551.577.37 (54).

Time-Depth-Area Curves of Maximum Precipitation for the Damodar Area

V. SATAKOPAN.

(*Received 25th November, 1949.*)

ABSTRACT. The paper describes the method of deriving the time-depth-area curves of rainfall for designing flood control reservoirs and gives such curves of maximum likely precipitation for the Damodar area from the recorded rainfall for the storm 16th to 18th June 1898.

A knowledge of the maximum rainfall that has occurred or is likely to occur over the catchment area of a river is essential for designing flood control reservoirs ; it enables the designer to estimate the largest quantity of water that will be caught in the basin from which he can derive the amount of water that will run off depending upon the watershed characteristics. The maximum rate at which the run off water will arrive at the point of outlet from the basin and the duration for which this rate will be maintained are the characteristics of "peak discharges" which are the most essential factors in the design of Flood Control reservoirs for the regulation of flood waters. The details of the methods of computation of these values will be found in any text book on Hydrology.[1]

2. For small catchments it is enough to know what is the maximum rainfall that is likely to occur over the catchment area as a whole because the phenomenon of flood water accumulation at the point of outlet is fairly simple and the peak discharge characteristics are easily determined. In the case of fairly big catchments, however, this phenomenon is complicated by two factors of variation, namely, (*i*) Rainfall amounts and intensity at different points of the catchment will not be the same and (*ii*) the run off water from different points of the catchment will arrive at the point of outlet at different times. It becomes, therefore, necessary, in studying the maximum flood characteristics of a large catchment area, to have a knowledge of the maximum rainfall that can occur in smaller areas in the catchment and to consider that sequence of timing of heavy precipitation in different areas consistent with the meteorological causes of the heavy precipitation, which will cause the largest accumulation of water at the point of outlet. It is well known also from experience that during storms there is generally an area of a central core of very heavy rainfall and that rainfall decreases all around this core as one proceeds from this area in all directions though the rate of decrease may be different in different directions. Therefore, it is clear that the maximum likely depth of rainfall over a small part of a catchment will be greater than the maximum depth of rainfall for the catchment as a whole. The storm map method is used in this article to construct a graph from which can be read off the likely depth of maximum precipitation over areas of different sizes in different durations of time in hours for the Damodar Catchment and its neighbourhood from the rainfall data of the storm of heaviest intensity that has occurred in the area.

3. A detailed analysis of the rainfall of Damodar Catchment based on all available data has already been made and the results are published elsewhere[2]. In table v on p. 335 of the publication the characteristics of 23 storms that have given fairly heavy precipitation in Damodar Catchment and its neighbourhood are given. It will be seen from the table that the storm of the period 16—19th June, 1898 has resulted in the heaviest intensity of rainfall in a day over an area equivalent to that of the Damo-

dar Catchment. It has given nearly 8·0 inches of rain over 7,200 square miles in a day.

4. That the storm had some unusual characteristics that contributed to its very heavy rate of precipitation will be evident from the following accounts :—

> " This storm formed in front of the advancing humid current in the northwest of the Bay on the 12th and 13th. It moved slowly northwards the centre passing over or near to Puri and False Point on 15th. It thence marched very slowly through southwest and central Bengal on the 16th, 17th and 18th, passed into north Bengal on the 19th and 20th and broke up at the foot of the Sikkim Hills.
>
> The storm, it may be noted, marched very slowly along a somewhat unusual track and was unchanged in character during advance through Bengal quite up to the foot of the hills, being most unique in this respect. Another noteworthy feature of the storm (related to its slow motion of about 3 miles per hour) was the heavy rainfall which accompanied its progress through Bengal. This storm gave very heavy rain to Chota Nagpur and Bengal, falls of 10 to 17 inches in 24 hours occurring at several stations ".3

