Report
on
Feasibilty Survey for the Establishment of Comprehensive Plan of the Flood Forecasting and Warning System in the Pampanga River Basin in the Philippines

MARCH 1970

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN

Preface

The Overseas Technical Co-operation Agency (OTCA) has the pleasure of presenting the report on the Flood Forecasting and Warning System in the Pampanga River Basin of the Survey team which was organized and dispatched to the Philippines by OTCA upon instruction from the Government of Japan as a preliminary survey on the Establishment of Comprehensive Plan of the Flood Forecasting and Warning System.

The team stayed in the Philippines from 19 November to 18 December 1969 and successfully completed the field survey including discussion with the Authorities concerned, and collection of data with the whole-hearted cooperation from the Government of the Philippines and other relevant organizations.

After its return to Japan, the team made further studies on data and information, and the results were hereby compiled into the present report for presentation.

Finally, on behalf of OTCA, I wish to take this opportunity to express my sincere gratitude for the generous cooperation and assistance extended to the team during its stay by the Government of the Philippines.

March, 1970

Keiichi Tatsuke
Director-General
Overseas Technical Cooperation Agency
Tokyo, Japan

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CHAPTER 1. INTRODUCTION

1-1 Foreword

The Pampanga River drains the Central Luzon plain which is the granary of the country. The area suffers a tremendous amount of flood damage which comprises more than one fourth of the average annual flood damage (about $7.2 million 1960 prices) suffered in the 13 major river basins in the Philippines.

The basin which is located near the city of Manila is densely populated. Expected rapid economic development in the area will increase the flood damage correspondingly. There is an urgent necessity, therefore, for establishing a flood forecasting and warning system in this area as well as carrying out the flood protection works.

The Philippine Government has confirmed its selection of this river basin for the establishment of a pilot flood forecasting and warning system as a part of the action programs agreed upon by the ECAFE/WMO Typhoon Committee at its inaugural session held at Bangkok in December 1968.

The Government of Japan, with the view of further promoting technical cooperation between the Philippines and Japan and mindful of the action programs decided upon by the ECAFE/WMO Typhoon Committee to which both Governments subscribe, has decided to make available to the Government of the Republic of the Philippines the services of a team of experts for the feasibility survey of the Pampanga River Basin for the purpose of evolving a comprehensive plan for the establishment of a pilot flood forecasting and warning system in the basin.

1-2 Members of Survey

The Survey Team consisted of a chief, a special consultant and seven other members; three river engineers, three hydrologists, a meteorologist and two telecommunication engineers as follows.

Mr. Yutaka Inada	Chief of the Team	Consulting Engineer, River Bureau, Ministry of Construction
Dr. Toshio Takenouchi	Special Consultant	Professor, Civil Engineering Department, Tokyo Institute of Technology
Dr. Kiyohide Takeuchi	Meteorologist	Deputy Head, Applied Meteorological Section, Observation Division, Japan Meteorological Agency
Mr. Terumi Nawata	River Engineer	Deputy Head, River Improvement Division, River Bureau, Ministry of Construction
Dr. Takeo Kinosita	Hydrologist	Head, Section of Hydrology, Public Works Research Institute, Ministry of Construction
Mr. Takayoshi Yamamoto	River Engineer	Chief, Operation Control Center for the Tone River Dams, Kanto Regional Construction Bureau, Ministry of Construction

FIG. I-I CATCHMENT AREA AND PROPOSED TELECOMMUNICATION SYSTEMS IN PAMPANGA RIVER BASIN

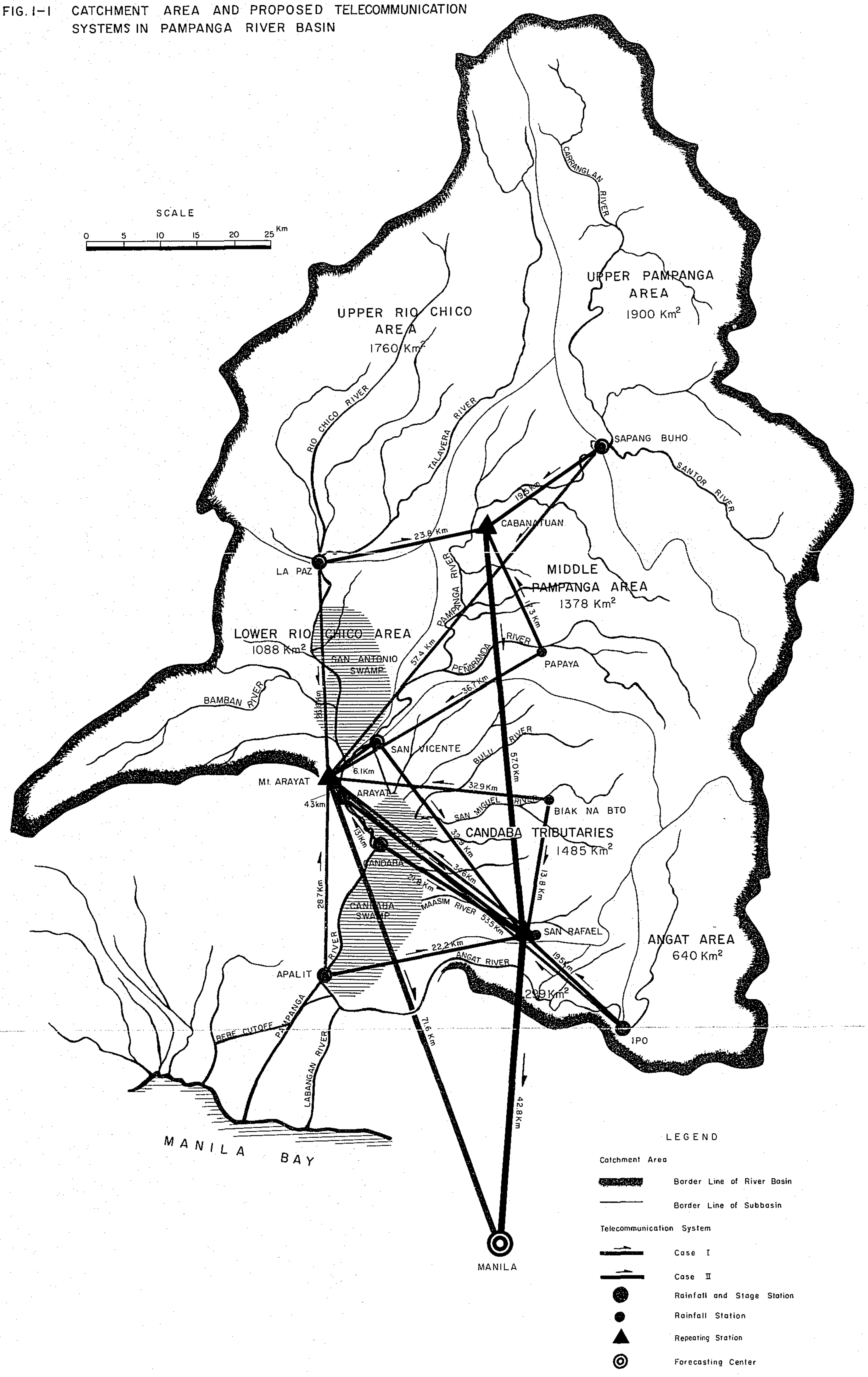
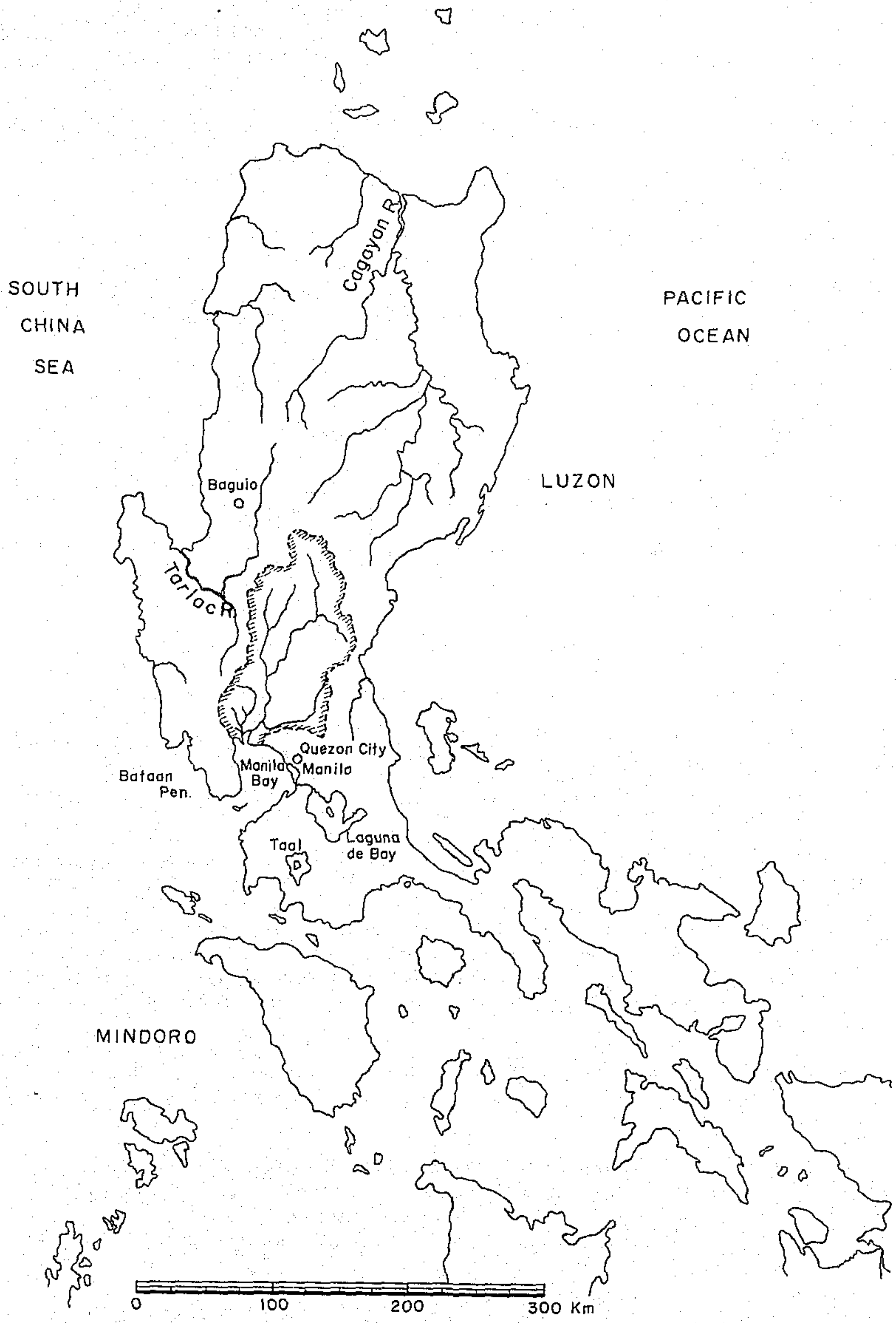


FIG. I-2 LOCATION MAP OF PAMPANGA RIVER BASIN



Mr. Osamu Tsumura	Telecommunication Engineer	Deputy Head, Electricity and Telecommunications Division, Minister's Secretariat, Ministry of Construction
Mr. Ken-ichi Sasaki	Hydrologist	Deputy Head, River Planning Section, River Division, Tohoku Regional Construction Bureau, Ministry of Construction
Mr. Kiyoshi Yamanaka	Telecommunication Engineer	Engineer, Electricity and Telecommunications Division, Minister's Secretariat, Ministry of Construction

1-3 Schedule of Survey

Having arrived at Manila on 19th of November, 1969, the Survey Team consisting of nine members conducted an on-the-spot investigation covering the following items, for one month till 18th of December.

1. Reconnaissance survey on the Pampanga River Basin.

2. Review of the existing network of meteorological and hydrological observation stations and their telecommunication systems.

3. Collection and study of existing meteorological and hydrological data.

4. Synoptical analysis of the meteorological situations which cause major floods on the basin.

5. Case studies of major floods.

6. Survey and data collection on damages and behaviors of floods on frequently inundated areas.

7. Looking over related river improvement projects and water resources development projects.

8. Collection of basic data concerning regulation, technical standard and equipments for telecommunication facilities which are adopted now.

9. Preliminary plan on a map for the telecommunication systems and facilities.

10. Cost estimation for necessary facilities and maintenance of the tentatively proposed flood forecasting system.

During their stay in Manila, they made the survey of the Pampanga River Basin in four times along with the collection of necessary data; they made the observations of river regime, present state of river improvement, overall conditions of the river basins and present situation of inundated area and of gauging facilities, besides the selection of suitable site to establish necessary facilities for flood forecasting and warning.

After having completed the reconnaissance, the Survey Team submitted their Interim Report to Mr. A. B. Deleña, Director of Bureau of Public Works, and Dr. Kintanar, Director of Weather Bureau, of the Philippines, on 16th of December, 1969.

Using the data and informations obtained by the on-the-spot investigation, the Survey Team conducted further the necessary analysis for establishing a system of flood forecasting and warning, the design of facilities to operate the system and the estimation of construction costs, as well as the examination of the system organization, of which results are put together in this report.

1-4 Summary of Recommendations

The Survey Team make the following recommendations for the flood forecasting and warning system of Pampanga River, on the basis of the reconnaissance and the analysis and the examination of the collected data.

1. It is desirable for the target areas of the flood forecasting and warning at the first stage to include the following three areas in the river basin which have comparatively large population and properties and suffered frequent flood damages. The other areas are recommended to be covered gradually by the extention of the system in the second stage.

   (1) Candaba area

   (2) Right bank area of the main Pampanga River below Arayat

   (3) Delta area below Apalit

2. The effective method of collecting the rainfall and water stage data for flood forecasting and warning is to apply VHF telemetering system on unmanned stations.

3. In view of the fact that the floods of Pampanga River are caused by localized rainfall groups, further investigation and examination need to be made in future of the representativeness of any gauging station for areal rainfalls. Therefore, the present gauging network selected for flood forecasting and warning, is selected so that flood forecasts to the target stations will be made basing on the water stage data in the upstream basins of the Pampanga and the Rio Chico Rivers from which sufficient time can be secured for the propagation of the flood, and on the rainfall data for the contribution from mid and downstream basins. As to the contribution from the Angat River, being a big tributary, the water stage data in the basin will be used for the forecasting.

4. The layout of the network of gauging stations at the first stage is as follows . The water level gauging stations will function concurrently as rain gauge stations, so that the efficiency of data collection may be improved.

   (1) Rainfall data to be used for flood forecasting will be those collected from the gauging stations of Sapang Buho, La Paz, San Vicente, Papaya, Biak na Bato, Arayat, Candaba, Apalit, Ipo Dam and San Rafael, and water stage data will be those collected from Sapang Buho, La Paz and Ipo Dam.

   (2) Arayat, Candaba and Apalit stations will be the target stations on which flood forecasts should be issued and at the same time observed stage data at the stations will be used for the forecasting.

   (3) Water stage data of the San Vicente station will be used for checking the issued forecast and knowing the inflow into the Candaba Swamp through the proposed floodway.

5. The discharge used for hydraulic computation of the storage of the Candaba Swamp is the sum of that obtained from the water levels at Sapang Buho and La Paz for the upstream basins, that obtained by run-off computation based on the rainfall data of the respective gauging stations for the mid and downstream basins, and that obtained from the water level at the Ipo Dam for the Angat River. It is possible by this computation to make the forecasts of the water level with fairly high accuracy to the target areas about one day in advance.

6. In order to transmit the data observed at the respective water level gauging and the rainfall gauging stations to the control station in Minila, it is proposed to establish one repeater station on Mt. Arayat, Case I, or two stations at Cabanatuan and San Rafael, Case II. After the serious consideration of these two proposals, it is believed that the Case II should be adopted, since the easiness and reliability of maintaining the flood forecasting and warning facilities are the most important factors for the operation of them. Although it may have a disadvantage of slight increasing in construction cost at the present moment. Before making the final decision, further consideration is required according to the results of the on-the-spot test of the electric field strength among the repeater stations and the control station.

7. It is desirable to make further investigation into the representativeness of rain gauge stations to the area in future.

8. The existing weather radar is to be used effectively as it can catch a coming storm outside of the telemetering network, and also measure the rainfall intensity qualitatively in the areas between the telemetering rain gauge stations.

9. The flood forecasting will be made by the forecasting center to be established in Manila, using the rainfall and water stage data provided by respective gauging stations and various informations supplied from Metereological Bureau and B.P.W. The required number of persons for flood forecasting will be about ten for the time being.

10. Monitor stations will be established at Sulipan, Apalit. The Apalit monitor station and the Cabanatuan repeater station will function as the centers to collect and transmit information respectively for the mid and downstream and the upstream areas.

11. Flood forecasting and warning will be disseminated mainly by radio broadcasting.

Chapter 2. Present State of the Basin of the Pampanga River

2.1 General Condition of Basin Situation

The Panpanga River flows through the middle of the Luzon Island and the north of Manila. It drains the area spreading from lat. 14°45'N to 16°10'N and from long. 120°20'E to 121°15'E, which covers a part or whole of the provinces of Pampanga, Bulacan, Tarlac, Nueva Ecija, Rizal, Nueva Viscaya and Quezon.

Catchment Area

The Basin of the Pampanga River faces Manila Bay on the south and is bordered by the Sierra Madre mountains on the east, the Caraballo mountains on the north, the Tarlac River and the Agno River on the northwest and the Zambales mountains on the west.

It has the total area of 10,540 km^2, of which 8,550 km^2 is the upper basin of Calumpit.

Topography

The Basin of the Pampanga River is divided into three kinds of topography; mountain, hill and plain. The mountains show dense contours of 100 m intervals on the map on a scale of 1:250,000, that is, they have steep slopes or their surface forms are very rugged. The Sierra Madre and the Zambales mountains make up the major part of them, including Mt. Arayat. They are composed of Mesozonic and Tertiary deposits and Tertiary and Quaternary volcanic rocks.

The hills are represented by sparese contours on the same map. The areas are distributed widely rolling gently at the foots of the mountain ranges on the east and west. They include the valleys between the mountains and the terraces on the river shores and are largely composed of diluvial deposit.

The plains occupy the areas on the same map where almost any contour is not recognized, that means they are flat lands composed of alluvial deposit with swamplands included.

These three divisions share respectively about one third of the total area, as shown on the Table 2-1.

Main Stream

The main stream of the Pampanga River has its source in the Caraballo mountains and flows approximately to the south for about 260 km draining water into Manila Bay. The distance to the main points from the river mouth is shown on Table 2-2. The main Pampanga River will be divided into the following sections taking into consideration of the topography and geology of the basin.

1. From its source to Sapang Buho -- The river flows through the mountains from its origin to Rizal. Pampanga is the name given to the lower reaches from the confluence of the Carranglan and the Pantabangan Rivers. At Sapang Buho, it joins the Santor River of about the same dimension. The annual runoff there is about 1400 mm.

2. From Sapang Buho to Arayat -- In the vicinity of Sapang Buho, the river flows through the valley between hills, with the bed slope of about 1/1000. The river bed slope decreases gradually toward downstream, being 1/2000 and 1/3000 respectively in the vicinity of Cabanatuan and Cabiao, along with which the surrounding topography changes from hills to plains. There lies the San Antonio Swamp between this river and the Rio Chico River upstream from the confluence of these two rivers. The length of the stream in this section is 108 km.

3. From Arayat to Calumpit - The embankment is built on the right bank and the Candaba Swamp extends widely to the left side. Downstream from Candaba, the profile of the minimum water levels in the channel shows almost horizontal line and even at the time of flood the water surface slopes is about 1/7000. All of this section is under the tidal influence. The Angat River joins it from the left at Calumpit. The length of stream in this section is 45 km.

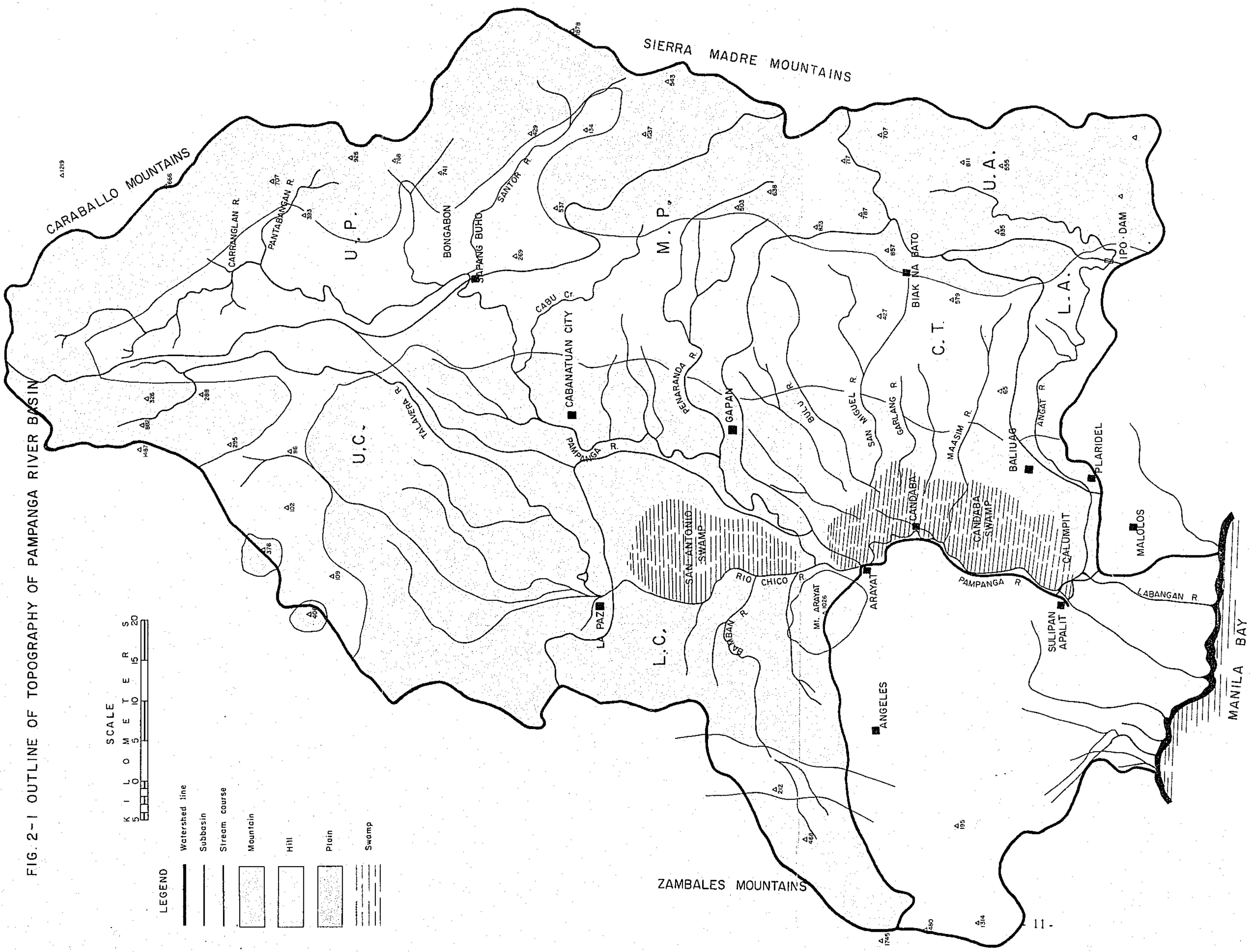


FIG. 2-1 OUTLINE OF TOPOGRAPHY OF PAMPANGA RIVER BASIN

Table 2-1 Areas classified topographically of the Upper Basin of Calumpit

	mountains km^2	hills km^2	plains km^2	Total km^2
Upper Pampanga	1,238	662	0	1,900
Middle Pampanga	323	567	488	1,378
Upper Rio Chico	288	412	1,060	1,760
Lower Rio Chico	242	79	767	1,088
Candaba Tributaries	77	663	745	1,485
Upper Angat	623	17	0	640
Lower Angat	61	200	38	299
Total	2,852	2,600	3,098	8,550
Percentage	33.3	30.4	36.3	100

Table 2-2 Distance from the river mouth

River mouth	0 km
Sulipan, Apalit	25
Candaba	52
Arayat	69
Cabanatuan	about 140
Sapang Buho	177

Note: The distance is measured along the right bank side of the low water channel, on the map of a scale of 1:50,000 issued by the Government of the Philippines.

4. From Calumpit to the river mouth -- This section forms a delta with the main stream branching into several channels. In the vicinity of Calumpit, there are three outlets leading to the delta from the Candaba Swamp, including a flood diversion channel. The three bridges of National Road No. 3 span these outlets. This area is also under tidal influence except at the time of flood.

Principal Tributaries and Swamps

The principal tributaries are the Rio Chico and the Angat Rivers.

The Basin of the Pampanga River is characterized markedly by its two swamps; Candaba Swamp lying between the Angat and the Pampanga Rivers, and San Antonio Swamp between the Rio Chico and the Pampanga Rivers.

Their surface areas and volumes vary with the magnitude of floods. During the flood in August 1960, the total surface area of these two swamps was about 344 km^2 (342 km^2 according to A Report on the Upper Pampanga River Project, prepared by the United States Bureau of Reclamation), representing 3.3% of the whole of the Pampanga River Basin. The volume is estimated to be 1,700,000,000 m^3 for the same flood. It corresponds to 200^{mm} in depth covering the whole area of the Pampanga River Basin upstream from Calumpit, which means very great retardation effect to reduce the peak discharges of floods on the lower reaches. Table 2-3 shows the dimensions of the swamps.

The Basin of the Angat River covers 939 km^2, or about 9% of the whole Basin of the Pampanga River. The Angat River is located in the southeastern part on the whole, and most of its basin is in mountainous district receiving much rainfall, with consequential yield of much runoff. The annual runoff reaches 2400 mm.

There are the Angat Dam and the Ipo Dam below the former and water stored in these dams is used for irrigation purpose. Because the Angat River generally drains water in the earlier stage of flood, the initial ponding of the Candaba Swamp is effected by this contribution.

The Rio Chico River has the basin of 2,848 km^2, sharing for about 27% of the whole Basin of the Pampanga River. This river originates in the northern mountains and a greater part of the basin is plain. The annual runoff is 1400 mm. The Rio Chico River and its tributary, the Talavela River, flow into the San Antonio Swamp, branching out into small streams.

Division of Basin

In order to understand the topography of the whole basin it will be convenient to divide it into the following sub-basins, corresponding to the four divisions of the Pampanga River channel mentioned above.

Upper Sub-basin

The portion of the Pampanga River upstream from Sanpang Buho will be designated as the upper stream. The Santor River of the same dimension as the Pampanga River joins it at this point. The characteristic of this sub-basin is the high percentage of mountainous areas. Furthermore, this sub-basin receives comparatively small rainfall seeing from distribution of rainfall associated with floods so far. Most of the mountains are covered with forest. Some portions are grassland. It has a small population.

The portion of the Rio Chico River upstream from La Paz will be designated as the upper stream of this river. Talavera and other tributaries, join it at this point.
It is significant to designate the portions upstream from these points as upper basins, in view of the shapes of basins and the longitudinal profiles of the rivers. As the river channels downstream from three sub-basins are sufficiently long, it is believed that necessary time can be adequately secured to give the forecast of flood.

Table 2-4 Annual runoff of respective basins

Sub-basin	Gauging station	Drainage area km^2	Mean discharge m^3/s	Annual runoff mm/year
Upper Pampanga	Malate	2,015	92.07	1,442
Middle "	San Agustin	6,487	272.23	1,324
Upper Rio Chico	Catalanacan	284	8.27	
	Pason Intsik	208	12.13	
	Lomboy	261	12.14	
	Sub-total	753	32.54	1,364
Angat	Pulilan	959	73.06	2,404

Note: Mean discharges are the averages for 3 years from 1960 to 1962, calculated on the basis of *Surface Water Supply Bulletin.*

Table 2-3 Dimensions of swamps

Swamp	Surface area*	2 Storage Volume *	3 Drainage area	2 / 3
San Antonio	124 km^2	700×10^6 m^3	6,126 km^2	110 mm
Candaba	220	1000×10^6	2,424	
Total	344	1700×10^6	8,550	200

* Flood in August 1960

Middle Sub-basin

The middle sub-basin is the portion along the Pampanga River downstream from Sapang Buho and the Rio Chico River downstream from La Paz to the confluence of these rivers.

In this sub-basin, tributaries such as the Cabu River and the Peñaranda River join to the Pampanga River at its left bank; these rivers flow down from the Sierra Madre mountains lying in the east.

The Rio Chico River is joined at its right bank by the Bamban River which flows down from Mt. Pinatubo.

This sub-basin includes the San Antonio Swamp.

The land use in the swamp is not yet developed, but other flat land is cultivated as paddy fields. Hills are used as paddy fields by irrigation facilities or as fields and stock farms.

Candaba Tributaries

Many tributaries flow into the Candaba Swamp, the principal ones among them being the San Miguel, the Garlang and the Massim Rivers. Their catchment areas are mainly hills, from which runoff has the direct influence on the water level of the swamp. They receive comparatively much rainfall. They have a large population and people are actively engaged in agriculture.

Angat Sub-basin

Most of this sub-basin is occupied by mountains. Its geological composition is of Cretaceous greywacke and Tertiary shale, sandstone, and conglomerate. It receives comparatively much rainfall. Wide area is irrigated by the reservoirs of the Angat and the Ipo dams.

Delta Area

Down stream from Calumpit, the Pampanga River branches out into several streams and forms a typical delta. There are many paddy fields on the upstream portion and many fish ponds on the downstream portion near to Manila Bay. This area is inundated for many days at each time of flood.

In normal condition, the tidal oscillation of Manila Bay fluctuates the river water level and also the water level of fish ponds. This area has a large population, and people are engaged in agriculture and fishery.

2-2 Characteristics of River Channels and Behavior and Damage of Flood

2-2-1 Characteristics of River Channels

The following characteristics may be mentioned for the channels of the Pampanga River system.

1. The two large natural retarding basins of San Antonio and Candaba Swamps lying in series in the midstream of the system have an effect to control floods, as a result of which, in the river channels downstream from the San Antonio Swamp, any rise of the water level during floods is small even though the flood discharge itself is large.

2. On the other hand, there are very great rises of the water levels in the channels, during floods, of the upperstream of the Pampanga and the Rio Chico Rivers flowing into the San Antonio Swamp and the San Miguel, the Maasim, the Angat Rivers and others flowing into the Candaba Swamp.

3. The gradient of the main stream is very gentle, which is a characteristic of rivers having the bed materials of clayish soil. The deepest portion of the river bed extends from the river mouth near to Candaba upstream for about 52 km, almost level at around 5 m below the mean sea level of Manila Bay; hence, in the normal conditions, this section is involved in the tidal reach.

4. The Candaba Swamp is a low land spreading out on the left bank of the Pampanga River between about 20 km and 55 km from the river mouth. It has about 220 km^2 of surface area and over 1,000 million m^3 of storage capacity at the water leverl of the flood in August 1960. The elevation of its bed is higher than the mean sea level of Manila Bay by about 2 m in the south and about 3 m in the north.

At the beginning of a flood, flood water of the rivers in the eastern basin such as the San Miguel and the Maasim Rivers flowing directly into the swamp and the portion of those from the Angat River in excess of the diverging capacities of three outlets, Bagbag, Calumpit and Sulipan, is drained into the swamp, and the water level in its southern portion is raised accordingly.

Then, in the northern part of the swamp, the flood waters of the main Pampanga River and from the San Antonio Swamp flow into the swamp through the river channel at Arayat as well as through the Cabiao-Candaba Floodway.

The slope of the swamp at the highest water level is gentle, being about 1/7000, and it is estimated that it flactuates with the rise and fall of the water level, ranging from about 1/5000 to 1/10,000.

5. The San Antonio Swamp stretches on the right bank of the Pampanga River about 60 km upstream from the river mouth, over the low land lying above the confluence with the Rio Chico River, between these two rivers. It has about 124 km^2 of surface area and about 700 million m^3 of storage capacity at the water level of the flood in August 1960. The elevation of its bed is around 8 m above the mean sea level of Manila Bay.

The length of streams from the headwaters of the Pampanga and the Rio Chico Rivers to their confluence are respectively about 190 km and 150 km. Although the Rio Chico River is a little shorter than the Pampanga, it should be noted that the gradient of the latter is steeper than that of the former.

6. Between the lower delta and the Candaba Swamp areas, a control section is formed from Apalit to Plaridel to deal with flood water. A similar control section is also formed from Arayat to Cabiao, between the Candaba Swamp and the San Antonio Swamp areas. Due to this, there is a head difference between the flood water surfaces on the both sides of this control section. Fig. 2-2 shows the profile of the maximum water level for a major flood. Fig. 2-2 reveals that there was a head difference of about 1.5 m by the control effect between Apalit and Plaridel in the flood of August 1960.

2-2-2 Present Status of River Improvement Works

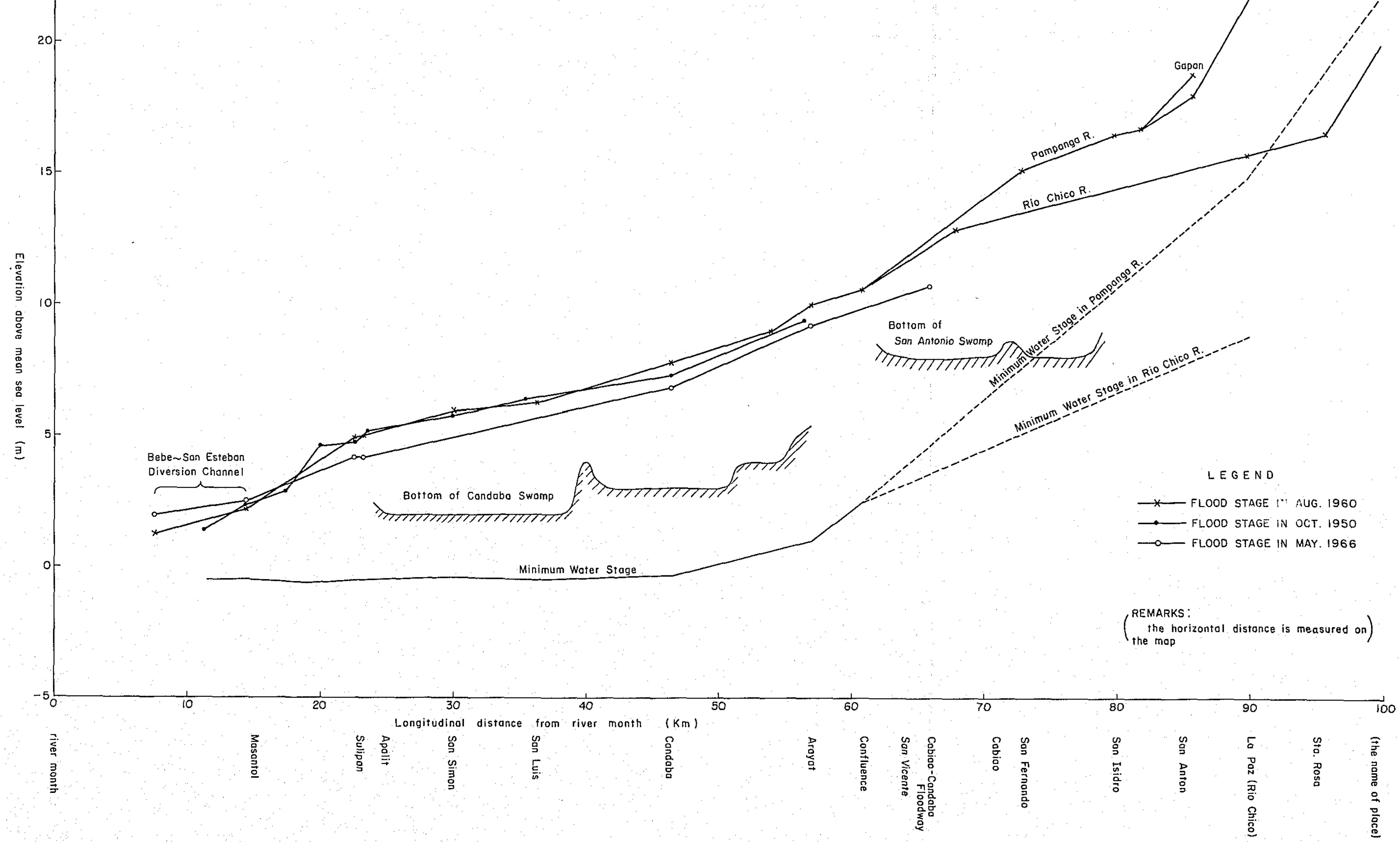
The river improvement projects now being executed are designed in a very reasonable way so that the maximum effects can be attained by the minimum costs; that is, the flood control functions of the two great natural retarding basins are conserved on the one hand, the more productive areas are protected against any inundation. Respective levels and floodways are outlined hereunder.

1. Masontol-Apalit-Arayat Setback Levee

This levee has been designed to protect the granary plain lying on the right bank of the Pampanga mid-stream against the flood of the river. The project which contains a long continuous levee of about 42 km in length, extending from Masantol via Apalit to Arayat is almost completed now.

A noteworthy point is that two fuse dikes of 1,000 m each are provided between Candaba and Arayat. These fuse dikes are built with their crests lowered than other sections, which intends to make the flood waters in excess of the designed flood water level to overtop them to the plain on the right bank and to minimize the flood damage by preventing water to inundate from any unexpected location of the Setback Levee.

FIG 2-2 LONGITUDINAL PROFILE OF MAXIMUM FLOOD STAGE HEIGHT



On the other hand, any levee is not planned on the left side between Apalit and Arayat facing to the Candaba Swamp, but the flood water exceeding the conveyance capacity of the normal river channels overflows into Candaba Swamp and is stored in it so that the peak discharge of the flood is reduced.

2. Calumpit-Plaridel-Bustos Dike

This dike is designed to protect the left side area of the Angat River against its inundation, but there are portions not yet completed in the section upstream from around Plaridel. On the other hand, any levee is not planned on the right side between Apalit and Pulilan facing to the Candaba Swamp in the same way as the section between Apalit and Arayat, but the flood water exceeding the normal conveyance capacity of the river channel overflows into the Candaba Swamp so that the peak discharge of the flood is reduced.

In the sections extending from Sulipan via Calumpit to Bagbag, the enbankments of National Road No.3 and the Manila Railroad function as levees to protect the lower delta area from floods and three outlet channels are built through the three places mentioned above. When the water level of the Candaba Swamp rises above certain extent, the flood water inundates into the lower delta area not only flowing through the three outlet channels and the culverts built under the national road and the railroad but over-topping the embankments of them.

Calumpit Pocket Dike has been already completed to protect a part of Calumpit town between National Road No.3 and the Candaba Swamp.

3. Bebe-San Esteban Diversion Channel

It is a diversion channel to reduce the damage caused by the flood of the Pampanga River in the western part of the lower delta area, and is almost completed.

4. Labangan Flood Channel

It is believed that this flood channel project is very effective to reduce inundations on the eastern and central part of the lower delta areas; the vicinity of Malolos, Paombong and Hagonoy, down stream from Bagbag Bridge; to decrease the ineffective consumption of the flood controlling capacity of the Candaba Swamp due to discharge at the initial stage of flood of the Angat River; and to reduce any damage around the Candaba Swamp by swiftly draining of the stored flood water at the last stage of the flood. The project plans to increase the width of the river at Bagbag Bridge to 500 m, but the work is not yet started. Implementation of the work at an early date is desired.

5. Arayat-Cabiao Ring Levee

With its northern and western sections constituting the left bank of the Pampanga River, the eastern section functioning as the right bank of Cabiao-Candaba Floodway, and the southern portion being the levee against Candaba Swamp, this Ring Levee protects the paddy field area of about 40 km^2 lying between Arayat and Cabiao. However, there is a special portion of the section facing to the northern part of Candaba Swamp of which formation is lower than the others.

6. Cabiao-Gapan Dike

This dike is to protect the paddy field area extending to the left bank of the upstream of the Pampanga River, around Cabiao, against the floods of the river. The works of many sections are not yet started.

On the other hand, any levee is not planned on the right bank of the Pampanga River between its confluence with the Rio Chico River and the San Antonio Swamp. The flood water exceeding the conveyance capacity of the main river channel at Arayat and the Cabiao-Candaba Floodway inundates over the San Antonio Swamp and is reserved in it so that the peak discharge of the flood is regulated.

7. Cabiao-Candaba Floodway

This floodway is intended to supplement the defficiency in the conveyance capacity of the main channel of the Pampanga River at Arayat so as to reduce flood damage around San Antonio Swamp, but levee on the left bank of the lower reach of floodway is not yet completed and any progress is not seen in the excavation of floodway. Although it is effective to increase the conveyance capacity of this floodway for reducing flood damage around the San Antonio Swamp, it results at the same time to decrease the flood controlling capacity of the San Antonio Swamp so much which may introduce a risk of intensified inundation around the Candaba Swamp. Therefore, it is desirable to implement this project carefully after advancing the river improvement works, of the downstream area, such as the completion of the Labangan Flood Channel in the lower delta area.

8. Improvement Works of Other Tributaries

Any progress of works is not made except that of the Gumain Floodway in the western part of the lower delta area.

2-2-3 Dangerous Places from Flood

Dangerous places from flood and the most important factors which require special regard in implementing the flood forecasting and warning system are summarized below, in the light of actual situations of flood damage in the past and the current status of river improvement works.

1. Flood water stage against the elevations of barrios in the Candaba Swamp as well as in the eastern and western parts.

2. Flood water stage against the height of the Arnedo Dike between Apalit and Arayat and the ground elevation of Candaba Town.

3. Flood water stage against the height of incomplete portion of the Arayat-Cabiao Ring Levee on its southern section.

4. Flood water stage against the height of fuse dike erected between Candaba and Arayat.

5. Flood water stage against the height of incomplete section on the Calumpit-Plaridel-Bustos Dike, upstream from Plaridel.

6. Flood discharge running into the lower delta area from the Candaba Swamp through three outlet channels of Sulipan, Calumpit and Bagbag.

7. Combined effects of the tidal movement of Manila Bay and flood discharge on the lowland in the lower delta area.

2-2-4 Flood Damages and Benefits of Flood Forecasting and Warning

The maximum areas of the actual inundations on the Pampanga River System have been calculated to be

147,920 ha by the Pampanga River ,

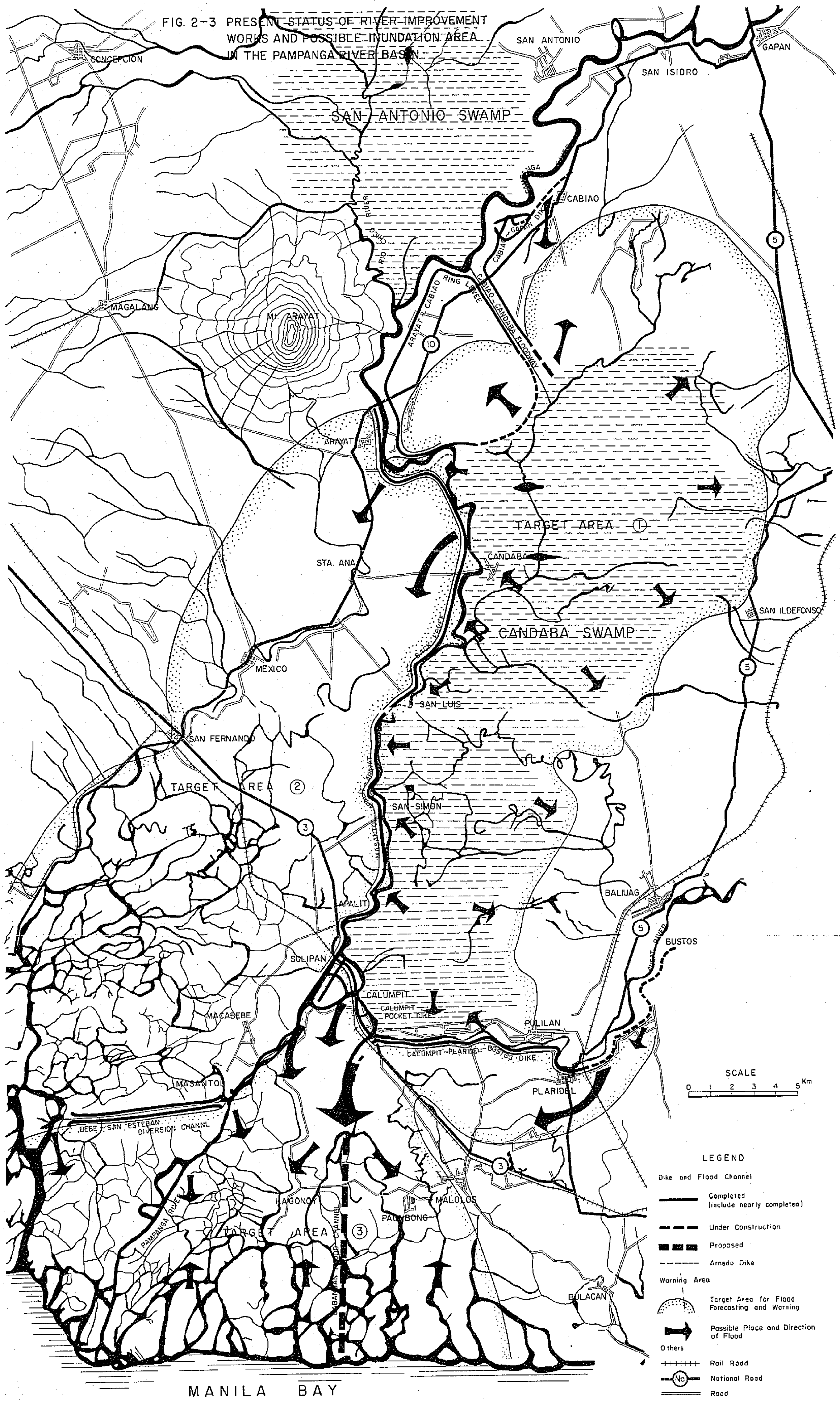
60,120 ha by the Rio Chico River, and

12,700 ha by the Angat River,

220,740 ha in total and

amounting to ₱18,000,000 in monetary term.

FIG. 2-3 PRESENT STATUS OF RIVER IMPROVEMENT WORKS AND POSSIBLE INUNDATION AREA IN THE PAMPANGA RIVER BASIN



The average damages per annum have been estimated as ₱9,400,000, accounting for about 25% of the average annual flood damages in the major Philippines' rivers. About 88% of this amount is due to the damages of agricultural crops and the damages of government properties account for only about 3%.

Fig. 2-4 shows the distribution of populations (as of 1960) in the target area of flood forecasting and warning. It is estimated that the present population is as much as 1.40 times of this figure basing on its increasing rate thereafter.

The actual patterns of flood damage in the past when the river improvement works were not completed may suggest us the possible behavior of flood damage in future due to incompletion of works as yet now.

It has to be recognized that flood damage will be more severe and concentrical than in the past due to the fact that the river improvement works are yet on the way.

The damage caused by a flood exceeding the magnitude of the flood for which the river improvement works are designed will be more serious than that caused under the natural conditions. Although the Survey Team have been explained by the persons concerned that there was no human loss in the past flood, this will not be always the case in future. Hence the flood forecasting and warning will acquire a greater importance.

Flood losses anticipated (by the flood of dimension smaller than that designed) in future after the current river improvement project has been completed will be those suffered by

1. residents in and around the Candaba Swamp and, in particular, in the area between the Apalit-Arayat Setback Levee and the Arnedo Dike (the present population is estimated as about 140,000), and

2. residents in the lower delta area downstream from Sulipan-Calumpit-Bagbag (the present population is estimated as about 230,000).

Since either of those flood losses is inevitable under the current river improvement project, it may be said that the object or the effect of the flood forecasting and warning system should be to reduce the public fear and keep them in peace and order for possible floods. However, it is believed that the followings are the effects which can never be ignored for the residents in the river basin.

1. Implementation of flood forecasting and warning enables the residents to avoid unuseful preparation for refuse and to evacuate more crops, livestocks, residential equipments etc. due to increased time for preparation. (In addition to such implementation, it is desirable to take measures for planned provision of shelters, arrangement of roads for evacuation, and control and guidance of refuge.)

2. Psychological effect to the people by giving forecast about recession of flood after they have taken shelter.

3. It is able to reduce damage by the effective operation of flood fighting according to flood forecasting and warning.

4. Any reduction in flood losses will result in the increase of personal properties and, indirectly, enable them to expect the improvement in the residents' willingness for labor and living.

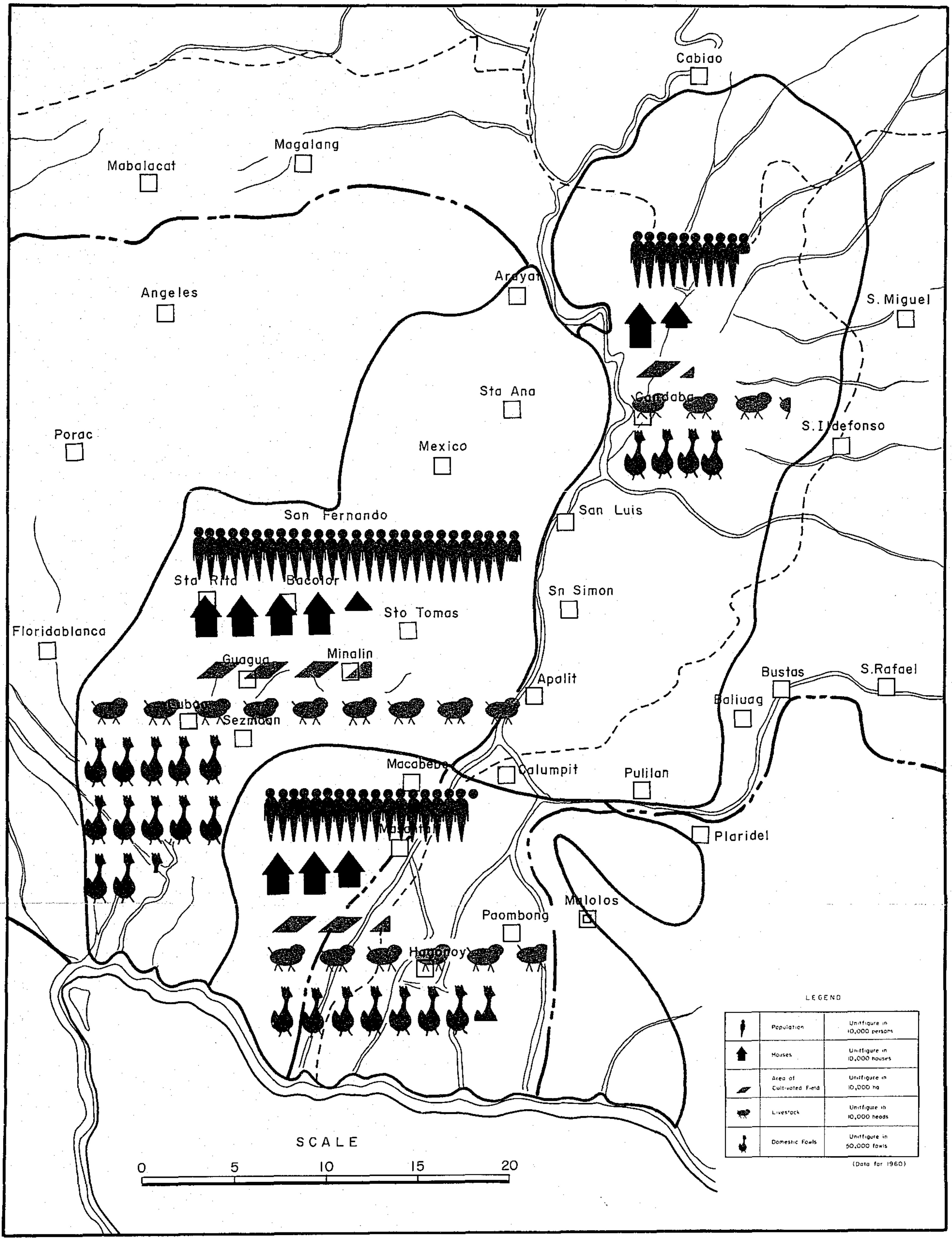
2-3 System of Data Acquisition

1. Bureau of Public Works (B.P.W.)

Rainfall and water level data are submitted monthly at normal time by the observer to B.P.W. or Apalit Office and compiled there in a monthly report.

At flood time, the rainfall and water level data at the hour designated by B.P.W. or Apalit Office are reported to them, in accordance with their directions, by the observer by telegram. Besides this, Apalit Office dispatch their staff to the station to make him conduct gauging and reporting. Communication between Apalit Office and B.P.W. is made by the public telephone.

FIG. 2-4 POPULATION AND PROPERTIES IN THE TARGET AREA



2. Weather Bureau (W.B.)

Metereological data at normal time are reported to the forecasting center established in the International Airport at interval of three hours by SSB from about fifty metereological stations existing all over the country. In an emergent case such as the time when a typhoon is approaching, the reporting interval is shortened to one hour. At present, Manila Port Area, the International Airport and U.S. Clark Base are equipped with meteorological radars which are used for usual metereological observations as well as tracking of typhoon. W.B. receives regularly the radar data from U.S. Clark Base through the microwave line and teletype.

Date obtained by the rain gauge stations established in the Pampanga River Basin are reported monthly to W.B. from the observers except the Cabanatuan Metereological Station from which data are sent every three hours as mentioned above.

Any special report is not made even at the time of flood.

2-4 Obtained Data

The data furnished to the Survey Team from B.P.W. of the Philippines are shown in the following tables.

The locations of gauging stations are as shown in Fig. 2-5.

The obtained daily rainfall data associated with major floods in the past are as follows:

Flood in August 1937;

Any data have not been available (the existing report gave the mean rainfall in the basin of 223 mm for 2 days, 296 mm for 3 days, 366 mm for 4 days, 404 mm for 5 days, 424 mm for 6 days and 464 mm for 7 days.)

Flood in August 1948;

Complete data of daily rainfall have been obtained for three gauging stations of No. 17, No. 18 and No. 20.

Flood in October 1950;

Complete data of daily rainfall have been obtained for three gauging stations of No. 17, No. 18 and No. 20.

Flood in August 1960;

Data of daily rainfall have been obtained almost completely for the following fourteen stations only with partial lack of observation, constituting the largest amount of data among the target floods for analysis. These data are those recorded at Nos. 1, 4, 5, 6, 7, 9, 11, 12, 13, 16, 17, 18, 20 and 31.

Flood in May 1966;

Data of daily rainfall have been obtained for eight gauging stations, although there is partial lack of observation not constituting any serious obstruction to the analysis. The stations are Nos. 4, 5, 7, 11, 31, 33, 34, and 35.

The obtained data of daily discharge associated with major floods in the past are as follows:

Flood in August 1948,
Flood in October 1950,
Flood in August 1960,
Flood in July 1962, and
Flood in May 1966.

Table 2-5 Obtained Data of Rainfall

NO.	NAME OF STATION	MANAGED BY	LOCATION	GIVEN DATA: DAILY RAINFALL: ANNUAL	GIVEN DATA: DAILY RAINFALL: MONTHLY	GIVEN DATA: HOURLY RAINFALL
1	Poblacion Carranglan	B.P.W.	Carranglan R. Basin Carranglan, N.E.	58,	57:Aug-Dec.59:Jan.-Sept. 60: Feb.-Dec.	
2	Pantabangan RGS	B.P.W.	Upper Pampanga R. Basin Pialuan, Pantabangan, N.E.			
3	Poblacion, Pantabangan	B.P.W.	Pantabangan R. Basin Pantabangan, N.E.			
4	Santor RGS	B.P.W.	Santor R. Basin Cayapo Gabaldon, N.E.	59, 60, 66	58:Jun.-Sept. Nov. Dec.67: Jan.- Nov. 68: Jul. Oct.-Dec.	
5	Santor RGS	B.P.W.	Santor R. Basin San Vicente Laur, N.E.	59, 60, 67, 68	58: Jun.-Oct. Dec. 66:May-Dec.	
6	Benituan RGS	B.P.W.	Benituan R. Basin Guimba, N.E.	60, 67	58:Jul. Sept.-Dec.59: Jan.-Jul. Sep.- Dec. 66: Jun.-Dec.68: Jan.-Apr.	
7	Lomboy	B.P.W.	Talavera R. Basin Lomboy, San Jose, N.E.	61, 62,	58:Jul.-Dec.59: Jan-Aug.60:May- Dec.63:Aug-Dec.64:Jan.Feb.66:Jan-Jul	
8	Pampanga RGS	B.P.W.	Pampanga R. Basin Arayat, Pampanga	62, 63	64: Jan.-Mar. May-Dec.	
9	Madlum RGS	B.P.W.	Madlum R. Basin San Miguel, Bulacan	59, 60	58:Jul.-Sept. Nov. Dec.	
10	Angat RIS North Canal	B.P.W.	Angat R. Basin San Rafael, Bulacan	57, 58	56:Jan-Apr.Jun-Dec.59:Jan-Aug.Oct.-Dec. 60:Jan.Feb.Apr.-Jun.Aug.Sep.Nov.Dec.	
11	Angat RIS South Canal	B.P.W.	Angat R. Basin Bustos, Bulacan	46-49, 53-58, 60, 66	45:Jul-Dec.50:Jan.Apr.May,Aug.Nov.Dec. 51:Jan.-Mar.Jun.Aug.Sep.52:Jul.-Dec.59: Jan.-Jul.	
12	Marcom Dam	B.P.W.	Upper Pam. R. Basin Talavera, N.E.	59, 60	58:Jul.-Sept. Nov. Dec.	
13	Rizal Dam	B.P.W.	Upper Pam. R. Basin Rizal, N.E.	56-59	55:Oct.-Dec.60: May-Sept.	
14	Peñaranda RIS	B.P.W.	Peñaranda R. Basin Tombo San Leonardo, N.E.	53-56	52: Jul.-Dec.	
15	Peñaranda RIS	B.P.W.	Peñaranda R. Basin Poblacion Gapan, N.E.	46-58	45:Apr-Dec.59:Jan-Jul. Oct.-Dec. 60: Jan-Jul. Sept.-Dec.	
16	Peñaranda RIS Main Canal	B.P.W.	Peñaranda R. Basin Peñaranda, N.E.	58, 60	49:Oct.-Dec.52:May. Jan. Oct. 53:May- Nov. 54: May-Nov.55-57:May-Dec. 59: Jan.-Jul. Oct.-Dec.	
17	Peñaranda RIS	B.P.W.	Peñaranda R. Basin San Josef Peñaranda, N.E.	46-58, 60	45: Apr.-Dec.59:Jan.-Jul. Oct.-Dec.	
18	Dibabuyan Dam	B.P.W.	Talavera R. Basin Munoz, N.E.	46-51, 53-57, 59, 60	45: Mar.-Dec.52:Jan. Feb. Apr.-Dec. 58: Jan.-Mar. May-Dec.	
19	Bicalbical Headgate	B.P.W.	Peñaranda R. Basin Peñaranda, N.E.	56		
20	Talavera RIS	B.P.W.	Talavera R. Basin San Jose, N.E.	46-51, 53-60	52:Jan. Feb. Apr. May. Jul.-Dec.	
21	Sumacbao RGS	B.P.W.	Pañaranda R. Basin Gen. Tinio, N.E.			
31	Cabanatuan	W.B.	15°29'N120°55'E	60-68	69:Jan-May, Aug.-Oct.	66:May 1-31 68:Aug.16,18,29 69: Jul.27,28,30, Sept. 8

Table 2-6 Obtained Data of Water Stage

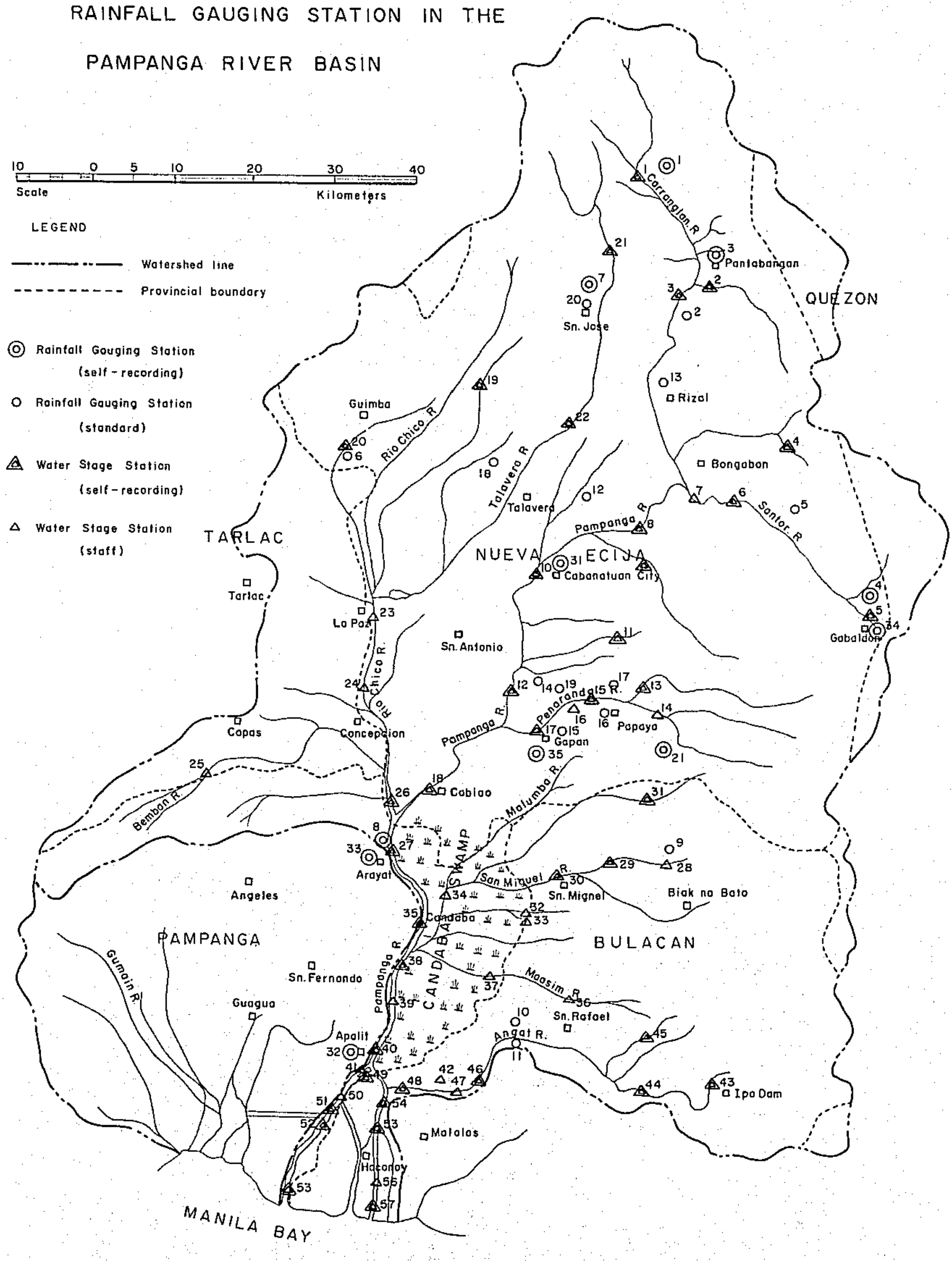
No.	Name	Location	Classification	Duration of Observation	Data	Remarks
1	Baluarte	Carranglan R.	Self-recording	11-25-58 To date	Continuous charts 2 times a day	Survey of discharge
2	Pantabangan	Pantabangan R.	Self-recording	11-27-58 To date	Continuous charts 2 times a day	Survey of discharge
3	Pisluan	Pampanga R.	Self-recording	4-59 To date	Continuous charts 2 times a day	Survey of discharge
4	Labi	Digmala R.	Self-recording	4-59 To date	Continuous charts 2 times a day	Survey of discharge
5	Cuyapa	Santor R.	Self-recording	5-57 To date	Continuous charts	Survey of discharge
6	San Vicente	Santor R.	Self-recording	1-57 To date	Continuous charts	Survey of discharge
7	Bangkerohan	Santor R.	Staff	12-59 To date	2 times a day	Survey of discharge
8	Malate	Pampanga R.	Self-recording	4-55 To date		
9	Cabu	Cabu R.	Self-recording	6-57 To date	Continuous charts 3 times a day	Survey of discharge
10	Valdefuente	Pampanga R.	Self-recording	3-19-64 To date		
11	Soledad	Tabuating R.	Self-recording	2-60 To date	2 times a day	Survey of discharge
12	San Antonio	Pampanga R.	Self-recording	10-58 To date	Continuous charts 2 times a day	Survey of discharge
13	Ilog na Munti	Chico R.	Self-recording	7-60 To date	2 times a day	Survey of discharge
14	Pias	Sumacbao R.	Staff	7-21 To date	2 times a day	Survey of discharge
15	San Josef (HW)	Peñaranda R.	Self-recording	9-45 To date	2 times a day	Survey of discharge
16	San Josef (R.R.Br.)	Peñaranda R.	Staff	10-11 To date	2 times a day	Survey of discharge
17	Poblacion	Peñaranda R.	Self-recording	9-45 To date	3 times a day	Survey of discharge
18	San Vicente	Pampanga R.	Self-recording	9-18-58 To 12-31-68	Continuous charts 2 times a day	Temporary station
19	Catalanacan	Baliwag R.	Self-recording	9-56 To date	Continuous charts	Survey of discharge
20	Pasong	Benituan R.	Self-recording	8-57 To date	Continuous charts 3 times a day	Survey of discharge
21	Lomboy	Talavera R.	Self-recording	7-56 To date	Continuous charts	Survey of discharge
22	Cabcaboloonan	Talavera R.	Self-recording	7-56 To date	2 times a day	Survey of discharge
23	Sto. Rosario	Rio Chico R.	Staff	7-60 To date	2 times a day	Survey of discharge
24	Sta. Monica	Rio Chico R.	Staff	11-58 To date	2 times a day	Survey of discharge
25	San Nicolas	Bamban R.	Staff	11-58 To date	3 times a day	Survey of discharge
26	Banga	Rio Chico R.	Self-recording	1-14 To date		
27	San Agustin	Pampanga R.	Self-recording	1-44 To date	Continuous charts	Survey of discharge
28	Sibul	Madlum R.	Staff	8-55 To	2 times a day	Survey of discharge
29	Sta. Ines	Balaong-Madlum R.	Self-recording	12-55 To date	Continuous charts 3 times a day	Survey of discharge
30	San Vicente	San Miguel R.	Self-recording	7-55 To date	3 times a day	Survey of discharge
31	Malibay	Bulu R.	Self-recording	2-64 To date		
32	Garlang	Garlang R.	Staff	3-55 To date	2 times a day	Survey of discharge
33	Garlang	Garlang R.	Staff	3-55 To date	2 times a day	Survey of discharge
34	Ducma	Candaba Swamps	Staff	6-53 To date	2 times a day	Survey of discharge
35	Pasig	Pampanga R.	Self-recording	10-58 To date	3 times a day	

No.	Name	Location	Classification	Duration of Observation		Data	Remarks
36	Diliman	Maasim R.	Staff	1-19	To date	Continuous charts 3 times a day	Survey of discharge
37	Bahay	Maasim R.	Staff	4-56	To date	2 times a day	
38	Sta. Cruz	Pampanga R.	Self-recording	8-48	To date	Continuous charts	
39	San Juan	Pampanga R.	Staff	4-46	To date	3 times a day	
40	Sulipan	Pampanga R.	Self-recording	1-46	To date	Continuous charts	
41	Sulipan	Sulipan Cut-off Channel	Staff	7-46	To date	2 times a day	
42	San Miguel	Francis R.	Staff	6-46	To date	3 times a day	
43	Above Ipo	Angat R.	Self-recording	1-57	To date	Continuous charts	Survey of discharge
44	Below Ipo	Angat R.	Self-recording	9-56	To date	Continuous charts 2 times a day	Survey of discharge
45	Pulong Sampaloc	Bayabas R.	Self-recording	6-1-64	To date		Survey of discharge
46	Longos	Angat R.	Self-recording	7-09	To date	Continuous charts 2 times a day	Survey of discharge
47	Pob. Pulilan	Angat R.	Staff	6-61	To date	3 times a day	
48	Pungo	Angat R.	Self-recording	6-61	To date	3 times a day	
49	Pob. Calumpit	Pampanga R.	Self-recording	5-17-10	To date	Continuous charts	
50	San Miguel	Pampanga R.	Staff	7-46	To date	3 times a day	
51	Bebe (C.O.C. No.1)	Bebe Cut-off Channel	Self-recording	4-56	To date	Continuous charts	
52	Bebe (C.D.C. No.2)	Bebe Cut-off Channel	Self-recording	4-56	To date	Continuous charts	
53	Budbud	Pampanga R.	Self-recording	12-9-60	To date	Continuous charts	
54	Bagbag	Labangan R.	Self-recording	1-46	To date	Continuous charts	
55	Halang	Labangan R.	Self-recording	7-61	To date	Continuous charts	
56	Halang	Labangan R.	Staff	6-61	To date	3 times a day	
57	Tibagin	Labangan R.	Self-recording	7-61	To date	Continuous charts	

Table 2-7 Obtained Data of Discharge

River	Location	Drainage Area	Daily Discharge		Hourly Discharge
Carranglan	Baluarte, Carranglan, N.E.	258 km^2		Jan. 1960 - Dec. 1962	May 20 - May 24, 1966
Pantabangan	Pob. Pantabangan, N.E.	253		Aug. 1960 - Dec. 1962	
Pampanga	Pialuan, Pantabangan, N.E.	832		Jan. 1962 - Dec. 1962	May 20 - May 30, 1966
Digmala	Labi, Bongabon, N.E.	52		Jan. 1960 - Dec. 1962	
Santor	Cuyapa, Gabaldon, N.E.	89		Jan. 1960 - Dec. 1962	
Santor	San Vicente, Laur, N.E.	544		Jan. 1960 - Dec. 1962	
Coronel (Santor)	Bangkerohan, Bongabon, N.E.	709		Jan. 1960 - Dec. 1962	Aug. 15 - Aug. 22, 1960, May 18 - May 26, 1966
Pampanga	Malate, Bongabon, N.E.	2015		Jan. 1960 - Dec. 1962	
Cabu	Cabu, Cabanatuan City	143		Jan. 1960 - Dec. 1962	
Tabuating	Soledad, Sta. Rosa, N.E.	81		Mar. 1960 - Dec. 1962	
Pampanga	San Anton, San Leonardo, N.E.	2851		Jan. 1960 - Dec. 1962	Aug. 1 - Aug. 23, 1960
Chico	Ilog Na Munti, Gen. Tinio, N.E.	149		Aug. 1960 - Dec. 1962	
Sumacbao	Pias, Gen. Tinio, N.E.	287		Aug. 1960 - Dec. 1962	
Peñaranda (HW)	San Josef, Peñaranda, N.E.	511	Sept. 1945 - Dec. 1956	Jan. 1960 - Dec. 1962	
Peñaranda (R.R.Br.)	San Josef, Peñaranda, N.E.	512		Jan. 1960 - Dec. 1962	
Peñaranda	Pob. Gapan, N.E.	573	Sept. 1945 - Dec. 1956	Jan. 1960 - Dec. 1962	
Pampanga	San Vicente, Cabiao, N.E.	3467		Jan. 1960 - Dec. 1962	
Baliwag	Catalnacan, Munoz, N.E.	284		Jan. 1960 - Dec. 1962	
Benituan	Pasong Intsik, Guimba, N.E.	208		Jan. 1960 - Dec. 1962	
Talavera	Lomboy, San Jose, N.E.	261		Jan. 1960 - Dec. 1962	
Talavera	Caboboloonan, Talavera, N.E.	431		Jan. 1960 - Dec. 1962	
Rio Chico	Sto. Rosario, Zaragoza, N.E.	1177		Oct. 1960 - Dec. 1962	
Rio Chico	Sta. Monica, Concepcion, Tarlac	2090		Aug. 1961 - Dec. 1962	
Parua	San Nicolas, Bamban, Tarlac	148		Jan. 1960 - Dec. 1962	
Pampanga	San Agustin, Arayat, Pampanga	6487	Jan. 1944 - Dec. 1956	Jan. 1960 - Dec. 1962	
Madlum	Sibul Spring, San Miguel, Bulacan	102		Jan. 1960 - Dec. 1962	
Balaong-Madlum	Sta. Ines, San Miguel, Bulacan	204		Jan. 1960 - Dec. 1962	
San Miguel	San Vicente, San Miguel, Bulacan	256		Jan. 1960 - Dec. 1962	
Bulo	Malibay, San Miguel, Bulacan				
Garlang Creek	Garlang, San Ildefonso, Bulacan	5		Jan. 1960 - Dec. 1962	
Garlang	Garlang, San Ildefonso, Bulacan	85		Jan. 1960 - Dec. 1962	
Pampanga	Pasig, Candaba, Pampanga	7468		Jan. 1960 - Dec. 1962	May 18 - June 2, 1966
Maasim	Diliman, San Rafael, Bulacan	150	Oct. 1945 - Dec. 1956	Jan. 1960 - Dec. 1962	
Maasim	Bahay-Pare, Candaba, Pampanga	174		June 1960 - Dec. 1962	
Angat	Above Ipo Dam, Norzagaray, Bul.	551		Jan. 1960 - Dec. 1962	
Angat	Below Ipo Dam, Norzagaray, Bul.	629		Jan. 1960 - Dec. 1962	
Angat	Longos, Pulilan (Plaridel Bridge) Bul.	959		Jan. 1960 - Dec. 1962	

FIG. 2-5 LOCATION OF WATER STAGE GAUGING STATION AND RAINFALL GAUGING STATION IN THE PAMPANGA RIVER BASIN



CHAPTER 3. ANALYSIS OF MAJOR FLOODS

In establishing the flood forecasting system, it is the most important to ascertain, whether adequate forecasts can be issued by the data collected from the selected observation network against any attack of flood in the same size as that in the past.

