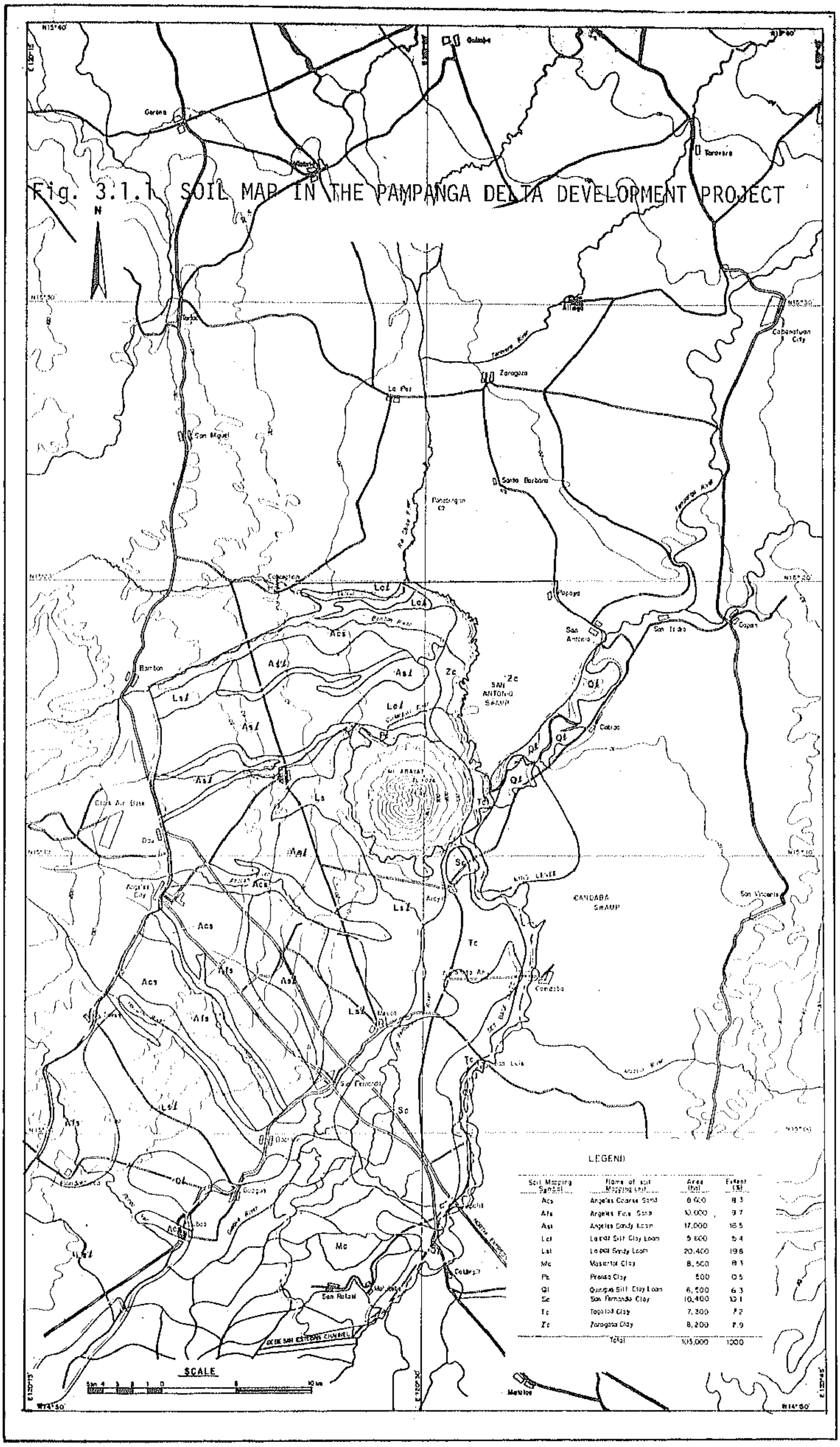
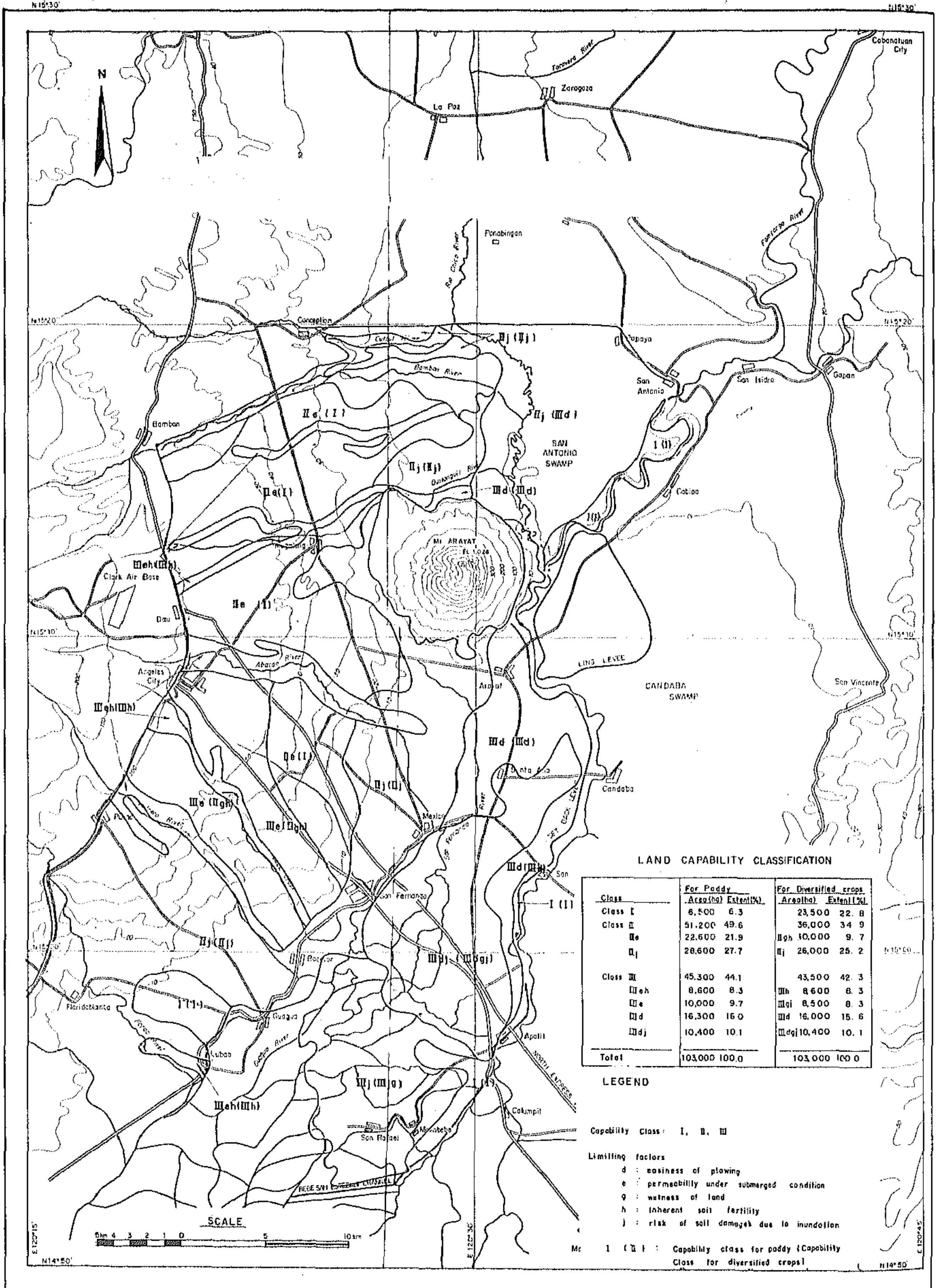
Fig. 3.1.1 SOIL MAP IN THE PAMPANGA DELTA DEVELOPMENT PROJECT



LEGEND

Soil Mapping Symbol	Name of soil Mapping unit	Area (ha)	Extent (%)
Acs	Angeles Coarse Sand	8,600	8.3
Afs	Angeles Fine Sand	10,000	9.7
Asl	Angeles Sandy Loam	17,000	16.5
Lcl	La Paz Silt Clay Loam	5,600	5.4
Lsl	La Paz Sandy Loam	20,400	19.8
Mc	Masantol Clay	8,500	8.3
Pc	Prensa Clay	500	0.5
Ql	Quingua Silt Clay Loam	6,500	6.3
Sc	San Fernando Clay	10,400	10.1
Tc	Tagulod Clay	7,300	7.2
Zc	Zaragoza Clay	8,200	7.9
	Total	103,000	100.0

Fig.3.1.2 LAND CAPABILITY MAP IN THE PAMPANGA DELTA DEVELOPMENT PROJECT



LAND CAPABILITY CLASSIFICATION

Class	For Paddy Area(ha)	For Paddy Extent(%)	For Diversified crops	Area(ha)	Extent(%)
Class I	6,500	6.3		23,500	22. 8
Class II	51,200	49.6		36,000	34 9
IIe	22,600	21.9	IIgh	10,000	9. 7
IIj	28,600	27.7	IIj	26,000	25. 2
Class III	45,300	44.1		43,500	42. 3
IIIeh	8,600	8.3	IIIh	8,600	8. 3
IIIe	10,000	9.7	IIIgi	8,500	8. 3
IIId	16,300	16 0	IIId	16,000	15. 6
IIIdj	10,400	10.1	IIIdgj	10,400	10. 1
Total	103,000	100.0		103,000	100 0

LEGEND

Capability Class : I, II, III

Limiting factors
- d : easiness of plowing
- e : permeability under submerged condition
- g : wetness of land
- h : inherent soil fertility
- j : risk of soil damages due to inundation

I (II) : Capability class for paddy (Capability Class for diversified crops)

Fig.3.3.1 PRESENT LAND USE IN AND AROUND THE RESERVOIR AREA

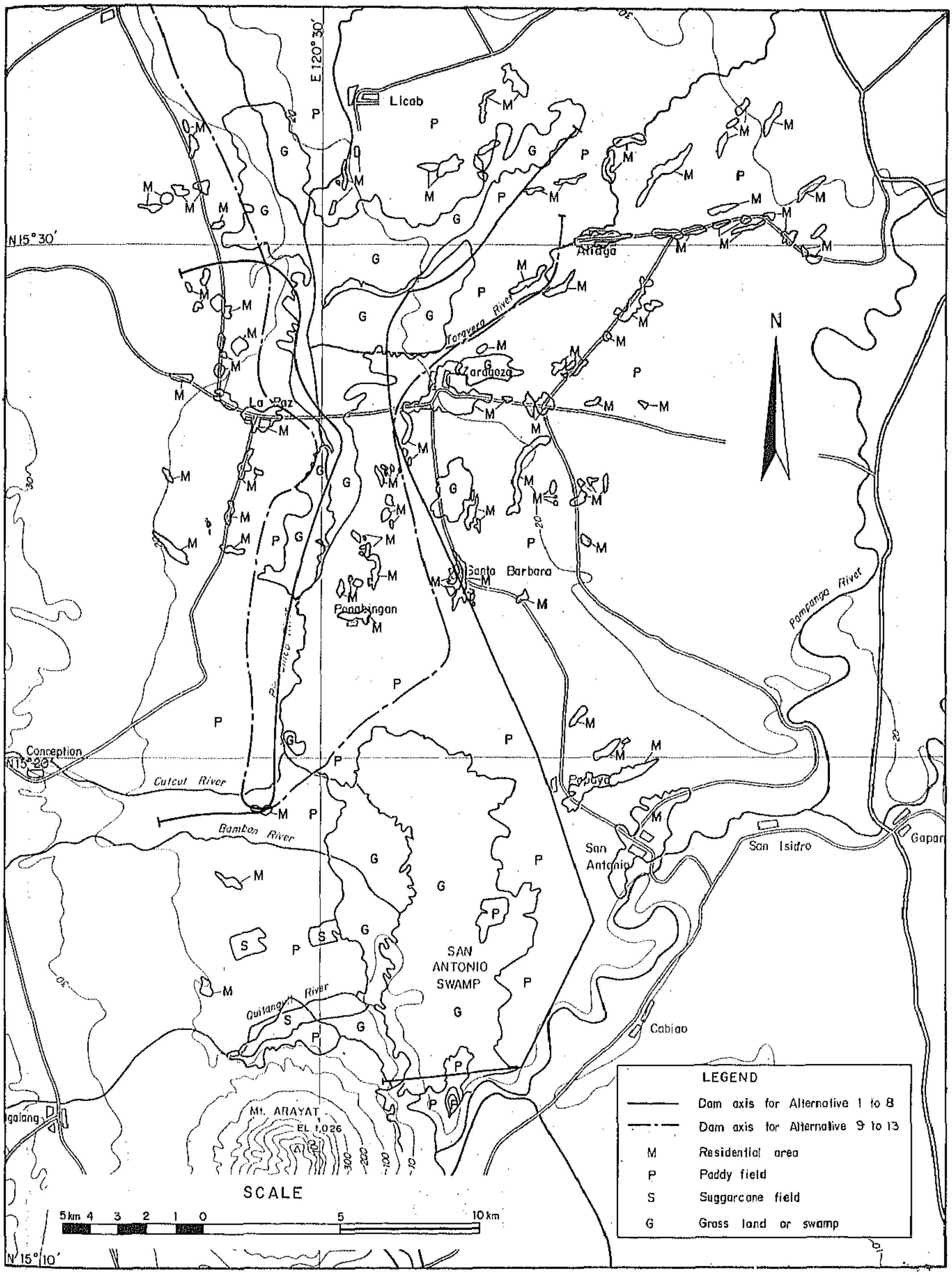


Fig. 3.3.2 NUMBER OF HOUSES WITHIN THE RESERVOIR AREA

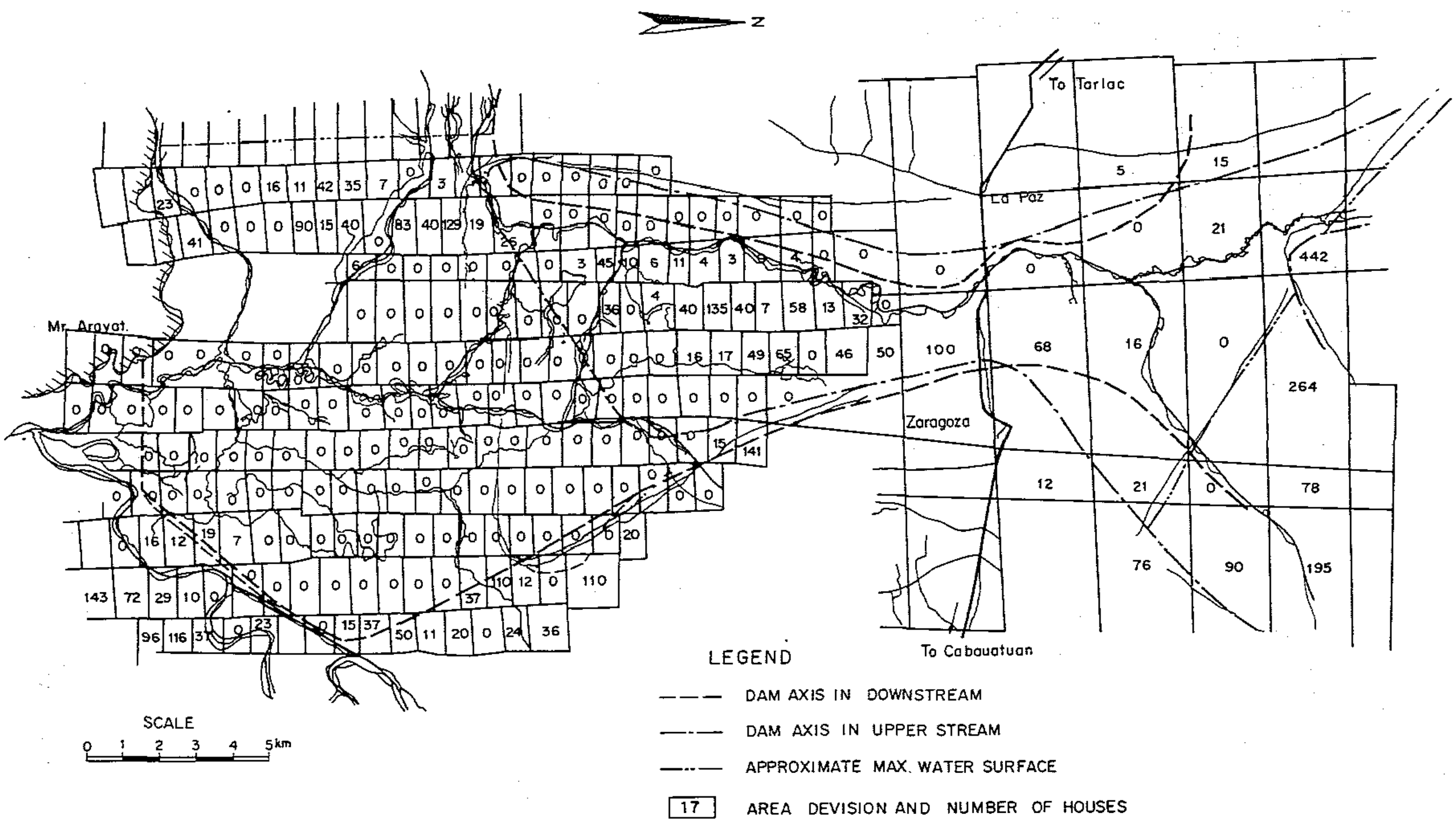


Fig.3.3.3 PRESENT LAND USE IN THE AREA TO BE IRRIGATED

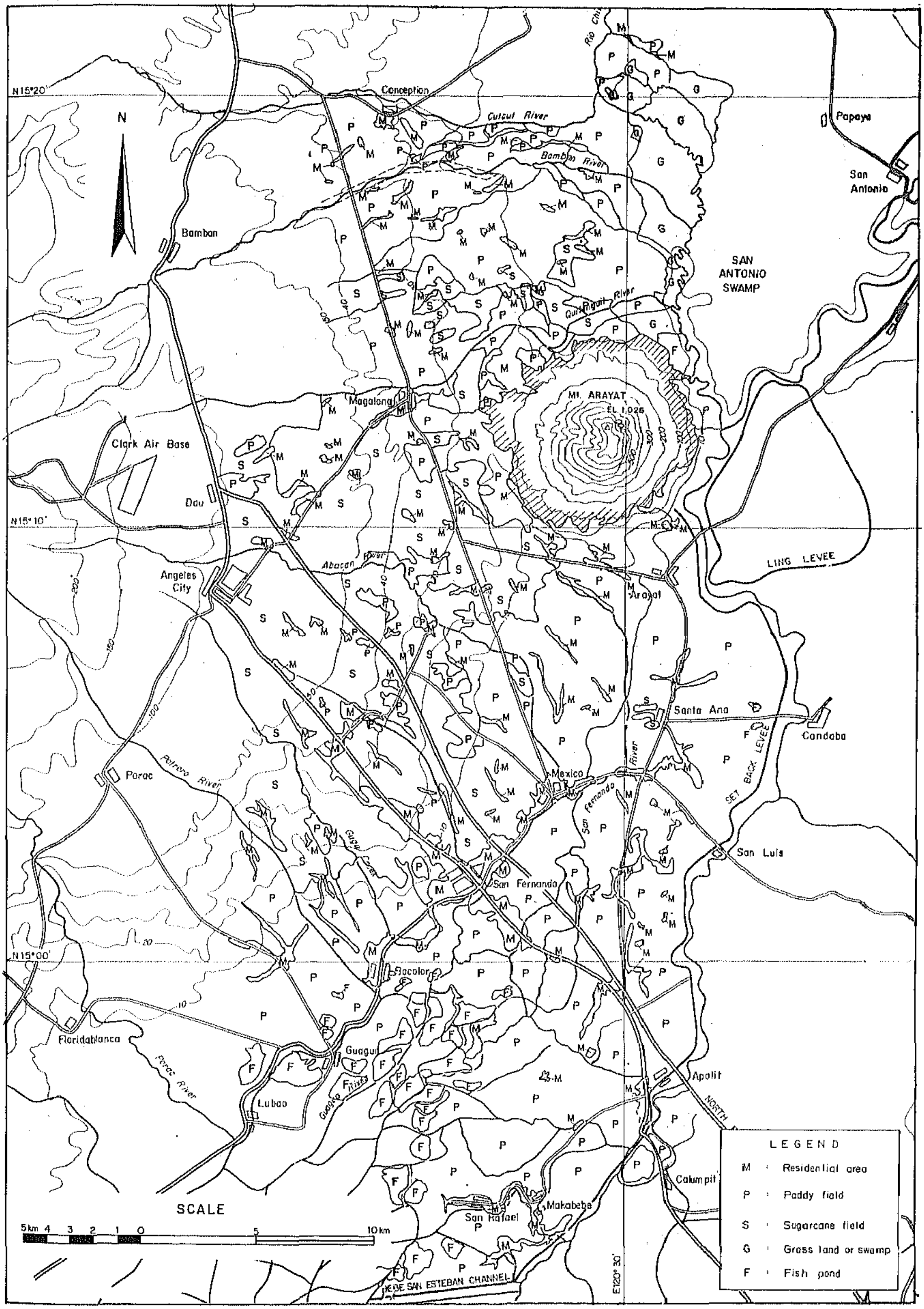
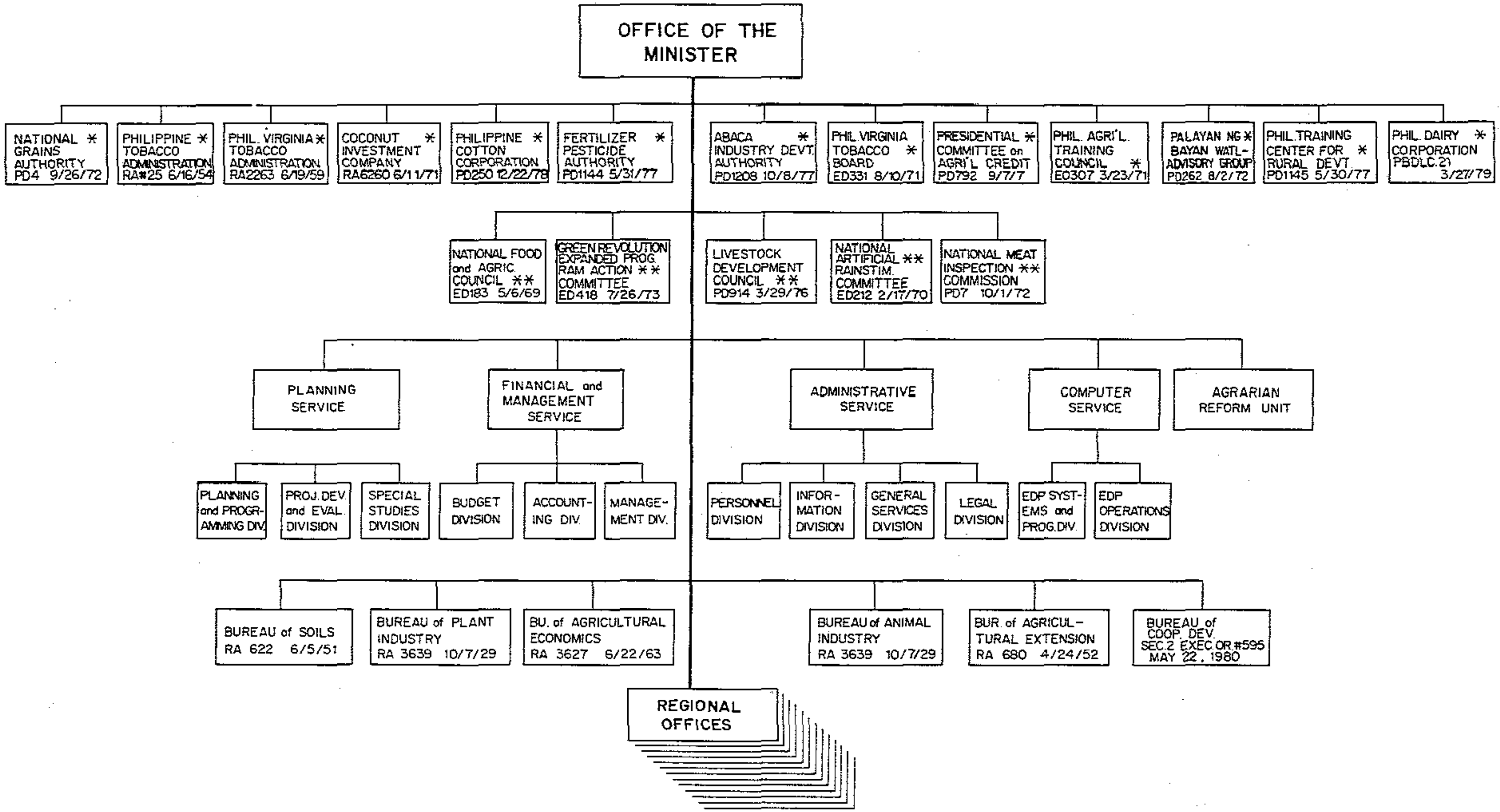


Fig. 3.3.4 ORGANIZATION CHART OF MINISTRY OF AGRICULTURE (AS OF JULY 1980)



