Fig. 2.1 LOCATION MAP OF RAINFALL STATIONS

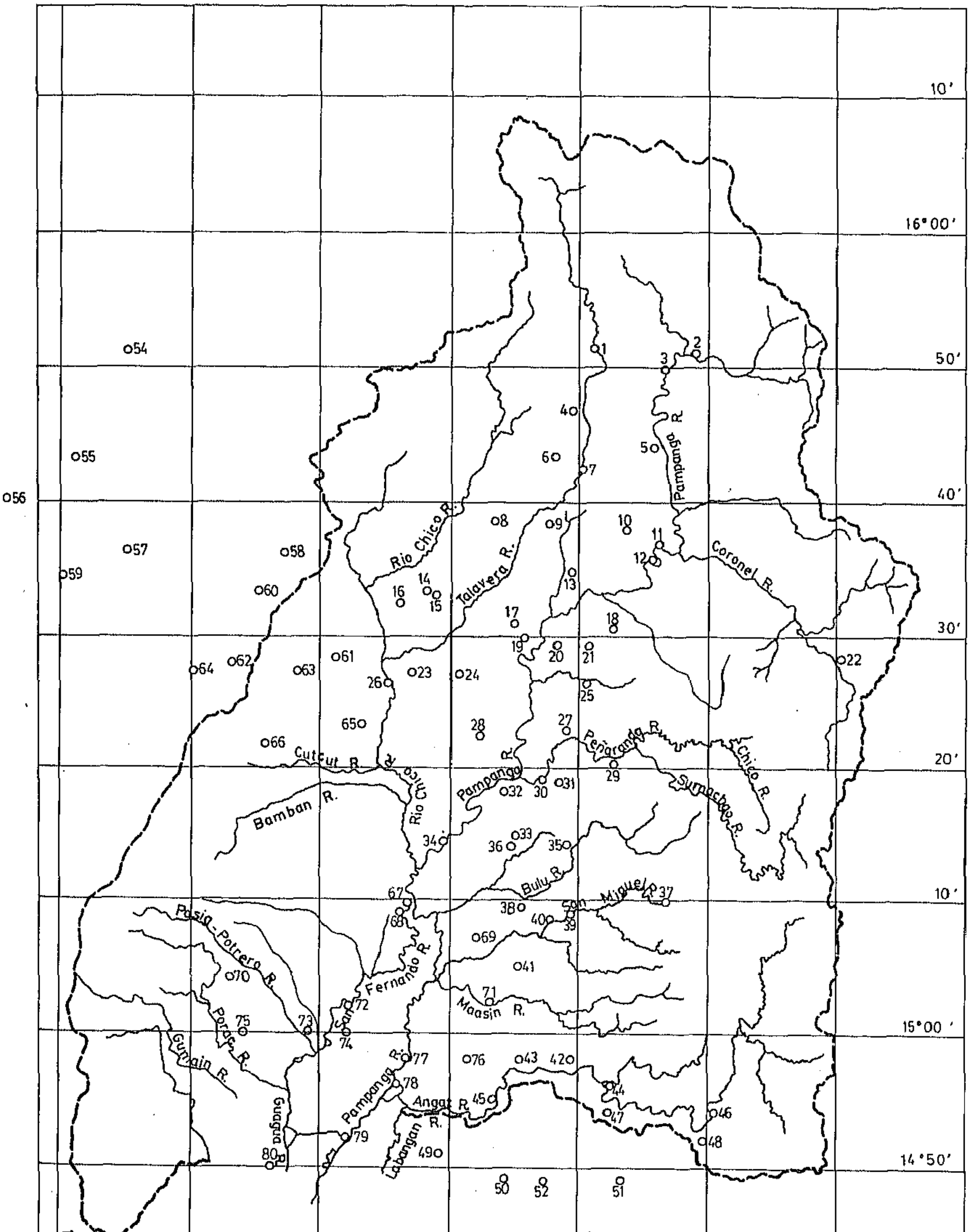


Fig. 2.2 AVAILABLE RECORDS OF DAILY RAINFALL

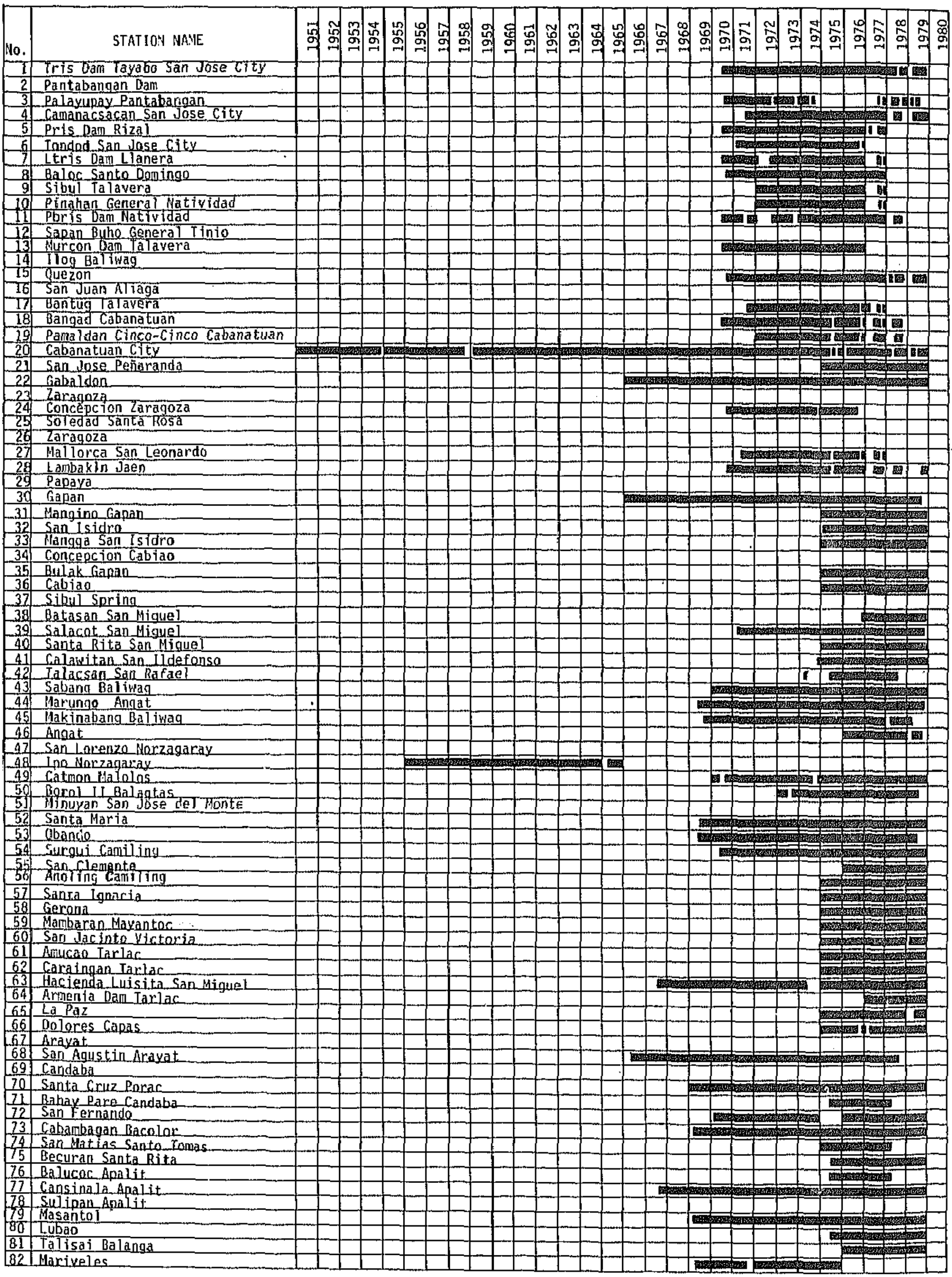
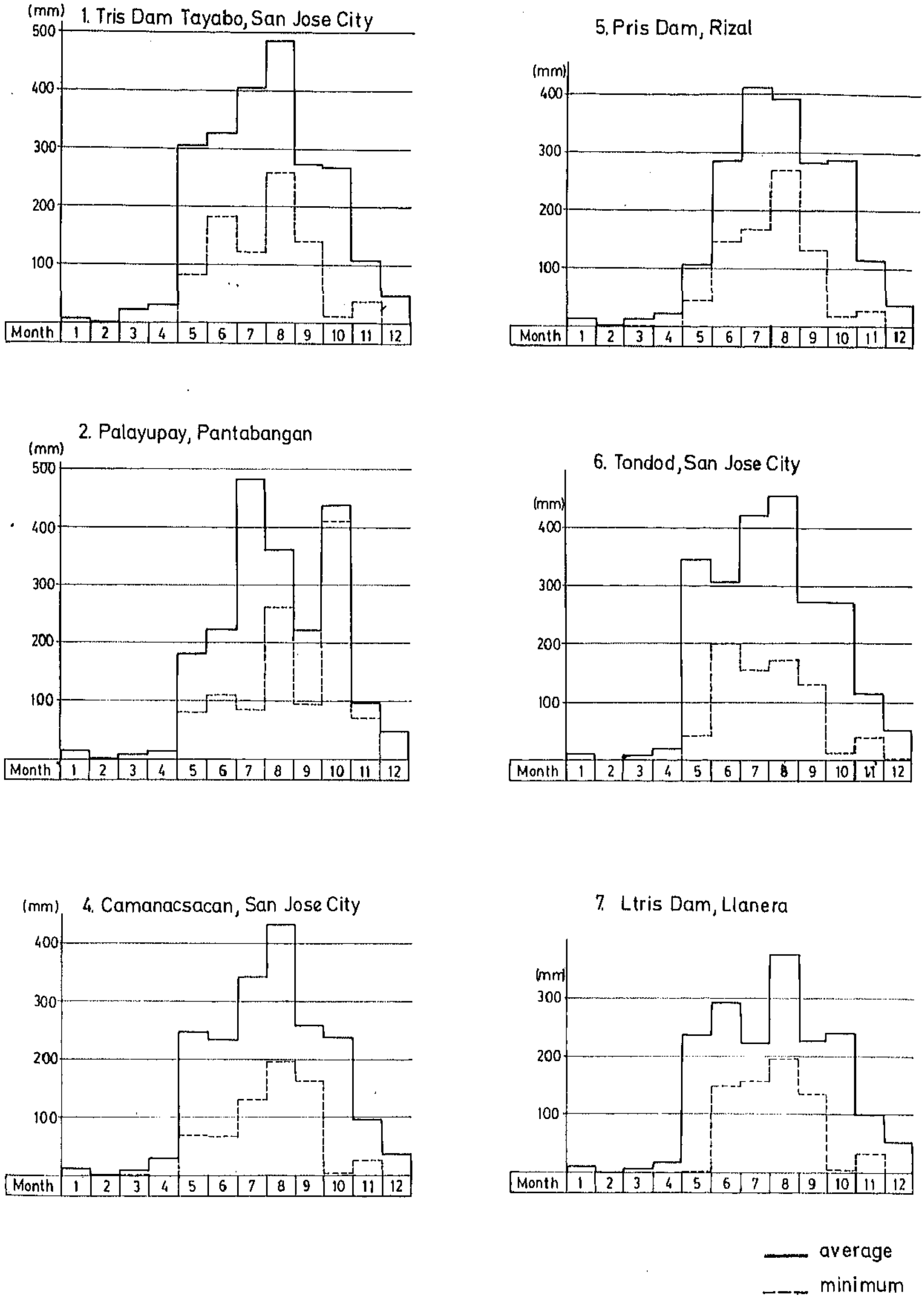


Fig. 23(1) ANNUAL PATTERN OF MEAN MONTHLY RAINFALL



1. Tris Dam Tayabo, San Jose City

5. Pris Dam, Rizal

2. Palayupay, Pantabangan

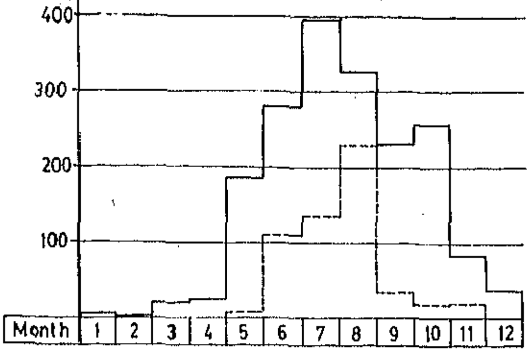
6. Tondod, San Jose City

4. Camanacsacan, San Jose City

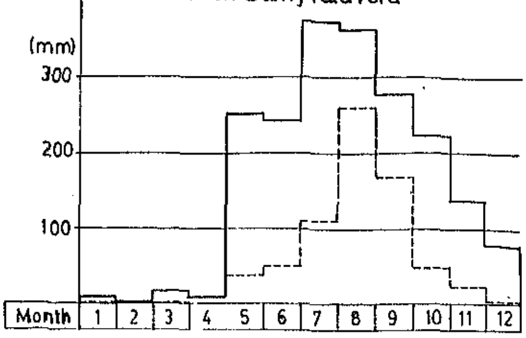
7. Ltris Dam, Llanera

Fig. 23(2) ANNUAL PATTERN OF MEAN MONTHLY RAINFALL

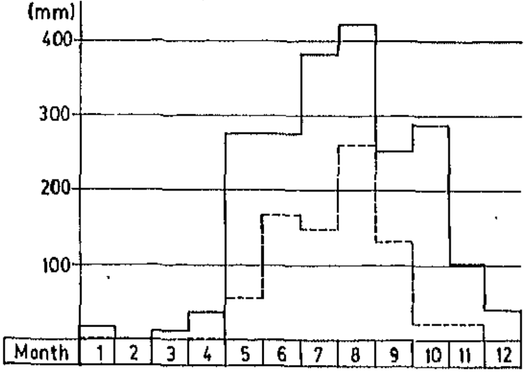
8. Baloc, Santo Domingo



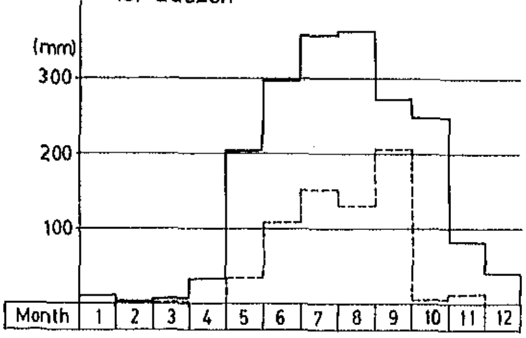
12. Murcon Dam, Talavera



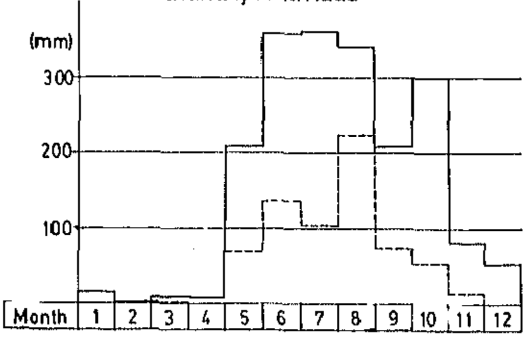
9. Sibul, Talavera



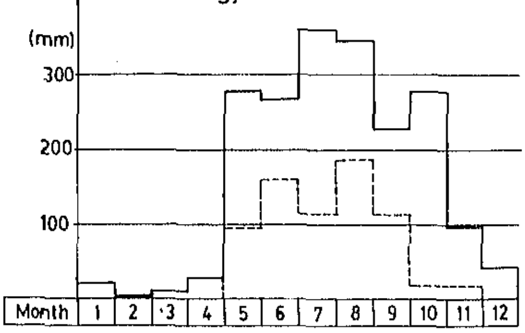
13. Quezon



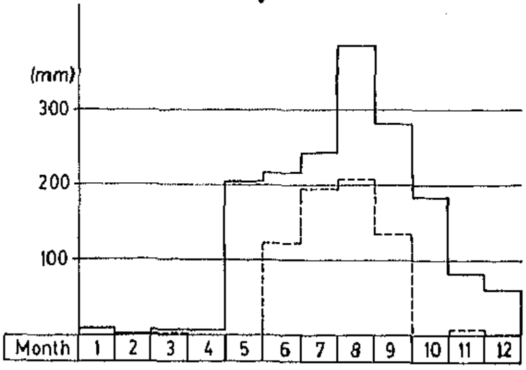
10. Piñahan, Natividad



14. Bantug, Talavera



11. Pbris Dam, Natividad



18. Bangad, Cabanatuan

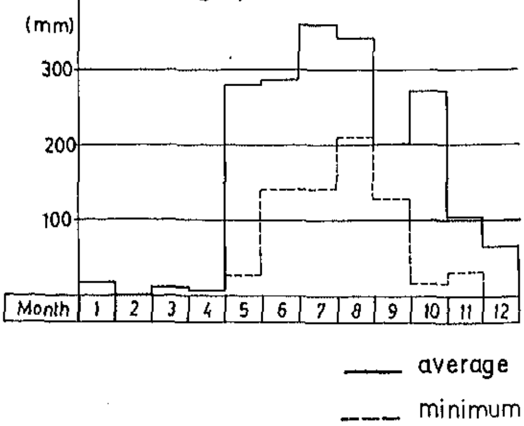
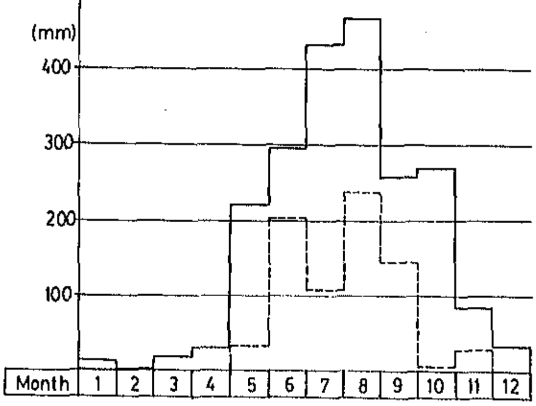
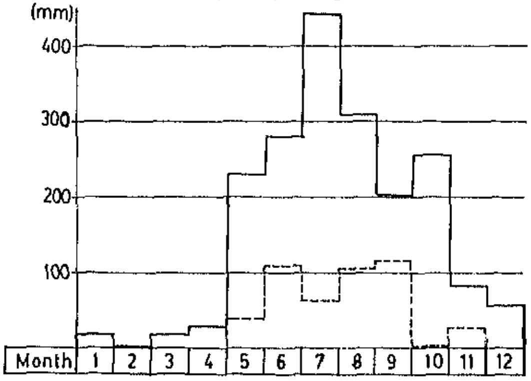


