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RUNOFF ANALYSIS AND FLOOD FORECASTING STUDY OF THE 1972 FLOOD IN THE PAMPANGA RIVER BASIN (PHILIPPINES)

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1. Introduction

The 1972 flood which hit the Central Luzon of the Philippines was unprecedented in its intensity and duration as well as its extent. The Pampanga, the largest river in the region, experienced a severe flood protracted for some 40 days with three significant peaks, two of which exceeded the highest ever observed.

Since the Pampanga river basin was selected by the Philippine Government for pilot flood forecasting and warning as a part of the Typhoon Committee's action programme, an intensive study on the hydrological characteristics of the basin was undertaken by a team of Japanese experts in 1969. It was suggested by the team that flood forecasting with time advantage of one day would be practicable if a telemeterized network system consisting of 10 raingauges was installed. Upon request of the Philippine Government, the Government of Japan have agreed to provide a complete set of telemetering equipment as recommended by the team of experts.

Meantime, Weather Bureau of the Philippines has intensified its hydrological network in the Pampanga basin. There are at present 27 raingauges, most of which are recording type, in the basin.

The Bureau of Public Works undertook discharge measurements at the height of the flood upon recommendation of the Typhoon Committee Secretariat. These measurements provided valuable information on the hydraulic characteristics of the river basin and discharge from the whole basin could be estimated from the water stage at the outlet of the basin.

In view of the unusually high flood condition and the arrangement made for additional hydrological data during that period, it was considered appropriate to undertake a fresh study on the runoff characteristics of the basin. The analysis was initiated with a view to attaining a cross-check between rainfall and runoff data through the water balance study, which was followed by a reconstitution of runoff from rainfall and further developed into an exercise of flood forecasting with a possible time advantage of two days.

2. Cause of the Flood

A number of typhoons and tropical depressions occurred in the Western Pacific during the months of June, July and August 1972 (Fig. 1). Two of them, KONSING and EDENG, landed in Luzon Island and brought considerable amount of rainfall over the Central Luzon. The other typhoons and depressions, though they did not hit the island directly, intensified the Southwest monsson in the northern parts of the Philippines and caused protracted heavy rainfall in the basin.

The rainfall spell from the end of June to end of August had three significant peaks, all in July. Most of the raingauges in the basin recorded the largest daily as well as monthly total in July (Table 1).

It is noteworthy that the rainfall was record breaking not only in its amount, but also in its intensity. Such conditions could be the cause of extra-ordinary flood in both small and large rivers.

Table 1: Record of rainfall in July 1972 at selected stations in the Pampanga basin in m m

Station	Maximum Daily Rainfall	Second Maximum Daily Rainfall	Total for the month
Toyabo (Nueva Ecija)	118.6(17)*	108.7(28)*	1290.2
Bangad (Cabanatuan City)	268.2(6)	123.4(7)	1146.5
Zaragoza (Nueva Ecija)	221.8(8)	201.2(7)	1680.3
Hacienda Luisita (Tarlac)	110.0(7)	107.9(27)	1590.0
Arayat (Pampanga)	196.8(7)	149.4(18)	1456.7
Apalit (Pampanga)	280.4(18)	206.2(17)	2580.3
Baliwag (Bulacan)	170.4(18)	161.5(7)	1523.7

*Number in parenthesis indicates date of occurrence.

3. Available hydrological data

There are 27 rain gauge stations in the basin (Table 2 and Fig. 2). Most of them are of tipping bucket type with automatic recorder. Period for which data are available is generally short, ranging from two to seven years. None of the stations is provided with telecommunication facility; the data recorded during a month is transmitted to the Weather Bureau by mail at the beginning of the following month.

When this study was undertaken, data of a number of stations were not available due to lack of communication resulting from the severe flood. However, considering the available data and the distribution of the stations in the basin, 14 stations as indicated in Fig. 2 were selected for calculation of the basin rainfall.

There are 57 river gauging stations on the main stream and tributaries of the Pampanga river system. Some of them are provided with automatic recorder. No station has been telemeterized.

Currentmeter observations are recorded periodically by the Bureau of Public Works except for the stations in the tidal range. For the purpose of water balance and flood forecasting study, the stage discharge relationship at the outlet of Candaba Swamp is needed, but currentmeter observations are not normally recorded there. However, special arrangement was made for recording currentmeter observations on the 14th and 28th July with respect to all the outlet channels (3 rivers and 7 culverts) from the Swamp. The total discharge was plotted on a graph paper, together with the data estimated from a low-water analysis made by the Japanese team. Thus the rating curve for the discharge from the Swamp with respect to the water stage at Sulipan was constructed (Fig. 3).

As part of the procedure required for the proposed flood forecasting, it is necessary to estimate the water stage at Candaba, the target point recommended by the Japanese team, from that of Sulipan. An extensive study on the hydro-dynamic characteristics of the Swamp may be required for the establishment of this relationship. For the sake of simplicity, however, an empirical curve showing this relationship (Fig. 3 - left side) was derived from the plots of water stages observed simultaneously at Sulipan and Candaba (Fig. 4 - below). Since the observed points show farily good consistency, the curve is considered accurate enough for the purpose of the present study.

