US Army Corps
of Engineers
Hydrologic Engineering Center

GENERALIZED COMPUTER PROGRAM

HMR52

Probable Maximum Storm (Eastern United States)

User's Manual

March 1984

CPD-46

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US Army Corps of Engineers
Hydrologic Engineering Center
609 Second Street
Davis, CA 95616-4687

(916) 756-1104

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Section 1

INTRODUCTION

1.1 Program Purpose

Computer program HMRS2 computes basin-average precipitation for Probable Maximum Storms (PMS) In accordance with the criteria specified in Hydrometeorological Report No. 52 (National Weather Service, 1982). That Hydrometeorological Report (HMR) describes a procedure for developing a temporal and spatial storm pattern to be associated with the Probable Maximum Precipitation (PMP) estimates provided in Hydrometeorological Report No. 51, “Probable Maximum Precipitation Estimates — United States East of the 105th Meridian.” The U.S. National Weather Service (NWS) has determined the application criteria in a cooperative effort with the U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation.

Other reports, HMR Nos. 36. 43, 49 and 55 (NWS, 1961. 1966, 1977, and 1983, respectively) describe the PMP in other regions of the U.S.. Fig 1, This program, HMR52, is applicable only to the eastern U.S., and is intended for areas of 10 to 20,000 mi^2. (HMR No. 52 also contains a 1-mi^2, 1—hr PMP). A time interval as small as 5 minutes can be used for storm definition. Before using the HPIR52 program, one should be thoroughly familiar with the procedures described in Hydrometeorological Report No. 52.

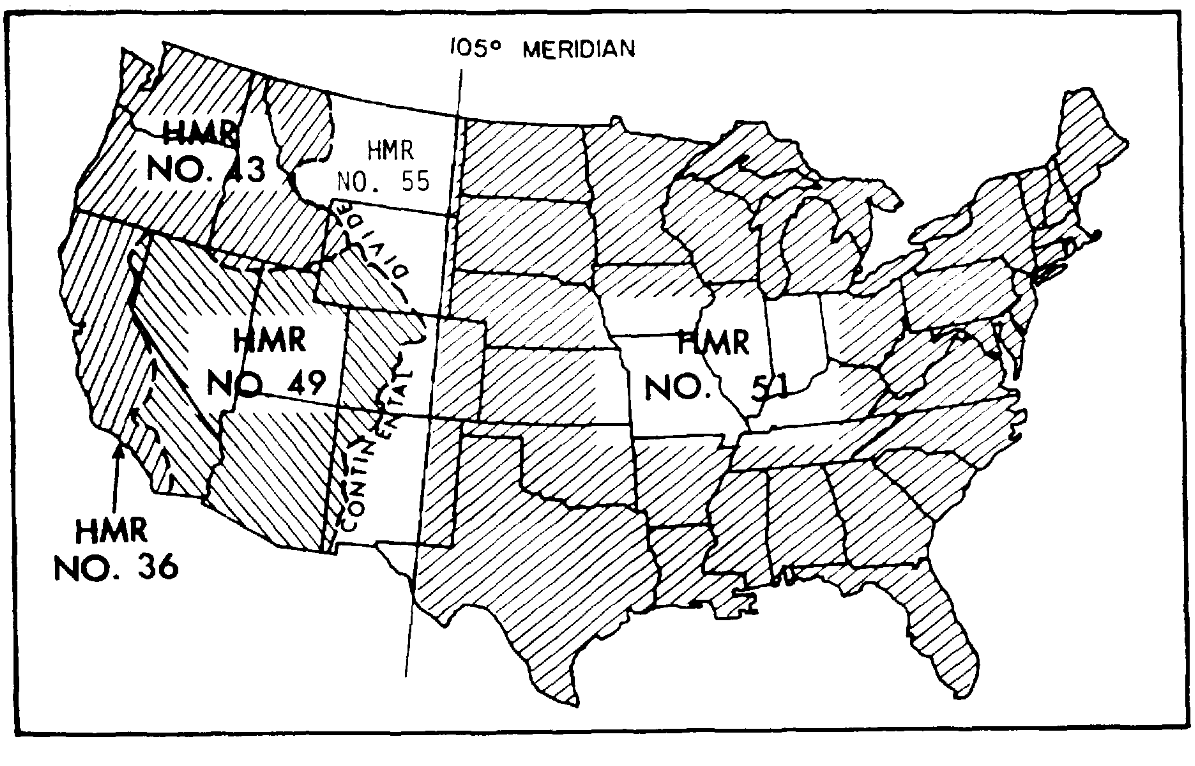


Figure 1. Regions Covered by Generalized PMP Studies (NWS, 1980)

The generalized PMP maps of HMR No. 51 are stippled In two regions, indicating estimates may be deficient because of orographic influences. Major projects within the stippled area should be considered on a case—by—case basis and expert hydrometeoro1og~ca1 guidance should be sought.

Data required for application of the HMR52 program are:

- X,Y coordinates describing the river basin and subbasin watershed boundaries;
- PMP from HMR No. 51 (NWSI 1978); and
- Storm orientation, size, centering, and timing.

The program computes the spatially averaged PMP for any of the subbasins or combinations thereof. The Probable Maximum Flood (PMF) can then be computed as the runoff from the PMS, using an appropriate precipitation—runoff program such as HEC-l (Hydrologic Engineering Center, HEC, 1981). A typical application of HMR52 does not produce a PMS. The PMS is defined by the Corps of Engineers to be that storm which produces the PMF. Thus, the PMS can only be determined by computing (and maximizing) runoff. That is, the runoff characteristics of a watershed must be considered in PMF (and therefore PMS) development.

HMR No. 52 requires that a critical storm—area size, orientation, centering and timing be determined which produces the maximum precipitation. The HMR52 computer program will optimize the storm—area size and orientation in order to produce the maximum basin—average precipitation. The user must provide the desired centering although the centroid of the basin area is provided as a default option.

The user must specify the time distribution for that storm. Using that time distribution information, the HMR52 program will produce a data file containing the incremental basin—average precipitation values for every subbasin requested. That precipitation data file will subsequently be input to a rainfall—runoff model, such as HEC—1, for computation of the resulting flood. The user then analyzes the various storm variables and recomputes the floods in order to determine the storm which produces the maximum runoff. That storm and runoff are defined as the PMS and PMF, respectively.

1.2 Computer Requirements

The HMR52 computer program requires a computer with 45K (decimal) words of core storage and 7 scratch tape/disk files. Plots of the basin geometry and storm patterns can be made on a line printer. Section 10 of this manual specifies detailed computer hardware and software requirements.

1.3 Acknowledgements

The computer program HMR52 was written by Paul B. Ely of the HEC. John C. Peters provided much valuable assistance in the design of the program’s capabilities and applications methodology.

Section 2

PROBABLE MAXIMUM STORM ANALYSIS PROCEDURE

2.1 Probable Maximum Precipitation Definition

Probable Maximum Precipitation (PMP) Is theoretically the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographical location at a certain time of the year. Hydrometeorological Report No. 51 (HMR No. 51) contains generalized (for any storm area) all-season estimates of PMP for the United States, east of the 105th meridian, Fig. 1.

2.2 Probable Maximum Storm Definition

Probable Maximum Storm (PMS) is a hypothetical storm which produces the Probable Maximum Flood from a particular drainage basin. Hydrometeorological Report No. 52 (HMR No. 52) provides criteria and step–by–step instructions for configuring a PMS using PMP estimates from HMR NO. 51. Key concepts upon which the procedures in HMR No. 52 are based are as follows.

2.2.1 Spatial Distribution

The spatial distribution of the PMP is governed by principals described under four headings: isohyetal shape, orientation, storm–area size, and spatial variability.

(i) Isohyetal shape. The PMS ‘is represented by elliptical isohyets, each of which has a ratio of major axis to minor axis of 2.5 to 1. Standard ellipses have been established containing areas from 10 to 60,000 mi^2 (Fig. 2)

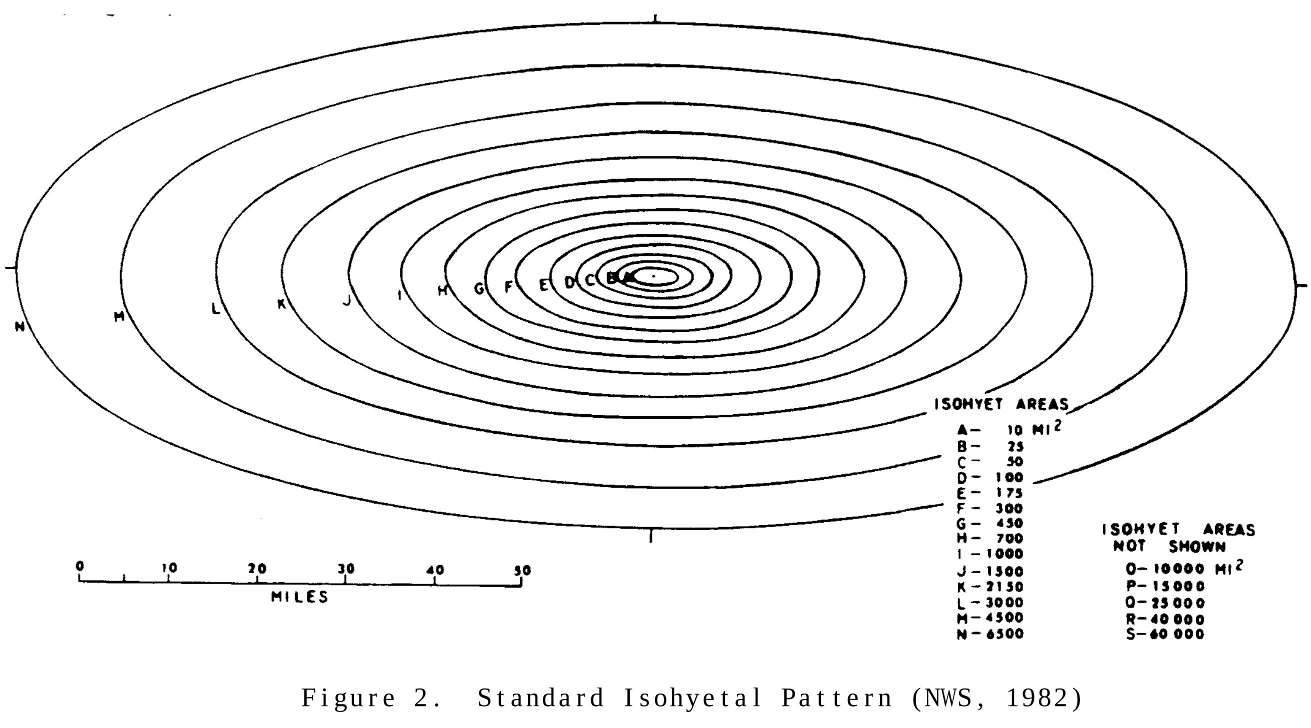


Figure 2. Standard Isohyetal Pattern (NWS, 1982)

(ii) Orientation. There is a preferred orientation for storms at a particular geographic location. That orientation is related to the general movement of storm systems and the direction of moisture–bearing winds. Contours of preferred orientation are shown in Fig. 3. When developing a PMS, it is generally desirable to orient the storm to produce maximum precipitation volume in the watershed. PMP will be reduced by an adjustment factor (shown in Fig. 4) when the storm orientation differs from the preferred orientation by more than ± 40 degrees.

(iii) Storm–Area Size. The average precipitation depth over an area is PMP for one and only one area size. This is the °storm–area size.' The average precipitation on areas larger or smaller than the storm–area size is less than PMP for the larger or smaller areas. Fig. 5 Illustrates this concept for a storm area of 1000 mi^2. The storm–area size is chosen to yield the maximum precipitation volume from a given drainage basin.

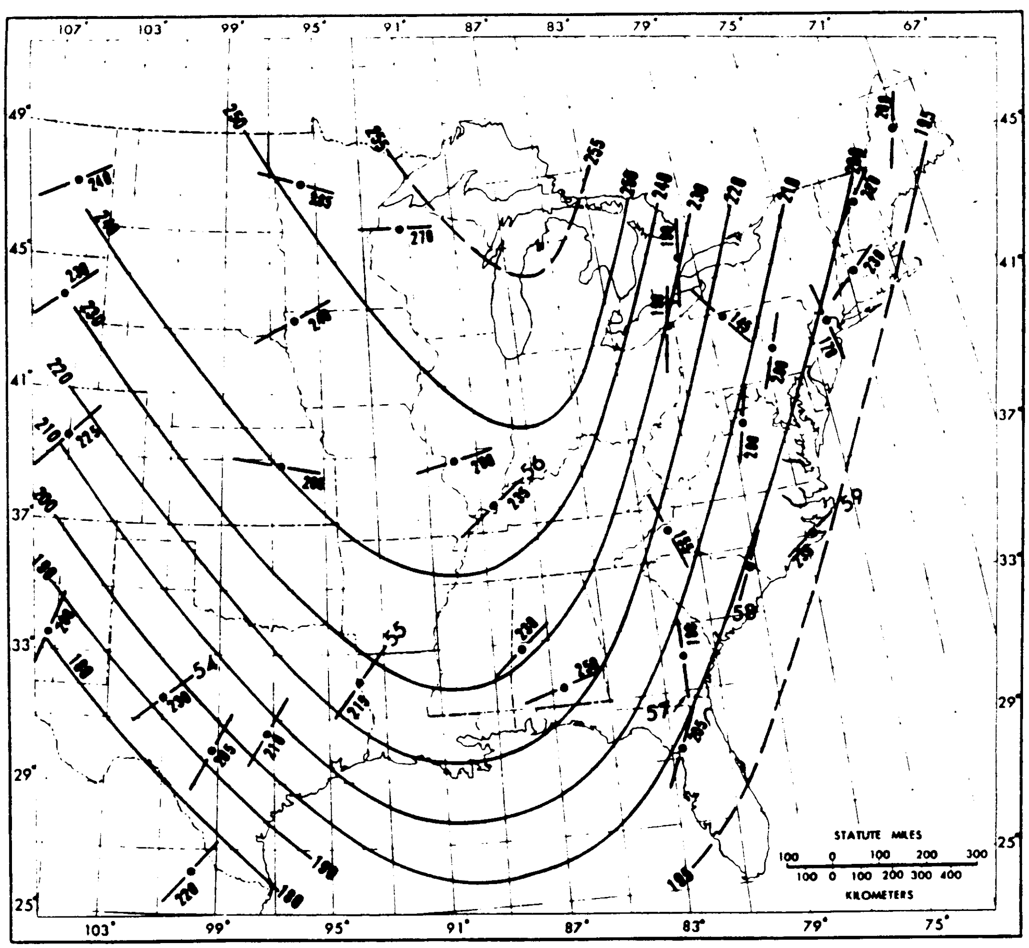


Figure 3. Preferred Orientation for PMS (NWS, 1982)

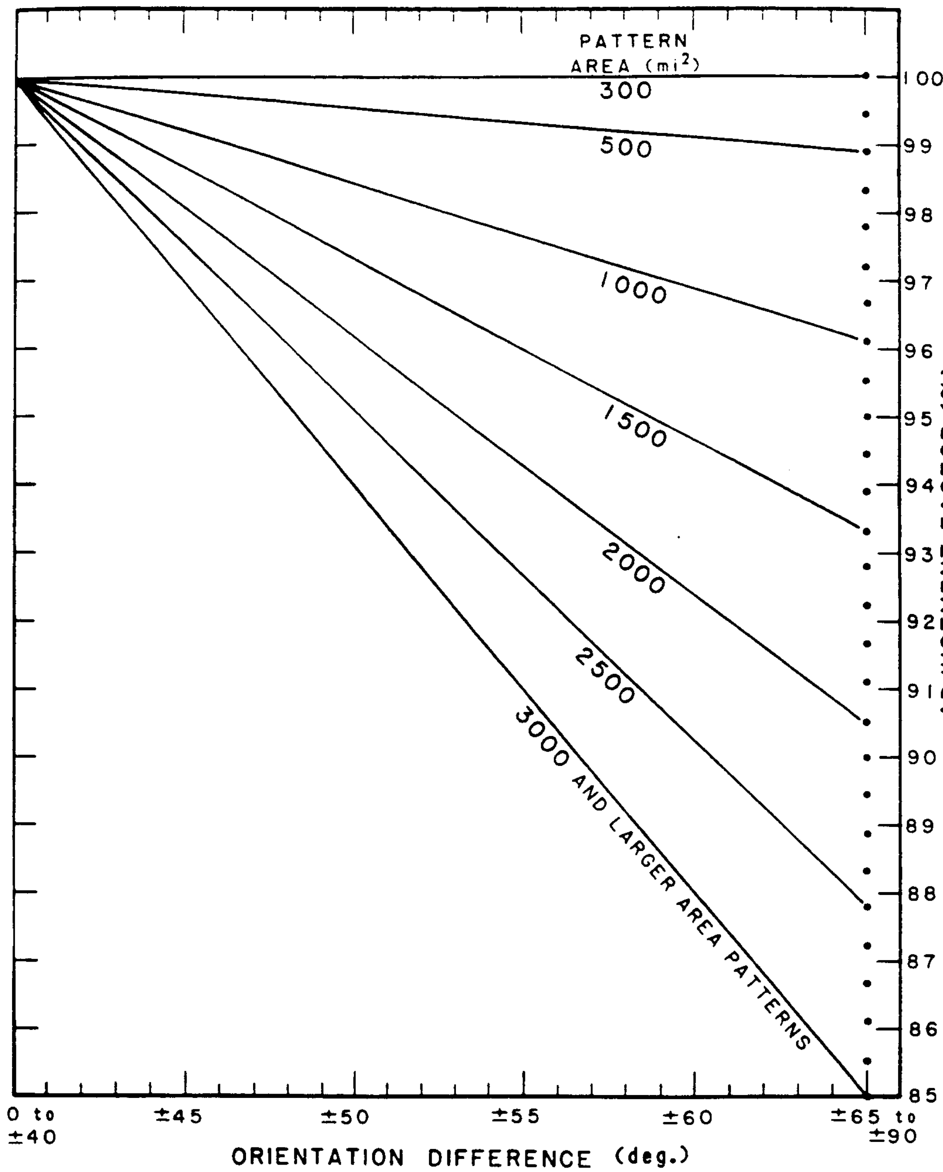


Figure 4. PMP Orientation Adjustment Factors (NWS, 1982)

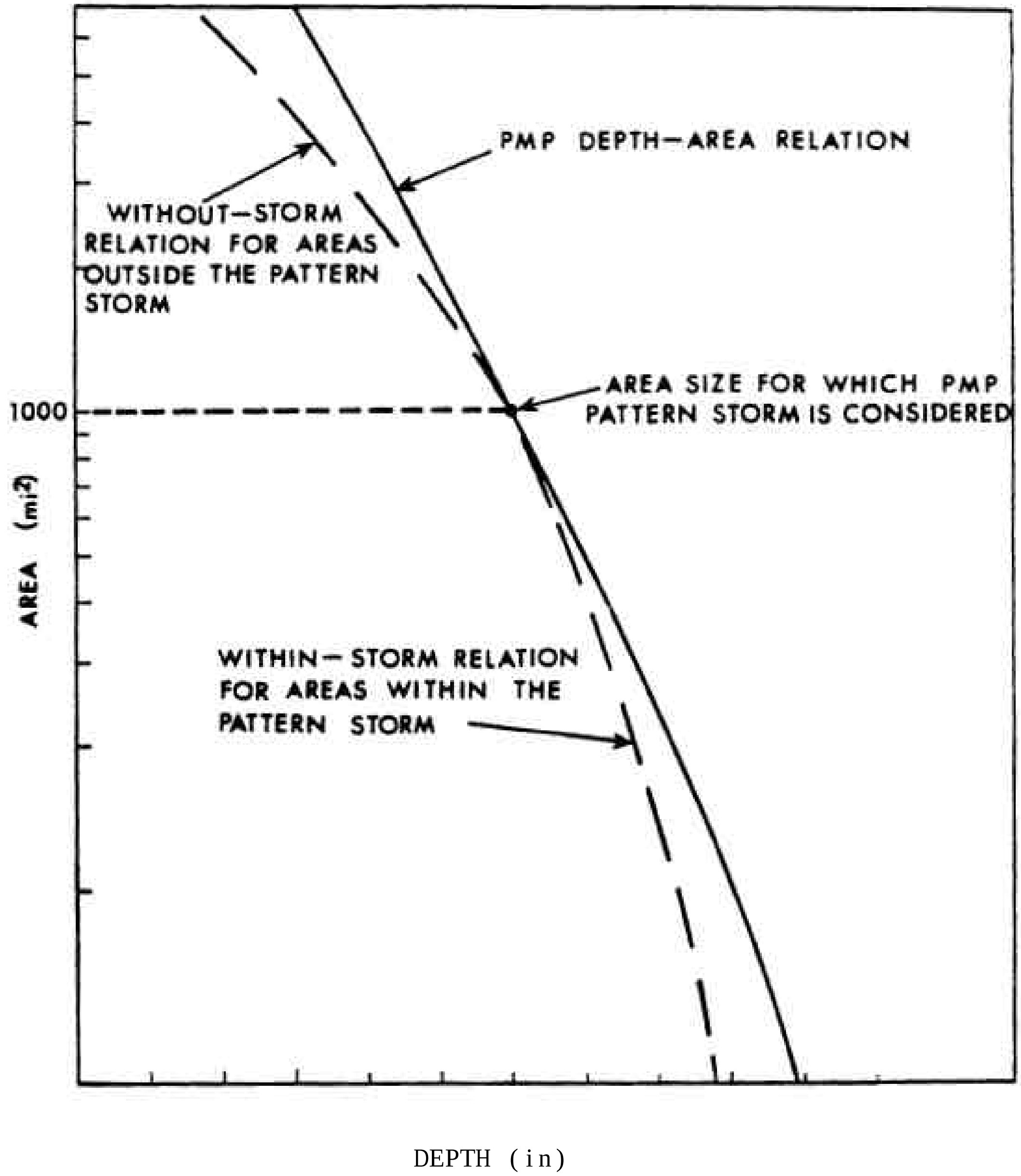


Figure 5. Comparison of PMP Depth—Area Relation with 1,000 mi^2 PMS (NWS, 1982)

(iv) Spatial Variability. Spatial variation of precipitation is a maximum during the 6-hr period when the maximum precipitation occurs. Spatial variation diminishes for the second and third largest 6—hr amounts. For the remaining 6—hr periods, the within—storm precipitation is uniform, but there is spatial variation in the residual precipitation occurring outside the elliptical boundary that corresponds to the storm—area size. HMR No. 52 contains nomograms which express spatial variation for each 6—hr period as a percent of PMP. Percentages for selected area sizes are tabulated in Tables 1 through 4. For each isohyet, the percent of PMP for the storm area is interpolated from Tables 1—4. Those percentages are multiplied times the PMP to obtain precipitation for each isohyet for each 6—hr interval. A graphical il1ustration of a typical spatial variation is shown in Fig. 6.

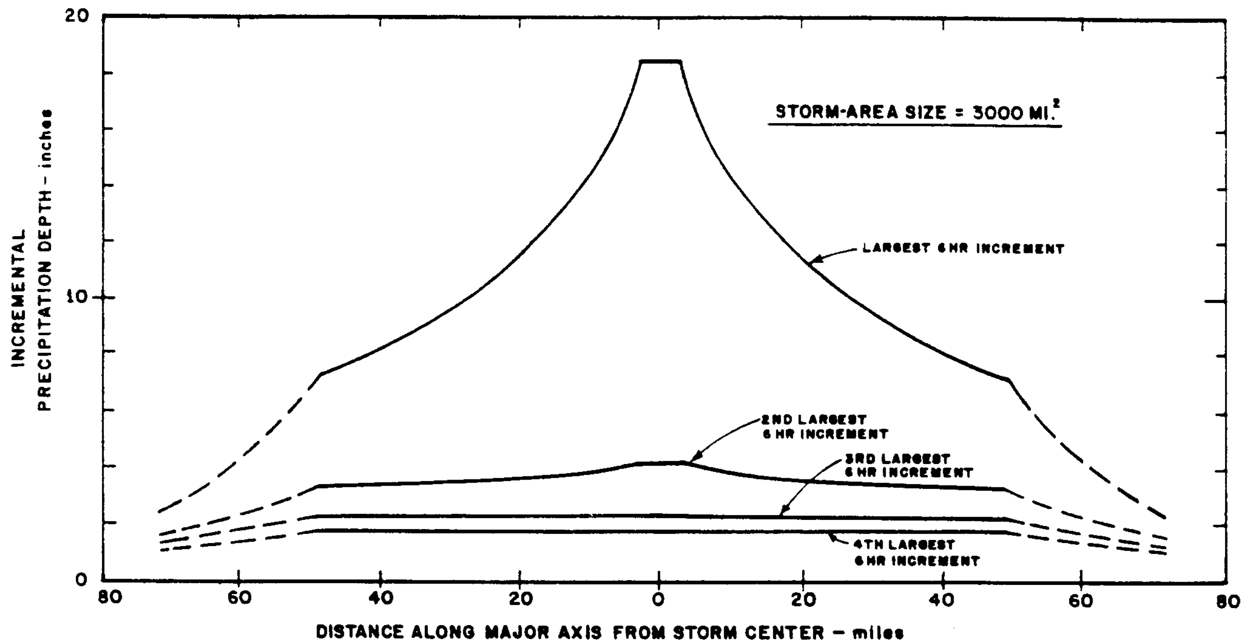


Figure 6. Spatial Variation in PMP Intensities

2.2.2 Temporal Distribution

The factors governing the temporal distribution of the PMS are as follows:

* PMP for all durations (up to 3 days) occurs in the same PMS. The PMP pattern is developed so that any duration of storms less than 72 hours is contained in the PMS.