Fig. 23(3) ANNUAL PATTERN OF MEAN MONTHLY RAINFALL

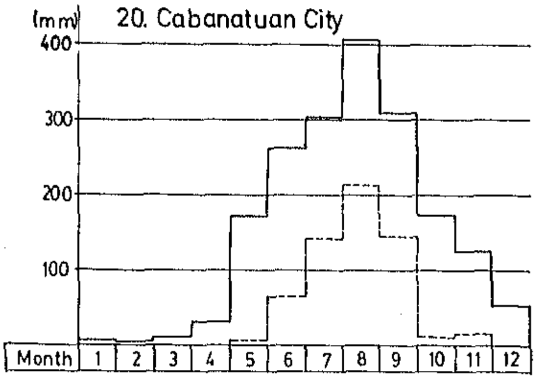
19. Pamaldan, Cabanatuan



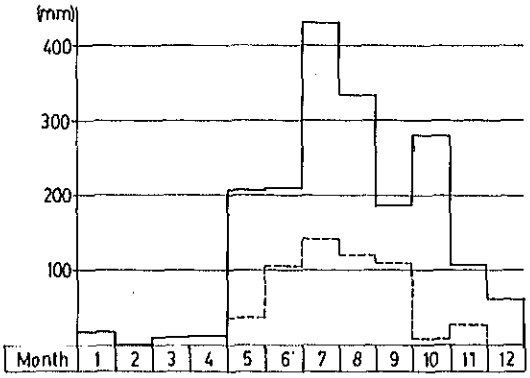
24. Concepcion, Zaragoza



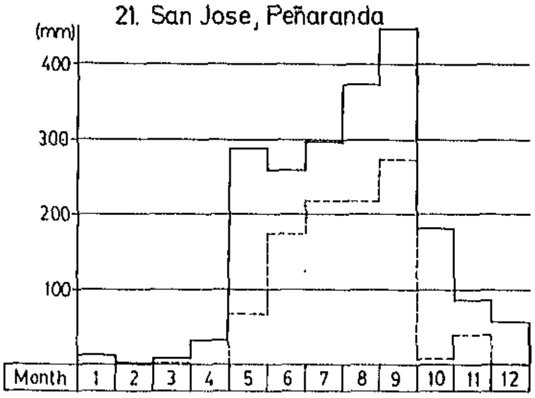
20. Cabanatuan City



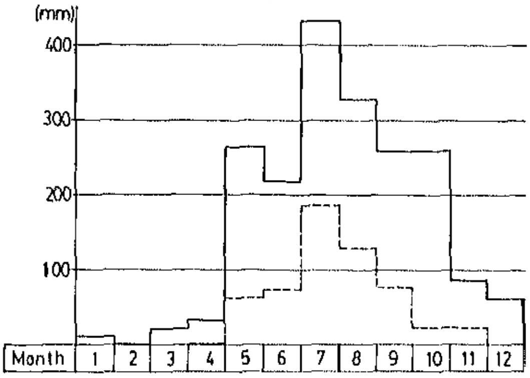
27. Mallorca, San Leonardo



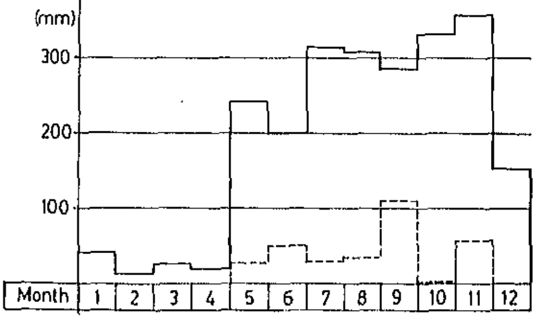
21. San Jose, Peñaranda



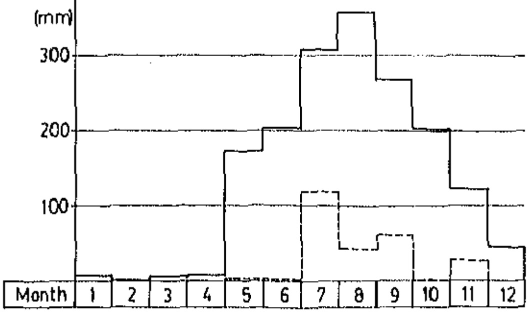
28. Lambakin, Jaen



22. Gabaldon



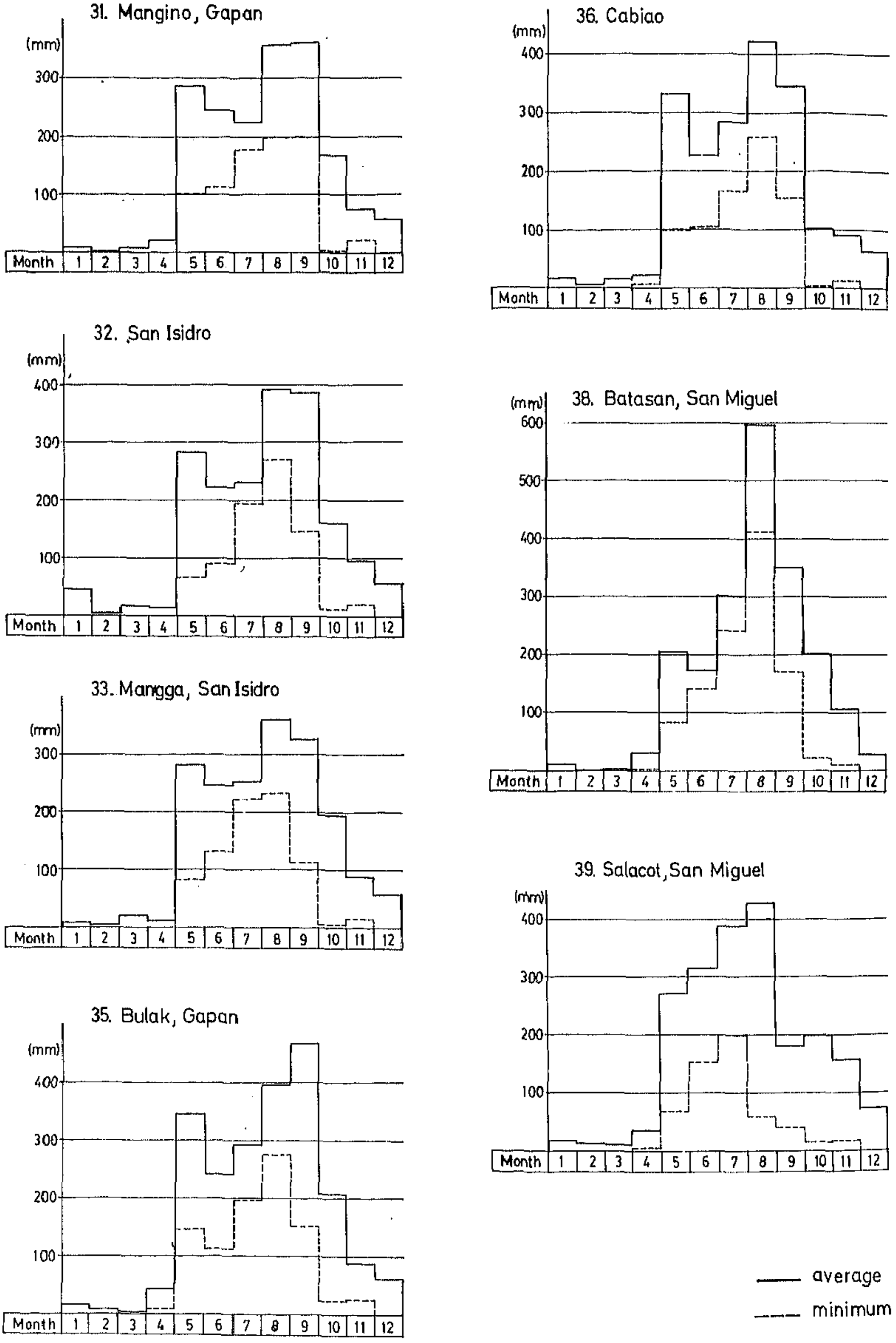
30. Gapan



——— average

– – – minimum

Fig. 23(4) ANNUAL PATTERN OF MEAN MONTHLY RAINFALL



31. Mangino, Gapan

32. San Isidro

33. Mangga, San Isidro

35. Bulak, Gapan

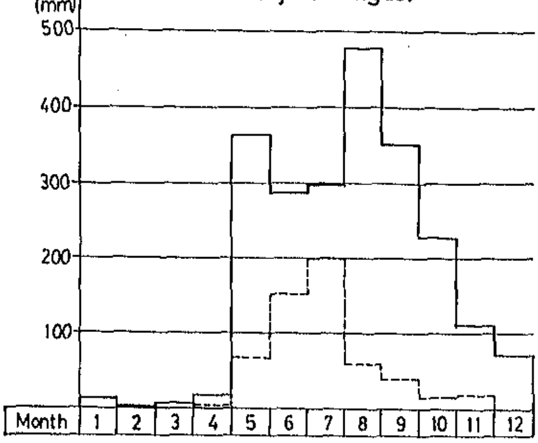
36. Cabiao

38. Batasan, San Miguel

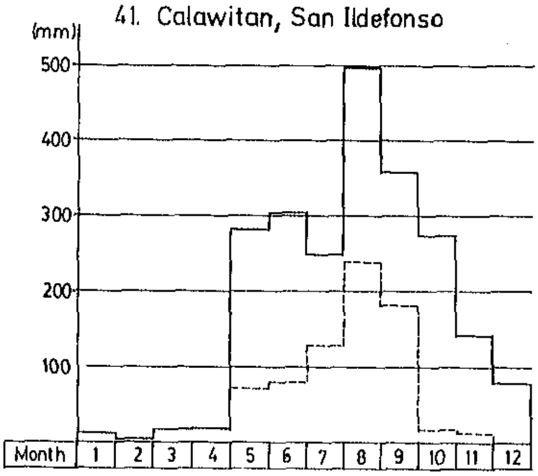
39. Salacot, San Miguel

Fig. 23(5) ANNUAL PATTERN OF MEAN MONTHLY RAINFALL

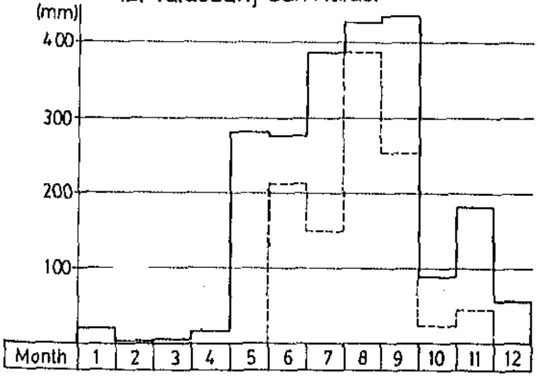
40. Santa Rita, San Miguel



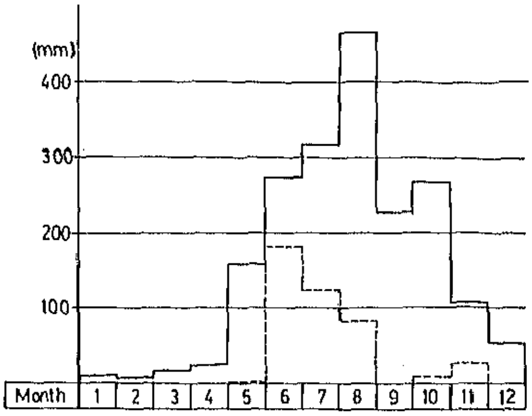
41. Calawitan, San Ildefonso



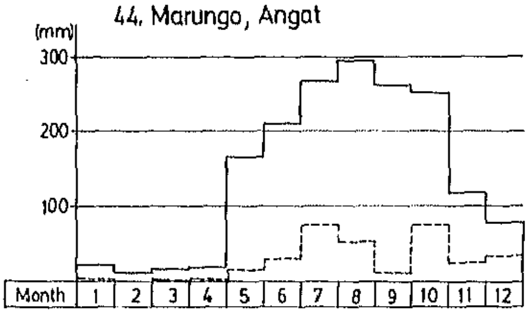
42. Talacsan, San Rafael



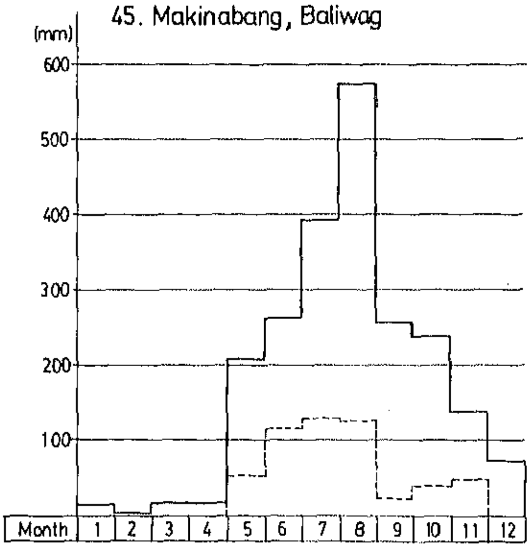
43. Sabang, Baliwag



44. Marungo, Angat



45. Makinabang, Baliwag



—— average
---- minimum

Fig. 23(6) ANNUAL PATTERN OF MEAN MONTHLY RAINFALL

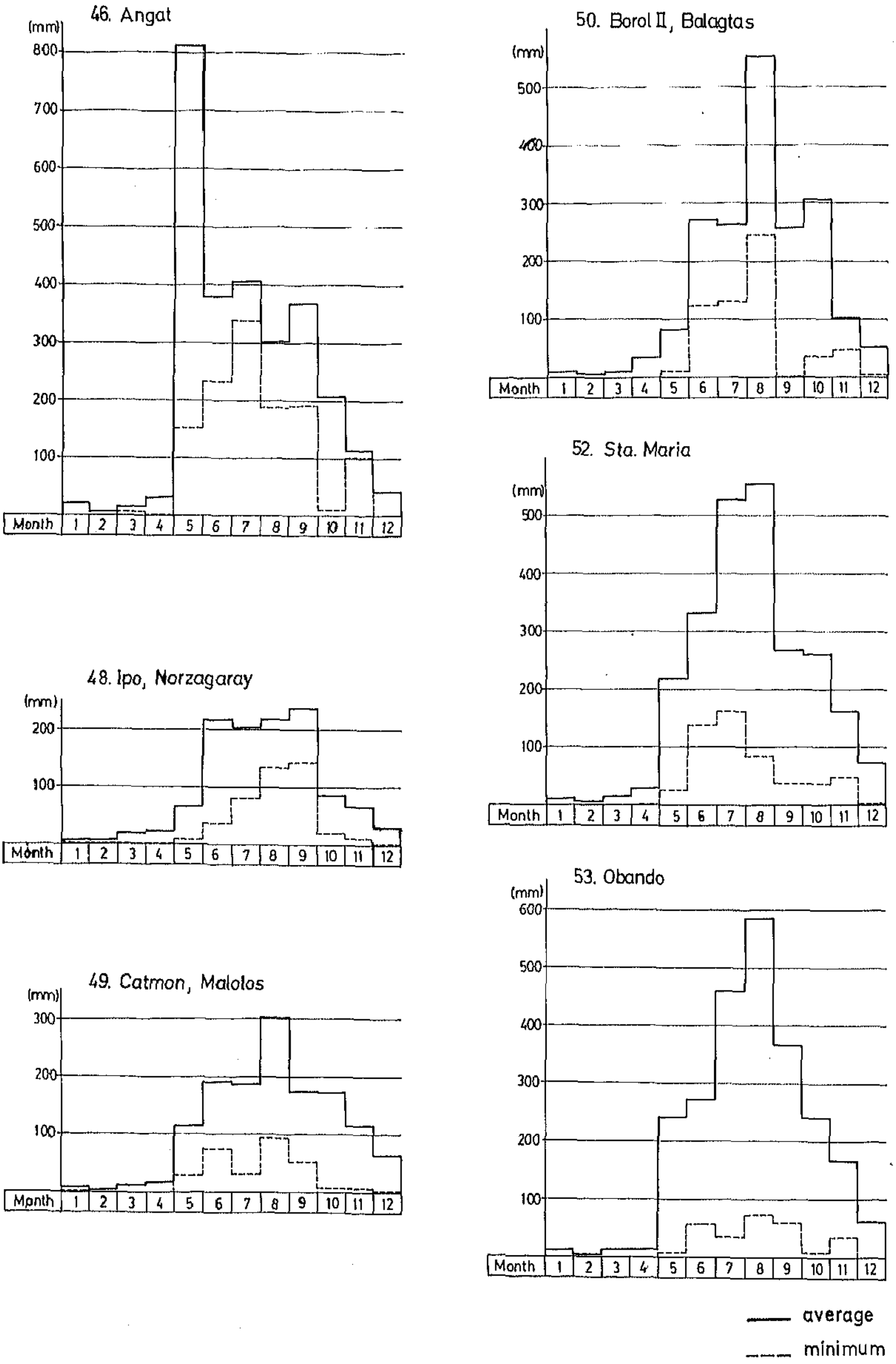


Fig. 23(7) ANNUAL PATTERN OF MEAN MONTHLY RAINFALL

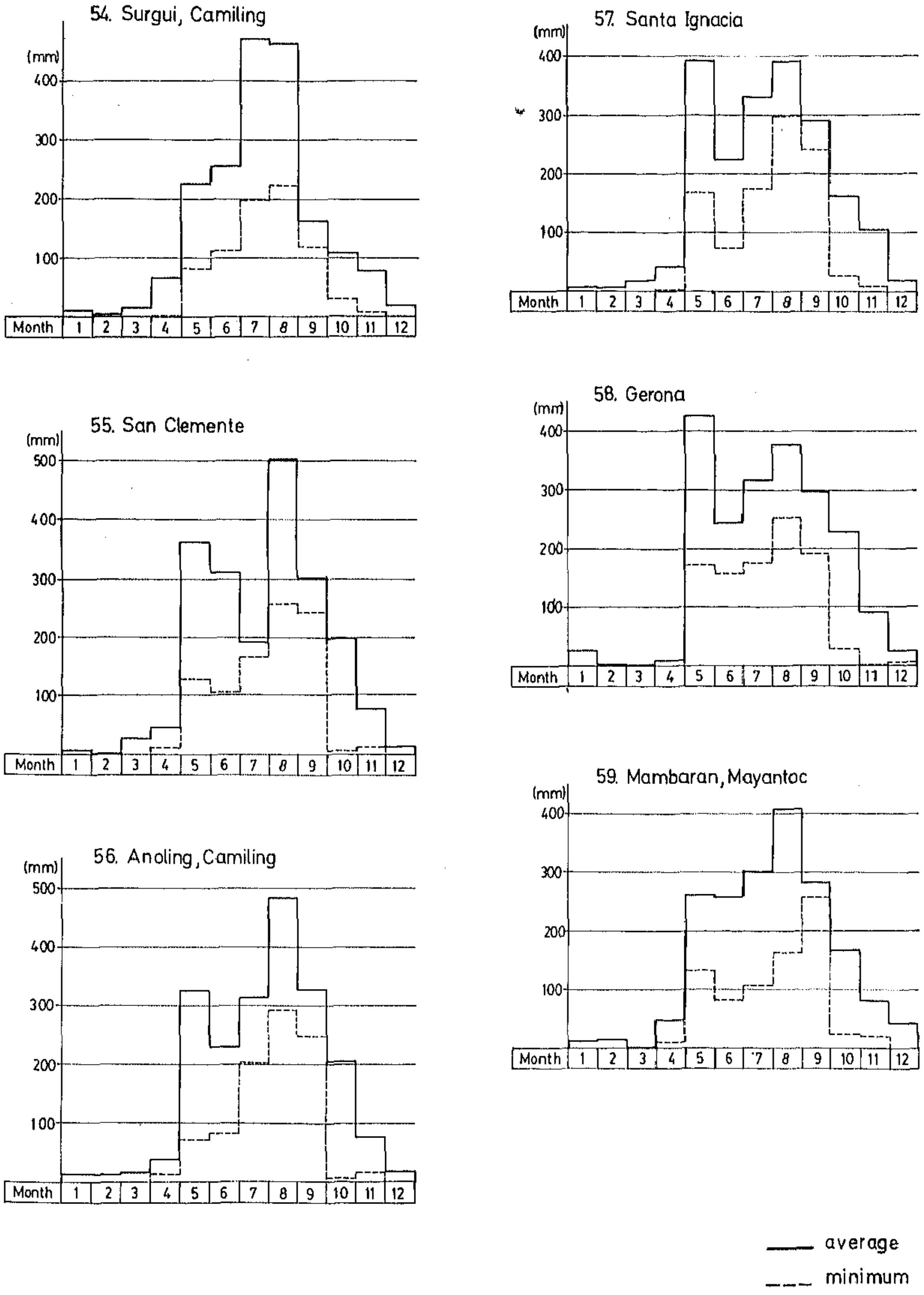
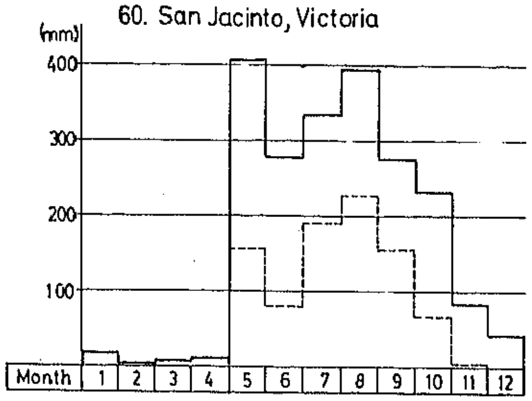
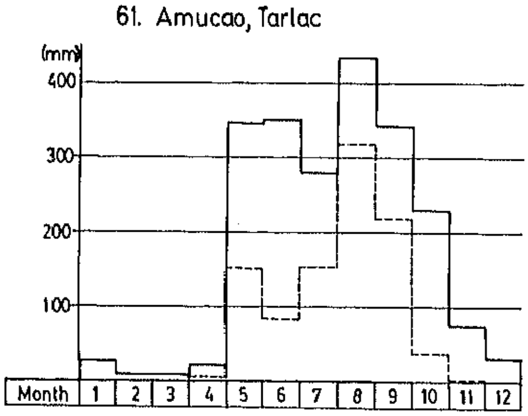
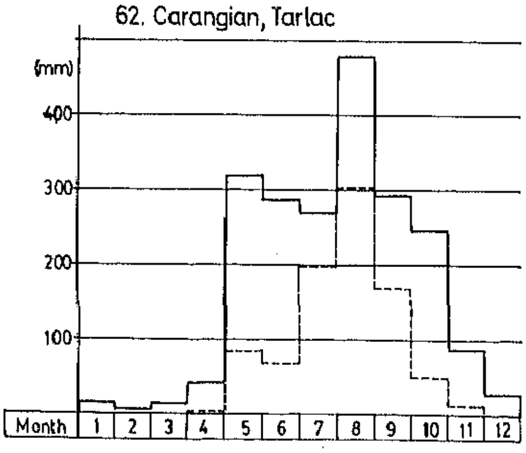
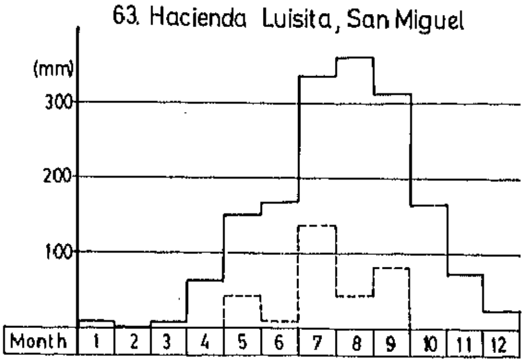


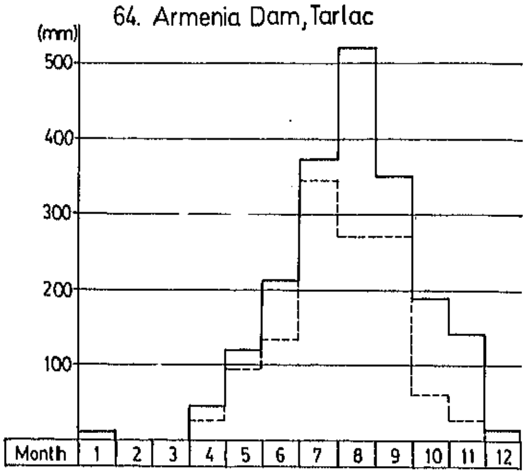
Fig. 23(8) ANNUAL PATTERN OF MEAN MONTHLY RAINFALL

