21 Yearly Maximum of 24-hour Rainfall (Daily Rainfall) in Pisco Basin (mm)

Year	ACNOCOC HA	CHOCLOC OCHA	COCAS	CUSICANC HA	PARIONA	SAN JUAN DE CASTROVI RREYNA	TAMBO	TICRAPO	TOTORA	TUNEL CERO	HACIENDA BERNALES	HUAMANI
1964			19.8					21.5				
1965			21.6				35.0	20.7				
1966			20.2	18.7				12.6	15.0			
1967			36.0	23.5		20.1		24.4	24.0			25.5
1968				12.3			24.0	10.0	20.0			0.0
1969				23.0				35.8	22.0			1.6
1970			22.1	25.3		33.3	13.3	40.2	23.0			33.5
1971	32.3		29.4	28.6		13.7	18.2	28.4	21.0	30.7		1.7
1972	29.2		30.8	26.9	40.0	28.0	30.7	32.0	27.0	28.2	29.5	18.8
1973	24.6		36.8	13.1	37.8	23.0			25.0	34.6	1.6	2.1
1974	31.1		20.6	9.7	36.9	12.1	21.0	14.0	22.0	24.2	0.0	4.1
1975	24.1	27.4	22.4	6.6	39.1	17.0	42.4	19.5	19.0	29.2	0.0	23.0
1976	26.4	36.1	21.4	6.6	34.4	17.2	40.0		20.0	22.8	20.8	12.5
1977	26.9		20.6	24.2	29.7	15.5	20.5	24.0	25.0	31.3	0.0	0.0
1978	28.1	22.9	14.4	20.0	20.6	7.8	32.0	5.4	20.0	19.5	0.6	0.0
1979	22.3	15.4	27.4		25.4	21.6	20.4	18.0	25.0	33.2	0.0	0.2
1980	23.0	14.8		19.0	44.4	40.0	21.2		35.0	27.3	0.0	0.3
1981	22.6	13.5	0.0	20.0	28.5		25.6	33.0	29.0	35.9		0.0
1982	32.1			10.1		17.1	15.7	10.9	29.0	52.2		0.0
1983	30.1	26.5		5.0		28.0	35.0	30.0	24.0		0.0	0.0
1984	28.7			20.0		24.0	40.0	20.8	37.0	38.3	0.0	0.4
1985	26.5	19.0		11.0	26.5	11.5	30.0	18.0	30.0	22.7	0.0	7.5
1986	29.2	36.0				14.7	30.0		27.0	35.3	0.0	
1987	22.4	24.4			14.8	12.3	20.0		13.0	23.1	0.0	0.0
1988	26.9	39.1			28.0	13.5	17.0			27.8	0.0	
1989	20.3					31.8	36.7			31.9	0.0	0.0
1990						13.1	29.0			54.5	0.0	
1991						11.0	40.0				0.0	0.0
1992												
1993	39.3					13.7				36.5	0.0	
1994	37.3					12.3	22.0			30.5	0.0	
1995	28.1					12.0	43.2			26.2	0.0	
1996	35.9					19.2	42.0			27.3	0.0	
1997	67.5					10.5	30.0			21.6	0.0	
1998	55.5					37.9	40.0			25.1	0.0	
1999	34.4					25.0	23.0			26.1	0.5	
2000	38.0					18.8	26.0				0.3	2.5
2001	29.3					23.2	16.0			29.6	1.3	2.2
2002	30.7					19.5				23.7	0.5	3.1
2003	57.7					10.5	22.0			27.4	0.0	2.7
2004	45.0					10.3	16.0			28.7	0.4	0.0
2005	36.1					16.1	27.0			47.8	4.6	13.0
2006	36.7					21.4	38.0			25.0	3.2	4.2
2007						18.4	16.5			35.8		0.0
2008	24.6					14.5	26.0			28.6	5.1	6.2
2009	58.4					17.2	38.0			36.2	1.3	8.3
2010												

(4) Isohyetal Map of Yearly Average Rainfall

The isohyetal map of yearly average rainfall in Pisco basin is as shown in the **Figure 2.20**.

There is big difference in the yearly rainfall data by areas in Pisco basin, for instance yearly rainfall is less than 25 mm in the minimum, on the other hand 750mm in the maximum, and the amount is small in the downstream area and becomes large toward the upstream with higher elevation.

In the objective section for flood protection, the yearly rainfall is not so much from 25~50mm.

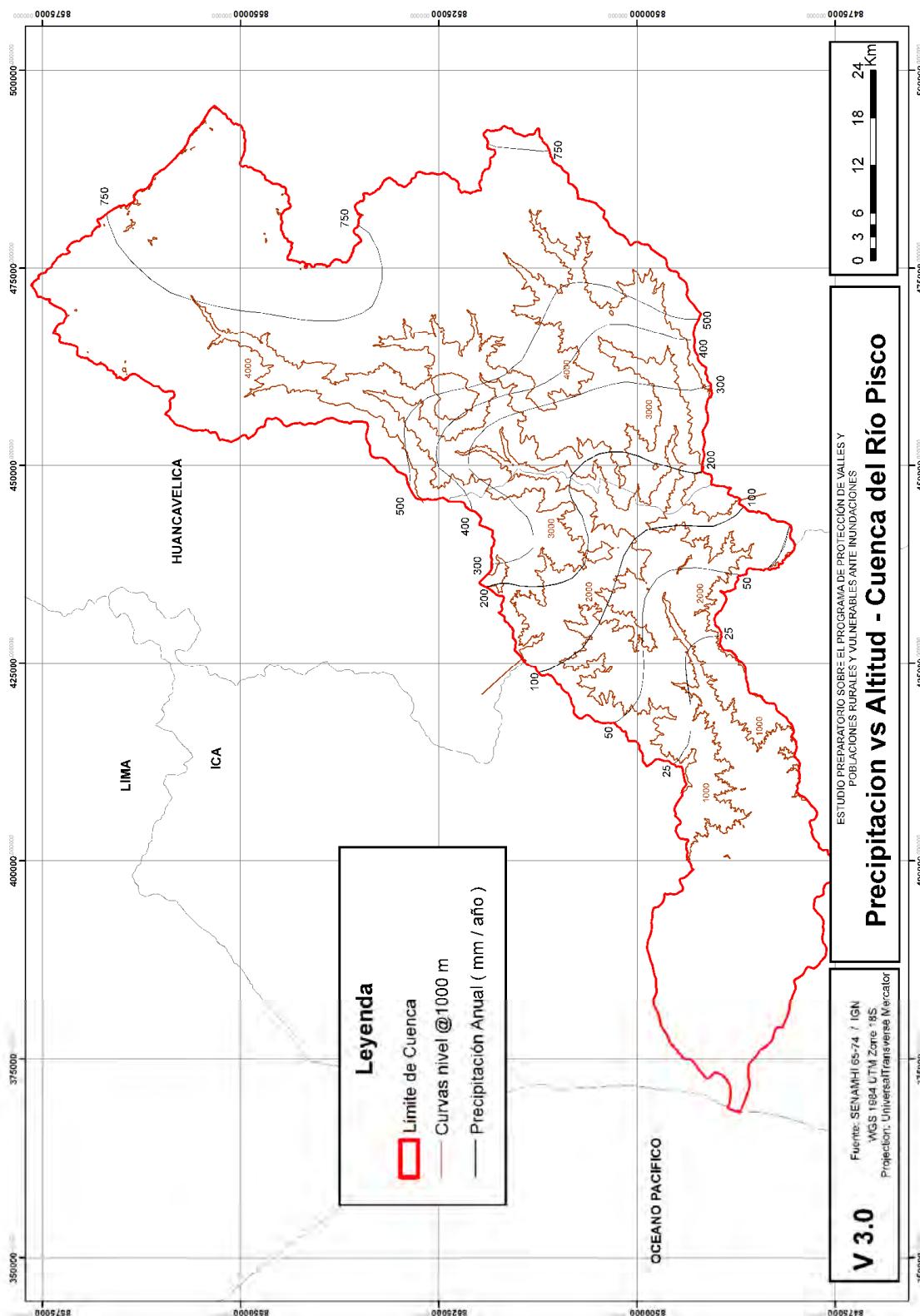


Figure 2.20 Isohyetal Map of Yearly Rainfall (Pisco Basin)

2.2.5 Yauca River

(1) Conditions of Rainfall Observation

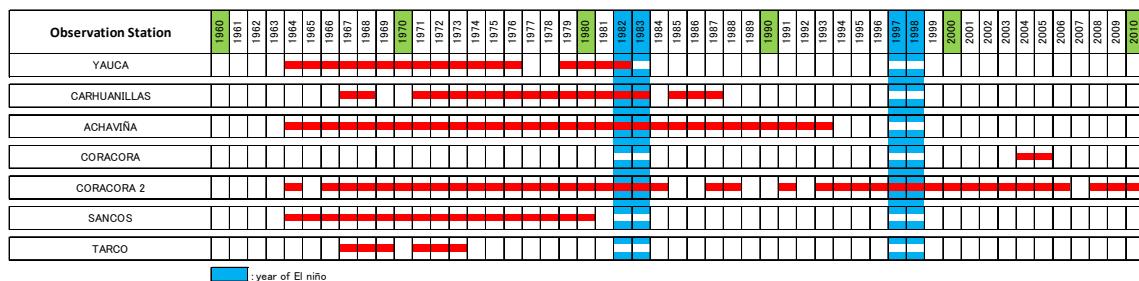
The rainfall observation stations and their observation period in Yauca basin are as shown in the **Table 2.22 – Table 2.23** and the **Figure 2.21**.

In Yauca basin, the rainfall has been observed in 7 stations, and the longest observation period is 47 years from 1964 to 2010.

Table 2.22 Rainfall Observation Station (Yauca river)

Station	Code	Longitud	Latitud	Height	Institution	Monitored Period
YAUCA	00743	74° 31'1	15° 40'1		SENAMHI	1964-1976, 1979-1982
CARHUANILLAS	157220	73° 44'1	15° 08'1	3,000	SENAMHI	1967-1968, 1971-1987
CHAVIÑA	000742	73° 50'1	14° 59'1	3,310	SENAMHI	1964-1982
CORA CORA	000743	73° 47'47	15° 01'1	3,172	SENAMHI	1964, 1966-1984, 1987-1988, 1991, 1993-2010
SANCOS	000740	73° 57'1	15° 04'1	2,800	SENAMHI	1964-1980
TARCO	157216	73° 45'1	15° 18'1	3,300	SENAMHI	1967-1969, 1971-1973

Table 2.23 Observation Period of Rainfall Data (Yauca river)



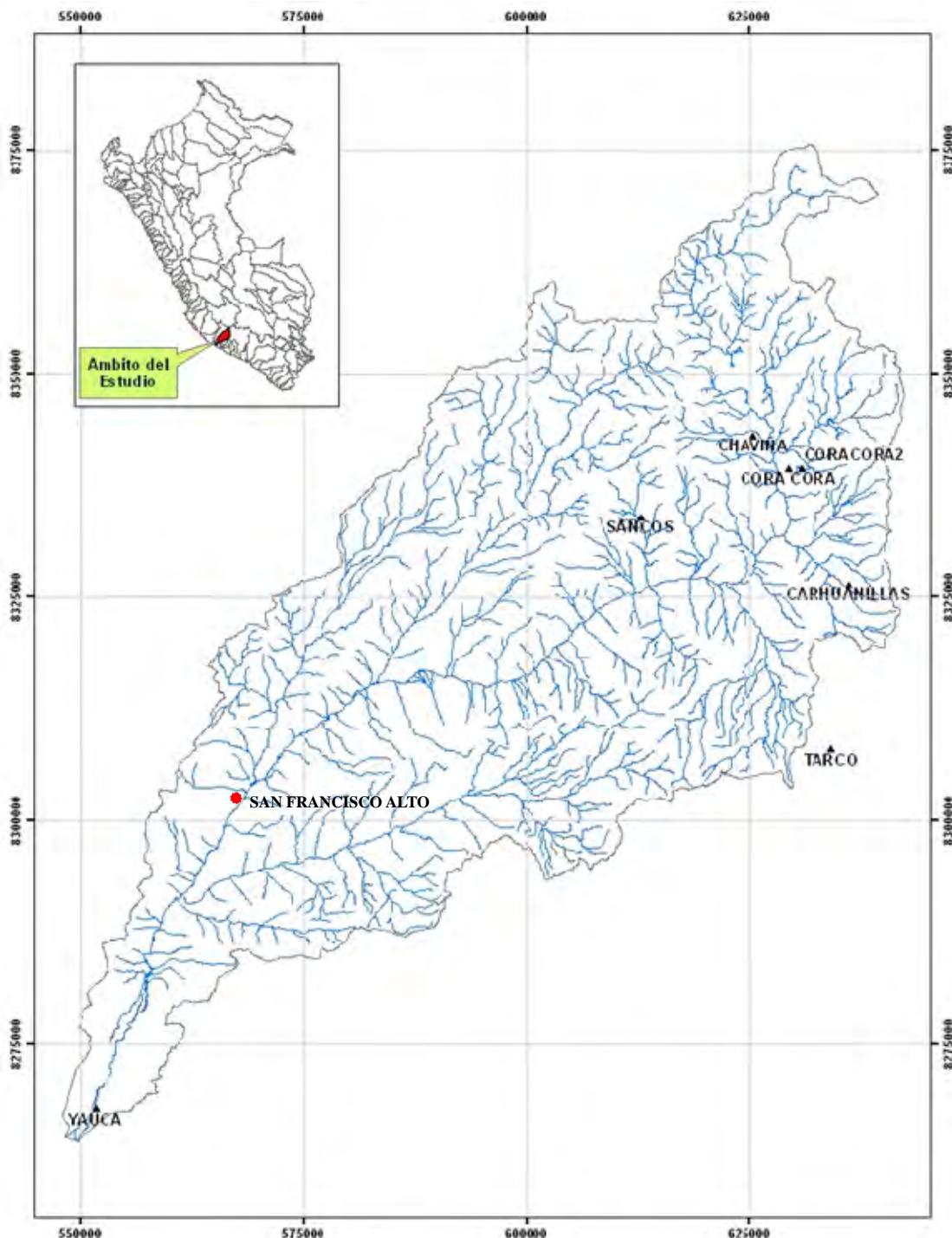


Figure 2.21 Location of Rainfall and Discharge Observation Station (Yauca river)

(2) Monthly Rainfall

The average monthly rainfall and its distribution of each station in Yauca basin are as shown in **Table 2.24** and the **Figure 2.22**. The observation data of Coracora station is so much different with the that of adjacent stations that the this data is excluded from the Study.

According to the Table and the Figure, the monthly rainfall is large from November to April and extremely small from May to September. And the yearly rainfall varies from 0.0 mm in Yauca to 540.54mm in Chaviña.

Table 2.24 Average Monthly Rainfall in Yauca Basin and Adjacent Basin (mm)

Observation Station	Month												Total
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	
TARCO	116.76	85.09	121.13	26.66	0.00	0.00	0.00	0.00	1.36	7.07	15.80	29.27	403.13
SANCOS	131.88	133.65	105.28	4.96	0.39	0.00	0.41	0.00	0.63	2.38	1.72	10.46	391.75
CORACORA2	102.06	118.34	104.25	19.40	2.08	1.09	1.76	2.54	6.13	7.09	10.78	34.86	410.36
CORA CORA	176.24	163.85	301.90	155.00	216.45	234.55	137.45	68.05	127.76	199.38	274.25	188.46	2,243.33
CHAVIÑA	115.10	142.42	161.44	32.21	5.12	0.87	0.93	3.86	10.45	11.79	10.76	45.59	540.54
CARHUANILLAS	116.28	150.78	145.02	37.01	1.26	0.00	0.64	2.03	3.57	9.73	13.91	32.15	512.38
YAUCA	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

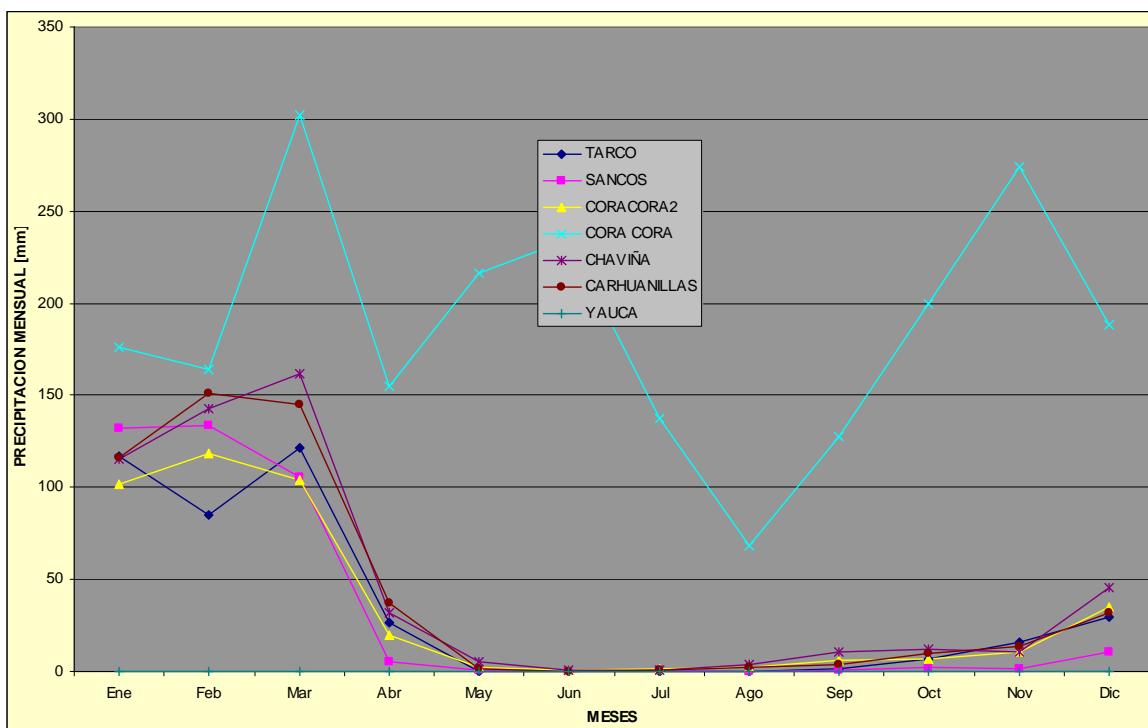


Figure 2.22 Distribution of Average Monthly Rainfall in Yauca Basin and Adjacent Basin (mm)

(3) Yearly Maximum of 24-hour Rainfall

The yearly maximum of 24-hour rainfall (daily rainfall) of each observation station in Yauca basin is as shown in the **Table 2.25**.

Table 2.25 Yearly Maximum of 24-hour Rainfall (Daily Rainfall) in Yauca Basin (mm)

Year	TARCO	SANCOS	CORACOR A2	CORA CORA	CHAVIÑA	CARHUANILLAS	YAUCA
1964		25.0			24.5		0.0
1965		25.2			26.5		0.0
1966			21.0		30.6		0.0
1967		53.4	35.7			45.0	0.0
1968	30.0	49.3	31.0			35.5	
1969	25.0	32.0	24.0		32.9		0.0
1970		40.1	28.5		29.7		0.0
1971	15.6	20.5	30.0		41.4	49.5	0.0
1972	10.9	57.5	27.0		57.3	32.0	0.0
1973		38.0	32.0		46.4	20.0	0.0
1974		28.0	30.0		34.0	30.0	
1975		61.9	28.0		30.9	53.0	0.0
1976		44.8			44.4	37.0	0.0
1977		45.2	36.5		20.0	32.0	
1978		33.0	15.4			79.5	
1979		13.8	20.8		22.8	13.1	0.0
1980			21.7		29.7	23.0	
1981			27.4		34.0	30.5	0.0
1982			25.4			12.1	
1983			13.5				
1984							
1985						15.1	
1986						19.1	
1987			34.8				
1988							
1989							
1990							
1991			30.2				
1992							
1993			30.4				
1994			30.0				
1995			28.0				
1996							
1997			30.7				
1998							
1999							
2000			28.0				
2001			31.6				
2002			29.1				
2003			29.0				
2004							
2005				157.8			
2006				59.5			
2007							
2008							
2009							
2010							

(4) Isohyetal Map of Yearly Average Rainfall

The isohyetal map of yearly average rainfall in Yauca basin is as shown in the **Figure 2.23**.