* The four 6-hr periods with the greatest precipitation may occur any time except during the first 24 hours of the storm.

* The 6–hr Increments of precipitation are arranged such that the increments decrease progressively to either side of the greatest 6–hr increment. An example of one such distribution is shown in Fig. 7.

* The 6–hr increments may be distributed into shorter intervals. Fig. 8 shows ratios of 1–hr to 6–hr precipitation for the 'A' isohyet of a 20,000 mi^2 storm. This ratio is determined for the storm–center location and used to adjust ratios read from Table 5 for each isohyet within the storm–area size. Maximum 5-, 15-, and 30-mm intervals are given only for the maximum 1–hr increment withln the maximum 6–hr increment.

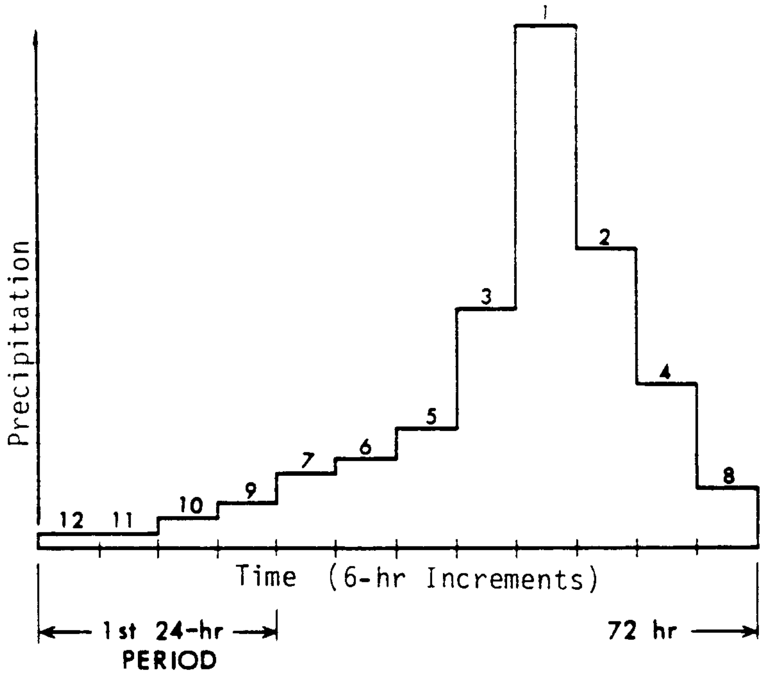


Figure 7. Schematic of One Temporal Sequence Allowed for 6-hr Increments of PMP (NWS, 1982)

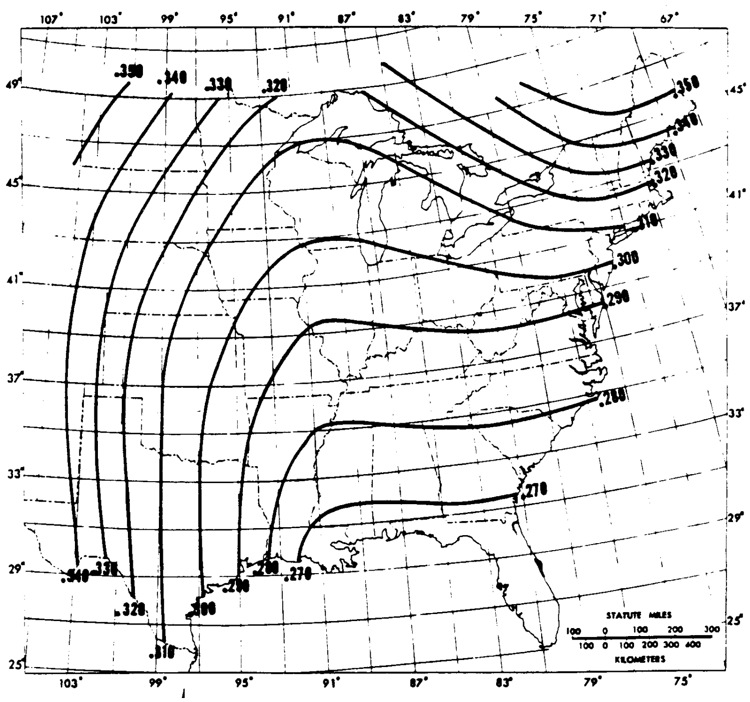


Figure 8. Ratio of 1-hr to 6-hr Precipitation for 'A' Isohyet of a 20,000 mi2 Storms (NWS, 1982)

TABLE 1
Spatial Variation in PMP for Largest 6-hour Increment

PERCENT OF LARGEST 6-HOUR PMP INCREMENT ISOHYET

STORM AREA	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
10	100.0	64.0	48.0	38.0	30.0	24.0	19.0	14.0	10.0	6.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	101.0	78.0	58.0	46.0	37.0	30.0	24.0	19.0	14.0	9.0	5.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	102.0	95.0	67.0	52.0	43.0	34.0	28.0	22.0	17.0	12.0	7.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	104.0	97.0	77.0	59.0	48.0	39.0	32.0	25.0	19.0	14.0	9.0	5.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
50	106.0	99.0	92.0	66.0	540.0	44.0	35.0	28.0	22.0	16.0	11.0	7.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
75	109.0	102.0	95.0	77.0	62.0	50.0	40.0	32.0	26.0	19.0	14.0	9.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0
100	112.0	105.0	98.0	90.0	68.0	55.0	44.0	35.0	28.0	21.0	16.0	11.0	6.0	1.0	0.0	0.0	0.0	0.0	0.0
140	116.0	108.0	101.0	93.0	78.0	61.0	49.0	39.0	32.0	24.0	18.0	13.0	8.0	2.0	0.0	0.0	0.0	0.0	0.0
175	119.0	111.0	103.0	96.0	89.0	66.0	53.0	42.0	34.0	26.0	20.0	15.0	9.0	3.0	0.0	0.0	0.0	0.0	0.0
220	122.0	114.0	106.0	99.0	92.0	73.0	58.0	46.0	37.0	28.0	22.0	17.0	10.0	4.0	0.0	0.0	0.0	0.0	0.0
300	126.0	118.0	110.0	103.0	96.0	88.0	65.0	51.0	42.0	32.0	25.0	19.0	12.0	6.0	1.0	0.0	0.0	0.0	0.0
360	129.0	121.0	113.0	105.0	98.0	90.0	73.0	56.0	45.0	35.0	27.0	21.0	13.0	7.0	2.0	0.0	0.0	0.0	0.0
450	132.0	124.0	116.0	108.0	101.0	93.0	86.0	63.0	50.0	38.0	30.0	23.0	15.0	8.0	3.0	0.0	0.0	0.0	0.0
560	136.0	128.0	120.0	111.0	104.0	95.0	89.0	72.0	56.0	43.0	33.0	25.0	16.0	9.0	3.0	0.0	0.0	0.0	0.0
700	140.0	132.0	124.0	115.0	107.0	98.0	92.0	84.0	63.0	48.0	36.0	27.0	18.0	10.0	4.0	0.0	0.0	0.0	0.0
850	145.0	136.0	128.0	119.0	110.0	101.0	94.0	87.0	72.0	54.0	40.0	30.0	19.0	11.0	4.0	0.0	0.0	0.0	0.0
1000	149.0	140.0	131.0	122.0	113.0	104.0	97.0	89.0	82.0	60.0	44.0	32.0	21.0	12.0	5.0	0.0	0.0	0.0	0.0
1200	155.0	145.0	136.0	126.0	116.0	107.0	100.0	92.0	85.0	68.0	49.0	35.0	23.0	14.0	6.0	0.0	0.0	0.0	0.0
1500	162.0	152.0	142.0	132.0	122.0	112.0	105.0	96.0	88.0	80.0	56.0	41.0	26.0	16.0	7.0	0.0	0.0	0.0	0.0
1800	169.0	158.0	147.0	137.0	126.0	117.0	108.0	99.0	91.0	83.0	64.0	46.0	29.0	18.0	8.0	1.0	0.0	0.0	0.0
2150	176.0	165.0	154.0	142.0	131.0	122.0	113.0	103.0	95.0	86.0	77.0	52.0	33.0	20.0	9.0	2.0	0.0	0.0	0.0
2600	184.0	172.0	160.0	148.0	137.0	127.0	118.0	108.0	99.0	89.0	80.0	62.0	38.0	22.0	11.0	3.0	0.0	0.0	0.0
3000	191.0	179.0	166.0	154.0	142.0	132.0	122.0	112.0	102.0	92.0	83.0	74.0	44.0	25.0	13.0	4.0	0.0	0.0	0.0
3800	203.0	189.0	176.0	163.0	150.0	140.0	130.0	119.0	108.0	98.0	89.0	79.0	56.0	31.0	15.0	6.0	0.0	0.0	0.0
4500	212.0	198.0	184.0	170.0	157.0	146.0	135.0	124.0	113.0	103.0	93.0	83.0	71.0	37.0	18.0	8.0	0.0	0.0	0.0
5500	223.0	209.0	194.0	180.0	166.0	153.0	142.0	131.0	119.0	108.0	98.0	88.0	76.0	48.0	23.0	10.0	0.0	0.0	0.0
6500	233.0	218.0	203.0	187.0	174.0	160.0	148.0	137.0	125.0	113.0	103.0	93.0	81.0	70.0	29.0	13.0	1.0	0.0	0.0
8000	247.0	230.0	214.0	198.0	183.0	169.0	157.0	144.0	132.0	120.0	110.0	99.0	87.0	75.0	40.0	18.0	3.0	0.0	0.0
10000	262.0	243.0	227.0	209.0	194.0	175.0	166.0	152.0	140.0	128.0	117.0	107.0	93.0	82.0	68.0	26.0	7.0	0.0	0.0
12000	274.0	255.0	238.0	219.0	203.0	186.0	174.0	159.0	147.0	135.0	123.0	113.0	99.0	87.0	73.0	38.0	11.0	0.0	0.0
15000	290.0	271.0	253.0	232.0	214.0	196.0	183.0	168.0	156.0	143.0	131.0	120.0	106.0	94.0	80.0	65.0	18.0	2.0	0.0
18000	304.0	183.0	264.0	242.0	224.0	205.0	192.0	176.0	164.0	150.0	138.0	127.0	113.0	101.0	86.0	71.0	28.0	6.0	0.0
20000	312.0	291.0	271.0	248.0	229.0	210.0	197.0	181.0	168.0	154.0.	142.0	131.0	117.0	104.0	89.0	74.0	36.0	8.0	0.0

TABLE 2
Spatial Variation in PMP for 2nd Largest 6-hour Increment

PERCENT OF SECOND LARGEST 6-HOUR PMP INCREMENT ISOHYET

STORM AREA	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
10	100.0	64.0	48.0	39.0	30.0	24.0	20.0	14.0	10.0	7.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	102.0	81.5	61.0	50.0	40.0	32.0	27.0	20.5	15.5	12.0	7.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	103.0	98.0	72.0	59.0	48.0	39.0	32.5	26.0	20.0	15.5	10.5	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	104.0	99.0	82.0	66.5	54.5	44.5	37.5	30.5	24.0	19.0	13.5	7.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0
50	105.5	100.5	96.5	76.0	62.5	51.0	43.5	36.0	29.0	23.0	17.0	11.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
75	107.0	102.0	98.0	86.0	72.0	59.5	50.0	42.0	34.5	27.5	21.0	14.5	7.0	0.0	0.0	0.0	0.0	0.0	0.0
100	108.0	103.0	99.0	95.0	79.0	65.0	55.0	47.0	38.5	31.0	24.0	17.0	9.0	1.0	0.0	0.0	0.0	0.0	0.0
140	109.0	104.0	100.5	96.5	88.0	73.0	62.0	52.5	43.5	35.0	27.5	20.5	12.0	3.5	0.0	0.0	0.0	0.0	0.0
175	110.0	105.0	101.5	97.5	95.0	79.0	66.5	56.5	47.0	38.5	30.0	23.0	14.5	5.0	0.0	0.0	0.0	0.0	0.0
220	110.5	106.0	102.5	98.5	96.0	85.0	72.0	61.0	51.0	42.0	33.0	26.0	17.0	7.5	0.0	0.0	0.0	0.0	0.0
300	111.5	107.0	103.5	100.0	97.5	95.0	80.0	67.5	57.0	47.0	37.5	30.0	20.5	10.0	1.0	0.0	0.0	0.0	0.0
360	112.0	108.0	104.0	101.0	98.5	96.0	85.0	72.0	61.0	50.0	40.5	33.0	23.0	12.0	3.0	0.0	0.0	0.0	0.0
450	113.0	109.0	105.0	102.0	99.5	97.0	95.0	77.5	66.0	54.5	44.5	36.5	25.5	14.0	4.5	0.0	0.0	0.0	0.0
560	114.0	109.5	106.0	102.5	100.5	98.0	96.0	85.0	72.5	60.0	49.0	40.0	28.5	17.0	6.5	0.0	0.0	0.0	0.0
700	114.5	110.0	107.0	104.0	101.0	99.0	97.0	95.0	78.0	65.5	54.0	44.0	32.0	19.5	9.0	0.0	0.0	0.0	0.0
850	115.0	111.0	107.5	104.5	102.0	100.0	98.0	96.0	85.0	71.0	58.5	48.0	35.0	22.0	11.0	0.0	0.0	0.0	0.0
1000	116.0	112.0	108.5	105.0	103.0	101.0	99.0	97.0	95.0	76.0	63.0	51.0	38.0	24.0	12.5	0.0	0.0	0.0	0.0
1200	116.5	112.5	109.0	106.0	104.0	102.0	99.5	97.0	96.0	82.5	68.0	55.0	41.0	27.0	14.5	0.0	0.0	0.0	0.0
1500	117.0	113.0	110.0	107.0	105.0	103.0	100.5	99.0	97.0	95.5	75.5	60.5	45.0	31.0	17.0	0.0	0.0	0.0	0.0
1800	118.0	114.0	110.5	108.0	105.5	104.0	101.5	99.5	98.0	96.0	83.0	66.0	49.5	34.0	19.5	1.5	0.0	0.0	0.0
2150	118.5	114.5	111.0	108.5	106.5	104.5	102.0	100.0	99.0	97.0	96.0	73.0	54.0	37.5	22.0	4.0	0.0	0.0	0.0
2600	119.0	115.5	112.0	109.5	107.0	105.5	103.0	101.0	99.5	98.0	96.5	83.0	60.5	41.5	25.5	7.0	0.0	0.0	0.0
3000	119.5	116.0	112.5	110.0	108.0	106.0	104.0	102.0	100.5	99.0	97.0	96.0	67.0	45.0	28.5	9.0	0.0	0.0	0.0
3800	120.5	117.0	113.5	111.0	109.0	107.0	105.0	103.0	101.5	100.0	98.0	97.0	81.0	52.5	34.0	13.5	0.0	0.0	0.0
4500	121.0	117.0	114.0	112.0	109.5	108.0	105.5	103.5	102.0	100.5	99.0	97.5	96.0	59.0	39.0	17.0	0.0	0.0	0.0
5500	122.0	118.0	115.0	112.5	110.5	108.5	106.5	104.5	103.0	101.5	100.0	98.5	97.0	72.5	46.0	22.0	0.0	0.0	0.0
6500	122.0	119.0	115.5	113.0	111.0	109.0	107.0	105.0	104.0	102.0	100.5	99.0	97.5	95.5	52.5	27.5	1.0	0.0	0.0
8000	123.0	120.0	116.5	114.0	112.0	110.0	108.0	106.0	104.5	103.0	101.5	100.0	98.5	96.0	66.0	37.0	6.0	0.0	0.0
10000	124.0	120.5	117.0	115.0	113.0	111.0	109.0	107.0	105.5	104.0	102.5	101.0	99.0	97.0	95.0	50.0	14.0	0.0	0.0
12000	124.5	121.0	118.0	116.0	114.0	112.0	110.0	108.0	106.5	105.0	103.0	102.0	100.0	98.0	96.0	64.0	21.0	0.0	0.0
15000	125.0	122.0	119.0	117.0	115.0	113.0	111.0	109.0	107.0	106.0	104.0	102.5	101.0	99.0	97.0	96.0	34.0	0.0	0.0
18000	126.0	122.5	119.5	118.0	116.0	113.5	112.0	110.0	108.0	106.5	105.0	103.5	102.0	99.5	97.5	96.5	47.0	4.5	0.0
20000	126.0	123.0	120.0	118.0	116.0	114.0	112.0	110.0	108.5	107.0	105.0	104.0	102.0	100.0	98.0	97.0	55.0	7.0	0.0

TABLE 3
Spatial Variation in PMP for 3rd Largest 6-hour Increment

PERCENT OF THIRD LARGEST 6-HOUR PMP INCREMENT ISOHYET

STORM AREA	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
10	100.0	65.0	48.0	39.0	30.0	24.0	20.0	14.0	10.0	6.5	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	100.6	83.5	63.0	51.0	40.0	33.0	28.0	21.0	16.5	12.5	7.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	101.0	99.0	74.5	60.5	48.5	40.0	34.0	27.0	21.5	17.0	11.5	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	101.3	99.4	85.5	69.0	55.5	46.5	39.5	32.5	26.5	21.0	15.0	8.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0
50	101.6	99.8	98.5	78.5	63.0	53.5	46.0	37.5	31.5	26.0	19.5	12.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
75	102.0	100.3	99.0	90.0	73.5	61.5	53.0	44.0	37.5	31.5	24.5	16.5	5.2	0.0	0.0	0.0	0.0	0.0	0.0
100	102.3	100.7	99.3	98.6	81.5	68.0	59.0	49.0	42.0	35.5	28.0	20.0	11.2	1.0	0.0	0.0	0.0	0.0	0.0
140	102.6	101.0	99.7	99.0	92.0	76.5	66.0	55.0	47.5	40.5	32.5	24.0	15.0	4.5	0.0	0.0	0.0	0.0	0.0
175	102.8	101.3	100.0	99.2	98.8	93.0	71.0	59.5	51.0	44.0	35.0	26.5	18.0	7.0	0.0	0.0	0.0	0.0	0.0
220	103.1	101.5	100.3	99.5	99.0	89.0	77.0	64.0	55.5	47.5	38.5	29.5	20.5	10.0	0.0	0.0	0.0	0.0	0.0
300	103.4	101.9	100.7	99.8	99.3	99.0	86.0	72.0	62.0	53.0	43.0	33.5	24.5	14.0	2.0	0.0	0.0	0.0	0.0
360	103.6	102.1	100.9	100.1	99.5	99.2	92.0	76.5	66.0	56.0	46.0	36.0	27.0	16.0	4.0	0.0	0.0	0.0	0.0
450	103.8	102.4	101.2	100.3	99.8	99.5	99.2	84.0	71.0	60.0	50.0	39.5	30.0	19.0	7.0	0.0	0.0	0.0	0.0
560	104.0	102.7	101.5	100.6	100.0	99.7	99.4	91.0	77.5	64.5	54.0	43.0	33.0	22.5	10.0	0.0	0.0	0.0	0.0
700	104.2	102.9	101.7	100.8	100.2	99.9	99.6	99.2	85.0	70.5	58.5	47.0	37.0	25.5	13.0	0.0	0.0	0.0	0.0
850	104.4	103.2	102.0	101.1	100.4	100.1	99.7	99.4	92.0	76.5	62.5	50.5	40.0	28.5	15.5	0.0	0.0	0.0	0.0
1000	104.6	103.3	102.3	101.3	100.6	100.3	99.9	99.6	99.3	82.5	67.0	54.0	43.0	31.0	17.5	0.0	0.0	0.0	0.0
1200	104.7	103.5	102.5	101.5	100.8	100.4	100.0	99.7	99.5	89.5	72.5	58.5	46.5	34.0	20.5	0.0	0.0	0.0	0.0
1500	105.0	103.8	102.7	101.7	101.0	100.7	100.3	100.0	99.7	99.4	81.0	65.5	51.5	38.0	24.0	0.0	0.0	0.0	0.0
1800	105.2	104.0	102.9	102.0	101.2	100.8	100.4	100.1	99.8	99.5	89.0	72.5	56.5	42.0	27.0	2.5	0.0	0.0	0.0
2150	105.3	104.2	103.2	102.0	101.3	101.0	100.6	100.3	100.0	99.7	99.5	80.5	61.0	46.5	30.5	5.5	0.0	0.0	0.0
2600	105.5	104.4	103.4	102.4	101.5	101.2	100.7	100.4	100.1	99.8	99.5	90.5	69.0	52.0	34.0	9.0	0.0	0.0	0.0
3000	105.7	104.6	103.5	102.5	101.7	101.3	100.9	100.5	100.2	99.9	99.6	99.3	76.0	57.0	37.5	12.0	0.0	0.0	0.0
3800	105.8	104.8	103.8	102.8	101.9	101.5	101.1	100.7	100.5	100.1	99.8	99.5	88.5	67.0	43.5	16.5	0.0	0.0	0.0
4500	106.0	105.0	104.0	103.1	102.1	101.7	101.2	100.9	100.6	100.2	99.9	99.6	99.3	76.0	49.0	21.0	0.0	0.0	0.0
5500	106.2	105.3	104.3	103.2	102.3	101.8	101.4	101.1	100.8	100.4	100.0	99.7	99.4	88.0	57.0	27.5	0.0	0.0	0.0
6500	106.4	105.5	104.5	103.5	102.5	102.0	101.5	101.2	100.9	100.5	100.2	99.8	99.5	98.9	65.0	34.5	1.0	0.0	0.0
8000	106.6	105.7	104.8	103.7	102.7	102.2	101.7	101.4	101.1	100.7	100.3	100.0	99.6	99.0	49.0	44.5	8.0	0.0	0.0
10000	106.8	106.0	105.0	104.0	102.8	102.4	101.9	101.6	101.3	100.9	100.5	100.2	99.8	99.2	98.7	59.0	18.0	0.0	0.0
12000	107.0	106.2	105.3	104.2	103.0	102.6	102.1	101.8	101.5	101.0	100.7	100.3	99.9	99.3	98.8	71.5	27.5	0.0	0.0
15000	107.2	106.5	105.5	104.4	103.3	102.8	102.3	102.0	101.7	101.2	100.8	100.5	100.1	99.5	99.0	98.0	42.0	1.0	0.0
18000	107.4	106.7	105.8	104.6	103.5	103.0	102.4	102.2	101.8	101.3	101.0	100.6	100.2	99.6	99.1	98.7	54.5	7.5	0.0
20000	107.5	106.8	105.9	104.7	103.6	103.0	102.5	102.2	101.9	101.4	101.1	100.7	100.2	99.7	99.2	98.2	66.0	12.0	0.0

TABLE 4

Spatial Variation in PMP for 4th through 12th 6-hour Increment

PERCENT OF FOURTH THROUGH TWELFTH LARGEST 6-HOUR PMP INCREMENT ISOHYET

STORM AREA	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
10	100.0	65.0	48.0	39.0	30.0	24.0	20.0	14.0	10.0	6.5	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	100.0	83.5	62.5	50.5	40.0	33.0	27.5	21.0	16.0	12.0	7.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	100.0	100.0	74.5	60.5	48.5	40.0	34.0	27.0	21.5	17.0	11.5	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	100.0	100.0	86.0	68.5	55.0	46.0	39.0	31.5	26.0	21.0	15.0	8.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0
50	100.0	100.0	100.0	78.5	63.0	53.5	46.0	37.5	31.5	26.0	19.5	12.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
75	100.0	100.0	100.0	89.5	73.0	61.5	53.0	44.0	37.0	31.0	24.0	16.0	8.5	0.0	0.0	0.0	0.0	0.0	0.0
100	100.0	100.0	100.0	100.0	81.5	68.0	59.0	49.0	42.0	35.5	28.0	20.0	11.5	1.0	0.0	0.0	0.0	0.0	0.0
140	100.0	100.0	100.0	100.0	91.0	76.5	65.5	55.0	47.5	40.0	32.0	23.5	15.0	4.0	0.0	0.0	0.0	0.0	0.0
175	100.0	100.0	100.0	100.0	100.0	83.0	71.0	58.5	51.0	44.0	35.0	26.5	18.0	7.0	0.0	0.0	0.0	0.0	0.0
220	100.0	100.0	100.0	100.0	100.0	89.0	77.0	64.0	55.0	47.0	38.5	29.0	20.5	9.5	0.0	0.0	0.0	0.0	0.0
300	100.0	100.0	100.0	100.0	100.0	100.0	86.0	72.0	62.0	53.0	43.0	33.5	24.5	14.0	2.0	0.0	0.0	0.0	0.0
360	100.0	100.0	100.0	100.0	100.0	100.0	91.5	77.0	65.5	55.5	46.0	36.0	27.0	16.0	4.0	0.0	0.0	0.0	0.0
450	100.0	100.0	100.0	100.0	100.0	100.0	100.0	84.0	71.0	60.0	50.0	39.5	30.0	19.0	7.0	0.0	0.0	0.0	0.0
560	100.0	100.0	100.0	100.0	100.0	100.0	100.0	91.0	77.5	64.5	53.5	43.0	33.0	22.0	8.5	0.0	0.0	0.0	0.0
700	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	85.0	70.5	58.5	4730	37.0	25.5	13.0	0.0	0.0	0.0	0.0
850	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	92.0	77.0	62.0	50.5	40.0	28.0	15.0	0.0	0.0	0.0	0.0
1000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	82.5	67.0	54.0	43.0	31.0	17.5	0.0	0.0	0.0	0.0
1200	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	89.5	72.0	58.5	46.5	33.5	20.0	0.0	0.0	0.0	0.0
1500	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	81.0	65.5	51.5	38.0	24.0	0.0	0.0	0.0	0.0
1800	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	89.0	72.5	56.0	41.5	26.5	2.5	0.0	0.0	0.0
2150	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	80.5	61.0	46.5	30.5	5.5	0.0	0.0	0.0
2600	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	90.0	69.0	51.5	33.5	9.0	0.0	0.0	0.0
3000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	76.0	57.0	37.5	12.0	0.0	0.0	0.0
3800	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	88.5	67.0	43.5	17.0	0.0	0.0	0.0
4500	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	76.0	49.0	21.0	0.0	0.0	0.0
5500	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	88.0	56.5	27.0	0.0	0.0	0.0
6500	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	65.0	34.5	1.0	0.0	0.0
8000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	79.0	44.0	8.0	0.0	0.0
10000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	59.0	18.0	0.0	0.0
12000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	71.0	27.0	0.0	0.0
15000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	42.0	1.0	0.0
18000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	54.0	7.0	0.0
20000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	66.0	12.0	0.0