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Table 2: Existing Rainfall Stations in the Pampanga River Basin

	Station	Date Established	Latitude	Longitude
1.	Tayabo, Sn Jose City, N.E.	July 1970	15° 47'N	120° 59'E
2.	Palayupay, Pantabangan, N.E.	August 1970	15° 50'N	121° 09'E
* 3.	Camanacsacan, Sn Jose City, N.E.	August 1971	15° 46'N	120° 59'E
* 4.	Tondod, Sn Jose City, N.E.	August 1971	15° 43'N	120° 58'E
5.	PRIS Dam, Rizal, N.E.	July 1970	15° 42'N	121° 07'E
6.	Baloc, Sto Domingo, N.E.	September 1970	15° 38'N	120° 53'E
7.	Sibul, Talavera, N.E.	August 1970	15° 38'N	120° 57'E
8.	LTRIS Dam, LLanera, N.E.	July 1970	15° 43'N	120° 37'E
* 9.	Piñahan, Gen Natividad, N.E.	August 1971	15° 37'N	121° 03'E
10.	Quezon, Nueva Ecija	September 1970	15° 34'N	120° 48'E
*11.	Bantug, Talavera, N.E.	August 1971	15° 33'N	120° 54'E
12.	Murcon Dam, Talavera, N.E.	July 1970	15° 35'N	120° 48'E
13.	PBRIS Dam, Gen Natividad, N.E.	July 1970	15° 33'N	121° 06'E
14.	Pamaldan, Cinco-Cinco, Cab. City	August 1971	15° 29'N	120° 55'E
15.	Gabaldon, Nueva Ecija	October 1965	15° 28'N	121° 20'E
16.	Zaragosa, Nueva Ecija	September 1970	15° 28'N	120° 48'E
17.	Cabanatuan City	June 1965	15° 29'N	120° 58'E
18.	Bangad, Cabanatuan City	July 1970	15° 30'N	121° 02'E
19.	Hacienda Luisita, Tarlac	August 1967	15° 27'N	120° 38'E
20.	Lambakin, Jaen, N.E.	September 1970	15° 21'N	120° 54'E
21.	Mallorca, Sn Leonardo, N.E.	August 1971	15° 23'N	120° 57'E
22.	Gapan, Nueva Ecija	June 1965	15° 19'N	120° 57'E
23.	Arayat, Pampanga	May 1966	15° 09'N	120° 46'E
24.	Sn Miguel, Bulacan	April 1971	15° 09'N	120° 59'E
25.	Sta Cruz, Porac, Pampanga	January 1969	15° 05'N	120° 33'E
26.	Apalit, Pampanga	August 1967	14° 57'N	120° 45'E
27.	Sabang, Baliwag, Bulacan	June 1971	14° 58'N	120° 55'E
28.	Angat, Norzagaray, Bulacan	August 1972	14° 52'N	121° 08'E

* Stations without Tipping Bucket Recording Raingauge.

4. Water balance study

Water balance was calculated for the basin above the outlet of the Candaba Swamp comprising a catchment area of 8,926 km^2 including that of the Angat river. Study was made in term of the water depth over the catchment area expressed in milimeter; thus, 1 mm/day of runoff corresponds to 103.3 m^3/sec of discharge from the basin or 100 m^3/sec of discharge corresponds to 0.967 mm/day of runoff.

Period of the study was set from the 21st July to the 31st August (72 days), including some margins prior to and after the flood. The following fundamental equation is used:

$$R - E - Q = \Delta S$$

where R denotes the basin rainfall

E, the consumptive use (loss by evaporation and evapo-transpiration)

Q, the runoff, and

Δ S, the change in storage.

Considering the distribution of the gauging sites, the basin rainfall was calculated by taking the arithmetic average of the 14 stations mentioned in the previous section (see Fig. 2). Total rainfall thus calculated for the period was 1900 mm.

As to the estimation of consumptive use, it was assumed to be the same as evoporation from water surface since the basin was considered fully saturated throughout the period under study. Following formula proposed by Rohwer was used

$$E = 0.372(1 + 0.600\ Vw)\ (1-0.000374\ Pa)\ (e_w - e_a)$$

where E = the consumptive use in mm/day

Vw: wind speed in m/sec

Pa: atmospheric pressure at the temperature of water surface in mb

e_w: saturation vapour pressure

e_a: actual vapour pressure in the air over water surface in mb.

From the meteorological data during the period, average values for the above factors were roughly estimated as follows:

V_w = 2 m/sec

Pa = 1000 mb

e_w = 31.3 (at assumed temperature 25°C)

e_a = 23.5 (at assumed relative humidity 75% and temperature 25° C)

Substituting these values in the above formula, E is estimated at about 4 mm/day as an average, which gives 288 mm for the whole period of 72 days.

The runoff was estimated from the water stage at Sulipan by means of the rating curve shown in Fig. 3. Water stage at Sulipan was read three times in the day time during the period. Therefore, the average of these three readings was taken as the representative value for the day. Daily runoff thus estimated was plotted in Fig. 4. The total runoff during the period was 1,572 mm.

Summarising the above study, following water balance is obtained:

$$\begin{aligned} & R - E - Q \\ &= 1900 - 228 - 1572 \\ &= 40 \ (= \Delta S) \end{aligned}$$

The 40 mm of increment in storage at the end of the flood seems to be rather too small. However, no incensistency between the components was observed.