5. The daily rainfall amounts for the dates 17th, 18th and 19th for this storm have been plotted on a map of Damodar Catchment and its neighbourhood and isohyets have been drawn. These are shown in Figs. 1, 2 and 3 below. Also the rainfall of two day periods i. e. 17th + 18th and 18th + 19th have been plotted and shown in Figs. 4 and 5. Fig. 6 shows finally the rainfall map for the whole period of three days with the isohyets drawn. The following table gives the main rainfall features of the three days :—

Duration of rain.	Rainfall in the Central core of the area.	Value of outermost isohyet drawn.	Area within the outermost isohyet	Mean precipitation over the area (inches).
24 hrs. ending at 8 a.m. on 17th.	Above 6"	1"	38048	2·65
24 hrs. ending at 8 a.m. on 18th.	17"	1"	46888	3·73
24 hrs. ending at 8 a.m. on 19th.	10"	1"	34768*	2·90
48 hrs. ending at 8 a.m. on 18th (17th+18th).	18"	2"	42472	6·64
48 hrs. ending at 8 a.m. on 19th (18th+19th).	Above 16"	2"	42872*	5·77
72 hrs ending at 8 a.m. on 19th (17th+18th+19th).	26"	2"	52788*	7·76

For a period of 24 hours ending 8 a. m. on 17th June the storm gave rainfall over 1" over an area of 38048 square miles, the area of heaviest rainfall being just to the south of the Damodar Catchment; the mean rainfall over an area of 38048 square miles worked out to be 2.65 inches. On 18th the area of rainfall over 1 inch was 46888 square miles giving a mean precipitation of 3.73 inches. On 19th the area of heavy precipitation shifted to the northeast and the map used did not cover all the area of precipitation over 1 inch. But this fact does not affect our study in this article because it will be seen that on the map of isohyets for three days, the area of heavy precipitation is well within the boundaries of our map. The storm has given a mean

* A small portion of the area of rainfall lies outside the map in these cases, but this fact is not likely to affect the conclusions deduced in this article.

rainfall of 6.64 inches over an area of 42472 square miles in 48 hours and of 7.76 inches over an area of 52788 square miles in 72 hours.

6. From these isohyetal maps, values of mean precipitation for areas within closed isohyets of different values have been calculated and plotted on a graph with mean precipitation as ordinate and the area covered by the isohyets as abcissa. The points corresponding to each period of duration i.e. of 24 hours, 48 hours and 72 hours have been joined by a smooth curve. These curves are shown in Fig. 2. The curves illustrate how the mean precipitation decreases with increase in area. It will be seen that among the three curves corresponding to the rainfall in a day i. e. 24 hours, the one for the 18th corresponds to the heaviest rainfall. For 48 hours, the curve for 17th + 18th represents heavier precipitation than on 18th and 19th. The heaviest rainfall conditions during the storm for durations of 24 hours, 48 hours and 72 hours are, therefore, represented by the curves of 18th, 17th + 18th and 17th + 18th + 19th respectively.

7. The values of mean precipitation corresponding to different areas ranging from 1000 square miles to 40,000 square miles have been read off from the three curves mentioned at the end of the previous paragraph and these values are given in the table below :—

Area in square miles.	Mean precipitation in inches during :		
	24 hours.	48 hours.	72 hours.
(1)	(2)	(3)	(4)
1,000	15·0	20·8	24·3
2,000	13·4	18·9	22·4
3,000	12·3	17·5	21·0
4,000	11·3	16·5	19·8
6,000	9·8	14·8	18·2
8,000	8·7	13·6	16·9
10,000	7·8	12·8	15·9
12,000	7·3	12·0	15·1
15,000	6·6	11·2	14·1
20,000	5·9	10·0	12·7
25,000	5·4	9·0	11·7
30,000	5·0	8·3	10·7
35,000	4·6	7·6	9·9
40,000	4·2	7·0	9·2