TABLE 5
RATIOS OF 1-HOUR TO 60HOUR PMP
(Offset by Ratio for Isohyet A for 20,000 sq. mi. Storm)

STORM AREA	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
								ISOHYET								
10	.2555															
17	.2470															
25	.2370	.2355														
35	.2255	.2240														
50	.2115	.2100	.2085													
75	.1935	.1920	.1905													
100	.1800	.1785	.1770	.1750												
140	.1625	.1610	.1595	.1575												
175	.1500	.1485	.1470	.1450	.1435											
220	.1375	.1355	.1340	.1320	.1305											
300	.1185	.1170	.1155	.1135	.1120	.1100										
360	.1070	.1055	.1040	.1020	.1005	.0985										
450	.0935	.0915	.0900	.0880	.0860	.0840	.0825									
560	.0790	.0775	.0760	.0735	.0715	.0700	.0690									
700	.0640	.0620	.0605	.0585	.0570	.0545	.0530	.0510								
850	.0515	.0490	.0475	.0455	.0440	.0420	.0405	.0385								
1000	.0405	.0380	.0365	.0340	.0320	.0305	.0290	.0270	.0255							
1200	.0280	.0255	.0240	.0215	.0195	.0180	.0165	.0145	.0125							
1500	.0135	.0110	.0090	.0075	.0060	.0035	.0020	.0000	-.0020	-.0070						
1800	.0030	.0005	-.0010	-.0030	-.0045	-.0060	-.0075	-.0095	-.0115	-.0165						
2150	-.0055	-.0075	-.0090	-.0110	-.0125	-.0145	-.0160	-.0180	-.0195	-.0235	-.0280					
2600	-.0130	-.0150	-.0165	-.0180	-.0195	-.0215	-.0230	-.0250	-.0270	-.0305	-.0345					
3000	-.0175	-.0200	-.0215	-.0230	-.0245	-.0260	-.0275	-.0295	-.0315	-.0350	-.0385	-.0425				
3800	-.0245	-.0260	-.0275	-.0290	-.0305	-.0320	-.0335	-.0355	-.0370	-.0405	-.0440	-.0465				
4500	-.0275	-.0290	-.0305	-.0320	-.0335	-.0350	-.0365	-.0385	-.0400	-.0435	-.0465	-.0490	-.0540			
5500	-.0295	-.0310	-.0325	-.0340	-.0355	-.0370	-.0375	-.0405	-.0420	-.0455	-.0485	-.0505	-.0555			
6500	-.0300	-.0315	-.0330	-.0345	-.0360	-.0375	-.0390	-.0405	-.0420	-.0455	-.0485	-.0510	-.0555	-.0610		
8000	-.0295	-.0310	-.0325	-.0340	-.0355	-.0370	-.0385	-.0400	-.0415	-.0445	-.0475	-.0505	-.0550	-.0605		
10000	-.0275	-.0290	-.0300	-.0315	-.0325	-.0340	-.0355	-.0370	-.0385	-.0415	-.0450	-.0480	-.0525	-.0575	-.0640	
12000	-.0240	-.0255	-.0265	-.0280	-.0290	-.0305	-.0320	-.0340	-.0355	-.0385	-.0415	-.0445	-.0490	-.0535	-.0605	
15000	-.0155	-.0170	-.0180	-.0200	-.0215	-.0230	-.0245	-.0365	-.0280	-.0310	-.0350	-.0380	-.0425	-.0475	-.0550	-.0630
18000	-.0065	-.0080	-.0095	-.0110	-.0125	-.0140	-.0155	-.0175	-.0195	-.0235	-.0270	-.0305	-.0345	-.0410	-.0475	-.0555
20000	.0000	-.0015	-.0030	-.0045	-.0060	-.0080	-.0095	-.0115	-.0135	-.0175	-.0210	-.0245	-.0290	-.0355	-.0415	-.0505
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P

Section 3

PROBABLE MAXIMUM PRECIPITATION DETERMINATION

3.1 All—Season PMP Estimates

Generally, a three—step process is followed in determining PMP in nonorographic regions: moisture maximization, transposition and envelopment. Those processes are briefly described below; HMR No. 51 gives a complete explanation of the PMP procedure.

Moisture maximization consists of increasing storm precipitation measured in a major historic event by a factor that reflects the maximum amount of moisture that could have existed in the atmosphere for the storm location and time of the year.

Transposition refers to the process of moving a storm (i.e., isohyetal pattern) from the location where it occurred to another location of interest. Transposition is carried out only within a region that is homogeneous with respect to terrain and meteorology.

Envelopment involves construction of smooth curves that envelope precipitation maxima for various durations and area sizes to compensate for data gaps. Also geographic smoothing is performed to insure regional consistency.

Using those principles, PMP's for various sized area and storm durations were calculated by the NWS. The results are generalized and plotted in a series of figures (18—47) in HMR No. 51. One of those plots, the all—season PMP for the 6—hr 10—mi^2 PMP. is illustrated here in Fig. 9.

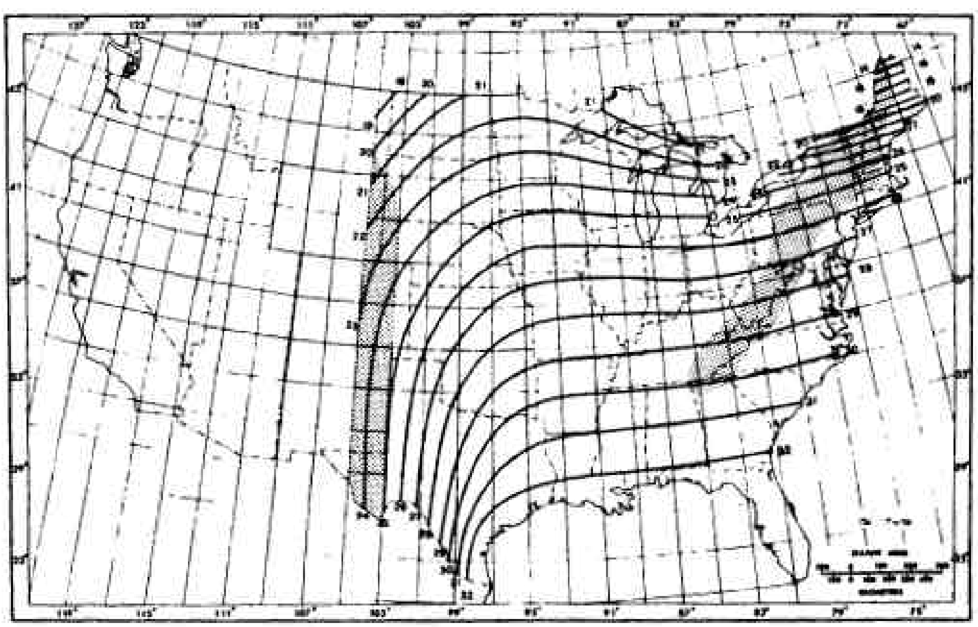


Figure 9. All—Season PMP (inches) for 6 hours, 10 mi^2 (NWS, 1978)

3.2 Example Calculation of PMP

It is desired to obtain PMP estimates for the Leon River basin above Belton Reservoir, Texas, Fig. 10. The drainage area Is 3,660 mi^2; the location of the centroid of the basin is 31°45’ N, 98°15’ W.

From the PMP maps in HMR No. 51, the PMP values for area sizes larger and smaller than the drainage area are determined. The all—season PMP for 6 hours and 10 mi^2 was shown in Fig. 9 (which is Fig. 18 in HMR No. 51). Values taken from figures 18 through 47 of HMR No, 51 are shown in Table 6.

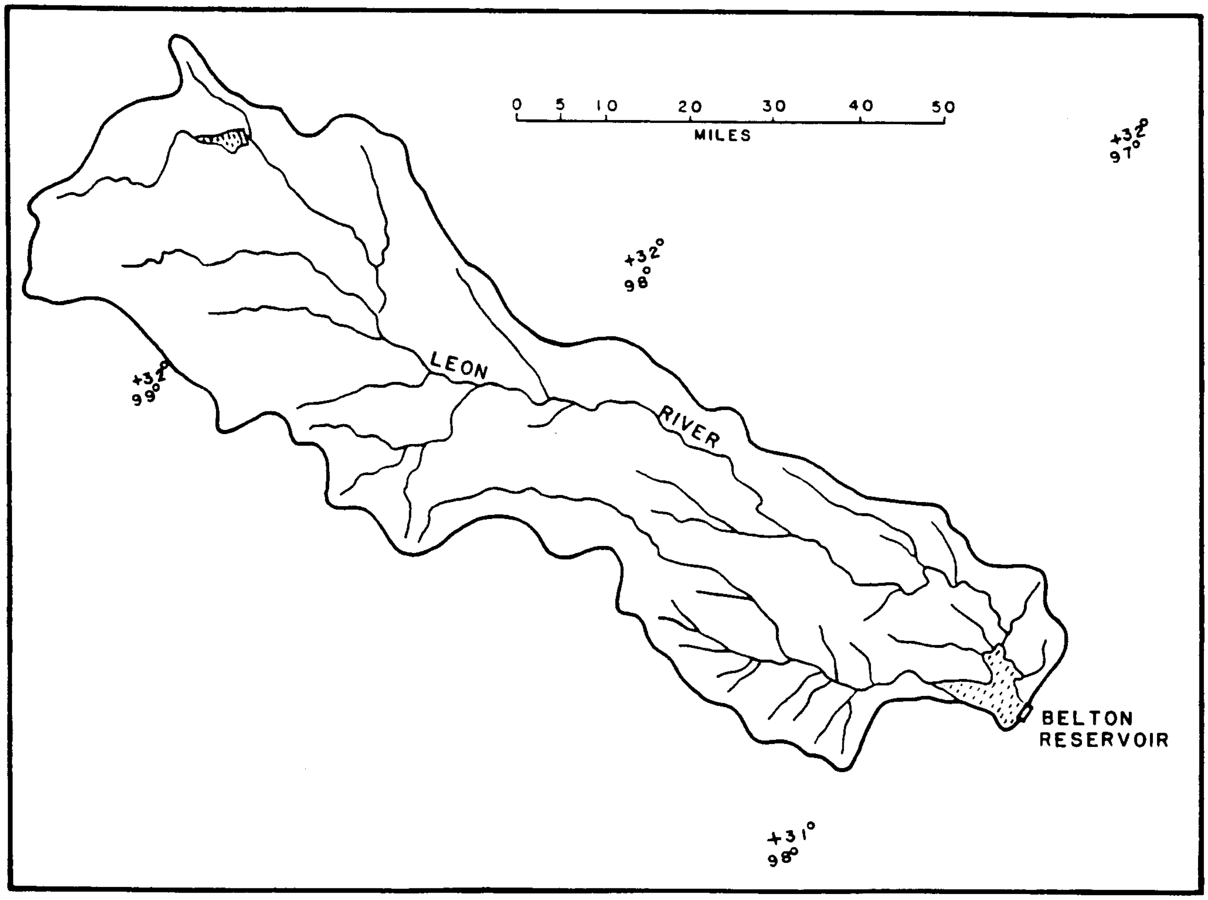


Figure 10. Leon River Basin, Texas (NWS, 1982)

Table 6

PMP Depths (by Area and Duration) for Leon River Basin

Area (mi^2)	Duration (hours) 6	12	24	48	72
10	29.8	36.2	41.8	46.7	49.8
200	22.3	27.4	33.0	37.5	41.4
1000	16.2	21.2	26.8	31.0	34.5
5000	9.3	13.1	18.1	22.6	25.9
10000	7.2	10.4	14.9	18.8	21.0
20000	5.2	8.2	11.7	15.4	18.4

From the depth—area—duration data in Table 6, plot PMP depth versus the logarithm of drainage area for each duration. Draw smooth curves for each duration. The curves should be parallel or converge slightly with increasing size, as illustrated in Fig. 11.

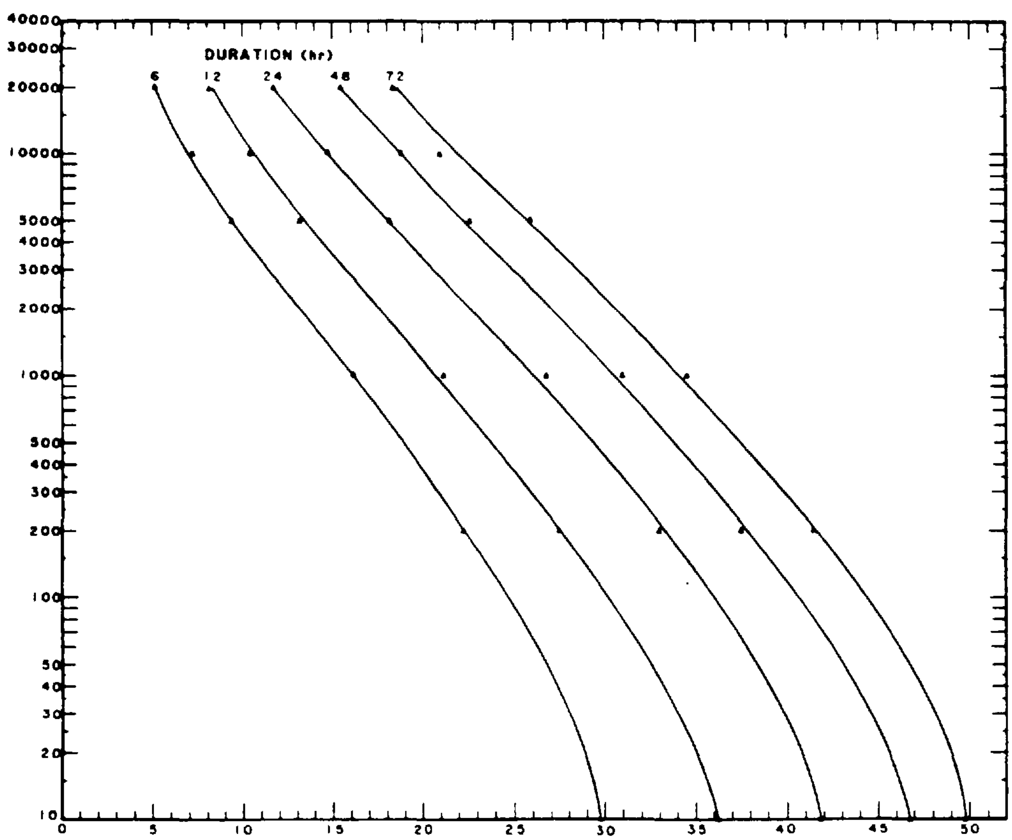


Figure 11. Depth-Area-Duration Curves for Leon River Basin (NWS, 1982)

It is highly recommended to physically plot the initial depth-area-duration values taken from the various figures (figures 18—47) in HMR 51 as shown in Hg. 11 of this users manual. This initial plotting of the basic input data serves two functions. One, it eliminates reader errors from basic misinterpretation of values read off the figures in HMR 51. Second, initial important smoothing of the basic precipitation data is applied.

Using the depth-area-duration graph of Fig. 11, determine PMP depths for the storm-area sizes of interest. A plot of the area-specific PMP values versus duration on linear graph paper can be used to obtain PMP depth for any duration between 6 and 72 hours. The above curve fitting is done automatically by the HMR52 program. The user need only provide the depth-area-duration data, e.g. Table 6, for the geographic location in question. Using this PMP data, the PMS is calculated as described in the next section.

Section 4

EXAMPLE CALCULATION OF A PMS

To illustrate the procedures given in HMR No. 52, suppose that it is desired to derive a storm for a storm-area size of 3,000 mi^2 for the Leon River basin. The storm is to be centered at 31°45’ N, 98°15’ W with an orientation of 314°, as shown in Fig. 12.

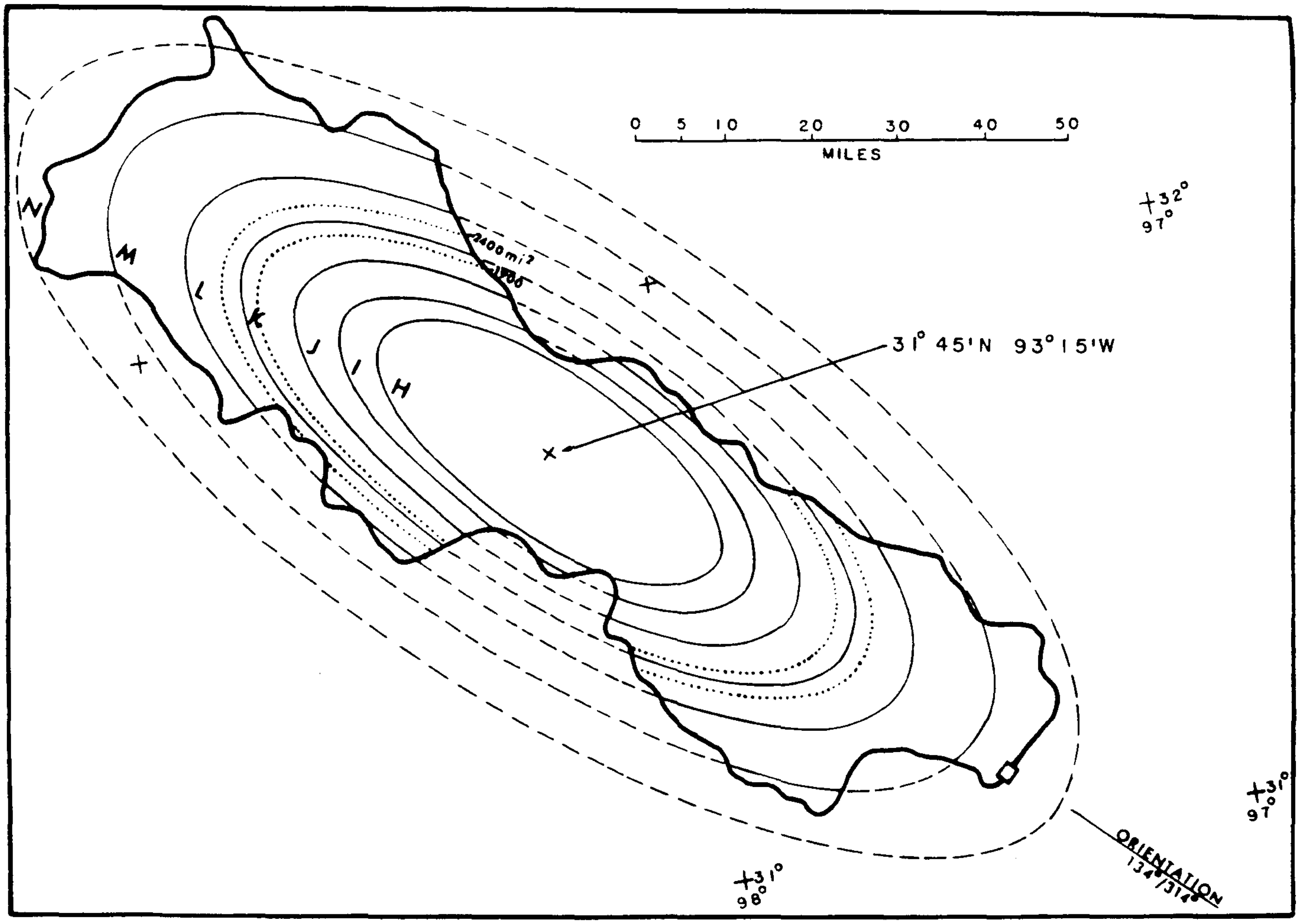


Figure 12. Isohyetal Pattern Placed on Leon River Basin (NWS, 1982)

4.1 Determination of PMP Intensity versus Duration

The PMP for an area of 3,000 mi^2 (determined from Fig. 11) is shown in Figg. 13. The incremental precipitation amounts, calculated (including additional smoothing) from the cumulative amounts given in Fig. 13, are as follows:

6–hr Increment	PMP Inches	Increment	Inches
1	11.40	7	1.00
2	4.14	8	1.00
3	2.71	9	0.90
4	2.11	10	0.90
5	1.64	11	0.80
6	1.20	12	0.80

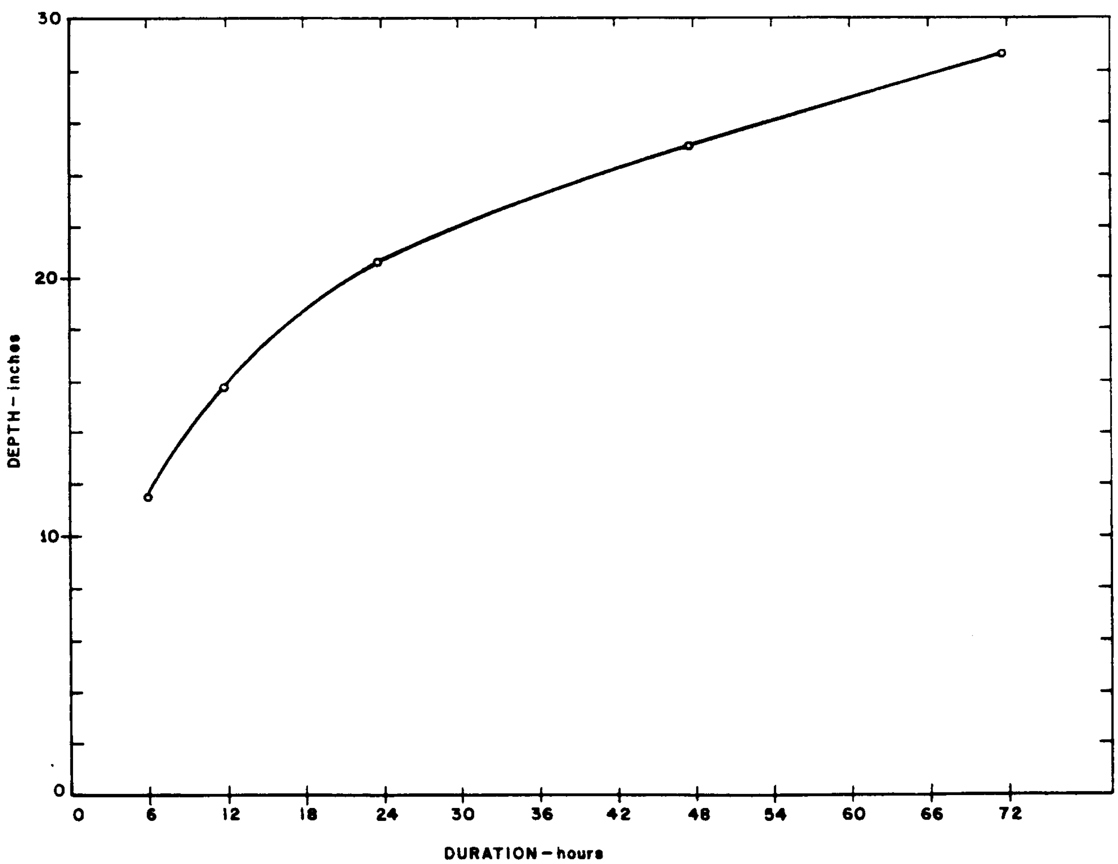


Figure 13. PMP Depth-Duration for 3,000 mi^2 Storm on Leon River Basin

4.2 Adjustment for Storm Orientation

From Fig. 3, the preferred orientation for this storm location is 208°, which differs by 106° from the selected orientation of 314°. From Fig. 4, the PMP must therefore be multiplied by 0.85. The adjusted PMP is as follows:

6-hr Increment	PMP Inches	Increment	Inches
1	9.69	7	0.85
2	3.52	8	0.85
3	2.30	9	0.77
4	1.79	10	0.77
5	1.39	11	0.68
6	1.02	12	0.68

4.3 Determination of Basin—Average Precipitation

The nomograms in Figs. 14 through 17 are required for determining the spatial distribution of precipitation. Tables 7 through 10 show computations to determine basin—average precipitation for the four largest 6—hr increments. Basin—average precipitation for the remaining increments (5th through 12th) can be obtained as a proportion of the 4th largest increment, because the same spatial distribution is used. For example, the 3,000 mi^2 PMP for the 5th largest increment is 1.39 inches. Basin-average precipitation for the increment is 1.39 (1.69/1.79) = 1.31 inches. Basin-average precipitation for the twelve increments is as follows:

6-hr Increment	PMP Inches	Increment	Inches
1	8.31	7	0.80
2	3.25	8	0.80
3	2.17	9	0.73
4	1.69	10	0.73
5	1.31	11	0.64
6	0.96	12	0.64

4.4 Temporal Arrangement

An acceptable temporal arrangement (Fig. 7) of the basin average Precipitation is as follows:

Day	6-hr Period	Basin-Average Precipitation	Day	6-hr Period	Basin-Average Precipitation
1	1	0.64 inches		7	1.31
	2	0.64		8	2.17
	3	0.73	3	9	8.31
	4	0.73		10	3.25
2	5	0.80		11	1.69
	6	0.96		12	0.80

Table 7

Basin—Average Precipitation for Largest 6—hr Increment

Isohyet	Area Within Isohyet sq.mi.	Area Within Isohyet and Basin (A) sq.mi.	Incremental Area) A sq.mi.	% of 3000 sq.mi. PMP (9.69 in.)	Isohyet Precipitation in.	Average Precipitation on) A in.	Volume of Precipitation in.-sq.mi.
A	10	10	10	191	18.51	18.51	185.1
B	25	25	15	179	17.35	17.93	268.9
C	50	50	25	166	16.09	16.72	418.0
D	100	100	50	154	14.92	15.51	775.5
E	175	175	75	142	13.76	14.34	1075.5
F	300	300	125	132	12.79	13.28	1660.0
G	45D	450	150	122	11.82	12.31	1846.5
H	700	700	25D	112	1D.85	11.34	2835.0
I	1000	971	271	102	9.88	10.37	2810.0
U	1500	1364	393	92	8.91	9.39	3690.3
K	2150	1852	488	83	8.04	8.48	4138.2
L	3000	2434	582	74	7.17	7.61	4429.0
M	4500	3171	737	44	4.26	6.01	4429.4
N	6500	3660	489	25	2.42	3.80	1858.2
							30419.9

Basin-Avg. Ppt. = 30419.9 ÷ 3660 = 8.31 in

Table 8

Basin—Average Precipitation for Second Largest 6—hr Increment

Isohyet	Area Within Isohyet sq.mi.	Area Within isohyet and Basin (A) sq.mi.	Incremental Area) A sq.mi.	% of 3000 sq.mi. PMP (3.52 in.)	Isohyet Precipitation in.	Average Precipitation on) A in.	Volume of Precipitation in.-sq.mi.
A	10	10	10	119.5	4.21	4.21	42.1
B	25	25	15	116	4.08	4.15	62.2
C	50	50	25	112.5	3.96	4.02	100.5
D	100	100	so	110	3.87	3.92	196.0
E	175	175	75	108	3.80	3.84	288.0
F	300	300	125	106	3.73	3.77	471.3
G	450	450	150	104	3.66	3.70	555.0
H	700	700	250	102	3.59	3.63	907.5
I	1000	971	271	100.5	3.54	3.56	964.8
J	1500	1364	393	99	3.48	3.51	1379.4
K	2150	1052	488	97	3.41	3.45	1683.6
L	3000	2434	582	96	3.38	3.40	1978.8
M	4500	3171	737	67	2.36	2.97	2188.9
N	6500	3660	489	45	1.58	2.17	1061.1
							11879.2

Basin-Avg. Ppt. = 11879.2 ÷3 660 = 3.25 in.