5. Reconstitution of runoff from rainfall

Reconstitution of runoff from the rainfall data of selected stations is generally undertaken in preparation for the flood forecasting from rainfall. The immediate objective in this study was to find an appropriate runoff model of the Pampanga basin as a whole.

In view of the possible large storage capacity in the basin which includes large swamp areas like Candaba, the tank model method proposed by Sugawara* was adopted. The storage type or the tank model is based on the hypothesis that runoff and infiltration are the functions of the amount of water stored in the basin.

The time of concentration was estimated at 2 days from the examination of the pluviograph and hydrograph of the basin (Fig. 4) Since the tank model cannot provide the time of concentration by itself, the time lag was imposed by shifting the estimated runoff two days later.

In determining the coefficients of the model to be adopted, some of the results of the water balance study were taken into account, namely, ΔS was about 350 mm at the peaks of the flood and 40 mm at the end of the period.

As for the rainfall data, those stations which had been proposed by the Japanese team for telemeterizing, or nearest to the proposed site, were adopted. The arithmetic average of this selected 10 stations was again taken as the basin rainfall.

The tank model was finalized after a number of trial and error. The model is shown by a schematic diagram in Fig. 4. The calculated runoff is also shown in the same Figure (Fig. 4). There is a reasonable agreement between the observed and calculated Runoff.

6. Flood Forecasting 2 days in advance

Since the proposed flood forecasting system includes a telemeterized water level gauge at Sulipan, it will be possible to feed back the forecast stage or discharge from time to time with the latest water stage observed at Sulipan. This procedure was introduced in the present study and the storage of water in the tank

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* On the Analysis of Runoff structure about several Japanese river by Sugawara_Japanese Journal of Geophysics, Vol 2, No. 4, 1961.

model was so adjusted that the computed runoff could be equal to the observed one. The entire procedure for the flood forecasting is described below:

1) Adjust the storage in the tank model so as to equalize the computed runoff to the observed;
2) Calculate basin rainfall R by taking arithmetic average of selected 10 stations;
3) Put R into the tank model and obtain runoff at Sulipan (Qs) valid 2 days later;
4) Convert Qs into water stage at Sulipan (Hs) by means of the stage discharge curve in Fig. 3 (right side);
5) Obtain water stage at Candaba (Hc) corresponding to Hs on the correlation curve in Fig. 3 (left side).

The result showed a good agreement with the observed hydrographs (Fig. 5).

It may be concluded from the above study that a flood forecasting from rainfall with the time advantage of two days would be practicable with the proposed telemetering network system in the Pampanga river basin.