In this chapter it is examined first in what month the floods occurred in the past and the natures of the typical floods. In the latter half of the chapter, flood runoff, flowing down of flood through river channels and behaviors of flood in the swamps are investigated to clarify the actual conditions of floods in the Pampanga River Basin. The results of these analyses will show clearly the justification of our proposal for the flood forecasting and warning system.

3-1 Flood Period

The distribution of rainfall occurrence through the year in the Pampanga River Basin is examined to determine the flood period in which flood forecasting and warning is required. Monthly rainfall data mainly from 1957 to 1960 are shown in Table A-2 when a comparatively large number of stations in the basin were in operation of synoptical observations. Thus two hundred and six observed monthly rainfall data are obtained excluding the months of absent observation. Further, the frequency of the occurrence of monthly rainfall exceeding 100, 200, 300, 400 and 500 mm are counted respectively as 261, 156, 84, 44 and 23 times. This frequency of the occurrence is shown by month in Fig. 3-1, which reveals that the occurrence of monthly rainfall exceeding 600 mm is mostly concentrated in August and that of other scales also occurs more or less in and around the same month. However, seeing from the frequency of the occurrence of rainfall more than 300 mm which has comparatively large possibility to associate with flood, the target period for flood forecasting will include the months from May to November. Further, taking account of the facts that one of the well–known floods in the past occurred in May 1966 and that a rainfall more than 400 mm was once recorded also in May, it is believed that the flood period should include the months from May to October and November should be treated according to them. This can be understood also by the illustration of monthly rainfall distribution at several gauging stations. (Fig. 3-2).

Fig. 3-3 shows the highest water level in the year and the month in which it occurred at San Agustin, Arayat. This also shows that the occurrence of floods is concentrated in August and September. Judging from Fig. 3-3, it reveals that any severe flood so far occurred in July, August and September.

Then the period of the occurrence of flood was considered as from June to December in the past stage data but the scale of flood in December was small.

3-2 Characteristics of Regional Rainfall Distribution

The annual rainfalls recorded at the gauging stations in the river basin are illustrated in Fig. 3-4 for the years from 1957 to 1960 and 1968 when comparatively many stations carried out synoptical rainfall observation. Although any definite conclusion cannot be made due to insufficient number of gauging stations which conducted such observation for each year, so far as these data are concerned, the flat land areas on the mid and downstream receive comparatively small amount of annual rainfall, and the eastern mountanious basins comprizing the Madlum and the Santor River Basins receive much. The northern mountainous area receives much rainfall next to the above. As almost no data is available for the river basin of the western mountainous area anything about rainfall is not clear, but this basin is supposed to have also much rainfall seeing from the data recorded at the Iba Zambales gauging station outside of the basin. However, since this gauging station is situated in the sea coast area, the rainfall pattern may be different; thus it needs to collect much more rainfall data and study them in order to reach any conclusion.

The regional distributions of rainfalls at the times of the well-known floods in 1960 and 1966 are shown in terms of monthly rainfalls in Fig. 3-5. This shows that the regional rainfall distribution associated with a flood varies with every flood, and no definite trend is indicated.

This may be easily imagined from the fact that the heavy rain is mostly due to a front or thunderstorm, localized in an extremely narrow range. Fig. 3-6 shows the comparison of daily rainfall distributions for several days in the several cases of recent days when heavy rain comparatively continued. Fig. 3-7 shows the comparison of daily rainfall distributions for the floods in 1960 and 1966. These Figures reveal that a severe storm which causes a large flood of the main river naturally brings considerable

FIG. 3-1 MONTHLY FREQUENCY DISTRIBUTION OF RAINFALL OCCURENCE FOR DIFFERENT INTENSITIES

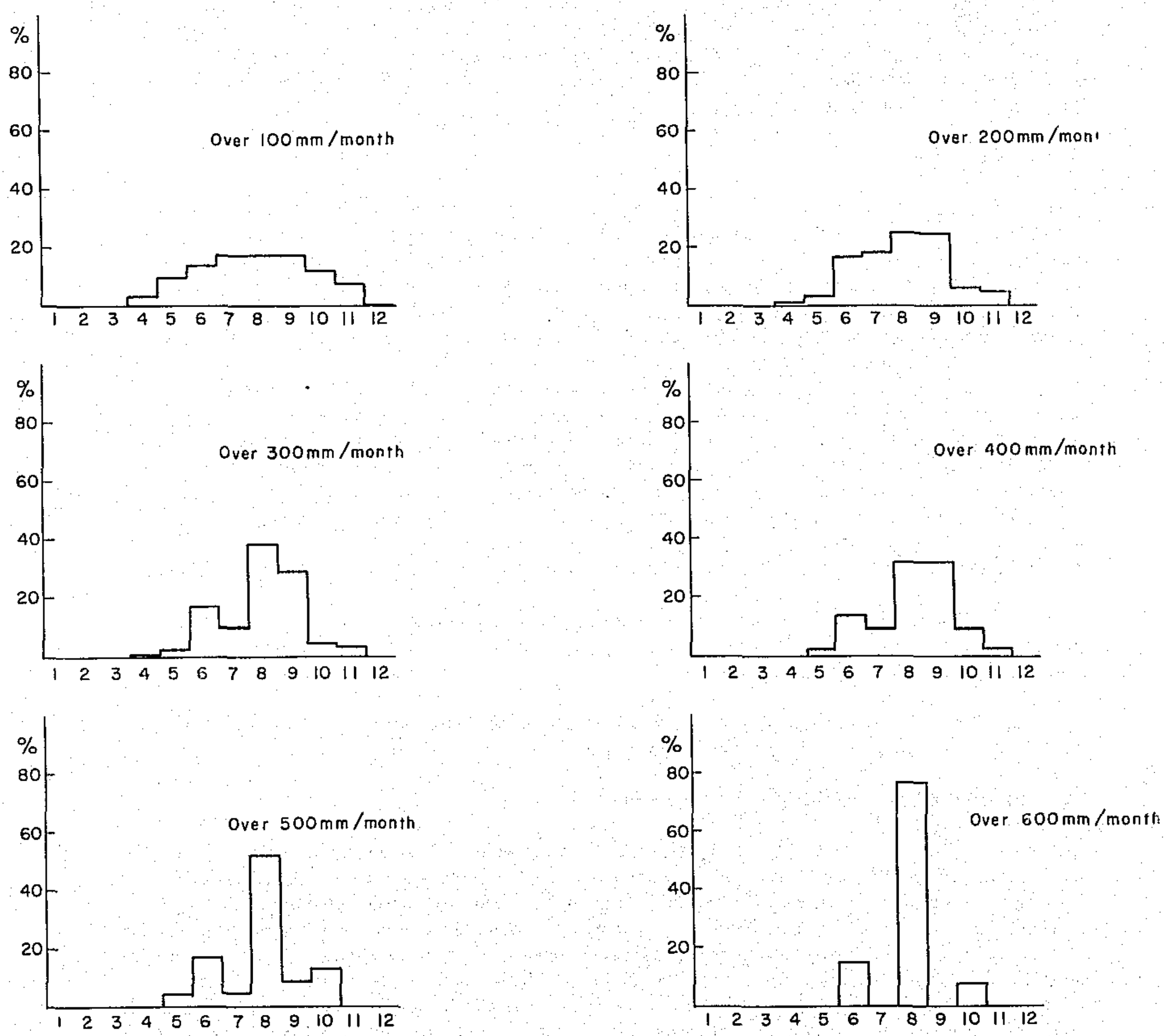


FIG 3-2 (1) MONTHLY RAINFALL

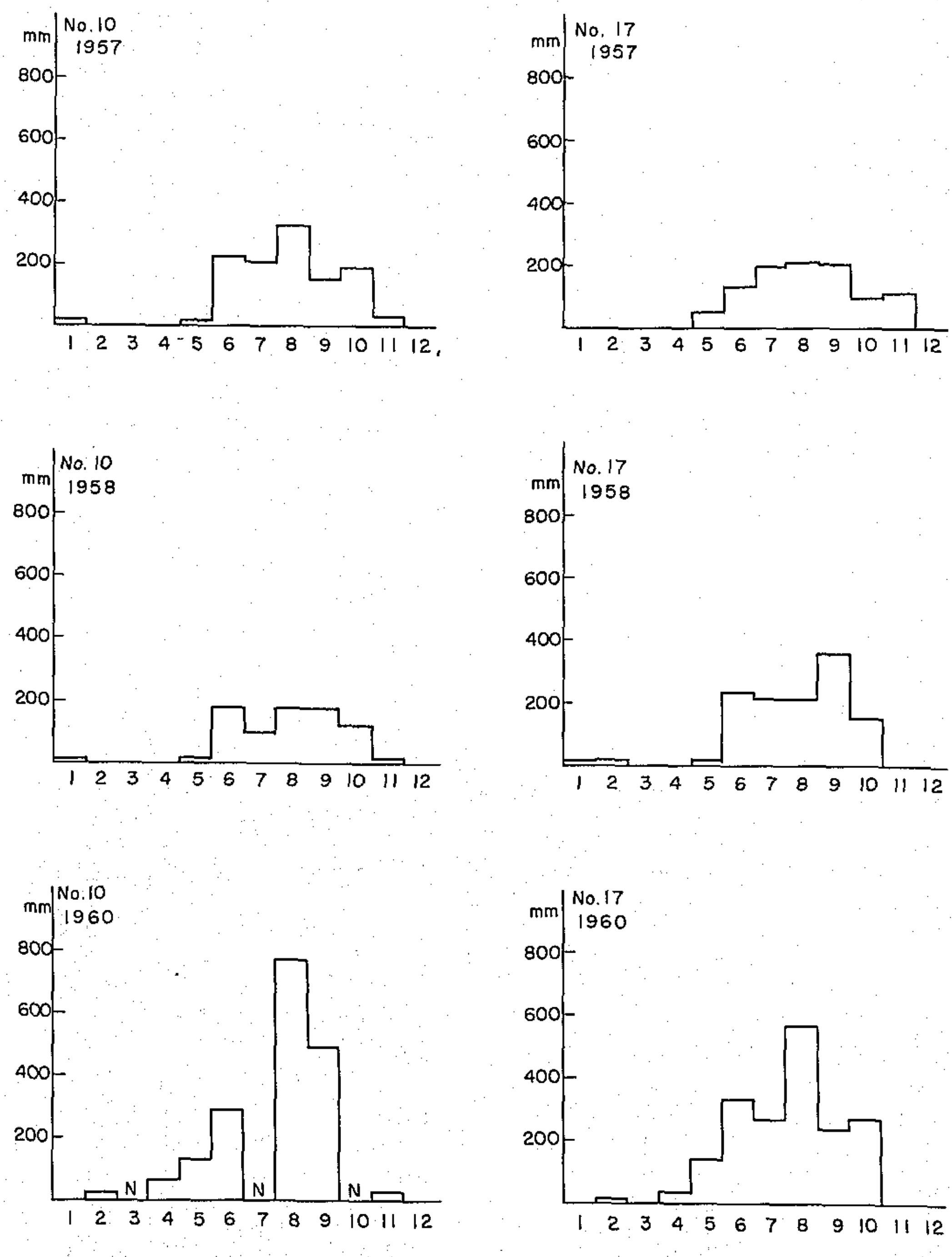
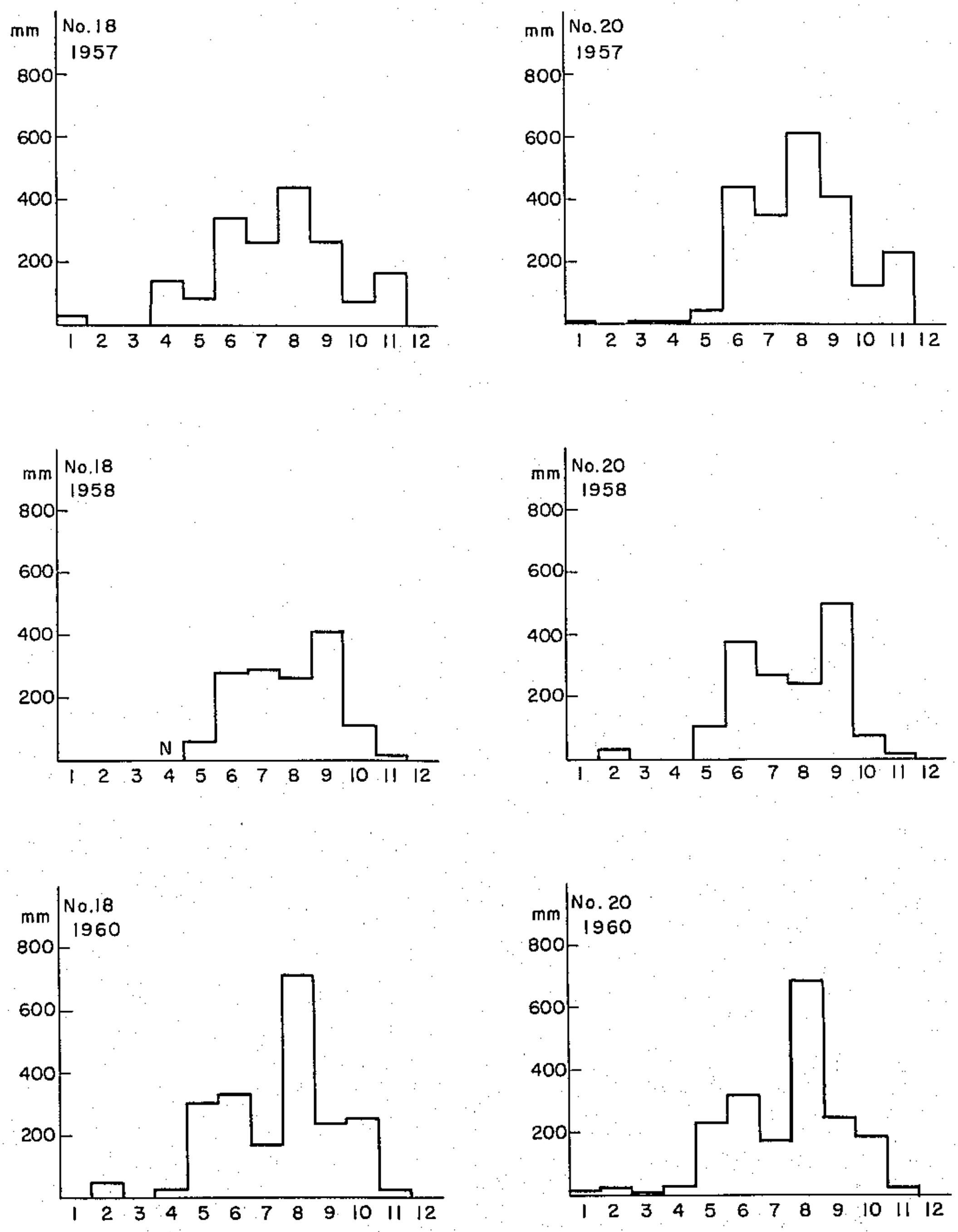


FIG. 3-2 (2) MONTHLY RAINFALL



FIG' 3-3 YEARLY MAXIMUM GAUGED HEIGHT AT SAN AGUSTIN AND YEARLY CHANGE IN THE MONTH OF ITS OCCURRENCE.

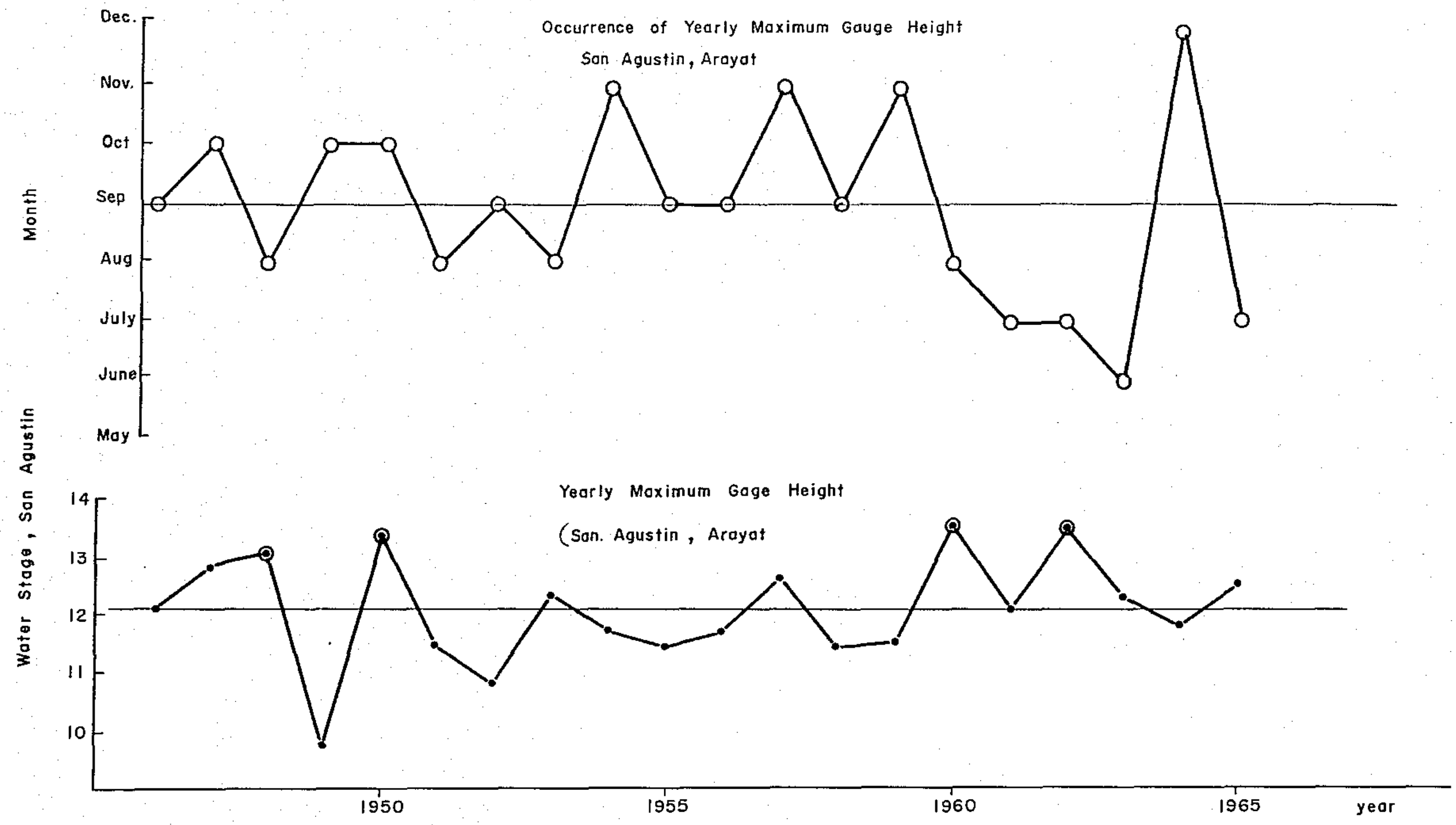


FIG 3-4 ANNUAL RAINFALL (mm)

FIG. 3-4 (1)

1957

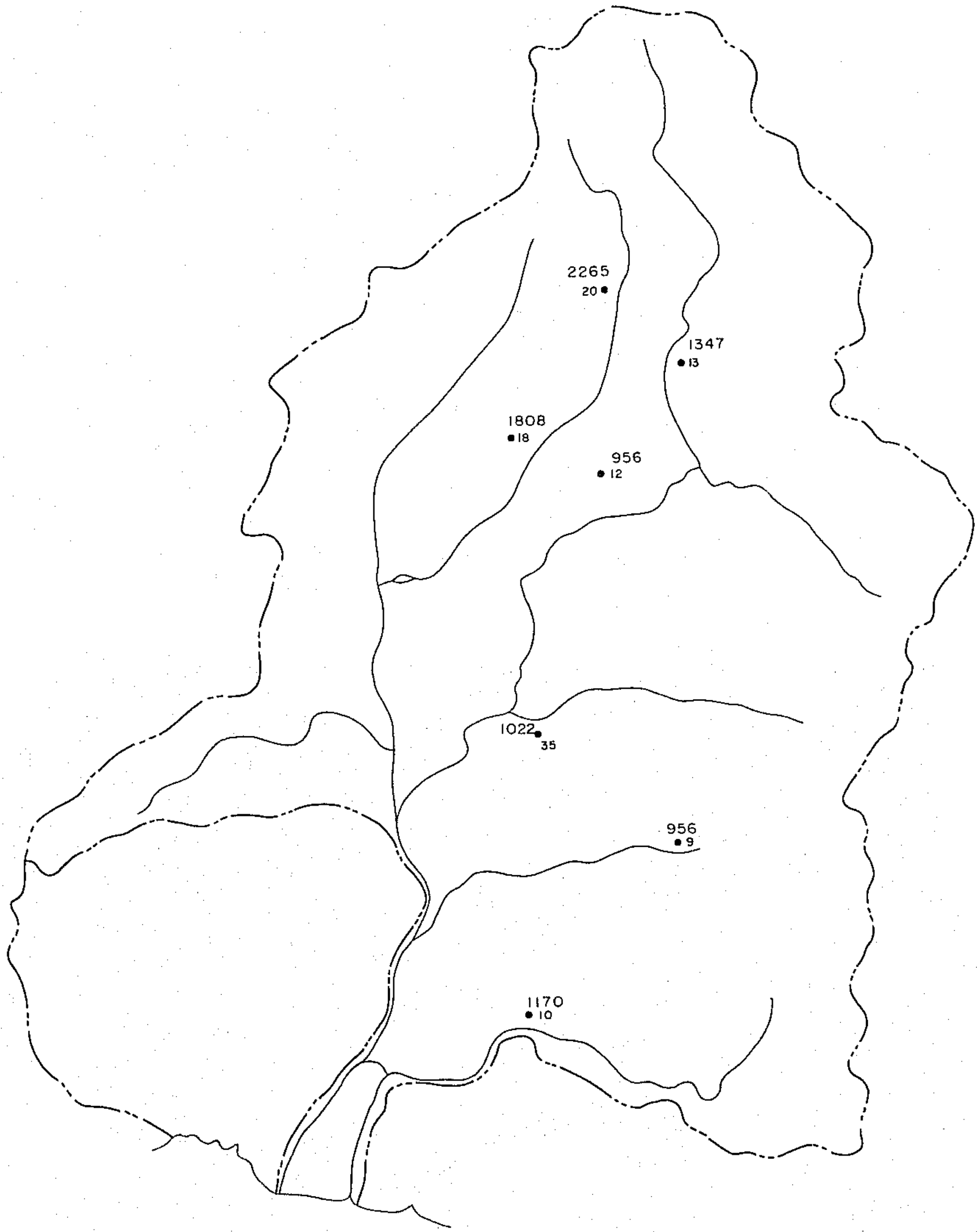


FIG 3-4 (2)

1958

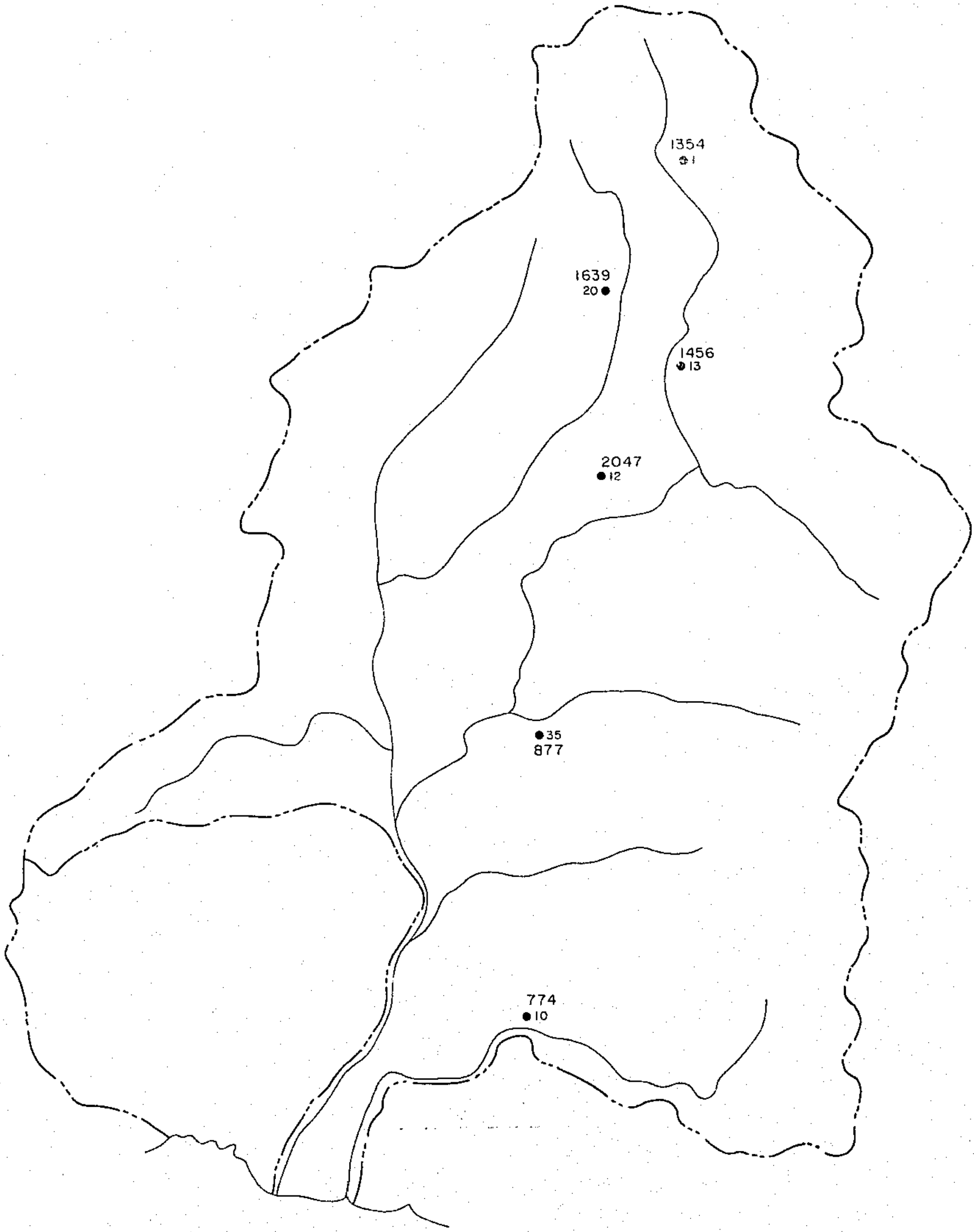


FIG. 3-4 (3)

1959

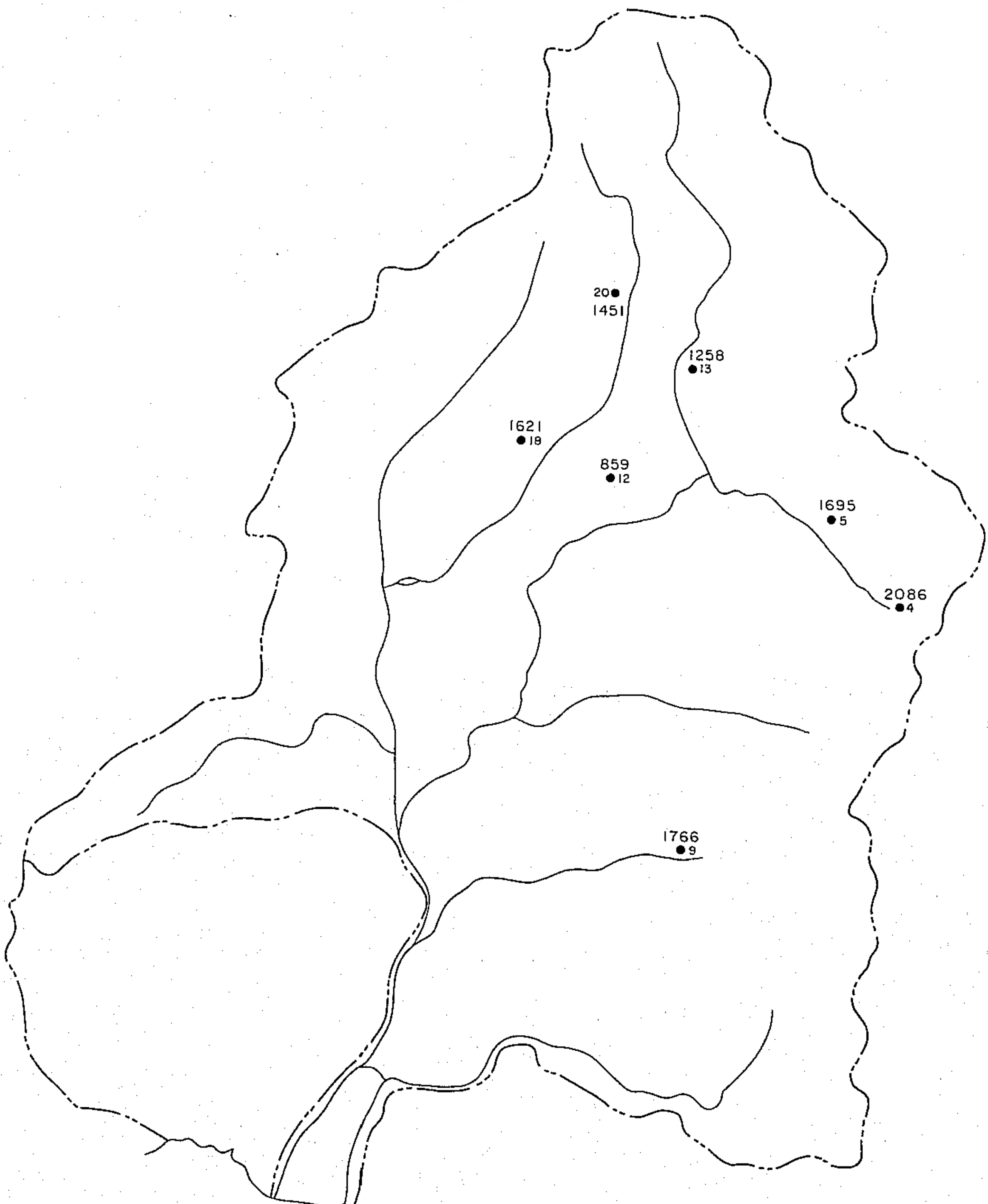


FIG. 3-4 (4)

1960

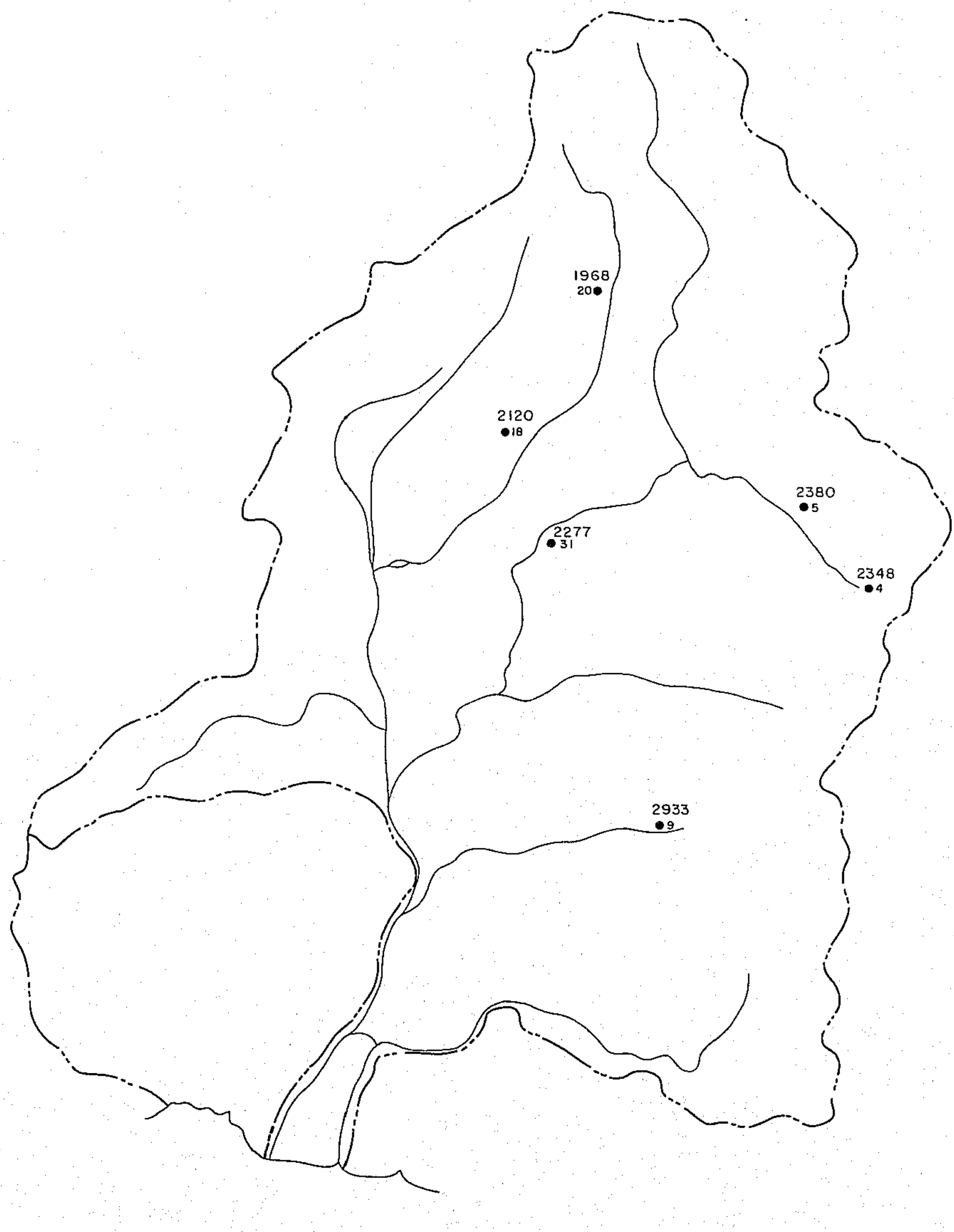


FIG. 3-4 (5)

1968

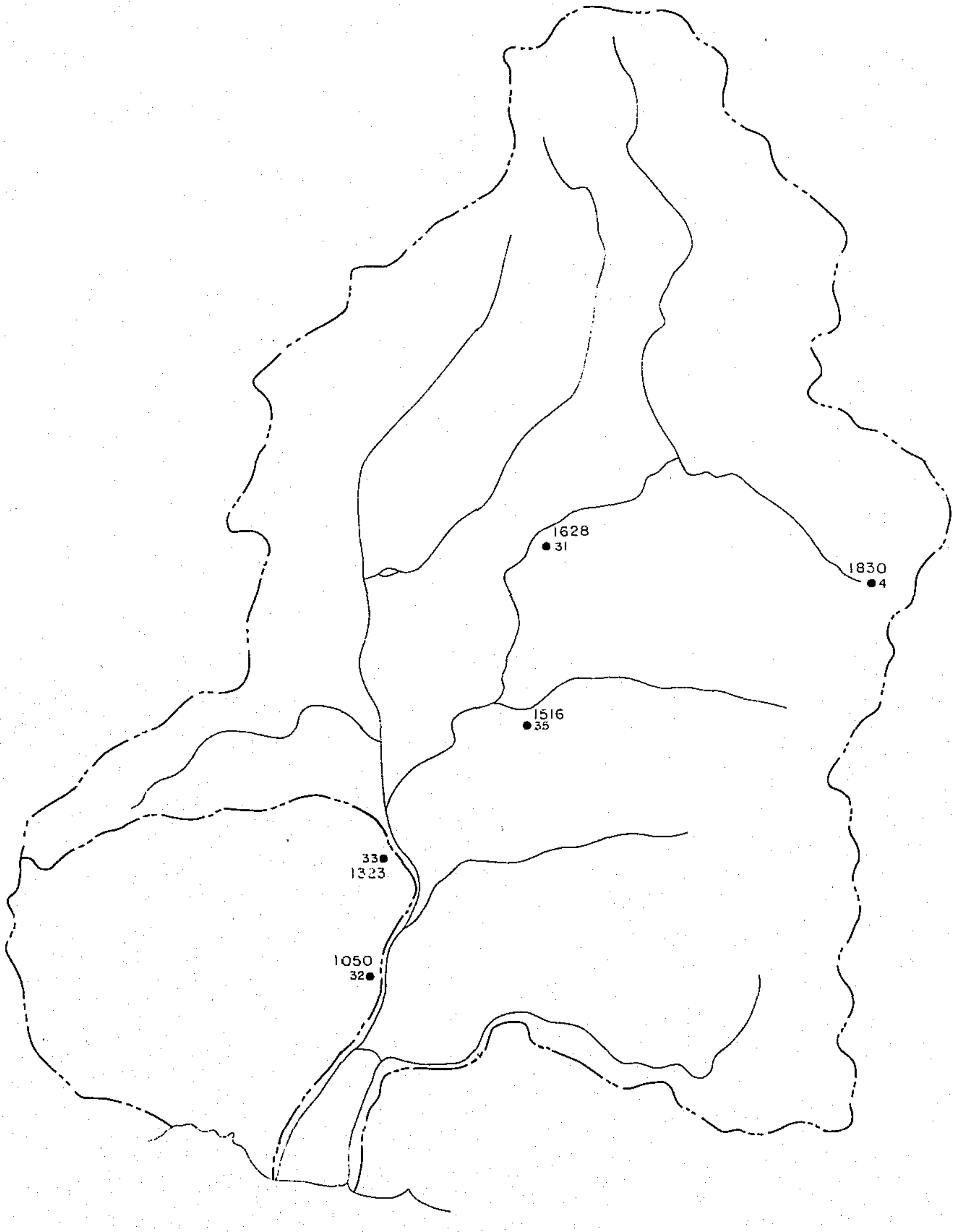


FIG 3-5 MONTHLY RAINFALL (mm)

FIG. 3-5 (1)

Aug, 1960

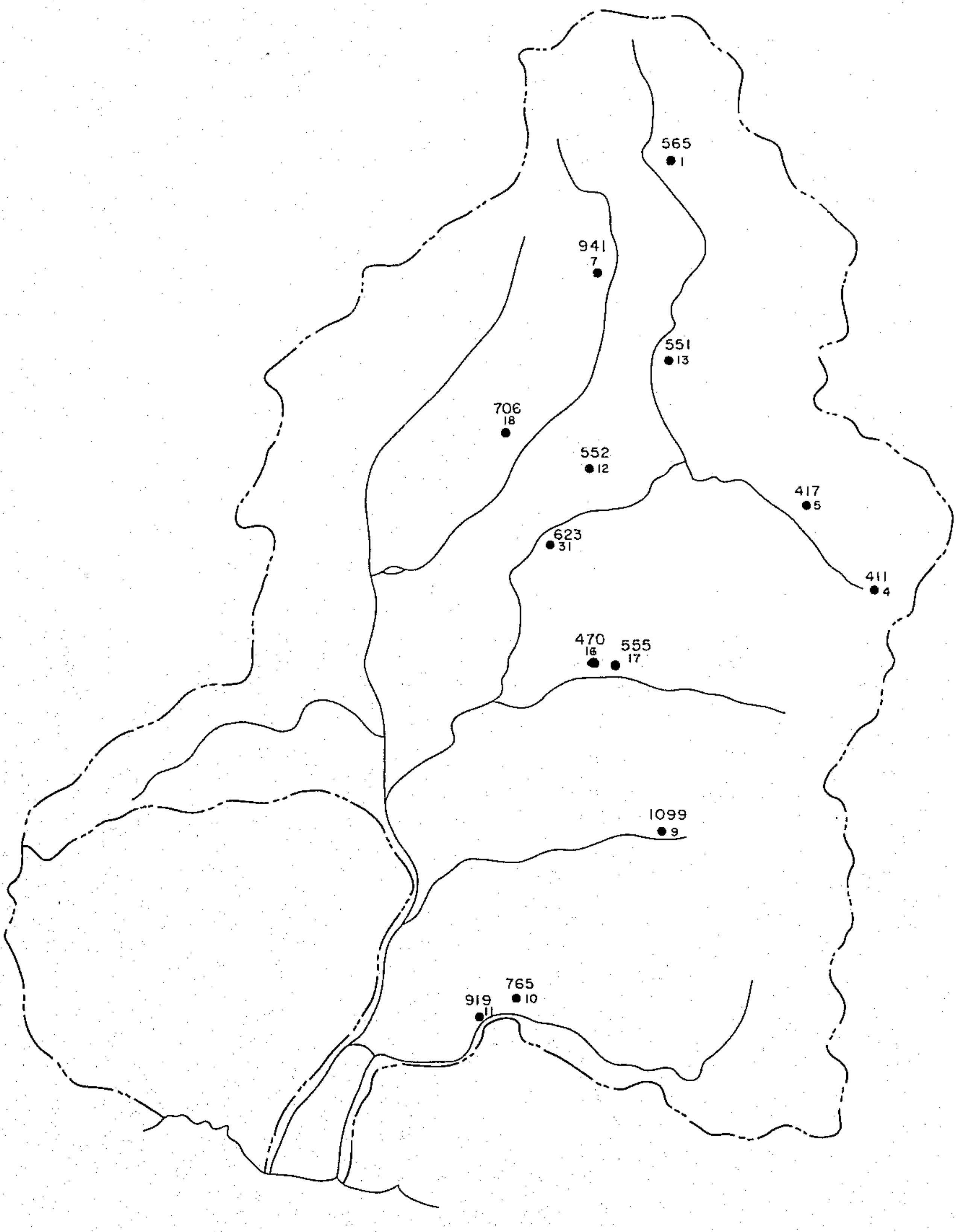
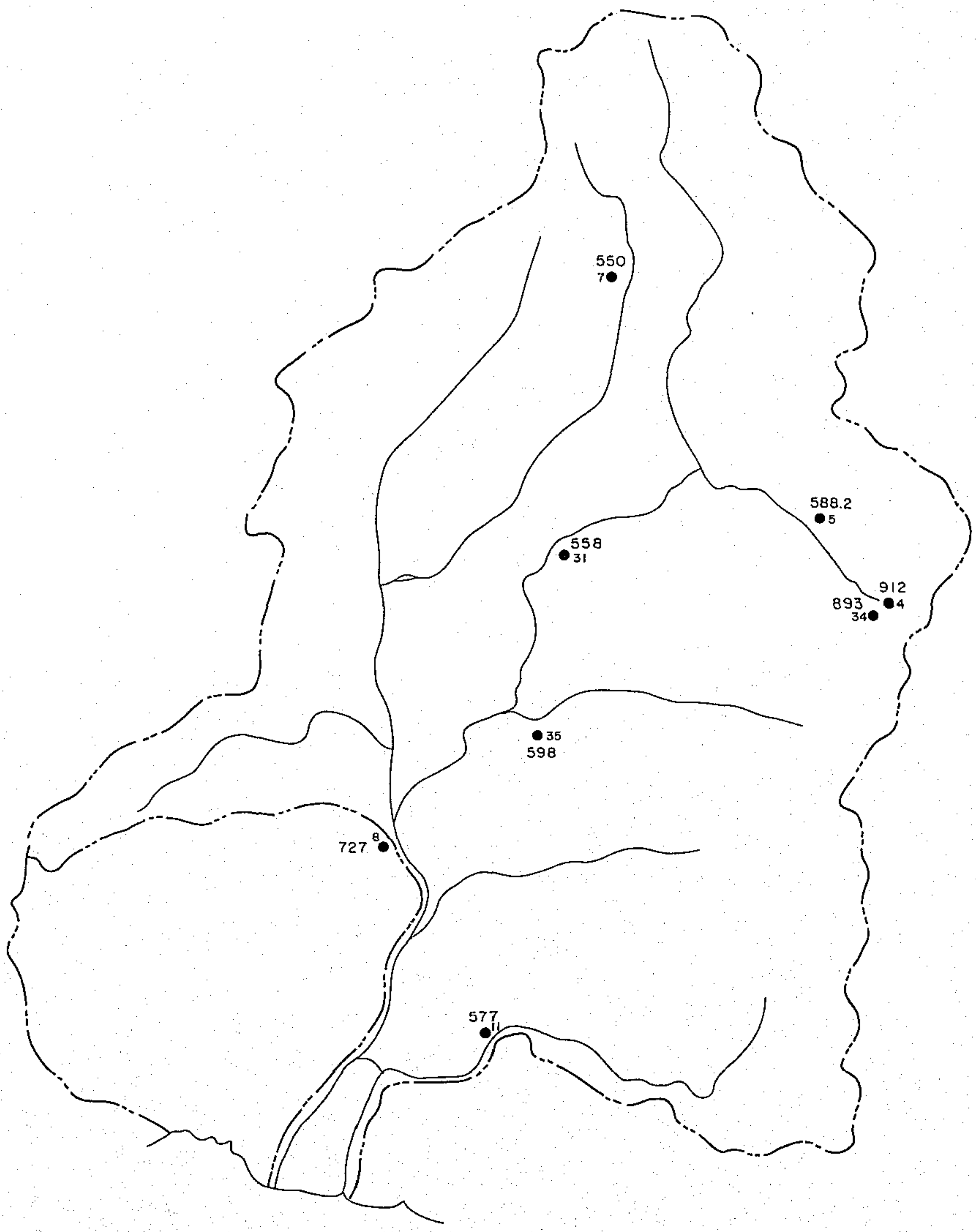


FIG. 3-5 (2)

May, 1966



amount of rainfall all over the river basin, showing a comparatively uniform distribution. In contrast with this, rainfall not having so much influence on the occurrence of flood of the main river has no clear pattern in daily rainfall distributions and no correlation can be found between various rainfall gauging stations.

3-3 Representativeness of Rain Gauge Station

As shown in Fig. 2-5, there are twenty rain gauge stations in the basin of 8,550 km^2, with three stations in the vicinity, namely Nos. 8, 32 and 33 stations, making twenty-three stations in total, or one station per 370 km^2 of the basin area. This number is not sufficient even if they are uniformly distributed in the area. Whereas, in this river basin, these gauging stations are mainly distributed in the flat land along the main river. The downstream basin of the Rio Chico River and the upstream basin of the Angat River have particularly a few gauging stations. In using their rainfall data as representing the whole river basin in spite of these restrictions, it is absolutely necessary to know to what extent the individual gauging station represents its nearby river basin. In this section, the simple correlation analysis of daily and 2-day rainfalls is made between different gauging stations, to examine the above-mentioned problem.

In order to see the simple correlation between gauging stations, daily and 2-day rainfalls recorded at several stations in the river basin are arranged as shown in Fig. 3-8.

No. 7 versus No. 20 stations and No. 16 versus No. 19 stations do not show any clear correlation between them although they are close to each other respectively. Fig. 3-9 shows for reference the correlations between 2-day rainfall of No. 18 gauging station with that of other gauge stations, arranged with the distance from No. 18 station to the other stations as parameter. As is clear from this figure, there exists no correlation and any influence of distance cannot be found. These data are taken from the cases where either of two stations observed rainfall exceeding 1.5 inches for daily rainfall or 2 inches for 2-day rainfall, but as is clear from the figure, either of the corresponding stations has 0 inch of rainfall in many cases. This shows that the rainfall is extremely localized as is often in the case where the rainfall is due to cumulo-nimbus. Therefore, from the technical standpoint of flood forecasting, it is dangerous to estimate simply the rainfall in the nearby basin basing on the data of a small number of gauging stations.

The representativeness of a gauging station for the basin, when there is considerable rainfall over the whole basin as in the case of heavy rain caused by a front, should be analyzed and examined in regard to many flood cases in the afore said way. The network of rain gauge stations for the purpose of flood forecasting must be determined after having made these examinations.

3-4 D-D Analysis

As a study of rainfall characteristics, the relation between rainfall duration and cumulative hourly rainfall will be examined. The analysis of this relation combining with the arrival time of flood is useful for forecasting the maximum possible flood.

Fig. 3-10 shows the maximum daily, maximum 2-day and to maximum 7-day rainfalls in the past data recorded at several gauging stations in the river basin. As is seen from the figure, the maximum 7 day rainfall recorded at No. 9 gauging station is 27 inches ≒ 685 mm, but those recorded at other stations are 20 inches ≒ 500 mm at the most. The 2 day rainfall of 23 inches ≒ 580 mm of No. 9 gauging station was recorded in October 1960 when the station received a concentrated heavy rain, and it may be considered as an exceptional case.

Next, the rainfalls in a series ranging from one-day to 7-day are drawn in Fig. 3-11. The same can be said as in the above as to a series of rainfall and, in particular, it can be said that the duration of concentrated heavy rain is one or two days followed by rapidly weakened rainfall thereafter. This can be understood from the fact that the rainfall is mostly due to cumulo-nimbus. However, only the rainfall in August 1960 maintained the same intensity for seven days, as is seen from the records of Nos. 18 and 20 gauging stations.