* ATTACHED AGENCIES

** AGENCIES UNDER THE ADMINISTRATIVE SUPERVISION OF THE M.A.

Fig.3.3.5 ORGANIZATION CHART OF REGIONAL OFFICE, REGION III MINISTRY OF AGRICULTURE

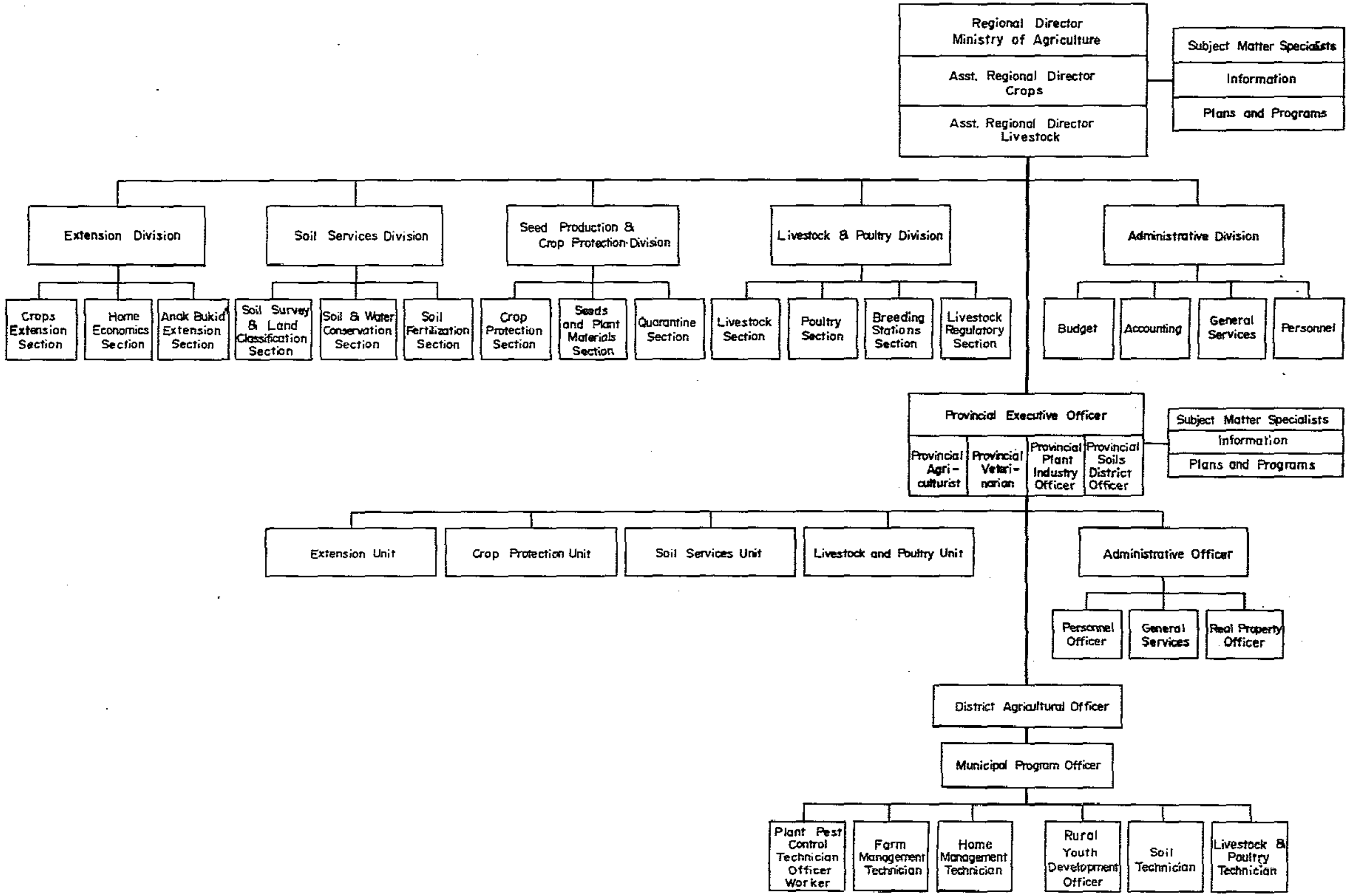


Fig. 3.3.6 ORGANIZATION CHART OF NATIONAL IRRIGATION ADMINISTRATION

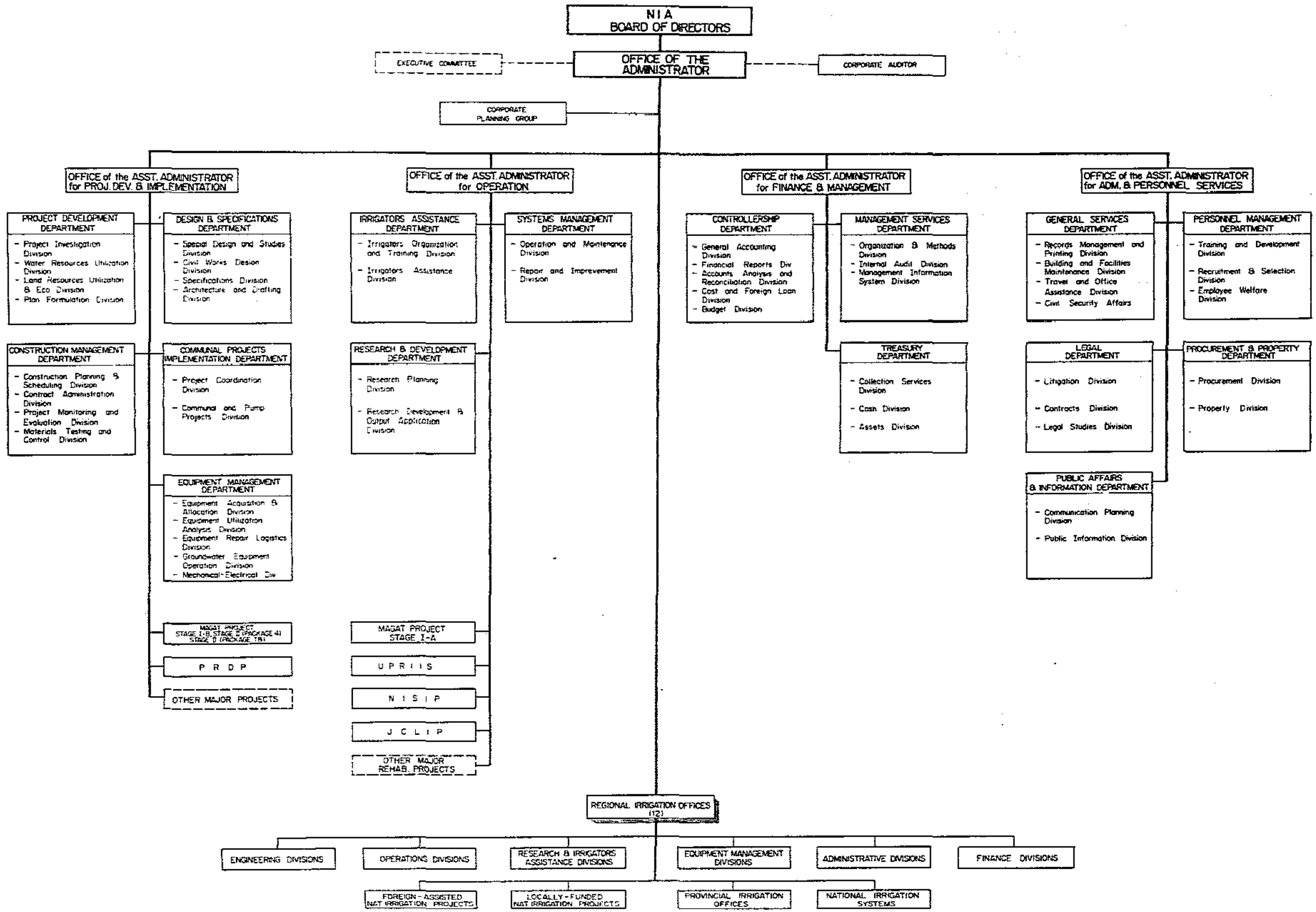


Fig. 3.4.1 EXISTING AND PROPOSED NATIONAL IRRIGATION PROJECT IN PAMPANGA RIVER BASIN

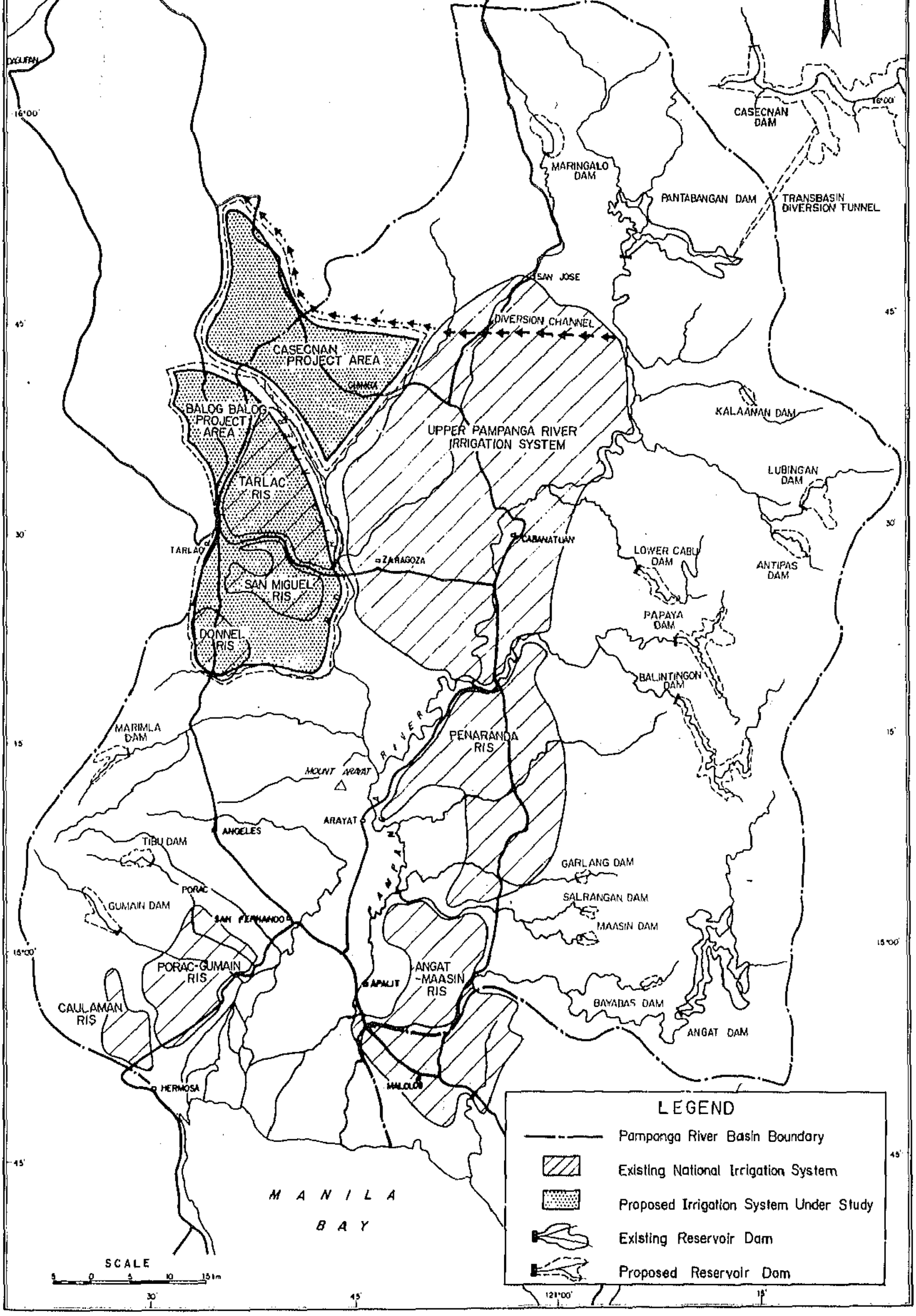
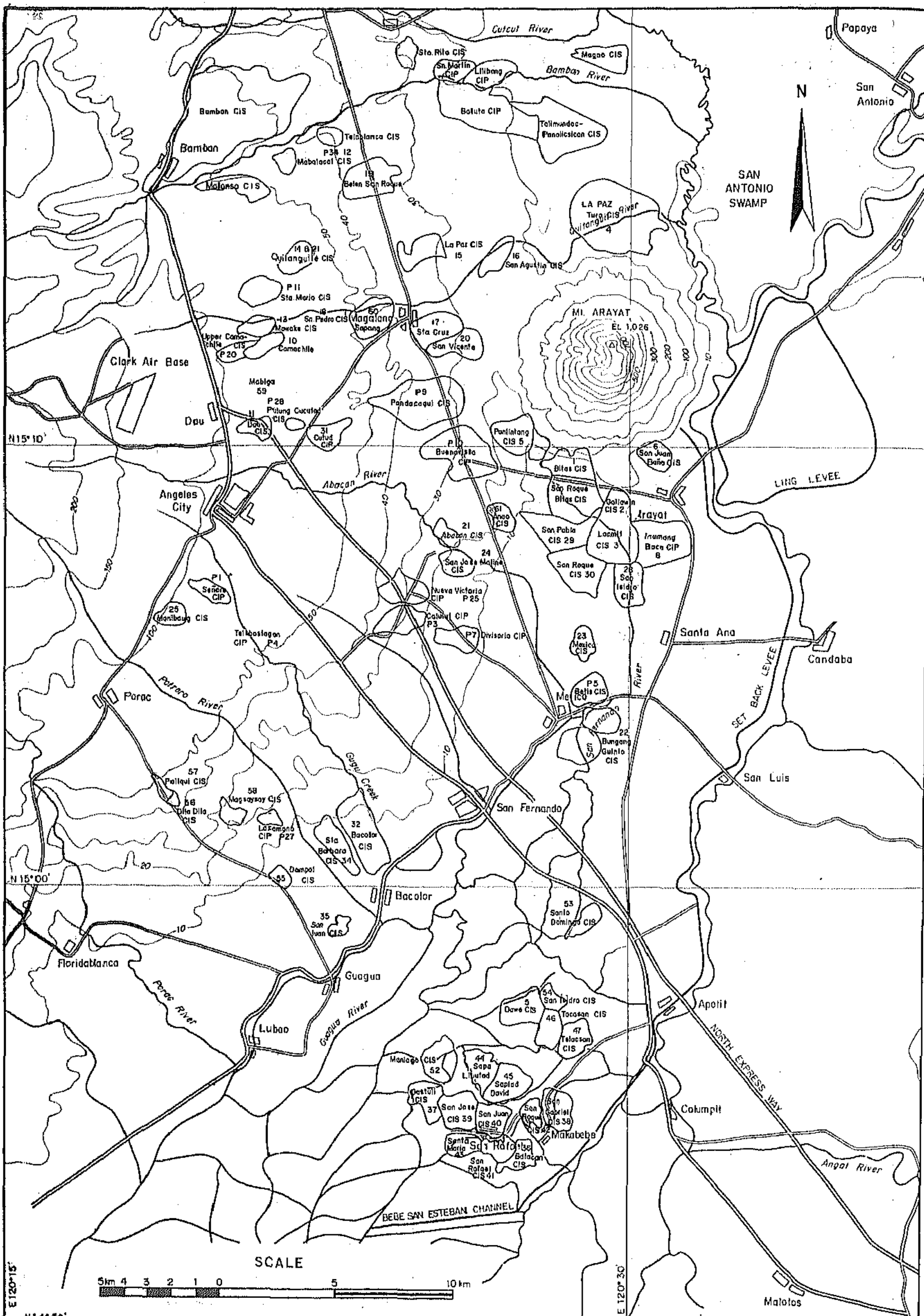


Fig. 3.4.2 LOCATION OF COMMUNAL IRRIGATION SYSTEM



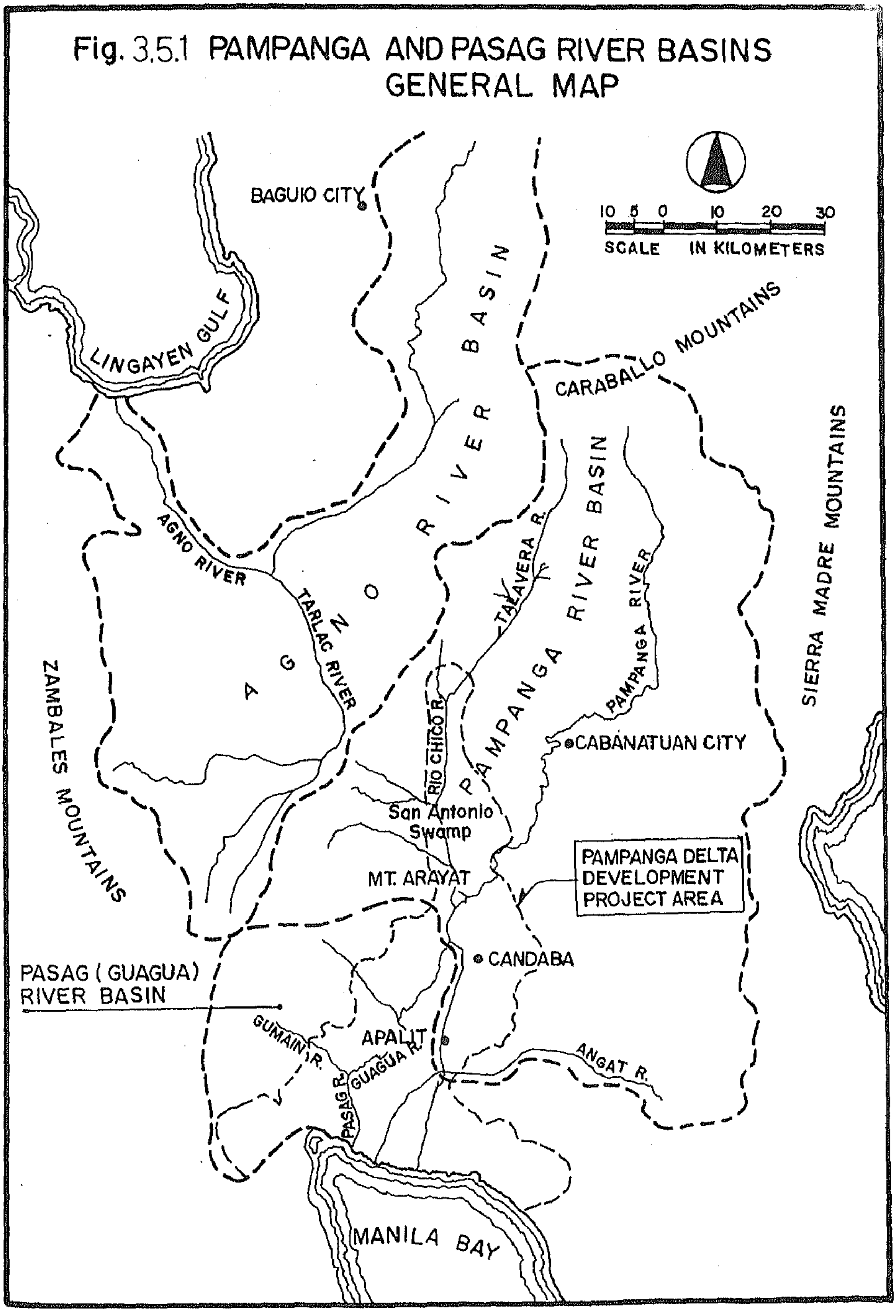


Fig. 3.5.1 PAMPANGA AND PASAG RIVER BASINS GENERAL MAP
BAGUIO CITY
10 5 0 10 20 30
SCALE IN KILOMETERS
LINGAYEN GULF
AGNO RIVER BASIN
CARABALLO MOUNTAINS
SIERRA MADRE MOUNTAINS
PAMPANGA RIVER BASIN
TALAVERA R.
PAMPANGA RIVER
AGNO RIVER
TARLAC RIVER
ZAMBALES MOUNTAINS
RIO CHICO R.
PAMPANGA
CABANATUAN CITY
San Antonio Swamp
MT. ARAYAT
PAMPANGA DELTA DEVELOPMENT PROJECT AREA
CANDABA
PASAG (GUAGUA) RIVER BASIN
GUMAIN R.
APALIT
GUAGUA R.
PASAG R.
ANGAT R.
MANILA BAY

Fig. 3.5.2 PAMPANGA AND PASAG (GUAGUA) RIVER BASINS MAIN HYDROGRAPHIC NETWORK AND CATAHMENT AREAS

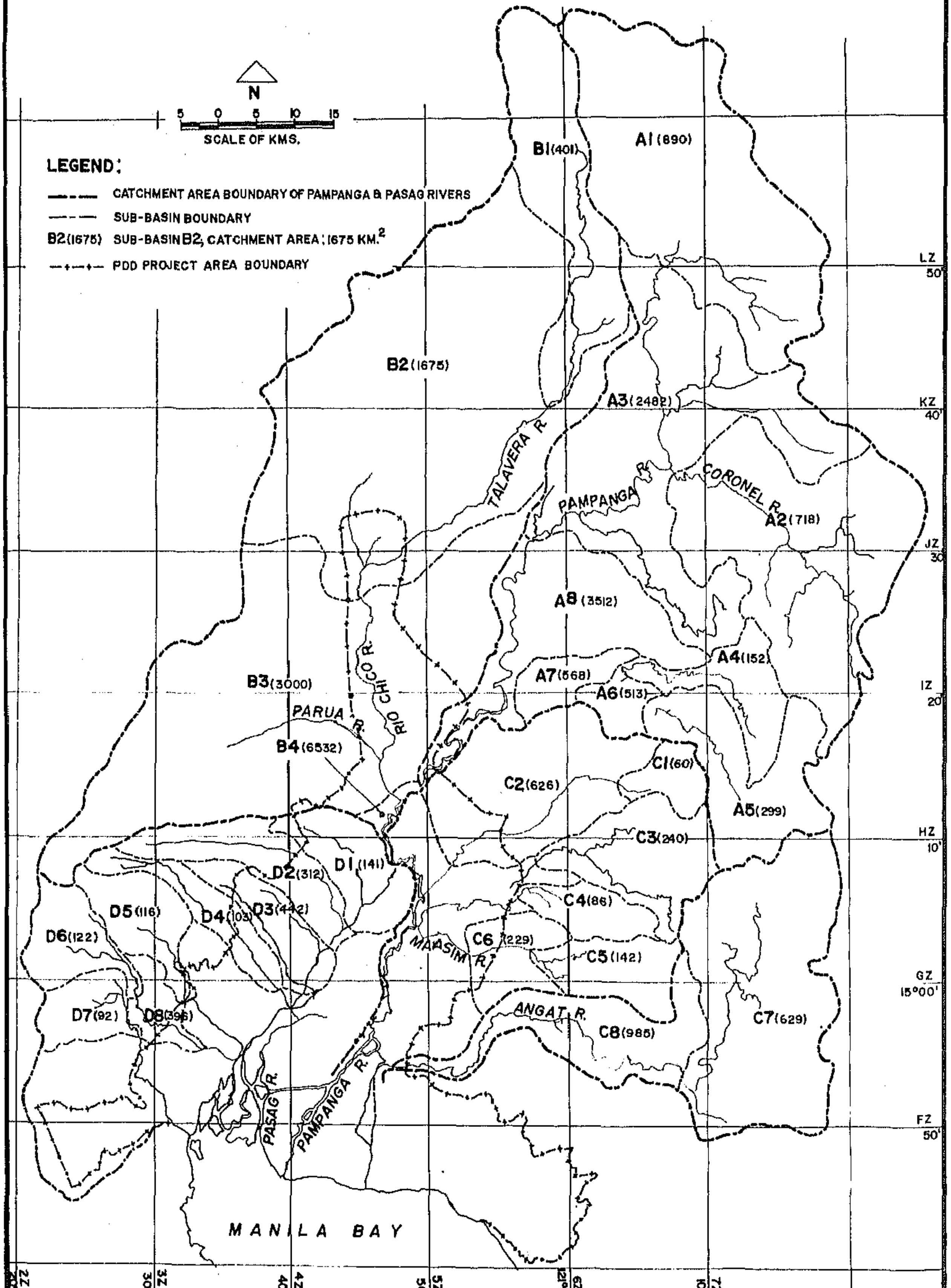


Fig. 3.5.3 LONGITUDINAL PROFILE OF PAMPANGA AND RIO CHICO RIVERS

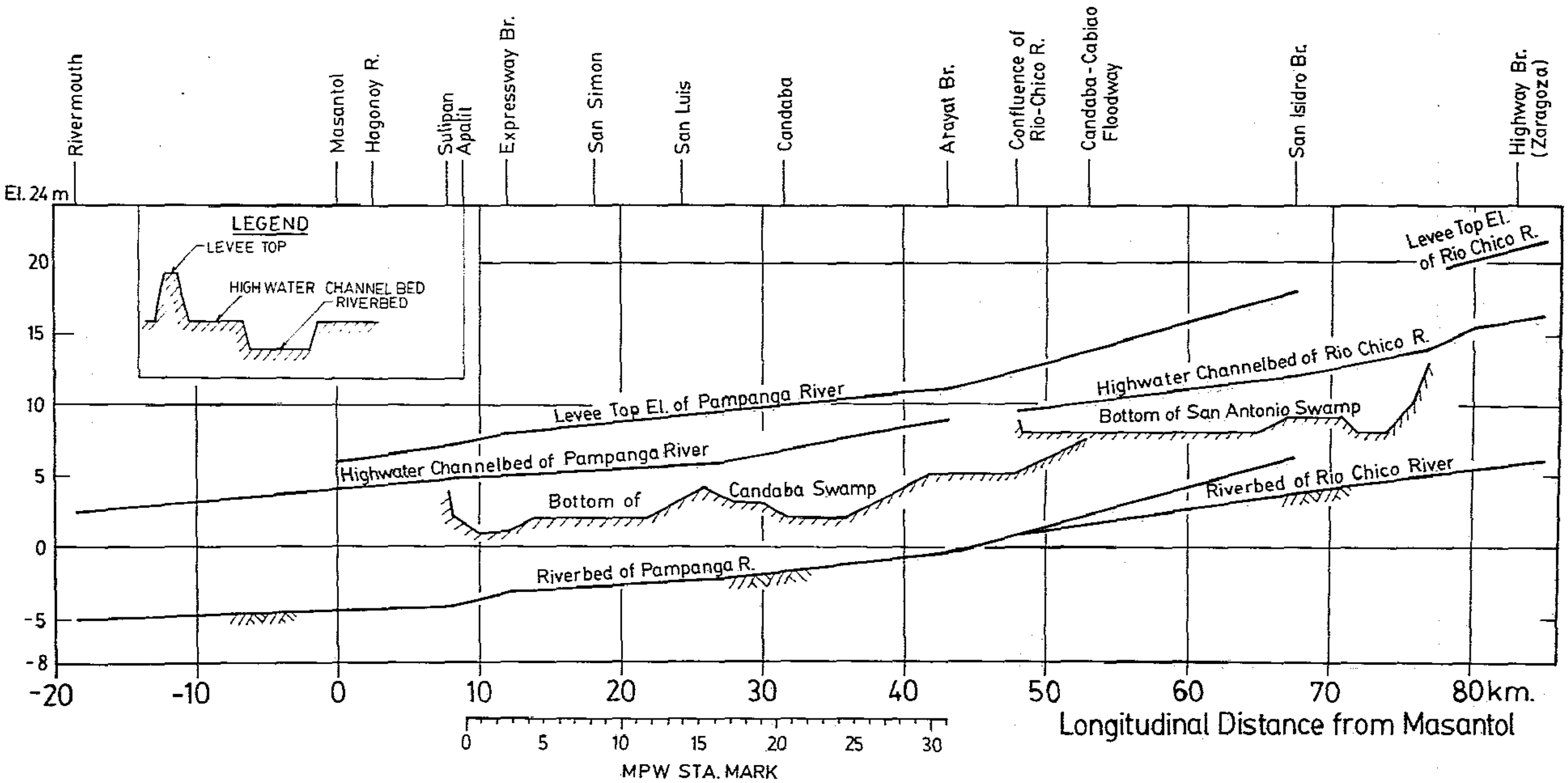


Fig. 3.5.4(1) ELEVATION - AREA, CAPACITY RELATIONS OF NORTH CANDABA SWAMP

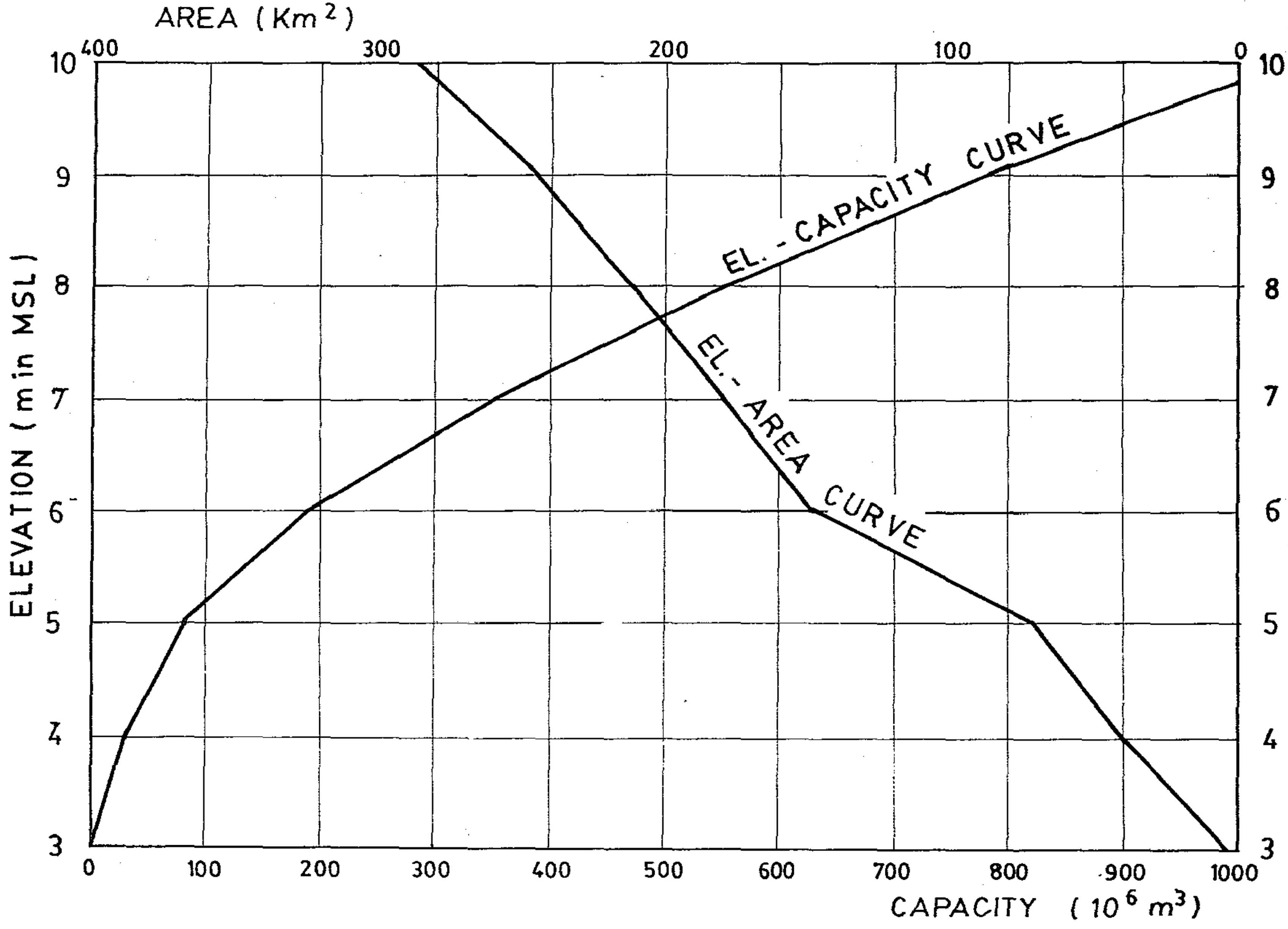
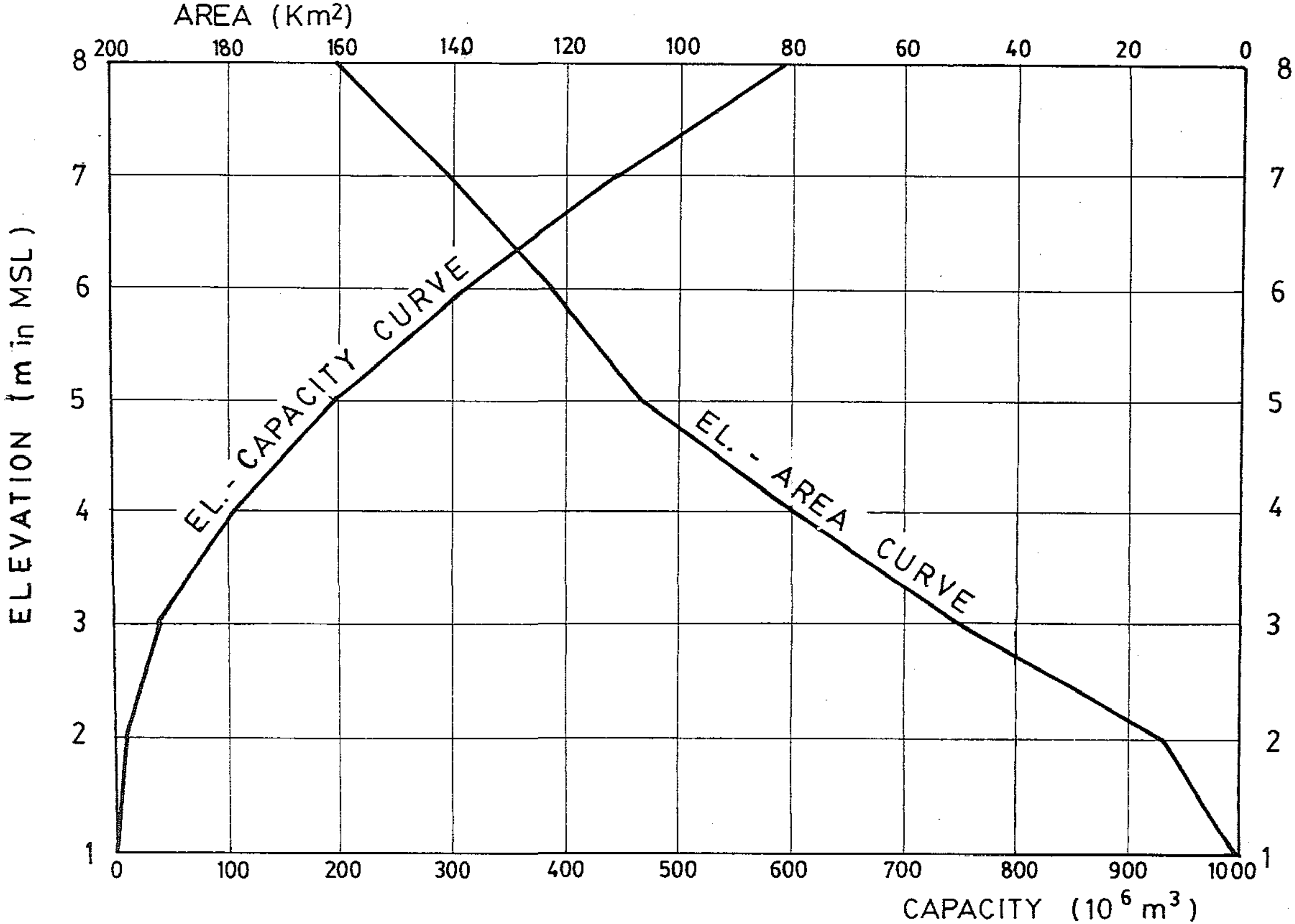


Fig. 3.5.4(2) ELEVATION-AREA, CAPACITY RELATIONS OF SOUTH CANDABA SWAMP



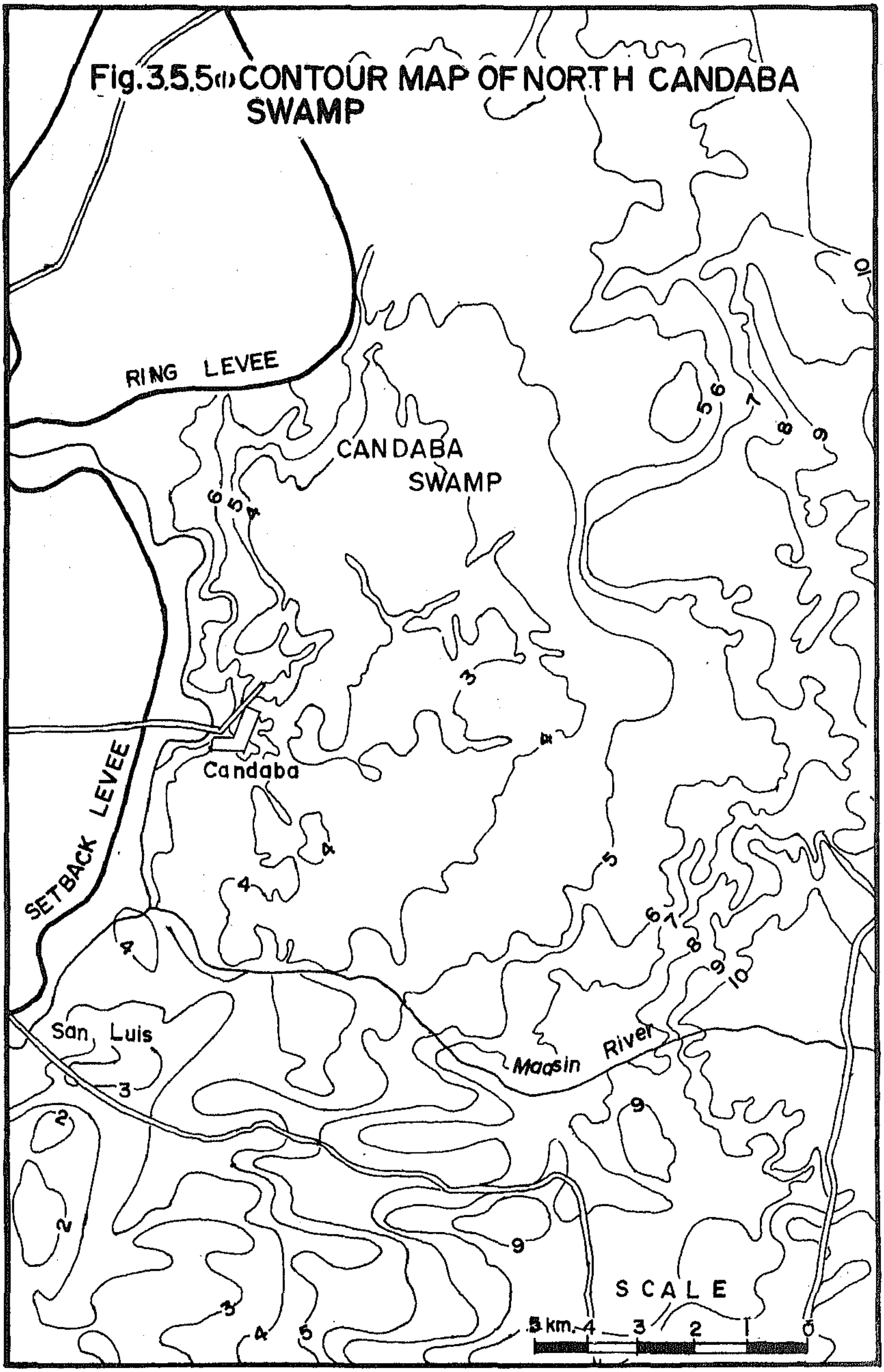


Fig. 3.5.5(1) CONTOUR MAP OF NORTH CANDABA SWAMP
RING LEVEE
CANDABA SWAMP
SETBACK LEVEE
Candaba
San Luis
Maasin River
SCALE
5 km. 4 3 2 1 0