There is big difference in the yearly rainfall data by areas in Yauca basin, for instance yearly rainfall is less than 25mm in the minimum, on the other hand 750mm in the maximum, and the amount is small in the downstream area and becomes large toward the upstream with higher elevation.

In the objective section for flood protection, the yearly rainfall is not so much from 25~50mm.

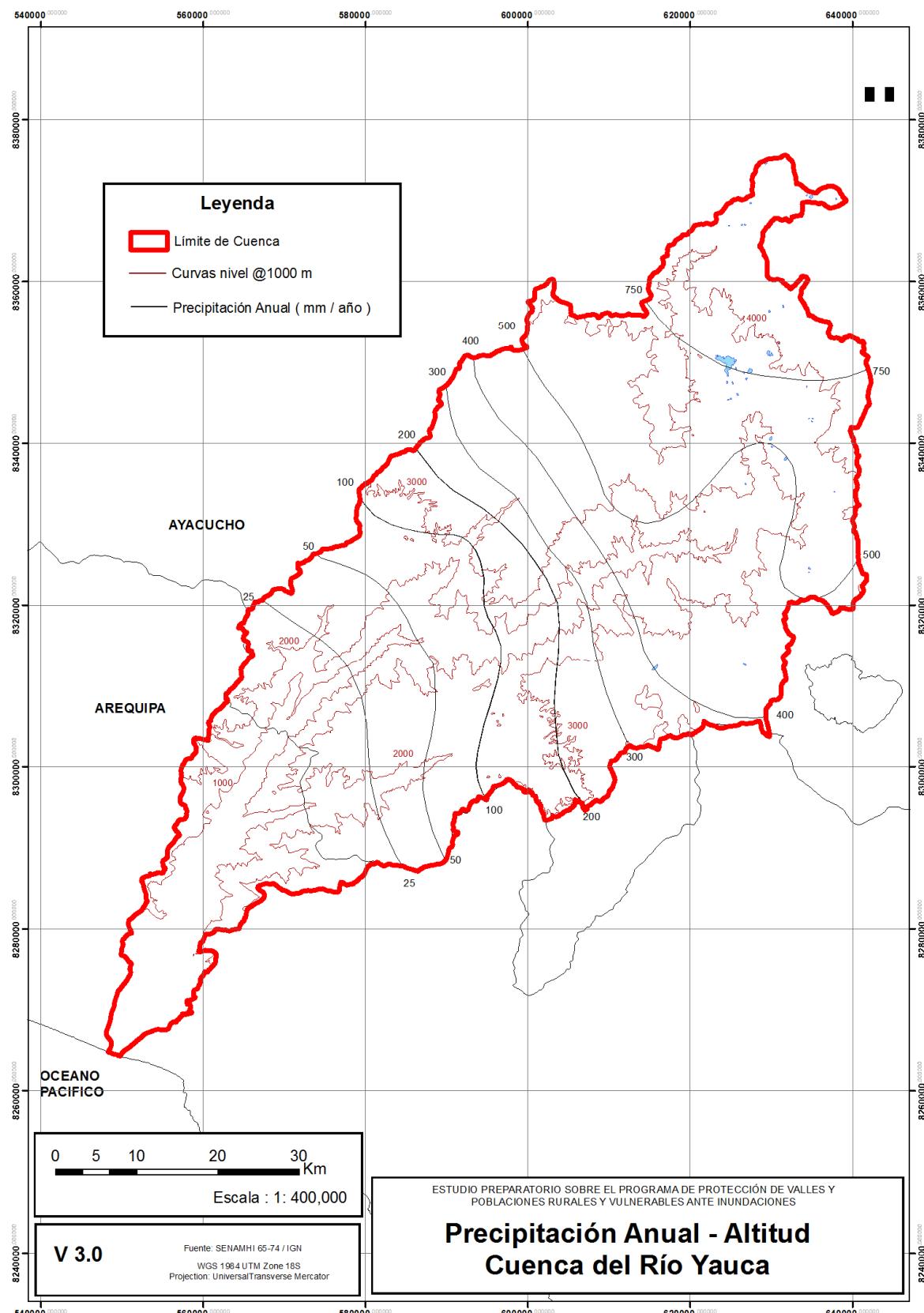


Figure 2.23 Isohyetal Map of Yearly Rainfall (Yauca Basin)

2.2.6 Majes-Camana River

(1) Conditions of Rainfall Observation

The rainfall observation stations and their observation period in Majes-Camana basin are as shown in the **Table 2.26 – Table 2.27** and the **Figure 2.24**.

In Majes-Camana basin, the rainfall has been observed in 48 stations, and the longest observation began from 1964. However some of station have no good quality of data such as lack of long period of observation, so that the 38 stations with good quality of data were selected suitable for run-off study. In the other hand, from the year 2011 Chivay station, located in the middle basin, began an automatic telemetric monitoring. The Study Team collected information from periods of precipitation in February 2011 and February 2012 (rainy season).

Table 2.26 Rainfall Observation Station (Majes-Camana river)

Weather station	Coordinates		
	Latitude	Longitude	Altitude (masl)
Andahua	15° 29'37	72° 20'57	3528
Aplao	16° 04'10	72° 29'26	645
Ayo	15° 40'45	72° 16'13	1956
Cabanaconde	15° 37'7	71° 58'7	3379
Camaná	16° 36'24	72° 41'49	15
Caravelí	15° 46'17	73° 21'42	1779
Chachas	15° 29'56	72° 16'2	3130
Chichas	15° 32'41	72° 54'59.7	2120
Chiguata	16° 24'1	71° 24'1	2943
Chinchayllapa	14° 55'1	72° 44'1	4497
Chivay	15° 38'17	71° 35'49	3661
Choco	15° 34'1	72° 07'1	3192
Chuquibamba	15° 50'17	72° 38'55	2832
Cotahuasi	15° 22'29	72° 53'28	5088
Crucero Alto	15° 46'1	70° 55'1	4470
El Frayle	16° 05'5	71° 11'14	4267
Huambo	15° 44'1	72° 06'1	3500
Imata	15° 50'12	71° 05'16	4445
La Angostura	15° 10'47	71° 38'58	4256
La Joya	16°35'33	71°55'9	1292
La Pampilla	16° 24'12.2	71° 31'.6	2400
Lagunillas	15° 46'46	70° 39'38	4250
Las Salinas	16° 19'5	71° 08'54	4322
Machahuay	15° 38'43	72° 30'8	3150
Madrigal	15° 36'59.7	71° 48'42	3262
Orcopampa	15° 15'39	72° 20'20	3801
Pampa de Arrieros	16° 03'48	71° 35'21	3715
Pampa de Majes	16° 19'40	72° 12'39	1434
Pampacolca	15° 42'51	72° 34'3	2950
Pampahuta	15° 29'1	70° 40'33.3	4320
Pillones	15° 58'44	71° 12'49	4455
Porpera	15° 21'1	71° 19'1	4152
Pullhuay	15° 09'1	72° 46'1	3113
Salamanca	15° 30'1	72° 50'1	3303
Sibayo	15° 29'8	71° 27'11	3827
Sumbay	15° 59'1	71° 22'1	4294
Tisco	15° 21'1	71° 27'1	4175
Yanaquihua	15° 46'59.8	72° 52'57	2815

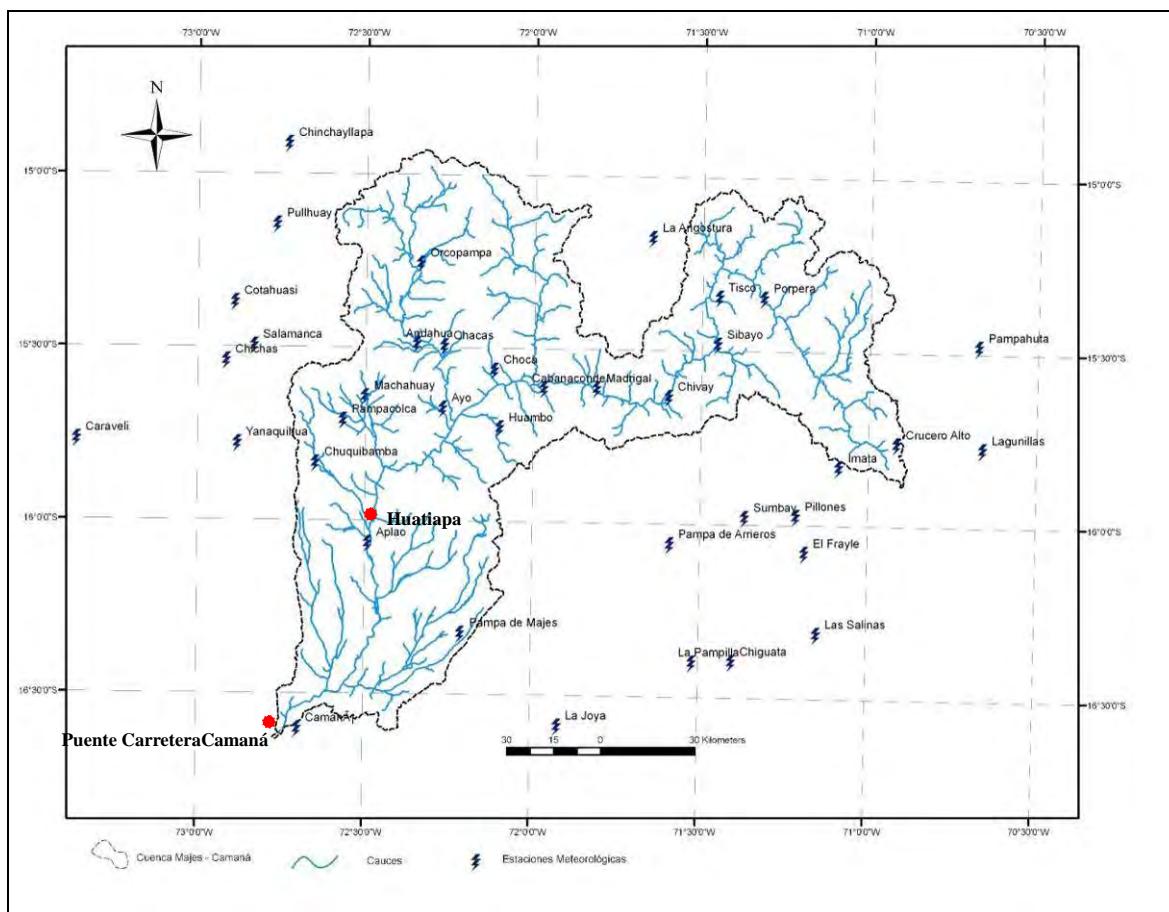


Figure 2.24 Location of Rainfall and Discharge Observation Station (Majes-Camana river)

(2) Monthly Rainfall

Among 48 rainfall observation stations in Majes-Camana basin and adjacent basin the rainfall data of 38 stations is used for analysis, excluding 10 stations due to short observation period less than 20 years, lack of recent 10 years data, far location from the objective basin.

The monthly rainfall data in TISCO with good quality of data is shown in the **Table 2.28** as an example.

Table 2.28 Monthly Rainfall in TISCO

TOTAL MONTHLY PRECIPITATION (mm)

BASIN Camaná - Majes	GAGE TISCO	DEPARTMENT AREQUIPA	LONGITUDE 71° 27'1	LATITUDE 15° 21'1
-------------------------	---------------	------------------------	-----------------------	----------------------

Year	Month												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1963											41.1	131.8	
1964	86.1	72.9	114.4	42.9	22.0	0.0	0.0	6.1	4.4	17.9	59.7	57.6	484.0
1965	75.0	161.1	85.9	42.5	0.3	0.0	9.2	0.0	24.0	22.0	10.4	151.7	582.1
1966	110.3	184.9	64.6	10.6	45.1	0.0	0.0	4.5	0.0	43.3	79.7	55.0	598.0
1967	103.8	161.0	220.2	64.5	13.1	0.6	8.2	9.4	41.8	23.6	12.7	90.5	749.4
1968	266.0	119.6	179.4	31.6	4.0	5.1	5.5	5.8	20.0	52.9	84.6	31.7	806.3
1969	150.1	113.0	52.5	0.0	0.0	0.0	0.0	0.0	0.0	4.0	60.8	97.7	478.0
1970	139.6	150.5	138.5	22.4	9.5	0.0	1.0	1.1	35.6	5.1	4.7	146.8	654.9
1971	140.0	183.5	101.2	30.1	2.6	0.9	0.0	0.0	0.0	5.0	2.2	132.7	598.2
1972	362.1	188.7	235.5	32.7	0.1	0.0	2.3	0.1	55.1	32.9	32.1	90.1	1031.7
1973	297.8	190.2	159.2	81.1	15.9	0.0	8.2	10.2	31.1	7.6	60.6	53.9	915.7
1974	290.2	172.9	44.7	80.7	1.5	14.5	0.0	111.1	9.3	4.3	7.5	50.2	786.8
1975	146.6	246.7	122.4	30.2	20.8	3.2	0.0	1.0	8.0	48.3	1.4	131.4	760.1
1976	153.0	107.7	166.8	41.6	9.3	7.5	4.6	2.3	58.9	0.5	0.6	71.9	624.7
1977	67.0	239.2	118.8	7.1	4.1	0.0	2.3	0.0	11.7	16.3	110.2	49.8	626.6
1978	317.6	24.1	78.7	68.9	0.0	4.0	0.0	1.0	2.3	26.9	78.6	60.0	662.2
1979	127.4	88.0	123.3	16.5	0.0	0.0	2.5	2.5	0.0	59.2	71.2	93.7	584.4
1980	72.5	43.1	183.6	2.2	0.0	0.0	13.5	25.9	28.1	94.1	2.1	30.2	495.3
1981	205.2	52.0	73.0	2.0	0.0	0.0	0.0	46.8	9.0	24.8	52.3	110.6	
1982	161.0	45.9	122.8	34.9	0.0	0.5	0.0	0.0	80.9	105.5	150.5	70.0	772.0
1983	46.7	93.7	81.0	47.9	12.0	0.5	0.5	0.0	35.2	18.0	2.5	32.4	370.5
1984	178.4	256.0	284.8	11.1	10.5	3.0	0.0	28.4	0.0	46.3	135.5	125.6	1079.6
1985	32.9	263.0	134.4	49.7	10.0	14.8	0.0	0.0	15.4	0.0	70.0	142.4	732.6
1986	105.9	162.7	178.9	98.4	12.5	0.0	2.8	52.2	18.1	11.0	11.0	149.6	803.1
1987	212.5	42.9	26.2	23.6	3.4	2.1	27.0	4.5	2.0	23.3	24.6	29.0	421.1
1988	216.9	72.5	97.0	63.5	8.5	0.0	0.0	4.0	6.8	0.0	4.0	30.2	503.4
1989	123.9	93.0	159.5	50.7	0.0	0.0	0.0	3.0	0.0	0.0	12.0	4.0	446.1
1990	118.4	27.6	58.5	25.6	12.5	39.5	0.0	13.0	5.0	52.5	0.0		
1991	150.6	72.7	162.3	10.7	3.5	30.7	3.0	1.6	3.5	29.2	48.6	0.0	516.4
1992	51.6	73.8	32.9	4.8	0.0	2.7	2.8	40.0	1.0	25.2	24.7	85.6	345.1
1993	230.9	82.4	133.9	49.9	6.2	1.3	0.3	25.1	15.5	34.2	63.7	106.1	749.5
1994	241.6	218.1	74.3	45.6	10.1	2.8	1.5	1.7	0.0	1.0	25.2	72.7	694.6
1995	121.5	135.0	215.7	27.8	3.7	0.1	0.0	2.8	8.6	13.1	22.3	122.0	672.7
1996	187.3	156.8	83.0	61.6	12.0	0.0	0.3	14.1	11.7	10.6	41.3	146.6	725.4
1997	175.0	201.8	86.5	31.7	18.1	0.0	0.0	33.1	64.8	14.0	60.1	102.2	787.3
1998	271.1	114.9	96.6	15.9	0.5	3.0	0.0	0.8	0.5	9.6	48.5	75.9	637.4
1999	199.2	273.9	198.2	30.5	6.0	0.1	1.2	0.6	23.5	75.3	10.7	90.3	909.5
2000	194.3	242.5	157.2	21.5	28.7	7.8	0.4	11.4	1.6	70.9	22.1	97.9	856.4
2001	240.3	239.0	144.2	108.9	31.3	5.4	16.5	12.0	8.4	18.7	8.6	35.9	869.0
2002	123.6	241.6	186.8	134.9	17.4	8.0	31.8	0.6	19.1	44.7	82.2	113.3	1004.1
2003	83.5	193.1	29.2	11.8	1.5	3.6	4.1	13.2	14.8			114.6	
2004	208.7	176.4	138.0	39.4	2.4	0.5	20.3	14.9	15.4	3.2	7.0	72.7	698.8
2005	124.4	207.0	127.5	56.9	0.5	0.0	0.1	0.7	23.2	11.6	18.8	103.4	674.1
2006	202.0	200.4	195.5	62.4	6.1	4.1	0.0	7.7	25.6	29.3	61.6	78.8	873.4
2007	187.0	179.7	180.4	38.4	9.1	0.1	9.7	0.8	16.1	13.7	22.9	96.2	753.8
2008	257.8	123.5	70.0	5.5	3.2	2.7	0.1	0.6	1.7	17.1	5.0	95.6	582.7
2009	104.6	203.6	133.3	65.6	2.8	0.0	11.1	2.4	23.9	9.9	47.9	64.6	669.7
2010	179.1	164.6	73.0	69.3	6.4	2.1	2.2	1.0	6.2	21.2	13.4	142.9	681.4
2011		233.8	96.9	104.8									
Pp Maxima	362.1	273.9	284.8	134.9	45.1	39.5	31.8	111.1	80.9	105.5	150.5	151.7	1079.6
Pp Media	166.8	153.2	128.4	43.7	8.5	3.6	4.1	10.8	16.7	25.8	38.7	85.9	687.9
Pp Minima	32.9	24.1	26.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	345.1

(3) Yearly Maximum of 24-hour Rainfall

The yearly maximum of 24-hour rainfall (daily rainfall) of each observation station in Majes-Camana basin is as shown in the **Table 2.29**.

(4) Isohyetal Map of Yearly Average Rainfall

The isohyetal map of yearly average rainfall in Majes-Camana basin is as shown in the **Figure 2.25**.

There is big difference in the yearly rainfall data by areas in Majes-Camana basin, for instance yearly rainfall is approximately 50mm in the minimum, on the other hand 750mm in the maximum, and the amount is small in the downstream area near the Pacific Oceans and becomes large toward the upstream with higher elevation.

In the objective section for flood protection, the yearly rainfall is not so much from 50~200mm.

