The second concept is that the analysis of 2-yr 24-hr precipitation-frequency values (fig. 59) represents an acceptable indicator of the terrain effects on the distribution of PMP in the eastern Tennessee Valley. The 100- and 2-yr precipitation-frequency analysis, as well as mean annual or seasonal precipitation maps, have been used in other studies for developing isohyetal patterns in orographic regions. In this study, a precipitation-frequency map was selected as being most representative of storm conditions. Mean annual or seasonal maps were not used since they were considered to unduly increase rainfall magnitudes on slopes for a storm situation. A portion of the increase on exposed slopes on mean annual or seasonal maps is attributable to the more frequent occurrence of light rains over higher elevations than over surrounding valleys.

Comparison of the isopluvial pattern on the 2- and 100-yr maps showed similar patterns. Though there is a tendency, in general, for the maxima in the isopluvial pattern to be at lower elevations for the longer return periods, this was not supported from the analysis prepared for this study. Therefore, the 2-yr map was selected for use here, because greater confidence can be placed in the results of the frequency analysis for the station record lengths available for this study.

The warping procedure is a function of basin area size and location. In the eastern region (both mountainous and non-mountainous areas) for basins ≤ 100 mi^2, the nonorographic elliptical pattern adjusted, as discussed in section 4.3.1, is used as the basis for the warping procedure. The 2-yr 24-hr isopluvial pattern covering the basin is converted to a percentage of the 2-yr 24-hr amount at the center of the isohyetal pattern. Then, the 2-yr 24-hr percental analysis and the elliptical pattern are graphically multiplied and the results analyzed to provide the warped isohyets.

For basins >100 mi^2 in the nonmountainous east, the nonorographic elliptical PMP isohyets adjusted for the TSF (sect. 3.5.2) and displaced according to the rules above are multiplied by the 2-yr 24-hr percental analysis (based on the center of the displaced pattern). In the mountainous east, the displaced elliptical PMP isohyets adjusted for the TAF (sect. 3.5.3) are multiplied by the 2-yr 24-hr percental analysis (based on the center of the displaced pattern).

Because all of these modifications may result in somewhat different basin average depths than was determined before areal distribution, it is important to adjust the final warped isohyets by ratioing to reestablish the original average depths. Refer to the procedures and examples in chapter 5 for clarification of these concepts.

Note: For those portions of the western region in figure 1 that are designated as rough in figure 67, no modification of the areal distribution is applied in this study, because the 2-yr 24-hr analysis for this region does not support any orographic modification.

5. PROCEDURES FOR COMPUTING PMP AND TVA PRECIPITATION AND DETERMINING AREAL DISTRIBUTION, INCLUDING EXAMPLES

5.1 Introduction

The basic concepts for deriving PMP and TVA precipitation are described in chapter 2 for basins less than 100 mi^2 and in chapter 3 for basins between 100 and 3,000 mi^2. The principles of areal distribution are presented in chapter 4 for all areas above 10 mi^2. This chapter deals with procedures needed to obtain answers for any number of possible options that might be considered. There are at least five types of options available in this study, as follows:

1. location (western vs. nonmountainous east vs. mountainous east) (refer to fig. 1)
2. area size (small basin vs. large basin)
3. precipitation (PMP vs. TVA)
4. basin average values vs. areally distributed values
5. values for primary basin vs. values for concurrent basins

The possible combinations of options are more than can reasonably be considered in terms of individual description of necessary steps. Therefore, we have elected to provide some key procedures and examples that will provide sufficient guidance on how to obtain answers for those options not explicitly described so that the user may develop his/her own stepwise procedure.

In this chapter, the individual procedures are presented as a series of steps designed to obtain a result. Note that references to "step" in any procedure always means within that particular procedure unless noted otherwise by a reference to another section.

5.2 Small Basin ($\leq$100-mi^2) Procedures (All Regions)

In chapter 2, consideration for terrain has been included in the analysis presented in figures 22 and 23 for 6-hr 1-mi^2 PMP and figures 24 and 25 for 6-hr 1-mi^2 TVA precipitation. Therefore, it is not necessary to differentiate the portion of the Tennessee Valley region that is orographic, when determining PMP or TVA precipitation. However, the effects of terrain on the elliptical pattern need to be considered in the non-mountainous and mountainous eastern regions.

5.2.1 Computation of PMP Estimate

The following steps outline the procedure for determining non-areally distributed PMP for basins within the Tennessee Valley that are smaller than 100 mi^2. If a decision is made not to consider areal distribution there can be no basin-averaged PMP nor evaluation of concurrent precipitation.

Step

1. Outline the basin of interest on figure 22 or 23, and determine an average value of the 6-hr 1-mi^2 PMP for the basin.

2. Obtain depth-durational values from 1 to 24 hr for the average value in step 1 from figure 41. These are storm-centered relations.

3. Use the depth-areal relations in figure 26 to reduce the depth-duration values in step 2 to the area size of the drainage. This figure provides storm-centered relations.

4. Plot the areally reduced values in step 3 and fit with a smooth curve. Obtain amounts for all required durations from the smooth curve. The results yield storm-centered average depth values of total-storm PMP for the basin of interest.

5. Obtain incremental amounts through successive subtraction of each durational value in step 4 from the next longer durational value.

6. Select a time distribution that is in accord with the instructions given in section 2.2.14 and arrange the incremental PMP from step 5 in that sequence.

5.2.2. Computation of TVA Precipitation

Step

1. Obtain the 6-hr 1-mi^2 TVA precipitation by placing an outline of the drainage over figures 24 or 25 and determine the average value for the basin.

2. Determine the length of the storm of interest. The factors that follow for selected durations (based on figs. 37-40) are obtained from table 7. Multiply the appropriate factor times the 6-hr 1-mi^2 TVA average depth from step 1 to adjust to the other durations of the storm:

Storm Duration (hr)	3	6	12	24
Factor	0.80	1.00	1.13	1.24

3. Refer to figures 37 to 40 to obtain respective hourly adjusted amounts based on the adjusted value from step 2. Enter these figures with the product from step 2 on the ordinate scale. If durations other than shown in figures 37 to 40 are required, smooth curves may be constructed as necessary to determine interpolated amounts.

4. Obtain the areal reduction factors from figure 26 for the duration of the storm. Multiply the depths from step 3 by the areal reduction factors. (Subtract consecutive durational amounts to obtain incremental values.)

5. Values from step 4 are plotted on a depth-duration diagram and a smooth curve fitted. The results are storm-centered average depths of TVA precipitation.

6. Choose a time sequence from the instructions in section 2.2.14 for hourly and 6-hr increments. The most critical sequence of the several sequences permitted is determined primarily on the basis of the derived hydrograph.

5.3 Procedure for Basins Between 100 and 3,000 mi^2

In the following sections, procedures are presented for computing PMP and TVA precipitation for large basins (100 to 3,000 mi^2). These procedures are adopted from the discussions in sections 3.3. and 3.4. Because of the different procedures proposed for individual basins dependent upon location in the Tennessee Valley, continued reference should be made to figures 67 and 68. These figures show the separation between eastern and western regions, as well as the distribution of rough, intermediate and smooth terrain types.

The computational processes have been broken down into units that cover PMP, TVA precipitation, areal distribution, terrain adjustments, and concurrent drainages. Where the processes differ regionally, the units have been separated to explain the respective differences.

5.3.1 Computation of PMP Estimate

In contrast to the small basin procedure, no map analysis of PMP has been made from which to obtain storm-area averaged PMP values. Instead, the following alternative method is used.

Step

1. Scale 6-, 12-, 18-, 24-, 48- and 72-hr precipitation depths for a few area sizes larger and smaller than the basin area from figure 52. These are nonorographic storm-averaged PMP values applicable to Knoxville Airport, TN.

2. From figure 54 or 55, read a regional adjustment percentage for the centroid of the drainage being considered.

3. Multiply the DAD values in step 1 by the adjustment in step 2 to create a set of DAD curves applicable to the location of the drainage. If areal distribution is not considered, the storm-averaged nonorographic PMP estimates are read off these DAD curves for the area size of the drainage. If basin-averaged values are desired, areal distribution is important; then, using the results of the procedure outlined in section 5.4, adjust the storm-averaged PMP for pattern orientation and basin shape to obtain basin-averaged PMP. The following steps are followed only if areal distribution is not required, but they will not provide basin-averaged results.

4. Plot the values in step 3 for the area size of the drainage as depth vs. duration and draw a smooth curve to enable interpolation of 6-hr amounts.

5. To obtain a 6-hr incremental PMP value, subtract each durational value from the next longer 6-hr durational value.

6. Determine the applicable TSF from section 5.4.3.1 for basins in the west or nonmountainous east, or the TAF from section 5.4.3.2 for basins in the mountainous east, or by the results of section 5.4.3.3 for basins in more than one region.

7. Multiply the appropriate terrain factor from step 6 times the incremental values from step 5.

8. Incrementally add the values in step 7 to get a depth-duration curve of total PMP. Unless areal distribution was considered in step 3, this total PMP estimated is not a basin-average value, but rather a storm-averaged value modified for terrain effects.

5.3.2 Computation of TVA Precipitation

Note: TVA precipitation values can be obtained following the procedure in Section 5.3.1, substituting figure 53 for figure 52 in Step 1, or if PMP has already been determined for the drainage, follow the steps below.

<u>Step</u>

1. Choose a TVA storm length from among 3, 6, 12, 24 or 72 hr.

2. For the duration chosen in step 1, read the corresponding value of total PMP from section 5.3.1, step 8 (see Note above).

3. From figure 67 or 68, determine whether the majority of the drainage is covered by rough, intermediate, or smooth terrain.

4. If step 3 is rough, multiply step 2 by 0.58; if step 3 is intermediate, multiply step 2 by 0.55, and if step 3 is smooth, multiply step 2 by 0.53, (see discussion, sect. 2.2.7.1).

5. For the storm length chosen in step 1 and the adjusted PMP from step 4, determine the durational values of TVA precipitation from the appropriate figure (37 to 40) for TVA storm lengths of 3 to 24 hr and from figure 79 for a TVA storm length of 72 hr. The results are storm-centered (unless areal distribution is applied) average TVA precipitation.

5.4. Computation of Areal Distribution of PMP and TVA Precipitation (Includes Modification for Terrain Effects)

The basic procedure for computing the areal distribution of PMP in this study is applicable to all basin areas (>10 mi^2), regardless of whether PMP has been derived from the small- or the large-basin procedures. Instances where the small- or large-basin procedures differ regarding input values needed for the areal distribution will be noted. The recommended procedure for areal distribution has been taken from HMR No. 52 (Hansen et al. 1982). For basins

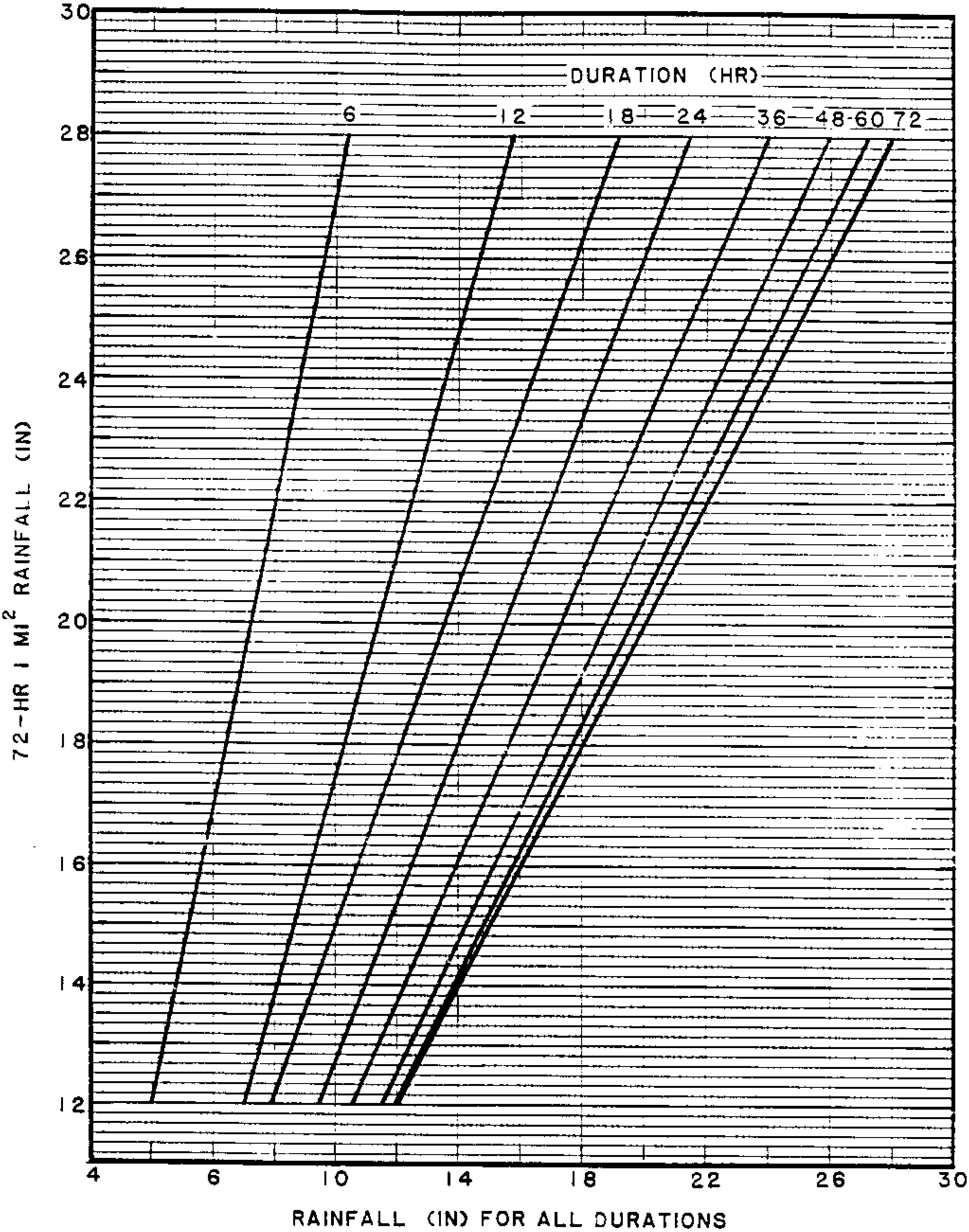

Figure 79.--Depth-duration relations for 72-hr TVA precipitation storm.

whose area size is less than 500 mi^2, it is necessary first to develop a set of depth-area-duration relations from both the small- and large-basin procedures. The following steps describe this procedure (TVA precipitation figures are given in parentheses). Areal distribution is the procedure that allows basin-averaged PMP and TVA precipitation to be determined from storm-averaged DAD relations.

Step (Small-basin DAD)

1. Determine the 6-hr 1-mi^2 PMP (TVA precipitation) for the location of the basin determined from figure 22 or 23 (24-25).

2. Use the depth-duration relation from figure 41 (fig. 37-40 for TVA precipitation) to obtain durational 1-mi^2 values.

3. Determine the respective adjustment percentages for 10, 50 and 100 mi^2 from figure 26.

4. Multiply step 3 times step 2 to obtain PMP (TVA precipitation) for 1, 10, 50, and 100 mi^2.

5. Plot values from step 4 on semi-log paper (area-log vs. depth-arithmetic scale) and smooth appropriately to obtain depth-area-duration values for area sizes between 1 and 100 mi^2 at the basin location.