Fig. 3.5.5(2) CONTOUR MAP OF SOUTH CANDABA SWAMP

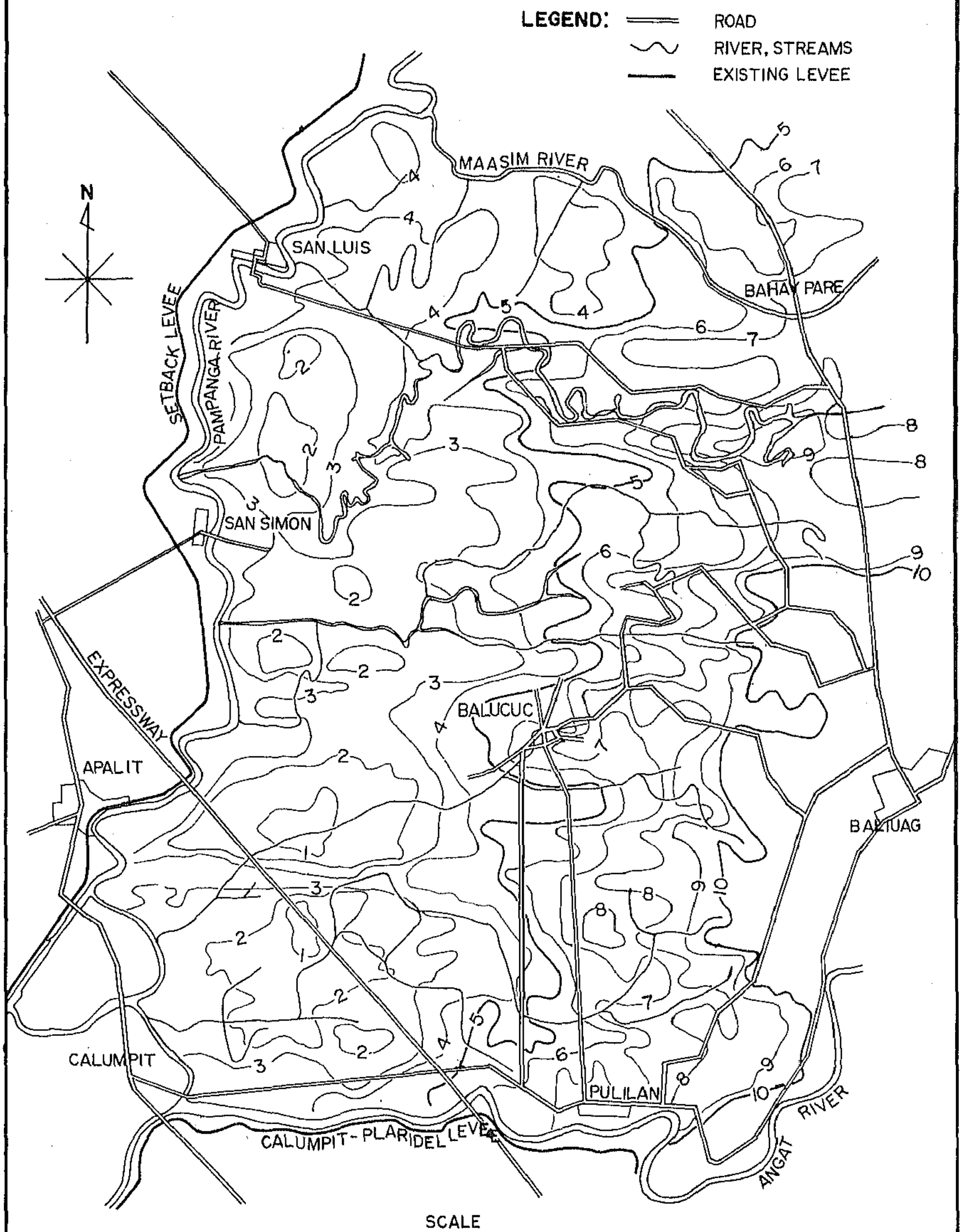


Fig.3.5.6 ELEVATION - AREA, CAPACITY RELATIONS OF SAN ANTONIO SWAMP

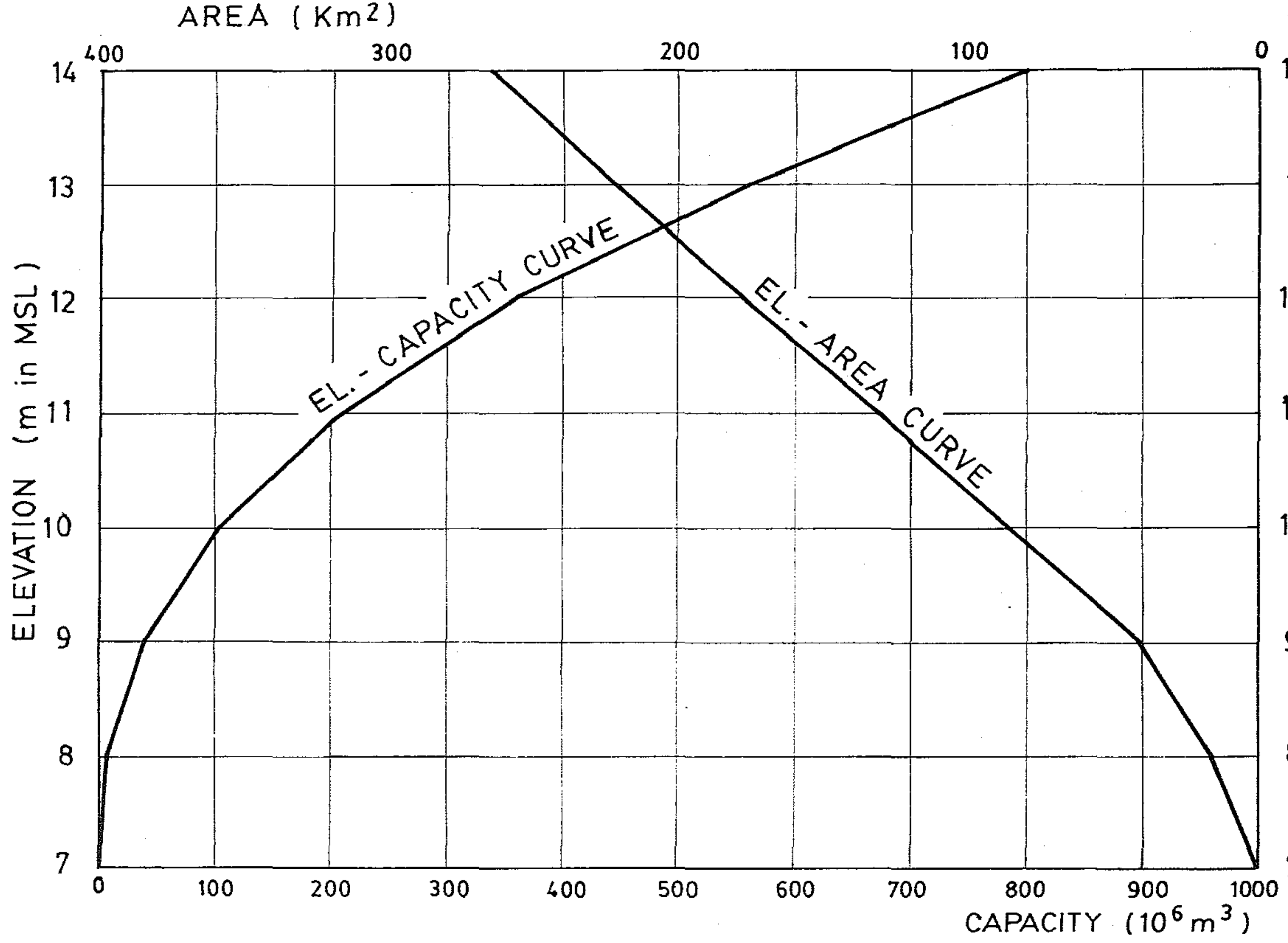


Fig. 3.5.7 CONTOUR MAP OF SAN ANTONIO SWAMP

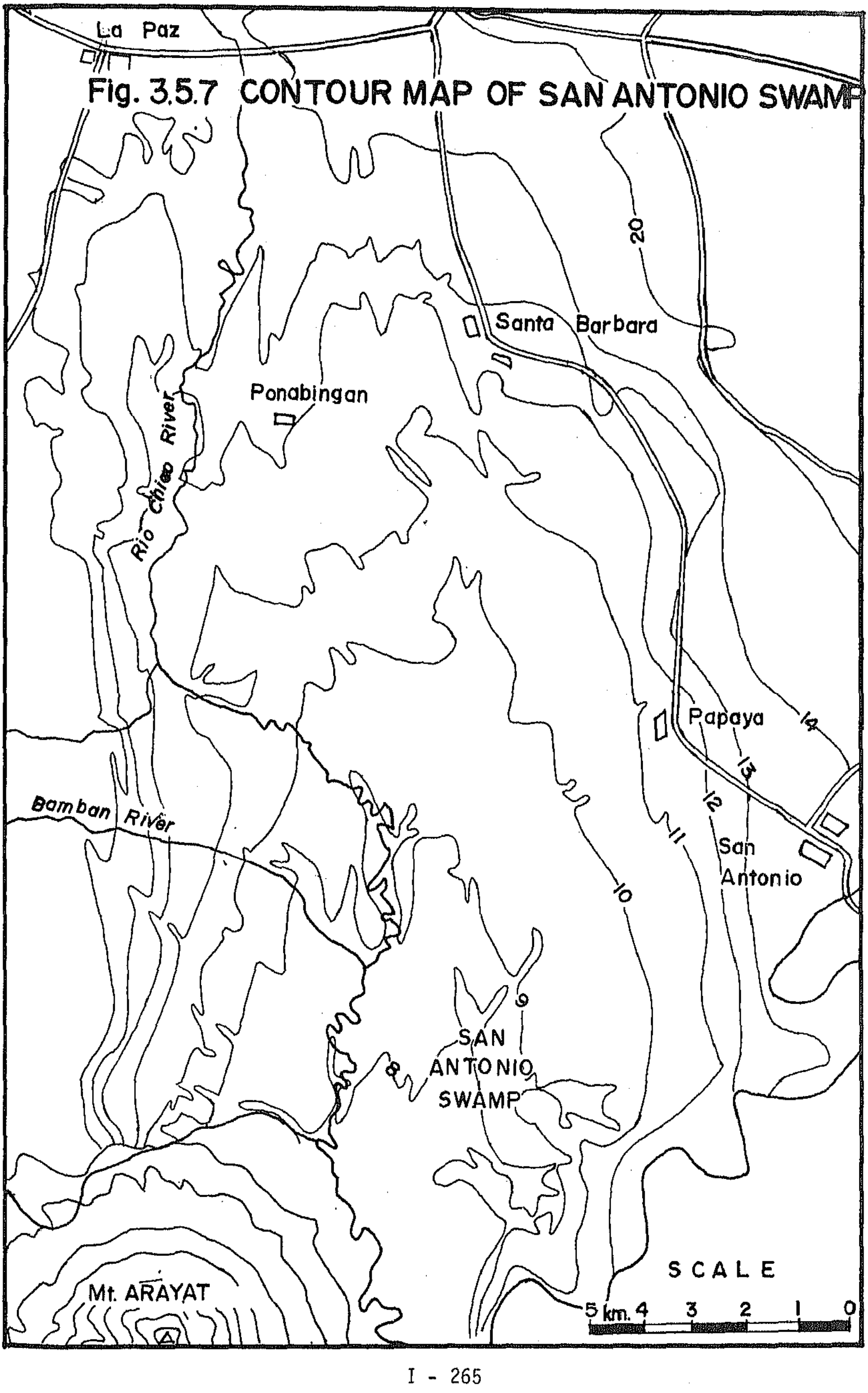


Fig. 3.5.8 LOCATION MAP OF RIVER CROSS-SECTION FOR SURVEY

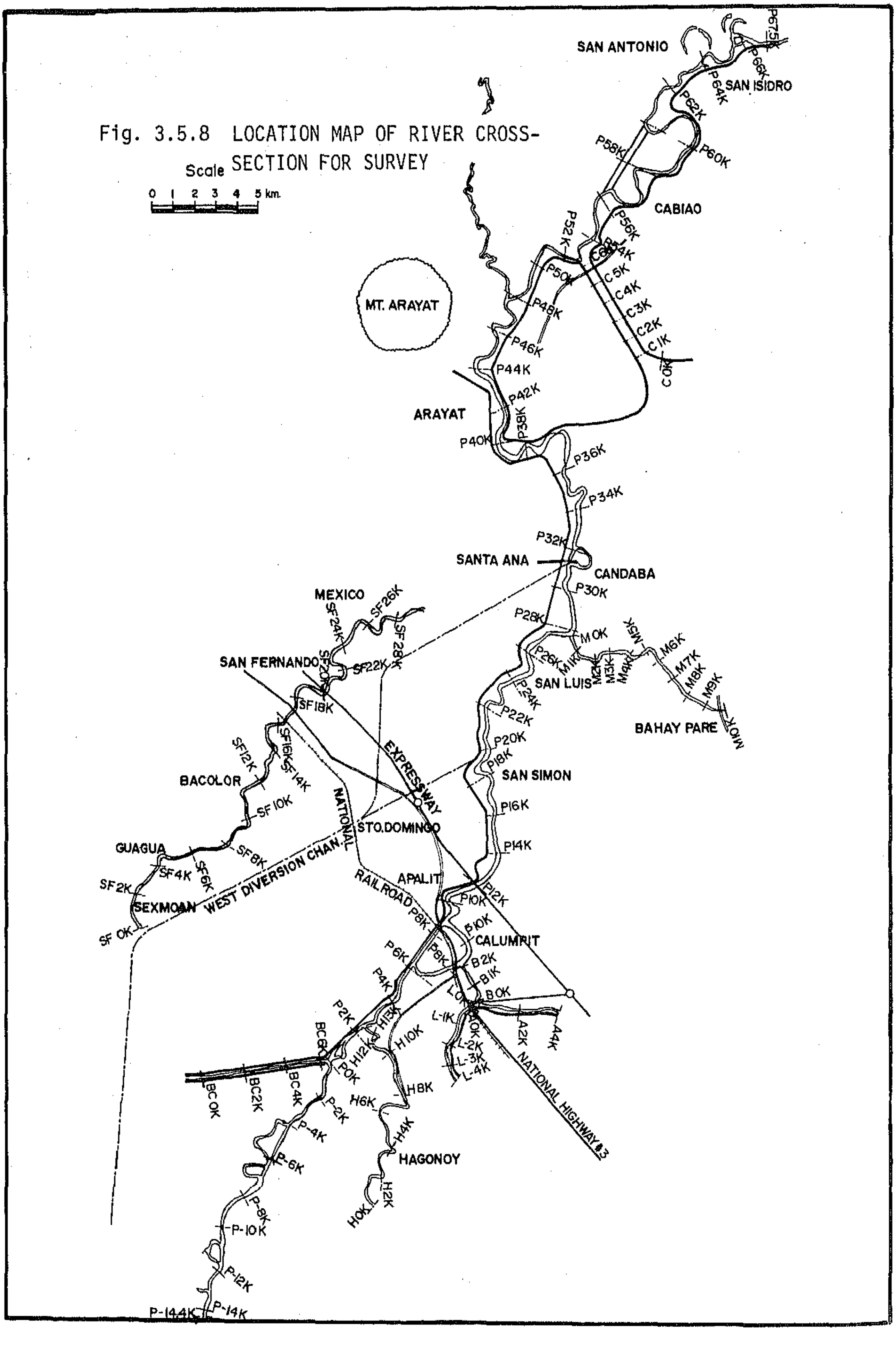
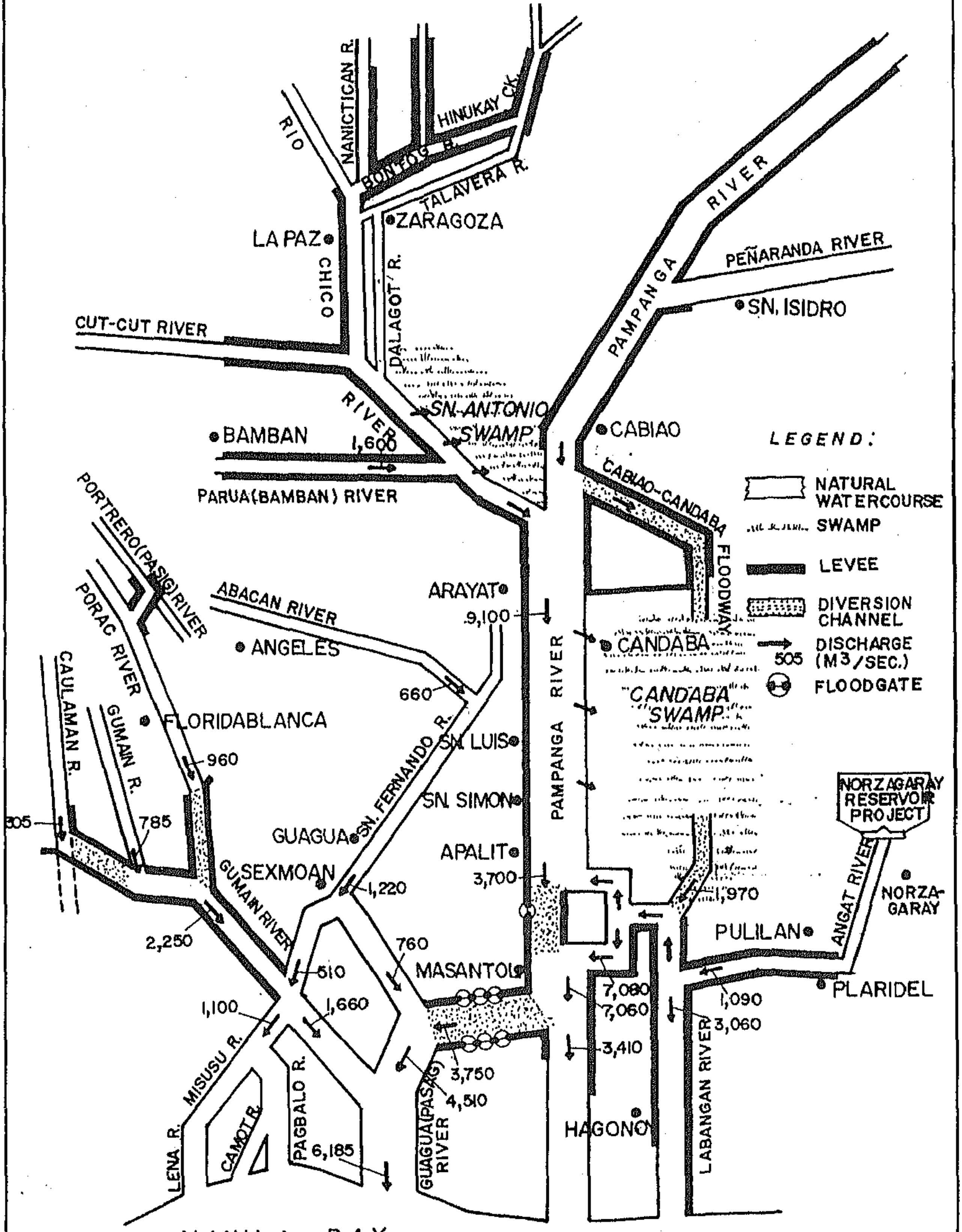
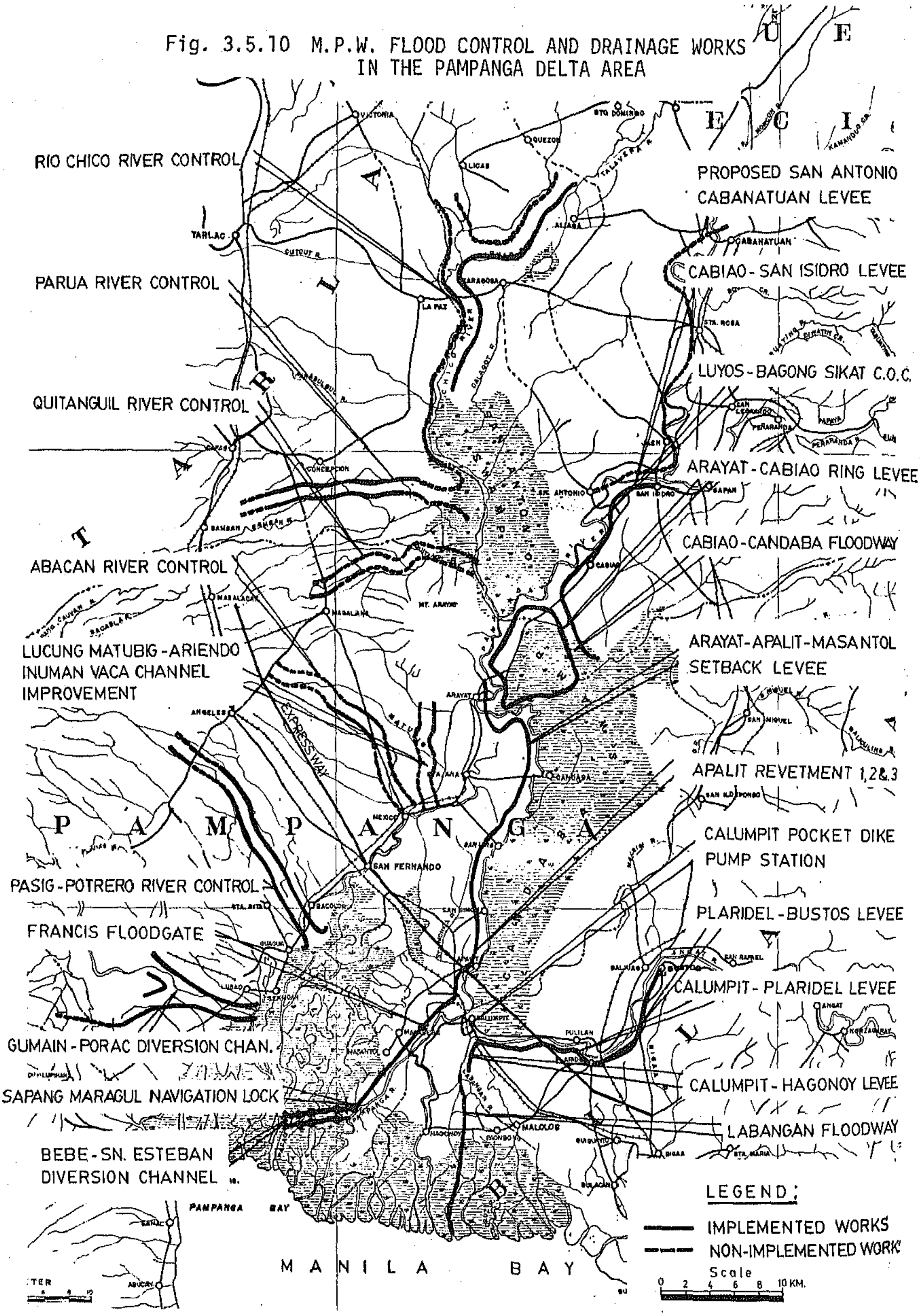


Fig. 3.5.9 MPW SCHEMATIC FLOOD FLOW DIAGRAM



NOTE: IN ACCORDANCE TO: PAMPANGA RIVER CONTROL SYSTEM AND ALLIED PROJECT – BPW 1958

Fig. 3.5.10 M.P.W. FLOOD CONTROL AND DRAINAGE WORKS IN THE PAMPANGA DELTA AREA



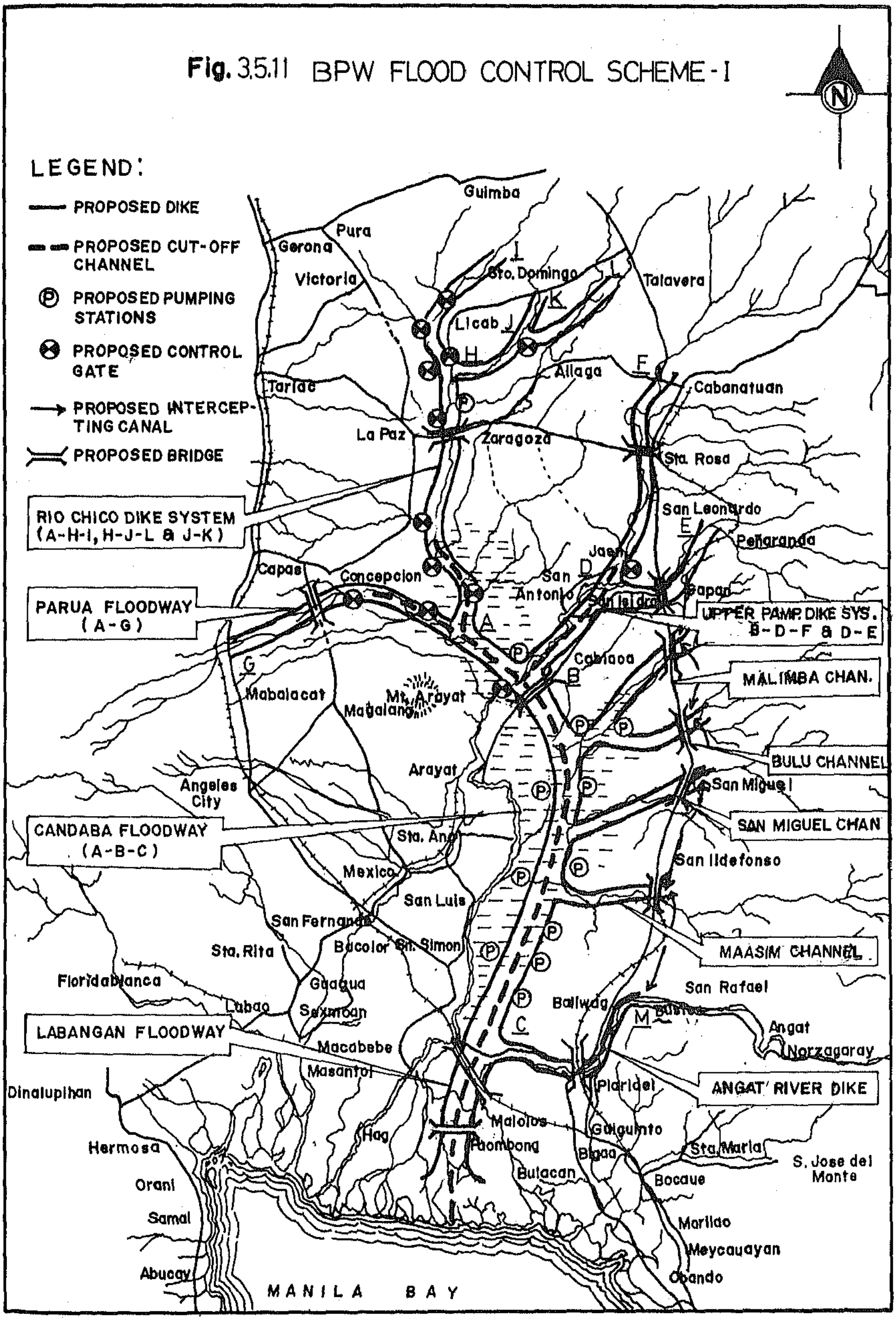


Fig. 3.5.11 BPW FLOOD CONTROL SCHEME - I
N
LEGEND:
PROPOSED DIKE
PROPOSED CUT-OFF CHANNEL
PROPOSED PUMPING STATIONS
PROPOSED CONTROL GATE
PROPOSED INTERCEPTING CANAL
PROPOSED BRIDGE
RIO CHICO DIKE SYSTEM (A-H-I, H-J-L & J-K)
PARUA FLOODWAY (A-G)
CANDABA FLOODWAY (A-B-C)
LABANGAN FLOODWAY
UPPER PAMP. DIKE SYS. B-D-F & D-E
MALIMBA CHAN.
BULU CHANNEL
SAN MIGUEL CHAN
MAASIM CHANNEL
ANGAT RIVER DIKE
Guimba
Pura
Gerona
Victoria
Sto. Domingo
Talavera
Licab
Aliaga
Cabanatuan
Tarlac
La Paz
Zaragoza
Sta. Rosa
San Leonardo
Peñaranda
Jaen
Capas
Concepcion
San Antonio
San Isidro
Gapan
Cabiaoa
Mabalacat
Magalang
Mt. Arayat
Arayat
Angeles City
San Miguel
Sta. Ana
San Ildefonso
Mexico
San Luis
San Fernando
Sta. Rita
Bacolor
Sn. Simon
Floridablanca
Guagua
Sexmoan
Lubao
Baliwag
San Rafael
Angat
Norzagaray
Macabebe
Masantol
Dinalupihan
Plaridel
Malolos
Guiguinto
Hagonoy
Paombong
Bigaa
Sta. Maria
S. Jose del Monte
Hermosa
Bulacan
Bocaue
Orani
Samal
Marilao
Meycauayan
Abucay
Obando
MANILA BAY
A
B
C
D
E
F
G
H
I
J
K
L
M

