551.482.11 : 551.508.77 : 551.506.9

On the derivation of unit hydrograph for estimating flood discharge at Ramgarh in Damodar Valley

S. K. GHOSE

Regional Meteorological Centre, Calcutta

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ABSTRACT. Rainfall data in the Damodar Valley area above Ramgarh and the rivergauge and discharge data at Ramgarh pertaining to a few rainstorms affecting the area have been studied by hydrograph analysis. The processed data have been utilised for deriving the unit graph for the area, which may be used as a tool for forecasting the flood hydrograph at Ramgarh.

1. Introduction

For the operation of the reservoirs, the D.V.C. engineers are interested to know the volume of inflow expected at the Panchet and Maithon reservoirs, as a result of precipitation upstream. This has engaged the attention of the engineers and hydrometeorologists for some time. The inflow into a reservoir has to be calculated by the computation of the flood hydrographs of the sub-basins in the upstream area and then successively routing the same into the reservoir. An attempt has been made in this paper to derive the unit hydrograph at Ramgarh, which may be used for forecasting the flood hydrograph at that point.

Fig. 1 shows a sketch of the Damodar Valley area. The area commanded by the different dams have been shown by shading. The sub-basin above Ramgarh has been indicated by a thick line on the map. The sub-basin has a number of raingauges belonging either to D.V.C. or Bihar State. A discharge measuring station belonging to the River Reserarch Institute (West Bengal) is also functioning at Ramgarh since 1945. The location of the raingauges and rivergauge and discharge station is also shown in the figure.

2. Data analysed

From the records of past floods in the Damodar Valley area, seven major storms affecting the Ramgarh sub-basin were selected (Table 1). Rainfall data during the storm periods were tabulated and the average rainfall of each day during the storm period was calculated. Daily discharge data at Ramgarh pertaining to the same period were also collected from the publications issued by the Damodar Valley Corporation (*see* Ref.).

3. Analysis of hydrograph and estimation of run-off

Daily discharge values (in 1000 cusecs) as observed at Ramgarh during the seven selected storm periods were plotted against the dates and the total storm hydrograph for each occasion was obtained (Figs. 2a to 2g). Hourly discharge values during flood occasions were also used to get the correct shape of the hydrograph. The base flow in each case was shown by a line and the same was separated from the total storm to obtain the surface run-off hydrograph. The area of the sub-basin upto Ramgarh was measured by a planimeter and was found to be 1505 sq. miles approximately. We know that volume discharged in one day at 1 c.f.s. is 1 S.F.D. Hence 1″ of run-off from an area of 1 sq. mile produces a discharge volume of $[(1760\times3)^2/12]/60\times60\times24=26\cdot89$ Second Foot Day (S.F.D.). The volume of discharge due to 1″ of run-off over 1505 sq. miles will be 40,500 S.F.D. or (81,000 S.F.D.)/ 2, *i.e.*, the volume becomes double in Second Foot $\frac{1}{2}$Day unit. Adding up the twelve-hourly (or $\frac{1}{2}$ Day) ordinates from the hydrograph, the discharge in SFD/2 was obtained. This discharge value was divided by 81,000 to give the depth of run-off in inches. Thus the surface run-off in inches in respect of all these seven storms was calculated and the values of rainfall and run-off are tabulated in Table 2.

4. Distribution of run-off

Daily rainfall values for each day of the storm period was distributed in twelve-hourly intervals as per records of the self-recording raingauges in and near the area. These successive twelve-hourly values of rainfall were added and the accumulated rainfall with twelve-hourly increments were entered as Σ rainfall in Table 3. Knowing the value of run-off, the distribution of the twelve-hourly accumulated rainfall, and the shape of the hydrograph, its concentration and recession, the surface run-off was distributed as Σ run-off to fit in with the Σ rainfall (Table 3). For giving this distribution, the rainfall run-off relation in respect of similar storms affecting the warm southeastern parts of U.S.A. was also consulted.

From the values of Σ run-off, the amount corresponding to each successive twelve-hour period (*i.e.*, $\triangle$ run-off) was obtained. The values in some cases was adjusted to fit in with the shape of the hydrograph and entered as "Adjusted $\triangle$ run-off" (Table 3).

5. Composite storm run-off

The twelve-hourly run-off values pertaining to each storm was tabulated, keeping the maximum run-off under the same column (Table 4). The vertical columns on addition give the twelve-hourly run-off of the composite storm in inches (10·10″). The corresponding discharge in (10^3 SFD/2) works out as 818·1. On the other hand, the run-off during each storm was also added at the end of each line to get the storm run-off (inches), and the same was converted to discharge (in 10^3 SFD/2). The total discharge resulting from the seven individual storms also comes to 818.1.