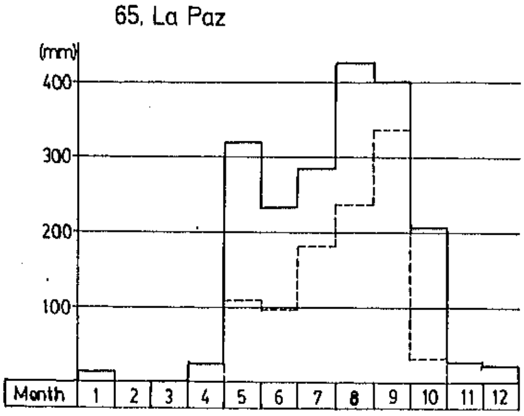

60. San Jacinto, Victoria

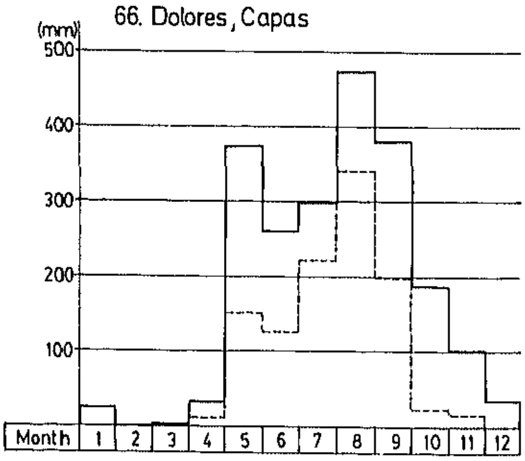

61. Amucao, Tarlac


62. Carangian, Tarlac


63. Hacienda Luisita, San Miguel


64. Armenia Dam, Tarlac

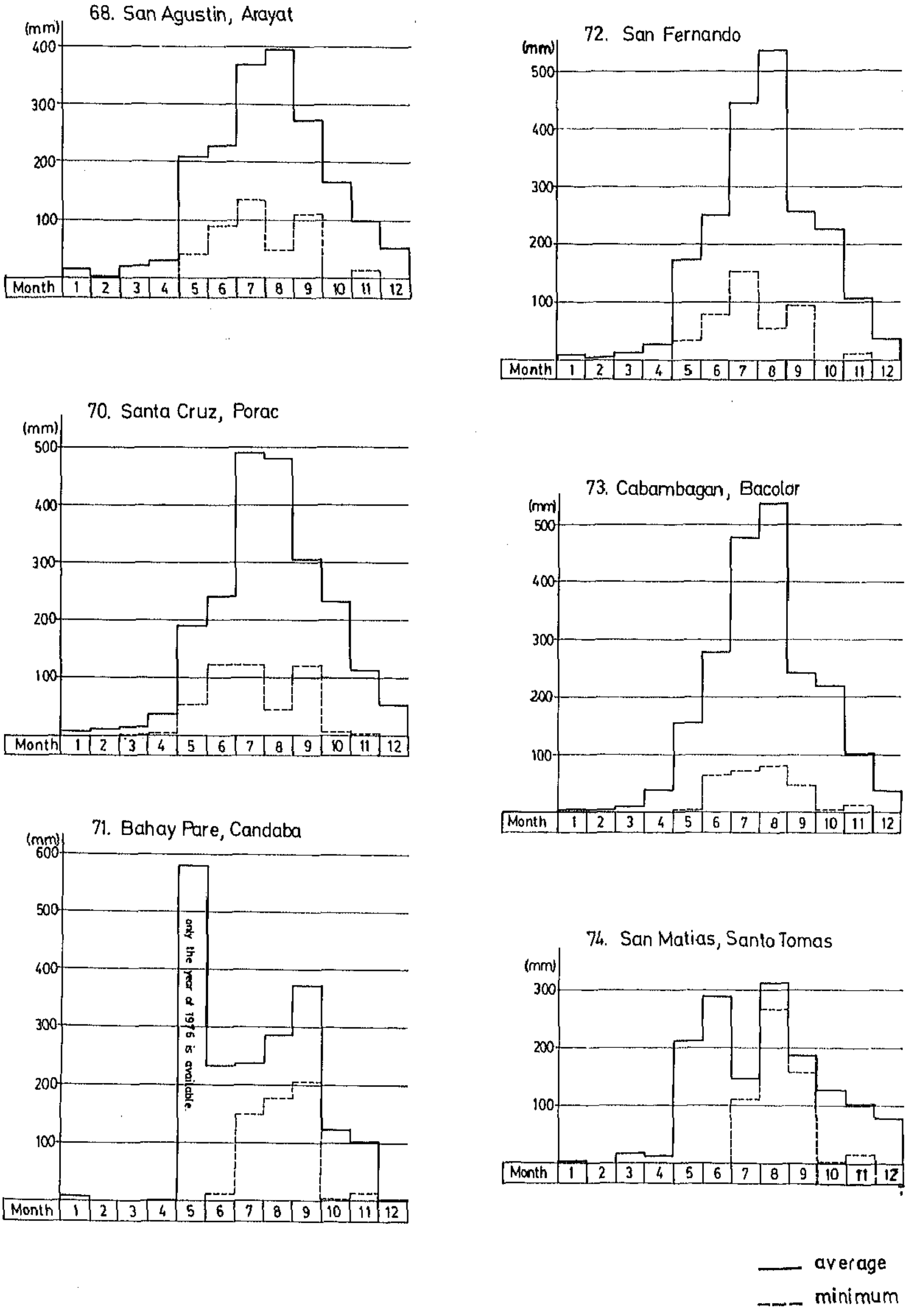

65. La Paz


66. Dolores, Capas

—— average

– – – minimum

Fig. 23(9) ANNUAL PATTERN OF MEAN MONTHLY RAINFALL


68. San Agustin, Arayat

72. San Fernando

70. Santa Cruz, Porac

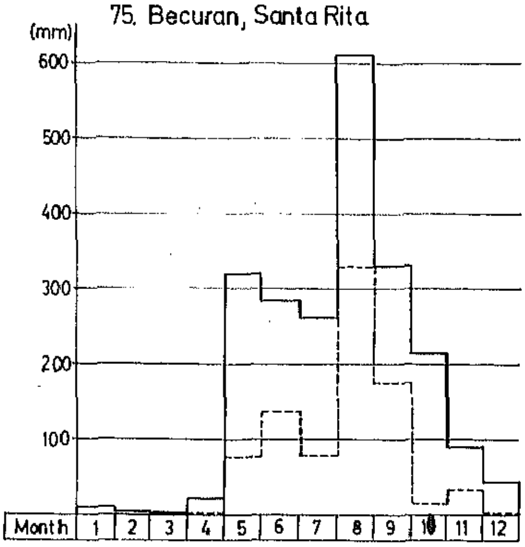
73. Cabambagan, Bacolor

71. Bahay Pare, Candaba

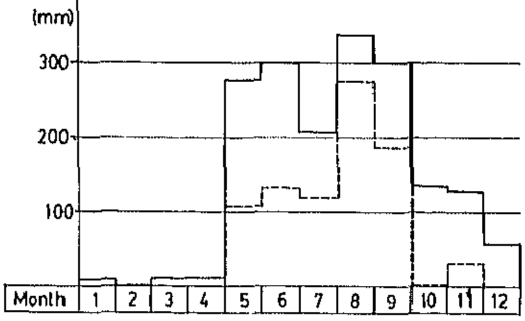
74. San Matias, Santo Tomas

Fig. 23(10) ANNUAL PATTERN OF MEAN MONTHLY RAINFALL

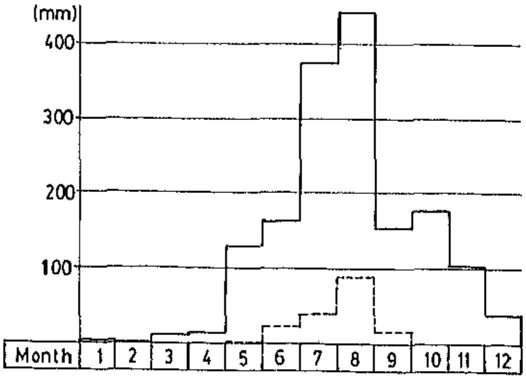
75. Becuran, Santa Rita



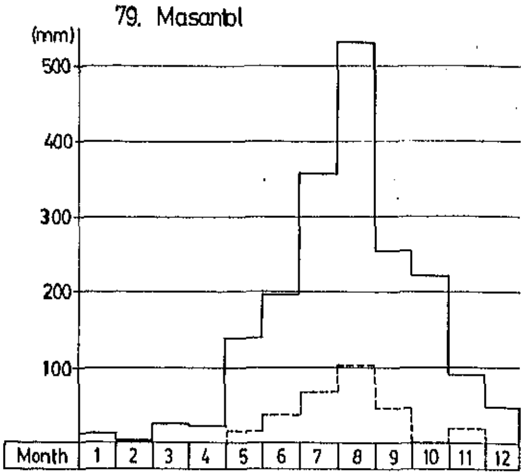
76. Balcoc, Apalit



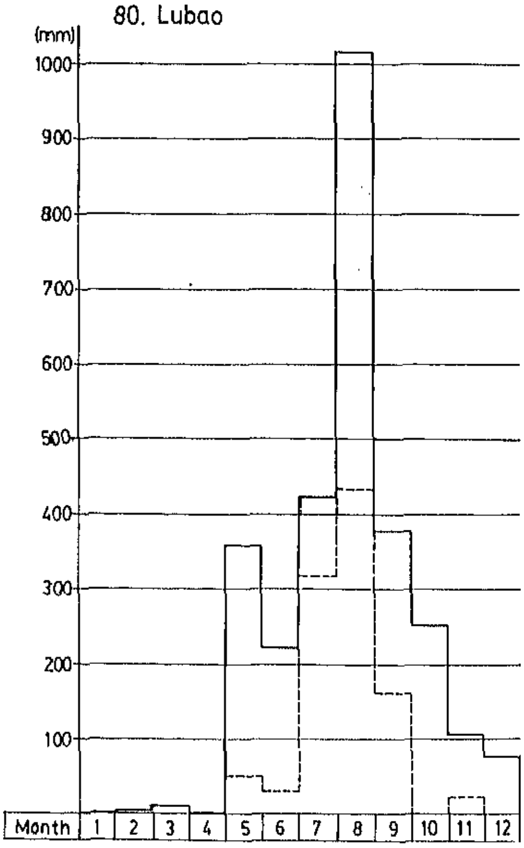
77. Cansinala, Apalit



79. Masantol



80. Lubao

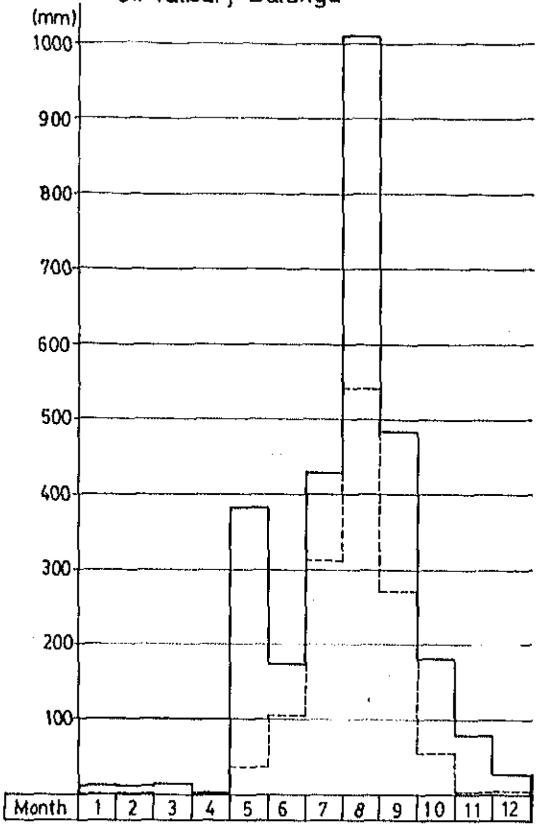


—— average

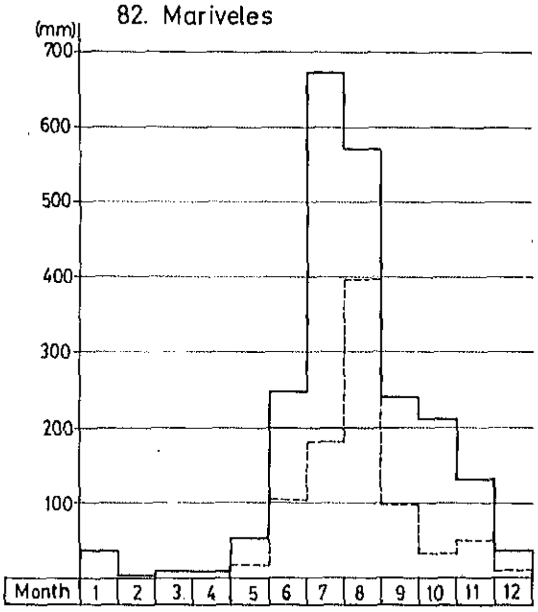
- - - minimum

Fig. 23(11) ANNUAL PATTERN OF MEAN MONTHLY RAINFALL

81. Talisai, Balanga



82. Mariveles



——— average

– – – minimum

Fig. 2.4 MEAN ANNUAL RAINFALL MAP

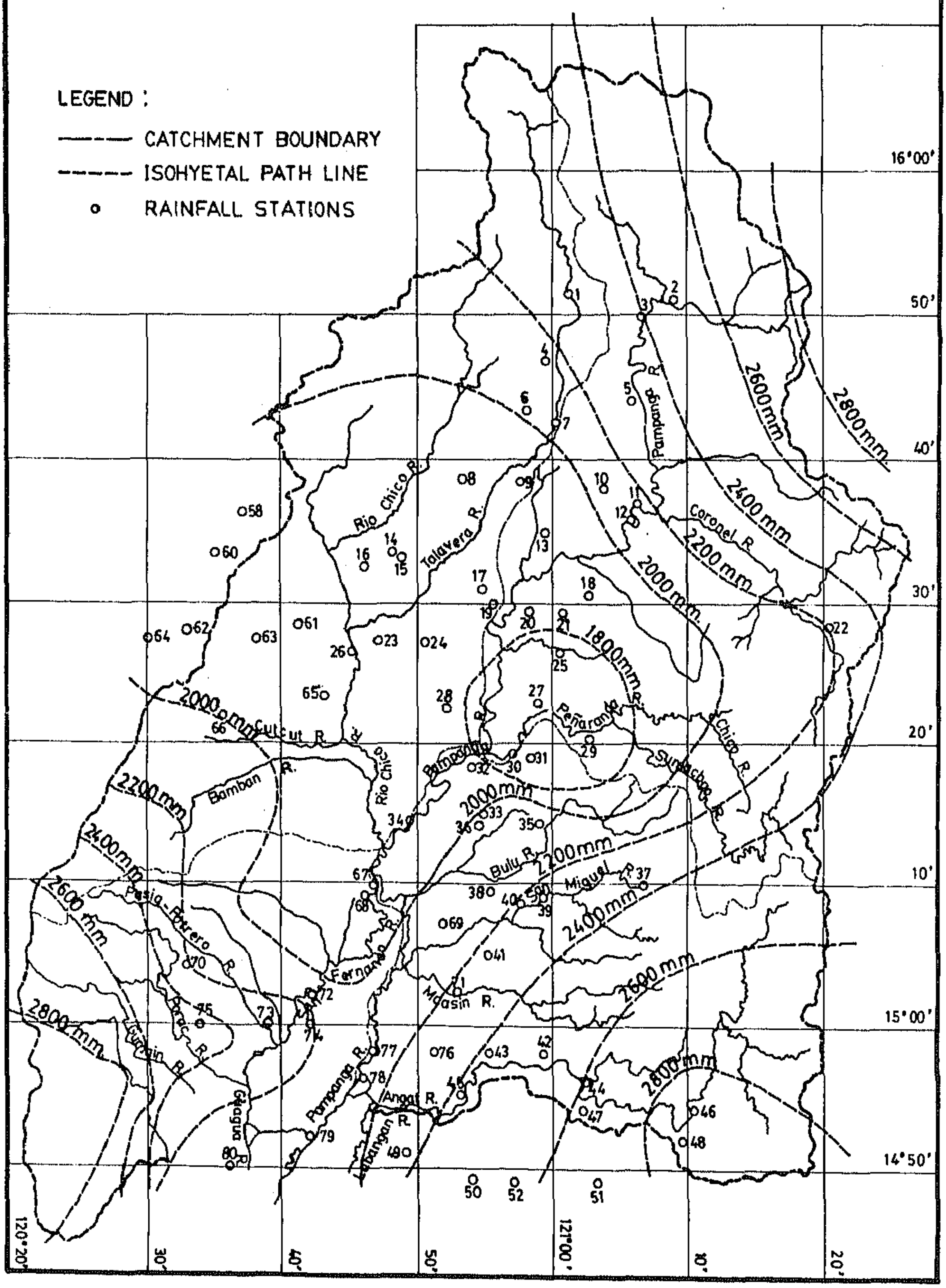


Fig. 2.5 LOCATION MAP OF STREAM GAGING STATIONS

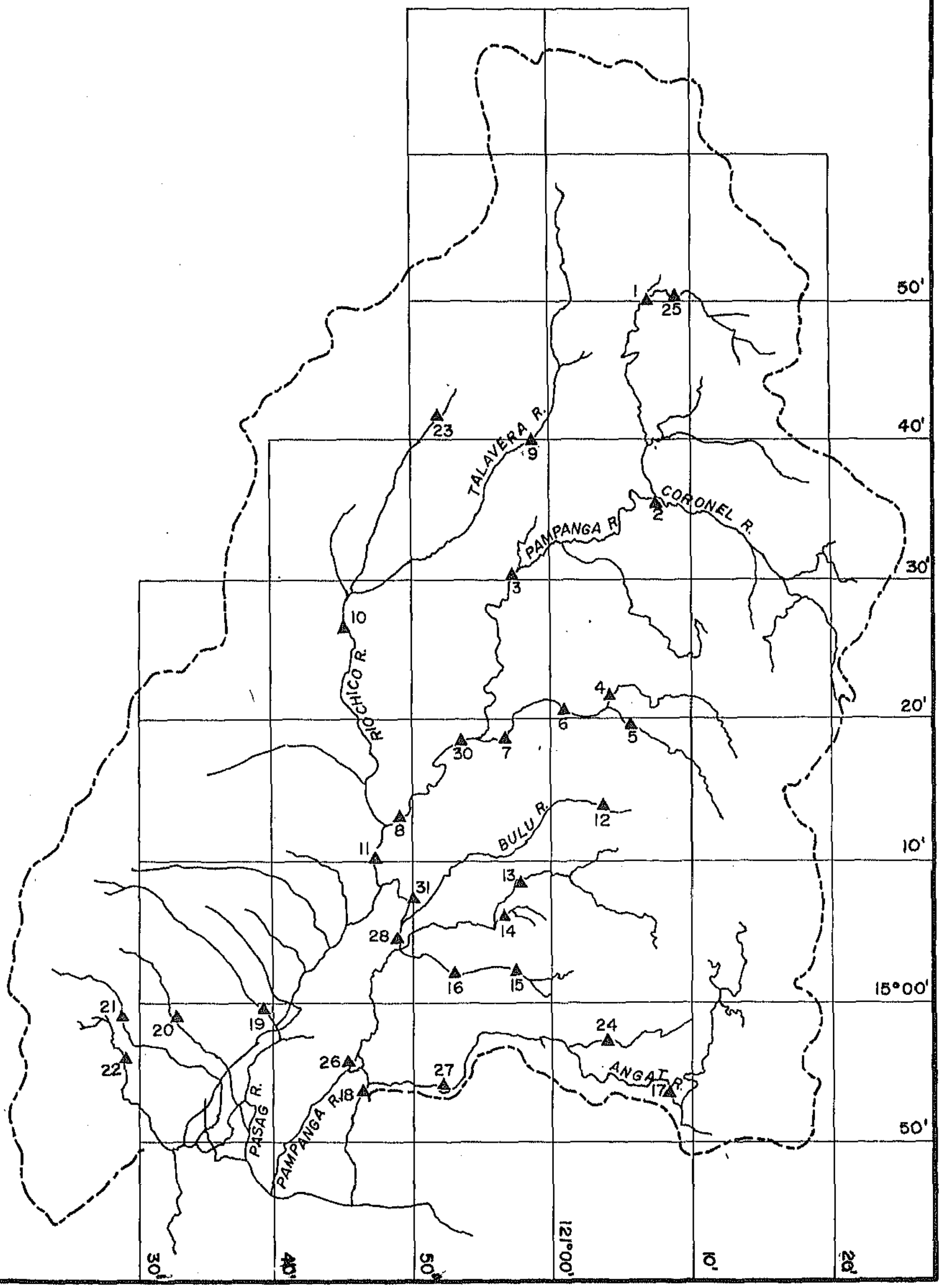


Fig. 2.6 AVAILABLE RECORDS OF GAGE HEIGHT

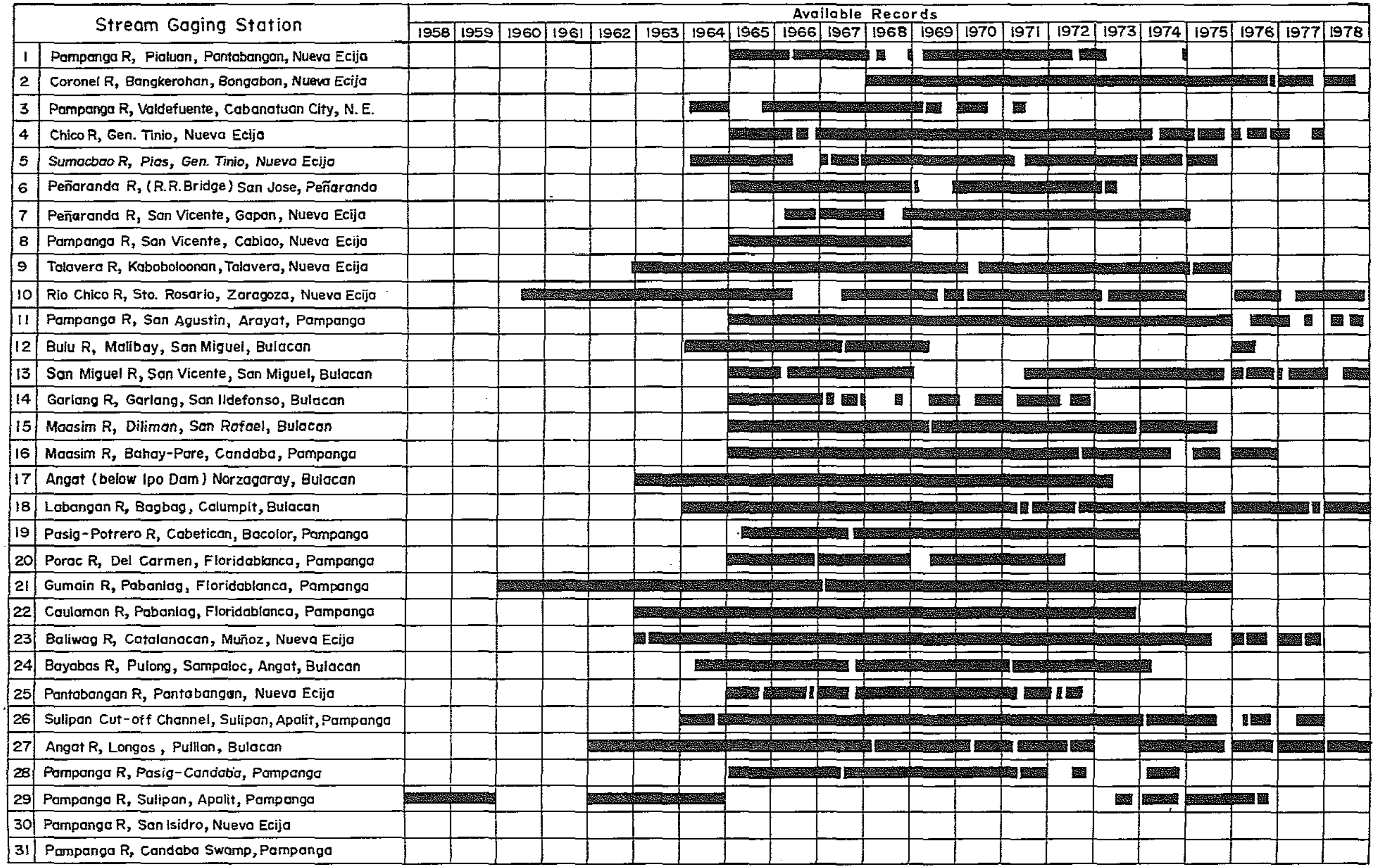
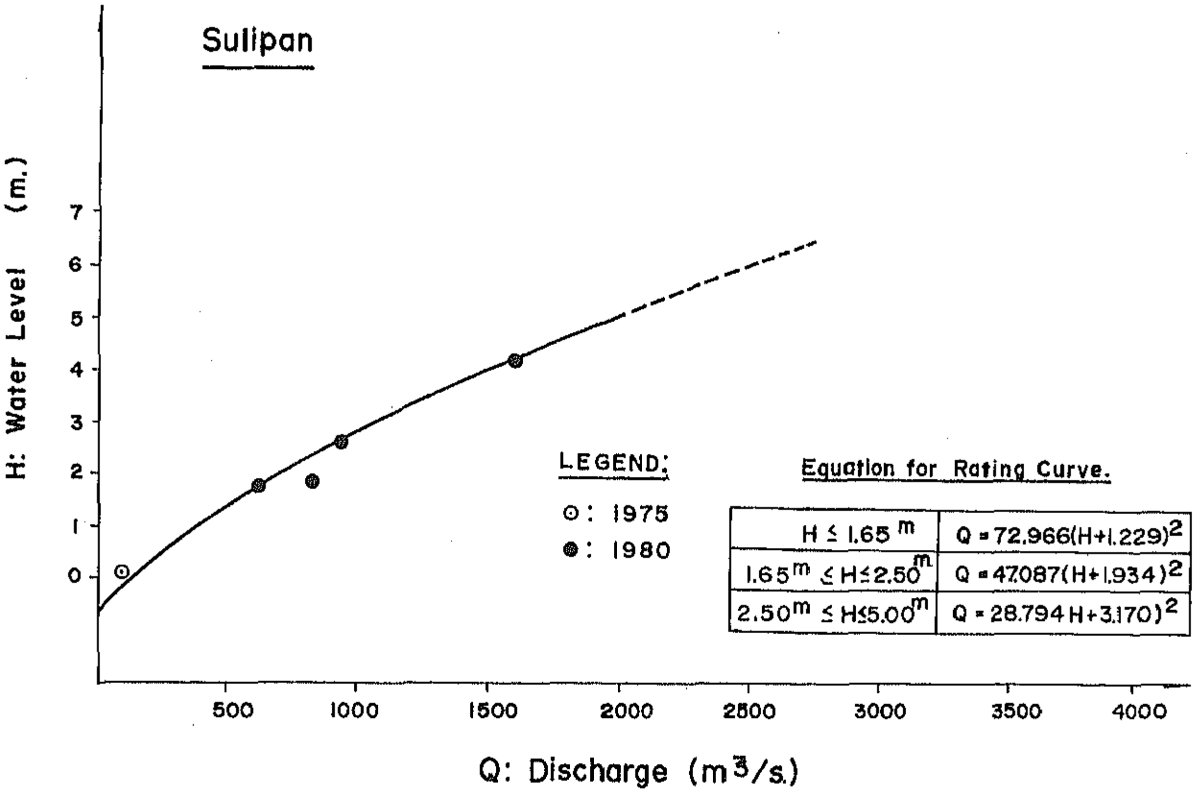
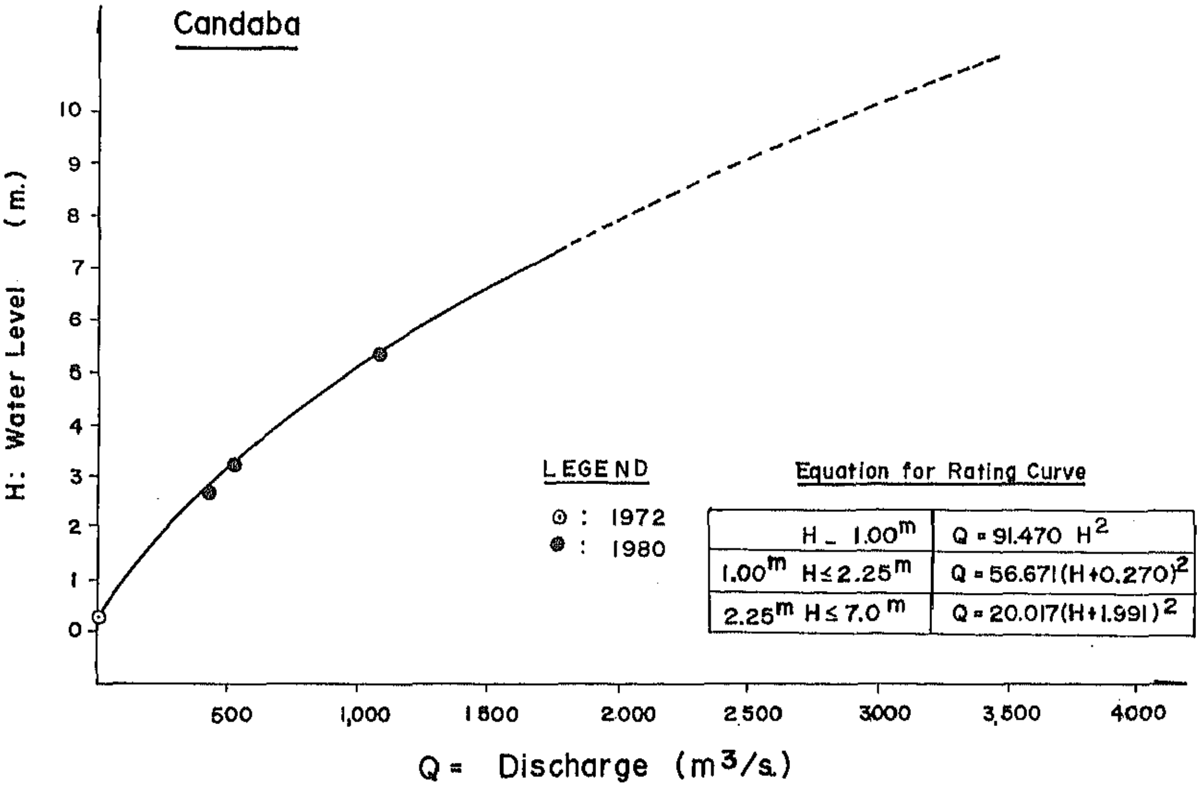


Fig. 2.7(1) DISCHARGE RATING CURVE



Equation for Rating Curve.

$H \leq 1.65^{m}$	$Q = 72.966(H+1.229)^2$
$1.65^{m} \leq H \leq 2.50^{m}$	$Q = 47.087(H+1.934)^2$
$2.50^{m} \leq H \leq 5.00^{m}$	$Q = 28.794 H+3.170)^2$



Equation for Rating Curve

$H \_ 1.00^{m}$	$Q = 91.470\ H^2$
$1.00^{m}\ H \leq 2.25^{m}$	$Q = 56.671(H+0.270)^2$
$2.25^{m}\ H \leq 7.0^{m}$	$Q = 20.017(H+1.991)^2$

Fig. 2.7(2) DISCHARGE RATING CURVE

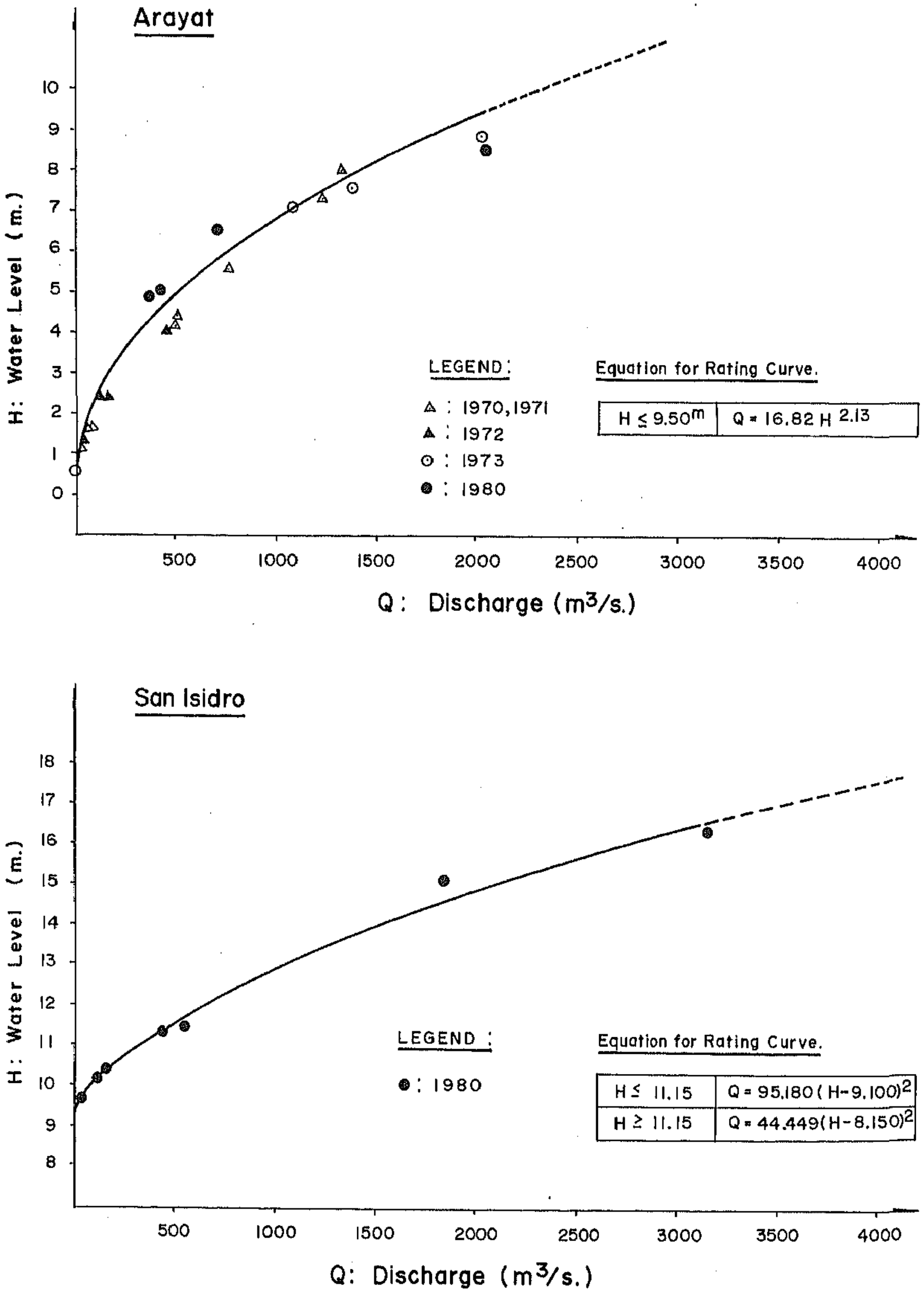


Fig. 2.7(3) DISCHARGE RATING CURVE

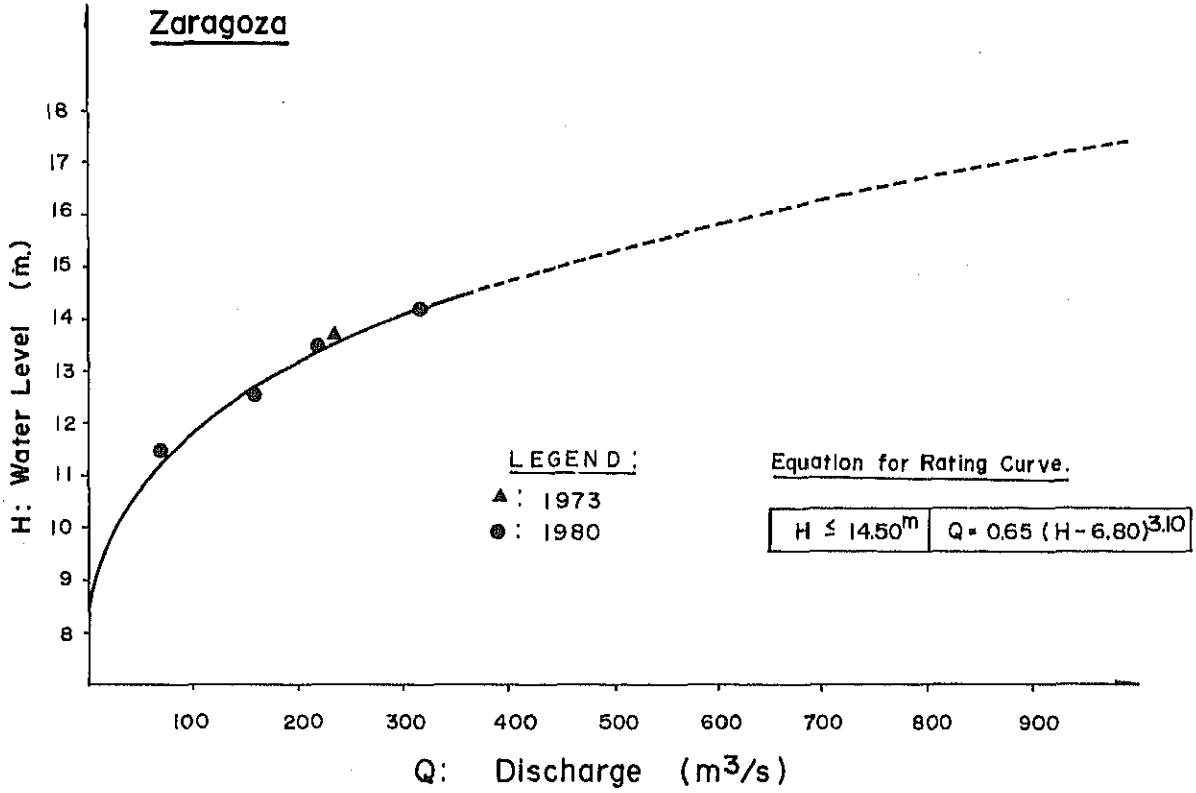


Fig. 2.8(1) ANNUAL PATTERN OF MEAN MONTHLY DISCHARGE

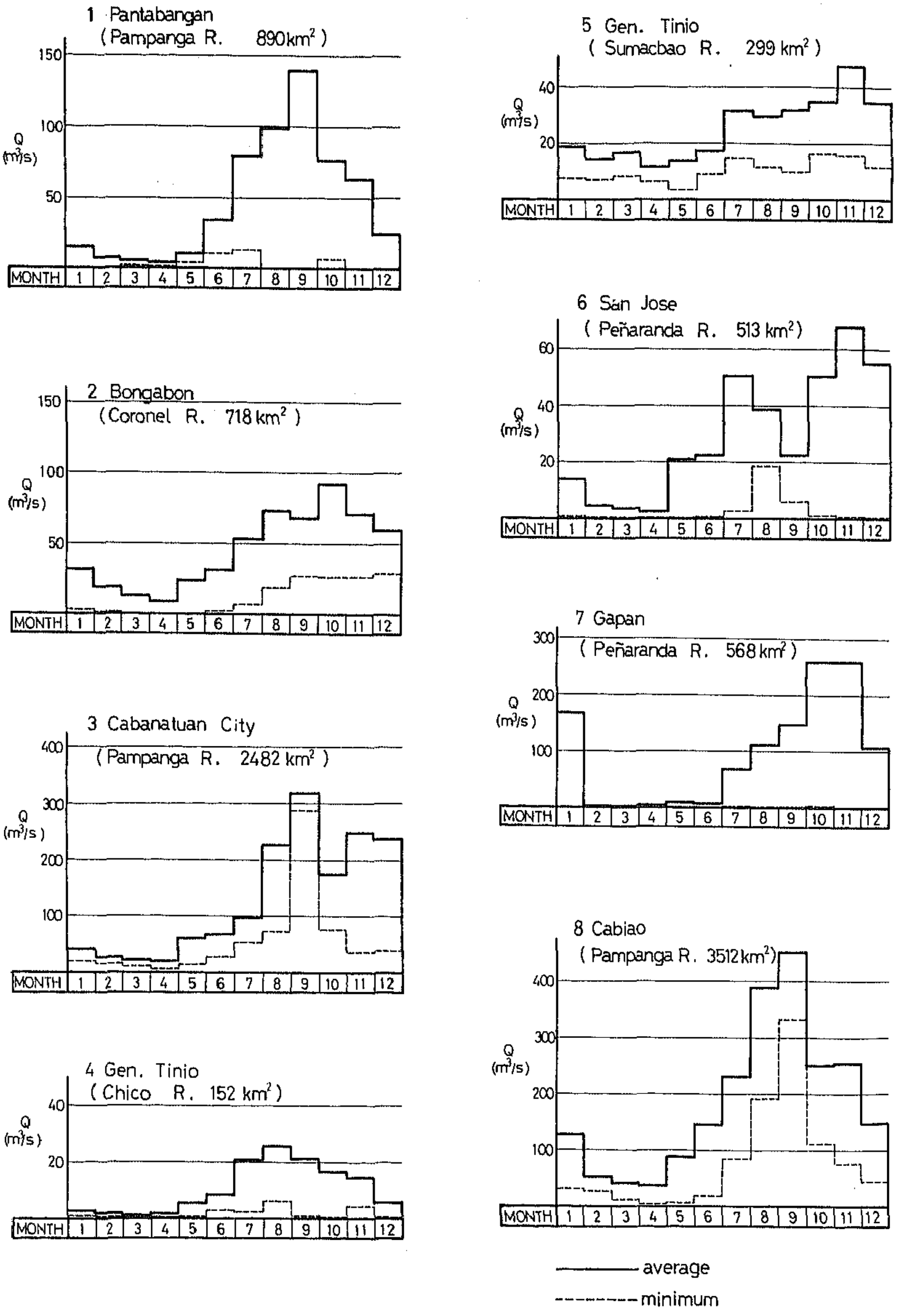


Fig. 2.8(2) ANNUAL PATTERN OF MEAN MONTHLY DISCHARGE

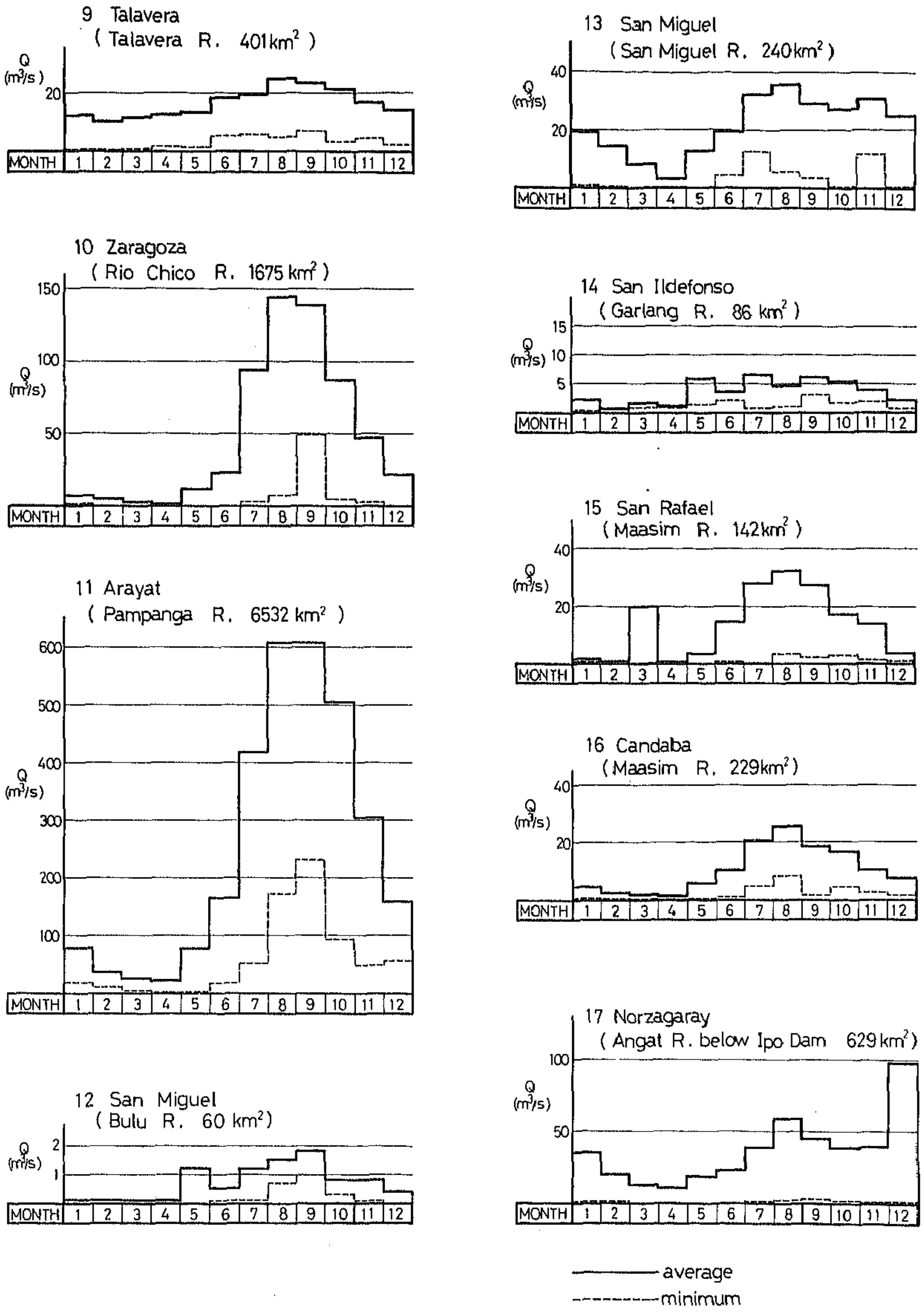


Fig. 2.8(3) ANNUAL PATTERN OF MEAN MONTHLY DISCHARGE

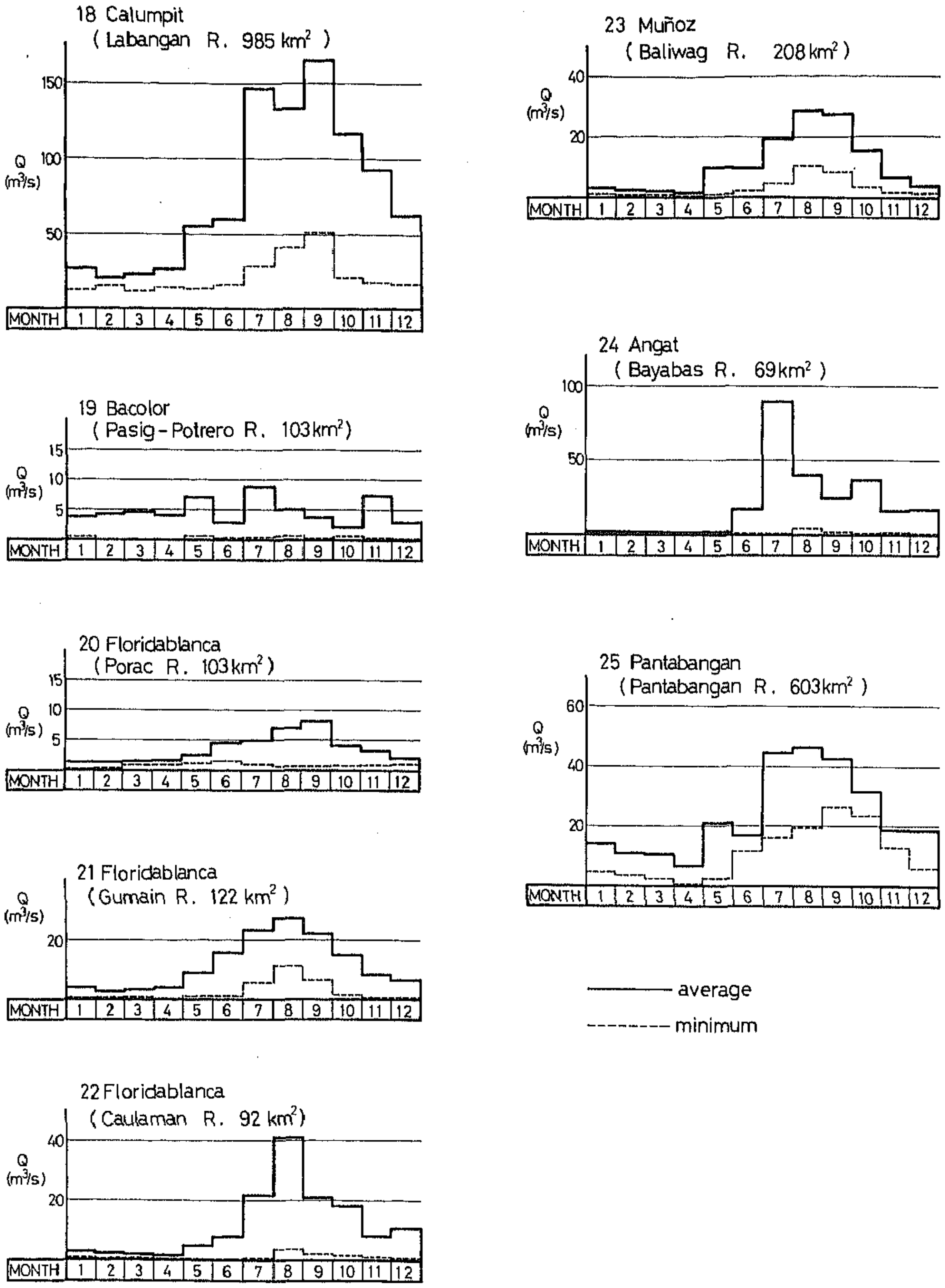


Fig. 2.8(4) ANNUAL PATTERN OF MEAN MONTHLY DISCHARGE

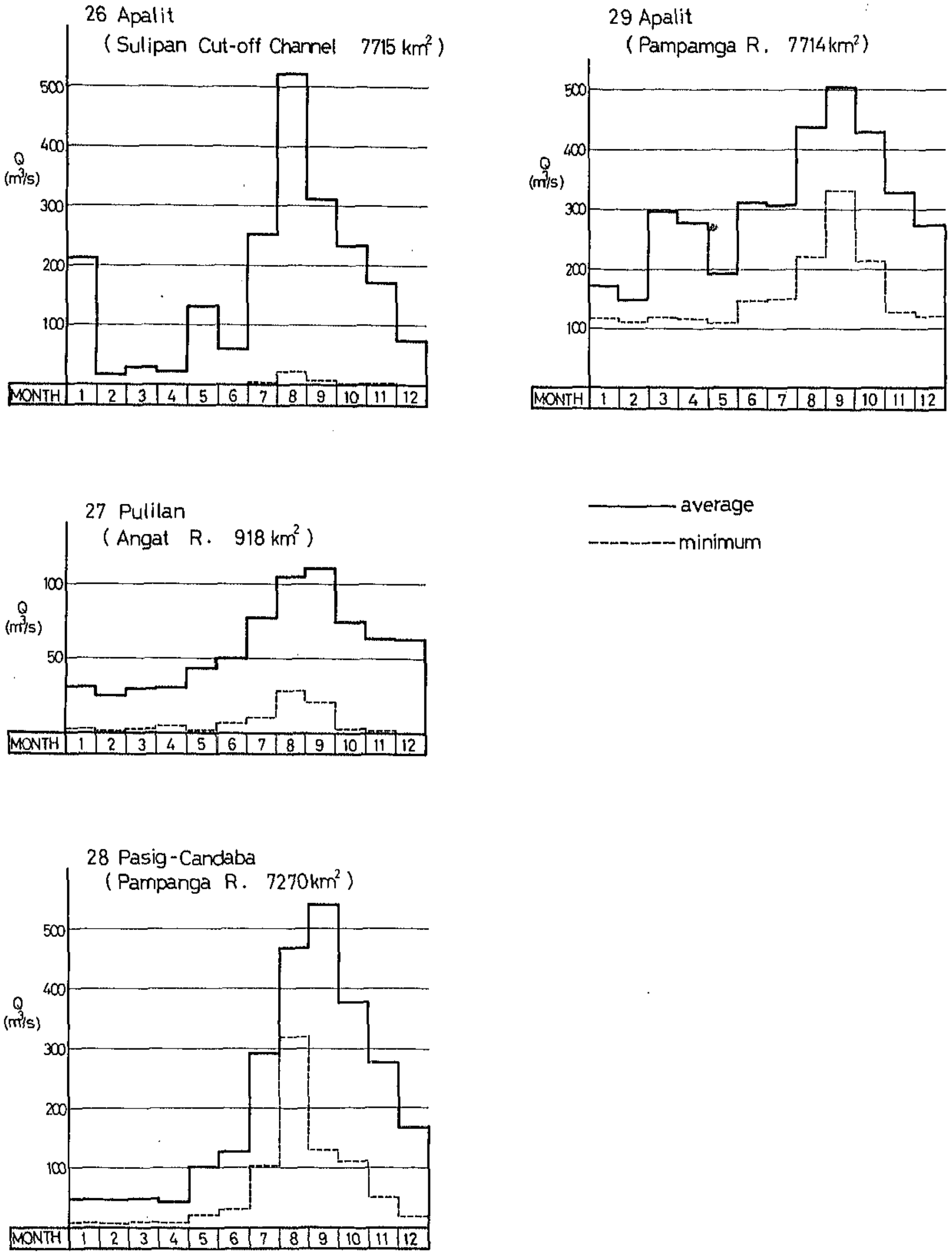
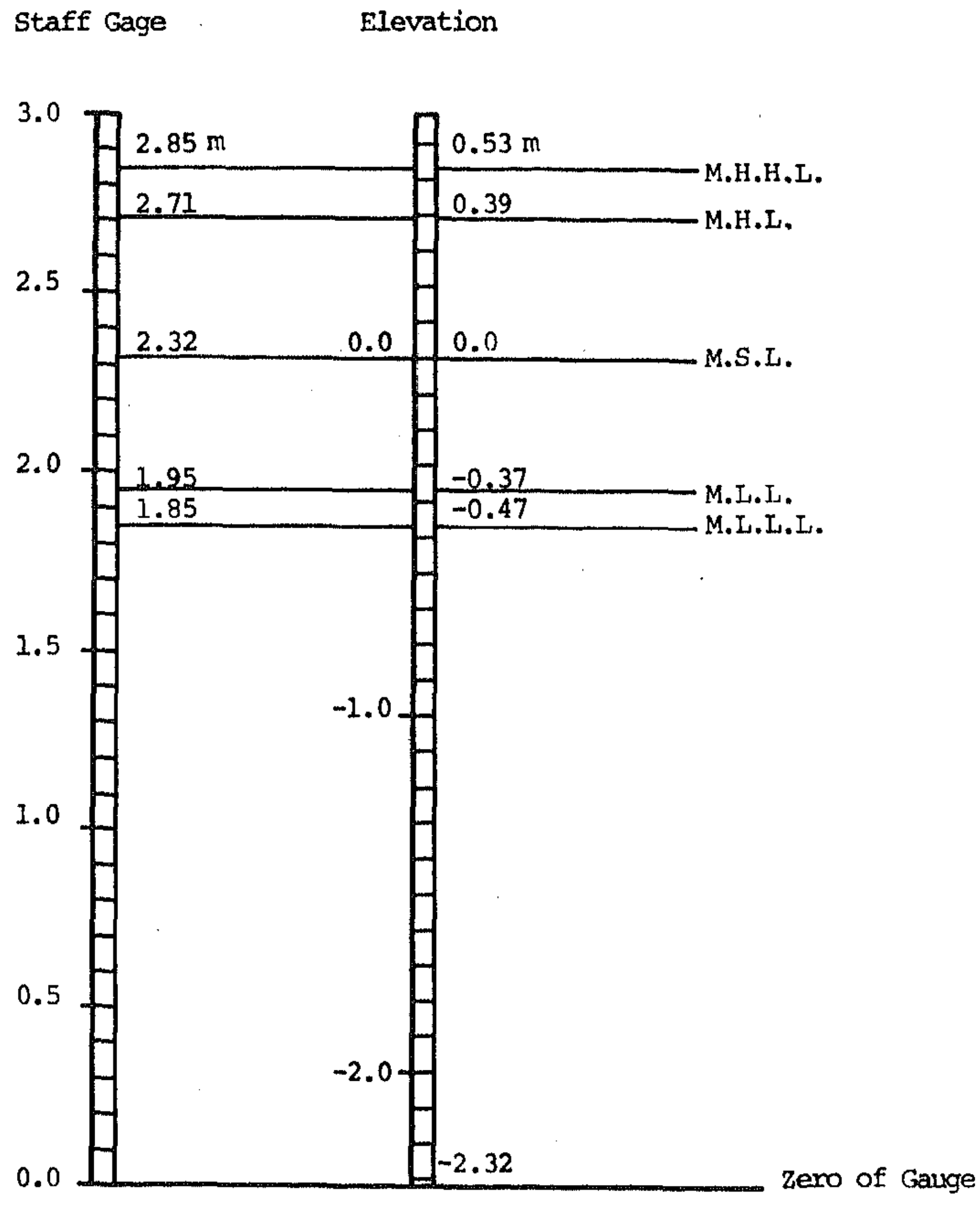


