12.5.2 PMP for Durations Less Than 1 hr

There are no data available in the meaningful relationships for PMP of less than 1 hr. As stated earlier, a large proportion of the 6-hr 1-mi^2 PMP local storm is expected to fall within 1 hr. This expectation is borne out by the analysis of 6-/1-hr ratios and subsequent depth-duration curve in figure 12.10. Without better resolution, it was decided that the depth-duration relationship in figure 12.10 was applicable to all durations, both less than and greater than 1 hr. These procedures are in line with previous local-storm study procedures (Hansen et al. 1977). A listing of short duration percentages of the 1-hr local storm derived from figure 12.10 is shown in table 12.4.

12.6 Depth-Area Relation

Thus far in the development of local-storm PMP, only PMP for an area size of 1 mi^2 has been considered. It is necessary to develop relations to enable PMP estimates to be made for larger areas. Unfortunately, depth-area data were available for only the Golden, CO (67) and Morgan, UT storms. Both of these storms were of very limited areal extent. The data do not permit a comprehensive study of depth-area relations. Therefore, data were sought from other sources. The depth-area data from HMR No. 49 were chosen as a likely and comparable data source.

Figure 12.11 shows depth-area relations for 1- and 3-hr durations for storms in HMR No. 49, plus the Golden, CO storm. Most of the data in figure 12.11 are a result of analysis of bucket surveys and other unofficial observations.

Given the lack of available data for the CD-103 region, it was decided to represent depth-area relations with the relations developed in HMR No. 49. This is an acceptable alternative, as there are many parallels between the local storms in HMR No. 49 and in the CD-103 region study (storm type, 6-/1-hr ratios, terrain, etc.).

The adopted depth-area-duration relations from HMR No. 49 are shown in figure 12.12. The general shape of the relations are given from the analysis of the 1- and 3-hr curves in figure 12.11. The 6-hr curve was estimated (as in HMR No. 49) from a group of selected storms in the eastern United States. Using the 1-, 3-, and 6-hr curves as a foundation, intermediate durations were interpolated and durations less than 1 hr were approximated.

12.7 Temporal Distribution of Incremental PMP

There is little information available regarding the time sequence of incremental 1- and 6-hr rainfalls for extreme local storms in the CD-103 region. Of the four storms listed in table 12.2, only two storms have durations greater than 1 hr; the duration of the Las Cruces, NM storm is 9 hr and the Golden, CO storm is 2 hr.

The Las Cruces storm is the only storm on the list that provides time distribution measurements. This information was derived from the mass curve of

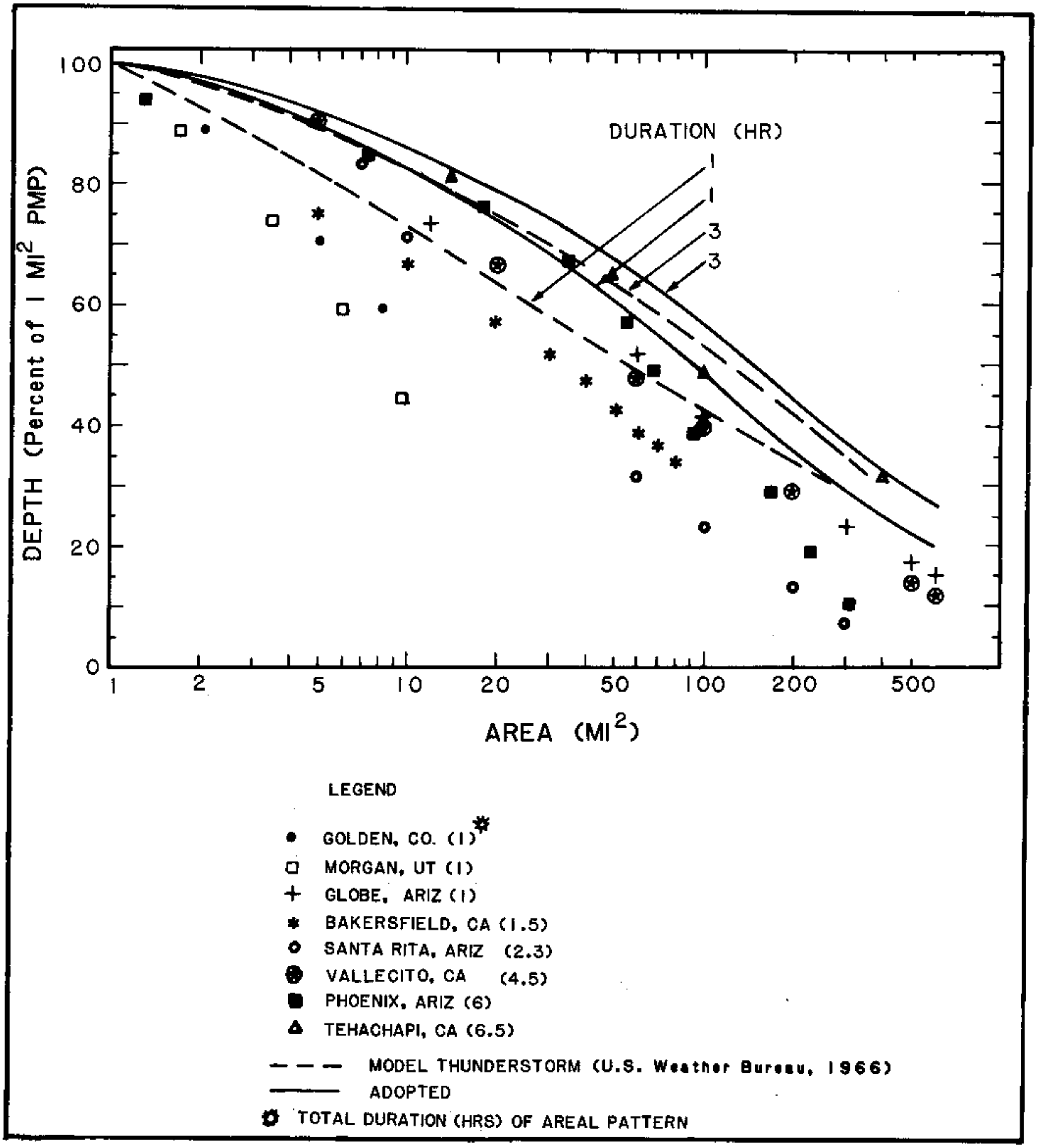

Figure 12.11.--Depth-area data for the Golden, CO (67) local storm and local-storm depth-area data from other regions compared with adopted curve from HMR No. 49 and model thunderstorm depth-area relation.

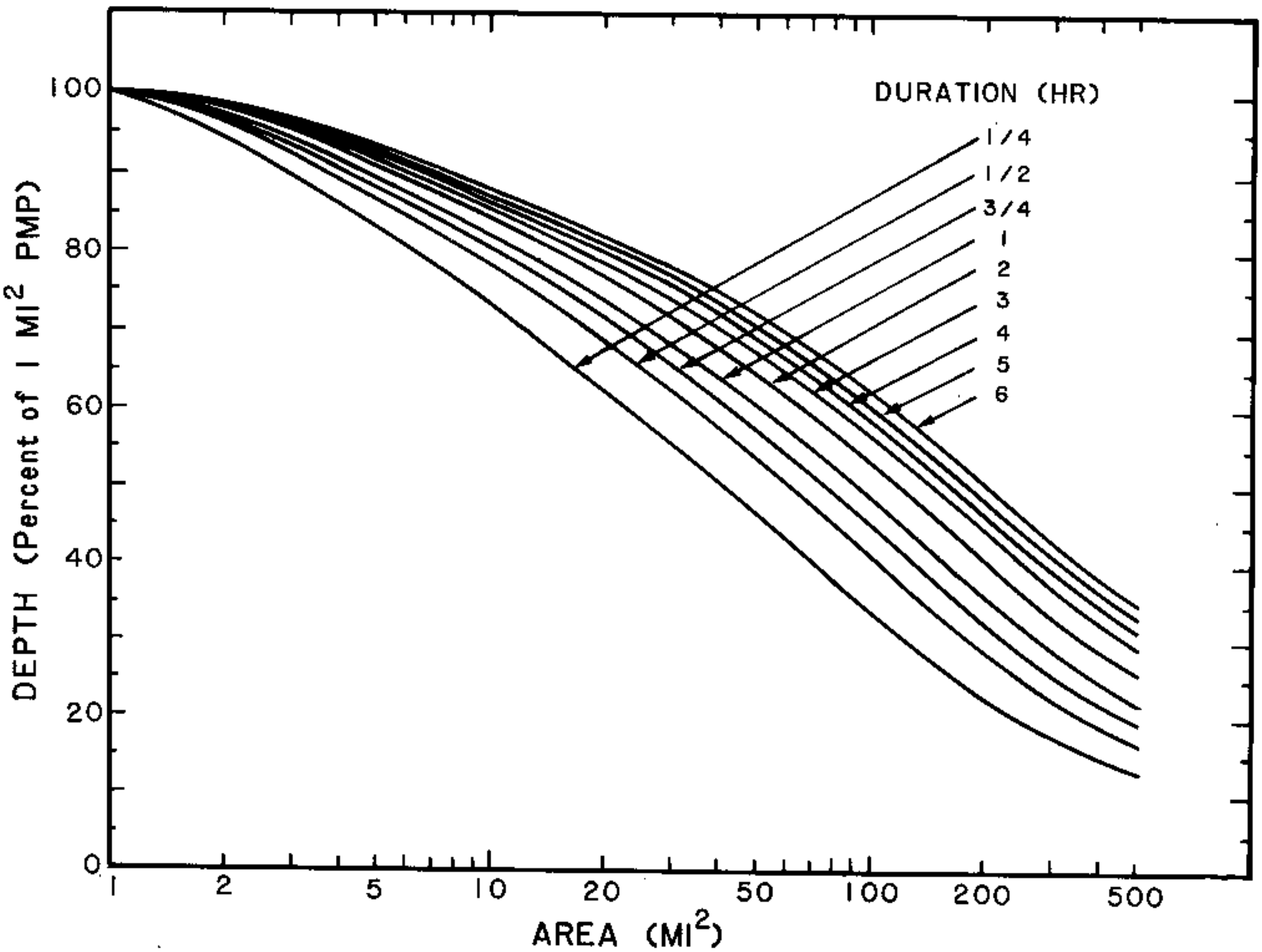

Figure 12.12.--Depth-area relations adopted for local-storm PMP in the CD-103 region (Hansen et al. 1977).

the storm in figure 12.9 that was constructed from a written account of the storm. The sequence of the hourly incremental rainfall for the storm shows that the storm decreased each succeeding hour after the first hour. However, meaningful conclusions cannot be drawn from this one example.

To supplement the lack of available data in the CD-103 region, data from HMR No. 49 was utilized. These data are presented in table 12.5 and include time distribution measurements from 6-hr storms, as utilized by the U.S. Weather Bureau (1947) and by the U.S. Army Corps of Engineers (1965). The choice of which of the two to apply is left to the user, as one sequence may be more critical than the other in a specific case.

There were no data available for the extreme local storms in the CD-103 region from which to determine the sequence of 15-min increments in the 1-hr storm. The 15-min incremental sequence taken from HMR No. 49 is, therefore, recommended. This incremental sequence appears in table 12.6. It is the result of percentages of total rainfall for thunderstorm rainfall determined by the U.S. Weather Bureau (1947).

Table 12.5.--Recommended chronological distribution of 1-hr incremental rainfall amounts for 6-hr local-storm PMP (Hansen et al. 1977)

Increment	Sequence position HMR No. 5*	EM1110-2-1411#
Largest hourly increment	third	fourth
Second largest	fourth	third
Third largest	second	fifth
Fourth largest	fifth	second
Fifth largest	last	last
Least	first	first

* U.S. Weather Bureau 1947

\# U.S. Corps of Engineers, Standard Project Flood Determinations, March 1952, revised March 1965

12.8 Seasonal Distribution

A brief analysis was undertaken to determine the season of occurrence of the local storm in the CD-103 region. The analysis took the form of recording the maximum 1-hr event at recorder stations throughout the CD-103 region (sec. 12.5.1). The period of record totaled 31 years (1948-78); however, many stations had fewer years than this maximum period of record. It was decided to use only stations that had 20 or more years of precipitation record. This removed stations whose data may not have been representative of the true conditions at the station because of an insufficient period of record.