6. Composite storm discharge

From the Figs. 2(a) to 2(g) the twelve-hourly values of discharge pertaining to each storm were picked up and tabulated. The discharge of the composite storm was also calculated and adjusted slightly so that the same becomes also equal to $818 \cdot 1 \times 10^3$ SFD/2 (Table 5).

7. Derivation of unit hydrograph

The twelve-hourly discharge values as obtained from the composite storm run-off (Table 4) and these obtained from composite storm discharges (Table 5) were used to drive the unit graph by Collins method (Collins 1939). The method envisages certain initial distribution or coefficients and involves processing of the discharge data so as to get the different sets of coefficients by trials until the coefficients of the residual unit graph and those of the assumed one are approximately the same. The adjusted coefficients were multiplied by the area of the basin and the twelve-hourly ordinates of the unit hydrogpraph were obtained (Table 6).

8. Derivation of the table for computation of flood hydrograph

The unit hydrograph was drawn on a graph paper (Fig. 3). Fom the above graph, the six-hourly ordinates of the unit hydrograph were picked up and tabulated in order to help the hydrologist to derive the shape of the flood hydrograph more precisely. The six-hourly ordinates of the unit hydrograph were multiplied by different factors to get the corresponding discharges with respect to run-off extending from 0·05 to 2·00 inches. Table 7 which gives these values will facilitate the drawing of the flood hydrograph.

9. Verification of the unit hydrograph

The values appearing in Table 7, which will be used to drive the flood hydrograph at Ramgarh, then tested with references to the seven rainstorms mentioned under Table 1. The twelve-hourly values of run-off (Δ run-off) were referred to Table 7 and the ordinates of hydrographs corresponding to successive values of Δ run-off were tabulated, at the interval of every six-hour (Tables 8a to 8g). The vertical columns were added to get the distribution of discharge due to surface run-off. The base flow was added to the above values to get the total storm hydrograph. The resulting discharge values were plotted in Figs. 2(a) to 2(g) and the forecast flood hydrograph at Ramgarh was drawn in dotted line. It may be seen that though there are minor variations between the two hydrographs, the forecast hydrograph in general corresponds well with the actual one.

It is well known that in any hydrological forecasting problem, there can be no final answer or solution. Starting with an initial simplified model attempts are to be made for perfection by successive trials and adjustments. Knowing the distribution of run-off, the unit hydrograph derived above may be used for forecasting the flood hydrograph at Ramgarh.

10. Conclusion

The above work was completed by the author as one of his assignments while on training at the U.S. Weather Bureau under the United Nations Expanded Programme of Technical Assistance. The author is thankful to Mr. Max. Kohler, Chief Research Hydrologist, U.S. Weather Bureau and Mr. Tor Nordenson, Chief, Hydrologic Research aud Investigation Laboratory, U.S. Weather Bureau for kindly going through the results and offering many valuable suggestions.

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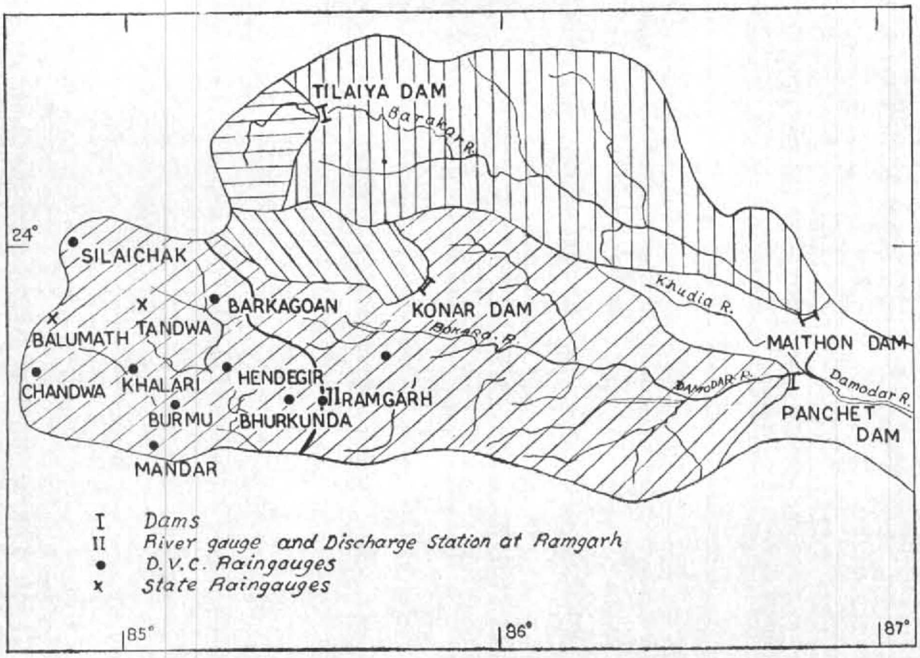