FIG. 3-6 (1) DISTRIBUTION OF DAILY RAINFALL

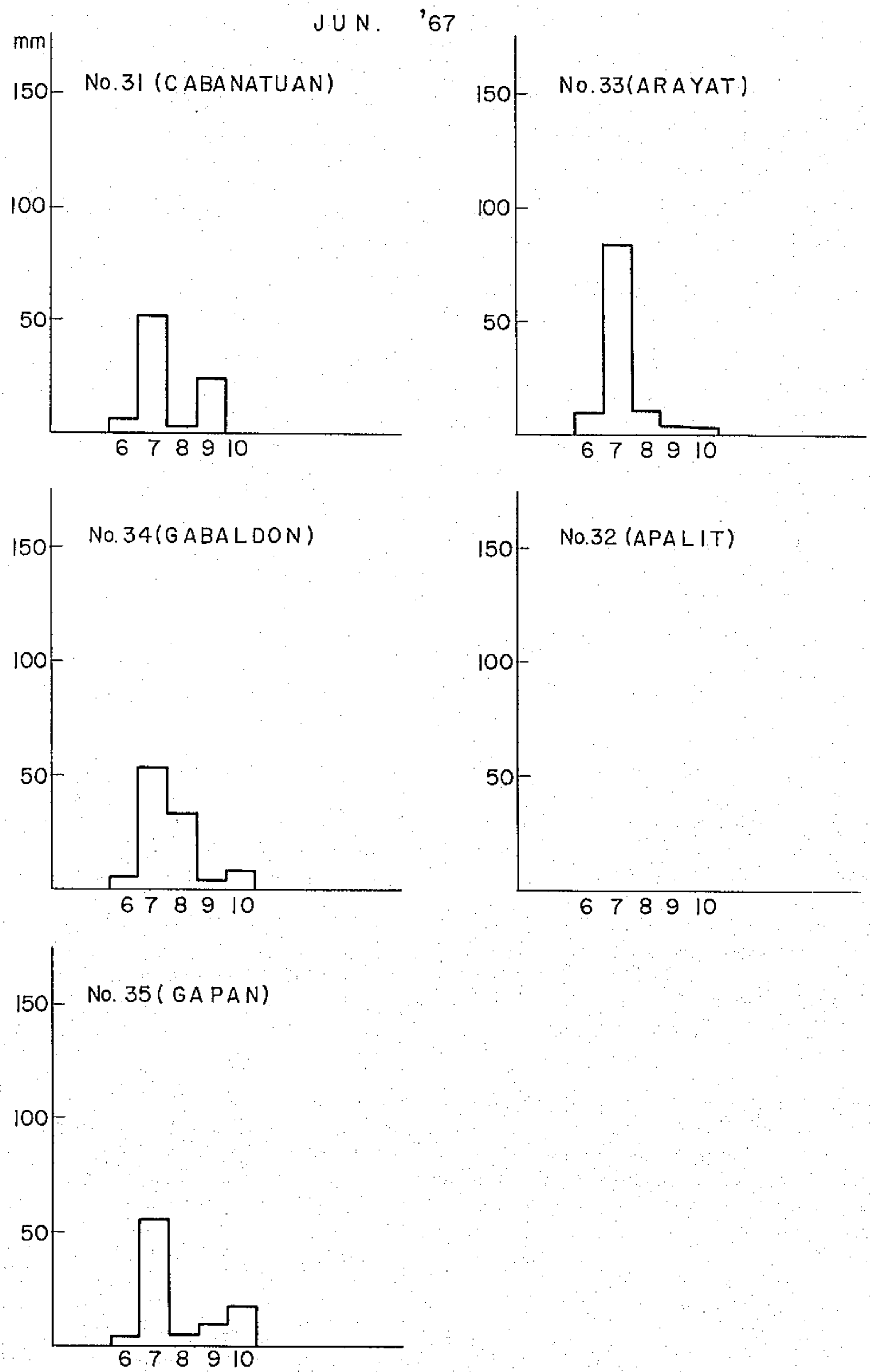


FIG. 3-6 (2) DISTRIBUTION OF DAILY RAINFALL

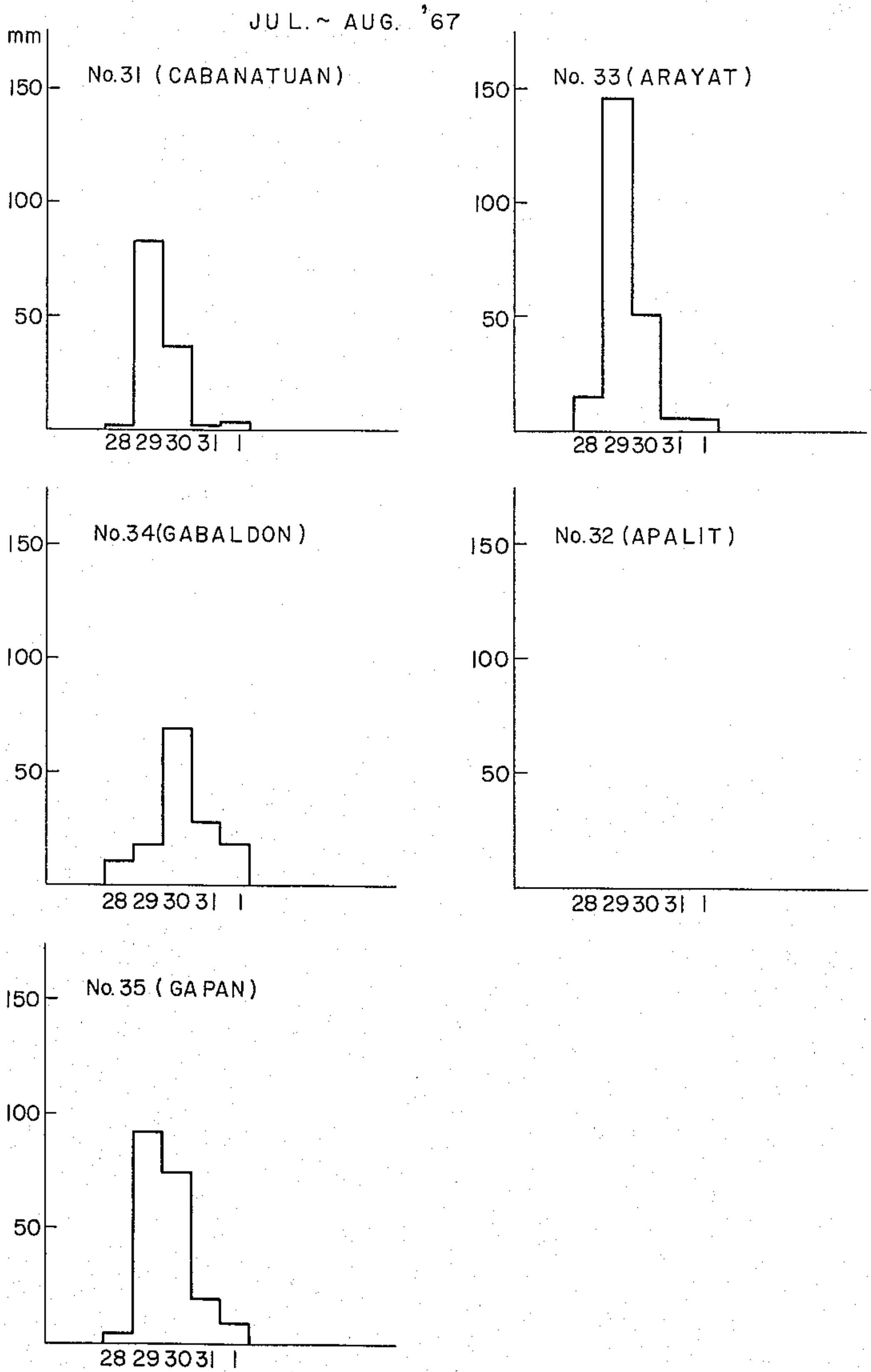


FIG. 3-6 (3) DISTRIBUTION OF DAILY RAINFALL

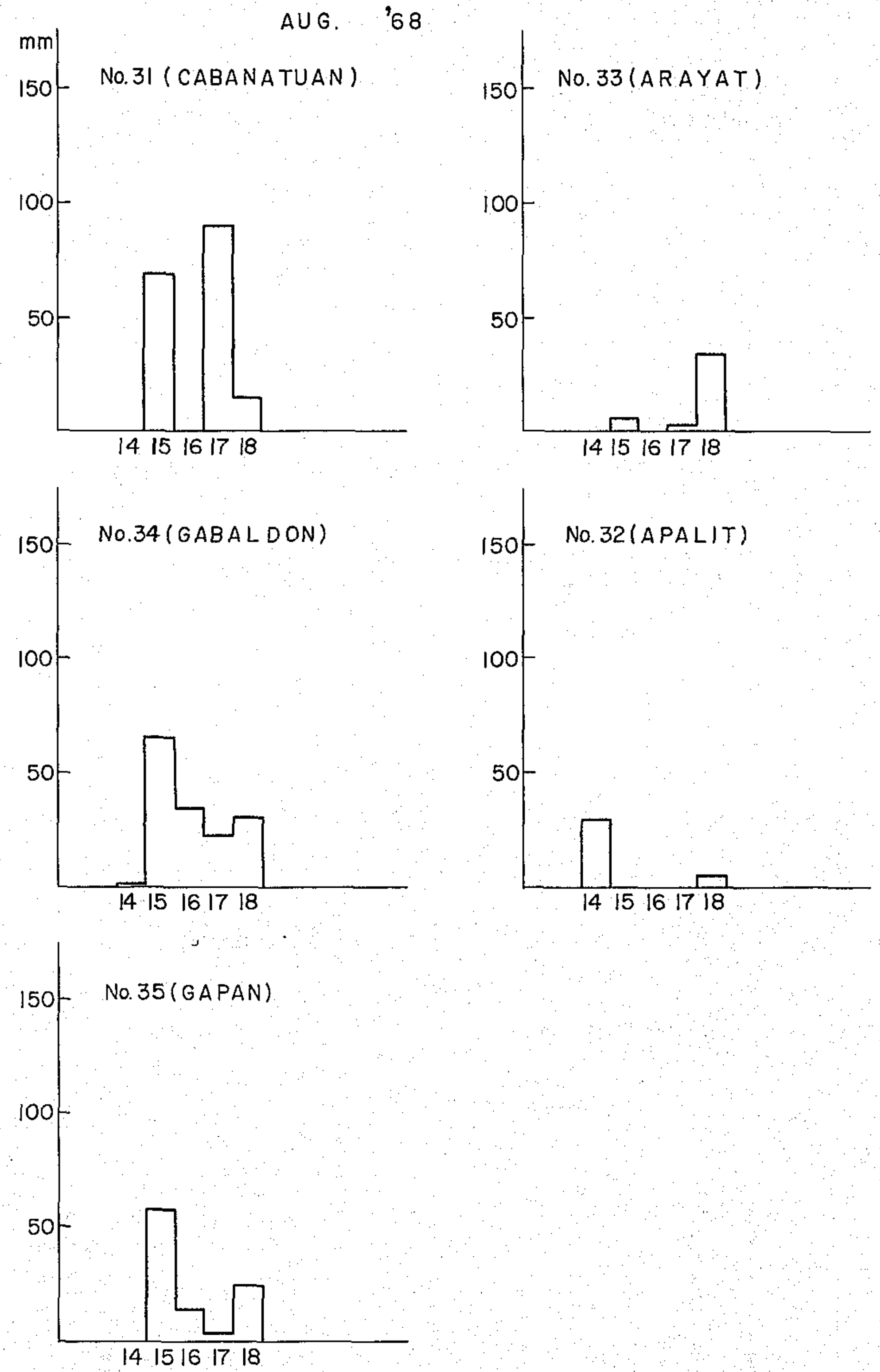


FIG. 3-6 (4) DISTRIBUTION OF DAILY RAINFALL

AUG. ~ SEP. '68

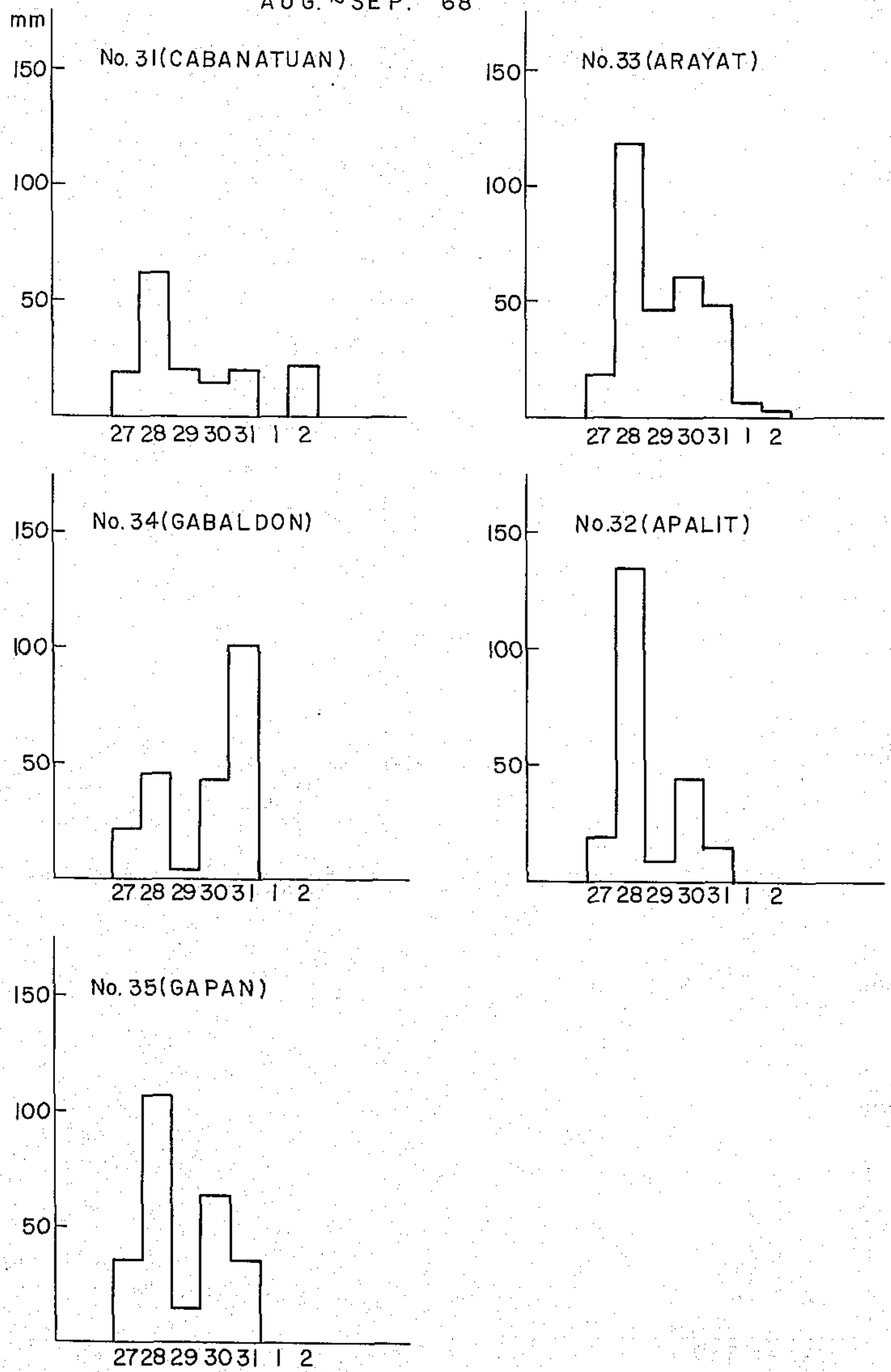


FIG. 3-6 (5) DISTRIBUTION OF DAILY RAILYFALL

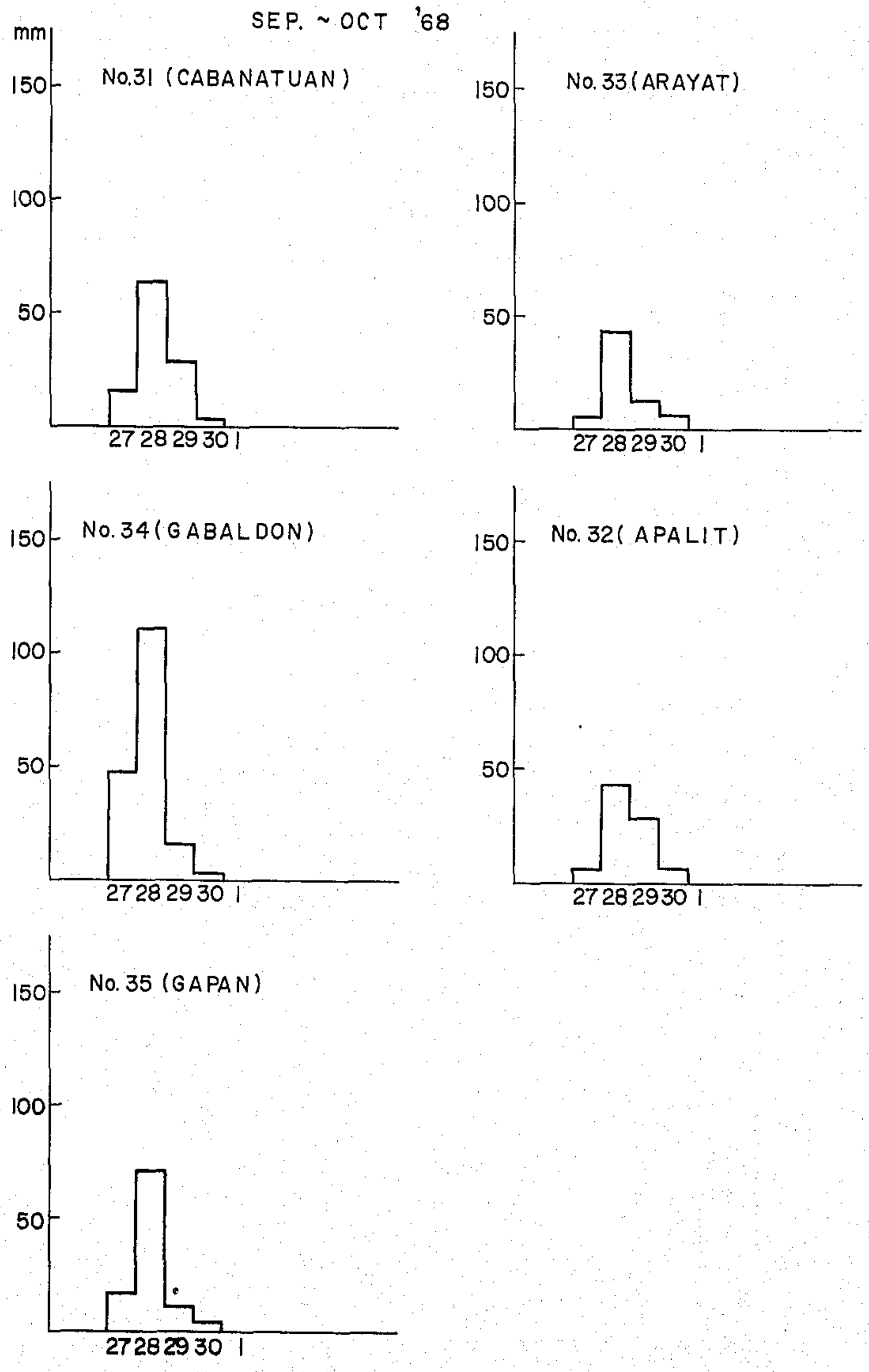


FIG. 3-6 (6) DISTRIBUTION OF DAILY RAINFALL

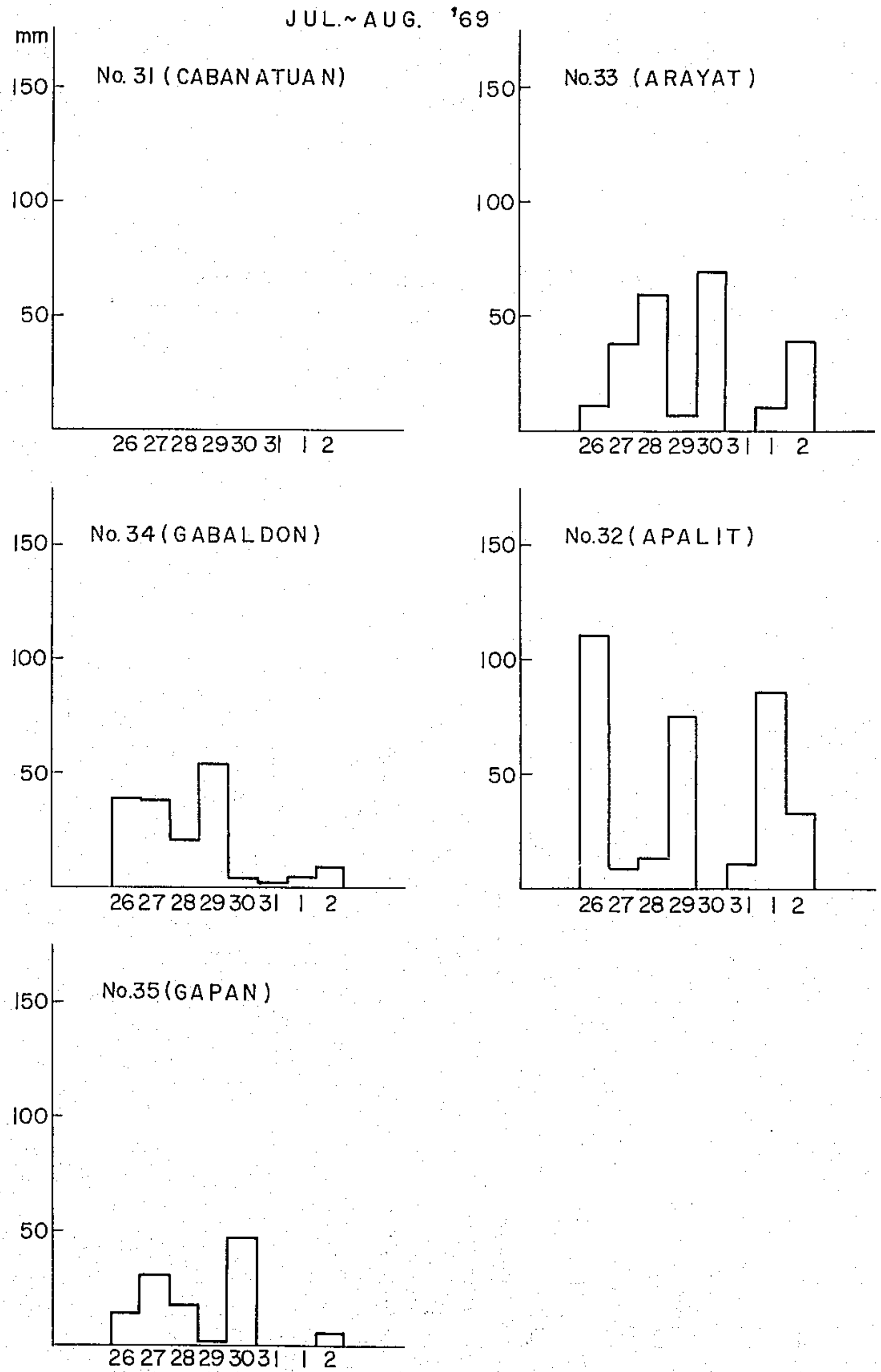


FIG 3-7 (1) DISTRIBUTION OF DAILY RAINFALL

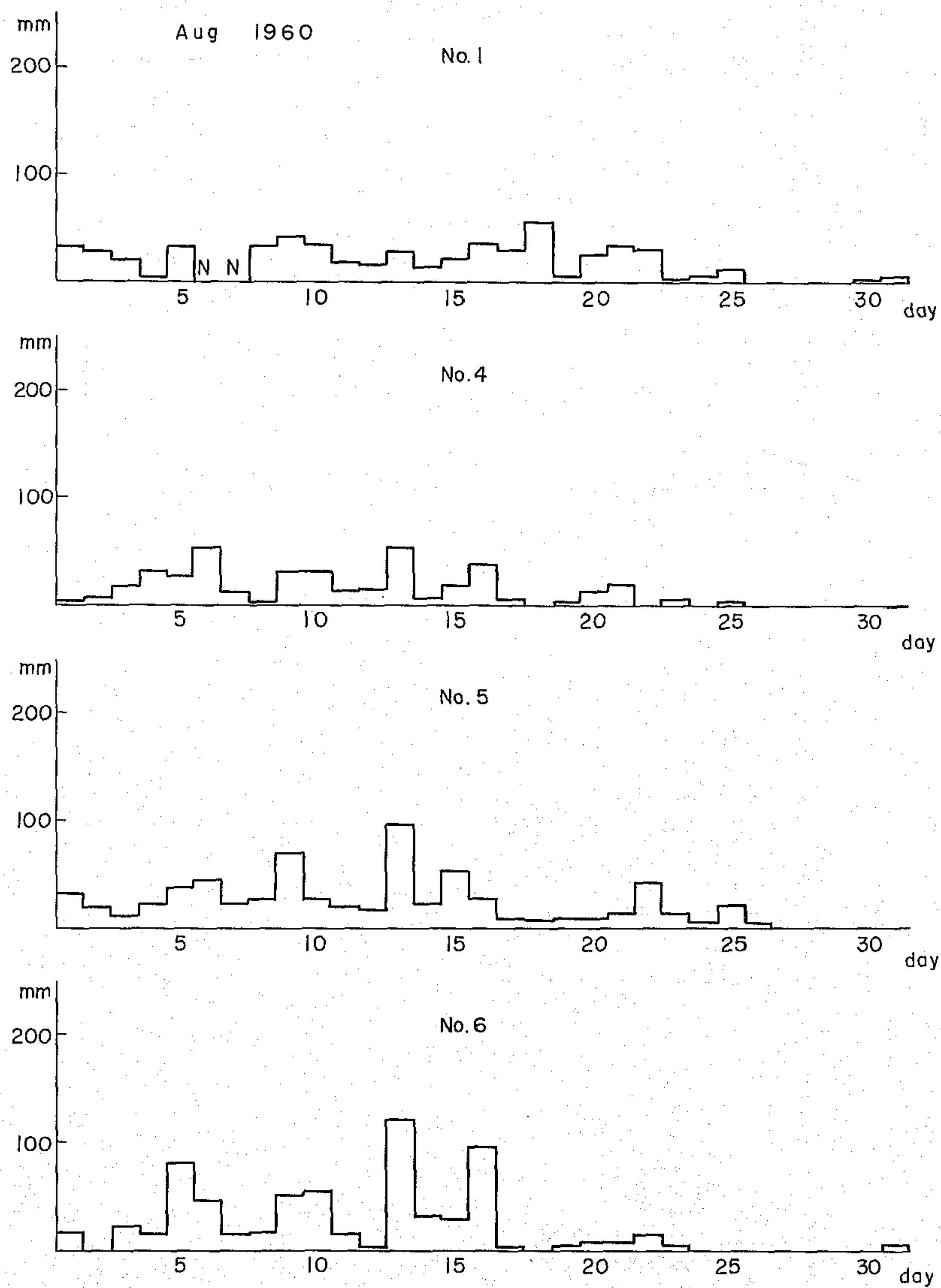


FIG. 3-7 (2) DISTRIBUTION OF DAILY RAINFALL

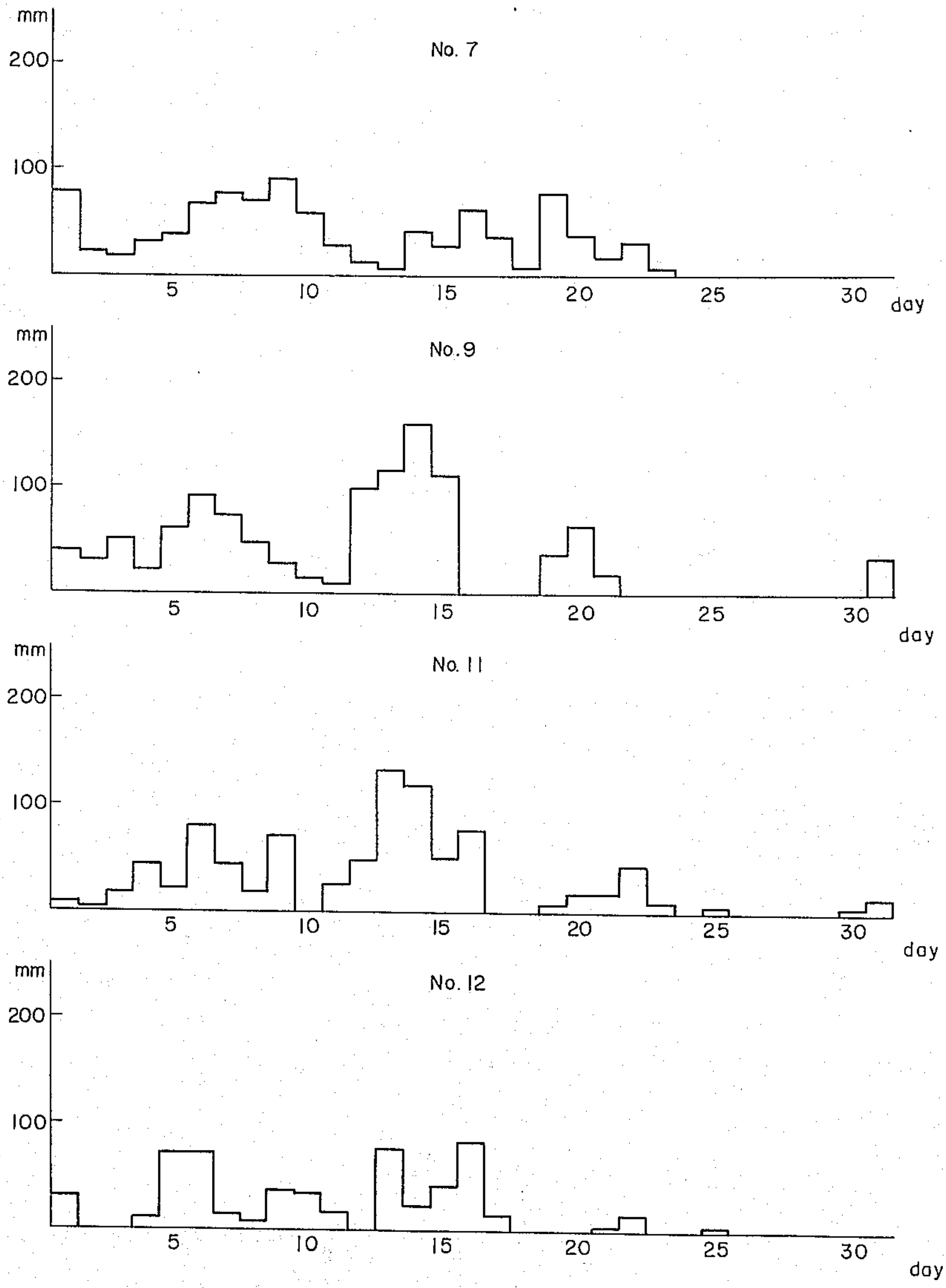


FIG. 3-7 (3) DISTRIBUTION OF DAILY RAINFALL

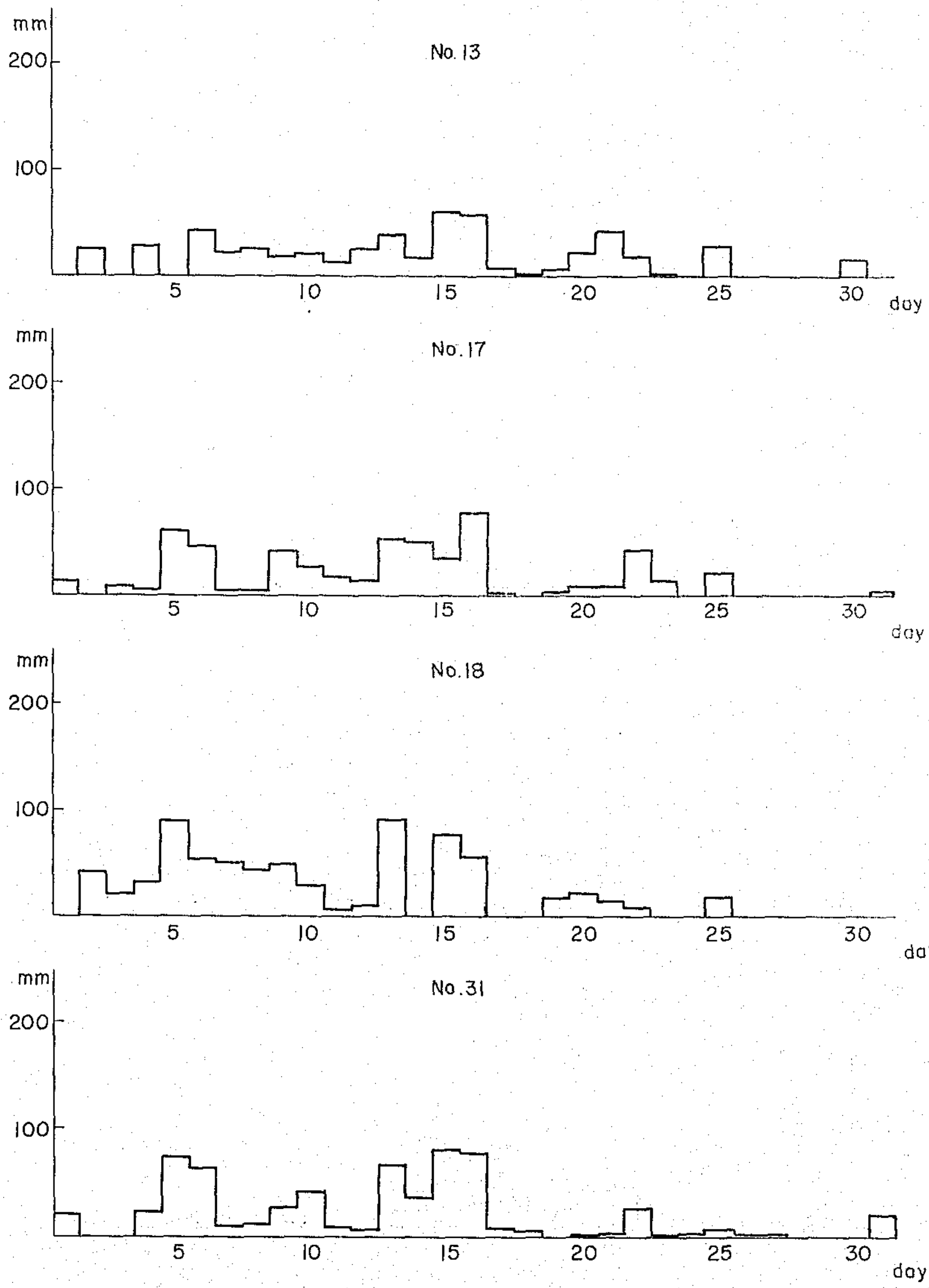


FIG. 3-7 (4) DISTRIBUTION OF DAILY RAINFALL

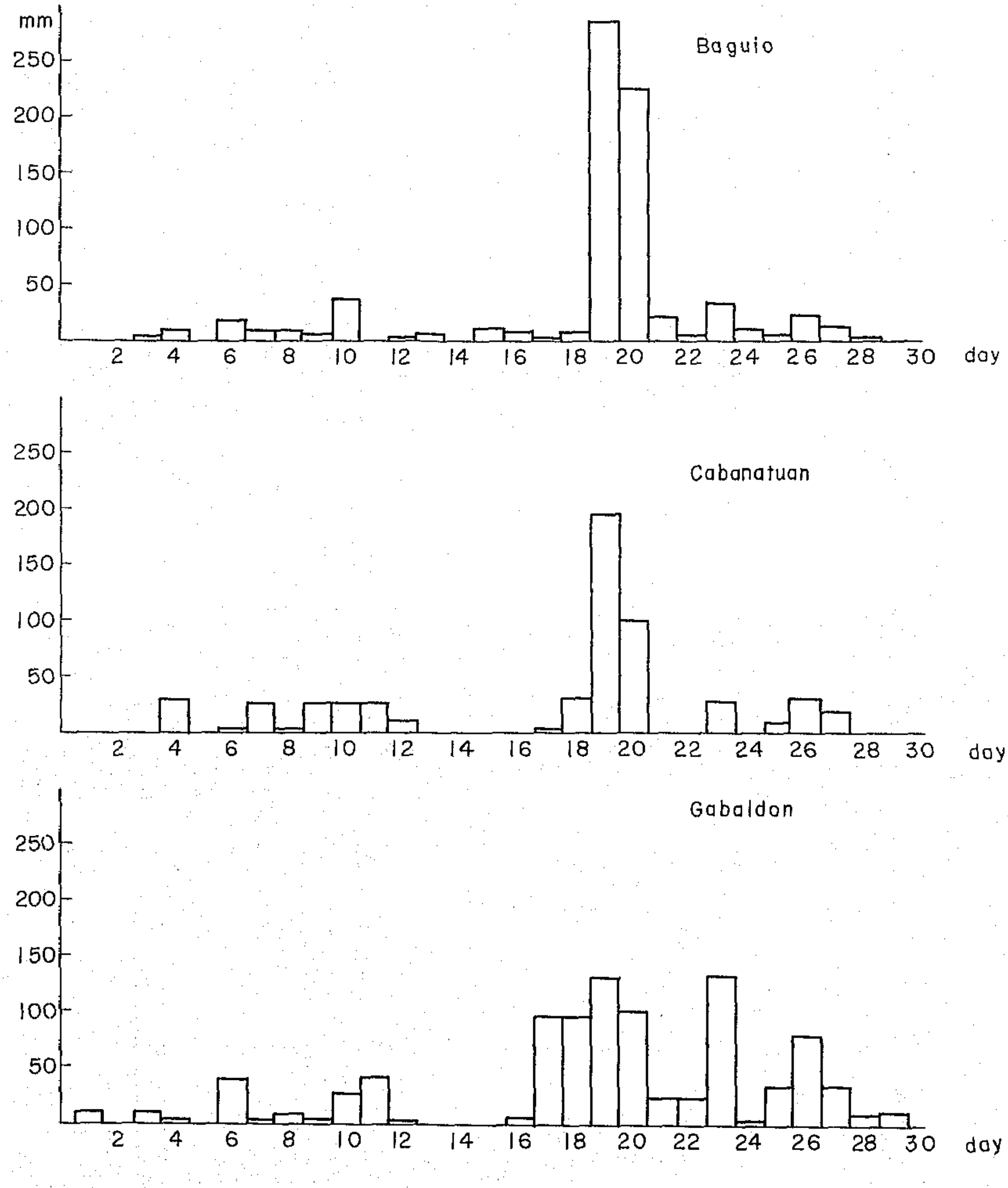


FIG. 3-7 (5) DISTRIBUTION OF DAILY RAINFALL

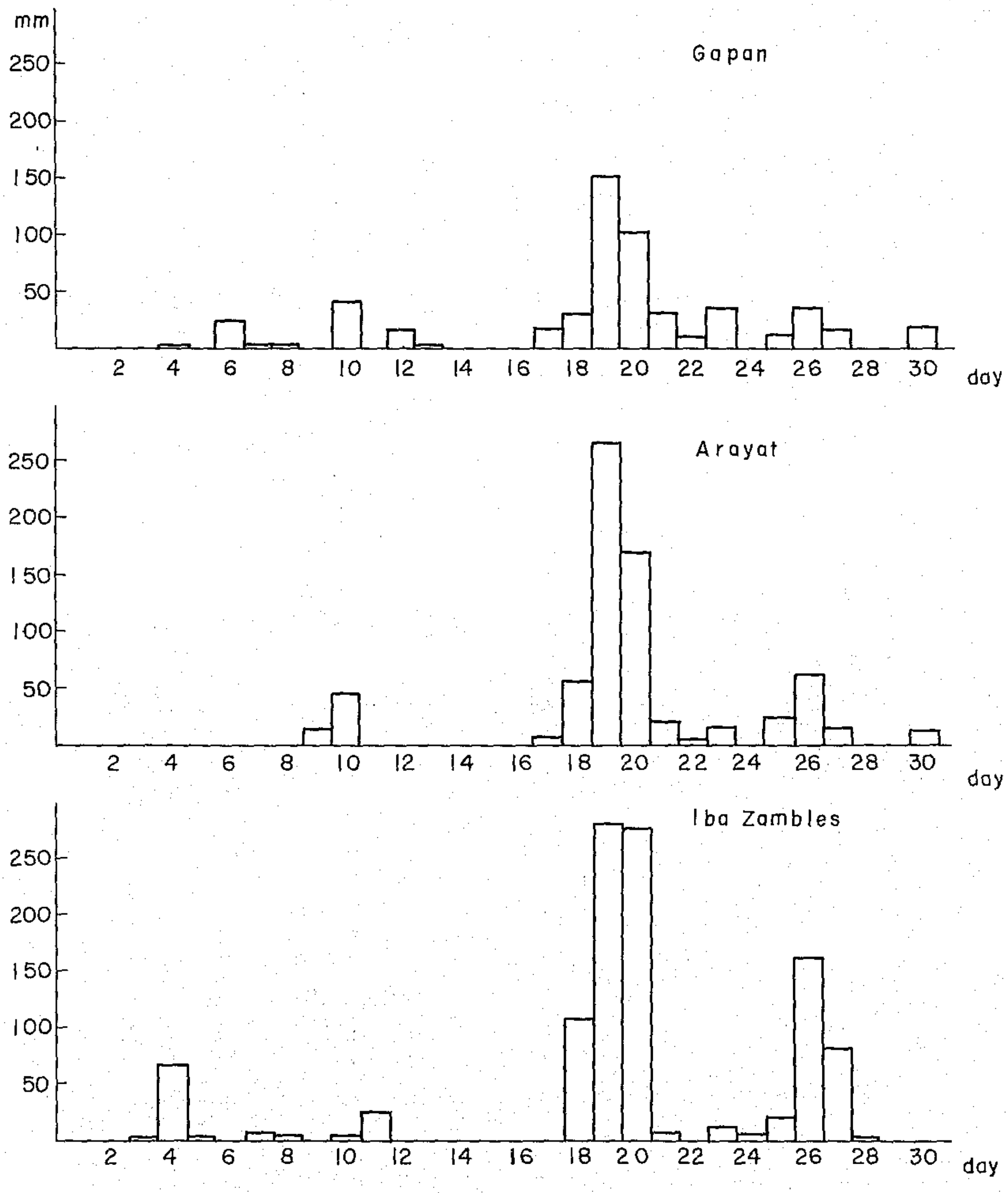


FIG. 3-7 (6) DISTRIBUTION OF DAILY RAINFALL

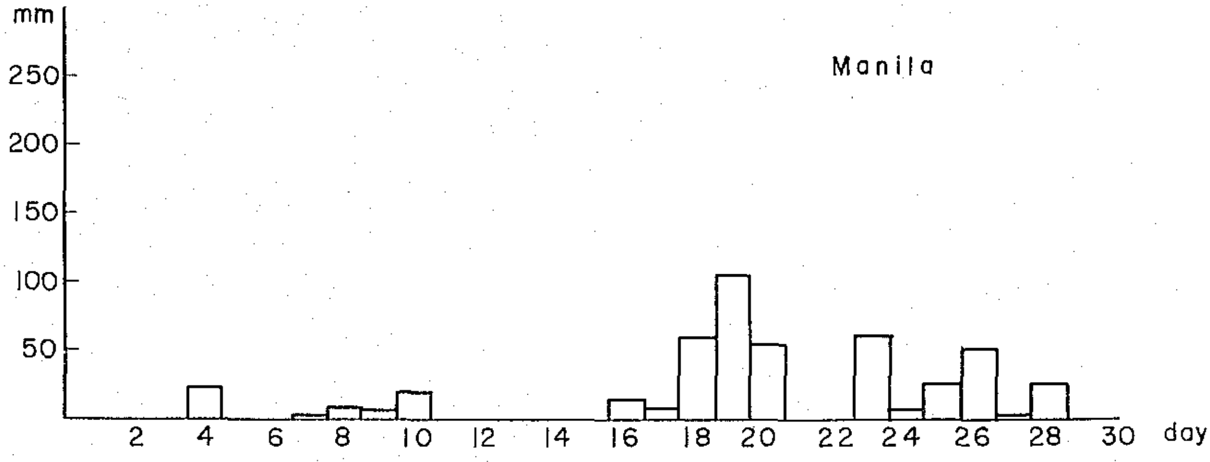


FIG. 3-8 (I) SIMPLE CORRELATION OF DAILY RAINFALL

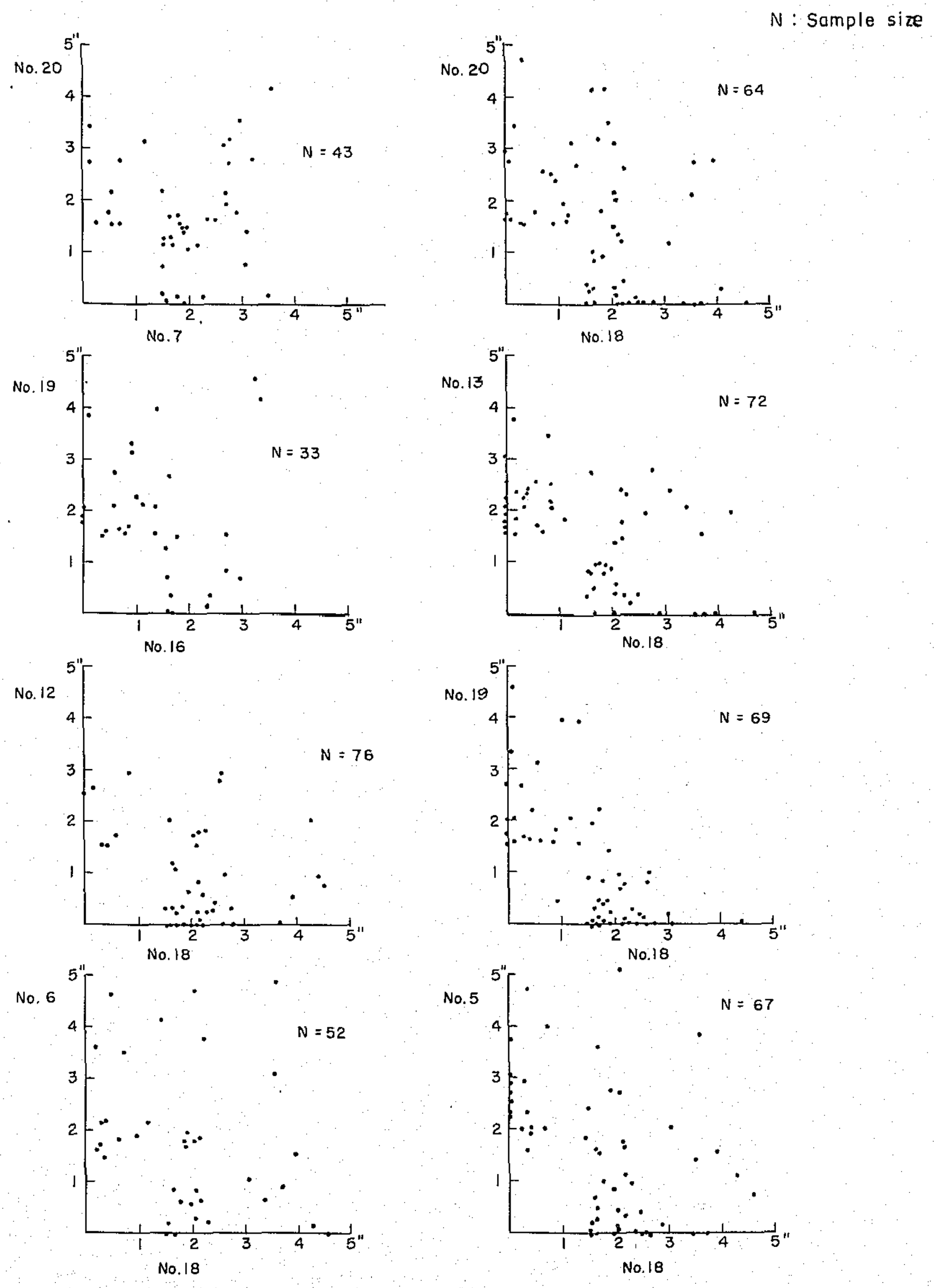


FIG. 3-8 (2) SIMPLE CORRELATION OF 2 DAYS RAINFALL

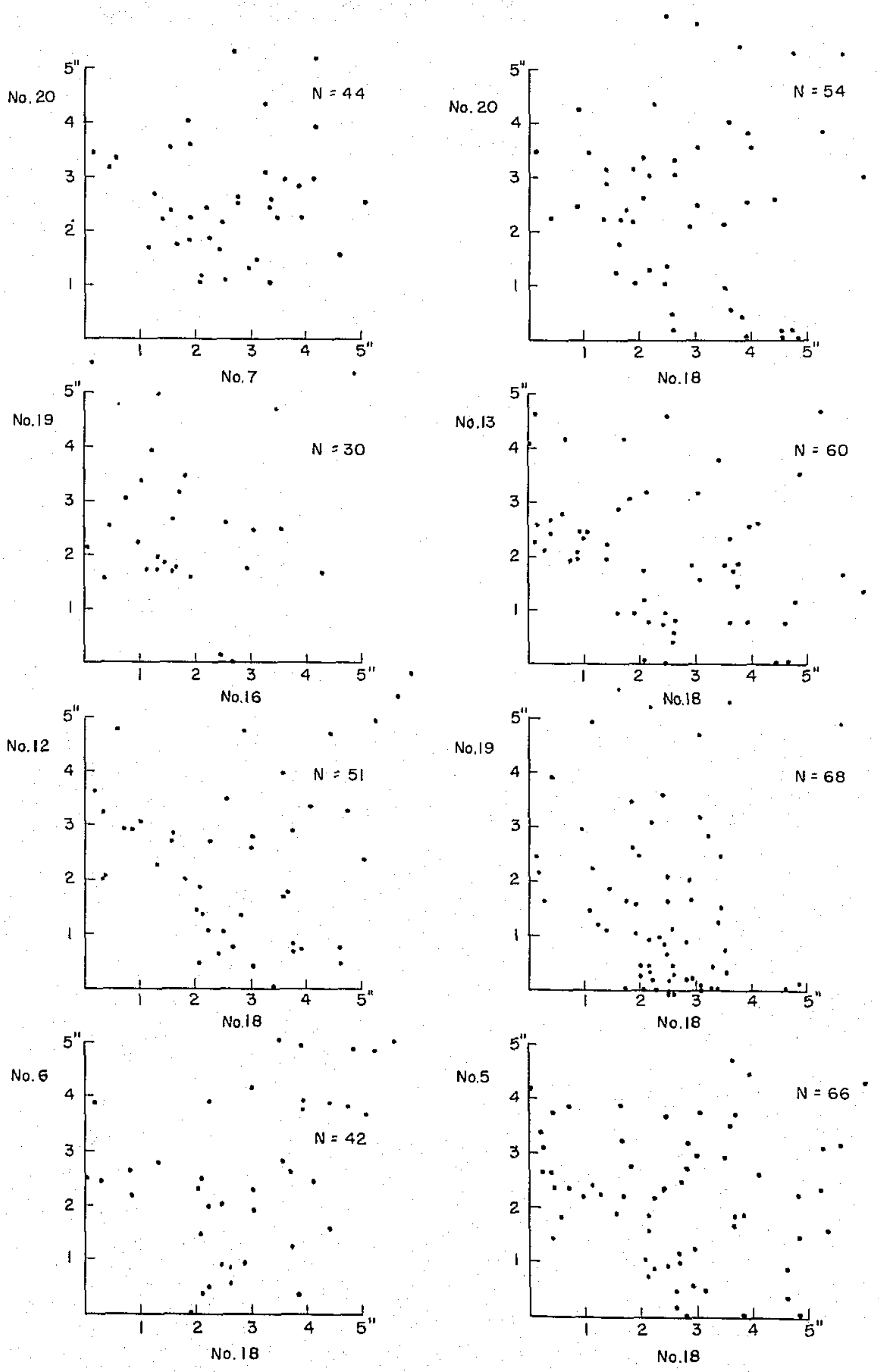


FIG. 3-9 CORRELATION COEFFICIENTS

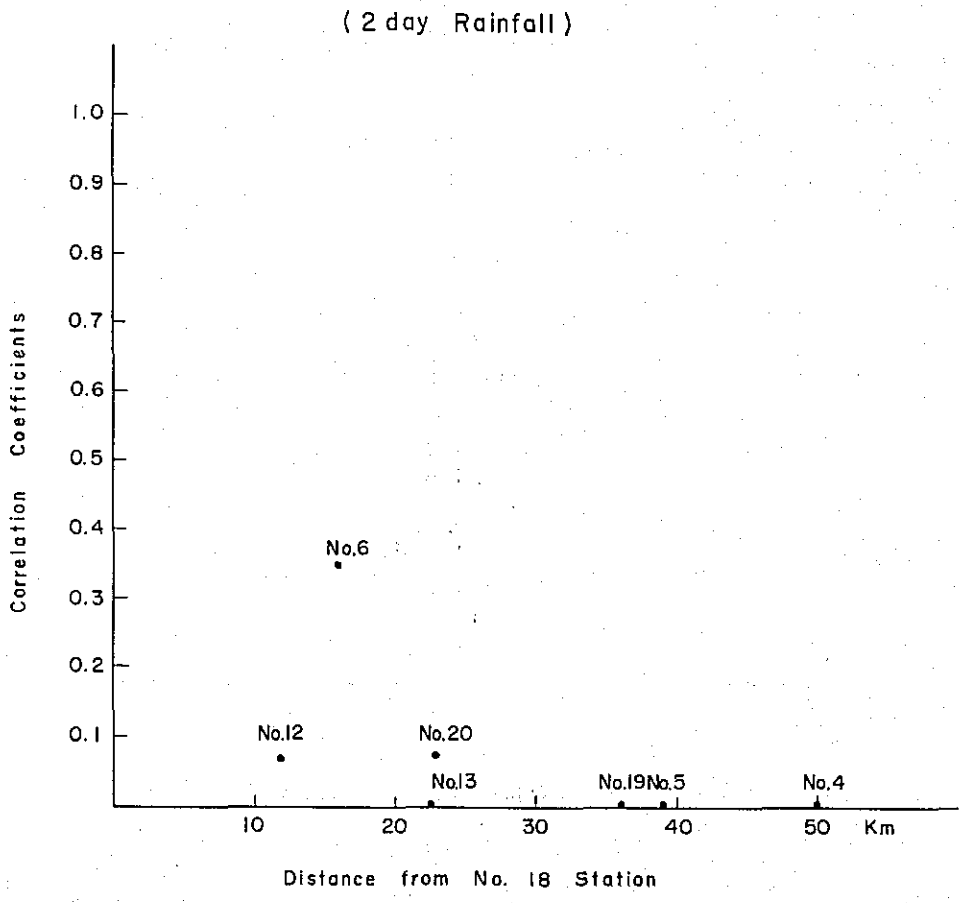


FIG. 3-10 MAXIMUM DURATION CURVE

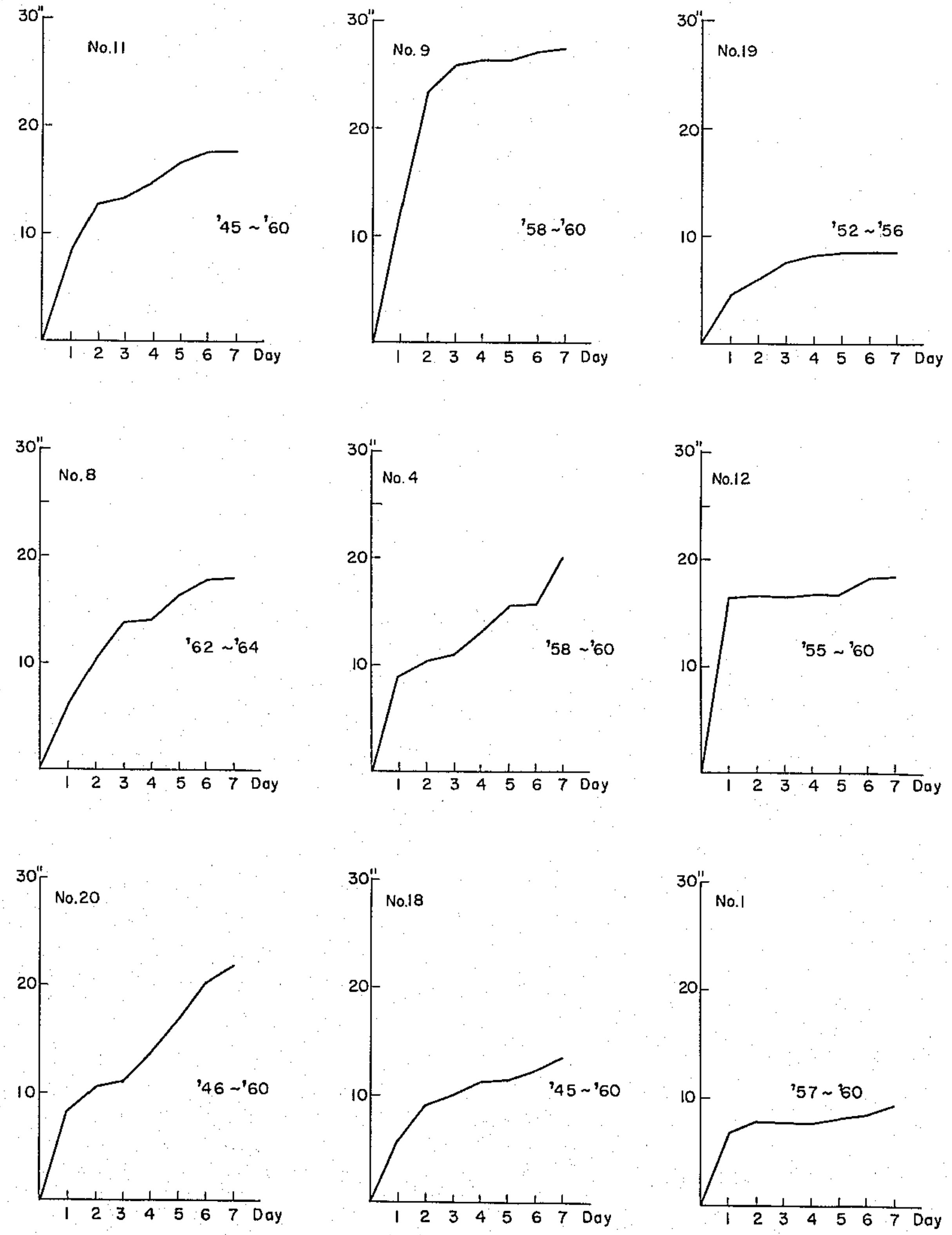
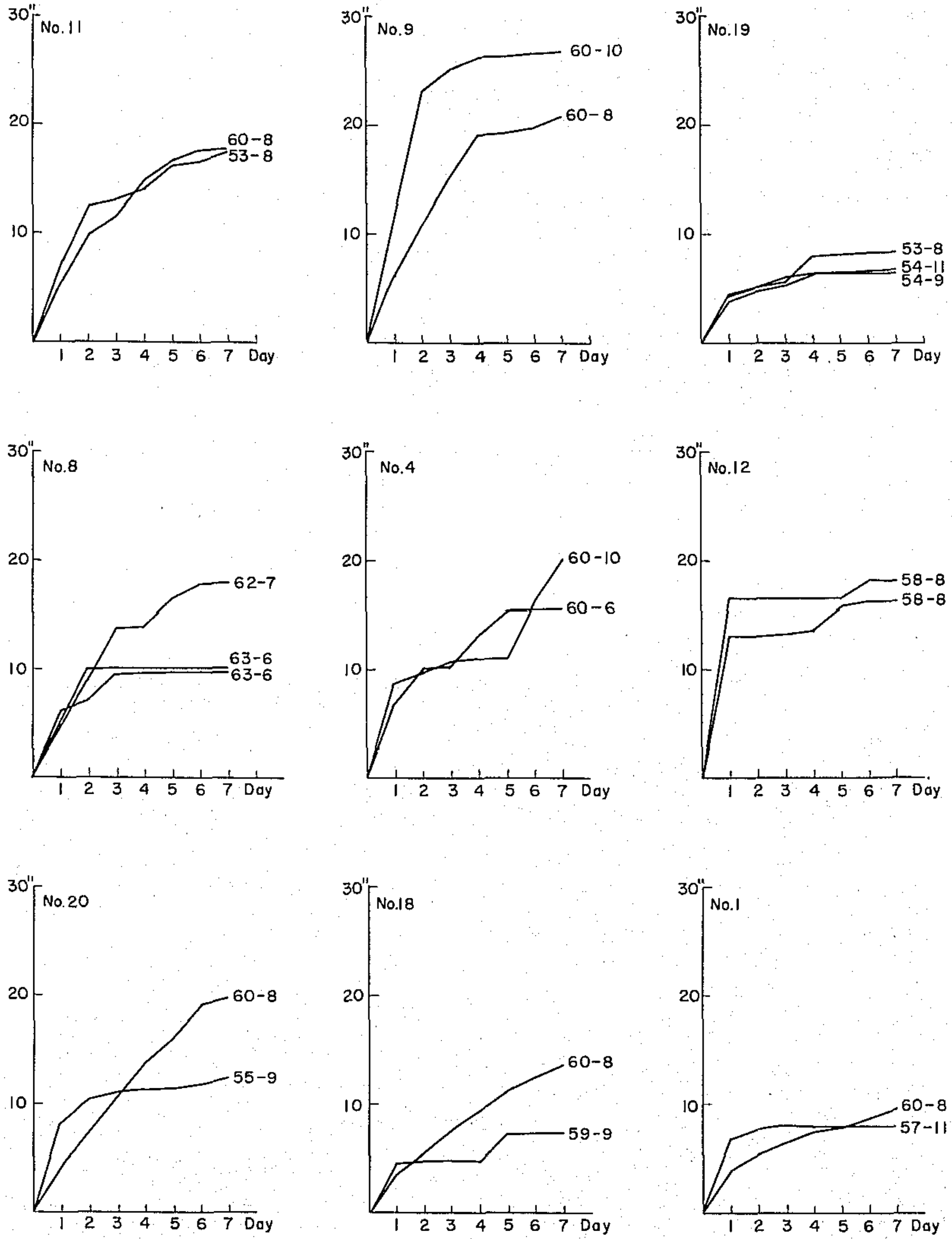


FIG. 3-11 DURATION CURVE



3-5 Characteristics of Time Distribution

Comparison of mass curve of hourly rainfall intensities in between the gauging stations. In Fig. 3-12 are arranged the percentages of cumulative hourly rainfall as to the total rainfall of the same day from obtained hourly rainfall data. As is clear from the figure, no similarity is recognized between the gauging stations. It may be understood that it is entirely meaningless to estimate the characteristics of time distribution of rainfall from the data of adjacent gauging stations. Some analyses are made in the above on the basis of the data obtained . However, the data include many localized heavy rainfalls which are not suitable in order to draw a general conclusion about the rainfall characteristics in the river basin. Therefore, it is desired to further the examination of the rainfall pattern associated with floods collecting much more data and to apply the results to the future development of flood forecasting technique.

3-6 Major Floods in Recent Years

Major floods recorded in documents or estimated as of the equivalent scale from the available data are listed as follows, showing the similar distribution to the frequency distribution of flood occurrence described in section 3-1.

August 1937,
August 1948,
October 1950,
August 1960,
July 1962, and
May 1966.

In this section, the situations of these major floods are described on the basis of the data so far available to the Survey Team.

Flood in August 1948

Precipitation:

The average rainfall on the basin was 580 mm/month in July and 320 mm/month in August. The characteristic of rainfall in this year was that they occurred in several groups. Among them, the rainfall of about 150 mm on 24th and 25th of July and that of about 170 mm during 21st-24th of August were remarkable. Besides these, there were rainfalls during 1st-3rd of September and 24th-27th of September.

Runoff:

The discharge of the Pampanga River at San Agustin reached the peak of 2080 m^3/s on 23rd of August and after having decreased to 500 m^3/s on 31st of the same month it again reached the peak of 2,200 m^3/s on 2nd of September. In particular, there was no rainfall to be recognized as the cause of the latter flood. It needs to pay attention to what extent such phenomenon will occur, although it cannot be revealed until denser network of observation will be operated.

Flood in October 1950

Precipitation:

The rainfall in September of this year exceeded 400 mm and a series of rainfalls occurred from the end of September to the beginning of October. In particular, it rained about 200 mm from 1st to 4th of October. This rainfall caused a big flood on the conditions that the basin had already stored sufficient water as it was the end of rainy season. After that, it passed to dry season without noticeable precipitation.

Runoff:

After the flood of medium size in September, the discharge of the Pampanga River was around 300 m^3/s at San Agustin when the basin received the rainfall, which caused the sudden increase in its discharge on 2nd of October followed by the peak discharge of 1370 m^3/s on 3rd. Then the discharge decreased gradually.

FIG. 3-12 HOURLY CUMULATIVE RAINFALL

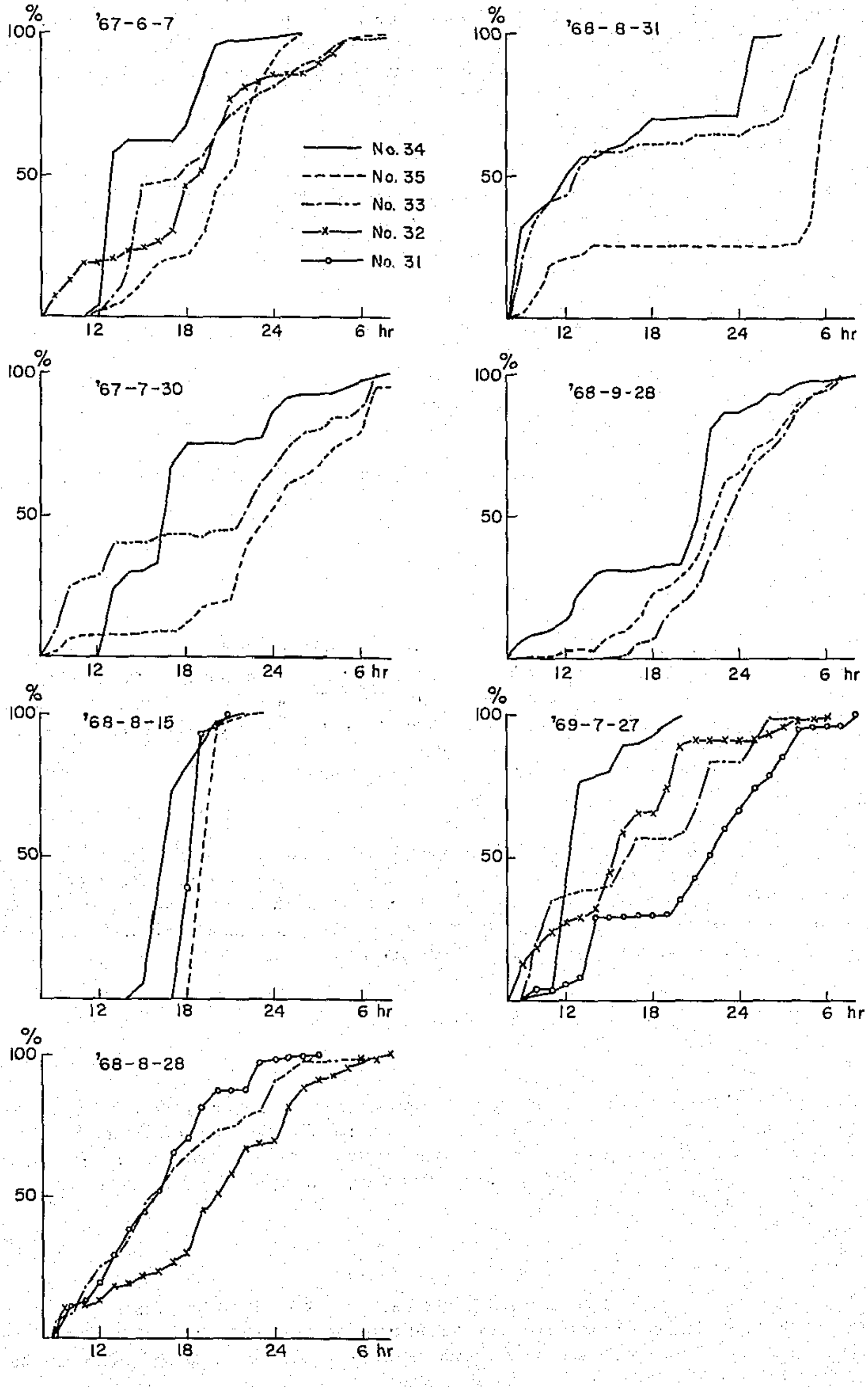


FIG. 3-13 FLOOD HYDROGRAPH OF PAMPANGA RIVER AT SAN AGUSTIN, AND HYETOGRAPH AT SAN JOSE AT THE TIME OF THE FLOOD IN AUGUST AND SEPTEMBER 1948

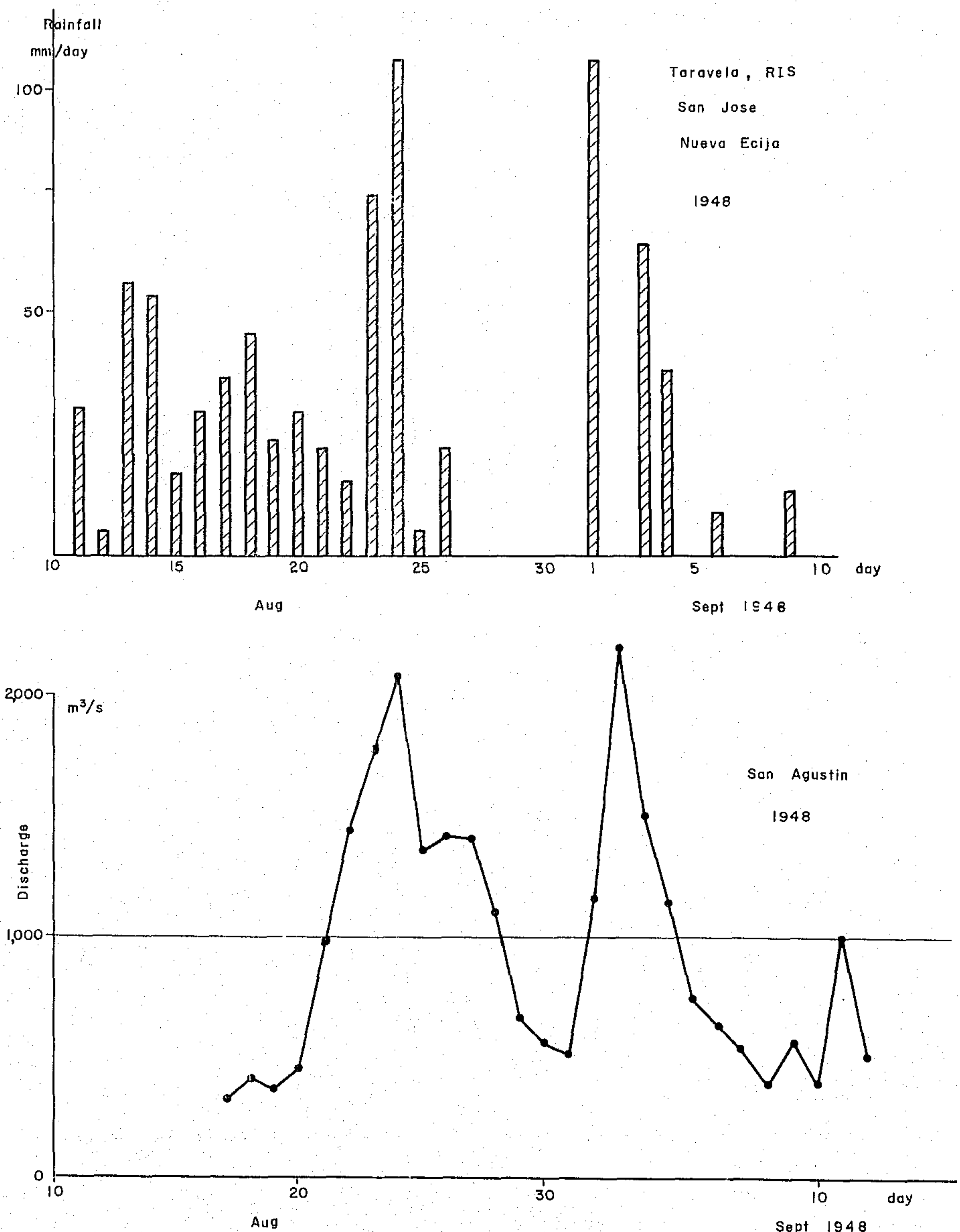
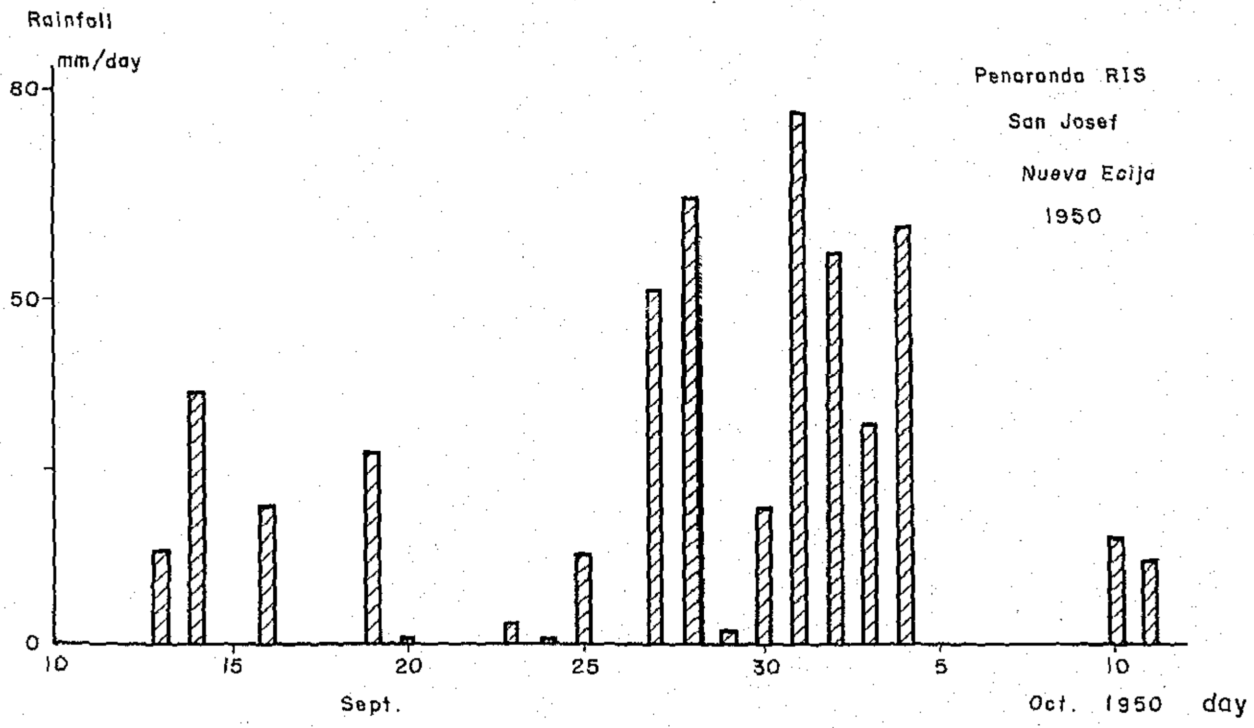
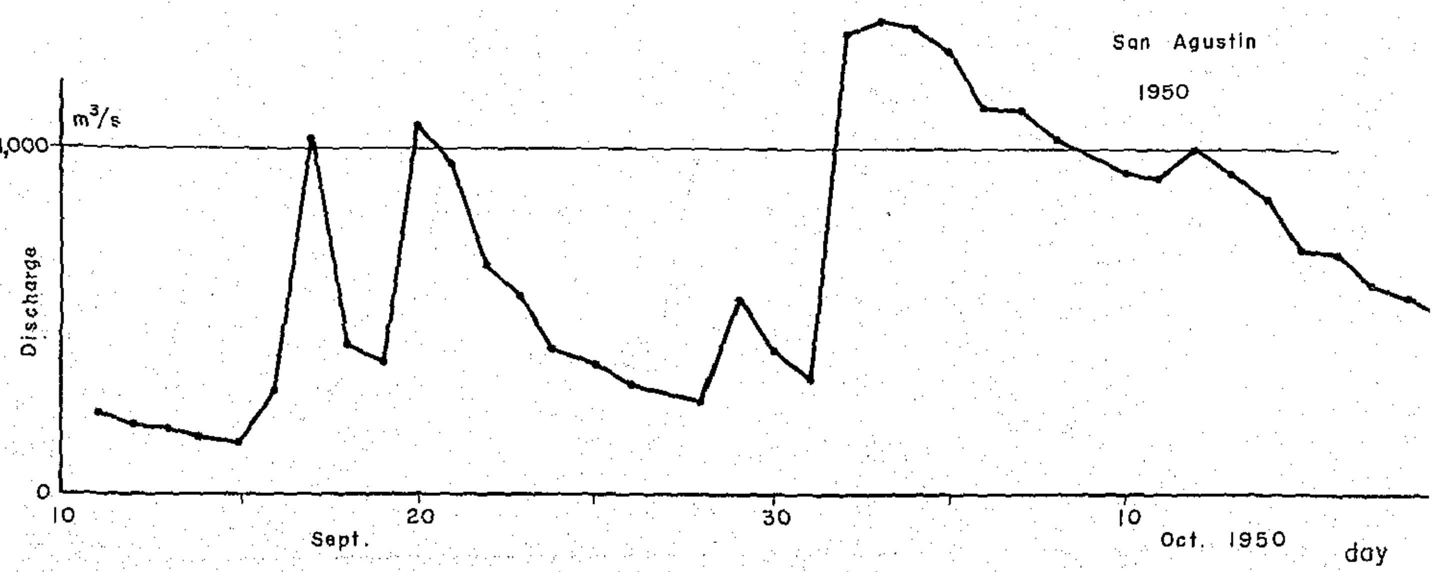


FIG. 3-14 FLOOD HYDROGRAPH OF PAMPANGA RIVER AT SAN AGUSTIN AND HYETOGRAPH AT SAN JOSEF, AT THE TIME OF THE FLOOD IN AUGUST AND SEPTEMBER 1950.





Flood in August 1960

Precipitation:

There was much rainfall in 1960, and particularly in July the lower basin received much rainfall concentrated in the last part of the month. In August, also large rainfall was recorded in general, reaching 700 mm/month of the average rainfall in the basin which corresponds to about 6,000 million m^3 of water only in the upper stream basin of Calumpit.

The maximum daily rainfall in the basin occured from, about 13th to 16th, with the largest magnitude of 160 mm/day. The upper basin of the Pampanga River received comparatively small precipitation and the upper stream of the Rio Chico River and the basin of Candaba Swamp received much.

The upper stream of the Rio Chico River received the first group of rainfall from 6th to 10th, ranking the first in the volume. The second group of rainfall fell from 13th to 16th, which included the highest peak although being the second in the volume. The third rainfall in a smaller scale came on around 20th.

In the southeast of the Pampanga River Basin, the first group of rainfall fell from 5th to 9th, ranking the second in the magniture. The second group of rain fell from 12th to 16th was the first both in the volume and in the peak intensity. The rainfall from 20th to 22nd was small.

Runoff:

At San Agustin on the Pampanga River, the peak discharge of 2,372 m^3/s was observed at 2 hours on 17th of August. At Pulilan on the Angat River, that of 1,673 m^3/s was gauged at 22 hours on 14th of August. These were respectively 0.37 and 1.75 $m^3/sec/km^2$ as expressed by specific runoff. There are distinct differences in the occurring time of the peak discharge and the specific runoff between these two rivers.

The peak discharges of the Candaba tributaries such as the San Miguel and the Garlang Rivers occurred on 14th. The concentration time of the runoff is less than one day. The peak discharge of Candaba Swamp as a whole occurred on 14th. The characteristic of this flood was that it had not only a great peak discharge but also a long duration. At San Agustin, it needed 21 days to reach the peak discharge since the daily discharge had exceeded 100 m^3/s on 27th of July. As the flood of medium size came on 10th of September, it was only 23rd of November when the daily discharge decreased to less than 100 m^3/s, taking about 120 days as from 27th of July.

Flood in July, 1962

Precipitation:

Although the magnitude of rainfall in the basin as a whole is not clear due to scarce data for July 1962, San Agustin received 350 mm of rainfall in total during three days from 19th to 21st, without any noticeable rainfalls around that period. Comparing with the other cases, it was a special pattern of a single rainfall, though the rainfall area deemed to be moving in the basin with one or two days lag.

Runoff:

At San Agustin on the Pampanga River, the peak discharge of 2,316 m^3/s was observed at 17 hours on 23rd of July. In the Angat River, that of 1,703 m^3/s was gauged at 1.30 hours on 21st of July. The peak discharges in the San Miguel, the Maasim and the Garlang Rivers occurred on 21st of July. The peak inflow into the basin of the Candaba Swamp as a whole occurred on 21st of July. The difference in the time of these peaks and in the specific runoff showed the same pattern as that of the flood in 1960. However, the duration of this flood was short in spite of its great peak discharge. The reason is deemed that it was a single rainfall although its areal distribution was not clear.

At San Agustin, it took five days for the daily discharge to reach the peak after it had exceeded 100 m^3/s on 20th of July. After that, the flood of midium size came in September, and it was on 24th of October when the daily discharge decreased below 100 m^3/s.

FIG. 3-15 FLOOD HYDROGRAPHS OF PAMPANGA RIVER AND RIO CHICO AT MANACNAC AND LA PAZ, AND HYETOGRAPH AT LOMBAY AND SAN JOSE, AT THE TIME OF THE FLOOD IN AUGUST 1960.

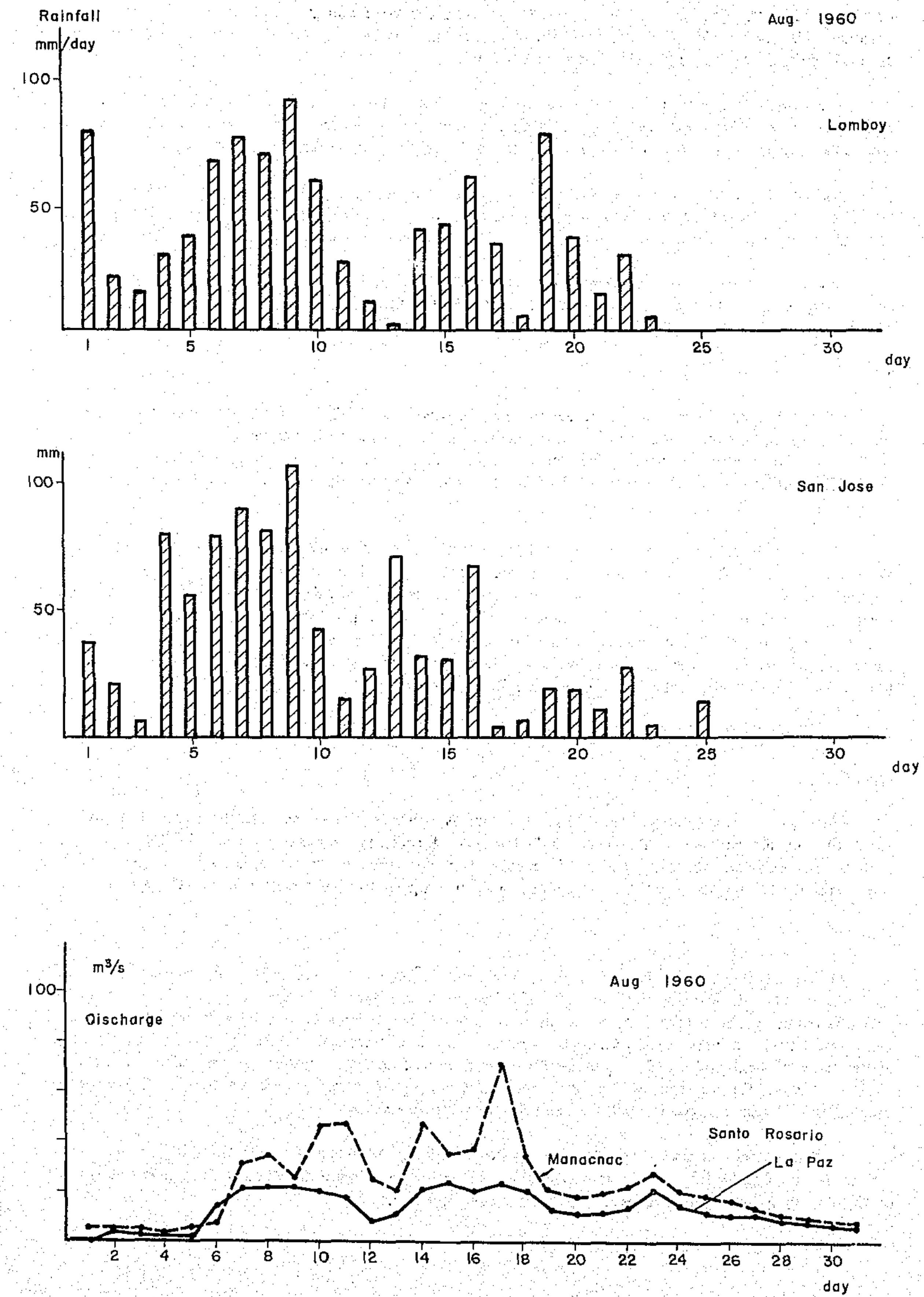


FIG. 3-16 FLOOD HYDROGRAPHS OF PAMPANGA RIVER AND ANGAT RIVER AT SAN AGUSTIN, DUCMA AND PULILAN, AND HYETOGRAPHS OF MADLUM, ANGAT

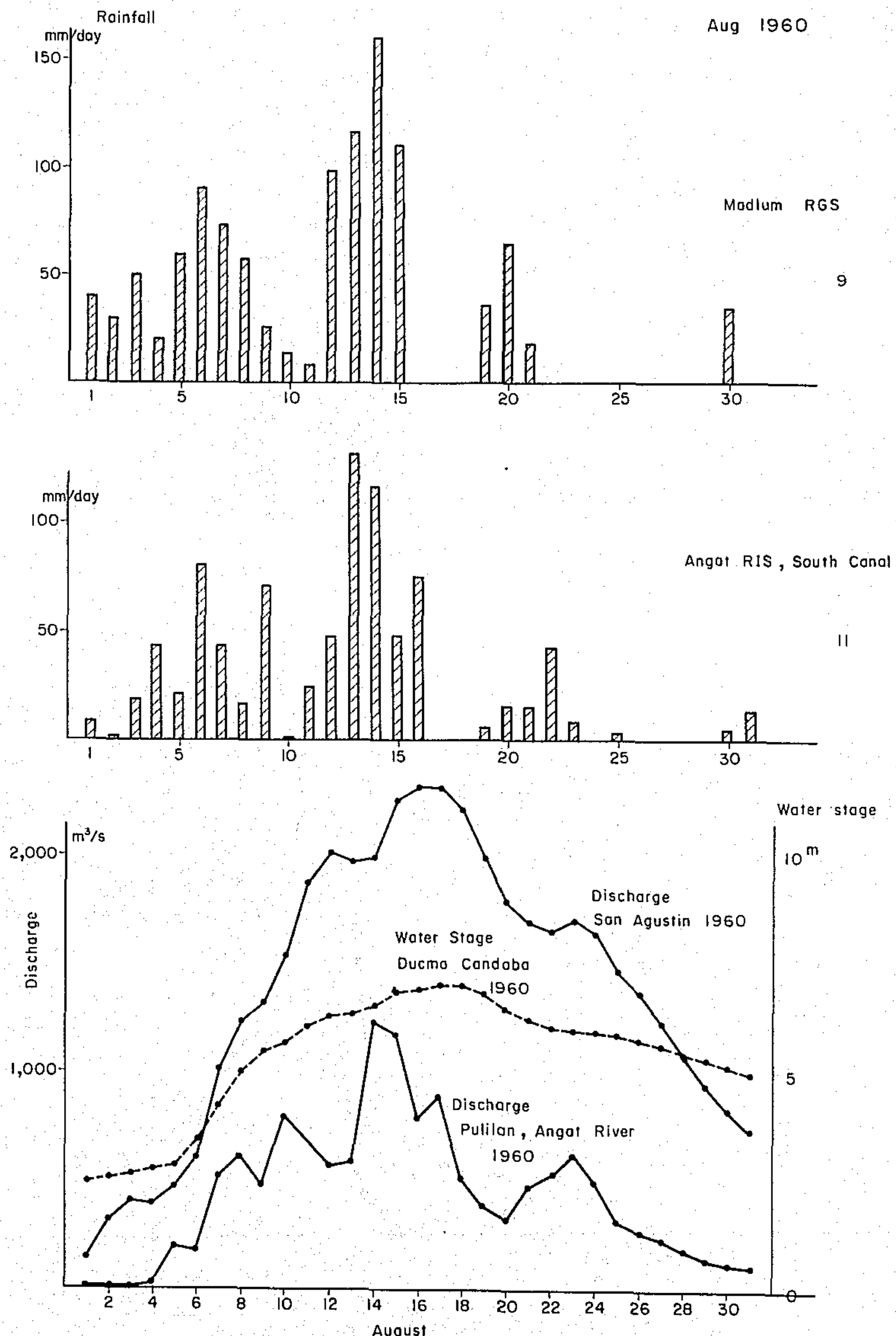
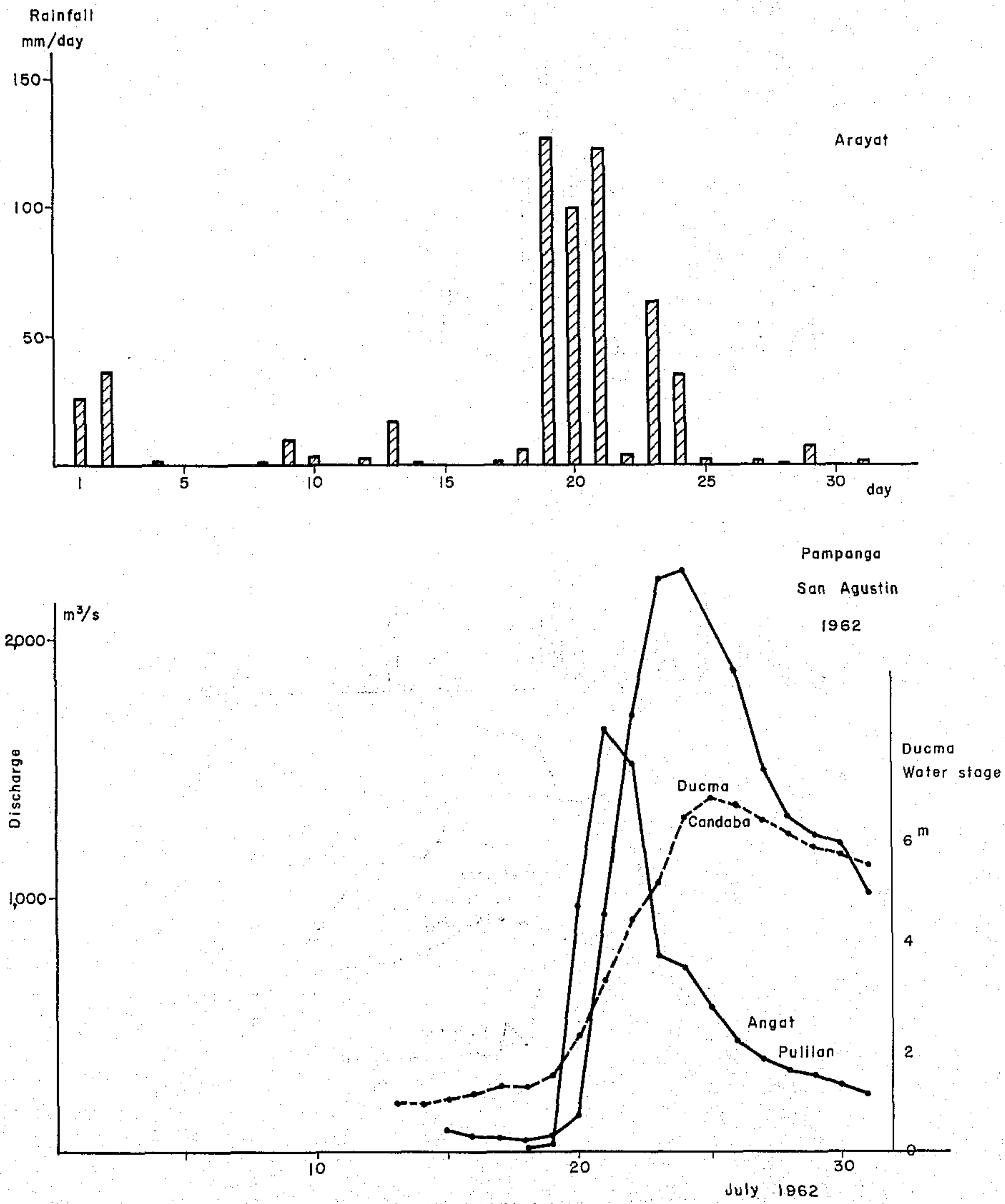


FIG. 3-17 FLOOD HYDROGRAPHS OF PAMPANGA RIVER AND ANGAT RIVER AT SAN AGUSTIN, DUCMA AND PULILAN, AND HYETOGRAPH AT ARAYAT, AT THE TIME OF THE FLOOD IN JULY 1962.