Fig. 3.5.12 BPW FLOOD CONTROL SCHEME-II

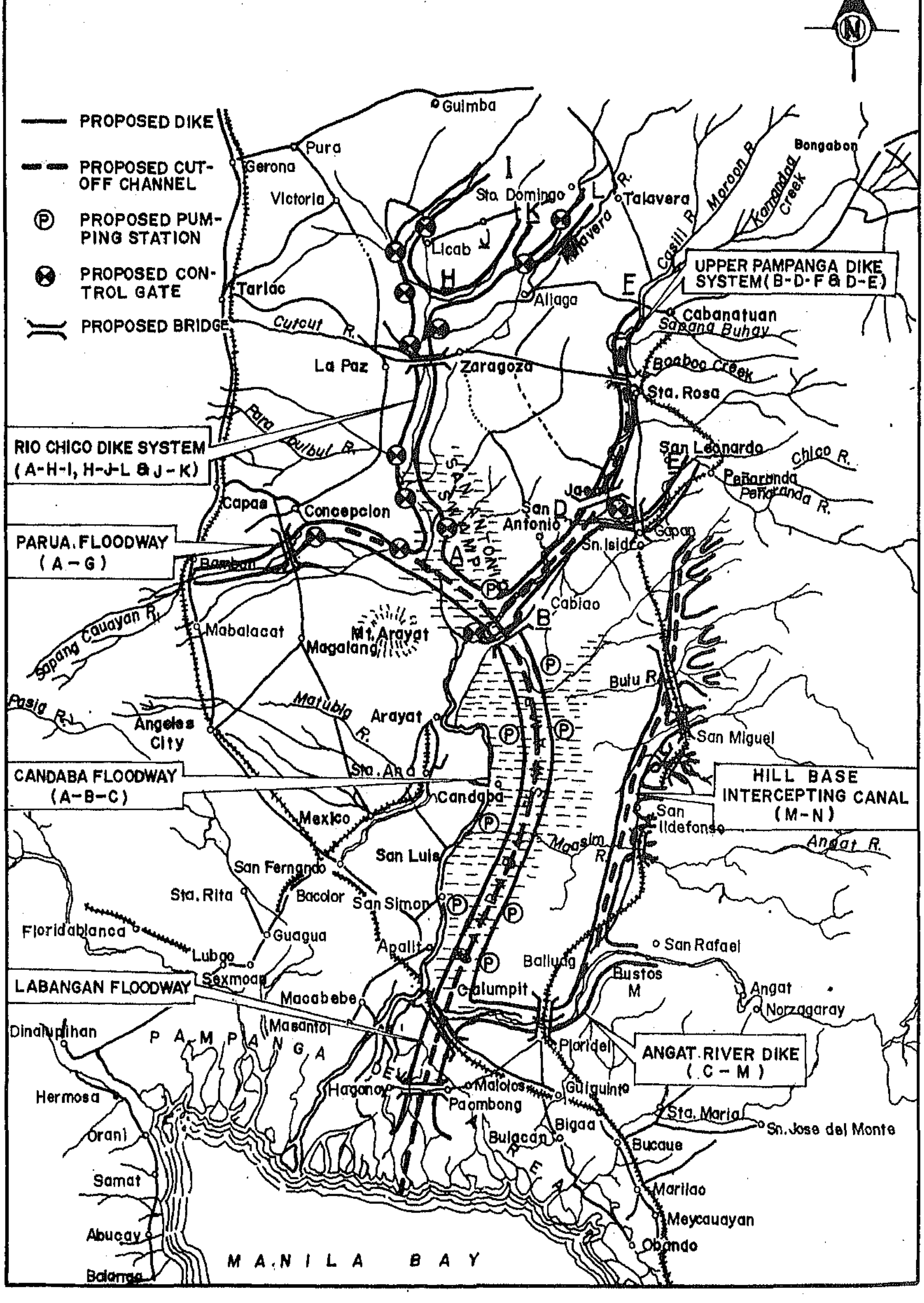


Fig. 3.5.13 BPW FLOOD CONTROL SCHEME-III

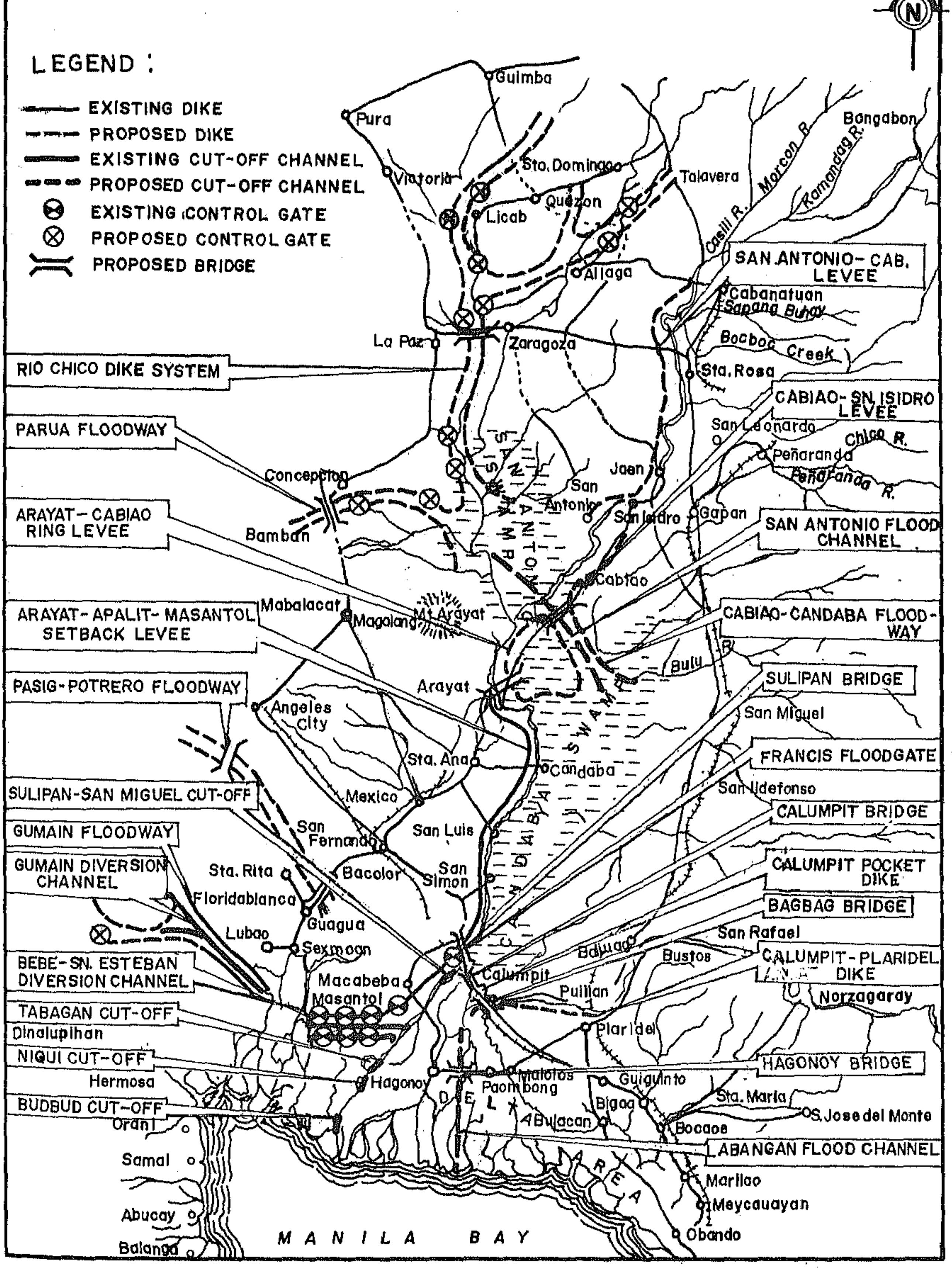


Fig. 3.5.14 RESERVOIR SITES IN THE PAMPANGA RIVER WATERSHED PROPOSED BY USBR, 1966

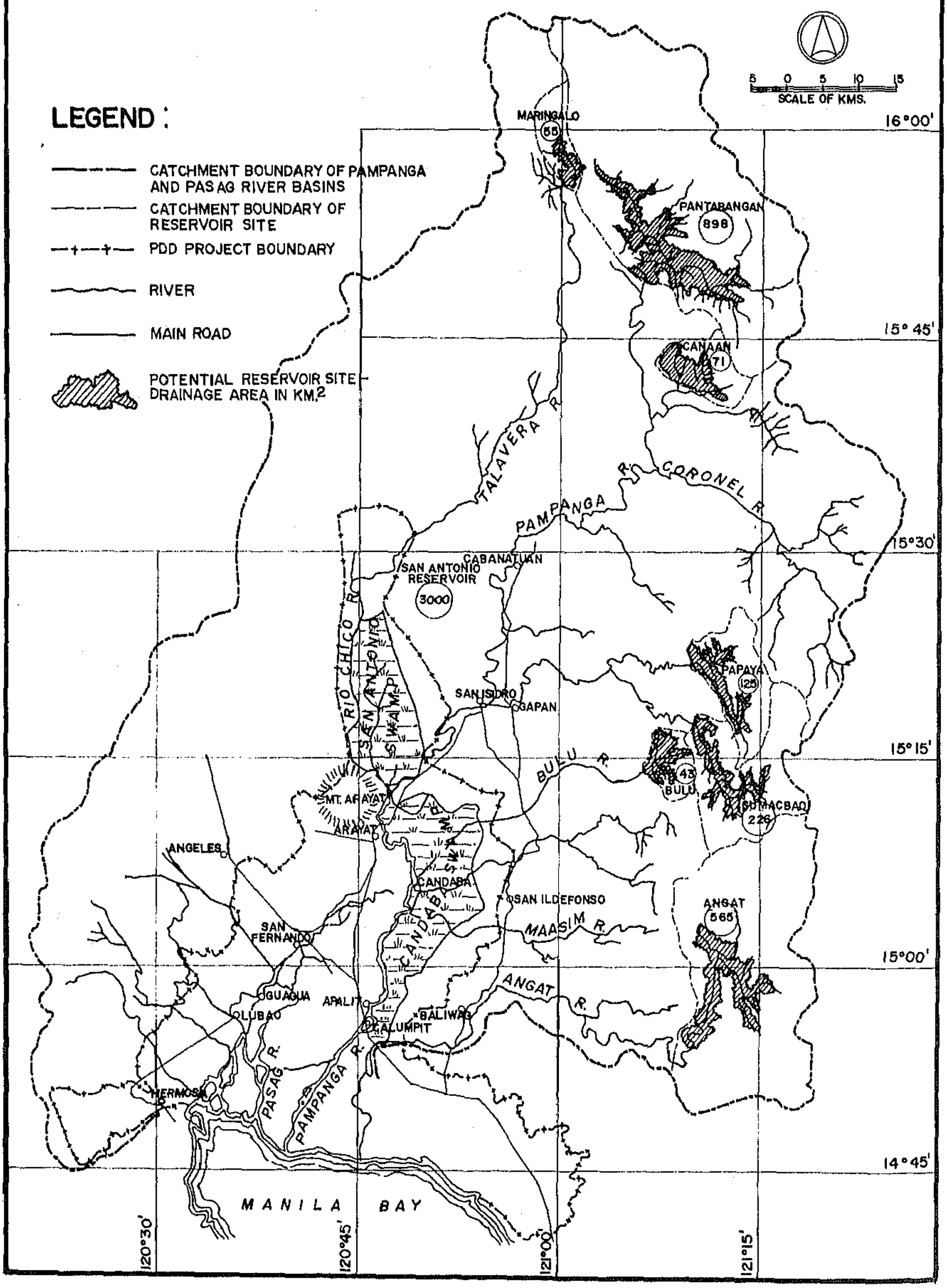


Fig. 3.5.15 POSSIBLE INUNDATION AREA AND TYPICAL FLOOD FLOW DIRECTIONS

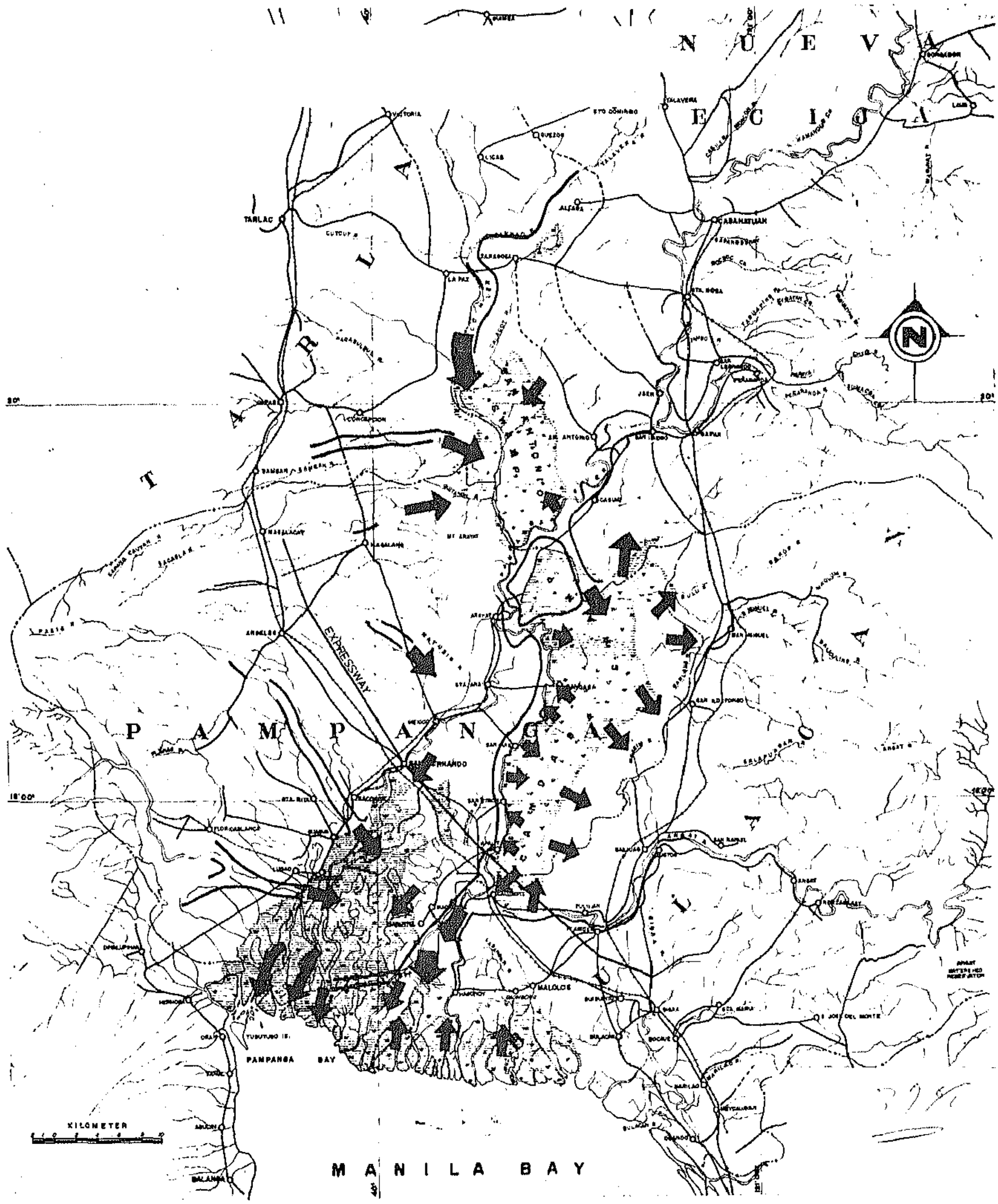


Fig. 3.6.1 LABANGAN FLOODWAY AND WATER CHANNEL SYSTEMS OF FISHPONDS

Fig. 4.1.1 LOCATIONS OF PROPOSED EAST AND WEST DIVERSION CHANNELS

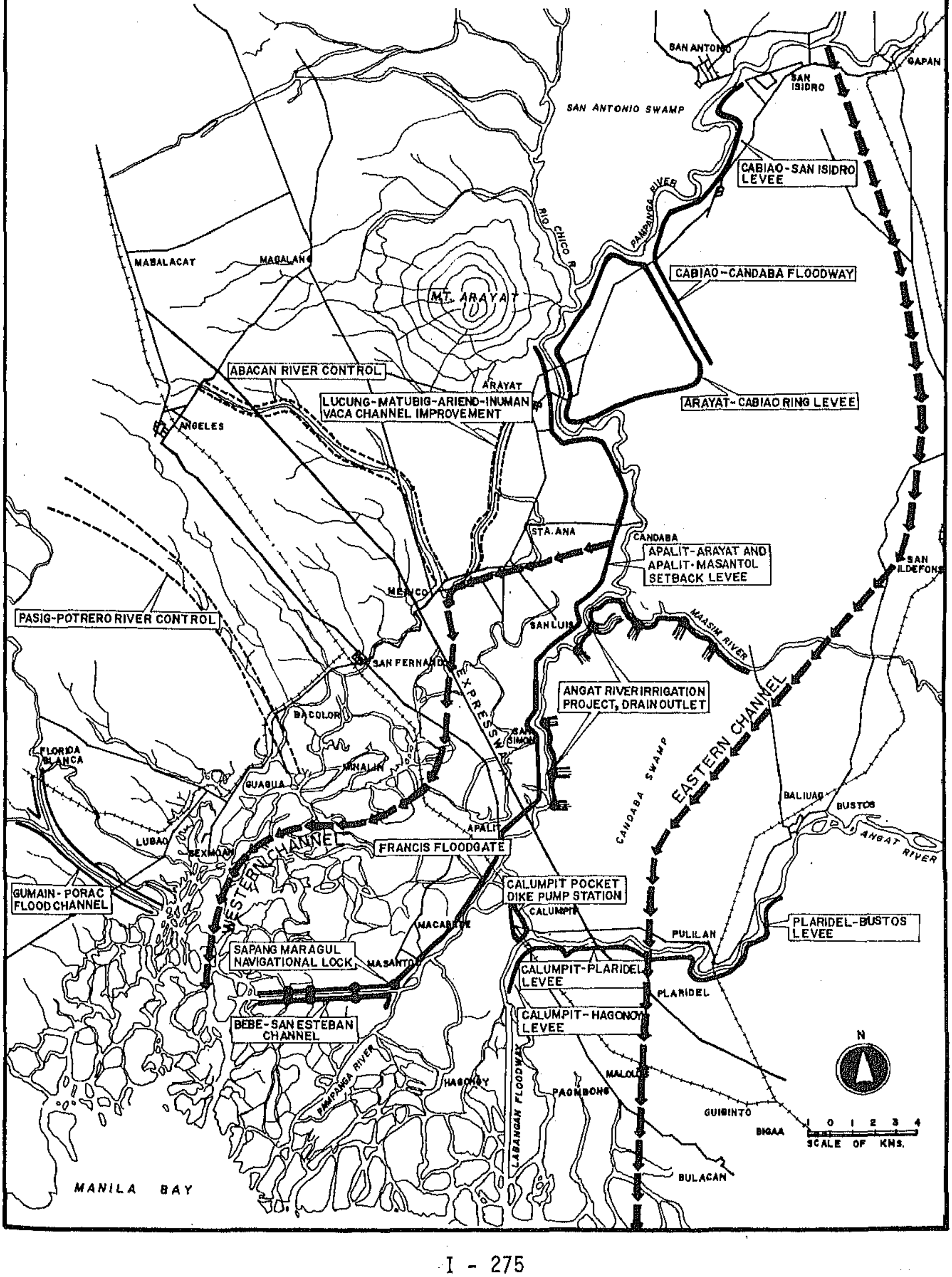


Fig. 4.1.2 PROFILE ALONG CENTERLINE OF WESTERN CHANNEL

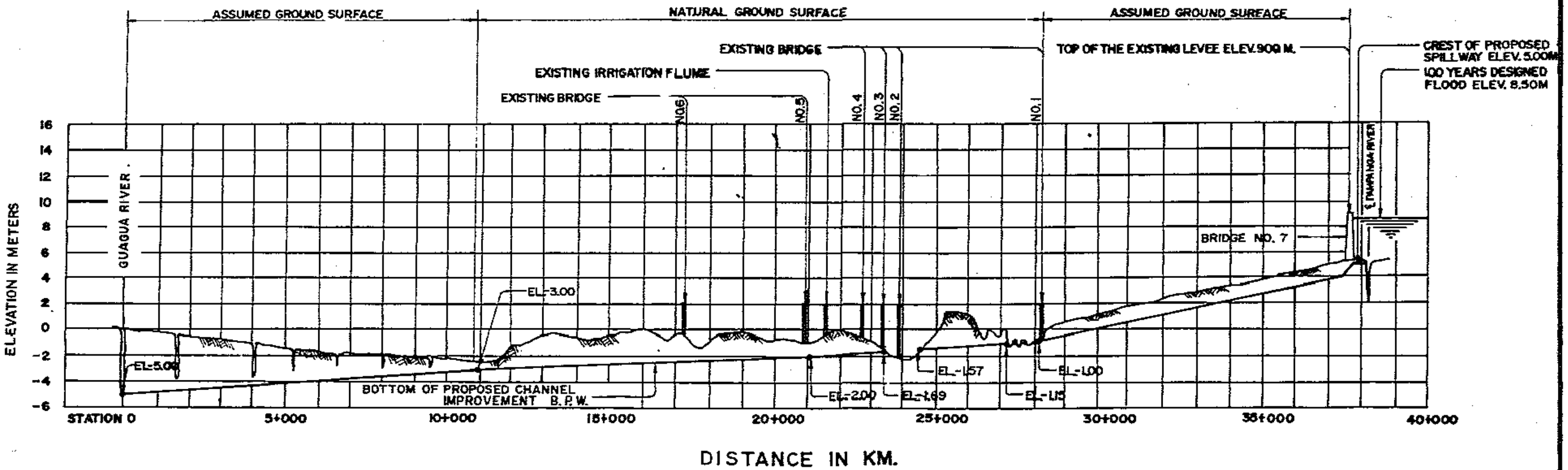
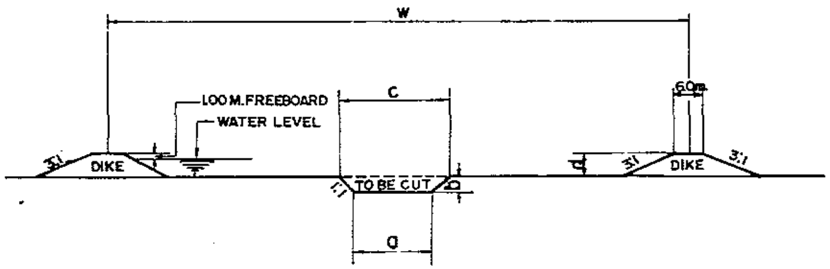


Fig. 4.1.3 TYPICAL SECTION OF FLOODWAY



STATION		LONGITUDINAL SLOPE	CROSS-SECTIONAL PARAMETERS				
FROM	TO		a	b	c	d	w
37+980	28+380	1/1585	100	1.50	103	3.00	637
28+380	21+300	1/6993	100	2.00	104	3.00	1557
21+300	11+000	1/10256	100	2.00	104	3.00	1957
11+000	0+000	1/5525	100	2.50	105	3.00	1290

NOTE: 1. ALL DIMENSIONS ARE IN METERS
2. DESIGN DISCHARGE Q = 1,500 M^3/SEC.