Table 9

Basin-Average Precipitation for Third Largest 6-hr Increment

Isohyet	Area Within Isohyet sq.mi.	Area Within Isohyet and Basin (A) sq.mi	Incremental Area)A sq.mi.	% of 3000 sq.mi. PMP (2.30 in.)	Isohyet Precipitation in.	Average Precipitation on)A in.	Volume of Precipitation in.-sq.mi
A	10	10	10	105.7	2.43	2.43	24.3
B	25	25	15	104.6	2.41	2.42	36.3
C	50	50	25	103.5	2.38	2.40	60.0
D	100	100	50	102.5	2.36	2.37	118.5
E	175	175	75	101.7	2.34	2.35	176.3
F	300	300	125	101.3	2.33	2.335	291.9
G	450	450	150	100.9	2.32	2.325	348.8
H	700	700	250	100.5	2.31	2.315	578.8
I	1000	971	271	100.2	2.30	2.305	624.7
J	1500	1364	393	99.9	2.30	2.30	903.9
K	2150	1852	488	99.6	2.29	2.295	1120.0
L	3000	2434	582	99.3	2.28	2.285	1329.9
M	4500	3171	737	76	1.75	2.07	1525.6
N	6500	3660	489	57	1.31	1.64	802.0
							7941.0

<u>Basin- Avg. Ppt.</u> = 7941.0 ÷ 3660 = <u>2.17 in</u>.

Table 10

Basin-Average Precipitation for Fourth Largest 6-hr Increment

Isohyet	Area Within Isohyet sq.mi.	Area Within Isohyet and Basin (A) sq.mi	Incremental Area)A sq.mi.	% of 3000 sq.mi. PMP (1.79 in.)	Isohyet Precipitation in.	Average Precipitation on)A in.	Volume of Precipitation in.-sq.mi
A	10	10	10	100	1.79	1.79	
B	25	25	15	100	1.79	1.79	
C	50	50	25	100	1.79	1.79	
D	100	100	50	100	1.79	1.79	
E	175	175	75	100	1.79	1.79	
F	300	300	125	100	1.79	1.79	
G	450	450	150	100	1.79	1.79	
H	700	700	250	100	1.79	1.79	
I	1000	971	271	100	1.79	1.79	
J	1500	1364	393	100	1.79	1.79	
K	2150	1852	488	100	1.79	1.79	
L	3000	2434	582	100	1.79	1.79	
M	4500	3171	737	76	1.36	1.62	1193.9
N	6500	3660	489	57	1.02	1.28	625.9

Basin-Avg. Ppt. = [1.79 (2434) + 1193.9 + 625.9] ÷ 3660 = 1.69 in.

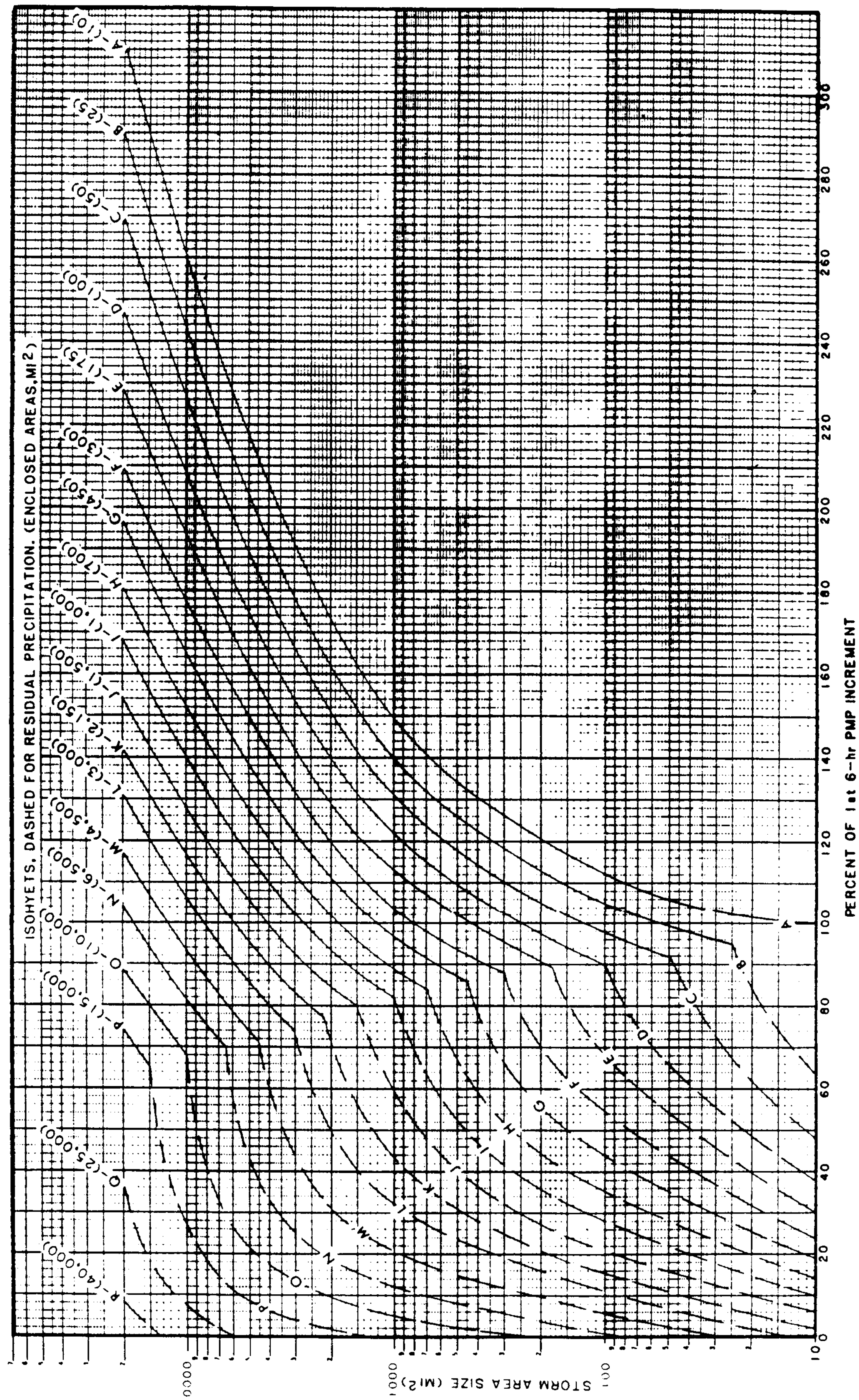


Figure 14. Nomogram for 1st 6-hr PMP Increment (NWS, 1982)

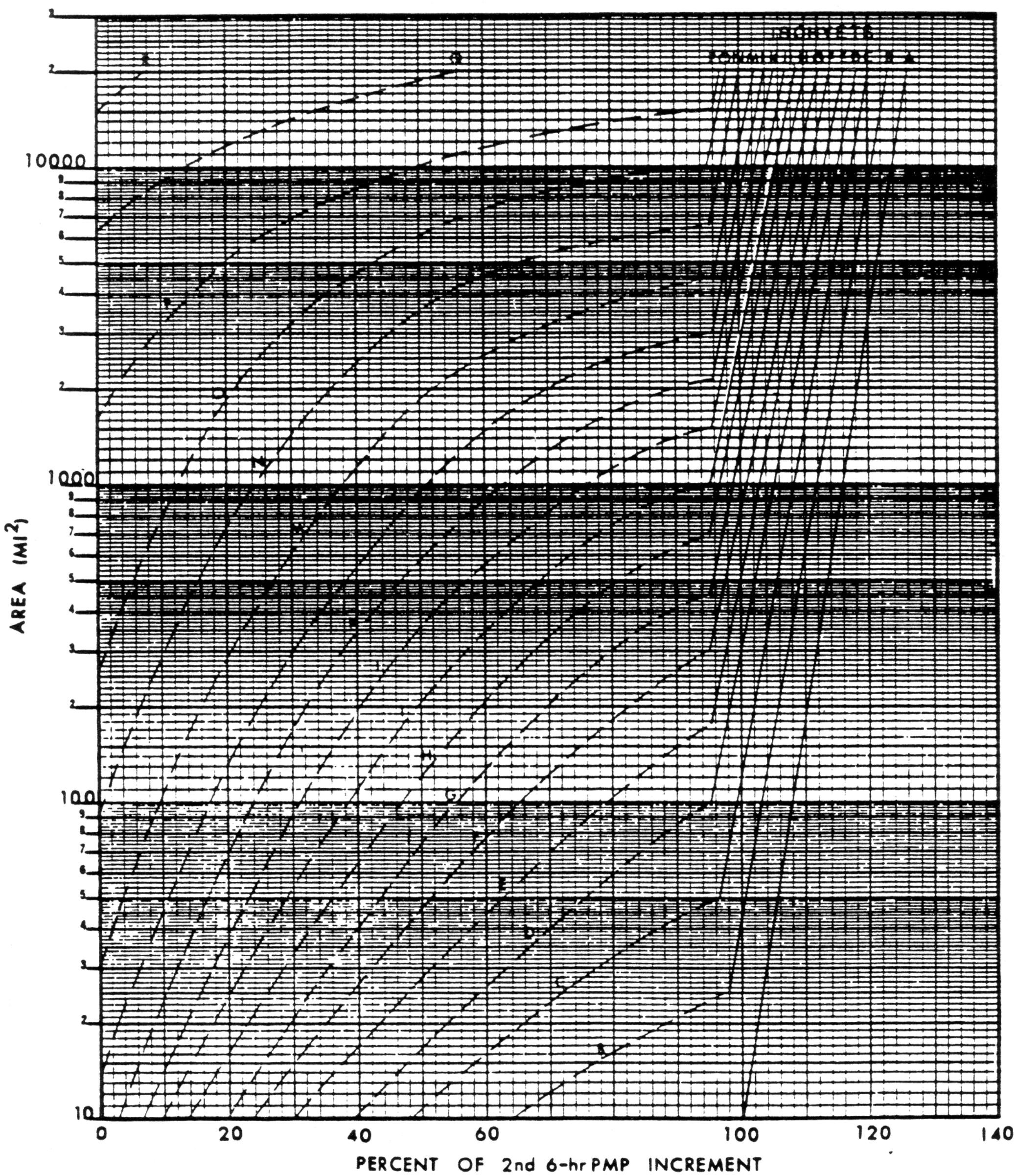


Figure 15. Nomogram for 2nd 6-hr PMP Increment (NWS, 1982)

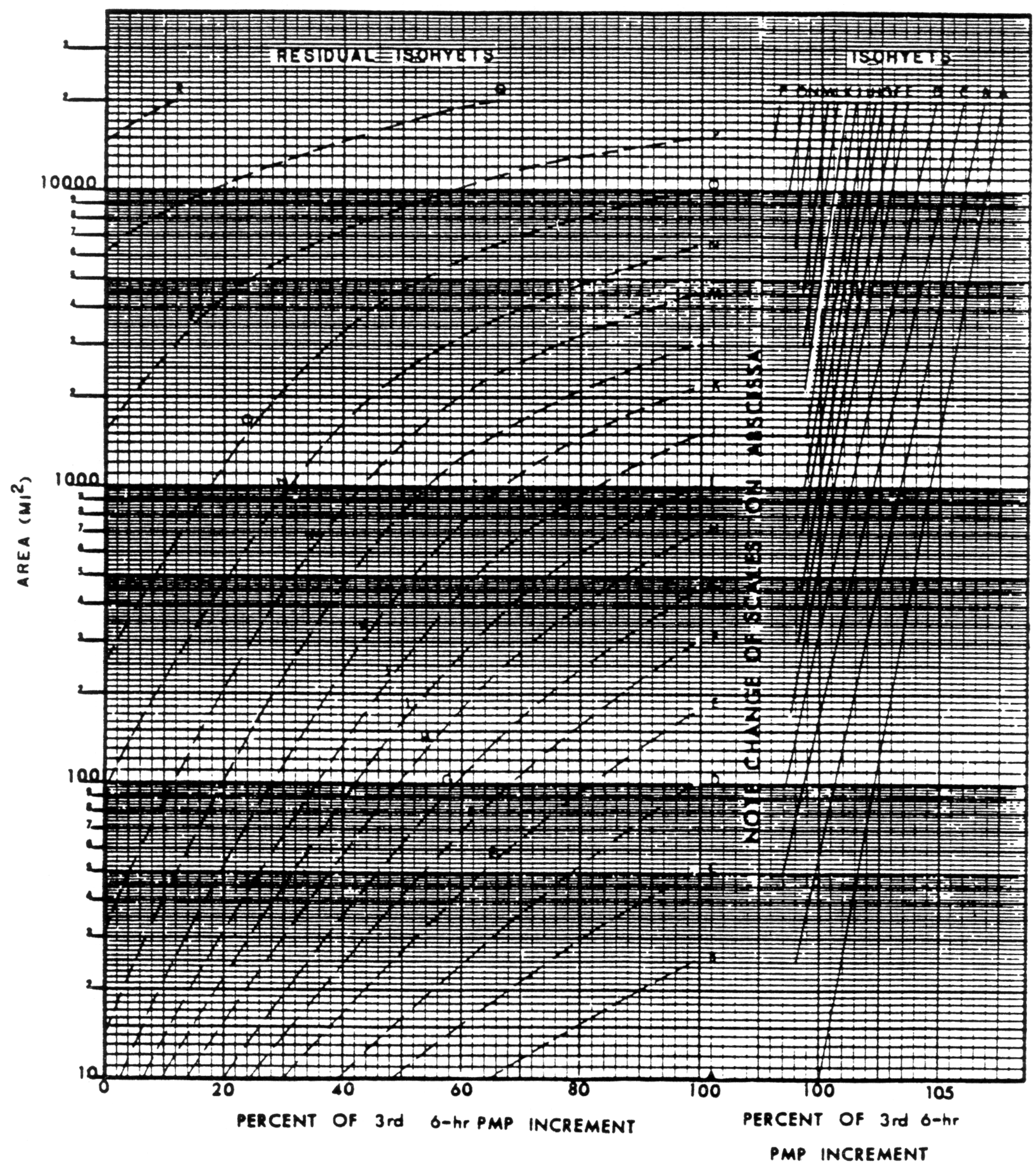


Figure 16. Nomogram for 3rd 6-hr PMP Increment (NWS, 1982)

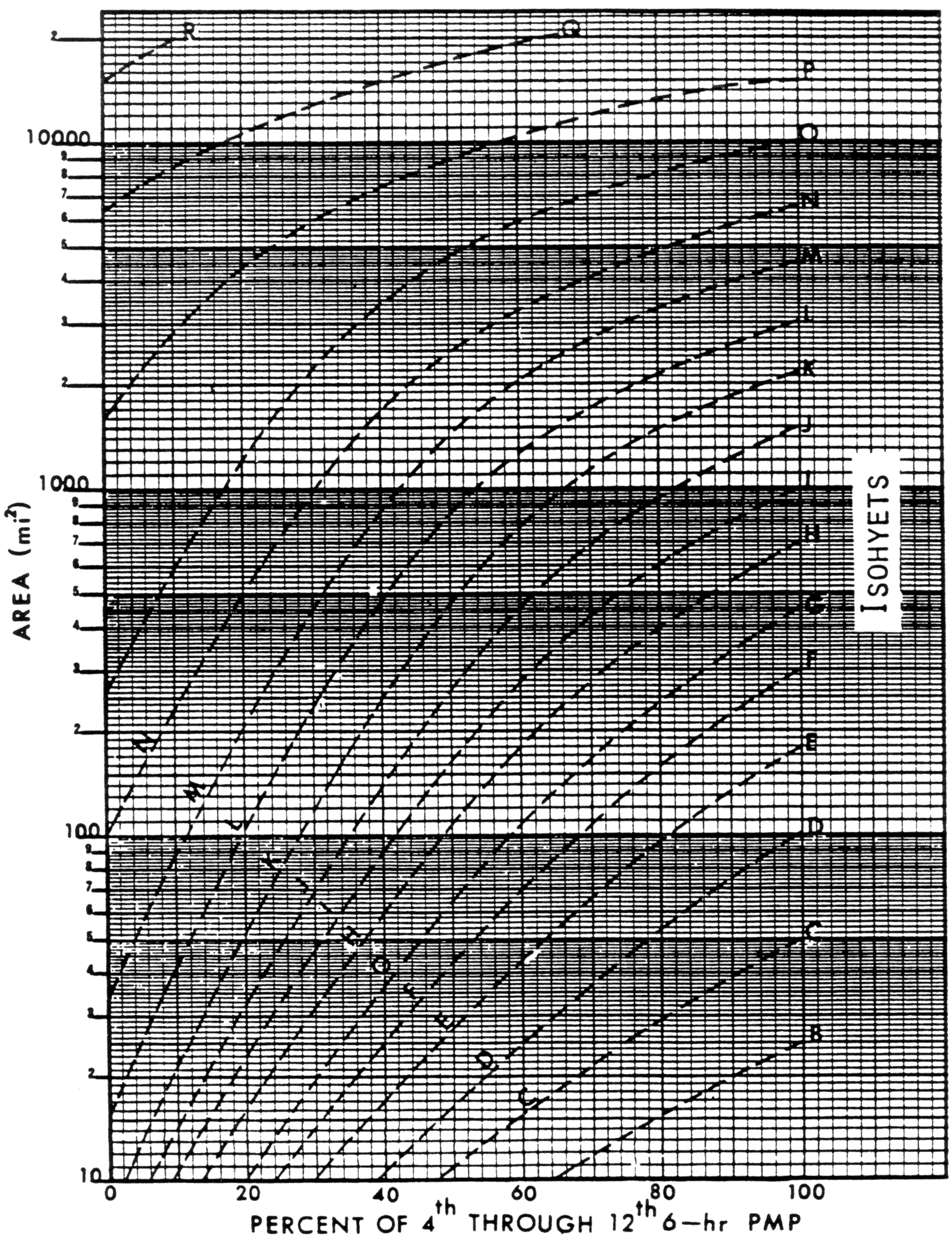


Figure 17. Nomogram for 4th through 12th 6-hr PMP Increment (NWS, 1982)

4.5 PMF Determination

The example just shown provides a storm for a specific storm–area size, storm centering and storm orientation. What would be required for a PMF analysis, however, would be the storm that produces the maximum peak discharge or runoff volume, depending on the project purpose, for the 3,660 mi^2 drainage basin. It is therefore necessary to try various combinations of storm–area size, centering, orientation and temporal distribution until maximization of peak discharge or runoff volume is achieved. Fig. 18 illustrates how basin average precipitation varies with storm–area size for the Leon River basin. For the particular centering and orientation used in the example, a storm–area size of 2,150 mi^2 produces the maximum basin average precipitation. As may be deduced from the example problem, voluminous computations are required to determine the PMS. The HMR52 computer program has been developed to facilitate that task.

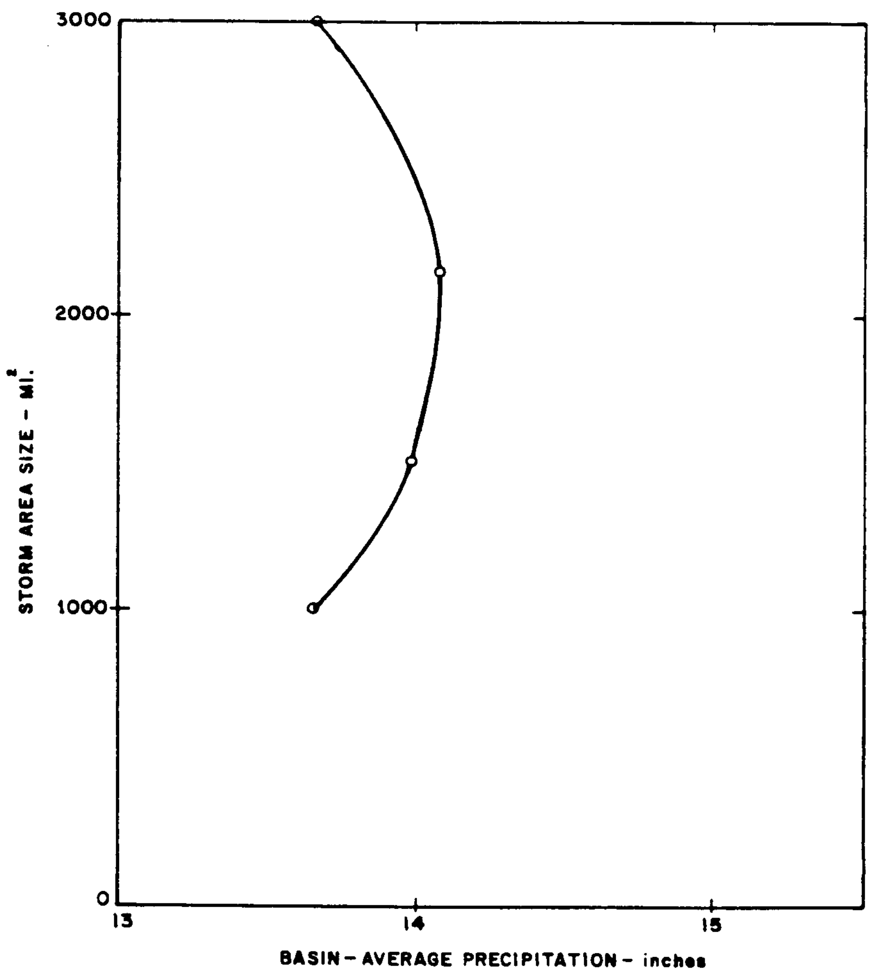


Figure 18. 18-hr Basin-Average Precipitation For 3,660 mi2 Leon River Basin

Section 5

COMPUTER PROGRAM HMR52 PROCEDURES

5.1 Digital Definition of Basin Geometry

The HMR52 computer program uses a digital definition of the watershed boundaries for computing basin-average precipitation from watershed area and superposed isohyetal patterns. The boundary of a drainage basin is defined by line segments joining a sequence of coordinate points. The sequence of boundary points should be counter-clockwise around the basin or subbasin. If the direction is clockwise the program will reverse the order to be counter-clockw,se for later calculations.

5.1.1 Geometric Properties

The following geometric properties of the watershed are calculated using the n boundary points having coordinates (x,, y,):

Area (A):

$$A = -(1/2) \sum_{i=1}^{n} (x_{i+1} - x_i)(y_{i+1} + y_i) \quad \ldots\ldots\ldots \quad (1)$$

Centroid coordinates (x_c, y_c) :

$$x_c = -[1/(6A)] \sum_{i=1}^{n} (x_{i+1} - x_i)(y^2_{i+1} + y_{i+1} y_i + y^2_i) \quad \ldots\ldots \quad (2)$$

$$y_c = -[(1/6A)] \sum_{i=1}^{n} (x_{i+1} - x_i)[y_{i+1}(2x_{i+1} + x_i) + y_i(x_{i+1} + 2x_i)] \quad \ldots\ldots\ldots \quad (3)$$

Moment of Inertia about x and y axes (I_x, I_y) :

$$I_x = -(1/12) \sum_{i=1}^{n} (x_{i+1} - x_i)(y^2_{i+1} + y^2_i)(y_{i+1} + y_i) \quad \ldots\ldots \quad (4)$$

$$I_y = -(1/12) \sum_{i=1}^{n} (x_{i+1} - x_i)[x^2_{i+1}(3y_{i+1} + y_i) + 2x_{i+1}x_i(y_{i+1} + y_i) + x_i^2(y_{i+1} + 3y_i)] \quad \ldots\ldots \quad (5)$$

Product of Inertia about the origin (P_{xy}):

$$P_{xy} = -(1/24) \sum_{i=1}^{n} (x_{i+1} - x_i) [y^2_{i+1} (3x_{i+1} + x_i) + 2y_{i+1}y_i(x_{i+1} + x_i) + y^2_i (x_{i+1} + 3x_i)] \quad . . . . . (6)$$

Angle to rotate coordinate axes to produce minimum moment of inertia about the x-axis. (θ_m)

$$(\theta_m) = (1/2) \arctan [-2P_{xy}/(I_x - I_y)] \qquad \text{for } I_x < I_y \quad . . . \quad (7a)$$

$$(\theta_m) = (1/2) \arctan \{[-2P_{xy}/(I_x - I_y)] - \pi/2\} \qquad \text{for } I_x > I_y \quad . . . \quad (7b)$$

5.1.2 Coordinate Systems

The basin is described in an x,y coordinate system with x-axis directed eastward and y-axis directed northward. Placement of the coordinate system origin and the coordinate units are arbitrary.