Flood in May, 1966

Precipitation:

Early in the month, the rainfall of about 40–50 mm/day fell intermittently, but it stopped raining simultaneously be around 13th–16th. Whereas, it began to rain again on 16th and the heavy rainfall hit the midstream basin of the Pampanga River concentrating on 19th, with the intensity of 260 mm/day recorded.

In the upper basins of the Pampanga and the Rio Chico Rivers, though the rainfall was intensified from about 18th but not so much as in the midstream, it continued to reach as much as 180 mm/day at the maximum on 22nd and 23rd, then it decayed.

Runoff:

At San Agustin on the Pampanga River, the daily discharge of 1,800 m^3/s was observed on 22nd of May. In the Angat River downstream from the Ipo Dam, the peak discharge was observed at 18 hours on 19th. This flood was not so severe, though it called attention because of its occurrence in recent. San Agustin, it took 4 days to reach the peak after the daily discharge had exceeded 100 m^3/s on 19th of May.

3-7 Summary of Description of Individual Flood

Precipitation:

In rainy season, rainfall groups which continue for 3 days - one week come in the Pampanga River system. The amount of rainfall of one group ranges from 200 mm to 500 mm. The rainfall group come on almost simultaneously over the whole basin but a detailed observation reveals that there are areal differences in the time and intensity of the rainfall.

Runoff:

It is pointed out that there are important differences in the time of occurrence and in the specific runoff between the runoff hydrograph of the Pampanga River at San Agustin and that of the Candaba tributaries and the Angat River. The runoff in the Pampanga River lags by about two days behind that of the Candaba tributaries and the Angat River, with the specific runoff of one severalth of the latters. This is probably due to the difference in the area of the basin and the influence of the swamp. Fig. 3-19 shows the relation between the area of the basin and the specific runoff. In the figure it is found that the specific runoff for the Angat River is the largest, that for the Pampanga River comes next and that for the Rio Chico River is the smallest.

The peak discharge of the Pampanga River at San Agustin is around 2000 m^3/s in every case. See Fig. 3-20. From the commencement to the peak it takes 3 or 5 days according to this figure, except the flood in 1960. It is the important time lag to the flood forecasting and warning procedure. This seems to be due to the retardation of the flood by San Antonio Swamp and the influence of diversion of water through the Cabiao Candaba Floodway. The duration of the flood in 1960 was very long, but that of others was comparatively short, although the discharge exceeding 1000 m^3/s at San Agustin continued for about ten days.

Rate of runoff

The rate of runoff, which depends on the distribution of rainfall gauging stations and the accuracy of discharge measurement, shows almost 1 in some cases. In the rainy season, it is well conceivable that the rate of runoff becomes 1 for the rain fell on the basin which was saturated enough with water by the antecedent rainfall. It is also conceivable that the rate of runoff is considerably less than 1 for the flood occurred in the early period of a rainy season. These considerations should be important in the future study.

FIG. 3-18 FLOOD HYDROGRAPHS OF PAMPANGA RIVER AT SAN AGUSTIN AND HYETOGRAPH AT GAPAN AND ARAYAT AT THE TIME OF THE FLOOD IN MAY 1966

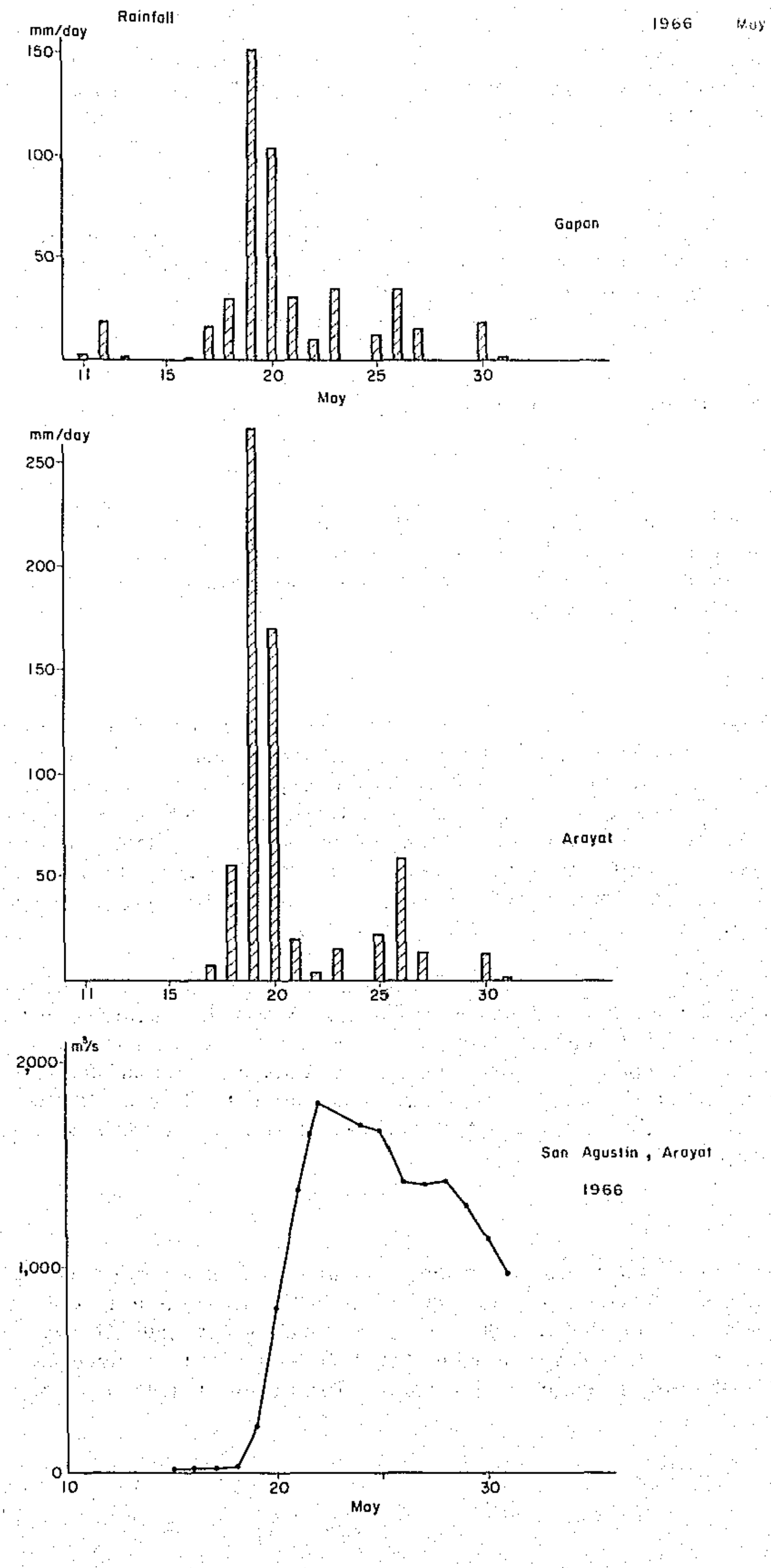


FIG. 3-19 SPECIFIC RUNOFF AND AREA OF BASIN (BASED ON THE PEAK VALUES OF THE FLOOD IN 1962 THE FLOOD IN 1960 SHOWED THE SAME TREND)

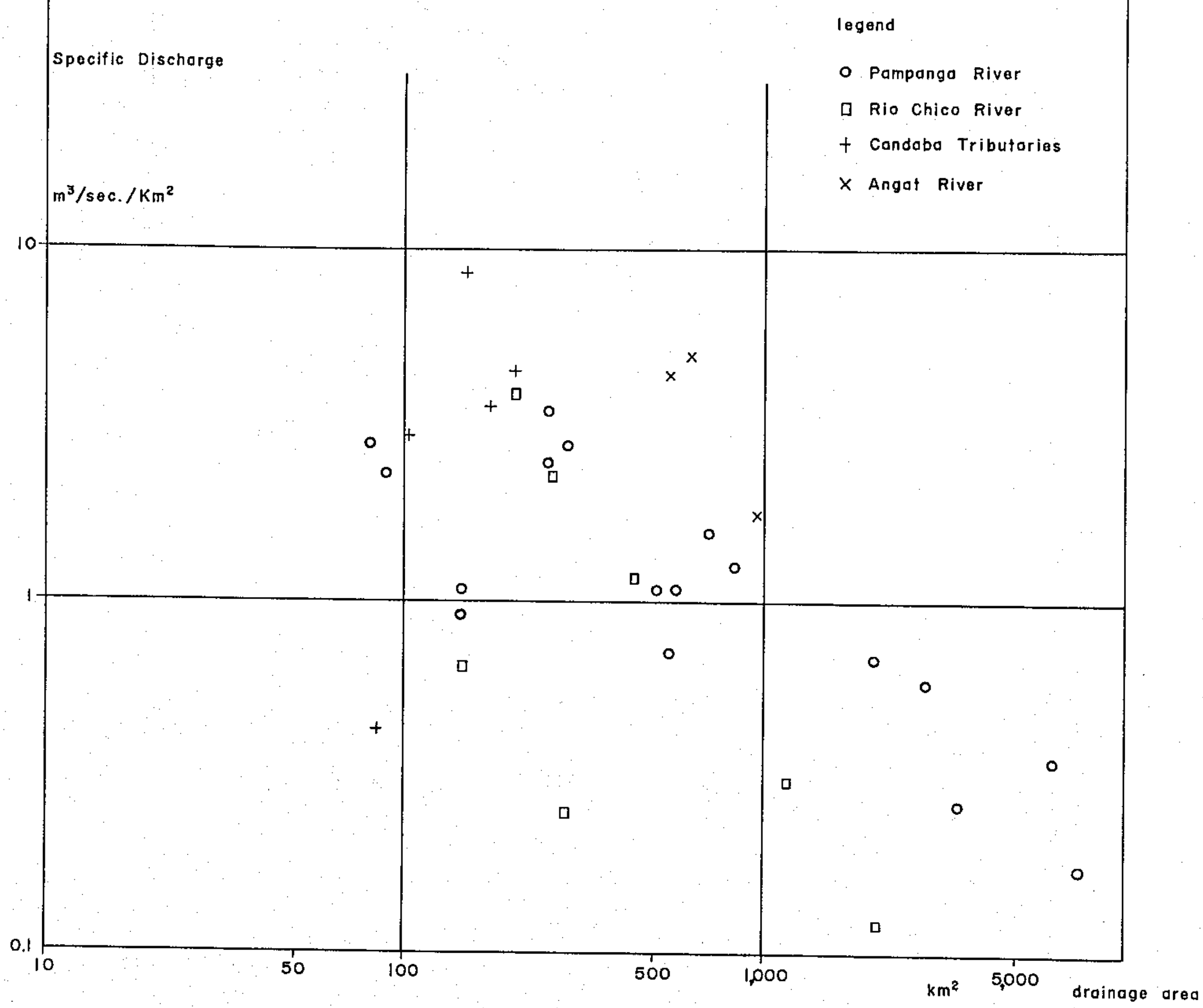
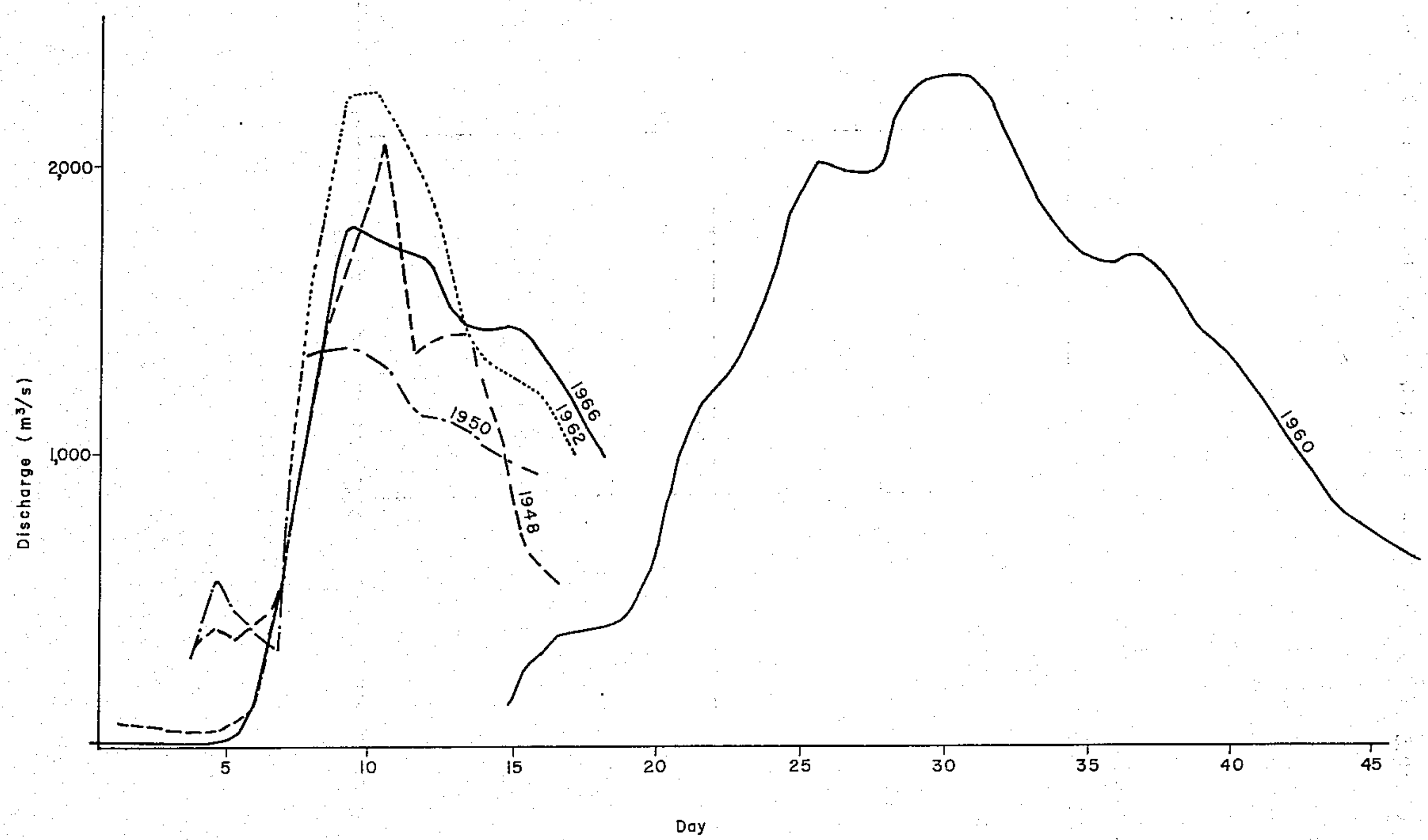


FIG. 3-20 COMPARISON OF FLOOD HYDROGRAPHS DISCHARGE, SAN AGUSTIN ARAYAT



3-8 Numerical Analysis of Major Floods

The object of the analyses made in this section is to clarify the availability of the flood forecasting system by analyzing the past floods.

(1-1) First, the mechanism of runoff from the basin, 8,550 km^2 in area, upstream from Calumpit (that is the inflow into Candaba Swamp) will be clarified from the macroscopic viewpoint. (See 3-8-1-1) Although the accuracy may be inferior it is possible to forecast any flood basing on the rainfall by this method, taking the whole basin as a lumped system.

(1-2) For operating the proposed flood forecasting system, the runoff of the middle part of the Pampanga River Basin has to be forecasted from the rainfall. Therefore, runoff analysis is made for each of these three sub-basins considering them respectively as a lumped system. (See 3-8-1-2).

(1-3) In order to improve the accuracy of the above method, it is necessary to know the characteristic of each sub-basin. An example of analysis technique is described in 3-8-1-3.

(2) The mechanism how flood wave propagates through the river channel is explained. The analysis with actually observed values and that with hydraulic computation of discharge through the river channel from Sapang Buho to Arayat are described in 3-8-2. As these will make clear the travel time of the flood from Sapang Buho, it will be able to forecast the discharge of only the main stream of the Pampanga, taking account of reduction of the peak discharge as well. Although the accuracy will be inferior, the discharge of the Pampanga River can be forecasted by adding the runoff from the tributaries to the above discharge.

This method is developed so that by accumulating the discharge joined from each of tributaries the accuracy of the flood routing may be improved.

(3) The behavior of the Candaba Swamp, that is water level variation caused by floods inflowing from respective rivers. This will enable to forecast the water level of Candaba Swamp.

The hydrological method of flood forecasting will be completed by integrating the above analyses as well as improving the accuracy of individual technique.

3-8-1 Runoff

The analysis of runoff is carried out through the processes of three stages; first, runoff estimation based on phenomenon from the macroscopic point of view, second, that based on respective sub-basins and lastly, estimation of runoff from divided sub-basins by use of hourly rainfall.

3-8-1-1 Runoff from Whole Basin

Daily inflow into the Candaba Swamp is estimated from daily average basin rainfall in the area of 8,550 km^2 upstream from Calumpit. This is a study from the macroscopic point of view, which will constitute a guiding principle for providing flood forecast in the present conditions with a little data and experiences.

Observed discharge data at the following stations are used for the estimation of runoff from the whole river basin.

The discharge data have been referred to *Surface Water Supply Bulletin.*

the Pampanga River	San Agustin
the San Miguel River	San Vicente
the Maasim River	Bahay-Pare
the Garlang River	Garlang
the Angat River	Pulilan

The sum of daily discharge at these stations is divided by the sum of catchment areas of the stations. This is the daily depth of runoff expressed in the unit of mm/day.

The rain gauging stations are as follows: Poblacion Carranglan (No. 1), Santor RGS. (No. 4), Santor RGS. (No.5), Benituan RGS. (No. 6), Lomboy (No. 7), Madlum RGS. (No. 9), Angat RIS. South canal (No. 11), Murcom Dam (No. 12), Rizal Dam (No. 13), Penaranda RIS. Main canal (No. 16), Panaranda RIS (No. 17), Dibabuyan Dam (No. 18), Talavera RIS. (No. 20), Cabanatuan (No. 31).

From these data, daily mean basin rainfall was computed by Thiessen method.

In the case of the flood in August 1960, as the monthly runoff was nearly equal to the monthly rainfall, the rate of runoff has been presumed as 1.

Fig. 3-21 shows runoff hydrograph computed by the unit hydrograph method. Besides the results 1 and 2 are computed from the unti hydrograph as used in *Hydraulic Desing Study*. This figure shows also the runoff 3 computed from the unit hydrograph determined by trial and error. The result shows that the peak on the unit hydrograph comes after 1.5 days after its beginning.

By the unit hydrograph method, the computed value of rising limb tends inevitably to be higher than the observed. This seems to be due to the influence of the basin storage and ponding of the San Antonio Swamp. The program of this procedure expressed by the algol statement is listed in appendix III.

Since it is difficult to simulate exactly the hydrograph for both rising limb and the peak by unit hydrograph method, the tank model runoff analysis is introduced.

The analysis by the tank model is carried out as follows. A river basin is simulated by a series of the tanks which has some holes and rainfall is stored in the tanks. It is presumed that the water stored in the tank flows out from the holes in proportion to the pressure. Usually, a scheme of four tanks in series is introduced. Running down of water from an upper tank to the joining lower tank simulates infiltration. The upper tank simulates flood runoff and the lower tank simulates groundwater runoff. There are two kinds of parameters, the elevation of hole and the discharge coefficient of hole, these must be determined by trial and error. The results attained are very good as shown in Fig. 3-22. To make the most preferable results of reconstitution test, the top tank must have a hole of small discharge coefficient for outflow to the down tank and also have three holes of which the uppermost hole being of fairly large discharge coefficient. These are the characteristics of this river when it is simulated by a tank model.

With the accumulation of observed data in the future it will be able to make a unit hydrograph or a tank model for each sub-basin and improvement in the accuracy of flood forecasting will be attained by adding runoff of each sub-basin computed from observed rainfall by the use of the unit hydrograph or the tank model. The method is described in 3-8-1-2 and 3-8-1-3 hereunder.

3-8-1-2 Runoff from the middle part of the Pampanga River Basin

In this flood forecasting system, the rainfall in the upper basins of both the Pampanga and the Rio Chico Rivers upstream from Sapang Buho and La Paz respectively are not measured, but the discharges are gauged at these points to compute the discharge of the stations in the target area by flood routing. In this case, the runoff from the middle part of the Pampanga River Basin must be forecasted separately.

Fig. 3-23 shows the relation between the discharge of the Rio Chico River and the rainfall in Benituan, presuming the former to be the balance of the discharge of San Agustin deducted that of San Vicente from it. Although in this correlation the discharge will represent not only the runoff of the lower basin of the Rio Chico River but that of the Rio Chico River as a whole. There can be found a lag time of about 1.5 days between the peak of rainfall and that of runoff, showing good correspondence.

FIG. 3-21 FLOOD SIMULATION BY UNIT HYDROGRAPH METHOD

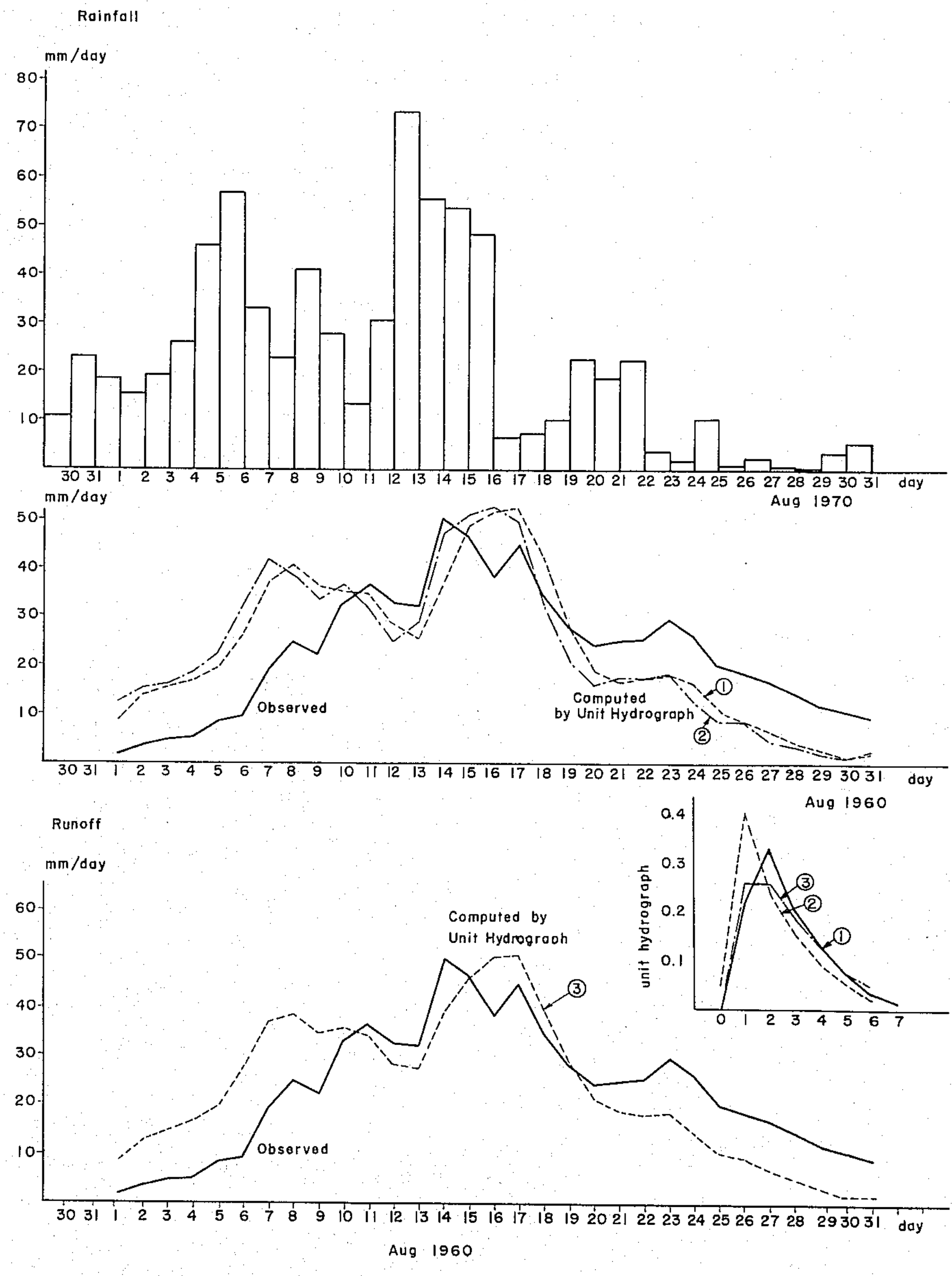


FIG: 3-22 RUNOFF COMPUTATION OF THE WHOLE PAMPANGA BASIN BY TANK MODEL METHOD.

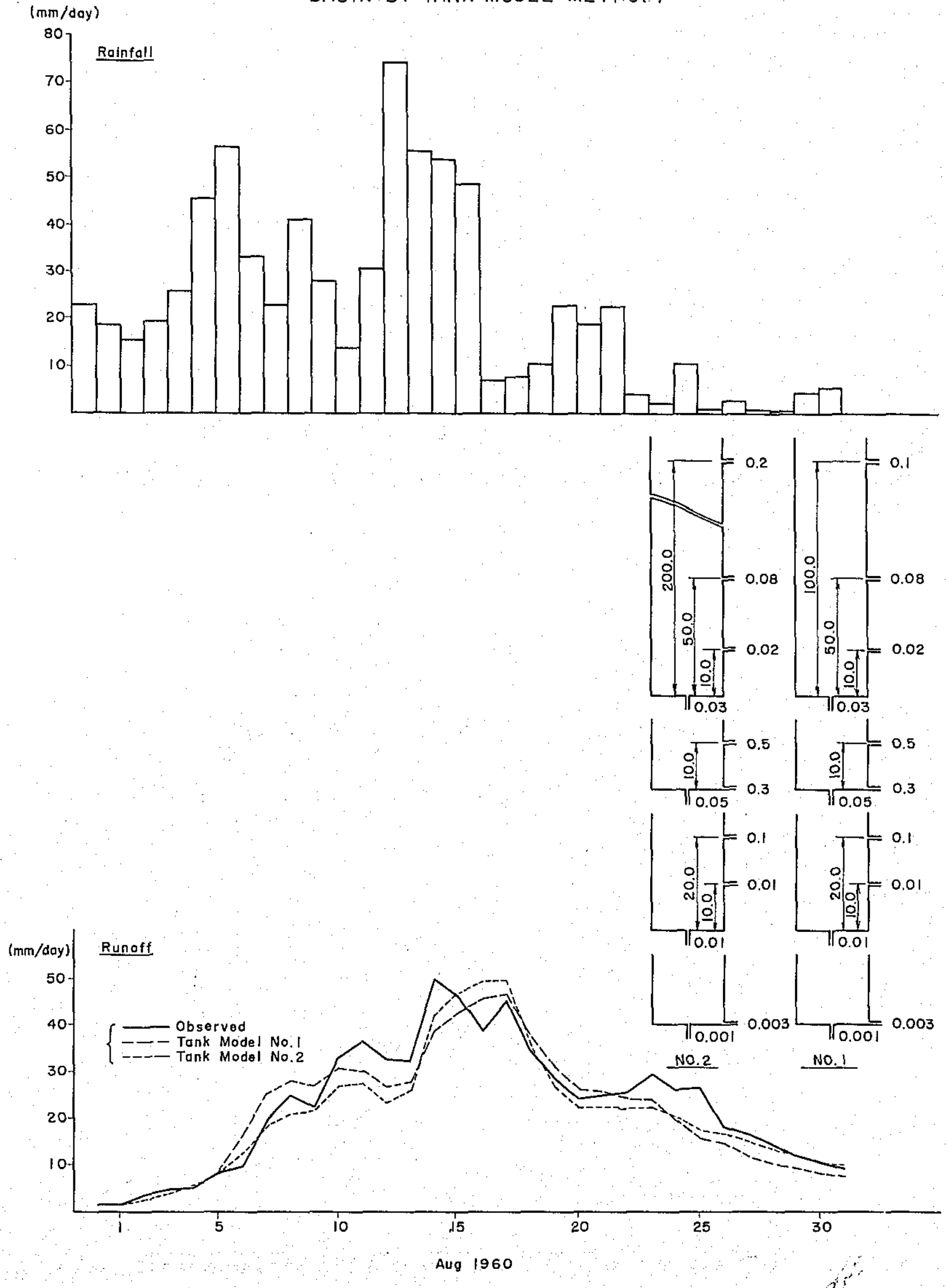
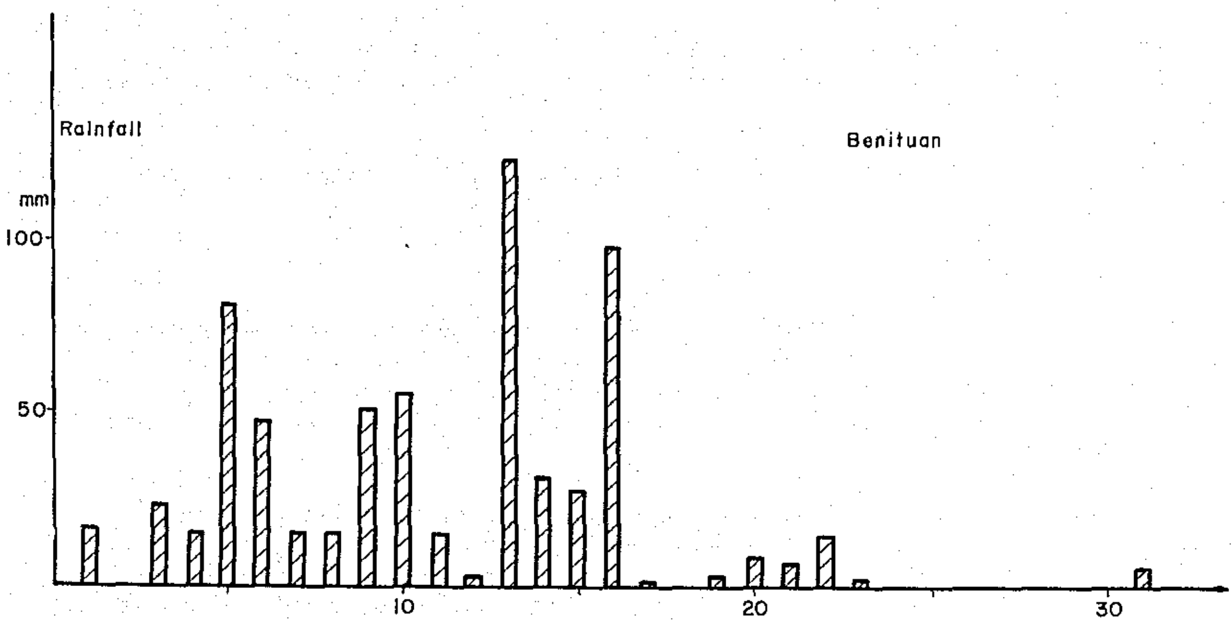
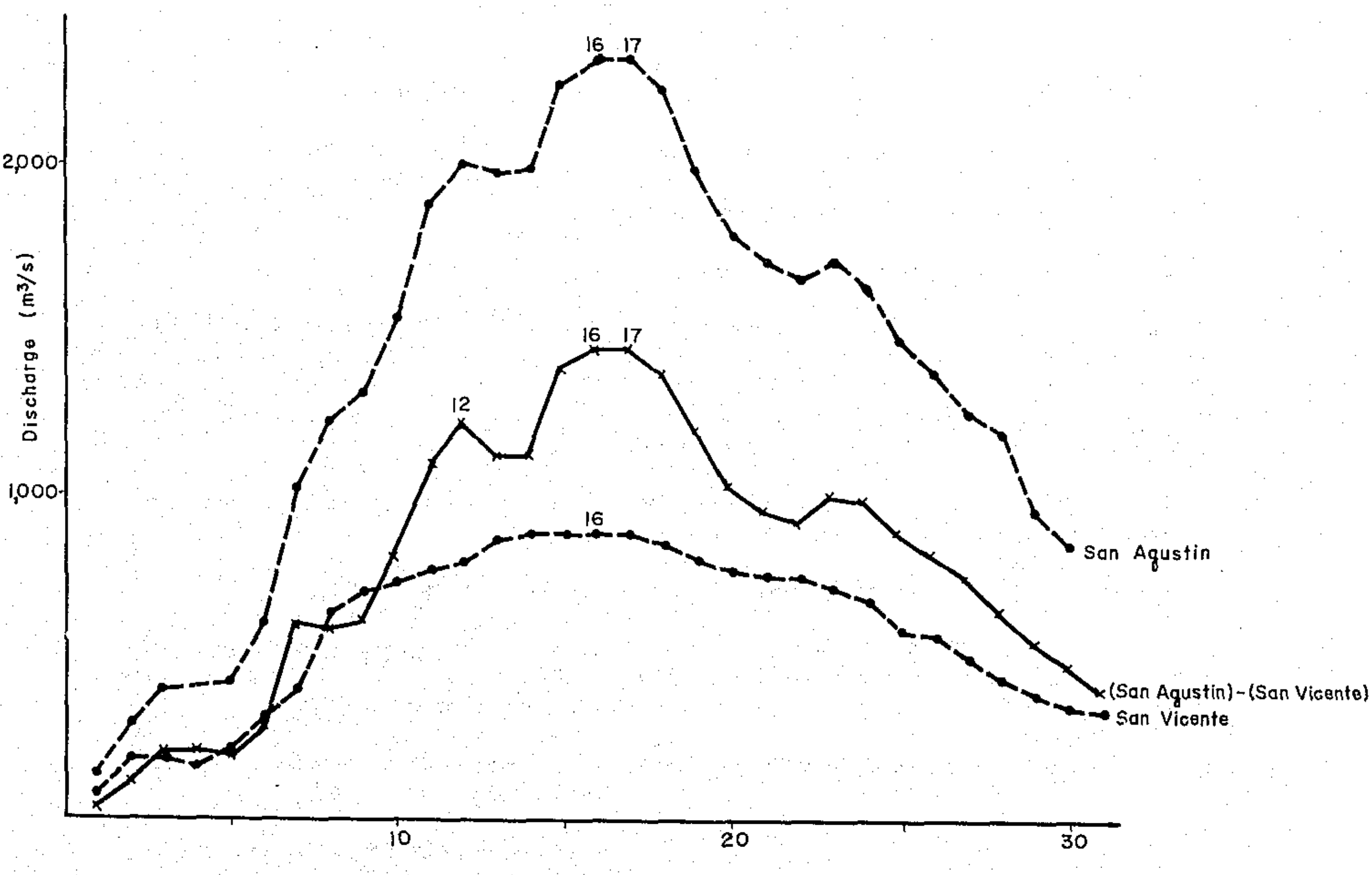


FIG. 3-23 RUNOFF IN (SAN AGUSTIN-SAN VICENTE)





In order to examine such correspondence more in detail, runoff analysis was carried out as to 2,466 km^2 of basins in the middle part of the Pampanga River Basin. In this, small number of rain gauging stations were used according to the proposed flood forecasting system. The measured discharge is the balance of the discharge used in 3-8-1-2 subtracted the discharges of Malate in Bongabon, and Santo Rosario near La Paz from it. Although this survey has some inadequacies in the time difference of rainfall, the representativeness of rain gauges, etc., this will be a help to evaluate the proposed flood forecasting system.

Here, the unit hydrograph was used to obtain the runoff hydrograph but if the technique is improved applying effective method such as tank model, satisfactory results will be certainly attained in future.

An example of the result is shown in Fig. 3-24. The unit hydrograph used here is not so different from that described in 3-8-1-1.

3-8-1-3 Runoff from Divided Sub-Basin

Properly speaking, an effective method as flood forecasting should be devised after having studied on the runoff characteristics of respective sub-basins, applying empirical rule of rainfall distribution.
As an example, daily mean water level of the San Miguel River at San Vicente is correlated to daily rainfall in the Angat, as shown in Fig. 3-25. The peak of water level corresponds to the peak of rainfall with lag of about one day.

In this, where the basin is small it needs to use hourly rainfall, but few data of this kind are available for the Pampanga River Basin. Accordingly, the hourly rainfall data available for the flood of August in 1960 are used to examine the method for estimating hourly runoff at Cuyapa, from the hourly rainfall in Gabaldon along the Santor River. The catchment area at Cuyapa is 89 km^2 and the rain gauge station is located near to the basin.

The observed water stage was converted into discharge using the rating curve which is given by B.P.W., and used it as observed discharge.

After several trial and error, the most suitable unit hydrograph was obtained.

Fig. 3-26 shows a comparison between observed runoff and computed one. This shows the lag of runoff from rainfall is about 8 hours, which will have a very important meaning for issuing flood forecast. The runoff coefficient exceeding 1 requires to reexamine the data.

3-8-2 Travel of Flood through the River Channel

As stated above, in the proposed flood forecasting system, the rainfall in the upper basins of the Pampanga and the Rio Chico Rivers are not to be gauged, but the discharges are gauged at Sapang Buho and La Paz. The travel time of flood through the river channel of the Pampanga and the Rio Chico Rivers from these stations to the target station is the effective time for flood forecasting. Flattening of the peak discharge is also important to be taken account into forecasting.

In order to examine the travel time of flood through the river channel in detail, the analysis of observed data and numerical estimation were carried out.

3-8-2-1 Travel Time of Flood through River Channel on the Basis of Observed Data

As the travel time of a flood wave varies with the discharge and the hydrograph, investigations must be made into a large number of floods. However, since the available data are restricted, approximate value of the travel time of the flood peak is estimated based on the data of floods in 1960, 1962 and 1966.

Along the Pampanga River: about 48 km from Malate of Bongabon to San Anton, 13 hours for the flood in 1960;

about 33 km from San Anton to San Vicente, 8 hours for the flood in 1962;

FIG. 3-24 FLOOD ANALYSIS

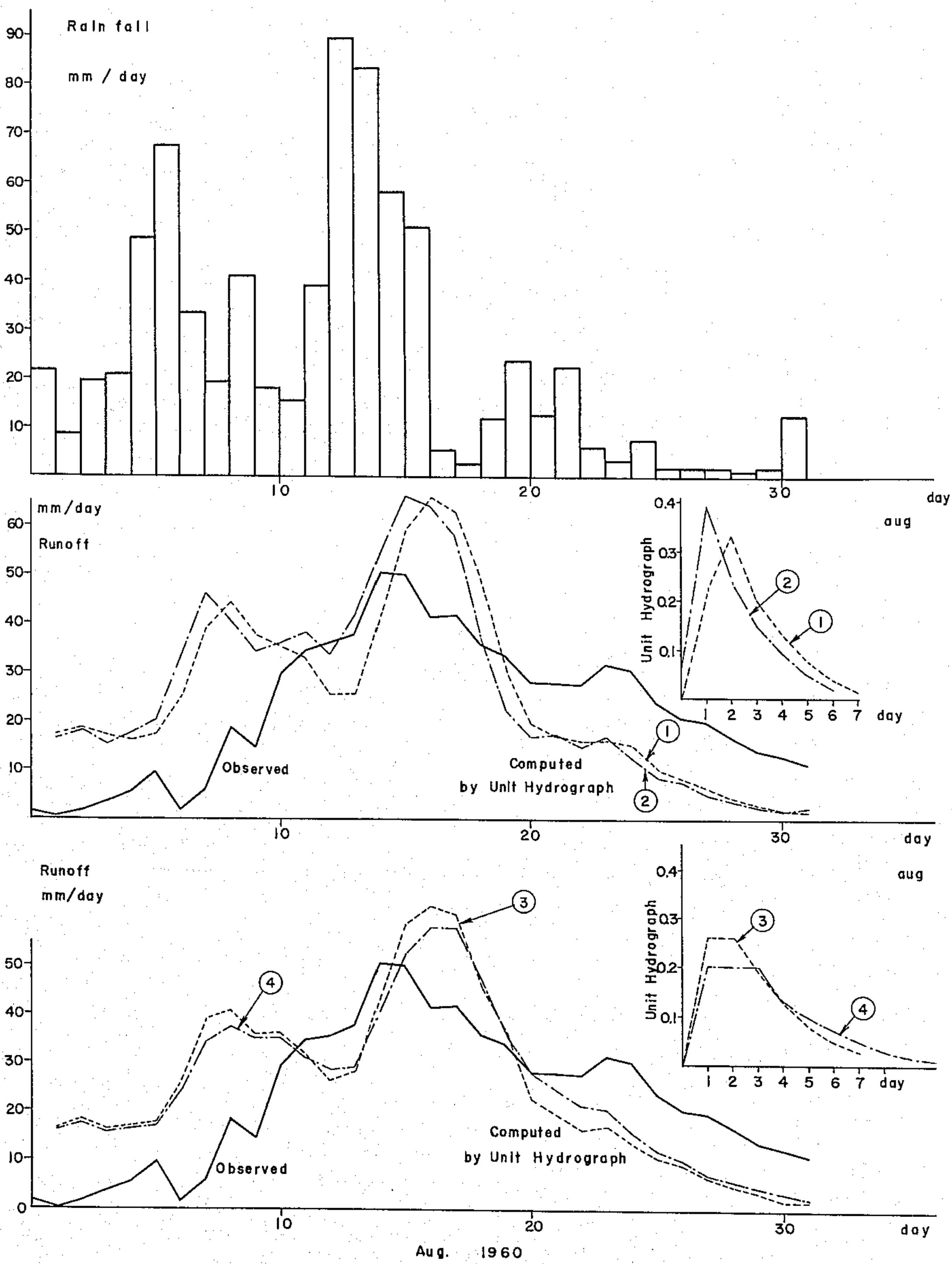
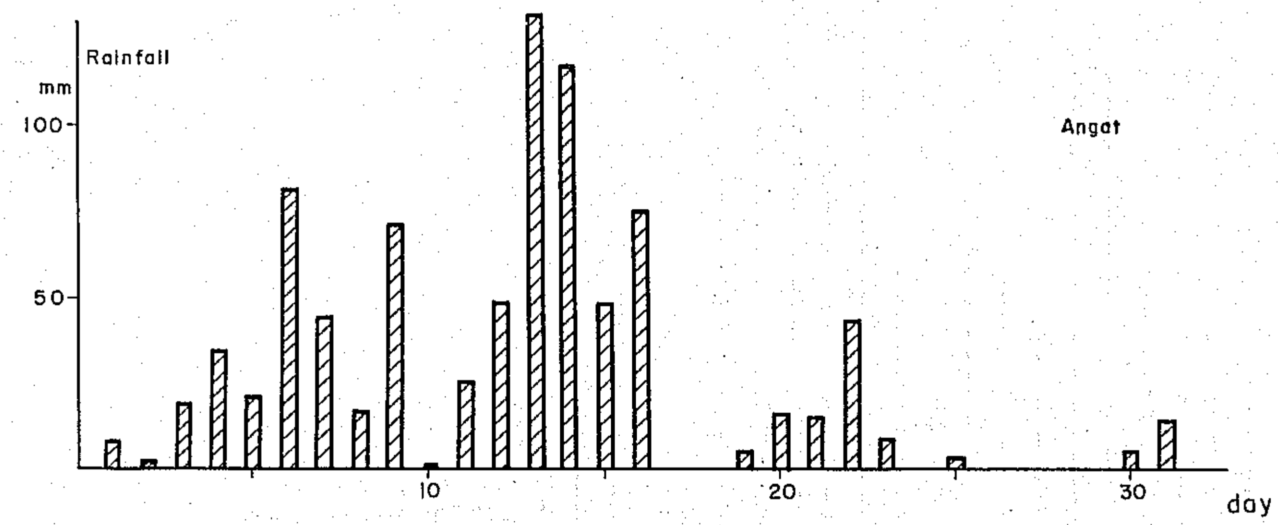


FIG. 3-25 RUNOFF OF SAN MIGUEL RIVER AT AUG, 1960



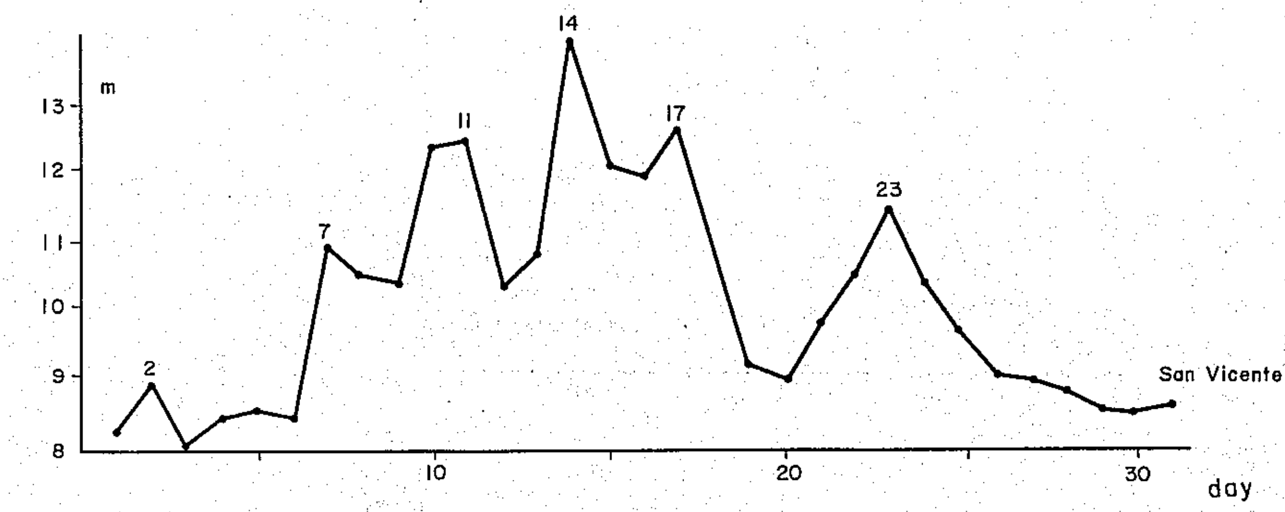
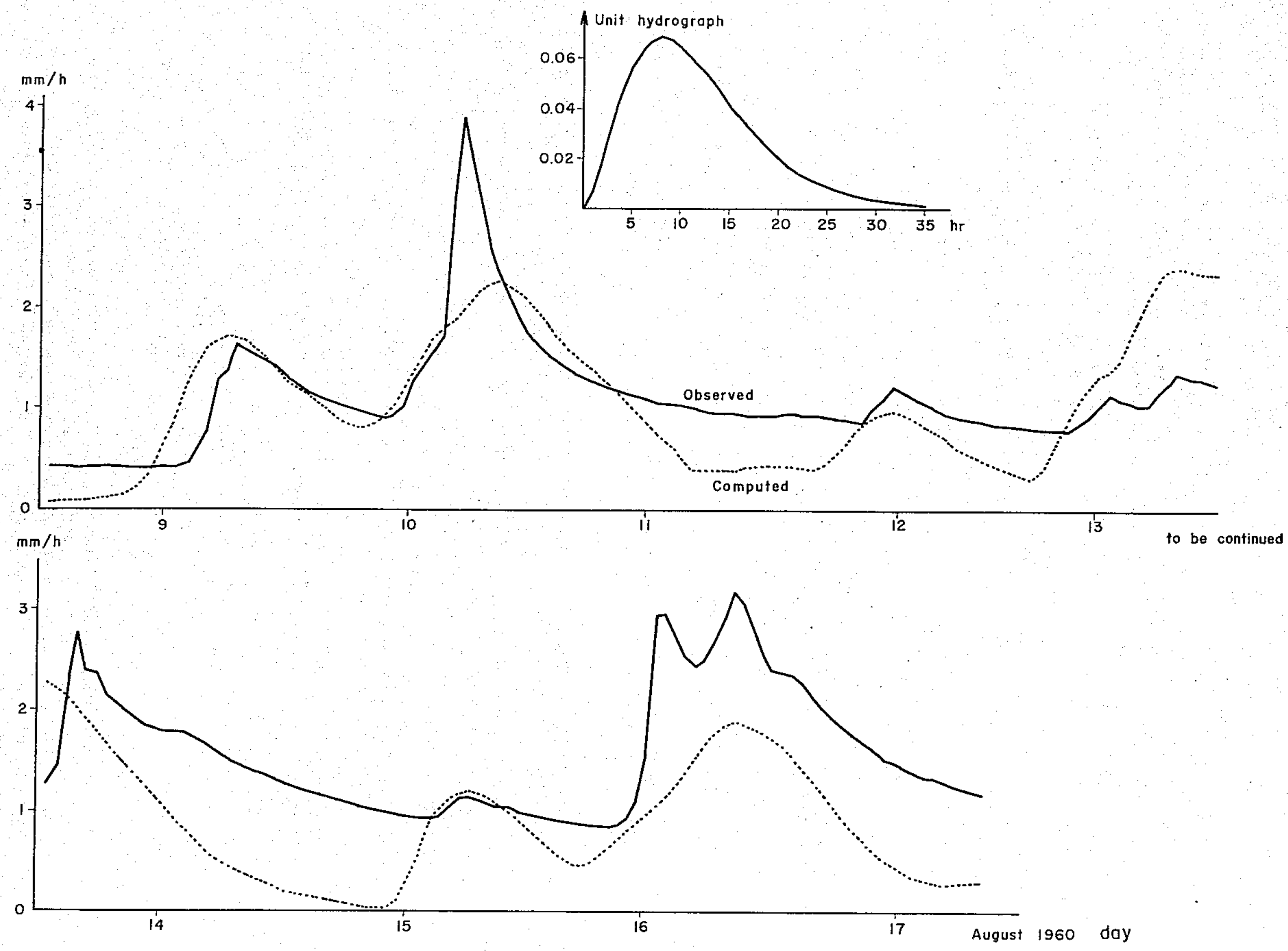


FIG. 3-26 OBSERVED AND COMPUTED RUNOFF AT CUYAPA



about 12 km from San Vicente to San Agustin of Arayat, 24 hours for the flood in 1962, though details are not clear because there were diverted flow into the floodway and confluence of the Rio Chico River;

about 23 km from San Agustin to Sulipan of Apalit, 24 hours for the flood in 1962, though details are not clear because the hydrograph is very flattened in the Candaba Swamp;

about 39 km from San Vicente to San Luis, about 3 days for the flood in 1966.

Along the Rio Chico River; flood wave is flattened in the San Antonio Swamp (though details are not clear because it joins to the main stream of the Pampanga),

18 hours for flood in 1960;

9 hours for flood in 1962;

Along the Angat River; from Ipo Dam to Calumpit;

15 hours for flood in 1960;

17 hours for flood in 1962.

Integrating these data, it may be presumed that the flood wave will come down from Malate to the confluence with the Rio Chico River along the main stream of the Pampanga River in one day.

Downstream from the confluence with the Rio Chico River, the flood wave is markedly flattened due to the storing effect of the Candaba Swamp and is retarded there about one or two days to reach Sulipan.

In the Rio Chico River, the propagation time of flood is about a half day from La Paz to the confluence with Pampanga River.

In the Angat River, it should be put at a half day, though the data show the time near to one day from the outflow of the Ipo Dam to Calumpit.

3-8-2-2 Hydraulic Study

The travel phenomena of flood wave from Sapang Buho to San Agustin on the Pampanga River will be simulated hydraulically as follows.

It is well known that flood flow can be expressed as unsteady flow with the equation of motion and the equation of continuity. The phenomenon can be simplified by this method and the propagation of flood can be clarified.

The basic equations are

$$-i + \frac{\partial h}{\partial X} + \frac{n^2 v^2}{R^{4/3}} = 0$$

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial X} = 0$$

It is presumed that the cross section of the channel of the Pampanga River is a rectangle. The width and the elevation of the river bed are determined based on the maps on the scale of 1 to 50000. Joint and diversion of streams are ignored and the coefficient of roughness n is put at 0.035 for the lower stream and 0.05 for the upper stream, with that for the midstream determined suitably by interpolation.

In order to convert into differential equation, it is presumed that:

$$\Delta x = 4 \text{ km}$$
$$\Delta t = 0.1 \text{ hr}$$

Accordingly, 108 km from Sapang Buho to San Agustin is divided into 27 cross sections. The program of this procedure expressed by the Fortran statement is listed in Appendix III.

The flood wave proportionate to $\frac{t}{To}e^{-t/To}$ is given to the river at Sapang Buho, and reduction in peak discharge in the channel of the Pampanga River and time for flowing down to San Agustin are found as arranged in Table 3-1.

Although there are some differences in accordance of the dimensions of floods, it is known that the travel time of a flood is about 20 hours. This agrees well with the results obtained from the observed data mentioned in 3-8-2-1. *This difference in time is very important and effective for the purpose of* flood forecasting.

Inundation on the flood plain is extremely simplified and put on the line of the computation, it is shown qualitatively that such inundation has an effect to delay the propagation of flood peak. The computing procedures will become more complicated if confluences from tributaries, overflowing into the *San Antonio Swamp etc. are taken into consideration, though it makes significant improvement of the* accuracy in the estimation of travel time and reduction of peak discharge. However, in the present computation, assumptions are confined to schematic conditions.

The channel of the Pampanga River is assumed to be a single channel which has neither tributary nor diversion. The flood hydrograph at Sapang Buho, the boundary condition of hydraulic equations, is made by the function A (t/To exp(−t/To), where A indicates the magnitude of the flood, and To is the time from the rise to the peak and equals to 5 days in this study. The longitudinal profile and the width of the low water channel are based on the map on the scale of 1 to 50000. Since the depth of the low water channel can hardly be measured on the map, two cases, a shallow channel and a deep one, are examined. The flood plain is roughly estimated by the map. For the last computation, the flood plain is assumed to be wider than the others.

In this table, the travel time from Sapang Buho and the peak discharge at San Anton and San Agustin, Arayat are listed. Decay of the peak discharge is not so clear in all cases. Remarkable characteristics are found in the difference of the travel time. Examples of discharge hydrograph are shown in Figs. 3-27 and 3-28. Travel time of flood peak and reduction in flood peak are shown in the Table 3-1.

It is necessary to perform the similar studies on the Rio Chico and the Angat Rivers in future.

3-8-3 Behavior of Swamp

The important districts in the target area for flood forecasting are the district around Candaba Swamp and the delta area downstream from it. Investigation must be made into how the water level of Candaba Swamp fluctuates due to the inflow of flood.

Fig. 3-29 shows the hydrograph of daily water level at the three flood forecasting points in the swamp area—San Agustin, Pasig and Sulipan —— at the time of the flood in 1960. The peak water level occurred on the same day at the two upstream points, *instead, it occurred earlier at the downstream* point and this seems to be due to the earlier flooding of the Angat River which flows into Swamp at the lowest stream. Therefore, the correlation of the water levels at these three points is not necessarily simple. In the case of the flood in 1966, the peak water levels at the three points occurred from the upper stream to the lower stream at the intervals of one day, probably due to the fact that the water level itself was lower than that of the flood in 1960. See Fig. 3-30.