Fig. 2.9 TIDE LEVELS AT MANILA HARBOR



Remarks,

M.H.H.L.	Mean Higher High Level
M.H.L.	Mean High Level
M.S.L.	Mean Sea Level
M.L.L.	Mean Low Level
M.L.L.L.	Mean Lower Low Level

Fig. 2.10 LOCATIONS OF WATER SAMPLING

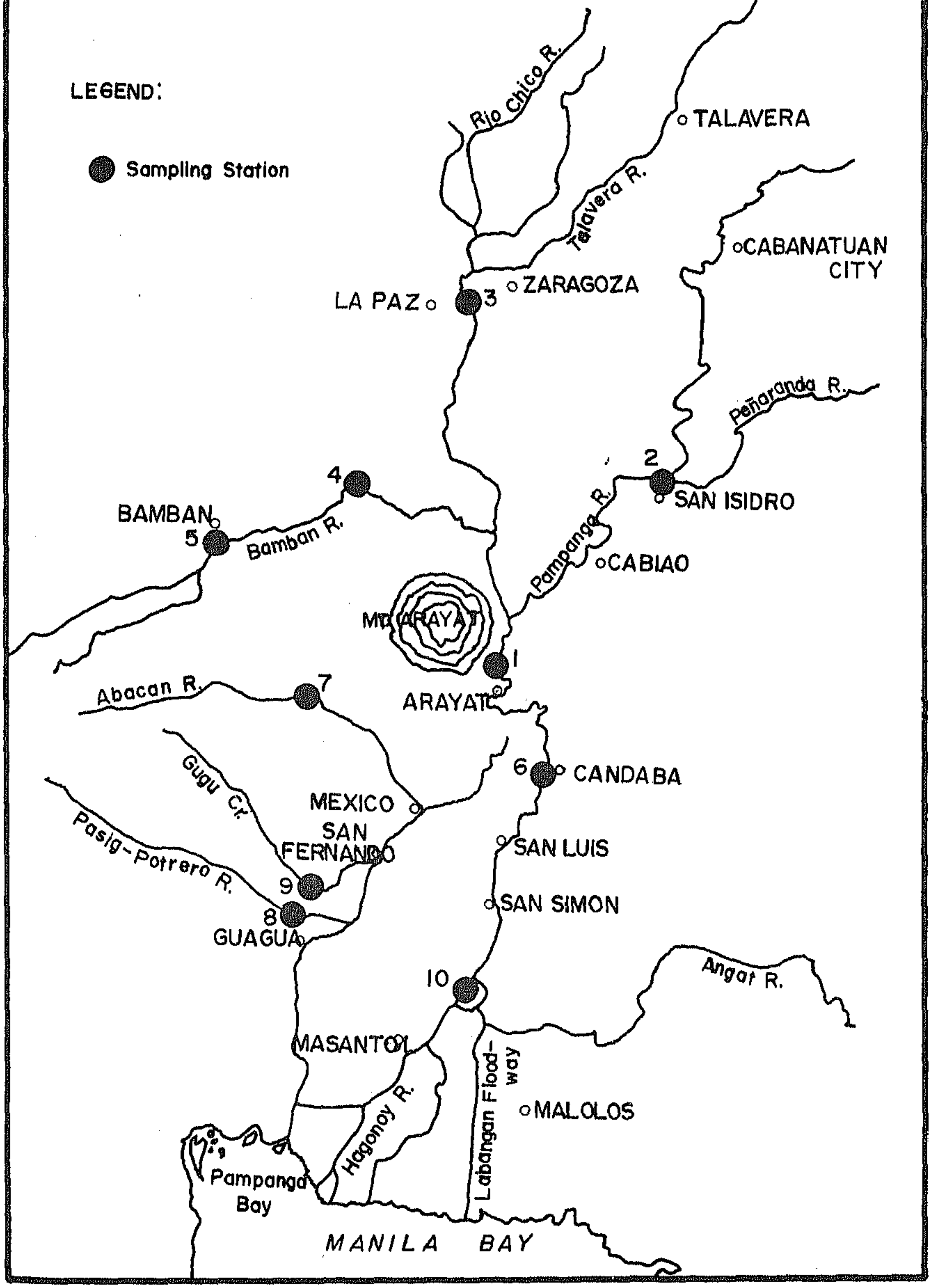


Fig. 2.11 LOCATION MAP OF THE SURVEY FOR SALINITY

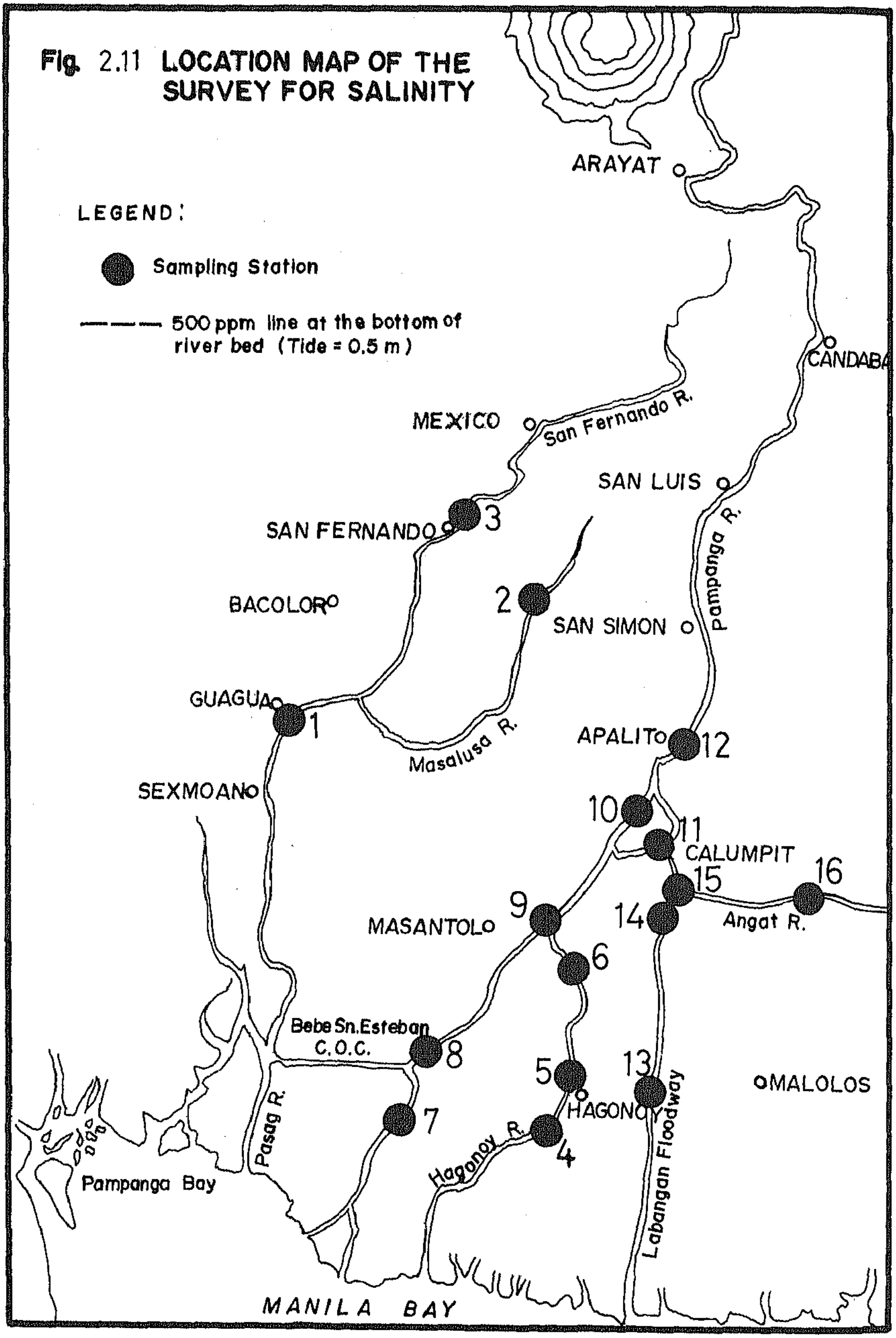


Fig. 2.12 CORRELATION CURVES BETWEEN ELECTRIC CONDUCTIVITY AND CHLORIDE CONCENTRATION

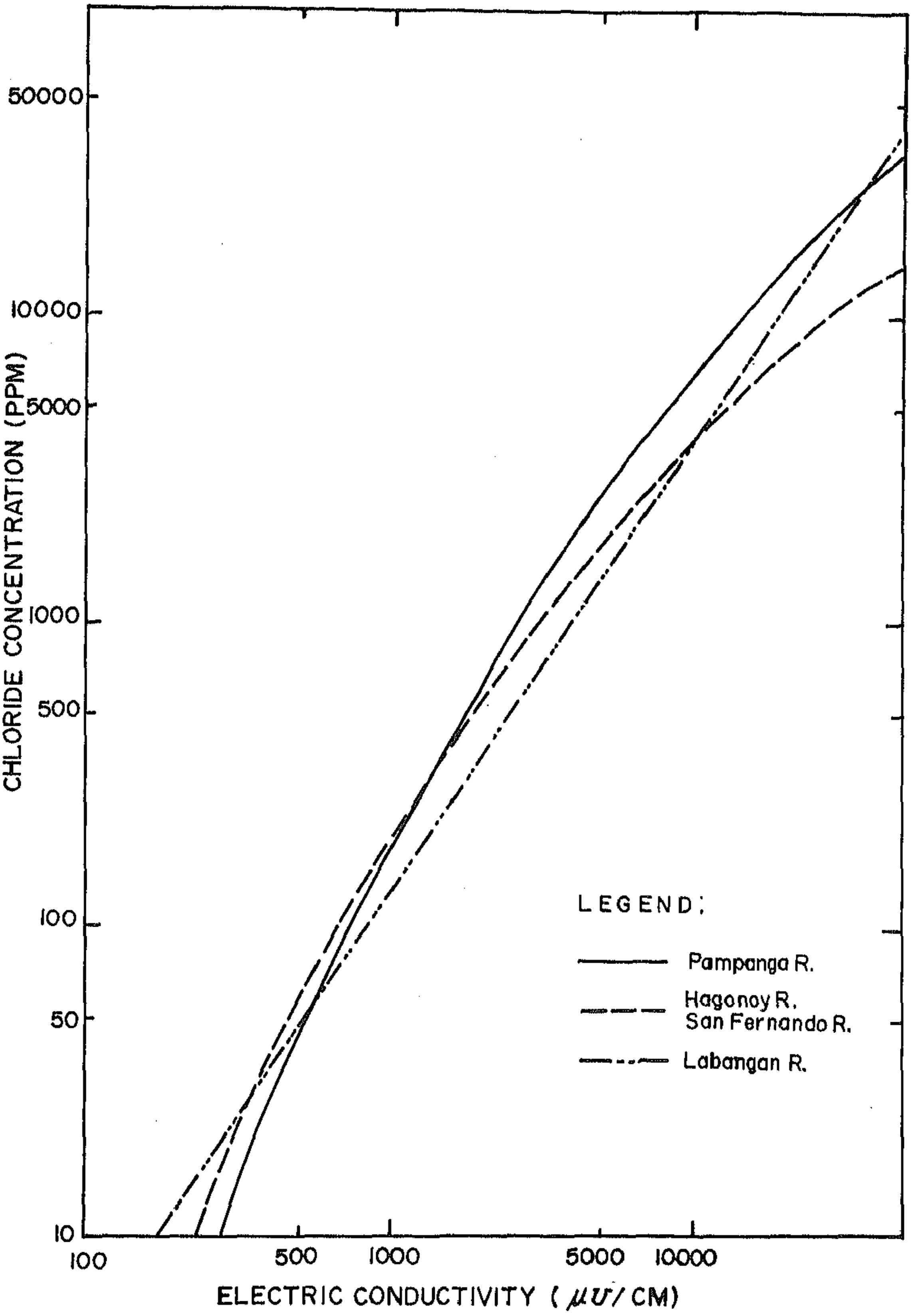


Fig. 2.13(1) CHLORIDE CONCENTRATION PROFILE OF PAMPANGA RIVER (WATER SURFACE)

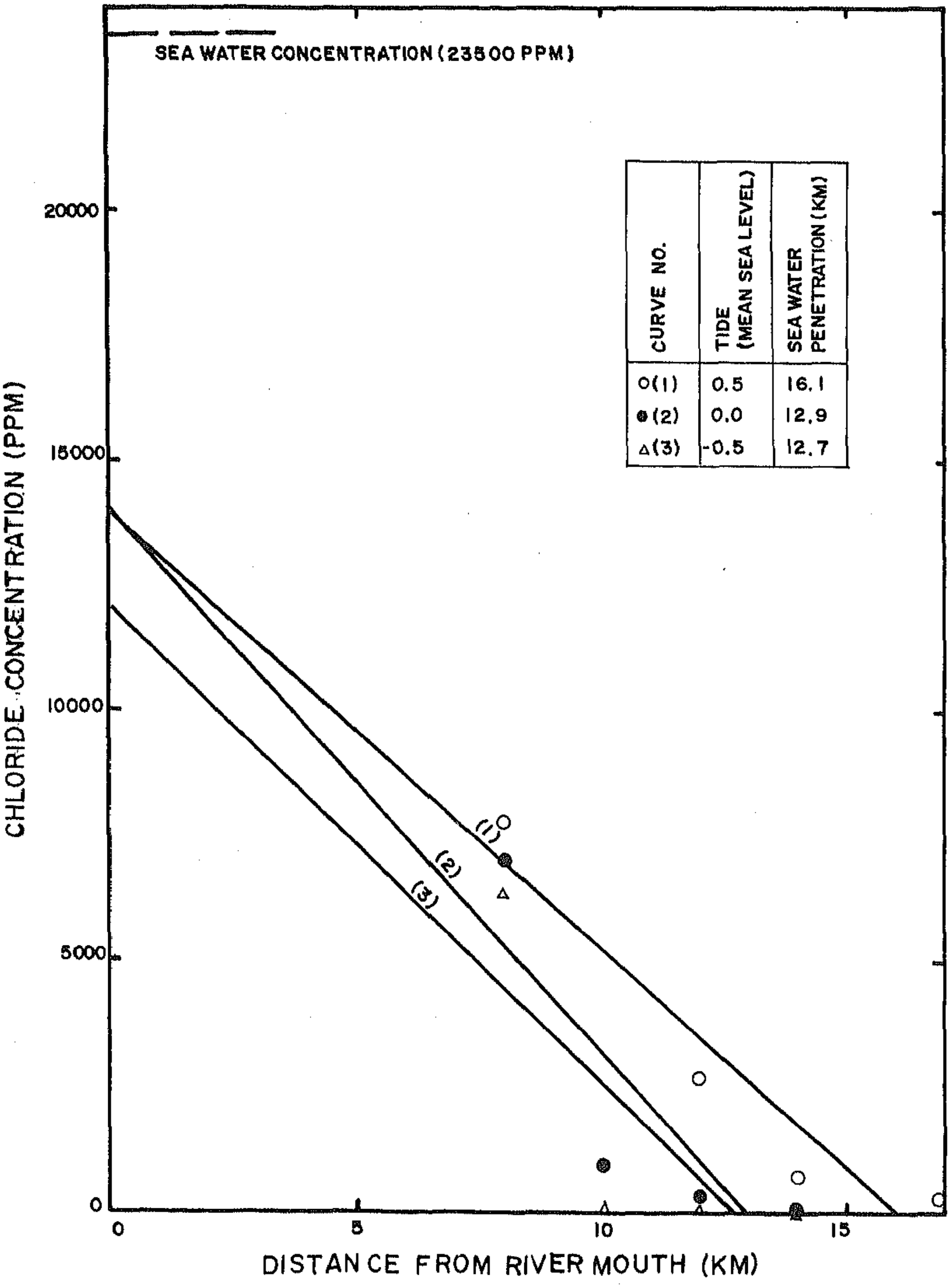
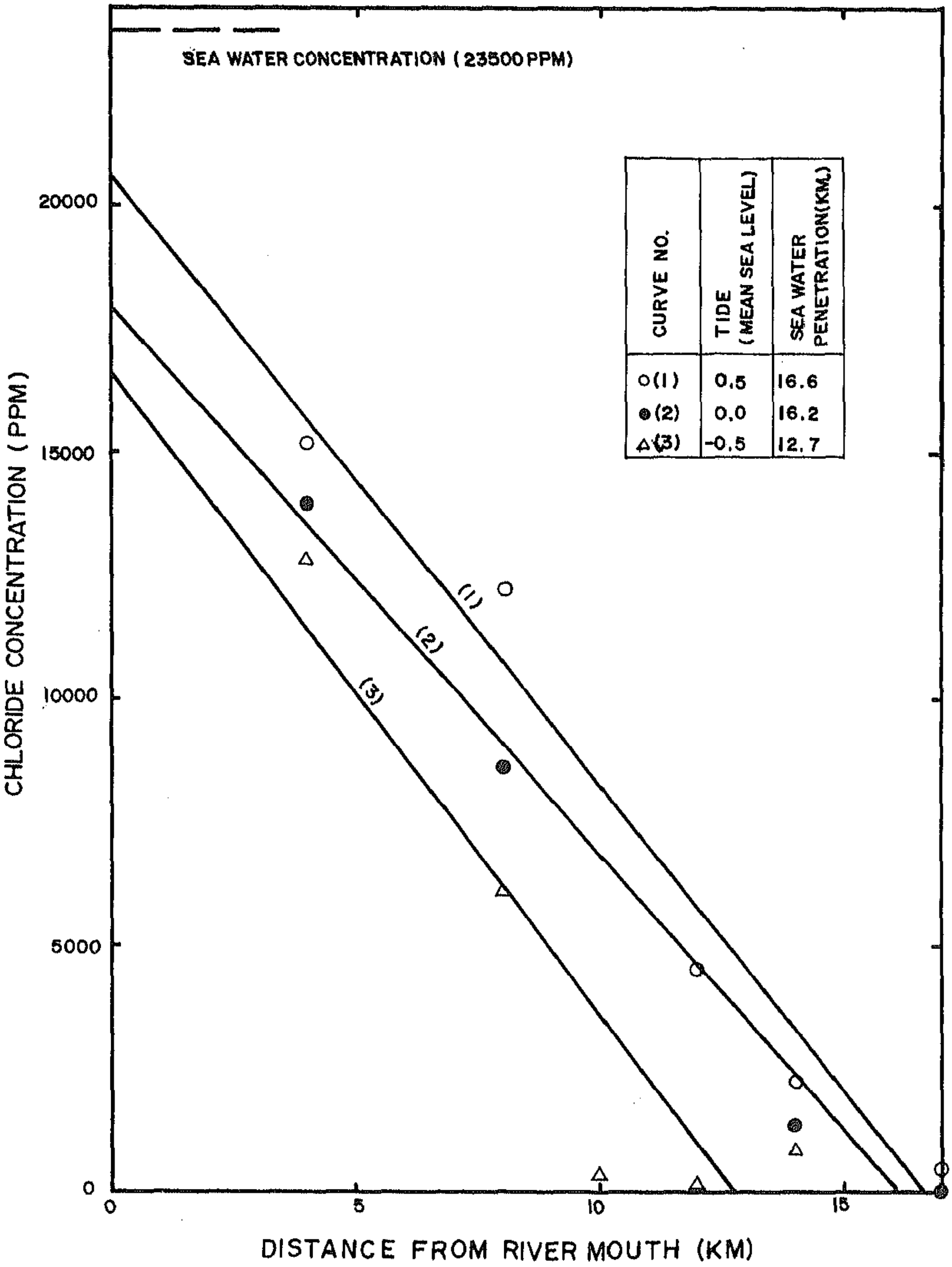


Fig. 213(2) CHLORIDE CONCENTRATION PROFILE OF PAMPANGA RIVER (CHANNEL BOTTOM)



CURVE NO.	TIDE (MEAN SEA LEVEL)	SEA WATER PENETRATION (KM.)
○ (1)	0.5	16.6
● (2)	0.0	16.2
△ (3)	-0.5	12.7

Fig. 2.14(1) ESTIMATED PROFILE OF SEAWATER INTRUSION ON PAMPANGA RIVER UNDER EXISTING CHANNEL CONDITIONS (CALCULATED RESULTS)

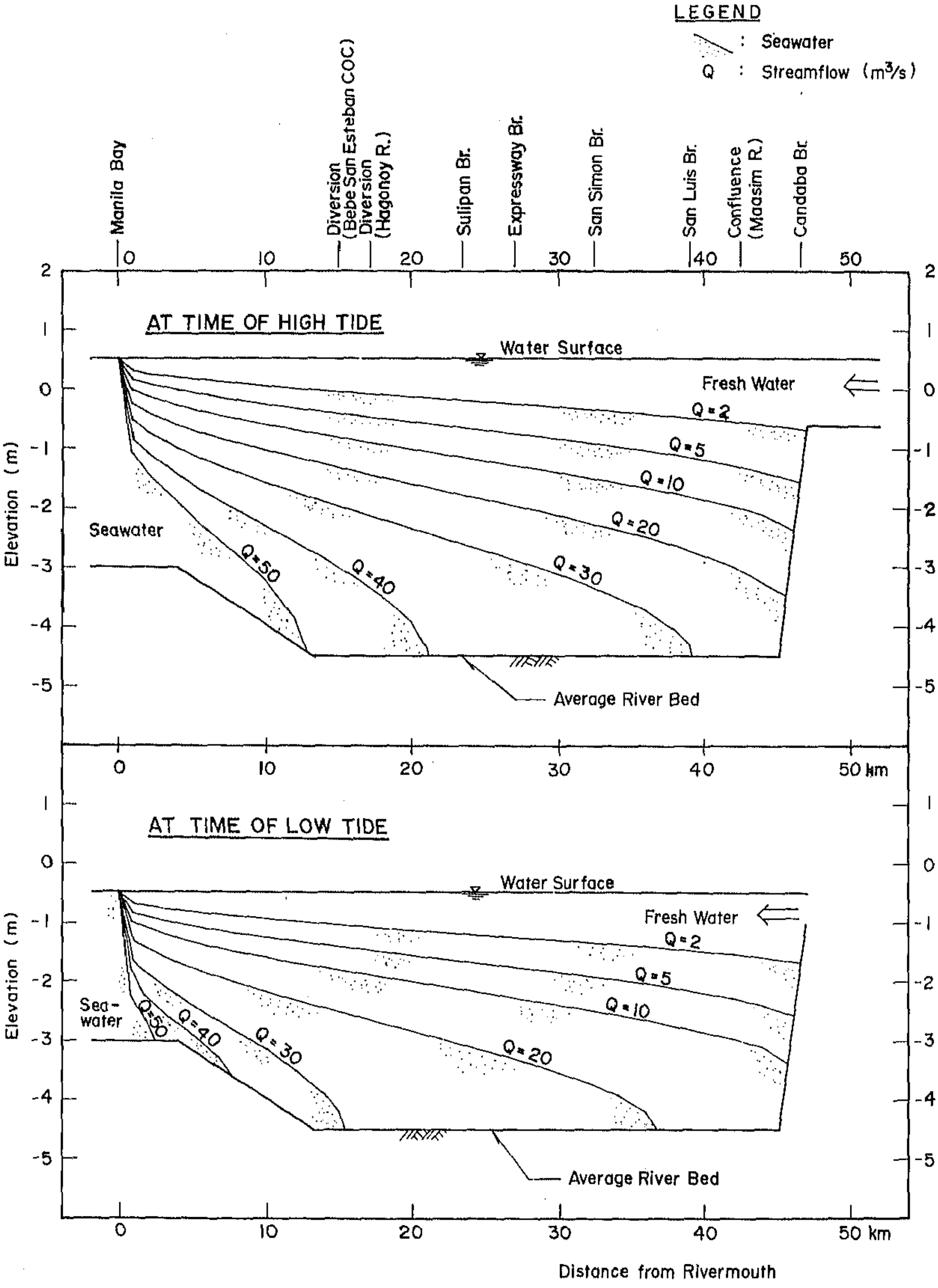


Fig. 2.14(2) ESTIMATED PROFILE OF SEAWATER INTRUSION ON LABANGAN FLOODWAY UNDER EXISTING CHANNEL CONDITION (CALCULATED RESULTS)

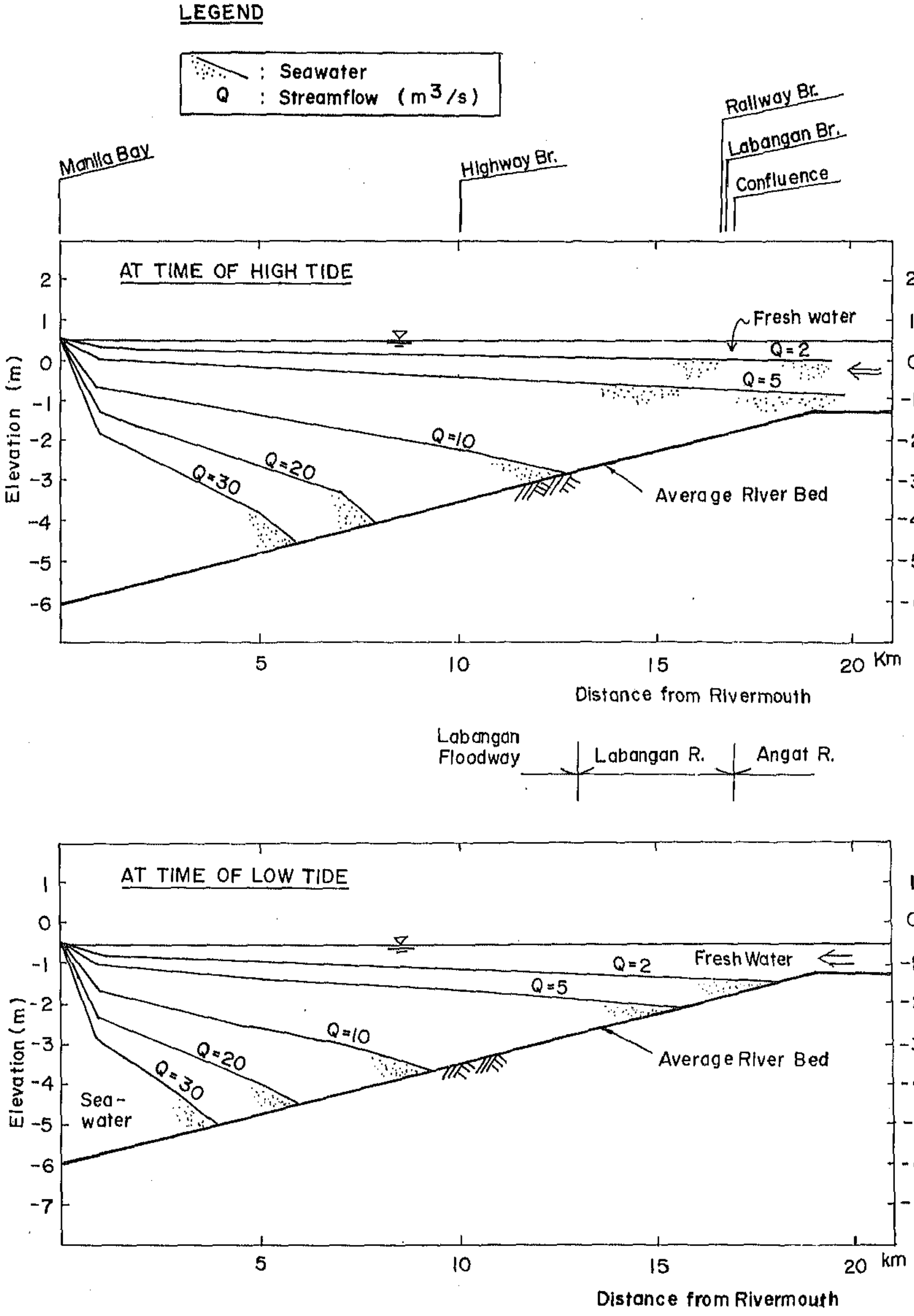
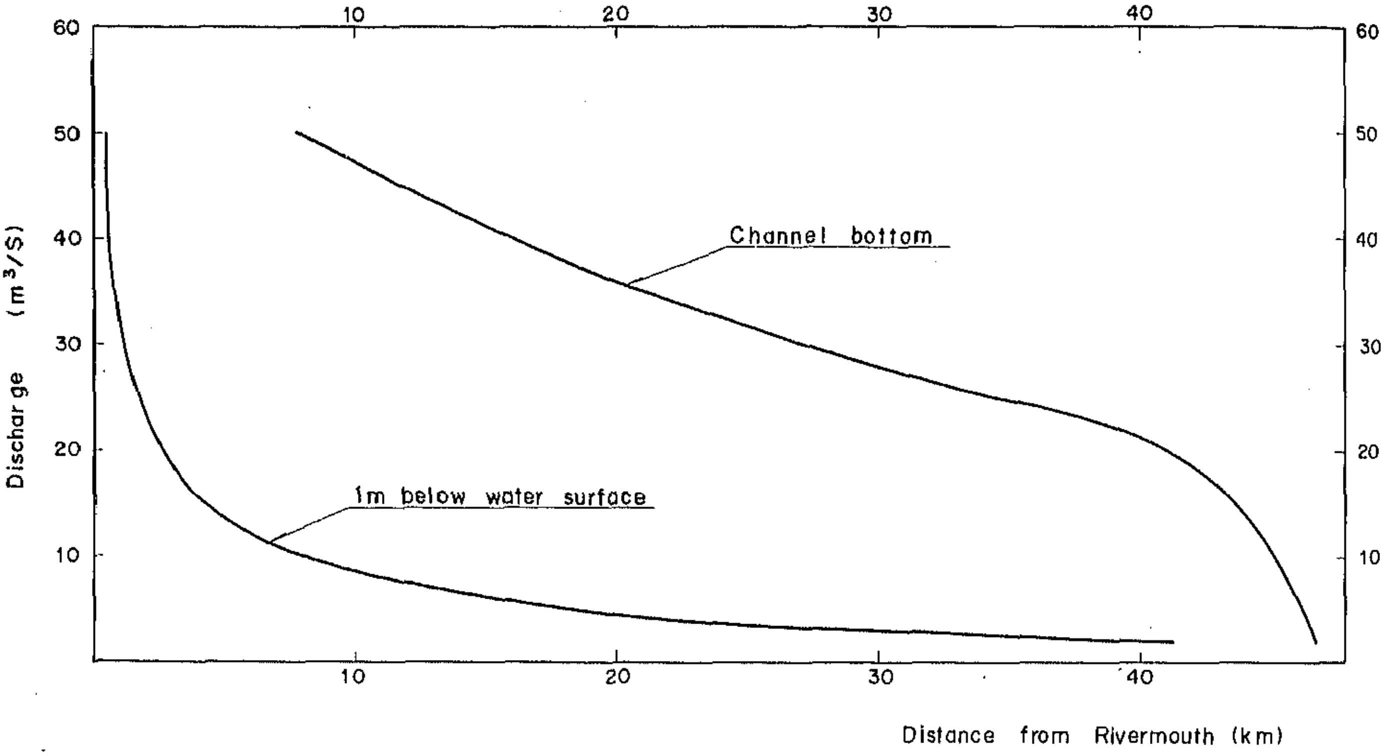