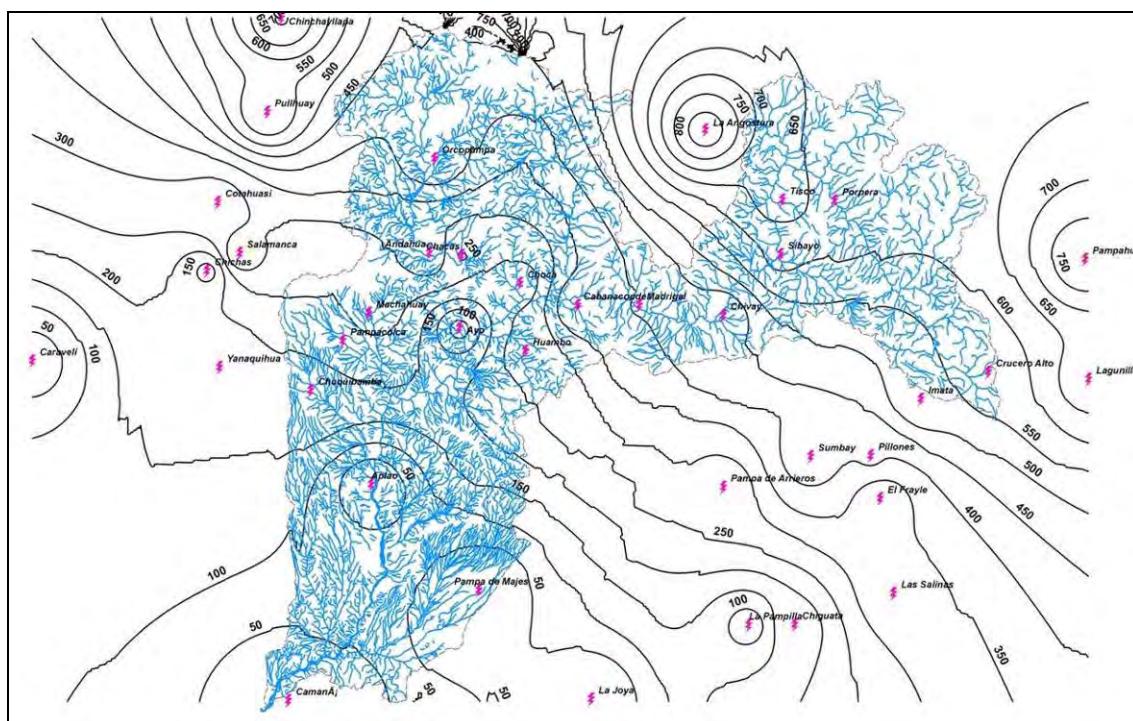


Figure 2.25 Isohyetal Map of Yearly Rainfall (Majes-Camana Basin)

(5) Storm duration

Information was collected on hourly rainfall of Chivay station located in the middle basin for the period February 2011 to February 2012. Using this information, a Depth-Duration Analysis was performed for 3 different periods of flood. Results are shown in **Figure 2.26**. Of the 3 cases of floods, the longest storm duration was measured in the period of February 2012 ($Q_p = 1.400$ m³/sec.) and the duration was 17 hours. Thus in the discharge analysis the used storm duration was 24 hours.

Furthermore, according to interviews with representatives of SENAMHI and Peruvian universities, on the Peruvian coast storm duration range is from 6 to 12 hours and for calculations for discharge

analysis the usually used storm duration is 24 hours. (Source: Estudio de Máximas Avenidas en las Cuencas de la Zona Centro de la Vertiente del Pacífico, Ministerio de Agricultura, Autoridad Nacional del Agua, Ing. Mg Sc. Ricardo Apaclla Nalvarte, 2010.)

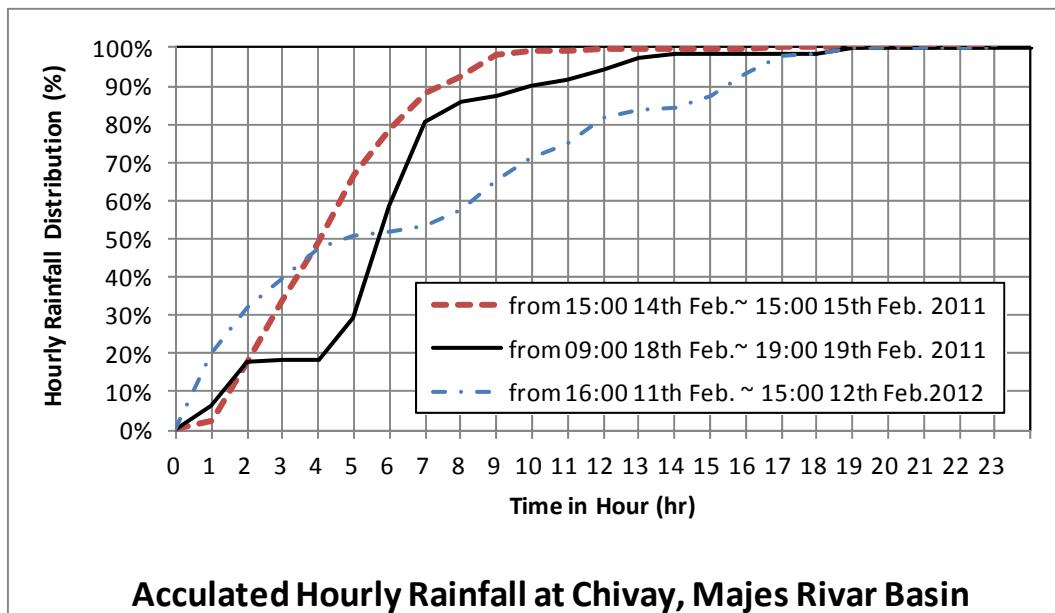


Figure 2.26 Storm Duration (Majes-Camana Basin)

2.3 Discharge

The discharge observation method is generally not automatic but manual at regular time of a day, once a day at 7 a.m. or twice a day at 7a.m. and 7p.m. for all of the stations in the study area so that there is no hourly data but only daily data (24 hour -discharge data). Consequently, there are no hourly rainfall data and all data are daily rainfall (24 hours). Being a fixed monitoring times, is not likely to have registered maximum instantaneous flows as flood peak flows.

The water level is observed by staff gauge, and the discharge is estimated applying the water level to the relation curve between the water level and discharge which is prepared beforehand by actual measurement of flow area and velocity.

However, from 2006 at the discharge gauging station at Huatiapa (Majes-Camana river) the water level measurements made by SENAMHI 4 times a day (7:00, 10:00, 14:00 and 18:00) using a limnigraphic ruler are compared to the water levels recorded by an automatic floater type monitoring system (starting in 2006). In times of flood the water level measurements are made every hour.

The rivers originate at high land connected with Andes Mountains and flow down through alluvial fan to the coast. The discharge observation stations are generally located at the middle stream or downstream of the alluvial fan (refer to the location map of rainfall observation stations). Since

there is hardly rainfall in the coastal area, the discharge will not enter from residual area of downstream basin so that the discharge observation shows the total discharge from the whole basin. Therefore it is desirable to select the reference point for run-off analysis at such observation station.

On the other hand, although the Huatiapa gauging station at the valley of Majes-Camana is recording water levels using an automatic floater type monitoring system, the data is only partially being ordered digitally through a computer, the in charge operator is making a manual record. The data of maximum annual discharge published by SENAMHI before year 2006, represents the maximum of daily mean discharges obtained from the mean discharge measured 2 or 4 times a day. Therefore it is necessary to establish measurement system to obtain real-time water level and discharge values and organize those observed data during inundation time by means of installation of an automatic telemetry system in each gauge in each watershed.

The location of these stations is as shown in the **Table 2.31**.

Table 2.31 Discharge Observation Stations (Chira river)

Observation Station	Latitude	Longitude	Elevation (m.a.s.l.)
Ardilla (Solana Baja)	4° 31'	80° 26'	150
Puente Sullana	4° 53'	80° 41'	32

(2) Yearly Maximum Daily Discharge

The yearly maximum daily discharge of each year is as shown in the **Table 2.32**.

Table 2.32 Yearly Maximum Daily Discharge (Chira river)(m³/s)

Year	Puente Sullana	Ardilla
1976		2,242.00
1977	848.33	1,647.90
1978	56.12	281.10
1979	177.69	348.00
1980	57.07	438.00
1981	455.55	830.30
1982	288.18	589.10
1983	3,227.08	2,469.30
1984	1,043.00	1,663.00
1985	88.40	243.80
1986	40.00	355.60
1987	551.80	1,180.30
1988	37.70	379.50
1989	558.00	936.00
1990	45.20	253.40
1991	121.00	668.60
1992	2,355.00	3,133.50
1993	1,400.00	1,654.00
1994	1,100.00	1,044.00
1995	58.00	276.10
1996	140.00	439.40
1997	925.00	1,275.80
1998	3,005.00	3,620.80
1999	1,195.20	1,927.00

2000	1,111.00	1,303.20
2001	2,252.90	2,264.80
2002	2,517.00	2,825.20
2003	169.00	371.90
2004	231.00	293.80
2005	480.00	629.00
2006	815.00	1,089.90
2007		431.10
2008		3,141.97
2009		2,387.93

2.3.2 Cañete River

(1) Discharge Observation Station

The discharge observation station in Cañete River is as shown in the **Table 2.33**. The observation is performed by SENAMHI and the water users committee.

Table 2.33 Discharge Observation station (Cañete river)

Observation Station	Latitude	Longitude	Elevation (m.a.s.l.)
SOSCI CAÑETE	13° 01'42	76° 11'40	330

(2) Yearly Maximum Daily Discharge

The yearly maximum daily discharge of each year is as shown in the **Table 2.34**.

Table 2.34 Yearly Maximum Daily Discharge (Cañete river) (m³/s)

Year	Yearly Maximum Daily Discharge	
	SENAMHI	water users
1926	-	455.00
1927	-	120.00
1928	-	198.00
1929	-	342.00
1930	-	263.00
1931	-	148.60
1932	-	850.00
1933	-	176.00
1934	-	305.00
1935	-	386.00
1936	-	265.00
1937	-	283.76
1938	-	401.99
1939	-	308.53
1940	-	141.28
1941	-	301.13
1942	-	319.22
1943	-	324.13
1944	-	396.65

*The Preparatory Study on Project of the Protection of Flood Plain and
Vulnerable Rural Population against Flood in the republic of Peru
Feasibility Study Report, Supporting Report, Annex-I Meteorology/Hydrology/Run-off Study*

1945	-	350.00
1946	-	354.00
1947	-	353.00
1948	-	279.00
1949	-	198.00
1950	-	244.74
1951	-	485.00
1952	-	360.00
1953	-	555.00
1954	-	657.00
1955	-	700.00
1956	-	470.00
1957	-	228.32
1958	-	270.40
1959	-	700.00
1960	-	488.75
1961	-	597.62
1962	-	566.24
1963	-	242.37
1964	-	153.06
1965	214.70	214.70
1966	207.00	201.00
1967	343.00	343.00
1968	154.00	154.00
1969	316.00	316.00
1970	408.00	408.00
1971	430.00	430.00
1972	900.00	900.00
1973	484.20	450.10
1974	-	326.00
1975	-	298.00
1976	294.92	332.00
1977	-	249.00
1978	-	216.00
1979	-	182.80
1980	-	100.10
1981	-	257.10
1982	-	120.00
1983	-	228.00
1984	-	425.50
1985	-	165.60
1986	-	370.50
1987	-	487.30
1988	206.00	420.30
1989	-	377.00
1990	-	189.00
1991	-	372.00
1992	-	164.30
1993	-	390.00
1994	-	550.00
1995	-	500.00
1996	-	310.00
1997	-	350.00
1998	-	348.00
1999	-	420.00
2000	-	350.00
2001	-	255.00
2002	-	204.00
2003	-	215.00
2004	-	196.00

2005	-	167.00
2006	-	250.00

2.3.3 Chincha River

(1) Discharge Observation Station

The discharge observation station in Cañete River is as shown in the **Table 2.35**. The observation is performed by SENAMHI and the water users committee.

Table 2.35 Discharge Observation station (Chincha river)

Observation Station	Latitude	Longitude	Elevation (m.a.s.l.)
CONTA	13° 27'	75° 58'	320

(2) Yearly Maximum Daily Discharge

The yearly maximum daily discharge of each year is as shown in the **Table 2.36**.

The Chincha river diverts to Chico river and Matagente river so that the discharge of Chincha river is a total of Chico and Matagente river.

Table 2.36 Yearly Maximum Daily Discharge (Chincha river) (m³/s)

year	SENAMHI	Water Users Committee			Adopted Discharge
		Total	Rio Chico	Rio Matagente	
1950	155.43	-	-	-	155.43
1951	395.75	-	-	-	395.75
1952	354.00	-	-	-	354.00
1953	1,268.80	-	-	-	1,268.80
1954	664.40	-	-	-	664.40
1955	241.45	-	-	-	241.45
1956	227.83	-	-	-	227.83
1957	226.53	-	-	-	226.53
1958	88.36	35.34	53.02	88.36	88.36
1959	301.42	120.57	180.85	301.42	301.42
1960	245.17	98.07	147.10	245.17	245.17
1961	492.83	197.13	295.69	492.82	492.82
1962	395.06	158.02	237.03	395.05	395.05
1963	337.84	135.14	202.70	337.84	337.84
1964	66.95	26.78	40.17	66.95	66.95

*The Preparatory Study on Project of the Protection of Flood Plain and
Vulnerable Rural Population against Flood in the republic of Peru
Feasibility Study Report, Supporting Report, Annex-IMeteorology/Hydrology/Run-off Study*

1965	154.12	61.65	92.47	154.12	154.12
1966	139.13	55.65	83.48	139.13	139.13
1967	1,202.58	481.03	721.55	1,202.58	1,202.58
1968	43.92	17.57	26.35	43.92	43.92
1969	72.14	28.86	43.28	72.14	72.14
1970	271.57	108.63	162.94	271.57	271.57
1971	497.84	199.13	298.71	497.84	497.84
1972	784.16	313.66	470.50	784.16	784.16
1973	137.53	55.01	82.52	137.53	137.53
1974	215.66	86.26	129.40	215.66	215.66
1975	246.87	98.75	148.12	246.87	246.87
1976	311.13	124.45	186.68	311.13	311.13
1977	97.10	38.84	58.26	97.10	97.10
1978	33.00	13.20	19.80	33.00	33.00
1979	51.90	20.76	31.14	51.90	51.90
1980	33.70	13.48	20.22	33.70	33.70
1981	83.95	33.58	50.37	83.95	83.95
1982	183.60	73.44	110.16	183.60	183.60
1983	81.20	32.48	48.72	81.20	81.20
1984	292.87	117.15	175.72	292.87	292.87
1985	71.42	51.88	77.82	129.70	129.70
1986	106.26	46.00	69.00	115.00	115.00
1987	-	42.00	63.00	105.00	105.00
1988	-	28.51	42.76	71.27	71.27
1989	-	71.38	107.07	178.45	178.45
1990	24.34	9.74	14.60	24.34	24.34
1991	-	41.00	61.49	102.49	102.49
1992	-	5.95	8.92	14.87	14.87
1993	-	51.73	77.59	129.32	129.32
1994	-	75.61	113.41	189.02	189.02
1995	-	121.47	182.21	303.68	303.68
1996	-	49.85	74.77	124.62	124.62
1997	-	10.60	15.89	26.49	26.49
1998	-	112.00	168.00	280.00	280.00
1999	-	165.74	248.61	414.35	414.35
2000	-	114.93	172.39	287.32	287.32
2001	-	81.72	122.59	204.31	204.31
2002	-	47.65	71.48	119.13	119.13

2003	-	52.38	78.57	130.95	130.95
2004	-	63.73	95.60	159.33	159.33
2005	-	14.24	21.36	35.60	35.60
2006	-	62.48	93.72	156.20	156.20

2.3.4 Pisco River

(1) Discharge Observation Station

The discharge observation station in Pisco River is as shown in the **Table 2.37**.

Table 2.37 Discharge Observation Station (Pisco river)

Observation Station	Latitude	Longitude	Elevation (m.a.s.l.)
LETRAYOC	13°40'	75°45'	640

(2) Yearly Maximum Daily Discharge

The yearly maximum daily discharge of each year is as shown in the **Table 2.38**.

Table 2.38 Yearly Maximum Daily Discharge (Pisco river) (m³/s)

Year	Yearly Maximum Daily Discharge	Year	Yearly Maximum Daily Discharge
1933	227.50	1971	194.45
1934	264.50	1972	509.87
1935	311.00	1973	293.62
1936	360.50	1974	194.68
1937	956.03	1975	141.88
1938	253.70	1976	237.62
1939	328.67	1977	231.26
1940	155.34	1978	80.33
1941	212.25	1979	213.13
1942	326.79	1980	91.23
1943	301.93	1981	252.00
1944	295.05	1982	274.00
1945	250.01	1983	273.00
1946	528.14	1984	485.65

1947	144.09	1985	200.50
1948	765.10	1986	355.00
1949	148.26	1987	146.20
1950	156.33	1988	369.50
1951	289.09	1989	272.50
1952	208.05	1990	49.38
1953	427.20	1991	325.00
1954	536.64	1992	47.75
1955	403.42	1993	118.00
1956	330.99	1994	312.50
1957	256.19	1995	354.37
1958	169.35	1996	190.00
1959	378.26	1997	150.00
1960	312.85	1998	800.00
1961	272.04	1999	355.00
1962	423.06	2000	215.00
1963	255.85	2001	240.00
1964	238.45	2002	300.00
1965	162.44	2003	176.25
1966	710.02	2004	215.00
1967	521.91	2005	137.50
1968	189.11	2006	350.00
1969	314.07	2007	250.00
1970	454.31	2008	300.00

2.3.5 Yauca River

(1) Discharge Observation Station

The discharge observation station in Yauca River is as shown in the **Table 2.39**.

Table 2.39 Discharge Observation station (Yauca River)

Observation Station	Latitude	Longitude	Elevation (m.a.s.l.)
SAN FRANCISCO ALTO	15° 41'	74° 32'	48.00

(2) Yearly Maximum Daily Discharge

The yearly maximum daily discharge of each year is as shown in the **Table 2.40**.

Table 2.40 Yearly Maximum Daily Discharge (Yauca river) (m³/s)

year	Max.
1961	109.82
1962	58.93
1963	54.11
1964	15.77
1965	36.54
1966	26.49
1967	211.06
1968	68.51
1969	64.97
1970	36.65
1971	20.70
1972	151.38
1973	123.13
1974	31.96
1975	137.20
1976	41.82
1977	69.11
1978	4.51
1979	20.10
1980	15.72
1981	23.56
1982	26.72
1983	12.60
1984	52.20
1985	17.65
1986	30.54
1987	24.06
1988	32.30
1989	198.39
1990	11.12
1991	42.60
1992	0.67
1993	19.57
1994	60.41
1995	20.93
1996	17.50
1997	13.09
1998	45.65
1999	195.03
2000	62.64
2001	118.06
2002	39.77
2003	45.81
2004	33.46
2005	6.61
2006	78.54
2007	50.14
2008	42.28

2.3.6 Majes-Camana River

(1) Discharge Observation Station

The discharge observation station in Majes-Camana river is as shown in the **Table 2.41**.

Table 2.41 Discharge Observation station (Majes-Camana river)

Observation Station	Latitude	Longitude	Elevation (m.a.s.l.)
Huatiapa	15°59'41.0" S	72°28'13.0" W	700
Puente Carretera Camaná	16°36'00.0" S	72°44'00.0" W	122

(2) Yearly Maximum Daily Discharge

The yearly maximum daily discharge of each year is as shown in the **Table 2.42**.