Fig. 1. Area commanded by different dams in Damodar Valley

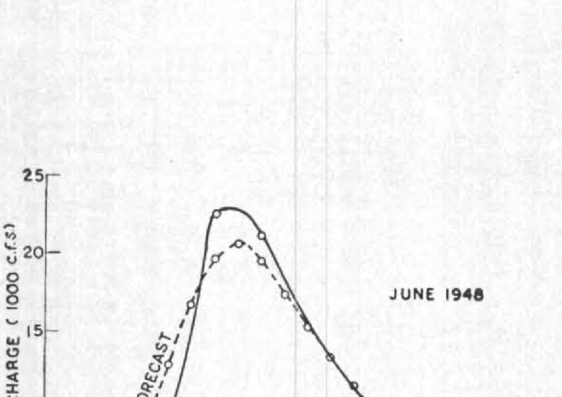


Fig. 2 (a)

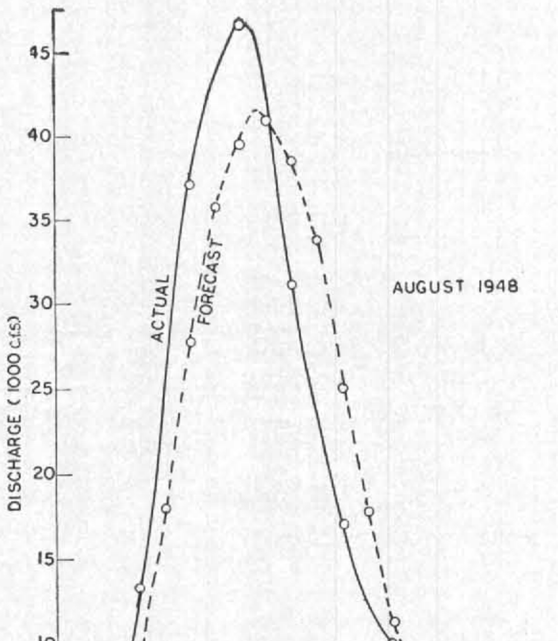


Fig. 2(b)

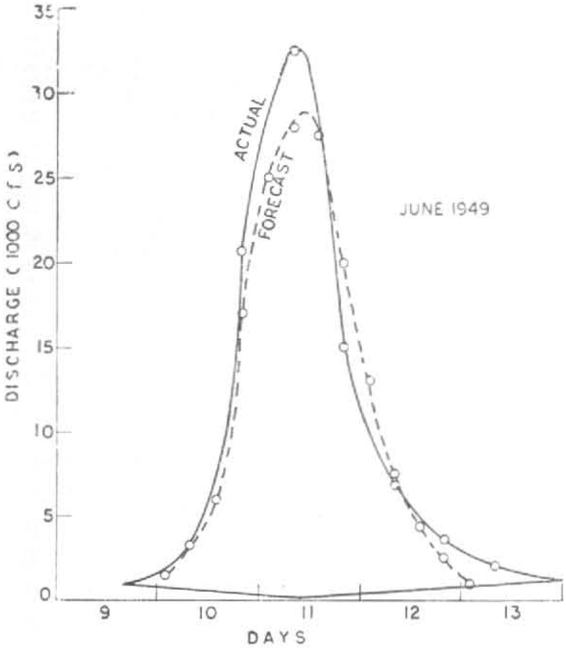


Fig. 2(c)

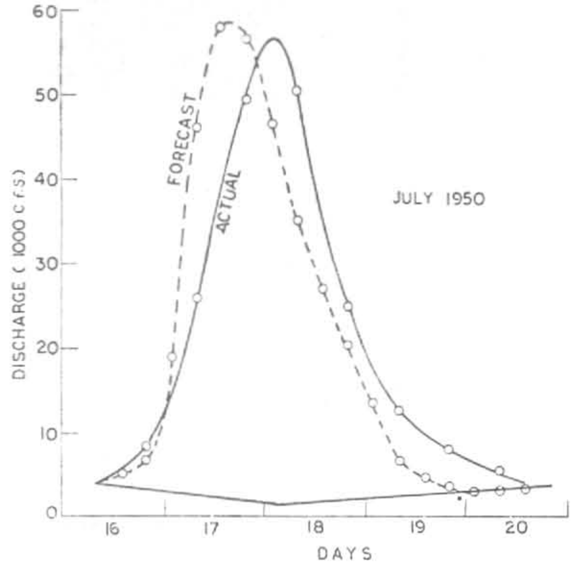


Fig. 2(d)