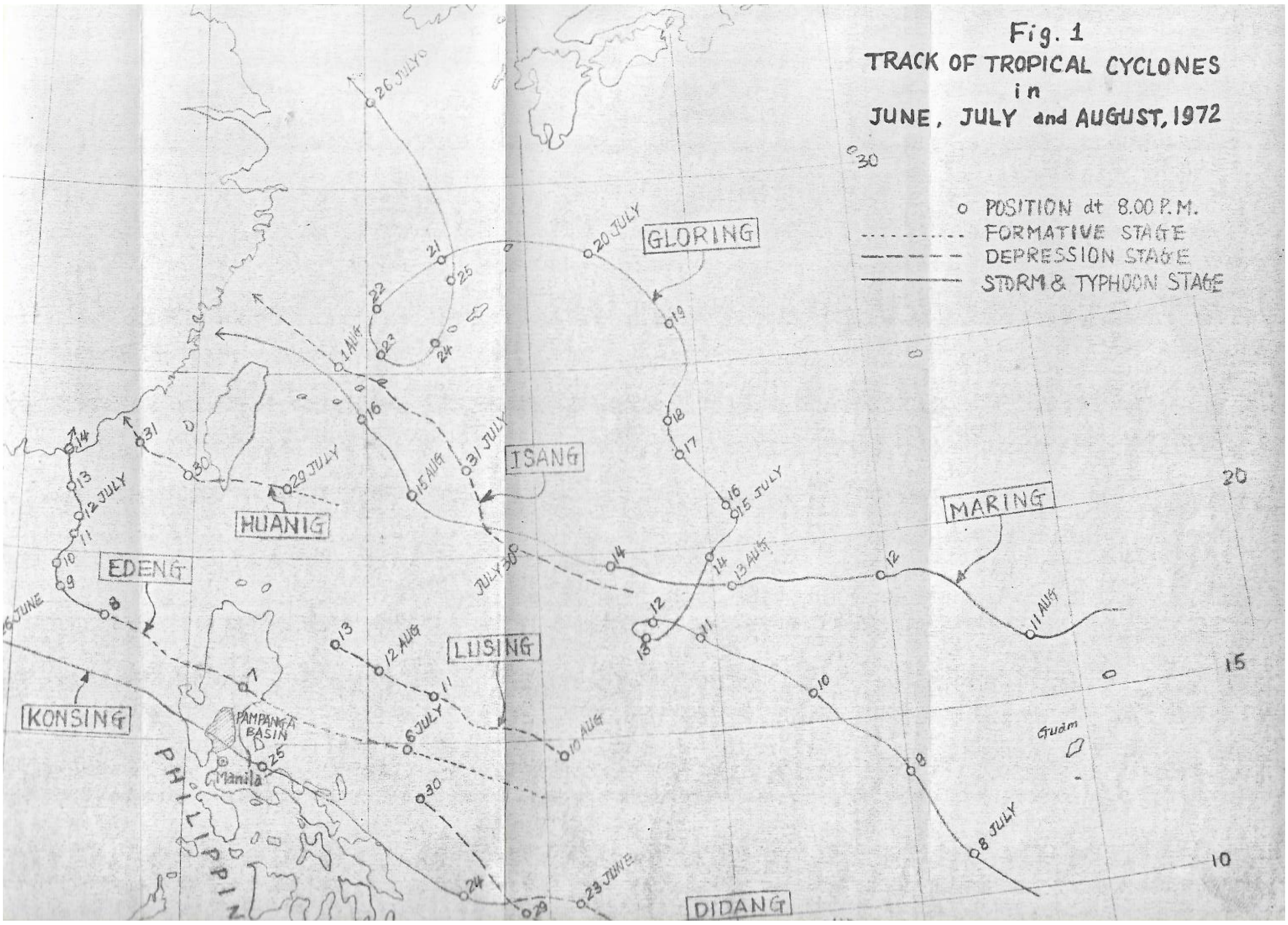


Fig. 1
TRACK OF TROPICAL CYCLONES in JUNE, JULY and