Table 12.7 shows the seasonal distribution of the maximum 1-hr events at selected stations in the CD-103 region. Most of the maxima occur in the summer months of June, July, and August. These months represent the months of greatest potential moisture influx into the region, as shown by the maximum persisting 12-hr 1000-mb dew-point charts of chapter 4. The months of May and September show fewer recorded maximum 1-hr events, while April and October show the least. No other months in the year produced maximum 1-hr events of record for this period. These results are not unlike those found in HMR No. 49.

Table 12.6.--Recommended chronological distribution of 15-min incremental rainfall amounts for 1-hr local-storm PMP (Hansen et al. 1977)

Increment	Sequence position
Largest 15-min increment	first
Second largest	second
Third largest	third
Fourth largest	fourth

Table 12.7.--Distribution of month of maximum 1-hr storm amounts for recording gage stations*

	Month							
	A	M	J	J	A	S	O	Total
Montana	2	4	16	14	10	3	0	49
Wyoming	0	4	2	14	5	1	0	26
Colorado	1	0	0	10	5	0	1	17
New Mexico	0	1	6	10	8	2	0	27
Totals	3	9	24	48	28	6	1	119

* All stations have 20 or more years of records

The seasonal distribution data suggest that extreme local storms most likely occur during the summer months of June, July, and August in the CD-103 region. There is also an indication that such storms are possible during the late spring and early fall. The adopted season of occurrence for the local-storm data in this report is the May-September period. No attempt was made to describe regional variation of the seasonal distribution because of limited data.

13. CONSISTENCY CHECKS

As has been noted in many hydrometeorological reports, evaluation of PMP estimates relies on comparisons against numerous forms of data and other PMP studies. There is no absolute standard to judge the adequacy of the level of PMP. The primary comparison is made against observed storm precipitation. For example, support for the level of PMP in HMR No. 51 is demonstrated by comparisons given in Technical Report NWS 25 (Riedel and Schreiner 1980).

In this chapter a number of comparisons will be discussed relative to the level of PMP obtained for the CD-103 study. The significance of each comparison is left to the reader. In the judgment of the authors, they support the level of PMP presented in this report.

13.1 Comparison With Storm Data

Many comments regarding the use of storm data in the development of the CD-103 PMP index maps have already been made (chapt. 8, 10, 11, and 12). In section 11.4, reference was made to maximized observed depths in establishing and verifying the areal reduction relations recommended for PMP. Five major storms controlled the PMP depth-area relations for some area size, duration, and location. Considering the geographic extent of the study region, this is comparable with other PMP studies.

The level of general-storm PMP in the 10-mi^2 index maps is controlled by seven storms (table 13.1). Cherry Creek (47) and Hale (101), Gibson Dam (75), Buffalo Gap (72), Virsylvia (35), White Sands (82), and Big Thompson (81). The first two storms are essentially the same event (sect. 2.4.1.5) and have been moisture maximized by 150 percent. Table 13.1 shows that at both 6 and 24 hr, the PMP undercuts or equals the moisture-maximized amounts for these two storms. Outside the region, a small undercutting at Hale would be necessary to meet the PMP established in HMR No. 51. The 15 percent undercutting at 6 hr at Cherry

Table 13.1.--Comparison between general- or local-storm PMP and observed and moisture-maximized rainfall depths (in.) from selected important storms for 10 mi^2

	Duration											
	1 hr			6 hr			24 hr			72 hr		
Storm (No.)	Obs.	Max.	PMP	Obs.	Max.	PMP	Obs.	Max.	PMP	Obs.	Max.	PMP
Gibson Dam (75)	1.1	1.9	5.8	6.0	10.2	11.0	14.9	25.3	26.0	-	-	34.5
Springbrook (32)	-	-	12.0	10.5	13.8	19.0	13.3	17.4	25.0	14.6	19.1	28.0
Savageton (38)	-	-	12.4	6.0	7.6	21.7	9.5	12.0	28.2	16.9	21.3	32.2
Big Elk Meadow (77)	1.1	1.9	7.8	4.0	6.8	17.9	11.8	20.1	30.3	17.8	30.3	37.7
Cherry Creek (47)	9.0[A]	13.5	15.6	20.6	30.9	26.3	22.2	33.3	33.3	-	-	37.6
Hale (101)	-	-	15.5[A]	16.5	24.8	24.5[B]	22.2	33.3	30.8[B]	-	-	35.6
Penrose (31)	-	-	13.2	10.4	15.7	24.4	12.0	18.1	31.8	12.0	18.1	38.0
Plum Creek (76)	-	-	15.4	11.5	14.7	25.6	13.2	16.9	32.0	16.7	21.4	35.9
Rancho Grande (60)	-	-	14.5	3.2	3.8	24.0	7.9	9.4	30.7	8.0	9.5	35.6
McColleum Ranch (58)	-	-	14.5	10.1	15.3	25.1	12.1	18.3	33.5	21.2	32.0	39.1
Buffalo Gap (72)	7.0	10.5	11.1	-	-	17.3	-	-	-	-	-	-
Masonville (55)	5.8[C]	8.7	8.9[D]	-	-	12.0[D]	-	-	-	-	-	-
Virsylvia (35)	3.8[E]	6.5	6.0	6.8[F]	11.6	12.0	-	-	-	-	-	-
White Sands (82)	5.4[G]	9.2	8.5	9.0[F]	15.3	14.5	-	-	-	-	-	-
Las Cruces (48)	3.5[H]	5.2	10.1[D]	8.8[I]	13.0	13.6[D]	-	-	-	-	-	-
Big Thompson (81)	4.8	7.1	7.3	10.1[J]	14.9	17.0	-	-	-	-	-	-
Golden (67)	4.3[C]	6.4	8.9[D]	-	-	12.0[D]	-	-	-	-	-	-

A. Estimated in HMR No. 52
B. From HMR No. 51
C. 1 hr 1 mi^2 X 0.825 to get 10 mi^2 for local storm
D. Local-storm PMP
E. 4 hr 1 mi^2 X .56 = 1 hr 1 mi^2 X .9 = 1-hr 10-mi^2 general storm
F. 4 hr 1 mi^2 X .9 = 4 hr 10 mi^2
G. 4 hr 1 mi^2 X .6 = 1 hr 1 mi^2 X .9 = 1-hr 10-mi^2 general storm
H. 9 hr 1 mi^2 X .43 (fig. 12.9) = 1 hr 1 mi^2 X .825 = 1-hr 10-mi^2 local storm
I. 9 hr 1 mi^2 = 6 hr 1 mi^2 (fig. 12.9) X .88 = 6-hr 10-mi^2 local storm
J. 4-hr 10-mi2 general storm

Creek was accepted to avoid an unreasonable increase in PMP at this location and its subsequent effects on a much larger region. The small envelopment of the Gibson Dam storm at 6 and 24 hr confirms that this storm served as a key to the analysis of PMP at that location.

At the shorter durations (1 and 6 hr), the White Sands moisture-maximized amounts are undercut by 8 and 5 percent, respectively (see discussion in section 10.3.2). The Virsylvia storm is undercut at 1 hr by 8 percent (see discussion in section 10.3.1). For 1 hr, the storms at Buffalo Gap and Big Thompson also are controlling, being enveloped by 6 and 3 percent, respectively.

For local storms, table 13.1 shows that the 1-hr PMP closely envelops the moisture-maximized Masonville amount, while at 6 hr, the moisture-maximized Las Cruces storm is enveloped by 5 percent. The comparable 1- and 6-hr general-storm PMP at Masonville, Las Cruces and Golden are 14.0, 8.0, 11.7 in. and 26.1, 14.3, 24.0 in., respectively. Only at Las Cruces does the local-storm PMP exceed general-storm PMP of all the storms compared in table 13.1.

The PMP index maps provide a realistic envelopment of the observed moisture-maximized storm data. No storms control for the 72-hr duration. However, the degree of envelopment of storm data by the 10-mi^2 index PMP for the Big Elk Meadow, CO (77) and McColleum Ranch, NM (58) storms is less than 25 percent, which is not considered an unusually large envelopment.

13.2 Comparison With Individual-Drainage PMP Estimates

The Hydrometeorological Branch, in the absence of appropriate generalized studies (sec. 1.7), have from time to time prepared individual-drainage PMP estimates. Since these estimates have been prepared over a period of years, the available storm sample and procedures for estimating PMP are not the same in all cases as those used in the present report. In addition, most of these estimates include, at least implicitly, a reduction that results from the difference between the storm centered isohyetal pattern that forms the basis for this report and the shape of the basin. Additional problems are encountered with explicit transposition limits when developing individual-drainage PMP estimates.

Some general comparisons can be made with estimates prepared since the mid-1960's. Differences between the recent individual-drainage estimates and the results of this report are less than 20 percent for all durations with no apparent bias toward either higher or lower estimates from this study. The estimates reviewed cover a range in area sizes from less than 10 mi^2 to over 7,000 mi^2. Though the majority of the estimates reviewed were in the southern half of the study area, no regional bias was apparent. These comparisons can only be viewed in a qualitative manner, since both estimates were developed using much of the same data and basic procedures.

13.3 Comparison to Other Generalized PMP Studies in the CD-103 Region

Weather Bureau Technical Paper No. 38 (TP-38) (U.S. Weather Bureau 1960) provided generalized PMP estimates for the United States west of the 105th meridian for areas less than 400 mi^2 and durations of 24 hr or less. TP-38 established PMP for this entire orographic region and provided a broadscale analysis of PMP in comparison to more recent studies (U.S. Weather Bureau 1961 and 1966, Hansen et al. 1977, and the present study). TP-38 presents maps of 1-,

Table 13.2.--Comparisons of ranges in general-storm PMP (in.) estimates from Technical Paper No. 38 and the CD-103 study

	1 hr		6 hr		24 hr	
	TP 38	CD-103	TP 38	CD-103	TP 38	CD-103
Montana	5-12.5	3.5-12.7	9.5-19.0	6.5-21.4	14.0-25.0	15.5-31.5
Wyoming	5-12.5	4.0-14.0	9.8-20.5	9.0-23.4	12.0-26.2	15.5-32.5
Colorado	7-14.1	3.5-15.5	13.8-23.0	7.0-26.7	17.0-28.2	14.8-36.5
New Mexico	8.8-15.5	4.0-14.6	13.5-25.0	8.5-25.2	17.0-31.0	14.9-34.3

6-, and 24-hr 10-mi^2 PMP which have been used to make comparisons with general storm amounts from the present study. Table 13.2 shows ranges of values from these analyses for the individual states. From each report, the maximum and minimum values were determined for general-storm PMP in the region between the Continental Divide and the 105th meridian (limit of TP-38). These are not always the maximum or minimum values within a particular state from either report.

From table 13.2, it is apparent that generally larger PMP estimates are given in the CD-103 study at 24 hr 10 mi^2 than were given in TP-38. This is partially a result of greater attention to orographic features in the current study, since many of the larger amounts are related to orographic features that were not well defined in TP-38. Another factor is the review and revision of the maximum persisting 12-hr 1000-mb dew points for both the maximum moisture and storm situations for the present study. Another factor is that TP-38 includes a mixture of generalized local storms under the definitions used in the present study. A final factor is additional storm data. Several major storms have occurred since TP-38 was completed, e.g., the June 6-8, 1964 (75) storm in Montana. At 1 and 6 hr, the PMP values appear comparable between the two studies.