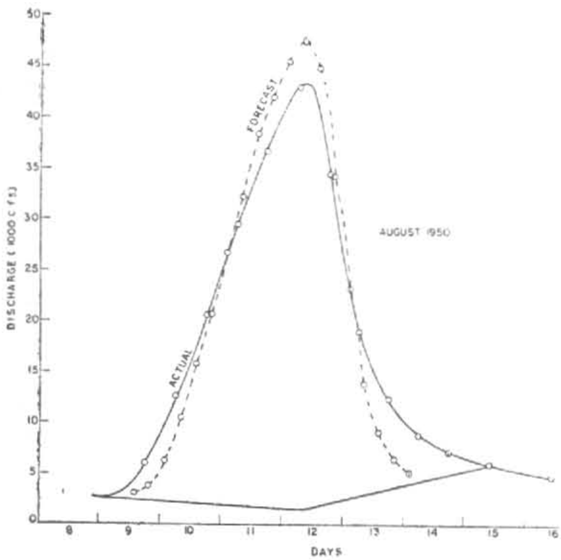
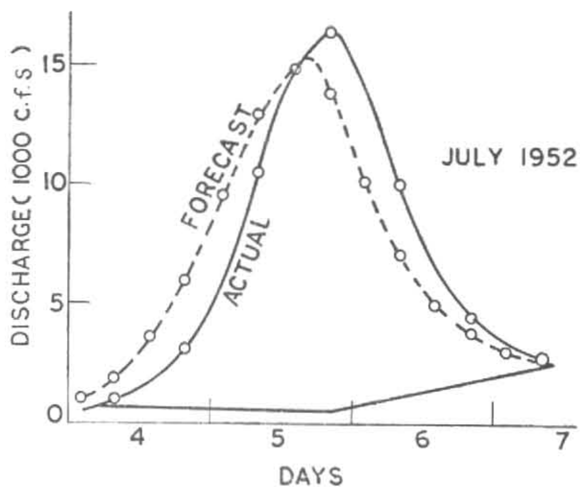


Fig. 2(e)



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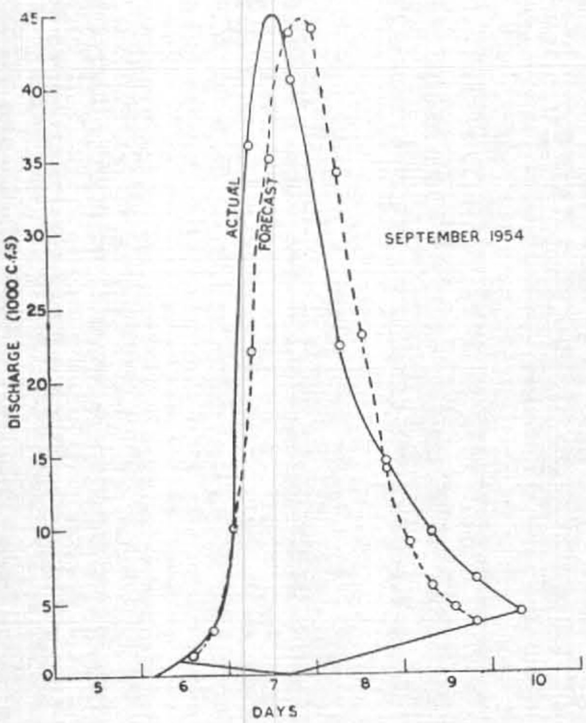

Fig. 2(g)

Dotted line represents forecast flood hydrograph at Ramgarh for the storm of September 1954