The isohyetal pattern of the PMS is described in a u,v coordinate system which has its origin at the storm center and axes parallel to the major and minor axes of the elliptical pattern. The coordinate units are in miles.

The transformation from the x,y axes to the u,v axes is given by:

$$u = (x - x_s) \cos \theta + (y - y_s) \sin \theta \, F_s \quad . . . . (8a)$$

$$v = (y - y_s) \cos \theta - (x - x_s) \sin \theta \, F_s \quad . . . . (8b)$$

where (x_s,y_s) is the position of the storm center, θ is the angle of rotation from the x-axis to the u-axis, and F_s is a scale factor in miles per x,y coordinate unit.

5.2 Calculation of PMP for a Storm Area

This calculation is made for a given storm area and depth-area-duration data from HMR No. 51. The procedure used is as follows:

5.2.1 Interpolation of PMP Depth-Area-Duration Curves

The user supplies PMP depths from HMR No. 51 for standard areas and durations that bracket the storm area of interest. Straight line Interpolation is used in the program to calculate PMP for the storm area for durations of 6, 12, 24, 48, and 72 hours (e.g. Fig. 19).

Between 10 and 200 mi^2, the error from using straight line interpolation versus curve fitting is significant. To reduce this error, an additional point is calculated midway between $\log_{10} 10$ and $\log_{10} 200$ mi^2. This area is approximately 44.7 mi^2, Fig. 19. The difference in PMP from 10 to 200 mi^2 for this curve was 8.5 Inches. To estimate PMP at 44.7 mi^2 for other locations an adjustment of 1/8.5 times the difference in PMP from 10 to 200 mi^2 is added to the PMP resulting from straight line interpolation.

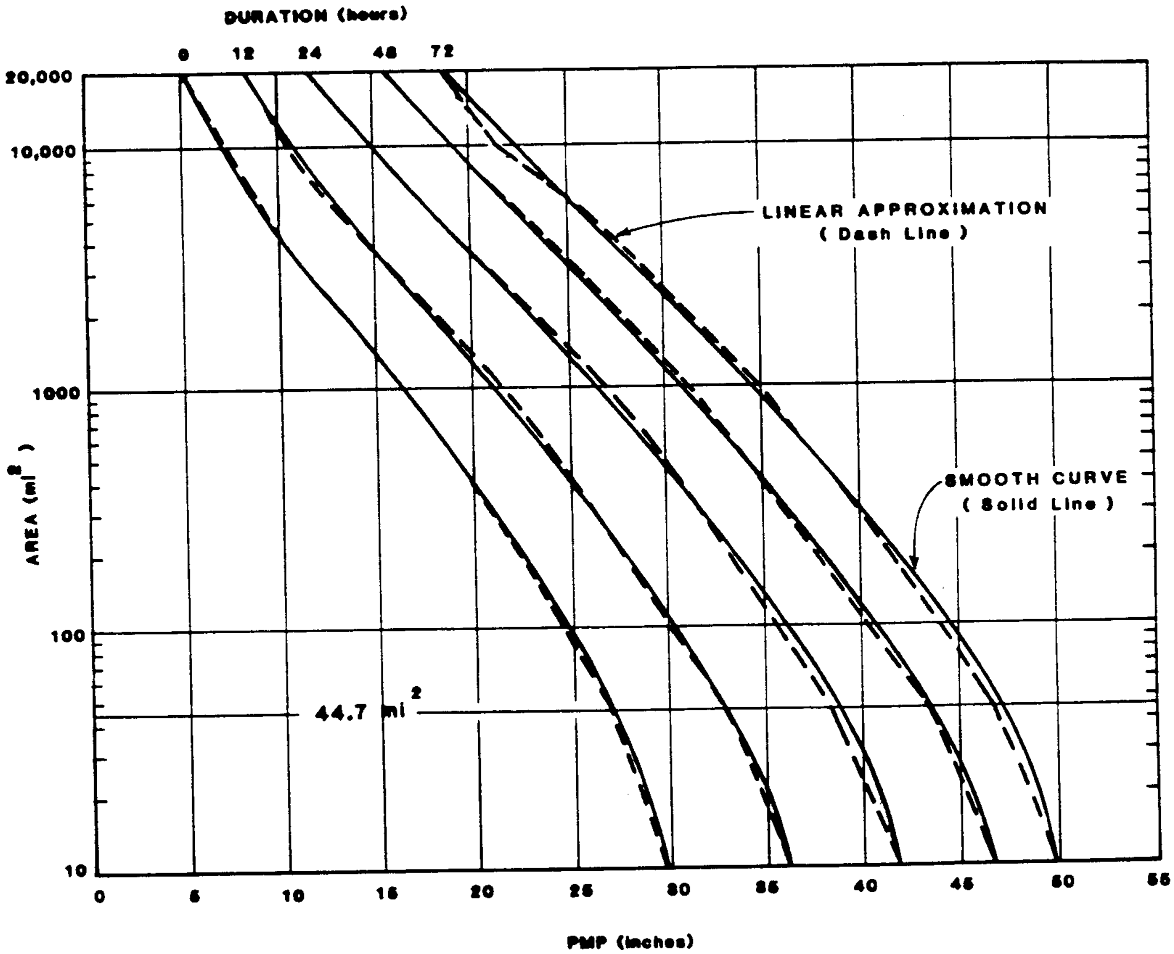


Figure 19. Linear Approximation of Depth—Area—Duration Relations

5.2.2 PMP Depth-Duratlon Curve Fitting

A logarithmic curve is fit through the depth versus log duration data using a least-squared-error fit.

The equation of the curve Is

$$P = a + b\,\ell n(D+S) \quad . . . . \qquad (9)$$

where P Is PMP In Inches; D is duration in 6-hr periods; S is a shift adjustment ranging from -1 to 2.5 6-hr periods; and a and b are derived constants. The shift adjustment is determined by trial and error to minimize the sum of squared errors to reproduce a curve such as was shown in Fig. 13.

5.2.3 Incremental PMP Calculation

PMP is computed from equation (9) for durations from 6 to 72 hours. Incremental 6-hr PMP Is then computed as the difference between the values of PMP for successive durations. The PMP for the i^{th} 6-hr period, P_i, is

$$P_i = a + b\,\ell n(i + S) - P_{i-1} \quad . . . . \qquad (10)$$

5.3 Calculation of PMS for Given Storm Area and Orientation

5.3.1 Orientation Adjustment

PMP is calculated for the storm-area size as described in Section 3. This PMP is multiplied by the orientation factor, F_o, which Is computed from

$$F_o = 1 - 0.15\, C_1 C_2 \quad . . . . \qquad (11)$$

$$\text{where } C_1 = \begin{cases} 0 & \text{for } |O_s - O_p| \le 40 \\ \dfrac{|O_s - O_p| - 40}{25} & \text{for } 40 \le |O_s - O_p| \le 65 \\ 1 & \text{for } |O_s - O_p| \ge 65 \end{cases}$$

$$\text{and } C_2 = \begin{cases} 0 & \text{for } A_s \le 300 \\ \dfrac{A_s - 300}{2700} & \text{for } 300 \le A_s \le 3000 \\ 1 & \text{for } A_s \ge 3000 \end{cases}$$

where O_s Is the storm orientation, O_p Is the preferred orientation and A_s, the storm area.

The adjusted PHP, P_i', for the i^{th} 6-hr period is calculated as

$$P_i' = P_i * F_0 \quad . . . . (12)$$

5.3.2 Isohyet values

The percent of PHP for each lsohyet Is Interpolated from the data In Tables 1 through 4 using straight line interpolation of percent versus natural log of area. Multiplying PMP by the percentages gives the precipitation amount for each isohyet for each 6-hr period for a given storm-area size. Thus, the PHP for the j^{th} lsohyet and i^{th} 6-hr period is

$$P_{i,j} = P_i' * PCT_j \quad . . . . (13)$$

where PCT_j Is the percentage of the PHP In the j^{th} Isohyet.

5.3.3 Calculation of area enclosed by an ellipse and the basin boundary

Coordinates of the boundary points are transformed to the PHS coordinate system using equatlons (8a) and (8b). The intersections of the ellipse with the basin boundary are located. Each arc of the ellipse between intersections Is approximated by 20 points located at equiangular Increments. The area of the basin encompassed by the ellipse (see Fig. 20) Is calculated from equation (1).

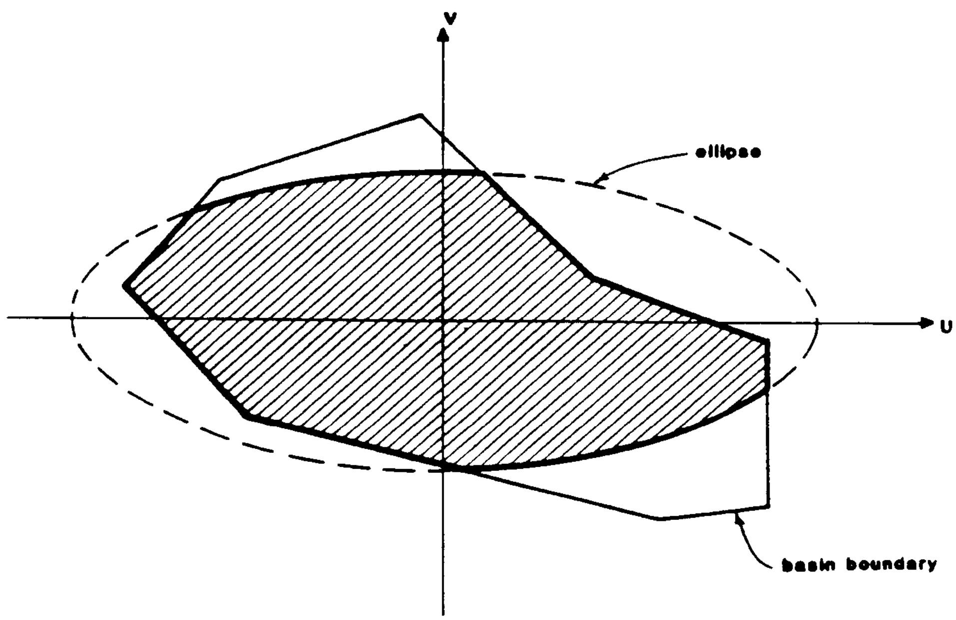


Figure 20. Basin Area Encompassed by Ellipse

5.3.4 Basin-average precipitation

The precipitation volume, V, between Isohyets is computed as the volume of a truncated cone (see Fig. 21). The volume for the i^{th} 6-hr period is

$$V_i = \frac{P_{i,j} - P_{i,j+1}}{3} \left(A_j + A_j A_{j+1} + A_{j+1}\right) \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (14)$$

where subscript j identifies the Isohyet and A is the drainage basin area encompassed by the ellipse corresponding to the Isohyet. Basin average precipitation is the sum of volumes between Isohyets divided by the drainage basin area.

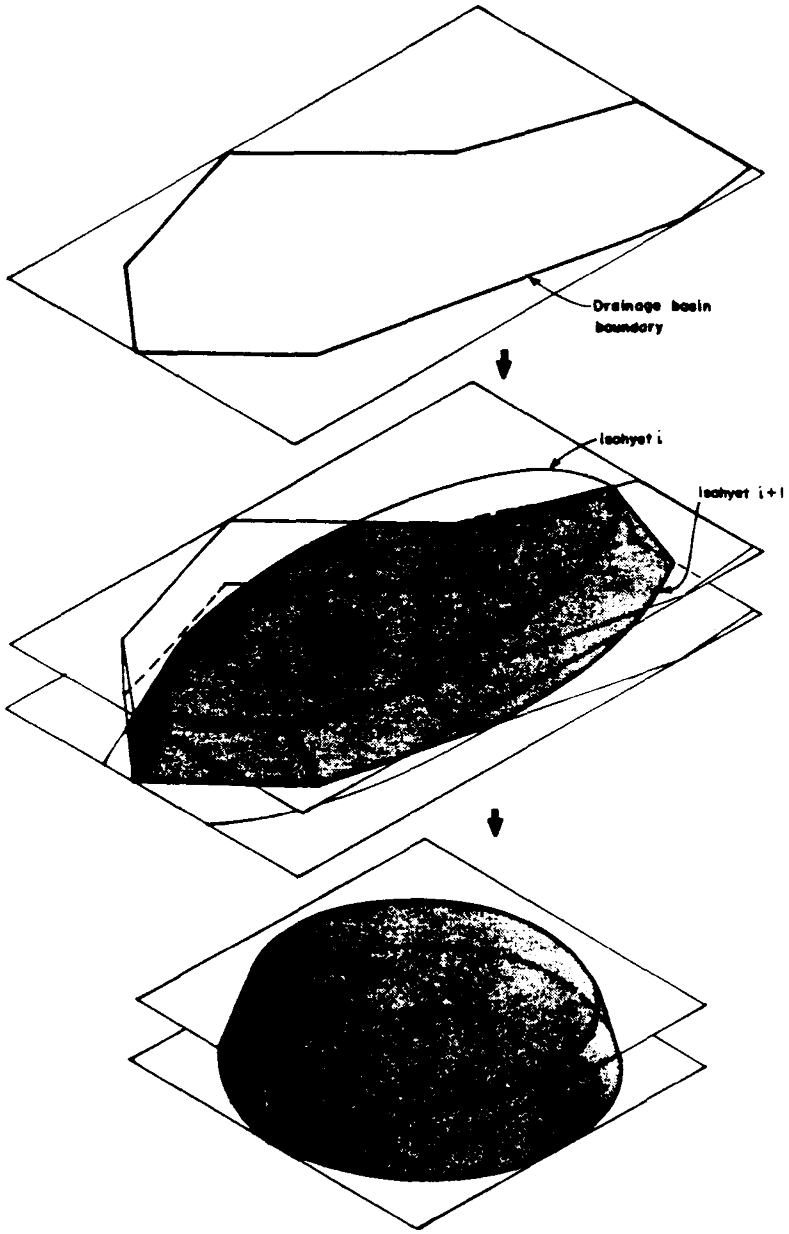


Figure 21. Representation of Precipitation Volume Between Two Isohyets with a Truncated Cone

5.4 Calculation of PMS for Time Intervals Less Than 6 Hours

After the storm-area size and orlentatlon have been determined, the program calculates the temporal distribution.The required data for this calculation are: the desired time Interval, Δt, In minutes; and the ratio of 1-hr to 6-hr preclpltatlon for the 20,000 mi^2 'A' Isohyet, referred to as R16A20, from Fig 8. The procedure used In the HMR52 program is as follows.

The NWS has developed a set of curves describing the 1-hr/6-hr ratio for each isohyet and various storm-area sizes (figure 40, NWS, 1982). Those curves have been tabulated by HEC into a set of discrete values as shown In Table 5. Those Table 5 values are automatically specified in the HMR52 program (see Computer Requirements section and Table 24). The value of that ratio for the j^{th} lsohyet, $R16TAB_j$, for a specific storm-area size, Is Interpolated from Table 5 data using straight line interpolation of logarlthms of the area. Those generalized values are adjusted by the required Input value, R16A20, to obtain the required ratio for the j^{th} isohyet, $R16_j$.

$$R16_j = R16TAB_j + R16A20 \quad . . . . \quad (15)$$

The 1-hr ralnfall for the j^{th} lsohyet Is computed as

$$Pl_j = R16_j * P_{1,j} \quad . . . . \quad (16)$$

where $P_{l,j}$ Is the maximum 6-hr precpitation for isohyet j calculated in equation' (13).

A least square quadratic equation is fit through the 0-, l-, 6-, 12-, 18-, and 24-hr precipitation amounts for each isohyet. For residual precipitation (outside the storm area) the 1-hr amount is omitted. Precipitation is interpolated for 5-, l0-, 15-, 30-min 2-, and 3-hr durations for each isohyet. The average precipitation over the basin is computed for each of these durations, Fig. 22.

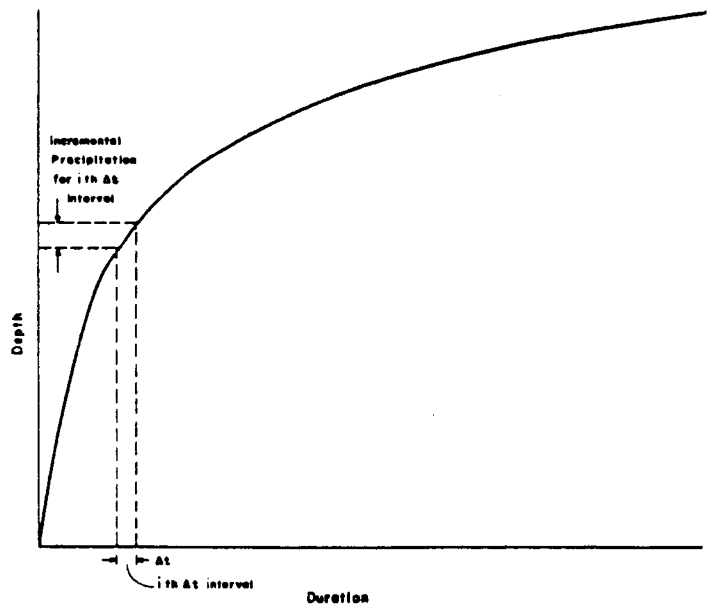


Figure 22. PMS Depth versus

Incremental precipitation is calculated for the total number of)t intervals from the basin–averaged depth versus duration data. This results in a sequence of intervals with decreasing precipitation intensity, Fig. 23. Incremental precipitation is assumed to be uniform within each 6-hr period beyond 24–hrs duration. These intervals are rearranged to form the PMS as follows:

> The position of the largest 6–hr increment may occur any time after the first 24 hours of the storm as shown in Fig. 24. The seventh position (hours 37–42) is chosen by default.
>
> The largest)t increment of precipitation is placed in the middle of the largest 6-hr precipitation interval. The remaining)t increments for that 6-hr period are arranged alternately before and after the largest increment.
>
> The remaining 6–hr intervals, with decreasing precipitation magnitude, are arranged alternately before and after the largest 6–hr–precipitation interval, except the second, third, and fourth largest 6–hr Increments cannot be placed in the first 24 hours of the storm. These increments are placed after the largest increment, if their normal position would fall in the first 24 hours of the PMS. The)t increments within the second, third and fourth largest 6–hr increment are arranged to increase towards the storm's peak precipitation. This results in a triangular–like hyetograph of PMS precipitation.

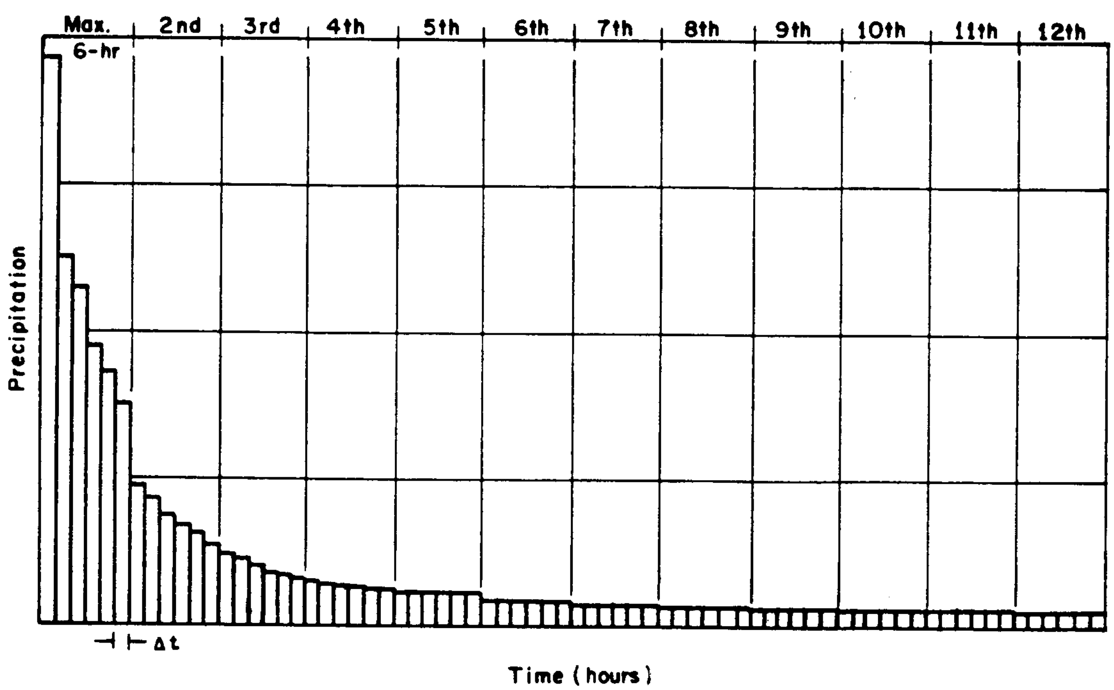


Figure 23. Incremental PMS Depth Histogram

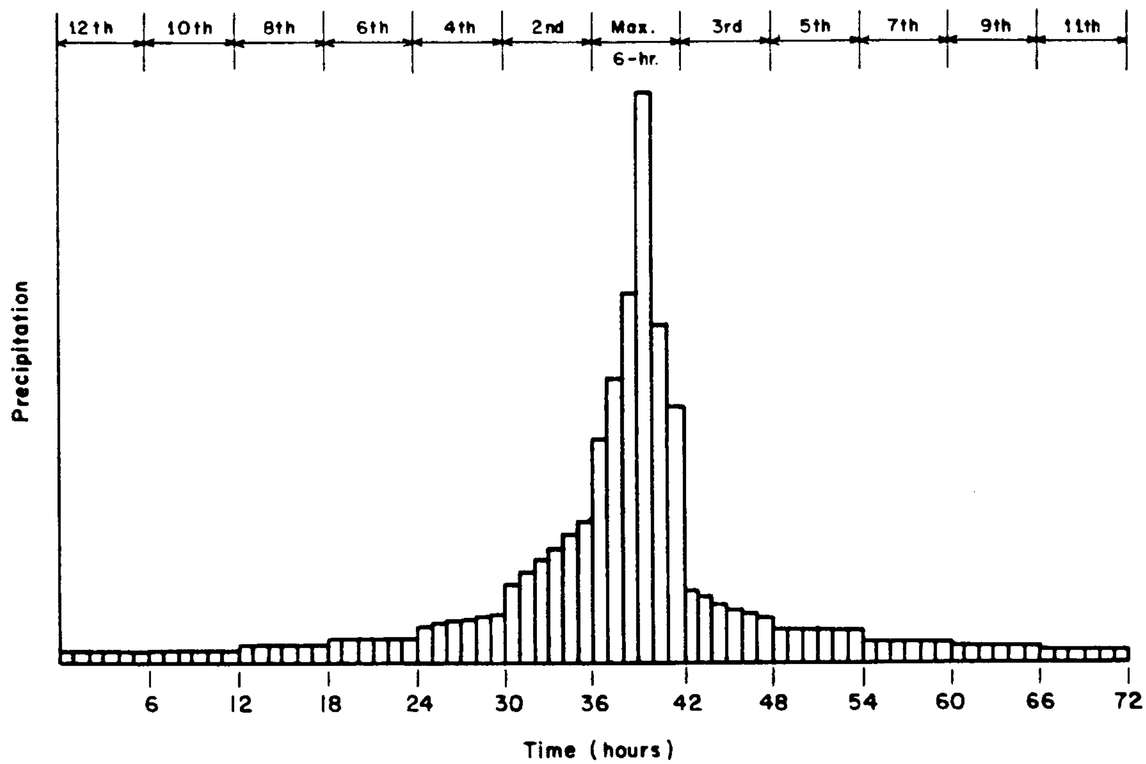


Figure 24. Example 1-hr Distribution of PMS

Section 6

OPTIMIZATION OF STORM-AREA SIZE AND ORIENTATION

The amount of precipitation on a basin is affected by the storm placement, storm-area size and storm orientation. HMR52 uses a procedure to estimate storm—area size and orientation which will produce maximum precipitation on the basin. This procedure will determine the optimal storm—area size and orientation for most basins. However, because of the interaction of storm placement and orientation, several trials should be made to verify that the optimal values have been found.

6.1 Storm Center

When the storm placement is not given, the storm center is placed at the basin centroid.

6.2 Storm-Area Size

If the storm orientation is not given, a trial orientation along the axis for which the basin has a minimum moment of inertia is used. This orientation is selected as an analytically determinable orientation which is most likely to produce maximum precipitation on the basin without regard to the orientation adjustment factor. Using the trial orientation the average precipitation on the basin is calculated for several storm—area sizes (see example is Section 9). The storm—area size which produces maximum precipitation is selected as the critical storm—area size. The critical storm—area size may need to be recomputed if other orientations or placements are used.