Table 3-1 Results of Hydraulic Study on Flood Routing

peak discharge at Sapang Buho	depth of the low water channel	San Anton		Arayat	
		Travel Time from Sapang Buho	peak discharge	Travel Time from Sapang Buho	peak discharge
m^3/s		hour	m^3/s	hour	m^3/s
735.8	shallow	33.5	734.1	58.6	730.5
1471.5	deep	13.8	1469.9	19.4	1469.5
1471.5	shallow	27.4	1468.1	54.3	1458.0
2207.3	deep	21.4	2203.2	37.7	2194.9
2207.3	shallow	24.0	2198.9	47.7	2180.9
2207.3	shallow	35.1	2186.4	82.6	2112.8

Table 3 (1) Monthly Rainfall (unit mm)

No. of Station	YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	Annual
10	56	2.0	0.0	2.0	108.7	N	24.8	100.5	201.4	234.6	113.5	77.2	99.5	
10	57	24.6	0.0	0.0	1.0	25.1	220.7	203.4	321.8	151.1	184.6	37.5	0.0	1170.1
10	58	5.5	3.3	4.3	1.0	19.8	170.4	93.4	171.1	176.2	119.3	10.1	0.0	774.9
10	59	3.0	0.0	5.0	0.0	20.3	99.0	157.7	286.5	N	47.2	70.1	4.8	
10	60	1.2	24.8	N	62.2	131.3	287.0	N	765.3	494.7	N	29.4	0.0	
9	59	0.0	0.0	0.0	0.0	132.3	63.7	263.1	717.2	225.0	186.9	170.6	6.8	1766.0
9	60	3.0	0.0	20.0	30.9	152.6	355.0	170.1	98.8	246.8	805.6	49.5	0.0	2932.9
8	62	0.0	1.2	N	84.3	N	156.4	561.8	354.3	500.8	67.5	51.0	N	
8	63	0.0	16.5	5.0	4.3	68.0	622.8	107.1	181.8	316.9	7.8	0.0	46.2	1376.9
8	64	0.0	0.0	31.7	N	N	325.1	255.0	276.8	77.9	74.6	184.6	53.3	
1	58	7.3	7.6	8.8	8.3	111.2	210.8	194.8	300.7	350.2	121.1	33.0	0.0	1354.3
1	59	11.4	18.0	27.4	8.8	100.5	47.2	91.9	226.5	192.7	N	N	N	
1	60	N	45.9	12.1	40.6	99.5	178.0	158.4	565.4	377.1	169.4	22.8	14.4	
4	59	23.3	23.8	128.2	31.7	148.3	39.1	231.9	318.5	253.7	198.6	492.7	196.0	2086.3
4	60	54.3	149.0	10.6	8.1	116.0	266.7	187.4	410.9	447.8	577.0	102.8	16.5	2347.7
5	59	5.0	0.0	0.0	16.7	179.5	151.1	262.3	380.2	149.8	189.2	340.8	20.3	1695.4
5	60	2.2	60.9	0.0	30.2	206.7	234.9	219.2	651.2	406.4	525.2	43.1	0.0	2380.4
12	56	0.0	0.0	0.0	44.9	120.6	50.0	175.5	269.4	255.0	74.1	133.6	55.6	1179.0
12	57	0.0	0.0	0.0	14.9	37.5	203.9	163.8	190.7	120.1	86.8	137.6	0.0	955.8
12	58	0.0	34.5	0.0	0.0	34.2	259.0	298.4	896.6	483.6	29.9	10.9	0.0	2047.4
12	59	0.0	0.0	0.0	0.0	44.7	47.2	78.4	314.1	237.9	0.0	136.3	0.0	859.0
13	56	0.0	0.0	0.0	127.0	50.5	39.1	223.5	250.1	396.2	62.2	233.4	58.9	1441.1
13	57	3.5	0.0	0.0	17.0	17.5	238.7	190.5	285.4	197.1	113.0	283.9	0.0	1346.9
13	58	3.5	6.8	0.0	0.0	24.3	416.5	231.9	266.7	402.8	65.0	38.6	0.0	1456.4
13	59	8.1	1.2	21.8	3.5	36.0	132.0	204.7	189.9	268.4	218.9	172.7	0.0	1257.8
15	55	0.0	0.0	0.0	0.0	0.0	90.6	0.0	67.3	40.6	19.0	56.8	0.0	274.5
15	56	0.0	0.0	0.0	178.3	40.6	26.9	166.1	174.4	291.3	37.0	123.6	51.5	1090.1
15	57	0.0	0.0	0.0	0.0	16.2	163.3	313.1	187.7	120.3	115.5	106.4	0.0	1022.8
15	58	4.5	2.5	0.0	0.0	18.2	200.6	217.9	180.8	48.0	190.7	13.2	0.0	876.8
15	59	3.3	0.0	9.3	0.0	48.2	54.1	155.1	N	N	20.0	100.3	0.0	
15	60	0.0	10.6	0.0	322.8	517.1	691.3	452.3	N	361.9	214.6	29.4	0.0	
18	55	0.0	0.0	0.0	0.0	146.0	165.3	242.3	235.9	312.1	108.2	83.0	11.1	1304.2
18	56	2.0	0.0	0.0	125.7	95.5	121.9	336.8	352.8	446.2	112.0	241.3	64.2	1898.6
18	57	31.2	0.0	2.0	143.2	72.1	344.1	262.3	441.7	268.4	79.2	163.8	0.0	1808.4
18	58	0.0	6.0	0.0	N	59.1	282.7	295.6	266.9	418.0	110.9	20.0	0.0	
18	59	0.0	0.0	18.0	0.0	192.2	80.2	127.5	599.1	364.4	144.0	95.5	0.0	1621.2
18	60	0.0	52.0	0.0	30.2	303.2	334.0	163.5	718.5	239.2	252.9	25.9	0.0	2119.8
6	59	5.0	0.0	52.3	1.7	124.9	85.0	92.9	N	154.1	112.0	81.5	4.5	
6	60	20.3	188.4	16.7	86.1	276.3	394.2	237.9	657.0	390.1	260.6	8.1	0.0	2536.1
14	54	0.0	0.0	0.0	14.4	18.5	98.2	203.7	324.8	256.5	227.8	103.1	0.0	1247.3
14	55	0.0	0.0	0.0	0.0	0.0	81.2	0.0	61.2	85.0	19.8	31.4	0.0	278.6
14	56	0.0	0.0	0.0	171.1	0.0	20.5	97.0	329.1	389.6	101.8	96.0	0.0	1205.4
20	55	0.0	0.0	0.0	0.0	119.6	271.5	389.6	611.1	458.7	161.2	76.7	0.0	2088.6
20	56	0.0	0.0	0.0	284.4	109.7	113.5	236.7	303.5	685.0	214.3	331.9	117.0	2396.4
20	57	11.1	0.0	14.2	9.1	42.1	443.2	351.5	619.5	408.9	128.0	232.1	5.3	2265.4
20	58	0.0	31.7	5.0	0.0	105.9	379.4	275.8	251.4	501.3	70.3	18.0	0.0	1639.2
20	59	0.0	0.0	21.5	7.3	174.4	102.6	155.7	384.8	273.5	130.5	200.4	0.0	1451.0
20	60	17.5	24.1	5.5	29.9	234.9	325.3	176.5	687.5	251.4	188.9	25.9	0.0	1967.9
31	60	2.5	49.5	10.1	55.6	160.2	245.1	231.6	622.5	452.8	403.0	39.8	3.3	2276.5
31	61	0.0	1.2	55.8	2.0	156.7	590.8	459.9	399.5	267.7	159.0	82.2	0.2	2175.4
31	62	4.5	0.0	2.7	37.0	133.3	308.3	467.6	280.1	453.3	35.0	57.6	0.2	1780.2
31	63	0.0	27.4	1.2	0.0	145.0	528.3	217.1	389.3	357.8	11.4	13.9	63.5	1755.3
11	58	17.2	7.6	12.9	4.5	88.9	305.3	436.1	331.7	332.4	226.5	20.3	0.0	1783.8
11	60	8.1	53.8	28.9	161.5	205.4	341.6	473.7	919.4	626.6	470.6	37.3	1.5	3328.9
17	57	0.0	0.0	0.0	0.0	49.0	130.5	197.8	215.9	206.7	95.7	110.9	0.0	1006.8
17	58	10.4	11.9	0.0	0.0	11.6	231.1	212.0	209.5	351.5	143.7	2.7	0.0	1242.4
17	60	3.0	13.4	0.0	36.3	135.6	331.2	267.7	561.3	239.5	266.9	3.5	0.0	1858.7

FIG. 3-27 HYDRAULIC STUDY ON FLOOD PROPAGATION (I)

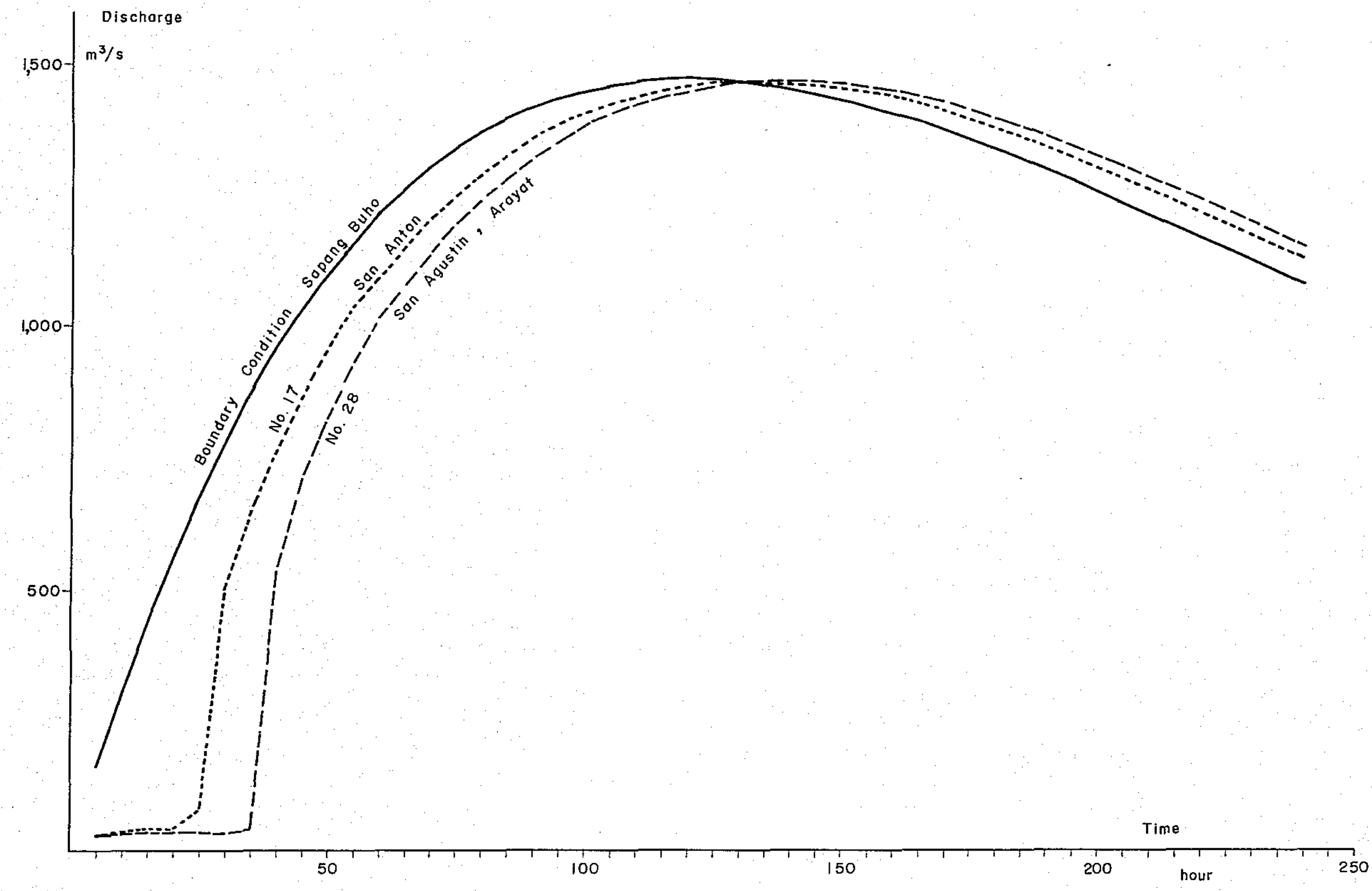


FIG 3-28 HYDRAULIC STUDY ON FLOOD PROPAGATION (2)

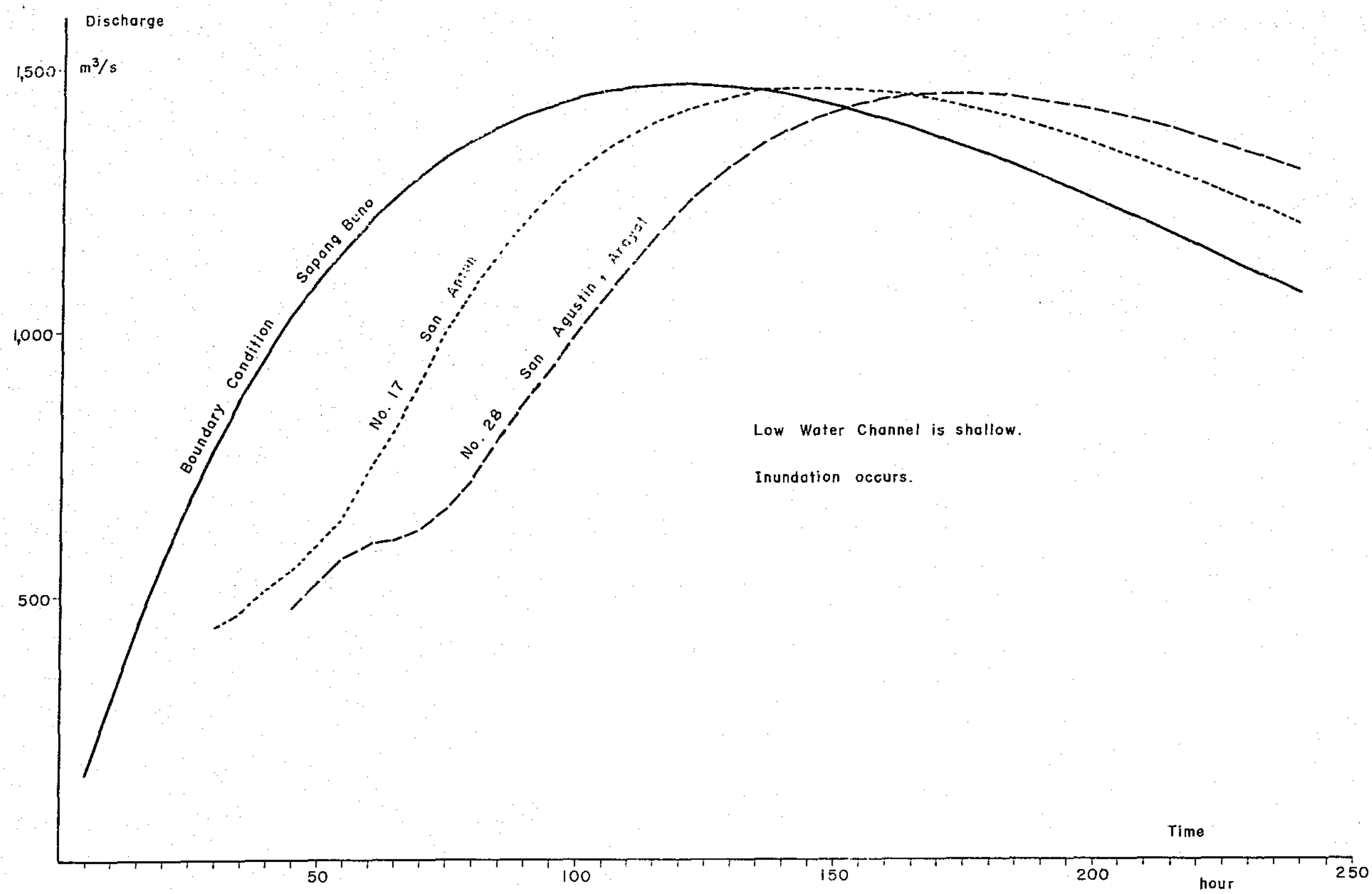


FIG. 3-29 FLOOD HYDROGRAPHS OF AUG, 1960

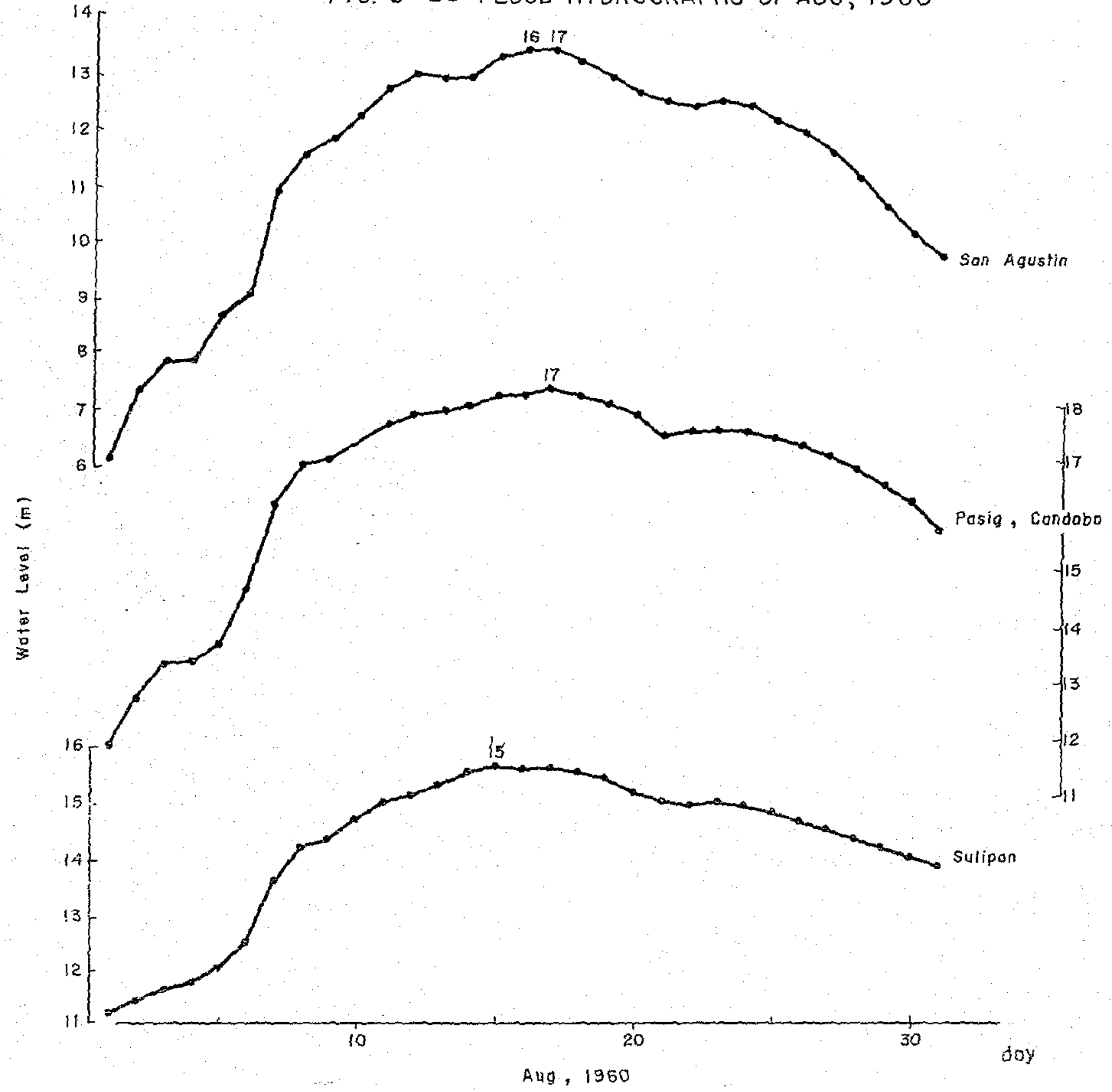
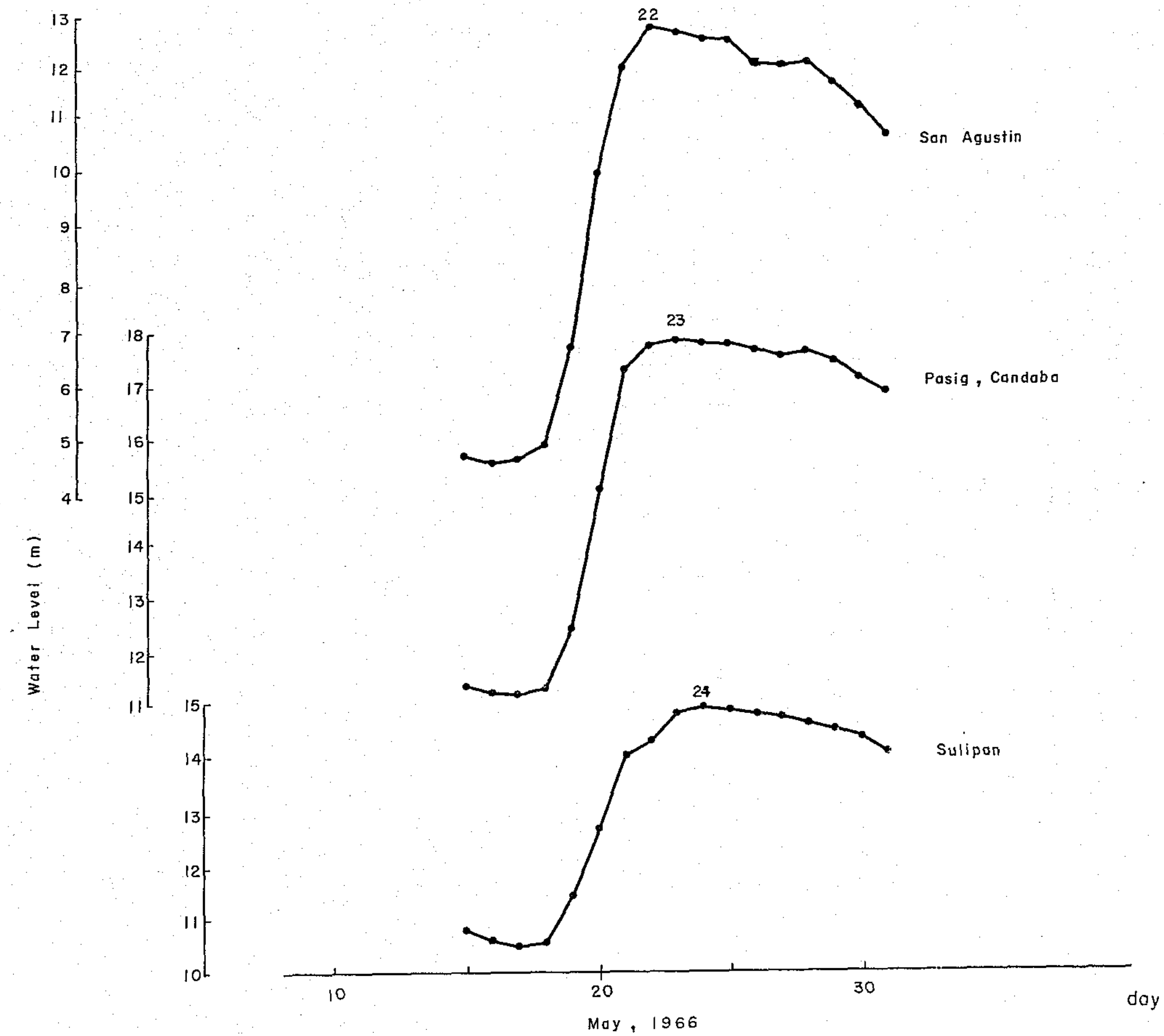


FIG. 3-30 FLOOD HYDROGRAPHS OF MAY 1966



Here, the following assumptions are made to grasp major trend.

1) The surface slope of the Candaba Swamp is constant throughout the flood period.

2) There is a functional relation between the storage of the Candaba Swamp and the water stage at Sulipan.

3) There is a functional relation between the discharge flowing down to the delta area through the section between Sulipan and Calumpit and the water stage at Sulipan.

These are expressed by the following formulas, putting the water level at Sulipan at H:

$$\frac{d\ (\text{Storage})}{dt} = \text{Inflow} - \text{Outflow}$$

$$\text{Storage} = f_1\ (H)$$

$$\text{Outflow} = f_2\ (H)$$

The functional relation, f_1 (H), between the water stage at Sulipan and the storage of the swamp is determined by the following method.

The contour map measured for the model experiments is adopted to determine the shape of the swamp.

Flood water in the swamp is given a certain surface slope and is related to the water level at Sulipan. This surface slope is determined after the case of the past great flood.

The functional relation, f_2 (H), between the water stage at Sulipan and the Candaba Swamp outflow is determined by interpolation between the data at the high water stage and those at the low water stage.

The data at the high water stage are obtained by the model experiment at B.P.W. and those at the low water stage are referred to *Surface Water Supply Bulletin of B.P.W.*

The functions of f_1 and f_2 used for computation are shown in Fig. 3-31. The program of this procedure expressed by the algol statement is listed in Appendix III.

The results of computations by these assumptions on the data of the flood in August 1960 and July 1962 are shown in Figs. 3-32 and 3-33.

In this case, the volume of inflow is computed as follows. Daily inflows from San Agustin, San Vicente, Garlang, Bahay-Pare and Pulilan were summed up, and added with contribution from the remaining basin computed using the area ratio.

These figures assure that the forecasting of the water level of the Candaba Swamp can be made adequately by this method, since they shows the good corresponding between the water levels observed and those computed.

However, as to very rapid variation in the water levels, the observed values show steeper change than the computed values. This should mean that, though the water level of the Candaba Swamp is presumed to fluctuate uniformly for the computation, this assumption is not necessarily effected in the case of rapid fluctuation.

If the swamp and the river channel are divided into small sections and hydraulic analysis is made as stated in the section 3-8-2-2 of flood routing, this problem will be solved.

Any change in the flood water level due to the tidal movement of Manila Bay is not taken into account of this computation. Although the tidal movement changes in a day, mean daily discharge is used for this computation. This problem will be also clarified by the improvement and increasing of measurement and analyses of data in future.

FIG. 3-31 RELATIONS FOR COMPUTATION, AS BETWEEN STORAGE OF CANDABA SWAMP AND WATER STAGE AT SULIPAN, AND OUTFLOW FROM CANDABA SWAMP AND WATER STAGE AT SULIPAN.

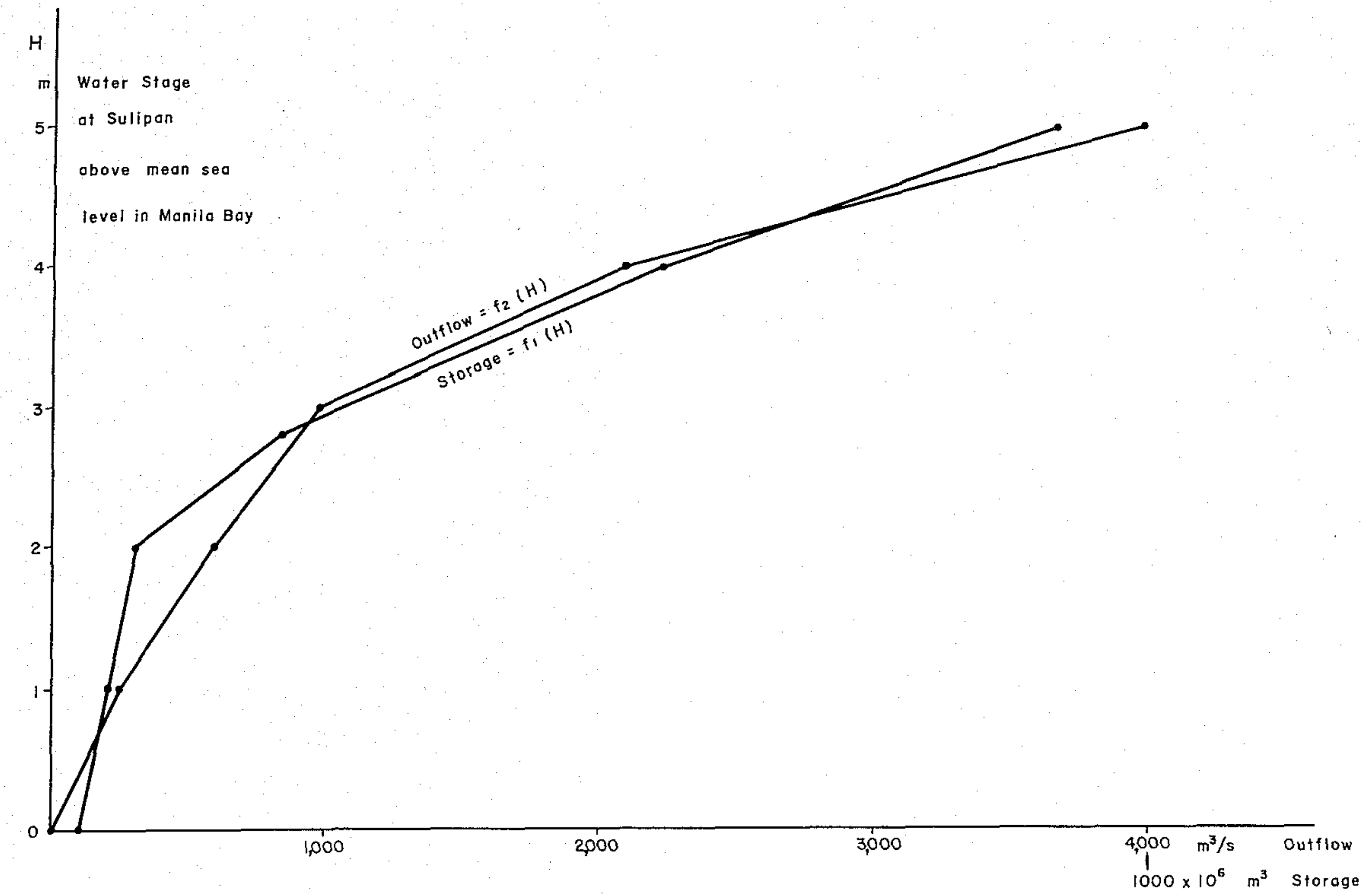


FIG 3-32 FLOOD IN 1960

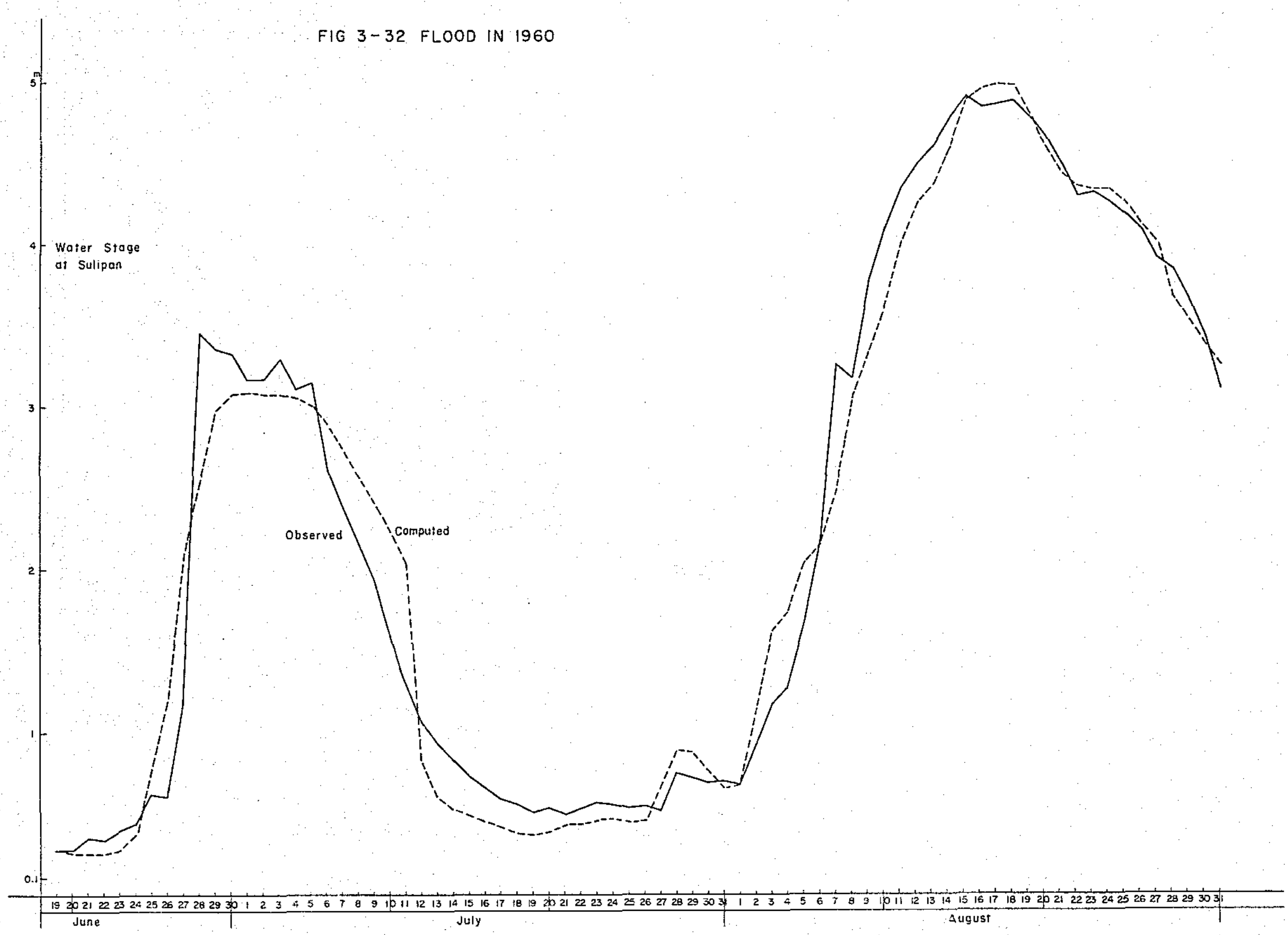
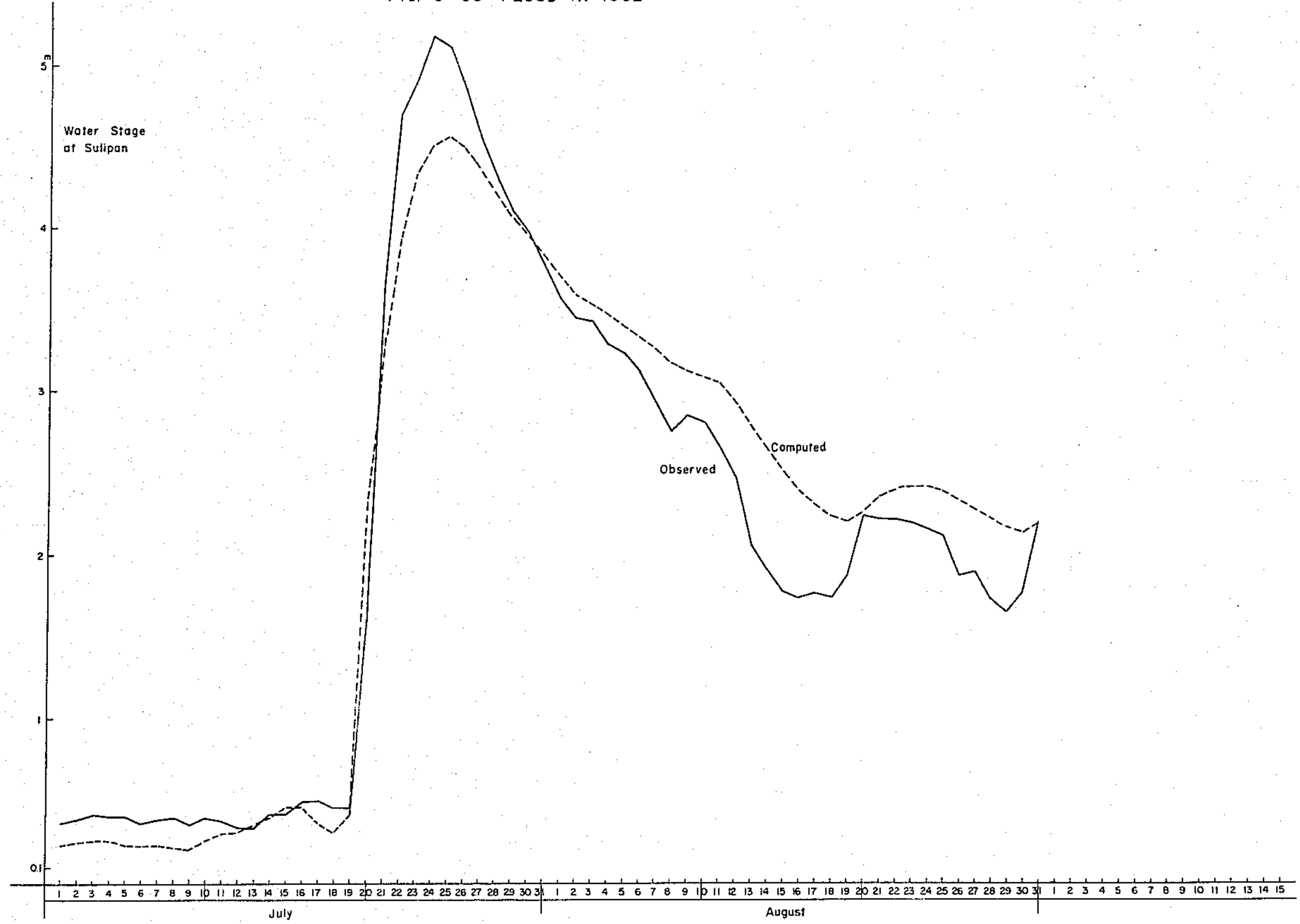


FIG. 3-33 FLOOD IN 1962



CHAPTER 4. RECOMMENDATION FOR THE PILOT FLOOD FORECASTING AND WARNING MEASURES, FACILITIES AND ORGANIZATION ON THE PAMPANGA RIVER BASIN

4-1 Forecasting System

4-1-1 Determination of Target Area

The present project is proposed as a pilot case of the flood forecasting and warning system for the Pampanga River Basin in the Philippines, as for the first stage of such system. Although valuable areas in the Pampanga River Basin are not necessarily confined to those selected here, the following three areas have been decided to be the target areas for the present project. In this, due consideration was taken of the distribution of population and houses, land use or land productivity, the economic effects of investments to be brought by the areal concentrativeness of those conditions. Also, account was taken of the topographic, climatic and hydrologic characteristics, the frequency of floods' attack, and the reliability of flood forecasting and warning based on the results of hydrologic observations in the past.

1. Candaba area

2. Right bank area of the main Pampanga River below Arayat

3. Delta area below Apalit

These target areas are shown in Fig. 4-1. In the preceding section, the state of flood runoffs and the actual situations of flood damages are studied about the major floods in this river basin. The flood forecasting system suitable for this basin will be discussed based on the results of these studies.

4-1-2 Selection of Location for Telemetering Station

The flood forecasting is to provide the residents in an area with the information about flood water level and time of comming up estimated at the forecasting site before any occurence of flood phenomenon, so that they can take swift and effective measures for refuge. Input informations of the flood forecasting system are the data provided by telemetering rain gauge or telemetering stream gauge upstream from the forecasting site.

The whole basin is divided into six parts, as shown in Fig. 1-1, taking into consideration both the hydrologic characteristic of the basin and the target areas for forecasting.

The relation between telemetering station and target area, and hydrologic methods of flood forecasting linking them are shown in Fig. 4-2 as a flow chart.

4-1-3 Site Locating of Telemetering Gauges

The Survey Team have drafted the flood forecasting systems in two cases shown in the following Fig. 4-1, with proposed network of the stream gauge station and the rain gauge station for respective cases.

Selected sites have respectively the significances as follows:

1. Sapang Buho (area of basin 1,900 km^2)

Since the upper Pampanga Area is separated into the basins of the main river and the Santor River, a tributary with the same weight as the former, it will need two or more telemetering rain gauge station depending on the pattern of rainfall, so that erroneous forecasting may not be made. Fortunately, as the upper Pampanga Area is sufficiently distant from the target areas above-mentioned and necessary time can be adequately secured for flood forecasting, it is believed more advisably to grasp the integrated discharge at the time when the rainfall has run off into the river channel.

Table 4-1 Location of telemetering station

Case I

Control Station	Repeater Station	River Stage Station	Rainfall Station
		Sapang Buho	Sapang Buho
		La Paz	La Paz
			Papaya
		San Vicente	San Vicente
Manila ←	Mt. Arayat* ←	Arayat	Arayat
			Biak na Bato
		Candaba	Candaba
			San Rafael
		Ipo Dam	Ipo Dam
		Apalit	Apalit

Case II

Control Station	Repeater Station	River Stage Station	Rainfall Station
		Sapang Buho	Sapang Buho
	Cabanatuan ←	La Paz	La Paz
	↓		Papaya
		San Vicente	San Vicente
		Arayat	Arayat
Manila ←	San Rafael ←		Biak na Bato
		Candaba	Candaba
			San Rafael
		Ipo Dam	Ipo Dam
		Apalit	Apalit

* East side of the mountain of which elevation about 200 m above the mean sea level of Manila Bay.

FIG 4-1 SCHEMATICAL DIAGRAM OF FLOOD FORECASTING SYSTEM IN THE PAMPANGA RIVER BASIN

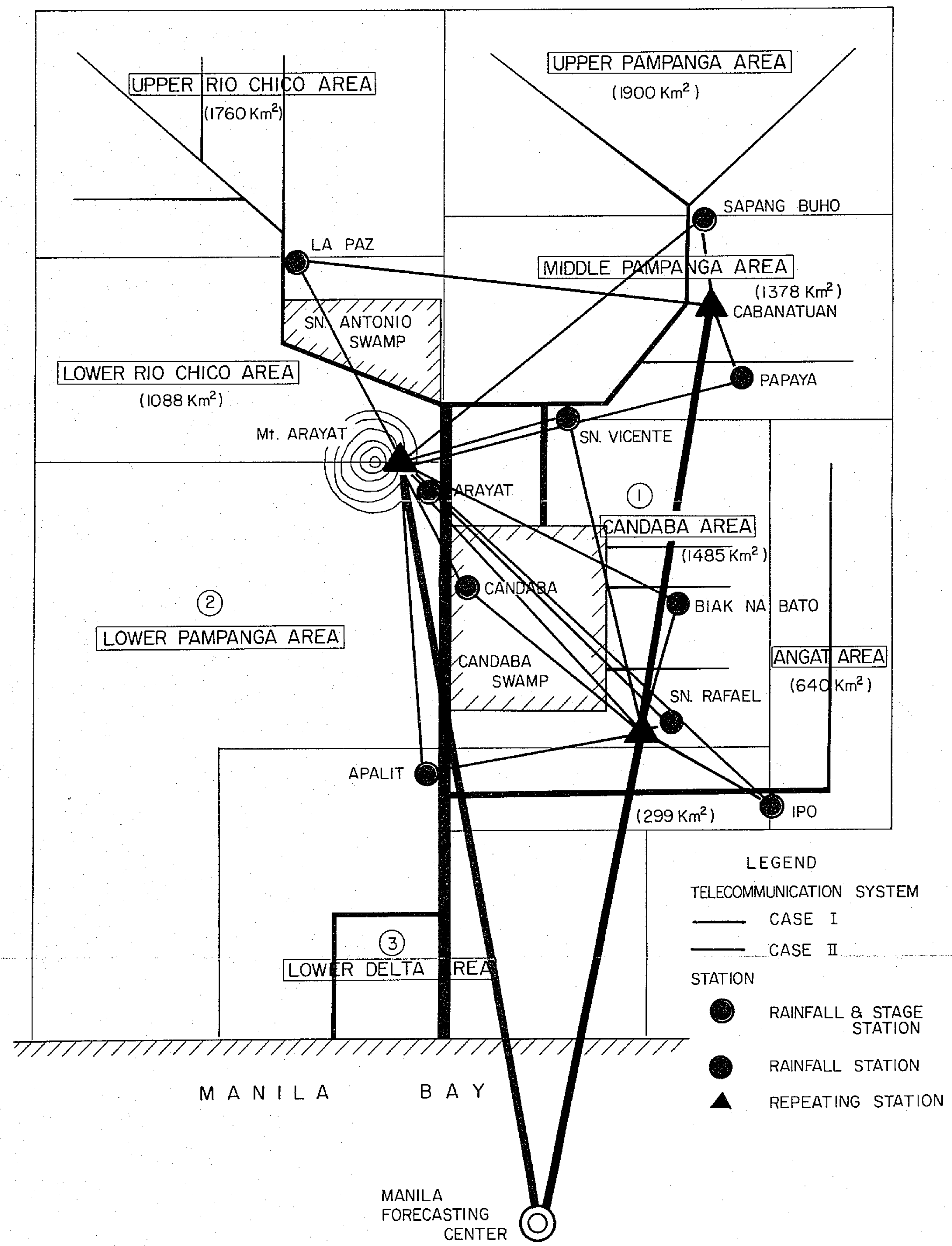
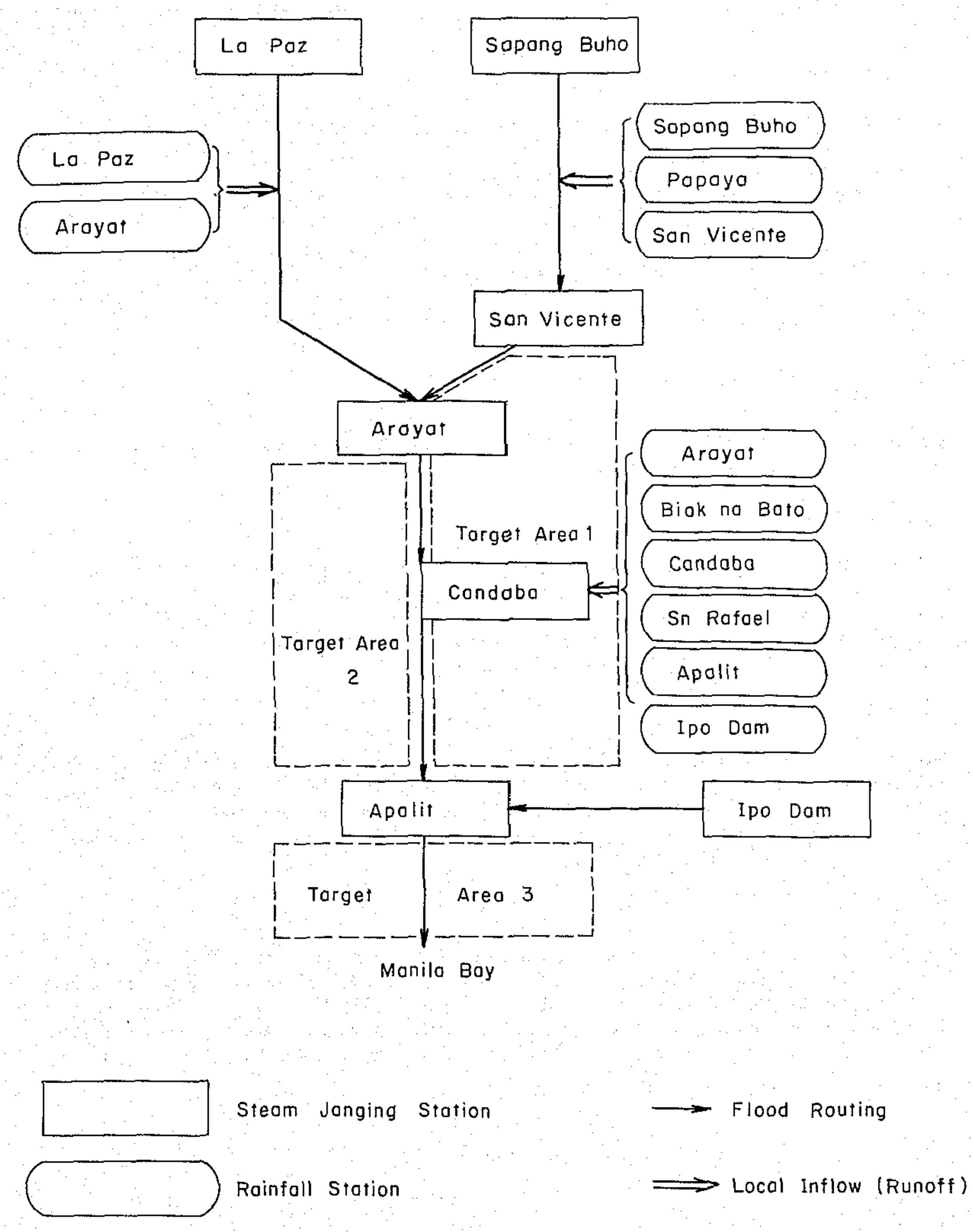


FIG 4-2 CONFIGURATION OF THE PAMPANGA RIVER BASIN



The Survey Team made the field investigation of the Malate site where the observations of water level and discharge are now conducted by B.P.W. and found that it is not a suitable site because of the river channel being unstable extremely; so the Team selected Sapang Buho immediately below the confluence with the Santor River, about 10 km upstream from Malate. A rain gauge will be installed at this site together with a river stage gauge to grasp the rainfall data of the middle Pampanga Area, in cooperation with the Papaya station. The length of the river channel between Sapang Buho and the confluence with the Rio Chico is about 100 km, and it is believed that the travel time of flood between them is more than 20 hours. As, of course, any gauging of flood water level and discharge has not conducted so far at Sapang Buho, it is necessary to start such gauging promptly, to grasp the relation between river stage and discharge.

2. La Paz (Area of basin 1,760 km^2)

La Paz has the same significance in regard to the upper Rio Chico area as Sapang Buho. The Talavera River and two other tributaries join the Rio Chicho River at the upper stream of this site, and the integrated discharge of these rivers will be grasped at this station for flood forecasting and warning. The length of the river channel from La Paz to the confluence with the main river is about 3.5 km.

Because, when a great flood occurs, the flood water will overflow from this site widely into the plains on the both banks, it cannot be expected to grasp the accurate discharge based on the river stage. However, being unable to find better site, it is compelled to select here. The rain gauge to be installed here will give an indication to know the amount of rainfall in the upper and lower Rio Chico areas.

3. Papaya

This station is chiefly for grasping the rainfall in the Peñaranda River watershed and estimating the discharge of the middle Pampanga Area.

4. San Vicente

This gauge station is selected for examining the discharge of the main Pampanga River upstream from this site which is gained by adding up the discharge of the upper Pampanga Area once grasped at Sapang Buho and that of the middle Pampanga area estimated from the amount of rainfalls gauged at the Sapang Buho and La Paz stations, and at the same time it grasps the amount of inflow into the Candaba Swamp through the Cabiao–Candaba Floodway.

5. Arayat

This gauge station of which data will give the amount of outflow from the San Antonio Swamp into the lower stream will constitute the most important station––hereinafter referred to as the flood forecasting base station––in the proposed flood forecasting and warning system. A proper regard is required for possible change in the relation between river stage and discharge due to excavation of the river channel and etc. under the river improvement project.

6. Biak na Bato

This station will, together with San Rafael station, inform the amount of rainfall for estimating the discharge from the Candaba tributaries. In this, of course, the amounts of rainfall gauged at the Papaya and San Rafael rain gauge stations as well as at the San Vicente, Arayat and Candaba stream gauge stations must be fully utilized as referrence data. The discharges from the Candaba tributaries must be carefully treated with as they have direct influences on the accuracy of flood forecasting and warning.

7. Candaba

This station will supply flood forecast to the target areas, 1 Candaba area and 2 the right bank area of the main Pampanga River below Arayat. That is, since the water level of the Candaba Swamp has the most direct influence on the Apalit-Arayat Arnedo Dike, areas within and around the Candaba Swamp, and the fuse dikes provided on Apalit Arayat Setback Levee, the flood forecast will consist mainly of forecast of the water level of the Candaba Swamp, so that the authorities concerned and the residents will be able to take necessary actions based on the forecast.

8. San Rafael

This station which will catch the data of rainfall in the southern part of the Candaba tributaries will be established independently in Case I or togethered with a repeater station in Case II.

9. Ipo

This station will grasp the discharge of the Angat River and forecast any overflow of the river into Plaridel and Pulilan on its lower stream. The length of the river channel between Ipo and Plaridel is about 70 km, and the travel time of flood between them is believed to be more than 12 hours.

10. Apalit

This station is the basic flood forecasting place to the target area 3, the delta area below Apalit. Since it is believed that the water level at Apalit indicates the discharge flowing down into the lower delta area from Candaba Swamp through the three outlet channels of Sulipan, Calumpit and Bagbag, flood forecast and warning for the target area will consist mainly of forecast of the water level at Apalit.

It is necessary to pay attention to the fact that the area especially low in the lower delta area is more affected by the tidal range of Manila Bay rather than the flood discharge. In particular, as smooth inflow and outflow of tide are difficult in some places. It seems that considerable time lag behind the normal ebb and flow is occurring, the river discharge combined with this may well cause inundation at unexpected place and time. Therefore, in order to realize an effective flood forecasting and warning for the lower delta area, regard should be also paid to the tidal range.

4-1-4 Procedure of Flood Estimation

1. Basin of the main Pampanga River

The discharge and the water level at Sapang Buho and the local inflow computed from the rainfall in the basin of middle Pampanga River will be used to estimate the runoff of the main Pampanga River for the proposed flood forecasting. The rainfall data of the Sapang Buho, Papaya and San Vicente stations will be used for estimating the local inflow. It is one of the measures to use the unit hydrograph mentioned in section 3-8 for the estimation of flood runoff. However, it is necessary to develop more accurate technique for estimating runoff in future.

The water level at San Vicent is used for checking the estimated runoff of the main Pampanga River and at the same time used for determining the inflow into the Cabiao-Candaba floodway.

2. Basin of the Rio Chico River

The water level and discharge at La Paz and the local inflow computed from the rainfall in the lower part of the Rio Chico River Basin will be used to estimate the runoff of the Rio Chico River for the proposed flood forecasting. The rainfall data of the La Paz and the Arayat stations will be used for estimating the local inflow. Concerning the technique of runoff estimation, the same thing as above 1 is referred to.

3. Candaba tributaries

The rainfall data at Arayat, Biak na Bato, Candaba, San Rafael and Apalit stations will be used to estimate the runoff of the Candaba tributaries in the proposed flood forecasting system. About the technique of runoff estimation, the same thing as above 1 is referred to.

The basin has the area of 1,485 km^2, including the swamp, of which water surface extends to as much as 300 km^2 at flood time. As the tributaries flowing into the swamp have short stream stems, except the Angat River lying in the southernmost, not sufficient time for flood forecasting is left if the runoff of these tributaries is to be measured based on the river stages. Therefore, the contribution of these tributaries is computed from the rainfall data for the proposed flood forecasting.

As for the Angat River, the discharge of the Ipo Dam is gauged to estimate the water level at Sulipan.

4. Swamp area

The water level of the swamp will be estimated for the forecasting purpose. This level is estimated on the assumption that the balance between the inflow and the outflow of the swamp is stored in it.

The swamp has a slender shape in the direction of the north and the south and the water surface area is 200 km^2, with the capacity of 1,000 million m^3 at the highest water stage in 1960 flood. In the analysis described in section 3-8, a good result has been obtained on the assumption that the water surface slope of the swamp is fixed and the outflow from the swamp has a functional relation with the water level at Sulipan. Whereas, a detailed examination reveals that the water level of the swamp does not show simple fluctuations. When the Angat River runs off soon, the lower reach has the peak of the water level soon. With the improvement in the accuracy of discharge gauging and the examination of the hydraulic characteristic of the swamp, in future, it will become possible to make sufficiently accurate forecasting of the water level in the swamp.

4-2 Telemetering Facilities

4-2-1 Data collection for Flood Forecasting

There are two systems usually used for collection of data, one is non attendant system using telemeter and the other is attendant system using radio telephone. The advantages and disadvantages of these two systems are discussed hereunder.

a. Time required for data collection.

No problem arises on the radio telephone system in which the number of gauging stations is small. However, in such a case as this project in which the number of item in data to be collected amounts to 17 and the number of stations is expected to increase in future, the operation at the control station will be difficult and much time is required for collecting data.

In the telemetering system, the gauging stations respond strictly in accordance with instructions from the control station and the required time is only 5 to 7 seconds per data per station.

Even if the number of gauging stations increases in future, necessary data for flood forecasting of the Pampanga River can be collected within about 3 minutes by the telemetering system.

b. Collecting data is possible at any time by telemeter.

In the case of the radio telephone system, it involves many difficulties to assign personnels for duty throughout a long flood period in conducting the gauging operation directed from the center at optional times.

The telemeter system enables us to conduct the gauging operation at any time and collect detailed data. For example, a peak stage can be accurately known by frequently observing the water level.

The telemeter system also enables us to collect data easily even from the place where the personnel is compelled to refuge or the place becomes in accessible during a flood. Therefore, it is possible to collect data safely by the telemetering system throughout a flood period.

c. Reading out and transmission.

Reading out by man involves personal difference and errors, but, in the case of telemetering system, since the reading out is conduced by machine and in digits, the operation is always accurate and stabilized and there is no mishearing as in the case of voice communications on radio telephone. Also, the results of every gauging are automatically recorded in print and preserved so that they may serve as definite evidences.

It is concluded that the telemetering system is suitable as the data collection system for flood forecasting of the Pampanga River, taking into consideration the great volume of gauging operations and the flood extending a long period of time.

4-2-2 Frequency Band

The HF band (from 3 MHz to 30 MHz) and the VHF band (from 30 MHz to 300 MHz) are compared with each other as follows.

The HF band has an advantage of no need of repeater station, but as the condition of the radio transmission varies from daytime to nighttime and is affected by the solar activity also, it is necessary to provide from two to four frequencies so that the optimum frequency can be selected at all times. The signal-noise ratio (S/N) of HF is inferior. All these make it unsuitable for non attendant telemetering system to adopt the HF band.

As the VHF band makes it possible to form a network with excellent S/N, stabilized throughout the year, a telemetering system using the VHF band is planned.

4-2-3 Network of telemetering system

As the result of the studies carried out on the basis of the map on the scale of 1 to 50,000, the following two plans have been selected for the network of telemetering system of the Pampanga River Basin.

Case I indicates a repeater station to be established on Mt. Arayat, through which all the gauging stations will be connected to the control station. Although it is better to locate the repeater station in the place as high altitude as possible, it will be suitable to locate it on the easternside slope of El. 200m, taking into consideration the convenience of maintenance. In this plan, 30 m above the ground level is sufficient for the hight of the antenna of the control station, and 7 m above the ground level for the antenna of the repeater station. The necessary frequencies in this case are the two frequencies separated by more than 2 MHz with each other in the VHF band (60 MHz or 150 MHz).

In case II, two repeater stations will be established, one at the site of El. 66 m, about 3 km to the northeast of San Rafael (hereinafter referred to as San Rafael) and the other at Cabanatuan. Six gauging stations at Apalit, Arayat, Candaba, San Vicente, Biak na Bato and the Ipo Dam are respectively connected to the control station through the San Rafael station, and the remaining three gauging stations at Sapang Buho, La Paz and Papaya are connected to the control station through Cabanatuan and San Rafael repeater stations. The San Rafael station is to function as a rain gauge station as well. The antenna height above the ground level needs to be more than 35 m for the control station and more than 30 m for both of the repeater stations. The necessary frequencies in this case are three frequencies separated by more than 2 MHz with each other in VHF band.

In addition, monitoring facilities have been planned in the Apalit Office. The data transmitted from respective gauging stations at the request of the control station are recorded in the typewriter of the control station and at the same time are monitored and recorded at the Apalit Office, to use them as the data for making a judgment of conditions necessary for the field office.

In both cases, about 7 m above the ground level suffices for the antenna height of the gauging and monitoring stations.

4-2-4 System design

Profile maps prepared from the map on the scale of 1 to 50,000 are shown in the APPENDIX V. The system design has been carried out on the assumption of adopting the most usual 150 MHz band among VHF bands. Various calculations have been made based on the following values, the free space loss 32.4 + 20 log F (MHz) + 20 log D (km), which are generally employed, fading loss 0.1 db/km, receiver noise power −117 dbm, S/N improvement factor 24 db and threshold level−108 dbm. (The last 3 values are usually used in Japan for calculating the radio propagations of 150 MHz band signals.) Calculations have also been made under the assumption that the transmitting power is 3 W and the antennas for the repeater stations and other stations are 3-stage collinear type and 3-element Yagi type respectively.

The calculated values are shown in Tables 4-2.

An example of radio circuit designed for transmission between the control station and Mt. Arayat is as follows.

①	Transmitting power 3 watt	$10 \log (3 \times 10^3) = 34.7$ dbm
②	Free space loss for 71.6 km	32.4 + 20 log 150 (MHz) + 20 log 71.6 (km) = 113 db
③	Additional loss	add 20 db of terrain factor
④	Feeding circuit loss	10D - 2V 50m x 0.06 db/m = 3 db
⑤	Antenna gain Yagi 3-element	8 db (isotropic gain), 3 stage collinear 6 db (isotropic gain)
⑥	Standard received power	①−②−③−④+⑤ = 87.3 dbm
⑦	Receiver noise power	−117 dbm
⑧	Carrier S/N	⑥ − ⑦ = 29.7 db
⑨	S/N improvement factor	24 db
⑩	Standard S/N	⑧ + ⑨ = 53.7 db
⑪	Fading depth	0.1 db/km x 71.6 km = 7.2 db
⑫	Total S/N (fading)	⑩ − ⑪ = 46.5 db
⑬	Minimum Power at threshold (Threshold level)	−108 dbm
⑭	Fading margin (standard)	⑥ − ⑬ = 20.7 db
⑮	Fading margin (fading)	⑭ − ⑪ = 13.5 db

4-2-5 Studies on the network of telemetering system

In planning the present telemetering network, the most attention has been given to designing a stabilized system with sufficient capacity, convenience of maintenance and capacity of expansion in future.

From the viewpoint of stability of channel, the Ipo Dam site has poor line-of-sight with large shielding loss anticipated. Therefore, it has been planned to raise the elevation of radio station building by laying the cable of about 300 m in length up to a nearby high point. Sufficient fading margin cannot be also secured between that point and Mt. Arayat. After reconnaissance of the site, it was found that the radio station could be easily raised up to a sufficient elevation by increasing the length of cable. Then, it will be easy to select an optimum site, where adequate margin can be secured, by conducting transmission test of radio wave.

Table 4-2(1) Design of Circuit (Case I)

STATION NAME / Classification	Unit	MANILA 71.6km MT. ARAYAT	MT. ARAYAT 28.7km APALIT	MT. ARAYAT 43 km ARAYAT	MT. ARAYAT 26.8km LAPAZ	MT. ARAYAT 13.1km CANDABA	MT. ARAYAT 36.7km PAPAYA	MT. ARAYAT 57.4km SPANG BUHO	MT. ARAYAT 6.1km SAN VICENTE	MT. ARAYAT 53.5km IPO DAM	MT. ARAYAT 32.9km BIAK NA BATO	MT. ARAYAT 34.6km SAN RAFAEL
Transmitting power	dbm	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7
Free space loss	db	−113										
Additional loss	db	−20										
Feeding circuit loss	db	−3										
Antenna gain (T)	db	8										
Antenna gain (R)	db	6										
Standard received power	dbm	−87.3										
Receiver noise power	dbm	−117										
Carrier S/N	db	29.7										
S/N improvement factor	db	24										
Standard S/N	db	53.7	64.7	80	66.2	64.9	62	47.1	71.3	40.2	57	56.2
Fading depth	db	7.2	2.9	0.4	2.7	1.3	3.7	5.8	0.6	5.4	3.3	3.5
Total S/N(Fading)	db	46.5										
Minimum power at threshold (Threshold level)	dbm	−108										
Fading margin (Standard)	db	20.7	34.7	50.1	36.2	34.9	30	17.1	43.6	10.2	27	16.2
Fading margin (Fading)	db	13.5	31.8	49.7	33.5	33.6	26.3	11.3	43.0	4.8	23.7	12.7

Table 4-2(2) Design of circuit (Case II)

STATION NAME / Classification	Unit	MANILA 42.8km SAN RAFAEL	SAN RAFAEL 22.2km APALIT	SAN RAFAEL 30.5km ARAYAT	SAN RAFAEL 21.8km CANDABA	SAN RAFAEL 32.9km SAN VICENTE	SAN RAFAEL 19.5km IPO DAM	SAN RAFAEL 13.8km BIAK NA BATO	SAN RAFAEL 57 km CABANATUAN	CABANATUAN 23.8km LA PAZ	CABANATUAN 19.5km SPANG BUHO	CABANATUAN 17.25km PAPAYA
Transmitting Power	dbm	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7
Free space loss	db	−108.5										
Additional loss	db	−20.0										
Feeding circuit loss	db	−30										
Antenna gain (T)		8										
Antenna gain (R)		6										
Standard received power	dbm	−82.8										
Receiver noise power	dbm	−117.0										
Carrier S/N	db	34.2										
S/N improvement factor	db	24.0										
Standard S/N		58.2	64.9	62.1	60.5	56.9	43.0	57.3	47.7	58.2	61.5	53.5
Fading depth	db	4.3	2.2	3.1	2.2	3.3	2.0	1.4	5.7	2.4	2.0	1.8
Total S/N (Fading)	db	53.9										
Minimum power at threshold (Threshold level)	dbm	−108										
Fading margin (standard)	db	25.2	34.9	32.1	30.5	26.9	13.0	27.3	17.7	28.2	31.5	23.5
Fading margin (fading)	db	20.9	32.7	29.0	28.3	23.6	11.0	25.9	12.0	25.8	29.5	21.7

It is expected that satisfactory circuit S/N ratio and fading margin can be secured for any other spans. An estimation based on the examination of map shows that about one hour will be needed to reach the proposed site of repeater station on Mt. Arayat from San Juan on foot, which seems to present a problem on maintenance. Therefore, the repeater station is planned to be equipped with two sets, working and standby, so that in case of the failure of the working set, the operation is automatically shifted to the standby set, together with a device by which these switching over of working and standby sets and supervising of operating conditions can be done by remote control from the control station.

It is possible to establish the San Rafael repeater station on a site being about 15-minute walk from the point accessible by motor car and the Cabanatuan repeater station on a site nearby the road. As this makes it comparatively easy to perform maintenance, repeater equipment is planned to have only working set.

Each one spare set of the telemetering terminal equipment and radio equipment for slave stations and radio equipment for repeater stations is to be stored at the control station, so that in case when any trouble happened in one of these stations a service man can be dispatched there from the control station to replace the defective set by a spare.

Future expansion of this network will involve mainly the establishment of telemetering rain gauge stations in the head water area. However, in Case I, Mt. Arayat will constitute a shield to the direction of Bamban. This obstacle can be overcome by using the San Vicente or La Paz station as an auxiliary repeater station. As to the rain gauge stations on the upper stream basin of the main Pampanga River, their sites are expected to be selected comparatively easily by transmission test as the elevation of the Mt. Arayat repeater station is sufficiently high.

In case where Case II is adopted, there seems to be little questions for radio transmission in the direction of Bamban, but rain gauge stations on the upper stream of the main Pampanga River will be required to be established on a site of comparatively high elevation in order to reduce any shielding loss due to the intermediate mountains standing between, because the ground height of the antenna of the repeater station is low.

In Case I, either Manila or Quezon City may be selected as the site of the control station, both of which are available for making good circuit to the repeater station. In Case II, the control station in Manila can obtain a good circuit to the repeater stations. The topography between Quezon City and San Rafael seems to constitute a shield, but it is impossible in this survey to examine it, as no detailed map of Quezon city has been made available. Therefore, further study is necessary for establishing the control station in Quezon City.

As aforementioned, the above examinations have been made on the basis of the map on the scale of 1 to 50,000, therefore, prior to implementing any of these plans it is definitely necessary to confirm the feasibility by transmitting test of radio waves and make modifications as may be required.

Comparison of advantages and disadvantages in Case I and Case II is summarized as Table 4-3.

Table 4-3 Advantages and Disadvantages in Case I and Case II

	Case I	Case II
Control station	Either Manila or Quezon City can be selected as the site. Necessary antenna height is 30 m above ground level.	Manila is suitable, but topographical study on propagation of electric wave has to be made for Quezon City as the site. Necessary antenna height is more than 35 m above ground level.
Repeater station	Sufficient antenna height is about 7m above ground level. As its site is on a mountainside requiring about one hour walk by estimate, some difficulties are involved for maintenance.	Necessary antenna height is more than 30 m above ground level. Either site permits motorcar to have access to the near point, thus no difficulties are involved for maintainance.
Number of necessary frequency	Two radio frequencies are necessary.	Three radio frequencies are necessary.
Circuit margin	Every station has sufficient margin.	Every station has sufficient margin.
Expansion in future	Comparatively few restrictions.	Some restrictions due to topographical reasons for stations in upstream areas.

4-2-6 Main Specification of Telemetering Equipment

(1) Control station

The control station is designed to be capable of calling up the rainfall or water level gauging stations dispersedly located at various points successibly at predetermined or optional times to make them transmit observation data for tabulating and recording in the control station. That is, the calling selection of stations and direction of data transmission can be carried out by the following three method

1. Automatic call of all gauging stations at fixed times (fixed time call of all stations).

2. Manual call of all gauging stations at optional times (Manual call of all stations).

3. Manual call of a particular station at optional time (optional call).

The fixed time call of all stations will be such that it can carry out automatic calling of all stations in a fixed order at the required intervals of data collection (four kinds of optional intervals ranging from 10 minutes to 24 hours can be predetermined and set), by means of the clock device instead of manual operation.

Manual call of all stations will be such that it can call all stations in a fixed order at any time by pushing the button when data collection is needed, irrespective of the clock device.

The optional call will be such that it can call any particular station by pushing the button concerned at any time.

Photograph 4-1 shows an example of a control station in Japan equipped with this kind of telemetering equipments, Fig. 4-3 is its block diagram, and Table 4-4 an example of recording form.

Table 4-4 Example of page type printing

Rainfall and Water Level Observation Values

DATE	TIME	NAME OF GAUGING STATION			
		STATION XX	STATION XX	STATION XX	STATION XX
05 12	0900	235	651	211	407
	0921	251			
	1632	263	679	250	437
05 13	0900	264	685	250	437

(2) Rainfall gauging system

The measurement of rainfall will be made by a tipping bucket rain gauge and converted into coded signals by a digital signal converter.

After accurate measuring of rainwater received through a receptacle at every 1 mm of rainfall with a tipping bucket, the signal converter will be driven by one digit. The signal converter is to be of three digit (0 to 999) decimal indication type.

An example of a rainfall gauge station in Japan is shown in Photograph 4-2(1), and the equipment of such station is shown in Photograph 4-2(2). A block diagram of a rainfall and water level gauging station is shown in Fig. 4-4.

(3) Water level gauging system

The water level gauge of float type which follows the change of water level will be installed. It is capable of converting the water level values accurately into coded signals by translating the change in levels of float which is hung by the wire with beads into the revolutions of sprocket pully, and in turn, by driving the analogue digital converter which is geared with pully shaft. The measurable range is from 0 to 999 cm (less than 10 m) in 3 decimal digits. If a range more than 10 m is needed, this will be satisfied by switching the scale of one digit for 2 cm of water level.

An example of a water level gauging station in Japan is shown in Photograph 4-3(1), and equipment of such station in Photograph 4-3(2).

(4) Control system of a repeater station

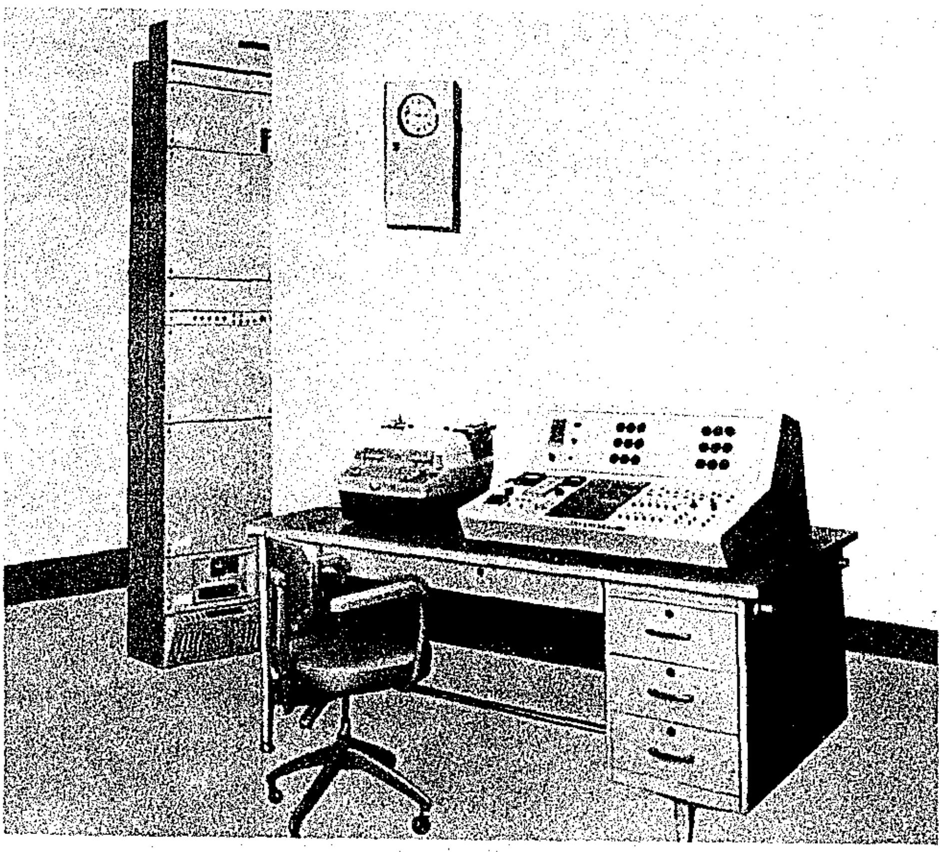
Since any repeater station is non-attendant and, in particular, difficulty is foreseen for the maintenance of Mt. Arayat station, its operating situation has to be watched from the control station. It is capable of keeping watch over power source condition while the working and standby sets of radio transmitter/receiver are in operation and coducting switch on control in case of any failure of these sets.

Since the repeater station other than Mt. Arayat is located at the site where maintenance is comparatively easy to perform, repairment of failure may be carried out whenever it occurs.
A block diagram of the repeater station is shown in Fig. 4-5.

(5) Monitor station

The Sulipan station will be equipped with the facilities to monitor the transmission of observed data which are to be collected to the control station.

Photo 4-1 Control Station



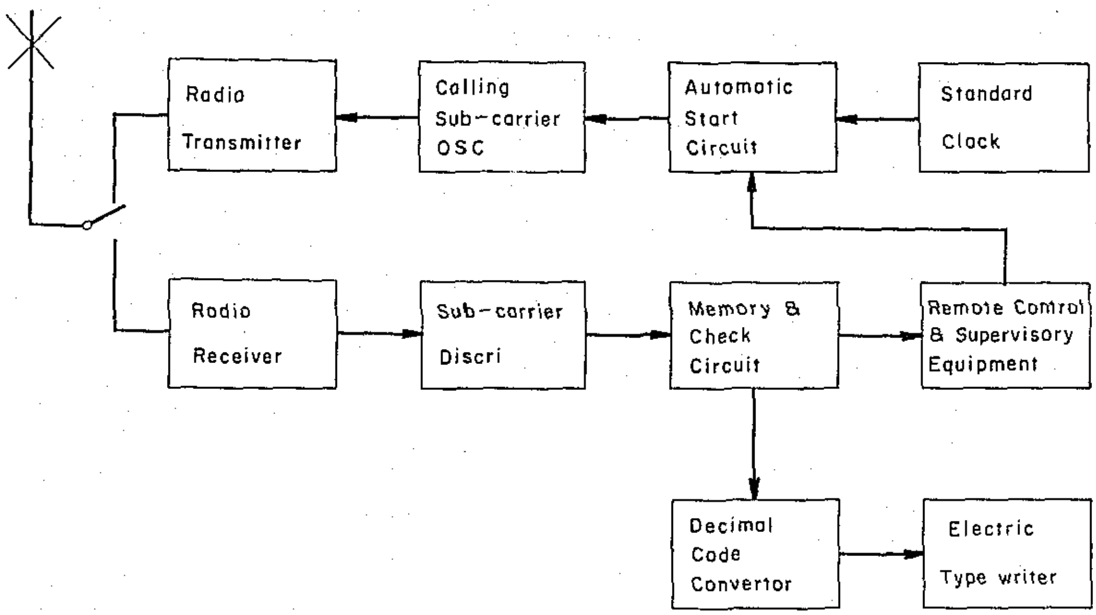


FIG 4-3 CONTROL STATION BLOCK DIAGRAM

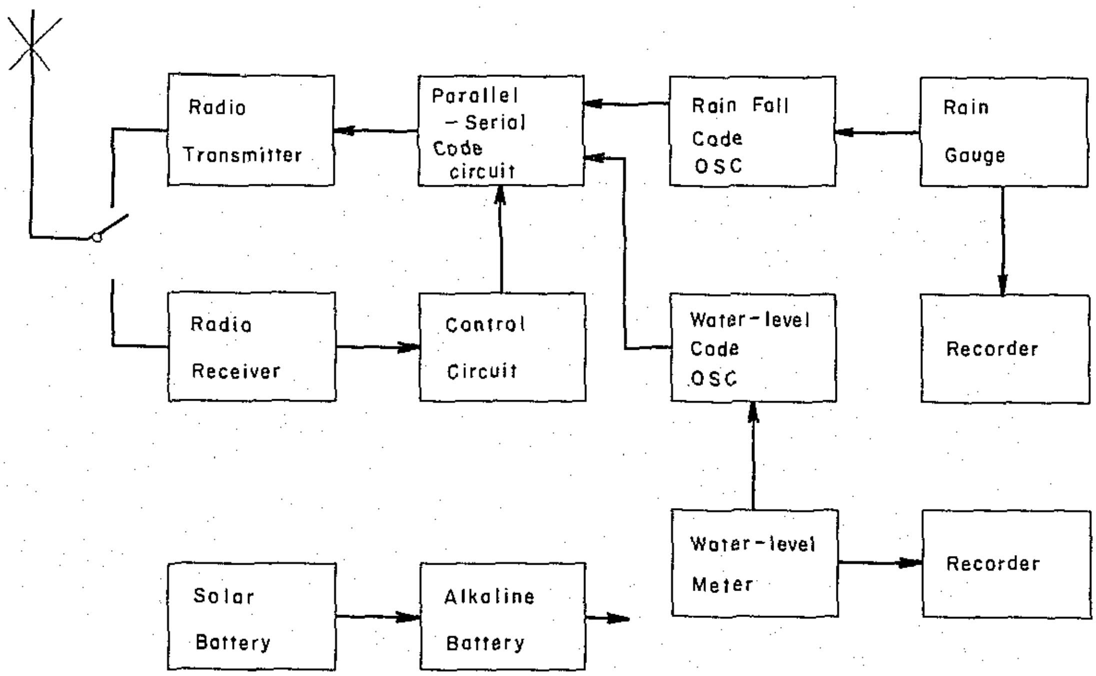


FIG 4-4 RAINFALL AND WATER LEVEL GAUGING STATION BLOCK DIAGRAM

Photo 4-2(1) Rain Gauge Station

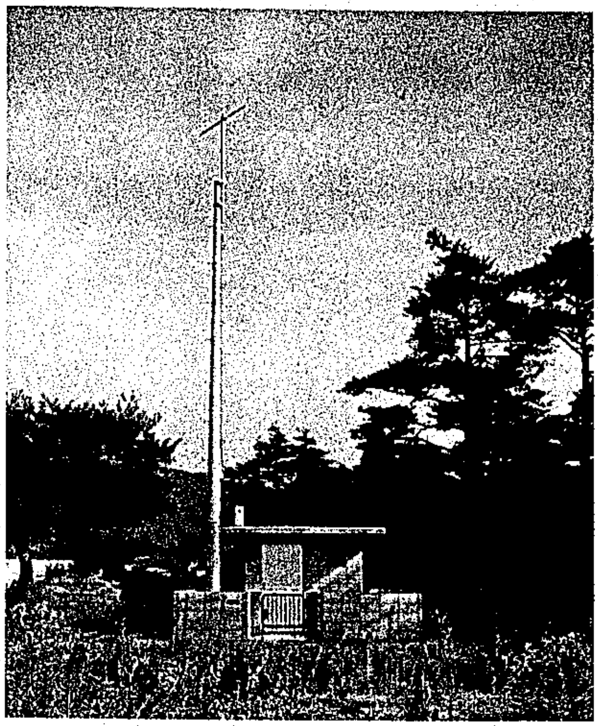


Photo 4-2(2) Facilities of Rain Guage Station

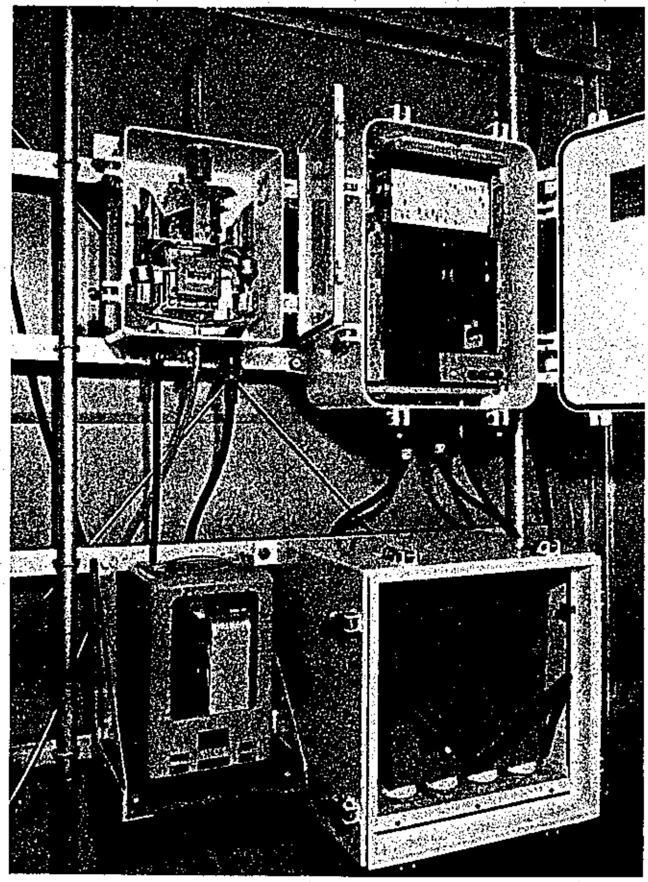
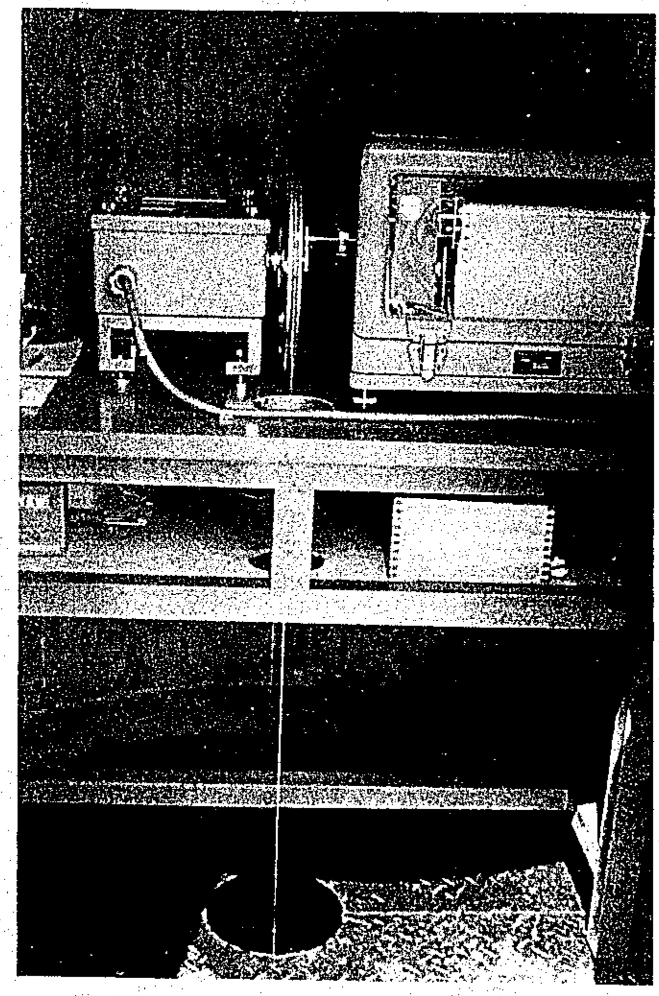


Photo 4-3(1) Water Level Gauging Station

Photo 4-3(2) Facilities of Water Level Gauging Station



The facilities can monitor, signals of measured data transmitted from respective gauging stations and record and indicate them but the monitoring station itself will not conduct any calling operation, different from a control station.