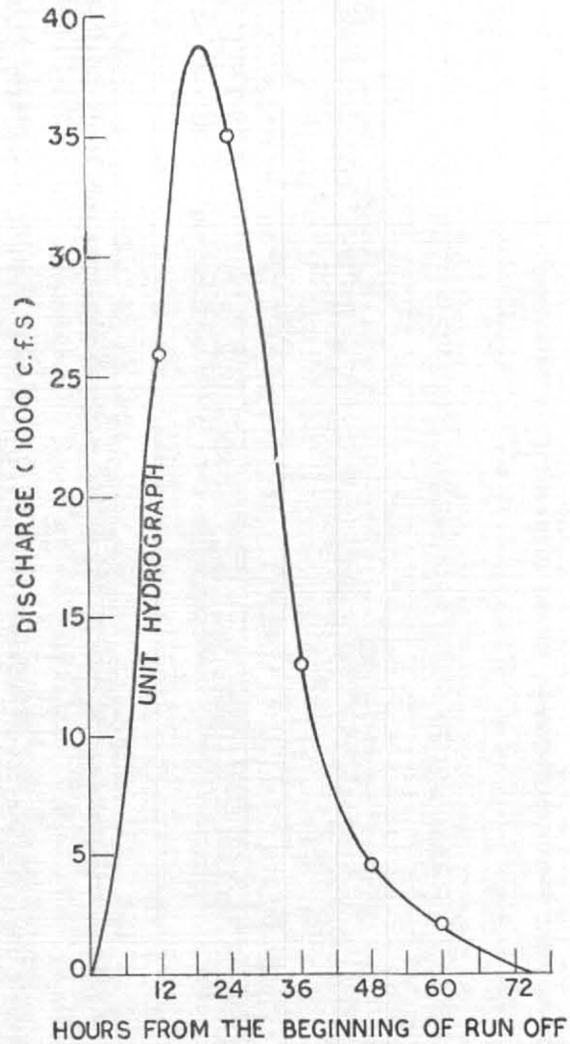

Fig. 3. The unit hydrograph

TABLE 1
Rain storms

I	25—28	June 1948
II	3—5	August 1948
III	10—12	June 1949
IV	16—18	July 1950
V	10—13	August 1950
VI	3—6	July 1952
VII	6—8	September 1954

TABLE 2
Rainfall/run-off values (in inches)

Storm	Rainfall	Run-off
I	4·85	1·07
II	4·05	1·78
III	3·68	0·94
IV	7·40	1·97
V	5·75	2·44
VI	2·50	0·49
VII	6·20	1·46

TABLE 3
Distribution of twelve hourly rainfall and run-off (inches)

				Storm I				
	Σ rainfall	·45	1·25	2·05	2·60	3·10	3·90	4·85
	Σ run-off	0	0	·15	·20	·30	·60	1·10
	Δ run-off	0	0	·15	·05	·10	·30	·50
Adjusted	Δ run-off	0	·15	·25	·30	·15	·15	·10
				Storm II				
	Σ rainfall	·35	1·30	2·30	3·20	4·05		
	Σ run-off	0	·20	·60	1·10	1·75		
	Δ run-off	0	·20	·40	·50	·65		
Adjusted	Δ run-off	0	·30	·60	·50	·35		
				Storm III				
	Σ rainfall	·70	1·45	2·40	3·48	3·68		
	Σ run-off	0	·10	·40	·80	·90		
	Δ run-off	0	·10	·30	·40	·10		
Adjusted	Δ run-off	0	·10	·50	·35	0		
				Storm IV				
	Σ rainfall	·70	1·45	2·50	3·60	6·50	7·40	
	Σ run-off	0	0	0	·15	1·20	1·95	
	Δ run-of	0	0	0	·15	1·05	·75	
Adjusted	Δ run-off	0	0	·15	1·30	·25	·25	
				Storm V				
	Σ rainfall	·70	1·35	2·10	2·85	3·85	4·90	5·75
	Σ run-off	0	·05	·25	·50	·95	1·70	2·40
	Δ run-off	0	·05	·20	·25	·45	·75	·70
Adjusted	Δ run-off	·05	·20	·25	·45	·75	·70	0
				Storm VI				
	Σ rainfall	·20	·65	1·10	1·70	2·35	2·45	2·50
	Σ run-off	0	0	·05	·20	·45	·45	·50
	Δ run-off	0	0	·05	·15	·25	0	·05
Adjusted	Δ run-off	0	0	·05	·15	·25	0	·05
				Storm VII				
	Σ rain-fall	·50	·80	1·70	2·70	4·50	6·20	
	Σ run-off	0	0	0	·10	·50	1·45	
	Δ run-off	0	0	0	·10	·40	·95	
Adjusted	Δ run-off	0	0	0	·10	·70	·65	

TABLE 4

Composite storm run-off (inches)
(12-hourly run-off values)

Storm	Maximum run-off								Σ Run-off (inch)	Σ Run-off (10^3 × SFD/2)
I			·15	·25	·30	·15	·15	·10	1·10	89·1
II				·30	·60	·50	·35		1·75	141·9
III				·10	·50	·35			·95	77·0
IV				·15	1·30	·25	·25		1·95	158·1
V	·05	·25	·35	·55	·60	·60			2·40	194·6
VI			·05	·15	·25	0	·05		·50	40·5
VII				·10	·70	·65			1·45	117·6
Composite (inch)	·05	·25	·55	1·60	4·25	2·50	·80	·10		
Adjusted Composite (inch)	·05	·20	·45	1·50	4·40	2·60	·80	·10	10·10	818·1
Composite (SFD/2)	4·05	16·20	36·45	121·50	356·40	210·60	64·80	8·1		818·1

TABLE 5

Composite storm discharge (10^3 c.f.s.)