AUGUST, 1972

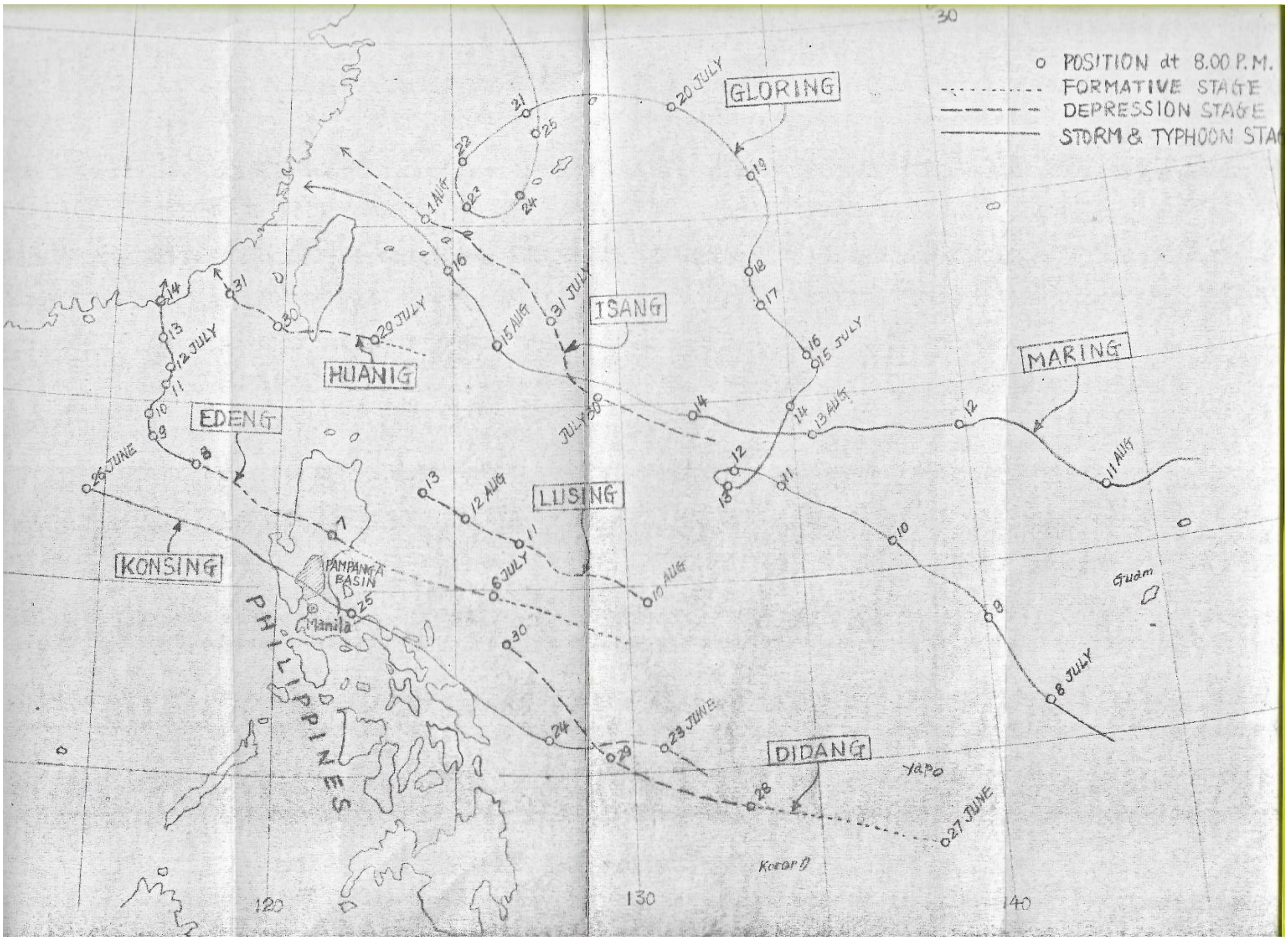


Fig. 2

EXISTING RAINGAUGES
and