Step

(Large-basin DAD)

5. Figure 52 (53) gives depth-area-duration relations for nonorographic PMP (TVA precipitation) at Knoxville Airport for storm areas between 100 and 3,000 mi^2, extrapolated to 5,000 mi^2 (dashed). From figure 54 or 55, determine the adjustment for the location of the subject drainage. Multiply the relations in figure 52 (53) by the adjustment from figures 54 and 55 to obtain storm averaged depth-area-duration relations applicable to the location of the drainage.

6. Determine the applicable TSF and/or BOF to obtain the TAF for 100 mi^2 from the procedure outlined in section 5.4.3.

7. Multiply the DAD relations from step 5 by the TAF from step 6 to obtain terrain adjusted DAD for all areas $\geq$100 mi^2.

8. Plot the DAD relations in steps 4 and 7 and observe the degree of agreement at 100 mi^2. Subjectively, smooth the relations across the interface (100 mi^2) to effect the least change to either set of original relations, yet maintain relations that are parallel or somewhat converging with increasing area. It is not expected that smoothing will influence relations for areas greater than 500 mi^2.

5.4.1 Western Basins

The following steps are necessary to determine the isohyetal values and are taken from HMR No. 52 (Hansen et al. 1982).

Step

1. Place the idealized isohyetal pattern from figure 72 over the drainage with an orientation such as to place the maximum volume of precipitation in the drainage. This is generally accomplished by fitting the greatest number of whole isohyets within the drainage outline.

2. Select from the DAD curves established in section 5.4 step 8 a set of standard storm area* sizes both smaller and larger than the drainage area (up to 3 or 4 on either side) and read off the values.

3. Obtain incremental differences for each of the first three 6-hr periods (0 to 6, 6 to 12, 12 to 18 hr) through successive subtraction for each area size considered in step 2. Plot the 6-hr incremental values on semi-log paper. Smooth the data such that the incremental rainfall amounts decrease or remain constant with increases in both duration and pattern area size. In drawing the smoothing curves, choose a scale for the abscissa (incremental depths) that allows values to be read off to the nearest hundredth. This is a computational device and does not indicate data are accurate to hundredths of an inch.

4. Given the placement of the isohyetal pattern that best fits the basin, and for basins >300 mi^2 only, determine the orientation (to the nearest whole degree) of the major axis of the pattern in terms of degrees from north. If this orientation does not fall between 135° and 315°, add 180° so that it does.

5. Determine the orientation preferred for PMP conditions at this location from figure 73. If the difference between orientations from steps 4 and 5 is less than or equal to 40°, then for the isohyetal pattern as placed over the drainage there is no reduction factor to consider. One can proceed to step 7, otherwise proceed to step 6.

6. When the orientation difference in step 5 is greater than 40°, determine the appropriate adjustment factors for the isohyets involved, from the model shown in figure 74 (read to tenths of percent e.g., 93.3). Note that the amount of reduction is dependent upon area size (only pattern areas larger than 300 mi^2 need to be reduced) and the difference between

*The standard isohyet area sizes are: 10, 25, 50, 100, 175, 300, 450, 700, 1,000 1,500 2,150, 3,000, 4,500, 6,500, 10,000, 15,000, 25,000, 40,000 and 60,000 mi^2 (sect. 4.2.1).

orientations. Multiply the factor from figure 74 times the corresponding 6-hr incremental amounts from step 3 for each pattern area size to obtain incremental values reduced for pattern orientation.

7. Determine the maximum volume of precipitation for the three largest 6-hr incremental periods resulting from placement of the pattern over the drainage. To do this, it is necessary to obtain the value to be assigned to each isohyet in the pattern that occurs over the drainage during each period. Guidance for determining the maximum volume is given in the following steps related to the format in figure 80. It is suggested that an ample number of copies of this figure be reproduced to serve in the computation procedure.

   Start by determining the maximum volume for the 1st 6-hr incremental period.

   a. Fill in the name of the drainage, drainage area, date of computation, and increment (either 1st, 2nd, or 3rd) in the appropriate boxes at top of form (fig. 80).

   b. Put the storm area size (mi^2) from step 2 for which the first computation is to be made under the heading at the upper left of form. After completion of computations for this area, use the second storm area from step 3 and so on, until all area sizes have been evaluated.

   c. Column I contains a list of isohyet percentages. Use only as many isohyets as needed to cover the drainage.

   d. For the storm area size in step 7b, list in column II the corresponding percentages read from table 12 (first 6-hr period) for those isohyets needed to cover the drainage; use table 13 and table 14 for the 2nd and 3rd 6-hr periods, respectively, when determining step 7.

   e. Under the heading amount (Amt.) in column III, place the incremental average depth that results from step 5 or 6 corresponding to storm area size and increment of computation. Multiply each of the percentages in column II by the Amt. at the head of column III to fill column III.

   f. Column IV represents the average depth between adjacent isohyets. The average depth of the "A " isohyet is taken to be the "A" value from column III. The average depth between all other isohyets which are totally enclosed by the drainage is the arithmetic average of paired values in column III. For incomplete isohyets covering portions of the drainage, a weighted estimate of the average depth is recommended if a portion of the drainage extends beyond a particular isohyet. The average depth for the extended portion of the drainage may be taken as between 0.5 and

Increment:________

Drainage:______________________________ Area:__________ Date:__________

	I	II	III	IV	V	VI		I	II	III	IV	V	VI
Area size	Iso.	Nomo.	Amt.	Avg. depth	ΔA	ΔV	Area size	Iso.	Nomo.	Amt.	Avg. depth	ΔA	ΔV
	A							A					
	B							B					
	C							C					
	D							D					
	E							E					
	F							F					
	G							G					
	H							H					
	I							I					
	J							J					
	K							K					
	L							L					
	M							M					
	N							N					
	O							O					
	P							P					
				Sum =							Sum =		

Area size		Amt.		Area size		Amt.	
	A				A		
	B				B		
	C				C		
	D				D		
	E				E		
	F				F		
	G				G		
	H				H		
	I				I		
	J				J		
	K				K		
	L				L		
	M				M		
	N				N		
	O				O		
	P				P		
			Sum =				Sum =

Figure 80.--Example of computation sheet showing typical format. See text for clarification and instructions for completing this form (Continued).

1.0 times the difference between the enclosing isohyets plus the lower isohyet. The weighting relation is given by:

$$F(X-Y) + Y$$

where X and Y are adjacent isohyet values (X>Y), and the weight factor, F, is between 0.5 and 1.0. If only a small portion of the drainage extends beyond X, then the weight factor may be taken closer to 1.0, and if the drainage extends nearly to Y, then a weight factor close to 0.5 is appropriate.

g. Column V lists the incremental areas between adjacent isohyets. For the isohyets enclosed by the drainage, the incremental area can be obtained from the 3rd column in table 11. For all other isohyets it will be necessary to planimeter the area of the drainage enclosed by each isohyet and make the appropriate successive subtractions. The sum of all the incremental areas in column V should equal the area of the drainage. It is important to note that if the computation in step 7e results in the zero isohyet's crossing the drainage, the appropriate total area is that contained within the zero isohyet, and not the total drainage area.

h. Column VI gives the incremental volume obtained by multiplying corresponding values in column IV times those in column V. The incremental volumes are summed to obtain the total volume of precipitation in the drainage for the specified pattern area size for that 6-hr period.

i. Steps 7b to 7h are repeated for all the other pattern area sizes elected in step 7b.

j. The storm area size from step 7b that results in the largest of the volumes obtained in steps h and i represents the preliminary maximum volume for the 1st 6-hr incremental period and specifies the storm area to which such volume relates. The area of maximum volume can be used as guidance in choosing pattern areas to compute volumes for the 2nd and 3rd 6-hr incremental period. Presumably, this guidance narrows in on the range of pattern area sizes considered and possibly reduces in some degree the number of computations. Compute the 2nd and 3rd 6-hr incremental volumes by repeating steps 7a to 7i, using the appropriate tables to obtain isohyet labels.

k. Sum the volumes from steps 7h to 7j at corresponding pattern area sizes and plot the results in terms of volume vs. area size (semi-log plot). Draw a smooth curve through the points to determine the area size that gives the maximum 18-hr volume in the drainage.

m. It is recommended, although not always necessary, that the user repeat steps 7b through 7k for one or two supplemental area sizes (area sizes other than those of the standard isohyetal pattern given in step 2) on either side of the area size of maximum volume in step 7k. This provides a check on the possibility that the maximum volume occurs between two of the standard isohyet area sizes. To make this check, an isohyet needs to be drawn for each supplemental area size in the initial isohyetal pattern positioned on the drainage, so that the corresponding incremental areas between isohyets can be determined (planimetered). In addition, supplemental cusp points need to be determined in figures 75, 76 and 77* for each of the area sizes considered. To find the appropriate cusp position, enter the ordinate at the supplemental area size and move horizontally to intersect a line between the two most adjacent cusps. This intermediate point will be the percentage for the supplemental isohyet when reading the other isohyet percentages in step 7d; otherwise follow the computational procedures outlined in steps 7a to 7k.

n. The largest 18-hr volume obtained from either step 7k or 7m then determines the final PMP storm area size for the pattern placement chosen.

8. Determine the areal distribution of PMP storm-area averaged depth over the basin (see note, sect. 4.3.2). This is accomplished in the following steps:

a. For the area size determined for the PMP storm in step 7n, use the data in step 2 and draw a depth-duration curve out to 72 hr and read off values from the smoothed curve for each 6 hr (6 to 72 hr).

b. Obtain 6-hr incremental amounts for the data in step 8a for the 4th through 12th 6-hr periods in accordance with step 3, and follow procedural step 5 to adjust these incremental values for isohyetal orientation, if needed.

c. Steps 8a and 8b give incremental average depths for each of the twelve 6-hr periods in the 72-hr storm. To obtain the values for the isohyets that cover the drainage, multiply the 1st 6-hr incremental depth by the 1st 6-hr percentages obtained from table 12, or from the nomogram (fig. 75) for the area size determined in step 7n. Then multiply the second 6-hr incremental depth by the second 6-hr percentages from table 13, or from the nomogram (fig. 76), for the same area size, and similarly for the third 6-hr increment (table 14, or fig. 77). Finally,

*These figures represent nomograms used to obtain the data provided in tables 12, 13 and 14.

multiply the fourth through 12th 6-hr incremental depth by the percentages in table 15, or from the nomogram (fig. 78). As a result of this step, a matrix of the following form can be completed (to the extent of whichever isohyets cover the drainage). This provides the areal distribution for basins in the western TVA region. If after obtaining PMP values TVA precipitation isohyetal values are desired, then it is unnecessary to start over by recomputing DAD curves from figure 53 for TVA precipitation. Instead, TVA precipitation can be obtained directly from PMP by multiplying the PMP label values by 0.58, 0.55 or 0.53 depending on whether the majority of the basin is considered as "rough," "intermediate," or "smooth," respectively.

	6-hr Increment											
Isohyet (in.)	1	2	3	4	5	6	7	8	9	10	11	12
A												
B												
C												
.												
.					Isohyet Values (in.)							
.												
etc.												

In the event that concurrent basins are of interest for a basin in the west, go to the procedures outlined in section 5.4.4.1, otherwise continue here.

d. To obtain incremental basin-average depths for the drainage, compute the volumes for each 6-hr increment for the storm area size of the PMP pattern determined in step 7j. Divide each incremental volume by the drainage area covered by precipitation.

If one compares the basin-averaged depth obtained in this step with the storm-averaged depth for the basin area from the DAD curves in step 5, section 5.4, generally the former will be less. This reduction represents the adjustment to total storm precipitation that occurs because of orientation (if $\geq$ 40° from the preferred orientation) and because of factors related to the irregular shape of the drainage.

5.4.2 Eastern Basins

In the eastern region, it is first necessary to establish the total PMP basin-centered storm pattern as in section 5.4.1, and then adjust this pattern to include the effects of terrain, as described in the following steps. Note that when applying this procedure to small basins (<100 mi^2), only steps 1, 5, 7, and 8 are to be used for both PMP and TVA precipitation.

Step

1. Determine the basin-centered isohyetal pattern placement and isohyet values as described in section 5.4.1 steps 1 to 8c. Determine the volume representing terrain adjusted total PMP for the basin, designated as V_x.

2. Adjust the nonorographic elliptical pattern from its basin-centered position in step 1 to reflect the broadscale effects of terrain (sect. 4.3.2) by moving the pattern toward the location of the maximum 2-yr 24-hr amount within the basin (fig. 59). Note that if peak discharge is critical, other placements may be considered in a series of trials to determine the location that results in maximum discharge. Keep the displaced center of the pattern at least 10 mi inside the basin boundary.

3. If concurrent basins are of interest go to section 5.4.4.2, otherwise to step 4 for the primary basin (one for which PMP is determined).

4. Determine the volume of precipitation within the primary basin by planimetering the displaced pattern in step 2. Adjust the isohyet values by the ratio of the basin-centered volume to the displaced volume for each 6-hr increment, in order to maintain the same volume as in the basin-centered position.

5. Calculate the basin warping factor, W. W is the inverse of the area-averaged 2-yr 24-hr precipitation field covering the basin (expressed as a percentage). W will be used in step 8 to maintain the same volume in the warped pattern as in the basin-averaged elliptical pattern. To convert the 2-yr 24-hr analysis to a percentage analysis, determine the 2-yr 24-hr value at the center of the displaced elliptical pattern. This value is set at 100 percent and the remainder of the 2-yr 24-hr analysis is expressed as a percentage of this central value.

6. Graphically multiply the adjusted isohyet values in step 4 by the 2-yr 24-hr percental analysis from step 5 to reflect the local terrain influence on the pattern. Make these calculations either at points of intersection between the two patterns, or on some uniform grid network that yields acceptable detail. Supplemental points may be necessary to verify some regions of non-uniform gradient.

7. Analyze the resulting product from step 6 to derive the terrain adjusted (warped) isohyetal pattern for the basin. Adjust the isohyet values in this step to maintain the volume established for V_x in step 1. However, rather than planimeter the pattern, it is only necessary to multiply the isohyets by the warping correction factor, W, from step 5. The resulting pattern and isohyet values represent the terrain adjusted total PMP or TVA precipitation for the basin.

5.4.3. Computation of Terrain Adjustments

This section covers the determination of terrain factors for the three basic regions of the Tennessee River Valley; the west, the nonmountainous east, and the mountainous east (refer to fig. 1). If concurrent basins are of interest, reference should be made to section 5.4.4. The following steps provide the procedures for obtaining the TSF (terrain stimulation factor), BOF (broadscale orographic factor), and TAF (total adjustment factor) for the PMP and TVA storm patterns.

5.4.3.1 Western and Nonmountainous Eastern Regions.

Step

1. From figures 67 and 68, determine the percentage of the basin influenced by intermediate and rough terrain.

2. Use figure 65 to get the adjustment for each percentage in step 1 and add the two adjustments.

3. Since the adjustments from figure 65 are for 100 mi^2, it is necessary to reduce these to the area size of the basin by the percentage obtained from figure 66, based on the entire basin area. The product is the terrain stimulation factor, TSF, to which 1.0 must be added to make this a positive factor (to increase the total precipitation). The BOF is 0 in these regions. Therefore, the total adjustment factor, TAF, is in fact the TSF. Round the TAF to the nearest 5 percent. Return to the next step in the computation procedure.

5.4.3.2 Mountainous East Region.

Step

1. By definition, all the mountainous east region is considered rough. Therefore, from figure 65, the TSF is 16 percent for a basin area of 100 mi^2.

2. From figure 66, obtain the percent adjustment to the TSF for area size of the basin. Multiply the adjustment times the 16 percent from step 1 to get the adjusted TSF for the basin. Add 1.00 to the TSF to make this a positive factor (to increase the total precipitation).