Another study covering part of the CD-103 region was made by NWS for the Upper Rio Grande drainage (U.S. Weather Bureau 1967). In this study, generalized charts of PMP were presented for two index levels--6 hr 1 mi^2 and 24 hr 1 mi^2. Areal reduction relations were given to obtain PMP for other areas to 400 mi^2. Table 13.3 shows a comparison of the ranges in PMP estimates for 6 and 24 hr 10 mi^2. The values from the CD-103 study are all from the general-storm PMP, whereas the Rio Grande study does not distinguish between local and general storms. The ranges in PMP estimates are greater in this study than in the Upper Rio Grande study. Minimum values for the 6-hr duration could be slightly higher

Table 13.3.--Comparison of ranges in PMP estimates (in.) from the Upper Rio Grande study and the CD-103 study

	6 hr		24 hr	
	Upper Rio Grande study	CD-103	Upper Rio Grande study	CD-103
Colorado	13.2-16.3	8.0-18.0	16.2-20.2	15.5-29.2
New Mexico	13.2-17.2	9.0-21.5	16.2-21.2	15.5-29.5

if the local storm was considered. The range would still be larger than for the Upper Rio Grande study. Reasons for these changes are somewhat similar to those cited in comparisons between this report and TP-38. In addition, some of the largest values in both studies are along the eastern edge of the basin and result from a reappraisal of the effects of spillover from east to west.

13.4 Comparison Between Local-Storm and General-Storm PMP

Differences between the local-storm and general-storm PMP at 1 hr 10 mi^2 were taken throughout the CD-103 region. This was done as follows: Points were taken at a sufficient density to cover the significant features of the terrain and the general-storm PMP field. Local-storm index PMP values at 5,000 ft were adjusted to the smoothed surface elevation and to 10 mi^2 at each point.

A definite relationship between terrain and controlling storm type was observed. The general storm controlled the "nonorographic" and "minimum nonorographic" areas, with the exception of a small, isolated area in central Wyoming where there is a break in the first upslopes to the south of the Big Horn Mountains. The general storm also controls most of the first upslopes (classified as "orographic" regions). The situation is different in the sheltered areas (classified as "sheltered orographic" and "sheltered least orographic"), with the local storm controlling a vast majority of these regions, the most notable exceptions being at very high elevations (generally above 10,000 ft), and the western portion of Texas.

The degree of general storm control over the local storm in nonorographic areas is governed principally by the agreed-upon transposition limits for the prototype PMP general storm with the degree of exceedance decreasing from the region where the storm occurred out towards the limits of transposition. The distribution of maximum persisting 12-hr 1000-mb dew points, and elevation variation in the exposed nonorographic areas, appear to be poor discriminators for level of control since similar effects are produced on each storm type by elevation and dew point. Hence, there is a rather smooth variation of level of general storm control in the nonorographic areas. The effect of transitioning into the orographic first upslope areas beyond the transposition limits is, in general, to reduce the dominance of the prototype PMP general storm mechanism over a purely convective, local mechanism, since the general storm mechanisms cannot be supported by the same degree of horizontal convergence forcing available in the nonorographic areas. This arises, in part, by upstream orographic "raining out" as well as by local orographic "stimulation" of convection.

As a result of this comparison, the general storm controls at all durations along the eastern part of the CD-103 region. This result is in agreement with what was expected for this region, and supports the fact that local storms are not controlling in the midwestern plains.

In the sheltered areas, however, the effect of upstream depletion of storm moisture for the general storm is very significant; hence, the local storm controls most of these areas, since it need not draw upon moisture at a distance. In some of the higher "sheltered orographic" areas the general storm regains control due to a significant reduction in convective-only potential at these elevations.

Table 13.4.--Maximum and minimum ratios of 10-mi^2 PMP estimates (in.) to 100-yr precipitation-frequency point values (in.) at 1, 6, and 24 hr

	Smallest Value			Largest Value		
Duration (hr)	1	6	24	1	6	24
State						
MT	3.4	4.1	4.9	6.8	8.8	8.3
WY	2.8	4.2	5.0	6.9	9.4	9.8
CO	2.2	3.0	4.2	6.9	9.0	8.8
NM	2.2	3.0	4.4	5.8	8.0	8.1

13.5 Comparison with NOAA Atlas 2 Amounts

Ratios of PMP at 10 mi^2 to 100-yr precipitation depths at durations of 6 and 24 hr across the United States, east and west of the CD-103 region have been published (Riedel and Schreiner 1980). In that publication, calculated ratios, especially those west of the Continental Divide, show a considerable variation within small sub-areas of the overall study region. For example, large variation occurs from the crests of the Sierra Nevada in California northeastward into the Granite Spring Valley in western Nevada; from the crests of the Cascades eastward into the area surrounding Moses Lake in Washington; and also from the higher elevations of the Sawtooth Mountains southeastward into the Snake River Plain in Idaho. Though somewhat smaller, significant variation of this ratio can be found from the crests of the Appalachians north and westward into the Ohio River Valley and St. Lawrence River Valley.

Similar variations in this ratio should be expected in the CD-103 region at those places where similar range crest-to-valley/plain topographic features are found. State-to-state or regional consistency of this ratio should be expected only to the extent that topographic variation is consistent from state-to-state in the region. What should be expected, however, in the absence of consistent state-to-state variation of topography, is that the extreme values of this ratio should not depart much from previously determined values unless some unique topographic reason can be found. Consistent relationships between topographic crests and valleys and ratio minima and maxima should also be expected.

Small ratio values, less than two for a particular location, are usually regarded as signifying a strong likelihood that PMP is approaching an observed depth of precipitation for a given duration. It is more difficult to agree upon what is too large a ratio. It would seem that an upper ratio value three times the lower value found in a region of an apparently related broadscale topographic feature and for a given duration is not too high based upon the published precedents (Riedel and Schreiner 1980).

The largest and smallest ratio values at 1, 6, and 24 hr were determined for each state in the CD-103 region, except Texas, western North Dakota, South Dakota and Nebraska, and are shown in table 13.4. The specific locations for extreme values were determined through visual inspection of the PMP and frequency charts and it is possible that there are some places where even smaller or larger values exist which were overlooked inadvertently.

The identified smallest values at the indicated durations are about what would be expected from the published precedent (Riedel and Schreiner 1980) except at 24 hr where the values seem somewhat high. At 24 hr the largest ratio values, especially in Wyoming and Colorado, in absolute value are without precedent. In those instances, the ratio values are considered to be somewhat anomalous in the sense that they result from the apparently chance juxtaposition of rather small 100-yr depths with a broadscale maximum in PMP distribution. It was considered desirable to retain these anomalies rather than change the overall distribution of PMP across the region. In neither case, however, was the extreme high value more than three times the topographically related low value. In brief, the data of table 13.4 indicate that PMP within the CD-103 region is neither too small nor too large based upon relationships and values already developed and published (Riedel and Schreiner 1980). This conclusion is reinforced by the possibility that the smallest ratio values would have been larger if the local storm rather than the general storm had set the level of PMP. Chances are extremely small, however, that a convective-only local storm will set the level of PMP near the orographic separation line (see sect. 1.5) where the highest ratios occur. Hence, comparisons with Riedel and Schreiner in terms of the high value not being more than three times the topographically-related low value are valid even when local-storm values are considered.

13.6 Comparison with Adjoining PMP Studies

The CD-103 PMP study represents the last major generalized PMP study to complete coverage of the conterminous United States. As such, it fills the space between previously completed PMP studies; HMR No. 51 and 52 to the east, and HMR No. 43 and 49 to the west. During the initial considerations to the development of HMR No. 55, the authors decided that the nonorographic eastern portions of the region should represent extensions of the HMR No. 51 and 52 results into this region. For the most part the isohyets in Plates I-IV tie into those to the east for all durations along the 103rd meridian.

Along the Continental Divide, however, initial considerations were set such that the CD-103 study should be developed independently of the studies to the west. The reasoning here was that HMR No. 55 results should not be influenced by the western results, and also, plans to update HMR No. 43 may bring about a change from the current level of PMP in the northwest. HMR No. 55 was published essentially independent from the western studies with the explanation that some discontinuity east to west was acceptable, because of differing meteorological environments to either side of the Divide.

The present study reconsidered this process particularly for the local storm but also with regard to the general storm. For the local storm, a 5,000-ft index map was developed to essentially tie into PMP for HMR No. 49. Although not specifically considered, the CD-103 local storm analysis in Montana appears to have good agreement with the local-storm results from HMR No. 43. The general-storm comparisons still show somewhat significant differences across the Divide, with the CD-103 values always being the greater.

To better represent the proper form of comparison, PMP was computed for each 15 minutes of latitude along the Divide from each study. At each location for 1 and 6 hr, the higher of the local- or general-storm amount was used in this comparison, since this represents the level of PMP that should be used at that duration. For HMR No. 43 and 49 at both 1 and 6 hr, the local-storm amounts

Table 13.5.--Comparison between PMP values along the Continental Divide from HMR No. 55A and HMR No. 43 or 49

Comparison Ratios	Duration (hr)					
	1		6		24	
Agreement	<10%	<20%	10%	<20%	<10%	<20%
HMR 55A/HMR 43 (23 pts.)	82.6%	100 %	30.4%	56.5%	0	0
HMR 55A/HMR 49 (48 pts.)	70.8%	87.5%	56.2%	77.1%	6.2%	16.7%

exceed the general-storm amounts. In only 60 percent of the 1-hr and 85 percent of the 6-hr amounts in HMR No. 55A are 1-hr local-storm amounts greater than general-storm amounts.

Table 13.5 shows the comparison between east (HMR No. 55A) and west (HMR No. 43 and 49) procedures in producing comparable PMP for points along the Continental Divide and at selected durations. The results in table 13.5 show that between 70 and 80 percent of the points along the Continental Divide show agreement within 10 percent at 1 hr. At 6 hr, agreement within 10 percent drops to between 30 and 60 percent, while at 24 hr there is almost no agreement within 10 percent. A similar degree of variability occurs at 72 hr as well, although this information was not included in table 13.5.

13.7 Conclusions from Consistency Checks

From the above considerations, adequate comparisons have been made against other data sources to judge the consistency of the CD-103 results. Both regionally and areally, the comparisons support the results from the present study. There have been several comparisons made. The primary measure of the adequacy of PMP estimates is a comparison with moisture-maximized storm precipitation amounts. Table 13.1 shows a number of storms for the 10-mi^2 area where the PMP is equivalent to moisture-maximized storm amounts. Both the number of storms and their geographic distribution throughout the region are comparable with results found in other studies. Comparison of PMP values for various area sizes determined using the index maps and appropriate depth-area relations also show results comparable to other regions.

Within the CD-103 region, there have been previous PMP estimates prepared. The present study uses many of the same techniques as the other investigations. Differences between the studies are attributable to several factors. Among these are: differences in available storm sample; revision of representative storm dew points; update and revision of maximum available moisture based on maximum persisting 12-hr 1000-mb dew points; and the amount of consideration given to topographic features. Nonetheless, the results are considered mutually supportive.

While PMP estimates are a result of deterministic methods as opposed to a stochastic or probabilistic approach, the comparisons between PMP and 100-yr values from NOAA Atlas 2 provide some guidance to regional consistency. The results indicate the PMP estimates are consistent within the study region and also with the results from surrounding regions.

Finally, comparison between results from this study and PMP from adjoining studies shows close agreement at 1 hr and decreasing agreement at longer durations. Some improvement may be possible when HMR No. 43 is revised.

14. PROCEDURES FOR COMPUTING PMP

The procedures developed in this report for computing general-storm averaged PMP estimates are straightforward. They are based on use of four 10-mi^2 PMP index maps (1-, 6-, 24-, and 72-hr analyses) and 21 sets of depth-area-duration relations developed in this study. The results obtained from use of these procedures represent storm-centered average depths applicable to a specific drainage of interest. At this time, no procedure is available that provides techniques to distribute the average depth throughout the drainage, nor are recommendations provided on temporal sequences for this region*. Such information will be the subject of a future study regarding individual drainage applications of the PMP values developed in this report.

Separate index maps have been provided for the local-storm PMP for the CD-103 region. Depth-area and depth-duration relations enable results to be obtained for basins up to 500 mi^2 and for up to 6 hr. The hydrologist should compute values for the basin by both procedures. The results from both procedures should be used in hydrologic trials to determine appropriate design values.

14.1 Stepwise Procedure, General Storm

Step

1. Drainage map outline

   Trace the outline of the drainage (at 1:1,000,000 scale) onto a transparent overlay.