Storm	12-hourly discharge												Σ Discharge (10^3 c.f.s.)
I			2·0	8·5	21·0	20·0	14·2	10·0	6·7	3·7	1·5		87·7
II				12·0	35·3	45·3	29·0	14·0	6·0	2·0			143·6
III				1·5	20·0	32·0	14·5	6·0	2·2				76·2
IV				2·0	19·7	47·0	49·0	23·5	11·5	3·0	2·8		158·5
V	3·5	10·8	18·5	27·4	34·5	41·5	32·4	16·0	8·5	4·5	2·0	0·5	197·1
VI			0·1	2·3	10·0	15·0	9·0	2·7	0				40·1
VII				2·2	34·5	39·5	21·0	12·0	6·8	3·0	0		119
Composite	3·5	10·8	20·6	55·9	175·0	241·3	169·2	84·2	41·7	16·2	6·3	0·5	822·2
Adjusted Composite	3·5	10·8	20·6	55·8	174·0	237·3	168·2	83·2	41·7	16·2	6·3	0·5	818·1

TABLE 6

Coefficients and ordinates of unit hydrograph

Coefficient of unit hydrograph on 1st trial	Coefficient of unit hydrograph on 2nd trial	Coefficient of residual unit hydro-graph	Adjusted coeffi-cients	Ordinates of 12-hour unit hydro-graph
·25	·30	·31	·32	25·9
·40	·44	·43	·43	35·0
·20	·16	·15	·16	13·0
·10	·07	·06	·06	4·9
·05	·03	·03	·03	2·4
		Total	1·00	81·0

TABLE 7

12-hour unit hydrograph with 6-hourly ordinates (10^3 c.f.s.)

Run-off (inch)	6-hour ordinates (c.f.s.)								
·05	·4	1·3	1·9	1·8	1·2	·7	·4	·2	·1
·10	·8	2·6	3·8	3·6	2·5	1·4	·8	·5	·2
·15	1·3	3·9	5·8	5·3	3·8	2·0	1·1	·8	·4
·20	1·7	5·2	7·7	7·1	5·0	2·7	1·5	1·0	·5
·25	2·1	6·5	9·6	8·9	6·2	3·4	1·9	1·2	·6
·30	2·5	7·8	11·6	10·7	7·5	4·0	2·2	1·5	·8
·35	2·9	9·1	13·5	12·4	8·8	4·7	2·6	1·8	·9
·40	3·4	10·4	15·4	14·2	10·0	5·4	3·0	2·0	1·0
·45	3·8	11·7	17·3	16·0	11·2	6·1	3·4	2·2	1·1
·50	4·2	13 0	19·2	17·8	12·5	6·8	3·8	2·5	1·2
·55	4·6	14·3	21·2	19·7	13·8	7·4	4·1	2·8	1·4
·60	5·0	15·6	23·1	21·4	15·0	8·1	4·5	3·0	1·5
·65	5·5	16·9	25·0	23·2	16·2	8·8	4·9	3·2	1·2
·70	5·9	18·2	27·0	25·0	17·5	9·4	5·2	3·5	1·8
·75	6·3	19·5	28·9	26·7	18·8	10·1	5·6	3·8	1·9
·80	6·7	20·8	30·8	28·5	20·0	10·8	6·0	4·0	2·0
·85	7·1	22·1	32·7	30·3	21·2	11·4	6·4	4·2	2·1
·90	7·6	23·4	34·6	32·1	22·5	12·2	6·8	4·5	2·2
·95	8·0	24·7	36·6	33·8	23·8	12·8	7·1	4·8	2·4
1·00	8·4	26·0	38·5	35·6	25·0	13·5	7·5	5·0	2·5
1·10	9·2	28·6	42·4	40·0	27·5	14·8	8·2	5·5	2·8
1·20	10·1	31·2	46·2	42·7	30·0	16·2	9·0	6·0	3·0
1·30	10·9	33·8	50·0	46·3	32·5	17·6	9·8	6·5	3·2
1·40	11·8	36·4	53·9	49·8	35·0	18·9	10·5	7·0	3·5
1·50	12·6	39·0	57·8	53·5	37·5	20·0	11·2	7·5	3·8
1·60	13·4	41·6	61·6	57·0	40·0	21·6	12·0	8·0	4·0
1·70	14·3	44·2	65·4	60·6	42·5	23·0	12·8	8·5	4·2
1·80	15·1	46·8	69·3	64·1	45·0	24·3	13·5	9·0	4·5
1·90	16·0	49·4	73·2	67·7	47·5	25·6	14·2	9·5	4·8
2·00	16·8	52·0	77·0	71·2	50·0	27·0	15·0	10·0	5·0

TABLE 8(a)