Table 2.42 Yearly Maximum Daily Discharge (Majes-Camana river) (m³/s)

Huatiapa

Year	Max. Discharge
1945	620.00
1946	619.00
1947	580.79
1948	506.50
1949	1012.80
1950	458.33
1951	687.32
1952	592.50
1953	980.00
1954	980.00
1955	2400.00
1956	445.30
1957	316.00
1958	985.50
1959	1400.00
1960	600.00
1965	171.94
1966	237.00
1967	420.00
1968	442.55
1969	308.60
1970	362.00
1971	356.00
1972	633.00
1973	1040.00
1974	902.00
1975	748.00
1976	514.00
1977	592.00
1978	1600.00
1979	410.00
1980	415.00
1981	1000.00
1982	345.00
1983	23.20
1984	1025.00
1986	750.00
2006	590.87
2007	366.33
2008	418.50
2009	400.22

Puente Carretera Camaná

Year	Max. Discharge
1961	301.10
1962	399.87
1963	340.16
1971	340.72
1972	800.42
1973	750.19
1974	950.00
1975	890.00
1977	1200.00
1978	2000.00
1979	150.70
1980	89.00
1981	530.00
1982	300.00
1983	40.00
1984	1300.00
1986	600.00

CHAPTER 3 RUN-OFF STUDY

3.1 Probable Flood Discharge Based on Observation Data

The reference point for run-off analysis was selected among the observation stations in each basin, and where the flood discharge with return period from 2 years to 100 years are calculated based on the observation data of yearly maximum daily discharge by statistical processing.

The results of calculation are as shown in the **Table 3.1**.

The following probable distribution models are used for hydrological statistic calculation, and the most adaptable value among models is adopted for each basin, for further details refer to the Appendix attached at end of this report.

- Distribution Normal or Gaussiana
- Log - Normal 3 parameters
- Log - Normal 2 parameters
- Gamma 2 or 3 parameters
- Log - Pearson III)
- Gumbel Distribution
- Generalized Extreme Values

Table 3.1 Probable Discharge at Reference Point

River/Reference Point	Return Period of 2years	Return Period of 5years	Return Period of 10years	Return Period of 25 years	Return Period of 50 years	Return Period of 100 years	(m ³ /s)
Chira/ Puente Sullana	888	1,726	2,281	2,983	3,503	4,019	
Cañete/ Socsi	313	454	547	665	753	840	
Chincha/ Conta	179	378	536	763	951	1,156	
Pisco/ Letrayoc	267	398	500	648	774	914	
Yauca/ San Francisco Alto	41	81	116	171	219	273	
Majes-Camana/ Huatiapa	560	901	1,169	1,565	1,906	2,292	

The maximum observation discharge is 900m³/sec in Socsi station in Cañete river in 1972, therefore the values of the above table are calculated including this discharge. As described later in the clause 3.3.2, the maximum discharge which can be observed in this station is estimated about 900m³/sec, therefore the values shown in the above table seem to be less than the actual discharge with high possibility.

*The Preparatory Study on Project of the Protection of Flood Plain and
Vulnerable Rural Population against Flood in the republic of Peru
Feasibility Study Report, Supporting Report, Annex-I Meteorology/Hydrology/Run-off Study*

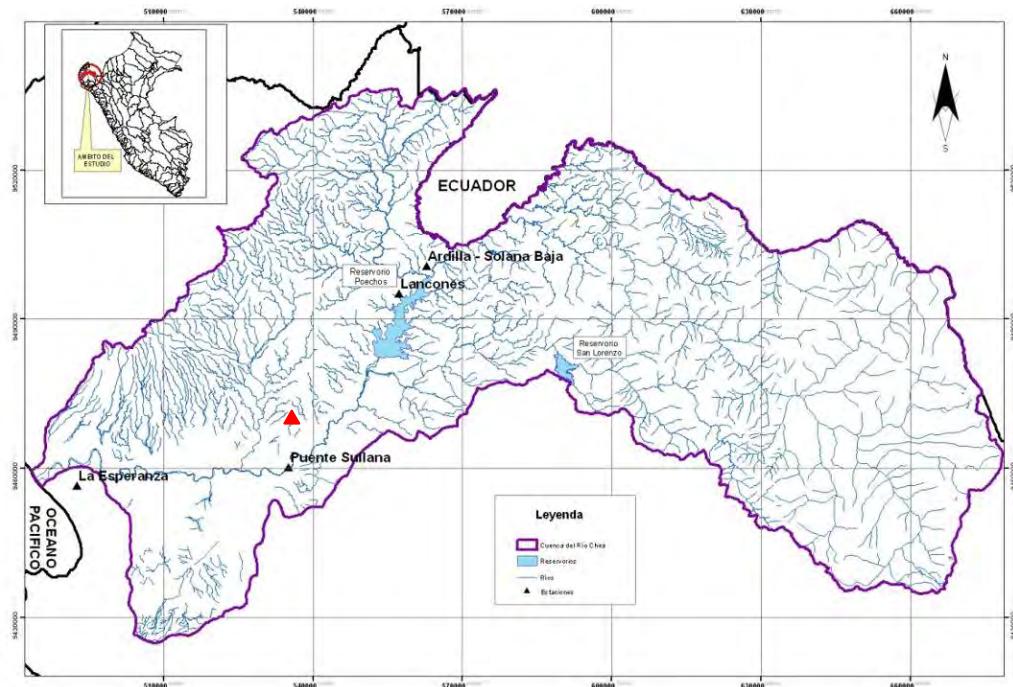


Figure 3.1 Location of the base station at Chira River Basin

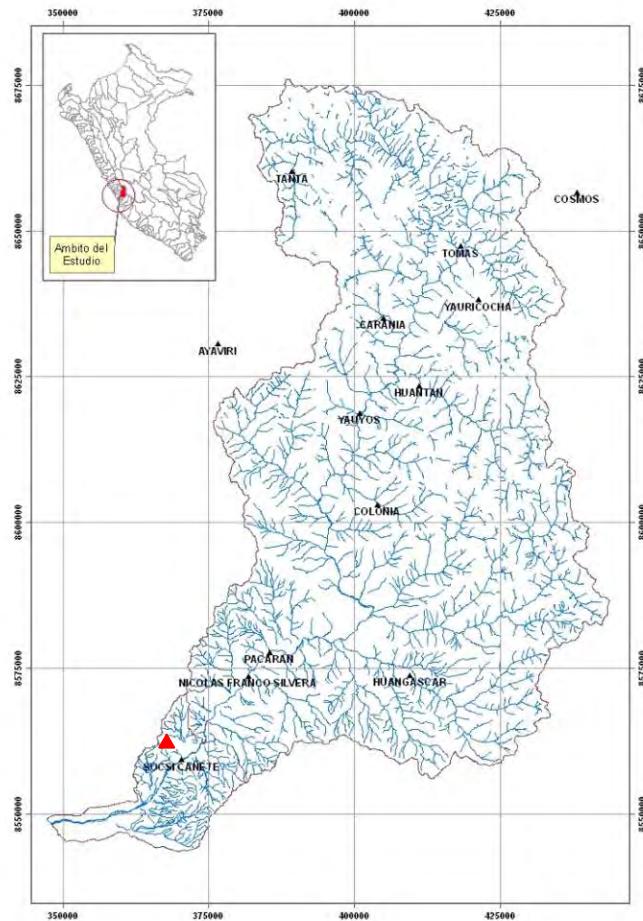


Figure 3.2 Location of the base station at Cañete River Basin

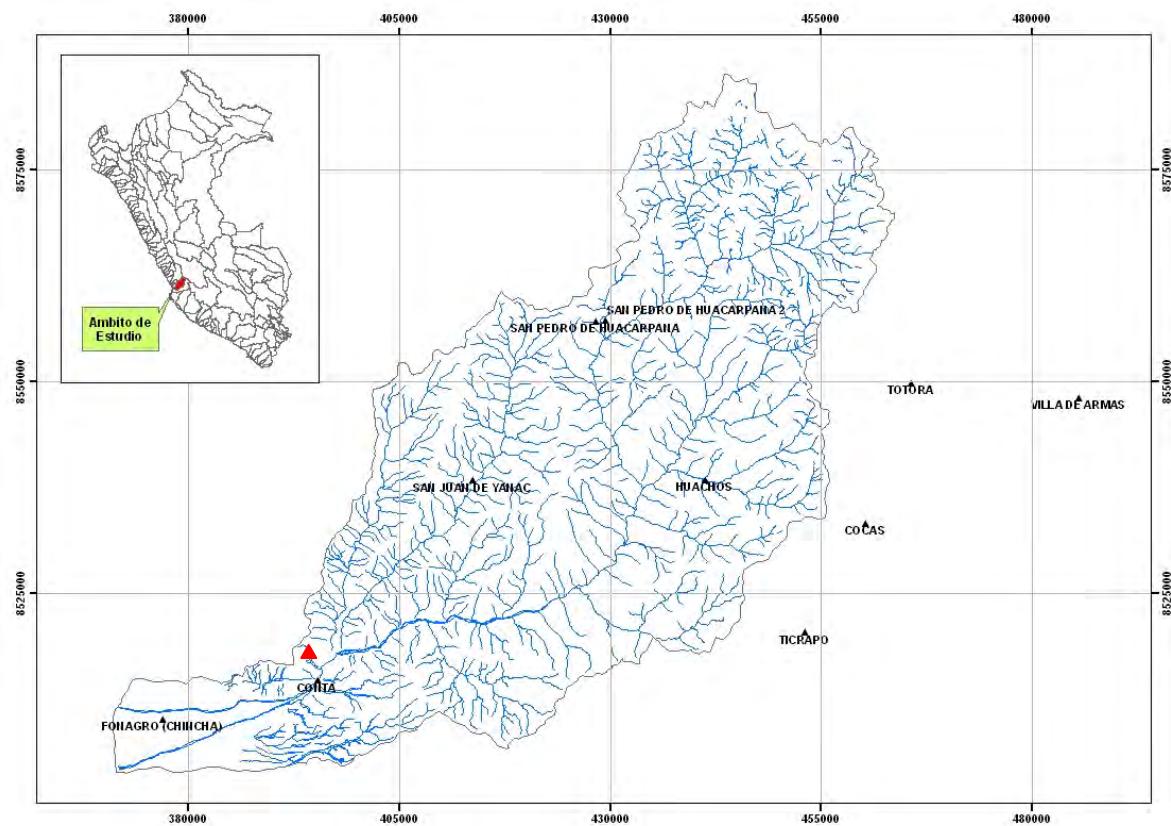


Figure 3.3 Location of the base station at Chincha River Basin

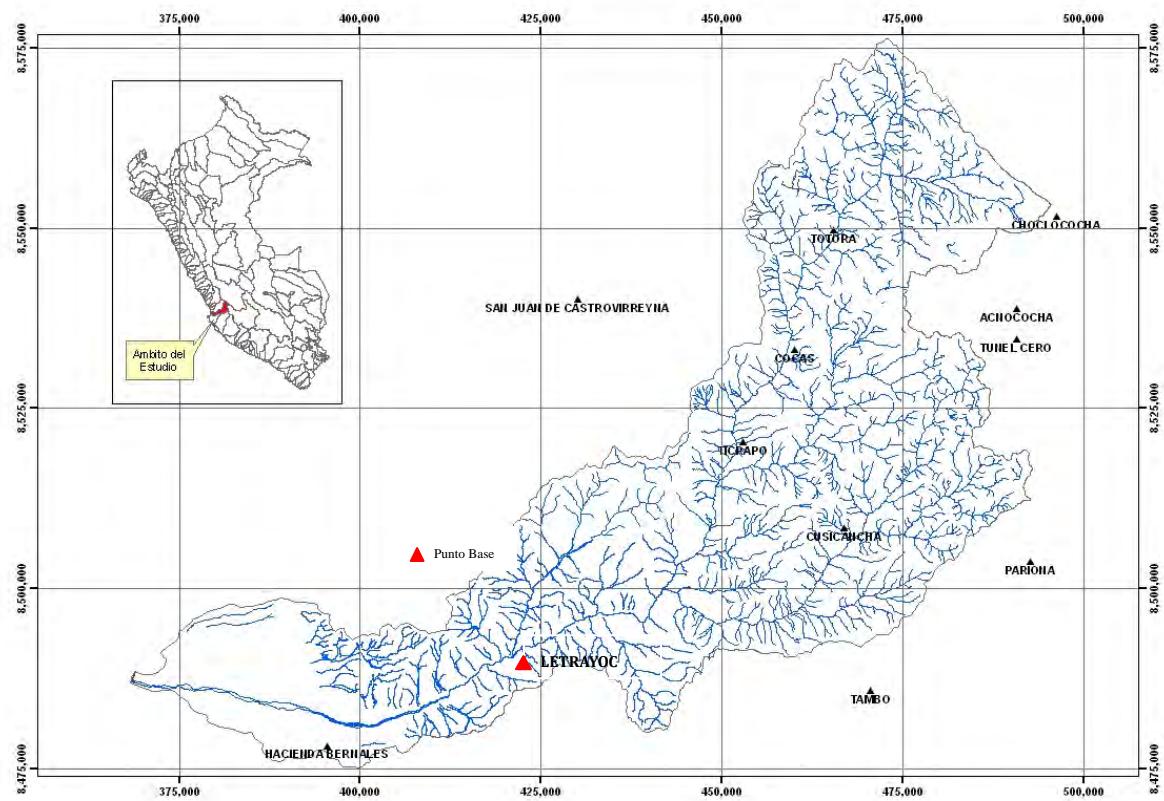


Figure 3.4 Location of the Base Station at Pisco River Basin

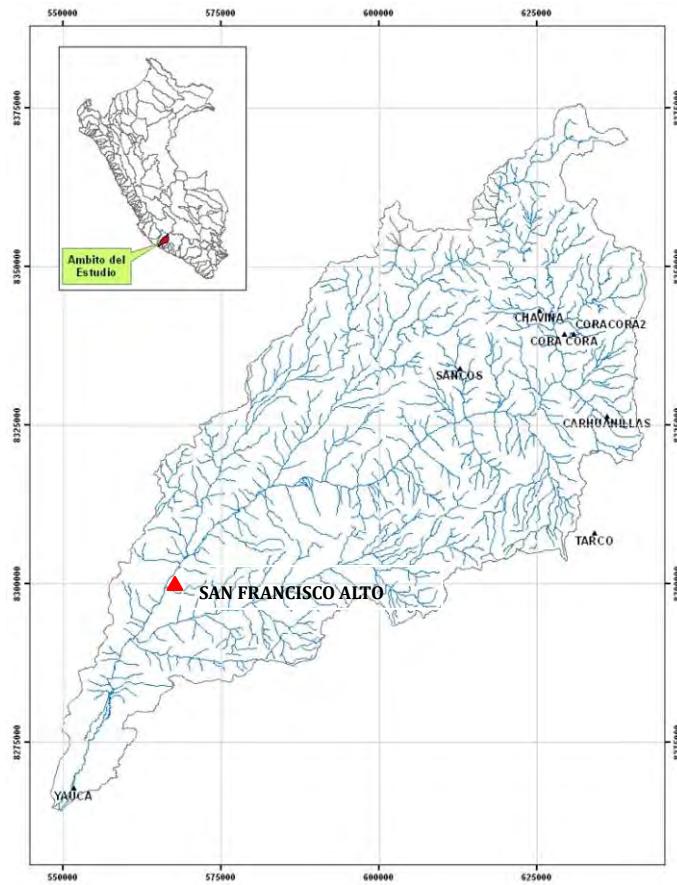


Figure 3.5 Location of the Base Station at Yauca River Basin

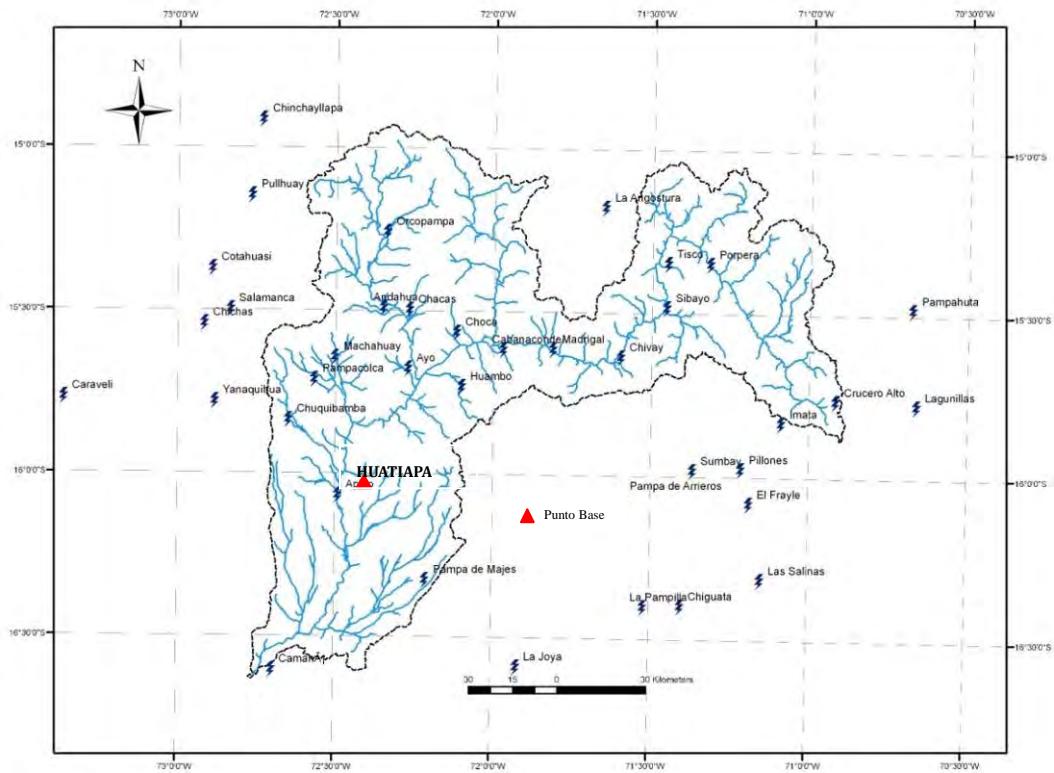


Figure 3.6 Location of the Base Station at Majes-Camaná River Basin

3.2 Run-off Analysis Based on Rainfall Data (HEC-HMS Method)

There is only daily discharge data in the objective study area, and the probable discharges calculated in the previous close 3.1 show the peak discharge. In order to perform the inundation analysis described later clause, the hourly distribution of flood discharge (flood hydrograph) is required. Therefore the run-off study based on rainfall data is performed in this clause.

The run-off analysis method is to be HEC-HMS (Hydrologic Engineering Center- Hydrologic Modeling System) which is developed by US Army Corps of Engineer. This system is the run-off analysis program for general purpose which is widely used in the North America and other areas in the world, and one of the most popular program in Peru.

3.2.1 HEC-HMS

HEC-HMS is designed to simulate the precipitation-runoff processes of dendritic watershed system. The basin model can be composed of sub-basin, reach, junction, diversion, reservoir etc. To simulate infiltration loss options for event modeling include SCS curve number, Initial Constant, Exponential, Green Ampt etc.

Several methods are included for transforming excess precipitation into surface runoff such as unit hydrograph methods including Clark, Snyder, SCS technique. Several methods including Muskingum, kinematic wave can be applied for flood routing in channel. And several methods can be applied for representing base flow contribution to sub-basin outflow.

Six different historical and synthetic precipitation methods are included. Four different methods for analyzing historical precipitation are included. The gage weights method uses an limited number of recording and no-recording gages and Thiessen technique is one possibility for determining the weights.