Fig. 2.15 RELATION CURVE BETWEEN RIVER DISCHARGE AND DISTANCE OF SEAWATER INTRUSION UNDER EXISTING CHANNEL CONDITIONS

Pampanga River



Labangan Floodway

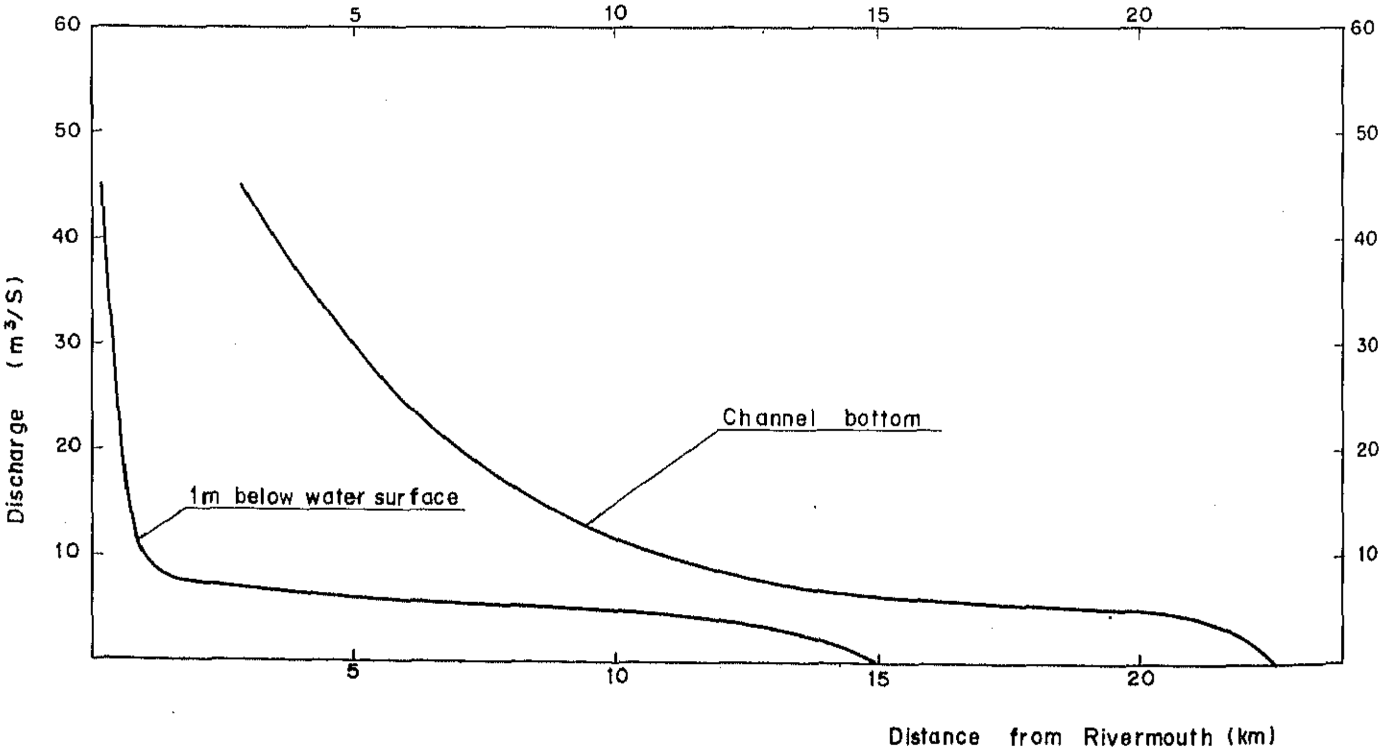


Fig. 2.16 LOCATION MAP OF SAMPLING OF RIVER BED MATERIAL

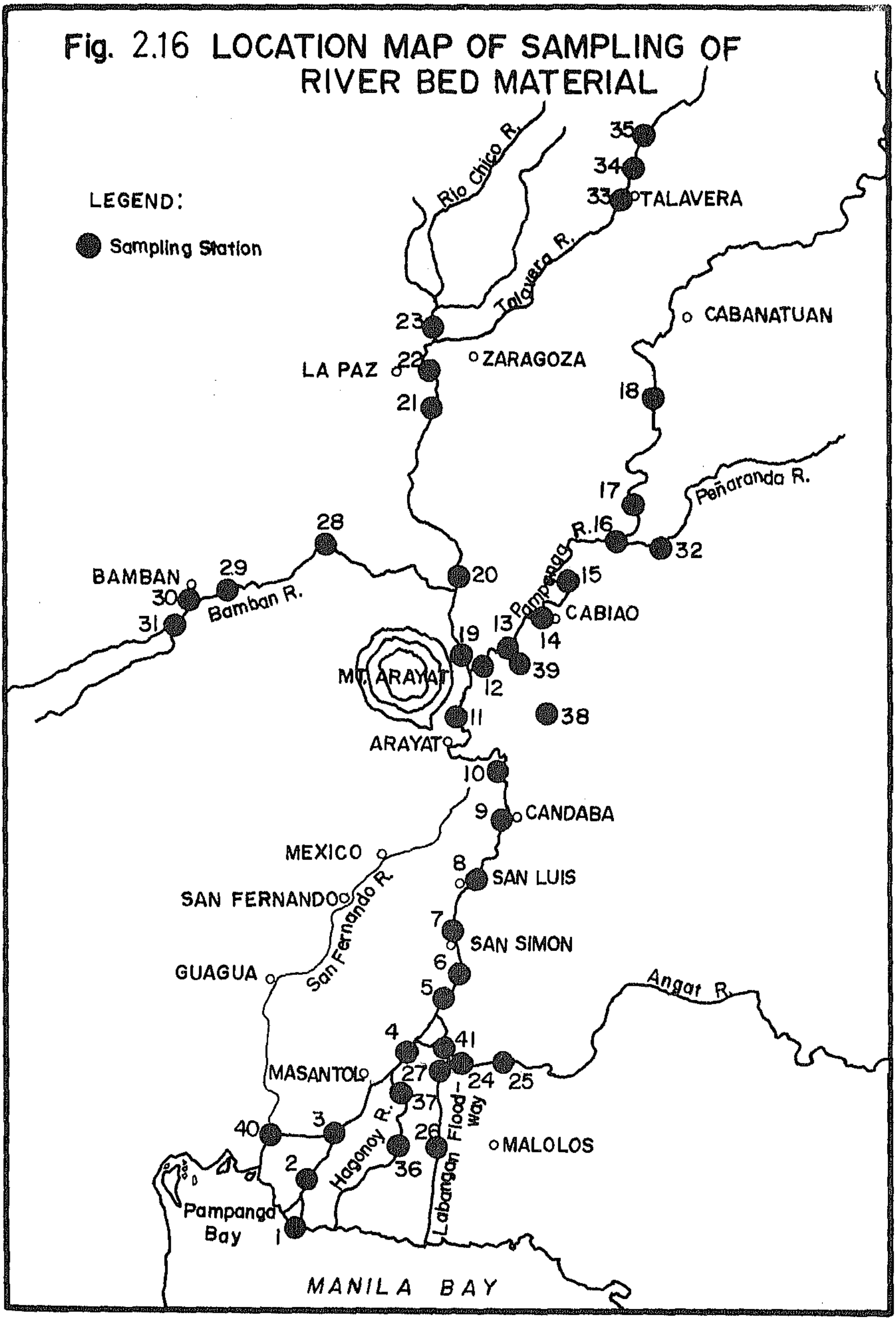


Fig. 2.17 RELATIONSHIP BETWEEN SEDIMENT DISCHARGE AND WATER DISCHARGE

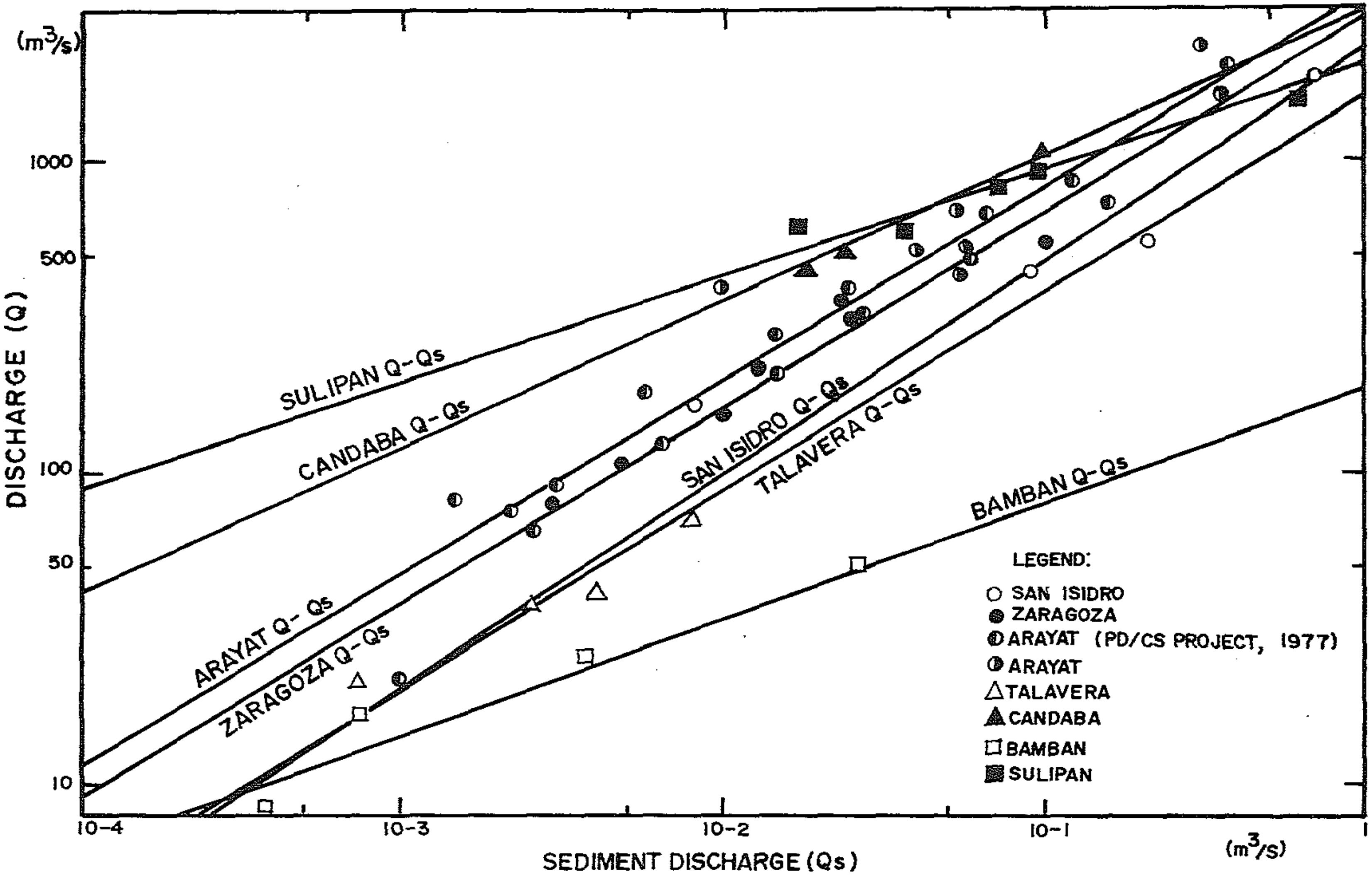


Fig. 3.1 COMPARISON OF OBSERVED AND RANDOMIZED RAINFALLS

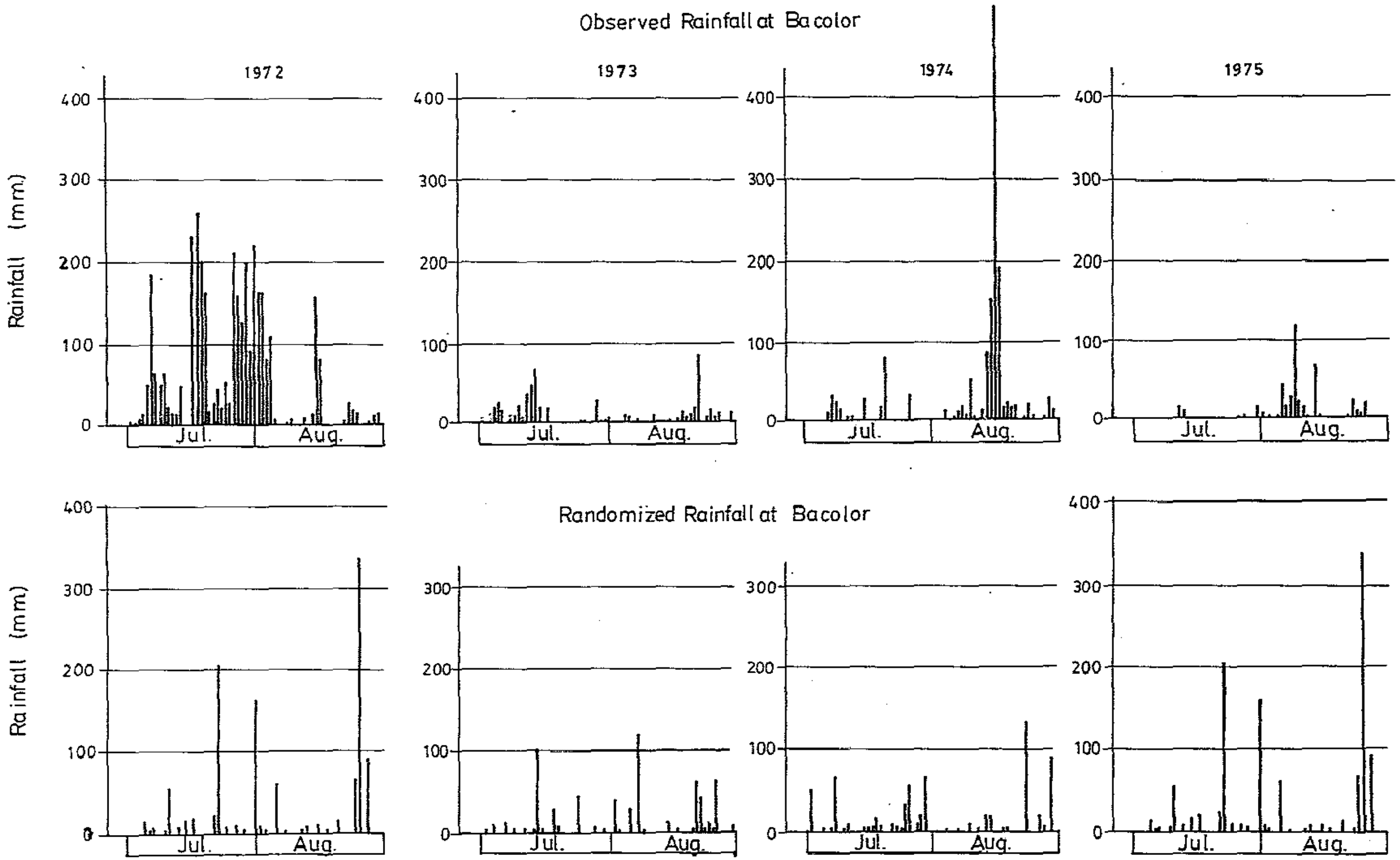


Fig. 3.2 PROBABLE RAINFALL AT CABANATUAN CITY

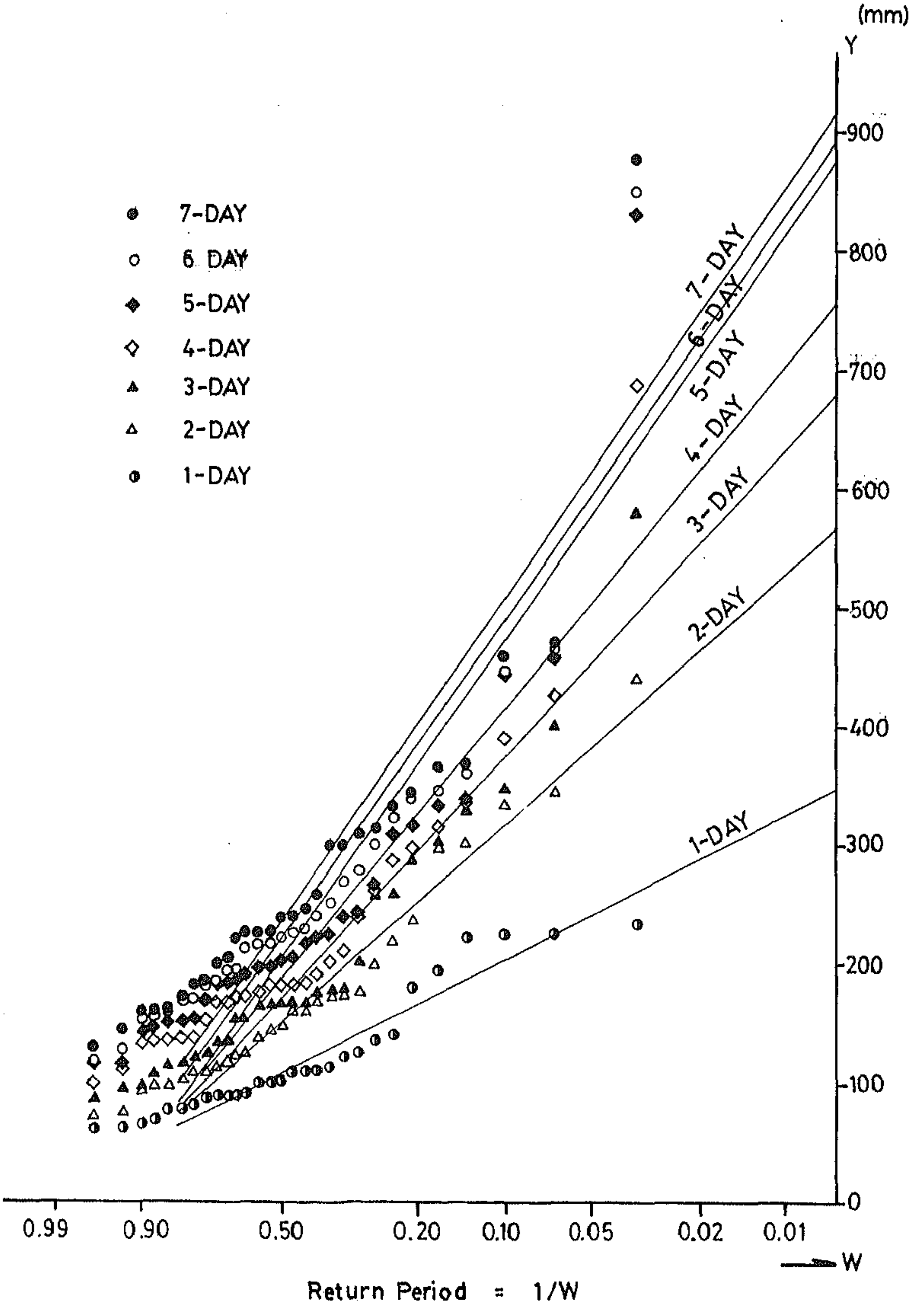


Fig. 3.3(1) CONTINUOUS RAINFALL CORRELATION BETWEEN CABANATUAN CITY AND BASIN AVERAGE

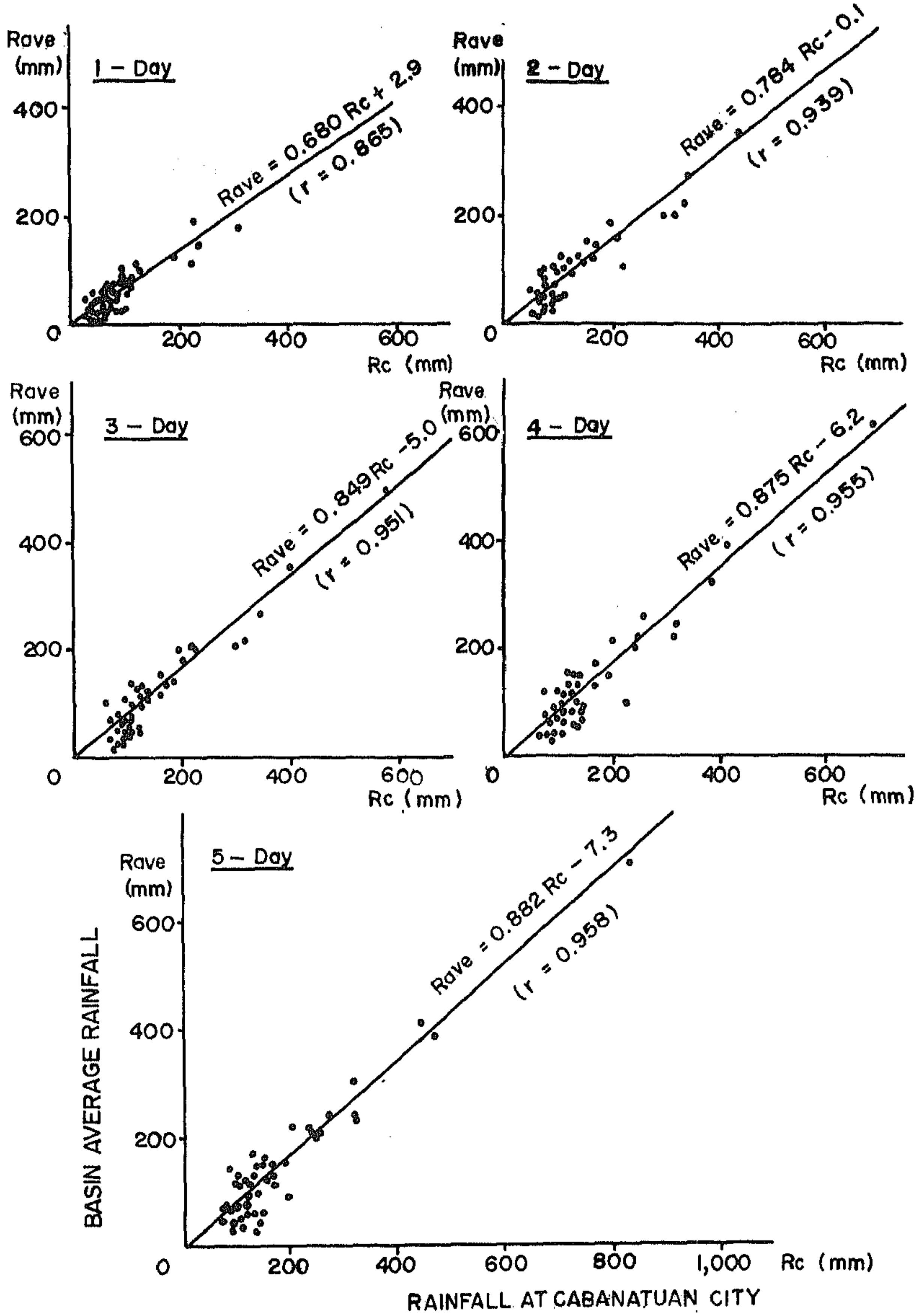


Fig. 3.3(2) CONTINUOUS RAINFALL CORRELATION BETWEEN CABANATUAN CITY AND BASIN AVERAGE

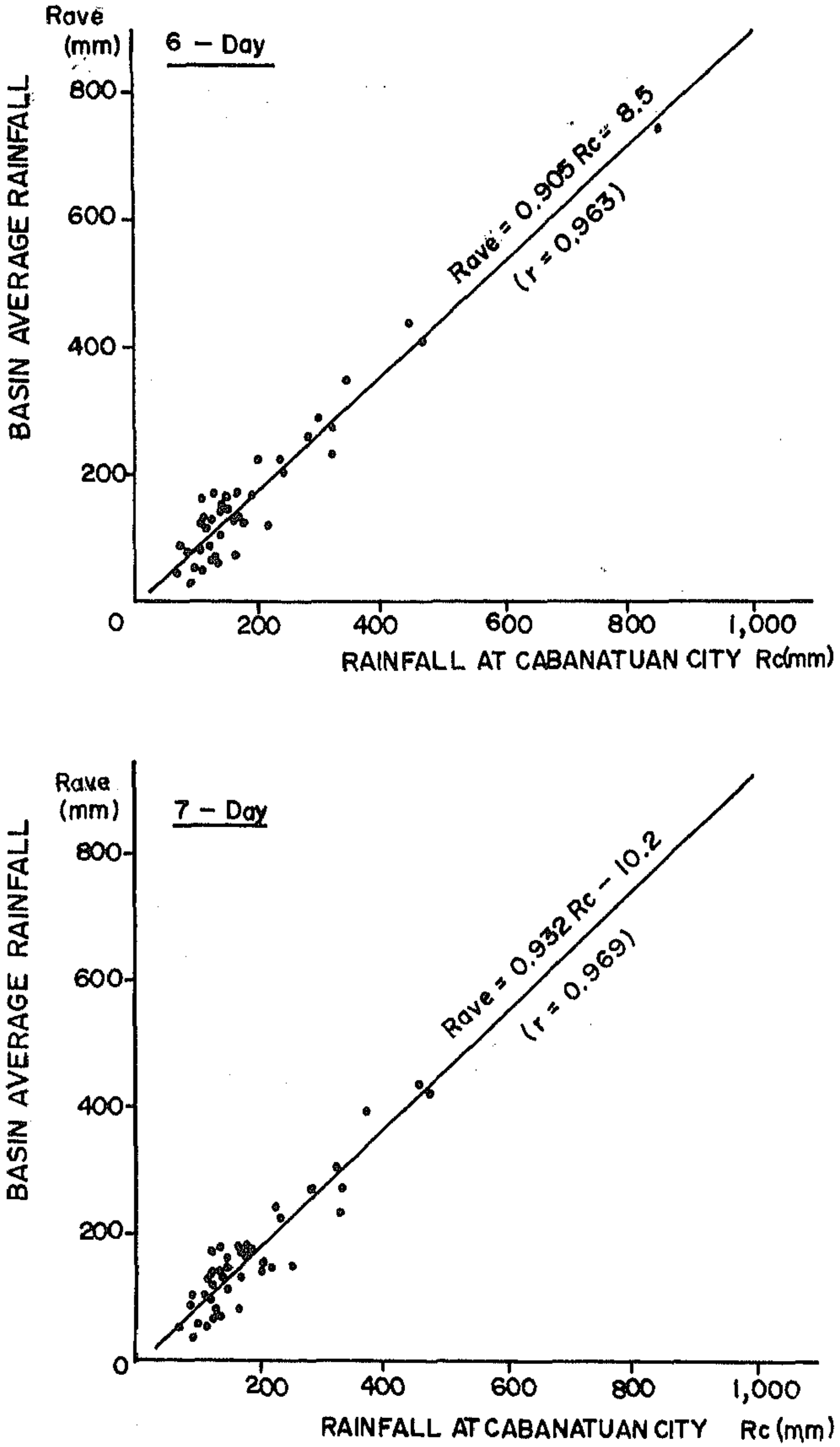