Storm I—Computation of flood hydrograph

		Run-off							Base flow	Total
		·15	·25	·30	·15	·15	·10	Total		
					DISCHARGE					
1948										
25 Jun	2 PM	1·3	X					1·3	1·3	2·6
	8 PM	3·9	X					3·9	1·2	5·1
26 Jun	2 AM	5·8	2·1	X				7·9	1·0	8·9
	8 AM	5·3	6·5	X				11·8	0·9	12·7
	2 PM	3·8	9·6	2·5	X			15·9	0·8	16·7
	8 PM	2·6	8·9	7·8	X			19·3	0·6	19·9
27 Jun	2 AM	1·1	6·2	11·6	1·3	X		20·2	0·5	20·7
	8 AM	0·8	3·4	10·7	3·9	X		18·8	0·7	19·5
	2 PM	0·4	1·9	7·5	5·8	1·3	X	16·9	0·8	17·7
	8 PM		1·2	4·0	5·3	3·9	X	14·4	1·0	15·4
28 Jun	2 AM		0·6	2·2	3·8	5·8	0·8	13·2	1·2	14·4
	8 AM			1·5	2·6	5·3	2·6	12·0	1·4	13·4
	2 PM			0·8	1·1	3·8	3·8	9·5	1·5	11·0
	8 PM				0·8	2·6	3·6	7·0	1·6	8·6
29 Jun	2 AM				0·4	1·1	2·5	4·0	1·7	5·7
	8 AM					0·8	1·4	2·2	1·9	4·1
	2 PM					0·4	0·8	1·2	2·1	3·3
	8 PM						0·5	0·5	2·3	2·8
30 Jun	2 PM						0·2	0·2	2·4	2·6

TABLE 8(b)

Storm II—Computation of flood hydrograph

		Run-off					Base flow	Total
		·30	·60	·50	·35	Total		
				DISCHARGE				
1948								
3 Aug	2 PM	2·5	X			2·5	1·5	4·0
	8 PM	7·8	X			7·8	1·5	9·3
4 Aug	2 AM	11·6	5·0	X		16·6	1·4	18·0
	8 AM	10·7	15·6	X		26·3	1·3	27·6
	2 PM	7·5	23·1	4·2	X	34·8	1·1	35·9
	8 PM	4·0	21·4	13·0	X	38·4	1·0	39·4
5 Aug	2 AM	2·2	15·0	19·2	2·9	39·3	1·4	40·7
	8 AM	1·5	8·1	17·8	9·1	36·5	1·9	38·4
	2 PM	0·8	4·5	12·5	13·5	31·3	2·4	33·7
	8 PM		3·0	6·8	12·4	22·2	2·8	25·0
6 Aug	2 AM		1·5	3·8	8·8	14·1	3·5	17·6
	8 AM			2·5	4·7	7·2	3·9	11·1
	2 PM			1·2	2·6	3·8	4·4	8·2
	8 PM				1·8	1·8	4·8	6·6
7 Aug	2 AM				0·9	0·9	5·4	6·3
	8 AM						5·9	5·9
	2 PM							
	8 PM							

TABLE 8(c)

Storm III—Computation of flood hydrograph

		Run-off				Base flow	Total
		·10	·50	·35	Total		
			DISCHARGE				
1949							
10 Jun	2 AM	0·8	X	X	0·8	0·7	1·5
	8 AM	2·6	X	X	2·6	0·6	3·2
	2 PM	3·8	4·2	X	8·0	0·6	8·6
	8 PM	3·6	13·0	X	16·6	0·5	17·1
11 Jun	2 AM	2·5	19·2	2·9	24·6	0·5	25·1
	8 AM	1·4	17·8	9·1	28·3	0·4	28·7
	2 PM	0·8	12·5	13·5	26·8	0·5	27·3
	8 PM	0·5	6·8	12·4	19·7	0·5	20·2
12 Jun	2 AM	0·2	3·8	8·8	12·8	0·6	13·4
	8 AM		2·5	4·7	7·2	0·7	7·9
	2 PM		1·2	2·6	3·8	0·8	4·6
	8 PM			1·8	1·8	0·9	2·7
13 Jun	2 AM			0·9	0·9	1·0	1·9
	8 AM						
	2 PM						
	8 PM						

TABLE 8(d)

Storm IV—Computation of flood hydrograph

		Run-off ·15	1·30	·25	·25	Total	Base flow	Total
				DISCHARGE				
1950								
16 Jul	2 PM	1·3	X	X	X	1·3	4·0	5·3
	8 PM	3·9	X	X	X	3·9	2·5	6·4
7 Jul	2 AM	5·8	10·9	X	X	16·7	2·5	19·2
	8 AM	5·3	33·8	X	X	39·1	2·0	41·1
	2 PM	3·8	50·0	2·1	X	55·9	2·0	57·9
	8 PM	2·0	46·3	6·5	X	54·8	1·7	56·5
18 Jul	2 AM	1·0	32·5	9·6	2·1	45·2	1·5	46·7
	8 AM	0·8	17·6	8·9	6·5	33·8	1·4	35·2
	2 PM	0·4	9·8	6·2	9·6	26·0	1·6	27·6
	8 PM		6·5	3·4	8·9	18·8	1·6	20·4
19 Jul	2 AM		3·2	1·9	6·2	11·3	1·7	13·0
	8 AM			1·2	3·4	4·6	2·0	6·6
	2 PM			0·6	1·9	2·5	2·1	4·6
	8 PM				1·2	1·2	2·3	3·5
20 Jul	2 AM				0·6	0·6	2·7	3·3
	2 AM						3·0	3·0
	8 PM						3·2	3·2
	8 PM						3·5	3·5