The frequency storm method uses statistical data to produce balanced storms with a specific exceedance probability. The SCS hypothetical storm method implements the primary distribution for design analysis using Natural Resources Conservation Service Criteria (NRCS). Most parameters for methods included in sub-basin and reach elements can be estimated automatically using optimization trials. Six different objective functions are available to estimate goodness-of-fit between the computed results and observed discharge.

The procedure of applying HEC-HMS in this analysis is as shown below. According to this procedure the summary of run-off analysis on Majes-Camana basin is described below. As to detail of run-off study for each basin refer to Appendix attached at the end of this report.

- (1) Preparation of Basin Model
- (2) Rainfall Analysis
 - 1) Calculation of Probable 24-hour Rainfall in Each Station
 - 2) Calculation of 24-hour Rainfall in Each Sub-basin

- 3) Selection of Type of 24-hour Rainfall Curve
- (3) Calculation of Infiltration Loss by SSC Method
 - 1) Selection of Initial Curve Number in Each Sub-basin
 - 2) Selection of Final Curve Number in Each Sub-basin
 - 3) Verification of Model
- (4) Calculation of Probable Flood Discharges and their Flood Hydrograph

3.2.2 Preparation of Basin Model

(1) Division of Basin

Majes-Camana basin is divided into 4 sub-basins each of which has similar hydraulic Characteristics, such as topography, distribution pattern of river channel, forestation conditions, surface soil conditions etc. The division of the basin is as shown in the **Figure 3.7.**



Figure 3.7 Majes-Camaná Basin’s Sub-division into Secondary Basins.

(2) Preparation of Basin Model

The sub-basin, reach and junction are represented schematically using the HEC-HMS model. In accordance with these, the whole basin model of Majes-Camana basin is expressed as shown in the **Figure 3.8.**

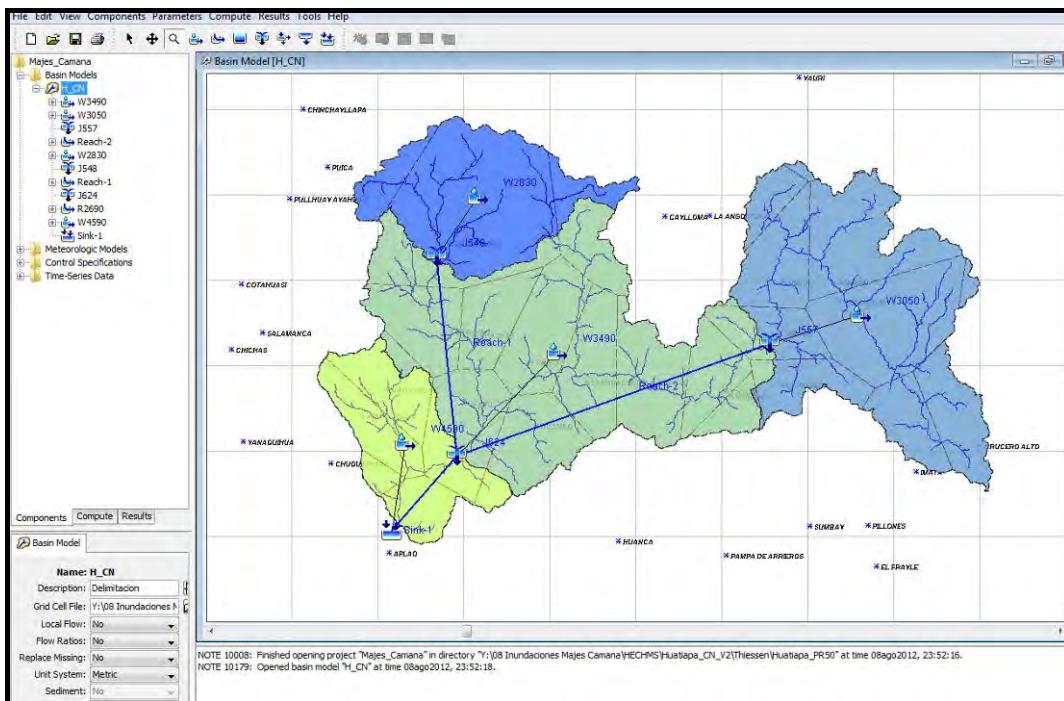


Figure 3.8 Majes-Camaná Basin HEC-HMS Model

3.2.3 Rainfall Analysis

(1) Probable 24-hour Daily Rainfall

The probable 24-hour rainfall in each observation station is calculated by statistical processing of yearly maximum rainfall of 24-hour as shown in the **Table 3.2**. Based on the table isohyetal map of 24-hour rainfall with return period of 50-year is as shown in the **Figure 3.9**.

Table 3.2 Probable 24-hour Daily Rainfall (m^3/s) for each Return Period

Station	Coordinates			Precipitation for T (years)						
	Latitude	Longitude	Altitude (masl)	2	5	10	25	50	100	200
Andahua	15° 29'37"	72° 20'57"	3538	24.30	31.33	34.83	38.29	40.33	42.02	43.43
Aplao	16° 04'10"	72° 29'26"	625	1.71	5.03	7.26	9.51	10.71	11.56	12.14
Ayo	15° 40'45"	72° 16'13"	1950	10.28	16.43	20.51	25.66	29.48	33.27	37.05
Cabanaconde	15° 37'7"	71° 58'7"	3369	26.58	37.88	45.89	56.58	64.95	73.67	82.79
Camaná	16° 36'24"	72° 41'49"	29	3.18	7.16	9.79	13.11	15.58	18.03	20.46
Caravelí	15° 46'17"	73° 21'42"	1757	7.67	16.07	22.60	31.46	38.30	45.21	52.15
Chachas	15° 29'56"	72° 16'2"	3130	22.21	28.60	32.08	35.83	38.24	40.37	42.30
Chichas	15° 32'41"	72° 54'59.7"	2120	16.28	23.47	27.01	30.37	32.23	33.67	34.80
Chiguata	16° 24'1"	71° 24'1"	2945	18.88	29.98	37.33	46.40	52.94	59.27	65.42
Chinchayllapa	14° 55'1"	72° 44'1"	4514	23.12	31.21	36.57	43.34	48.37	53.35	58.32
Chivay	15° 38'17"	71° 35'49"	3663	24.50	32.74	38.20	45.09	50.21	55.29	60.35
Choco	15° 34'1"	72° 07'1"	3160	16.10	22.92	27.45	33.16	37.39	41.60	45.79
Chuquibamba	15° 50'17"	72° 38'55"	2839	21.65	36.96	47.09	59.89	69.39	78.82	88.21
Cotahuasi	15° 22'29"	72° 53'28"	5086	21.20	29.97	35.78	43.12	48.56	53.96	59.35
Crucero Alto	15° 46'1"	70° 55'1"	4486	25.33	31.66	35.20	39.10	41.67	44.02	46.17
El Frayle	16° 05'5"	71° 11'14"	4110	22.33	29.95	35.43	42.89	48.83	55.12	61.82
Huambo	15° 44'1"	72° 06'1"	3500	22.87	30.14	34.96	41.05	45.57	50.05	54.52
Imata	15° 50'12"	71° 05'16"	4451	28.35	37.09	42.87	50.18	55.60	60.98	66.34
La Angostura	15° 10'47"	71° 38'58"	4260	35.90	45.89	53.22	63.31	71.46	80.18	89.57
La Joya	16°35'33"	71°55'9"	1279	1.22	4.74	7.89	11.93	14.65	16.98	18.92
La Pampilla	16° 24'12.2"	71° 31'6"	2388	12.65	21.64	27.66	35.01	40.23	45.20	49.94
Lagunillas	15° 46'46"	70° 39'38"	4385	28.55	34.30	37.75	41.81	44.67	47.40	50.05
Las Salinas	16° 19'5"	71° 08'54"	3369	18.05	25.72	30.80	37.22	41.98	46.70	51.41
Machahuay	15° 38'43"	72° 30'8"	3000	21.06	29.80	34.71	40.03	43.45	46.46	49.14
Madrigal	15° 36'59.7"	71° 48'42"	3238	23.63	30.07	33.66	37.59	40.17	42.50	44.63
Orcopampa	15° 15'39"	72° 20'20"	3805	21.51	29.58	36.83	48.66	59.81	73.37	89.92
Pampa de Arrieros	16° 03'48"	71° 35'21"	3720	18.86	32.08	40.82	51.88	60.07	68.21	76.32
Pampa de Majes	16° 19'40"	72° 12'39"	1442	2.07	6.68	10.56	15.55	18.98	22.04	24.69
Pampacolca	15° 42'51"	72° 34'3"	2895	21.13	29.11	34.40	41.08	46.04	50.95	55.86
Pampahuta	15° 29'1"	70° 40'33.3"	4317	34.18	39.66	42.87	46.58	49.14	51.57	53.89
Pillones	15° 58'44"	71° 12'49"	4428	24.00	32.95	38.88	46.36	51.92	57.43	62.92
Porpera	15° 21'1"	71° 19'1"	4142	27.40	40.61	49.37	60.42	68.63	76.77	84.88
Pullhuay	15° 09'1"	72° 46'1"	3098	24.47	32.43	37.63	44.15	48.97	53.77	58.60
Salamanca	15° 30'1"	72° 50'1"	3153	19.86	26.64	31.13	36.81	41.02	45.20	49.36
Sibayo	15° 29'8"	71° 27'11"	3839	31.25	38.61	42.98	48.06	51.59	54.93	58.13
Sumbay	15° 59'1"	71° 22'1"	4300	25.43	35.57	43.10	53.56	62.08	71.26	81.17
Tisco	15° 21'1"	71° 27'1"	4198	33.41	42.74	51.24	65.12	78.15	93.95	113.15
Yanaquihua	15° 46'59.8"	72° 52'57"	2834	20.70	35.78	45.76	58.38	67.74	77.03	86.29

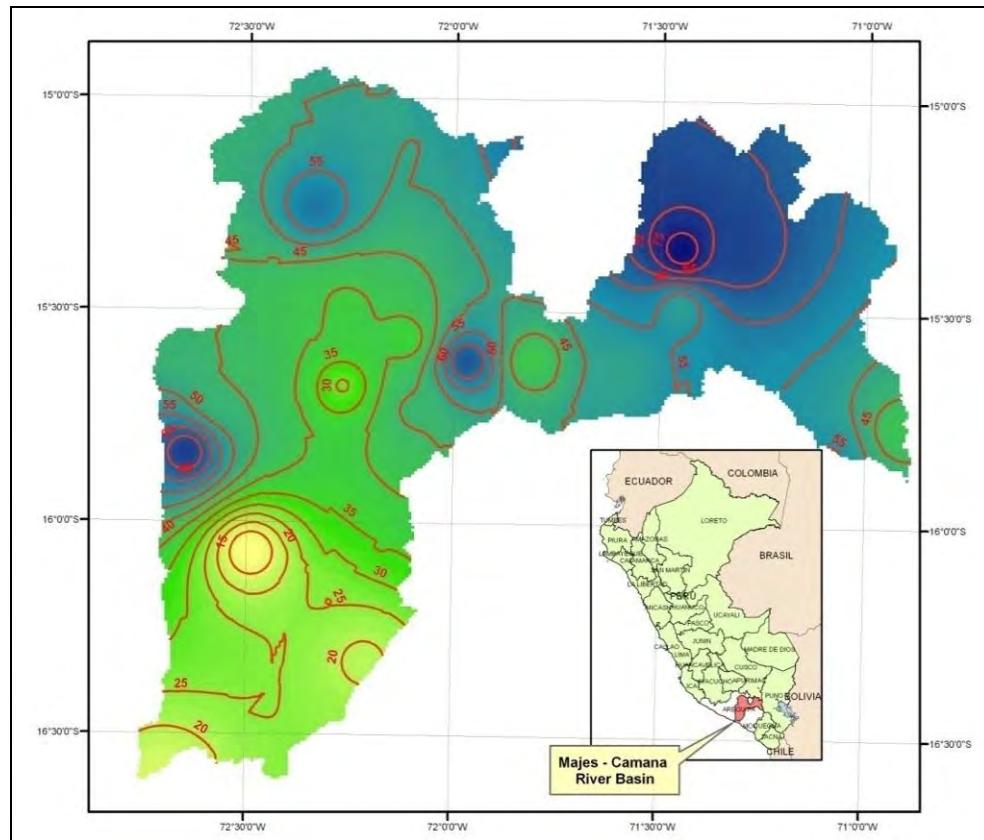


Figure 3.9 Isohyetal Map of 24h-hour Rainfall with Return Period of 50-year (Majes-Camaná)

(2) 24-hour Rainfall in Sub-basin

Based on the 24-hour maximum rainfall and using the method of Thiessen polygons rainfalls were calculated for each sub-basin. **Figure 3.10** shows the Thiessen polygons and distribution of rainfall stations.

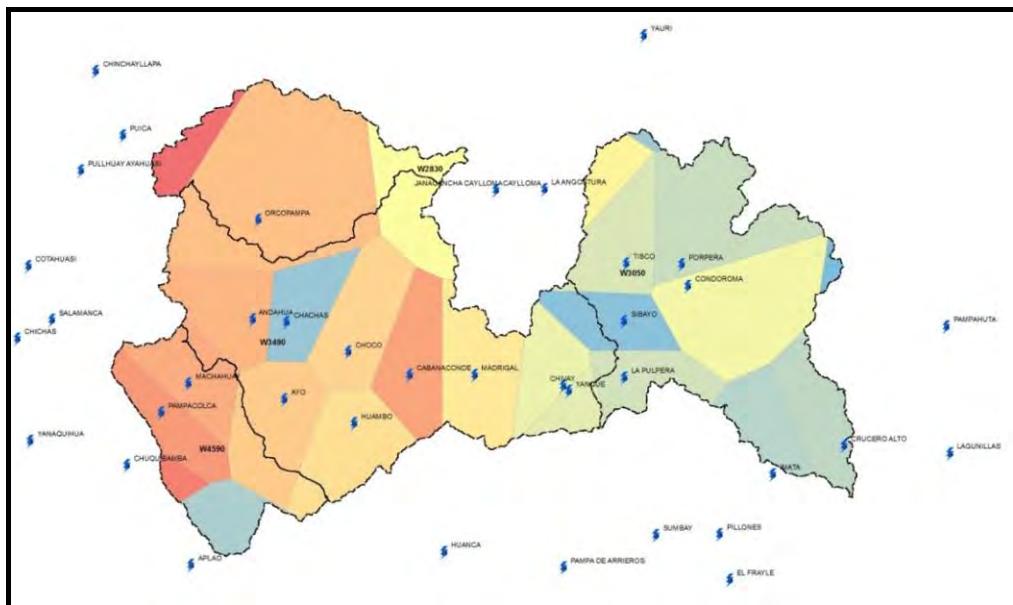


Figure 3.10 Thiessen Polygons and Distribution of Rainfall Stations

It is usually required to determine for each sub-basin the probabilistic rainfall using the maximum values of precipitation for each year calculated from the average precipitation. However, since the rainfall information is incomplete, it is difficult to calculate average rainfall, this is the reason why there was no choice but to use probabilistic rainfall average of each sub-basin calculated from probabilistic rainfall information from each of the rainfall stations. The results of this calculation are presented in the **Table 3.3**. Same methodology is used for other basins.

Table 3.3 Probabilistic Rainfall for each Sub-basin Calculated Using 24-hour Maximum Rainfall (Majes-Camaná)

Sub-Basin	Average Areal Rainfall (mm.)				
	T5	T10	T25	T50	T100
W2830	29.60	36.80	48.68	59.96	73.45
W3050	38.20	46.10	55.14	62.47	70.23
W3490	29.25	34.14	40.63	45.15	50.03
W4590	23.05	27.70	33.23	36.98	40.77

(3) Selection of Type of 24-hour Rainfall Curve

There is not hourly rainfall observation data but 24-hour rainfall observation data (daily rainfall data) so that the hourly data cannot but being estimated by 24-hour rainfall data.

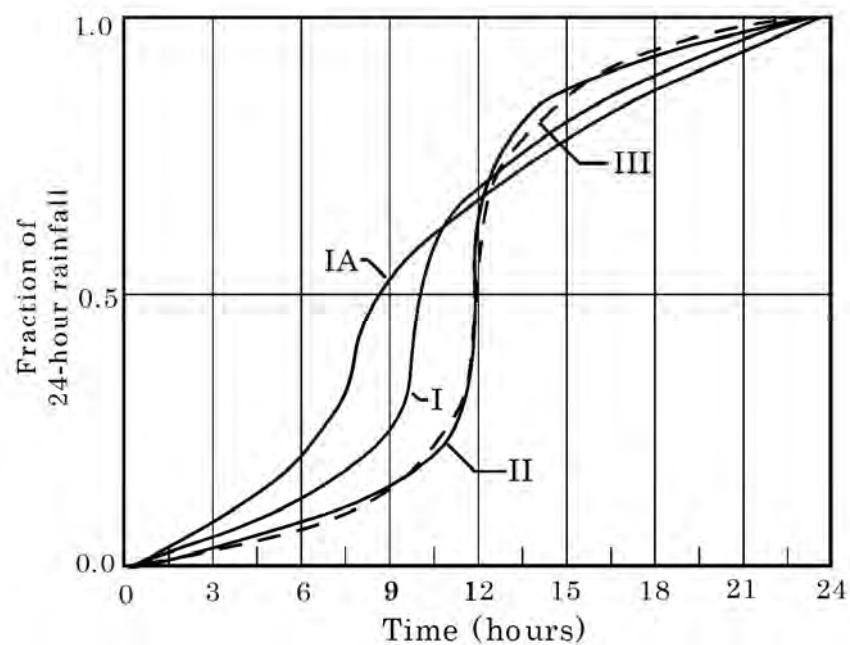
SCS (Soil Conservation Service) hypothetical storm which is generally used in HEC-HMS is used for 24-hour rainfall curve. This method is developed through the analysis of rainfall data in USA, which is expressed 4 types of rainfall curve with non-dimension as shown in the **Table 3.4** and the

Figure 3.11. The distribution of rainfall is as shown in the **Figure 3.12** assuming time interval. And the applied area of 4 types in USA is as shown in the **Figure 3.13**, according to which the type II is recommended to be applied to major part of USA. In addition to this it is said that 24-hour rainfall can be applicable for most of basins.

Since there is no hourly rainfall data in the study area, it is difficult to judge the type of rainfall, however the type is determined actually based on a few study examples in Peru. Miplo Mining Company analyzed the hourly rainfall data which was obtained from Chavin station installed western slope of Peru (between Cañete basin and highland of Chincha basin), and judged the rainfall type of this area belongs to type II and that the type II can be applied the central and south of coastal area. In the north area of Peru, the hourly rainfall in El niño phenomena in El Tigre station was analyzed and concluded the rainfall type belonged type I and type IA. Based on these study results, type II is applied for Cañete, Chincha, Pisco and Yauca; type I for Chira Basin and type IA for Majes-Camana basin.