With the values from this table a set of graphs have been drawn in Fig. 8 with duration of rainfall as the ordinate and mean precipitation as abcissa, the different curves representing different sizes of area. The curves are simple free hand smooth curves passing through the three points in each case. From this figure it will be easy to read off the maximum depth of precipitation that is likely to occur over area of any size from 1,000 square miles to 40,000 square miles for any duration between 24 and 72 hours. For example the maximum depth of rainfall that is likely to occur over an area of 2,500 square miles during a period of 36 hours is 15·9 inches and for an area of 14,000 square miles and a period of 64 hours the depth of rainfall is 13·6 inches and so on. This graph can be used generally in determining the characteristics of heavy rainfall in the neighbourhood of Damodar Catchment *i.e.* for other catchments round about also. Analysis of a few storms that have given intense precipitation by the above method for any area will result in a Time—depth—area curves as in Fig. 8 which will be useful for flood control projects.

8. It will however be seen that the range of values for which the graphs are available in Fig. 8 is limited. One would desire to have a few graphs for areas of size smaller than 1,000 square miles such as 500, 200 and 100 square miles. Also, it will be useful if the curves can be extended for durations shorter than 24 hours. Limitations imposed by available data deny us the knowledge of the likely values for these ranges. The distribution of raingauges being sparse say one in 25 to 30 miles, it is not possible to draw isohyets in the central core of heavy precipitation covering smaller areas than 1,000 square miles. If we had a raingauge station for every 10 miles that would have enabled us to go down to areas of 100 square miles in constructing the graphs in Fig. 8. As for extending the graphs for shorter duration, it would have been possible if rainfall were recorded for periods less than 24 hours at all raingauge stations. Rainfall is recorded only once a day at present at raingauge stations. Even if rainfall data of a certain percentage of raingauge stations are available for shorter durations say for 6 hours, 12 hours etc. it would be possible to extend the curves for shorter durations. There is no doubt that the rainfall organisation in India has to be improved on the above lines if we have to depend upon them for giving complete information for the development and operation of multipurpose waterways projects in India.

REFERENCES:

1. Pickels, G. W., *Drainage and Flood Control Engineering*, McGraw—Hill Book Company (1941),
2. Satakopan, V., *Ind. Met. Dept. Memoirs Vol. XXVII Part VI* (1949).
3. Ind. Met. Dept., *Monthly Weather Review and Annual Summary* (1898).

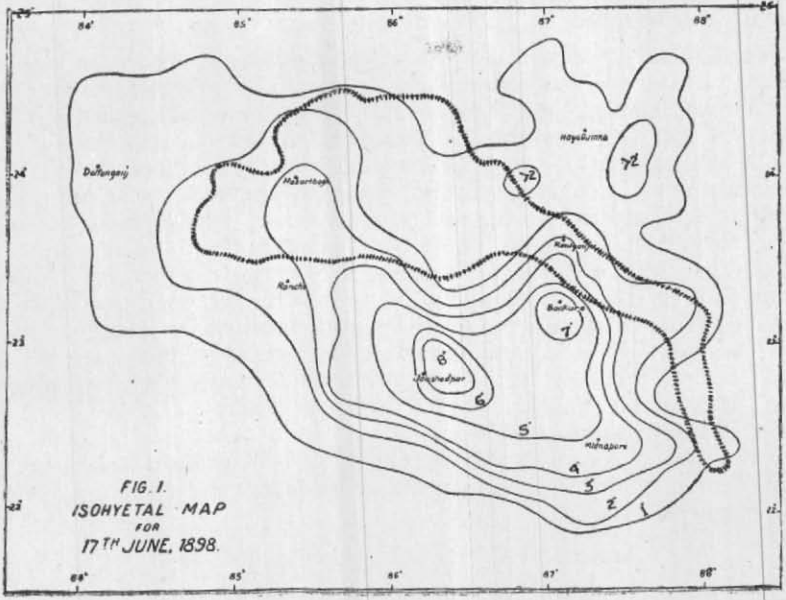

FIG. 1.
ISOHYETAL MAP
FOR
17TH JUNE, 1898.