2. Determination of 1-, 6-, 24-, and 72-hr index PMP estimates

   Place the overlay of drainage shape on each of the 1-, 6-, 24-, and 72-hr 10-mi^2 PMP index maps in plates I to IV# and read off sufficient point values to obtain a representative index average depth at each duration. Although greater accuracy may be obtained by planimetering the index map analyses for the drainage area, this effort is generally unnecessary for most drainages less than 1,000 mi^2. In highly complex regions of PMP and for larger drainages, planimetering may be necessary.

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*For PMP estimates east of the orographic separation line (nonorographic region shown in fig. 3.1), HMR No. 52 procedures may be applied to areally and temporally distribute PMP obtained from this report. As cautioned in section 1.8, for the nonorographic region west of the 105th meridian, HMR No. 52 procedures are tentative and it may be necessary to derive modifications to the procedures upon further study.

#Plates I and II as revised 3/87.

3. Selection of appropriate subregion and subdivision

From plate V determine the subdivision/subregion that contains the drainage in order to select the appropriate set of depth-area-duration relations. If the drainage is large enough, or so placed, that it involves more than one subdivision, determine the proportionate amount of the drainage that lies in each classification. This consideration will be clarified in the examples given in section 14.2.

4. Determine areal reduction factors

Select the depth-area-duration relations (fig. 11.3 through 11.23, as appropriate) that correspond to the subdivision(s) and/or subregion(s) obtained in step 3, and determine the appropriate reductions (in percent of average 10-mi^2 amount) to apply to the index average depths from step 2 for the drainage area. Weight the percentage amounts by the proportionate areas determined from step 3, if the drainage covers more than one subunit.

5. Computation of average 1-, 6-, 24-, and 72-hr PMP estimates for drainage

Multiply the resulting percentage reduction(s) from step 4 corresponding to the area of the drainage by the average index PMP estimates from step 2.

6. Depth-duration curve for drainage

Plot the results obtained in step 5 on linear graph paper as depth vs. duration, and draw a smooth curve of best fit.

7. PMP estimates for intermediate durations

Interpolate PMP estimates from the curve in step 6 for other durations, as needed.

8. Incremental PMP estimates

If incremental depths are desired, subtract each durational depth in step 7 from the depth at the next longer duration.

14.2 Example of General-Storm PMP Computation

The Pecos River above Los Esteros Dam will be used in an example of the procedures outlined in section 14.1. The drainage shown in figure 14.1 covers 2,479 mi^2. When considered relative to plate Vc, this drainage is separated into two subdivisions, orographic and minimum nonorographic, of the E subregion. The procedural steps are as follows:

1. Drainage map outline

A drainage outline was determined from a topographic chart and is shown in figure 14.1.

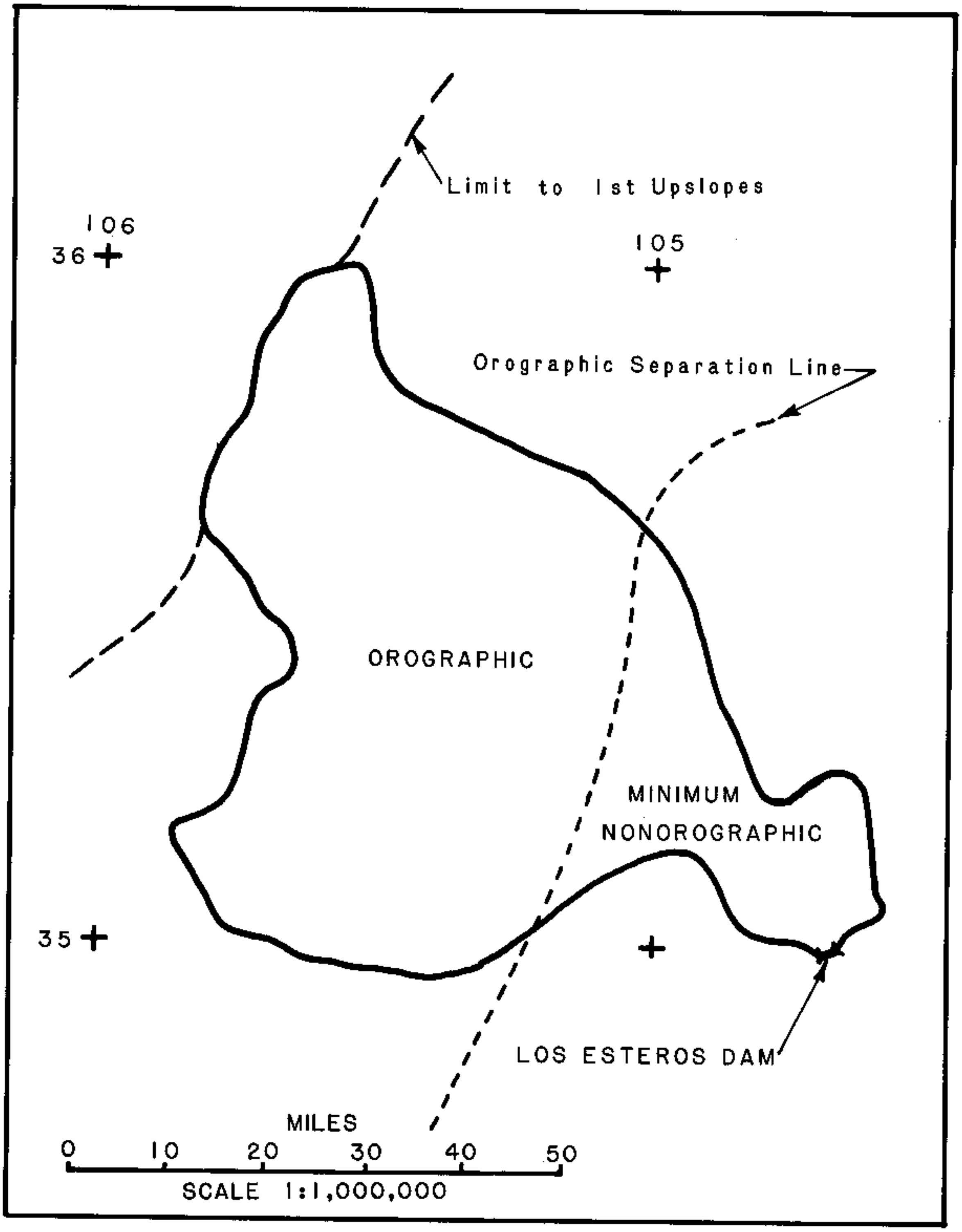

Figure 14.1.--Outline of the drainage for the Pecos River above Los Esteros Dam, NM (2,479 mi^2) showing position of DAD subdivision boundaries.

2. Determination of 1-, 6-, 24-, and 72-hr index PMP estimates

The drainage shape on figure 14.1 was placed over the individual PMP index maps, plates Ic to IVc, and a sufficient number of grid-point values read off to obtain the index average depth estimates for each of the four durations:

Duration (hr)	1	6	24	72
PMP (in.)	12.20*	21.00	29.17	33.92

3. Selection of appropriate subregion and subdivision

Placing the drainage shape over the subdivision/subregion map (place Vc, at 1:1,000,000 scale), this drainage covered portions of both the E orographic and E minimum nonorographic subunits. It was estimated that approximately 75 percent of the drainage was in the orographic subdivision and the remaining 25 percent in the minimum nonorographic subdivision.

4. Determine areal reduction factors

Using the DAD relations in figures 11.10 (orographic) and 11.8 (minimum nonorographic), reduction factors were read at the area of the drainage, 2,479 mi^2;

Duration (hr)	1	6	24	72
orographic (%)	21.8	34.5	42.2	46.6
min. nonorog. (%)	18.2	30.7	35.8	41.2
Weighted percentage				
75% [orographic (%)]	16.4	25.9	31.6	35.0
25% [min. nonorog. (%)]	4.6	7.7	9.0	10.3
Sum (%)	21.0	33.6	40.6	45.3

5. Computation of average 1-, 6-, 24-, and 72-hr PMP estimates for drainage

Multiply the results from step 4 by the drainage average index PMP depths from step 2,

Duration (hr)	1	6	24	72
Areal-adj. PMP (in.)	2.56	7.06	11.84	15.36

* Values should be read from the maps only to the nearest tenth of an inch. Hundredths obtained from the average are for computational convenience in this example. The user should be aware of the degree of precision possible in applying the procedures of this report.

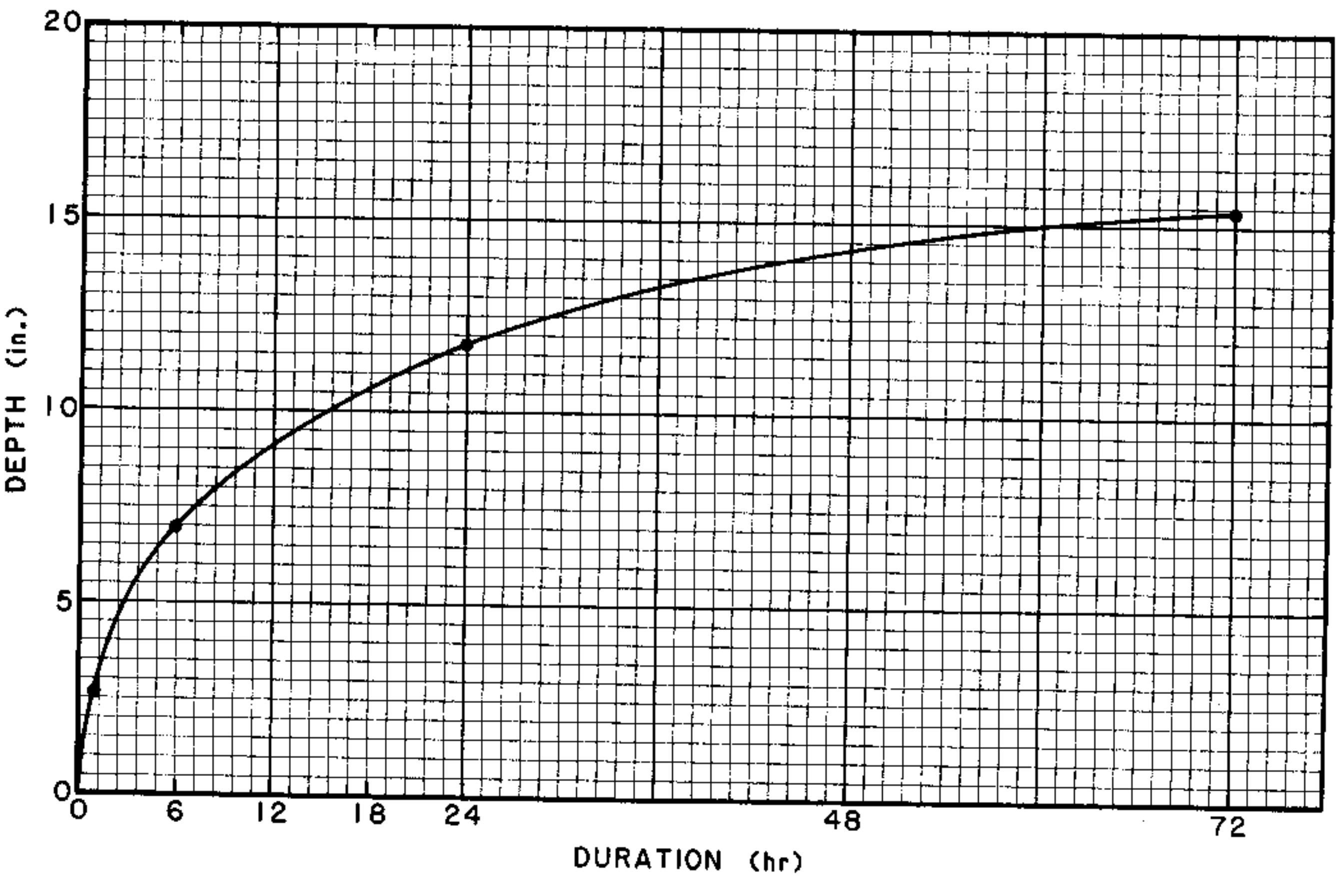

Figure 14.2.--Depth-duration curve for PMP estimates for Pecos River drainage above Los Esteros Dam, NM (2,479 mi²).