Fig. 4.1.4 PAMPANGA AND PASAG (GUAGUA) RIVER BASINS EXISTING AND POTENTIAL STORAGE RESERVOIRS SITES

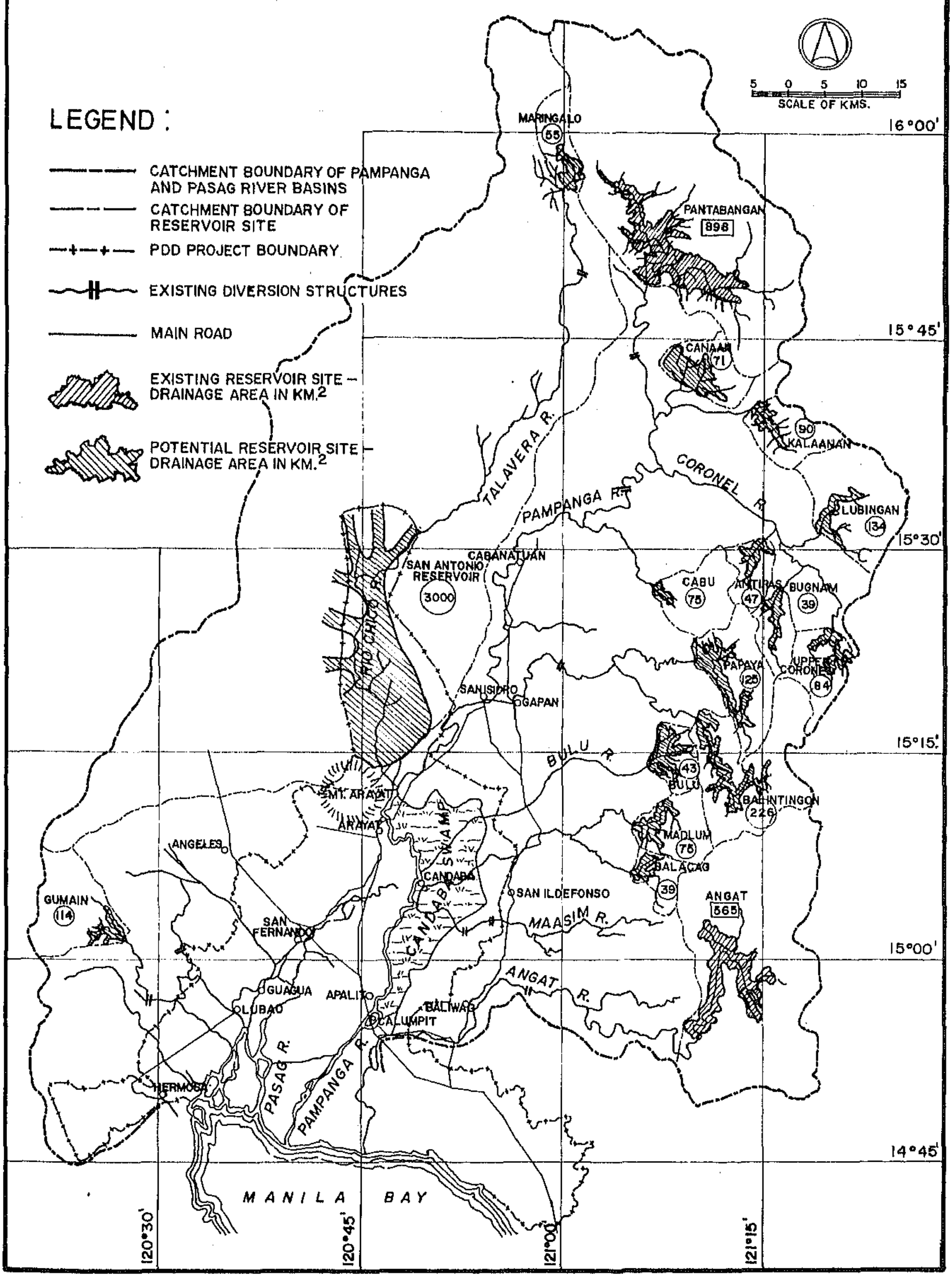


Fig. 4.1.5 COMPARISON OF OBSERVED AND RANDOMIZED RAINFALLS

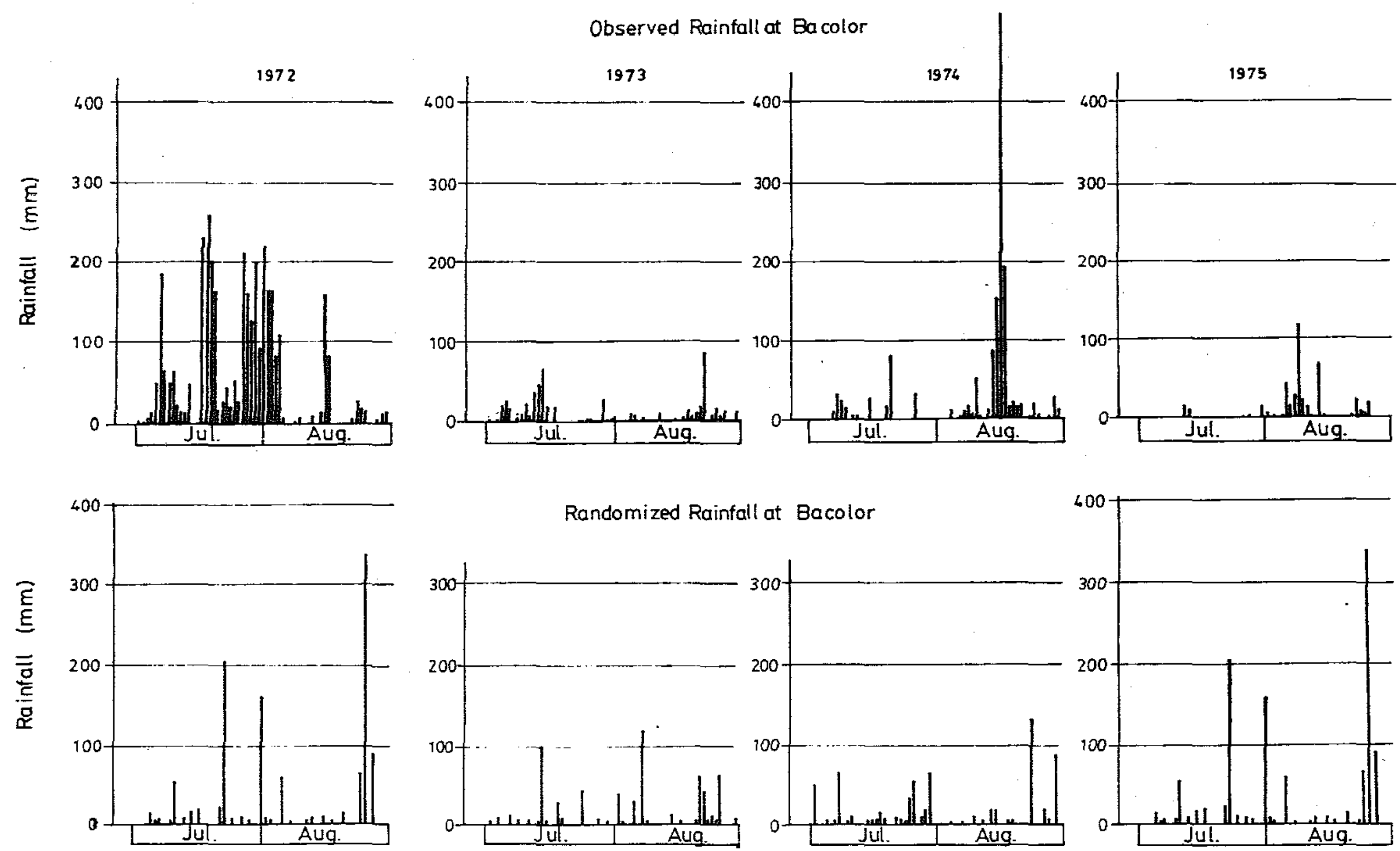


Fig. 4.2.1 HYDRAULIC SIMULATION MODEL FOR FLOOD CONTROL PLANS

Case 1 : Flood Control by San Antonio Reservoir

Case 2 : Flood Control by West Diversion Channel

Case 3 : Flood Control by Channel Improvement of Main Pampanga River

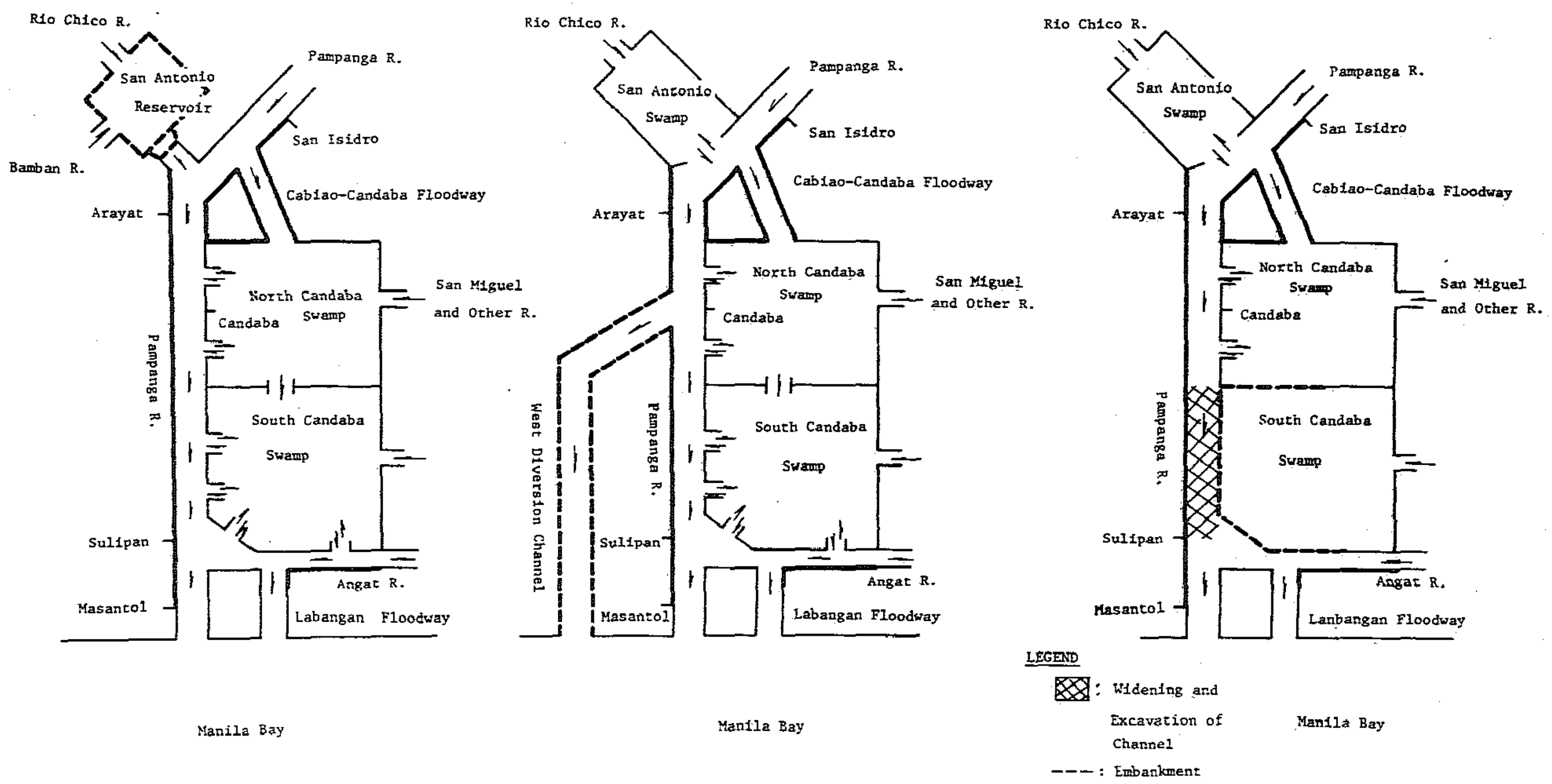
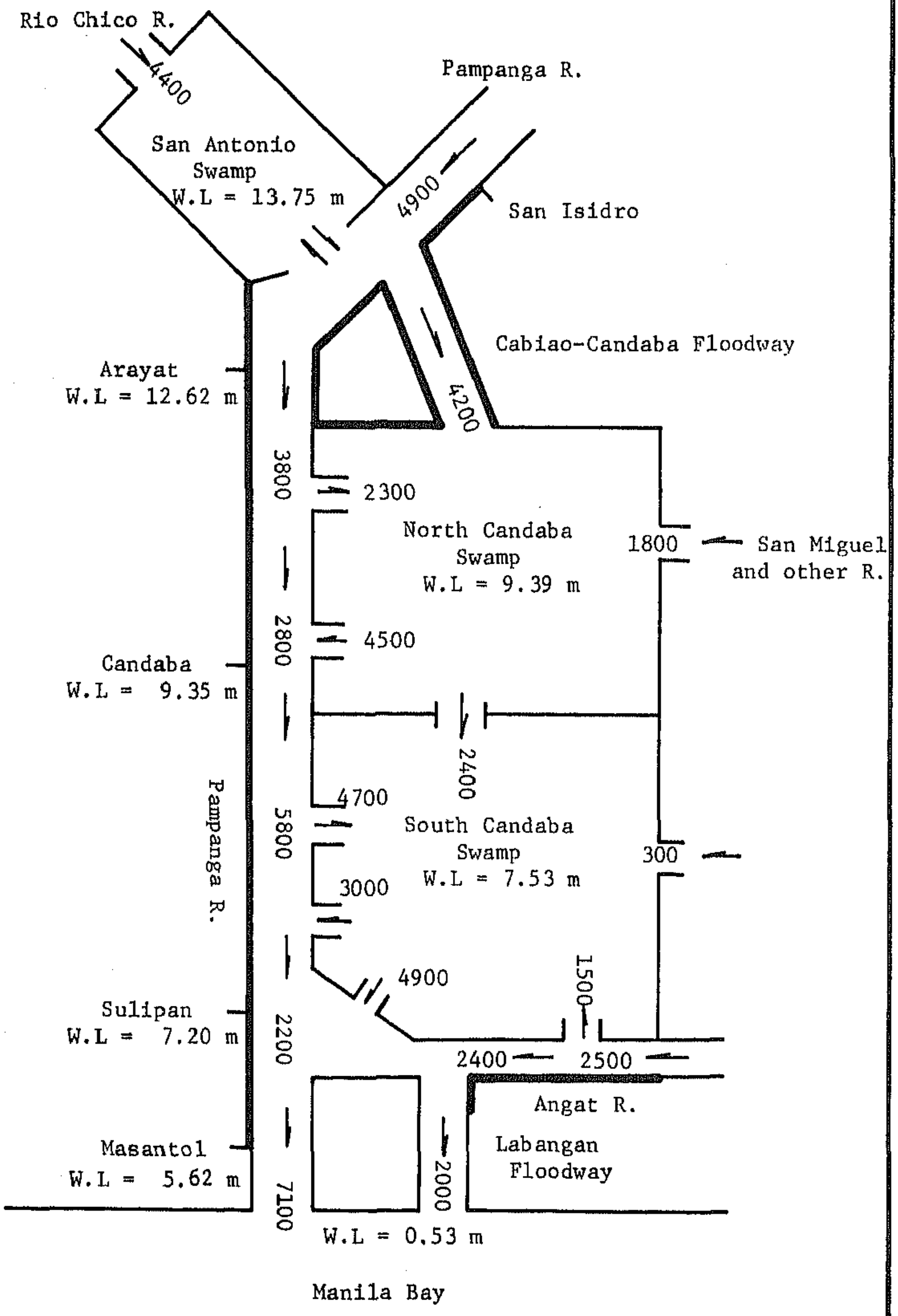


Fig. 4.2.2 DESIGN FLOOD DISCHARGE DISTRIBUTION UNDER PRESENT CONDITION

(100 yr. Return Period)

(Unit: m^3/s)



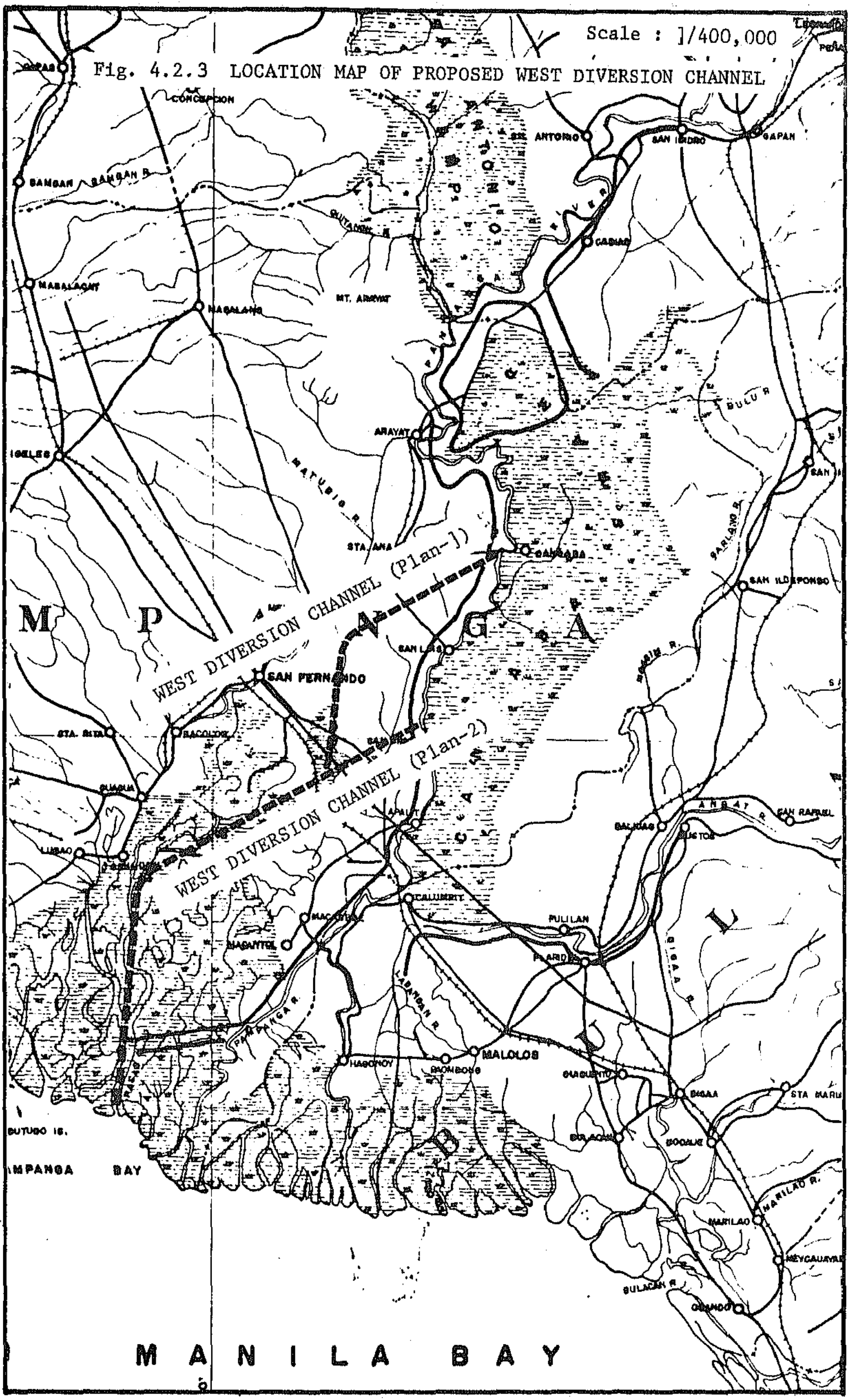


Fig. 4.2.3 LOCATION MAP OF PROPOSED WEST DIVERSION CHANNEL

Fig. 4.2.4 (1) DESIGN FLOOD DISCHARGE DISTRIBUTION (WEST DIVERSION CHANNEL PLAN - 1)

Case: 100-yr Flood, existing dams (Pantabangan and Angat) upstream and West Diversion Channel (Plan-1) downstream

(Unit: m^3/s)

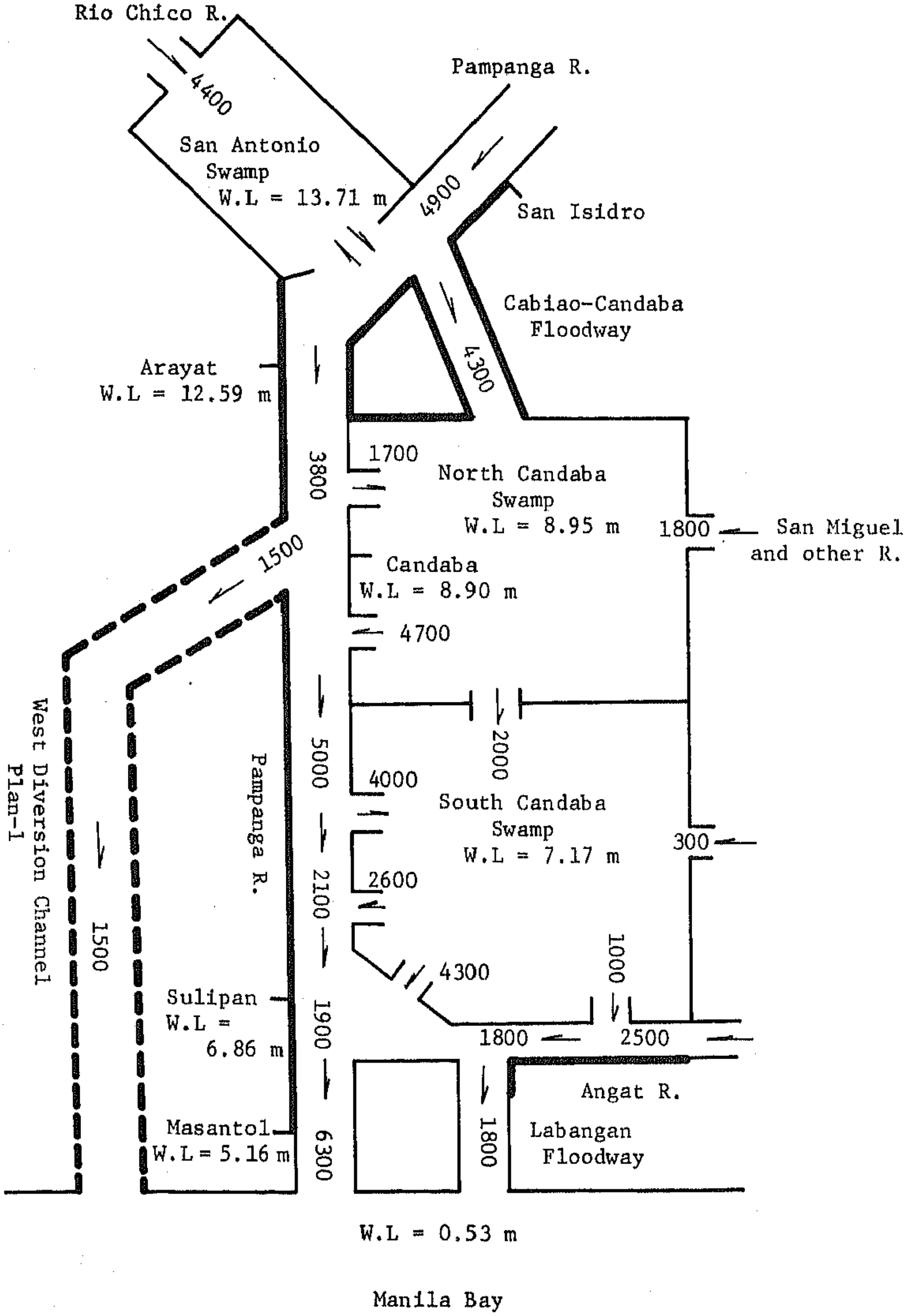


Fig. 4.2.4 (2) DESIGN FLOOD DISCHARGE DISTRIBUTION
(WEST DIVERSION CHANNEL PLAN - 2)

Case: 100-yr Flood, existing dams (Pantabangan and Angat) upstream and West Diversion Channel (Plan-2) downstream

(Unit: m^3/s)

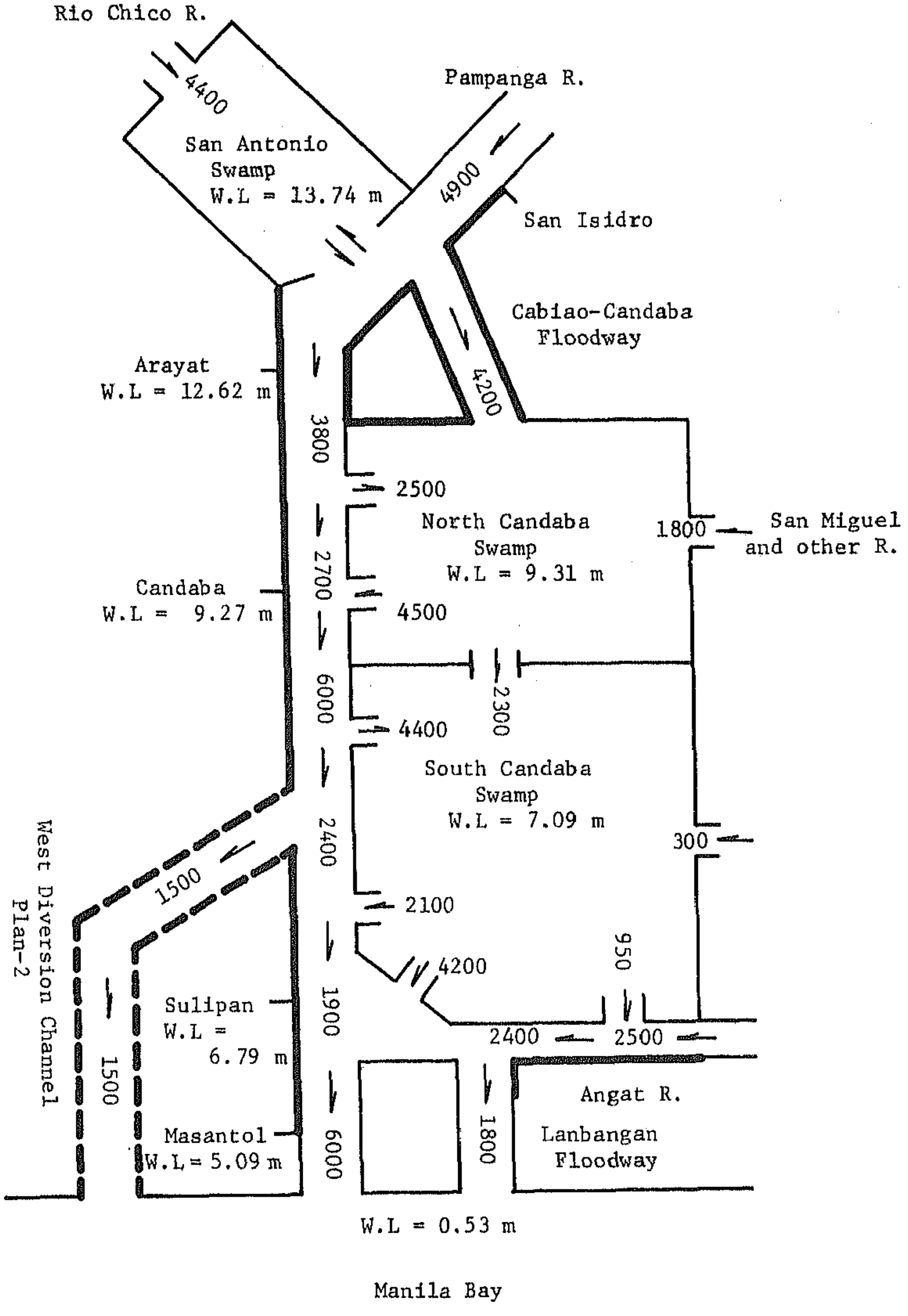


Fig 4.2.5 LONGITUDINAL PROFILE OF PROPOSED WEST DIVERSION CHANNEL (PLAN I)

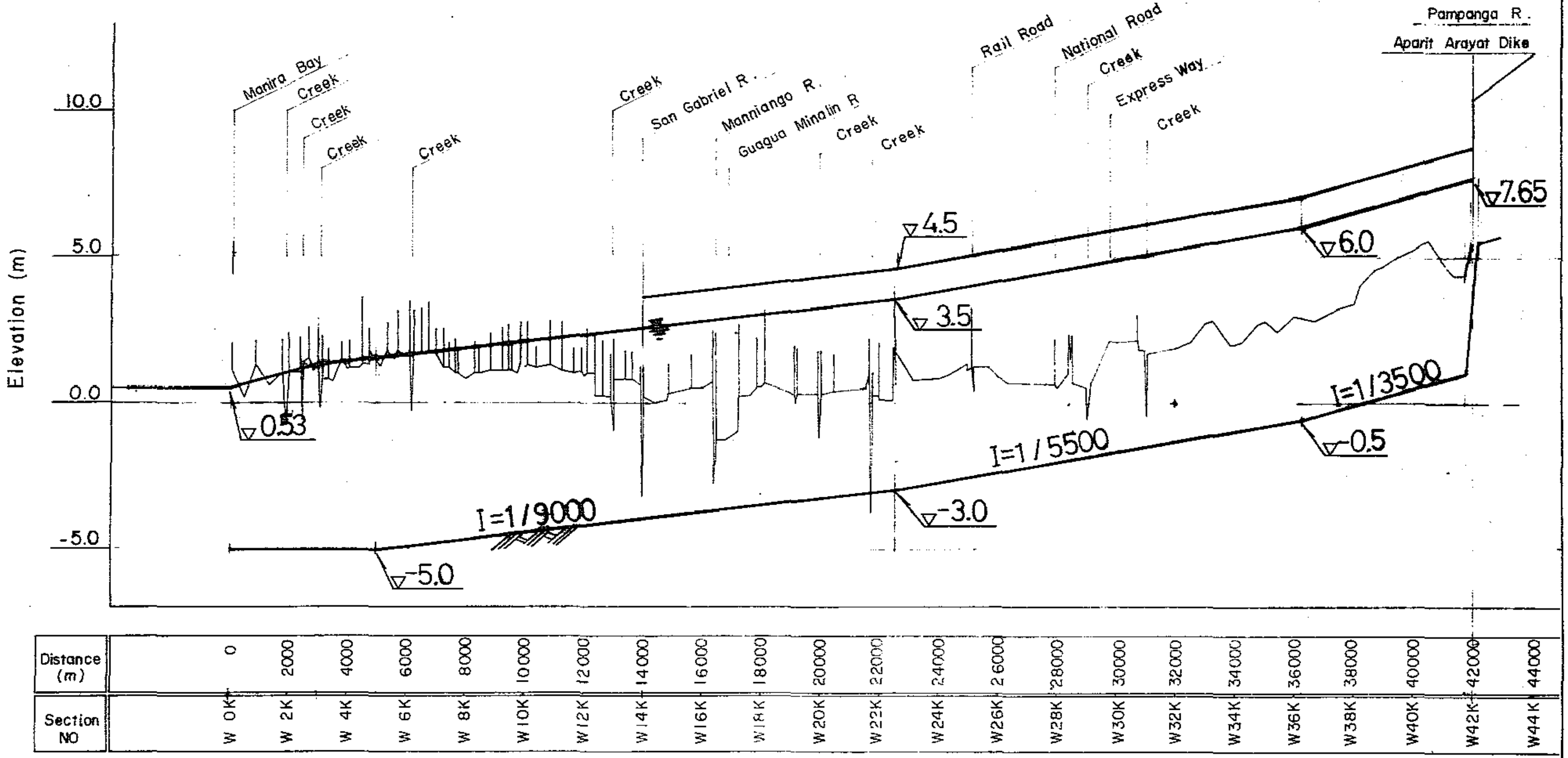
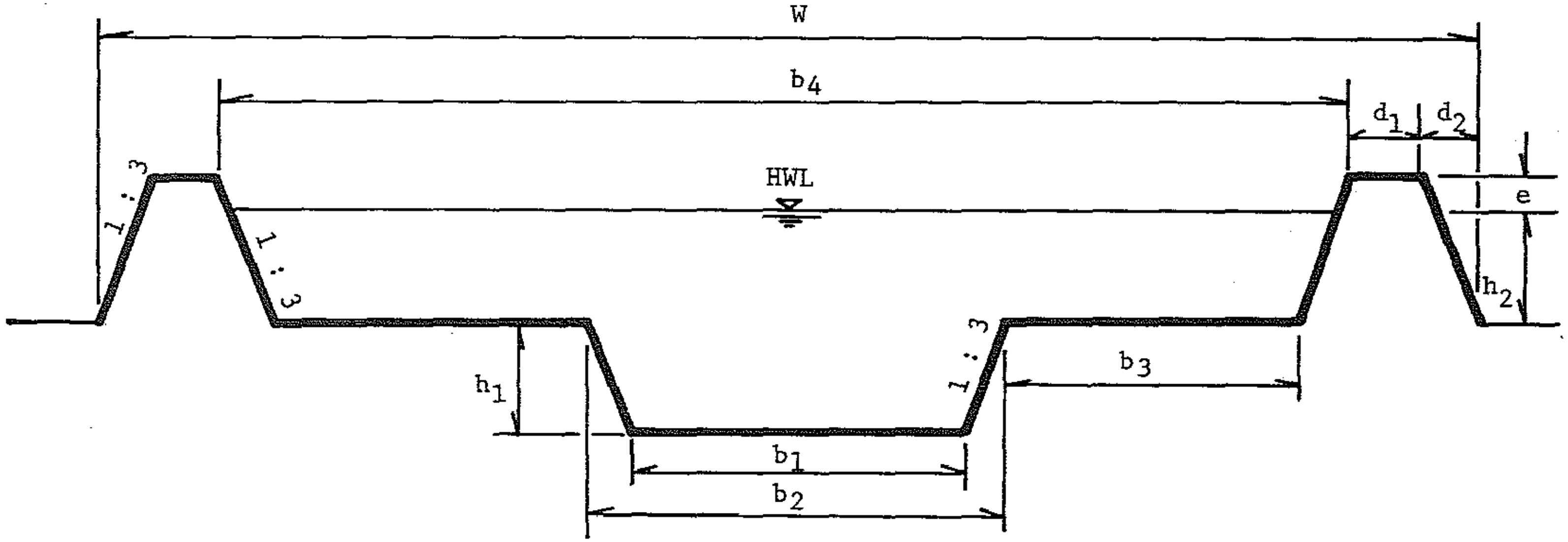


Fig. 4.2.6 STANDARD CROSS-SECTION OF PLANNED WEST DIVERSION CHANNEL (PLAN-1)



Station		Longitudinal Slope		Cross-section parameter (m)									
from	to	High-water surface	Channel bed	h_1	h_2	e	b_1	b_2	b_3	b_4	d_1	d_2	w
0k	∿ 14k	Level	1/9,000	5.5 ∿ 4.0	0.5 ∿ 2.5	-	155	185	250	685	-	-	-
14k	∿ 22.5k	1/9,000	1/9,000	4.0	2.5	1.0	151	175	110	440	6.0	10.5	473
22.5k	∿ 36.2k	1/5,500	1/5,500	4.0	2.5	1.0	121	145	85	360	6.0	10.5	393
36.2k	∿ 42k	1/3,500	1/3,500	4.0	2.5	1.0	95	119	65	270	6.0	10.5	303

Fig 4.2.7   LONGITUDINAL PROFILE OF PROPOSED WEST DIVERSION CHANNEL (PLAN 2)

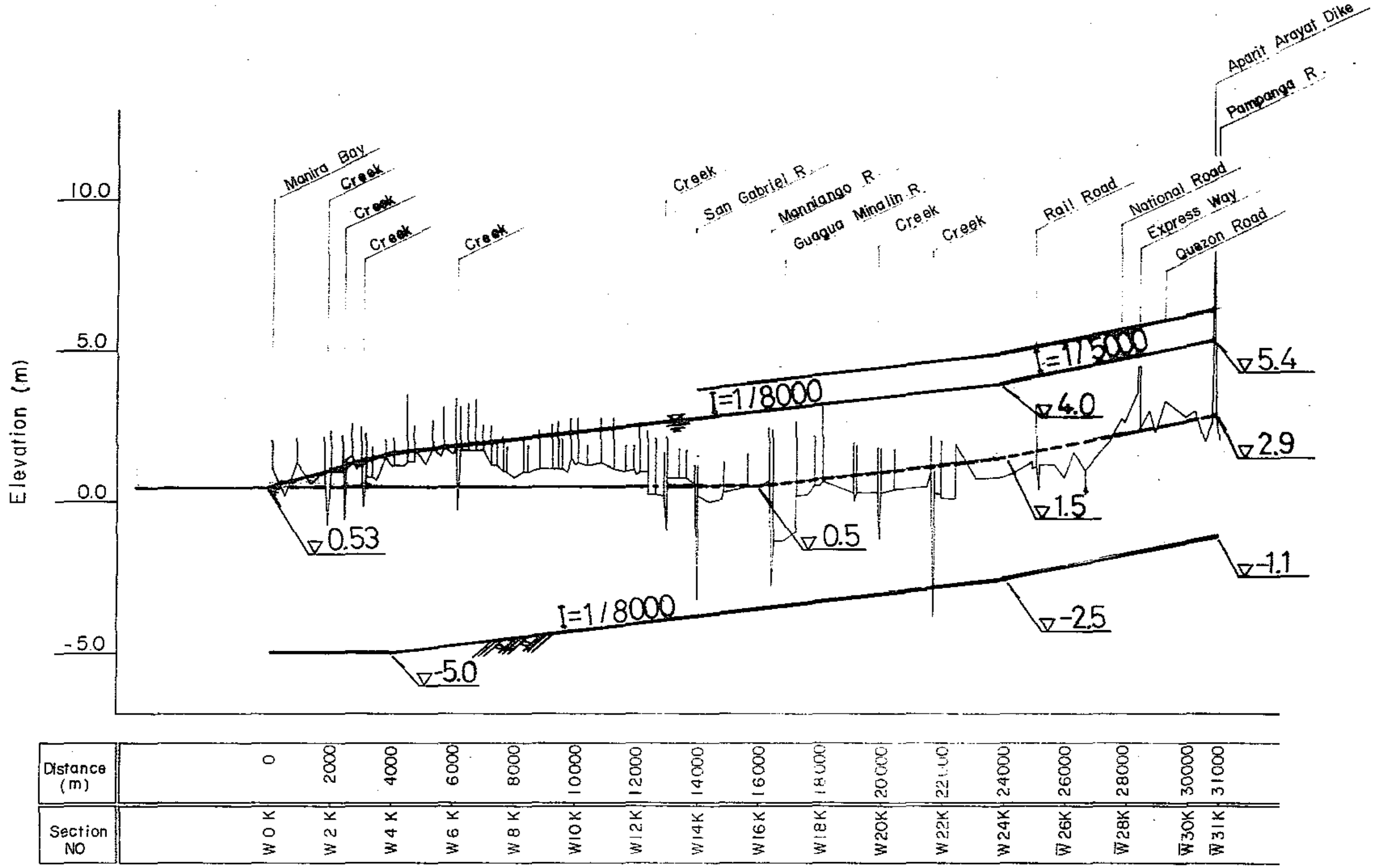
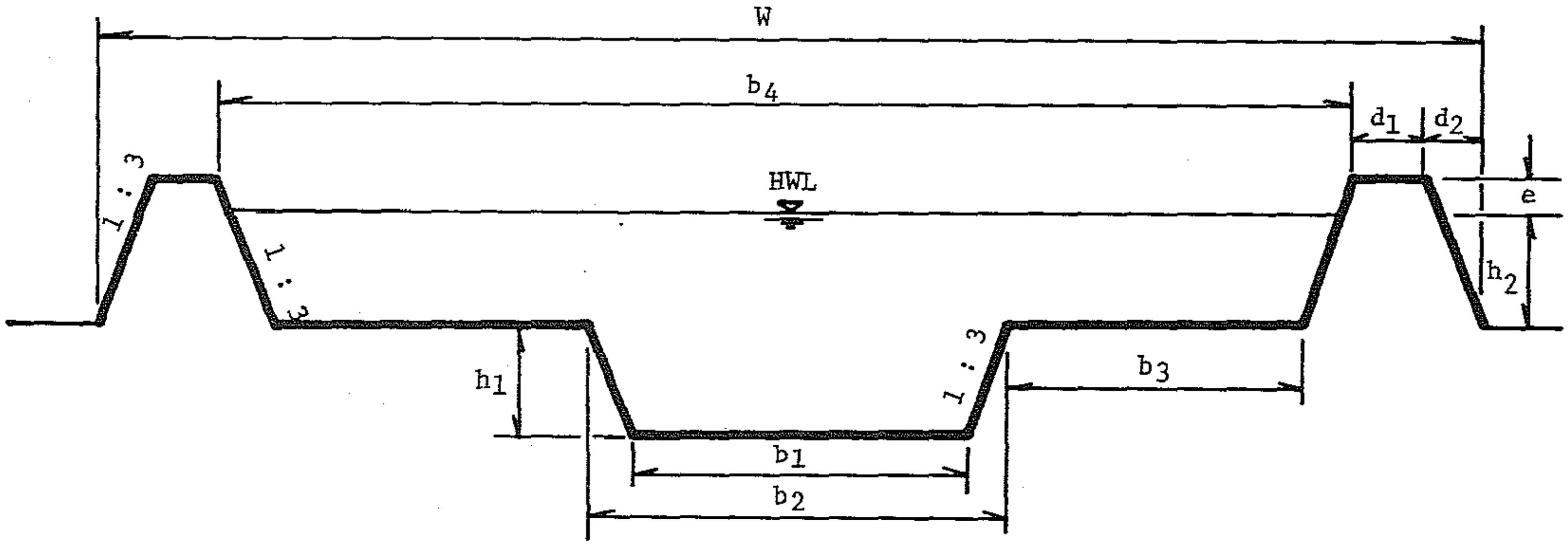