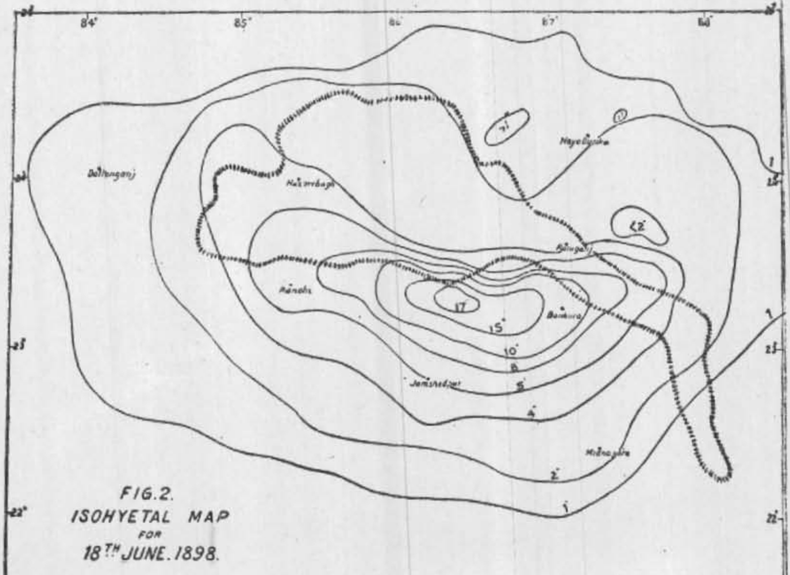

FIG. 2.
ISOHYETAL MAP
FOR
18TH JUNE. 1898.

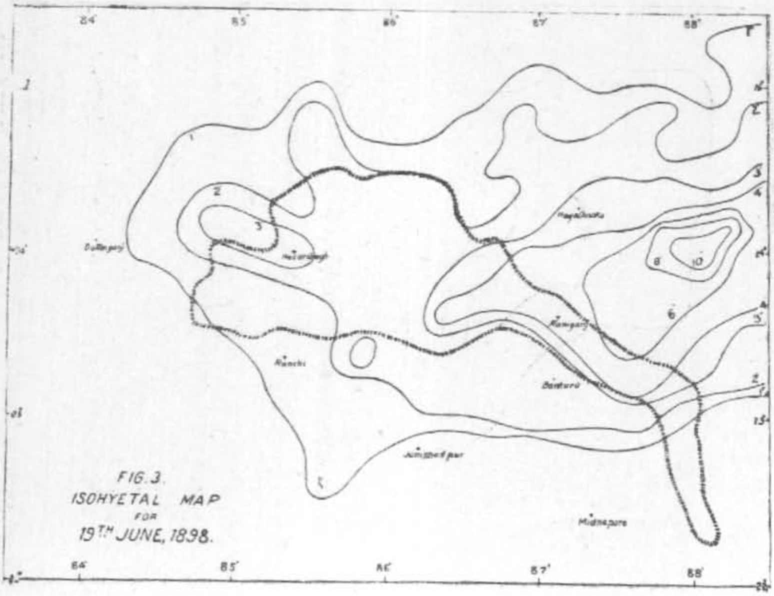

FIG. 3.
ISOHYETAL MAP
FOR
19TH JUNE, 1898.