A block diagram of the monitor station is shown in Fig. 4-6.

(6) Power source

Since most of gauging and repeater stations are established in the areas scarcely provided with power sources, the solar cell battery will be used for supplying power to the radio transmitter/receiver and signal converter. As it needs to have the battery charged in order to supply enough power even during nighttime or bad weather, the floating charge system will be adopted combining the solar cell battery with the storage battery. The control station will be equipped with a standby generator for an emergent purpose. An example of the solar cell battery is shown in Photograph 4-4.

4-2-7 Maintenance of Telemetering System

(1) Regular inspection

Daily inspection

The control station will call gauging stations and inspect operating conditions of respective equipment by the printer etc.

Monthly inspection

Inspection of the power source, terminal and radio equipments of the control, repeater and slave stations will be conducted (half-monthly in a rainy season). Measurement of the signal level and S/N ratio of each equipment will also be conducted before and after the flood season.

Annual inspection

Inspection and adjustment of each part of the system will be conducted, of which work is to be contracted to the manufacturers.

(2) Measures after inspection

If it is found that a measured value differs from the standard value, the equipment should be adjusted or repaired in standard conditions.

The results of inspection will be recorded in the Inspection Report shown in Table 4-5

(3) Maintenance cost and others

Inspection will be conducted half-monthly in the rainy season and monthly in the dry season.

In the rainy season	12 times	18 times
In the dry season	6 times	

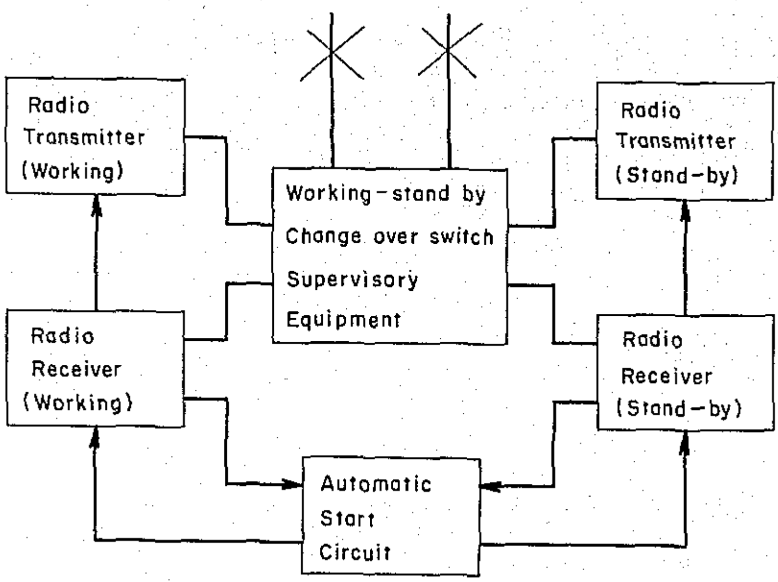


FIG 4-5 REPEATER STATION BLOCK DIAGRAM

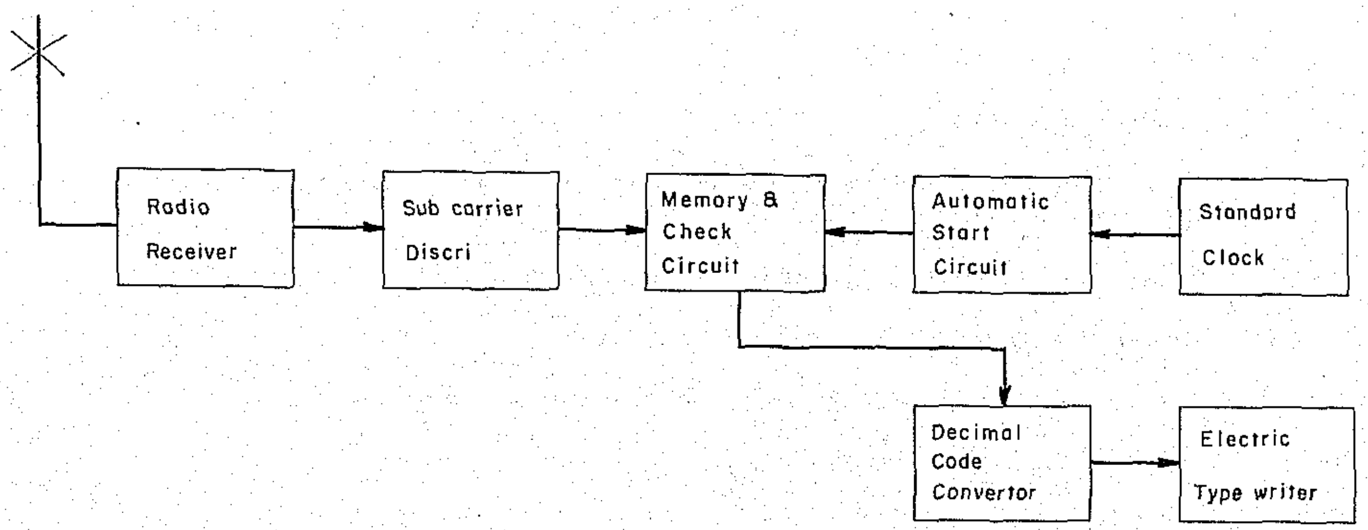
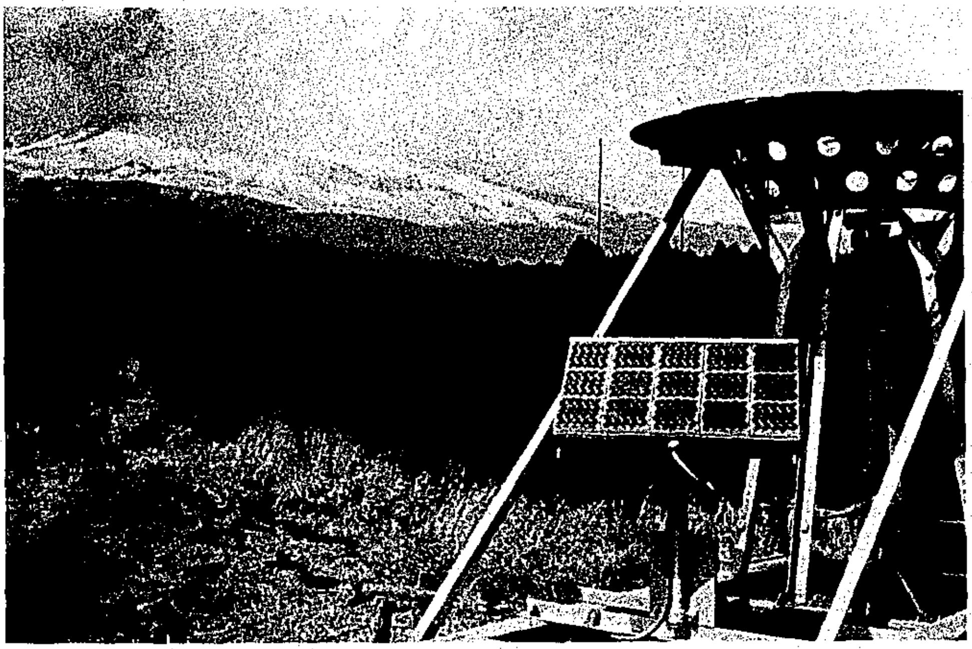


FIG 4-6 MONITOR STATION BLOCK DIAGRAM

Photo 4-4 Solar Cell Battery



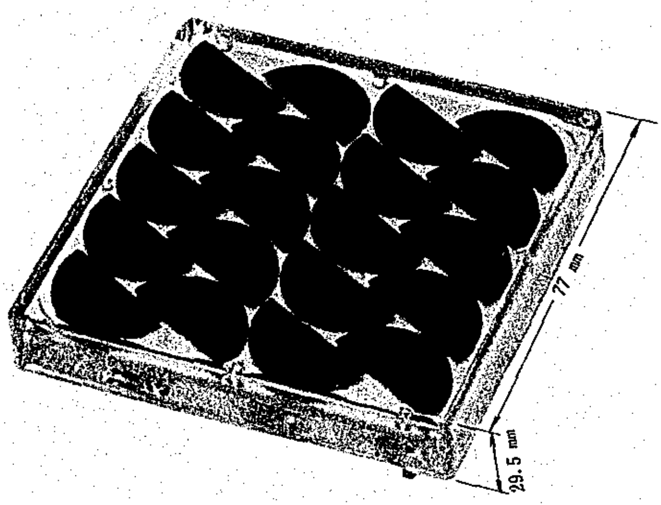


Table 4-5 Inspection Report for Telemetering equipments

Item \ Station Name		MANILA Action	MANILA Note	SULIPAN Action	SULIPAN Note	
Antenna	Antenna Feeding Circuit					
Radio	Transmitter Receiver Power					
Telemeter	Carrier Transmitter Receiver Measure					
Sources of Electricity	Battery Solar Cell Charger Reserve Generator					
Others						
Circuit S/N						
Synthesis Action						
Statement	Describe here any trouble and serious problem.					

Table 4-6 Maintenance cost of telecommunication system

a. Fuel of a service car	
Gasoline	₱ 2,000
Mobile oil, waste, etc.	₱ 200
b. Periodic service cost of Jeep	₱ 1,900
c. Maintenance, repair and service cost	
Control station	₱ 1,500
Gauging station	₱10,000
d. Annual periodic maintenance cost (one service man to be dispatched from the manufacturer for two weeks)	
Air passenger fare (round trip)	₱ 1,200
Subsistence	₱ 2,300
TOTAL	₱19,100 Say ₱20,000 ($5,130)

4-3 Housing Facilities

4-3-1 Rain Gauge Station

The following Table 4-7 shows the rain gauge stations which need to be well arranged in order to collect rainfall data for flood forecasting computation.

Table 4-7 List of rain gauge stations

No.	Station	Location of Station	River Basin	Remarks
1	Papaya	Papaya, N.E.	Peñaranda R.	
2	Biak na Bato	Biak na Bato, Bulacan	San Miguel R.	
3	Sapang Buho	Bongabon, N.E.	Upper Pampanga R.	To be installed in the telemeter house of the water level gauging station.
4	San Vicente	Cabiao, N.E.	Upper Pampanga R.	To be installed in the telemeter house of the water level gauging station.
5	Sto. Rosario	Zaragoza, N.E.	Rio Chico R.	To be installed in the hut of the water level gauging station.
6	San Agustin (Arayat)	Arayat, Pampanga	Middle Pampanga R.	To be installed in the telemeter station house of the water level gauging station.
7	Candaba	Candaba, Pampanga	Candaba Swamp	To be installed in the hut of the water level gauging station.
8	Sulipan (Apalit)	Apalit, Pampanga	Lower Pampanga R.	To be installed in the telemeter station house of the water level gauging station.
9	Ipo Dam Below	Norzagaray, Bulacan	Angat R.	To be installed in the telemeter station house of the water level gauging station.
10	San Rafael	San Rafael, Bulacan	Angat R.	In case II, to be installed in the repeater station house.

i) As Papaya and Biak na Bato stations will be newly established for only rainfall observation, concrete hollowed block (C.H.B.) structure with floor space of 1.75 m x 1.85 m is adopted for the station house. A receptacle of the rain gauge is set on the roof of the house and the main part of rain gauge and telemeter equipments are installed in the house (Type B). A telepole is made of steel pipe and an antenna is fixed to the telepole at 7 m in height above ground level.

ii) Five rain gauges at Sapang Buho, San Vicente, San Agustin, Sulipan and Ipo Dam Below are to be installed in the water level gauging station. The house of C.H.B. structure with floor space of 1.75 m x 1.85 m is to be built for each rain gauge. A receptacle of the rain gauge is set on the roof of the house, with the main part of rain gauge and telemeter equipments installed in the house (Type B). A water gauge is installed in the water level gauging house. A telepole is made of steel pipe and an antenna is fixed to the telepole at 7 m in height above ground level.

iii) At Sto. Rosario and Candaba each rain gauge will be installed in the house of water level gauging station. A receptacle of the rain gauge is set on the roof of the house, and the water gauge, the telemeter equipment as well as the main part of the rain gauge are installed together in the house (an automatic water level recorder station - - Type B).

iv) As the San Rafael station is to be newly established as a rain gauge station in Case I, the station house and the telepole are to be the same as those of Papaya and Biak na Bato gauge stations.

In case II a repeater station will be established at San Rafael, then a receptacle of the rain gauge is set on the roof of the station house, with repeater and telemeter equipments as well as the main part of the rain gauge installed in the house. The house of C.H.B. structure with floor space of 1.75 m x 2.25 m and a relay steel tower about 30 m high will be erected at the station.

4-3-2 Water Level Gauging Station

The following Table 4-8 shows the basic water level gauging stations to be well arranged to collect water level data for flood forecasting computation.

Table 4-8 List of the basic water level gauging stations

No.	Station	Location of Station	River Basin	Remarks
1	Sapang Buho	Bongabon, N.E. N.E.	Upper Pampanga R.	To be newly established.
2	San Vicente	San Vicente, Cabiao, N.E.	Upper Pampanga R.	
3	Sto. Rozario (La Paz)	Zaragoza, N.E.	Rio Chico R.	Automatic operation of recording.
4	San Agustin (Arayat)	Arayat, Pampanga	Middle Pampanga R.	
5	Candaba	Candaba, Pampanga	Candaba Swamp Pampanga R.	To be newly established.
6	Sulipan (Apalit)	Apalit, Pampanga	Lower Pampanga R.	
7	Ipo Dam Below	Norzagaray, Bulacan	Angat R.	

i) The Sapang Buho gauging station will be established immediately below the confluence of the main river with the left tributary, Santor River. Since this station is located on the transition zone from hilly area to plain, the slope of river bed is steep and great velocity of flood flow is expected. Then a water level gauging station of reinforced concrete structure has been designed for this station. The river cross section of this site consists of terrace with a sheer cliff about 20 m on the left bank and gently sloping sedimentary layers about 5 m above the normal water level on the right bank. The gauging station is to be built on the left bank more preferable in veiw of topography and access to road. As it is believed that the elevation of flood level will not exceed 10 m above the normal water level estimating from the discharge at Malate in the past, the depth of the gauging well is decided as 10 m. The inner diameter of this well will be 0.6 m as the water level gauge of float type is adopted. The concrete tube of 0.4 m in inner diameter is used to conduct water into the gauging well from the low water channel and a gauging house of C.H.B. structure is erected on the gauging well. The catwalk of I beam is provided to ease the maintenance and inspection (Water stage station, Type A). The telemeter equipment which is installed in a station house to be built on the terrace of the left bank, taking account of the propagation of radio wave, is used jointly with the rainfall gauge station. (Station House, Type B.).

ii) The Sto. Rosario (La Paz gauging station which is situated below the confluence of Rio Chico with the left tributaries of Talavera River and two others, being now equipped with staff gauge, will be with self-recording gauge and telemeterized. Topographically, this site is in a very flat plain, through which the low water channel of about 30 m in width meanders. As it is expected that its whole neighborhood will be inundated by a flood of medium scale, this water level gauging station will consist of gauging well of corrugated pipe supported by a steel scaffold. As the water level gauge will be of float type, the inner diameter of this well will be 0.6 m. The depth of the gauging well is 8 m as the elevation of flood level is estimated not to exceed the normal water level by more than 8 m. The gauging house of duralumin structure is erected on a steel scaffold. (Water level gauging station, Type B.). An antenna is fixed to the steel pipe telepole of 7 m in height fixed to the scaffold.

iii) The Candaba gauging station will be established in Candaba Swamp. As the ground is soft and there is no flow velocity at the site, a light weight structure such as a gauging well consisting of corrugated pipe supported by a steel scaffold is designed for this station. The depth of the well is 8 m, as the rise of flood level is estimated to be about 5 m. The gauging house of duralumin structure is erected on a steel scaffold. (Water level gauging station, Type B.). An antenna is fixed to the steel pipe telepole of 7 m in height fixed to the scaffold.

iv) San Vicente, San Agustin, Sulipan and Ipo Dam Below gauging stations will use the existing gauging facilities, in addition to the new station house to be built in the vicinity for receiving the rain gauge and the telemeter equipment.

4-3-3 Discharge Gauging Station

As the water level forecasting at downstream point is made using the amount of discharge, it is necessary to grasp such amounts at the upstream basic point and the downstream forecasting point. In order to improve the accuracy of flood forecasting, it is necessary to revise the constants of the formulas continuously by the discharge data under the latest conditions of the river channel. Therefore, discharge gauging stations will be well arranged to carry out the flood discharge measurement at the minimum necessary number of points as shown in the following Table 4-9.

Table 4-9 List of the discharge gauging stations

No.	Station	Location of station	River	Method	Remarks
1	Sapang Buho	Bongabon, N.E. N.E.	Upper Pampanga R.	Dropping of float	To be newly established.
2	Sto. Rozario (La Paz)	Zaragosa, N.E.	Rio Chico R.	Boat, Current meter	
3	San Agustin (Arayat)	Arayat, Pampanga	Middle Pampanga R.	Bridge, Current meter	
4	Sulipan (Apalit)	Apalit, Pampanga	Lower Pampanga R.	Bridge Current meter	Sulipin Br. Bagbag Br. Calumpit Br.
5	Ipo Dam Below	Norzagaray Bulacan	Angat R.	Cable car, Current meter	

i) Since Sapang Buho is situated on the place of the topography above-mentioned and the flow velocity there is estimated to be great during flood, the measurement of discharge will be conducted using floats. Float dropper facilities will be required. The estimated width of the stream during flood being about 150 m at this point, the span of cable will be of 150 m. On the left bank, the cable is fastened to the anchor block on the terrace, and on the right bank, a tower of 10 m in height above ground level is erected. (See General View of Float Dropper Facilities.) Remote control of float dropping operation is conducted on the left bank, and material storehouse and a rest hut for the gauging staffs is provided on the terrace of the same bank.

ii) As the width of the river is wide and the flow velocity is small at the point of the Sto. Rozario gauging station, discharge measurement will be conducted with a boat.

iii) Discharge measurement will be conducted at San Agustin and Sulipan gauging stations with current meters on the bridges. At Sulipan, the measurement is made concurrently on Sulipan, Bagbag and Calumpit Bridges.

iv) Discharge measurement at the Ipo Dam Below gauging station is to be carried out by the existing cable car.

Thus, these gauging stations do not need any new facilities, but it is desirable to build a cabin for the gauging staffs to rest.

4-3-4 Houses of Control Station and Repeater Station

i) Manila control station

If the control station is established in Manila City, a steel tower of 30 m in height above ground level is required in Case I and that of 35 m in Case II. Such steel tower is erected ordinarily on the roof of building. Then, supposing the height of building is 20 m, a steel tower of 10 m for Case I or that of 15 m for Case II is required (Steel tower, Type A.).

It is desirable to secure a room for the station near to the steel tower.

ii) Mt. Arayat repeater station

As Mt. Arayat repeater station is built on the mountainside more than 200 m in altitude, radio tower of about 7 m in height above the ground level will suffice. Accordingly, two telepoles of steel pile, 7 m in height above the ground level will be erected.

A station house will be of C.H.B. structure, with floor space of 1.75 m x 2.25 m to place the repeater equipment. (Station House, Type A.).

iii) Both Cabanatuan and San Rafael repeater stations require radio tower of 30 m in height above the ground level. The self-standing steel square tower will be erected as one which can stand against a wind velocity of 60 m/s. (Steel Tower, Type B.).

A station house will be of C.H.B. structure with floor space of 1.75 m x 2.25 m to place the repeater equipment in it. In the San Rafael station house the rain gauge will be also put in it. (Station house, Type A.).

See Appendix with reference to drawings of Station House (Types A & B), Water Stage Station (Types A & B), Equipment of Float Dropper for Sapang Buho, Telepole and Steel Tower for Wireless (Types A & B).

4-4 Flood Forecasting and Warning Organization

It may be said that the flood forecasting and warning service consists of the following four operations.

1. Observation and collection of data.

2. Analysis of flood estimation.

3. Issuance and dissemination of flood forecast and warning.

4. Instruction for flood damage prevention measures such as flood fighting, evacuation of residents, etc.

The effective functioning of the flood forecasting and warning system will naturally require these operations to be carried out smoothly. For this purpose the following plans are proposed as to the organization and system for conducting each of the operations.

4-4-1 Establishment of Flood Forecasting Center

It is desirable to establish a flood forecasting center as an efficient organization for carrying out collectively analysis of data, estimation of flood and issuance of flood forecast which constitutes the important parts of the flood forecasting activity. This center is to receive the data of rainfall and water level directly from the telemetering stations to be newly established; it is also to be supplied with all the meteorological data and the information about typhoon obtained by W. B. as well as the hydraulic and hydrological data and the information about river conditions procured by B.P.W. By analyzing all these data and informations the center conduct the operations for estimating the occurrence, magnitude and arriving time of a flood, and for issuing the forecast and warning as to the dimension of inundation, change in behaviour of flood regarding the time, etc.

The members necessary to operate the flood forecasting center are to include at least the followings.

a director — He will have the power to execute the flood forecasting and warning and assume the whole responsibility in respect of them. Therefore, it is necessary to assign a hydrologist or a river engineer (of division chief level) who has a high degree of expert knowledge and a rich experience in such field.

a chief in charge of forecasting

He will analyze the meteorological, hydrological and hydraulic data and prepare the flood forecasting and warning messages. It is necessary to assign a hydrologist or a river engineer (of branch chief level) being technically excellent, who is able to act in behalf of the director when a flood lasts for a long time.

a meteorologist — He will analyze the meteorological data furnished by the telemetering stations and W. B. to estimate a flood.

a hydrologist — He will analyze the hydraulic and hydrological data to estimate a flood.

Three assistant engineers

They will take charge of the arrangement of data and the delivery of forecast and warning.

In addition to the above principal members, a small number of clerical employees and drivers will be necessary.

The activities of the flood forecasting center except at the time of flood include the researches for the purpose of improving the accuracy of flood forecasting and warning and the betterment of the system. Although the forecasting and warning operations are to be carried out by the staffs above-mentioned, it is necessary to provide any shift for the time of a flood extending over many days. One or two relieving groups for the staffs other than the director and the chief will enable the continuous operation of the center. In this connection, a good policy is to provide with the staffs for that purpose in W.B. and B.P.W., in view of the daily operations of these bureaus, so that they can be dispatched to the center only at the time of a flood.

For maintaining and repairing the telemetering system to be newly installed, a telecommunication engineer and two or more assistant engineers are required. This team of staffs to be attached to B.P.W. or W.B., being regularly stationed in Manila, makes a periodical patrol once a week or so for maintaining the slave telemetering stations and the repeater stations and also is dispatched at once to the station to repair if any trouble in equipment occurred. For this purpose it is necessary to furnish them at least a jeep so that they can have a quick movement in their activities.

For the purpose of improving the accuracy of the flood forecasting it is necessary to carry out the measurement of discharge during a flood period at seven points on the five important sites for the time being. A group of five or six men will be needed for gauging the discharge by means of float or current meter. It is necessary for B.P.W. to have some engineers who will be able to be the heads of several discharge measurement groups.

Since the data of various observations currently obtained by W.B. and B.P.W. serve for improving the accuracy of the flood forecasting and the expansion of such forecasting system, it is disirable to strengthen the present observing organization, particularly the Cabanatuan Office of W.B. and the Apalit Office of B.P.W., so that they can collect fresh data at the place and carry out the activities adapted to the actual conditions.

4-4-2 Kinds and Contents of Flood Forecasting and Warning and Its Disseminating System

The measures to be taken against a flood on receiving flood forecasting will include

(a) evacuation of general residents,

(b) flood fighting,

(c) Securing of facilities for public services such as road traffic, electricity supply and communication, and

(d) securing of public peace and order by the police, P.C. and armed forces.

Therefore, it is desirable to issue flood forecast and warning classified in three kinds, that is flood cuation, flood warning and flood information.

The flood caution is for showing the extent of the estimated scale of a possible great flood to the general residents and the persons concerned, in order to call their attention to make necessary preparations for the flood. The flood warning is for warning the general residents and the persons concerned to take the measures against the flood, by showing the estimated dimension and time of occurrence of the coming great flood. The flood information is given showing the present condition of a flood and its estimated change regarding the time thenceforth, so that appropriate measures can be taken against the flood.

In order to disseminate these flood forecasting, warning and information to those who need them, the following channels will be used.

a) General residents -- The flood forecasting and warning delivered to those who assume the responsibility for the safety of the residents, giving them an instruction to take refuge (city or province governors, or municipality governors, are disseminated to the general residents through barrio captains.

b) Persons concerned with flood fighting -- The flood forecasting and warning are transmitted to the head in charge of flood fighting (municipality governors or barrio captains). However, where the city or the province is in the leading position for flood fighting such forecast and warning are to be transmitted to the governor. It is desirable that the Apalit Office play an leading role keeping close contact with the field.

c) Public utilities -- The flood forecast and warning are transmitted to their head offices, who in turn transmit them to their respective local agencies.

d) Police force, P.C. and Armed Force -- The flood forecast and warning are transmitted to their central headquarters, who in turn transmit them to their outstation detachment.

The study of communication means for dissemination of the flood forecasting and warning through the above-mentioned channels reveals that those who have their exclusive communication facilities are few except the police, P.C. and armed forces. Therefore, the general practice is to use the telephone and telegram. However, in case where there is no exclusive communication facilities, the multistage relaying method necessitates much time and has possibility of many errors and interferences, and it is presumable that the communication by these means becomes impossible due to inundation during the flood period. Accordingly, it is proposed for the time being to adopt the delivery by means of radio and television broadcastings even though the means is only one way transmission. Any transmission channel is always necessary to have an auxiliary channel, for which it is necessary to make arrangement for the use of exclusive communication facilities of various organization such as the police and military radio channel.

Fig. 4-7 Flow Diagram of Flood Forecasting and Warning Service

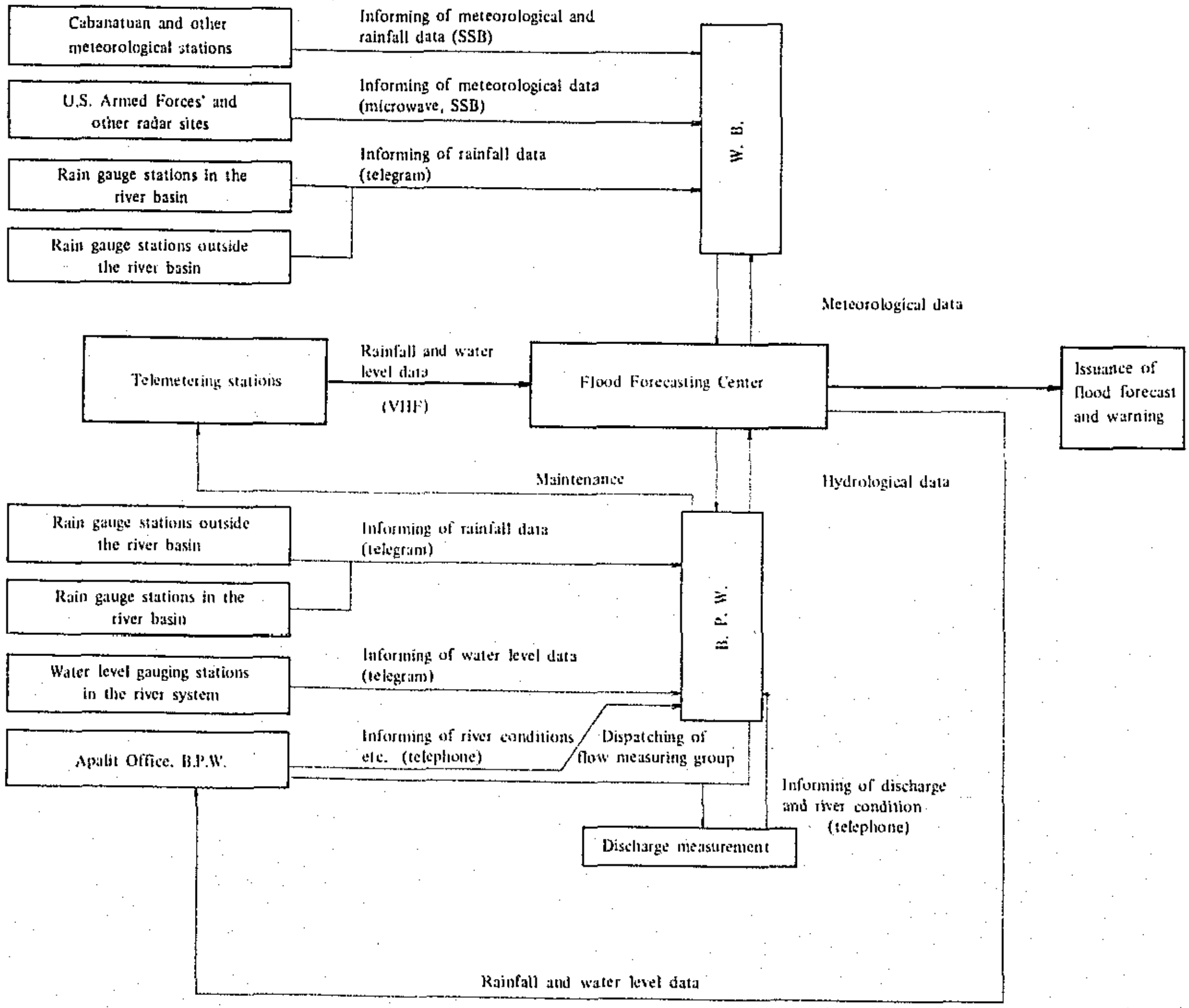
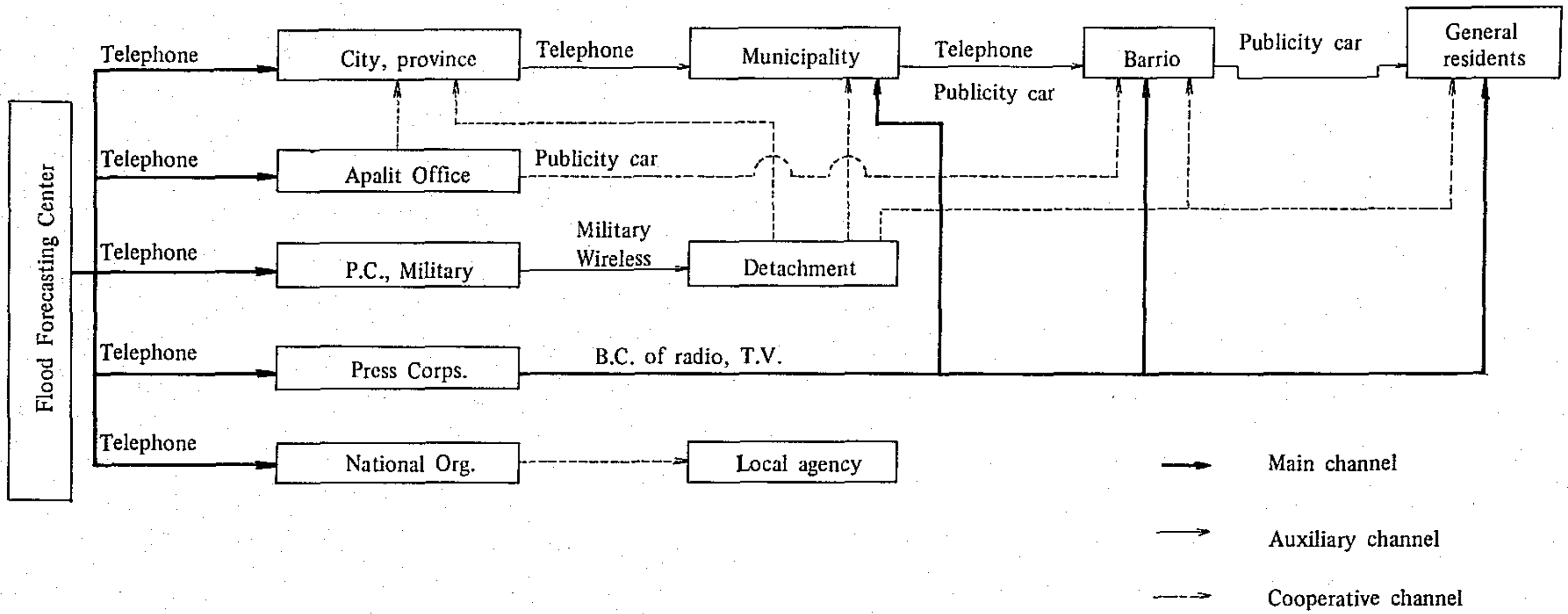


Fig. 4-8 Communication System of Flood Forecast and Warning



4-4-3 Others

The task of the flood forecasting center is to furnish the publics with the information in the form of flood forecast and warning prepared by analyzing the information based on the data supplied by W.B. and B.P.W. It will have a close relation with the task which has been performed by W.B. and B.P.W., and such operations as the maintenance of the telemetring stations and the dispatchment of supporting staffs at the time of a flood will rather constitute a joint task of these three. Thus it is necessary to define in detail the operations to be allotted among them so as to secure their satisfactory cooperation. Since the radio and television broadcastings are to be used as the main channel of disseminating the flood forecast and warning, it is necessary to establish a cooperative system for executing flood forecasting, in view of the obligatory broadcasting of flood forecast by the radio and television stations and the use of the exclusive communication facilities such as the military radio channel. Further, it is desirous from the standpoint of the importance of flood forecasting and measures against flood to arrange the statutory regulations by the making of a law and others to define the responsibility and power in carrying out these tasks.

5. Cost Estimation

5-1 Conditions for Cost Estimation

The cost of establishing the flood forecasting and warning facilities has been estimated on the following policies.

1. The existing facilities for gauging rainfall, water level and discharge will be used for the proposed system and no cost is estimated because any new facilities will not replace them.

2. Where the gauging facilities are existing, only the radio station houses will be newly built and of which cost is estimated.

3. Where the gauging facilities are to be newly built, they will be designed so that they also serve as telemetering station houses as far as possible and of which cost is estimated.

4. The costs of these facilities and discharge gauging facilities will apply those estimated by B.P.W. staffs of the Philippines. These prices have been estimated in peso at the unit cost as of December 1969.

5. The telemetering equipment and its associating water level gauge, rain gauge and spare parts, materials for installing them and the service car for maintaining facilities have been estimated in U.S. dollars, F.O.B. price at Yokohama, at the unit cost as of January 1970, on the basis of those manufactured in Japan.

6. Ocean freight from Yokohama to Manila, premium, handling charges and transportation cost from Manila to the sites of the equipments and materials mentioned in paragraph 5 above have been estimated in peso at the price as of December 1969, based on the estimation data prepared by B.P.W. of the Philippines.

7. Installation and adjustment costs are those necessary for Japanese engineers to install and adjust the equipments at the site and have been estimated in U.S. dollars, at the price as of January 1970.

8. Field guidance cost is that for one engineer specialized in flood forecasting and warning and two engineers specialized in radio telecommunication to conduct technical guidances for one and two years respectively in the Philippines, and has been estimated in U.S. dollars, at the price as of January 1970.

9. Training cost is that necessary for training two engineers in charge of flood forecasting and warning and three those in charge of telecommunication for three months in Japan, and has been estimated in U.S. dollars, at the price as of January 1970.

10. The exchange rate of U.S. dollar into peso is:

1 U.S.$ = 3.9 peso

5-2 Estimated Cost

The total cost for establishing the flood forecasting and warning system of the Pampanga River is estimated around U.S.$203,620 or ₱794,140 for Case I and U.S.$224,920 or ₱877,210 for Case II.

Table 5-1 Estimated Cost in Case I and Case II

	Case I		Case II	
	US$	₱	US$	₱
1. Housing facilities	26,590	103,700	47,740	186,200
2. Telecommunication equipment, installation & transportation cost, etc.	144,620	564,030	144,770	564,600
3. Training cost, etc.	32,410	126,410	32,410	126,410
Total cost	203,620	794,140	224,920	877,210

As a whole it is a little more economical to adopt Case I than Case II. As to the facilities, the construction costs of gauging and repeater station houses are the same in the both case, but the construction cost of an antenna in Case II will need another ₱80,000 or so more than that in Case I, because antenna towers of about 30 m high are required at Cabanatuan and San Rafael for Case II, though an antenna pole of about 7 m to be erected on Mt. Arayat will suffice for Case I.

Costs of telecommunication equipment for Case I are higher by about ₱10,000 than those for Case II. This is due to that the repeater station for Case I needs auxiliary equipment and monitor as it is to be built on Mt. Arayat being difficult for maintenance.

Training cost etc. are the same for both Case I and Case II.
Details of the respective cost are as shown in Tables 5-2 and 5-3.

The Survey Team propose two alternative cases as the flood forecasting and warning system of the Pampanga River. The comparison of these two cases reveals that Case I is a little more advantageous in view of the construction cost as a whole and considerable more advantageous in respect of housing facilities cost, but from the standpoint of easiness and reliability in maintaining the repeater station, Case II is more advantageous. There is scarecely noticed any difference of advantage between them as to possible expansion of facilities in future.

Although further examinations should be carried out based on the results of the on-the-spot test of field strength among respective gauging stations, repeater stations and control station before making the final dicision on these two cases, it is believed that the proposed Case II should be adopted, since the easiness and reliability of maintaining the flood forecasting and warning facilities are the factors to be very seriously considered in operating them, though it has a disadvantage of some increasing in construction cost at the present moment.

Annual expenses for operating the organization and facilities proposed in this report should be appropriated in a separate account. Salary of staffs working at, and light, fuel and water expenses for keeping the flood forecasting center together with expenses for maintaining the flood forecasting and warning facilities will amount to about ₱10,000 annually.

Table 5-2 Cost of Flood Forecasting and Warning System (Case I)

I Housing Facilities, etc.

	Papaya	Biak na Bato	Sapang Buho	San Vicente	La Paz	Arayat	Apalit	Candaba	Ipo Dam	San Rafael	Mt. Arayat	Manila	Sulipan	Total
1. Name of Station	Papaya	Biak na Bato	Sapang Buho	San Vicente	La Paz	Arayat	Apalit	Candaba	Ipo Dam	San Rafael	Mt. Arayat	Manila	Sulipan	Total
2. Kind of Station	Rain Self-Reporting Long-Operation	Rain Self-Reporting Long-Operation	Rain Water Self-Reporting Long-Operation	Rain Water Self-Reporting Long-Operation	Rain Water Self-Reporting Long-Operation	Rain Water Self-Reporting Long-Operation	Rain Water Self-Reporting Long-Operation	Rain Water Self-Reporting Long-Operation	Rain Water Self-Reporting Long-Operation	Rain Self-Reporting Long-Operation	Relay	Master	Monitor	–
3. Well	–	–	Type-A ₱14,500	(existing)	Type-B ₱13,500	(existing)	(existing)	Type-B ₱13,500	(existing)	–	–	–	–	₱ 41,500
4. Station House	Type-B ₱ 1,500	Type-B ₱ 1,500	Type-B ₱ 1,500	Type-B ₱ 1,500	–	Type-B ₱ 1,500	Type-B ₱ 1,500	–	Type-B ₱ 1,500	Type-B ₱ 1,500	Type-A ₱ 1,700	–	–	₱ 13,700
5. Antenna Tower or Pole	Pole ₱ 1,300	Pole ₱ 1,300	Pole ₱ 1,300	Pole ₱ 1,300	Pole ₱ 1,300	Pole ₱ 1,300	Pole ₱ 1,300	Pole ₱ 1,300	Pole ₱ 1,300	Pole ₱ 1,300	Pole 2@₱1,300 ₱ 2,600	Tower Type-A(10m) ₱ 8,000	Pole ₱ 1,300	₱ 24,900
6. Float Dropper Equipment	–	–	₱18,000	–	(Boat)	(Bridge)	(Bridge)	–	(existing)	–	–	–	–	₱ 18,000
7. Rest Cottage	–	–	₱ 800	–	₱ 800	₱ 800	3@₱ 800 ₱ 2,400	–	₱ 800	–	–	–	–	₱ 5,600
8. Total														₱103,700 ($ 26,590)

II Equipment, Transportation Cost, etc.

	Papaya	Biak na Bato	Sapang Buho	San Vicente	La Paz	Arayat	Apalit	Candaba	Ipo Dam	San Rafael	Mt. Arayat	Manila	Sulipan	Total
1. Telecommunication Equipment (F. O. B.)	₱18,230	₱18,230	₱23,820	₱23,820	₱23,820	₱23,820	₱23,820	₱23,820	₱23,820	₱18,230	₱43,510	₱59,420	₱50,190	₱374,550 ($ 96,040)
2. Accessories (Including Graphic Panels Spare Parts, Measuring Instruments, Spare Generator)														₱ 83,960
3. Installation Materials														₱ 20,630
4. Service Car														₱ 15,000
5. Marine Transportation, Insurance, Harbour Cost														₱ 12,910
6. Inland Transportation														₱ 4,800
7. Installation & Adjustment														₱ 52,180
8. Total														₱564,030 ($144,620)

III Technical Aid

			Total
1. Expenditure for Training in Japan	Civil engineers *Telecommunication engineers*	2 persons X 3 months *3 persons X 3 months*	₱ 43,180
2. Expenditure for Training in the Philippines	Civil engineer Telecommunication engineer	1 person X 1 year 1 person X 2 years	₱ 83,230
3. Total			₱126,410 ($ 32,410)

Grand Total ₱794,140 ($203,620)

Table 5-3 Cost of Flood Forecasting and Warning System (Case II)

I Housing Facilities, etc.

1. Name of Station	Papaya	Biak na Bato	Sapang Buho	San Vicente	La Paz	Arayat	Apalit	Candaba	Ipo Dam	Cabanatuan	San Rafael	Manila	Sulipan	Total
2. Kind of Station	Rain Self-Reporting Long-Operation	Rain Self-Reporting Long-Operation	Rain Water Self-Reporting Long-Operation	Rain Water Self-Reporting Long-Operation	Rain Water Self-Reporting Long-Operation	Rain Water Self-Reporting Long-Operation	Rain Water Self-Reporting Long-Operation	Rain Water Self-Reporting Long-Operation	Rain Water Self-Reporting Long-Operation	Relay	Rain Relay Self-Reporting Long-Operation	Master	Monitor	–
3. Well	–	–	Type-A ₱14,500	(existing)	Type-B ₱13,500	(existing)	(existing)	Type-B ₱13,500	(existing)	–	–	–	–	₱ 41,500
4. Station House	Type-B ₱ 1,500	Type-B ₱ 1,500	Type-B ₱ 1,500	Type-B ₱ 1,500	–	Type-B ₱ 1,500	Type-B ₱ 1,500	–	Type-B ₱ 1,500	Type-A ₱ 1,700	Type-A ₱ 1,700	–	–	₱ 13,900
5. Antenna Tower or Pole	Pole ₱ 1,300	Pole ₱ 1,300	Pole ₱ 1,300	Pole ₱ 1,300	Pole ₱ 1,300	Pole ₱ 1,300	Pole ₱ 1,300	Pole ₱ 1,300	Pole ₱ 1,300	Tower Type-B ₱41,100	Tower Type-B ₱41,100	Tower Type-A(15m) ₱12,000	Pole ₱ 1,300	₱107,200
6. Float Dropper Equipment	–	–	₱18,000	–	(Boat)	(Bridge)	(Bridge)	–	(existing)	–	–	–	–	₱ 18,000
7. Rest Cottage	–	–	₱ 800	–	₱ 800	₱ 800	3@ ₱800 ₱ 2,400	–	₱ 800	–	–	–	–	₱ 5,600
8. Total														₱186,200 ($ 47,740)

II Equipment, Transportation Cost, etc.

	Papaya	Biak na Bato	Sapang Buho	San Vicente	La Paz	Arayat	Apalit	Candaba	Ipo Dam	Cabanatuan	San Rafael	Manila	Sulipan	Total
1. Telecommunication Equipment (F. O. B.)	₱18,230	₱18,230	₱23,820	₱23,820	₱23,820	₱23,820	₱23,820	₱23,820	₱23,820	₱18,740	₱30,280	₱59,420	₱50,190	₱361,830 ($ 92,780)

2. Accessories Equipment (Including Graphic Panels, Spare Parts, Measuring Instruments, Spare Generator)	₱ 83,960
3. Installation Materials	₱ 22,190
4. Service Car	₱ 15,000
5. Marine Transportation, Insurance, Harbours Cost	₱ 13,370
6. Inland Transportation	₱ 4,930
7. Installation & Adjustment	₱ 63,320
8. Total	₱564,600 ($144,770)

III Technical Aid

1. Expenditure for Training in Japan	Civil engineers Telecommunication engineers	2 persons X 3 months 3 persons X 3 months	₱ 43,180
2. Expenditure for Training in the Philippines	Civil engineer Telecommunication engineer	1 person X 1 year 1 person X 2 years	₱ 83,230
3. Total			₱126,410 ($ 32,410)

Grand Total ₱877,210 ($224,920)

APPENDIX I

INTERIM REPORT

on

Feasibility Survey for the Establishment of
Comprehensive Plan of the Flood Fore-
casting and Warning System in
the Pampanga River Basin
in the Philippines

THE JAPANESE GOVERNMENT SURVEY TEAM
for
Flood Forecasting and Warning
under
The Colombo Plan
16 December 1969

The Japanese Survey Team consisting of nine experts has implemented their feasibility survey for establishment of comprehensive plan of the flood forecasting system on the Pampanga River Basin in the Philippines. The team arrived at Manila on 19 November 1969 and has finished their works in the Philippines on 18 December 1969 along the line of a plan of operation which was agreed by the Government of the Philippines and the Government of Japan.

This is the interim report resuming the results of the survey and study up to the end of their terms. It is understood that the final feasibility report will be submitted to the Government of the Philippines by the end of March 1970.

I. Works implimented

1. Field works

During the period, the survey team has conducted field reconnaissance survey of whole Pampanga River Basin, middle and lower basin, upper basin and Angat area respectively to observe the features of the basin, river channel system existing observation facilities, river improvement works, proposed places for telemetering system and telecommunication facilities etc.

2. Collection and study of data

All available data of the following items are collected and studied by the experts.

a. Meteorological, Hydrological and Hydraulic observed data.

b. Facilities for flood protection and river improvement.

c. Population, properties and other important factors in frequently inundated areas.

d. Existing related river improvement project and water resources development projects and hydraulic analysis of floods.

3. Preliminary selection of location for proposed flood forecasting and warning system and preliminary design and cost estimation for necessary facilities.

II. Target area and basic places for flood forecasting and warning services

It is considered that the target areas for flood forecasting and warning service are to be focused on the following three blocks of the middle and lower river basin.

1. Candaba Area
2. Right bank area of the main Pampanga River below Arayat Mountain.
3. Delta area below Apalit.

Most important factors which have to be taken into account for flood forecast are over topping or collapse of Cabiao-Gapan Dike and Cabiao-Candaba ring levee for the upper stream side of block No. 1, water elevation and its duration time of inundation in the Candaba Swamp and densely populated area around Arayat-Apalit Arnedo Dike for entire block No. 1, conditions of Candaba fuse dike for block No. 2 and Calumpit-Plaridel Dike and Apalit-Bagbag discharge for block No. 3 respectively.

III. Measures and facilities for flood forecasting and warning services

To approach to the above mentioned purpose the survey team considered so far at the end of their field survey the following measures are recommendable as the first stage of the project.

1. For Upper Pampanga River Basin, the flood runoff is to be forecast and observed at Sapang Buho from observed data on the proposed telemetering rainfall and river stage station at Sapang Buho. The flood discharge is routed to San Vicente with modification by intervening flow computed from the rainfall at Papaya.

2. Contribution from Rio Chico is to be estimated and observed at La Paz and routed to the joining point to the Pampanga River.

3. Arayat and Candaba stations are considered necessary for giving indication of hydraulic behaviour of the main river channel and Candaba Swamp.

4. Contribution to Candaba Swamp from east bank side is to be computed from rainfall at Biak na Bato and San Rafael stations.

5. Computing method to trace the hydraulic behaviour for middle and lower reaches will be introduced.

6. Sulipan station is required for flood forecasting to the lower delta area.

The comparison of SSB system and VHF telemetering system has been conducted carefully by the telecommunication experts and it is concluded that the adoption of VHF telemetering system is the most reasonable and practicable.

The attached figure shows two alternative proposed systems. Although these two systems are preliminary proposal and may be changed after further study, one of which will be finalized without much change by the time of submission of the report.

Both proposed systems include seven telemetering rainfall and river stage gauges, three telemetering rainfall gauges and one master station.

The difference between two alternative systems is whether having installation of one relay station at the side of Mt. Arayat or two relay stations in case of difficulty of accessibility to the side of the mountain.

By use of this system it is considered to procure the fairly good flood forecast to the target area about one day in advance.

It was noticed the deficiency of observed data on the hill and mountainous area for extending the forecasting period. Continuation of observation and establishment of new rain gauge stations on these area are desired, although the existing weather radar at Manila can be utilized for estimating the rainfall in the basin qualitatively. Telemeterization of these stations is recommended as for second stage of this project.

IV. Cost estimation

The rough cost estimation is shown as follows:

	Case I	Case II
Telecommunication Equipments and Instrument (F.O.B.)	$100,000	$115,000
Housing Facilities	$22,000	$55,000
Transportation, Installation and others	$68,000	$70,000
T O T A L - -	$190,000	$240,000

FORECASTING SYSTEM

Target Area for Flood Forecasting and Warning Service	Marked Site	Forecasting Station	Telemetering Station
1. Candaba Area	Cabiao-Gapan Dike Cabiao-Candaba Ring Levee Candaba Swamp Apalit-Arayat Arnedo Dike	(San Antonio Swamp) Arayat Candaba	H. R. La Paz H. R. Sapang Buho H. R. San Vicente R. Papaya H. R. Arayat R. Biak na Bato
2. Right Bank Area of the Main Pampanga River below Mt. Arayat	Candaba Fuse Dike	Apalit	H. R. Candaba R. San Rafael
3. Delta Area below Apalit	Calumpit-Plaridel Dike Apalit-Bagbag Discharge		H. R. Ipo Dam H. R. Apalit

Legend
H: Water stage
R: Rainfall

APPENDIX II

Rainfall Data

Table A-1 Daily Rainfall (unit mm)

Aug. 1948 Oct. 1950

No. of Station	17	18	20	No. of Stations	17	18	19
1	0.0	0.0	0.0	1	77.2	69.3	52.3
2	51.3	0.0	17.0	2	56.8	90.4	94.2
3	17.5	1.0	0.0	3	31.2	26.4	26.9
4	0.0	31.2	3.0	4	60.1	33.7	29.9
5	0.0	0.0	24.1	5	0.0	0.0	8.8
6	0.0	49.0	6.0	6	0.0	0.0	0.0
7	10.4	10.1	0.0	7	0.0	1.0	35.0
8	0.0	2.2	13.9	8	0.0	0.0	0.0
9	8.1	0.0	0.0	9	0.0	1.2	27.9
10	0.0	0.0	0.0	10	14.9	13.9	0.0
11	0.0	30.9	30.9	11	11.9	2.0	17.0
12	10.1	60.1	5.0	12	0.0	0.0	0.0
13	0.0	1.0	56.8	13	0.0	0.0	5.0
14	0.0	9.3	54.1	14	0.0	2.0	11.9
15	0.0	11.1	17.0	15	0.0	0.0	0.0
16	8.6	11.4	29.9	16	3.0	0.0	0.0
17	15.2	43.1	37.0	17	0.0	0.0	8.1
18	0.0	18.2	45.9	18	9.3	0.0	20.0
19	26.6	5.0	24.1	19	2.7	4.0	0.0
20	42.9	22.0	29.9	20	0.0	0.0	0.0
21	48.7	30.2	22.0	21	0.0	0.0	10.9
22	31.2	33.0	15.2	22	5.8	1.0	0.0
23	26.4	33.5	74.4	23	8.1	0.0	0.0
24	22.6	81.2	102.6	24	6.8	0.0	0.0
25	51.3	7.3	5.0	25	12.1	1.0	0.0
26	7.6	2.0	22.0	26	0.0	1.0	0.0
27	0.0	0.0	0.0	27	0.0	0.0	0.0
28	0.0	0.0	0.0	28	0.0	27.1	16.0
29	2.0	13.9	0.0	29	7.1	0.0	0.0
30	1.5	0.0	0.0	30	4.8	1.0	7.1
31	50.0	8.8	0.0	31	0.0	0.0	0.0

Aug. 1960

No. of Station	1	4	5	6	7	9	11	12	13	16	17	18	20	31
1	34.2	2.5	31.2	16.2	78.7	40.1	8.3	30.2	0.0	8.1	12.9	0.0	36.5	21.8
2	29.2	7.6	18.2	0.0	21.5	30.7	2.0	0.0	24.6	1.5	0.0	41.9	21.0	0.0
3	20.3	17.7	5.0	22.8	16.5	50.2	18.5	0.0	0.0	10.1	9.9	21.0	6.0	0.0
4	3.8	31.7	21.3	14.9	30.4	20.8	44.1	10.9	29.9	6.3	5.3	32.0	79.2	22.8
5	33.0	26.6	36.5	81.0	38.1	60.4	21.0	70.6	0.0	42.6	62.9	89.1	55.6	74.6
6	N	53.3	44.1	46.9	67.3	90.4	80.7	70.3	44.9	28.4	46.9	54.1	78.7	63.2
7	N	11.4	21.3	14.9	76.2	73.1	44.1	13.4	21.3	2.0	3.0	50.0	89.9	9.6
8	32.5	1.2	25.4	15.2	70.3	48.0	17.2	7.1	25.1	3.8	4.0	44.9	80.7	10.1
9	41.1	30.4	69.8	51.0	90.9	25.9	70.8	37.0	18.2	28.7	40.1	48.0	105.6	27.1
10	34.2	31.7	25.4	55.1	59.6	13.9	0.5	33.7	21.5	23.3	25.9	28.9	41.9	40.6
11	16.5	12.7	18.2	14.9	28.4	7.8	25.4	16.0	14.2	11.9	17.0	5.0	14.4	7.8
12	15.2	13.9	15.4	2.5	10.9	98.0	48.2	0.0	25.4	9.6	13.9	9.3	26.4	5.0
13	29.2	52.0	97.5	122.9	3.0	116.3	132.0	76.9	39.6	30.7	52.0	90.9	70.3	65.0
14	13.9	5.8	22.3	30.4	41.4	160.0	117.8	22.3	19.5	32.7	50.0	0.0	31.7	35.0
15	20.3	17.7	52.3	27.6	27.1	110.2	49.2	41.4	60.4	30.7	34.0	76.9	30.2	81.2
16	35.5	38.1	25.1	96.5	62.2	0.0	75.9	84.8	58.4	45.2	77.9	56.8	67.3	77.2
17	29.2	3.8	8.3	1.5	35.5	0.0	0.0	14.9	8.3	5.8	1.0	0.0	4.3	6.6
18	56.3	0.0	6.8	0.0	6.3	0.0	0.0	0.0	1.0	9.9	0.0	0.0	6.3	3.3
19	5.0	1.2	8.3	3.0	78.7	36.0	5.5	0.0	6.8	6.0	3.0	17.0	19.3	0.0
20	25.4	12.7	9.1	7.6	38.1	64.0	16.2	0.0	22.6	13.4	9.9	22.0	19.0	2.2
21	33.5	19.0	14.7	7.6	15.7	18.2	15.7	2.7	42.4	11.6	9.9	14.9	11.1	3.8
22	30.4	0.0	40.8	14.4	31.2	0.0	43.4	16.0	19.0	29.2	43.9	8.8	26.6	27.6
23	2.5	6.3	14.4	2.0	5.5	0.0	9.1	0.0	1.0	12.7	12.9	0.0	4.3	1.0
24	5.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	12.1	0.0	0.0	0.0	2.2
25	11.9	2.5	21.3	0.0	0.0	0.0	3.8	3.3	29.2	22.8	21.0	19.0	14.2	8.8
26	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	6.8	0.0	0.0	0.0	1.2
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	0.0	0.0	0.0	1.5
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0
30	1.2	0.0	0.0	0.0	0.0	0.0	4.3	0.0	17.0	3.0	0.0	0.0	0.0	0.0
31	5.0	0.0	0.0	5.0	1.2	34.0	13.2	0.0	0.0	3.0	3.0	0.0	0.0	22.0

May 1966

No. of Station	4	5	7	11	31	33	34	35
1	10.4	0.0	0.0	0.0	0.0	N	10.4	0.0
2	10.1	0.0	0.0	0.0	0.0	N	0.0	0.0
3	2.7	0.0	0.0	0.0	0.0	N	10.2	0.0
4	0.0	0.0	0.0	5.5	31.5	N	2.8	2.0
5	0.0	0.0	0.0	0.0	0.0	N	0.0	0.0
6	40.3	0.0	0.0	0.0	1.3	N	40.1	25.9
7	1.5	0.0	26.6	0.0	27.9	N	1.5	2.3
8	9.6	0.0	53.3	2.0	1.3	N	9.6	2.0
9	4.0	16.2	3.8	46.7	26.7	13.0	4.1	0.0
10	26.4	14.7	40.6	35.5	25.1	46.0	26.4	43.1
11	41.9	0.0	0.0	0.0	27.9	0.0	41.9	3.1
12	0.5	0.0	10.1	0.0	10.2	0.0	0.5	19.3
13	0.0	11.1	0.0	20.8	0.0	0.0	0.0	1.5
14	0.0	10.1	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	6.0	0.0	0.0	5.5	2.8	0.0	6.1	0.5
17	98.2	0.0	0.0	14.2	3.6	7.9	98.3	18.1
18	99.0	0.0	2.5	44.7	31.0	56.1	99.1	30.2
19	81.7	134.8	27.9	183.1	197.4	266.4	132.0	152.2
20	103.6	113.2	12.7	108.4	105.9	170.4	103.7	104.1
21	23.1	84.0	78.7	2.0	0.5	22.9	23.1	31.0
22	22.6	76.2	180.3	25.9	0.0	4.8	22.6	10.4
23	134.8	64.0	60.9	5.3	29.0	16.0	134.9	35.5
24	3.0	11.1	0.0	0.5	0.0	0.0	3.1	0.0
25	34.5	9.3	7.6	17.7	8.6	23.1	34.5	12.9
26	80.0	10.6	17.0	50.5	31.3	62.8	80.1	35.0
27	35.0	11.6	5.0	4.5	19.0	14.5	35.1	16.0
28	10.4	0.0	0.0	0.0	0.0	0.0	10.4	0.0
29	11.6	9.1	0.0	0.0	0.0	0.0	11.7	0.0
30	0.0	10.6	3.0	0.0	3.3	14.2	0.0	18.8
31	0.0	0.0	19.0	1.7	2.5	2.0	0.3	1.5

Table A－2 Monthly Rainfall (unit mm)

No. of Station	YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	Annual
10	56	2.0	0.0	2.0	108.7	N	24.8	100.5	201.4	234.6	113.5	77.2	99.5	
10	57	24.6	0.0	0.0	1.0	25.1	220.7	203.4	321.8	151.1	184.6	37.5	0.0	1170.1
10	58	5.5	3.3	4.3	1.0	19.8	170.4	93.4	171.1	176.2	119.3	10.1	0.0	774.9
10	59	3.0	0.0	5.0	0.0	20.3	99.0	157.7	286.5	N	47.2	70.1	4.8	
10	60	1.2	24.8	N	62.2	131.3	287.0	N	765.3	494.7	N	29.4	0.0	
9	59	0.0	0.0	0.0	0.0	132.3	63.7	263.1	717.2	225.0	186.9	170.6	6.8	1766.0
9	60	3.0	0.0	20.0	30.9	152.6	355.0	170.1	98.8	246.8	805.6	49.5	0.0	2932.9
8	62	0.0	1.2	N	84.3	N	156.4	561.8	354.3	500.8	67.5	51.0	N	
8	63	0.0	16.5	5.0	4.3	68.0	622.8	107.1	181.8	316.9	7.8	0.0	46.2	1376.9
8	64	0.0	0.0	31.7	N	N	325.1	255.0	276.8	77.9	74.6	184.6	53.3	
1	58	7.3	7.6	8.8	8.3	111.2	210.8	194.8	300.7	350.2	121.1	33.0	0.0	1354.3
1	59	11.4	18.0	27.4	8.8	100.5	47.2	91.9	226.5	192.7	N	N	N	
1	60	N	45.9	12.1	40.6	99.5	178.0	158.4	565.4	377.1	169.4	22.8	14.4	
4	59	23.3	23.8	128.2	31.7	148.3	39.1	231.9	318.5	253.7	198.6	492.7	196.0	2086.3
4	60	54.3	149.0	10.6	8.1	116.0	266.7	187.4	410.9	447.8	577.0	102.8	16.5	2347.7
5	59	5.0	0.0	0.0	16.7	179.5	151.1	262.3	380.2	149.8	189.2	340.8	20.3	1695.4
5	60	2.2	60.9	0.0	30.2	206.7	234.9	219.2	651.2	406.4	525.2	43.1	0.0	2380.4
12	56	0.0	0.0	0.0	44.9	120.6	50.0	175.5	269.4	255.0	74.1	133.6	55.6	1179.0
12	57	0.0	0.0	0.0	14.9	37.5	203.9	163.8	190.7	120.1	86.8	137.6	0.0	955.8
12	58	0.0	34.5	0.0	0.0	34.2	259.0	298.4	896.6	483.6	29.9	10.9	0.0	2047.4
12	59	0.0	0.0	0.0	0.0	44.7	47.2	78.4	314.1	237.9	0.0	136.3	0.0	859.0
13	56	0.0	0.0	0.0	127.0	50.5	39.1	223.5	250.1	396.2	62.2	233.4	58.9	1441.1
13	57	3.5	0.0	0.0	17.0	17.5	238.7	190.5	285.4	197.1	113.0	283.9	0.0	1346.9
13	58	3.5	6.8	0.0	0.0	24.3	416.5	231.9	266.7	402.8	65.0	38.6	0.0	1456.4
13	59	8.1	1.2	21.8	3.5	36.0	132.0	204.7	189.9	268.4	218.9	172.7	0.0	1257.8
15	55	0.0	0.0	0.0	0.0	0.0	90.6	0.0	67.3	40.6	19.0	56.8	0.0	274.5
15	56	0.0	0.0	0.0	178.3	40.6	26.9	166.1	174.4	291.3	37.0	123.6	51.5	1090.1
15	57	0.0	0.0	0.0	0.0	16.2	163.3	313.1	187.7	120.3	115.5	106.4	0.0	1022.8
15	58	4.5	2.5	0.0	0.0	18.2	200.6	217.9	180.8	48.0	190.7	13.2	0.0	876.8
15	59	3.3	0.0	9.3	0.0	48.2	54.1	155.1	N	N	20.0	100.3	0.0	
15	60	0.0	10.6	0.0	322.8	517.1	691.3	452.3	N	361.9	214.6	29.4	0.0	
18	55	0.0	0.0	0.0	0.0	146.0	165.3	242.3	235.9	312.1	108.2	83.0	11.1	1304.2
18	56	2.0	0.0	0.0	125.7	95.5	121.9	336.8	352.8	446.2	112.0	241.3	64.2	1898.6
18	57	31.2	0.0	2.0	143.2	72.1	344.1	262.3	441.7	268.4	79.2	163.8	0.0	1808.4
18	58	0.0	6.0	0.0	N	59.1	282.7	295.6	266.9	418.0	110.9	20.0	0.0	
18	59	0.0	0.0	18.0	0.0	192.2	80.2	127.5	599.1	364.4	144.0	95.5	0.0	1621.2
18	60	0.0	52.0	0.0	30.2	303.2	334.0	163.5	718.5	239.2	252.9	25.9	0.0	2119.8
6	59	5.0	0.0	52.3	1.7	124.9	85.0	92.9	N	154.1	112.0	81.5	4.5	
6	60	20.3	188.4	16.7	86.1	276.3	394.2	237.9	657.0	390.1	260.6	8.1	0.0	2536.1
14	54	0.0	0.0	0.0	14.4	18.5	98.2	203.7	324.8	256.5	227.8	103.1	0.0	1247.3
14	55	0.0	0.0	0.0	0.0	0.0	81.2	0.0	61.2	85.0	19.8	31.4	0.0	278.8
14	56	0.0	0.0	0.0	171.1	0.0	20.5	97.0	329.1	389.6	101.8	96.0	0.0	1205.4
20	55	0.0	0.0	0.0	0.0	119.6	271.5	389.6	611.1	458.7	161.2	76.7	0.0	2088.6
20	56	0.0	0.0	0.0	284.4	109.7	113.5	236.7	303.5	685.0	214.3	331.9	117.0	2396.4
20	57	11.1	0.0	14.2	9.1	42.1	443.2	351.5	619.5	408.9	128.0	232.1	5.3	2265.4
20	58	0.0	31.7	5.0	0.0	105.9	379.4	275.8	251.4	501.3	70.3	18.0	0.0	1639.2
20	59	0.0	0.0	21.5	7.3	174.4	102.6	155.7	384.8	273.5	130.5	200.4	0.0	1451.0
20	60	17.5	24.1	5.5	29.9	234.9	325.3	176.5	687.5	251.4	188.9	25.9	0.0	1967.9
31	60	2.5	49.5	10.1	55.6	160.2	245.1	231.6	622.5	452.8	403.0	39.8	3.3	2276.5
31	61	0.0	1.2	55.8	2.0	156.7	590.8	459.9	399.5	267.7	159.0	82.2	0.2	2175.4
31	62	4.5	0.0	2.7	37.0	133.3	308.3	467.6	280.1	453.3	35.0	57.6	0.2	1780.2
31	63	0.0	27.4	1.2	0.0	145.0	528.3	217.1	389.3	357.8	11.4	13.9	63.5	1755.3
11	58	17.2	7.6	12.9	4.5	88.9	305.3	436.1	331.7	332.4	226.5	20.3	0.0	1783.8
11	60	8.1	53.8	28.9	161.5	205.4	341.6	473.7	919.4	626.6	470.6	37.3	1.5	3328.9
17	57	0.0	0.0	0.0	0.0	49.0	130.5	197.8	215.9	206.7	95.7	110.9	0.0	1006.8
17	58	10.4	11.9	0.0	0.0	11.6	231.1	212.0	209.5	351.5	143.7	2.7	0.0	1242.4
17	60	3.0	13.4	0.0	36.3	135.6	331.2	267.7	561.3	239.5	266.9	3.5	0.0	1858.7