6. Depth-duration curve for drainage

The PMP estimates from step 5 have been plotted and a depth-duration curve drawn as shown in figure 14.2.

7. PMP estimates for intermediate durations

Intermediate 6-hr depths are read from the smooth curve in figure 14.2.

Duration (hr)	6	12	18	24	30	36	42	48	54	60	66	72
PMP (in.)	7.0	9.0	10.6	11.8	12.6	13.3	13.9	14.3	14.7	15.0	15.2	15.4

8. Incremental PMP estimates

Incremental PMP depth from step 7 are:

Duration (hr)	6	12	18	24	30	36	42	48	54	60	66	72
PMP (in.)	7.0	2.0	1.6	1.2	0.8	0.7	0.6	0.4	0.4	0.3	0.2	0.2

14.3 Stepwise Procedure, Local Storm

1. Index 1-hr 1-mi^2 PMP estimate at 5,000-ft elevation

Locate the drainage in Plate VI a-c, and determine the drainage average index 1-mi^2 1-hr PMP in inches at 5,000 ft. This is readily accomplished by eye because of the smooth gradient, and linear interpolation is assumed to apply.

2. Adjustment for mean elevation of drainage

Determine the mean drainage elevation to the nearest 100 ft. An adjustment needs to be determined and applied to the depth from step 1 if this elevation differs from 5,000 ft by more than 1,000 ft. If the mean terrain elevation of the drainage is greater than 6,000 ft or less than 4,000 ft, the correct vertical adjustment factor can be obtained by reference to figure 14.3. This is a nomogram of vertical elevation adjustments as discussed in section 12.3.2.4. To use the nomogram, enter the horizontal scale (abscissa) at the maximum persisting 12-hr 1000-mb dew point obtained from figure 4.11 for the location of the drainage. Move vertically in the figure to intersect the mean elevation of the drainage (to the nearest 100 ft) and read off the adjustment factor on the vertical scale (ordinate).

As an example of this determination, take a drainage that has a mean elevation of 7,800 ft and a maximum persisting 12-hr dew point of 70°F. Entering figure 14.3 at 70° on the abscissa and moving vertically to 7,800 ft, an adjustment factor of 0.82 is read from the ordinate.

3. Index 1-hr 1-mi^2 PMP estimate at mean elevation of drainage

Multiply the adjustment factor determined in step 2, if needed, by the index 1-mi^2 1-hr depth from step 1 to obtain a representative surface adjusted index PMP estimate.

4. Depth-duration curve for 1 mi^2

Refer to table 12.4 to obtain the 1-mi^2 factors for durations up to 6 hr. Multiply these factors by the estimate from step 3. These can be plotted on linear graph paper and a smooth curve drawn to obtain intermediate durational amounts if these are needed for the 1-mi^2 area.

5. Areal reduction factors

To obtain areal reduction factors, use the relations provided in figure 12.20. Find the drainage area on the abscissa and read the corresponding reduction factors as percent of the 1-mi^2 PMP.

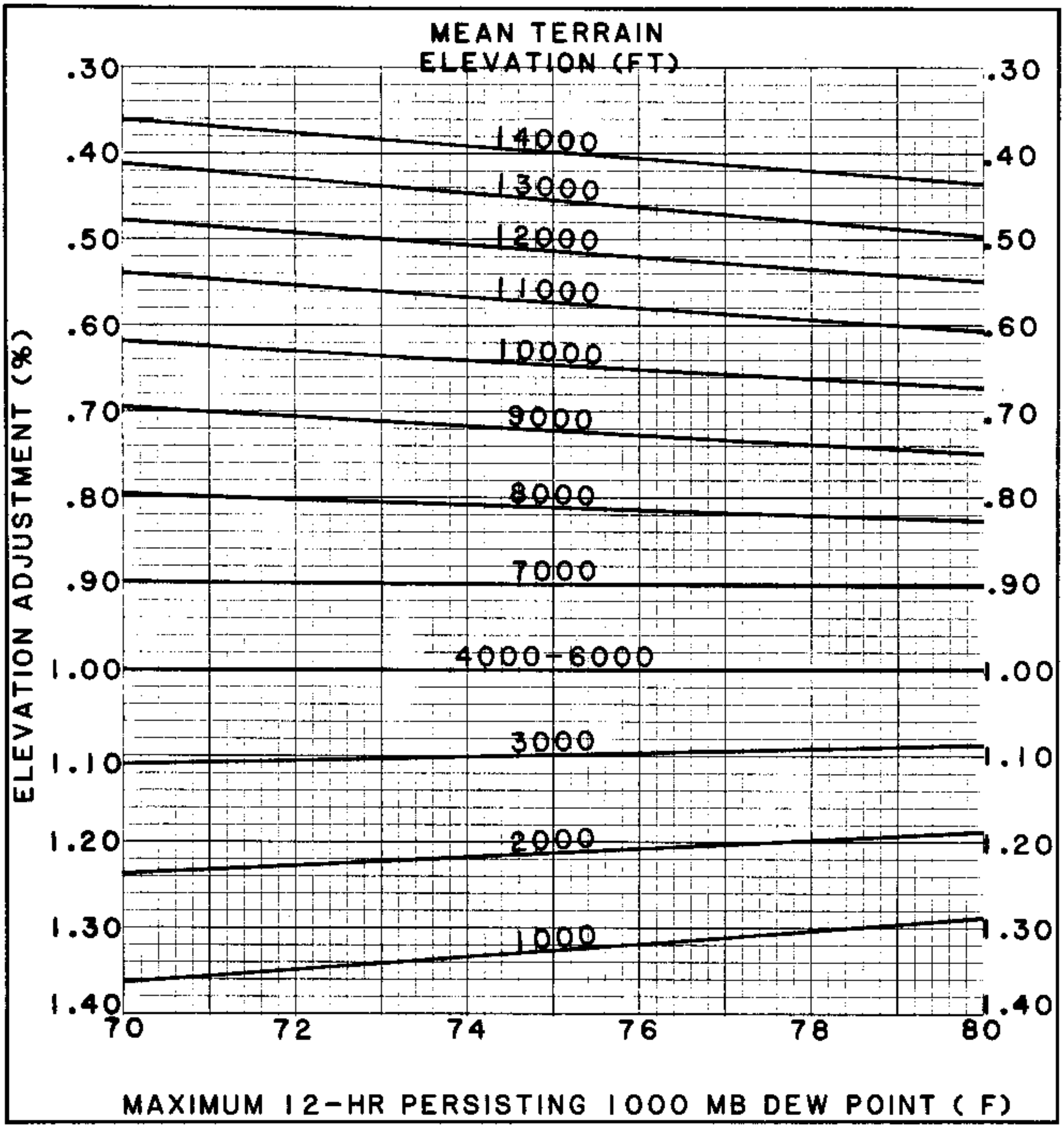

Figure 14.3.--Adjustment for elevation for local-storm PMP based on procedures developed in the report and maximum persisting 12-hr 1000-mb dew point (F).

6. PMP estimates for basin

Multiply percentages of step 5 by the index PMP amounts from step 4. These values should be plotted on linear graph paper and a smooth curve drawn through the points. Values for the intermediate durations may be determined from this curve.

7. Incremental PMP amounts

If needed, local-storm PMP incremental amounts obtained through subtraction of adjacent amounts in step 6 may be arranged in temporal sequences recommended in tables 12.5 and 12.6.

No example is believed necessary for local-storm PMP determination, as the adjustment for elevation is the only complex element in the determination, and an example calculation of this factor is given in step 2.

15. FUTURE STUDIES

There are several problems involved in the development of design estimates that should be resolved. The purpose of this chapter is to briefly discuss these needed future studies.

15.1 Seasonal Variation

In the present study, it has been possible to develop only all-season PMP estimates. Although no attempt has been made to define the season of occurrence, some observations are possible. In the northern portion of the study region among the more important storms are Gibson Dam, MT (75), June 6-8, 1964; Warrick, MT (10), June 6-8, 1906; Springbrook, MT (32), June 17-21, 1921; and Savageton, WY (38), September 27-October 1, 1923. Through the central portion of the study region, Cherry Creek (47) and Hale (101), CO, May 30-31, 1935, Plum Creek (76), CO, June 13-20, 1965, Big Elk Meadow (77), CO May 4-8, 1969, and Big Thompson, July 31, 1976 are important in determining PMP estimates. In the extreme southern part of the study region, tropical storms or their remnants will be the causative mechanism for the longer duration PMP event. Such storms as Rancho Grande (60), NM, August 26-September 1, 1942, and Meek (27), NM, September 15-17, 1919 are typical of these events. Shorter duration storms similar to that at White Sands, NM, August 19, 1978 are important in this region. These storm dates suggest that the all-season PMP event will occur from early summer through fall. In those portions of the study region where snowmelt can be a critical factor, the probable maximum flood (PMF) may be the result of the lesser magnitude spring PMP event and accompanying snowmelt. The definition of the seasonal variation of PMP is, therefore, a necessary addition to the present report.

15.2 Permissible Snowpack With PMP and Snowmelt Criteria

To adequately evaluate the spring PMF, two additional factors are required. The first is an evaluation of the snowpack that could exist prior to the PMP event. The question to be answered is the depth and extent of the snow cover. Could, for example, the probable maximum snowpack (PMSP) occur just prior to the

PMP, or would there be some lesser limit. If the latter is the case, it is necessary to define a rainfall event compatible with the PMSP.

The second factor, snowmelt criteria, such as temporal sequences of wind, temperature, and dew-point, are needed to develop the PMF from a combination of rainfall and snowmelt. It might be necessary to develop dual criteria--one set appropriate for the spring PMP together with an appropriate snowpack, and a second consistent with the PMSP and the accompanying rainfall event. The need for dual criteria can be determined only after adequate investigation.

15.3 Individual-Drainage Estimates of PMP

PMP estimates from this report are storm centered all-season estimates, as are those of HMR No. 51 (Schreiner and Riedel, 1978). HMR No. 52 (Hansen et al. 1982), provides procedures to develop estimates for individual drainages east of the OSL, though application to nonorographic regions west of the 105th meridian in eastern Montana and eastern Wyoming should be done with caution. The procedures of HMR No. 52 were developed for nonorographic regions. It will be necessary to develop similar procedures for the entire CD-103 region. Techniques developed for an application manual to apply to the CD-103 region would be required to deal with orographic problems in a generalized manner.

15.4 Temporal Variation

The procedures in this report provide only a depth-duration curve of general-storm PMP rainfall. The computation of a basin discharge hydrograph requires knowledge of the appropriate time distribution of the rainfall. In HMR No. 52, recommendations are made for appropriate temporal distributions in the nonorographic portions of the CD-103 region.* The necessary time distribution must be determined from studies of major storms. Because of the diversity of storm types and terrain throughout the CD-103 region, the time distribution could vary from Montana to New Mexico. This regional variation would have to be considered in any future studies of this problem.

15.5 Antecedent Rainfall

The only published study of rainfall antecedent to a PMP event was concerned with small basins in Texas (Miller and Ho, 1988). This study restricted consideration to values appropriate for basins of less than 400 mi^2 and for a limited geographic region, only a small portion of which was in the present study region. A comprehensive study of antecedent rainfall for this region would consider the area size of both the basin and the storm, the season of occurrence of PMP, the possibility of geographic variation of antecedent rainfall amounts, and the possible varying percentages of antecedent rainfall based upon the dry interval between the PMP event and the antecedent rainfall.

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*Since storms west of the 105th meridian were not fully evaluated in preparing HMR No. 52, care should be exercised in using these time distributions west of the 105th meridian.

15.6 Summary

This study produced estimates of all-season PMP for durations from 1 to 72 hr for area sizes to 20,000 mi^2 in nonorographic regions, and 5,000 mi^2 in orographic regions. These studies provide valuable information for hydrologists and engineers. However, additional information may be needed before a complete evaluation can be made of the PMF. Some of these additional pieces of information are the areal distribution and seasonal variation of PMP, snowpack and snowmelt criteria, and antecedent rainfall.