3. Determine the 6-hr 1-mi^2 average PMP from figure 23 for the basin. Divide this amount by 1.16, since the basin is entirely rough. This removes all the thunderstorm-induced terrain effect in the basin.

4. Multiply step 3 times step 2.

5. The nonorographic smooth 1-mi^2 PMP at 6 hr from figure 16 is 34.4 in. Locate the basin on figure 69 and read the percentage reduction caused by the sheltering effect of the mountains.

Multiply the 34.4 in. by the reduction factor (1.0 minus the amount from fig. 69).

6. Divide step 4 by step 5 to get the percentage of orographic increase applicable to the drainage.

7. From figure 63, determine the optimum wind flow direction applicable to the largest percentage of the basin covered by one of the possible directions.

8. For the percentage in step 7, use figure 64 to obtain the orographic adjustment for optimum wind direction.

9. Multiply step 8 times step 6 to obtain the orographically modified TSF.

10. Use figure 14 to determine the percentage of the basin covered by primary upslopes, secondary upslopes, and sheltered regions. Multiply these percentages by 0.55, 0.10 and 0.05, respectively (sect. 3.4.1). Add the results and round off to the nearest 0.05 to obtain the broadscale orographic factor, BOF. (Note: If BOF is for a basin whose area is between 100 and 110 mi^2, figure 70 should be used to adjust BOF.)

11. Add the BOF of step 10 to the modified TSF of step 9 to get the total adjustment factor, TAF. Round to nearest 5 percent. Return to the next step in the computation procedure.

5.4.3.3 Basins Partially in Two or More Regions. Some basins in the Tennessee River watershed may not be located entirely in the nonmountainous east, or entirely in the mountainous east, or in the west regions. In these situations neither the computation of the nonorographic PMP (TVA precipitation) nor the computation of the broadscale orographic factors (mountainous east only) is affected. It is only necessary to modify somewhat the procedure for computing the terrain stimulation factor, TSF. There are five steps needed in making the modification.

Step

1. Delineate the boundaries between all pertinent regions, and determine the percent of total basin area covered by each region.

2. Compute the TSF for each regional portion of the basin separately according to the procedures outlined in sections 5.4.3.1 (steps 1 to 3) and 5.4.3.2 (steps 1 to 9).

3. Weight the various TSF's in step 2 by the respective percentages determined in step 1 to obtain a total-basin TSF.

4. If one of the regions is the mountainous east, compute the BOF for that portion of the total drainage as described in section 5.4.3.2 (step 10).

5. Add the results obtained from step 3 and step 4 to obtain the TAF for the total basin. Round to the nearest 5 percent.

As an example, suppose that 80 percent of a particular basin is within the mountainous east and the TSF and BOF for that part of the basin is 1.10 and 0.05 percent, respectively. At the same time, the remaining 20 percent of the basin, in the nonmountainous east, has a TSF of 1.05 percent. Then the TSF for the entire basin is the weighted average, or 0.80 (1.10) plus 0.20 (1.05) = 1.09. Combining this 1.09 and the BOF of 0.05, gives a TAF for the entire basin of 1.14, rounded to the nearest 5 percent, or 1.15. Return to the next step in the computation procedure.

5.4.4 Computation for Concurrent Basins

Candidate concurrent basins are those for which basin-averaged nonorographic precipitation amounts of 0.1 in. or more occur in any 6-hr increment.

5.4.4.1 Western Basins. In the western region, if concurrent basins are of interest, the isohyetal total PMP pattern centered as in section 5.4.1 step 1 and having the isohyet percentages from section 5.4.1 step 8c needs to be expanded to cover the additional basins. The following steps need be considered before basin-averaged depths can be obtained for the individual basins.

Step

1. Determine the total area size of the primary and concurrent basins of interest in your application.

2. Determine the terrain stimulation factor, TSF, for each concurrent basin according to section 5.4.3. Apply the areal adjustment factor from figure 66 for the combined area from step 1 to each concurrent TSF. If the combined area exceeds 500 mi^2, the areal adjustment factor will be 0.25.

3. Adjust the TSF of each concurrent basin by dividing that TSF by the TSF of the primary basin.

4. Multiply the isohyet analysis labels within each basin by the respective adjusted TSF from step 3 to obtain the terrain adjusted isohyets. This step will produce a total isohyetal pattern with discontinuities at the border of each basin.

5. Changes to the isohyet analysis in the PMP basin should be held to a minimum, thus the recommendation is to make adjustments mostly in concurrent basins by smoothing across the discontinuities.

6. Basin-average depths for a concurrent basin are then determined by planimetering the portion of the pattern covering the basin to get the volume, and dividing by the basin area, as is done for the PMP basin in section 5.4.1 steps 8d and e.

5.4.4.2 Eastern Basins. In the eastern region, the displaced isohyetal pattern from section 5.4.2 step 2 is expanded to cover the concurrent basins. The following steps need to be considered before basin-averaged depths can be obtained for individual basin.

Step

1. Primary and concurrent basins may be in either the nonmountainous or mountainous east, or both. For those in the nonmountainous east, determine the TSF from section 5.4.3.1. For those in the nonmountainous east, determine the TAF from section 5.4.3.2. Adjust the concurrent basin TSF's or TAF's by the areal factor from figure 66 for the combined area of the primary plus concurrent basins being considered. Note the areal factor will be 0.25 for all combined areas greater than 500 mi^2.

   Adjust the TSF or TAF of each concurrent basin by dividing by the respective TSF or TAF of the primary basin (based on its location).

2. Calculate the warping factor, W, for the primary basin and each concurrent basin. W is the inverse of the basin-averaged 2-yr 24-hr precipitation analysis (expressed as a percentage). This requires that the 2-yr 24-hr analysis in figure 59 be converted to a percentage analysis based on the 2-yr 24-hr value at the center of the displaced elliptical pattern. The W determined for each basin is likely to be different.

3. Determine the volume of precipitation within the primary basin by planimetering the displaced pattern. Adjust the isohyet values by the ratio of the displaced pattern volume to the pattern volume at the basin-centered position. Do not adjust concurrent basins by this volume ratio. This will result in discontinuities at all boundaries between concurrent and primary basins.

4. Multiply the adjusted isohyets in step 3 by the appropriate adjusted TSF or TAF from step 1 for each concurrent basin. This step will result in discontinuous isohyets at the border of each basin. Planimeter the resulting isohyets of total PMP to determine the new volume representing terrain adjusted basin-averaged total PMP, designated as V_x for each basin.

5. Graphically multiply the adjusted isohyet labels in step 4 by the 2-yr 24-hr percental analysis from step 2 to reflect the local terrain influence on the pattern. Make these calculations either at points of intersection between the two patterns or on some uniform grid network that yields acceptable detail. Supplemental points may be necessary to verify some regions of non-uniform gradient.

6. Analyze the results from step 5 to derive the terrain adjusted (warped) isohyetal pattern. At this time, it is possible to smooth across the borders to eliminate the discontinuities resulting from step 4, although a smooth isohyetal pattern is not required by this procedure. Adjust each isohyet value to maintain the respective volume, V_x, for each basin in step 4.

To make this adjustment, multiply the isohyets in each basin by the respective warping correction factor, W, for that basin (step 2). The resulting pattern and isohyet value represent the terrain adjusted basin-averaged total PMP for the primary basin and concurrent basins of interest.

7. In order to obtain the areal distribution of TVA precipitation, multiply the smooth PMP isohyet labels obtained in step 6 by an appropriate adjustment factor. This factor is 0.58 (rough), or 0.55 (intermediate). In the mountainous east, all basins are rough and the 0.58 factor applies.

5.4.5 Cautionary Remarks

The procedures outlined in the previous sections are complex. During the development and evaluation of these procedures, it has become apparent that it is not possible to anticipate all possible uses to which these methods will be applied. Nevertheless, in our attempts to understand and control the outcomes that may occur, there appears to be at least two areas where it will be necessary to make comparisons before the results can be accepted. The first involves PMP for small areas (<100 mi^2). When determining the areal distribution for a relatively large drainage (>500 mi^2), particularly in an orographic region, one should compare the average depths for small areas in the large-scale pattern against comparable PMP estimates for that same location from the small-basin study (chapt. 2). The results from the small-area procedure should always equal or exceed results obtained as part of a large-area pattern distribution. In the event that PMP from the small-area PMP procedure in Chapter 2 is exceeded in such a comparison, the large-area storm isohyets are to be reduced proportionately so that the maximum value equals the small-area isohyet value. Excess volume that derives from this reduction is to be distributed throughout the remainder of the pattern within the drainage.

This comparison for small-basin PMP should always be made and is not particularly difficult or time consuming to do. Although we do not know how likely it is that this comparison will reveal problems (those instances when the portion of the large-pattern area averaged values for 100 mi^2 or less exceed comparable values from the small-area procedure), we expect that in most cases any exceedance will be small, and may be the result of incorrect planimetering or other form of calculation error. No redistribution of volume excess should be considered until all calculation steps have been confirmed.

The second comparison is somewhat more difficult, although it is expected that the number of occurrences for making it may be less than the first comparison discussed above. This comparison is as follows: for any large drainage that contains subdrainages, the area average depths of rainfall for individual subdrainages, based on the computation of spatially-distributed PMP for the total drainage, needs to be compared against areal average depths from PMP developed specifically for the subdrainages. That is to say, the site-specific PMP estimate for any subdrainage should exceed any areal average amount derived from a portion of a pattern used to spatially distribute PMP determined for a larger drainage that contains the subdrainage(s).

Again, in the complex procedures outlined in this study, a number of adjustment factors are used in the orographic and areal distribution steps. It is not possible to anticipate all the possible combinations of these factors, and it is conceivable that on occasion there may result a situation wherein the results obtained for a partial pattern over a subdrainage may exceed the site-specific PMP estimate for that subdrainage. The only subdrainage that needs to be compared to the one or more that may make up a large drainage is the one that contains the major portion of the pattern center. Therefore, if such an exceedance is discovered, a redistribution of precipitation must be made. As guidance in making this redistribution, it is recommended that the isohyets of the large drainage pattern be reduced proportionately to the degree necessary to match the area-averaged depths from the site-specific PMP. A volume of precipitation equal to the excess needs to be distributed throughout the remaining subdrainages of the large drainage. In all likelihood, the addition of these excess quantities to other subdrainages will not cause them, in turn, to exceed their site-specific PMP estimates.

In line with this comparison is the fact that table 22 in chapter 6 provides storm-averaged site-specific PMP for 26 basins. Thus, when any of these drainages are contained in larger drainages for which PMP is determined, the process to compare results is somewhat simplified. However, there are uncountable drainages within the Tennessee Valley that have not been evaluated for PMP using procedures in this report. The comparison process mentioned above requires that when large-basin PMP is determined, it is also necessary to consider and compare site-specific PMP estimates for some subdrainages. This additional burden of effort can be considerable, and the authors expect that with time and experience some guidance will be developed by users to indicate when such comparisons are necessary.

5.5 Examples of Computations

As pointed out in the introduction to this chapter, because of the five major options considered in this study, there are numerous possible combinations that may be of interest. Examples of such combinations are: small-basin TVA precipitation for a basin in the nonmountainous east, areal distribution of PMP for a basin in the western region, areally distributed PMP for a basin and the precipitation for concurrent drainages in the mountainous east. Since it would be difficult to present examples for all combinations that might be considered, this section provides a few selected examples that are believed representative. As such, it is hoped they will provide guidance to the computational process needed for any other possible consideration of interest.

5.5.1 PMP for a Small Basin

Take as an example a hypothetical 50-mi^2 basin in the orographically controlled upper Hiwassee drainage (see fig. 82 for basin outline). Following are details of the PMP computation, according to the steps outlined in section 5.2.1.

<u>Step</u>

1. Placement of the drainage outline (not shown) over figure 23 permits determination of a storm-averaged 6-hr 1-mi^2 PMP of 38.6 in. (chosen arbitrarily for this example).

2. Depth-durational values from 1 to 24 hr from figure 41 for a 6-hr 1-mi^2 amount of 38.6 in. are:

Duration (hr)	1	2	3	4	5	6	12	18	24
PMP (in.)	18.5	26.0	30.2	33.9	36.5	38.6	43.6	45.9	47.8

3. Areal reduction percentages of the 1-mi^2 amount from figure 26 are:

Duration (hr)	1	2	3	4	5	6	12	18	24
Reduction factor (%)	64.0	70.0	72.2	73.1	73.9	74.3	76.2	77.5	78.2

which are multiplied times the values from step 2 to obtain:

50 mi^2 PMP (in.)	11.8	18.2	21.8	24.8	27.0	28.7	33.2	35.6	37.4

4. The values from step 3 may be plotted and a smooth line fit to the points. Assume for this example that the results in step 3 represent a smooth line and no further smoothing is required and the values in step 3 are the average PMP for the basin.

5. Successively subtract amounts in step 4 to obtain average incremental values.

Duration (hr)	1	2	3	4	5	6	12	18	24
50-mi^2 PMP (in.)	11.8	6.4	3.6	3.0	2.2	1.7	4.5	2.4	1.8

6. Select a time sequence from section 2.2.14 that provides the hydrologically most critical hydrograph. Since this example does not allow for determining critical hydrological combinations, one possible sequence is offered as an example.

   a. Hourly sequence of maximum 6-hr PMP,

      Example: 6, 5, 4, 3, 1, 2; where 1 refers to the highest hourly amount.

   b. 6-hr sequence of 24-hr storm,

      Example: 4, 2, 1, 3; where 1 refers to the highest 6-hr amount, or in terms of depths (in.), 1.8, 4.5, 28.7 and 2.4.

The example sequence in terms of incremental PMP values from step 5 is:

Temporal Sequence (hr from beginning of storm)		PMP increments (in.) a.		b.	
1-6				1.8	Sequence of 6-hr increments
7-12				4.5	
13	Hourly sequence of Max. 6 hr.	1.7	=	28.7	
14		2.2			
15		3.0			
16		3.6			
17		11.8			
18		6.4			
19-24				2.4	

5.5.2 Areal Distribution of PMP for a Small Basin

The example provided here follows the procedure outlined in section 5.4. No consideration is given in this example to concurrent drainages; see description in section 5.4.4 for guidance if needed. To determine the areal distribution and the basin-averaged PMP as described in the section 5.4, the following steps should be completed. The basin used in this section is the same basin described in section 5.5.1, namely the 50-mi^2 Hiwassee basin.

<u>Step</u> (for PMP)

(for small-basin procedure)

1. Storm-averaged 6-hr 1-mi^2 PMP for the location of the basin as described in section 5.5.1 is 38.6 in. from figure 23.

2. From figure 41 obtain for 38.6 in. at 1 mi^2,

Duration (hr)	1	6	12	18	24
PMP (in.)	18.8	38.6	43.4	45.8	47.8

3. From figure 26,

Area (mi^2)			Percent		
10	85.3	88.5	89.2	89.8	90.2
50	65.3	74.9	76.8	77.8	78.3
100	55.0	68.8	71.7	72.7	73.2

4. Step 3 times step 2,

Area (mi^2)			Inches		
10	16.0	34.2	38.7	41.1	43.1
50	12.3	28.9	33.3	35.6	37.4
100	10.3	26.6	31.1	33.3	35.0

(for large-basin procedure)

5. From figure 52, the PMP D-A-D values (in.) valid at Knoxville Airport are:

Area (mi²)	Duration (hr)					
	6	12	18	24	48	72
100*	19.2	22.3	24.7	26.6	29.7	31.7
175*	18.3	21.3	23.8	25.6	28.7	30.6
200*	17.9	21.0	23.4	25.2	28.3	30.2
300*	16.9	20.0	22.4	24.2	27.3	29.2
450*	15.8	18.8	21.2	23.0	26.1	28.0
500	15.5	18.6	20.9	22.7	25.8	27.8
700*	14.5	17.5	19.8	21.6	24.7	26.7
1000*	13.4	16.4	18.7	20.5	23.6	25.6
1500*	12.2	15.1	17.3	19.0	22.1	24.1
2150*	11.0	13.9	16.0	17.7	20.8	22.8
3000*	10.0	12.9	14.9	16.6	19.7	21.6
4500*	8.7	11.6	13.5	15.2	18.3	20.1
5000	8.4	11.2	13.2	14.9	18.0	19.8

*Standard area sizes

Regional adjustment factor from figure 55 is 103.5 percent.