Fig. 3.4 SUB-BASINS OF PAMPANGA BASIN FOR RUNOFF ANALYSIS

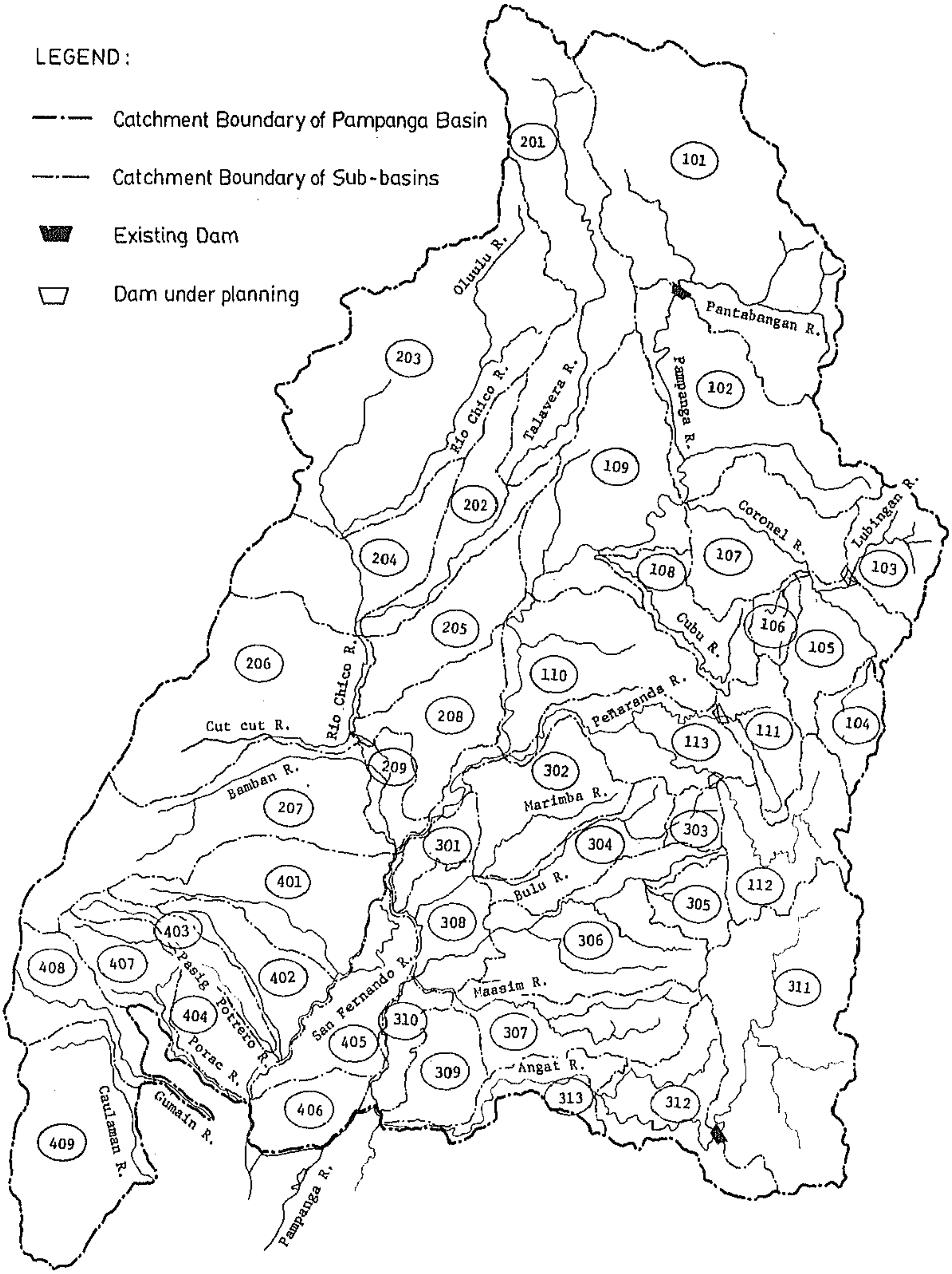


Fig. 3.5 RUNOFF CALCULATION MODEL DIAGRAM

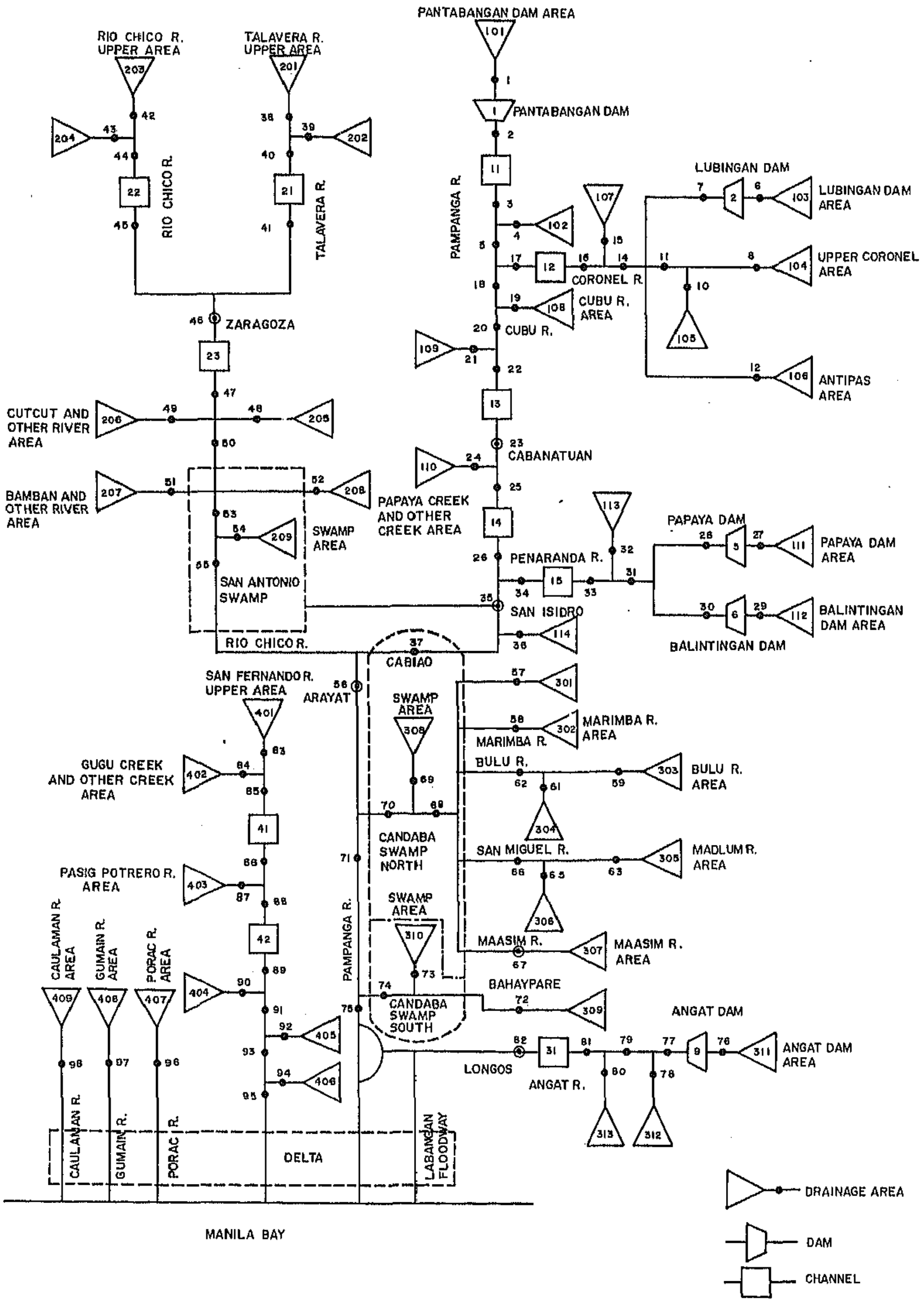


Fig. 3.6(1) DISCHARGE HYDROGRAPH

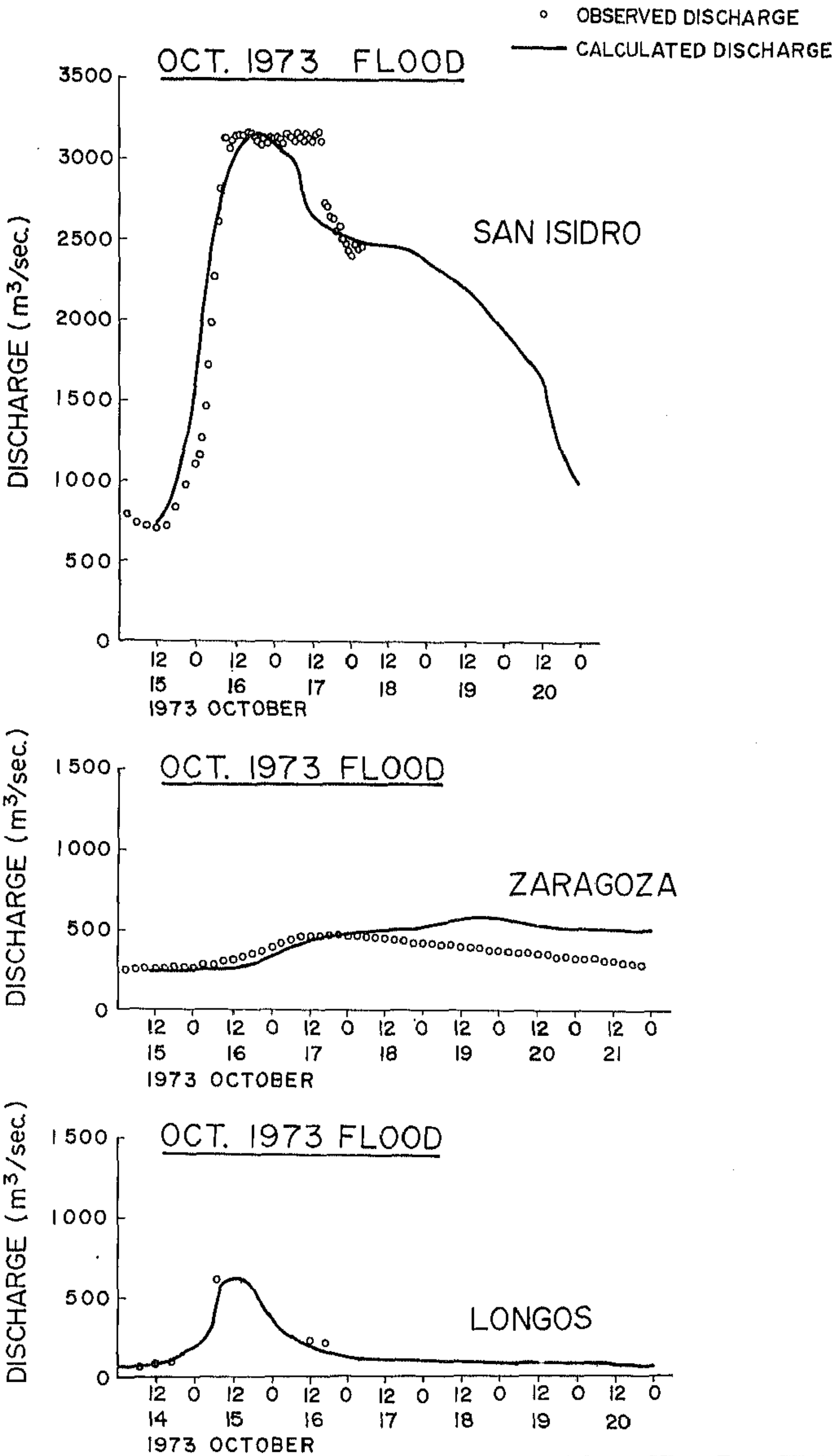


Fig. 3.6(2) DISCHARGE HYDROGRAPH

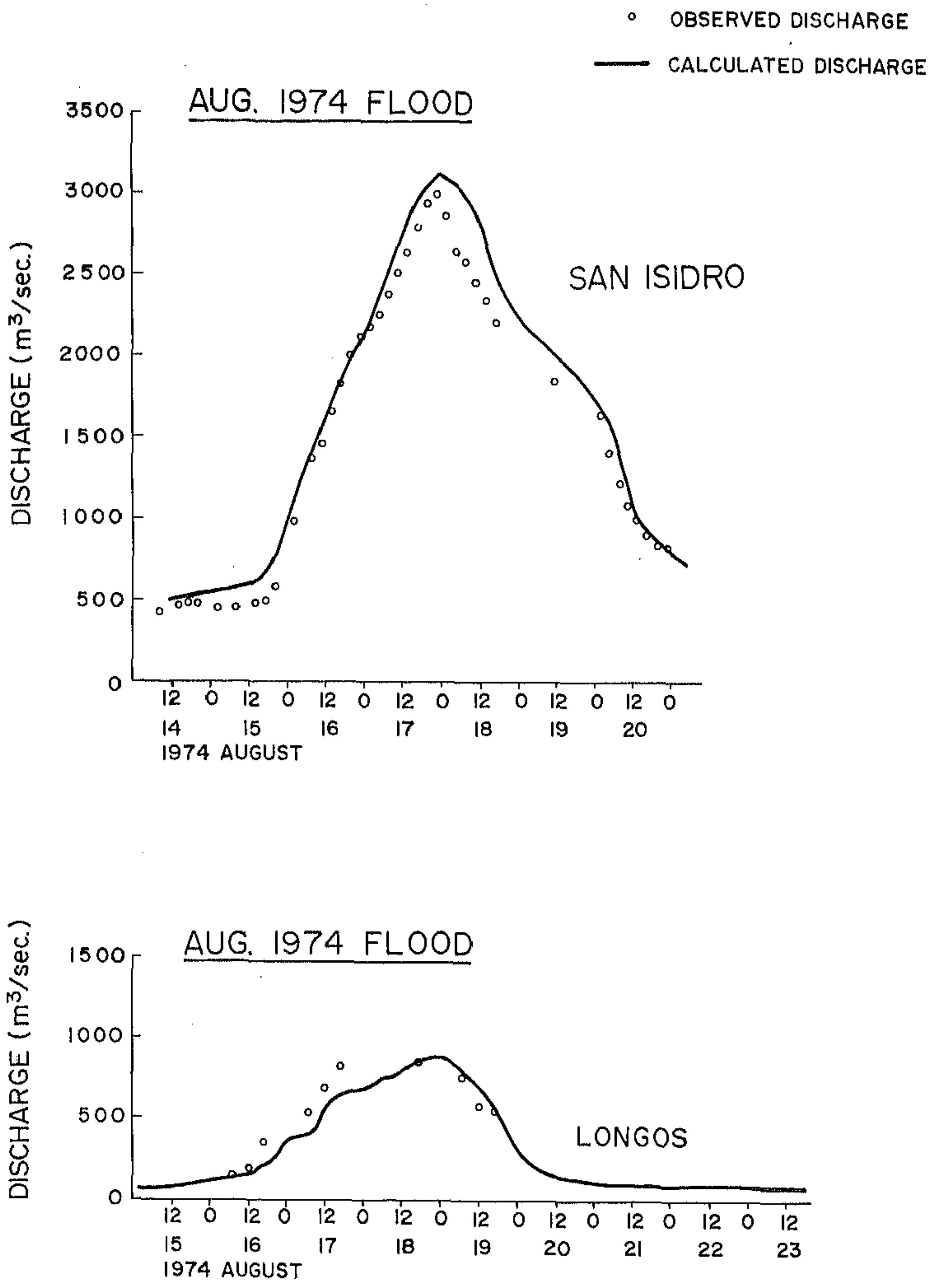


Fig. 3.6(3) DISCHARGE HYDROGRAPH

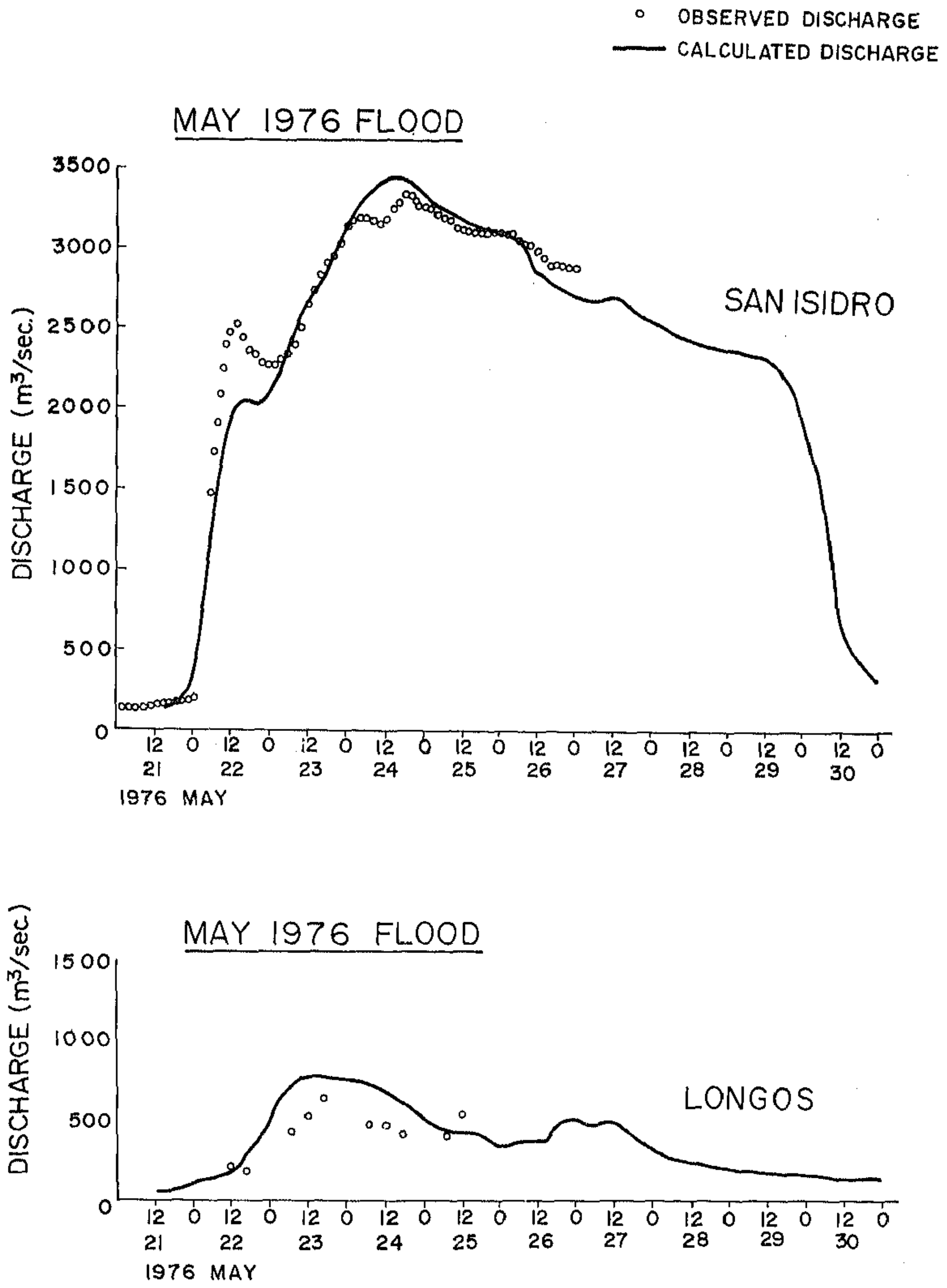


Fig. 4.1 NET WORK OF HYDRAULIC SIMULATION MODEL

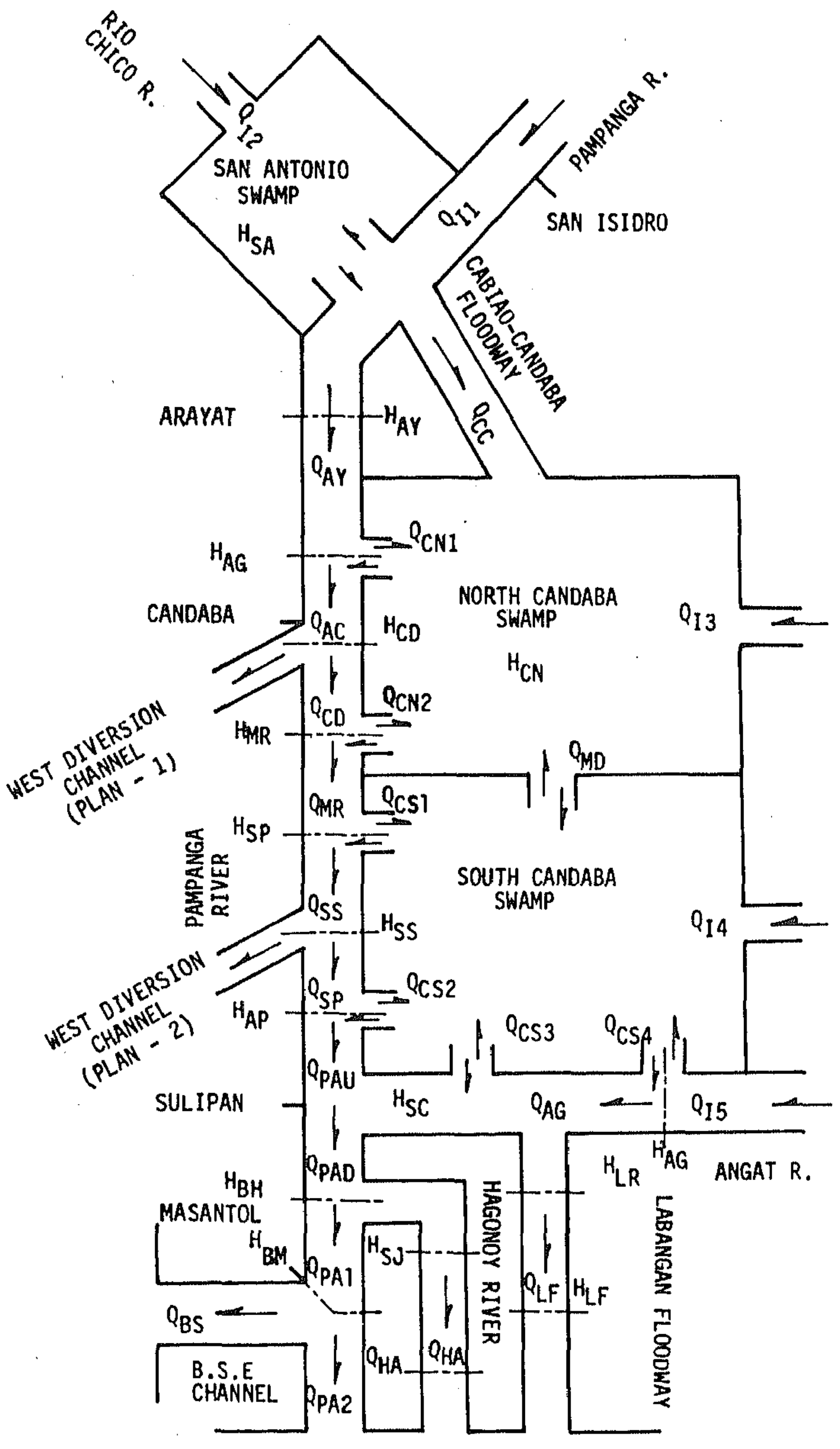
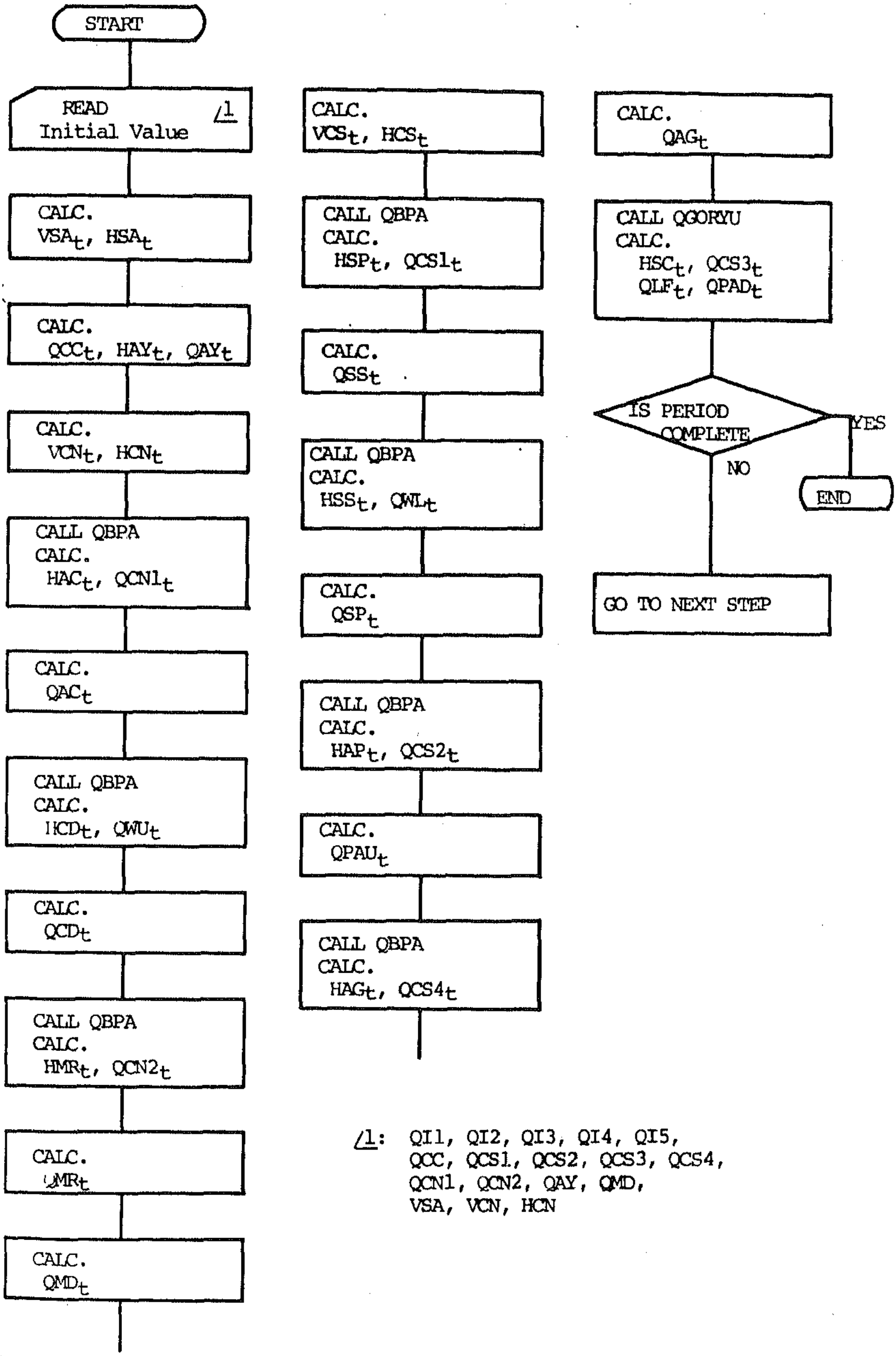


Fig. 4.2 (1) **FLOW CHART OF PROGRAM**



⁄1: QI1, QI2, QI3, QI4, QI5,
QCC, QCS1, QCS2, QCS3, QCS4,
QCN1, QCN2, QAY, QMD,
VSA, VCN, HCN

Fig. 4.2 (2) FLOW CHART OF PROGRAM

SUBROUTINE GORYU

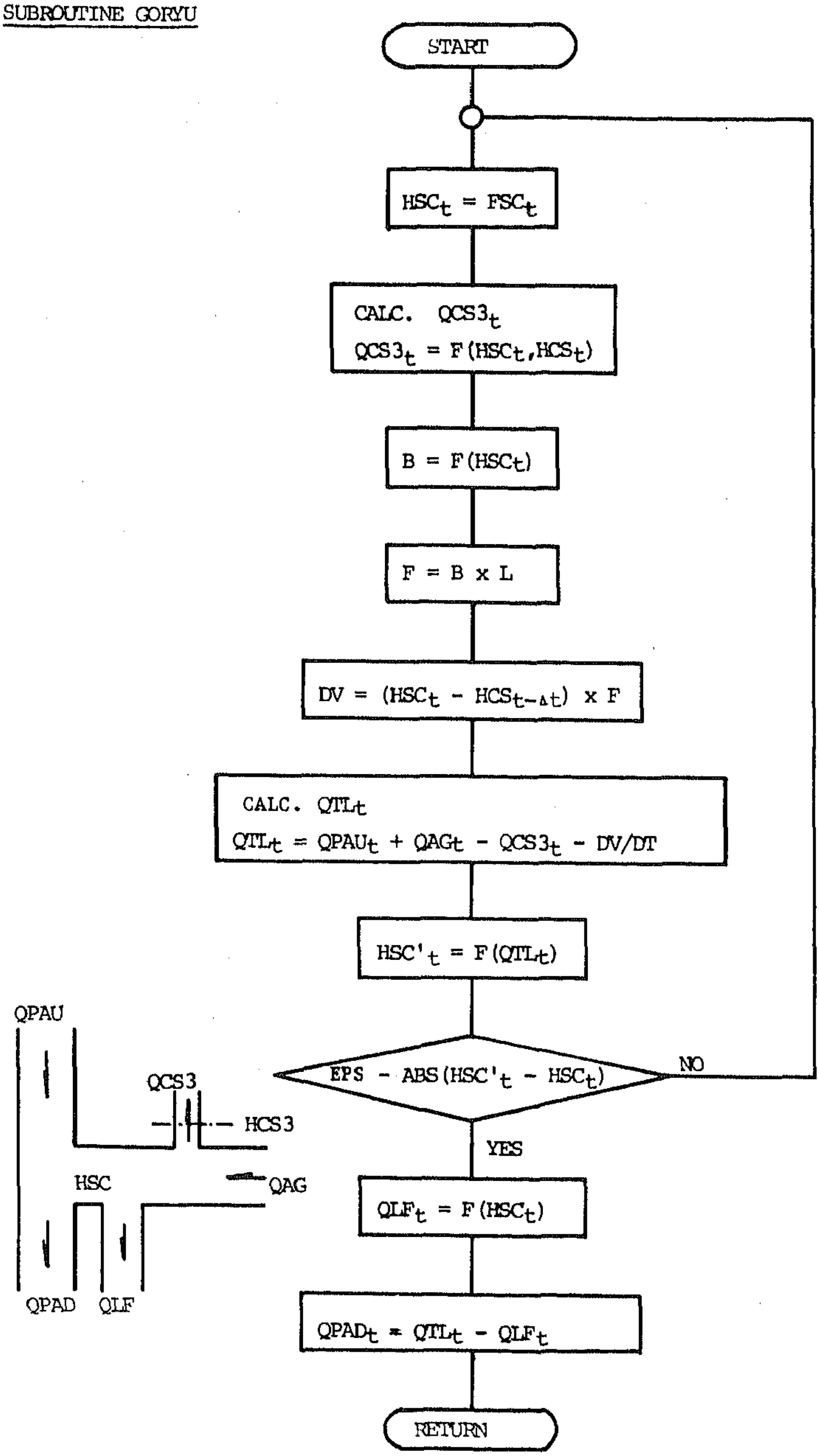


Fig. 4.2 (3) FLOW CHART OF PROGRAM

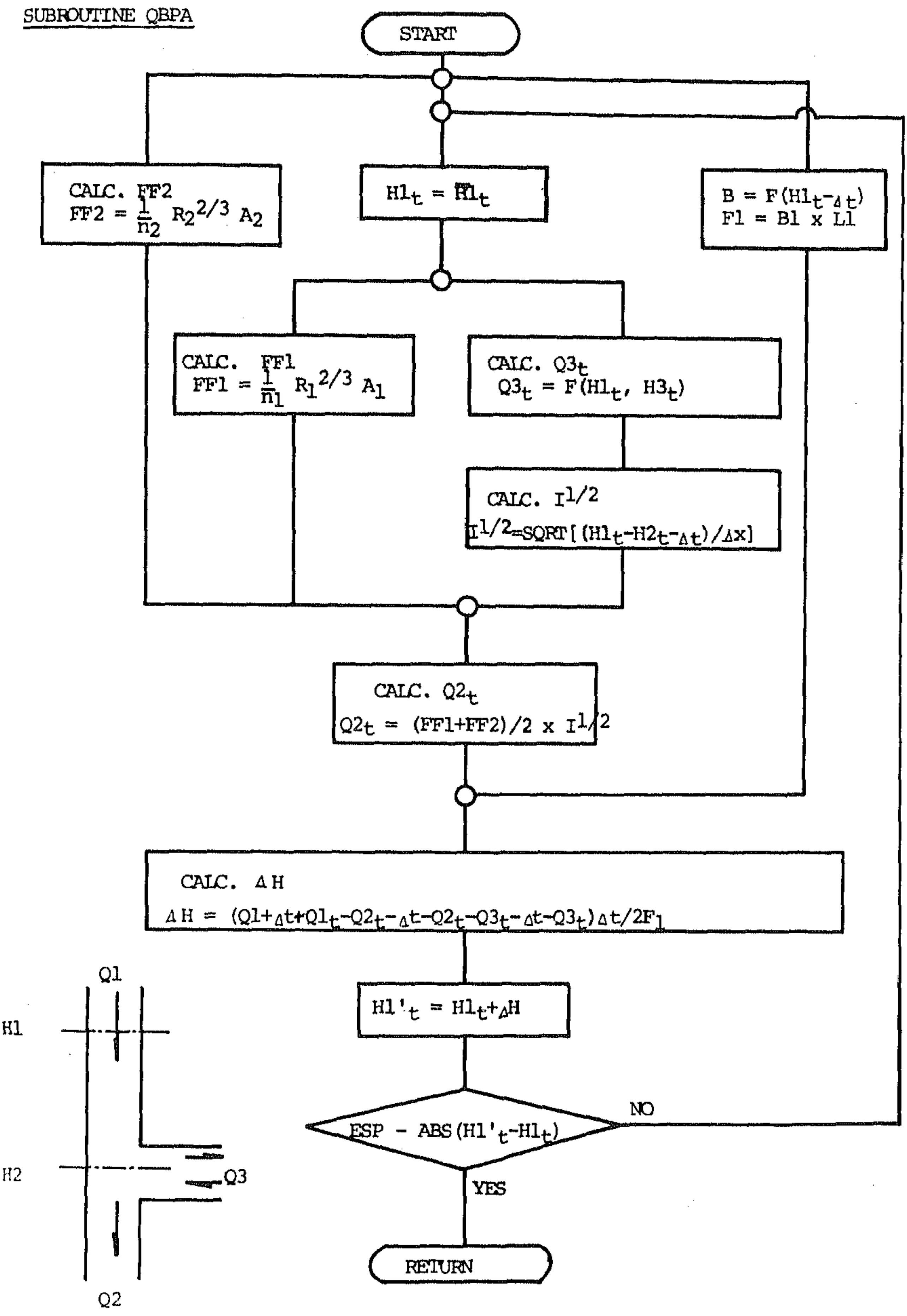
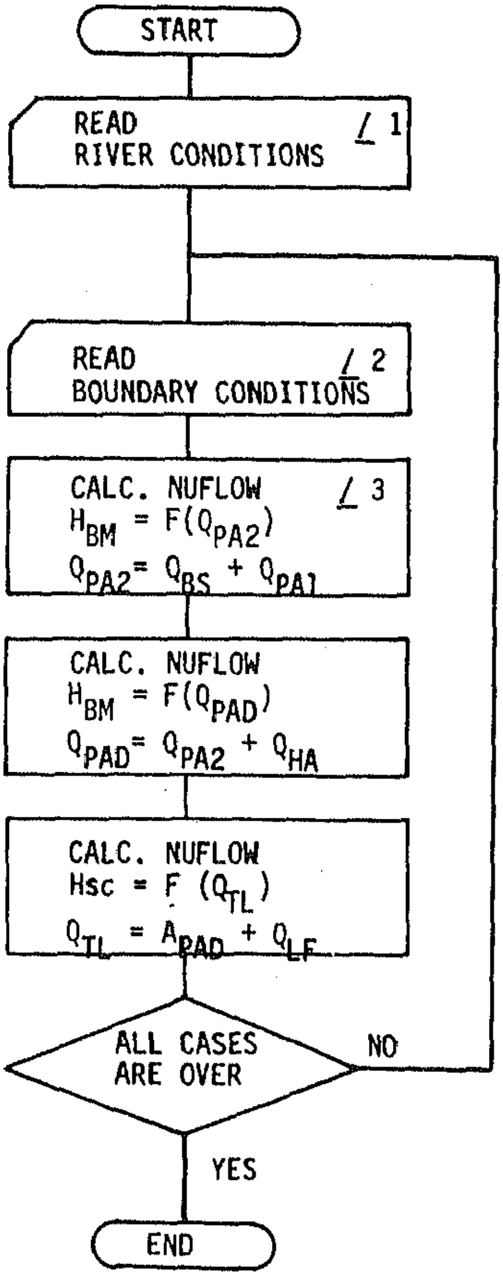