ACKNOWLEDGMENTS

The authors express their appreciation to the many who have contributed to this revision and to its predecessor HMR No. 55. In particular, Mr. John F. Miller, senior author of HMR No. 55 and at the time Chief of the Water Management Information Division, National Weather Service. He retired from that position in 1985, and has been closely involved with the efforts to revise the study while a consulting meteorologist for the U.S. Bureau of Reclamation. We also wish to acknowledge the efforts and advice of Dr. Don T. Jensen, as a coauthor of HMR No. 55. He left the U.S. Bureau of Reclamation in 1983 for a position with the Soil Conservation Service.

Mr. Eugene Stallings, NWS (formerly with the U.S. Army Corps of Engineers); Mr. Arthur Cudworth, Bureau of Reclamation (since retired); and Mr. Wendell Styner, Soil Conservation Service have been major sources of help during the many meetings held during the course of this study. Mr. Chris Moeller and Mr. Roger Watkins (both no longer with NWS) contributed to the investigations in HMR No. 55, some of which have been carried over into this revision. Mr. Moeller was responsible for the initial local-storm PMP, while much of the revised local storm was done by Mr. Frank Bartlo, NWS. Mr. Watkins contributed to the study of storms, maximum persisting dew points and storm transposition. Technical assistance was provided by Mr. Keith Bell, Mrs. Marion Choate (retired NWS), and Ms. Roxanne Johnson. Without their able assistance these reports would not have been possible. We also acknowledge the assistance of Mr. Scott Kroczynski in proofing and handling the publishing of this report. The many drafts along with the final camera-ready versions of both reports were under the control of Mrs. Helen V. Rodgers.

Finally, HMR No. 55 was reviewed by many hydrologists, meteorologists and hydrometeorologists within the four cooperating agencies. While it is not possible to name all these individuals, they have made a significant contribution to the results of this study by their review of both the final manuscript and many of the earlier versions. HMR 55A has come about from the comments and reviews of many of these same individuals along with users of HMR No. 55, and it is hoped by the current authors that the cooperative spirit that produced this report has yielded an improved study.

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APPENDIX A

Generalized PMP Studies for Conterminuous United States

Hydrometeorological Report	Geographical Region	Scope
No. 36 (U.S. Weather Bureau 1961 Revision, U.S. Weather Bureau 1969)	Pacific coast drainage of California	General-storm PMP; areas up to 5,000 mi^2, 6 to 72 hr, seasonal values October through April
No. 43 (U.S. Weather Bureau 1966 addendum 1981)	Columbia River and coastal drainages of Oregon and Washington	General-storm PMP, areas up to 5,000 mi^2 west of Cascades Ridge, areas up to 1,000 mi^2 east of Cascades Ridge, 6 to 72 hr, seasonal values October through June. Local-storm PMP east of Cascades Ridge, areas up to 500 mi^2, durations to 6 hr, seasonal values May through September.
No. 49 (Hansen et al. 1977)	Colorado River and Great Basin drainage. Also provides local storm for all of California	General-storm PMP, areas up to 5,000 mi^2, 6 to 72 hr, monthly values. Local-storm PMP, areas areas up to 500 mi^2, durations up to 6 hr, all season values.
No. 51 (Schreiner and Riedel 1978)	U.S. east of 103rd meridian*	PMP from 10 to 20,000 mi^2, 6 to 72 hr, all season values.
No. 52 (Hansen et al. 1982)	U.S. east of 105th meridian*	PMP from 10 to 20,000 mi^2, duration $\leq$ 6 hr all season values (Application report).
No. 53 (Ho and Riedel 1980)	U.S. east of 103rd meridian*	PMP for 10 mi^2, 6 to 72 hr, monthly values.
No. 55 (Miller et al. 1984) *(Revised 1987, HMR No. 55A)	U.S. between Continental Divide and 103rd meridian	General-storm PMP, areas 10 to 20,000 mi^2 in nonorographic regions and 10 to 5,000 mi^2 in orographic regions , 1 to 72 hr, all-season values. Local-storm PMP, for selected portions of study region, up to 500 mi^2, durations $<$ 6 hr, all-season values.

* Reports 51, 52, and 53 originally provided PMP for the U.S. east of the 105th meridian, PMP between the 103rd and 105th meridian from these reports are now superseded by HMR 55. Application portion of HMR 52 is valid for Eastern U.S. out to the 105th meridian.

APPENDIX B

Storms Important for Estimates of PMP in CD-103 Region

This appendix contains a listing of the maximum observed average areal rainfall depths for the storms important to development of general-storm PMP estimates in the CD-103 region. The storms included are the storms listed in table 2.2, except those short-duration storms for which DAD data for 6 hr or more and 10 mi^2 or larger are not presently available. Average depths are given for selected area sizes and durations. The area sizes selected are those considered in HMR No. 51 with the addition of 2,000 mi^2. Orographic storms provide data to 5,000 mi^2, while areas to 20,000 mi^2 are given for least orographic storms. It should be noted that for some storms, additional data are available on the original pertinent data sheets (contact NWS authors). Other information in the listing is:

a. Storm index number. The number used throughout this report for storm identification, assigned by the authors.

b. Date of storm.

c. Storm assignment number. This number is assigned by the U.S. Army Corps of Engineers, Bureau of Reclamation, or the Hydrometeorological Service Section of the Atmospheric Environment Service, Canadian Department of the Environment, to storms included in their respective formal storm study programs. Those storms without an assignment number are part of the unofficial storm studies conducted by the Hydrometeorological Branch, NWS.

d. Name of nearest town or habitation to the maximum rainfall center.

e. Latitude and longitude of the maximum rainfall center (approximate).

f. In-place moisture adjustment (see table 5.3).

The locations of these storms are shown in figure 2.1, where each storm is identified by the storm index number.

Storm Index No. 1 | Date - 5/29-31/1894 | Storm Assignment No. MR 6-14
Max. Rainfall Center: | Ward District, CO. | Lat. 40°04' Long. 105°32'
Moisture Adjustment 244

Maximum average depth of rainfall in inches

Area (mi^2)	Duration of rainfall in hours						
	6	12	18	24	36	48	60
10	1.7	3.3	4.7	5.6	7.3	8.2	8.5
100	1.7	3.2	4.3	5.2	6.5	7.3	7.5
200	1.7	3.1	4.2	5.0	6.3	7.0	7.2
500	1.7	3.0	4.0	4.8	5.9	6.6	6.8
1000	1.6	2.9	3.8	4.6	5.7	6.3	6.5
2000	1.6	2.7	3.6	4.4	5.3	5.9	6.1
5000	1.5	2.5	3.2	3.9	4.7	5.3	5.5

Storm Index No. 6 | Date - 5/1-3/1904 | Storm Assignment No. MR 4-6
Max. Rainfall Center: | Boxelder, CO | Lat. 40°59' Long. 105°11'
Moisture Adjustment 200

Maximum average depth of rainfall in inches

Area (mi^2)	Duration of rainfall in hours					
	6	12	18	24	36	48
10	2.1	2.8	3.5	4.3	6.2	6.4
100	2.0	2.5	3.3	3.9	5.8	6.1
200	1.9	2.4	3.2	3.8	5.7	6.0
500	1.7	2.2	2.9	3.6	5.3	5.5
1000	1.6	2.1	2.7	3.4	4.8	5.0
2000	1.4	1.9	2.5	3.1	4.3	4.5
5000	1.0	1.7	2.1	2.6	3.6	3.9

Storm Index No. 8 | Date - 9/26-30/1904 | Storm Assignment No. SW 1-6
Max. Rainfall Center | Rociada, NM | Lat. 35°52' Long. 105°20'
Moisture Adjustment 138

Maximum average depth of rainfall in inches

Area (mi^2)	Duration of rainfall in hours								
	6	12	18	24	36	48	60	72	90
10	3.8	4.2	5.2	6.6	7.3	7.3	7.3	7.3	7.9
100	3.1	3.8	4.7	6.3	7.0	7.0	7.0	7.0	7.6
200	2.9	3.7	4.6	6.2	6.8	6.9	6.9	6.9	7.5
500	2.6	3.5	4.3	5.8	6.5	6.5	6.6	6.7	7.3
1000	2.4	3.3	4.1	5.4	6.2	6.4	6.4	6.5	7.2
2000	2.2	3.1	3.9	5.0	5.9	6.1	6.2	6.3	7.0
5000	1.8	2.8	3.5	4.4	5.5	5.7	5.8	6.0	6.8

Storm Index No. 10	Date - 6/6-8/1906	Storm Assignment No. MR 5-13
Max. Rainfall Center:	Warrick, MT	Lat. 48°04' Long. 109°39'
	Moisture Adjustment 188	

Area (mi^2)	Maximum average depth of rainfall in inches — Duration of rainfall in hours						
	6	12	18	24	36	48	60
10	6.0	7.8	8.4	10.2	11.6	13.1	13.3
100	5.0	7.1	7.6	9.2	10.5	11.8	12.2
200	4.6	6.6	7.1	8.7	9.9	11.2	11.5
500	4.0	5.9	6.3	7.8	8.8	10.0	10.3
1000	3.5	5.0	5.4	6.7	7.6	8.7	8.9
2000	2.9	4.0	4.2	5.4	6.1	7.1	7.3
5000	2.1	3.0	3.2	4.2	4.9	5.7	5.9

Storm Index No. 13	Date - 6/3-6/1908	Storm Assignment No. MR 5-15
Max. Rainfall Center:	Evans, MT	Lat. 47°11' Long. 111°08'
	Moisture Adjustment 191	

Area (mi^2)	Maximum average depth of rainfall in inches — Duration of rainfall in hours							
	6	12	18	24	36	48	60	72
10	1.9	3.7	5.5	6.5	6.9	7.9	8.0	8.0
100	1.8	3.6	5.0	6.2	6.7	7.5	7.7	7.7
200	1.7	3.5	4.8	6.0	6.5	7.3	7.5	7.6
500	1.7	3.3	4.6	5.7	6.2	7.0	7.1	7.3
1000	1.6	3.0	4.3	5.3	5.7	6.5	6.6	6.9
2000	1.5	2.7	3.9	4.7	5.1	5.9	6.0	6.3
5000	1.2	2.3	3.3	3.8	4.3	4.7	4.8	5.3

Storm Index No. 86	Date - 10/18-19/1908	Storm Assignment No. SW 2-23
Max. Rainfall Center:	May Valley, CO	Lat. 38°03' Long. 102°38'
	Moisture Adjustment 165	

Area (mi^2)	Maximum average depth of rainfall in inches — Duration of rainfall in hours				
	6	12	18	24	36
10	4.2	6.0	6.3	6.3	6.3
100	4.1	5.9	6.3	6.3	6.3
200	4.0	5.9	6.2	6.3	6.3
500	3.8	5.6	6.1	6.2	6.2
1000	3.5	5.4	5.8	5.9	5.9
2000	3.2	5.0	5.5	5.6	5.6
5000	2.7	4.5	5.1	5.2	5.3
10000	2.4	4.0	4.6	4.7	4.9
20000	2.1	3.4	4.0	4.2	4.4

Storm Index No. 20	Date - 4/29-5/2/14	Storm Assignment No. SW 1-16
Max. Rainfall Center:	Clayton, NM	Lat. 36°20' Long. 103°06'
	Moisture Adjustment 158	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours					
	6	12	18	24	36	48
10	5.3	6.8	8.6	9.0	9.0	9.6
100	4.8	6.7	8.2	8.8	8.9	9.4
200	4.6	6.5	8.0	8.7	8.8	9.3
500	4.2	6.2	7.8	8.3	8.5	9.0
1000	3.9	5.8	7.4	7.9	8.2	8.7
2000	3.5	5.0	6.7	7.2	7.6	8.1
5000	2.8	3.8	5.4	6.2	6.8	7.3
10000	2.0	3.0	4.5	5.2	6.0	6.5
20000	1.4	2.3	3.5	4.2	5.1	5.6