PROPOSED FLOOD FORECASTING NETWORK
in
THE PAMPANGA RIVER BASIN

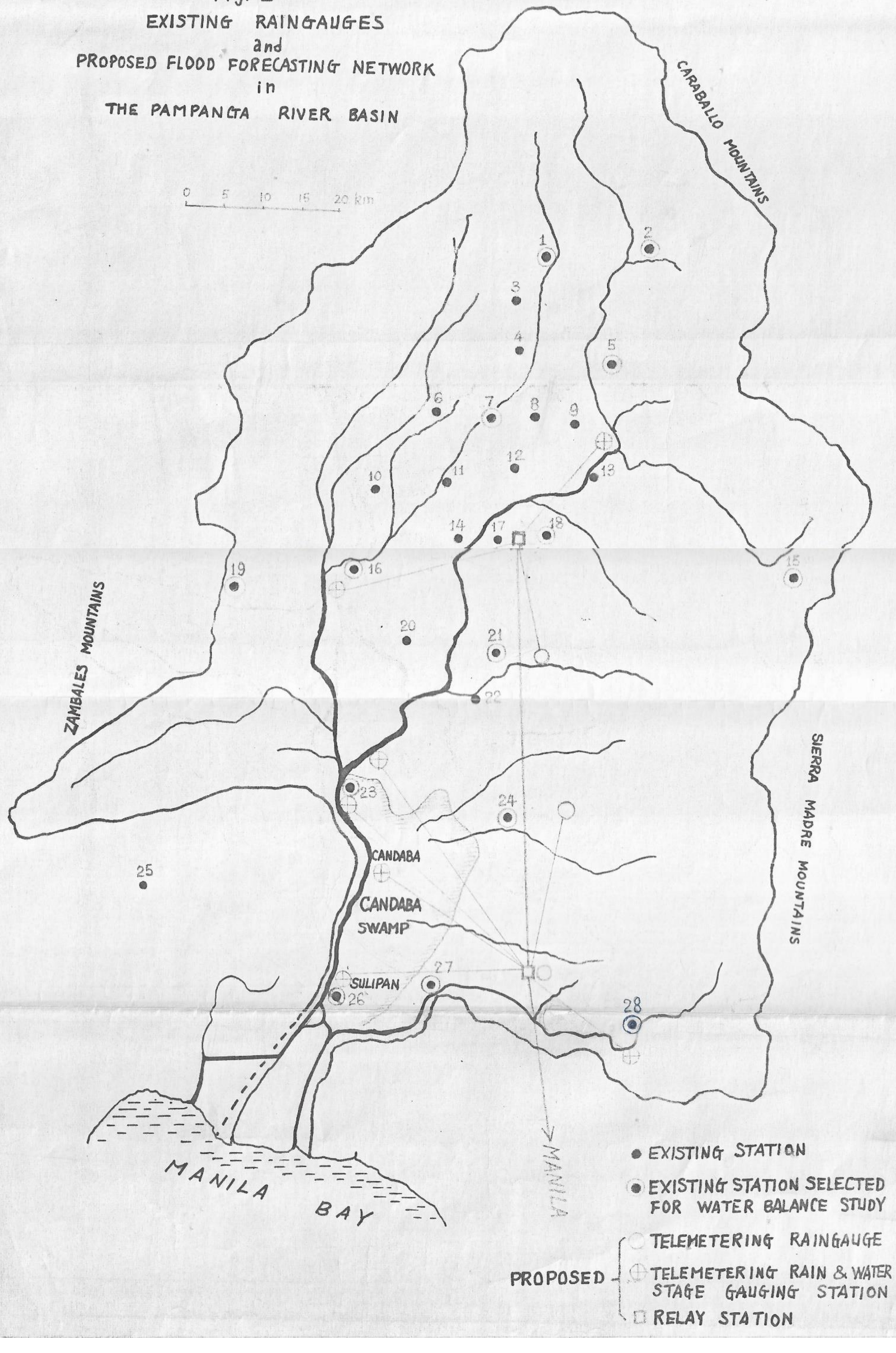