Table 3.4 Accumulated Curve of 24-hour Rainfall in SCS Hypothetical Storm

Time (hr)	t/24	24 hr precipitation temporal distribution			
		Type I	Type IA	Type II	Type III
0.00	0.000	0.000	0.000	0.000	0.000
2.00	0.083	0.035	0.050	0.022	0.020
4.00	0.167	0.076	0.116	0.048	0.043
6.00	0.250	0.125	0.206	0.080	0.072
7.00	0.292	0.156	0.268	0.098	0.089
8.00	0.333	0.194	0.425	0.120	0.115
8.50	0.354	0.219	0.480	0.133	0.130
9.00	0.375	0.254	0.520	0.147	0.148
9.50	0.396	0.303	0.550	0.163	0.167
9.75	0.406	0.362	0.564	0.172	0.178
10.00	0.417	0.515	0.577	0.181	0.189
10.50	0.438	0.583	0.601	0.204	0.216
11.00	0.458	0.624	0.624	0.235	0.250
11.50	0.479	0.654	0.645	0.283	0.298
11.75	0.490	0.669	0.655	0.357	0.339
12.00	0.500	0.682	0.664	0.663	0.500
12.50	0.521	0.706	0.683	0.735	0.702
13.00	0.542	0.727	0.701	0.772	0.751
13.50	0.563	0.748	0.719	0.799	0.785
14.00	0.583	0.767	0.736	0.820	0.811
16.00	0.667	0.830	0.800	0.880	0.886
20.00	0.833	0.926	0.906	0.952	0.957
24.00	1.000	1.000	1.000	1.000	1.000



Source :Urban water hydrology for small watersheds(TR-55) Appendix B

Figure 3.11 Distribution of 24hour Rainfall in Each Type

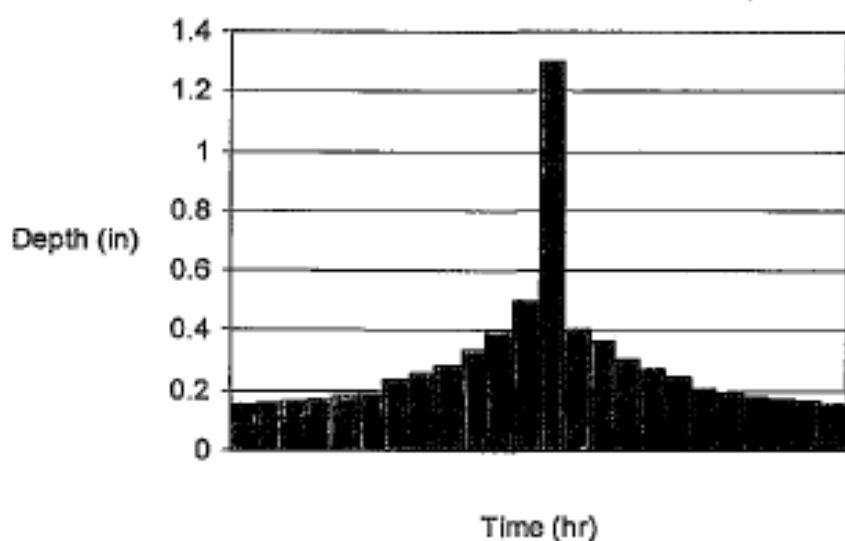
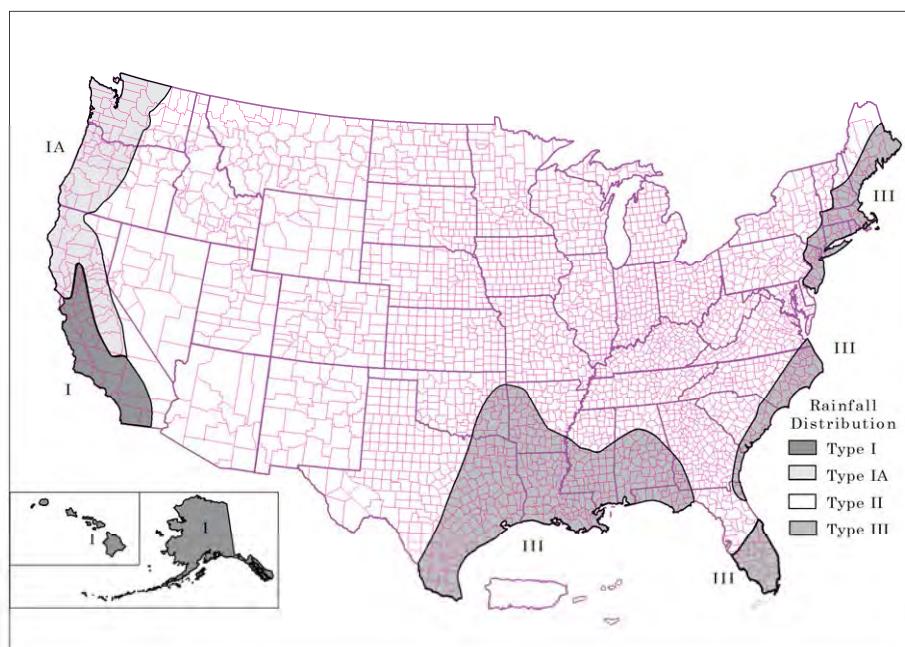


Figure 3.12 Division of 24-hour Rainfall



Source :Urban water hydrology for small watersheds(TR-55) Appendix B

Figure 3.13 Type of 24-hour Rainfall and Applied Area

3.2.4 Excess Rainfall by SSC Method

(1) Basic Formula

SSC Curve Number (CN) Loss Model is to estimate the excess rainfall based on the function of accumulated rainfall, soil conditions, land use, initial rainfall loss etc. in the following formula.

$$P_e = \frac{(P - I_a)^2}{P - I_a + S}$$

where; P_e : Excess rainfall at time t;

P : Accumulated rainfall at time t;

I_a : Initial loss;

S : Possible storage volume

Assuming $I_a = 0.2 S$

$$P_e = \frac{(P_e - 0.2S)^2}{P + 0.8S}$$

Relation S and CN representing basin characteristics is as shown below.

$$S = \frac{1000}{CN} - 10$$

Assuming CN, the relation Pe and P is calculated as shown the **Figure 3.14**.

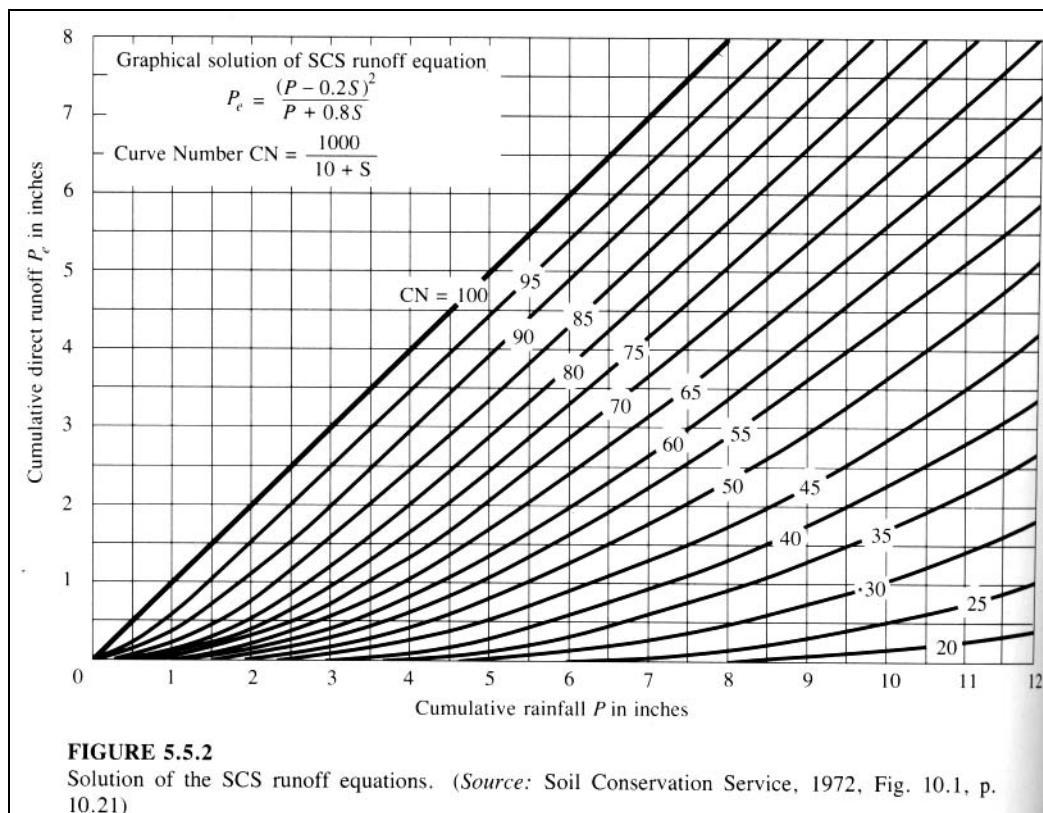


Figure 3.14 Relation among CN, P and P_e

(2) Selection of CN in Sub-basin

Referring to the **Table 3.5** and based on the land use and soil conditions, CN of each sub-division is determined. The initial value of CN in Majes-Camana basin is determined as shown in the **Figure 3.15**.

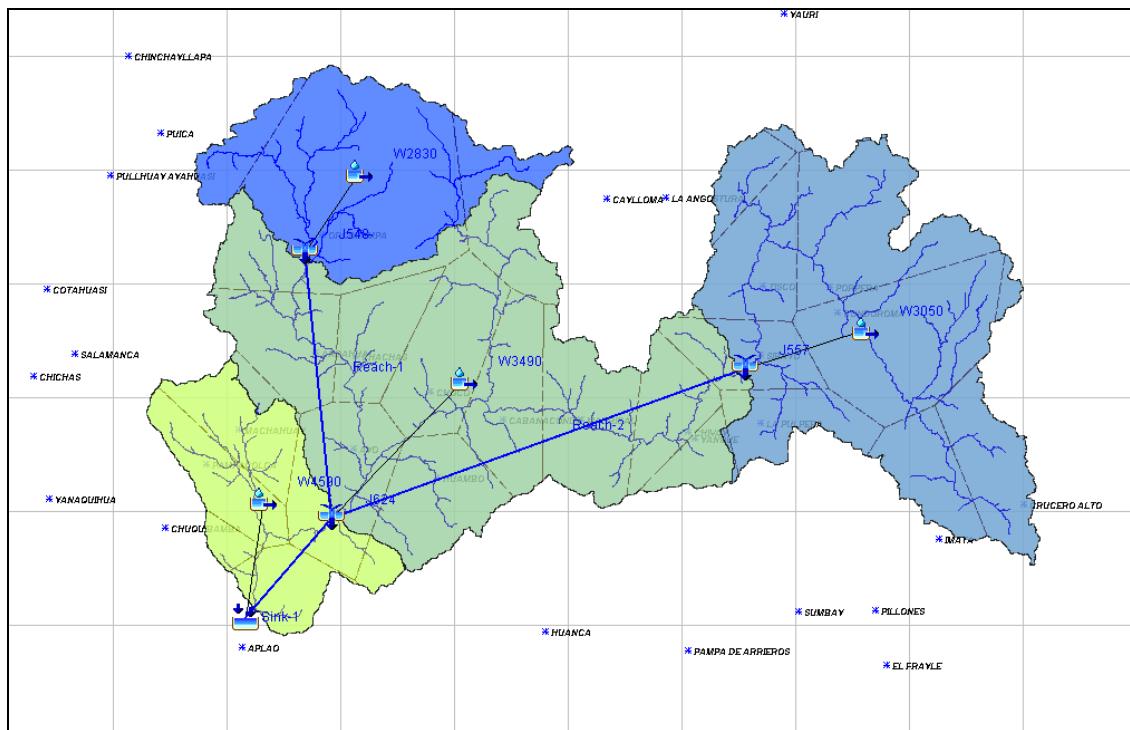


Figure 3.5 Value of CN selected for Majes-Camana Basin

Table 3.15 Used Values of CN

Sub-basin	Conditions of Sub-Basin	Final CN
Upper Basin - Colca	Barren area with scarce vegetation.	79
Middle Basin - Colca	Pastures, shrub, small trees.	74
Upper Basin - Andahua	Barren area with scarce vegetation.	79
Lower Basin - Majes	Desert, hyper arid area	79

Table 3.16(1) CN Value Depending on Land Use and Soil Conditions (1/3)

Land Use Description	Hydrologic Soil Group			
	A	B	C	D
Cultivated land ¹ : without conservation treatment	72	81	88	91
with conservation treatment	62	71	78	81
Pasture or range land: poor condition	68	79	86	89
good condition	39	61	74	80
Meadow: good condition	30	58	71	78
Wood or forest land: thin stand, poor cover, no mulch	45	66	77	83
good cover ²	25	55	70	77
Open Spaces, lawns, parks, golf courses, cemeteries, etc.				
good condition: grass cover on 75% or more of the area	39	61	74	80
fair condition: grass cover on 50% to 75% of the area	49	69	79	84
Commercial and business areas (85% impervious)	89	92	94	95
Industrial districts (72% impervious)	81	88	91	93
Residential ³ :				
Average lot size	Average % impervious ⁴			
1/8 acre or less	65	77	85	90
1/4 acre	38	61	75	83
1/3 acre	30	57	72	81
1/2 acre	25	54	70	80
1 acre	20	51	68	79
Paved parking lots, roofs, driveways, etc. ⁵	98	98	98	98
Streets and roads:				
paved with curbs and storm sewers ⁵	98	98	98	98
gravel	76	85	89	91
dirt	72	82	87	89

¹For a more detailed description of agricultural land use curve numbers, refer to Soil Conservation Service, 1972, Chap. 9

²Good cover is protected from grazing and litter and brush cover soil.

³Curve numbers are computed assuming the runoff from the house and driveway is directed towards the street with a minimum of roof water directed to lawns where additional infiltration could occur.

⁴The remaining pervious areas (lawn) are considered to be in good pasture condition for these curve numbers.

⁵In some warmer climates of the country a curve number of 95 may be used.

Table 3.16(2) CN Value Depending on Land Use and Soil Conditions (2/3)

TABLE 3.16.1 SCS Runoff Curve Numbers (Continued)

c. Other agricultural areas		Hydrologic condition	Curve numbers for hydrologic soil group			
Cover type	Cover description		A	B	C	D
Pasture, grassland, or range—continuous forage for grazing*	Poor	68	79	86	89	
	Fair	49	69	79	84	
	Good	39	61	74	80	
Meadow—continuous grass, protected from grazing and generally mowed for hay	—	30	58	71	78	
Brush—brush-weed-grass mixture with brush the major element†	Poor	48	67	77	83	
	Fair	35	56	70	77	
	Good	30	48	65	73	
Woods-grass combination (orchard or tree farm)‡	Poor	57	73	82	86	
	Fair	43	65	76	82	
	Good	32	58	72	79	
Woods§	Poor	45	66	77	83	
	Fair	36	60	73	79	
	Good	30	55	70	77	
Farmsteads—buildings, lanes, driveways, and surrounding lots	—	59	74	82	86	

* Poor: <50% ground cover or heavily grazed with no mulch. Fair: 50 to 75% ground cover and not heavily grazed. Good: >75% ground cover and lightly or only occasionally grazed.
† Poor: <50% ground cover. Fair: 50 to 75% ground cover. Good: >75% ground cover.
‡ CNs shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CNs for woods and pasture.
§ Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning. Fair: Woods are grazed but not burned, and some forest litter covers the soil. Good: Woods are protected from grazing, and litter and brush adequately cover the soil.
Source: Ref. 105.

d. Arid and semiarid range areas		Hydrologic condition*	Curve numbers for hydrologic soil group			
Cover type	Cover description		A†	B	C	D
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element	Poor	80	87	93		
	Fair	71	81	89		
	Good	62	74	85		
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush	Poor	66	74	79		
	Fair	48	57	63		
	Good	30	41	48		
Piñon-juniper—piñon, juniper, or both: grass understory	Poor	75	85	89		
	Fair	58	73	80		
	Good	41	61	71		
Sagebrush with grass understory	Poor	67	80	85		
	Fair	51	63	70		
	Good	35	47	55		

Table 3.16(3) CN Value Depending on Land Use and Soil Conditions (3/3)

SCS Runoff Curve Numbers (<i>Continued</i>)					
d. Arid and semiarid range areas		Cover description	Curve numbers for hydrologic soil group		
Cover type	Hydrologic condition*		A†	B	C
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

* Poor: <30% ground cover (litter, grass, and brush overstory).
 Fair: 30 to 70% ground cover.
 Good: >70% ground cover.
 † Curve numbers for group A have been developed only for desert shrub.
 Source: Ref. 105.

Source: Maidment (1993).

Note: Hydrological Soil Group

Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sand or gravel and have a high rate of water transmission (greater than 0.30 in/hr).

Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.30 in/hr).

Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05-0.15 in/hr).

Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-0.05 in/hr).

[Sample of previous investigation study which uses the HEC-HMS for discharge analysis for coastal catchments and their respective values used CN]



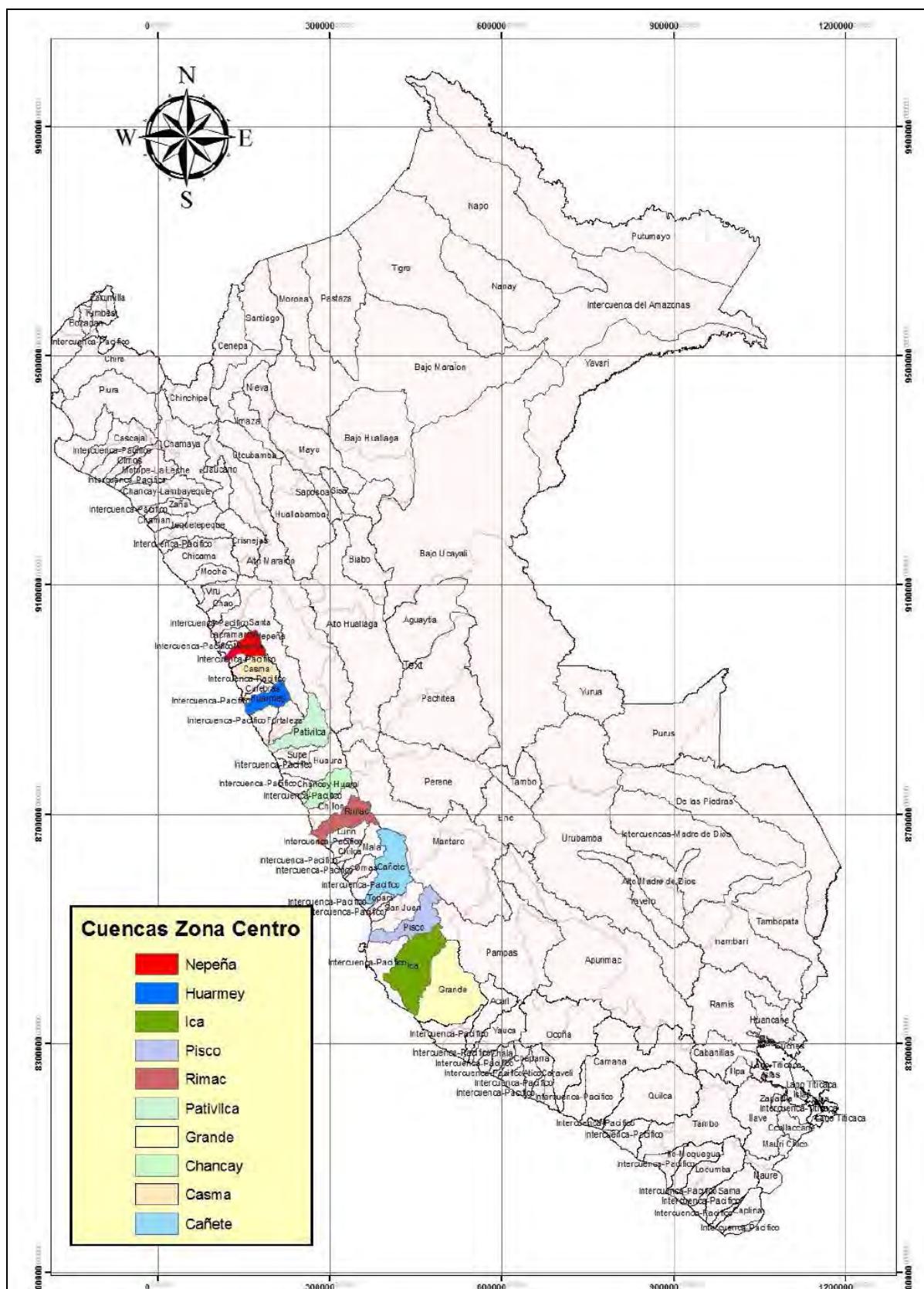


Fig. N°1: Ubicación de las cuencas en estudio

Figure 3.6 Location of Nearby Catchments

Table 3.17 CN Values for Ica River Basin

Cuadro N°35: Características de las subcuenca.-Río Ica						
Dren	Nombre	Río	Area (Km2)	RivLen (m)	River S (m/m)	CN
112	W1120	R40	474,88	35171,64	0,044382	85
113	W1130	R20	842,51	2583,67	0,043736	85
124	W1240	R260	908,17	7498,26	0,067749	78
134	W1340	R440	1018,90	28218,07	0,042845	72
177	W1770	R560	750,36	8107,34	0,008881	74
178	W1780	R710	965,16	6776,21	0,009445	76
179	W1790	R970	595,95	12454,52	0,002168	79
220	W2200	R670	1697,10	10137,58	0,064611	76
190	W1900	R750	459,60	5833,19	0,010629	75
198	W1980	R980	119,35	15376,46	0,011511	73
201	W2010	R1030	289,45	5874,87	0,032511	79

Table 3.18 CN Values for Grande River Basin

Cuadro N°36: Características de las subcuenca.-Río Grande						
Dren	Nombre	Río	Area (Km2)	RivLen (m)	River S (m/m)	CN
149	W1490	R20	927,91	5747,12	0,031668	80
170	W1700	R530	948,76	1241,53	0,109542	76
179	W1790	R320	947,40	2232,24	0,147833	80
187	W1870	R250	566,49	9459,92	0,098098	77
197	W1970	R550	855,11	6760,31	0,086978	78
204	W2040	R620	1051,50	5935,73	0,061324	80
210	W2100	R690	145,92	3653,87	0,024631	80
213	W2130	R740	810,28	3536,00	0,071267	79
215	W2150	R720	660,50	5948,33	0,018156	80
216	W2160	R760	73,08	8468,42	0,005314	78
220	W2200	R770	29,61	4812,62	0,004571	79
225	W2250	R830	378,12	14997,89	0,014002	75
226	W2260	R780	1158,10	774,97	0,006452	81
247	W2470	R1090	707,13	10774,12	0,080749	78
248	W2480	R910	777,04	13762,14	0,023398	75
268	W2680	R1320	455,98	1577,07	0,019023	79
277	W2770	R1260	617,04	7087,90	0,012133	77

3.2.5 Probable Flood Discharge and Hydrograph

The probable flood discharge and hydrograph are calculated by HEC-HM. The kinematic wave method is applied for the flood routing of river channel.