6.3 Storm Orientation

Because of interaction between basin shape and the orientation adjustment factor, the trial orientation used to select storm—area size may not produce maximum precipitation on the basin. Using the critical size selected above, the storm precipitation is calculated for orientations at 10—degree increments between 135 degrees and 315 degrees. Storm precipitation is then calculated for orientations at plus or minus 5 degrees from the previous best orientation. The orientation which yields maximum precipitation on the basin is chosen as the critical orientation.

If the critical orientation is not the same as was used to select the critical storm—area size, the storm—area size may have to be recomputed using the critical orientation. This is the user's responsibility. It is not done automatically.

6.4 User Control of Optimization

Precipitation on the basin for the purposes of selecting storm—area size and orientation is the cumulative precipitation for the 3 largest 6—hr Periods. The number of periods may be changed by the user.

Storm placement, storm—area size, or orientation may be fixed by the user. In addition the trial orientation used to select critical storm—area size may be specified by the user.

Section 1

INPUT DATA REQUIREMENTS

Input data are described in detail in the Appendix. Table 11 shows the sections of an input data file required to calculate a PMS.

Drainage-Basin-Geometry data Includes coordinates of points on the basin boundary and a scale factor.

Required Hydrometeorological data are the preferred storm orientation from Fig. 3 and PMP estimates from figures 18-47 in HMR No. 51.

The Storm—Specification data define the storm—area size, orientation, and location of the storm center. Calculation of a temporal storm distribution requires the desired time Interval and ratio of 1-hr to 6-hr precipitation from Hg. 8.

Three example input data sets are given In this document:

Leon River--Table 11

Jones Reservoir--Table 14

Ouachita River--Appendix A Example

The Leon River application is for computation of the PMS over a single basin for given storm—area size, orientation, centering, and time pattern.

The Jones Reservoir application is for a multi-subbasin river basin in which the storm-area size and orientation are optimized by the program for the river basin as a whole. The storm centering was not specified so the default centering of the basin centroid is used. The time pattern is given. After computation of the PMS for the entire river basin, the PMS is calculated for each subbasin.

The Ouachlta River example is similar to the Jones Reservoir application except that given storm—area size, orientation and centering data are provided after the optimization is completed. That given PMS is then calculated and subbasin precipitation is computed for the given PMS data, not the optimized values.

Table 11

Sample Input for HMR52

Job Description (Identification)

```
ID PROBABLE MAXIMUM STORM CALCULATION FOR EXAMPLE 1 IN HMR NO. 52
ID LEON RIVER AT BELTON RESERVOIR
```

Drainage Basin Geometry

```
BN  LEON
BS1.0062
BX  46.4    53.4    52.2    52.5    46.1    42.8    34.3    30.0    24.7    22.2
BX  18.7    16.6    14.2    12.6     2.1    -1.2    -1.5    -3.9    -7.3    -7.7
BX -12.4   -19.3   -20.7   -25.8   -28.1   -30.5   -31.3   -38.6   -42.4   -44.8
BX -51.6   -53.6   -55.1   -51.6   -45.6   -36.9   -36.7   -29.5   -29.1   -25.6
BX -25.8   -22.6   -18.6    -9.7    -4.7    -2.5     3.6     5.5     3.2     3.6
BX   5.8     9.6    13.1    15.5    19.8    23.7    26.6    29.4    35.4    38.9
BX  44.0
BY -45.9   -38.4   -32.8   -29.7   -27.7   -19.7   -15.5   -10.7    -8.0    -2.6
BY  -1.2     3.4     5.5     8.5     9.5    15.9    19.5    22.3    33.5    37.7
BY  42.0    41.8    44.9    48.7    55.4    56.4    50.1    49.8    47.5    43.9
BY  42.1    33.6    31.4    28.8    28.2    14.6    10.0    10.6     7.6     4.6
BY  -1.6    -2.9    -9.6    -7.8    -9.4   -14.0   -14.5   -17.2   -20.7   -22.5
BY -23.5   -34.0   -36.7   -41.0   -43.4   -46.7   -45.6   -41.6   -41.0   -42.0
BY -46.9
```

Hydrometeorological Data from HMR No. 51 and 52

```
HO   208
HP    10    29.8    36.2    41.8    46.7    49.8
HP   200    22.3    27.4    33.0    37.5    41.4
HP  1000    16.2    21.2    26.8    31.0    34.5
HP  5000     9.3    13.1    18.1    22.6    25.9
HP 10000     7.2    10.4    14.9    18.8    21.0
HP 20000     5.2     8.2    11.7    15.4    18.4
```

Storm Specification

```
SA  3000     134
SC  -2.2     2.4
ST   120    .306
```

End-of-Job

```
ZZ
```

Section 8

PROGRAM OUTPUT

8.1 Printout

HMR52 printed output begins with a list of the input data, Table 12(a). If data were entered using the free–format option, this list shows the data values in their proper fields.

Table 12(b) shows input PMP from HMR No. 51 and PMP increments for each 6–hr interval and standard storm–area size as interpolated from the HMR No. 51 depth-area--duration data.

Table 12(c) shows coordinates of subbasin boundary points and subbasin area and centroid location calculated from these coordinates.

Table 12(d) shows the basin area within each isohyet and the precipitation amount assigned to the isohyets for each 6–hr interval. This table also shows the basin-average depths calculated from these areas and isohyet values.

When a temporal distribution is requested for an interval less than 6 hours, HMR52 computes a depth versus duration relation for each isohyet. These relations are shown in Table 12(e). They are used to calculate an average depth versus duration relation which is used to calculate incremental precipitation for the temporal distribution in Table 12(f).

8.2 Error Messages

The HMR52 program recognizes some input and computational errors and prints error messages accordingly. These error messages have an Identification Number and Title; Appendix B contains an explanation of each error message.

When an error is detected by HMR52, the program will read through the remaining data and check for Input errors. No calculations will be made using the remaining data.

The computer operating system may also print error messages. When an error occurs, the user should first ascertain if it is generated by HMR52 or by the system. If it is generated by HMR52 (i.e., in the format given in Appendix B) refer to that appendix and take the indicated actions. If the error is system generated, computer systems personnel should be contacted to ascertain the meaning of the error. If these system errors cannot be resolved in–house or if there is an error in the HMR52 program, the HEC should be contacted.

Table 12

Sample Output from HMR52

TABLE 12(a)
Sample Output from HMR52

HEC PROBABLE MAXIMUM STORM INPUT DATA

LINE	ID	1	2	3	4	5	6	7	8	9	10
1	ID	PROBABLE MAXIMUM STORM CALCULATION FOR EXAMPLE 1 IN HMR NO. 52									
2	ID	LEON RIVER AT BELTON RESERVOIR									
3	BN	LEON									
4	BS	1.0062									
5	BX	46.4	53.4	52.2	52.5	46.1	42.8	34.3	30.0	24.7	22.2
6	BX	18.7	16.6	14.2	12.6	2.1	-1.2	-1.5	-3.9	-7.3	-7.7
7	BX	-12.4	-19.3	-20.7	-25.8	-28.1	-30.5	-31.3	-38.6	-42.4	-44.8
8	BX	-51.6	-53.6	-55.1	-51.6	-45.6	-36.9	-36.7	-29.5	-29.1	-25.6
9	BX	-25.8	-22.6	-18.6	-9.7	-4.7	-2.5	3.6	5.5	3.2	3.6
10	BX	5.8	9.6	13.1	15.5	19.8	23.7	26.6	29.4	35.4	38.9
11	BX	44.0									
12	BY	-45.9	-38.4	-32.8	-29.7	-27.7	-19.7	-15.5	-10.7	-8.0	-2.6
13	BY	-1.2	3.4	5.5	8.5	9.5	15.9	19.5	22.3	33.5	37.7
14	BY	42.0	41.8	44.9	48.7	55.4	56.4	50.1	49.8	47.5	43.9
15	BY	42.1	33.6	31.4	28.8	28.2	14.6	10.0	10.6	7.6	4.6
16	BY	-1.6	-2.9	-9.6	-7.8	-9.4	-14.0	-14.5	-17.2	-20.7	-22.5
17	BY	-23.5	-34.0	-36.7	-41.0	-43.4	-46.7	-45.6	-41.6	-41.0	-42.0
18	BY	-46.9									
	**										
19	HO	208									
20	HP	10	29.8	36.2	41.8	46.7	49.8				
21	HP	200	22.3	27.4	33.0	37.5	41.4				
22	HP	1000	16.2	21.2	26.8	31.0	34.5				
23	HP	5000	9.3	13.1	18.1	22.6	25.9				
24	HP	10000	7.2	10.4	14.9	18.8	21.0				
25	HP	20000	5.2	8.2	11.7	15.4	18.4				
	**										
26	SA	3000	134								
27	SC	-2.2	2.4								
28	ST	120	.306								
29	ZZ										

```
*****************************************
*                                       *
*   PROBABLE MAXIMUM STORM  (HMR52)     *
*         NOVEMBER 1982                 *
*       REVISED 31 AUG 84               *
*                                       *
*                                       *
*                                       *
*****************************************
```



```
*****************************************
*                                       *
*     U.S. ARMY CORPS OF ENGINEERS      *
*  THE HYDROLOGIC ENGINEERING CENTER    *
*          609 SECOND STREET            *
*      DAVIS, CALIFORNIA 95616          *
*  (916) 551-1748 OR (FTS) 460-1748     *
*                                       *
*****************************************
```


PROBABLE MAXIMUM STORM CALCULATION FOR EXAMPLE 1 IN HMR NO. 52
LEON RIVER AT BELTON RESERVOIR
PROGRAM IS GIVEN THE STORM AREA AND ORIENTATION

PMP DEPTHS FROM HMR 51

AREA			DURATION		
(SQ. MI.)	6-HR	12-HR	24-HR	48-HR	72-HR
10.	29.80	36.20	41.80	46.70	49.80
200.	22.30	27.40	33.00	37.50	41.40
1000.	16.20	21.20	26.80	31.00	34.50
5000.	9.30	13.10	18.10	22.60	25.90
10000.	7.20	10.40	14.90	18.80	21.00
20000.	5.20	8.20	11.70	15.40	18.40

STORM AREA						PMP DEPTHS FOR 6-HOUR INCREMENTS						
10.	29.71	6.47	3.29	2.22	1.68	1.35	1.13	.97	.85	.76	.68	.62
25.	27.96	6.17	3.25	2.22	1.69	1.36	1.14	.98	.86	.77	.69	.63
50.	26.51	5.91	3.21	2.21	1.69	1.37	1.15	.99	.87	.78	.70	.64
100.	24.37	5.54	3.14	2.21	1.70	1.38	1.17	1.01	.89	.79	.72	.65
175.	22.65	5.25	3.09	2.20	1.71	1.40	1.18	1.02	.90	.81	.73	.67
300.	20.70	5.18	3.05	2.17	1.69	1.38	1.17	1.01	.89	.80	.72	.66
450.	19.14	5.21	3.03	2.14	1.66	1.36	1.15	.99	.87	.78	.71	.65
700.	17.46	5.21	3.00	2.12	1.64	1.33	1.13	.97	.86	.77	.69	.63
1000.	16.10	5.23	2.98	2.09	1.62	1.32	1.11	.96	.85	.76	.68	.62
1500.	14.37	4.91	2.90	2.07	1.61	1.31	1.11	.96	.85	.76	.69	.63
2150.	12.83	4.64	2.83	2.04	1.59	1.31	1.11	.97	.85	.77	.69	.63
3000.	11.40	4.39	2.75	2.01	1.59	1.31	1.11	.97	.86	.77	.70	.64
4500.	9.67	4.09	2.66	1.98	1.57	1.31	1.12	.98	.87	.78	.71	.65
6500.	8.39	3.88	2.50	1.85	1.47	1.22	1.04	.91	.81	.72	.66	.60
10000.	7.06	3.64	2.27	1.65	1.30	1.07	.91	.80	.70	.63	.57	.52
15000.	5.98	3.18	2.12	1.60	1.28	1.07	.92	.80	.71	.64	.58	.54
20000.	5.23	2.84	2.00	1.55	1.26	1.07	.92	.81	.73	.66	.60	.55

TABLE 12(c)
Sample Output from HMR52 (continued)

BOUNDARY COORDINATES FOR LEON

X	46.4	53.4	52.2	52.5	46.1	42.8	34.3	30.0	24.7	22.2
Y	-45.9	-38.4	-32.8	-29.7	-27.7	-19.7	-15.5	-10.7	-8.0	-2.6
X	18.7	16.6	14.2	12.6	2.1	-1.2	-1.5	-3.9	-7.3	-7.7
Y	-1.2	3.4	5.5	8.5	9.5	15.9	19.5	22.3	33.5	37.7
X	-12.4	-19.3	-20.7	-25.8	-28.1	-30.5	-31.3	-38.6	-42.4	-44.8
Y	42.0	41.8	44.9	48.7	55.4	56.4	50.1	49.8	47.5	43.9
X	-51.6	-53.6	-55.1	-51.6	-45.6	-36.9	-36.7	-29.5	-29.1	-25.6
Y	42.1	33.6	31.4	28.8	28.2	14.6	10.0	10.6	7.6	4.6
X	-25.8	-22.6	-18.6	-9.7	-4.7	-2.5	3.6	5.5	3.2	3.6
Y	-1.6	-2.9	-9.6	-7.8	-9.4	-14.0	-14.5	-17.2	-20.7	-22.5
X	5.8	9.6	13.1	15.5	19.8	23.7	26.6	29.4	35.4	38.9
Y	-23.5	-34.0	-36.7	-41.0	-43.4	-46.7	-45.6	-41.6	-41.0	-42.0
X	44.0									
Y	-46.9									

SCALE = 1.0062 MILES PER COORDINATE UNIT

BASIN AREA = 3660.5 SQ. MI.

BASIN CENTROID COORDINATES, X = -2.2, Y = 2.4

TABLE 12(d)
Sample Output from HMR52 (continued)

PROBABLE MAXIMUM STORM FOR LEON
STORM AREA = 3000. SQ. MI., ORIENTATION = 134., PREFERRED ORIENTATION = 208.
STORM CENTER COORDINATES, X = -2.2, Y = 2.4

	ISOHYET AREA (SQ.MI.)	AREA WITHIN BASIN (SQ.MI.)	DEPTHS (INCHES) FOR 6-HOUR INCREMENTS OF PMS 1	2	3	4	5	6	7	8	9	10	11	12
A	10.	10.	18.51	4.46	2.47	1.71	1.35	1.11	0.95	0.82	0.73	0.66	0.59	0.54
B	25.	25.	17.34	4.33	2.45	1.71	1.35	1.11	0.95	0.82	0.73	0.66	0.59	0.54
C	50.	50.	16.09	4.20	2.42	1.71	1.35	1.11	0.95	0.82	0.73	0.66	0.59	0.54
D	100.	100.	14.92	4.11	2.40	1.71	1.35	1.11	0.95	0.82	0.73	0.66	0.59	0.54
E	175.	175.	13.76	4.03	2.38	1.71	1.35	1.11	0.95	0.82	0.73	0.66	0.59	0.54
F	300.	300.	12.79	3.96	2.37	1.71	1.35	1.11	0.95	0.82	0.73	0.66	0.59	0.54
G	450.	450.	11.82	3.88	2.36	1.71	1.35	1.11	0.95	0.82	0.73	0.66	0.59	0.54
H	700.	687.	10.85	3.81	2.35	1.71	1.35	1.11	0.95	0.82	0.73	0.66	0.59	0.54
I	1000.	976.	9.88	3.75	2.35	1.71	1.35	1.11	0.95	0.82	0.73	0.66	0.59	0.54
J	1500.	1397.	8.91	3.70	2.34	1.71	1.35	1.11	0.95	0.82	0.73	0.66	0.59	0.54
K	2150.	1888.	8.04	3.62	2.33	1.71	1.35	1.11	0.95	0.82	0.73	0.66	0.59	0.54
L	3000.	2442.	7.17	3.58	2.32	1.71	1.35	1.11	0.95	0.82	0.73	0.66	0.59	0.54
M	4500.	3246.	4.26	2.50	1.78	1.30	1.02	0.85	0.72	0.63	0.56	0.50	0.45	0.41
N	6500.	3653.	2.42	1.68	1.33	0.97	0.77	0.63	0.54	0.47	0.42	0.37	0.34	0.31
O	10000.	3660.	1.26	1.06	0.88	0.64	0.51	0.42	0.36	0.31	0.27	0.25	0.22	0.20
P	15000.	3660.	0.39	0.34	0.28	0.21	0.16	0.13	0.11	0.10	0.09	0.08	0.07	0.07
Q	25000.	3660.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R	40000.	3660.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	60000.	3660.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AVERAGE DEPTH			8.24	3.41	2.19	1.60	1.26	1.04	0.89	0.77	0.68	0.61	0.56	0.51

TABLE 12(e)
Sample Output from HMR52 (continued)

TIME INTERVAL = 120. MINUTES
1-HR TO 6-HR RATIO FOR ISOHYET A AT 20000 SQ. MI. =0.306

DEPTH VS. DURATION

ISOHYET	5MIN	10MIN	15MIN	30MIN	1-HR	2-HR	3-HR	6-HR	12-HR	18-HR	24-HR	30-HR	36-HR	42-HR	48-HR	54-HR	60-HR	66-HR	72-HR
A	0.53	1.05	1.57	3.02	5.32	8.76	11.94	18.51	22.97	25.44	27.15	28.50	29.61	30.56	31.39	32.12	32.77	33.37	33.91
B	0.49	0.98	1.46	2.81	4.96	8.18	11.16	17.34	21.68	24.12	25.83	27.18	28.29	29.24	30.07	30.80	31.45	32.05	32.59
C	0.45	0.90	1.34	2.59	4.58	7.56	10.32	16.09	20.29	22.71	24.42	25.77	26.88	27.83	28.65	29.38	30.04	30.63	31.17
D	0.42	0.83	1.24	2.39	4.22	6.99	9.54	14.92	19.03	21.43	23.14	24.49	25.60	26.55	27.37	28.10	28.76	29.35	29.89
E	0.38	0.76	1.13	2.19	3.87	6.42	8.76	13.76	17.79	20.17	21.88	23.23	24.34	25.29	26.11	26.84	27.50	28.09	28.64
F	0.35	0.70	1.05	2.02	3.58	5.94	8.11	12.79	16.75	19.12	20.83	22.18	23.29	24.24	25.06	25.79	26.45	27.04	27.58
G	0.33	0.65	0.96	1.86	3.29	5.47	7.46	11.82	15.70	18.07	19.78	21.12	22.24	23.18	24.01	24.74	25.39	25.99	26.53
H	0.30	0.59	0.88	1.69	3.00	4.99	6.82	10.85	14.66	17.01	18.72	20.07	21.18	22.13	22.96	23.69	24.34	24.94	25.48
I	0.27	0.53	0.79	1.53	2.71	4.52	6.17	9.88	13.64	15.98	17.69	19.04	20.15	21.10	21.92	22.65	23.31	23.90	24.45
J	0.24	0.47	0.70	1.36	2.42	4.04	5.52	8.91	12.61	14.95	16.66	18.01	19.12	20.07	20.89	21.62	22.28	22.87	23.41
K	0.21	0.42	0.62	1.20	2.15	3.61	4.94	8.04	11.66	14.00	15.71	17.05	18.17	19.11	19.94	20.67	21.32	21.92	22.46
L	0.18	0.37	0.55	1.05	1.89	3.18	4.36	7.17	10.75	13.08	14.79	16.14	17.25	18.20	19.02	19.75	20.41	21.00	21.54
M	0.07	0.14	0.21	0.41	0.82	1.61	2.36	4.26	6.77	8.54	9.84	10.87	11.71	12.43	13.06	13.61	14.11	14.56	14.98
N	0.04	0.08	0.11	0.23	0.45	0.89	1.31	2.42	4.10	5.44	6.41	7.18	7.81	8.35	8.82	9.24	9.61	9.95	10.26
O	0.02	0.04	0.06	0.11	0.22	0.44	0.65	1.26	2.32	3.20	3.84	4.35	4.77	5.12	5.43	5.70	5.95	6.17	6.38
P	0.01	0.01	0.02	0.03	0.07	0.13	0.20	0.39	0.72	1.00	1.21	1.37	1.50	1.62	1.72	1.81	1.88	1.96	2.02
Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AVERAGE	0.21	0.42	0.63	1.21	2.18	3.69	5.07	8.24	11.64	13.84	15.43	16.69	17.73	18.62	19.39	20.07	20.68	21.24	21.75

TABLE 12(f)
Sample Output from HMR52 (continued)

PROBABLE MAXIMUM STORM FOR LEON

DAY 1

TIME	PRECIPITATION INCR	TOTAL	TIME	PRECIPITATION INCR	TOTAL	TIME	PRECIPITATION INCR	TOTAL	TIME	PRECIPITATION INCR	TOTAL
0200	0.17	0.17	0800	0.20	0.71	1400	0.26	1.38	2000	0.35	2.24
0400	0.17	0.34	1000	0.20	0.92	1600	0.26	1.63	2200	0.35	2.58
0600	0.17	0.51	1200	0.20	1.12	1800	0.26	1.89	2400	0.35	2.93
6-HR TOTAL	0.51			0.61			0.77			1.04	

DAY 2

TIME	PRECIPITATION INCR	TOTAL	TIME	PRECIPITATION INCR	TOTAL	TIME	PRECIPITATION INCR	TOTAL	TIME	PRECIPITATION INCR	TOTAL
0200	0.49	3.42	0800	0.95	5.48	1400	2.57	10.51	2000	0.83	17.00
0400	0.53	3.95	1000	1.12	6.59	1600	3.69	14.19	2200	0.72	17.72
0600	0.58	4.53	1200	1.34	7.94	1800	1.98	16.17	2400	0.64	18.36
6-HR TOTAL	1.60			3.41			8.24			2.19	

DAY 3

TIME	PRECIPITATION INCR	TOTAL	TIME	PRECIPITATION INCR	TOTAL	TIME	PRECIPITATION INCR	TOTAL	TIME	PRECIPITATION INCR	TOTAL
0200	0.42	18.78	0800	0.30	19.92	1400	0.23	20.74	2000	0.19	21.38
0400	0.42	19.20	1000	0.30	20.21	1600	0.23	20.96	2200	0.19	21.56
0600	0.42	19.62	1200	0.30	20.51	1800	0.23	21.19	2400	0.19	21.75
6-HR TOTAL	1.26			0.89			0.68			0.56	

8.3 Precipitation File for Rainfall-Runoff Model Usage

Hyetographs may be written to a file for use in a rainfall-runoff model such as HEC-1.

8.2.1 Punch File

The option of writing hyetographs to a punch or card-image file is available. Each hyetograph is preceded by a line giving the subbasin name and time interval (see Table 13.) The punch data must be merged with input data for the rainfall-runoff model.

8.2.2 DSS File

For computer systems where the HEC Data Storage System (HECDSS) is available, hyetographs may be transferred to HEC-1 through a DSS file. See Section 9 for an example.

Table 13

"PUNCH" Output file from HMR52

	LEON		INTERVAL = 120 MIN							
PI	0.169	0.169	0.169	0.204	0.204	0.204	0.257	0.257	0.257	0.347
PI	0.347	0.347	0.486	0.528	0.584	0.950		1.343	2.571	3.685
PI	1.980	0.826	0.720	0.644	0.420	0.420	0.420	0.295	0.29s	0.295
PI	0.228	0.228	0.228	0.185	0.185	0.185				

Sectlon 9

EXAMPLE APPLICATION

9.1 Introduction

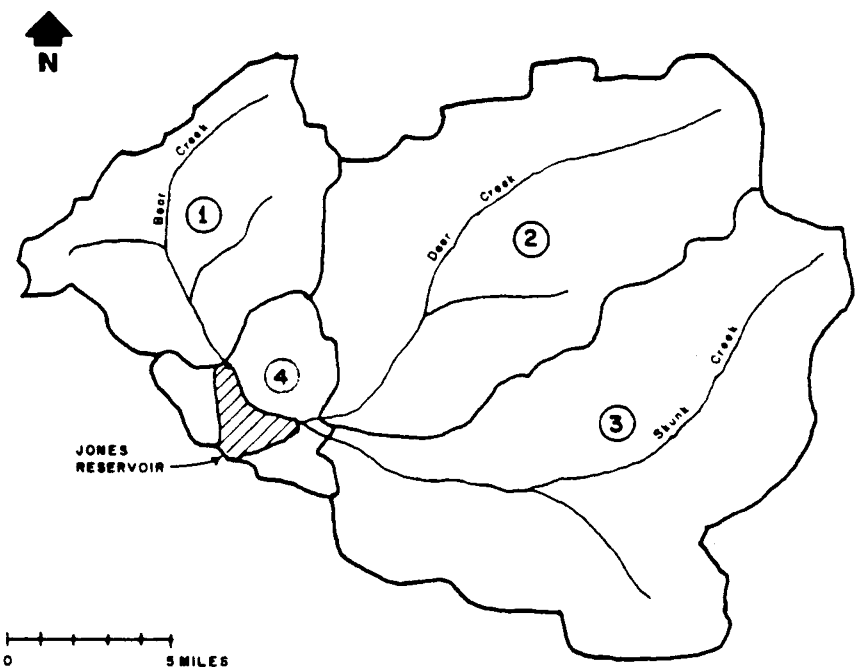
Fig. 25 shows the watershed above Jones Reservoir. HMR52 is used to develop PMS hyetographs for the four subbasins. HEC-1 is used to calculate and route the PMF through Jones Reservoir. The hyetographs are transferred from HMR52 to HEC-1 using the HEC Data Storage System (DSS). The HMR52 input data for this example are shown in Table 14.

9.2 HMR52 Input and Output

9.2.1 PMS for Total Basin

Data for total basin are shown on lines 2-32 of Table 14. The boundary of the total watershed was digitized and entered on BX and BY cards. Depth-area-duration data from HMR No. 51 have been put on HP cards. The preferred storm orlentatlon is on an HO card.