Multiplying 103.5 percent times the Knoxville DAD data (up to 24 hr only) yields for some area sizes:

Area (mi²)	Duration (hr)			
	6	12	18	24
3000	10.35	13.35	15.42	17.18
1000	13.87	16.97	19.35	21.22
500	16.04	19.25	21.63	23.49
200	18.53	21.74	24.22	26.08
100	19.87	23.08	25.56	27.53

6. Steps for TSF from section 5.4.3.2.

6-1. TSF is 16 percent for basin area of 100 mi²

6-2. No adjustment for area size, therefore, TSF is 1.16

6-3. In order to obtain the average 6-hr 1-mi² PMP from figure 23 for a 100-mi² basin, place the isohyetal pattern from figure 72 over the 50-mi² Hiwassee basin. Place the pattern so as to include as many of the larger PMP isohyets as possible. From table 11, isohyet D encloses 100 mi² area. Therefore, for that portion of the isohyetal pattern that is included within isohyet D, obtain the average 6-hr 1-mi² PMP. For the Hiwassee basin, the average 6-hr 1-mi² PMP for that portion of the basin within isohyet D turns out to be 39.0 in.

$$\frac{39.0}{1.16} = 33.62 \text{ in.}$$

6-4. Since we are considering a 100-mi^2 basin, no adjustment is needed from figure 66 to adjust the 16 percent. Therefore, 33.62 X 1.16 = 39.0 in.

6-5. Smooth 6-hr 1-mi^2 PMP from figure 16 is 34.4 in. From figure 69, the sheltering effect is 2 percent and subtract from 1.00 to get a 98 percent reduction factor. Multiply 34.4 X 0.98 = 33.71 in.

6-6. $\frac{39.0}{33.7}$ = 1.16 as orographic increase applicable to basin.

6-7. From figure 63, 100 percent of basin exposed to southwest winds.

6-8. Adjustment from figure 64 is 100 percent.

6-9. 1.00 X 1.16 = 1.16 for orographically modified TSF.

6-10. From figure 14, 100 percent of basin is located in sheltered area; thus, the BOF equation from section 3.4.1 takes the form:

BOF = 0 (0.55) + 0 (0.10) + 1.00 (0.05) = 0.05

Since the area size being considered for determining the TAF is 100 mi^2, it is necessary to refer to figure 70 for an additional adjustment of 0.50.

Therefore,
BOF = 0.05 X 0.5 = 0.025, which when rounded to nearest 0.05 gives:

BOF = 0.05

In this example the adjustment in figure 70 is ineffective, but its effect is substantial in situations where the basin is in the primary upslope region of figure 14.

6-11. TAF is now determined by adding the TSF (step 6-9) and the BOF (step 6-10), 1.16 + .05, respectively, to equal 1.21 rounded to the nearest 0.05 gives:

TAF = 1.20

7. Multiply 1.20 times the (regionally adjusted) depths (in.) in step 5, or

Pattern area (mi^2)	Duration (hr)			
	6	12	18	24
3000	12.4	16.0	18.5	20.6
1000	16.6	20.4	23.2	25.5
500	19.3	23.1	26.0	28.2
200	22.2	26.1	29.1	31.3
100	23.8	27.7	30.7	33.0

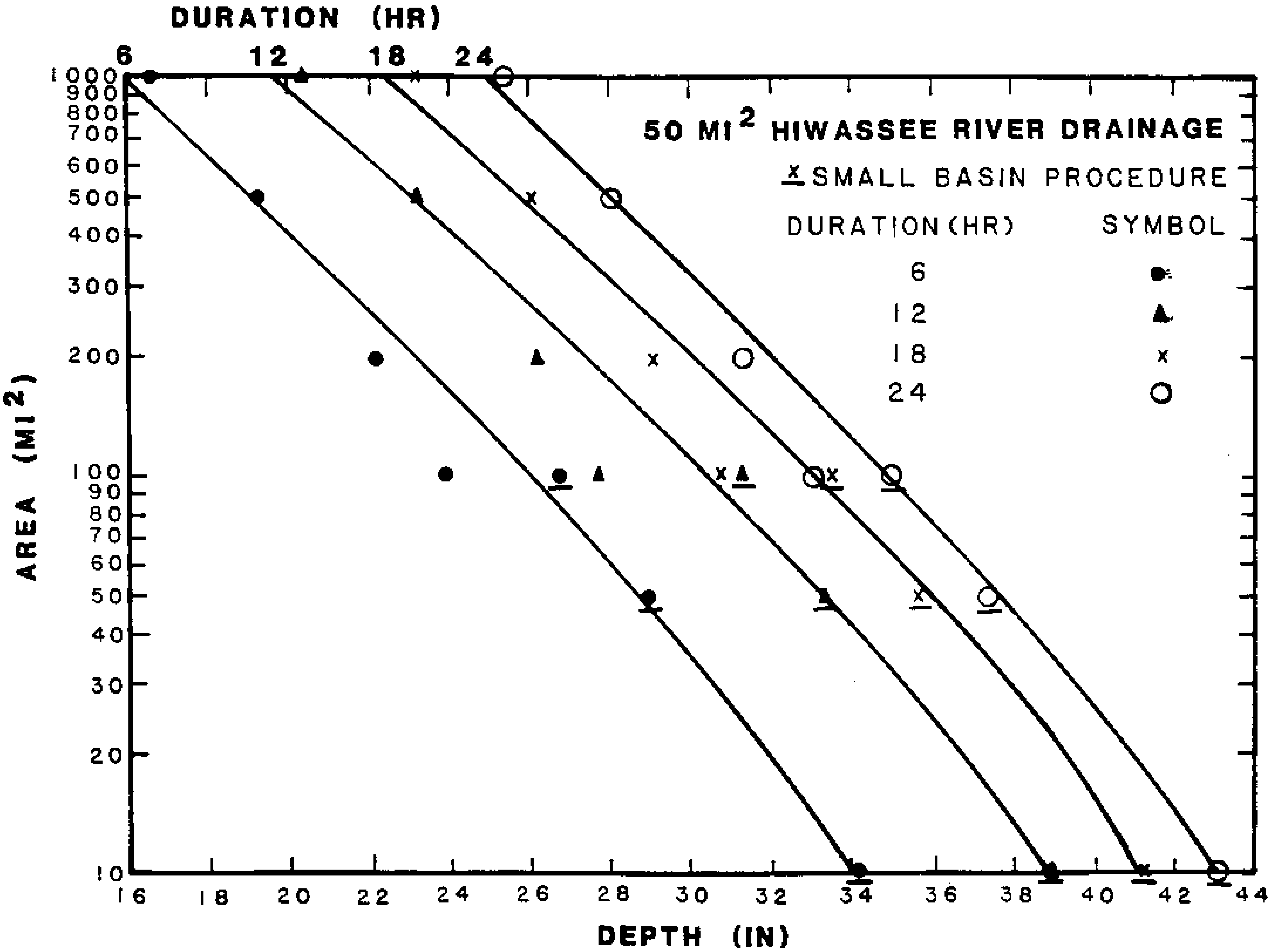

Figure 81.--DAD data valid for Hiwassee River drainage.

8. Data in step 4 and step 7 are plotted in figure 81. Note the two values plotted at 100 mi^2 - one depth obtained from the small basin procedure (steps 1-4) and the other depth from the large basin procedure (steps 1-7).

Areal distribution according to section 5.4.2. First refer to steps 1 to 8c in section 5.4.1 as follows:

1. Place the isohyetal pattern from figure 72 over the drainage as shown in figure 82 to obtain most complete isohyets within basin to provide maximum volume. The "C" isohyet is enclosed by the basin, while the "E" isohyet encloses the basin.

2. From figure 81, read off <u>depth</u> area values for selected standard area sizes (refer to footnote, page 129).

Pattern area (mi^2)	Duration (hr) 6	12	18	24
10	34.1	38.8	41.1	43.0
25	31.2	36.0	38.6	39.9
50	28.8	33.3	36.0	37.4
100	26.1	30.5	33.2	35.0
175	23.7	28.0	30.6	31.3
300	21.3	25.4	28.2	29.8
450	19.5	23.4	26.4	28.7
700	17.6	21.3	24.2	26.5

3. Incremental differences from step 2.

Pattern area (mi^2)	6-hr period 1	2	3
10	34.1	4.7	2.3
25	31.2	4.8	2.6
50	28.8	4.5	2.7
100	26.1	4.4	2.7
175	23.7	4.3	2.6
300	21.3	4.1	2.8
450	19.5	3.9	3.0
700	17.6	3.7	2.9

Plot these data (not shown) and "eye fit" smooth lines. Read comparable areal values from the smoothed lines. See section 5.4.1, step 3, for guidance in smoothing.

Pattern area (mi^2)	1	2	3
10	34.5	5.00	2.84
25	30.5	4.72	2.77
50	28.2	4.50	2.75
100	25.4	4.28	2.70
175	23.2	4.13	2.66
300	21.0	3.95	2.63
450	19.5	3.83	2.60
700	17.8	3.70	2.57

4. Since the basin is less than 300 mi^2, adjustment for isohyetal orientation is not considered in this example.

5. Not applicable.

6. Not applicable.

7. Determine the maximum volume of precipitation according to figure 80. From substeps a to j, we obtain the following results for volumetric water of three greatest 6-hr increments:

Pattern area (mi^2)	1	2	3	Total
10	1186.94	172.41	98.33	1457.68
25	1288.53	206.26	122.02	1616.81
50	1328.14	217.72	132.39	1678.25
100	1309.88	218.99	135.49	1664.36
175	1271.53	216.22	134.60	1622.45
300	1226.30	210.96	133.89	1571.15
450	1194.55	207.51	132.97	1535.02
700	1160.01	203.57	132.05	1495.63

From steps k to n and the above results, the maximum volume occurs for a storm pattern area of 50 mi^2. It is possible that by using supplementary isohyets, the maximum volume may occur at some non-standard area size; however, at these small areas, the effect of such additional accuracy is believed small and no such check has been made in this example.

8. These steps give the temporal distribution of storm-averaged PMP over the basin.

a.

Duration (hr)	6	12	18	24
PMP (in.)	28.2	32.7	35.4	37.4

(smoothed)

b.

6-hr increm.	1	2	3	4
PMP (in.)	28.2	4.5	2.8	2.0

c. Multiply each incremental amount in step b. times the respective index percents from tables 12, 13, 14, and 15. This gives the following incremental values for the isohyets covering the drainage.

	6-hr increment			
Isohyet	1	2	3	4
A	29.89	4.73	2.79	2.00
B	27.92	4.52	2.74	2.00
C	25.94	4.32	2.71	2.00
D	18.61	3.42	2.16	1.57
E	15.23	2.84	1.75	1.26

Concurrent precipitation is not considered in this example.

d. To obtain basin-averaged incremental depths, compute the volumes of the PMP for each 6-hr increment for the drainage by planimetering the isohyetal pattern from step c that occurs within the basin, and divide each incremental volume by the basin area.

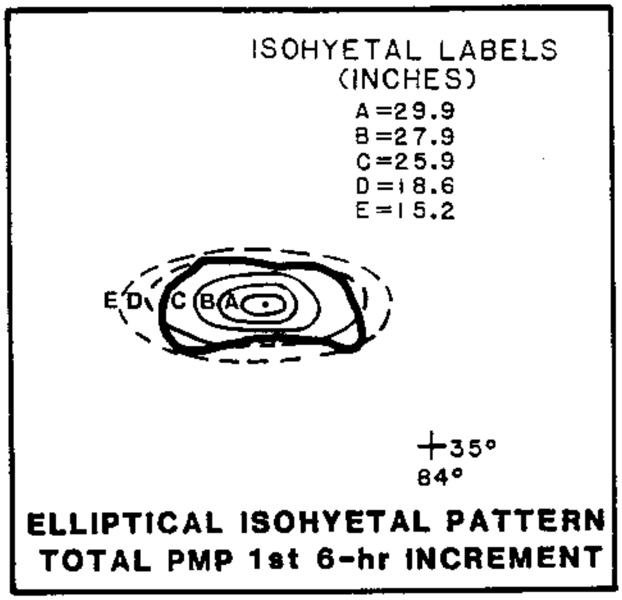

Figure 82.--Elliptical pattern centered over Hiwassee River drainage.

6-hr increm.	1	2	3	4
PMP (in.)	26.56	4.35	2.64	1.53

By summation of these incremental amounts, the basin-averaged total is 35.08 in. for 24-hr duration. This can be compared to the 24-hr storm-averaged PMP from step 8a of 37.4 in. for a reduction of a little more than 6 percent that is related to basin shape.

Return to step procedure of section 5.4.2, to determine the orographic modification to the elliptical pattern just obtained.

Step

1. See step 8c of previous section.

2-4. Not applicable.

5. Basin centered pattern in figure 82 is placed over the 2-yr 24-hr analysis in figure 59 and the pattern center determined to be 2.95 in. There is no lateral displacement for small basins (<100 mi^2). Convert the 2-yr 24-hr analysis covering the drainage to a percentage of the center value of 2.95 in. This is shown in figure 83.

6. Not applicable.

7. Multiply the isopercental analysis in figure 83 times the isohyetal values in figure 82 and analyzing the resulting values provides the degree of warping reflected in the 2-yr 24-hr analysis.

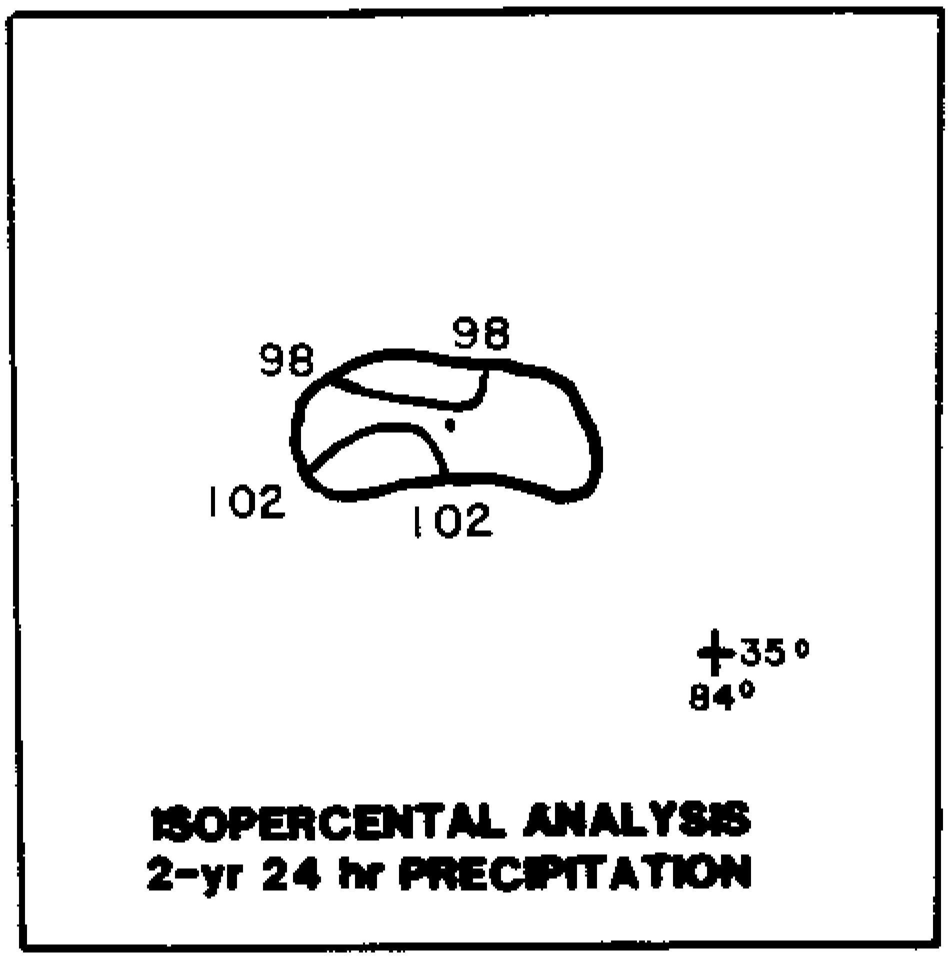

Figure 83.--Isopercental analysis of 2-yr 24-hr precipitation over the Hiwassee River drainage.