APPENDIX III

Programs of Flood Computation

Program of Unit Hydrograph

```
PROGRAM UHG
    begin
  external        READARRAY, PRINTI, PRINTF, PRINTS, PRINTR, SPACE, CRLF.,
  real            RUNOFF.,
  integer         I, IEND, J, JEND, K, KEND, IJ, IBEGIN.,
  array           RAIN(/0.,200/), U(/0.,15/).,
            READ(IJ)., READ(IBEGIN)., READ(IEND).,
            READARRAY(RAIN,IJ,IEND).,
         for I.=IJ step 1 until IEND do
      RAIN(/I/)=RAIN(/I/)*25.4/4.0.,
            READ(KEND).,
         for K.=1 step 1 until KEND do
         begin
                  READ(JEND).,
                  READARRAY(U,0, JEND).,
                  PRINTI(5,K).,
                  for J.=0 step 1 until JEND do
         begin
            if J-J//8*8 eq 0 then CRLF(1).,
                  PRINTF (8.4, U(/J/).,
         end.,
                  CRLF (5).,
         for I.= IBEGIN step 1 until IEND do
            begin
                RUNOFF.=0.0.,
                for J.=0 step 1 until JEND do
                   RUNOFF.=RUNOFF+U(/J/)*RAIN(/I-J/).,
                PRINTI (5, I).,
                PRINTF (10.4, RAIN(/I/).,
                PRINTF (10.4, RUNOFF).,
                CRLF (1).,
            end .,
            CRLF (10).,
            end .,
         end .,
              eop
```

```
      PROGRAM FLOOD FL
      DIMENSION A(50),AC(50),B(50),BD(50),C(50),H(50),Q(50),Z(50),FN(50)
     1,QINP(500),QDFP(500),IARRAY(100)
  777 CONTINUE
      READ 200,IEND,IDEF,DX,AE,BE,CE,T
      IF(EOF,60) 111, 888
  888 CONTINUE
  200 FORMAT (2I5,5F10.2)
      READ 201,CONST,TAU,QFULL
  201 FORMAT (3F10.2)
      READ 202,DT
  202 FORMAT (F10.2)
      READ 210,(B(I), I=1, IEND)
  210 FORMAT (10F8.0)
      READ 210,(BD(I),I=1,IEND)
      READ 210,(C(I), I=1,IEND)
      READ 210,(Z(I), I=1,IEND)
      READ 210,(FN(I), I=1, IEND)
      READ 210,(H(I), I=1, IEND)
      K=1
      D=DT/DX
      DO 120 I=1,IEND
      A(I)=(H(I)-Z(I))*B(I)
      AC(I)=C(I)*B(I)
  120 CONTINUE
      JEND=INT (T/DT)
      DO 110 J=1,JEND
      TIME=FLOAT (J)*DT/TAU
      QIN=CONST*TIME*EXP (-TIME)
      IU=IEND-1
      DO 100 I=1,IU
      II=I+1
      SLOPE=H(I)-H(II)
      IF(SLOPE) 50,50,51
   50 PRINT 300,J,I
  300 FORMAT(43H SLOPE IS NOT POSITIVE,COMPUTATION ENDS AT 2I5)
      GO TO 777
   51 DEP=H(I)-Z(I)
      DEPD=H(II)-Z(II)
    0 Q(I)=SQRT (SLOPE/DX)*(0.5*(DEP+DEPD))**0.667*(DEP*B(I)+DEPD*B(II))
    1 /(2.0* FN(I))
  100 CONTINUE
      HE=H(IEND)-Z(IEND)
      Q(IEND)=AE* HE**1.667
      A(1)=(QIN-Q(1))*D+A(1)
      DO 101 I=2,IEND
      II=I-I
      A(I)=(Q(II)-Q(I))*D+A(I)
  101 CONTINUE
      DO 102 I=1,IEND
      AA=A(I)-AC(I)
      IF(AA) 52,52,53
   52 H(I)=Z(I)+A(I)/B(I)
      GO TO 102
   53 H(I)=Z(I)+C(I)+AA/BD(I)
  102 CONTINUE
```

```
      HOUR=FLOAT(J)*DT/3600,
      PRINT 301,HOUR,QIN
 301  FORMAT (2F8.1)
      PRINT 302,(Q(I),I=1,IEND)
 302  FORMAT(15F8.1)
      HO=FLOAT (IFIX(HOUR))
      IF (HOUR-HO) 54,55,54
  55  QINP(K)=QIN
      QDFP(K)=Q(IDEF)
      K=K+1
  54  CONTINUE
 110  CONTINUE
      KEND=K-1
      PRINT 1000
1000  FORMAT (10(/))
      DO 103 K=1,KEND
      INF=IFIX(100.*QINP(K)/QFULL-0.5)
      IDF=IFIX(100.*QDFP(K)/QFULL-0.5)
      DO  550  I=I,  100
      IARRAY(I) = 1H
 550  CONTINUE
      IARRAY(INF) = 1H*
      IARRAY(IDF) = 1HX
      PRINT 551, (IARRAY(I), I=1, 100)
 551  FORMAT (5X, 1HI, 100A1)
 103  CONTINUE
      GO TO 777
 111  STOP
      END
```

Program of Forecasting of Swamp Water Stage

```
PROGRAM        SWS
  begin
  external     READARRAY, PRINTI, PRINTF, PRINTS, SPACE, CRLF.,
      real     HI, DT, QQ, Y, HH, HFULL.,
      integer  K, KEND, J, JEND, I, IEND, IH, IHO, IS.,
      array    H,Q,S,SPQ,SMQ (/1.,15/), F(/0.,200/), HOBS (/1.,200/).,
               READ (KEND).,
               READARRAY(H, 1, KEND).,
               READARRAY(S, 1, KEND).,
               READ(IEND).,
               READARRAY (F, 0, IEND).,
               READARRAY (HOBS, 1, IEND).,
               READ(HI)., READ(HFULL).,
               READ(DT)., READ(JEND).,
      for J.=1 step 1 until JEND do
        begin
                     READARRAY(Q, 1, KEND).,
            for K.=1 step 1 until KEND do
                     PRINTF (5.1, Q(/K/)).,
                     CRLF(5).,
      for K.=1 step 1 until KEND do
        begin
            SPQ(/K/) = S(/K/) + 0.5*Q(/K/)* DT.,
            SMQ(/K/) = S(/K/) - 0.5*Q(/K/)* DT.,
        end.,
        K.=1.,
  LA.. if H(/K/) less HI and HI less H(/ K+1/)
      then begin QQ. = (Q(/ K+1/) - Q(/K/) * (HI - H(/K/))
                       /(H(/K+1/)-H(/K/) + Q(/K/).,
                        go to LB.,
        end
      else begin K. = K + 1.,
                        go to LA.,
            end.,
  LB.. for I. = 1 step 1 until IEND do
        begin
            K. = 1
  LC.. if Q(/K/) less QQ and QQ less Q(/K+1/)
      then begin      Y. = (SMQ(/K+1/) - SMQ(/K/))*(QQ-Q(/K/))
                       / (Q(/K+1/)-Q(/K/))+SMQ(/K/)+0.5*DT
                       * (F(/I-1/)+F(/I/)).,
                     go to LD.,
            end
      else begin      K.= K+1.,
                     go to LC.,
            end
  LD.. K. = 1.,
  LE.. if SPQ(/K/) less Y and Y less SPQ(/K+1/)
      then begin      QQ.=(Q(/K+1/)-Q(/K/))*(Y-SPQ(/K/))
                        /(SPQ(/K+1/)-SPQ(/K/))+Q(/K/).,
                     HH.=(H(/K+1/)-H(/K/))*(QQ-Q(/K/))
                        /(Q(/K+1/)-Q(/K/))+H(/K/).,
                     go to LF.,
            end
      then begin      K. = K+1.,
                     if KEND not greater K
            then
                     begin PRINTS (020HH-S CURVE SCALE OVER).,
                           CRLF(1).,
```

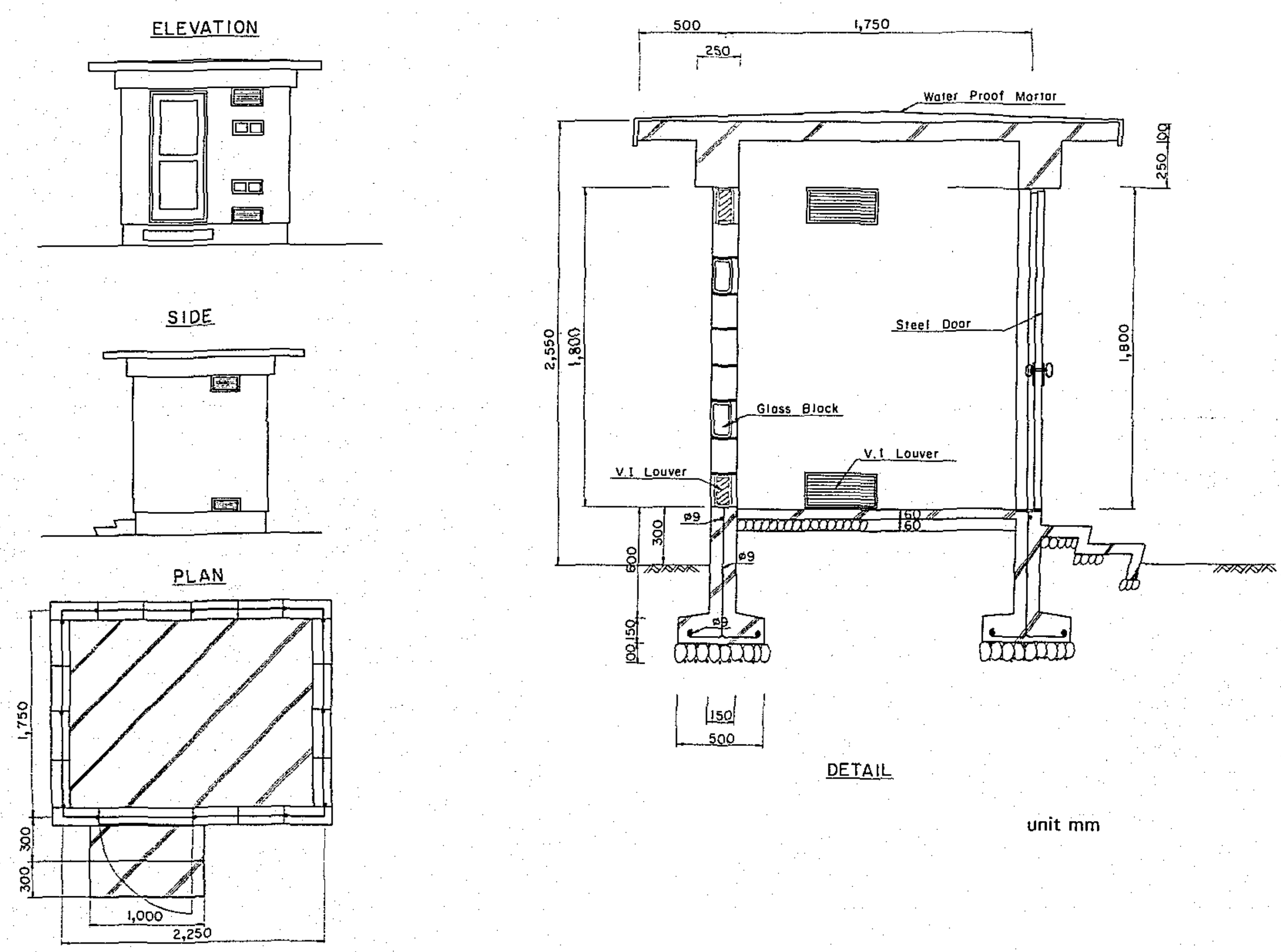
```
                           go to LZ.,
                end
              else go to LE.,
            end.,
LF.. PRINTI (3, I).,
     PRINTF (10.2, F(/I/)).,
     PRINTF (10.2, QQ).,
     PRINTF (10.2, HH).,
     PRINTF (10.2, HOBS(/I/)).,
     CRLF(1).,
     IH.=100.0*HH/HFULL - 0.5.,
     IHO.=100.0*HOBS(/I/)/HFULL - 0.5.,
     if IH less IHO
       then
         begin PRINTS (001HI).,
               SPACE(IH).,
               PRINTS (001HX).,
               IS.=IHO-IH-1.,
               SPACE(IS).,
               PRINTS (001HO).,
               CRLF(1).,
               go to LG.,
         end
       else
         begin if IH equal IHO
           then
             begin    PRINTS (001HI).,
                      SPACE (IH).,
                      PRINTS (001HX).,
                      CRLF (1).,
                      go to LG.,
             end
           else
             begin    PRINTS (001HI).,
                      SPACE (IHO).,
                      PRINTS (001HO).,
                      IS.= IH-IHO-1.,
                      SPACE(IS).,
                      PRINTS (001HX).,
                      CRLF(1).,
             end.,
         end.,
 LG..end.,
 LZ..
     end.,
 end.,
     eop
```

APPENDIX IV

Drawings of Facilities

NO.	NAME OF STATION	MANAGED BY	LOCATION	GIVEN DATA		
				DAILY RAINFALL		HOURLY RAINFALL
				ANNUAL	MONTHLY	
32	Apalit	W.B.		68,	67:Sep.-Dec. 69:Jan.-Apr.Jun.-Sep.	68:Aug.29, Jul. 24, Oct. 14 67:Nov.5 69:Jul.21,28,29,31,Jan,20
33	Arayat	W.B.	15°08'N120°47'E	68	66:Jun.-Dec.67: Jan.-Aug.Nov.Dec. 69: Jan.-Aug.	66:May10-31 67:Jun.3,4Jul.30,31. Aug. 15 68: Jul.25, Aug.29,31,Sep.29 69:May22, Jul, 21,29,31
34	Gabaldon	W.B.	15°21'N121°21'E	66~68	65:Nov.Dec.69: Jan.-Sept.	66:May67:Jun.8,Jul,31,Aug.14,19 Oct.13,17,Nov.4,5,9,68:Jul26, Aug.14,16,Sept.29,Oct.16Nov.30 69:Sep.24, Aug. 31, Jul. 30
35	Gapan	W.B.		66~68	65: Jul.-Dec. 69: Jan-Sep.	66: May68,Aug.16,31, 68Sep.29 69: Sep.7, Aug.8 67: Nov. 5,Sep.2,4,5,Aug.24,Jul.5,30 Jun.8
36	Dagupan	W.B.	16°03N120°20'E		60: Jul. Aug.	66: May
37	Iba, Zambales	W.B.	15°20'N119°58'E		60: Jul,Aug. 66: May	
38	Manila, C.O.	W.B.	14°35'N120°59'E (Port Area)		60: Jul, Aug. 66: May	66: May (Defective)
39	Baguio	W.B.	16°25'N120°36'E		60: Jul.~Sept.	66: May 69:May 30, Jun.9, Jul.3
40	W.B.F.C.	W.B.	14°31'N121°00'E			66: May (Defective)

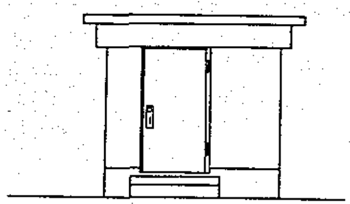
FIG. A-Ⅳ(1) STATION HOUSE, TYPE : A $1.^{m}75 \times 2.^{m}25$



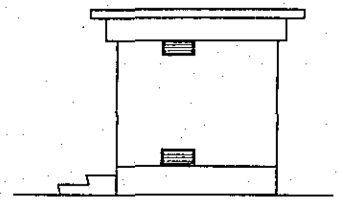
unit mm

FIG. A-Ⅳ(2) STATION HOUSE, TYPE : B $1^{m}.75 \times 1^{m}.85$

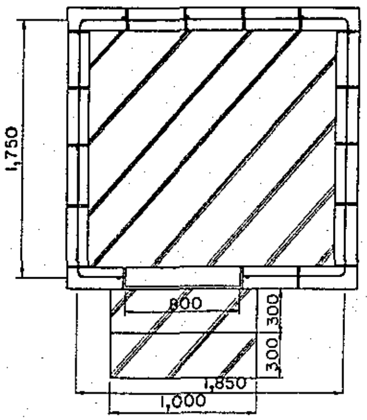
ELEVATION

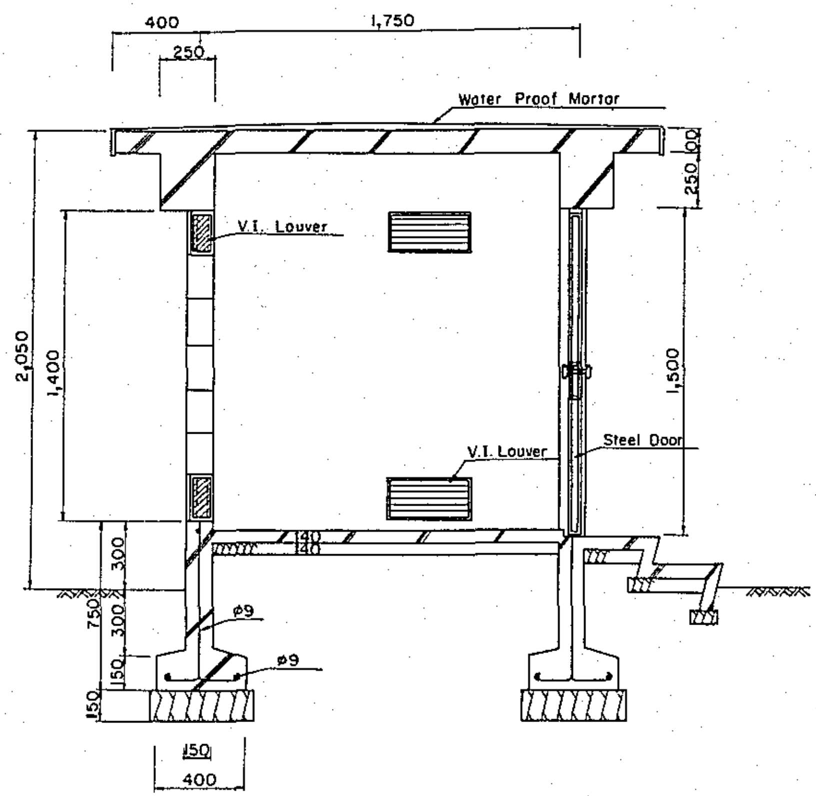


ELEVATION (SIDE)



PLAN

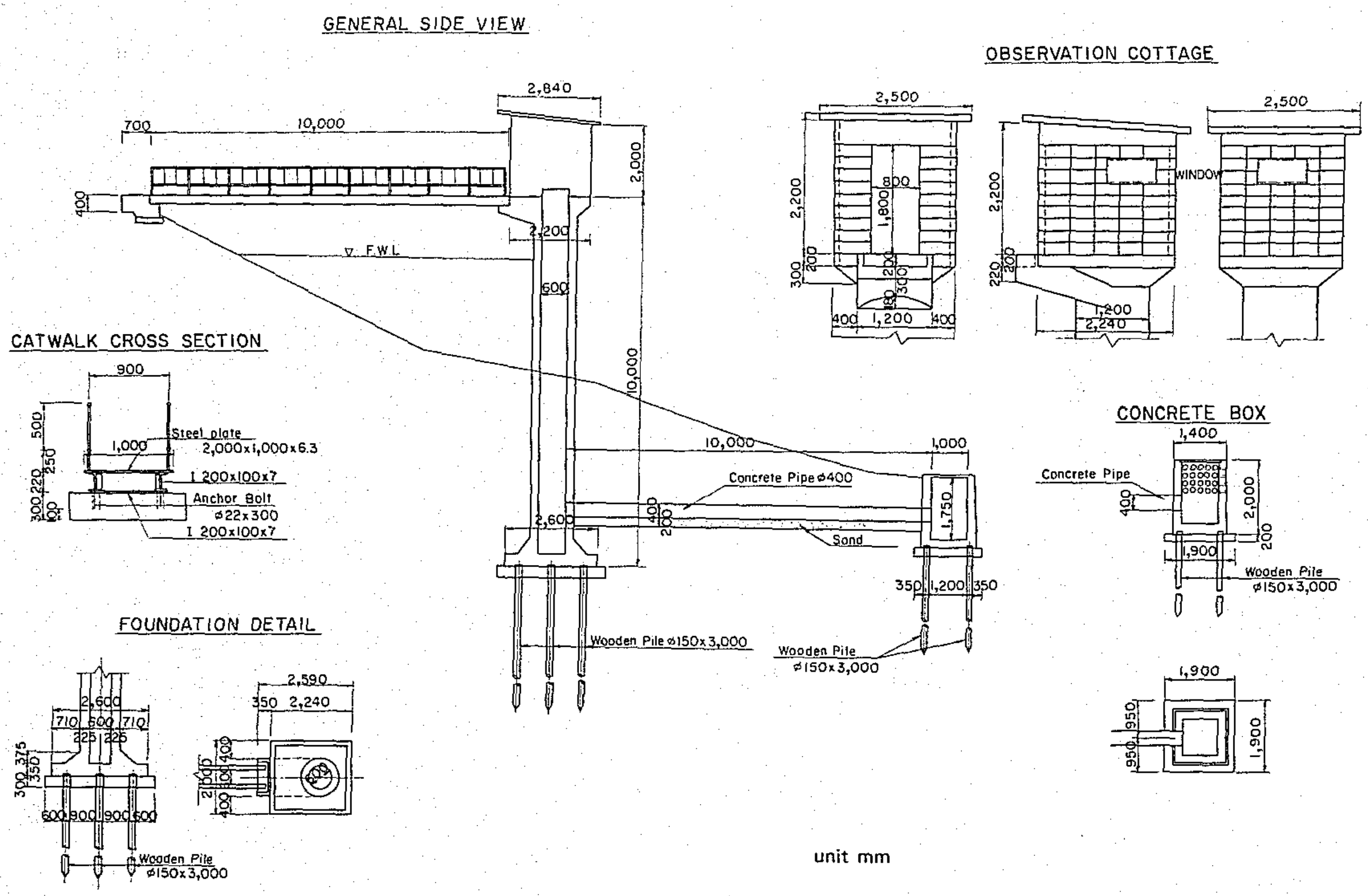




DETAIL

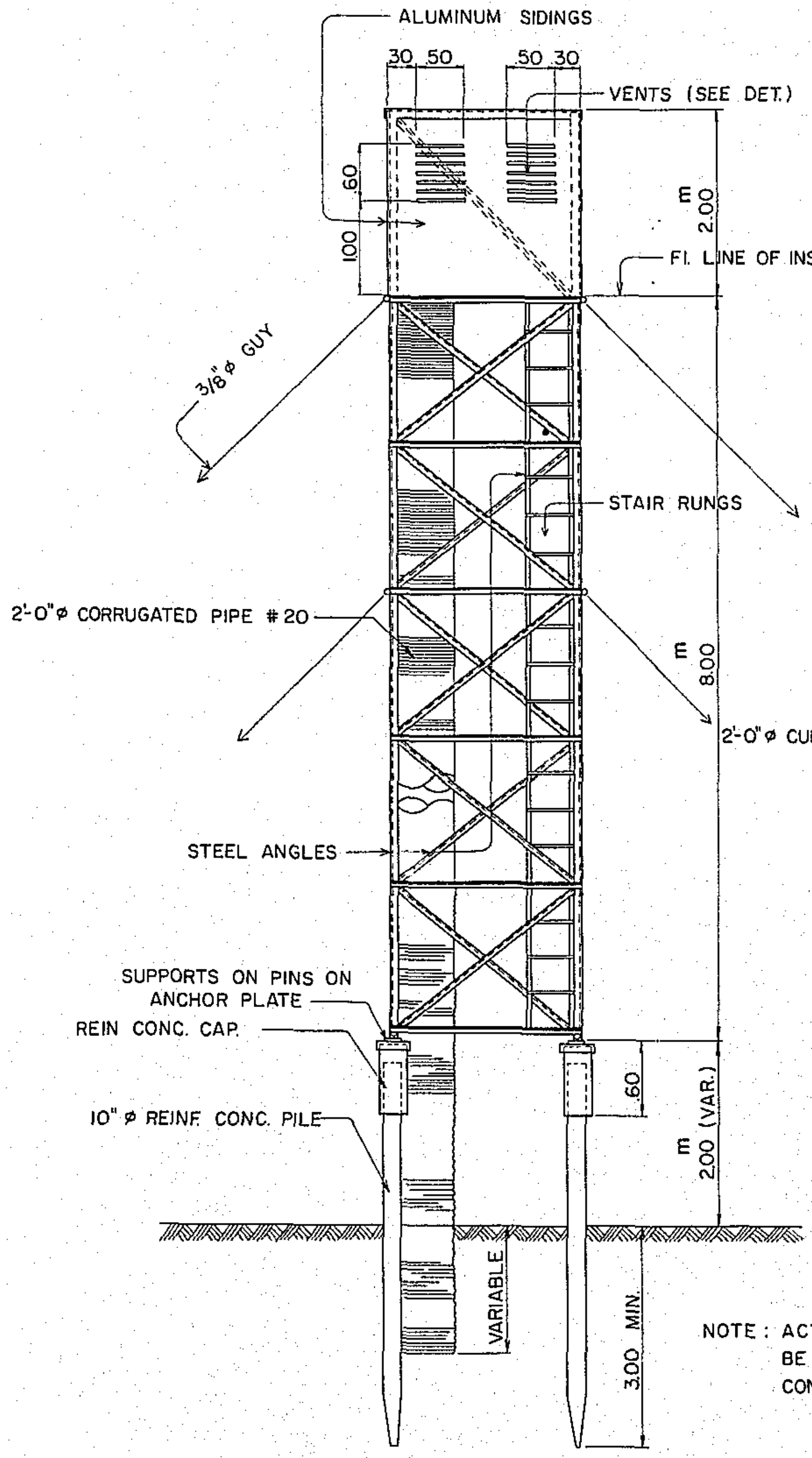
unit mm

FIG. A-Ⅳ(3) WATER STAGE STATION. TYPE : A R.F. CONC

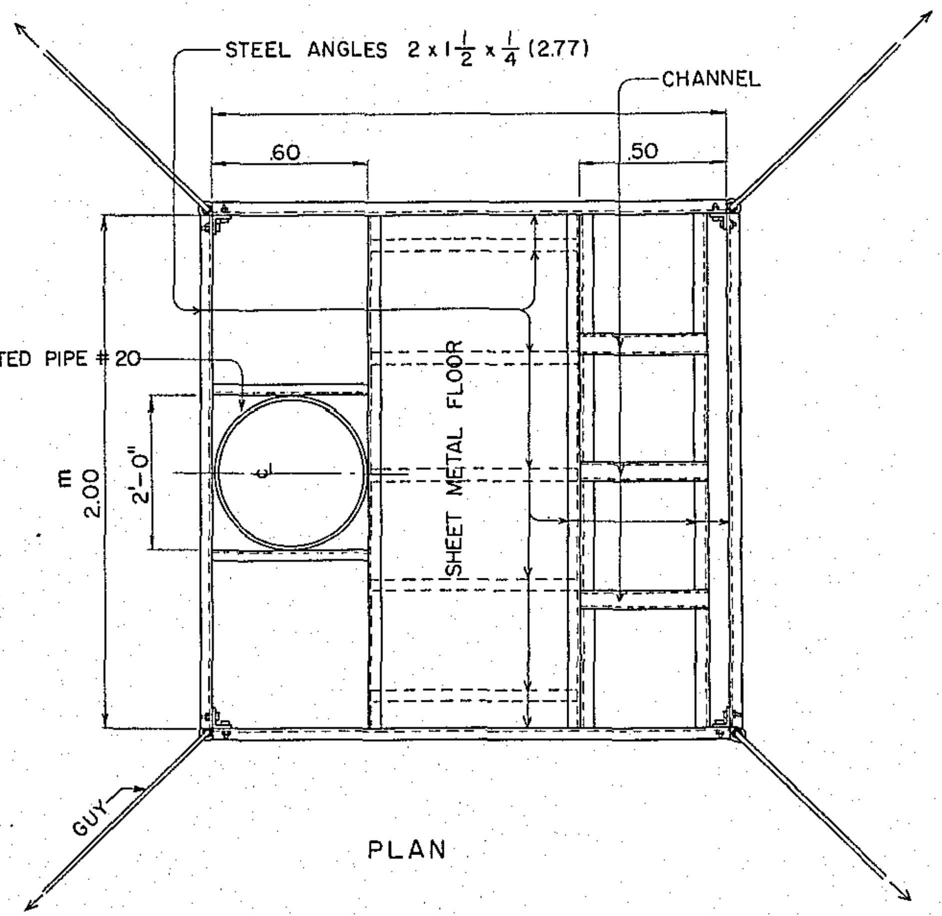


unit mm

FIG. A-IV(4) WATER STAGE STATION, TYPE : B CORRUGATED

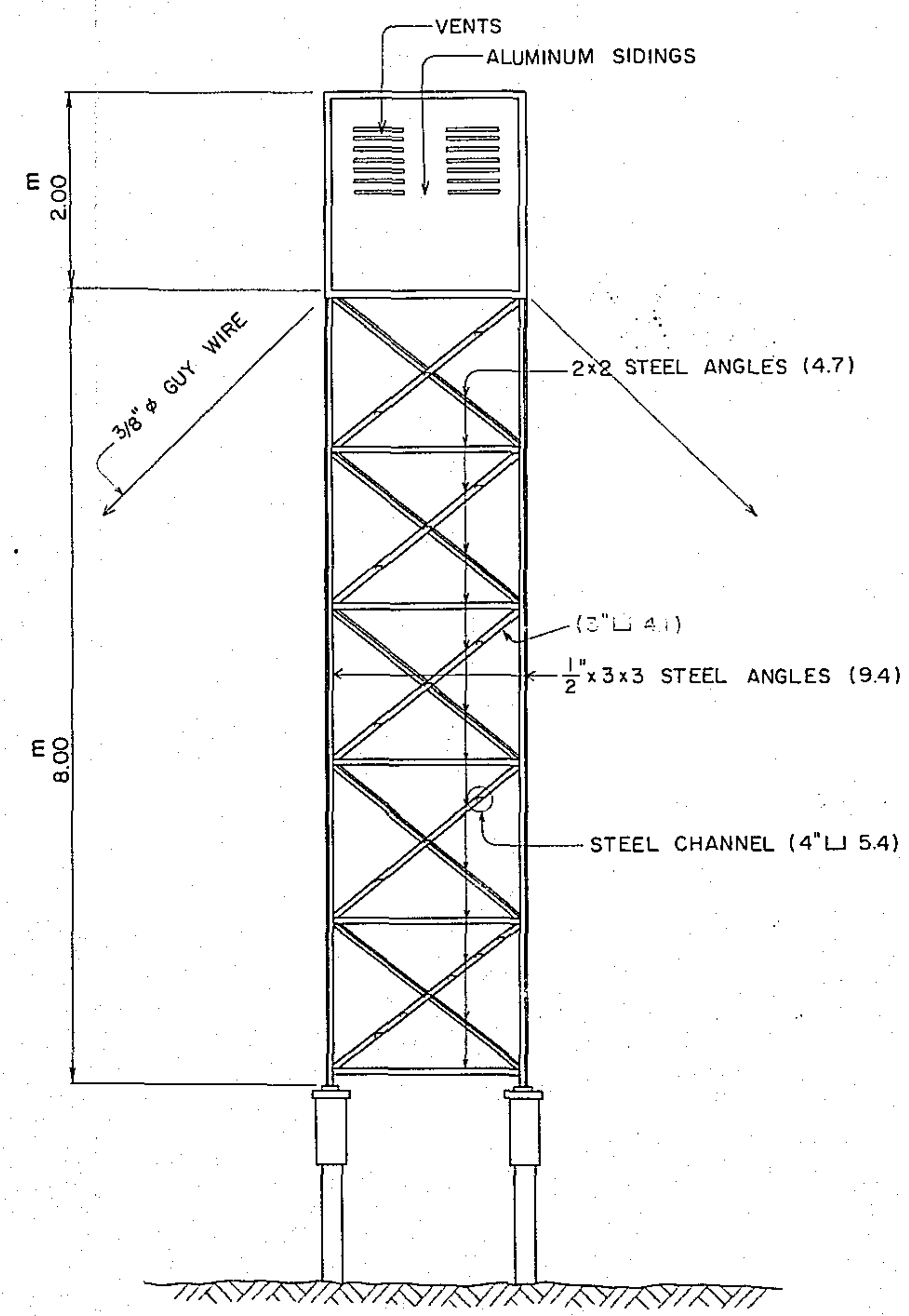


ELEVATION



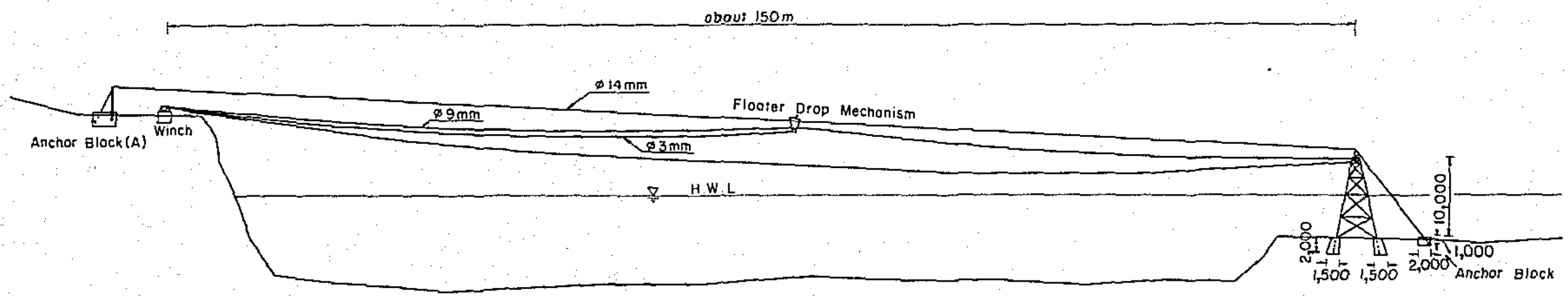
PLAN

NOTE : ACTUAL S.B. PRESSURE TO BE DETERMINED DURING CONSTRUCTION.

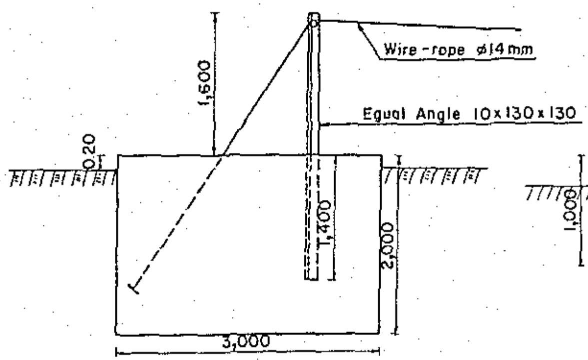


SCHEMATIC DIAGRAM OF STEEL STEPS

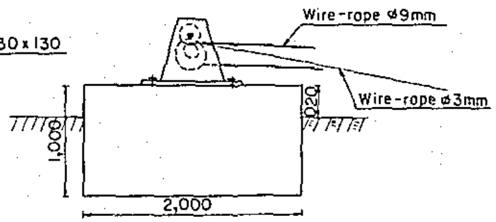
FIG. A-Ⅳ (5) FLOATER DROPPING FACILITIES (SAPANG BUHO)



Detail of Anchor Block (A)



Detail of Winch



Detail of Floater Drop Mechanism

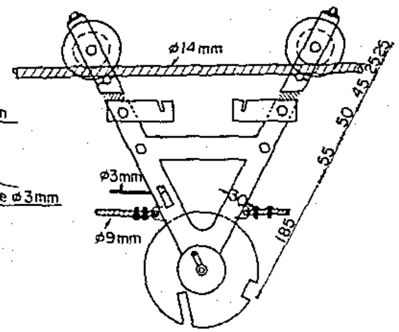


Fig A-IV (6) TELE POLE

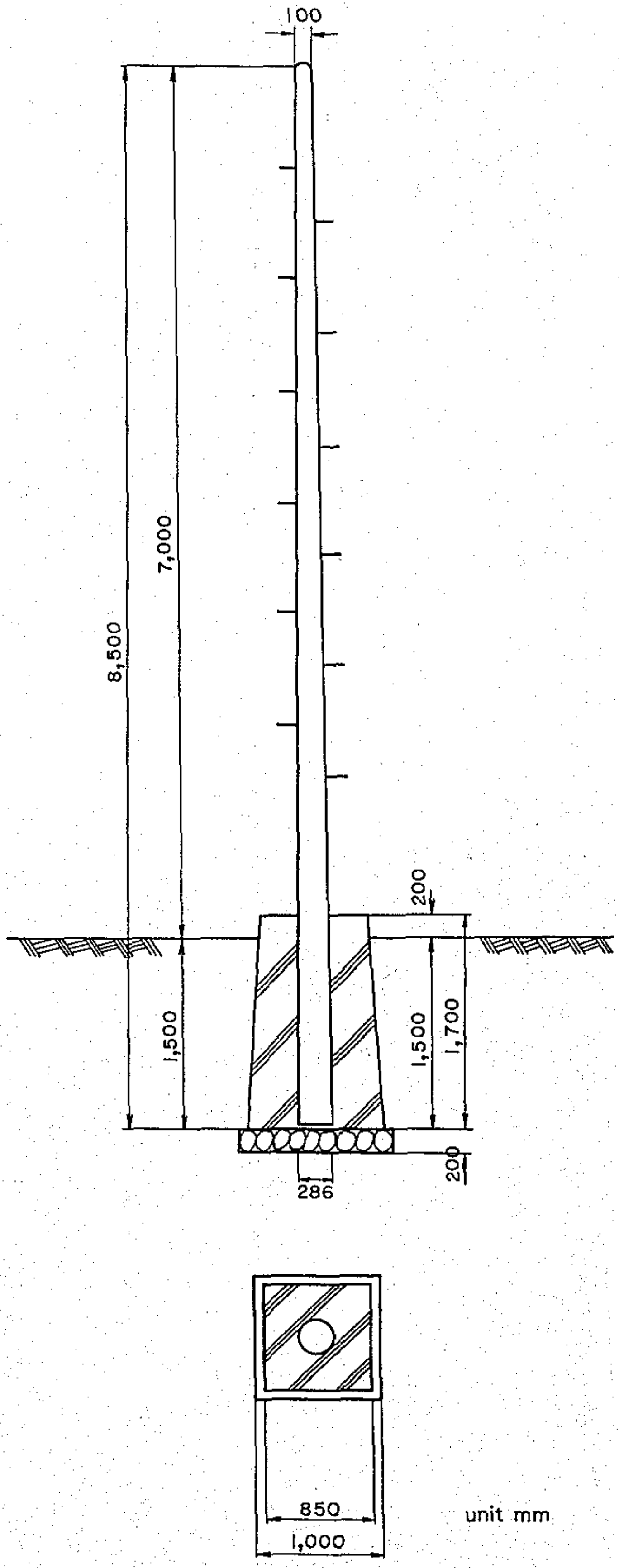


FIG. A-IV(7) STEEL TOWER FOR WIRELESS, TYPE : A H=10M

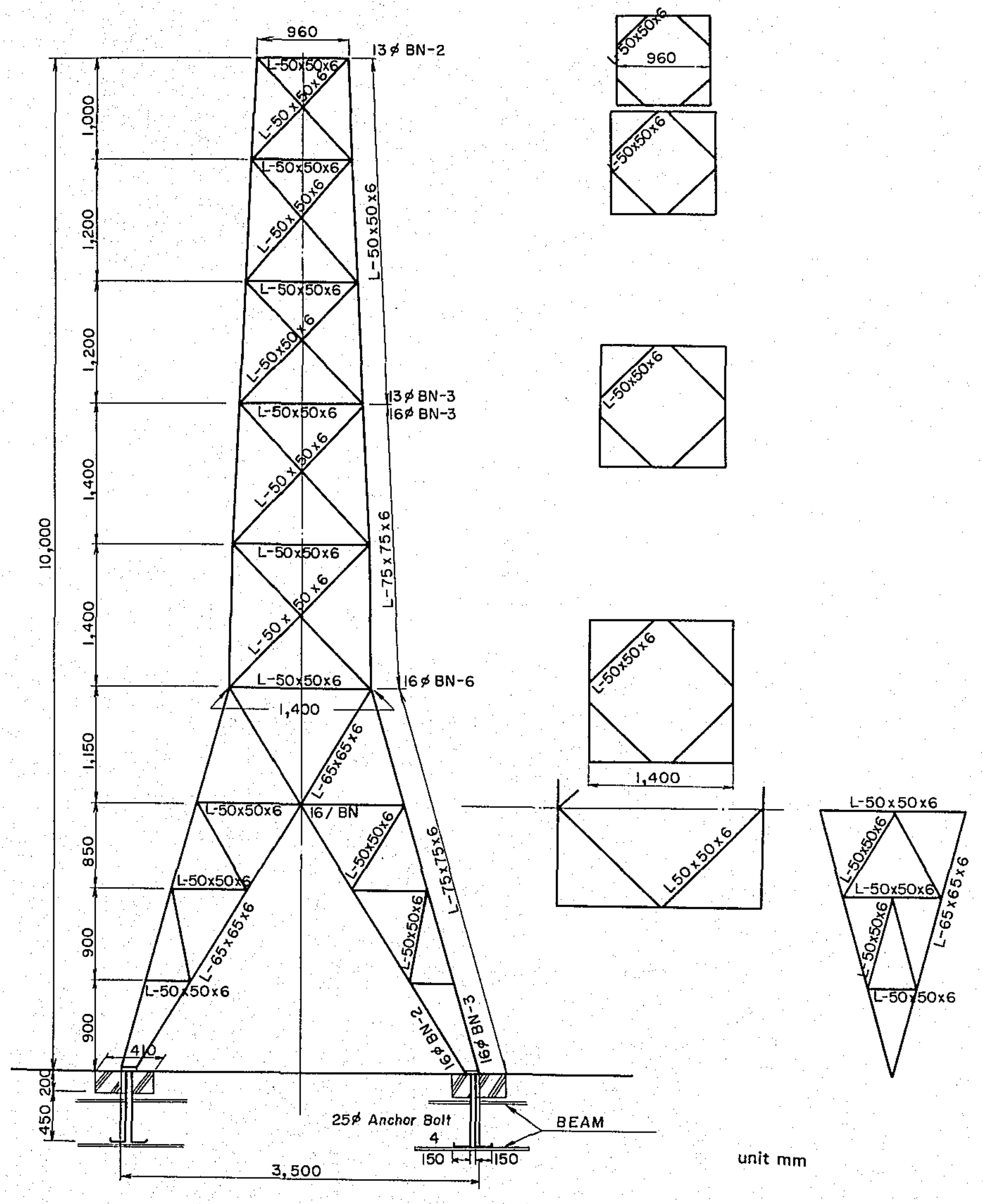
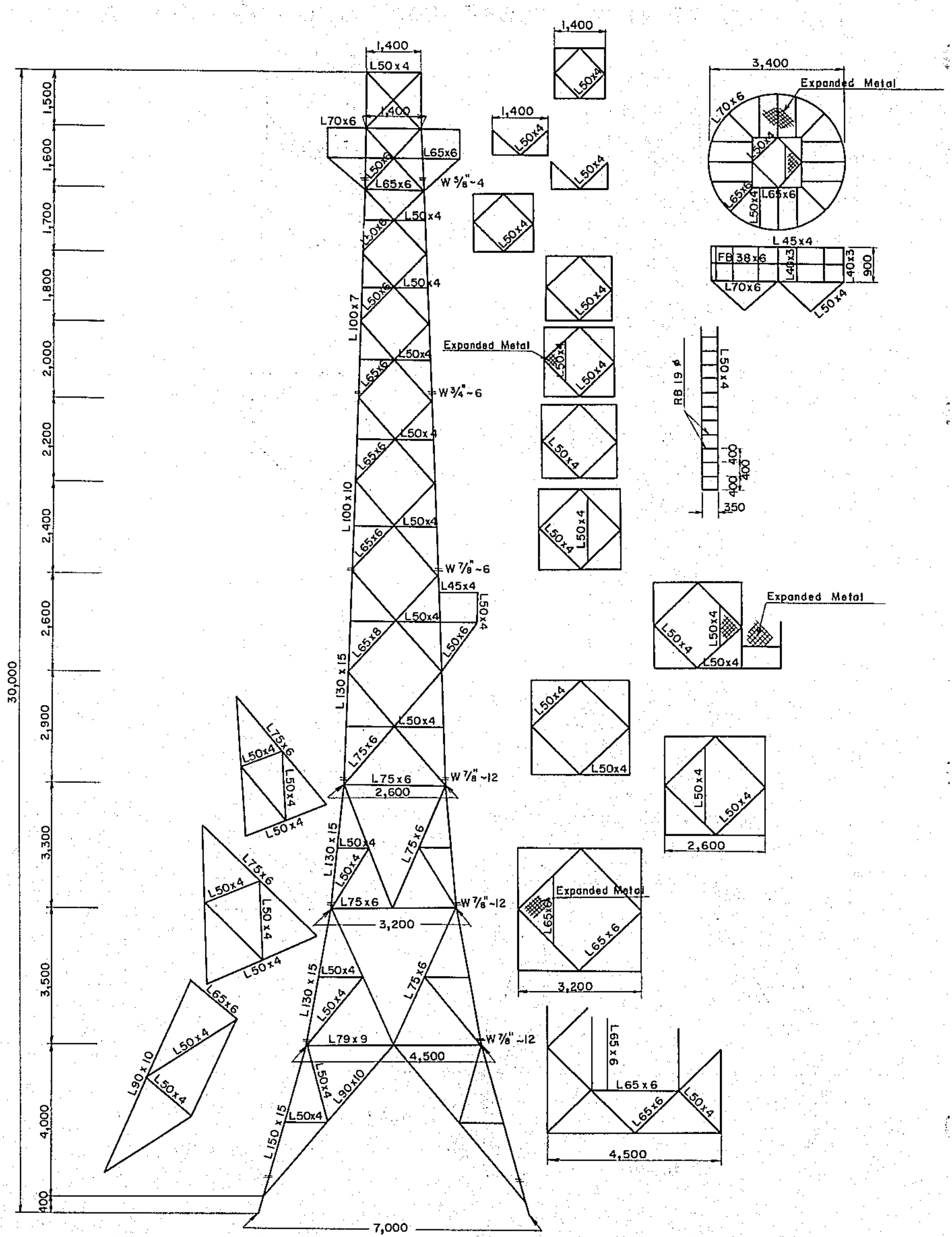
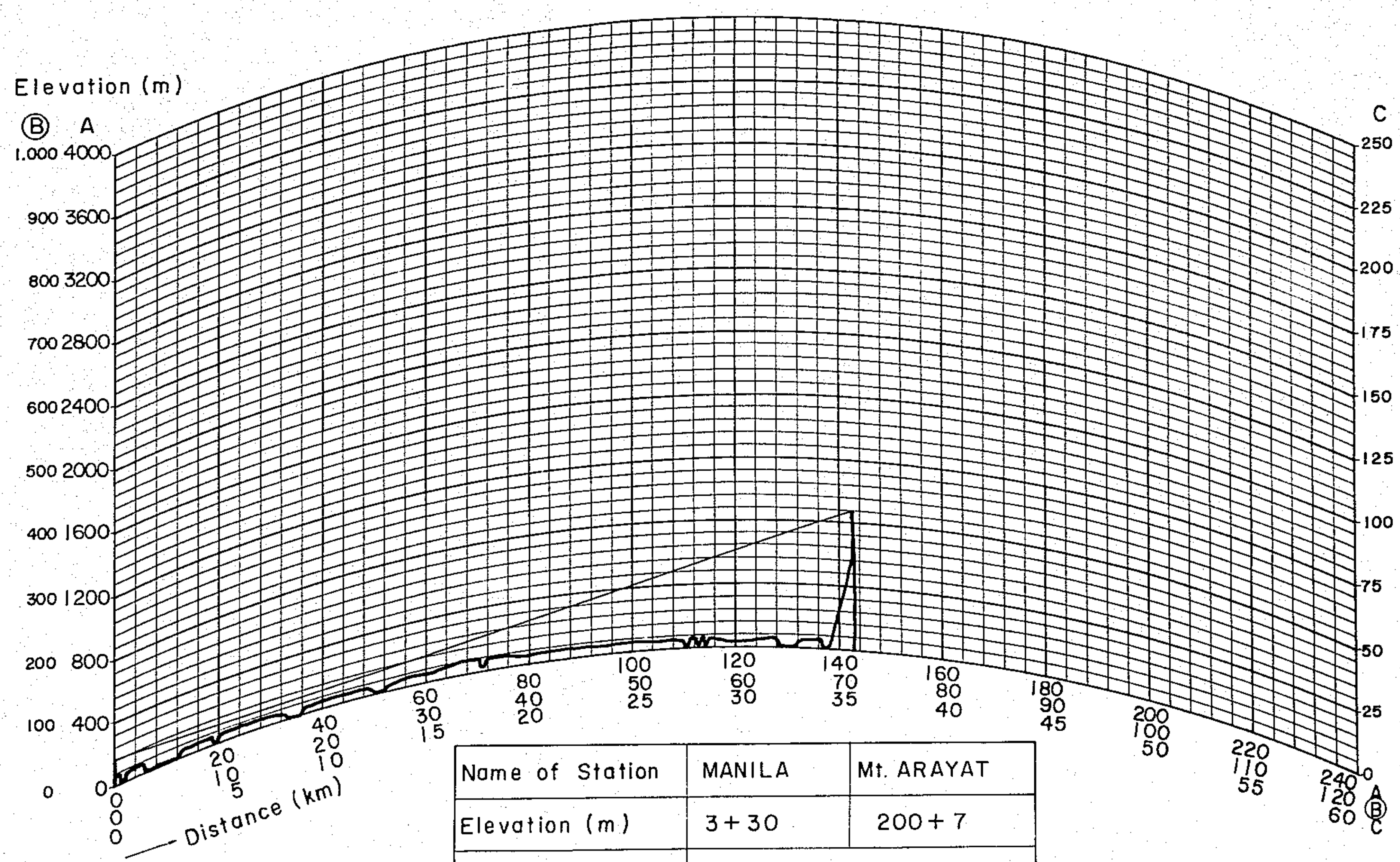


FIG. A-IV(8) STEEL TOWER FOR WIRELESS, TYPE : B H = 30M



unit mm

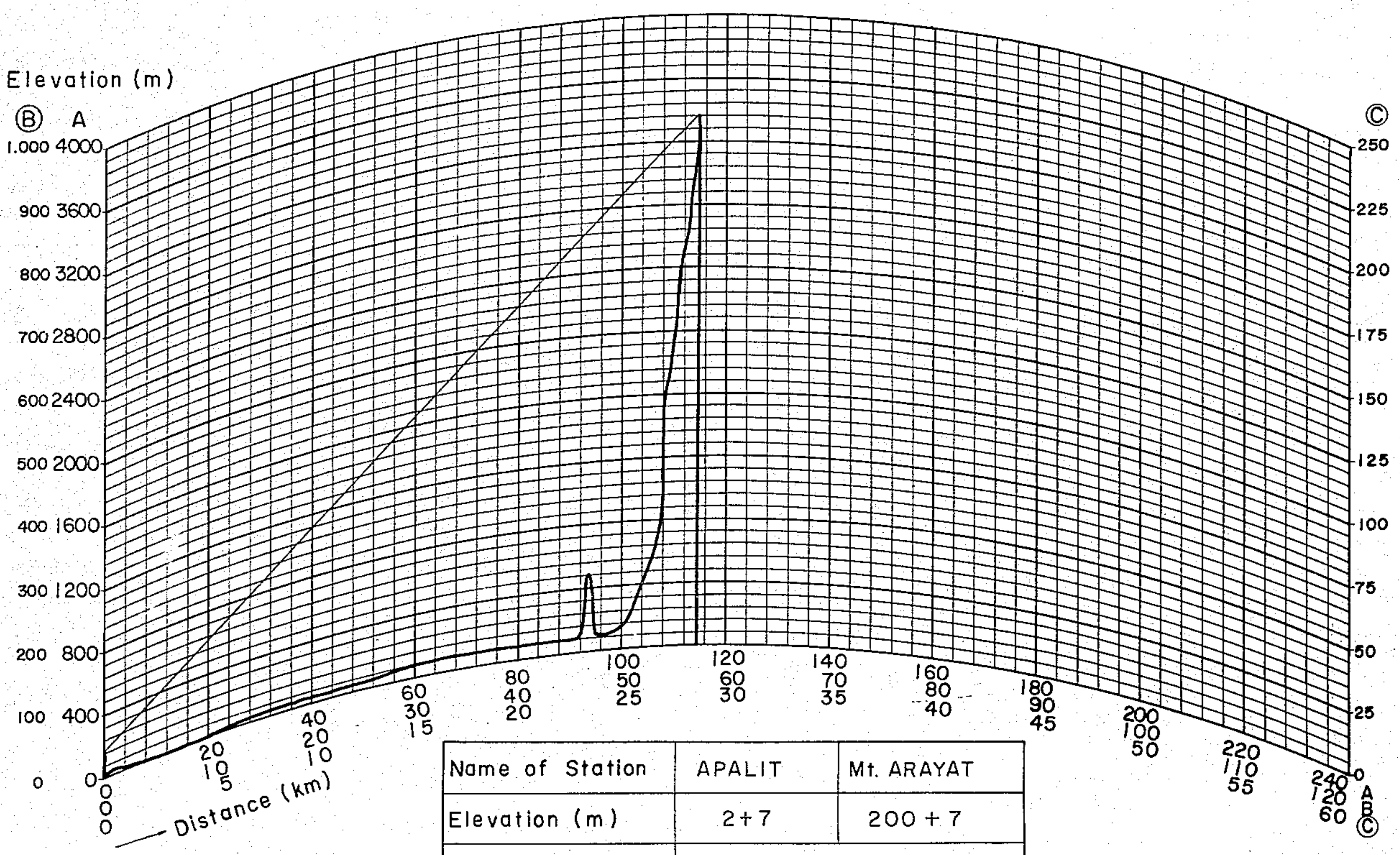
Profile map



Name of Station	MANILA	Mt. ARAYAT
Elevation (m)	3 + 30	200 + 7
Distance (km)	71.6	

No. 1

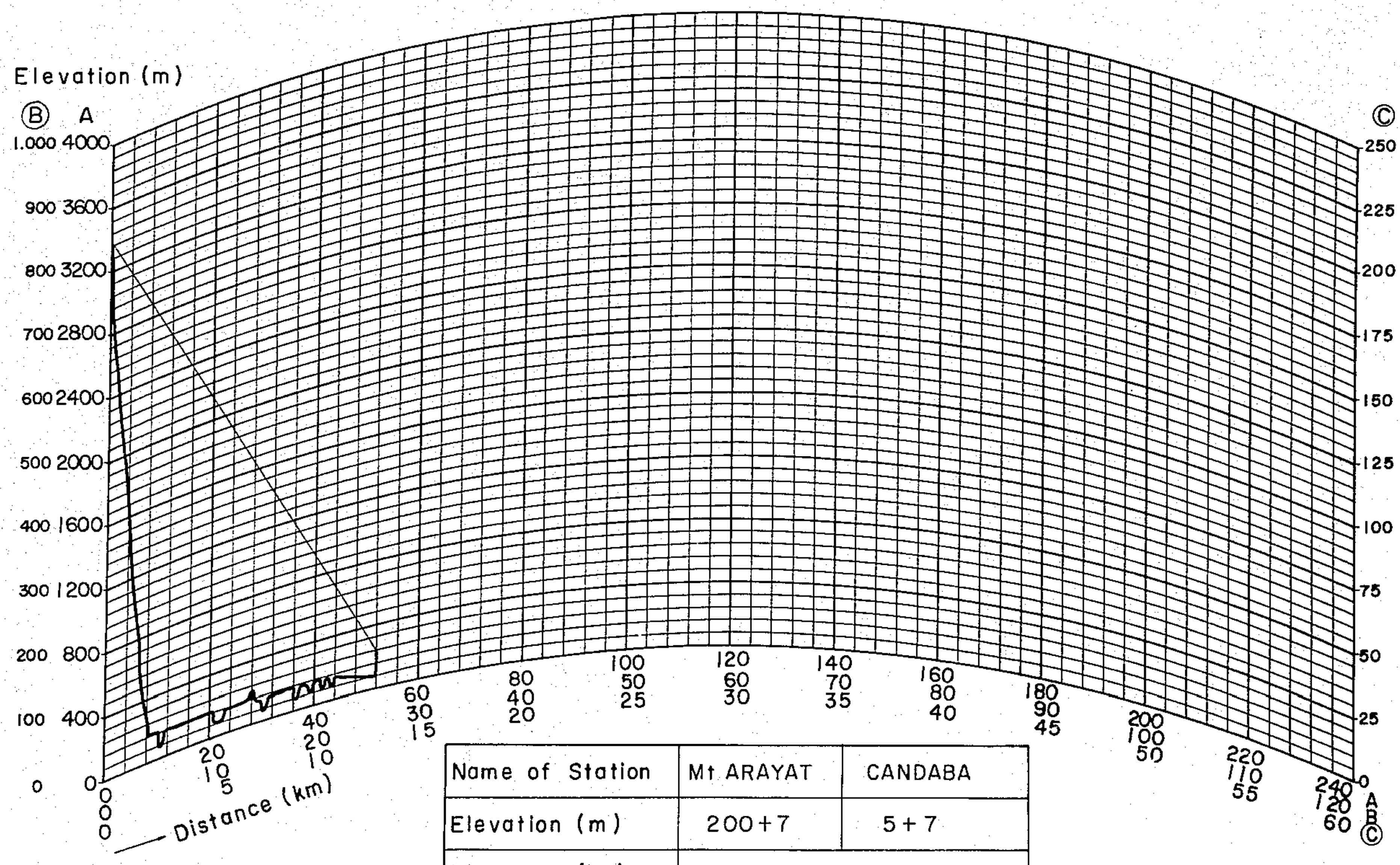
Profile map



Name of Station	APALIT	Mt. ARAYAT
Elevation (m)	2+7	200 + 7
Distance (km)	28.7	

No.

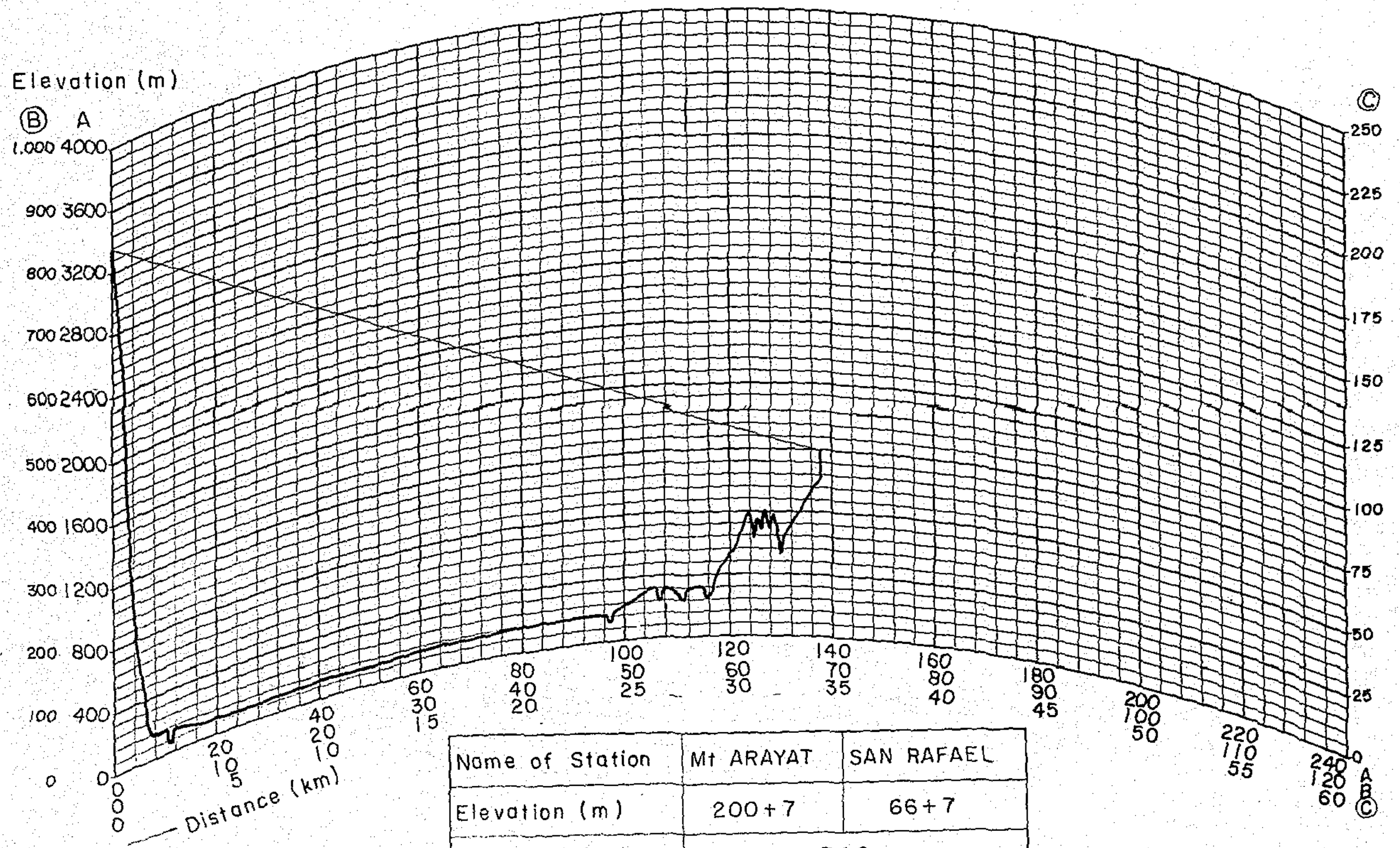
Profile map



Name of Station	Mt ARAYAT	CANDABA
Elevation (m)	200+7	5+7
Distance (km)	13.1	

No. 3

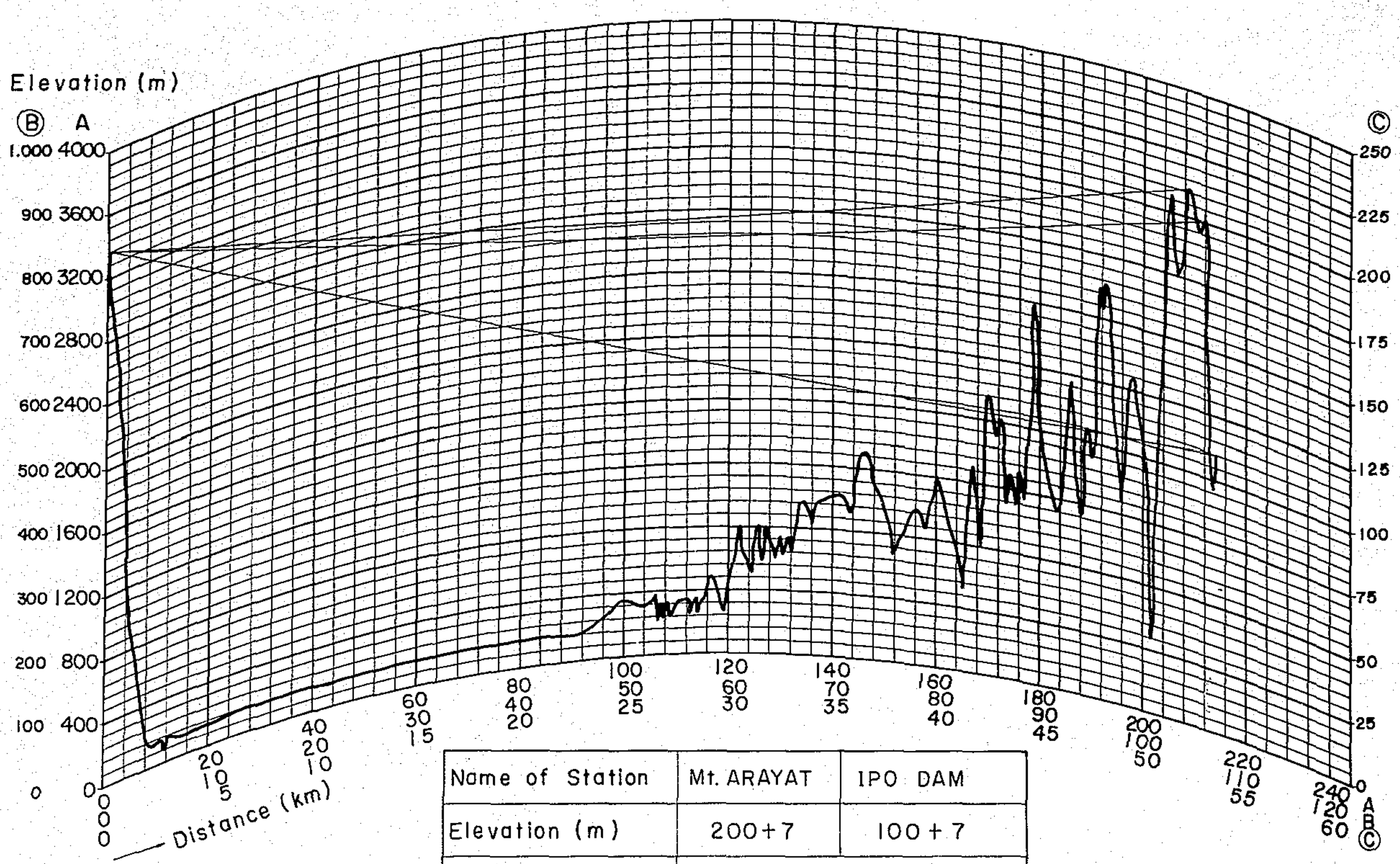
Profile map



Name of Station	Mt ARAYAT	SAN RAFAEL
Elevation (m)	200+7	66+7
Distance (km)	34.6	

No. 4

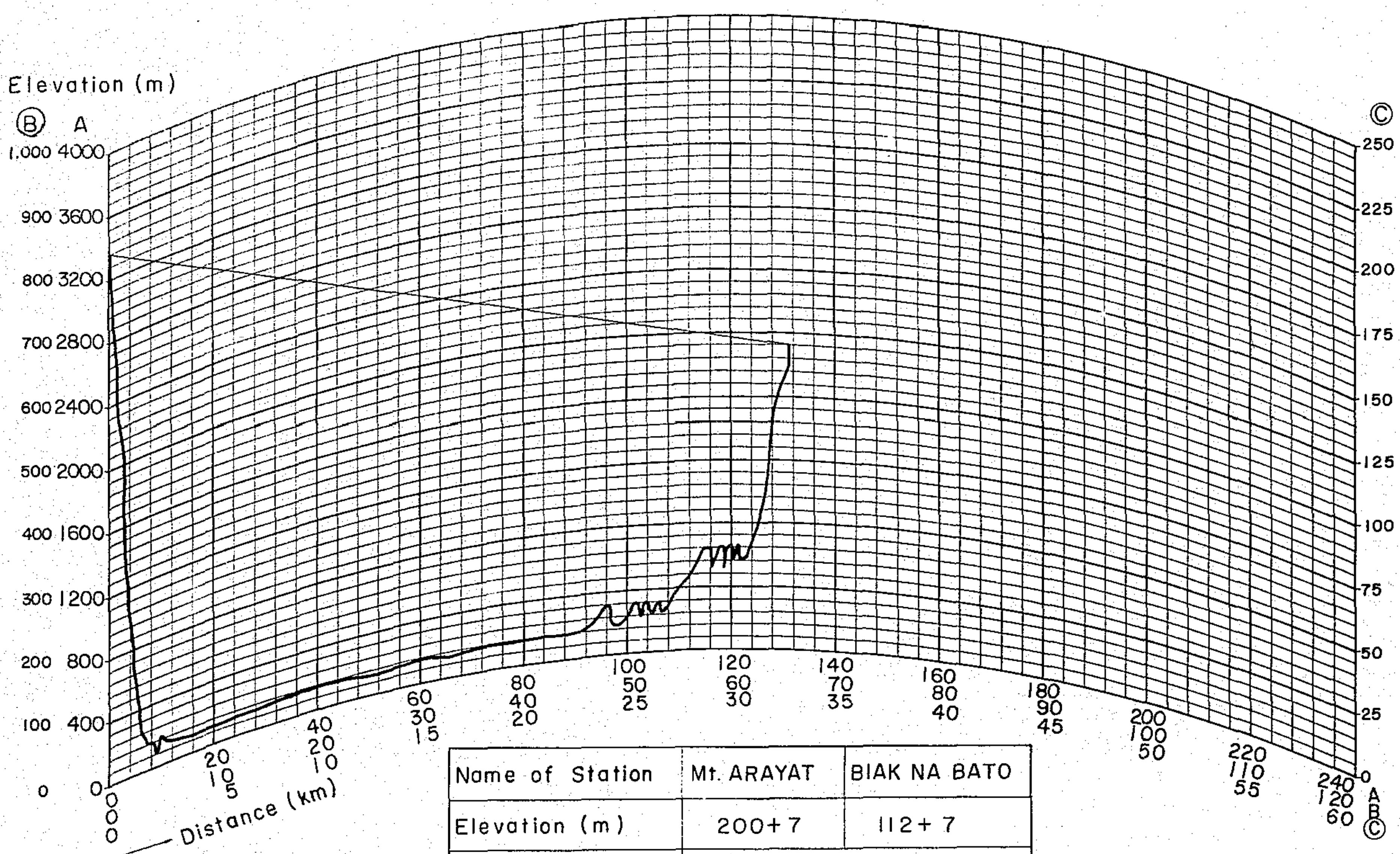
Profile map



Name of Station	Mt. ARAYAT	IPO DAM
Elevation (m)	200+7	100+7
Distance (km)	53.5	

No. 5

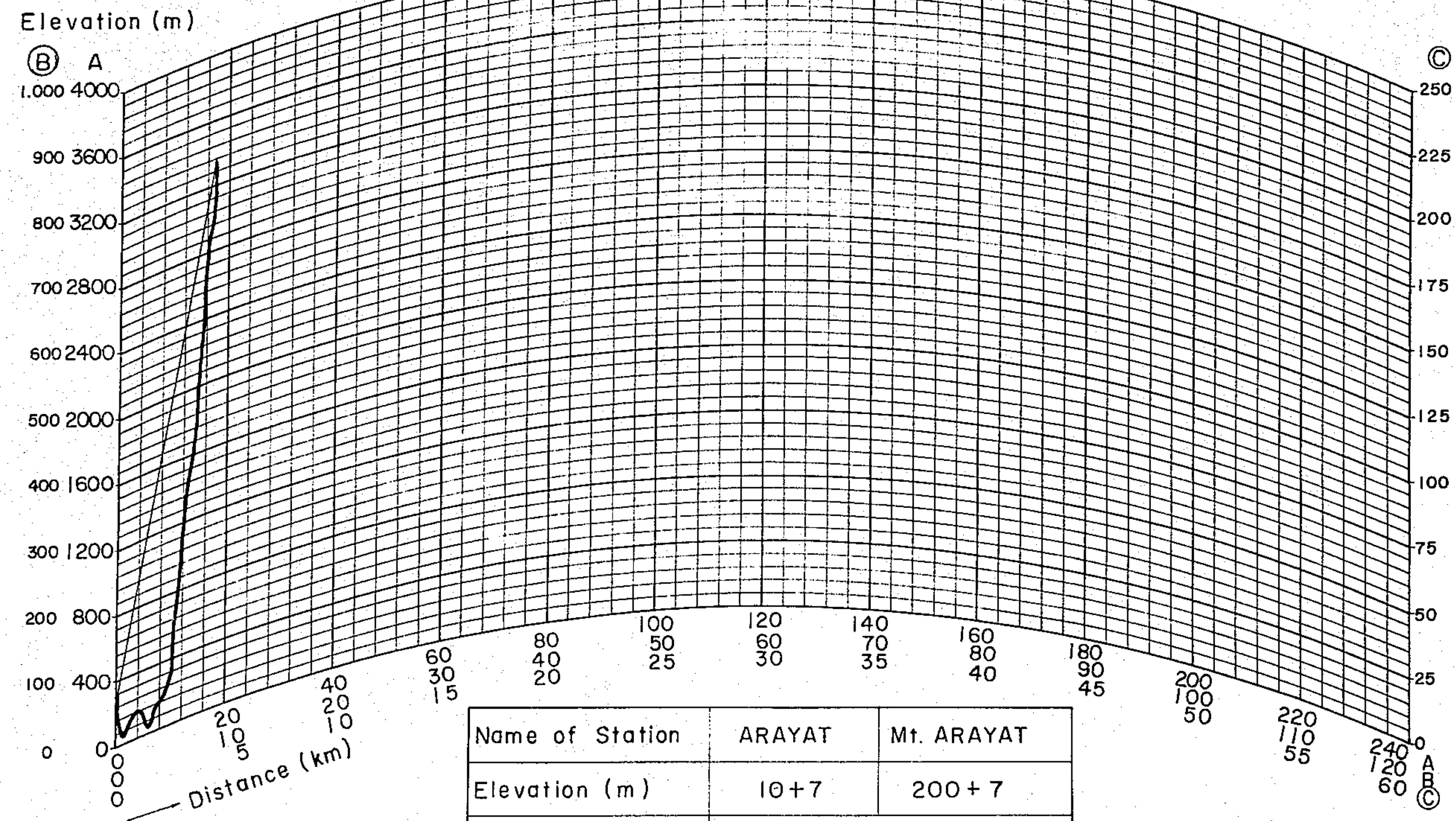
Profile map



Name of Station	Mt. ARAYAT	BIAK NA BATO
Elevation (m)	200+7	112+7
Distance (km)	32.9	