Fig. 4.2.8 STANDARD CROSS-SECTION OF PLANNED WEST DIVERSION CHANNEL (PLAN-2)



Station	Longitudinal Slope		Cross-section parameter (m)									
from to	High-water surface	Channel bed	h_1	h_2	e	b_1	b_2	b_3	b_4	d_1	d_2	w
0k ∿ 4k	Level	Level	5.5	0.5 ∿ 1.0	-	145	178	250	696	-	-	-
4k ∿ 14k	Level	1/8,000	5.5 ∿ 4.0	1.0 ∿ 2.5	-	145	178	250	696	-	-	-
14k ∿ 24k	1/8,000	1/8,000	4.0	2.5	1.0	145	169	100	390	6.0	10.5	423
24k ∿ 31k	1/5,000	1/5,000	4.0	2.5	1.0	115	139	70	300	6.0	10.5	333

Fig. 4.2.9 LOCATION MAP OF CHANNEL IMPROVEMENT PLAN (PLAN-1)

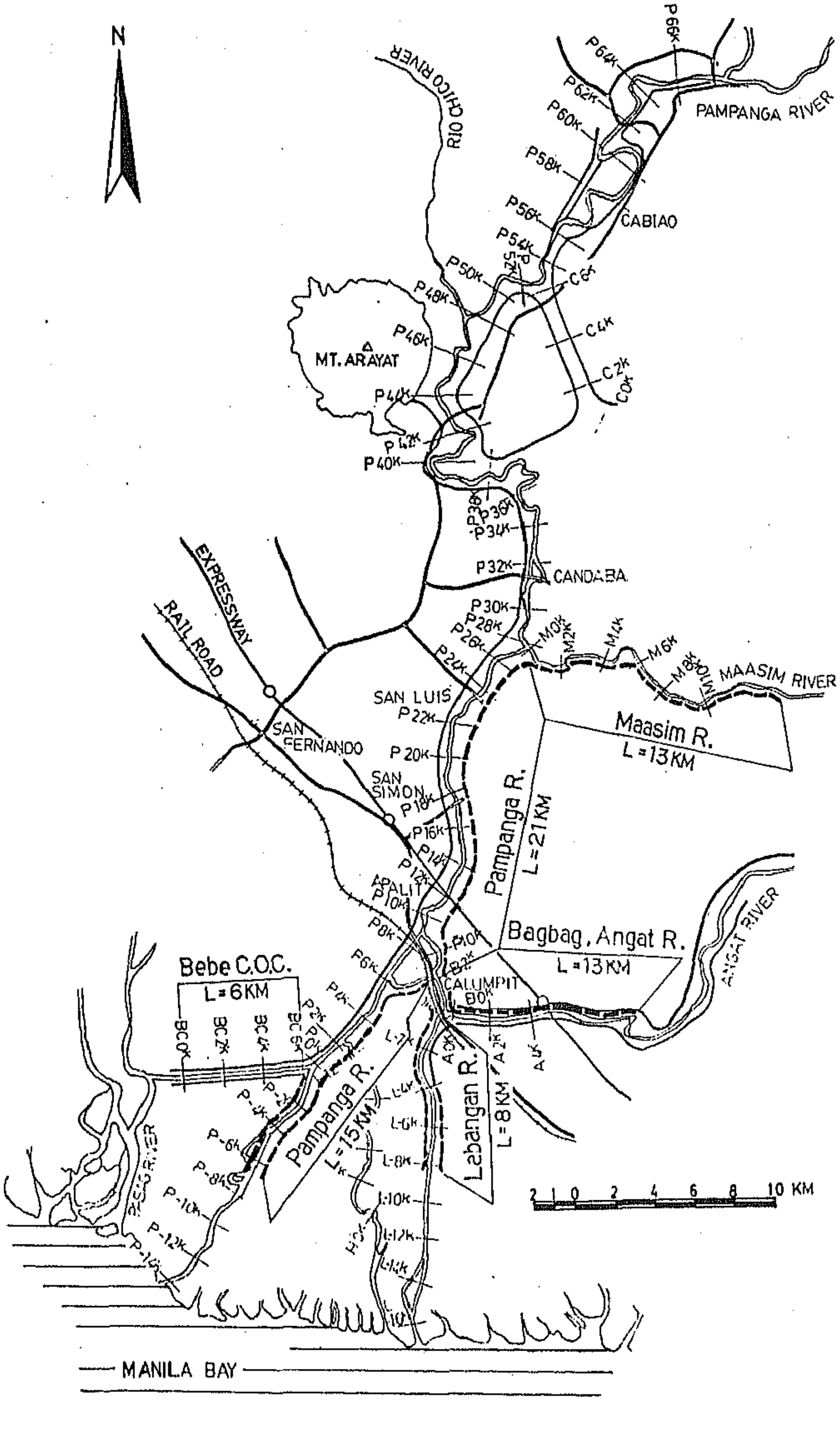


Fig. 4.2.10 (1) DESIGN FLOOD DISCHARGE DISTRIBUTION (CHANNEL IMPROVEMENT PLAN - 1)

Case: 100-yr Flood, existing dams (Pantabangan and Angat) upstream and Channel Improvement downstream

(Unit: m^3/s)

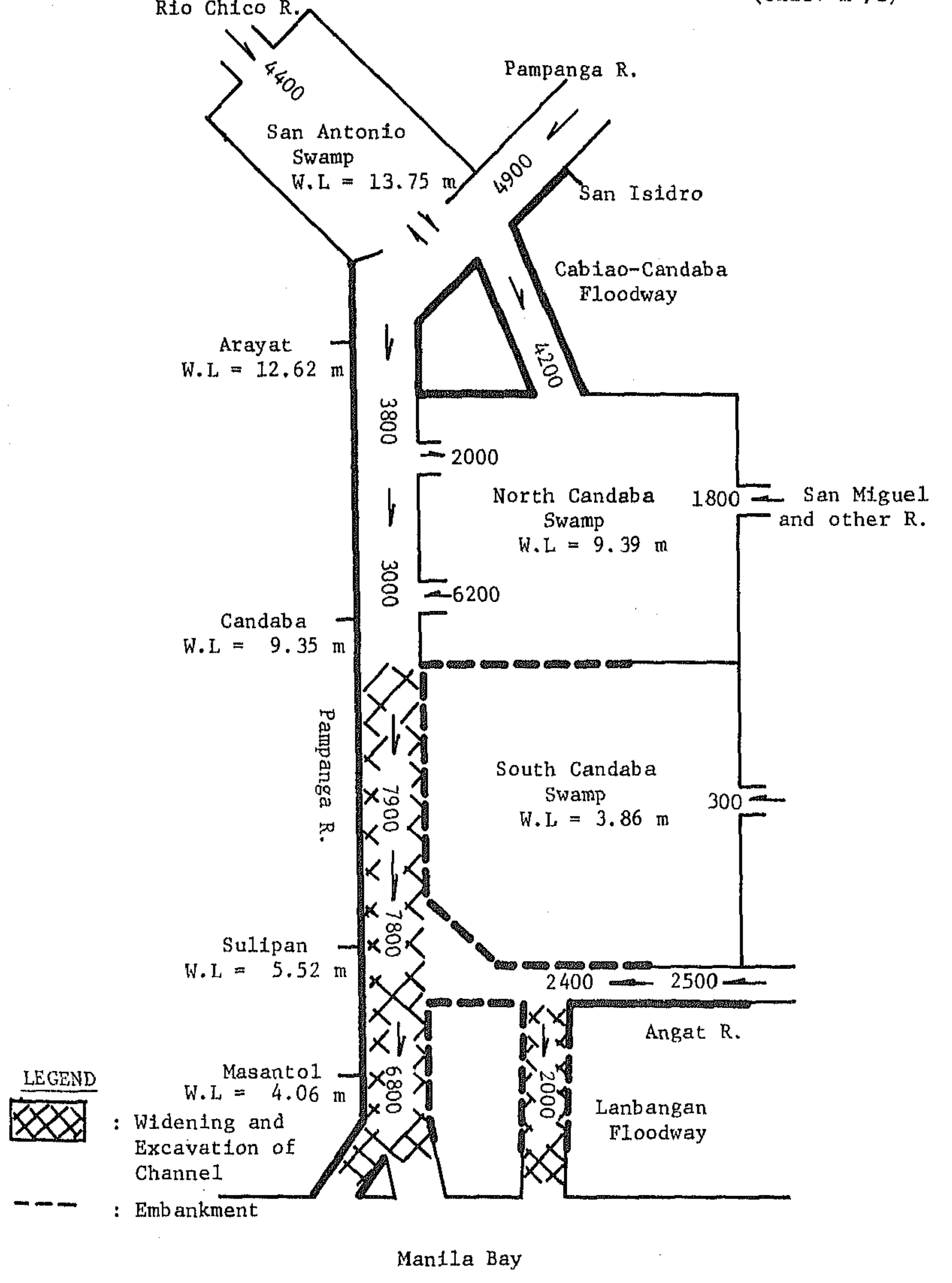


Fig. 4.2.10 (2) DESIGN FLOOD DISCHARGE DISTRIBUTION (CHANNEL IMPROVEMENT PLAN - 2)

Case: 100-yr Flood, existing dams (Pantabangan and Angat) upstream and Channel Improvement downstream

(Unit: m^3/s)

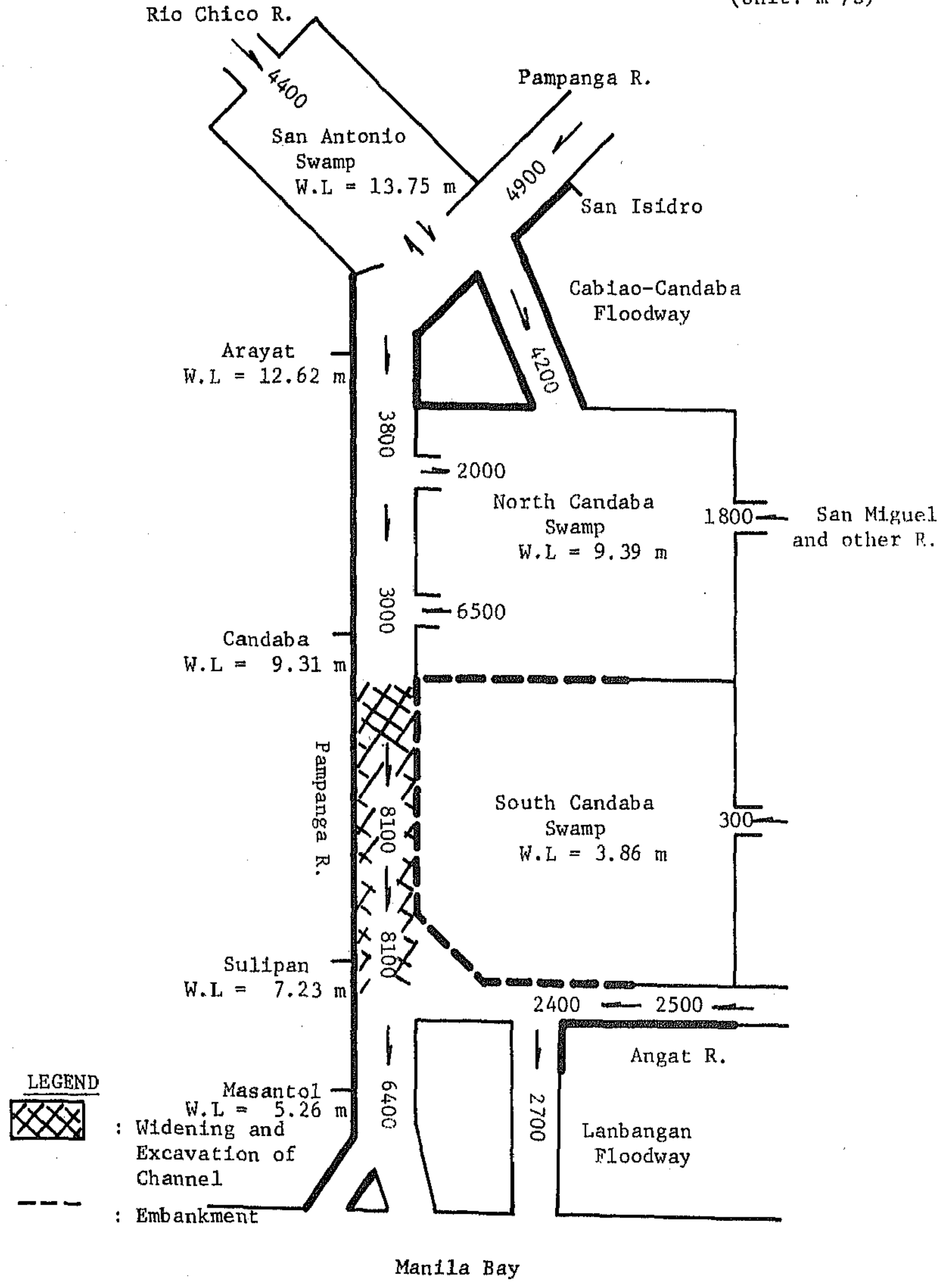


Fig. 4.2.11 PROPOSED LONGITUDINAL PROFILE OF PAMPANGA RIVER (PLAN 1)

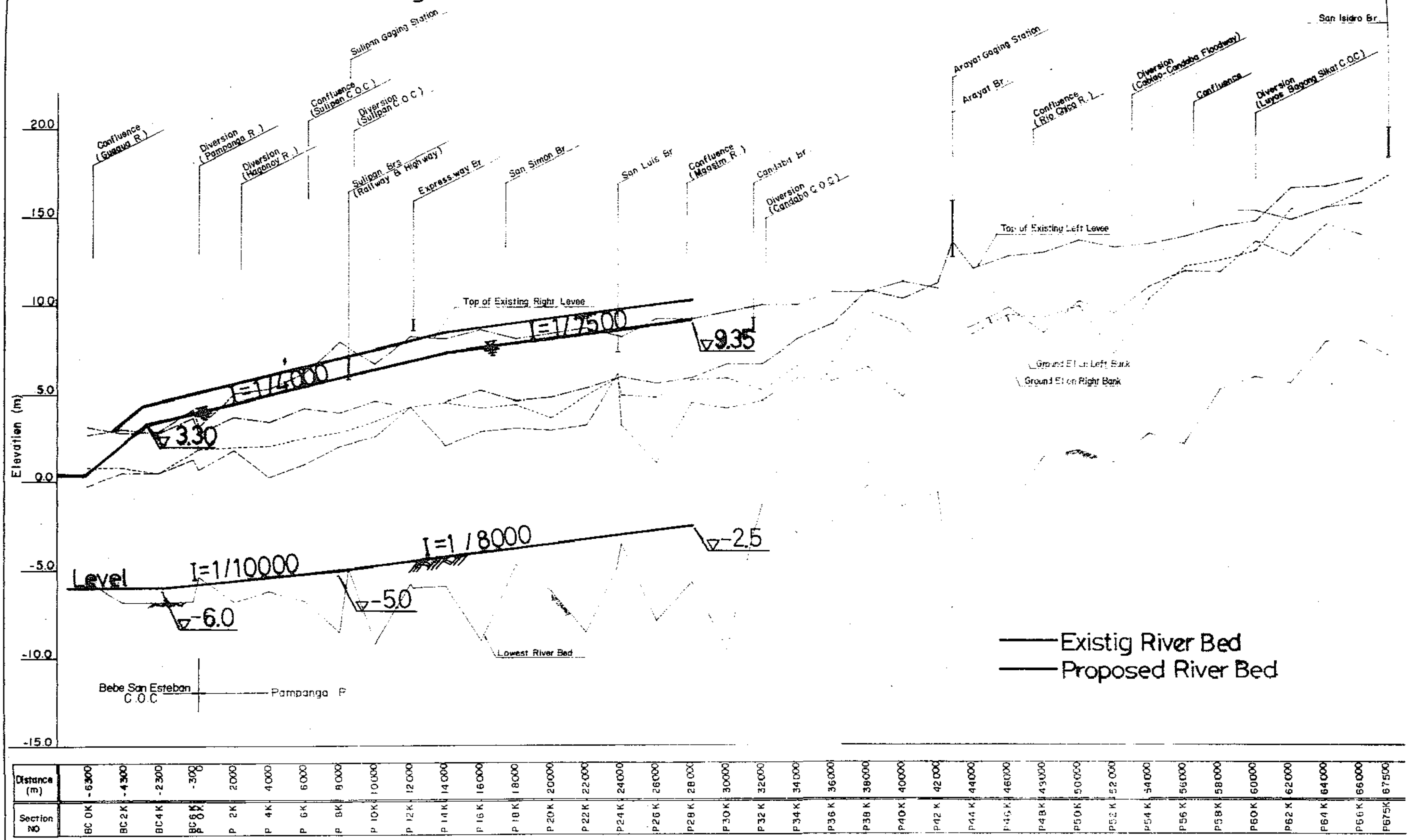
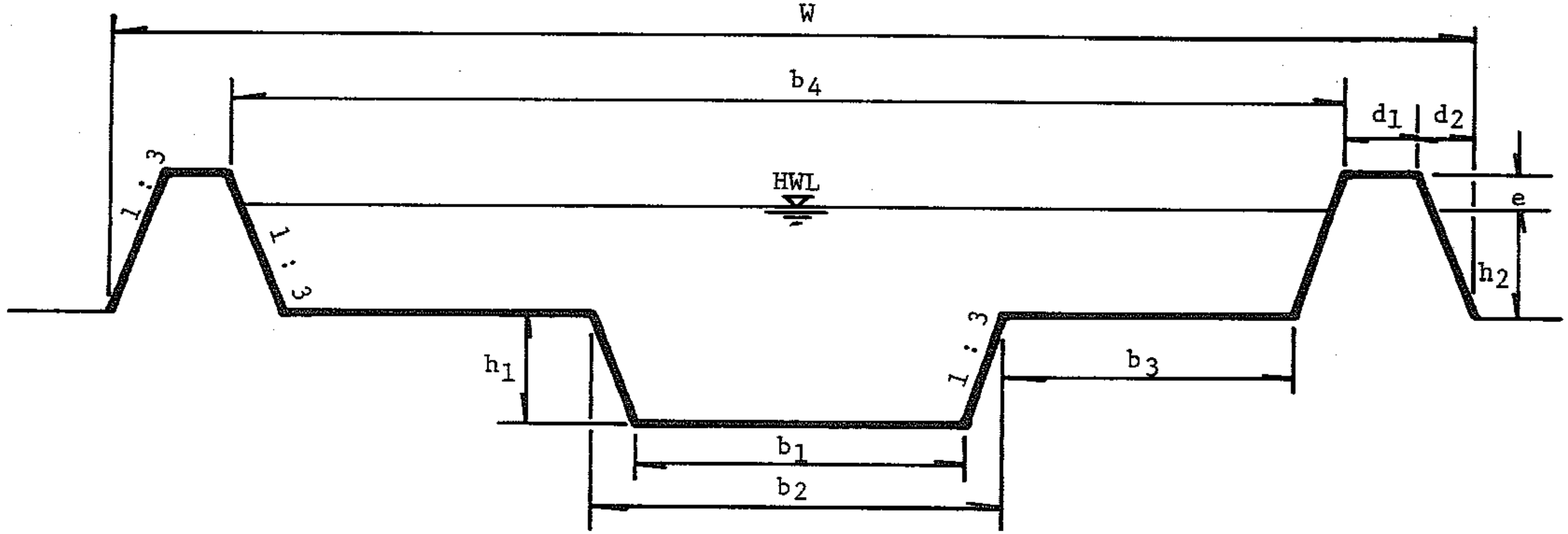


Fig. 4.2.12 STANDARD CROSS-SECTION OF PAMPANGA RIVER (PLAN-1)



Station from to	Longitudinal Slope High-water surface	Longitudinal Slope Channel bed	Cross-section parameter (m) h_1	h_2	e	b_1	b_2	b_3	b_4	d_1	d_2	w
BC0 ∿ BC6	1/4,000	Level	6.5 ∿ 7.0	0.5 ∿ 2.8	1.5	100	142	20	200	6.0	9	230
P 0 ∿ P 8	1/4,000	1/10,000	7.0 ∿ 7.5	2.8	1.5	240	285	210	703	6.0	13	741
P 8 ∿ P28	1/7,500	1/8,000	8.0	3.8	1.5	230	278	350	1006	6.0	16	1050