Storm-area size and orientation are shown as zeroes on the SA card, so HMR52 will select the storm-area size and orlentatlon which produce maximum precipitation on the watershed. Tables 15(a) and 15(b) show average 6-hr Incremental depths for various storm-area sizes and orientations used In the selection process. By default, HMR52 will maximize the basin-average precipitation for the three largest 6-hr Increments.



25. Jones Reservoir Watershed

TABLE 14
HMR52 Input for Jones Reservoir

HEC PROBABLE MAXIMUM STORM INPUT DATA

LINE	ID	1	2	3	4	5	6	7	8	9	10
1	ID	HMR52 INPUT DATA FOR SAMPLE PMP CALCULATION									
2	BN	TOTAL									
3	BS	1									
4	BX	27.9	27.4	27.4	26.9	26.8	26.5	26.6	26.2	25.9	25.4
5	BX	25.1	23.5	23.4	22.6	22.5	21.6	21.3	20.3	19.9	19.7
6	BX	18.4	18.2	18.4	18.4	18.2	19.3	19.8	20.7	20.8	21.8
7	BX	22.4	22.2	22.4	23.0	23.3	23.7	24.1	24.5	24.8	25.3
8	BX	25.4	26.5	27.5	27.7	27.8	28.5	29.6	30.8	31.2	31.7
9	BX	32.2	34.5	34.6	34.9	35.7	36.4	37.4	38.2	39.3	39.6
10	BX	39.4	39.5	38.6	39.0	40.0	40.7	41.4	41.8	42.2	41.9
11	BX	42.2	43.4	43.0	43.0	41.6	41.0	40.6	40.5	40.5	40.1
12	BX	39.5	39.1	38.9	38.4	38.0	37.6	35.7	35.6	35.4	33.7
13	BX	33.5	30.9	30.9	30.7	30.1	29.9	29.2	28.2		
14	BY	89.1	89.8	90.1	90.1	90.8	91.4	92.3	92.2	92.3	92.0
15	BY	92.0	90.6	90.3	89.9	89.5	89.2	89.3	87.9	87.9	87.3
16	BY	86.6	86.1	85.9	85.4	85.0	85.0	85.4	84.6	83.9	83.2
17	BY	83.2	82.9	82.4	81.4	80.7	80.4	80.4	80.0	80.0	79.8
18	BY	79.5	79.2	78.8	78.1	77.2	76.6	76.1	76.3	76.2	75.5
19	BY	75.4	75.3	74.4	74.0	73.8	73.8	73.9	73.9	74.2	74.7
20	BY	75.6	76.4	77.3	78.0	78.4	79.0	79.6	80.3	81.1	82.0
21	BY	83.8	85.0	86.5	86.9	87.1	87.4	87.7	88.2	90.6	91.3
22	BY	91.8	92.1	92.2	92.2	92.1	91.5	91.4	91.8	92.0	92.0
23	BY	90.9	90.6	90.1	89.7	89.7	89.8	89.2	89.0		
24	HO	203									
25	HP	10	25.5	29.2	32.0	35.2	36.8				
26	HP	200	17.2	20.5	23.2	26.2	27.5				
27	HP	1000	12.3	15.5	18.5	21.3	22.2				
28	HP	5000	7.5	10.8	13.2	16.1	17.2				
29	HP	10000	5.7	9.0	11.0	13.5	14.9				
30	HP	20000	4.1	7.1	9.1	11.8	13.0				
31	SA	0	0								
32	ST	120	.30								
33	BN	1									
34	BX	18.2	19.3	19.8	20.7	20.8	21.2	21.8	22.4	22.8	23.5
35	BX	24.1	24.6	25.0	25.2	26.5	27.0	27.4	27.4	27.5	27.9
36	BX	27.9	27.4	27.4	26.9	26.8	26.5	26.6	26.2	25.9	25.4
37	BX	25.1	23.5	23.4	22.6	22.5	21.6	21.3	20.3	19.9	19.8
38	BX	19.7	18.4	18.2	18.4	18.4	18.2				
39	BY	84.9	85.0	85.3	84.6	83.9	83.6	83.2	83.2	83.3	82.7
40	BY	82.7	83.4	84.2	84.5	85.1	84.8	85.6	87.9	88.1	88.5
41	BY	89.1	89.8	90.1	90.1	90.8	91.4	92.3	92.2	92.3	92.0
42	BY	92.0	90.6	90.3	89.9	89.5	89.2	89.3	87.9	87.9	87.6
43	BY	87.3	86.6	86.1	85.9	85.4	85.0				
44	ZW	A=SAMPLE									
45	BN	2									
46	BX	27.4	27.4	27.0	27.3	27.4	27.7	27.9	27.8	27.2	27.3
47	BX	27.6	28.1	28.7	29.6	29.8	31.0	31.8	32.3	32.7	33.0
48	BX	33.5	33.9	34.7	35.2	35.5	35.6	35.8	36.1	36.4	37.0

TABLE 14
HMR52 Input for Jones Reservoir (continued)

HEC PROBABLE MAXIMUM STORM INPUT DATA

LINE	ID	1	2	3	4	5	6	7	8	9	10
49	BX	38.1	38.2	38.5	38.9	39.4	39.5	39.7	39.8	40.2	40.5
50	BX	40.5	40.5	40.5	40.1	39.5	39.1	38.9	38.4	38.0	37.6
51	BX	36.6	35.6	35.6	35.4	34.8	33.7	33.6	33.5	32.5	30.9
52	BX	30.9	30.7	30.1	29.9	29.2	29.0	28.2	27.9	27.9	27.5
53	BY	87.9	85.6	84.8	84.2	83.6	83.6	82.6	82.1	81.3	81.0
54	BY	81.0	80.9	80.7	80.7	80.6	80.7	81.1	81.7	82.2	82.5
55	BY	82.4	82.9	83.3	83.3	83.6	84.2	84.8	85.1	85.2	85.2
56	BY	85.9	86.4	86.6	86.6	86.6	86.5	86.9	87.8	88.2	88.2
57	BY	89.0	89.8	90.6	91.3	91.8	92.1	92.2	92.2	92.1	91.5
58	BY	91.5	91.4	91.8	92.0	92.0	91.9	91.1	90.9	90.8	90.6
59	BY	90.1	89.7	89.7	89.8	89.2	89.1	89.0	89.1	88.5	88.1
60	ZW										
61	BN	3									
62	BX	27.6	27.1	27.6	27.7	27.7	27.5	27.7	27.8	28.5	29.6
63	BX	30.3	30.8	31.2	31.7	32.2	34.5	34.6	34.9	35.7	36.4
64	BX	37.4	37.9	38.2	39.1	39.3	39.6	39.4	39.5	39.1	38.6
65	BX	38.8	39.0	40.0	40.7	41.4	41.8	42.2	41.9	42.0	42.2
66	BX	42.8	43.3	43.0	43.0	42.4	41.6	41.0	40.6	40.5	40.1
67	BX	39.7	39.7	39.5	39.0	38.4	38.2	38.1	37.0	36.2	35.9
68	BX	35.7	35.5	35.1	34.8	33.9	33.5	33.0	32.5	32.3	32.1
69	BX	31.7	31.2	30.8	29.5	28.4	28.1	27.6			
70	BY	80.9	80.1	79.8	79.5	78.8	78.8	78.1	77.2	76.6	76.1
71	BY	76.2	76.3	76.2	75.5	75.4	75.3	74.4	74.0	73.8	73.8
72	BY	73.9	73.9	73.9	74.1	74.2	74.7	75.6	76.3	76.8	77.3
73	BY	77.6	78.0	78.4	79.0	79.6	80.3	81.1	81.9	83.1	83.8
74	BY	84.3	85.0	86.5	86.9	87.0	87.1	87.4	87.7	88.2	88.1
75	BY	87.7	87.0	86.5	86.7	86.5	86.4	85.9	85.2	85.1	84.9
76	BY	84.5	83.6	83.3	83.3	82.9	82.5	82.5	82.1	81.9	81.5
77	BY	81.1	80.8	80.7	80.6	80.7	80.8	80.9			
78	ZW										
79	BN	4									
80	BX	27.6	27.1	27.6	27.7	27.7	27.5	26.9	26.5	26.0	25.4
81	BX	25.3	24.8	24.5	24.1	23.7	23.3	23.0	22.7	22.3	22.2
82	BX	22.4	22.8	23.5	24.0	24.6	25.0	25.2	26.5	27.0	27.3
83	BX	27.4	27.7	27.9	27.8	27.2	27.3	27.6			
84	BY	80.9	80.1	79.8	79.5	78.8	78.8	79.0	79.2	79.3	79.5
85	BY	79.8	80.0	80.0	80.4	80.4	80.7	81.4	81.9	82.3	82.9
86	BY	83.2	83.3	82.7	82.7	83.4	84.2	84.5	85.1	84.8	84.2
87	BY	83.6	83.6	82.6	82.1	81.3	81.0	81.0			
88	ZW										
89	ZZ										

TABLE 15(a)
Selection of Storm-Area Size

VARYING STORM AREA SIZE AND FIXED ORIENTATION

STORM AREA	ORIEN-TATION	BASIN-AVERAGED INCREMENTAL DEPTHS FOR 6-HR PERIODS												SUM OF DEPTHS FOR 3 PEAK 6-HR PERIODS
10.	285.	9.62	1.54	0.71	0.48	0.37	0.30	0.25	0.21	0.19	0.17	0.15	0.14	11.87
25.	285.	12.06	1.96	1.05	0.71	0.54	0.44	0.37	0.32	0.28	0.25	0.22	0.20	15.07
50.	285.	13.82	2.40	1.28	0.88	0.67	0.54	0.45	0.39	0.34	0.30	0.27	0.25	17.50
100.	285.	14.81	2.76	1.48	1.01	0.77	0.62	0.52	0.45	0.39	0.35	0.32	0.29	19.05
175.	285.	15.23	2.99	1.59	1.09	0.83	0.67	0.56	0.48	0.42	0.38	0.34	0.31	19.82
300.	285.	15.38	3.21	1.67	1.13	0.86	0.69	0.58	0.50	0.44	0.39	0.35	0.32	20.25
450.	285.	15.07	3.32	1.68	1.13	0.85	0.69	0.57	0.49	0.43	0.39	0.35	0.32	20.07
700.	285.	14.48	3.40	1.66	1.11	0.83	0.67	0.56	0.48	0.42	0.37	0.34	0.31	19.54
1000.	285.	13.78	3.42	1.63	1.08	0.81	0.65	0.54	0.47	0.41	0.36	0.33	0.30	18.84
1500.	285.	13.04	3.33	1.58	1.04	0.78	0.63	0.52	0.45	0.39	0.35	0.32	0.29	17.95
2150.	285.	12.23	3.22	1.51	0.99	0.75	0.60	0.50	0.43	0.38	0.33	0.30	0.27	16.96
3000.	285.	11.31	3.05	1.42	0.93	0.70	0.56	0.47	0.40	0.35	0.32	0.28	0.26	15.78
4500.	285.	10.84	3.05	1.41	0.92	0.70	0.56	0.47	0.40	0.35	0.31	0.28	0.26	15.30
6500.	285.	10.45	3.00	1.37	0.89	0.67	0.54	0.45	0.39	0.34	0.30	0.27	0.25	14.82
10000.	285.	9.76	2.97	1.31	0.85	0.63	0.51	0.42	0.36	0.32	0.28	0.26	0.23	14.05
15000.	285.	9.04	2.86	1.30	0.85	0.64	0.52	0.43	0.37	0.33	0.29	0.26	0.24	13.21
20000.	285.	8.34	2.78	1.30	0.85	0.64	0.52	0.44	0.38	0.33	0.29	0.26	0.24	12.41

TABLE 15(b)
Selection of Storm Orientation

FIXED STORM AREA SIZE AND VARYING ORIENTATION

STORM AREA	ORIEN-TATION	BASIN-AVERAGED INCREMENTAL DEPTHS FOR 6-HR PERIODS												SUM OF DEPTHS FOR 3 PEAK 6-HR PERIODS
300.	140.	14.85	3.14	1.64	1.11	0.84	0.68	0.57	0.49	0.43	0.38	0.34	0.31	19.62
300.	150.	14.60	3.10	1.62	1.10	0.83	0.67	0.56	0.48	0.42	0.38	0.34	0.31	19.31
300.	160.	14.37	3.07	1.60	1.09	0.83	0.66	0.56	0.48	0.42	0.37	0.34	0.31	19.04
300.	170.	14.18	3.04	1.59	1.08	0.82	0.66	0.55	0.48	0.42	0.37	0.33	0.30	18.81
300.	180.	14.03	3.02	1.58	1.07	0.81	0.66	0.55	0.47	0.41	0.37	0.33	0.30	18.63
300.	190.	13.96	3.01	1.58	1.07	0.81	0.65	0.55	0.47	0.41	0.37	0.33	0.30	18.54
300.	200.	13.96	3.01	1.57	1.07	0.81	0.65	0.55	0.47	0.41	0.37	0.33	0.30	18.54
300.	210.	14.04	3.02	1.58	1.07	0.81	0.65	0.55	0.47	0.41	0.37	0.33	0.30	18.64
300.	220.	14.19	3.03	1.59	1.08	0.82	0.66	0.55	0.47	0.42	0.37	0.33	0.30	18.81
300.	230.	14.40	3.07	1.60	1.09	0.82	0.66	0.56	0.48	0.42	0.37	0.34	0.31	19.06
300.	240.	14.63	3.10	1.62	1.10	0.83	0.67	0.56	0.48	0.42	0.38	0.34	0.31	19.34
300.	250.	14.88	3.14	1.63	1.11	0.84	0.68	0.57	0.49	0.43	0.38	0.34	0.31	19.65
300.	260.	15.11	3.17	1.65	1.12	0.85	0.68	0.57	0.49	0.43	0.38	0.35	0.32	19.93
300.	270.	15.28	3.19	1.66	1.13	0.85	0.69	0.58	0.50	0.43	0.39	0.35	0.32	20.13
300.	280.	15.37	3.20	1.66	1.13	0.86	0.69	0.58	0.50	0.44	0.39	0.35	0.32	20.24
300.	290.	15.37	3.21	1.67	1.13	0.86	0.69	0.58	0.50	0.44	0.39	0.35	0.32	20.25
300.	300.	15.28	3.19	1.66	1.13	0.86	0.69	0.58	0.50	0.44	0.39	0.35	0.32	20.14
300.	310.	15.10	3.17	1.65	1.12	0.85	0.68	0.57	0.49	0.43	0.39	0.35	0.32	19.92
300.	280.	15.37	3.20	1.66	1.13	0.86	0.69	0.58	0.50	0.44	0.39	0.35	0.32	20.24
300.	290.	15.37	3.21	1.67	1.13	0.86	0.69	0.58	0.50	0.44	0.39	0.35	0.32	20.24

In Table 15(a), storm precipitation is calculated for various storm-area sizes. Storm orlentatlon was chosen for this table by minimizing the moment of lnertla about the major axis of the elliptical storm pattern. In Table 15(b) the storm-area size is fixed at the size which produced maxlmum precipitation on the watershed in Table 15(a), and orientation is varled from 140 to 310 by ten-degree increments. The last two storms in Table 15(b) have orientations which are flve degrees to elther side of the best prevlous orlentatlon. By coincidence, the best orlentatlon is 285 , so the last two lines are repeats of storms calculated prevlously.

9.2.2 Subbasin Hyetographs

Data for the four subbasins follows the data for the total watershed in the HMR52 input, Table 14. HMR52 uses the same storm specifications as were developed for the total basin to calculate portions of the storm occurring over each subbasin. These storms are shown in Tables 16 through 19.

A ZW card is included with data for each subbasin to indicate that the storm hyetographs are to be written to a DSS file.

NOTE - HECDSS has been developed for Corps of Engineers use at selected computer sites. DSS subroutlnes are not generally avallable to non-Corps users. Users without access to DSS should use the punch (tape) file option of the program, see section 8.2.1.

9.3 HEC-1 Input and Output

The rainfall-runoff model HEC-1 was used to calculate the runoff from the storm hyetographs. Table 20 shows HEC-1 input data for this application, and Table 21 shows HEC-1 summary output for the storm generated by HMR52.

9.4 PMF Calculation

The objective of calculating a PMF is to obtain the largest flood which may reasonably occur over the watershed. Because of hydrologic characteristics of a watershed, the largest flood may not result from the storm which produces the most precipitation.

Several trials were made to calculate the PMF for Jones Reservoir. Results from these trlals are tabulated in Table 22.

Trial 1: used storm-area size and orientation selected by HMR52; default value for position of peak 6-hr interval; basin centroid for storm center location, see Fig. 26.

Trial 2: same as trial 1, except peak 6-hr interval is shifted to the 10th position (hours 54-60). This ralsed the peak flow slightly so the 10th posltlon was used for subsequent trials, except trlal 6.

Trial 3: same as trial 2, except the isohyetal pattern was centered on the watershed by visual adjustment of the storm center.

Trial 4: same as trial 3, except a smaller storm-area size was used.

Trial 5: Since subbasins 1, 2, and 3 produce most of the runoff, the storm was centered over these subbasins.

Trial 6: same as trial 1, except the order of the 6-hr increments is as shown in Fig. 7.

9.5 Conclusions and Recommendations

The adopted PMF for this watershed would be the flood calculated in trial 2. The results from trial 1, using program defaults, could easily be adopted for the PMF, since the difference is less than 0.4 percent for peak inflow and less than 0.7 percent for peak outflow.

In most cases default values in HMR52 will suffice to determine the PMF. Exceptions will occur where the basin has an irregular shape or unusual hydrologic characteristics. Consideration of the following characteristics may be useful in selecting parameters for alternative trials:

relative timing of runoff from subbaslns

direction of major stream

proximity of storm center to a major stream

relationship between storm-area lsohyet and basin boundary

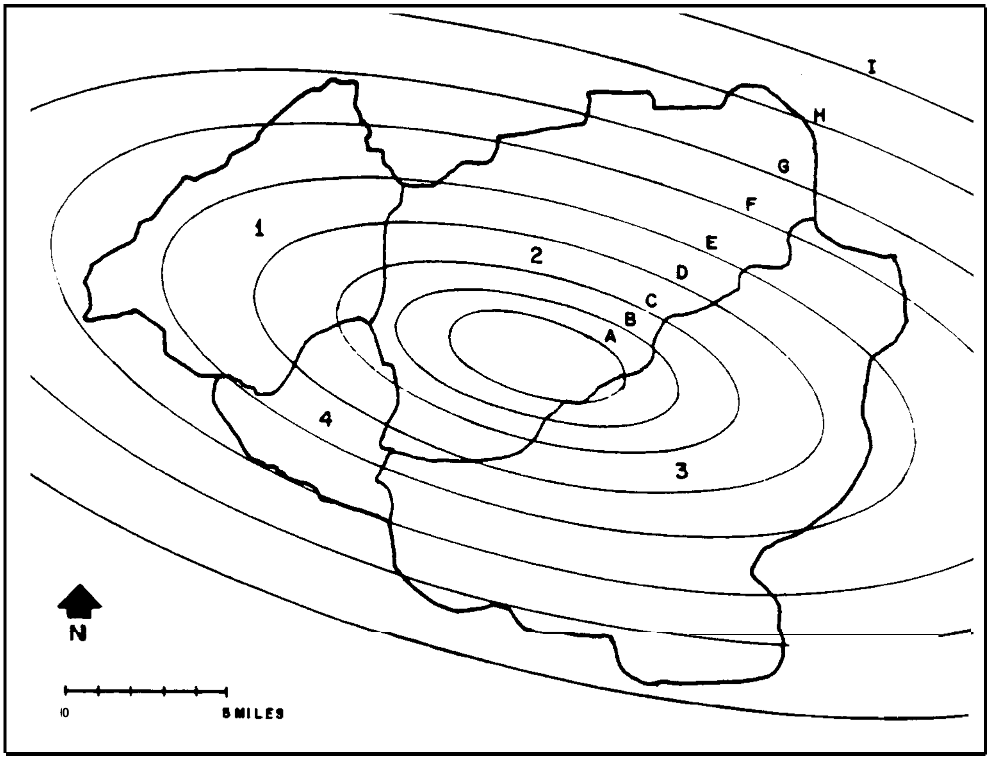


Figure 26. Storm Pattern for Trials 1, 2, and 6

TABLE 16
Probable Maximum Storm for Subbasin 1

DAY 1

TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL
0200	0.11	0.11	0800	0.13	0.46	1400	0.17	0.89	2000	0.23	1.46
0400	0.11	0.22	1000	0.13	0.59	1600	0.17	1.06	2200	0.23	1.70
0600	0.11	0.33	1200	0.13	0.72	1800	0.17	1.23	2400	0.23	1.93
6-HR TOTAL	0.33			0.40			0.51			0.70	

DAY 2

TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL
0200	0.34	2.28	0800	0.82	3.91	1400	3.94	10.27	2000	0.67	22.50
0400	0.38	2.66	1000	1.05	4.95	1600	8.99	19.26	2200	0.55	23.05
0600	0.43	3.09	1200	1.37	6.32	1800	2.57	21.83	2400	0.48	23.53
6-HR TOTAL	1.15			3.24			15.51			1.69	

DAY 3

TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL
0200	0.29	23.82	0800	0.20	24.60	1400	0.15	25.14	2000	0.12	25.55
0400	0.29	24.11	1000	0.20	24.79	1600	0.15	25.29	2200	0.12	25.67
0600	0.29	24.40	1200	0.20	24.99	1800	0.15	25.44	2400	0.12	25.79
6-HR TOTAL	0.87			0.59			0.45			0.36	

TABLE 17
Probable Maximum Storm for Subbasin 2

DAY 1

TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL
0200	0.11	0.11	0800	0.13	0.44	1400	0.16	0.87	2000	0.23	1.42
0400	0.11	0.21	1000	0.13	0.57	1600	0.16	1.03	2200	0.23	1.65
0600	0.11	0.32	1200	0.13	0.70	1800	0.16	1.19	2400	0.23	1.88
6-HR TOTAL	0.32			0.39			0.49			0.68	

DAY 2

TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL
0200	0.33	2.21	0800	0.81	3.81	1400	4.13	10.36	2000	0.66	22.64
0400	0.37	2.58	1000	1.04	4.85	1600	8.94	19.29	2200	0.54	23.18
0600	0.42	3.00	1200	1.38	6.23	1800	2.69	21.98	2400	0.47	23.64
6-HR TOTAL	1.12			3.23			15.75			1.66	

DAY 3

TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL
0200	0.28	23.93	0800	0.19	24.68	1400	0.14	25.21	2000	0.12	25.61
0400	0.28	24.21	1000	0.19	24.87	1600	0.14	25.35	2200	0.12	25.73
0600	0.28	24.49	1200	0.19	25.06	1800	0.14	25.50	2400	0.12	25.84
6-HR TOTAL	0.85			0.57			0.43			0.35	

TABLE 18
Probable Maximum Storm for Subbasin 3

DAY 1

TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL
0200	0.11	0.11	0800	0.13	0.45	1400	0.16	0.87	2000	0.23	1.43
0400	0.11	0.21	1000	0.13	0.58	1600	0.16	1.03	2200	0.23	1.66
0600	0.11	0.32	1200	0.13	0.70	1800	0.16	1.20	2400	0.23	1.89
6-HR TOTAL	0.32			0.39			0.49			0.69	

DAY 2

TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL
0200	0.34	2.22	0800	0.80	3.81	1400	3.93	10.10	2000	0.65	21.77
0400	0.37	2.59	1000	1.02	4.83	1600	8.44	18.54	2200	0.54	22.30
0600	0.42	3.01	1200	1.34	6.17	1800	2.57	21.11	2400	0.47	22.77
6-HR TOTAL	1.12			3.16			14.94			1.65	

DAY 3

TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL
0200	0.28	23.05	0800	0.19	23.81	1400	0.14	24.34	2000	0.12	24.75
0400	0.28	23.34	1000	0.19	24.00	1600	0.14	24.48	2200	0.12	24.86
0600	0.28	23.62	1200	0.19	24.20	1800	0.14	24.63	2400	0.12	24.98
6-HR TOTAL	0.85			0.57			0.43			0.35	

TABLE 19
Probable Maximum Storm for Subbasin 4

DAY 1

TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL
0200	0.11	0.11	0800	0.13	0.46	1400	0.17	0.89	2000	0.24	1.47
0400	0.11	0.22	1000	0.13	0.59	1600	0.17	1.06	2200	0.24	1.70
0600	0.11	0.33	1200	0.13	0.72	1800	0.17	1.23	2400	0.24	1.94
6-HR TOTAL	0.33			0.40			0.51			0.71	

DAY 2

TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL
0200	0.35	2.28	0800	0.82	3.92	1400	3.95	10.30	2000	0.67	22.63
0400	0.38	2.66	1000	1.05	4.97	1600	9.08	19.38	2200	0.55	23.18
0600	0.43	3.09	1200	1.38	6.34	1800	2.58	21.96	2400	0.48	23.66
6-HR TOTAL	1.16			3.25			15.62			1.70	

DAY 3

TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL	TIME	PRECIPITATION INCR	PRECIPITATION TOTAL
0200	0.29	23.95	0800	0.20	24.73	1400	0.15	25.27	2000	0.12	25.69
0400	0.29	24.24	1000	0.20	24.93	1600	0.15	25.42	2200	0.12	25.81
0600	0.29	24.53	1200	0.20	25.12	1800	0.15	25.57	2400	0.12	25.93
6-HR TOTAL	0.88			0.59			0.45			0.36	

TABLE 20
HEC-1 Input for Jones Reservoir Watershed

```
                                        HEC-1 INPUT                                                        PAGE  1

ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

ID        HEC1 DATA FOR SAMPLE PMF CALCULATION
IT     120 01JAN99    0000      50
IO       5

KK       1
KM         BEAR CREEK INFLOW INTO JONES RESERVOUR
BA    51.80
ZR  =PI A=SAMPLE C=PRECIP-INC
LU       1      .06
US    9.00      .45
BF     -3.     -.35  1.0092

KK       4
KM         LOCAL RUNOFF INTO JONES RESERVOIR
BA    20.30
ZR  =PI
LU       1      .06      10
US    2.60      .45
UA      10       13      20      29      40      53      70      82      93     100

KK     1+4
KM     BEAR CREEK AND LOCAL INFLOW COMBINED
HC       2

KK       2
KM    DEER CREEK INTO JONES RESERVOIR
BA    98.60
ZR  =PI
LU       1      .06
US   11.00      .45
UA

KK       3
KM     SKUNK HOLLOW INTO JONES RES
BA  116.90
ZR  =PI
US   14.00      .45

KK     2+3
KM       COMBINED FLOW FROM DEER CR AND SKUNK HOLLOW
HC       2

KK  INFLOW
KM     TOTAL INFLOW INTO JONES RES
HC       2

KK    JONES
KM    ROUTE THROUGH JONES RES
RS       1     FLOW      -1
SV   12869    13000   22000   36000   54000   82000  110700  118000  126000  134000
SV  143000   146500
SQ       0    12000   13000   14000   15000   16000   17000   30000   54000   86000
SQ  128000   160000
ZZ
```

Table 21

HEC-1 Summary Output for Trial 1

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA
HYDROGRAPH AT	1	29528.	48.00	28056.	20818.	11805.	51.80
HYDROGRAPH AT	4	26798.	42.00	21758.	12922.	8339.	20.30
2 COMBINED AT	1+4	43374.	44.00	42278.	33231.	20144.	72.10
HYDROGRAPH AT	2	48055.	50.00	46176.	36320.	20357.	98.60
HYDROGRAPH AT	3	44777.	52.00	43877.	36318.	20591.	116.90
2 COMBINED AT	2+3	90924.	52.00	88749.	72386.	40948.	215.50
2 COMBINED AT	INFLOW	127493.	50.00	124553.	103675.	61092.	287.60
ROUTED TO	JONES	94664.	60.00	91656.	74403.	42765.	287.60

Table 22

Summary of PMF Calculations

Trial	Position of Peak 6-hr Interval	Storm Area mi²	Orientation degrees	Storm Center x miles	Storm Center y miles	Total Rainfall inches	Peak Inflow cfs	Peak Outflow cfs
1	7	300	285	32.2	83.8	25.50	127,500	94,650
2	10	300	285	32.2	83.8	25.50	128,000	95,300
3	10	300	285	31.0	83.6	25.44	127,650	95,250
4	10	175	290	31.0	83.6	24.86	125,200	91,650
5	10	300	296	32.7	84.0	25.41	127,200	93,900
6	9*	300	285	32.2	83.8	25.50	125,100	94,300

*Temporal distribution based on Fig. 7.