Storm Index No. 23	Date - 7/19-28/15	Storm Assignment No. SW 1-18
Max. Rainfall Center:	Tajique, NM	Lat. 34°46' Long. 106°20'
	Moisture Adjustment 177	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours							
	6	12	18	24	36	48	60	72
10	4.6	4.9	5.1	5.2	6.2	6.2		6.5
100	4.5	4.8	5.0	5.0	6.0	6.0		6.4
200	4.4	4.7	4.9	4.9	5.8	5.8		6.2
500	4.1	4.3	4.6	4.6	5.5	5.5		5.8
1000	3.6	3.8	4.1	4.1	5.0	5.0		5.3
2000	2.7	3.0	3.3	3.3	4.0	4.1		4.5
5000	1.7	2.1	2.4	2.4	2.8	3.0		3.4

Storm Index No. 25	Date - 8/7-8/16	Storm Assignment No. SW 1-20
Max. Rainfall Center:	Lakewood, NM	Lat. 32°38' Long. 104°21'
	Moisture Adjustment 117	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours			
	6	12	18	24
10	4.8	5.2	5.8	6.0
100	3.9	4.9	5.8	6.0
200	3.6	4.8	5.6	5.9
500	3.1	4.5	5.2	5.6
1000	2.8	4.2	4.7	5.2
2000	2.4	3.6	4.2	4.6
5000	1.8	2.6	3.2	3.7
10000	1.1	2.0	2.6	3.2

Storm Index No. 27	Date - 9/15-17/19	Storm Assignment No. GM 5-15B
Max. Rainfall Center:	Meek, NM	Lat. 33°41' Long. 105°11'
	Moisture Adjustment 170	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours					
	6	12	18	24	36	48
10	3.8	4.5	6.2	7.4	9.1	9.5
100	3.2	4.2	5.1	6.4	7.9	8.3
200	3.0	4.1	4.7	6.0	7.5	7.9
500	2.7	3.8	4.3	5.4	7.0	7.3
1000	2.5	3.4	4.0	5.0	6.5	6.9
2000	2.2	3.1	3.6	4.6	6.0	6.5
5000	1.9	2.7	3.2	4.0	5.3	5.9

Storm Index No. 30	Date - 4/14-16/21	Storm Assignment No. MR 4-19
Max. Rainfall Center:	Fry's Ranch, CO	Lat. 40°43' Long. 105°43'
	Moisture Adjustment 185	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours				
	6	12	18	24	36
10	2.2	4.3	6.1	7.3	7.5
100	2.1	4.2	5.7	6.9	7.2
200	2.0	3.9	5.4	6.6	6.9
500	1.7	3.4	4.6	5.6	5.8
1000	1.6	3.0	4.0	4.8	5.2
2000	1.4	2.6	3.4	4.2	4.4
5000	1.1	2.3	3.1	3.8	4.1

Storm Index No. 31	Date - 6/2-6/21	Storm Assignment No. SW 1-23
Max. Rainfall Center:	Penrose, CO	Lat. 38°27' Long. 105°04'
	Moisture Adjustment 151	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours							
	6	12	18	24	36	48	60	72
10	10.4	11.3	12.0	12.0	12.0	12.0	12.0	12.0
100	8.8	10.4	11.0	11.1	11.1	11.2	11.2	11.2
200	7.9	9.7	10.3	10.4	10.5	10.7	10.7	10.7
500	6.5	8.4	9.0	9.1	9.4	9.6	9.7	9.7
1000	5.4	7.1	7.8	7.8	8.2	8.6	8.7	8.7
2000	4.2	5.4	6.1	6.2	6.9	7.1	7.4	7.4
5000	2.7	4.0	4.3	4.4	5.6	5.7	6.0	6.2

Storm Index No. 32	Date - 6/17-21/21	Storm Assignment No. MR 4-21
Max. Rainfall Center:	Springbrook, MT	Lat. 47°18' Long. 105°35'
	Moisture Adjustment 131	

Maximum average depth of rainfall in inches

Area (mi^2)	Duration of rainfall in hours							
	6	12	18	24	36	48	60	72
10	10.5	11.7	12.9	13.3	13.4	14.2	14.5	14.6
100	8.5	11.1	12.6	13.0	13.3	14.1	14.2	14.4
200	8.3	10.8	12.3	12.7	13.0	13.8	13.9	14.2
500	7.9	10.3	11.6	12.0	12.3	13.0	13.2	13.4
1000	7.4	9.6	10.8	11.3	11.5	12.1	12.3	12.5
2000	6.6	8.5	9.7	10.1	10.4	11.0	11.2	11.4
5000	4.9	6.2	7.3	7.7	8.0	9.0	9.3	9.5
10000	3.0	4.3	5.1	5.6	5.8	7.3	7.6	7.7
20000	1.6	2.7	3.4	3.9	4.2	5.2	5.5	5.8

Storm Index No. 38	Date - 9/27-10/1/23	Storm Assignment No. MR 4-23
Max. Rainfall Center:	Savageton, WY	Lat. 43°52' Long. 105°47'
	Moisture Adjustment 126	

Maximum average depth of rainfall in inches

Area (mi^2)	Duration of rainfall in hours							
	6	12	18	24	36	48	60	72
10	6.0	9.1	9.3	9.5	16.5	16.9	16.9	16.9
100	5.1	8.4	8.7	9.0	15.5	15.9	15.9	15.9
200	4.9	8.0	8.4	8.6	14.8	15.2	15.2	15.2
500	4.3	7.1	7.5	7.7	13.2	13.4	13.6	13.7
1000	3.7	6.2	6.4	6.6	11.4	11.6	11.7	11.8
2000	3.0	5.0	5.3	5.5	9.5	9.7	9.8	9.9
5000	2.2	3.6	3.8	4.0	7.0	7.2	7.4	7.6
10000	1.6	2.5	2.7	3.0	5.3	5.7	6.1	6.3
20000	1.2	1.8	2.1	2.5	3.9	4.7	5.1	5.5

Storm Index No. 44	Date - 10/9-12/30	Storm Assignment No. SW 2-6
Max. Rainfall Center:	Porter, NM	Lat. 35°12' Long. 103°17'
	Moisture Adjustment 140	

Maximum average depth of rainfall in inches

Area (mi^2)	Duration of rainfall in hours					
	6	12	18	24	36	48
10	5.7	6.3	8.5	9.9	9.9	9.9
100	5.3	5.9	7.6	9.1	9.1	9.1
200	5.1	5.7	7.2	8.7	8.7	8.7
500	4.6	5.3	6.5	7.9	8.0	8.0
1000	4.1	4.9	6.0	7.2	7.4	7.4
2000	3.6	4.4	5.4	6.5	6.7	6.8
5000	2.9	3.7	4.6	5.4	5.8	5.9
10000	2.3	3.2	3.9	4.5	5.1	5.2
20000	1.7	2.5	3.2	3.6	4.3	4.4

Storm Index No. 46	Date - 9/9-11/33	Storm Assignment No. R7 1-25A
Max. Rainfall Center:	Kassler, CO	Lat. 39°30' Long. 105°06'
	Moisture Adjustment 193	

Maximum average depth of rainfall in inches

Area (mi^2)	Duration of rainfall in hours						
	6	12	18	24	36	48	60
10	3.9	4.0	4.0	4.2	4.4	4.5	4.5
100	3.8	3.9	3.9	4.1	4.3	4.4	4.4
200	3.7	3.8	3.8	4.0	4.2	4.3	4.3
500	3.4	3.5	3.5	3.7	3.9	4.0	4.1
1000	3.0	3.2	3.2	3.3	3.6	3.7	3.9
2000	2.5	2.8	2.8	2.8	3.3	3.4	3.6
5000	1.8	2.0	2.0	2.1	2.7	2.8	3.0

Storm Index No. 47	Date - 5/30-31/35	Storm Assignment No. MR 3-28A
Max. Rainfall Center:	Cherry Ck., CO	Lat. 39°13' Long. 104°32'
	Moisture Adjustment 163	

Maximum average depth of rainfall in inches

Area (mi^2)	Duration of rainfall in hours			
	6	12	18	24
10	20.6	22.2	22.2	22.2
100	13.7	15.4	15.4	15.4
200	11.2	12.6	12.6	12.6
500	7.8	9.3	9.3	9.3
1000	5.8	7.2	7.2	7.2
2000	4.1	5.3	5.5	5.5
5000	2.4	3.5	3.8	4.0

Storm Index No. 101	Date - 5/30-31/35	Storm Assignment No. MR 3-28A
Max. Rainfall Center:	Hale, CO	Lat. 39°36' Long. 102°08'
	Moisture Adjustment 156	

Maximum average depth of rainfall in inches

Area (mi^2)	Duration of rainfall in hours			
	6	12	18	24
10	16.5[x]	22.2	22.2	22.2
100	11.0[x]	15.4	15.4	15.4
200	9.9[x]	12.6	12.6	12.6
1000	4.6[x]	7.2	7.2	7.2
5000	1.9[x]	3.5	3.8	4.0

[x]From original depth-area analysis of total storm pattern

Storm Index No. 105	Date - 9/14-18/36	Storm Assignment No. GM 5-7
Max. Rainfall Center:	Broome, TX	Lat. 31°47' Long. 100°50'
	Moisture Adjustment 117	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours							
	6	12	18	24	36	48	60	72
10	16.0	22.0	24.1	26.0	26.0	27.6	28.0	30.0
100	10.9	15.4	18.3	20.4	21.7	23.5	25.8	28.6
200	9.5	13.6	16.5	18.5	20.0	21.4	24.5	27.7
500	7.7	11.2	14.0	15.8	17.2	18.2	22.1	25.7
1000	6.4	9.5	12.0	13.8	14.8	15.4	19.9	23.6
2000	5.2	7.9	9.9	11.6	12.3	13.0	17.1	20.9
5000	3.7	5.8	7.3	8.7	9.4	10.2	13.5	16.5
10000	2.7	4.3	5.5	6.7	7.4	8.4	11.1	13.2
20000	1.9	3.0	3.9	4.9	5.8	6.8	8.9	10.4

Storm Index No. 53	Date - 8/30-9/4/38	Storm Assignment No. MR 5-8
Max. Rainfall Center:	Loveland, CO	Lat. 40°23' Long. 105°04'
	Moisture Adjustment 134	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours							
	6	12	18	24	36	48	60	72
10	6.4	6.8	7.0	7.0	9.9	9.9	10.6	10.6
100	4.4	4.8	5.2	5.2	8.9	8.9	9.4	9.4
200	3.6	4.2	4.6	4.6	7.8	7.9	8.4	8.4
500	2.3	3.1	3.1	3.4	6.1	6.2	6.6	6.7
1000	1.6	2.9	2.9	3.1	5.0	5.1	5.4	5.7
2000	1.3	2.4	2.5	2.7	4.0	4.1	4.4	4.6
5000	1.0	1.6	1.7	2.1	3.2	3.4	3.6	3.8

Storm Index No. 108	Date - 6/19-20/1939	Storm Assignment No. -
Max. Rainfall Center:	Snyder, TX	Lat. 32°44' Long. 100°55'
	Moisture Adjustment 123	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours
	6
10	18.8
100	14.2
200	11.9
500	8.6
1000	6.5
2000	4.7
5000	-

Storm Index No. 56	Date - 5/20-25/41	Storm Assignment No. GM 5-18
Max. Rainfall Center:	Prairieview, NM	Lat. 33°07' Long. 103°12'
	Moisture Adjustment 132	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours							
	6	12	18	24	36	48	60	72
10	3.8	4.8	6.0	6.5	7.0	7.4	7.4	8.4
100	3.0	4.0	5.2	6.3	6.8	6.9	7.0	8.1
200	2.7	3.7	4.7	6.0	6.6	6.7	6.9	8.0
500	2.3	3.3	4.1	5.4	6.1	6.4	6.7	7.7
1000	2.1	3.0	3.7	4.9	5.7	6.1	6.4	7.5
2000	1.8	2.7	3.2	4.3	5.2	5.7	6.1	7.2
5000	1.4	2.2	2.7	3.5	4.4	5.0	5.6	6.6
10000	1.2	1.9	2.2	2.9	3.7	4.4	5.0	5.9
20000	0.9	1.5	1.8	2.3	3.0	3.7	4.3	5.1