TABLE 8(e)

Storm V—Computation of flood hydrograph

		Run-off ·05	·25	·35	·55	·60	·60	Total	Base flow	Total
					DISCHARGE					
1950										
9 Aug	2 PM	0·4	X	X	X	X	X	0·4	2·5	2·0
	8 PM	1·3	X	X	X	X	X	1·3	2·5	3·8
10 Aug	2 AM	1·9	2·1	X	X	X	X	4·0	2·4	6·4
	8 AM	1·8	6·5	X	X	X	X	8·3	2·2	10·5
	2 PM	1·2	9·6	2·9	X	X	X	13·7	2·1	15·8
	8 PM	0·7	8·9	9·1	X	X	X	18·7	2·0	20·7
11 Aug	2 AM	0·4	6·2	13·5	4·6	X	X	24·7	2·0	26·7
	8 AM	0·2	3·4	12·4	14·3	X	X	30·3	1·9	32·2
	2 PM	0·1	1·9	8·8	21·2	5·0	X	37·0	1·7	38·7
	8 PM		1·2	4·7	19·7	15·6	X	41·2	1·6	42·8
12 Aug	2 AM		0·6	2·6	13·8	23·1	5·0	45·1	1·5	46·6
	8 AM			1·8	7·4	21·4	15·6	46·2	1·5	47·7
	2 PM			0·9	4·1	15·0	23·1	43·1	1·6	44·7
	8 PM				2·8	8·1	21·4	32·3	1·8	34·1
13 Aug	2 AM				1·4	4·5	15·0	20·9	2·3	23·2
	8 AM					3·0	8·1	11·1	2·7	13·8
	2 PM					1·5	4·5	6·0	3·1	9·1
	8 PM						3·0	3·0	3·5	6·5
14 Aug	2 AM						1·5	1·5	3·6	5·1
	8 AM								4·1	4·1
	2 PM								4·6	4·6
	8 PM								5·0	5·0
15 Aug	2 AM								5·4	5·4
	8 AM								6·0	6·0

TABLE 8(f)

Storm VI—Computation of flood hydrograph

		Run-off ·05	·15	·25	·05	Total	Base flow	Total
				DISCHARGE				
1952								
4 July	2 AM	0·4	X	X	X	0·4	0·5	0·9
	8 AM	1·3	X	X	X	1·3	0·5	1·8
	2 PM	1·9	1·3	X	X	3·2	0·5	3·7
	8 PM	1·8	3·9	X	X	5·7	0·4	6·1
5 July	2 AM	1·2	5·8	2·1	X	9·1	0·4	9·5
	8 AM	0·7	5·3	6·5	X	12·5	0·4	12·9
	2 PM	0·4	3·8	9·6	0·4	14·2	0·4	14·6
	8 PM	0·2	2·0	8·9	1·3	13·4	0·4	13·8
6 July	2 AM	0·1	1·1	6·2	1·9	9·3	0·8	10·1
	8 AM		0·8	3·4	1·8	6·0	1·0	7·0
	2 PM		0·4	1·9	1·2	3·5	1·5	5·0
	8 PM			1·2	0·7	1·9	1·8	3·7
7 July	2 AM			0·6	0·4	1·0	2·0	3·0
	8 AM				0·2	0·2	2·5	2·7
	2 PM				0·1	0·1		0·1

TABLE 8(g)

Storm VII—Computation of flood hydrograph

		Run-off ·10	·70	·65	Total	Base flow	Total
				DISCHARGE			
1954							
6 September	2 PM	0·8	X	X	0·8	0·5	1·3
	8 PM	2·6	X	X	2·6	0·4	3·0
7 September	2 AM	3·8	5·9	X	9·7	0·3	10·0
	8 AM	3·6	18·2	X	21·8	0·2	22·0
	2 PM	2·5	27·0	5·5	35·0	0·0	35·0
	8 PM	1·4	25·0	16·9	43·3	0·4	43·7
8 September	2 AM	0·8	17·5	25·0	43·3	0·6	43·9
	8 AM	0·5	9·4	23·2	33·1	1·0	34·2
	2 PM	0·2	5·2	16·2	21·6	1·3	22·9
	8 PM		3·5	8·8	12·3	1·8	14·1
9 September	2 AM		1·8	4·9	6·7	2·3	9·0
	8 AM			3·2	3·2	2·6	5·8
	2 PM			1·6	1·6	3·0	4·6
	8 PM					4·5	3·5
						3·3	3·3