The calculation results are as shown in the **Table 3.19 – Table 3.20** and the **Figure 3.7**.

Table 3.21 shows the comparison between the historical and the maximum rate calculated by the discharge analysis for a return period of 50 years. We can notice that the values are consistent with each other, except in the case of the Cañete River Basin. In the case of the basin Canete, as explained below (3.3.2) there is a problem with the accuracy of the data measuring station.

These results are to be used for discharge capacity analysis of river channel, inundation analysis and flood protection planning.

Table 3.19 Probable Flood Discharge

(m³/s)

River/Reference Point	Return Period of 2-year	Return Period of 5-year	Return Period of 10-year	Return Period of 25-year	Return Period of 50-year	Return Period of 100-year
Chira/ Puente Sullana	890	1,727	2,276	2,995	3,540	4,058
Cañete/ Socsi	331	408	822	1,496	2,175	2,751
Chincha/ Conta	203	472	580	807	917	1,171
Pisco/ Letrayoc	213	287	451	688	855	962
Yauca/ San Francisco Alto	24	37	90	167	263	400
Majes-Camana/ Huatiapa	360	638	1,007	1,566	2,084	2,703

Table 3.20 Probable Specific Flood Discharge

(m³/s/km²)

River/Reference Point	Return Period of 2-year	Return Period of 5-year	Return Period of 10-year	Return Period of 25-year	Return Period of 50-year	Return Period of 100-year	Basin Area Km2
Chira/ Puente Sullana	0.066	0.129	0.170	0.224	0.264	0.303	13,390
Cañete/ Socsi	0.058	0.072	0.145	0.264	0.383	0.485	5,676
Chincha/ Conta	0.068	0.158	0.195	0.271	0.308	0.393	2,981
Pisco/ Letrayoc	0.069	0.093	0.147	0.224	0.279	0.313	3,070
Yauca/ San Francisco Alto	0.008	0.012	0.028	0.052	0.082	0.125	3,198
Majes-Camana/ Huatiapa	0.024	0.050	0.078	0.122	0.162	0.210	12,854

* Basin area is up stream area of reference point

* Chira basin includes territory of Ecuador

Table 3.21 Comparison of Historical Maximum Discharge and the Peak Discharge Calculated ($t=50$)

(m³/s)

Basin/Base point	Historical Maximum Discharge	Measurement Period	Calculated Peak Discharge ($t=1/50$)
hira Puente Sullana	3,228	34	3,540
Cañete Socsi	900	81	2,175
Chincha Conta	1,203	57	917
Pisco Letrayoc	957	76	855
Yauca San Francisco Alto	212	48	263
Majes-Camaná Huatiapa	2,400	41	2,084

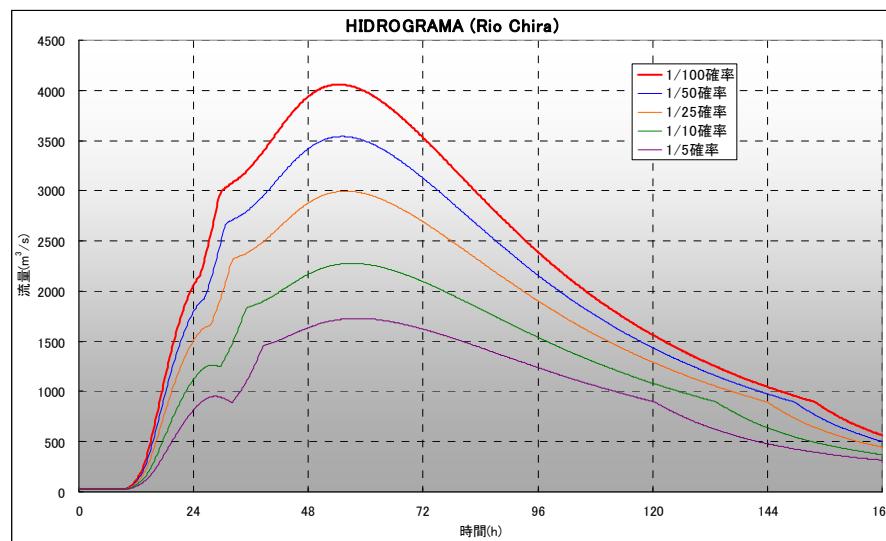


Figure 3.7 Flood Hydrograph in Chira Basin

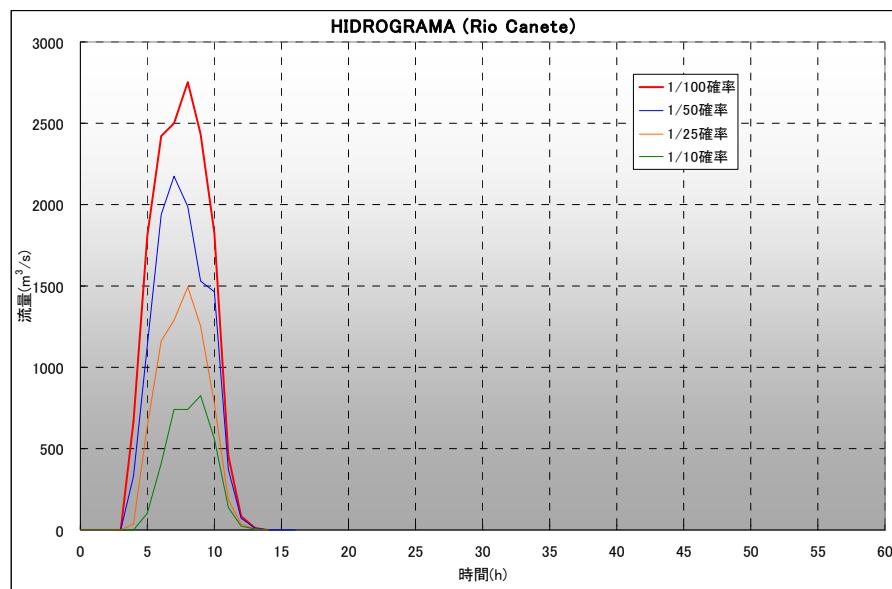


Figure 3.8 Flood Hydrograph in Cañete Basin

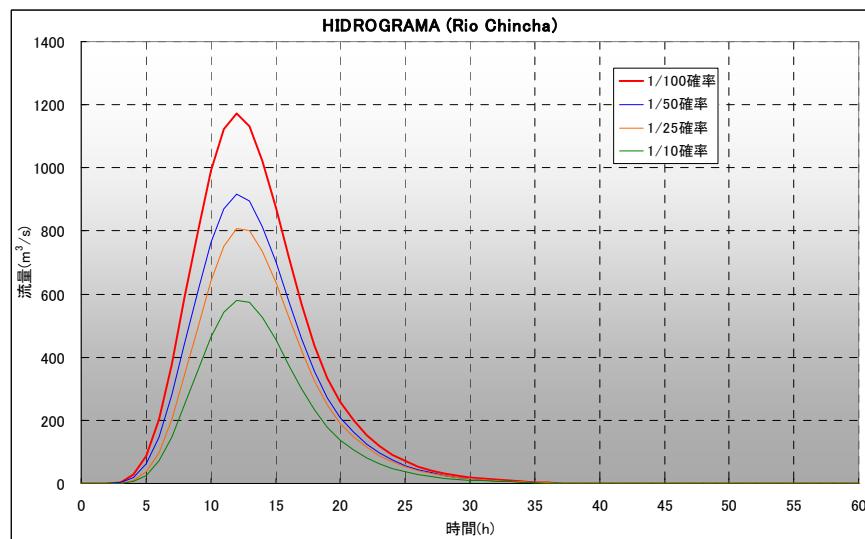


Figure 3.9 Flood Hydrograph in Chincha Basin

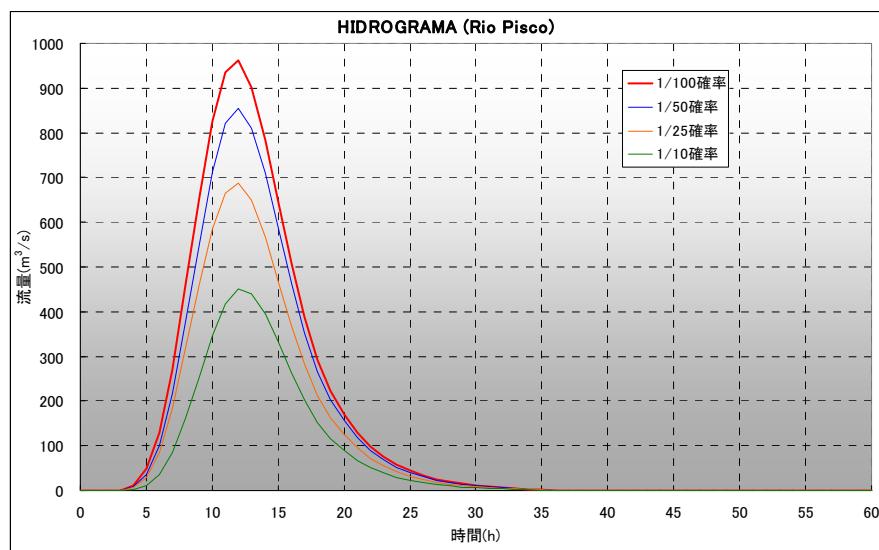


Figure 3.10 Flood Hydrograph in Pisco Basin

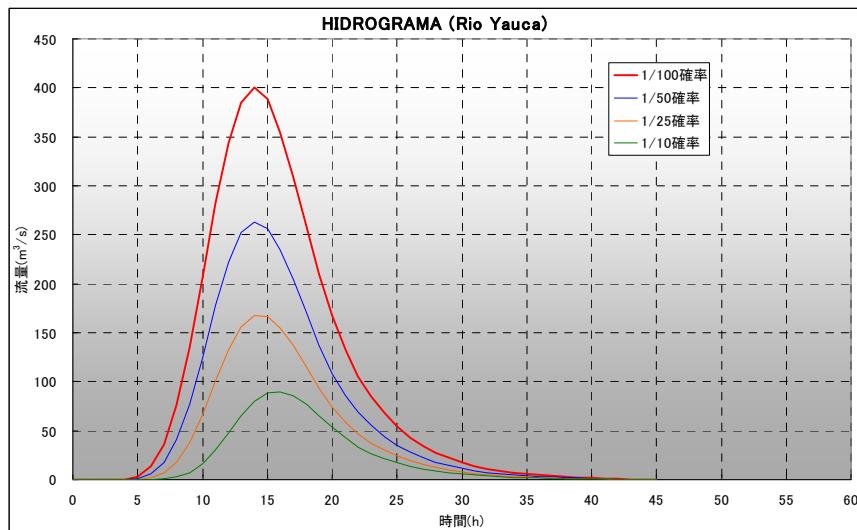


Figure 3.11 Flood Hydrograph in Yauca Basin

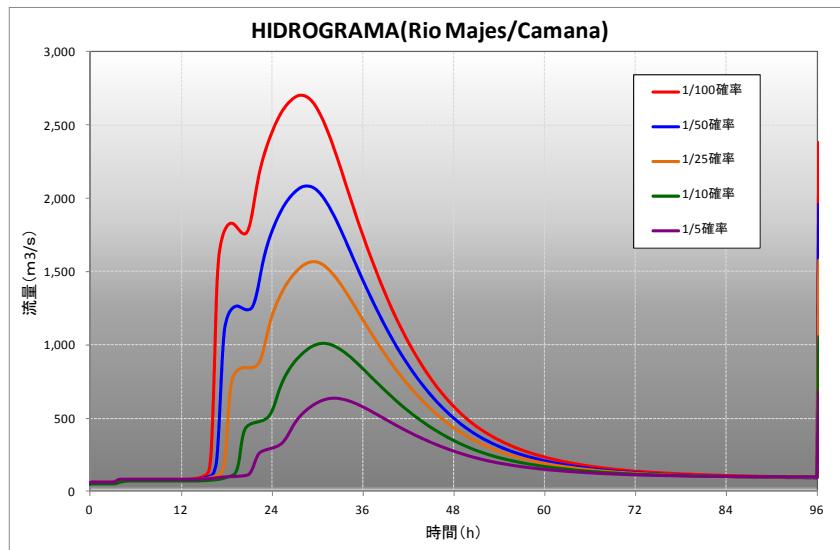


Figure 3.12 Flood Hydrograph in Majes-Camana Basin

3.3 Consideration on Results of Analysis

3.3.1 Verification of Peak Discharge

In **Figure 3.13** to **3.16** is plotted the specific probabilistic return flow and the results of discharges analyzes conducted for each river in coastal area of Peru. (Source: "Estudio Hidrológico - Meteorológico en la Vertiente del Pacífico del Perú con Fines de Evaluación y Pronóstico del Fenómeno El Niño para Prevención y Mitigación de Desastres", Ministerio de Economía y Finanzas, Asociación BCEOM - Sofi Consult S.A. ORSTOM, Nov. 1999.)

Comparing the Creager envelopes curves and the calculated specific flows for each of the basins we can conclude that calculated probabilistic discharges are within the acceptable range.

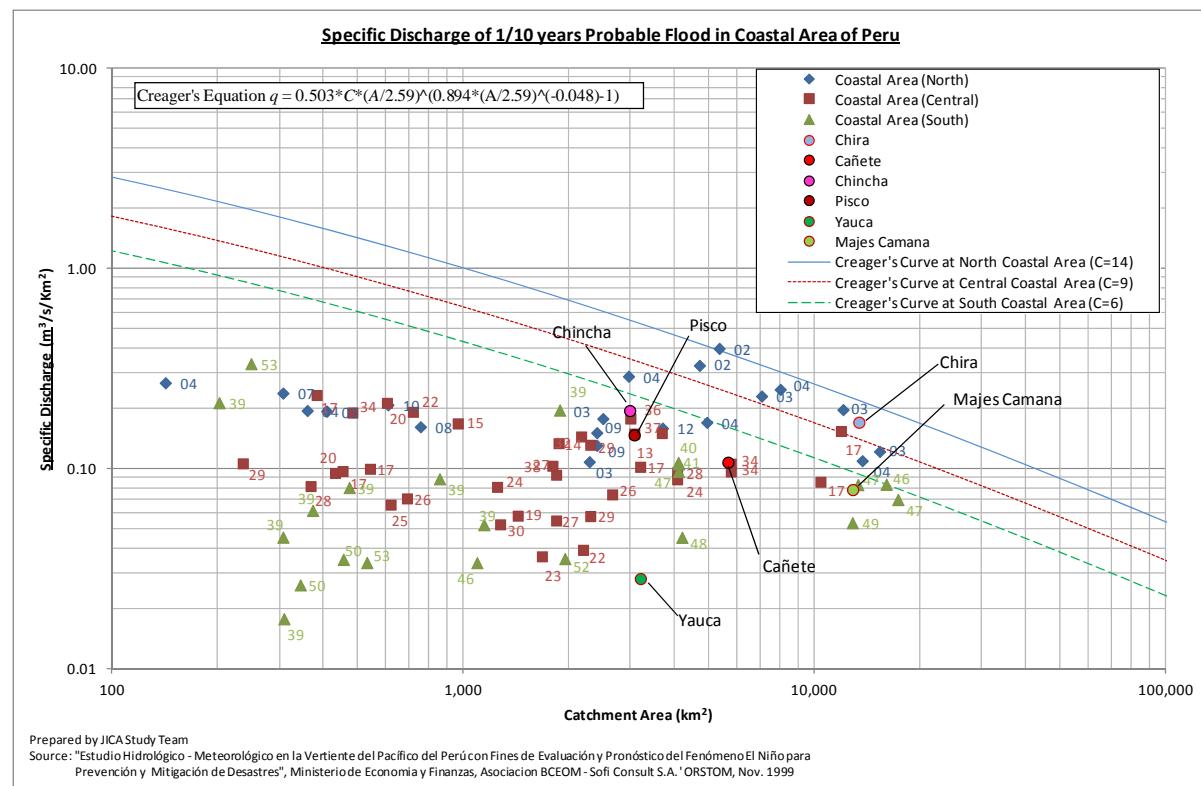


Figure 3.13 Probabilistic Specific Discharges and Calculated Peak Discharges (t=1/10)