Fig. 4.2 (4) FLOW CHART OF PROGRAM

SUBROUTINE F(H-Q)

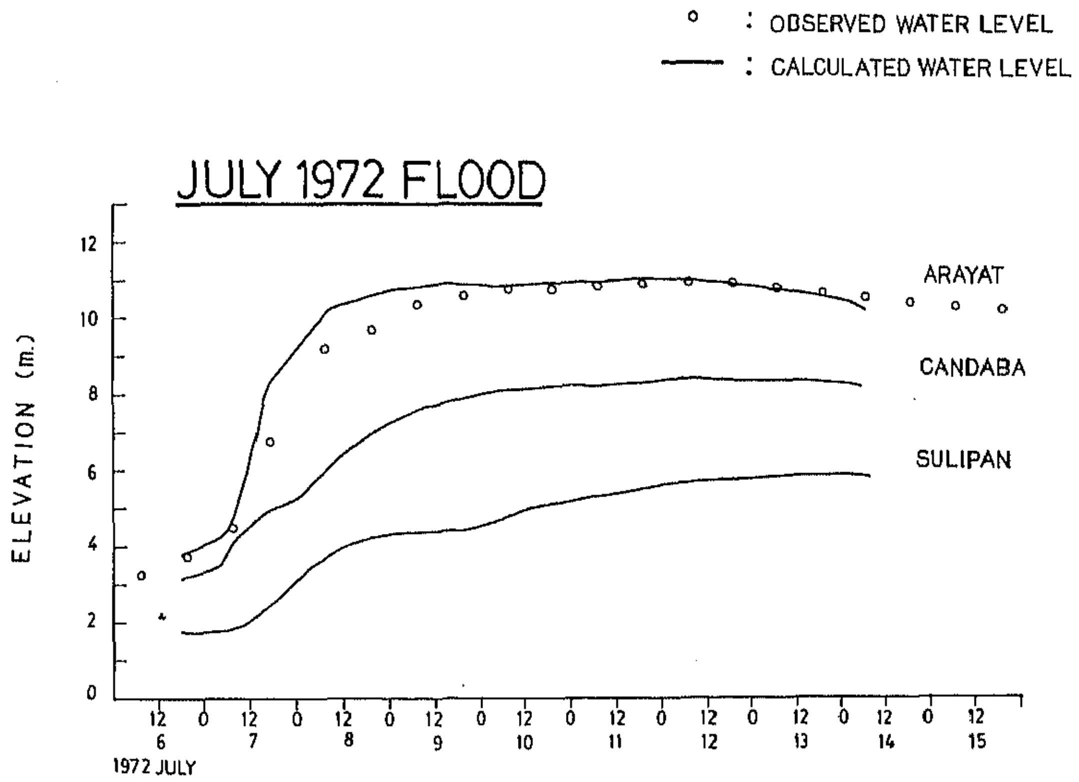


∠ 1 Cross-section, Distance
Coefficient of roughness

∠ 2 H_{MB}, Q_{BS}, Q_{PA1}, Q_{HA}, Q_{LF}

∠ 3 NUFLOW: Non-uniform flow

Fig. 4.3(1) WATER LEVEL HYDROGRAPH


JULY 1972 FLOOD

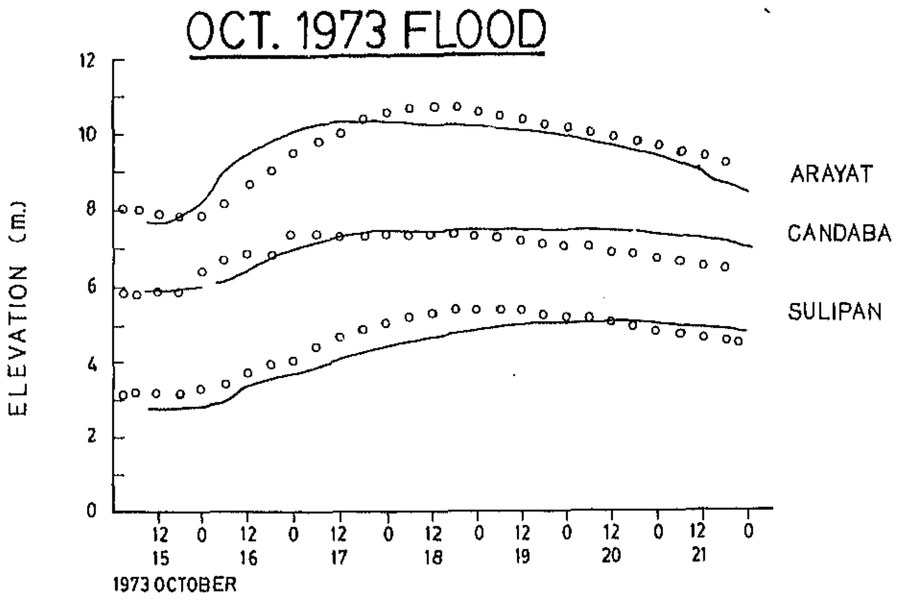
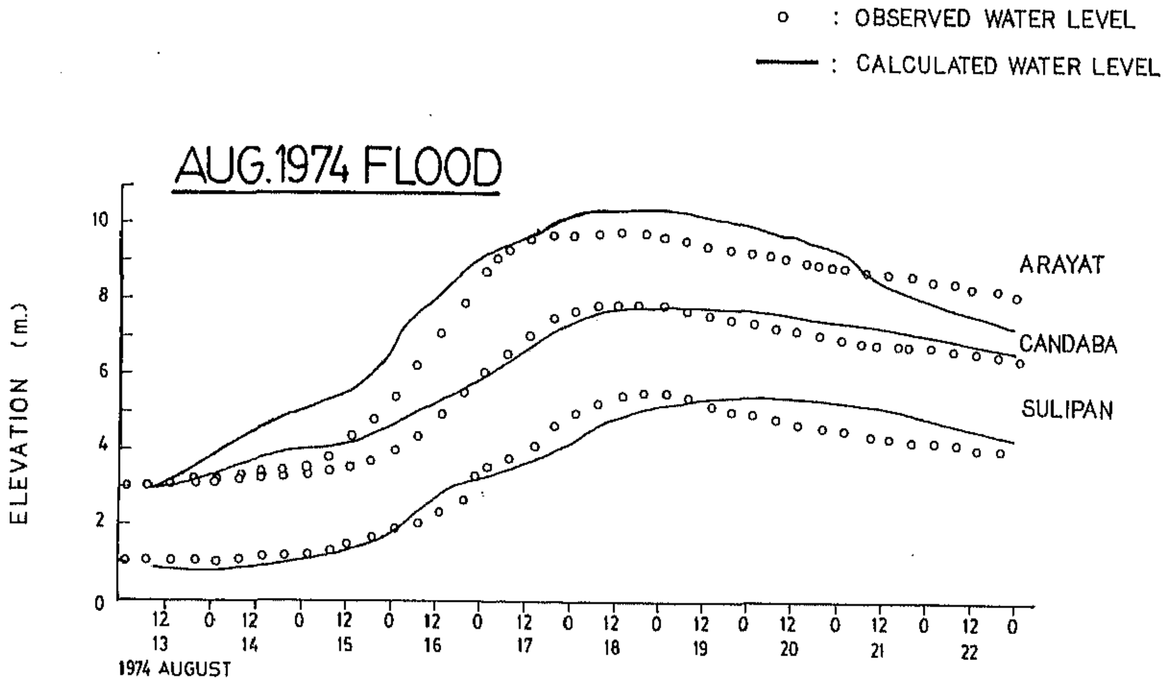

OCT. 1973 FLOOD

Fig. 4.3(2) WATER LEVEL HYDROGRAPH


AUG.1974 FLOOD

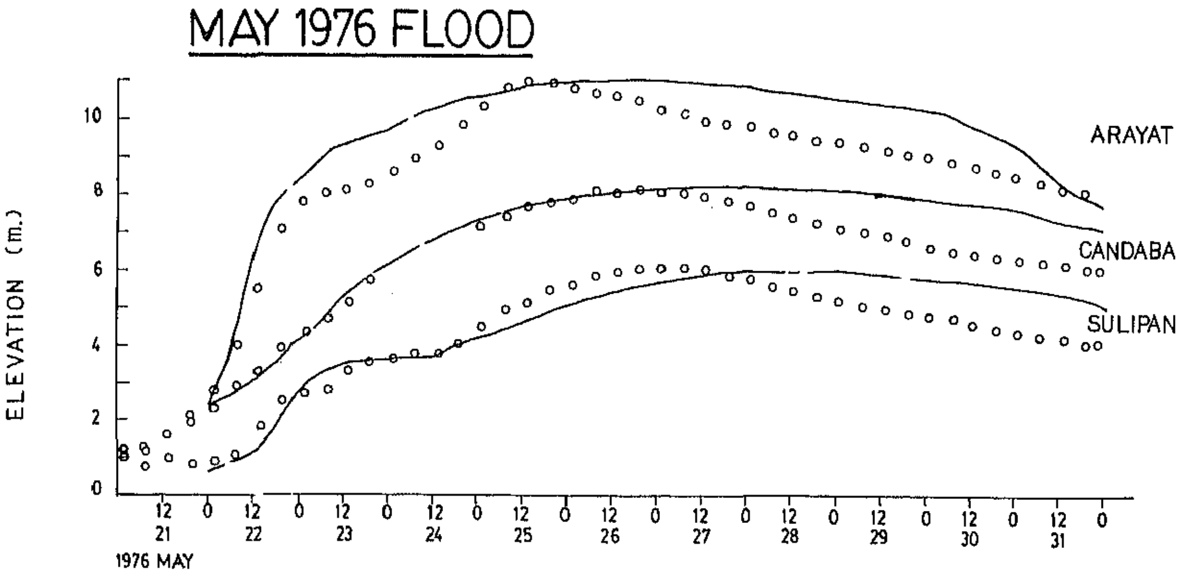
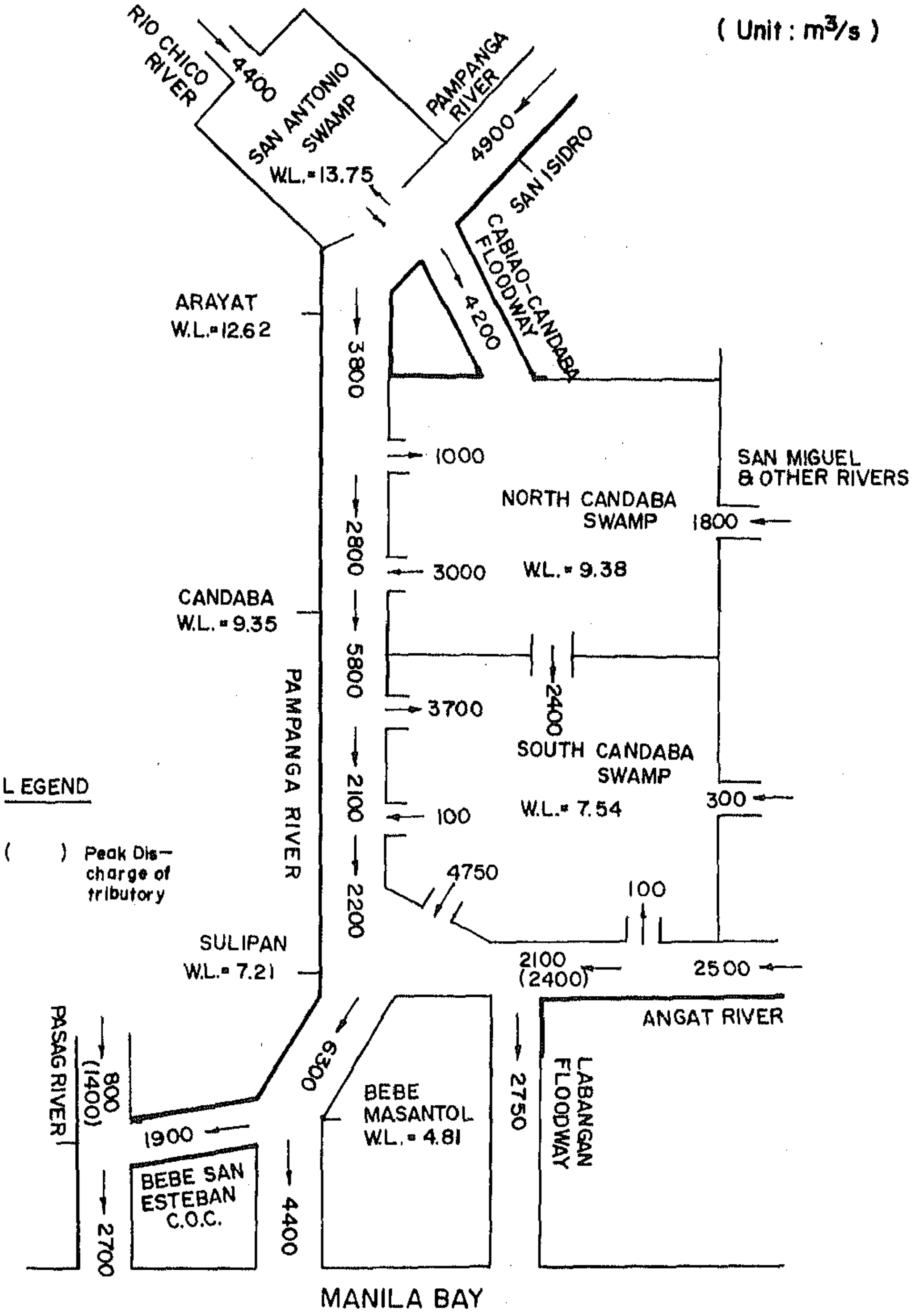

MAY 1976 FLOOD

Fig. 4.4 FLOOD DISCHARGE DISTRIBUTION UNDER PRESENT CONDITION (100 year RETURN PERIOD)



APPENDIX III

GEOLOGY AND SOIL MECHANICS

APPENDIX III GEOLOGY AND SOIL MECHANICS

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APPENDIX III GEOLOGY AND SOIL MECHANICS

CHAPTER 1 INTRODUCTION

The explorations and studies on geology and soil mechanics aim at obtaining basic geotechnical data of foundations for various concrete and earth structures and of construction materials.

The investigation on geotechnical engineering of this project has been carried out at several stages, namely review of previous investigation reports, reconnaissance geological survey, field tests and laboratory tests, since 1980.

It should be noted that the additional geotechnical investigation was carried out during the period from July to August 1981, because of the modification of project scheme, i.e., a pumping irrigation system with pumping station or a gravity irrigation system with diversion dam was proposed as alternatives instead of the construction of San Antonio Reservoir Dam, as seen in Appendix I "Project Formulation".

Results of geotechnical investigations and interpretations on them are presented hereinbelow.

CHAPTER 2 GEOLOGY AND TOPOGRAPHY

2.1 Introduction

Geology of the Central Luzon has been studied by a number of authorities: the most recent published reports on the subject are those of Sandoval and Mamaril (1970), and Miguel and Arroyo (1971).[/1] As the report of engineering geology, recent publications are those of "Irrigation Development Plan for Central Luzon, Appendix F Geology" prepared by National Irrigation Administration (1978), and "Pampanga Delta/Candaba Swamp Area Development Project" prepared by Planning and Project Development Office, Department of Public Works, Transportation and Communications (1970).

Topographically the study area in the geological survey can be categorized by three zones: (1) The Zambales Mountains including the zone of the volcanic highlands, (2) The Sierra Madre Mountains, and (3) The Central Luzon Plain. General geology and geological classification of the each zone is illustrated on Fig. 2.1 and 2.2 and shown in Table 2.1 (1), (2) and (3).

2.2 Geology

(1) Zambales Mountains

Zambales Mountains is underlying by Cretaceous-Paleogene ultramafic and mafic plutonic rocks. The Ultimate rocks are typically pyroxenites, gables and northosites associated with basalt, pegmatites, diabase dikes and asbestos seam.

The southern part of the Zambales Mountains is covered by ultramafic and mafic plutonic rock. The Pliocene-Quaternary volcanic rocks; chiefly consisting of pyroclastics and/or volcanic debris at the foot of volcaneous. On the northern part of the Mountains, Ultramafic and mafic plutonic rocks are outcropped. Pliocene-Pleistocene marine and terrestrial sediments are deposites at margin of core of the Mountains. In the regions lying north of the above, Pliocene-Pleistocene rocks are missing and the ultramafic rocks extend to the Central plains.

The Bataan-Zambales Volcanic Highland area consists of four large Pliocene-Pleistocene strata volcanoes. This area extends over the area of border of the central plain and of the western side of the Manila Bay from north to south.

[/1]: Pampanga/Candaba Swamp Area Development Project-Groundwater Studies Appendix D -1977-.

(2) Sierra Madre Mountains

Sierra Madre Mountains extend over the area from the Laguna de Bay to the end of Northern Luzon along the east coast of Luzon Island. Geologically and topographically the Mountains are segmented by the Philippine Fault into a north and south. This fault gets through the broad Liggaya Valley running from near Digaya Bay to Laur in the Central Luzon Plain.

The northern Sierra Madre Mountains consist of plutonic rocks flanked by Cretaceous to early Tertiary metasedimentary rocks. The Pre-Jurassic metamorphic basement rocks are outcropped on the rugged Mingan Mountain on the Liggaya Valley.

The southern Sierra Madre Mountains are a dissected range which consists of folded, faulted and metamorphosed Cretaceous to early Tertiary rocks overlain by Tertiary marine sedimentary rocks along the western slope. Limestone beds out-crop along the lower foothills and margin of the Central plain.

(3) Central Luzon Plain

Central Luzon Plain which is located at between the Zambales Mountains and the Sierra Madre Mountains, is a large and elongated basin filled with sediments ranging from the Oligocene to the Recent. The maximum depth of the sediments is 6,000 to 7,000 meters. The occurrence of the Palaeocene to Pliocene rocks on both sides of the basin suggests that the same rocks also underlain the cap of Recent sediments. The limestones are much more predominant on the eastern side.

The plain is a low flat featureless plain but five non-active volcanic cones protrude above the plain including Mt. Arayat which consists of basaltic rocks.

The lower part of the plain is composed of loosely compacted gravel, sand, silt and clay associated with volcanic tuff and pyrocrastics.

2.3 Topography

(1) Zambales Mountains

The Zambales Mountains extend over the mountain range from north to south on the west side of the Central Luzon Plain. The range extends from the Bataan peninsula to the Pangasinan Province. Zambales Mountains is divided into northern Zambales Mountain and the southern Bataan Zambales Volcanic Highlands. Northern Zambales Mountains have relatively gently slope. The Bataan Zambales Volcanic Highlands consist of steep shape core and volcanic highlands which surround steep shape mountain core.

(2) Sierra Madre Mountains

The Sierra Madre Mountains is located at along the eastern coastal zone of the Luzon Island from Laguna de Bay to the upper end of northern Luzon. The range is divided into north range and south range by the Philippine Fault which passed through the Liggaya Valley running from near the Digaya Bay to Laur in the Central Luzon Plain. Northern range consists of core of plutonic rocks which are surrounded by metasedimentary rocks.

The southern range forms topographically well dissected mountains consisting of metamorphosed rocks overlain by marine sedimentary rocks along the western slopes.

(3) Central Luzon Plain

The Central Luzon Plain is bordered by mountain ranges on the east and west sides. It opens on the Manila Bay in the south and on the Lingayen Gulf in the north. The Plain consists of the flat alluvial plain, swamps and delta land. Some non-active volcanic cones protrude above the flat alluvial plain.

The objective area is located on the southern part of the Central Luzon Plain which consists of alluvial fan, flood plain, the San Antonio Swamp, the Candaba Swamp and delta plain. Mt. Arayat is located on the border line between the San Antonio Swamp and the Candaba Swamp.

CHAPTER 3 SUBSURFACE EXPLORATION

3.1 General

The main purposes of subsurface exploration are to obtain the geotechnical characteristics of grounds for structure foundations and of materials for construction use.

The explorations were carried out twice, namely from January to March in 1981 and from July to August in 1981. The latter exploration was concentrated mainly on the sites of diversion dam and pumping station which were selected as alternatives of the San Antonio reservoir dam during the study of project formulation.

The explorations consist of the review of previous investigation report reconnaissance geological survey, drillings with Standard Penetration Test (SPT), Dutch Cone Penetration Test (DPT), Test Pittings, soil sampling and laboratory soil tests. Summary of work quantity of explorations is shown in Table 3.1 - 3.2. Locations of subsurface exploration are illustrated on Fig. 3.1 - 3.2. The results of explorations are compiled in "Data Book".

3.2 Exploration for Structure Foundation

(1) Main objectives of explorations for structure foundation are the San Antonio reservoir dam, diversion dam, pumping station, levees, canals and their related structures, and salinity control gates.

Geotechnical features to be made clear for the above objectives are such characteristics as strength/bearing capacity, settlement and permeability.

Brief explanation on SPT and DPT which were executed to obtain the above characteristics, are made below. Locations and work quantities are listed in detail in Table 3.3 - 3.4.

(2) Standard Penetration Test (SPT)

SPT is carried out to get penetration resistances of subsoil, and to get soil samples for identification of soil by using split tube sampler. From the above informations, strength/bearing capacity characteristics is estimated.

SPT was made in accordance with the method designated in "Earth Manual, second edition 1974" prepared by the U.S. Department of the Interior, Water Resources and Energy Service.

(3) Dutch Cone Penetration Test (DPT)

DPT is one of the handy double tube penetration test equipments, and it is used broadly all over the world. From its cone penetration resistance, strength characteristics is obtained as well as from SPT.

DPT was made in accordance with the method designated in "A Method of Double Tube Dutch Cone Penetration Test (1972)" prepared by the Japanese Society of Soil Mechanics and Foundation Engineering.

3.3 Exploration for Construction Materials

(1) Main objectives of explorations for construction materials are impervious materials for levees and canals, rock materials for masonry works or concrete aggregates, and sand-gravel materials for concrete aggregates.

In order to investigate quality and quantity of these materials, the explorations composed of core drillings, test pittings and laboratory soil tests were carried out. The locations of core drillings and test pittings are shown on Fig. 3.3 and 3.1 respectively.

Brief explanation on core drillings, test pittings and laboratory soil tests are made below.

(2) Core Drilling

Core drillings are carried out to obtain such geotechnical data of quarry site as degree of weathering, hardness, etc. of rock and quantity available.

Details of core drillings are shown in Table 3.5.

(3) Test Pitting

Test pitting aims to know subsurface conditions of borrow areas for impervious soil and sand-gravel, and to take disturbed soil samples for laboratory test.

Depths of pit were 3 m for impervious soil and 2 m for sand-gravel. In case ground water table was high, auger boring was subsidiary used.

(4) Laboratory Soil Test

Laboratory soil tests are indispensable for impervious soil to obtain such characteristics as shear strength, permeability, compaction, etc.

Summary of test items and test results are shown in Table 3.6.

CHAPTER 4 FOUNDATION OF PROPOSED STRUCTURE

4.1 San Antonio Reservoir Dam

Dam of the reservoir surrounds the San Antonio Swamp as shown on Fig. 3.1. Penetration tests were made on the proposed dam axis line. Location of the points tested is shown on Fig. 3.1. Surface materials of the San Antonio Swamp are mostly composed of soft and unconsolidated clay or silty clay, occurring locally silt and/or silty sand. On the western side out of the reservoir, surface of the plain is covered with poorly computed sand layer. Subsurface geology is illustrated on Fig. 2.2. Correlated columnar sections of the dam site are sections of the dam site as shown on Fig. 4.1.

(1) Section A-A' Line

Generally, on this section uppermost layer consists of sandy materials then sand and gravel were deposited under 9 meters from surface. At the left bank of the Rio Chico River, sand and gravel appear from 14 meters depth. Bearing capacity of the sandy layers are medium to low.

(2) Section B-B' Line

The thick sandy layers are deposited at west side and the banks of the Rio Chico River. On the contrary this clayey layers are deposited at the San Antonio Swamp. Bearing capacity of the both type layers are medium and/or high.

(3) Section C-C' Line

On this section uppermost layer consists of sandy materials with medium bearing capacity then clayey layers are deposited. Talus deposites are located at the surface of the foot of Mt. Arayat.

4.2 Diversion Dam

As seen on Fig. 4.2, relatively firm layer, weathered tuff breccia, was encountered at around 5 or 7 meters depth along the dam axis according to the results of SPT and Dutch cone sounding. In-situ test results between SPT and Dutch cone sounding show rather good conformity in the depth of firm layer which is composed of weathered tuff breccia.

On the other hand, the Dutch cone sounding results along the center line of spillway gate section show that such relatively firm layer as the above underlies at slightly deeper position, i.e. 10 to 12 m, than that along the dam axis. This fact may suggest that the peak of ridge which extends from the foot of Mt. Arayat approximately conform to the diversion dam axis.

Accordingly the diversion dam may be founded directly on the weathered tuff breccia although a few meters highly weathered upper portion will be required to be cut away, because N-value of this layer is more than 50 nos. of blow. It shall be noted, however, that the thickness or distribution of the layer has not been confirmed yet because of the mechanical limitation in capacity of wash boring and Dutch cone sounding.

4.3 Pumping Station

As seen on Fig. 4.3, Dutch cone sounding result shows that considerably firm sandy stratum of which qc value is about 200 kg/cm^2 or more, was found at about 28 m depth from the ground surface, although thin sandy strata were recognized to be intercalating at shallower depth. The result of Dutch cone sounding does not conform to the result of electric prospecting, but roughly conform to that of SPT for the Arayat bridge foundation which locate close to the proposed pumping station.

Such firm sandy stratum is considered to be a suitable bearing stratum for the foundation of pumping station, while thin firm strata are not.

4.4 Levee, Canal Embankment and Related Structure

The project area along the levees and canal routes is covered with thick Quarternary sedimentary deposit mainly composed of normally consolidated clayey layers and poorly cemented sandy layers. In general, it may be pointed out that relatively firm layer on which large scaled structures will be founded is encountered at deeper position toward downstream.

(1) Correlated columnar sections of the project area are shown on Fig. 4.1. From these soil profiles, Quarternary deposits in the back swamp on which levees and canals will be founded are roughly divided into following five layers.

Uppermost layer is composed of silty or clayey soil having thickness of about 5 to 10 m. The strength parameters of this layer are estimated as below:

$$Cu = 0.15\ (kg/cm^2) = 1.5\ (t/m^2)$$

$$\phi u = 0$$

Second layer underlying the uppermost layer is composed of sandy soil having thickness of about 1 to 5 m. This layer, however, seems to exist only along the present Pampanga river banks, and not in the back swamp located far from the river. The west main canal is situated on the back swamp, while the east main canals and the levees are situated close to the Pampanga river. The sandy layer is expected to much contribute to pile foundation as a bearing stratum. The pile length may be 5 to 10 m. N-value of 10 is rather conservative as the design value. Estimated shear strength parameters are as below.

$Cu = 0$

$\phi u = 30°$

Third layer is mainly composed of silty and clayey soil intercalating thin sandy layers. This layer distributes approximately 8 to 25 m in depth. N-value of it roughly ranges from 2 to 5. Estimated shear strength parameters are as below.

$Cu = 0.2\ (kg/cm^2) = 2\ (t/m^2)$

$\phi u = 0$

Fourth layer comprise with alteration of silty or clayey layer and sandy layer. This seems to be getting harder downward, that is, N-value ranges from 10 to 40 toward deeper portion. It may extend down to 50 or 60 m in depth. However, it shall be noted that this estimation is made from only one bore hole.

Fifth layer is remarkably hard, that is, N-value is more than 50. The layer is hard enough to support any large scaled structural foundation. Estimated shear strength parameters are as below.

$Cu = 0$

$\phi u = 45°$

(2) On the other hand, natural levees develop well on both banks along the Pampanga river. They are quite suitable for small scaled structural foundation. It is expected to have N-value of more than 10. The following shear strength parameters are recommendable for this layer.

$Cu = 0$

$\phi u = 30°$

(3) Settlement Characteristics

Since the project area is covered with thick clayey sedimentary deposits, fairly large consolidation settlement due to applied loads is expected. Amount of settlement can be estimated by using laboratory consolidation test results. Since the consolidation test, however, has been carried out only for undisturbed soil samples taken from the limited drilling holes and depths, precise prediction of settlement may not be executed for the whole project area. In this situation, three subsoil models and their settlement characteristics (e vs. log P curve) have been established, which corresponds to the route division of Pampanga river improvement (see "Data Book").

(4) Permeability Characteristics

The result of grain size analyses suggests that permeability of soft ground may be fairly small, although no field permeability test was carried out. The coefficient of permeability may be in the order of 10^{-5} cm/sec at most, which will not result in any practical problem.

4.5 Salinity Control Gates

Salinity control gates are located at downstream stretch of the river. Since these gates require relatively large bearing capacity for their foundation, and also require to minimize uneven settlement for their smooth gate operation, pile foundations supported by the hard fifth layer aforementioned are recommended. The required pile length may be 50 or 60 m.

CHAPTER 5 CONSTRUCTION MATERIALS

5.1 Impervious Material

The geotechnical surveys for embankment materials are composed of the test pitting in-situ (see Fig. 5.1 - 5.2) and laboratory soil tests for impervious materials taken from the test pittings. The test pits located close to the levees and canals are such six pits as PE-1 to PE-6. In the design of embankment, it is expected that use of riverside land materials such as dredged material, etc. is more economical. The engineering properties of material in the above test pits are deemed to represent those of riverside land materials as well as those of protected low land ones, according to the field observation and laboratory tests. Therefore, the following discussions are valid for the materials both from riverside land and protected low land.

(1) Shear Strength

According to the triaxial compression tests, the average shear strength parameters are as below.

UU-test; $Cu = 0.38\ kg/cm^2$ $\phi = 11.0°$

$\overline{CU}$-test; $C' = 0.18$ $\phi' = 32.3°$

In slope stability analysis of embankment, UU-test result is applicable against short-term stability (end of construction) and $\overline{CU}$-test is against long-term stability, respectively. On the other hand, it is applicable to determine a typical section of embankment by using the Taylor's stability diagram and UU-test result as a preliminary design. Following values are recommendable for embankment design.

UU-test; $Cu = 0.25\ kg/cm^2$, $\phi u = 0$

$\overline{CU}$-test; $c' = 0.1\ kg/cm^2$, $\phi' = 25°$

(2) Permeability

All impervious materials which belong to CH or CL in the unified soil classification system are relatively high plastic cohesive soils. This kind of cohesive soil is generally impervious after compaction under proper water content. The laboratory permeability test result has proved it, that is, the coefficient of permeability ranges from the order of 10^{-6} to 10^{-7} cm/sec excluding a few exceptions under Standard Proctor effort and natural moisture content. These coefficient of permeability are low enough for the required imperviousness of levee and canal embankments. The following design value is recommendable.

$k = 1 \times 10^{-5}$ cm/sec

(3) Compaction/Trafficability

Proctor compaction test shows that the discrepancy in optimum moisture content (OMC) and natural moisture content (NMC) is more than 10% in most test cases. The fact suggests that trafficability of compaction equipment in construction may be rather poor. Dewatering during material handling may be primarily necessary.

(4) Cracking/Piping

Most of earth materials are very fine graded, that is, fines under #200 sieve is more than 80%. Such fine materials may cause cracking in embankment in case compacted under dryer moisture content than OMC. However, since they are relatively high plastic materials PI $\geq$ 15, if compaction would be made under wetter moisture content than OMC, it might not result in cracking and piping phenomena.

5.2 Rock Material

Rock materials used for the project may be exploited from Mt. Arayat which is located at the north fringe of project area. Main body of Mt. Arayat is composed of basaltic rocks. The surface portion of mountain slope is generally covered with clayey top soils and weathered basalt having thickness of 7 to 12 m.

Rock materials for masonry work and concrete coarse aggregate may be exploited from relatively fresh basalt beneath the weathered portion, while those for concrete fine aggregates be exploited also from a part of weathered basalt.