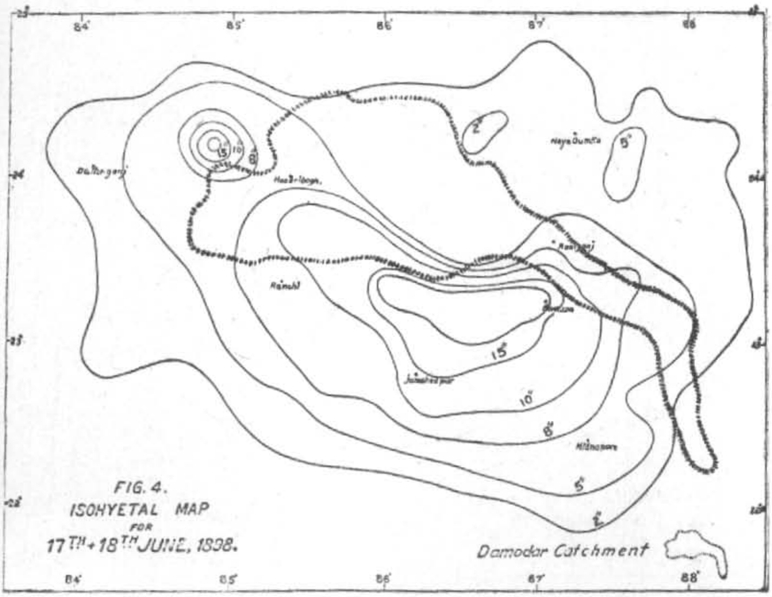

FIG. 4.
ISOHYETAL MAP
FOR
17TH + 18TH JUNE, 1898.

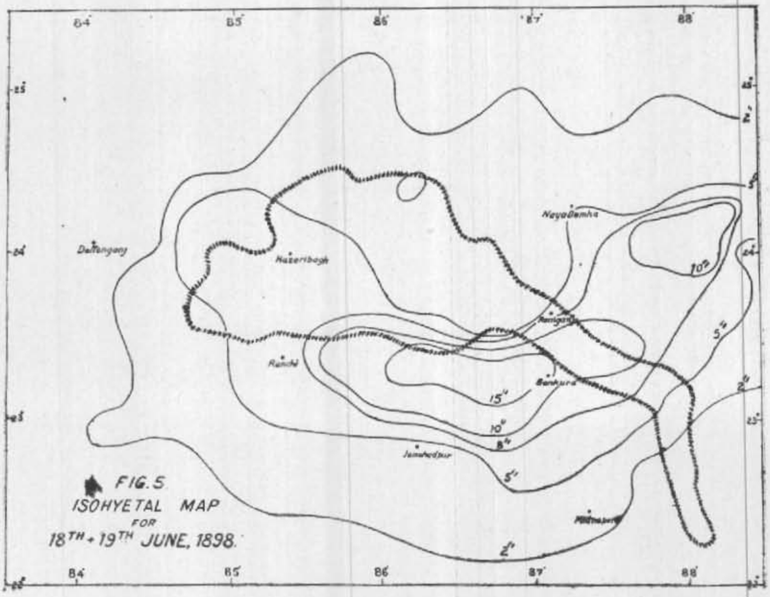

FIG. 5
ISOHYETAL MAP
FOR
18TH + 19TH JUNE, 1898.

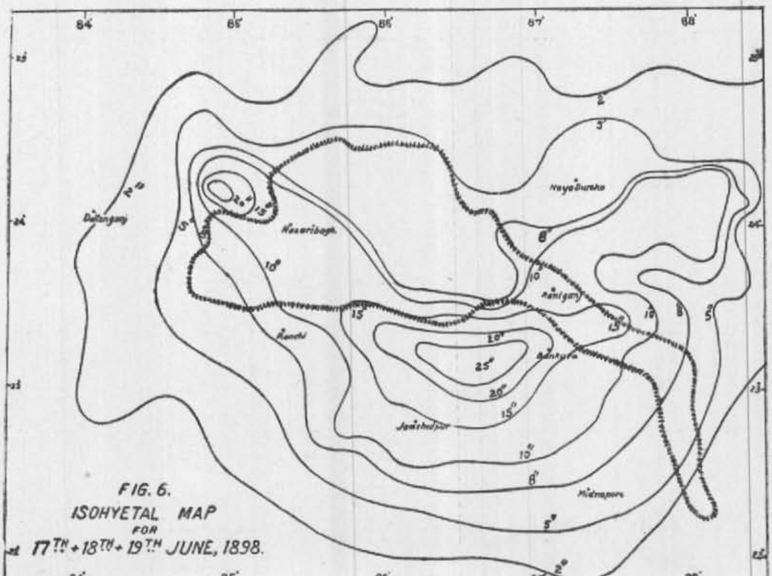

FIG. 6.
ISOHYETAL MAP
FOR
17TH + 18TH + 19TH JUNE, 1898.