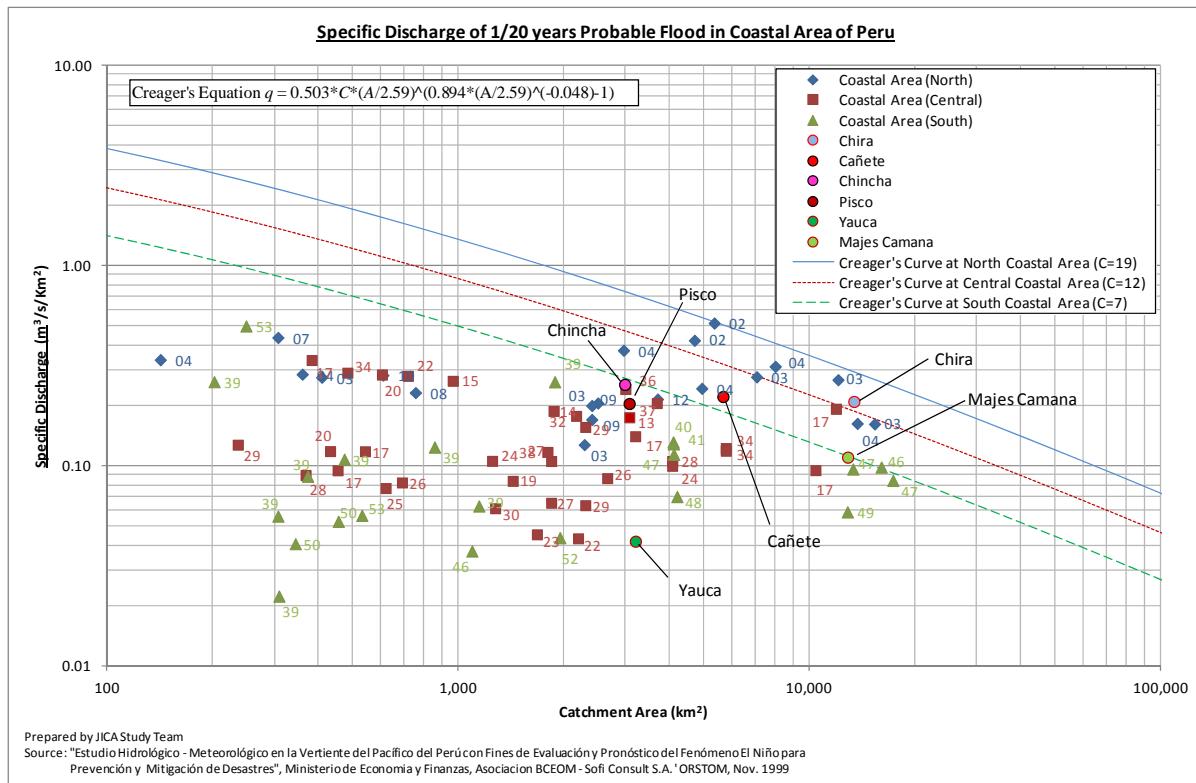


Figure 3.14 Probabilistic Specific Discharges and Calculated Peak Discharges (t=1/20)

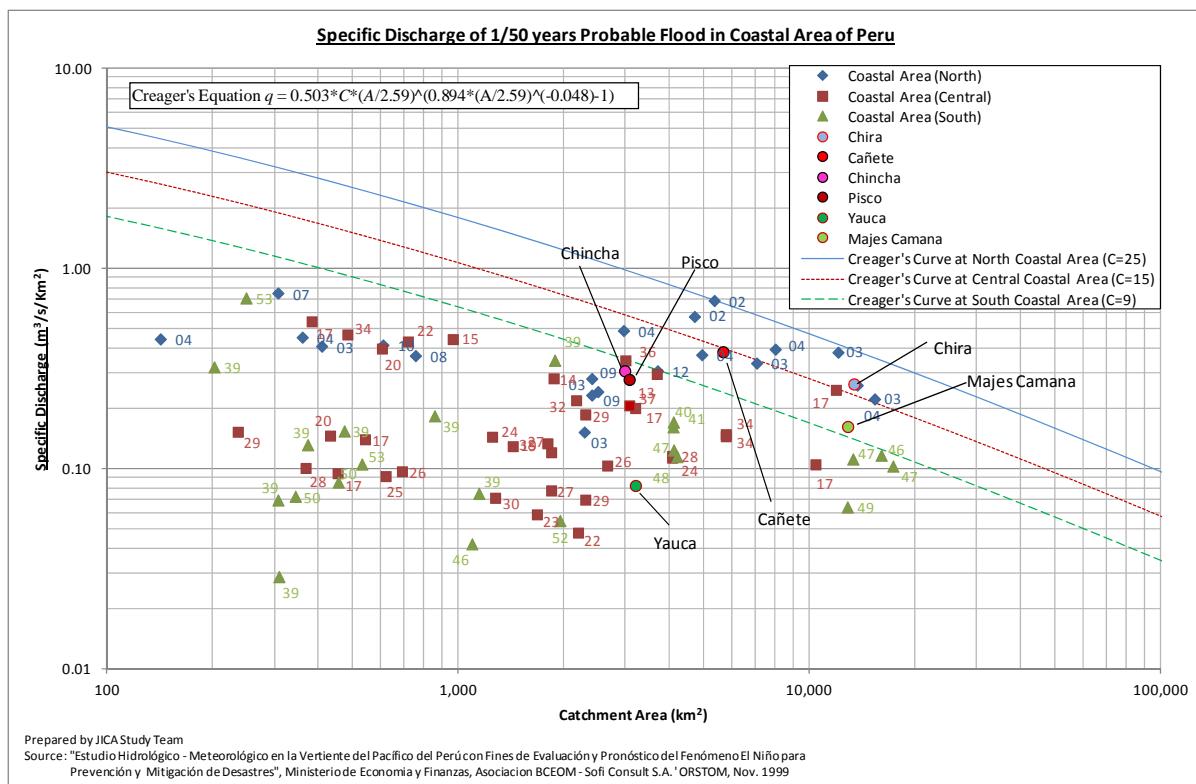


Figure 3.15 Probabilistic Specific Discharges and Calculated Peak Discharges (t=1/50)

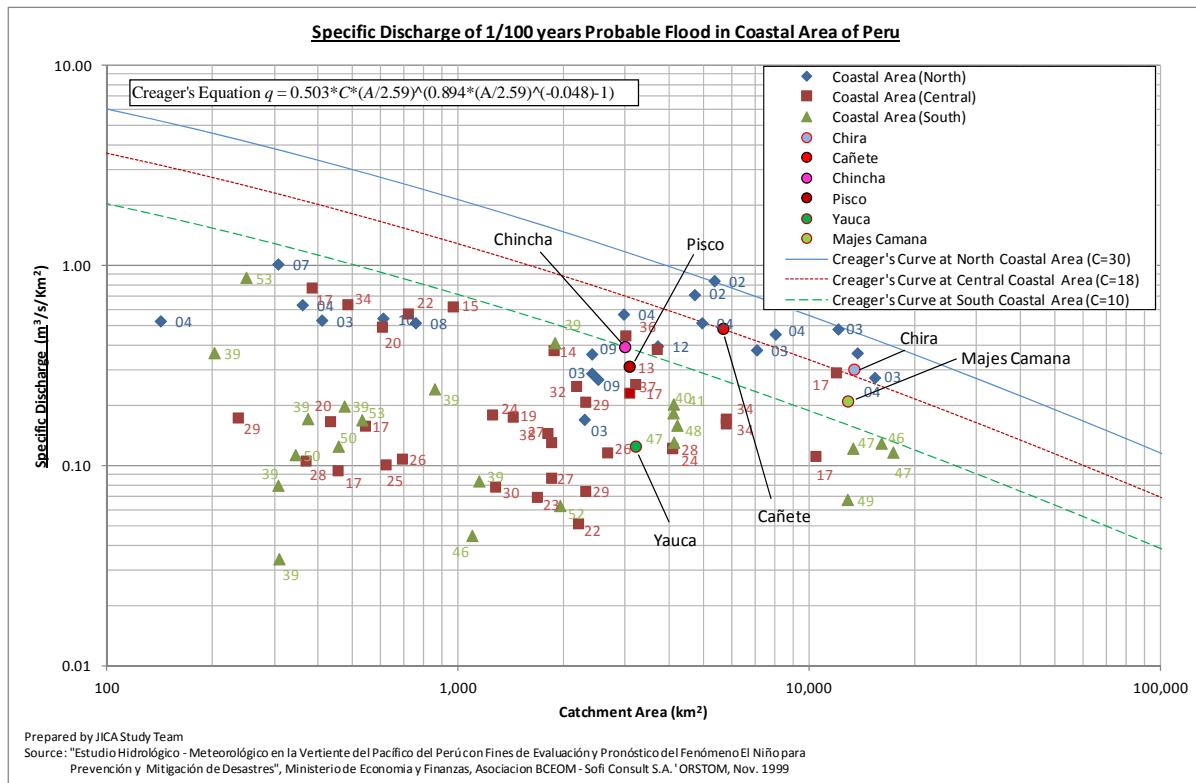


Figure 3.16 Probabilistic Specific Discharges and Calculated Peak Discharges (t=1/100)

3.3.2 Flood Discharge with Return Period of 50-year in Cañete Basin

(1) Upper Limit of Discharge Observation in Socsi Station

The cross section of river channel at Socsi discharge observation station is as shown in the **Figure 3.17**, in which the area at maximum water level (water depth: 2.77m) is as follows:

$$A = (28.17+37.92)*1.0/2+(55.50+66.28)*0.70/2+(66.28+70.88)*1.07/2 = 149.0\text{m}^2$$

The flood discharge velocity at Socsi station is estimated 5~6 m/sec as the station is located at upstream of the objective study area.

Assuming the velocity is 6 m/sec, the discharge will be as follows:

$$Q = AV = 149.0 \times 6.0 = 894\text{m}^3/\text{sec}$$

The maximum observation record in the past is 900 m^3/sec , and which is almost equal to the above discharge, that is to say, the discharge more than this value is difficult to measure in this station.

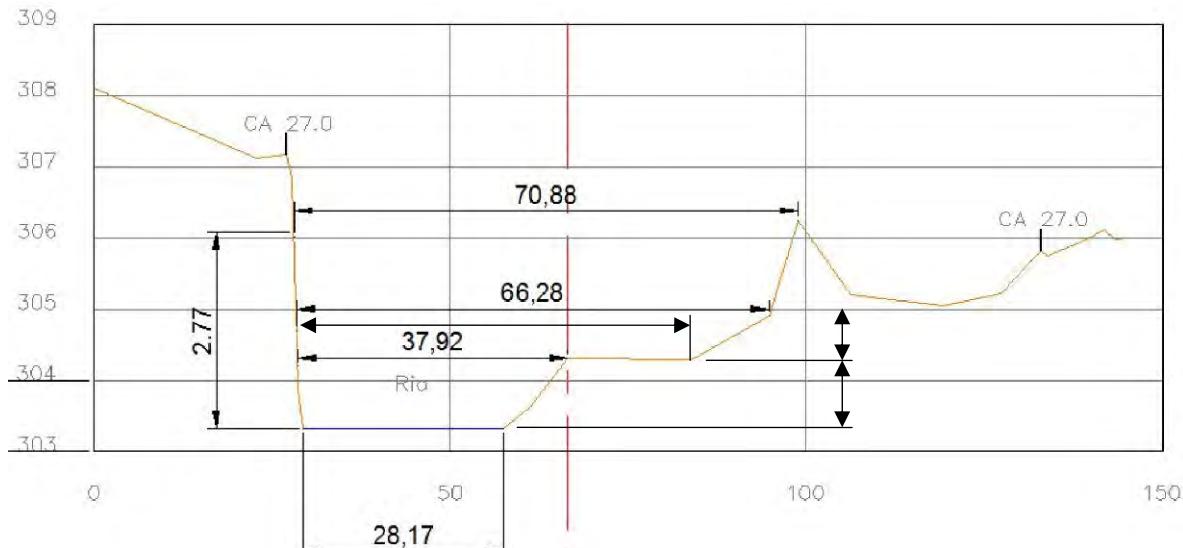


Figure 3.17 Cross section at Sosci Station

(2) Comparison with Adjacent Basin for Probable Flood Discharge

The appropriateness of the discharge obtained from two methods (based of observation data and HEC-HMS analysis) is verified comparing Cañete with the adjacent basins such as Chincha and Pisco which have similar basin characteristics such as topography, surface geology etc.

Cañete basin is located nearest to the capital Lima, and south to which Chincha basin and Pisco basin in this order, therefore the Chincha basin is the most similar to Cañete basin.

1) Run-off Characteristics

The run-off characteristics based on the observation data is as shown in the **Table 3.22**, and the Maximum discharge in Cañete basin is observed extremely small compared with the other basins.

Table 3.22 Run-off Characteristics of Each Basin

Item	Cañete Sosci	Chincha Conta	Pisco Letrayoc
Basin Area (km ²)	5,676	2,981	3,096
Max. Discharge (m ³ /s)	900.0	1,268.8	956.0
Ave. discharge (m ³ /s)	338.8	240.3	296.6
Peak Discharge/Basin Area	0.159	0.426	0.306
Average Discharge/Basin Area	0.060	0.081	0.096
Peak Discharge/Average Discharge	2.657	5.280	3.223

The probable discharges calculated from yearly maximum observation data and their ratio to the value of Chincha basin are as shown in the **Table 3.23** together with specific discharge. Those values of Cañete basin are also extremely small compared with the other basins.

Table 3.23 Comparison of Probable Flood Discharge and Specific Discharge

Items	Cañete		Chincha		Pisco	
Basin Area/Ratio	Basin Area	Ratio	Basin Area	Ratio	Basin Area	Ratio
Basin Area(km^2)	5,676	1.904	2,981	1.000	3,096	1.039
Discharge(m^3/sec)/Ratio	Discharge	Ratio	Discharge	Ratio	Discharge	Ratio
Probability:1/5year	454	1.201	378	1.000	398	1.053
Probability:1/10year	547	1.021	536	1.000	500	0.933
Probability:1/25year	665	0.872	763	1.000	648	0.849
Probability:1/50year	753	0.792	951	1.000	774	0.814
Probability:1/100year	840	0.727	1156	1.000	914	0.791
Specific Discharge($\text{m}^3/\text{sec}/\text{km}^2$)/Ratio	Specific Discharge	Ratio	Specific Discharge	Ratio	Specific Discharge	Ratio
Probability:1/5year	0.080	0.631	0.127	1.000	0.129	1.014
Probability:1/10year	0.096	0.563	0.180	1.000	0.161	0.898
Probability:1/25year	0.117	0.458	0.256	1.000	0.209	0.818
Probability:1/50year	0.133	0.416	0.319	1.000	0.250	0.784
Probability:1/100year	0.148	0.382	0.388	1.000	0.295	0.761

2) Rainfall Characteristics

The probable 24-hour rainfall at the reference point of each basin is as shown in the **Table 3.24**. The rainfall amount in Cañete basin is larger than in the other basins.

Table 3.24 Probable 24-hour Rainfall at Reference Point (mm)

Probable Year	Cañete	Chincha	Pisco
1/5 year	25.5	23.4	28.9
1/10 year	30.3	27.4	33.2
1/25 year	37.3	32.2	38.8
1/50 year	43.1	35.6	42.6
1/100 year	49.4	39.1	46.9

In order to estimate the total rainfall amount which affects the flood discharge, the total rainfall amount in the basin is calculated by multiplying the probable 24-hour rainfall amount with total basin area, of which result is as shown in the **Table 3.25**.

Table 3.25 Probable Total 24-hour Rainfall Amount at Reference Point (1,000m³)

Probable Year	Cañete	Chincha	Pisco
1/5 year	144,738	69,755	89,474
1/10 year	171,983	81,679	102,787
1/25 year	211,715	95,988	120,125
1/50 year	244,636	106,124	131,890
1/100 year	280,394	116,557	145,202

3) Evaluation of Probable Observation Discharge in Cañete Basin

a) Probable Specific Discharge at Reference Point

The probable specific discharge is as shown in the **Table 3.26**, in which the probable specific discharge in Cañete basin is extremely small compared with the other basins so that it can be concluded that the probable discharge calculated based on the observation data in Cañete basin is questionable.

Table 3.26 Probable Specific Discharge at Reference Point (m³/sec/km²)

Probable Year	Cañete	Chincha	Pisco
1/5 year	0.080	0.127	0.129
1/10 year	0.096	0.180	0.161
1/25 year	0.117	0.256	0.209
1/50 year	0.133	0.319	0.250
1/100 year	0.148	0.388	0.295

b) Ratio between Probable Observation Discharge and Probable Total Rainfall Amount

The ratio between the probable observation discharge and the probable total rainfall amount in the basin is as shown in the **Table 3.27**, in which the ratio in Cañete basin does not increase in spite of increase of probability. Generally the more probability increases, the more the ratio increases as shown in the other basins. Therefore, the probable observation discharge in Cañete basin is questionable at this point.

Table 3.27 Ratio between Probable Observation Discharge and Total Rainfall Amount

Probable Year	Cañete	Chincha	Pisco	Average of 3Basin	Average of Chincha and Pisco
1/5 year	0.0031	0.0054	0.0044	0.0043	0.0049
1/10 year	0.0032	0.0066	0.0049	0.0049	0.0057
1/25 year	0.0031	0.0079	0.0054	0.0055	0.0067
1/50 year	0.0031	0.0090	0.0059	0.0060	0.0074
1/100 year	0.0030	0.0099	0.0063	0.0064	0.0081

c) Estimation of Discharge in Cañete Basin from Data of Other Basins

The probable discharges in Cañete basin are estimated with the ratio between the probable discharge and the total rainfall amount in the other basins.

The estimation is performed in case of using the ratio in Chincha basin which is the nearest basin and the average ratio of Chincha and Pisco basins. However the application of Chincha data seems to be more appropriate as the Chincha basin is just adjacent basin.

Table 3.28 Estimation of Probable Discharges in Cañete Basin based on Data of Other Basin

(ratio, m³/sec)

	Chincha	Pisco	Average	Discharge in Cañete	
				Ratio of Chincha	Ratio of Average
1/5 year	0.0054	0.0044	0.0049	784.3	714.1
1/10 year	0.0066	0.0049	0.0057	1128.6	982.6
1/25 year	0.0079	0.0054	0.0067	1682.9	1412.5
1/50 year	0.0090	0.0059	0.0074	2192.2	1813.9
1/100 year	0.0099	0.0063	0.0081	2780.9	2273.0

Note: Ratio: between probable discharge and total 24-hour rainfall in the basin.

Discharge: ratio x total 24-hour rainfall in Cañete basin

(Conclusion)

The comparison among the probable observation discharge in Cañete basin, the estimated discharge based on the ratio between probable discharge and the probable total 24-hour rainfall amount in Chincha basin and the probable discharge obtained from HEC-HMS run-off analysis using 24-hour rainfall data is as shown in the **Table 3.29**.

According to the Table is generally larger than, and in the high probability discharge is extremely same as.

In accordance with the above, it is difficult to adopt the probable discharge based on observation data, and it is appropriate that the probable discharge obtained based on HEC-HMS analysis using 24-hour rainfall data should be used in the further study of this Project.

Table 3.29 Comparison of Probable Discharge in Cañete Basin

Occurrence Probability	Observation Discharge①		Estimated Dicharge by Data of Chincha②		Discharge by HEC-HMS ③	
	Discharge(m ³ /sec)	Ratio to Rainfall	Discharge(m ³ /sec)	Ratio to Rainfall	Discharge(m ³ /sec)	Ratio to Rainfall
1/5year	454	0.0031	784.3	0.0052	408	0.0028
1/10year	547	0.0032	1128.6	0.0073	822	0.0048
1/25year	665	0.0031	1682.9	0.0089	1496	0.0071
1/50year	753	0.0031	2192.2	0.0099	2175	0.0089
1/100year	840	0.0030	2780.9	0.0099	2751	0.0098

Appendix

Appendix-1 Hydrologic Study of Majes-Camana River Basin

Appendix-2 Hydrologic Study of Cañete River Basin

Appendix-3 Hydrologic Study of Chincha River Basin

Appendix-4 Hydrologic Study of Pisco River Basin

Appendix-5 Hydrologic Study of Chira River Basin

Appendix-6 Hydrologic Study of Yauca River Basin