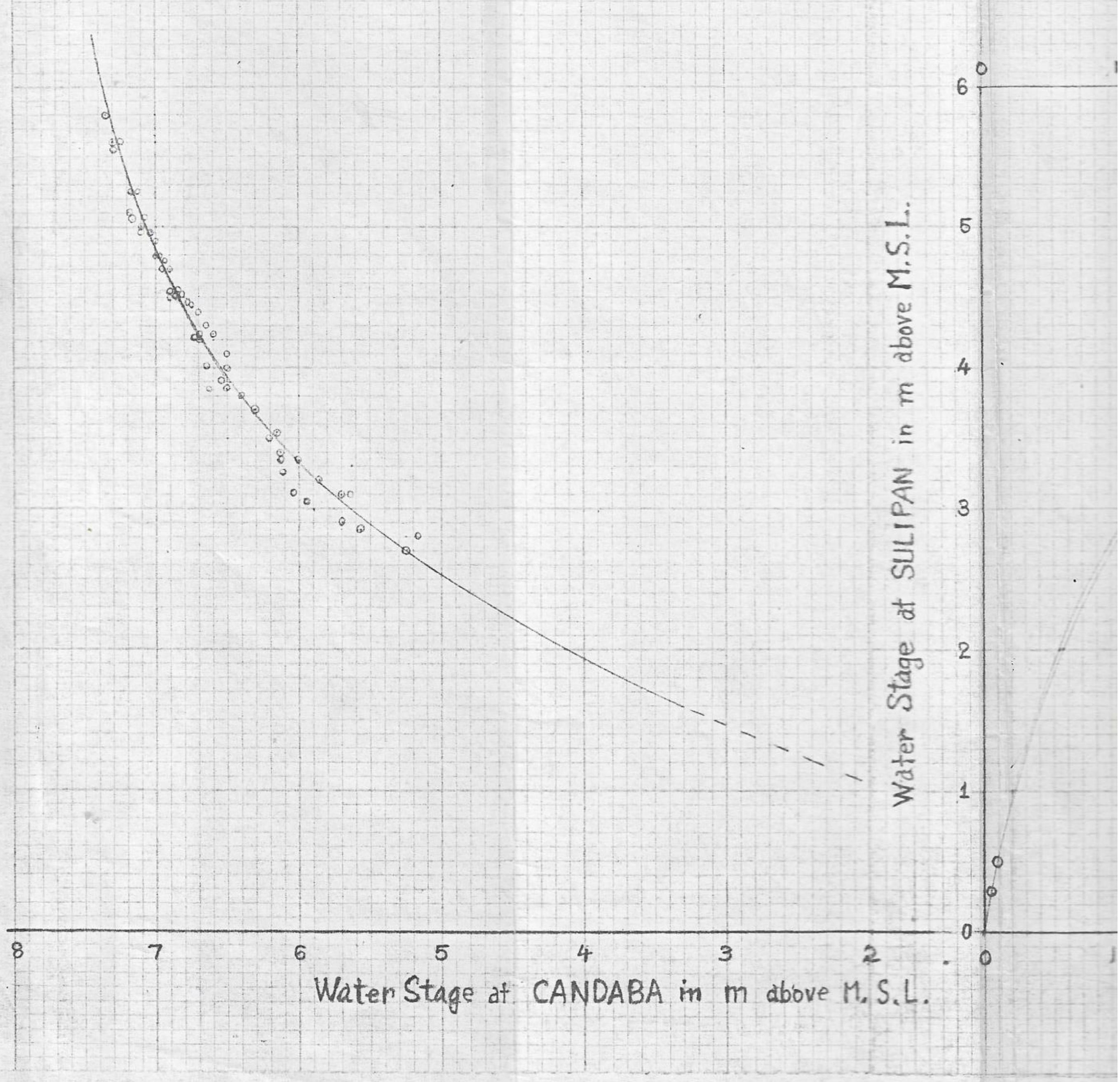
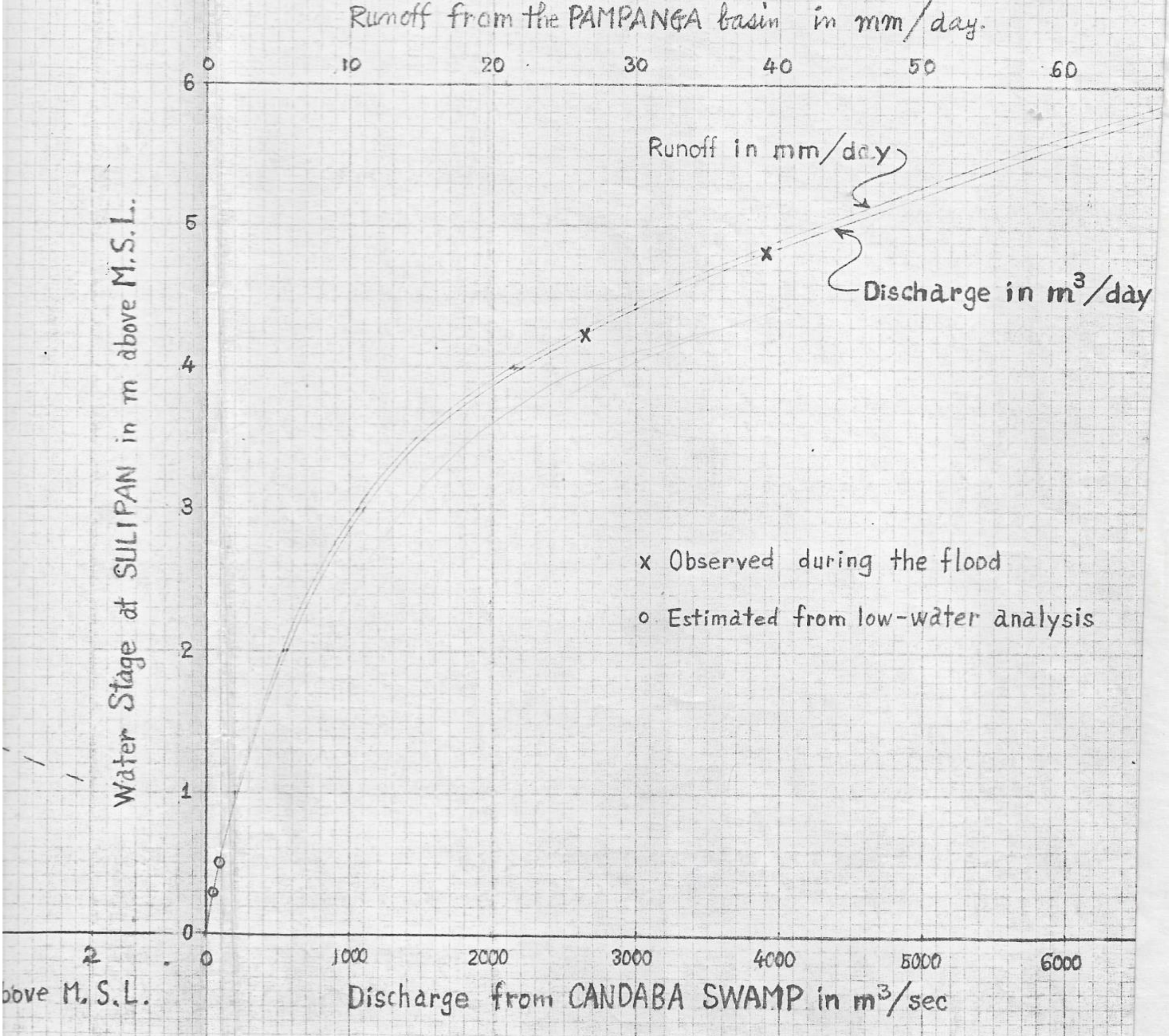