No. 6

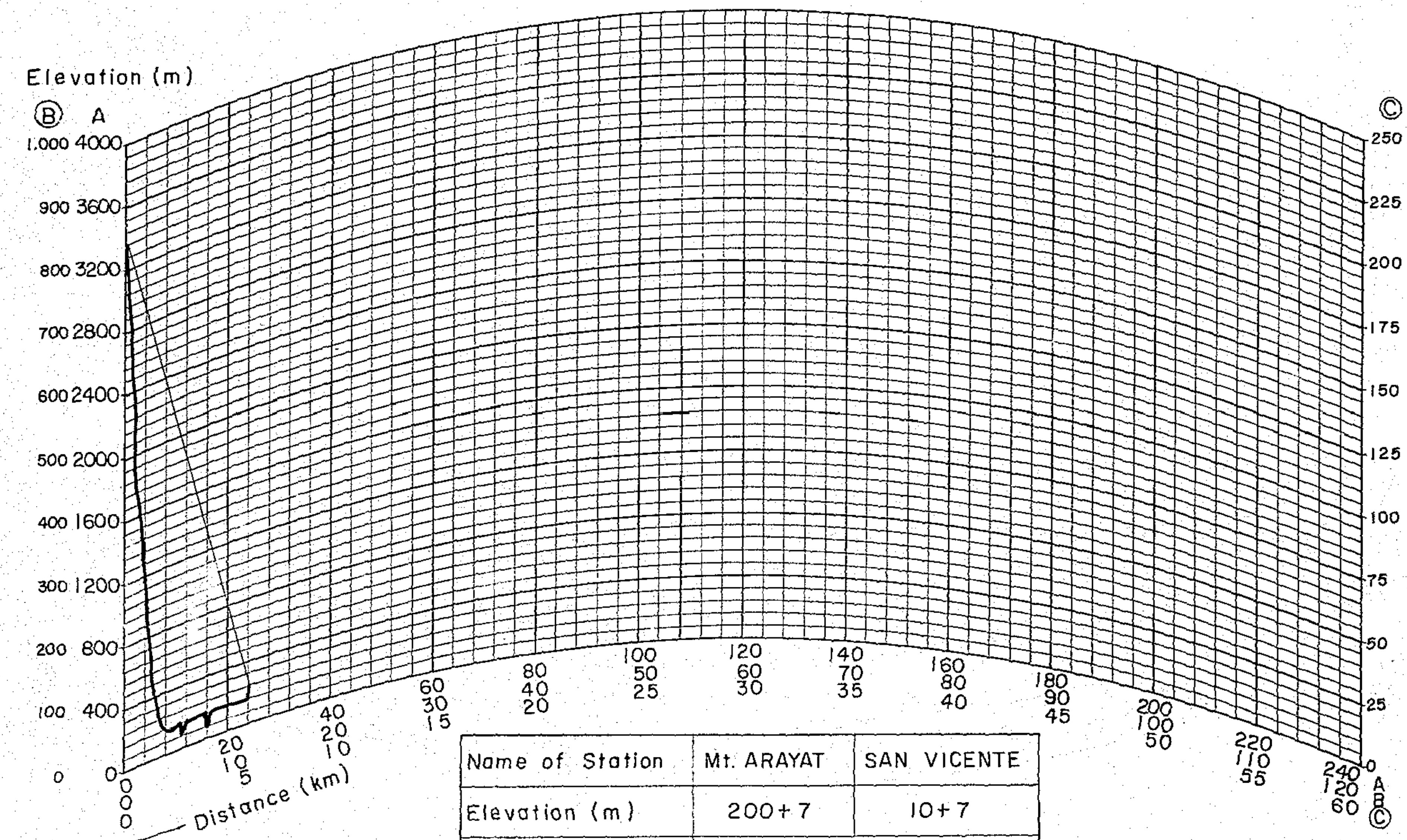
Profile map



Name of Station	ARAYAT	Mt. ARAYAT
Elevation (m)	10+7	200+7
Distance (km)	4.3	

No. 7

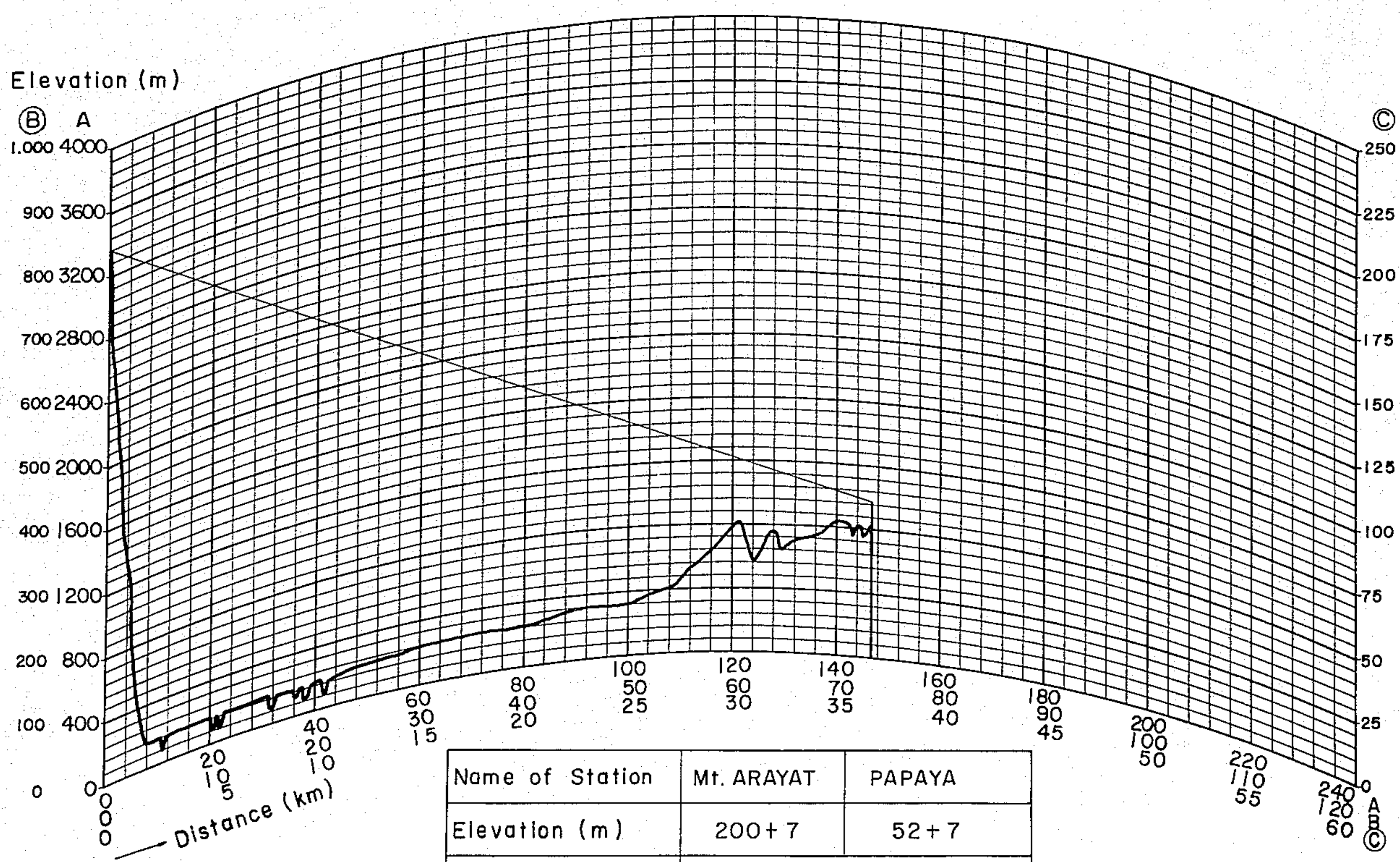
Profile map



Name of Station	Mt. ARAYAT	SAN VICENTE
Elevation (m)	200+7	10+7
Distance (km)	6.1	

No. 8

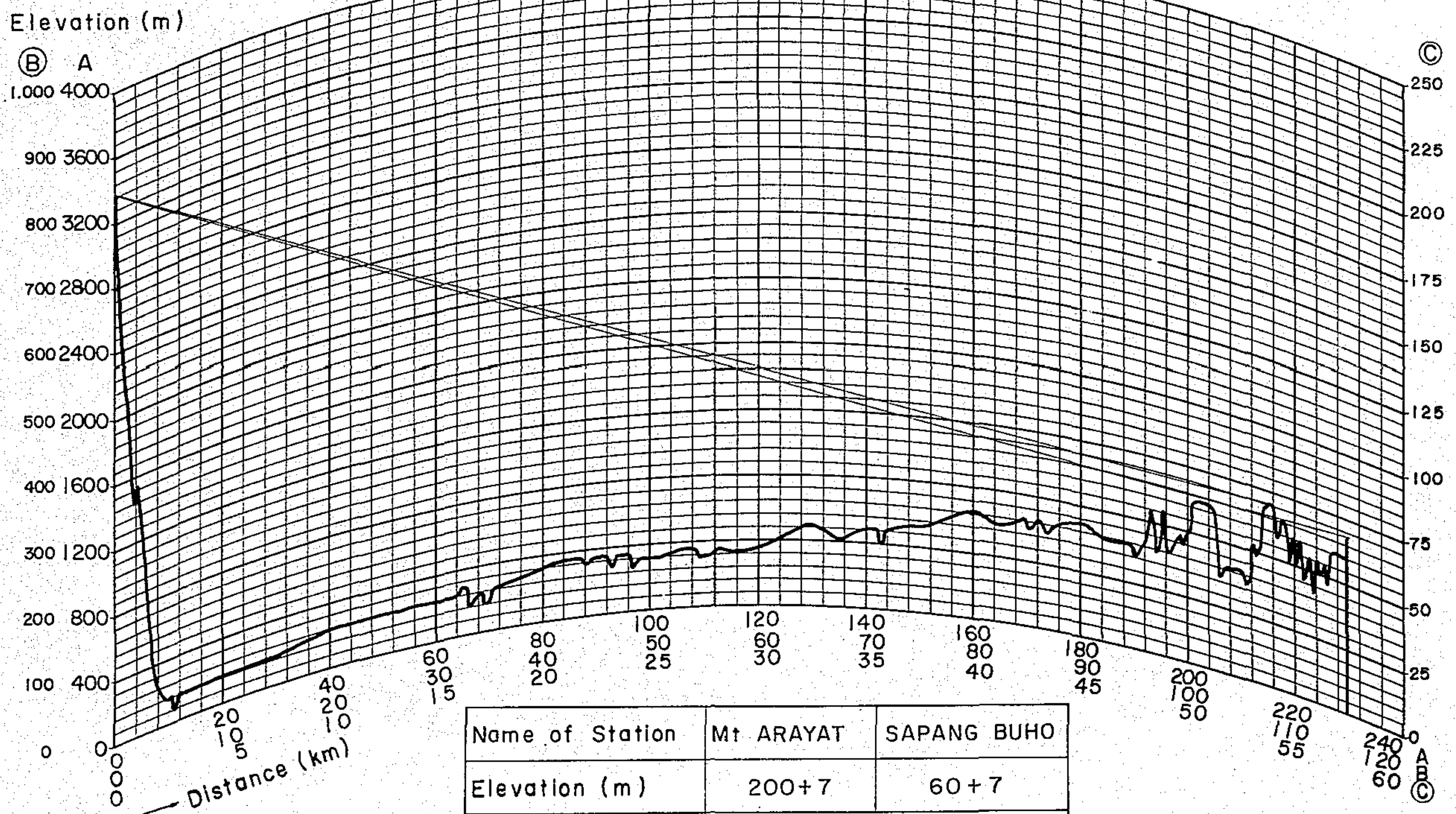
Profile map



Name of Station	Mt. ARAYAT	PAPAYA
Elevation (m)	200+7	52+7
Distance (km)	36.7	

No. 9

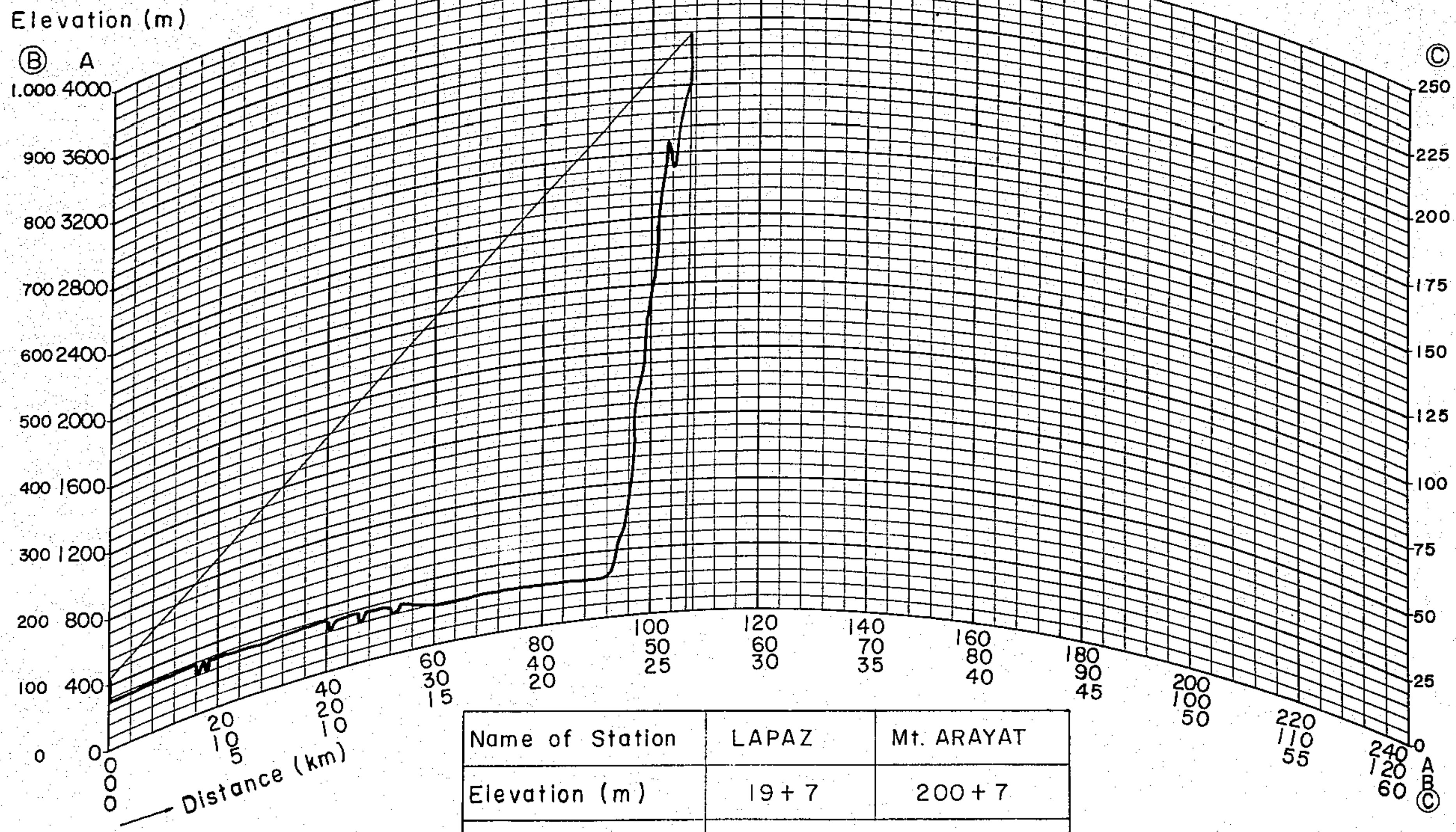
Profile map



Name of Station	Mt ARAYAT	SAPANG BUHO
Elevation (m)	200+7	60+7
Distance (km)	57.4	

No. 10

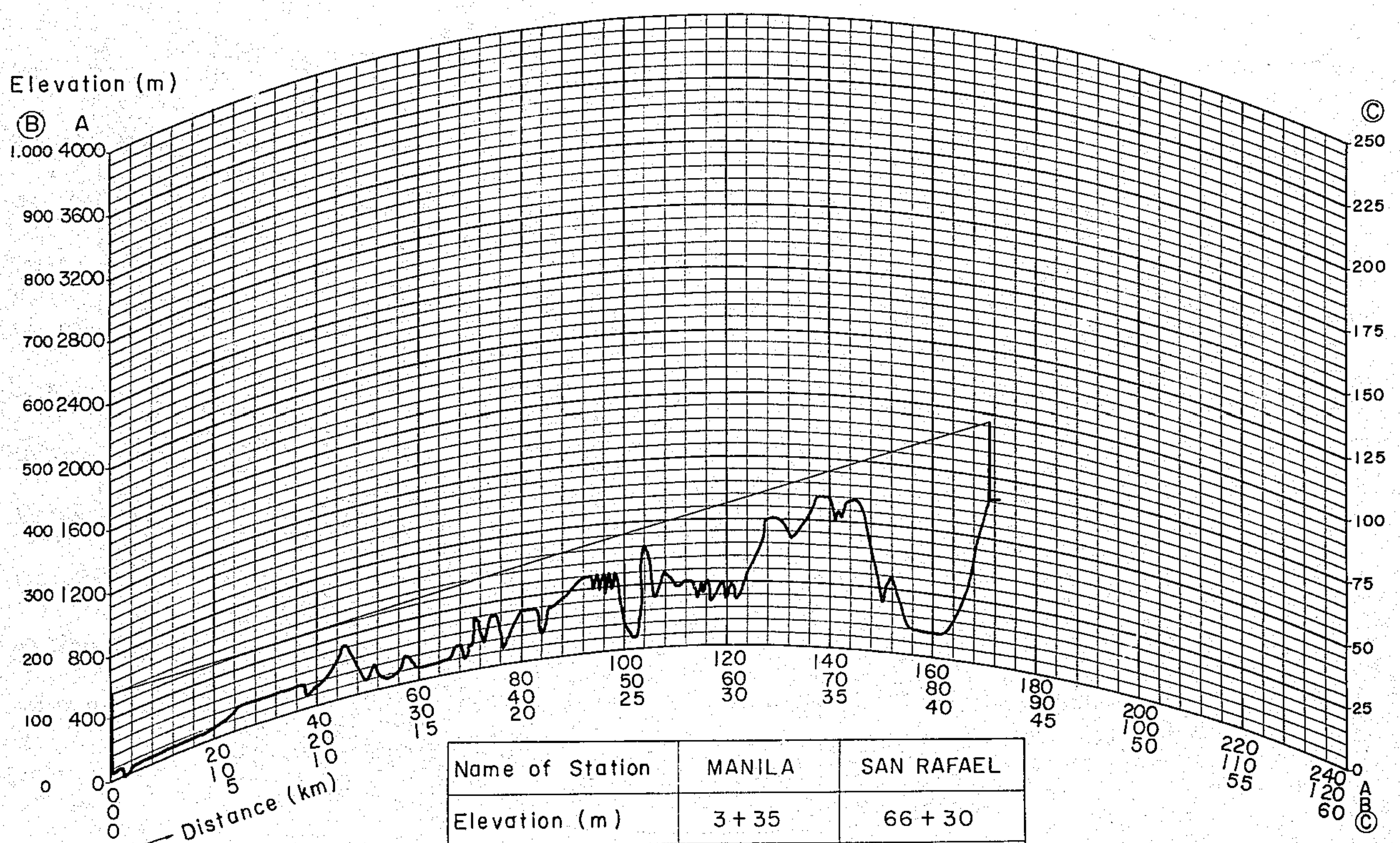
Profile map



Name of Station	LAPAZ	Mt. ARAYAT
Elevation (m)	19 + 7	200 + 7
Distance (km)	26.8	

No. 11

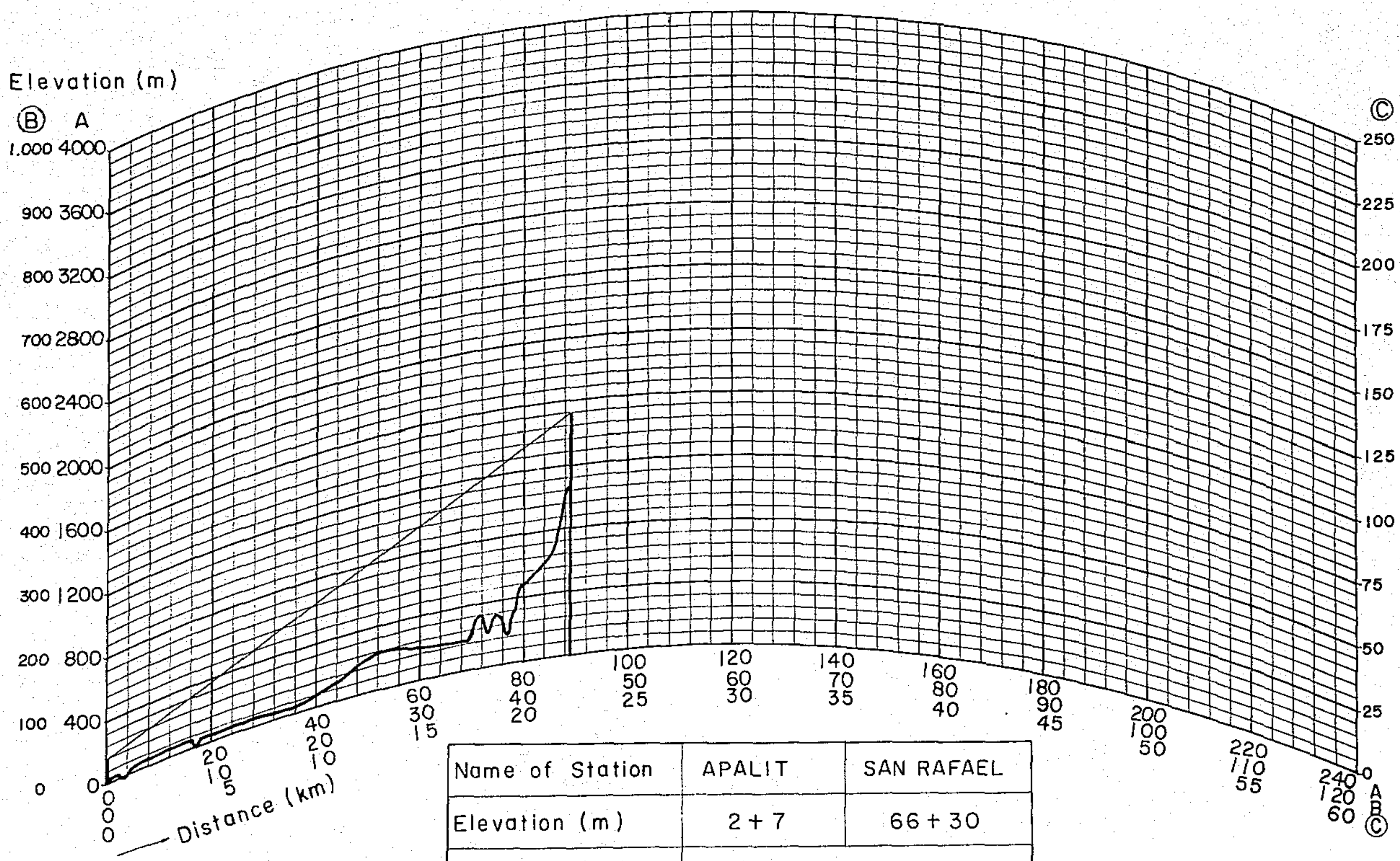
Profile map



Name of Station	MANILA	SAN RAFAEL
Elevation (m)	3 + 35	66 + 30
Distance (km)	42.8	

No. 12

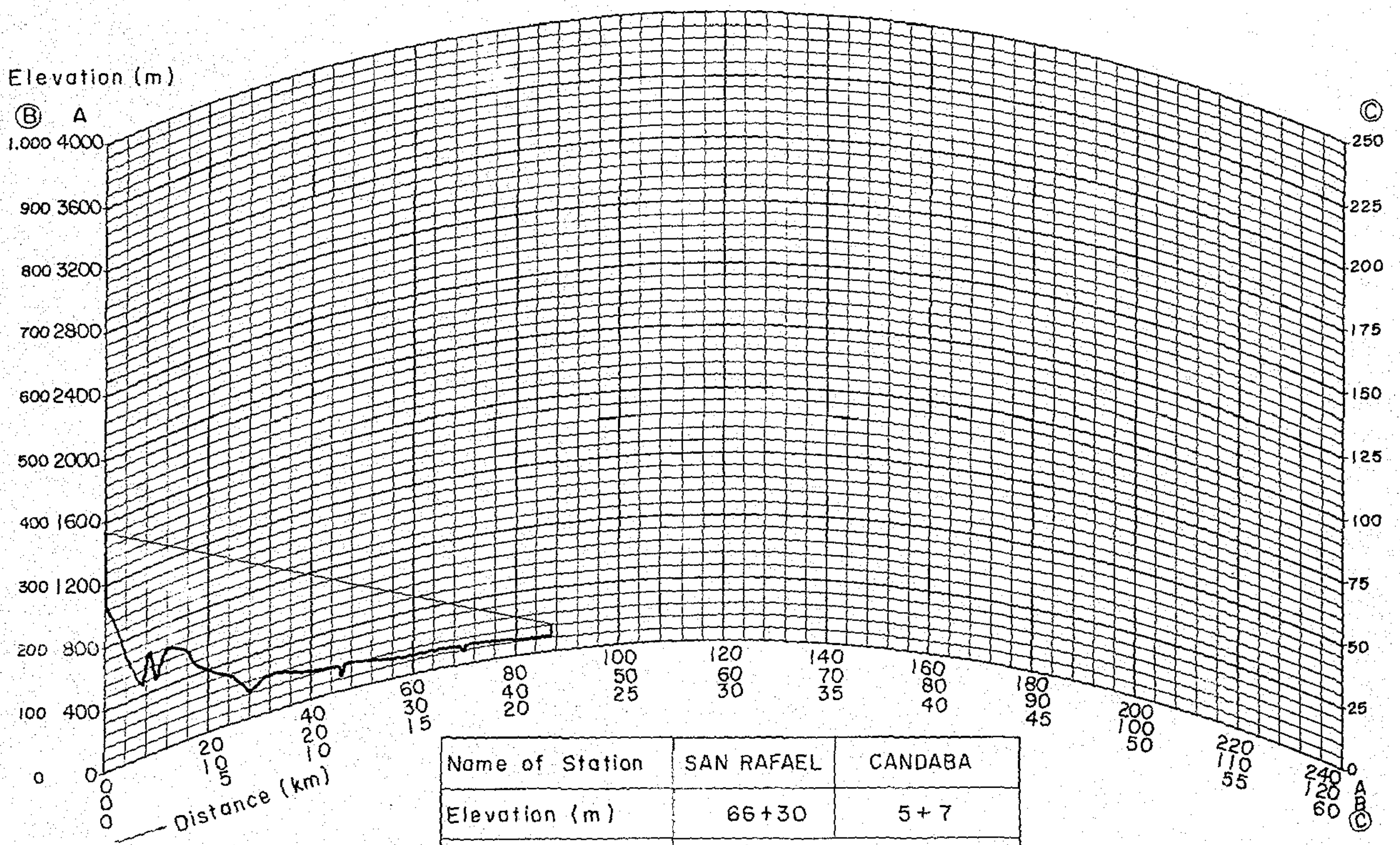
Profile map



Name of Station	APALIT	SAN RAFAEL
Elevation (m)	2 + 7	66 + 30
Distance (km)	22.2	

No. 13

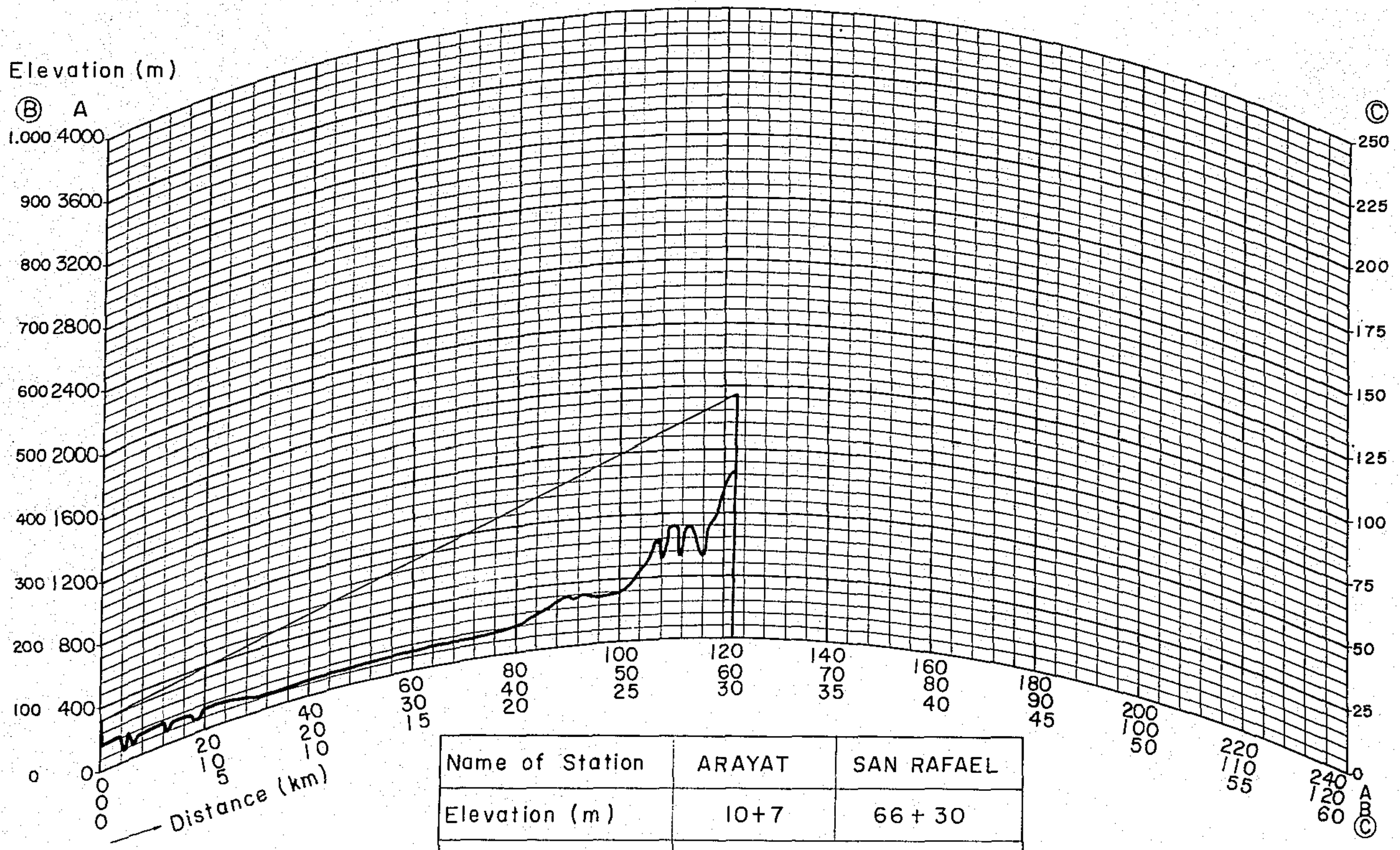
Profile map



Name of Station	SAN RAFAEL	CANDABA
Elevation (m)	66+30	5+7
Distance (km)	21.8	

No. 14

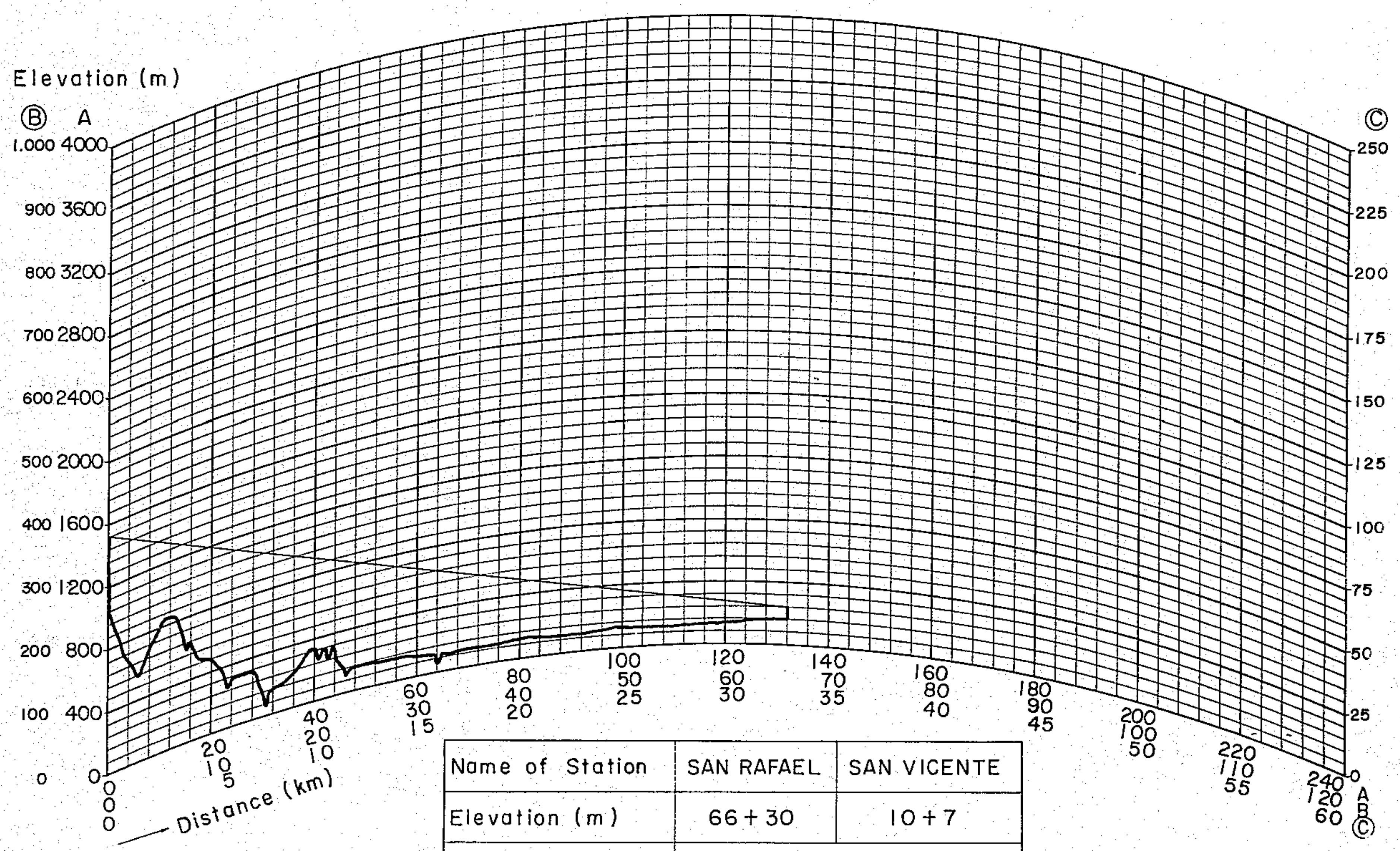
Profile map



Name of Station	ARAYAT	SAN RAFAEL
Elevation (m)	10+7	66 + 30
Distance (km)	30.5	

No. 15

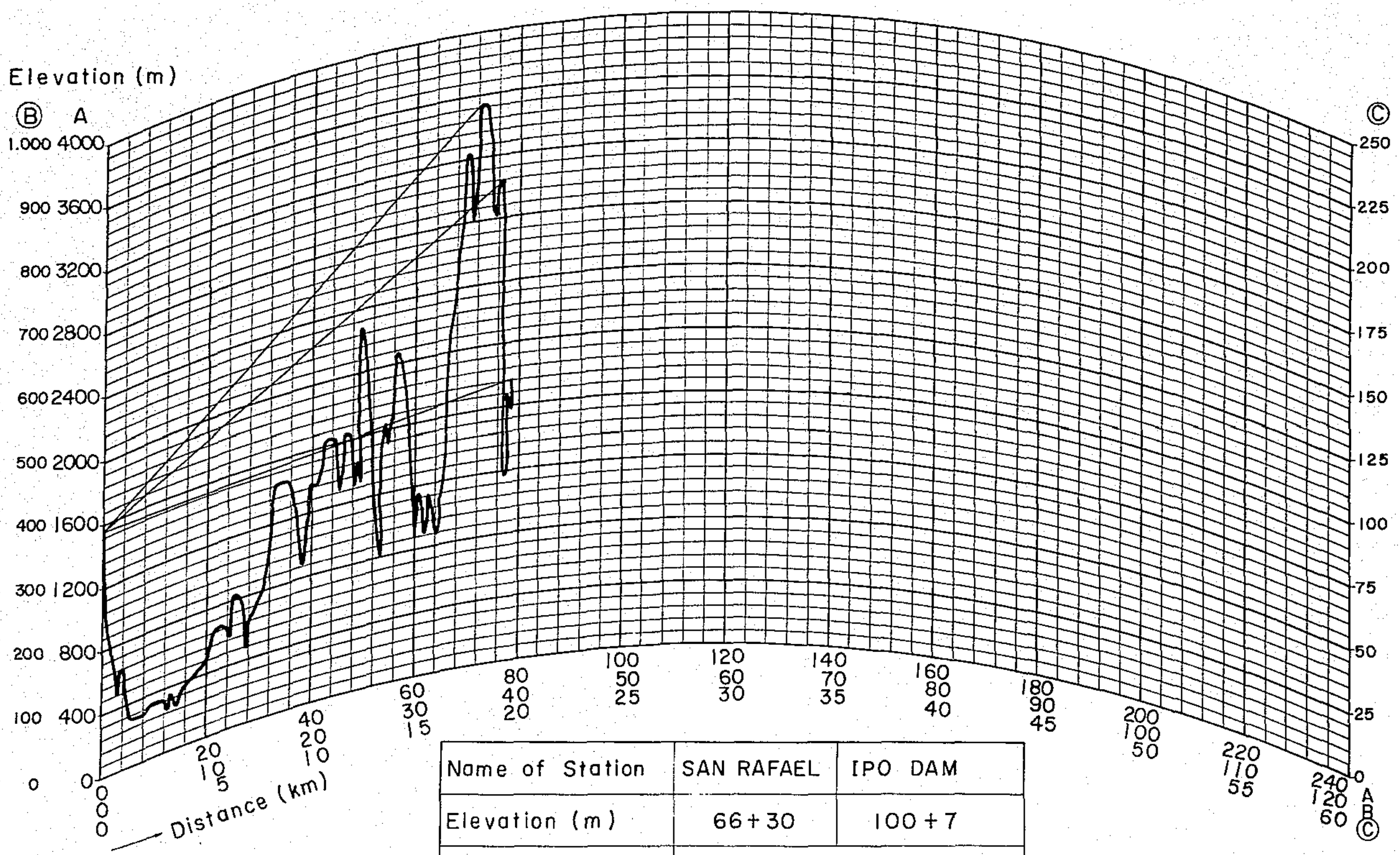
Profile map



Name of Station	SAN RAFAEL	SAN VICENTE
Elevation (m)	66 + 30	10 + 7
Distance (km)	32.9	

No. 16

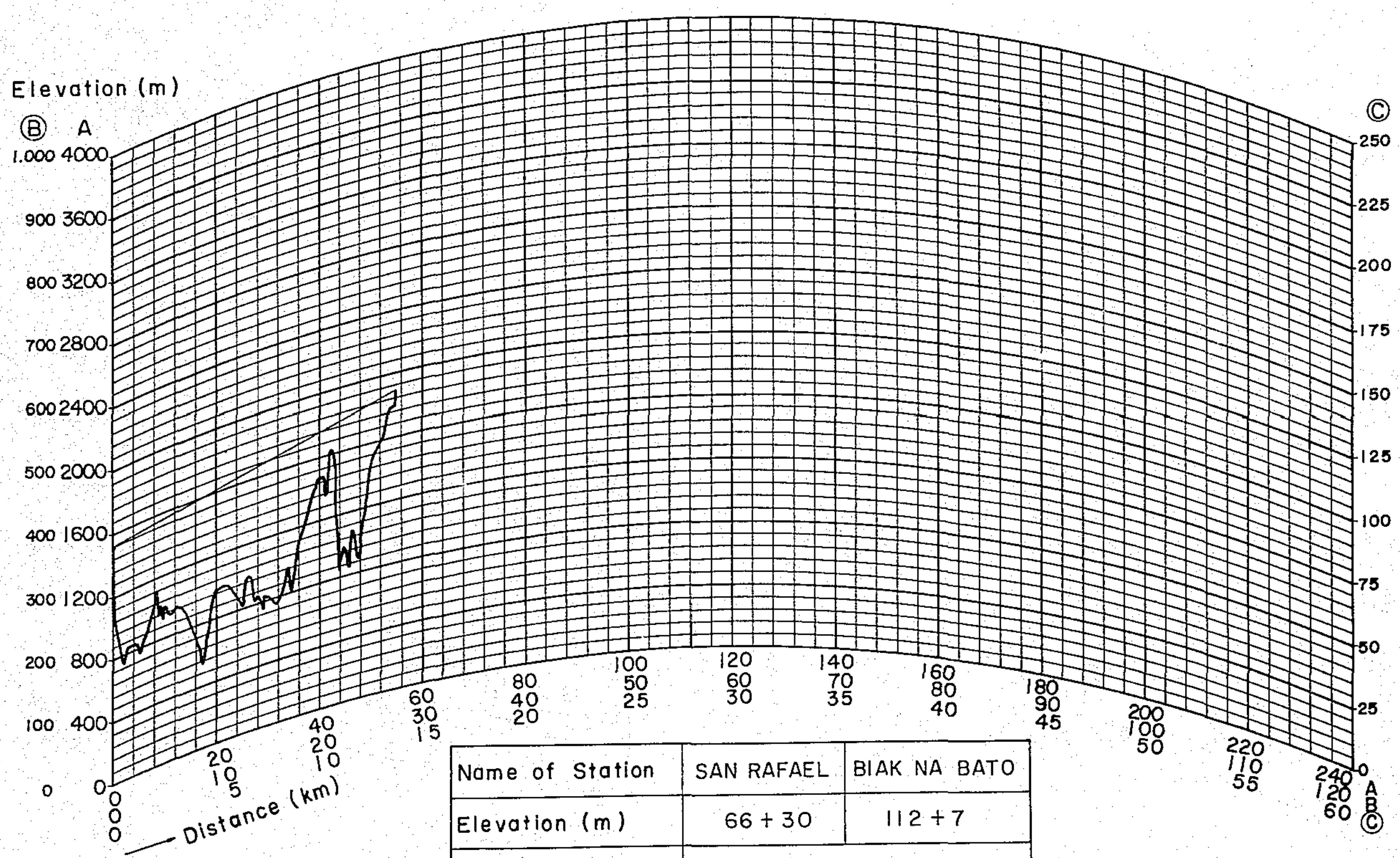
Profile map



Name of Station	SAN RAFAEL	IPO DAM
Elevation (m)	66 + 30	100 + 7
Distance (km)	19.5	

No. 17

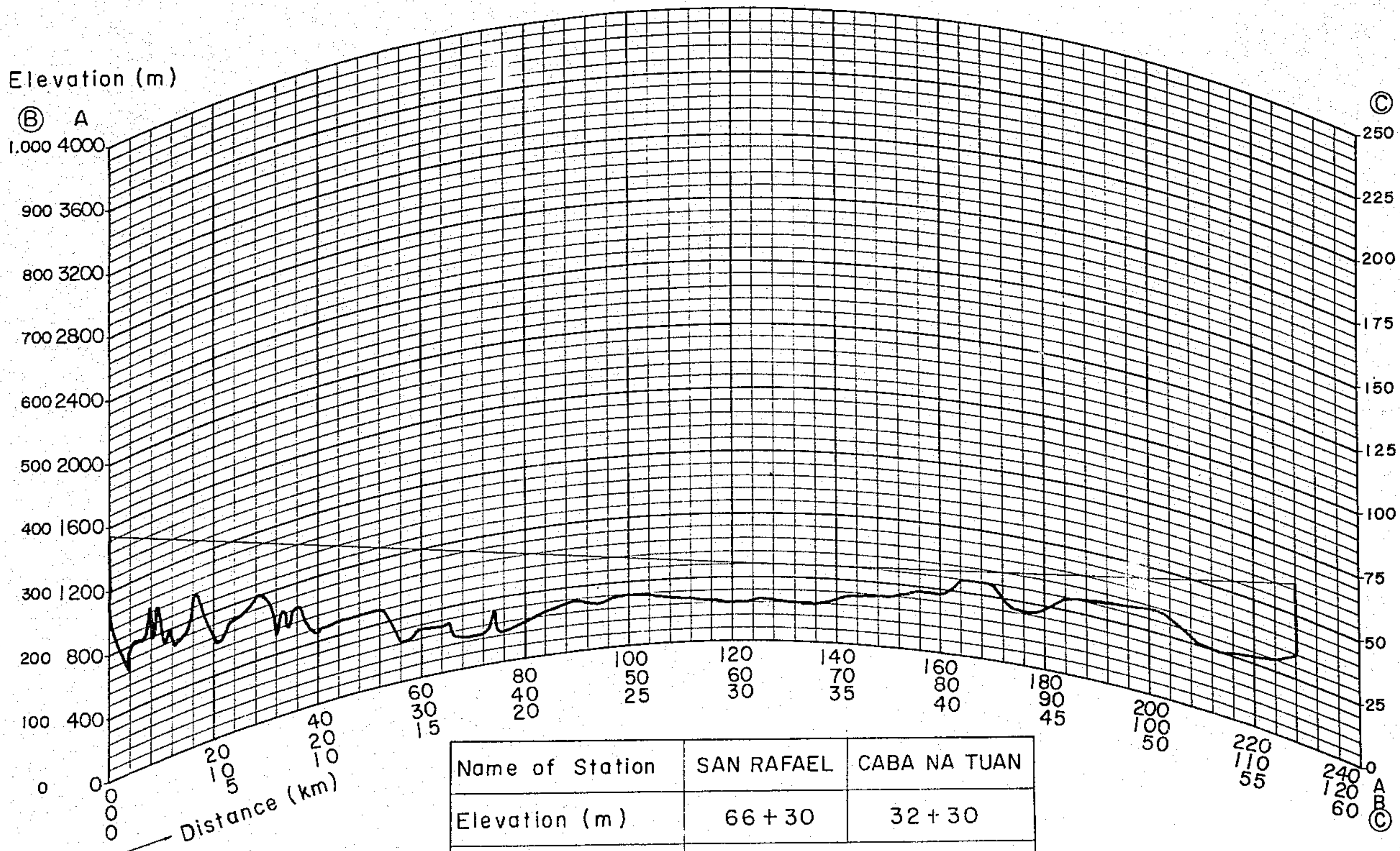
Profile map



Name of Station	SAN RAFAEL	BIAK NA BATO
Elevation (m)	66 + 30	112 + 7
Distance (km)	13.8	

No. 18

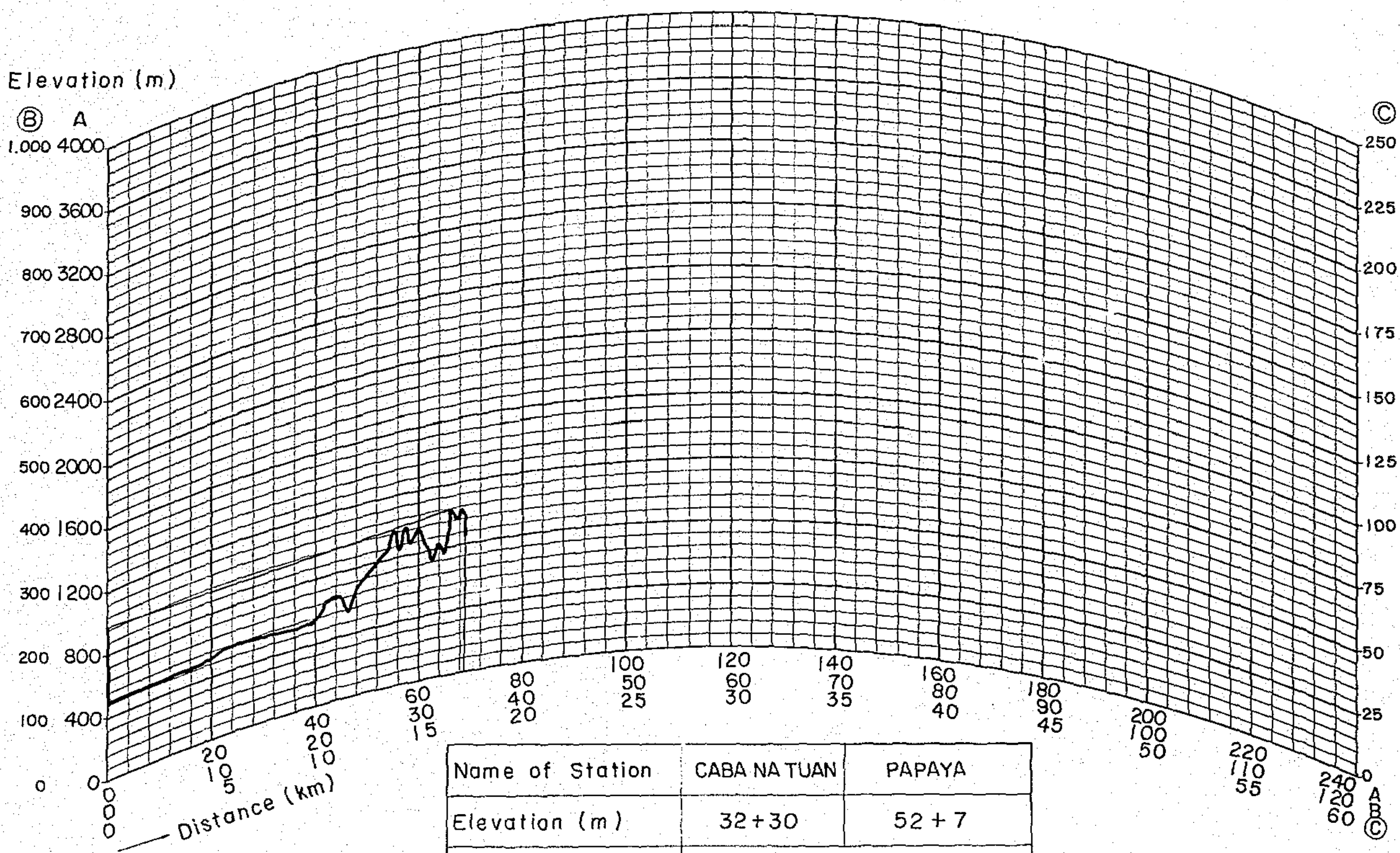
Profile map



Name of Station	SAN RAFAEL	CABA NA TUAN
Elevation (m)	66 + 30	32 + 30
Distance (km)	57	

No. 19

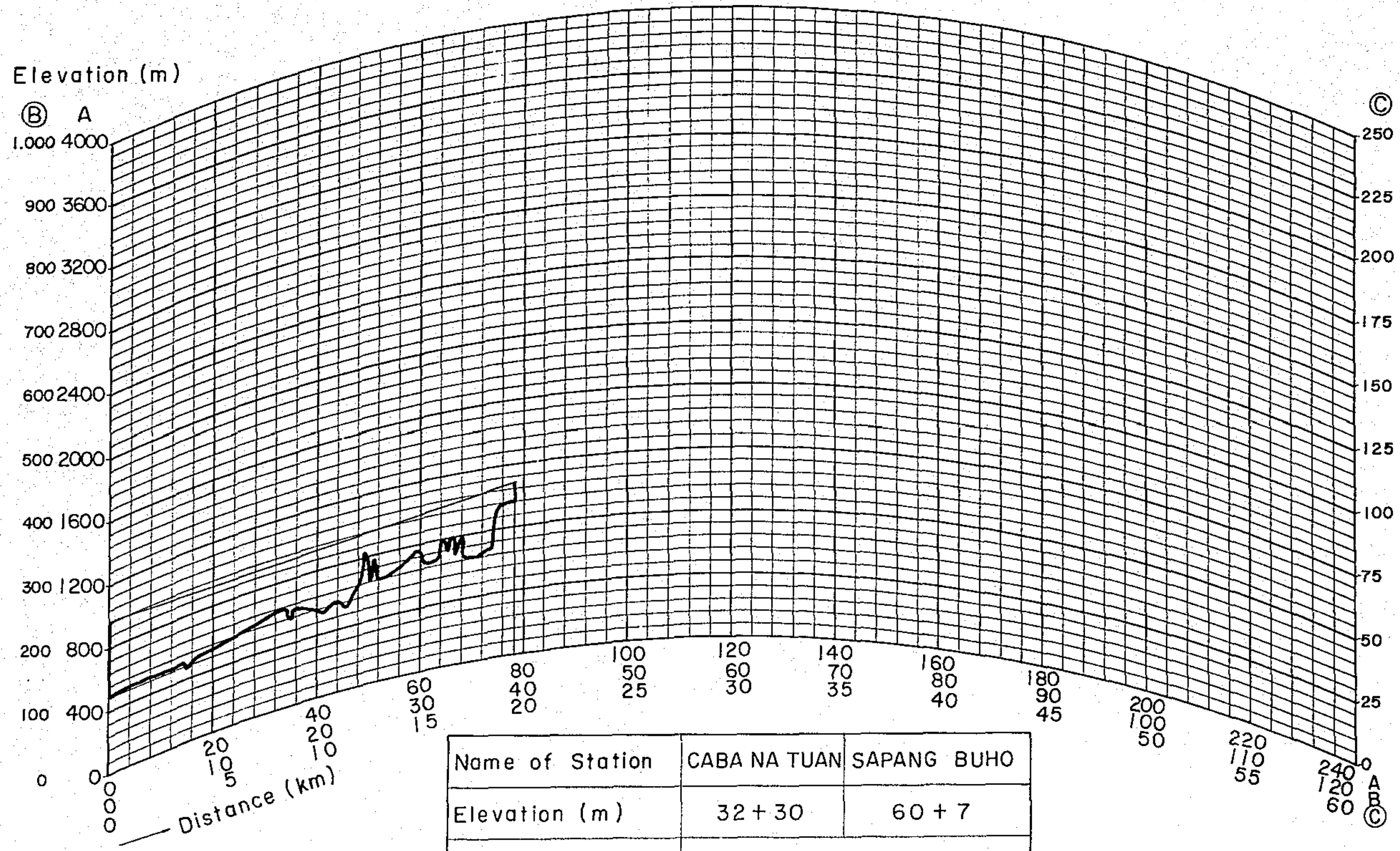
Profile map



Name of Station	CABA NA TUAN	PAPAYA
Elevation (m)	32+30	52+7
Distance (km)	17.25	

No. 20

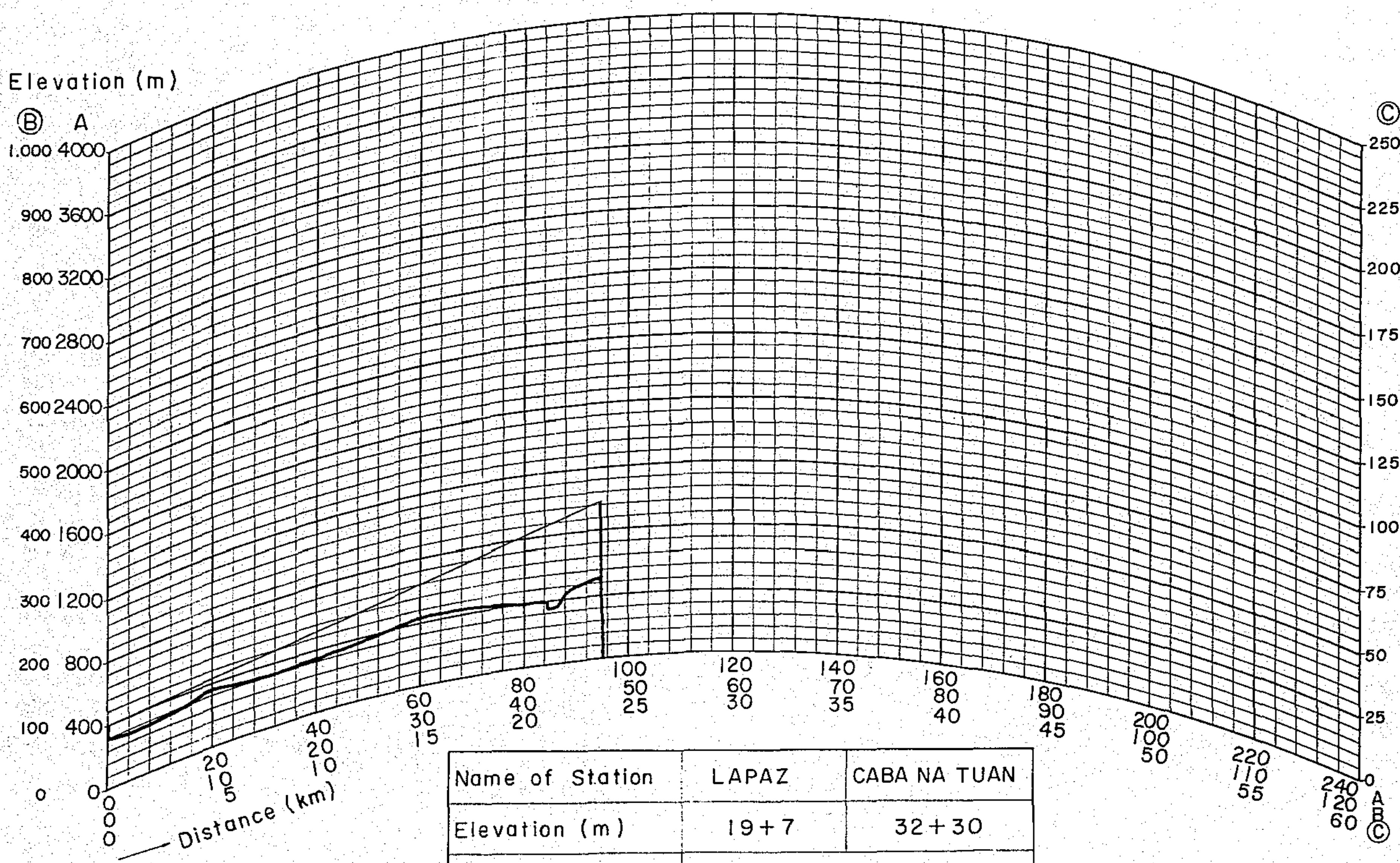
Profile map



Name of Station	CABA NA TUAN	SAPANG BUHO
Elevation (m)	32 + 30	60 + 7
Distance (km)	19.5	

No. 21

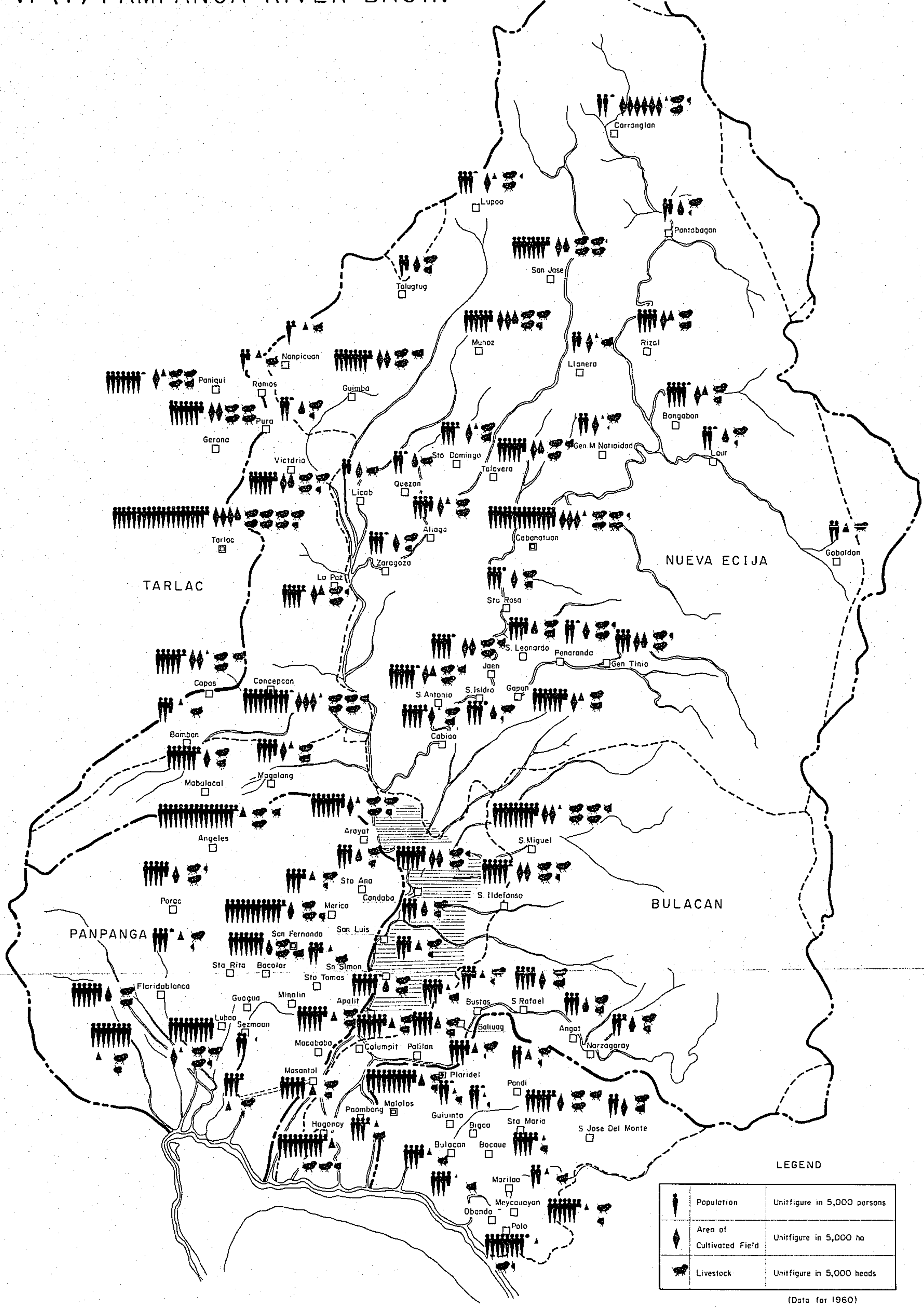
Profile map



Name of Station	LAPAZ	CABA NA TUAN
Elevation (m)	19+7	32+30
Distance (km)	23.8	

No. 22

FIG A-Ⅵ (I) PAMPANGA RIVER BASIN



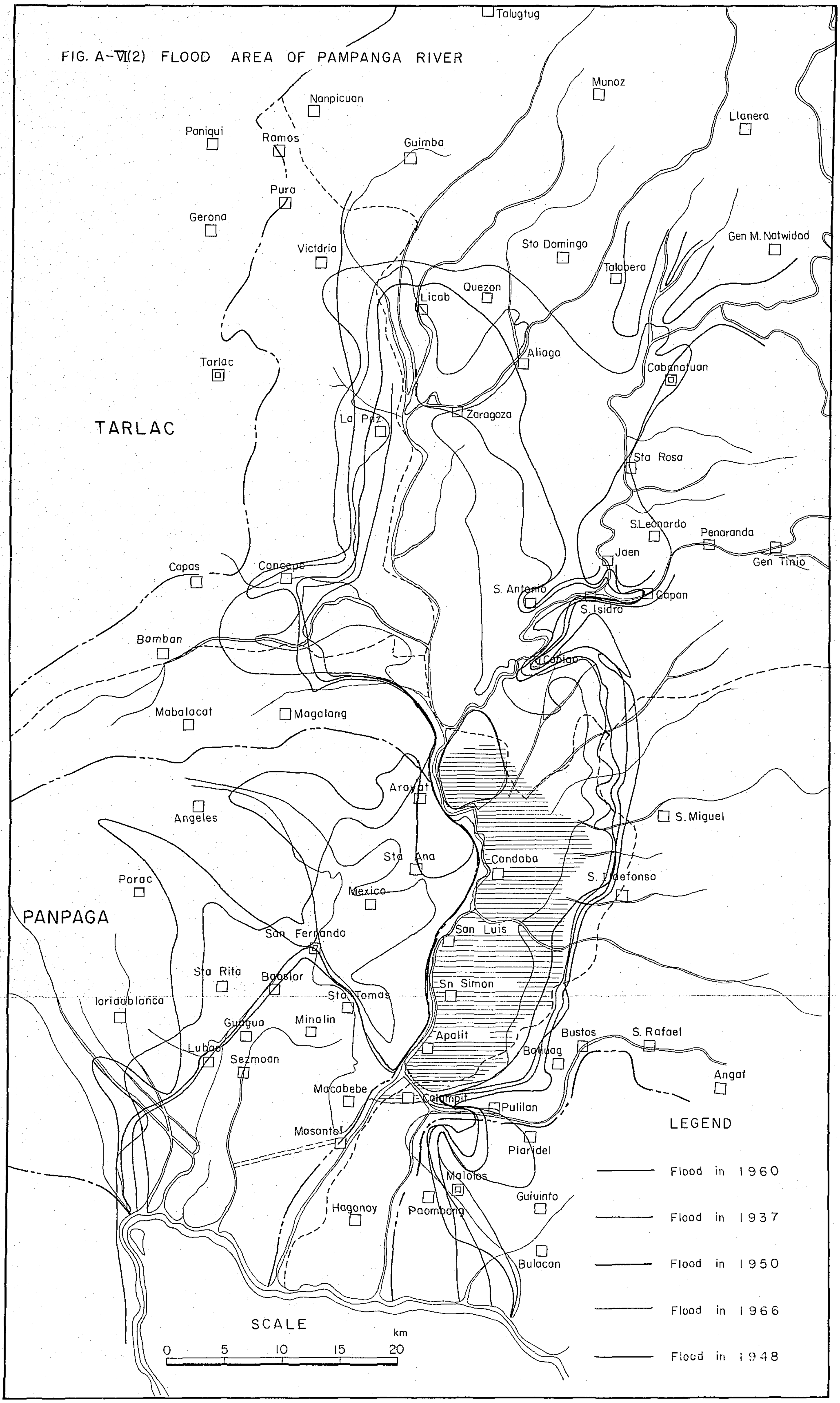


FIG. A-Ⅵ(2) FLOOD AREA OF PAMPANGA RIVER