5.3 Sand-Gravel Material

Three sand-gravel material sources, the villages "Porac", "Peñaranda" and "Sta. Rosa" were surveyed for concrete aggregates. The material qualities of these sources are generally good for concrete aggregates according to the laboratory test results, although some gradation adjustment would be required by screening or crushing process.

CHAPTER 6 EARTHQUAKE ENGINEERING

6.1 General

The Phillippine archipellago is situated on the Circum-Pacific earthquake zone and has frequently experienced strong earthquakes up today. The Phillippine Weather Bureau prepared a earthquake map in 1955 in which the annual average numbers of felt earthquakes are shown during the period of 56 years from 1862 to 1918, as shown on Fig. 6.1.

From the figure, it is clearly seen that the most seismically active zone exists in the region of the Samar Leyte and east part of Mindanao islands, followed by the northern Luzon and the Manila-Taal regions.

The tectonic and seismic map of Luzon island is shown on Fig. 6.2 prepared by National Irrigation Administration in the "Report of Irrigation Development Plan for Central Luzon (1978)". Epicentral map of significant earthquake for Luzon from 1949 to 1978 is illustrated on Fig. 6.3. Data on violent earthquakes that have affected Manila so far are listed in Table 6.1.

6.2 Design Earthquake Coefficient

(1) Earthquake Data

According to the Weather Bureau, 190 earthquakes with magnitude of more than 5.0 are recorded within 300 km of radius from Mt. Arayat which is selected as the representation point in the project area. For the study on earthquake of the project, 48 numbers of earthquakes are examined out of the said 190 earthquakes, as shown in Table 6.2.

(2) Estimation of Horizontal Ground Acceleration

Horizontal ground acceleration is estimated by Iwasaki's formula[1] for the ground condition of Type III as follows:

$$\mathrm{Hmax} = 59.0 \times 10^{0.261M} \times (\Delta + 10)^{-0.886}$$

where, Hmax: Horizontal ground acceleration (gal)
M: Magnitude of earthquake (Gutenberg-Richter)
Δ: Epicentral distance (km)
Type III Ground: Alluvium with thickness of less than 25 m

The calculated ground accelerations at Mt. Arayat are listed in Table 6.3.

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[1] "Statistical Analysis of Strong-Motion Acceleration Records" by T. Iwasaki et al. Civil Engineering Journal Vol. 23, No. 9

(3) Estimation of Maximum Ground Acceleration In a Probable Return Period

The procedure of estimation is based on the plotting position of earthquake data as nonannual exceedence series as below.

1. Arranging of data in order of magnitude of acceleration Table 6.3

2. The average number ($\overline{X}$) of expected earthquake during N years in future, of which ground acceleration is equal to or exceeds the m-th ground acceleration of earthquake record in the past n years, is given as follow:

   $$\overline{X} = N \cdot \frac{m}{n}$$

3. Return period (TE) is defined as the N years if the $\overline{X}$ is one in the above equation as below.

   $$TE = N = 1 \times \frac{n}{m} = \frac{n}{m}$$

4. The correlation between ground acceleration and return periods is plotted on log-logarithms as shown on Fig. 6.4.

5. The expectancy of ground acceleration for required return period is obtained graphically or by the least square method as follows:

Return Period (TE)	Max. Ground Acceleration
50 (years)	66 (gal)
100	84
200	106

(4) Conclusion

1. Estimated max. ground acceleration is 84 gal, in case the return period is 100 years which is practicable from the standing point of the project life.

2. Since the recording period of earthquake data, however, is only 30 years, there may be some possibility that the estimation is too optimistic.

3. It is known that several projects in the Phillippines adopted the earthquake coefficient of 0.12 (120 gal).

4. Considering the above circumstances, it is recommended that the earthquake coefficient of 0.12 is applied for this project.

Table 2.1 (1) GEOLOGICAL CLASSIFICATION

ZAMBALES MOUNTAINS

Sedimentary and Metamorphic			Igneous Rocks	
Symbol	Rocks	Age	Symbol	Rocks
R	Alluvium fluvistile coral reel Flood plain deposite	Alluvium		
$N_3 + Q_1$	Marine and terrestrial sediments (molasse) Reef limestone Pyroclastics, Marl	Pleistocene	QVP	Pyroclastics Volcanic debris
N_2	Marine clastics (malasse) Tuff, Tuttites, Tuffaceous sedimentary rocks, Calcarenite, Silty limestone	Pliocene	QV	Pyroxene andesite, Dacite Basaltic rocks
N_1	Marine deposits Wackes, Shales, Reef limestone Conglomerate Basic to intermediate flows, Pyroclastics	Miocene	none	
		Oligocene		
		Palaeocene	UV UC	Spilites, Basaltic Andesite Peridotite Gabbro, Diabase. (Ultramafic Plutomicrocks.
		Cretaceous	K	Spilitic and basic flows Graywackes.

Table 2.1 (2) GEOLOGICAL CLASSIFICATION

SIERRA MADRE MOUNTAINS

Sedimentary and Metamorphic Rocks			Igneous Rocks	
Symbol	Rocks	Age	Symbol	Rocks
R	Alluvial plain deposites	Alluvium		
$N_3 + Q_1$	Molase, Reef limestone Pyroclastics, Marl Laterites	Pleistocene		
	Molase, Tuff, Tuttites. Tuffaceous sedimentary rocks, Calcarenite. Silty limestone	Pliecene	NI	Quartz diorite, Granodiorite, Diorite porphyry. Dacite.
		Miocene		
N_1	Marine deposites. Wackes, Shales, Reef limestone, Conglomerate Basic to intermediate flows, Pyroclastics.	Oligocene	P_{g2}	Keratophyre. Andesite flows Pyroclastics. Chert
P_{g1}	Wackes, Shales, Conglomerate, Reef limestone, Calcarenite, Dacite and Andestic flows, Pyroclastics	Eocene Palaeogene	P_{g1}	Dacite and andesite flows Include Eocene Sedimentary rocks.
KP_g	Graywacks, Metamorphosed shale. Spilitic, basic and intermediate flows, Pyroclastics	Palaeocene		
K	Graywacke-shale, Spilitis	Cretaceous	K ?	Spilitic and basic flows. Graywackes Include Cretaceous sedimentary rocks. ?
BC	Metamorphic rocks Amphiblite, Quartzofeldspathic and mica schist. Phyllite slate Marble.	Pre-Jurassic		

Table 2.1 (3) GEOLOGICAL CLASSIFICATION

LUZON PLAIN

Sedimentary and Metamorphic Rocks			Igneous Rocks	
Symbol	Rocks	Age	Symbol	Rocks
R	Sand Gravel Clay Silt Molase Pyroclastic Marl. Tuff	Alluvium	R	
$N_3 + Q_1$		Pleis-tocene	QV	Andesite Dacite Andestic plugs Basalt
		Pliocene		
	Molase Tuff Tuffaceous sedimentary Silty limestone	Miocene	?	
?		Oligocene		

Table 3.1 SUMMARY OF WORK QUANTITY (Jan. 1981 - Mar. 1981)

Boring or Test Item	Reservoir (Upstream Area)					Canal (Downstream Area)			
				Test Pit					
	Boring or Sounding		Quarry Site	Embankment Material	Filter Material or Aggregate	Boring or Sounding z		Test Pit	Total
A. Boring and Others									
1. Boring	380 m (15 holes)		2 x 20 m	–	–	270 m (10 holes)		–	690 m (25 holes)
2. Standard Penetration Test	380 sets		(Core Boring)	–	–	270 sets		–	650 sets
3. Dutch Core Penetration Test	350 m (15 holes)		–	–	–	300 m (10 holes)		–	650 m (25 holes)
4. Test Pit	–		–	10 places (8 locations)	9 places (3 locations)	–		6 places (6 location)	25 places
5. Sampling, Disturbed	380 pcs.		–	10 x 2 = 20 pcs.	9 x 1 = 9 pcs.	270 pcs.		6 x 2 = 12 pcs.	689 pcs.
6. Sampling, Undisturbed	1hole x 2pcs + 1hole x 4pcs = 6pcs		–	–	–	4 hole x 4 pcs = 16 pcs		–	
B. Soil Test	Disturbed* Sample	Undisturbed Sample		Disturbed Sample	Disturbed Sample	Distrubed* Sample	Undistrubed Sample	Disturbed Sample	
1. Physical Test									
a. Specific Gravity	75	6	–	20	9	50	16	12	188
b. Moisture Content	380	6	–	20	9	270	16	12	713
c. Grading Analysis	75	6	–	20	9	50	16	12	188
d. Liquid Limit	75	6	–	20	–	50	16	12	179
e. Plastic Limit	75	6	–	20	–	50	16	12	179
f. Shrinkage Limit	75	6	–	20	–	50	16	12	179
2. Mechanical Test									
a. *Permeability*	–	–	–	10	4	–	–	6	20
b. Compaction	–	–	–	20	–	–	–	12	32
c. Unconfines Compression	–	12	–	–	–	–	32	–	44
d. Consolidation	–	6	–	4	–	–	16	2	28
e. Triaxial Compression (CU)	–	2	–	4	–	–	2	2	10
f. - do - (UU)	–	–	–	10	–	–	–	6	16
g. Abrasion	–	–	–	–	4	–	–	–	4
h. Soundness	–	–	–	–	4	–	–	–	4

C. Location Survey   To determine the elevation and coordinate of boring hole and Dutch core hole.

NOTE: Investigation with * is made by NIA laboratory. Others are all made by Technotest.

Table 3.2 WORK QUANTITY OF ADDITIONAL SURVEY
(JUL. 1981 - AUG. 1981)

	Diversion Damsite	Pumping Station Site
Boring with SPT	3 numbers 18.5 m in total	—
Dutch cone sounding	4 numbers 35 m in total	1 number 29 m
Electrical prospecting	2 lines 1,900 m	2 lines 800 m

Remarks: No Laboratory test was carried out in this survey.

Table 3.3 LIST OF STANDARD PENETRATION TEST

Site	No.	Depth (m)	Sample Number	Location
Upstream	B-1	20	2	Right bank of Pampanga River
Upstream	B-2	20	3	Right bank of Pampanga River
Upstream	B-3	20	4	Right bank of Pampanga River
Upstream	B-4	30	4	Right bank of Pampanga River
Upstream	B-5	20	3	Mid-land of San Antonio Swamp
Upstream	B-5	20	2	Left bank of Pampanga River
Upstream	B-7	20	3	Left bank of Pampanga River
Upstream	B-8	20	3	Left bank of Pampanga River
Upstream	B-9	20	3	Left bank of Pampanga River
Upstream	B-11	30	4	Spillway
Upstream	B-12	30	4	Intake
Upstream	B-13	30	2	Intake of canal
Upstream	B-14	30	2	Intake of canal
Upstream	B-15	30	2	Intake of canal
Downstream	B-16	30	4	Intake of short cut canal
Downstream	B-17	20	3	Candaba swamp
Downstream	B-18	30	4	Left bank of Pampanga River
Downstream	B-19	30	4	Intake of short cut canal
Downstream	B-20	20	3	Left bank of Pampanga River
Downstream	B-21	60	8	Water gate (weir)
Downstream	B-22	30	4	Water gate (weir)
Downstream	B-23	30	4	Water gate (weir)
Downstream	B-24	30	4	Water gate (weir)
Downstream	B-25	20	3	Short cut canal
Sub-total		650	82	
	BH-1	5		Diversion dam
	BH-2a	5.5		Diversion dam
	BH-2b	8		Diversion dam
Sub-total		18.5		
Grand Total		668.5		

Table 3.4 LIST OF DUTCH CONE PENETRATION TEST

Site	No.	Depth (m)	Location
Upstream	D-1	20	Left bank of Pampanga River
Upstream	D-2	20	Left bank of Pampanga River
Upstream	D-3	20	Left bank of Pampanga River
Upstream	D-4	20	Left bank of Pampanga River (B-8)
Upstream	D-5	20	Left bank of Pampanga River
Upstream	D-6	20	Left bank of Pampanga River
Upstream	D-7	30	Mid-land of San Antonio Swamp
Upstream	D-8	20	Light bank of Pampanga River
Upstream	D-9	20	Light bank of Pampanga River
Upstream	D-10	20	Light bank of Pampanga River
Upstream	D-11	20	Mid-land of San Antonio Swamp
Upstream	D-12	30	Mid-land of San Antonio Swamp
Upstream	D-13	30	Right bank of Pampanga River
Upstream	D-14	30	Right bank of Pampanga River
Upstream	D-15	30	Right bank of Pampanga River
Downstream	D-16	30	Intake of short cut canal
Downstream	D-17	30	Left bank of Pampanga River
Downstream	D-18	30	Right bank of Pampanga River
Downstream	D-19	30	B-19
Downstream	D-20	30	Left bank of Pampanga River
Downstream	D-21	30	Right bank of Angat River
Downstream	D-22	30	Short cut canal
Downstream	D-23	30	Short cut canal
Downstream	D-24	30	Short cut canal
Downstream	D-25	30	Short cut canal
Sub-total		650	
	DC-1	7	Diversion dam
	DC-2	7	Diversion dam
	DC-3	10	Diversion dam
	DC-4	11	Diversion dam
	DC-5	29	Pumping station
Sub-total		64	
Grand total		714	

Table 3.5 LIST OF CORE DRILLING

Site	No.	Depth (m)	Location
Quarry	BR-26	20	East foot of Mt. Arayat
	BR-27	20	
Total		40	

Table 3.6 (1) SUMMARY OF LABORATORY TEST RESULTS

Pit No or Hole No	Depth	Class	Gradation (passing), Consistency								Gs	Compaction			K at Wn	Un-confined compression	Triaxial comp. at Wn				Consolidation		Soundness	Abraision	Remarks
	(m)		MS (mm)	4.75 (mm)	2.00 (mm)	0.074 (mm)	0.005 (mm)	WL (%)	SL (%)	IP (%)		Wn (%)	OMC (%)	MDD (t/m^3)	(cm/s)	(kg/cm^2)	Cu (kg/cm^2)	φu (deg.)	C'(Ccu) (kg/cm^2)	φ'(φcu) (deg.)	Cv (10^{-4} cm^2/s)	Sat 1kg/cm^2 (%)	(%)	(%)	
Disturbed sample of Earth test pit																									Ic: Relative consistency
PE-1	0.6/1.5	CL	2	100	100	73	13	32	21	13	2.50	31.4	17.5	1.70	7.1×10^{-7}		0.5	26	0	36	45	3.7			0.05
	1.5/2.5	CL	2	100	100	47	9	31	22	14	2.61	32.9	17.0	1.71	9.4×10^{-7}		0.11	3.5							-0.14
-2	0.7/1.0	CH	5	100	99	92	56	61	17	38	2.55	32.4	22.8	1.54	6.5×10^{-7}		0.30	10							0.75
	1.0/1.3	CH	5	100	99	90	55	93	24	56	2.25	118.4	26.0	1.29											-0.45
-3	1.0/2.2	CL	2	100	100	85	26	33	19	15	2.62	25.6	20.0	1.68	7.4×10^{-7}		0.24	5.5	0.2	30	55	7.3			0.49
	2.2/3.0	CL	2	100	100	87	28	33	21	16	2.45	26.7	22.5	1.52			0.74	23							0.39
04	0.4/0.9	CH	5	100	99	98	78	57	16	36	2.50	32.6	20.0	1.60											0.68
	1.5/1.7	CH	5	100	99	98	65	85	22	50	2.30	37.1	25.0	1.30	6.4×10^{-7}		0.46	9							0.96
-5	0.5/1.1	CL	2	100	100	95	22	33	21	17	2.62	25.2	20.5	1.64			0.34	3							0.46
	1.1/2.5	CL	2	100	100	59	9	48	27	27	2.64	33.2	19.8	1.70	9.5×10^{-6}		0.35	16	0.34	31	53	3.9			0.55
-6	0.7/1.0	CL	2	100	100	82	18	30	17	9	2.64	26.8	16.5	1.77	9.9×10^{-5}		0.42	3							0.36
-7	0.6/1.3	CH	5	100	99	96	55	60	15	37	2.50	26.9	22.6	1.54											0.89
	1.3/2.0	CH	5	100	99	97	63	74	12	51	2.25	33.1	26.0	1.29	6.9×10^{-7}		0.75	9							0.80
	2.0/2.6	CH	2	100	100	95	33	55	17	36	2.50	28.5	20.0	1.62											0.74
-8	0.6/1.2	CL	2	100	100	95	27	45	19	24	2.50	38.9	18.8	1.60	6.7×10^{-7}		0.22	5							0.25
	1.2/2.0	CL	2	100	100	91	27	42	21	21	2.58	25.9	21.3	1.60	6.9×10^{-7}		0.12	6	0.15 (0.28)	33 (19)	23	12.7			0.77
-9	0.6/1.9	CH	5	100	99	91	15	58	25	39	2.55	16.7	20.0	1.61	6.1×10^{-7}		0.70	11							1.06
	1.9/3.0	CL	2	100	100	65	12	42	23	22	2.63	18.9	19.3	1.66											1.05
-10	0.4/1.9	CL	5	100	98	71	31	49	19	28	2.51	20.2	18.8	1.60											1.03
	1.9/2.9	CL	5	100	99	58	18	34	18	16	2.51	30.2	18.8	1.66	9.2×10^{-6}		0.60	3							0.24
-11	0.7/1.2	CH	2	100	100	98	71	64	12	43	2.50	34.5	22.5	1.53	6.4×10^{-7}										0.69
	1.2/1.8	CH	2	100	100	98	77	73	14	47	2.25	37.7	26.8	1.30			0.46	8	0.48 (0.38)	22 (22)	9	5.6			0.75

Table 3.6 (2) SUMMARY OF LABORATORY TEST RESULTS

Pit No or Hole No	Depth (m)	Class	Gradation (passing). MS (mm)	4.75 (mm)	2.00 (mm)	0.074 (mm)	0.005 (mm)	Consistency WL (%)	SL (%)	IP (%)	Gs	Compaction Wn (%)	OMC (%)	MDD (t/m^3)	K at Wn (cm/s)	Un-confined compression (kg/cm^2)	Triaxial comp. at Wn Cu (kg/cm^2)	ϕu (deg.)	C'(Ccu) (kg/cm^2)	$\phi'(\phi cu)$ (deg.)	Consolidation Cv ($10^{-4} cm^2/s$)	Sat 1kg/cm^2 (%)	Soundness (%)	Abrasion (%)	Remarks
PE-12	0 /0.2	CH	5	100	99	96	87	66	11	46	2.50	36.8	24.0	1.51	$6.7x10^{-7}$		0.28	8							0.63
-13	0.5/1.6	CL	5	100	99	88	20	45	23	26	2.55	31.0													0.54
	1.6/2.6	CL	5	100	99	75	11	35	24	15	2.64	31.5	19.5	1.65	$9.0x10^{-6}$		0.23	6	(0.24)	(15)	40	4.4			0.23
-14	0.2/0.5	CL	5	100	99	39	9	33	19	16	2.55	25.5	25.0	1.52	$1.1x10^{-5}$		0.27	16			31	4.0			0.47
	1.5/2.0		2	100	100	33	9		N.P.		2.50	14.5							0.10 (0.38)	38 (34)					
-15	0.4/0.8	CL	5	100	99	78	35	46	20	26	2.50	37.6	21.5	1.58	$6.8x10^{-7}$		0.60	19							0.32
	0.8/0.9	CL	5	100	99	81	25	46	26	31	2.55	39.1													0.22
-16	0.2/1.1	CL-CH	5	100	99	89	44	50	17	32	2.55	22.9	15.0	1.69											0.85
	1.1/1.9	CL	5	100	99	87	38	46	19	25	2.45	31.9	21.3	1.62	$6.4x10^{-7}$		0.30	11	0.60 (0.70)	24 (18)	32				0.56
Disturbed sample of Sand-gravel test pit																									
PSG-1	0/1.9		40	69	59	2	-				2.66[/1] (2.67)	2.9			$9.0x10^{-3}$[/2]								3.4[/3]	23.1[/3]	
-2	0/1.8		40	87	73	9	-				2.65 (2.66)	0.9													
-3	2.7/3.2		25	89	77	1	-				2.67 (2.65)	5.5			$7.4x10^{-3}$								3.1	21.8	
-4	1.2/1.8		50	59	49	-	-				2.71 (2.67)	4.9													
-5	2.0/2.8		25	73	61	3	-				2.70 (2.67)	1.3													
-6	0/1.0		25	62	47	1	-				2.71 (2.60)	2.6			$7.0x10^{-2}$								2.8	20.1	
-7	0/0.6		75	36	25	3	-				2.68 (2.66)	2.4													
-8	0.4/2.0		40	46	33	4	-				2.68 (2.66)	1.1			$9.6x10^{-3}$								2.7	19.8	
-9	0.4/2.0		75	50	34	6	-				2.71 (2.67)	3.7													
FS-1			10	99	95	16	-				2.70	17.5													At D-6
-2			20	99	93	5	-				2.65	16.6													At Conception
-3			10	99	95	3	-				2.67	10.7													At B-3

/1: Figure non-bracketed is of sand (-5mm) and bracketed is of gravel at surface dry condition.

/2: Sample compacted with standard proctor energy.

/3: Tested for gravels only.

Table 3.6 (3) SUMMARY OF LABORATORY TEST RESULTS

Pit No or Hole No	Depth	Class	Gradation (passing), Consistency								Gs	Compaction			Kat Wn	Un-confined compres-sion	Triaxial comp. at Wn				Consolidation		Sound-ness	Abrai-sion	Remarks
			MS	4.75	2.00	0.074	0.005	WL	SL	IP		Wn	OMC	MDD			Cu	ϕu	C'(Ccu)	$\phi'(\phi_{cu})$	Cv	Cc			
	(m)		(mm)	(mm)	(mm)	(mm)	(mm)	(%)	(%)	(%)		(%)	(%)	(t/m^3)	(cm/s)	(kg/cm^2)	(kg/cm^2)	(deg.)	(kg/cm^2)	(deg.)	(10^{-4} cm^2/s)		(%)	(%)	
Undisturbed sample of thin-wall coring																									
B-3	2.5	CH	2	100	100	98	66	60	22	39	2.30	36.9				1.96					13	0.285			
	5.0	CL	2	100	100	97	37	46	23	19	2.41	42.2				0.86 1.94			0 (0.30)	33 (17)	47	0.326			
-16	2.5	CL	5	100	99	96	38	36	22	18	2.46	37.9									63	0.265			
	5.0	CH	5	100	99	93	59	71	15	47	2.45	43.6				0.10 0.11					6	0.470			
	7.5	CH	5	100	99	87	14	82	19	58	2.65	65.2				0.24 0.14					56	0.319			
	10.0	CL	2	100	1C0	99	21	48	23	26	2.31	43.0							0.05 (0.45)	34 (19)	13	0.345			
-19	2.5	CL	2	100	100	99	41	43	18	27	2.40	45.8				5.39 2.92					50	0.373			
	5.0	CH	2	100	100	98	54	56	14	32	2.60	68.6				1.14 0.95			0 (0.70)	37 (24)	33	0.302			
	7.5	CL	5	100	99	59	33	47	20	29	2.69	49.4				0.15 0.19					47	0.278			
	10.0	CH	10	97	92	86	39	71	23	45	2.62	79.0				0.64 0.79					27	1.185			
-24	5.0		10	99	99	80	17	37	27		2.65	47.2				0.25 0.24					43	0.301			
	7.5		5	100	99	77	13	35	26		2.58	47.7				0.32 0.31					60	0.345			
	10.0		2	100	100	67	12	36	24		2.60	38.5				0.25 0.21					35	0.279			
D-22	2.5	CH	5	100	99	87	33	84	26	55	2.51	86.3				0.17 0.16					4	0.640			
	5.0	CH	10	98	93	79	28	53	22	29	2.62	58.1				0.16 0.82					54	0.365			
	7.5	CH	10	94	91	63	18	92	20	63	2.54	93.1				0.14 0.12					7	0.700			
	10.0	CL	5	100	99	85	20	48	24	24	2.69	55.6				0.49 0.30					34	0.319			

Table 6.1 VIOLENT EARTHQUAKES THAT HAVE AFFECTED MANILA IN HISTORICAL TIMES

Date	Intensity in Manila	Remarks
1589	VII	Violent
1599 Jun. 21	VIII	Destructive
1601 Jan. 1	IX	Destructive, many persons injured
1601 Jan. 16	VII	Violent
1645 Nov. 30	X	Very destructive, large number of people killed and injured
1645 Dec. 5	VII	Violent
1658 Aug. 20	IX	Destructive, few killed and many injured
1665 Dec. 5	VII	Vilent
1677 Dec. 7	IX	Destructive, three killed and many injured
1684 Aug. 24	VII	Violent
1750 Mar. 10	VII	Violent
1767 Nov. 13	VII	Violent
1770 Dec.	VII	Violent
1771 Feb. 2	VIII	Destructive
1796 Oct.	VIII	Destructive
1797 Feb.	VII	Violent
1824 Oct. 26	VIII	Destructive
1828 Nov. 9	VII	Violent
1829 Dec. 17	VII	Violent
1830 Jan. 18	IX	Destructive, several victims
1852 Sep. 16	IX	Destructive
1862 Mar. 4	VII	Violent
1862 Jun. 3	X	Very destructive, 320 killed and many injured
1863 Jul. 3	VIII	Very violent
1869 Oct. 1	VIII	Destructive
1872 Dec. 29	VIII	Very violent
1877 Jun. 2	VII	Violent
1880 Jul. 18	X	Very destructive, 20 victims
1881 Aug. 15	VII	Violent
1885 Nov. 19	VII	Violent
1889 May 26	VIII	Destructive
1901 Feb. 14	VII	Violent
1923 Nov. 1	VII	Violent
1923 Nov. 4	VII	Violent
1937	VII or less	Strong, damaged few buildings
1968 Aug. 2	VII	Destructive, more than 300 persons killed

Table 6.2 (1) VIOLENT EARTHQUAKES THAT HAVE AFFECTED PROJECT AREA IN 1949-1978

No.	Date	Epicenter		M	Δ	I
		N	E		(km)	
(1)	$o < \Delta < 100$ km, $M \geqq 5.0$					
1	1962 Oct. 28	14°48'	199°42'	5.0	98.0	Iba-VI
2	1963 Feb. 25	15°30'	121°18'	5.0	67.0	Baler-V
3	1963 May 17	15°50'	120°10'	5.0	73.0	Iba-V
4	1967 May 5	15.3°	119.8°	5.1	98.0	Iba-IV
5	1968 Jun. 6	14.9°	119.9°	5.4	100.0	Iba-II
6	1968 Aug. 6	15.5°	121.9°	5.1	80.0	Manila-II
7	1968 Aug. 10	15.5°	121.6°	5.4	80.0	Manila-IV
8	1968 Aug. 13	15.6°	121.8°	5.1	85.0	Manila-II
9	1968 Aug. 22	15.6°	121.5°	5.2	80.0	Manila-IV
10	1968 Aug. 29	15.4°	121.9°	5.3	85.0	Baler-II
11	1968 Aug. 29	15.9°	121.7°	5.2	95.0	Manila-V
12	1968 Sep. 19	14.9°	120.1°	5.1	67.0	Manila-III
13	1968 Sep. 22	15.7°	121.9°	5.3	99.0	Baler-IV
14	1969 Oct. 6	15.1°	119.8°	5.6	85.0	Iba-VI
15	1970 Apr. 7	15.8°	121.7°	6.4	95.0	Major earth
16	1970 Apr. 7	15.8°	121.8°	5.1	95.0	Baguio-III
17	1970 Apr. 7	15.4°	121.7°	5.1	80.0	Lucena-II
18	1970 Apr. 7	15.7°	121.9°	5.7	95.0	Baguio-IV
19	1970 Apr. 7	15.5°	121.9°	5.5	95.0	Tomalig-II
20	1970 Apr. 7	15.4°	121.8°	5.2	85.0	Baguio-II
21	1970 Apr. 8	15.3°	121.6°	5.2	80.0	Baler-IV
22	1970 Apr. 8	15.4°	121.8°	5.7	85.0	Baler-V
23	1970 Apr. 12	15.2°	122.0°	5.5	100.0	Pasay-IV
24	1970 Apr. 12	15.1°	121.9°	5.0	80.0	Manila-III
25	1970 Apr. 22	15.3°	121.8°	5.0	80.0	Manila-II
26	1970 May 1	15.7°	121.8°	5.5	95.0	Baler-V
27	1970 May 6	15.7°	121.7°	5.2	95.0	Manila-III
28	1970 Jun. 16	15.4°	122.0°	5.1	95.0	Manila-III

Table 6.2 (2) VIOLENT EARTHQUAKES THAT HAVE AFFECTED PROJECT AREA IN 1949-1978

No.	Date	Epicenter		M	Δ (km)	I
		N	E			
29	1971 Jul. 4	15.6°	121.9°	5.5	90.0	Baler-V
30	1971 Jul. 20	15.3°	120.3°	5.4	45.0	Iba-II
31	1971 Jul. 20	15.3°	120.3°	5.4	45.0	Iba-VI
32	1972 Mar. 16	15.7°	121.8°	5.1	90.0	Baler-VI
33	1973 Jul. 18	14.9°	119.9°	5.1	95.0	Manila-III
34	1976 Feb. 13	15.6°	121.7°	5.4	85.0	Manila-V
35	1977 Jan. 10	15.3°	121.8°	5.0	85.0	Baguio-II
36	1977 May 12	16.0°	121.1°	5.0	98.0	Baguio-VI
37	1977 May 21	15.7°	120.8°	5.7	45.0	Dagupan-IV
38	1977 Jul. 17	14.9°	120.0°	5.2	80.0	Iba-III
(2)	100 < Δ < 300 km, M ≥ 6.0					
39	1949 Dec. 21	17.0°	121°38'	6.2	185.0	Tuguegarao-VII
40	1950 Jan. 3	17.0°	121°38'	6.2	185.0	Tuguegarao-VII
41	1957 Jun. 11	17°40'	120.0°	6.2	240.0	Vigan-VII
42	1968 Aug.	16.5°	122.3°	7.3	185.0	Manila
43	1970 Feb. 5	12.6°	122.2°	6.0	280.0	Romblon-VI
44	1972 Apr. 25	13.4°	120.3°	6.2	160.0	Lubang-VI
45	1973 Mar. 17	13.4°	122.8°	7.0	245.0	Visayas-VI
46	1977 Mar. 18	16.8°	122.3°	6.2	200.0	Tuguegarao-VII
47	1977 Jul. 21	16.9°	122.4°	6.1	215.0	Tuguegarao-VII
48	1977 Aug. 29	17.4°	117.9°	6.0	235.0	Manila-II

Remarks:
Δ: Distance from epicenter
M: Magnitude
I: Seismic intensity

Table 6.3 COMPUTED MAX ACCELERATION IN
ORDER OF MAGNITUDE (BY IWASAKI)

m	No.	Magnitude M	Distance Δ (km)	Acceleration H max (gal)	Return Period T_E (years)
1	37	5.7	45	52.0	30
2	15	6.4	95	44.7	15
3	30	5.4	45	43.6	10
4	31	5.4	45	43.6	7.5
5	22	5.7	85	32.1	6.0
6	14	5.6	85	30.2	5.0
7	18	5.7	95	29.3	4.3
8	7	5.4	80	28.1	3.8
9	29	5.5	90	27.2	3.3
10	12	5.1	67	26.9	3.0
11	34	5.4	85	26.8	2.7
12	19	5.5	95	26.1	2.5
13	26	5.5	95	26.1	2.3
14	2	5.0	67	25.4	2.1
15	10	5.3	85	25.3	2.0
16	9	5.2	80	25.0	1.9
17	21	5.2	80	25.0	1.8
18	23	5.5	100	25.0	1.7
19	38	5.2	80	25.0	1.6
20	20	5.2	85	23.8	1.5
21	3	5.0	73	23.7	1.4
22	5	5.4	100	23.5	1.4
23	6	5.1	80	23.4	1.3
24	17	5.1	80	23.4	1.3
25	13	5.3	99	22.4	1.2
26	8	5.1	85	22.3	1.2
27	24	5.0	80	22.1	1.1
28	25	5.0	80	22.1	1.07
29	27	5.2	95	21.8	1.03
30	11	5.2	95	21.8	1.0
31	32	5.1	90	21.3	0.97
32	35	5.0	85	21.1	0.94
33	33	5.1	95	20.4	0.91
34	28	5.1	95	20.4	0.88
35	16	5.1	95	20.4	0.86
36	4	5.1	98	19.9	0.83
37	1	5.0	98	18.8	0.81
38	36	5.0	98	18.8	0.79

Remarks: $T_E = 30/m$