Fig. 4.2.13 METEOROLOGIC CONDITION AND PROPOSED CROPPING PATTERN

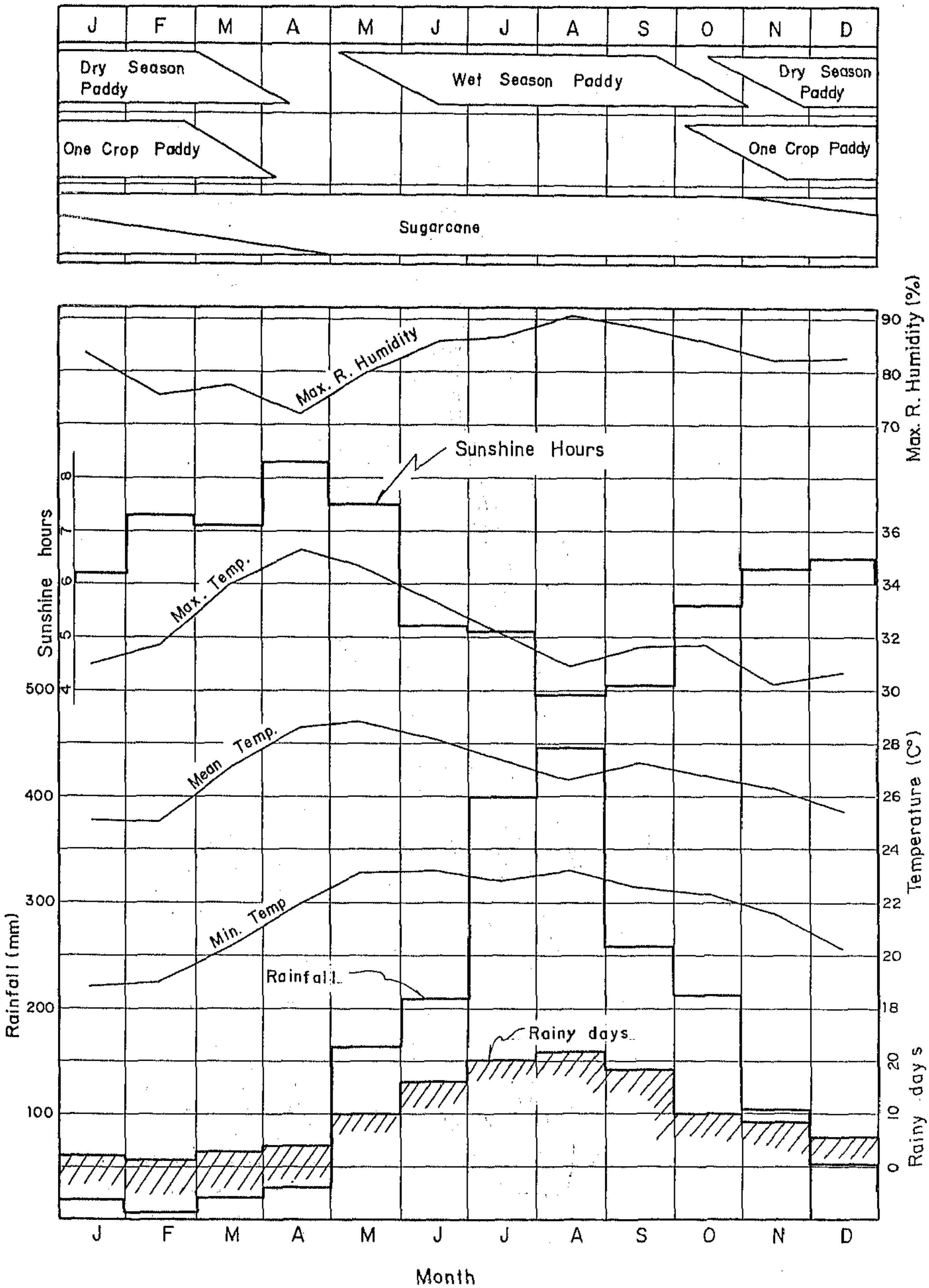


Fig. 4.2.14 GENERAL LAYOUT OF IRRIGATION PLAN FOR ALTERNATIVE 1 to 8

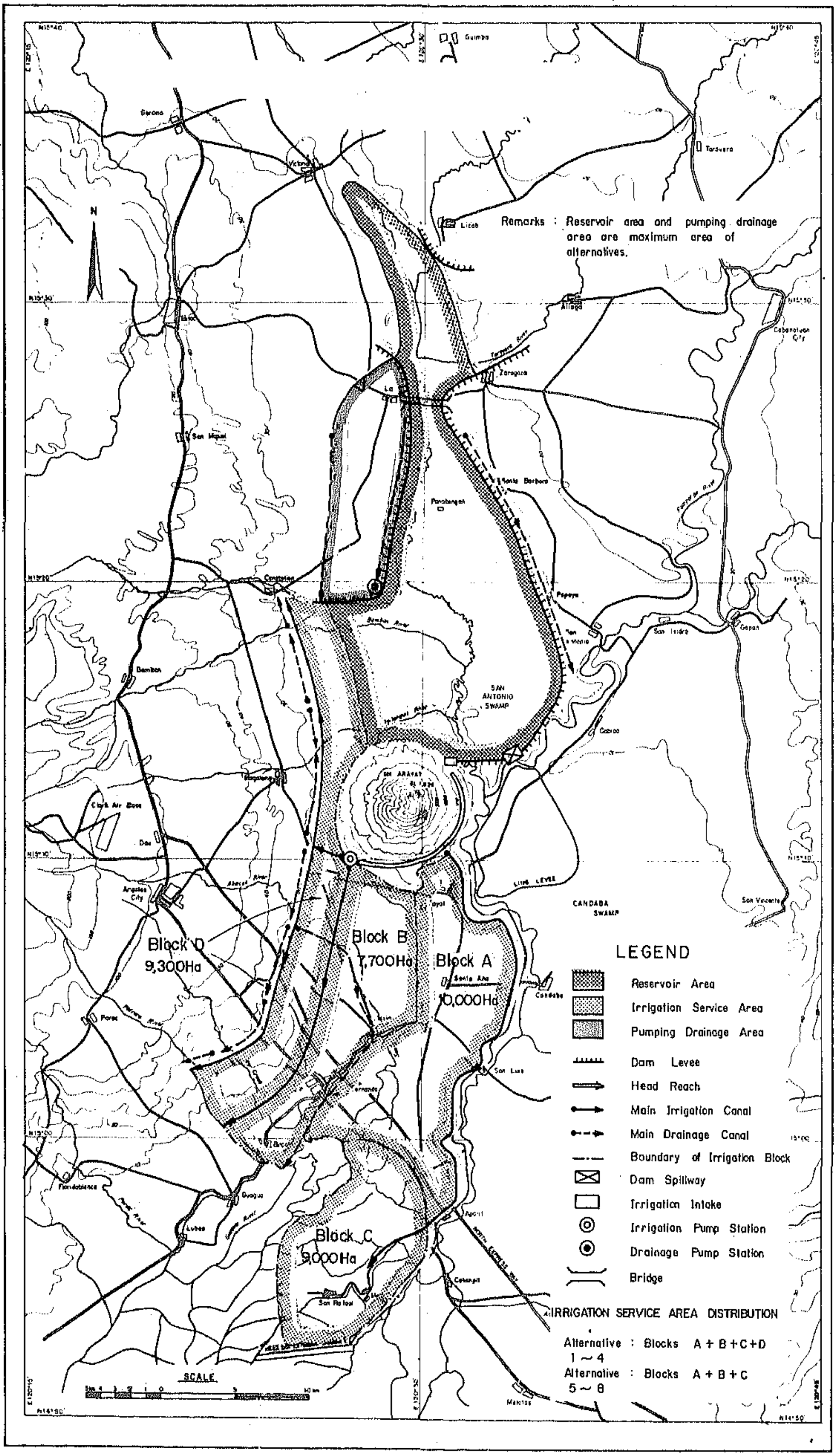


Fig. 4.2.15 GENERAL LAYOUT OF IRRIGATION PLAN FOR ALTERNATIVE 9 to 13

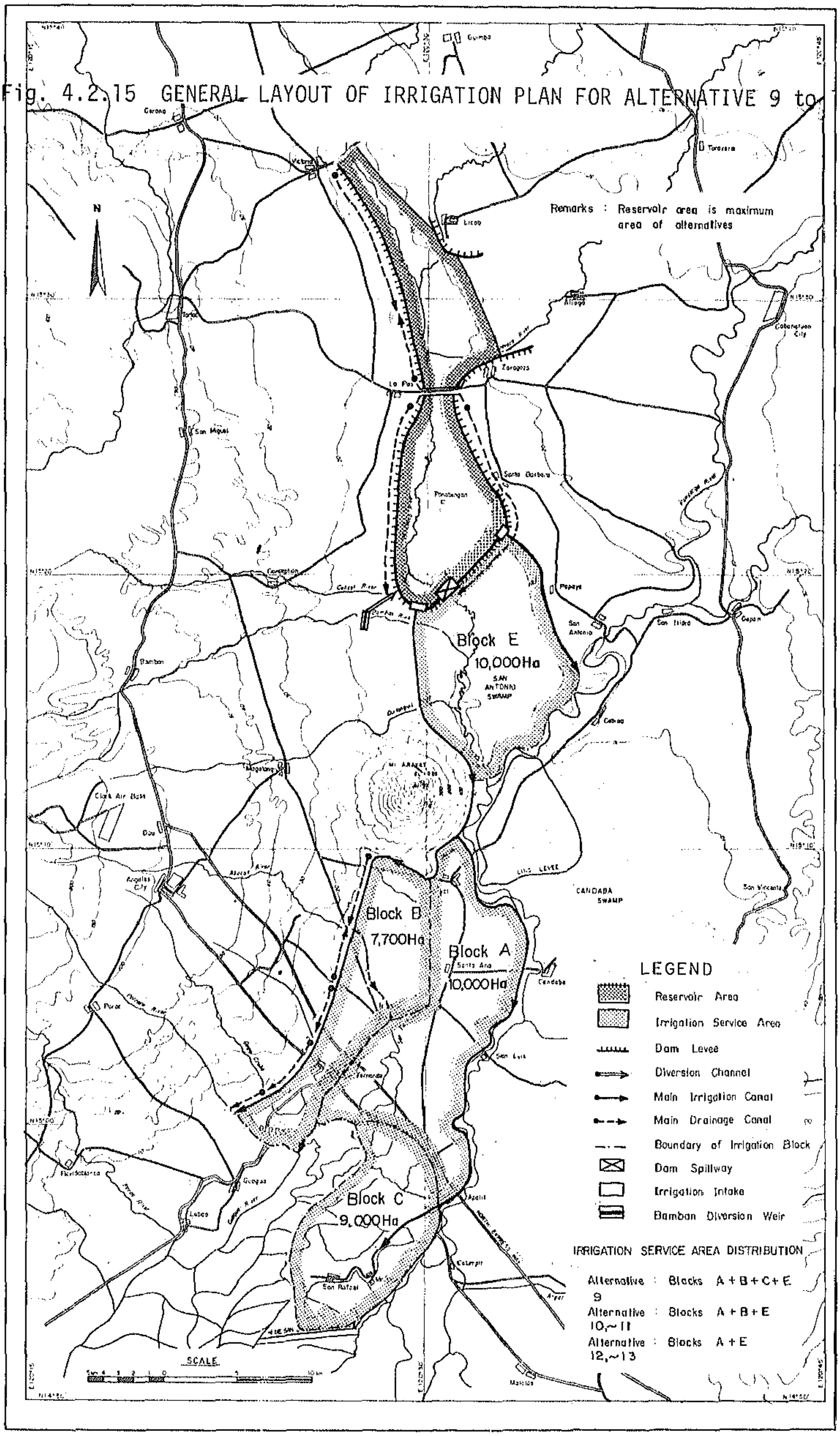


Fig. 4.2.16 GENERAL LAYOUT OF IRRIGATION PLAN FOR ALTERNATIVE 14 AND 15

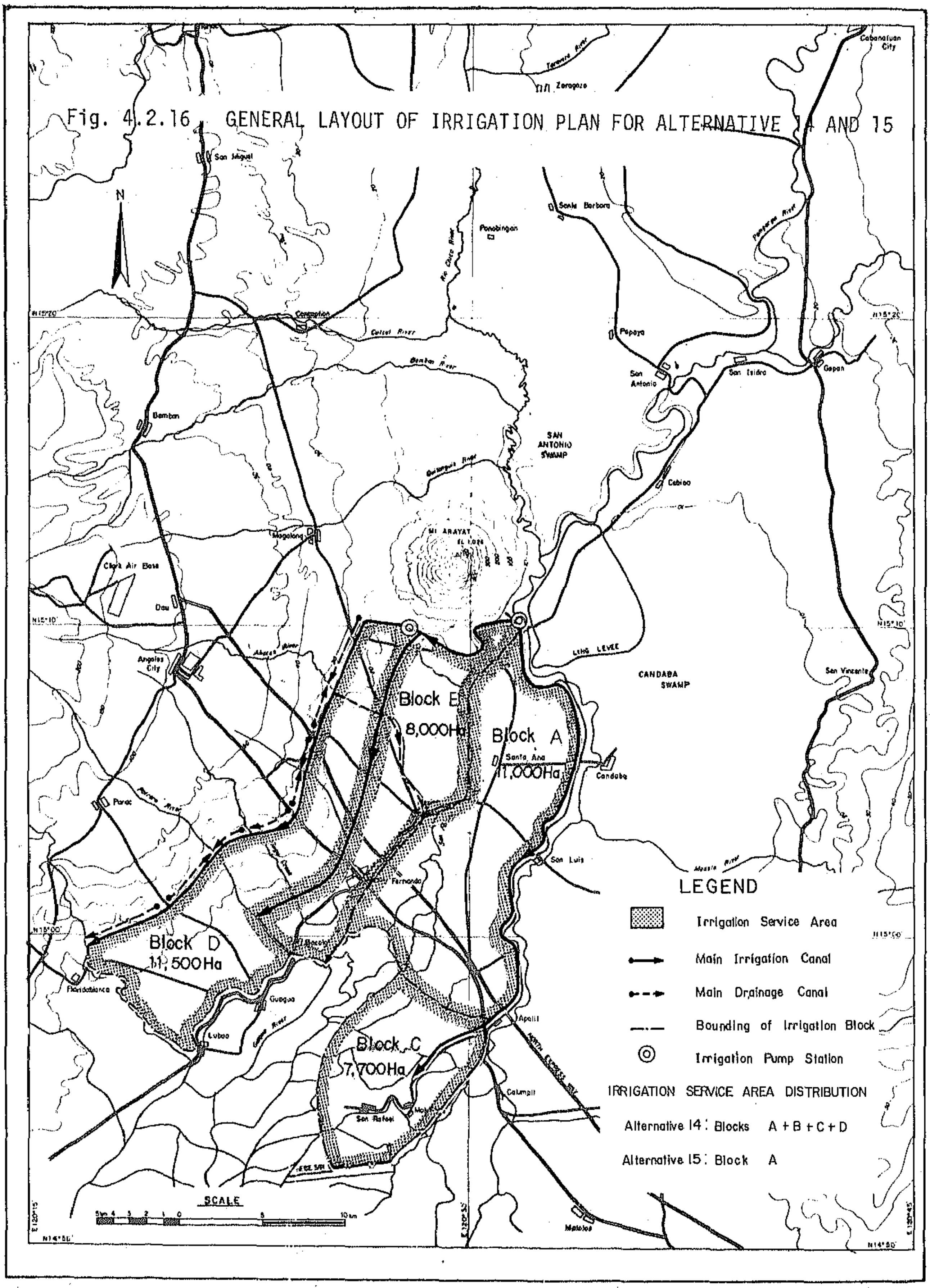


Fig. 4.2.17 SEASONAL VARIATION OF CROP COEFFICIENT OF PADDY

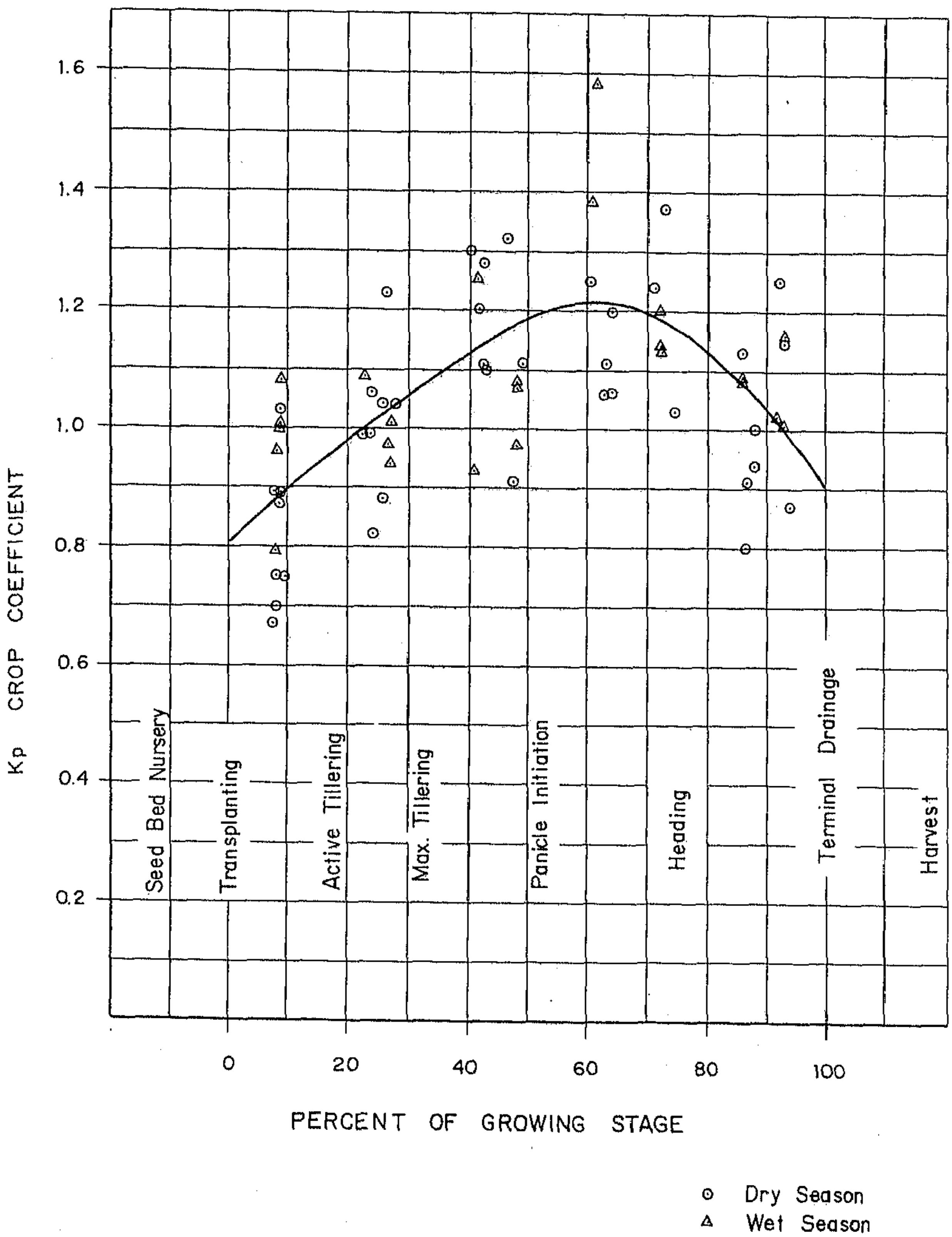
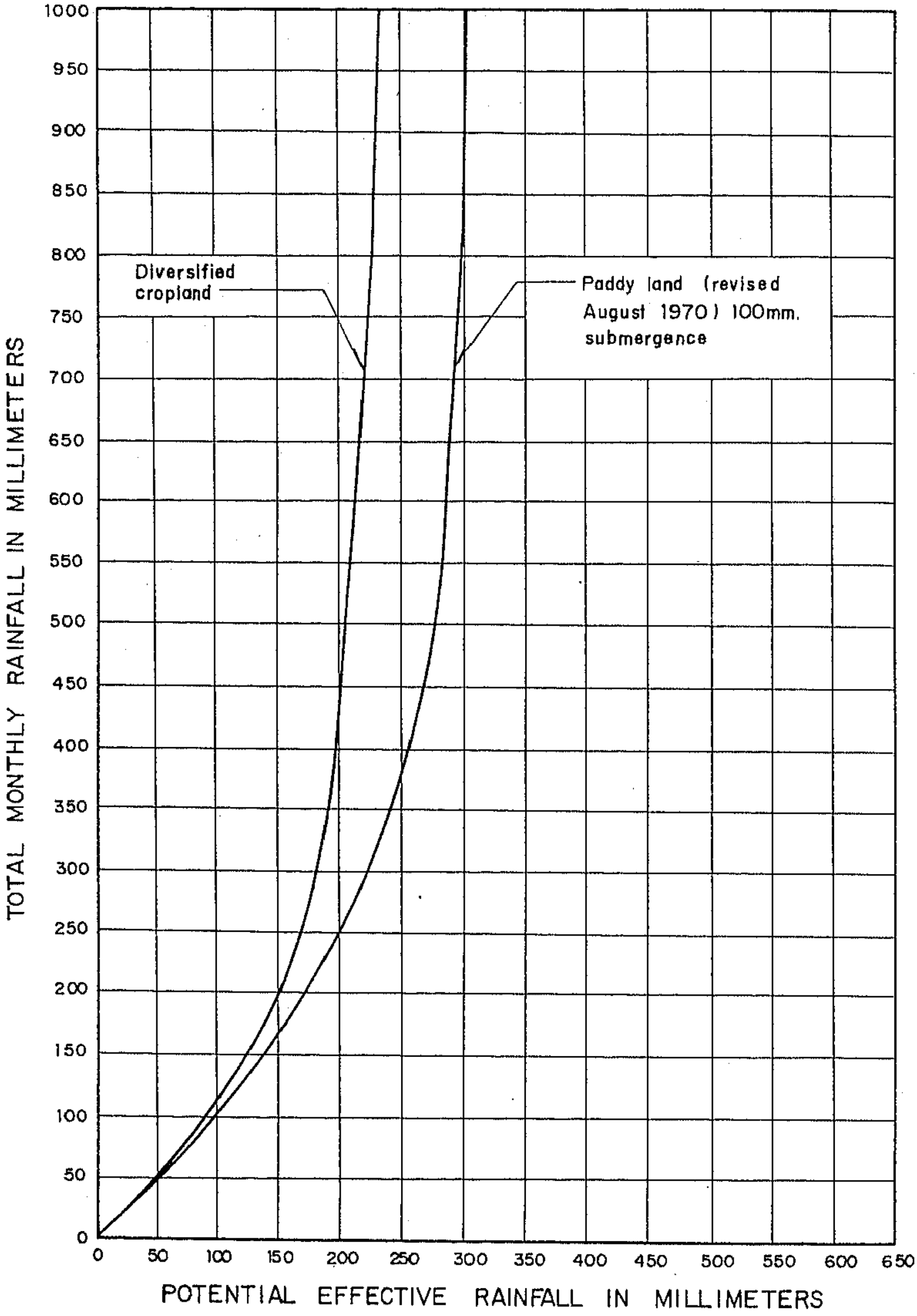