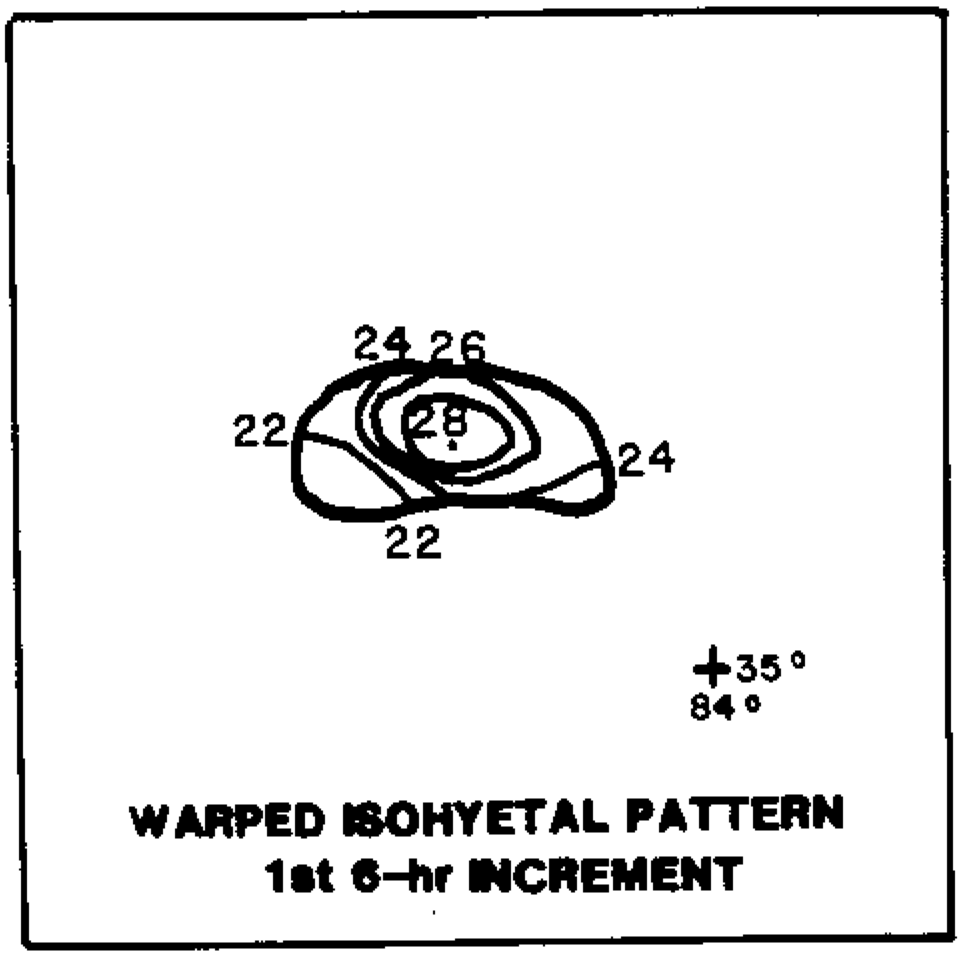

Figure 84.--Resulting isohyetal pattern of total PMP, 1st 6-hr increment for Hiwassee River drainage.

8. Planimeter the pattern as warped in step 7 to get the volume, V_x. The isohyetal values in the warped pattern (fig. 83) are then multiplied by the ratio of V_o/V_x, where V_o represents the volume from step 7 (page 207) in the areal computation of this example. This maintains the initial volume through the warping process, and the resulting pattern and isohyetal labels are shown in figure 84.

5.5.3 PMP and TVA precipitation for a large basin in the mountainous east.

The basin which is presented as an example for computing total PMP and TVA precipitation for a basin located in the mountainous east is the 295-mi^2 Little Tennessee River basin above Franklin, NC. This basin is subbasin 8 on figure 100

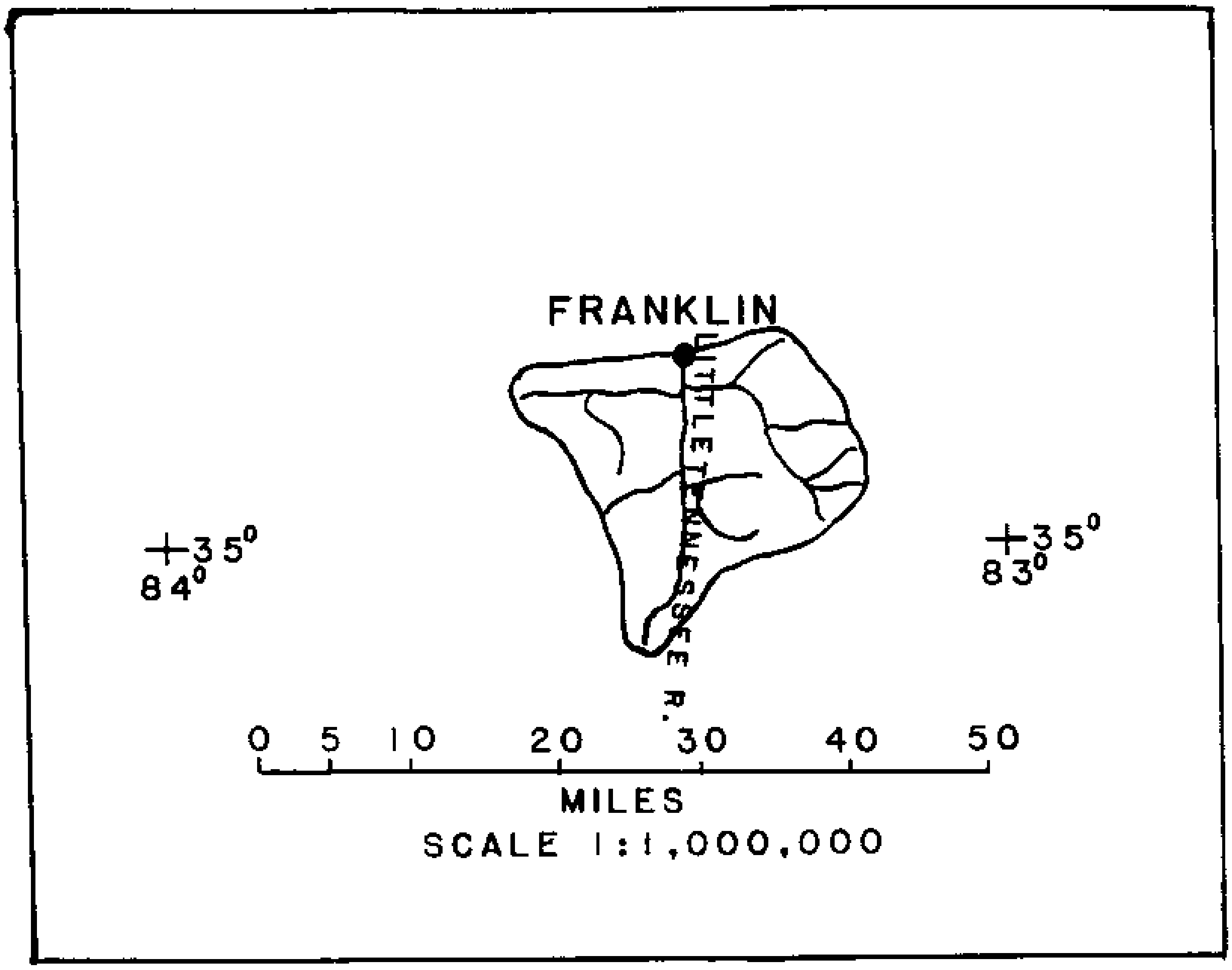

Figure 85.--Little Tennessee River basin (295 mi^2) above Franklin, NC showing drainage.

(chapt. 6), and is shown in figure 85. Individual steps for computing the total storm-averaged PMP and TVA precipitation follows the procedure outline in sections 5.3.1, 5.3.2, and 5.4.3.2. An example of areal distribution applied to this basin is presented in section 5.5.5.

<u>Step</u> (for PMP)

1. Scale 6-, 12-, 18-, 24-, 48-, and 72-hr storm-centered PMP depths for the area size of the basin (295 mi^2) from figure 52. These are storm-averaged nonorographic values applicable to Knoxville, TN.

Duration (hr)	6	12	18	24	48	72
PMP (in.)	16.8	19.9	22.2	24.1	27.2	29.2

2. From figure 55, read the regional adjustment percentage for the centroid of the drainage (35°05'N, 83°23'W), or 1.03.

3. Multiply step 2 times step 1,

Duration (hr	6	12	18	24	48	72
PMP (in.)	17.3	20.5	22.9	24.8	28.0	30.1

These are the storm-averaged nonorographic PMP values applicable for the 295-mi^2 drainage. Areal distribution of these depths will not be considered in this example (see sect. 5.5.5).

4. These values can be plotted on a depth-duration curve and a smooth curve fit to obtain complete 6-hr values (not done in this example).

5. Incremental depths are obtained through subtraction of successive 6-hr depths.

6-hr Increment (hr)	1	2	3	4	5-8	9-12
PMP (in.)	17.3	3.2	2.4	1.9	3.2	2.1

where the second 3.2 is the sum of the amounts for the 5th through 8th increments and the 2.1 is the sum of the amounts for the 9th through 12th increments.

6. Determine the TAF from section 5.4.3.2 for this basin in the mountainous east.

<u>Step</u> (for TAF, step sequence from sect. 5.4.3.2)

6-1. By definition, all basins in the mountainous east are rough. Therefore, the adjustment from figure 65 is 16 percent.

6-2. From figure 66, for a 295 mi^2, the adjustment is 42 percent. Therefore,

adjusted TSF = .16 X .42 = 0.067
add 1.0 to get a positive factor or 1.067

6-3. 6-hr 1-mi^2 PMP for basin from figure 23 = 40.3 in. Dividing 40.3 by 1.16 (since the basin is 100 percent rough) removes all of the thunderstorm induced terrain effect,

40.3/1.16 = 34.7

6-4. Multiplying step 6-3 times step 6-2,
34.7 x 1.067 = 37.0 in.

6-5. Nonorographic smooth 1-mi^2 PMP at 6 hr from figure 16 is 34.4 in. From figure 69 the reduction percentage due to sheltering is 2 percent. Multiply the reduction factor (1.0 - 0.02) = .98 times 34.4 to get 33.7 in.

6-6. Divide step 6-4 by step 6-5 to get the percentage orographic increase, or;

$$\frac{37.0}{33.7} = 1.10$$

6-7. The optimum wind from figure 63 is southerly, and 70 percent of the basin is exposed to winds from this direction.

6-8. From figure 64 for the percentage in step 6-7, we get a 95 percent orographic adjustment for optimum wind.

6-9. Multiply step 6-8 times step 6-6 to get the orographically modified TSF, or;

0.95 x 1.10 = 1.05

6-10. Figure 14 shows 50 percent of basin covered by primary upslopes, 30 percent covered by secondary upslopes, and 20 percent by sheltered areas. Multiply these percentages by 0.55, 0.10 and 0.05, respectively, and add to get the broadscale orographic factor, BOF;

0.50 x 0.55 = 0.275
0.30 x 0.10 = 0.030
0.20 x 0.05 = 0.010

BOF = 0.315 = 0.30 rounded to nearest 0.05. (Since the primary basin is 295 mi^2, there is no adjustment to BOF from figure 70).

6-11. BOF + TSF = TAF
0.30 + 1.05 = 1.35
(to nearest 5 percent.)

7. Multiply TAF from step 6-11 by the incremental values in step 5 to get the orographic and terrain adjusted incremental (storm-averaged) PMP for this basin,

6-hr increment (hr)	1	2	3	4	5-8	9-12
PMP (in.)	23.4	4.3	3.2	2.6	4.3	2.8

where the 4.3 is the sum of the amounts for the 5th through the 8th increments and the 2.8 is the sum of the amounts for the 9th through the 12th increments.

8.

Increment	1	2	3	4	5-8	9-12
PMP (in.)	23.4	27.7	30.9	33.5	37.8	40.6

where the 37.8-in. amount is the total after 8 increments and the 40.6 in. is the total after 12 increments.

When these values are plotted on a depth-duration curve smoothed values are obtained. The resulting values for subbasin 8 are shown in table 22.

In the event the TVA precipitation for a 72-hr TVA storm was of interest, the following procedures apply:

Step (for TVA precip., step sequence from sect. 5.3.2)

1. 72-hr storm

2. From step 8 of this example for total PMP at 72 hr, we get a value of 40.6 in.

3. From figure 68, the basin is totally rough by definition. Therefore, to convert the 72-hr or 24-hr PMP to 72-hr TVA or 24-hr TVA precipitation, it is necessary to use the 0.58 factor (rough basins) from section 2.2.7.1.

4. Multiply step 2 by step 3

   40.6 x 0.58 (for rough basins) = 23.5 in.

5. From figure 79 for the 72-hr TVA storm, and for a value of 23.5 in. we get the distribution of TVA precipitation, adjusted for terrain and orographic influence,

Duration (hr)	6	12	18	24	36	48	60	72
TVA precip. (in.)	8.6	13.3	16.2	18.2	20.3	21.7	23.0	23.5

   This example demonstrates the fact that in this study, if TVA precipitation is desired, it is often quicker to first compute the PMP estimate. The additional steps needed to compute PMP are not many and the steps to determine the terrain adjustment factor are also necessary for TVA precipitation.

5.5.4 Areal Distribution of PMP and TVA Precipitation for Large Basin in West

For this example, the Duck River above Columbia, TN (1,208 mi^2 centered at 35°34'N, 86°32'W) is chosen to demonstrate the computational procedure outlined in sections 5.3.1, 5.4.1 and 5.4.3.1. The basin outline is shown in figure 86.

Step (for PMP sect. 5.3.1)

1. Scale precipitation storm-centered depths for various durations and area sizes at Knoxville, TN (not shown) from figure 52.

2. The regional adjustment factor is obtained from figure 54 for the centroid of this basin, or 104.5 percent.

3. Multiply step 2 times step 1 to create a set of DAD curves applicable for the location of the basin. These are shown in figure 87 for the Duck River basin. From figure 87 storm-averaged nonorographic PMP can be obtained. This rainfall is obtained by reading off values from figure 87 for an area size of 1,208 mi^2.

	Duration (hr)											
PMP (in.)	6	12	18	24	30	36	42	48	54	60	66	72
1,208 mi^2	13.2	16.8	19.0	20.6	21.7	22.8	23.7	24.5	25.2	25.8	26.4	26.8

   However, for this example, it was decided that areal distribution of the PMP is of interest to obtain basin-averaged values.