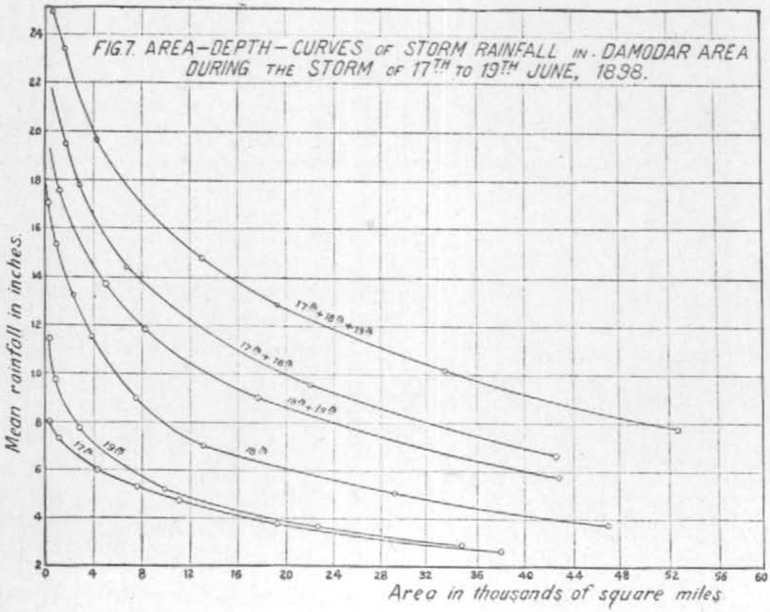

FIG. 7. AREA–DEPTH–CURVES OF STORM RAINFALL IN DAMODAR AREA DURING THE STORM OF 17TH TO 19TH JUNE, 1838.

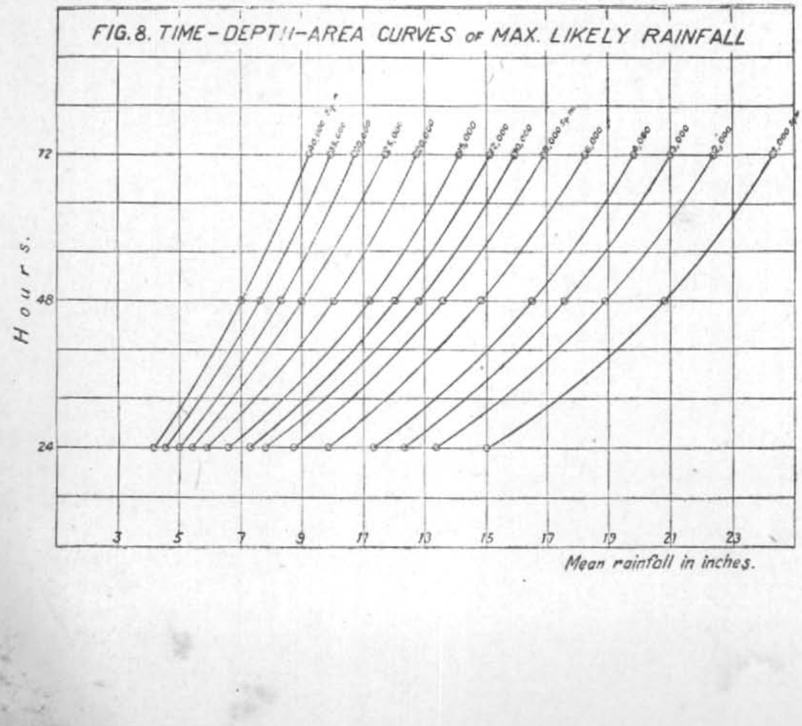

FIG. 8. TIME–DEPTH–AREA CURVES OF MAX. LIKELY RAINFALL