Fig. 4.2.18 RAINFALL — POTENTIAL EFFECTIVE RAINFALL CURVE



Source NIA CENTRAL LUZON STUDY

Fig. 4.2.19 CONTOUR MAP OF THE RESERVOIR AREA

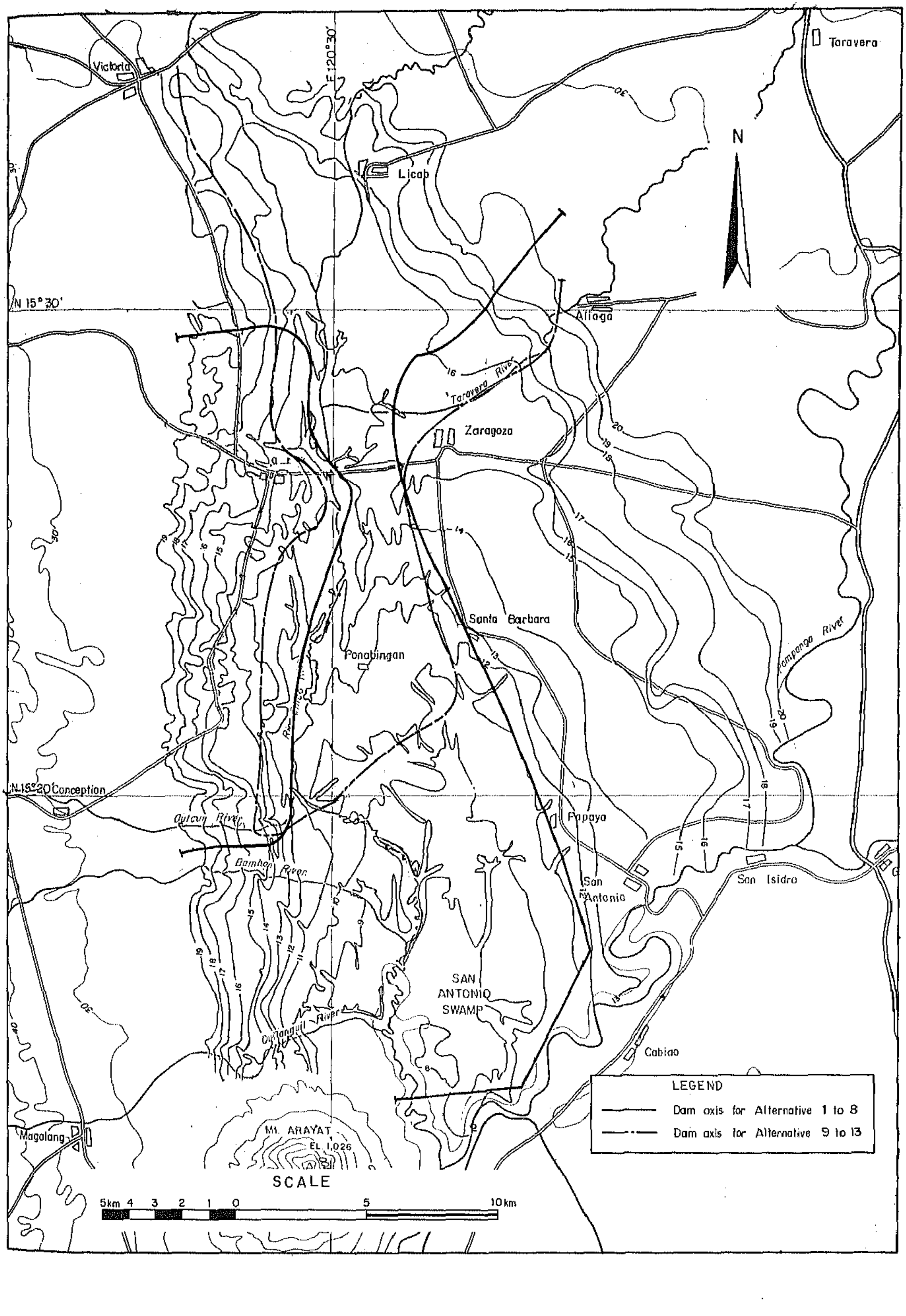


Fig. 4.2.20 RESERVOIR AREA AND VOLUME CURVE FOR ALTERNATIVE 1 to 8

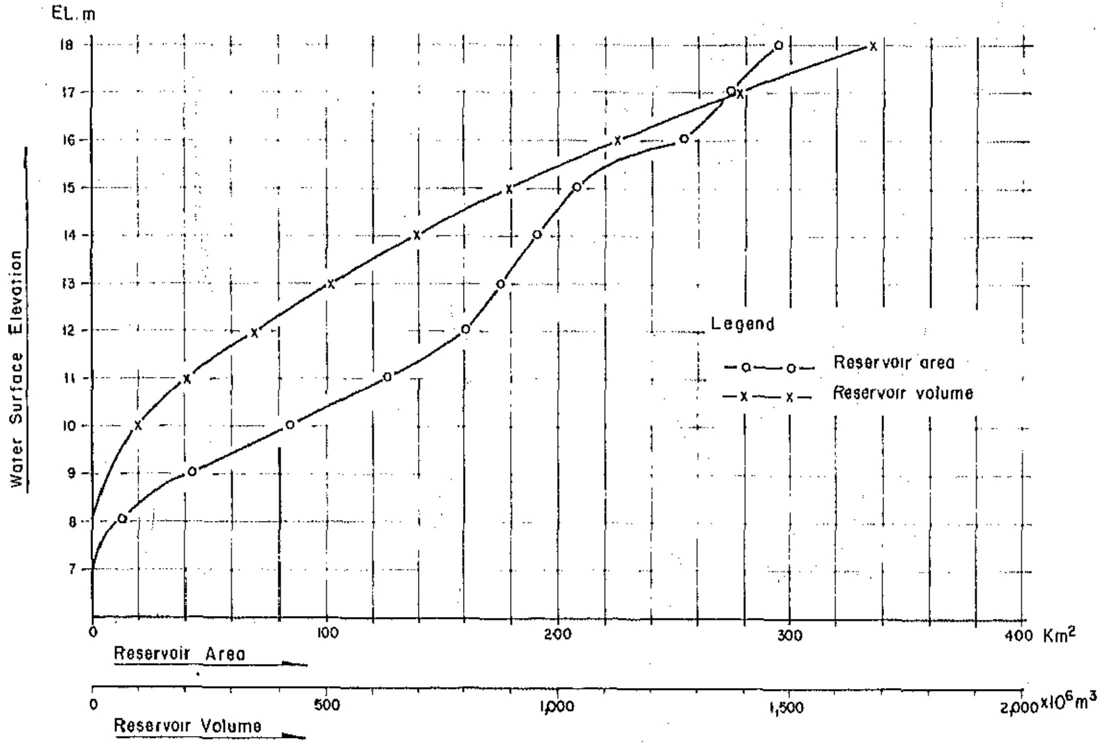


Fig. 4.2.21 RESERVOIR AREA AND VOLUME CURVE FOR ALTERNATIVE 9 to 13

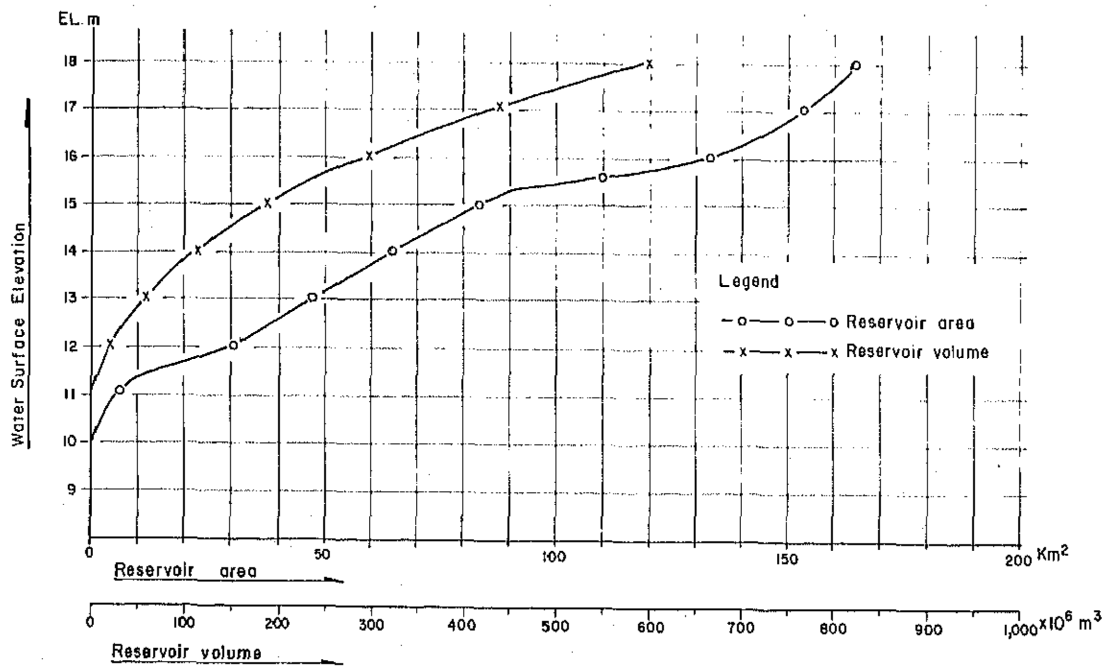


Fig. 4.2.22 TYPICAL SECTION OF DAM

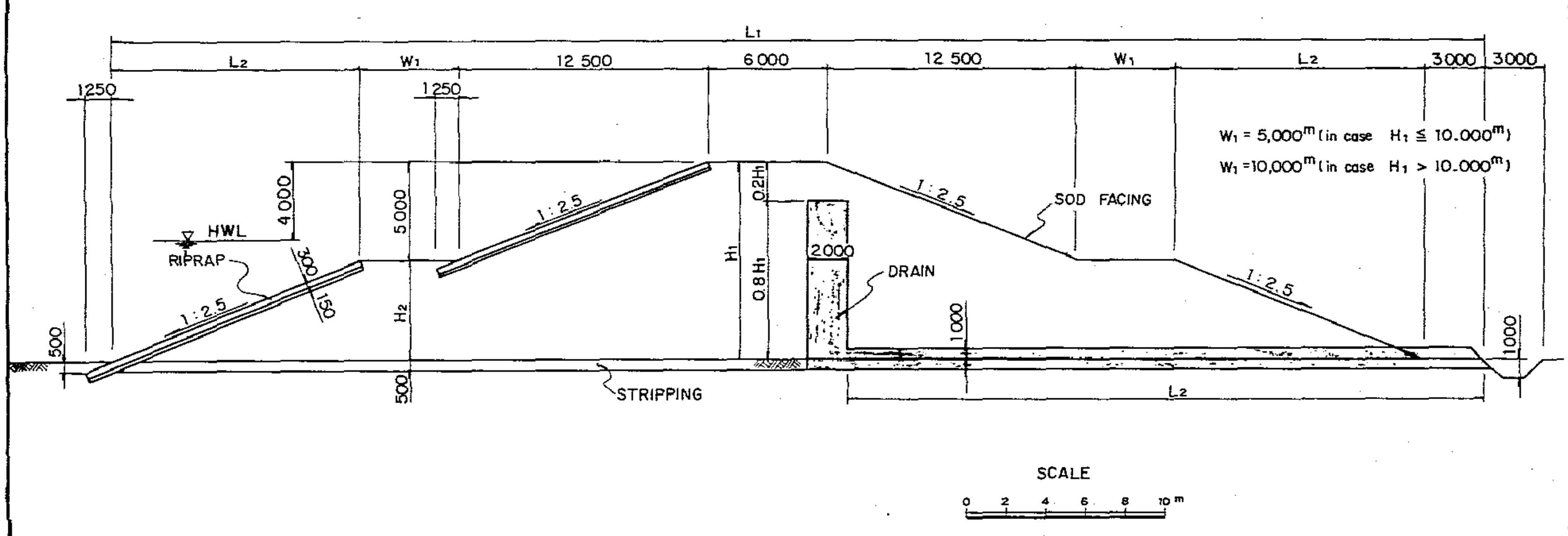


Fig. 4.2.23 CORRELATION OF PUMPING DRAINAGE AREA, DISCHARGE, AND REQUIRED PUMPING HEAD

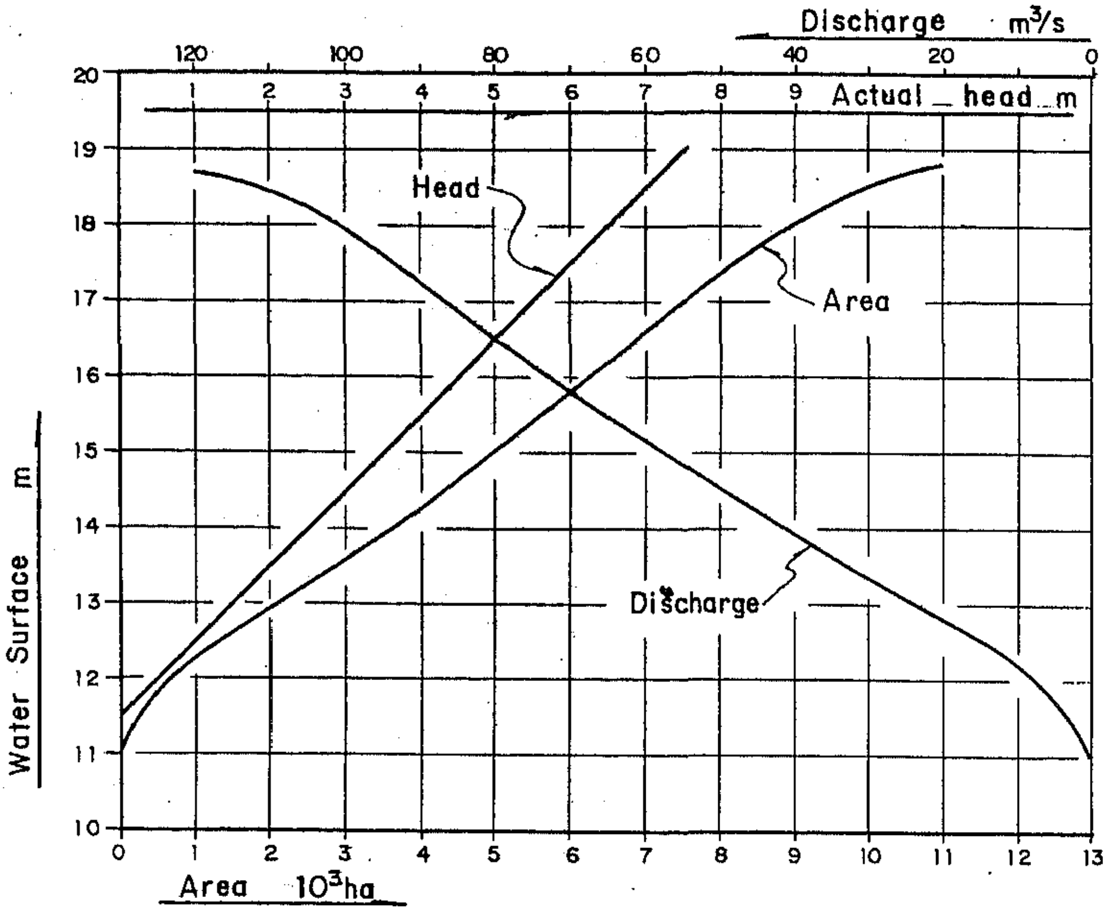


Fig. 4.2.24 CORRELATION OF EQUIPMENT COST AND Q&M COST FOR DRAINAGE PUMPING FACILITIES

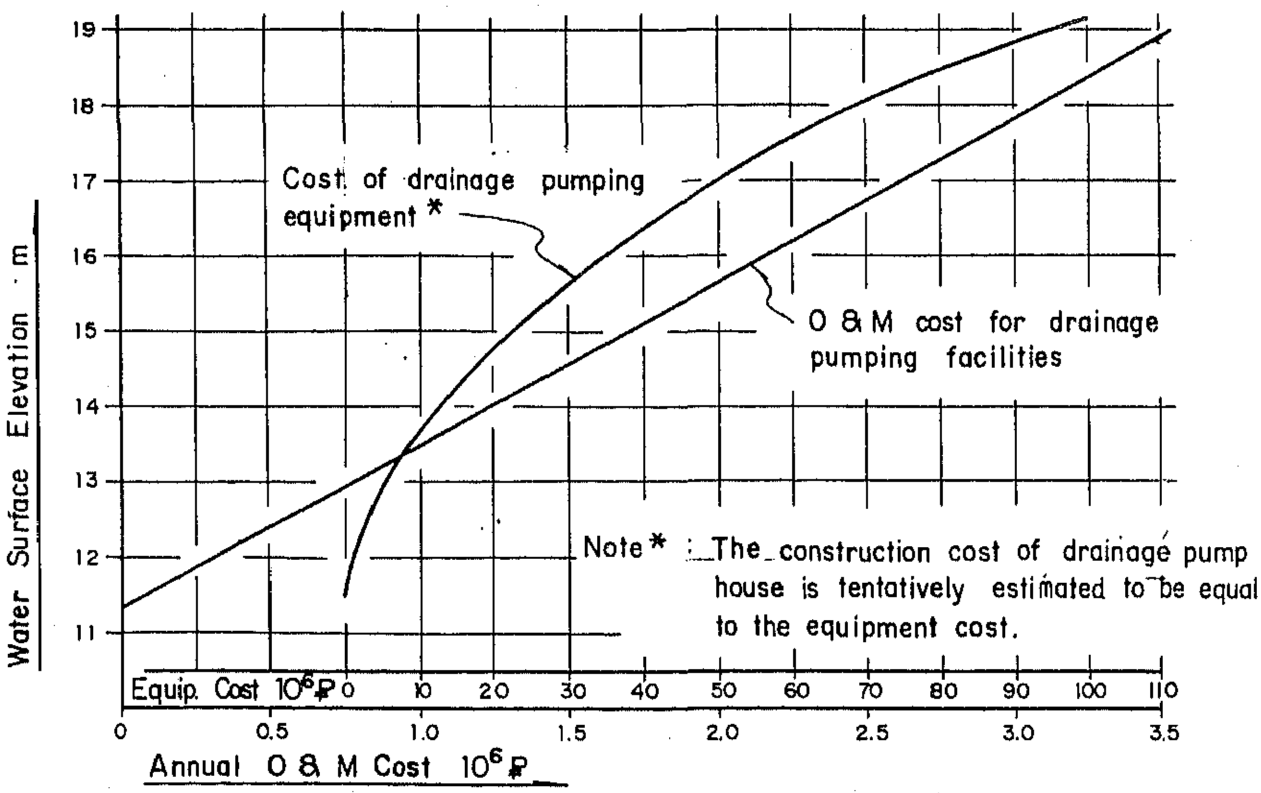


Fig. 4.2.25 DAM CREST EL - WORK QUANTITY CURVE FOR ALTERNATIVE 1 to 8

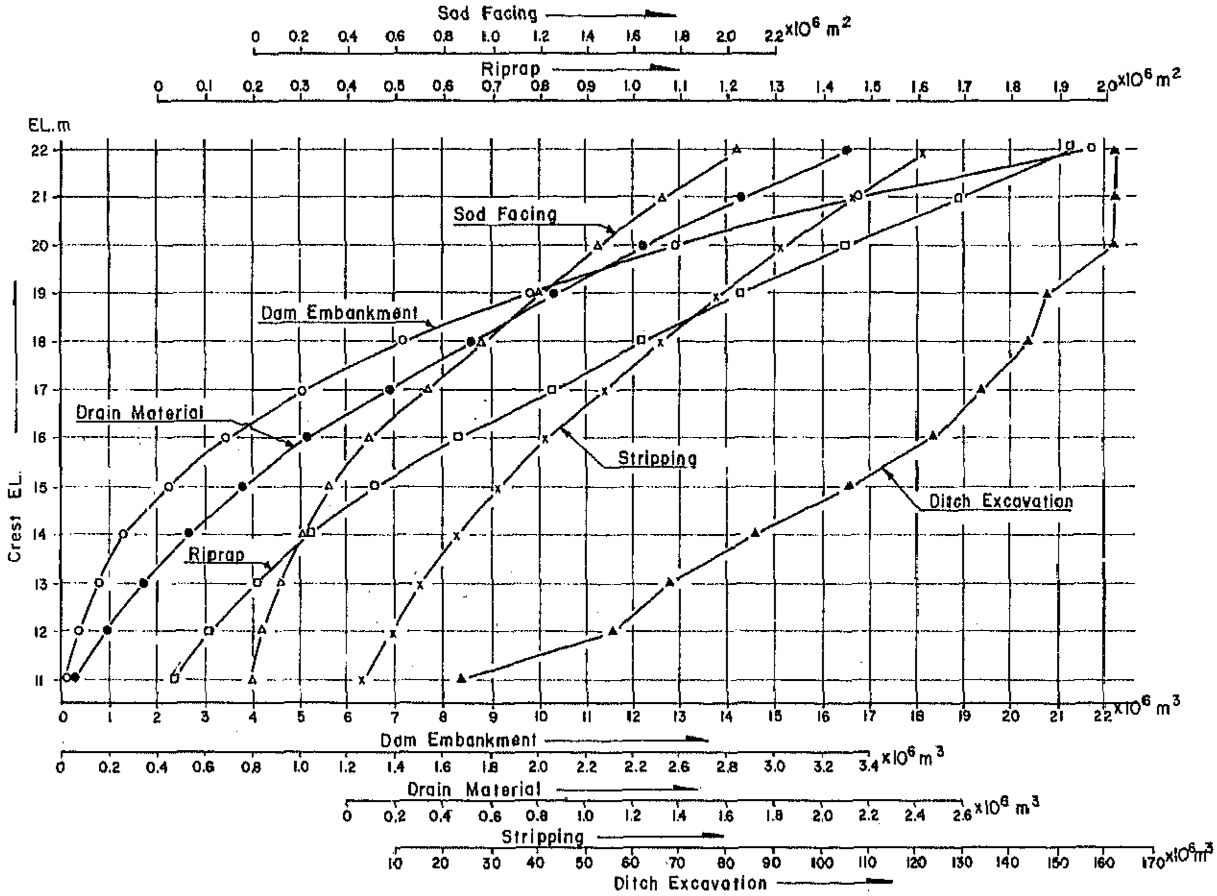


Fig. 4.2.26 DAM CREST EL - WORK QUANTITY CURVE FOR ALTERNATIVE 9 to 13

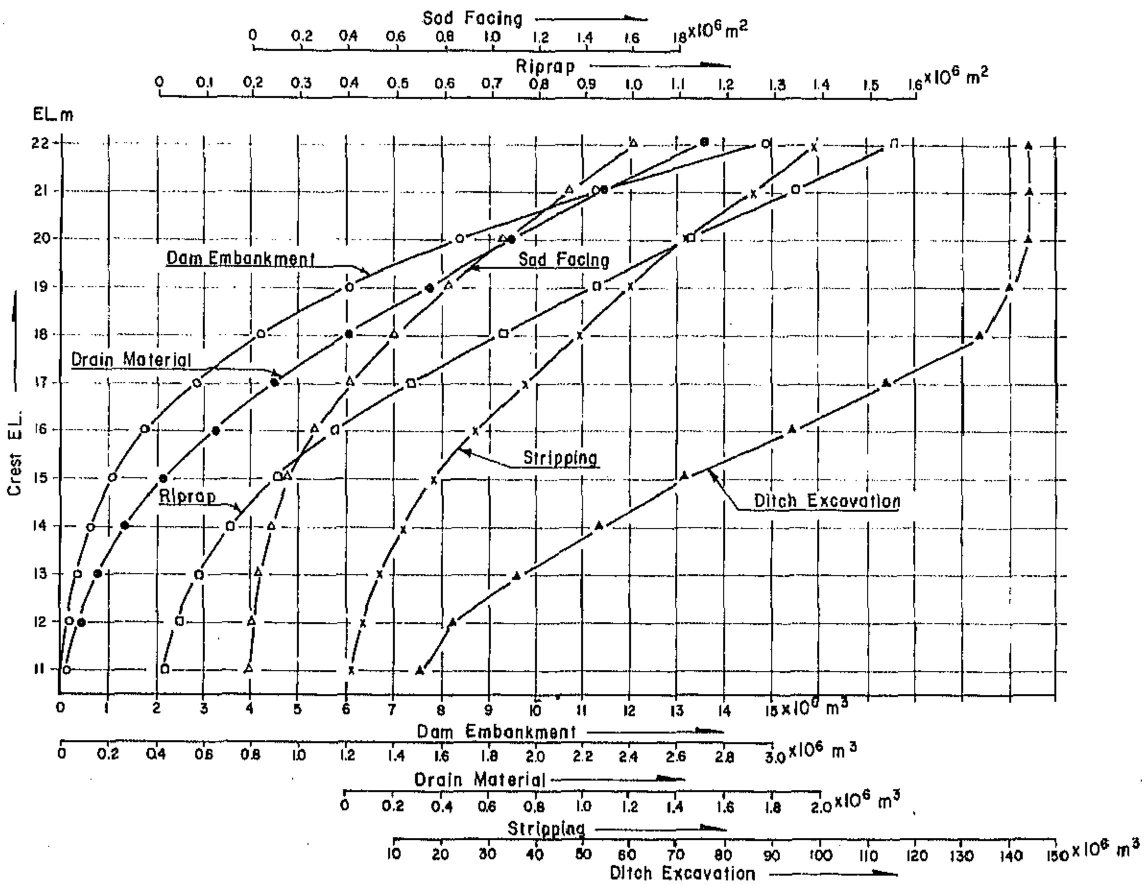


Fig. 4.2.27 DAM CREST ELEVATION – CONSTRUCTION COST CURVE ALTERNATIVES 1 TO 13

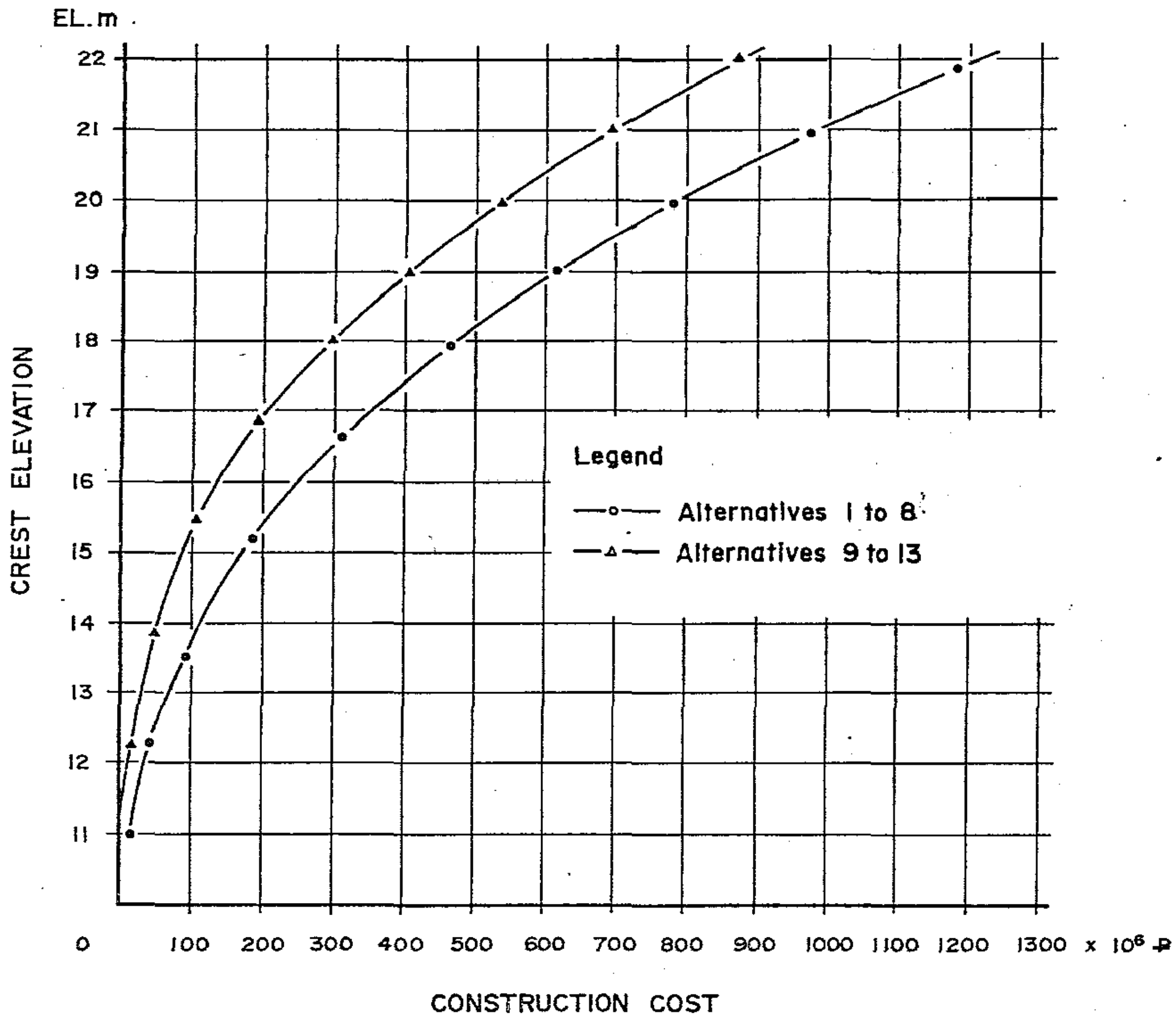


Fig. 4.2.28 CORRELATION OF RESERVOIR WATER SURFACE ELEVATION, DRAINAGE EARTH WORK VOLUME, AND DRAINAGE CONSTRUCTION COST

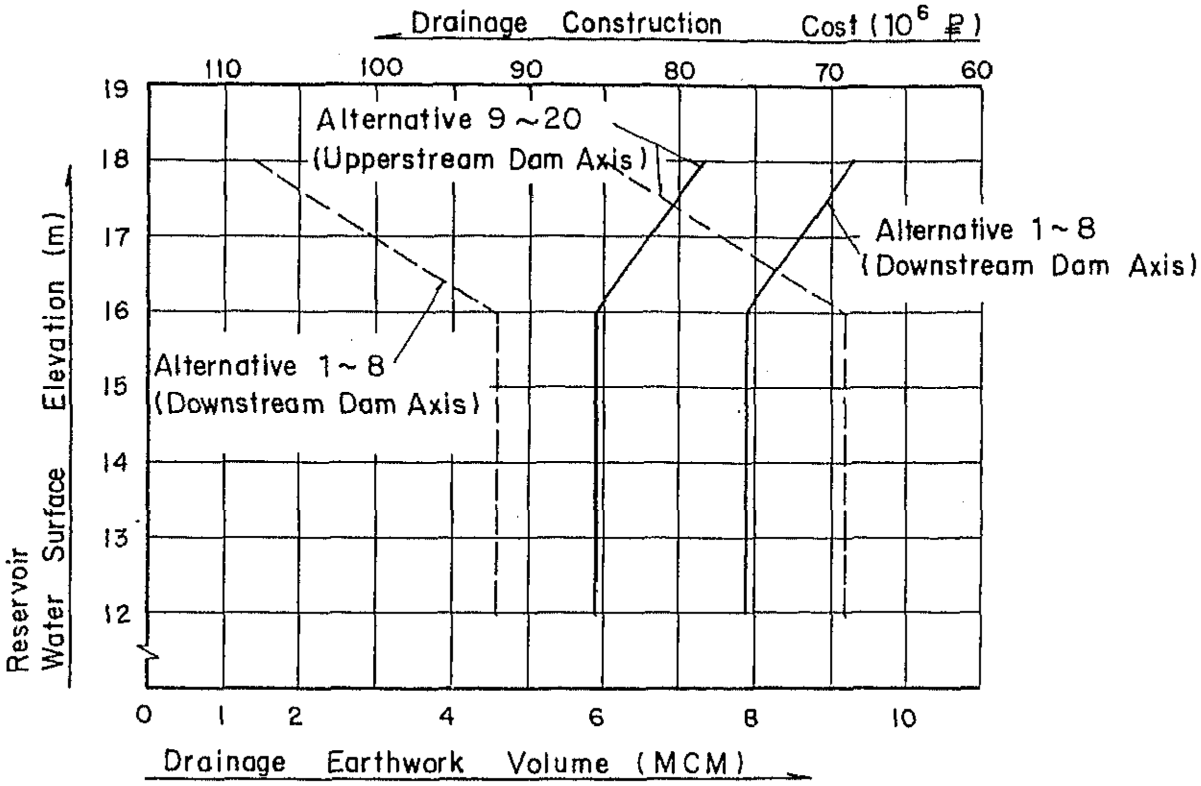


Fig. 4.2.29 CONSTRUCTION SCHEDULE

	Work Item	1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year
Alternative 1 to 13	Dam Construction	10%	30%	30%	30%		
	Major Irrigation Facilities		20%	40%	40%		
	Minor Irrigation Facilities				30%	35%	35%
Alternative 14 & 15	Pump House and Major Irrigation Facilities	20%	40%	40%			
	Mechanical and Elect. Works		20%	80%			
	Minor Irrigation Facilities			30%	35%	35%	

Remarks: % shows annual disbursement ratio

APPENDIX II

HYDROLOGY

APPENDIX II HYDROLOGY

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

Page

APPENDIX II HYDROLOGY

CHAPTER 1 INTRODUCTION

This Appendix II presents water resources in the Pampanga River Basin including rainfall, streamflow, tide, water quality, sea water intrusion and sedimentation, studies on runoff flood discharge, and hydraulic analysis in the downstream from San Antonio Swamp by simulation model. The hydraulic analysis of the proposed flood control works in the downstream of the Pampanga River are not included in this Appendix.

CHAPTER 2 WATER RESOURCES

2.1 Rainfall

2.1.1 Rainfall Records

Rainfall observations in the Pampanga River Basin have been made at 82 stations as shown in Table 2.1. Location of these stations is shown in Fig. 2.1. Collected existing data from PAGASA show that only 9 of them have continuous records covering more than 10 years as shown in Fig. 2.2 Collected records of daily rainfall are compiled in Data Book./1

2.1.2 Mean Monthly Rainfall

For the convenience to know the general pattern of the rainfall in the basin, the mean monthly rainfalls at 67 stations are presented in Fig. 2.3 which show their annual pattern of average and minimum values.

2.1.3 Rainfall Characteristics

As shown in Fig. 2.4, the mean annual rainfall varies from less than 2,000 mm in the central part of the basin to over 2,800 mm in the mountainous eastern and southwestern portions. This variation is caused primarily by the effect of the topography and the rain-bearing seasonal winds. During the northern or northeastern monsoon period, October - January, the basin is shielded by the Caraballo Mountains on the north and northeast. During the period from February to April, the basin is shielded on the east from the eastern trade winds by the Sierra Madre Mountains. During the remainder of the year, the basin is shielded from the southwest monsoon winds by the Zambales Mountains on the south.

Heavy precipitation generally occurs in the period of May through October during the southwest monsoon and August is generally the month of heaviest rainfall. More than half of the rainfall in the basin is associated with typhoons. Nearly 90 percent of the mean annual precipitation recorded at Cabanatuan City occurred during the period of May - October as shown in Table 2.2. The mean annual rainfall for each sub-basin is as follows:

/1: Data Book I Rainfall, Feasibility Report on the Pampanga Delta Development Project, Feb. 1982, JICA

Sub-basin		Mean Annual Rainfall (mm)
a.	Upper Pampanga	2,310
b.	Rio Chico-Talavera	2,020
c.	Sierra Madre Mountains	2,400
	Average for Pampanga Basin	2,250
d.	Zambales Mountains	2,340
	Average for Whole Basin	2,260

2.2 Streamflow

2.2.1 Water Level Records

There are available records of gage height at 29 gage stations in the Pampanga and Guagua Basins from the beginning 1969. The locations and available periods of the records are shown in Figs.2.5 and 2.6 respectively. Water level records at those stations are mainly kept in National Water Resources Council (NWRC), but water level records in the stations for the flood forecasting are kept at PAGASA. Most of water level data are on the daily-basis, but the data of PAGASA are on the hourly-basis during flood period. As is shown in Fig. 2.6, the observation of water level has been stopped at many stations since 1975. Only a few of them have continued up to 1978, but in 1979, the observations of water level at all the stations were stopped except the stations for the flood forecasting network of the Pampanga River Basin.

2.2.2 Streamflow

Discharge rating curves at 27 stations were prepared on the basis of the previous discharge measurement data at the time of the study of PD/CS Area Development Project. To supplement the data on discharge, the measurement was carried out by the Team at 5 stations in the period of August through November, 1980. The results are shwon in Table 2.3. Based on the supplemented data, the rating curves at 3 stations were revised and the curves at 2 stations were newly made as shown in Fig. 2.7. The discharge rating curves at 29 stations are shown in Table 2.4 in the form of formula.

2.2.3 Mean Monthly Discharge

The daily water level at 29 stations were converted into daily discharges using the discharge rating curve at each gage station. For the purpose of knowing the general pattern of the river discharge in the basin, the mean monthly discharges in terms of average and minimum values are presented conveniently in Fig. 2.8.

2.2.4 Mean 10-day Discharge

Using the daily discharges, the discharges necessary for irrigation studies are provided as 10-day average discharge. Discharges during the periods of no record are estimated by use of a linear regression equation based on correlation studies between the other gage stations. The estimated correlation coefficients between stations are listed in Table 2.5 and the formulae of the cross-correlation are shown in Table 2.6. 10-day average discharges during the period of 1968 through 1978 are shown in Table 2.7 for the stations of Arayat, Zaragoza and Floridablanca, the Gumain River. The inflows to the San Antonio Swamp are estimated as shown in Table 2.8 based on the data at the gage stations around the swamp.

2.2.5 Streamflow Characteristics

The mean monthly discharges at each gage station illustrated in Fig. 2.8 show their general annual pattern of average and minimum values. Generally, the annual pattern of the streamflow varies widely according to the year, and the Pampanga and Rio Chico River Basins have almost the same characteristics throughout the year. The wet season flow appears during the months of June through November, but occasionally, June and November have a small discharge, less than 50 m^3/s at Arayat and 1 m^3/s at Zaragoza. The drought flow appears during the months of January through April, especially the streamflow becomes extremely small in March and April. The average minimum discharge of the past 14 years is 26.8 m^3/s at Arayat and 0.9 m^3/s at Zaragoza. December is a transitional month to the dry season flow and May is also a transitional month to the wet season flow, but occasionally, large discharge occurs in May caused by heavy rainfall.

2.3 Tide

Tides in Manila Bay range from -0.7 m to +0.8 m in MSL. According to the data collected from BCGS, the tide levels in Manila Harbor are as follows:

Elevation above Mean Sea Level in Meter			
Mean Higher High Level (MHHL)	Mean High Level (MHL)	Mean Low Level (MLL)	Mean Lower Low Level (MLLL)
0.53	0.39	-0.37	-0.47

These levels are illustrated in Fig. 2.9. The levels were determined from 29 years series (1951-1979) of the actual observations. The maximum, minimum and average levels are shown in Table 2.9.

2.4 Water Quality

To know the quality of river water, water sampling was carried out by the Team at 10 locations as shown in Fig. 2.10 during high-water flow condition in September 1980 and low-water flow condition in January 1981. The samples were analyzed by the Soil and Water Laboratory of NIA, Muñoz, Nueva Ecija. The results of water quality analysis are shown in Table 2.10 which indicate that the water is generally acceptable for irrigation usage.

2.5 Seawater Intrusion

2.5.1 Data on Salinity

According to the Report on PD/CS Area Development Project, the measurement of the salt content was carried out at 3 stations along the Bulacan River and at 4 stations along the Pampanga River between 4 and 18 km upstream from the mouths of the rivers during lowstream flow in March 1977. To supplement the data, the measurement was carried out by the Team in January and by MPW during the period from March to April, 1981 at 16 stations along the Pampanga main stream, the Labangan Floodway and other rivers relevant to the Project. The stations of the measurement are as follows:

River	Station in Distance from River Mouth
Pampanga	10 km, 14 km, 17 km, 22.5 km, 22.6 km, 25 km
Labangan	9.5 km, 16.5 km, 17 km, 22 km
San Fernando	22.5 km, 31 km, 35 km
Hagonoy	9 km, 13 km, 18.5 km

The locations of the above stations are shown in Fig. 2.11.

The water samples were taken each 1 m from 30 cm below the water surface to channel bottom. In order to simplify the measurement in the field, the salt content of the water was measured in terms of electric conductivity. Then they were converted to the chloride concentration which belongs to dissolved common salt (NaCl). The results of the measurement are listed in Table 2.11.

The correlation curves between electric conductivity and chloride concentration as shown in Fig. 2.12 are used for conversion in this study. For making correlation curve, the chloride concentration of the samples were analyzed at the laboratory of the Metropolitan Water Works and Sewerage System according to the procedure of the American Public Health Association. The chloride concentration is about 23,500 ppm in seawater, and fresh water normally contains less than 10 ppm of chloride.

2.5.2 Estimation of Seawater Intrusion

Salty sea-water penetrates farther near the river bottom than at the surface. In the intermediate zone, it can be detected a linearly increasing rate of the chloride concentration in the river mouth. As the correlation between chloride concentration and the distance has a linear function in the most of the cases, the chloride concentration profile of the Pampanga River was drawn with regard to the water surface and the river bed as shown in Fig. 2.13.

The figures show that seawater penetration in the Pampanga River increases from 13 km at low tide to 16 km at the peak of the tide, near the water surface. Near the channel bottom, salty water penetrated from a minimum of 13 km to 17 km during the observation period. The maximum points of seawater intrusion in the San Fernando River is estimated at 32 km from the river mouth based on the observed data.

However, the seawater intrusion is influenced not only by fluctuations of tide but also by river's streamflow change. From these observed data, it is difficult to estimate the maximum point of seawater intrusion at the time of various streamflow. Hence, with regard to the Pampanga mainstream and the Labangan Floodway, the possible intrusion distances at the time of various streamflow are estimated by calculation in the following:

Equation

The form and length of salt wedge may be expressed in the following equations, assuming that the boundary face between salt water and fresh water exists clearly.

Equation for Form of Salt Wedge:

$$\frac{X}{L_i} = \left(\frac{N_2}{N_*}\right)^2 \left(3-2\,\frac{N_2}{N*}\right) \quad \text{.......} \quad (2.1)$$

where, X: distance from the foot of salt wedge (m)

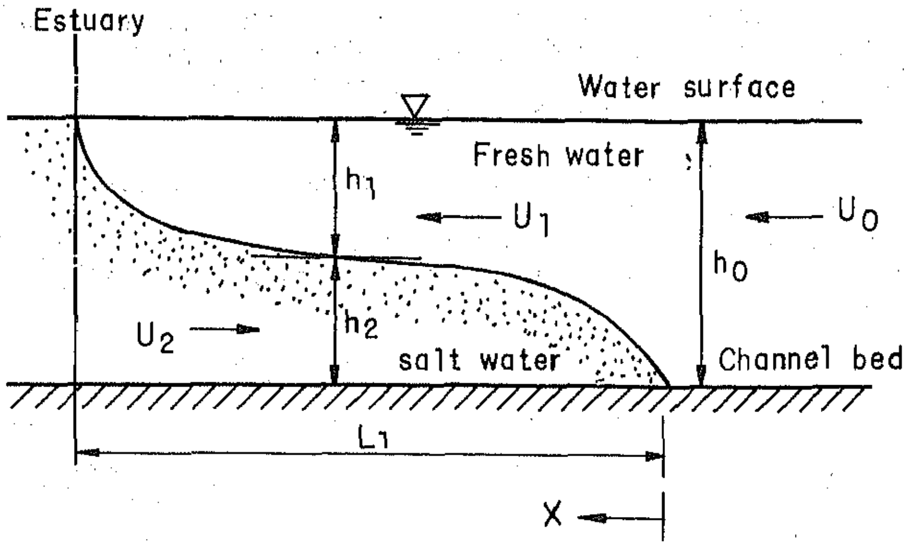
L_i: length of salt wedge (m)

$N_2 = \frac{h_2}{(h_1+h_2)}$: ratio of salt water depth

h_1: fresh water depth (m)

h_2: salt water depth (m)

$n*$: ratio of salt water depth at estuary



Equation for Length of Salt Wedge:

$$Y K F_i^{\,2} = \frac{1}{6} n_*^{\,2}(3-2n_*) - F_i^{\,2}\left[\frac{n_*}{1-n_*} + \log_e(1-n_*)\right] \quad \ldots\ldots\ldots \quad (2.2)$$

where, $Y = \dfrac{L_i}{h_1+h_2}$: ratio of salt wedge length and total depth of water

$K = \dfrac{T_i}{r_2 U_o^{\,2}}$: coefficient of resistance

T_1: shearing force between two-faces (t/m^2)

r_1: density of fresh water

r_2: density of sea water

U_o: velocity of fresh water (m/s)

$F_i = \dfrac{U_o}{\sqrt{egho}}$: internal Froude number

g: acceleration of gravity (9.8 m/sec^2)

$e = (\dfrac{r_2 - r_1}{r_2})$: ratio of density of salt water

Using the above mentioned equations, the seawater intrusion to the river is calculated for various streamflow at the time of high and low tides applying the corresponding rectangular cross-sections of the exiting channel. In the calculation, the value of K in equation (2.2) is determined as 0.009 based on the observed data.

The calculated results of salt wedge for various streamflow are shown in Table 2.12, and they are illustrated in Fig. 2.14. Based on the calculated results, the seawater intrusion to the Pampanga River and the Labangan Floodway during a drought is estimated as follows:

Seawater Intrusion to the River

River	Discharge (m^3/s)	Tide Level (MSL)	Seawater Intrusion (km)	
			1 m below Surface	Bottom
Pampanga River	5	0.53	18.8	46.6
	10	0.53	8.2	46.2
	20	0.53	2.8	45.2
	5	-0.47	18.0	46.2
	10	-0.47	7.7	45.4
	20	-0.47	2.4	36.7
Labangan Floodway	5	0.53	13.0	24.7
	2	-0.47	18.0	18.0
	5	-0.47	7.5	15.6

2.5.3 Frequency of Seawater Intrusion to River at Present

To know the frequency of seawater intrusion to the Pampanga River and the Labangan Floodway at present, the average distance of seawater intrusion in the affected period are estimated applying streamflow during the period from 1968 to 1978. The procedure for estimating the frequency is as follows:

i) Compute the median values of seawater intrusion distance at the time of high and low tides with regard to 1 m below water surface and channel bottom.

ii) Plot the median values of seawater intrusion determined in step i versus the river discharge on section paper and fit a smooth curve through the data (Fig. 2.15).

iii) Using 10-day average discharge at Arayat, the Pampanga River and at Bahay Pare, the Massim River, estimate the discharge of the Pampanga River at the confluence of the Maasim River added to the estimated discharge from the catchment area between Arayat and Candaba (Table 2.13(1)). Using 10-day average discharge at Pulilan, the Angat River, estimate the discharge of the Labangan Floodway deducted the discharge to the Pampanga River through the Bag-Bag River (Table 2.13(2)).

iv) Applying the river discharge obtained in step iii, estimate the seawater intrusion distance in the said rivers for each year.

The estimated distance of seawater intrusion and its affected period are shown in Table 2.14, and they are summarized in terms of average as follows:

Average Distance and Affected Period of Seawater Intrusion under the Existing Condition

Depth	Pampanga River		Labangan Floodway	
	Distance (km)	Period (day)	Distance (km)	Period (day)
At Channel Bottom	22.7	145	11.3	338
At 1m below Water Surface	1.3	138	4.6	293

2.6 Sedimentation

2.6.1 Data on Sediment

According to the Report on Irrigation Development Plan for Central Luzon, the average sediment yields at 15 stations are presented in Table 2.15. On the other hand, according to the Report on Balog-Balog Irrigation Project, the sedimentation value of 3,500 $m^3/km^2/year$ was adopted for reservoir planning based on the results of a recent survey of the actual siltation of two existing reservoirs in the upper basin of the Agno River as shown below:

Reservoir	$10^6 m^3/year$	$m^3/km^2/year$
Ambuklao	2.3	3,500
Binga	1.9	6,200

To supplement the data on sediment discharge, sediment sampling was carried out by the Team at 7 sections during the months of August through November 1980 as in Table 2.16. Furthermore, for estimation of bed load of river channel, sampling of river bed materials was also carried out by the Team in November 1980. The locations of the sampling are shown in Fig. 2.16. The sampled bed materials were analyzed at the Soil and Water Laboratory of NIA. The results are shown in Table 2.17.

2.6.2 Method of Estimating Sediment Discharge

In order to estimate sediment transport from the basin, sediment discharges at 6 stations are calculated by use of a formula and the data on sediment discharges observed by the Team during a period from August to November 1980, applying the following values based on the longitudinal profile of the river and the results of sieve analysis of bed materials.

Site	dm (mm)	d_{50} (mm)	I	n
Talavera	4.86	1.55	1/1,000	0.035
Zaragoza	0.13	0.08	1/5,000 - 1/70,000	0.030
Bamban	1.55	0.25	1/300	0.035
San Isidro	9.60	3.08	1/4,000 - 1/25,000	0.030
Arayat	0.10	0.07	1/10,000- 1/30,000	0.030
Candaba	0.12	0.07	1/5,000 - 1/30,000	0.030
Sulipan	0.10	0.07	1/9,000 - 1/30,000	0.030

The data on sediment discharge (suspended load including wash load) observed by the Team are plotted on log paper as shown in Fig. 2.17 to obtain a relationship between sediment discharge and water discharge. However, it is difficult to make-up a formula from this figure because of limited samples. On the other hand, relationship between sediment discharge and water discharge may be expressed in the following equations.

For bed load : $Q_B = K_1Q^{P1}$

For suspended load : $Q_S = K_2Q^{P2}$ .... (2.3)

where, Q_B: bed load (m^3/s)

Q_S: suspended load (m^3/s)

Q: water discharge (m^3/s)