Section 10

COMPUTER REQUIREHENTS

10.1 Source Lanquage

HMR52 source code is written in FORTRAN 77. It must be copmiled with a Fortran 77 compiler or a Fortran compiler which can Interpret IF-THEN-ELSE-ENDIF statements.

10.2 Core Storage

Program HMR52 uses 22DK bytes on a Harris 500 computer or 45K words (decimal) on a CDC 7600. Table 23 gives storage requirements and compile and execution times. Data for other computers will be added to the table as it is supplied by users.

Table 23

Memory and Time Requirements

Computer	Harris 500	CDC Cyber 175
Memory	220K bytes	45K words
Compile time (CPU sec)	93	6.57
Execution time* (CPU sec)	43	16.3

time is for example data in Sectlon 9, Table 14.

10.3 File Structure

HMR52 uses 6 disk files:

- lnput, card or card image;
- output, formatted for 132 column printer;
- punch;
- two scratch files; and
- a table file.

File characteristics are listed in Table 24.

The table file (unit INP52) contains data listed in Tables l-5. Data on this file are read into the program's working storage at the beginning of each execution.

10.4 HEC-Supplled Magnetic Tape

HEC programs are distributed on half inch by 2400 foot magnetic tapes. Files on the tape for HMR52 are the source code, a file containing data from Tables l-4 and 10, sample input data, and the current Input description for HMR52.

The source code on the tape conforms to ANSI standards for Fortran 77. The code is not intended for a particular computer, although minor changes may be necessary to use the program on different machines.

The sample input data are the same as used in Section 9. This data may be used to verify that the program is working correctly.

10.5 Machine-Specific Code

The only code in the HMR52 source code which is specific to a particular computer is the use of subroutines DATE and TIME in subroutine BANNER. These subroutines return the current date and time. This informatlon is printed on the banner output page to identify when a run is made. Some code modifications may be required since subroutines DATE and TIME are not standard on all machines. These subroutine calls can be removed without affecting the program's performance.

Table 24

File Characteristics

Fortran Unit No.	Variable Name	Description	Maximum Record Length
5	INP	Input data	80 characters
6	IPRT	Printer output	132 characters
7	IPNCH	File output*	80 characters
19	SCRTCH	scratch; used to convert time from 411 to A4 format	5 characters
20	IC	working data file; contains reformatted input data with line number and next card is appended to beginning of each card	89 characters
52	INP52	contains data tables from HMR No. 52	80 characters

* This file maybe punched or saved on disk/tape for use as input to a rainfall-runoff model.

Section 11

REFERENCES

Hydrologic Engineering Center, 1981, HEC-1 Flood Hydrograph Package Users Manual, U.S. Army Corps of Engineers, Davis, California.

National Weather Service, 1961. Hydrometeorological Report No. 36, Interim Report - Probable Maximum Precipitation in California National Oceanic and Atmospheric Administration Washington, D.C.

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National Weather Service, 1982. Hydrometeorological Report No. 52, Application of Probable Maximum Precipitation Estimates - United States East of the 105th Meridian National Oceanic and Atmospheric Administration Silver Spring, Maryland

National Weather Service, 1983. Hydrometeorological Report No. 55, PMP Estimates, United States Between the Continental Divide and the 103rd Meridian (draft), National Oceanic and Atmospheric Administration Silver Spring, Maryland.

Riedel, John T., 1977. The PMF Concept, from "The Evaluation of Dam Safety," pp. 415-436, American Society of Engineers, New York, N.Y.

APPENDIX A

HMR52 INPUT DESCRIPTION

TABLE OF CONTENTS

HMR52 INPUT DESCRIPTION

INPUT FORMAT

Input data is read from cards or card images. Each card is divided into a two-column card identification field (columns 1 and 2) and ten data fields. The first data field has six columns (columns 3-8). The remaining nine flelds each have eight columns.

Field 0 (zero) is the card identification field (columns 1 and 2). Field 1 is the first data field (beginning in column 3).

Under the value heading a plus (+) is used to indicate where numeric values should be entered. A blank numeric value is interpreted as a zero. (AN) indicates that alphanumeric characters may be entered.

Data may be entered on the cards in either FREE FORMAT or FIXED FORMAT (default). The FORMAT (fixed or free) is controlled by a switch which can be changed at anytime by inseting a *FIX or a *FREE card In the data deck.

For FREE FORMAT each item is separated by one or more blanks or a comma. A blank field is designated by two successive commas. There may be more or less than ten coordinates on a BX or BY card. The FREE FORMAT reader will treat these cards as If they were on continuous cards.

For FIXED FORMAT each number which does not contain a decimal point must be right justified in its field.

A *FIX card indicates that the following data cards use FIXED FORMAT, and a *FREE indicates FREE FORMAT. The format may be changed as often as desired and at any location In the data deck.

Comments may be placed anywhere in the input deck on cards with double asterisks (**) in the card identification field.

HMR52 INPUT DESCRIPTION

CARD SEQUENCE

Cards are grouped by drainage basin. A BN card is used to indicate the beginning of data for a basin. The next cards are the BS, BX, and BY cards which describe the basin boundary. Next come the HO and HP cards which have meterological data from HMR No. 52 and HMR No. 51, then the SA, SC, SD, and ST cards containing data for a particular storm.

The cards for a drainage basin may be followed by another group, beginning with a BN card for a different drainage basin, or a GO card followed by different storm data for the current basin, or a ZZ card indicating the end of data for this job.

Within a card group (beginning with BN or GO card) the cards may be placed in any order. However, it is helpful to use a consistent order such as alphabetlcal order.

DATA REPETITION

Once data has been read by the program it is retained in memory until a new card of the same type is read. For example, the HO or HP cards need only occur in the data for the first dralnage basin and not repeated for each subsequent basin. Similarly, once the storm area and orientation have been established, they will be used for all subsequent calculations until a new SA card Is read.

The only cards which must be Included for each new drainage basin are the BN, BX, and BY cards. All other cards may be omitted for a new basin and the storm will be calculated using data from the previous basin.

BA CARD - BASIN AREA

This card is an optional card which is placed after the BN card. A BA card is required when a storm is calculated using isohyet areas on SI cards and boundary coordinates are not given. The area on a BA card is not used If boundary coordinates are given.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	BA	Card identification.
1	BAREA	+	Subbasin area in square miles.

BN CARD - BASIN NAME

The BN card is placed at the beginning of data for each drainage basin and identifies the basin.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	BN	Card identification.
1	NAME	AN	Alphanumeric name for drainage basin described by data on following cards. (Maximum 8 characters for FREE FORMAT, 6 characters for FIXED FORMAT.)

BS CARD - SCALE

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	BS	Card identification
1	SCALXY	+	Scale of boundary coordinates In miles per coordinate unit.

BX CARD - BOUNDARY COORDINATES

BX and BY cards contain X and Y coordinates for points on the basin boundary. The points may be entered in either clockwise or counter-clockwise direction. The beginning point should not be repeated since the program automatically closes the boundary.

The program counts the number of boundary points by finding the last non-zero value on a series of BX or BY cards.

If both BA and SI cards are used, BX and BY card may be omitted.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	BX	Card identification
1-10	XB	+	X-coordinates of drainage basin boundary. Corresponding to y-coordinates on BY cards. (Maximum - 100 values.)

BY CARD - BOUNDARY COORDINATES

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	BY	Card identification
1-10	YB	+	Y-coordinates of drainage basin boundary corresponding to x-coordinates on BX card. (Maximum - 100 values.)

GO CARD - COMPUTE STORM WITH CURRENT DATA

The GO card is used to indicate the end of data for a PMS calculation. The computer will calculate the PMS using the current data before reading the next card. A GO card is not required if the next card is a BN card or a ZZ card.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	GO	Card

HO CARD - PREFERRED ORIENTATION

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	HO	Card identification.
1	PORNT	+	Preferred probable maximum storm orientation from HMR No. 52.

HP CARD - DEPTH-AREA-DURATION DATA

Use one HP card for each storm area (10, 200, 1000, 5000, 10000, and 20000 square miles). Six HP cards are required, one for each area.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	HP	Card identification.
1	AREA51	+	Storm area from HMR No. 51 for PMP in Fields 2-6.
2	H51DAD(1,J)	+	Probable maximum precipitation for 6 hour duration for storm area in Field 1, from HMR No. 51.
3-6	H51DAD(I,J)	+	Similar to Field 2 for durations of 12, 24, 48 and 72 hours.

ID CARD - JOB IDENTIFICATION

The contents of this card are read and printed immediately after being read. There is no limit on the number of ID cards. ID cards are usually placed at the beginning of a data set to provide title information. They may be placed within a data set to describe individual basins or storm calculations.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	ID	Card identification.
1-10	TITLE	AN	Alphanumeric job title or description.

PL CARD - PLOT CONTROL

The PL card is used to control printer plots of the drainage basin boundary and PMS Isohyets.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	PL	Card identification
1	PLTYP	0	No plots.
		1	Plot dralnage basin boundary.
		2	Plot drainage basin boundary with PMS isohyets.
		3	Make two plots, a plot of drainage basin boundary and a plot of the boundary with PMS isohyets.
2	CHRPIN	+	Characters per inch for printer plot. Default is 10.)
3	LINPIN	+	Lines per inch for printer plot. (Default is 6.)

PU CARD - SAVE PMS ON FILE

The PU Card is used to control writing the PMS to a file. The default format is (2HPI,F6.2,9F8.2).

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	PU	Card identification.
1	PUNCH	ON	Write PMS precipitation to save file
		OFF	Do not write PHS to save file (default).
2-10	PUNFMT	AN	Format to be used in writing to save file. If Fields 2-10 are blank the prevlously defined format will be used.

NOTE: For program files maintained by HEC on HARRIS the save file is W8 by default, and may be changed at the execution time by:

HMR52, PUNCH=save file.

On CDC computers the save file is TAPE7 by default and may be changed at execution time by:

HMR52, INfile, OUTfile, SAVEfile.

On MS-DOS compatible microcomputers (PC's), the save file Is UNIT8 by default and may be changed at execution time by:

HMR52, INfile, OUTfile, SAVEfile.

SA CARD - STORM AREA AND ORIENTATION

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	SA	Card identification.
1	PMSA	+	Probable maximum storm area size in square miles. If PMSA is zero, the program will compute PMS for several area sizes and select the area size which produces maximum precipitaion on the dralnage basin for the specified number of 6-hour periods.
2	ORNT	+	Probable maximum storm orientation in degrees, clockwise from north. (Range is 135-315 degrees.) If ORNT is less than or equal to zero, the program will compute PMS for several orientations and select the orientation which produces maximum precipitation on the dralnage basin for the specified number of 6-hour periods.
		0	If ORNT is zero, the orientation which minimizes moment-of-inertia for the drainage basin about the major axis will be used to estimate PHSA when Field 1 is zero. If ORNT is negative, the absolute value of ORNT will be used to estimate PMSA when Field 1 is zero.
3	NINCS	+	Number of 6-hour periods to use for computing maximum precipitaiton on the drainage (default is 3).

SC
SD

SC CARD - STORM CENTER COORDINATES

The storm center will be located at the drainage basin centroid if an SC card is not used.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IO	SC	Card identification.
1	XCEN	+	X-coordinate of storm center.
2	YCEN	+	Y-coordinate of storm center.

SD CARD - ARRANGEMENT OF 6-HR INCREMENTS IN PMS TEMPORAL DISTRIBUTION

This card gives the arrangement of 6-hr increments of precipitation in the PMS. The default arrangement (if no SD card is given) is: 12, 10, 8, 6, 4, 2, 1, 3, 5, 7, 9, 11 where the numbers indicate the largest (1) to smallest (12) 6-hr Increment.

If SO cards are included in a data set, all twelve increments must be listed on two cards.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IO	SO	Card identification.
1	RELMAG(1)	+	Relative magnitude of first 6-hr period of PMS.
2-10		+	Relative magnitude of remaining 6-hr periods of PMS.

Continue with eleventh period in Field 1 of second SO card.

SI CARD - STORM ISOHYET AREAS

This card is optional. If SI cards are used the program will not calculate the basin area within each isohyet, but it will use the areas given on SI cards. Storm area and orientation must be given when SI cards are used.

If both SI and BA cards are used, then BX and BY cards may be omitted.

If SI cards are used, then there must be two SI cards.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	SI	Card identification.
1	AREAIB(1)	+	Area within both basin boundary and isohyet A In square miles.
2-10	AREAIB(2-10)	+	Area within basin boundary and isohyet in square miles for isohyets B through J.

SECOND SI CARD

FIELD	VARIABLE	VALUE	DESCRIPTION
1-9	AREAIB(11-19)	+	Area within basin boundary and isohyet in square miles for isohyets K through S.
10	AREAIB(20)	+	Area in square miles withing basin boundary and isohyet corresponding to the storm area

ST CARD - TEMPORAL DISTRIBUTION

This card gives data for the temporal distribution of the PMS for Intervals less than 6 hours.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	ST	Card identification
1	TIMINT	+	Time interval in minutes to be used for temporal distribution of PMS. (Range of 5 min to 360 min).
2	R16A20	+	Ratio of lhr to 6 hr precipitation for isohyet A of 20,000 sq ml storm from Figure 39 of HMR No. 52. (Range 0.27 to 0.35).
3	POSMAX	+	Position of maximum 6-hr Increment In PMS temporal distribution. Remaining 6-hr Increments In descending order will be placed alternately, before and after maximum increment. This arrangement will replace any distributions from previous SD or ST cards. (Range 5 to 12, default=7).
		0	Use previously established arrangement of 6-hr Increments of PMS.
4	RATIO	+	PMS precipitation will be multiplied by this ratio. (Default = 1.0.)

ZW CARD - WRITE PMS TO DSS

The ZW card is included with data for each basin for which the hyetograph is to be saved on DSS.

Each data record (hyetograph) is identified by a 6-part pathname, each part being designated by letters A through F.

Part A is project identification or description 16 characters maximum. Default is blank.

Past B is hyetograph location, 8 characters maximum. Default is basin name from BN card, Field 1.

Part C is parameter name, 12 characters maximum. Default is PRECIP-INC.

Part D Is start date of hyetograph. Default is OlJAN1999. Hyetographs are stored in blocks of 1 month or 1 day dependlng on time interval. The hyetograph will start at 0000 hours on the date given on the ZW card, but the date In the pathname will be the beginning date of the block.

Part E is time interval. This will be derived by the program.

Part F is alternative or description of hyetograph, 24 characters maximum. Default is blank.

The format of the ZW card is

ZW A=Part A, B=Part B, C=Part C, D=Part D, F=Part F

One or more of the pathname parts may be omitted from the ZW card. Once parts A, C, D, or F have been set they will retain their values until reset on a ZW card.

For example:

ZW A= F=PHS-1

will set part A to blank, and part F to PMS-1.

ZZ CARD - END OF DATA

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	zz	Card

EXAMPLE

```
ID PROBABLE MAXIMUM STORM CALCULATION FOR EXAMPLE 2 IN HMR NO. 52
ID DUACHITA RIVER BASIN
*FREE
BN OUACHITA
** CALCULATE STORM OVER ENTIRE BASIN
BS .79365
BX 108 108 107 97 98 97 95 93 88 83 77 71 67 66 64 62
BX 59 54 48 40 38 39 37 26 18 12 8 6 4 6 8 9 15 25 27
BX 30 33 35 38 41 47 53 56 67 70 76 80 82 85 90 100 105
BY 17 21 24 32 34 36 37 44 48 48 46 46 50 54 55 54 50 47
BY 47 43 41 38 37 42 39 40 40 42 41 37 34 28 23 19 20
BY 20 19 23 21 21 24 22 23 16 15 10 10 14 11 12 10 12
HP 10 30.0 35.9 40.6 44.6 47.1
HP 200 22.2 27.0 31.2 34.7 37.7
HP 1000 16.3 21.0 25.3 29.0 31.2
HP 5000 9.5 13.5 17.7 21.6 24.2
HP 10000 7.3 10.7 14.0 18.0 20.8
HP 20000 5.3 8.5 11.6 14.9 17.2
HO 235
**
** FIND STORM AREA AND ORIENTATION FOR PMS CENTERED AT BASIN CENTROID
SA 0 0
GO
**
** CALCULATE STORM CENTERED BETWEEN RENNEL DAM AND BLAKELY HT. DAM
** USING GIVEN STORM AREA AND ORIENTATION
SC 87.9 20.1
SA 2150 280
GO
**
** CALCULATE STORM FOR EACH SUBBASIN USING LAST SET OF PARAMETERS
BN PINERIDG
BX 26 18 12 B 6 4 6 8 9 15 25 27 30 33 35 33 35 33 35
BY 42 39 40 40 42 41 37 34 28 23 19 20 20 19 23 27 31 35 38
BN WASHITA
BX 35 38 40 40 44 47 57 63 58 55 54 51 53 48 40 38 39 37 35 33
BX 35 33
BY 23 21 21 23 25 30 31 35 42 42 44 44 47 47 43 41 38 37 38 35
BY 31 27
BN BLAKELY
BX 53 51 54 55 58 63 57 47 44 40 40 41 47 53 56 59 64 72 79 84 85
BX 96 95 93 88 83 77 71 67 66 64 62 59 54
BY 47 44 44 42 42 35 31 30 25 23 21 21 24 22 23 21 23 22 28 28 30
BY 36 37 44 48 48 46 46 50 54 55 54 50 47
BN RENNEL
BX 108 108 107 97 98 97 96 85 84 79 72 64 59 67 70 76 80 82 85 90 100 105
BY 17 21 24 32 34 36 36 30 28 28 22 23 21 16 15 10 10 14 11 12 10 12
ZZ
```

APPENDIX B

ERROR MESSAGES

Error Number	Error Message and Descrtptlon
1	STORM AREA AND ORIENTATION MUST BE GIVEN WHEN ISHOYET AREAS ARE GIVEN ON SI CARDS Storm area is required to identify the division between within-storm and residual rainfall. Storm orientation is required to calculate orientation adjustment of PMP.
2	BOTH BA AND SI CARDS MUST BE USED WHEN BOUNDARY COORDINATES ARE NOT GIVEN. The program cannot calculate basin area or areas enclosed by isohyets and basin boundary without boundary coordinates. These values must be given on BA and SI cards If boundary coordinates are not given.
3	AREA WITHIN BASIN DOES NOT INCREASE WITH ISOHYET SIZE. Al = xxxx.xx, A2 = xxxx.xx This error occurs when the program is computing basin-average precipitation and the area within the basin and an isohyet is smaller than the basin area inside the next smaller isohyet. This error may be caused by an incorrect entry for the basin area inside the storm-area Isohyet on an SI card. This error may also be caused by incorrect boundary coordinates. If the basin boundary crosses itself the program may compute a wrong basin area inside an isohyet.
4	BX CARD NO. nnn BX CARDS HAVE ALREADY BEEN READ FOR THIS BASIN. A BN CARD MAY BE MISSING. OR A CARD MAY BE OUT OF ORDER. BX cards for a single basin may not be intermingled with other card types. A BN card is used to identify the beginning of data for a basin.

5 BY CARD NO. nnn
BY CARDS HAVE ALREADY BEEN READ FOR THIS BASIN.
A BN CARD MAY BE MISSING, OR A CARD MAY BE OUT OF ORDER,

BY cards for a single basin may not be intermingled with other card types. A BN card is used to identify the beginning of data for a basin.

6 BA CARD NO. nnn
BASIN AREA ON BA CARD IS NOT GREATER THAN ZERO.
AREA = xxxx.xxx

Basin area must be greater than zero. If program is to calculate area from boundary coordinates BA card should not be used.

7 HP CARD NO. nnn
DEPTH DOES NOT INCREASE WITH DURATION FOR AREA = xxxxx.

PMP depths on the HP card for area xxxxx should increase from field 2 to 6.

8 INVALID AREA ON HP CARD NO. nnn, PMP AREA = xxxxx.

PMP area, field 1 of HP card, must be 10, 200, 1000, 5000, 10000, or 20000 square miles.

9 SD CARD NO. nnn
MAGNITUDE (m) IS NOT IN RANGE 1 TO 12.

Values on the SD card are Integers from 1 to 12 which indicate the relative magnitude of 6-hour precipitation increments. "1" indicates the largest increment and "12" indicates the smallest increment.

10 SD CARD NO. nnn
A RELATIVE MAGNITUDE WAS REPEATED
The values on the SD card are unique Integers from 1 to 12. No value may be repeated on a set of SD cards.

11 SO CARD NO. nnn
TWO SD CARDS ARE REQUIRED.

Twelve values are read from SD cards. This requires two SD cards in sequence.

12 SI CARD NO. nnn
AREA FOR ISOHYET il (nl) IS LESS THAN AREA
FOR ISOHYET il

Areas enclosed by isohyets and the basin boundary cannot decrease as isohyet area increases.

13 ST CARD NO. nnn
TIME INTERVAL CANNOT BE LESS THAN 5 MINUTES

The program will not calculate a temporal distribution for a time interval smaller than 5 minutes.

14 ST CARD NO. nnn
TIME INTERVAL MUST DIVIDE 60 MINUTES INTO EQUAL
PARTS WITH NO REMAINDER

The time interval for temporal distribution must be 5, 6, 10, 12, 15, 20, or 30 minutes.

15 ST CARD NO. nnn
TIME INTERVAL MAY NOT BE GREATER THAN 6 HOURS (360 MINUTES)

The program will not calculate a temporal distribution for a time interval greater than 6 hours.

16 ST CARD NO. nnn
TIME INTERVAL MUST DIVIDE 6 HOURS INTO EQUAL
PARTS WITH NO REMAINDER

The time Interval for temporal distribution must be 1, 2, 3, or 6 hours.

17 ST CARD NO. nnn
l-HR TO 6-HR RATIO FOR ISOHYET A OF 20000 SQ. MI.
STORM MUST BE IN THE RANGE 0.27 TO 0.35

The range of the l-hour to 6-hour ratio from figure 39 of Hydrometeorological Report No. 52 is 0.270 to 0.300. A value outside this range is consldered to be a mistake.

18 ST CARD NO. nnn
POSITION OF MAXIMUM 6-HR INCREMENT MUST
BE IN RANGE 5 TO 12

The maximum 6-hour precipitation increment may not occur in the first 24 hours 1 to 4) of a storm.

19 ARRAY ON CARD NO. nnn
(Id) EXCEEDS DIMENSION OF kkk

The program attempted to read more data than allowed from an xx card. The maximum number of values that can be read from xx cards is kkk.

----

n ERRORS DETECTED IN INPUT DATA FOR BASIN aaaaaaaa.
REMAINING DATA WILL BE CHECKED FOR ERRORS.

n ERRORS DETECTED IN CALCULATIONS FOR BASIN aaaaaaaa.
REMAINING DATA WILL BE CHECKED FOR ERRORS.

When an error is detected by HMR52, the program will read through the remaining data and check for input errors. No calculations will be made using the remaining data.

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