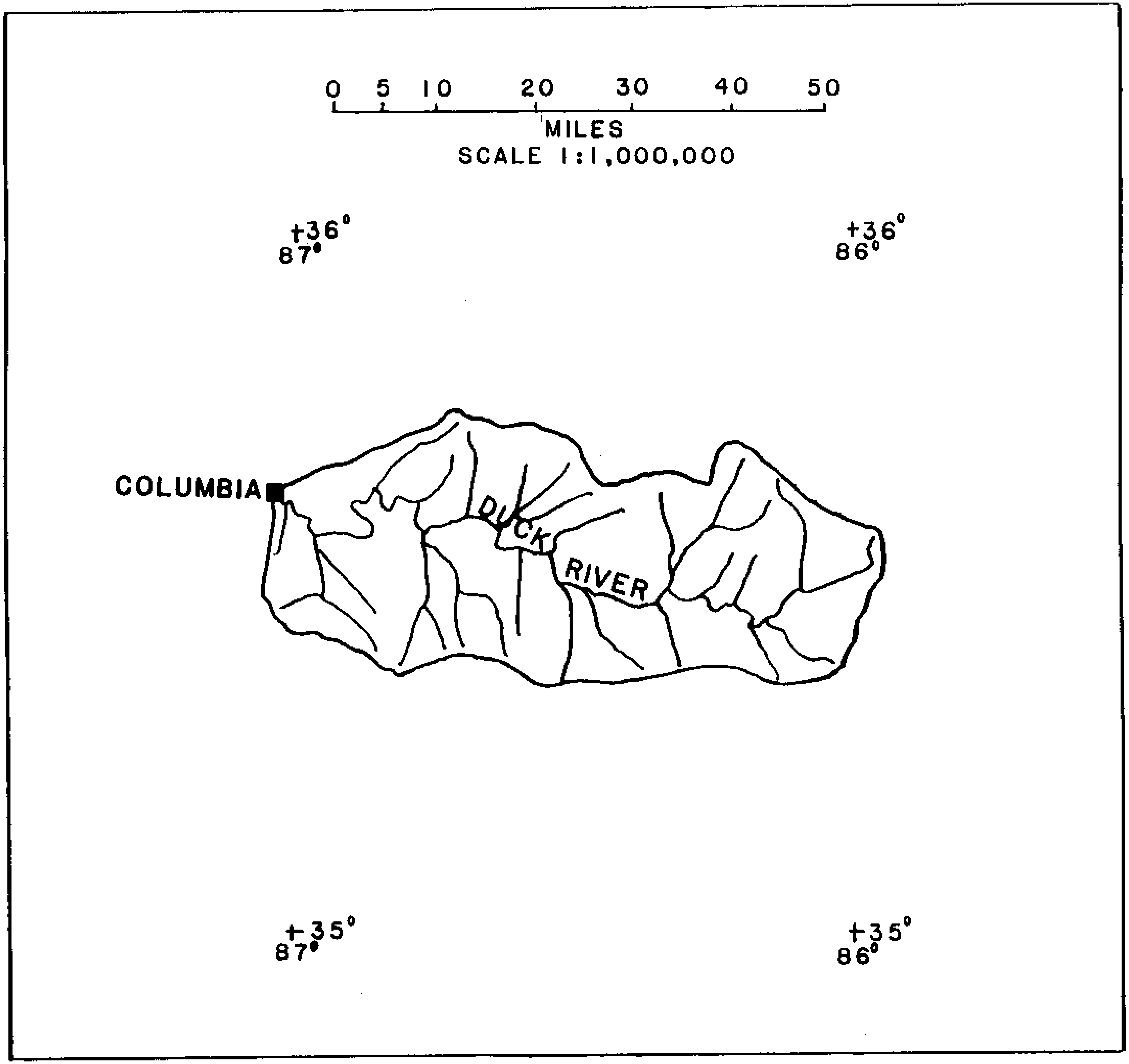

Figure 86.--Duck River drainage (1,208 mi^2) above Columbia, TN.

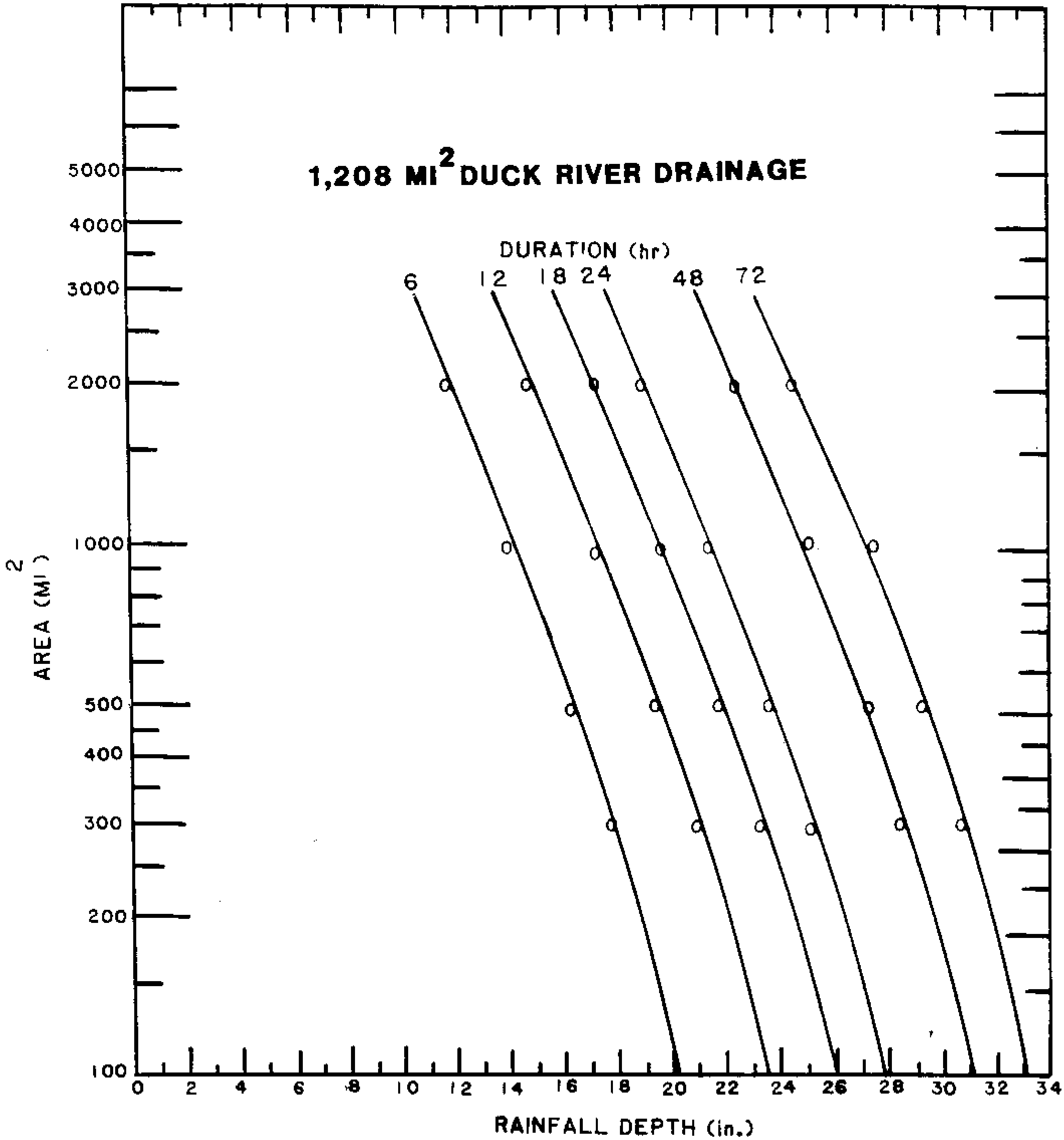

Figure 87.--DAD data valid for Duck River drainage; center 35°34'N, 86°32'W.

Step (areal distribution sect. 5.4.1)

3-1. Place the idealized isohyetal pattern from figure 72 over the basin to put the maximum volume into the drainage. This is shown in figure 88. Our judgment of best fit enclosed the "G" isohyet within the basin, while the "K" isohyet encloses the basin.

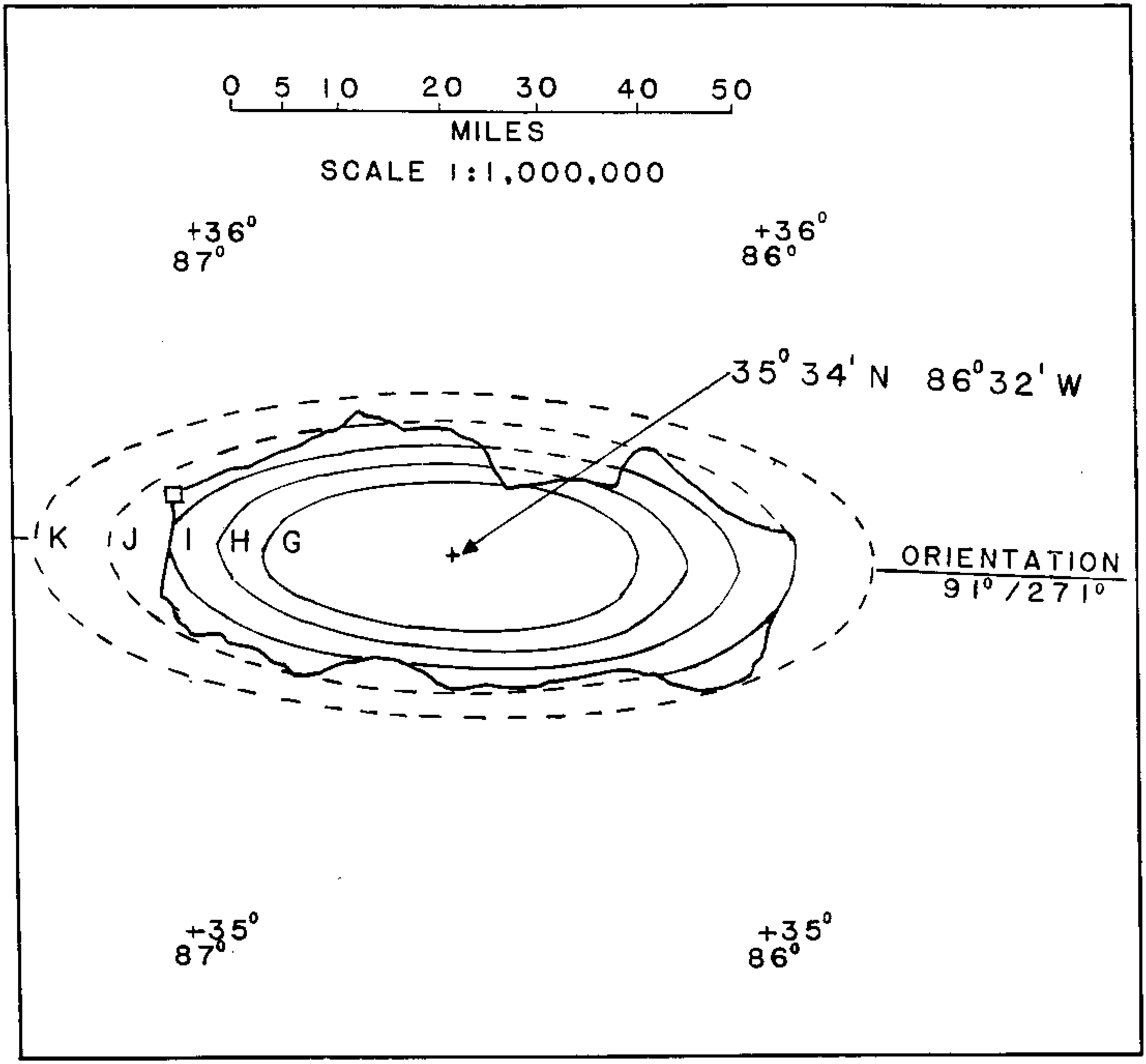

Figure 88.--Elliptical pattern centered over the Duck River drainage.

3-2. From step 3 for PMP in this example, read off a set of depth-duration values for 3 to 4 standard area sizes both larger and smaller than 1,208 mi^2 (Duck River drainage area) as follows;

Standard Area (mi^2)	Duration (hr) 6	12	18	24	48	72
300	17.7	21.0	23.4	26.2	28.5	30.8
450	16.5	19.9	22.2	24.0	27.3	29.6
700	15.2	18.5	20.8	22.6	26.0	28.2
1000	14.0	17.2	19.5	21.4	24.9	27.2
1500	12.7	15.8	18.1	20.1	23.4	25.6
2150	11.5	14.5	16.8	18.7	22.0	24.2
3000	10.3	13.2	15.5	17.5	20.9	22.9

Incremental differences for each of the first three 6-hr periods are shown below.

Standard Area (mi^2)	6-hr Periods 1	2	3
300	17.7	3.3	2.4
450	16.5	3.4	2.3
700	15.2	3.3	2.3
1000	14.0	3.2	2.3
1500	12.7	3.1	2.3
2150	11.5	3.0	2.3
3000	10.3	2.9	2.3

In figure 89, the data from the above table are smoothed resulting in the following incremental data (read to hundredths of an inch).

Standard Area (mi^2)	6-hr Periods 1	2	3
300	17.80	3.33	2.40
450	16.52	3.29	2.38
700	15.10	3.23	2.33
1000	13.98	3.19	2.31
1500	12.70	3.15	2.28
2150	11.35	3.10	2.25
3000	10.50	2.92	2.20

3-4. The orientation of the pattern placed as in figure 87 of step 3-1 is 091°/271°. The 91°, measured from north, lies outside the specified range (135° to 315°), and we accordingly added 180° to get the orientation of 271° for this example.

3-5. From figure 73, the preferred orientation for this location is 237°. The absolute difference between this step and step 3-4, or |237°-271°| = 34°, is less than the 40° threshold needed before reductions apply. Therefore, no adjustment for orientation is necessary in this example.

3-6. Since the difference in step 3-5 is less than 40°, the orientation adjustment is equal to 1.0.

3-7. Determine the maximum volume of precipitation for the PMP patterns corresponding to the 7 area sizes listed in step 3-3. Following the procedure outlined in steps 7a through 7j, this fills in table 16. (It should be noted, however, that computing some additional non-standard PMP pattern sizes such as 1,200 and 1,800 mi^2 might be in order. For simplicity we will not make these supplemental computations here.)