Fig. 3 CORELATION BETWEEN STAGE AND



(Fig. 3)

N STAGE AND DISCHARGE ON CANDABA SWAMP



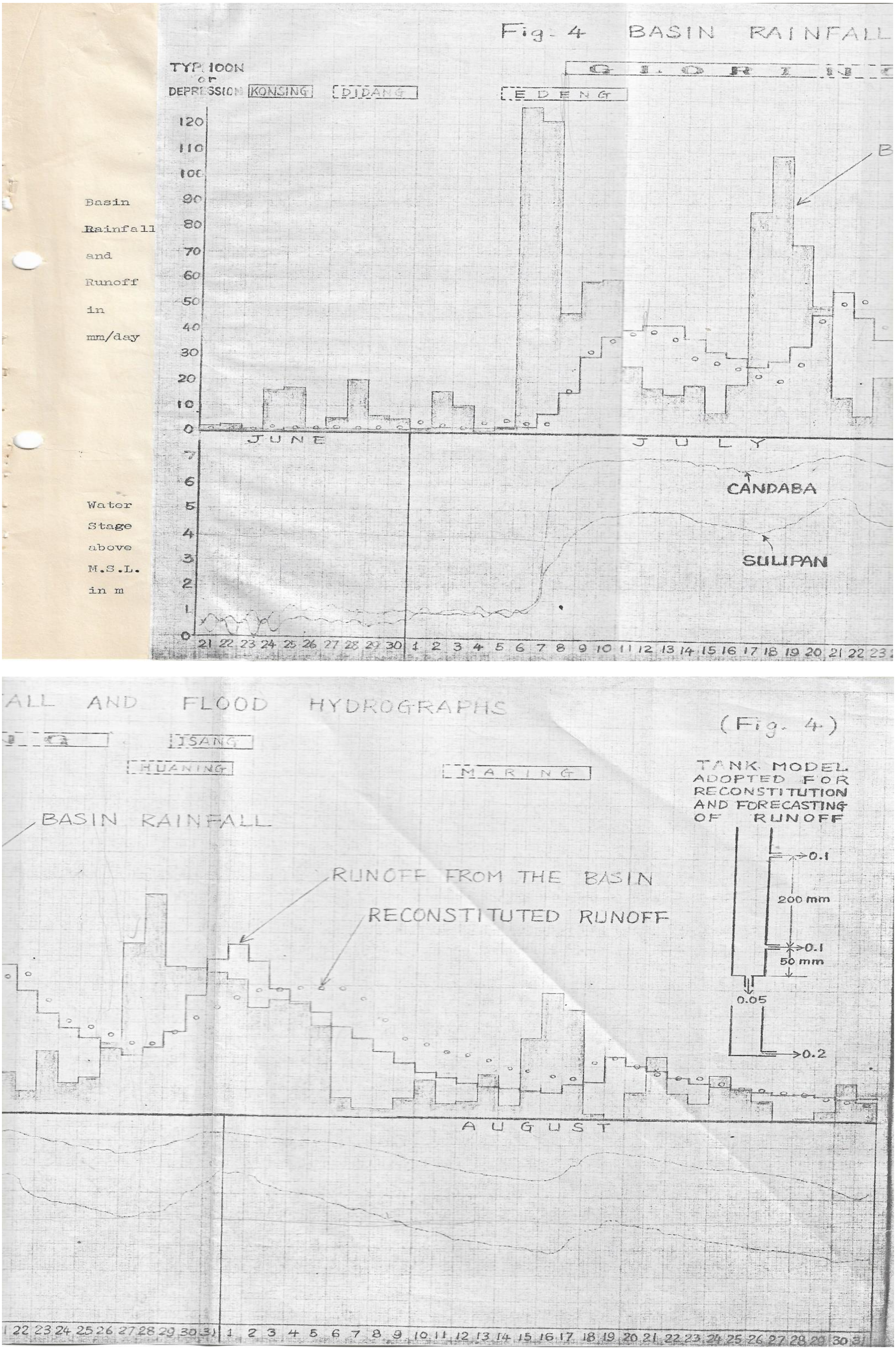


Fig. 4 BASIN RAINFALL AND FLOOD HYDROGRAPHS
(Fig. 4)
TYPHOON or DEPRESSION
KONSING
DIDANG
EDENG
GLORING
ISANG
HUANING
MARING
Basin Rainfall and Runoff in mm/day
Water Stage above M.S.L. in m
BASIN RAINFALL
RUNOFF FROM THE BASIN
RECONSTITUTED RUNOFF
TANK MODEL ADOPTED FOR RECONSTITUTION AND FORECASTING OF RUNOFF
0.1
200 mm
0.1
50 mm
0.05
0.2
JUNE
JULY
AUGUST
CANDABA
SULIPAN

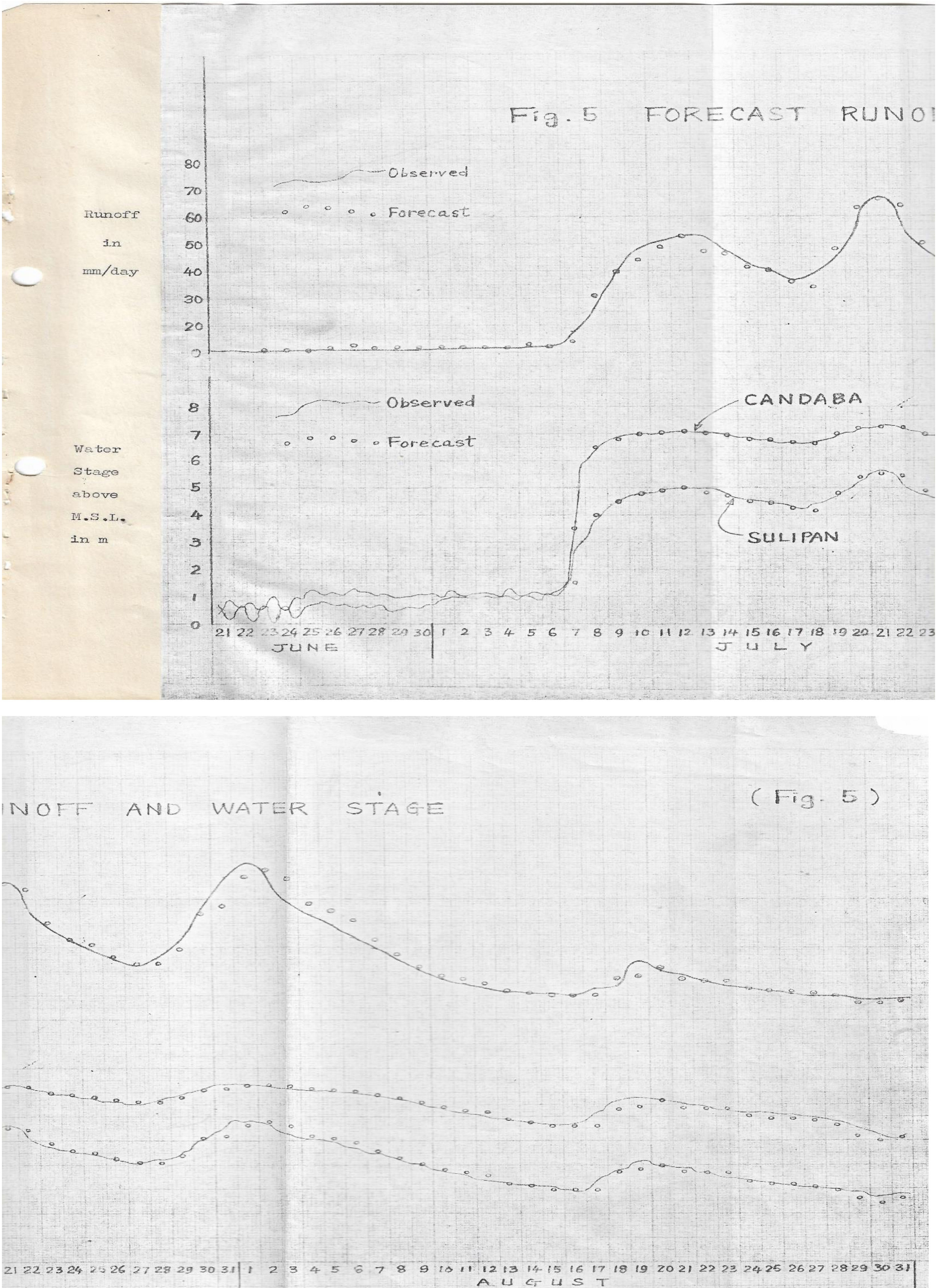


Fig. 5 FORECAST RUNOFF AND WATER STAGE
(Fig. 5)
Runoff in mm/day
80
70
60
50
40
30
20
0
Observed
Forecast
Water Stage above M.S.L. in m
8
7
6
5
4
3
2
1
0
CANDABA
SULIPAN
21 22 23 24 25 26 27 28 29 30
JUNE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
JULY
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
AUGUST