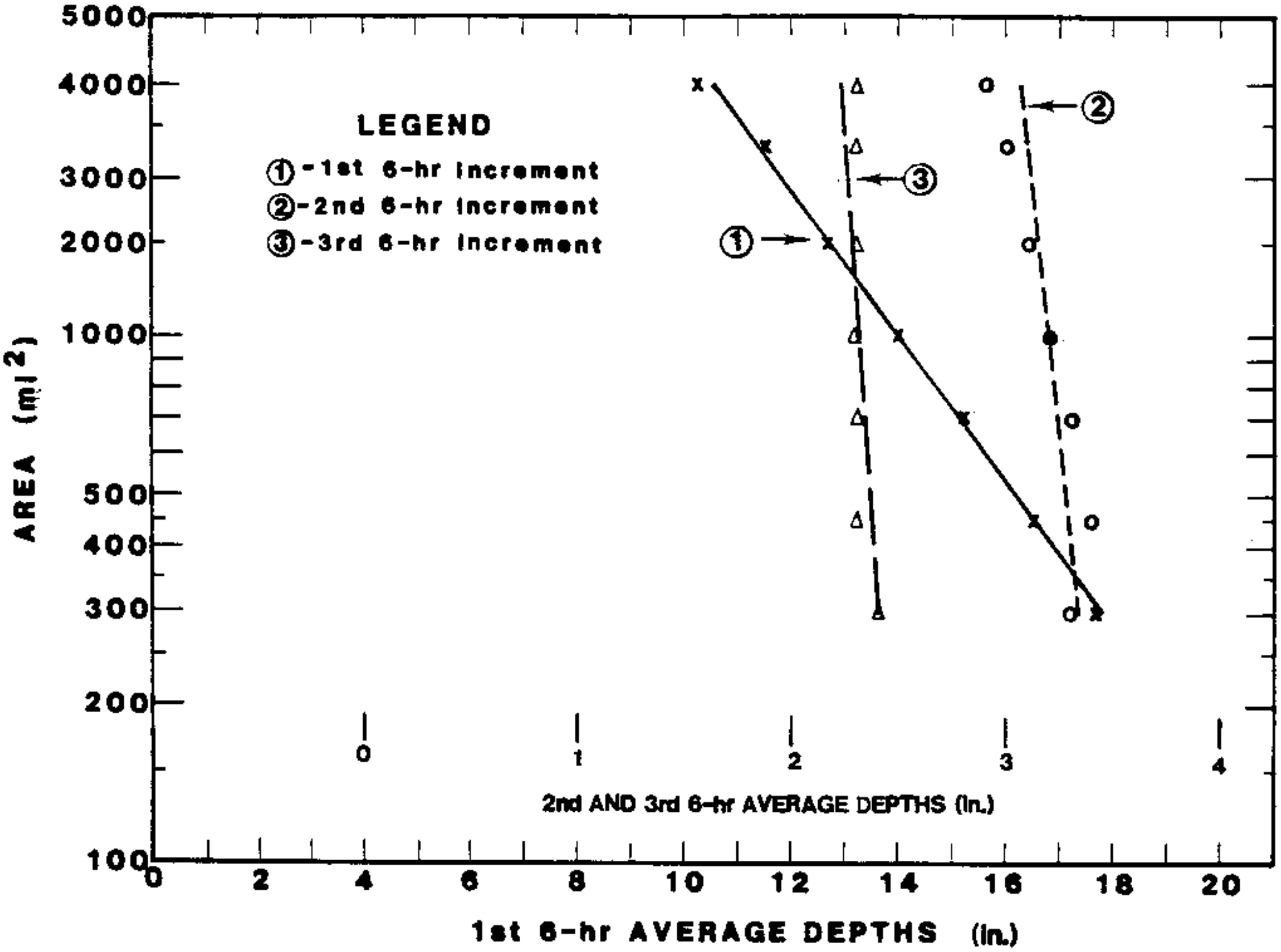

Figure 89.--Smoothing curves for the first three 6-hr incremental depth-area data, Duck River basin.

For each pattern area size, the volumetric precipitation is added for the 3 largest 6-hr amounts and plotted in figure 90. The results show a maximum volume occurring at an area size of 1,500 mi^2. This is the PMP storm-area size. (If supplementary isohyets had been tested, it is possible the maximum volume might occur at a slightly larger or smaller area size.)

3-8a. Determine the basin-averaged PMP over the basin. To do this read off the storm-averaged 6-hr values for a smoothed depth-duration curve for a 1,500-mi^2 area based on the data from figure 87, and for the basin as located in figure 88. This gives, using figure 91,

Duration (hr)	6	12	18	24	30	36	42	48	54	60	66	72
PMP (in.)	12.7	15.8	18.1	20.1	21.3	22.3	23.2	23.8	24.3	24.8	25.2	25.6

Table 16.—Completed computation sheets for 1st, 2nd, and 3rd 6-hr increments for Duck River basin

Increment: 1

Drainage: Duck River above Columbia, Tenn. Area: 1,208 mi^2 Date:

I		II	III	IV	V	VI	I		II	III	IV	V	VI
Area size	Iso.	Nomo.	Amt. 17.80	Avg. depth	ΔA	ΔV	Area size	Iso.	Nomo.	Amt. 13.98	Avg. depth	ΔA	ΔV
300/1*	A	126.5	22.52	22.52	10	225.2	1000/1	A	149	20.83	20.83	10	208.3
	B	118	21.00	21.76	15	326.4		B	140	19.57	20.20	15	303.0
	C	110.5	19.67	20.34	25	508.4		C	131	18.31	18.94	25	473.6
	D	103	18.33	19.00	50	950.1		D	122	17.06	17.68	50	884.2
	E	96	17.09	17.71	75	1328.3		E	113	15.80	16.43	75	1232.0
	F	88	15.66	16.38	125	2047.0		F	104	14.54	15.17	125	1896.0
	G	66	11.75	13.71	150	2055.9		G	97	13.56	14.05	150	2107.5
	H	52	9.26	10.50	224	2351.1		H	89	12.44	13.00	224	2910.6
	I	42	7.48	8.37	285	2383.6		I	82	11.46	11.95	285	3405.6
	J	32	5.70	6.59	232	1528.0		J	59.5	8.32	9.89	232	2294.8
(.85x)#	K	25	4.45	5.51	81	448.5	(.85x)	K	43.5	6.08	7.98	81	649.9
				Sum =		14152.5						Sum =	16365.5
Area size			Amt. 16.52				Area size			Amt. 12.70			
450/1	A	132.5	21.89	21.89	10	218.9	1500/1	A	162	20.57	20.57	10	205.7
	B	124	20.48	21.19	15	317.8		B	152	19.30	19.94	15	299.1
	C	116	19.16	19.82	25	495.6		C	142	18.03	18.67	25	466.7
	D	108	17.84	18.50	50	925.1		D	132	16.76	17.40	50	869.9
	E	101	16.69	17.26	75	1294.8		E	122	15.49	16.13	75	1209.7
	F	93	15.36	16.02	125	2003.1		F	112.5	14.29	14.89	125	1861.3
	G	86	14.21	14.79	150	2217.8		G	104.5	13.27	13.78	150	2066.9
	H	63	10.41	12.31	224	2755.3		H	96	12.19	12.73	224	2850.3
	I	50	8.26	9.33	285	2659.4		I	88.5	11.24	11.72	285	3338.1
	J	38.5	6.36	7.31	232	1696.0		J	80	10.16	10.70	232	2482.4
(.85x)#	K	30.0	4.96	6.15	81	500.6	(.85x)	K	56	7.11	9.70	81	789.9
				Sum =		15084.3						Sum =	16440.0
Area size			Amt. 15.10				Area size			Amt. 11.35			
700/1	A	140.5	21.22	21.22	10	212.2	2150/1	A	176	19.98	19.98	10	199.8
	B	132	19.93	20.57	15	308.6		B	165	18.73	19.35	15	290.3
	C	124	18.72	19.33	25	483.2		C	153.4	17.41	18.07	25	451.7
	D	115	17.37	18.04	50	902.2		D	142.5	16.17	16.79	50	839.5
	E	107.5	16.23	16.80	75	1259.9		E	131	14.87	15.52	75	1164.1
	F	98	14.80	15.52	125	1939.4		F	122	13.85	14.36	125	1794.7
	G	91.5	13.82	14.31	150	2146.1		G	113	12.83	13.34	150	2000.4
	H	84	12.86	13.25	224	2966.3		H	103	11.69	12.26	224	2744.2
	I	64	9.66	11.17	285	3183.7		I	95	10.78	11.24	285	3201.5
	J	48	7.25	8.46	232	1961.9		J	86	9.76	10.27	232	2383.2
(.85x)	K	36	5.44	6.98	81	567.9	(.85x)	K	77	9.74	9.61	81	782.2
				Sum =		15431.4						Sum =	15851.6

*300/1 = Computation for the 300-mi^2 PMP pattern, 1st 6-hr increment.
#weights applied for partial areas

Table 16.--Completed computation sheets for 1st, 2nd, and 3rd 6-hr increments for Duck River basin (continued).

Increment: 1, 2

Drainage: Duck River above Columbia, Tenn. Area: 1,208 mi^2 Date:

I		II	III	IV	V	VI
Area size	Iso.	Nomo.	Amt. 10.50	Avg. depth	ΔA	ΔV
3000/1	A	191	20.06	20.06	10	200.6
	B	178.5	18.74	19.40	15	291.0
	C	166	17.43	18.09	25	452.2
	D	154	16.17	16.80	50	840.0
	E	142	14.91	15.54	75	1165.5
	F	132	13.86	14.39	125	1798.1
	G	122	12.81	13.34	150	2000.2
	H	112	11.76	12.29	224	2750.2
	I	102.5	10.76	11.26	285	3208.6
	J	92	9.66	10.21	232	2369.1
(.85x)	K	83	8.72	9.52	81	774.9
					Sum =	15850.4

I		II	III	IV	V	VI
Area size	Iso.	Nomo.	Amt. 3.23	Avg. depth	ΔA	ΔV
800/2	A	114.5	3.70	3.70	10	37.0
	B	110.5	3.57	3.63	15	54.5
	C	107	3.46	3.51	25	87.8
	D	104	3.36	3.41	50	170.4
	E	101	3.26	3.31	75	248.3
	F	99	3.20	3.23	125	403.7
	G	97.1	3.14	3.17	150	475.1
	H	95	3.07	3.10	224	694.7
	I	78	2.52	2.79	285	796.1
	J	66	2.13	2.33	232	539.6
(.85x)	K	54	1.74	2.07	81	168.8
					Sum =	3676.0

Area size			Amt. 3.33			
300/2	A	112	3.73	3.73	10	37.3
	B	107	3.56	3.65	15	54.7
	C	103.5	3.45	3.50	25	87.6
	D	100	3.33	3.39	50	169.4
	E	98	3.26	3.30	75	247.2
	F	95	3.16	3.21	125	401.7
	G	80	2.66	2.91	150	437.1
	H	67.5	2.25	2.46	224	549.8
	I	57	1.90	2.07	285	590.6
	J	47	1.57	1.73	232	401.7
(.85x)	K	38	1.27	1.52	81	123.8
					Sum =	3100.9

Area size			Amt. 3.19			
1000/2	A	116	3.70	3.70	10	37.0
	B	112	3.57	3.64	15	54.5
	C	108.5	3.46	3.52	25	87.9
	D	105	3.35	3.41	50	170.3
	E	103	3.29	3.32	75	248.8
	F	101	3.22	3.25	125	406.7
	G	99	3.16	3.19	150	478.0
	H	97	3.09	3.13	224	699.9
	I	95	3.03	3.06	285	872.5
	J	76	2.42	2.73	232	632.8
(.85x)	K	63	2.01	2.36	81	192.3
					Sum =	3880.7

Area size			Amt. 3.29			
450/2	A	113	3.72	3.72	10	37.2
	B	109	3.59	3.65	15	54.8
	C	105	3.45	3.52	25	88.0
	D	102	3.36	3.41	50	170.3
	E	99.5	3.27	3.31	75	248.6
	F	97	3.19	3.23	125	404.1
	G	95	3.13	3.16	150	473.8
	H	77.5	2.55	2.84	224	635.3
	I	66	2.17	2.36	285	672.6
	J	55	1.01	1.99	232	461.8
(.85x)	K	45	1.48	1.76	81	143.3
					Sum =	3389.8

Area size			Amt. 3.15			
1500/2	A	117	3.69	3.69	10	36.9
	B	113	3.56	3.62	15	54.3
	C	110	3.47	3.51	25	87.8
	D	107	3.37	3.42	50	170.9
	E	105	3.31	3.34	75	250.4
	F	103	3.24	3.28	125	409.5
	G	101	3.18	3.21	150	481.9
	H	99	3.12	3.15	224	705.2
	I	97	3.06	3.09	285	879.5
	J	95	2.99	3.02	232	701.6
(.85x)	K	75.5	2.38	2.90	81	236.1
					Sum =	4014.2

Table 16.--Completed computation sheets for 1st, 2nd, and 3rd 6-hr increments for Duck River basin (continued).

Drainage: Duck River above Columbia, Tenn. Area: 1,208 mi^2 Increment: 2, 3 Date:

Area size	I Iso.	II Nomo.	III Amt. 3.10	IV Avg. depth	V ΔA	VI ΔV
2150/2	A	118.5	3.67	3.67	10	36.7
	B	114.5	3.55	3.61	15	54.2
	C	111.5	3.46	3.50	25	87.6
	D	108.5	3.36	3.41	50	170.5
	E	106.5	3.30	3.33	75	249.9
	F	104.5	3.24	3.27	125	408.8
	G	102.1	3.17	3.20	150	480.3
	H	100	3.10	3.13	224	701.3
	I	99	3.07	3.08	285	878.8
	J	97	3.01	3.04	232	704.8
(.85x)	K	96.5	2.99	3.00	81	244.6
					Sum =	4017.5

Area size	I Iso.	II Nomo.	III Amt. 2.38	IV Avg. depth	V ΔA	VI ΔV
450/3	A	103.8	2.47	2.47	10	24.7
	B	102.4	2.44	2.45	15	36.8
	C	101.2	2.41	2.42	25	60.6
	D	100.3	2.39	2.40	50	119.9
	E	99.8	2.38	2.38	75	178.6
	F	99.5	2.37	2.37	125	296.5
	G	99.2	2.36	2.36	150	354.7
	H	84	2.00	2.18	224	488.1
	I	71.2	1.69	1.85	285	526.2
	J	60	1.43	1.56	232	362.2
(.85x)	K	50	1.19	1.39	81	113.3
					Sum =	2561.6

Area size	Iso.	Nomo.	Amt. 2.92			
3000/2	A	119.5	3.49	3.49	10	34.9
	B	116	3.39	3.44	15	51.6
	C	112.5	3.29	3.34	25	83.4
	D	110	3.21	3.25	50	162.4
	E	108	3.15	3.18	75	238.7
	F	106	3.10	3.12	125	390.5
	G	104	3.04	3.07	150	459.9
	H	101.9	2.98	3.01	224	673.0
	I	100.5	2.93	2.96	285	841.9
	J	99	2.89	2.91	232	675.8
(.85x)	K	97	2.83	2.88	81	234.6
					Sum =	3846.7

Area size	Iso.	Nomo.	Amt. 2.33			
700/3	A	104.2	2.43	2.43	10	24.3
	B	102.9	2.40	2.41	15	36.2
	C	101.7	2.37	2.38	25	59.6
	D	100.9	2.35	2.36	50	118.0
	E	100.2	2.33	2.34	75	175.7
	F	99.9	2.33	2.33	125	291.4
	G	99.6	2.32	2.32	150	348.6
	H	99.2	2.31	2.32	224	518.5
	I	85	1.98	2.15	285	611.4
	J	70.5	1.64	1.81	232	420.3
(.85x)	K	58.5	1.36	1.60	81	130.3
					Sum =	2734.3

Area size	Iso.	Nomo.	Amt. 2.40			
300/3	A	103.4	2.48	2.48	10	24.8
	B	101.9	2.45	2.46	15	36.9
	C	100.7	2.42	2.43	25	60.8
	D	99.8	2.40	2.41	50	120.3
	E	99.3	2.38	2.39	75	179.2
	F	99	2.38	2.38	125	297.4
	G	86	2.06	2.22	150	333.0
	H	72	1.73	1.90	224	424.5
	I	62	1.49	1.61	285	458.1
	J	53	1.27	1.38	232	320.2
(.85x)	K	43	1.03	1.24	81	100.6
					Sum =	2355.8

Area size	Iso.	Nomo.	Amt. 2.31			
1000/3	A	104.6	2.42	2.42	10	24.2
	B	103.3	2.39	2.40	15	36.0
	C	102.2	2.36	2.37	25	59.3
	D	101.3	2.34	2.35	50	117.5
	E	100.6	2.32	2.33	75	174.9
	F	100.3	2.32	2.32	125	290.1
	G	99.9	2.31	2.31	150	346.8
	H	99.6	2.30	2.30	224	515.8
	I	99.3	2.29	2.30	285	654.5
	J	82.5	1.91	2.10	232	487.2
(.85x)	K	67.0	1.55	1.85	81	150.8
					Sum =	2857.1

Table 16.--Completed computation sheets for 1st, 2nd, and 3rd 6-hr increments for Duck River basin (continued).

Increment: 1, 2

Drainage: Duck River above Columbia, Tenn. Area: 1,208 mi^2 Date:

I		II	III	IV	V	VI
Area size	Iso.	Nomo.	Amt. 10.50	Avg. depth	ΔA	ΔV
3000/1	A	191	20.06	20.06	10	200.6
	B	178.5	18.74	19.40	15	291.0
	C	166	17.43	18.09	25	452.2
	D	154	16.17	16.80	50	840.0
	E	142	14.91	15.54	75	1165.5
	F	132	13.86	14.39	125	1798.1
	G	122	12.81	13.34	150	2000.2
	H	112	11.76	12.29	224	2750.2
	I	102.5	10.76	11.26	285	3208.6
	J	92	9.66	10.21	232	2369.1
(.85x)	K	83	8.72	9.52	81	774.9
						Sum = 15850.4

I		II	III	IV	V	VI
Area size	Iso.	Nomo.	Amt. 3.23	Avg. depth	ΔA	ΔV
800/2	A	114.5	3.70	3.70	10	37.0
	B	110.5	3.57	3.63	15	54.5
	C	107	3.46	3.51	25	87.8
	D	104	3.36	3.41	50	170.4
	E	101	3.26	3.31	75	248.3
	F	99	3.20	3.23	125	403.7
	G	97.1	3.14	3.17	150	475.1
	H	95	3.07	3.10	224	694.7
	I	78	2.52	2.79	285	796.1
	J	66	2.13	2.33	232	539.6
(.85x)	K	54	1.74	2.07	81	168.8
						Sum = 3676.0

Area size			Amt. 3.33			
300/2	A	112	3.73	3.73	10	37.3
	B	107	3.56	3.65	15	54.7
	C	103.5	3.45	3.50	25	87.6
	D	100	3.33	3.39	50	169.4
	E	98	3.26	3.30	75	247.2
	F	95	3.16	3.21	125	401.7
	G	80	2.66	2.91	150	437.1
	H	67.5	2.25	2.46	224	549.8
	I	57	1.90	2.07	285	590.6
	J	47	1.57	1.73	232	401.7
(.85x)	K	38	1.27	1.52	81	123.8
						Sum = 3100.9

Area size			Amt. 3.19			
1000/2	A	116	3.70	3.70	10	37.0
	B	112	3.57	3.64	15	54.5
	C	108.5	3.46	3.52	25	87.9
	D	105	3.35	3.41	50	170.3
	E	103	3.29	3.32	75	248.8
	F	101	3.22	3.25	125	406.7
	G	99	3.16	3.19	150	478.0
	H	97	3.09	3.13	224	699.9
	I	95	3.03	3.06	285	872.5
	J	76	2.42	2.73	232	632.8
(.85x)	K	63	2.01	2.36	81	192.3
						Sum = 3880.7

Area size			Amt. 3.29			
450/2	A	113	3.72	3.72	10	37.2
	B	109	3.59	3.65	15	54.8
	C	105	3.45	3.52	25	88.0
	D	102	3.36	3.41	50	170.3
	E	99.5	3.27	3.31	75	248.6
	F	97	3.19	3.23	125	404.1
	G	95	3.13	3.16	150	473.8
	H	77.5	2.55	2.84	224	635.3
	I	66	2.17	2.36	285	672.6
	J	55	1.01	1.99	232	461.8
(.85x)	K	45	1.48	1.76	81	143.3
						Sum = 3389.8

Area size			Amt. 3.15			
1500/2	A	117	3.69	3.69	10	36.9
	B	113	3.56	3.62	15	54.3
	C	110	3.47	3.51	25	87.8
	D	107	3.37	3.42	50	170.9
	E	105	3.31	3.34	75	250.4
	F	103	3.24	3.28	125	409.5
	G	101	3.18	3.21	150	481.9
	H	99	3.12	3.15	224	705.2
	I	97	3.06	3.09	285	879.5
	J	95	2.99	3.02	232	701.6
(.85x)	K	75.5	2.38	2.90	81	236.1
						Sum = 4014.2

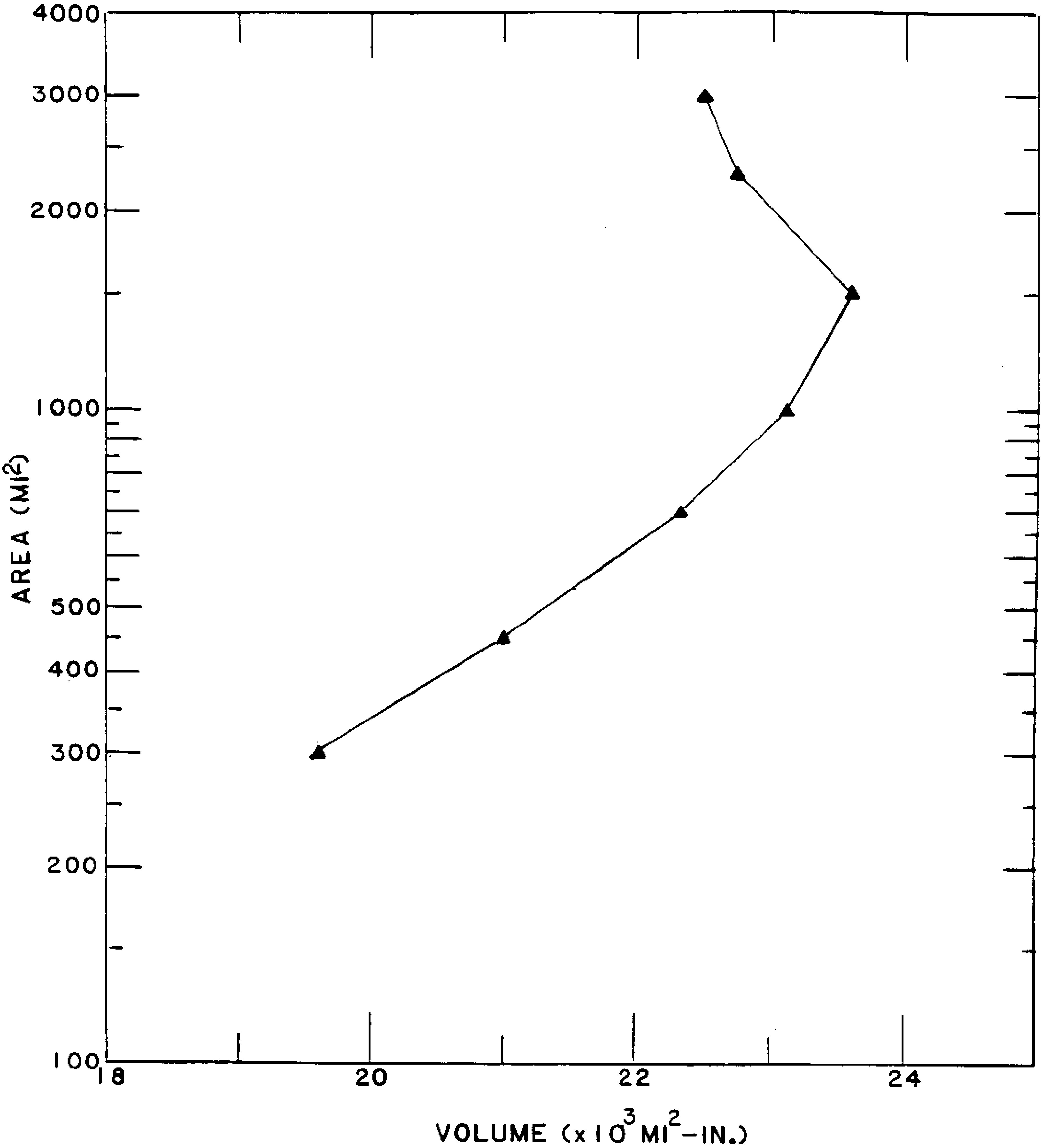

Figure 90.—Volume vs. area curve for the first three 6-hr increments for Duck River basin.

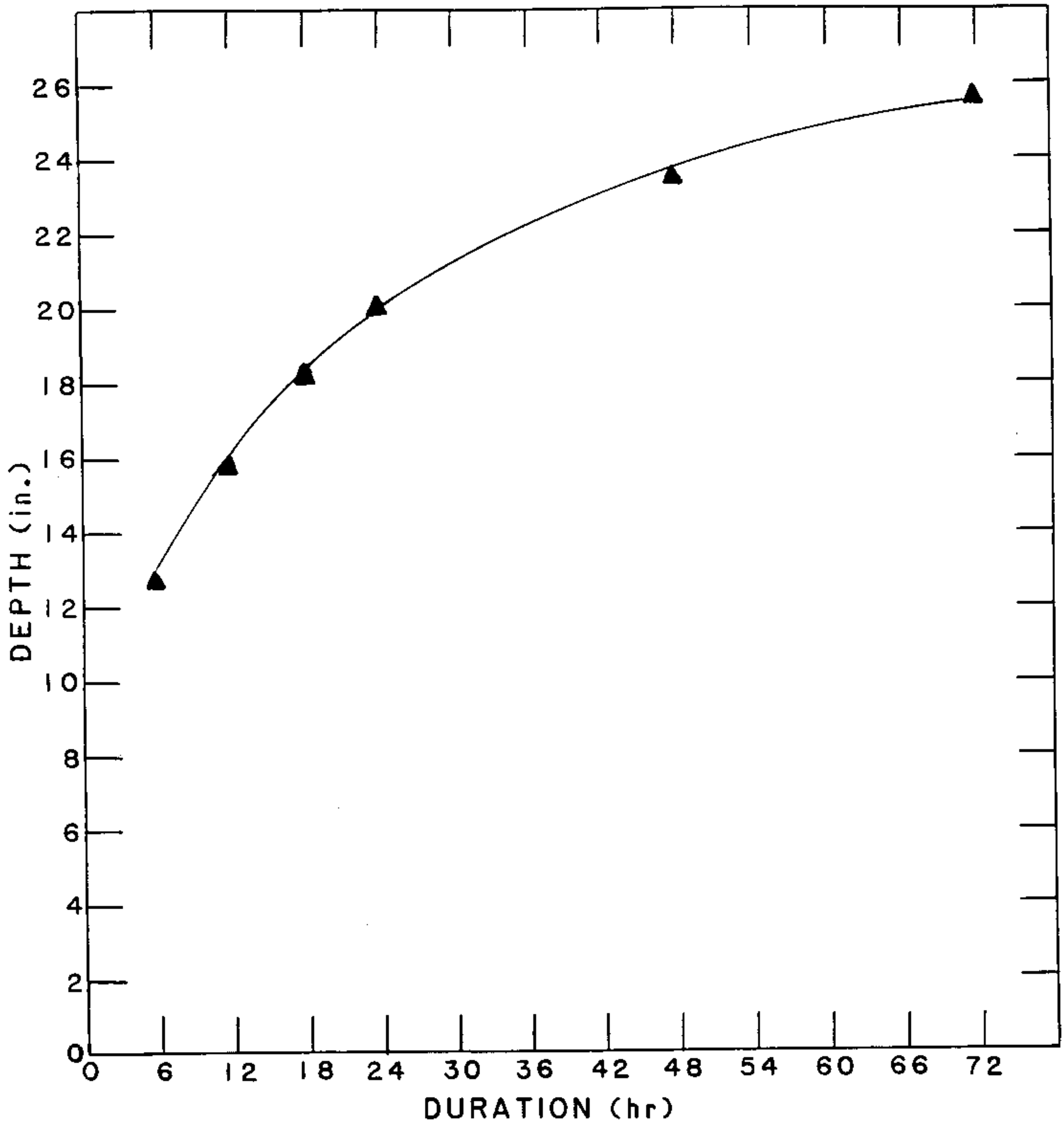

Figure 91.—Depth-duration curve for 1,500 mi^2 for Duck River basin.

b. Subtract each 6-hr value in step 3-8a from the next lower durational value to get incremental amounts.

6-hr Increm.	1	2	3	4	5	6	7	8	9	10	11	12
PMP(in.)	12.7	3.1	2.3	2.0	1.2	1.0	0.9	0.6	0.5	0.5	0.4	0.4

ℓe 17. **Isohyet values (in.) of PMP for Duck River example**

	6-hr Periods											
Isohyet	1	2	3	4	5	6	7	8	9	10	11	12
A	20.57	3.69	2.39	2.00	1.20	1.00	0.90	0.60	0.50	0.50	0.40	0.40
B	19.30	3.56	2.37	2.00	1.20	1.00	0.90	0.60	0.50	0.50	0.40	0.40
C	18.03	3.47	2.34	2.00	1.20	1.00	0.90	0.60	0.50	0.50	0.40	0.40
D	16.76	3.37	2.32	2.00	1.20	1.00	0.90	0.60	0.50	0.50	0.40	0.40
E	15.49	3.31	2.30	2.00	1.20	1.00	0.90	0.60	0.50	0.50	0.40	0.40
F	14.29	3.24	2.30	2.00	1.20	1.00	0.90	0.60	0.50	0.50	0.40	0.40
G	13.27	3.18	2.29	2.00	1.20	1.00	0.90	0.60	0.50	0.50	0.40	0.40
H	12.19	3.12	2.28	2.00	1.20	1.00	0.90	0.60	0.50	0.50	0.40	0.40
I	11.24	3.06	2.27	2.00	1.20	1.00	0.90	0.60	0.50	0.50	0.40	0.40
J	10.16	2.99	2.27	2.00	1.20	1.00	0.90	0.60	0.50	0.50	0.40	0.40
K	7.11	2.38	1.85	1.63	0.97	0.81	0.73	0.49	0.41	0.41	0.32	0.32

c. Isohyet values (labels) are obtained by multiplying each incremental depth times the respective percentages from tables 12, 13, 14 and 15. The results are shown in table 17. Concurrent basins are not discussed in this example.

d. The basin-averaged incremental 6-hr PMP for all 12 6-hr increments are obtained from the data in step 3-8c. Planimeter the isohyet pattern in figure 88 with the percentages given for the 1st 6-hr period, and determine the incremental volume of precipitation in the drainage. As shown in table 16, this amounts to 16,440 mi^2 in. Dividing this by the basin area gives an average depth for the 1st 6-hr period. Note that total area for this drainage in table 16 is measured as 1,272 mi^2, not the 1,208 mi^2 given initially. The larger number represents the error obtained in the planimetering step and is used here to get the average depth of 12.9 in. Had the incremental depths in table 16 been adjusted initially, somewhat lower volumes would have been obtained. Either approach may be used to get the average depth. The remaining 6-hr incremental depths, are then:

6-hr increm.	1	2	3	4	5	6	7	8	9	10	11	12
PMP (in.)	12.9	3.2	2.3	2.0	1.2	1.0	0.9	0.6	0.5	0.5	0.4	0.4

If these incremental depths are summed, we get 25.9 in. which can be compared with the 72-hr storm-area averaged nonorographic PMP for 1,208-mi^2 (from fig. 87) of 26.8 in. The reduction of roughly 3 percent is caused by factors related to the shape of the basin.

e. Determine the TSF from section 5.4.3.1