Storm Index No. 58	Date - 9/20-23/41	Storm Assignment No. GM 5-19
Max. Rainfall Center:	McColleum Ranch, NM	Lat. 32°10' Long. 104°44'
	Moisture Adjustment 151	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours							
	6	12	18	24	36	48	60	72
10	10.1	11.2	11.5	12.1	16.9	18.7	21.0	21.2
100	5.9	8.3	8.7	9.0	11.7	13.0	14.7	15.0
200	5.2	7.3	7.8	8.1	9.7	10.8	12.4	12.7
500	4.4	6.2	6.8	6.9	7.9	9.1	10.2	10.5
1000	3.8	5.5	6.1	6.3	7.1	8.3	9.4	9.6
2000	3.3	4.8	5.5	5.6	6.4	7.5	8.6	8.8
5000	2.6	3.9	4.6	4.8	5.6	6.6	7.5	7.8
10000	2.0	3.2	4.0	4.2	4.9	5.9	6.7	7.0
20000	1.5	2.6	3.3	3.7	4.4	5.2	5.9	6.2

Storm Index No. 60	Date - 8/29-9/1/42	Storm Assignment No. SW 2-29
Max. Rainfall Center:	Rancho Grande, NM	Lat. 34°56' Long. 105°06'
	Moisture Adjustment 119	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours							
	6	12	18	24	36	48	60	72
10	3.2	5.9	7.0	7.9	8.0	8.0	8.0	8.0
100	2.7	5.2	6.7	7.6	8.0	8.0	8.0	8.0
200	2.6	5.1	6.7	7.6	8.0	8.0	8.0	8.0
500	2.4	4.7	6.5	7.4	7.7	7.8	7.8	7.8
1000	2.3	4.2	6.1	6.8	7.2	7.2	7.2	7.2
2000	2.1	4.0	4.9	5.8	6.4	6.4	6.4	6.5
5000	1.9	3.6	4.5	5.5	6.0	6.0	6.0	6.1

Storm Index No. 68	Date - 6/16-17/48	Storm Assignment No. -
Max. Rainfall Center:	Dupuyer, MT	Lat. 48°12' Long. 112° 30'
	Moisture Adjustment 220	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours					
	6	12	18	24	36	48
10	4.4	6.1	8.3	8.6	8.9	9.3
100	(4.0)	(5.1)	(6.9)	(7.3)	(7.9)	(8.8)*
1000	1.8	3.7	5.1	5.6	6.0	7.0
2000	1.6	3.1	4.3	4.7	5.1	5.9

*Interpolated

Storm Index No. 111	Date - 6/23-24/48	Storm Assignment No. -
Max. Rainfall Center:	Del Rio, TX	Lat. 29°22' Long. 100°37'
	Moisture Adjustment 135	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours			
	6	12	18	24
10	13.2	20.7	25.2	26.2
100	11.3	18.2	22.5	23.8
200	10.3	16.9	21.1	22.5
500	8.8	15.2	19.0	20.2
1000	7.7	13.6	16.8	17.9
2000	6.3	11.4	14.1	15.1
5000	4.7	8.0	9.9	10.8
10000	3.2	5.5	6.8	7.2

Storm Index No. 71	Date - 6/1-4/53	Storm Assignment No. -
Max. Rainfall Center:	Belt, MT	Lat. 47°25' Long. 110°50'
	Moisture Adjustment 148	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours					
	6	12	18	24	36	48
10		5.8	7.7	8.6		10.4
100		5.1	6.8	7.5		9.0
200		4.7	6.2	7.0		8.4
500		4.0	5.5	6.1		7.5
1000		3.4	4.8	5.4		6.8
2000		2.8	4.0	4.4		5.9
5000		2.3	3.1	3.5		4.8

Storm Index No. 112	Date - 6/23-28/54	Storm Assignment No. SW 3-22
Max. Rainfall Center:	Vic Pierce, TX	Lat. 30°22' Long. 101°23'
	Moisture Adjustment 130	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours							
	6	12	18	24	36	48	60	72
10	16.0	20.1	22.5	26.7	32.0	34.6	34.6	34.6
100	12.6	16.5	19.7	23.6	29.2	31.5	31.5	31.5
200	10.9	14.9	18.6	22.5	27.5	29.5	29.5	29.5
500	8.4	12.0	16.6	20.5	24.5	26.3	26.3	26.3
1000	6.6	9.7	14.6	18.4	21.5	23.0	23.0	23.0
2000	4.8	7.5	11.8	14.7	17.6	19.4	19.4	19.4
5000	2.8	4.9	7.4	8.9	11.9	13.7	14.3	14.3
10000	1.7	3.2	4.7	5.7	8.0	9.8	10.4	10.5
20000	1.2	2.0	2.8	3.6	5.2	6.5	7.0	7.2

Storm Index No. 75	Date - 6/6-8/64	Storm Assignment No. -
Max. Rainfall Center:	Gibson Dam, MT	Lat. 48°33' Long. 113°32'
	Moisture Adjustment 200	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours				
	6	12	18	24	36
10	6.0x	10.6x	13.6x	14.9x	16.4x
100	5.8x	10.2x	13.2x	14.6x	16.0x
200	5.6x	10.0x	12.8x	14.2x	15.5x
500	5.1x	9.1x	11.8x	13.2x	14.4x
1000	4.6x	8.4x	11.0x	12.3x	13.4x
2000	4.2x	7.6x	10.0x	11.3x	12.3x
5000	3.4x	6.4x	8.2x	9.6x	10.4x

Storm Index No. 76	Date - 6/13-20/65	Storm Assignment No. -
Max. Rainfall Center:	Plum Creek, CO	Lat. 39°05' Long. 104°20'
	Moisture Adjustment 128	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours							
	6	12	18	24	36	48	60	72
10	11.5x	12.5x	12.6x	13.2	14.6	15.4	16.2	16.7
100	7.7x	8.5x	8.7x	12.4	13.6	14.4	15.1	15.6
200	6.9x	7.8x	8.0x	11.9	13.0	13.8	14.5	14.8
1000	5.0x	5.6x	5.7x	9.5	10.6	11.2	11.8	12.3
5000	2.8	3.4	4.0	6.0	7.0	7.1	7.6	8.0
10000	2.0	2.5	3.0	3.9	4.8	5.2	5.8	6.1
20000	1.4	1.7	2.1	2.4	3.1	3.5	4.2	4.4

x from USBR analysis

Storm Index No. 114	Date - 6/24/66	Storm Assignment No. -
Max. Rainfall Center:	Glen Ullin, ND	Lat. 47°21' Long. 101°19'
	Moisture Adjustment 152	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours	
	6	12
10	11.1	11.9
100	9.6	10.1
200	8.6	9.1
500	6.9	7.5
1000	5.4	5.9

Storm Index No. 77	Date - 5/4-8/69	Storm Assignment No. -
Max. Rainfall Center:	Big Elk Meadow, CO	Lat. 40°16' Long. 105°25'
	Moisture Adjustment 182	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours							
	6	12	18	24	36	48	60	72
10	4.0	7.2	9.6	11.8	14.0	15.1	16.9	17.8
100	3.0	5.4	7.1	8.6	10.7	11.8	12.9	14.0
200	2.7	4.8	6.3	7.8	9.7	10.7	11.7	12.8
500	2.2	4.0	5.3	6.5	8.3	9.2	10.2	11.2
1000	1.9	3.4	4.6	5.5	7.2	8.1	9.0	10.0
2000	1.5	2.9	3.8	4.6	6.0	7.0	7.8	8.7
5000	1.1	2.1	2.7	3.4	4.6	5.5	6.1	6.9

Storm Index No. 78	Date - 6/9/72	Storm Assignment No. -
Max. Rainfall Center:	Rapid City, SD	Lat. 44°12' Long. 103°31'
	Moisture Adjustment 120	

Maximum average depth of rainfall in inches

Area (mi²)	Duration of rainfall in hours	
	6	12
10	-	14.9
100		12.4
200		10.9
500		8.6
1000		6.7
2000		5.0

Storm Index No. 79	Date - 5/5-6/73	Storm Assignment No. -
Max. Rainfall Center:	Broomfield, CO	Lat. 39°55' Long. 105°06'
	Moisture Adjustment 194	

Area (mi^2)	Maximum average depth of rainfall in inches — Duration of rainfall in hours				
	6	12	18	24	36*
10	2.9	4.9	5.9	6.3	6.3
100	2.4	4.8	5.2	5.8	5.8
500	2.1	3.8	4.8	5.1	5.2
1000	2.0	3.5	4.3	4.7	4.8
5000	1.7	2.8	3.4	3.8	3.9

* 30 hr

Storm Index No. 116	Date - 8/1-3/78	Storm Assignment No. -
Max. Rainfall Center:	Medina, TX	Lat. 29°55' Long. 99°21'
	Moisture Adjustment 117	

Area (mi^2)	Maximum average depth of rainfall in inches — Duration of rainfall in hours						
	6	12	18	24	36	48	60#
10	17.0	20.8	23.8	27.2	31.9	40.0	42.5
100	15.3	19.9	21.8	23.8	27.1	31.6	32.6
200	13.8	17.9	19.4	21.5	24.1	28.5	29.4
500	11.3	14.5	15.8	17.8	20.0	24.3	25.0
1000	9.1	12.0	13.1	15.0	16.9	20.5	21.1
2000^x	7.1	9.9	10.9	12.6	14.2	16.8	17.3

55 hr

x 1800 mi^2

APPENDIX C

Table of Precipitable Water

DEPTH OF PRECIPITABLE WATER (W, .01 in.)
BETWEEN 1000-MB SURFACE AND INDICATED HEIGHT (H, 1000 ft) ABOVE 1000-MB SURFACE,
AS A FUNCTION OF 1000-MB TEMPERATURE (T_{1000}, F),
IN A SATURATED ATMOSPHERE WITH PSEUDOADIABATIC LAPSE RATE

Temperature at 1000 mb

Height 100's ft	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
1	02	02	02	02	02	02	02	02	02	02	02	02	02	02	03	03	03	03	03	03	03
2	03	03	03	04	04	04	04	04	04	04	04	05	05	05	05	05	05	06	06	06	06
3	05	05	05	05	05	06	06	06	06	06	07	07	07	07	07	08	08	08	08	09	09
4	06	06	07	07	07	07	08	08	08	08	09	09	09	10	10	10	11	11	11	12	12
5	08	08	08	09	09	09	10	10	10	11	11	11	12	12	12	13	13	14	14	15	15
6	09	10	10	10	11	11	11	12	12	13	13	13	14	14	15	15	16	16	17	17	18
7	11	11	12	12	12	13	13	14	14	15	15	16	16	17	17	18	18	19	19	20	21
8	12	13	13	14	14	15	15	16	16	17	17	18	18	19	20	20	21	21	22	23	24
9	14	14	15	15	16	16	17	17	18	19	19	20	21	21	22	23	23	24	25	26	27
10	15	16	16	17	17	18	19	19	20	21	21	22	23	23	24	25	26	27	28	28	29
11	17	17	18	19	19	20	20	21	22	23	23	24	25	26	27	28	28	29	30	31	32
12	18	19	19	20	21	22	22	23	24	25	25	26	27	28	29	30	31	32	33	34	35
13	20	20	21	22	22	23	24	25	26	27	27	28	29	30	31	32	33	34	36	37	38
14	21	22	22	23	24	25	26	27	28	28	29	30	31	32	34	34	36	37	38	39	41
15	22	23	24	25	26	27	27	28	29	30	31	32	34	35	36	37	38	39	41	42	43
16	24	25	26	26	27	28	29	30	31	32	33	35	36	37	38	39	41	42	43	45	46
17	25	26	27	28	29	30	31	32	33	34	35	37	38	39	40	42	43	44	46	47	49
18	26	27	28	29	30	32	33	34	35	36	37	39	40	41	43	44	45	47	48	50	52
19	28	29	30	31	32	33	34	35	37	38	39	41	42	43	45	46	48	49	51	53	54
20	29	30	31	32	34	35	36	37	38	40	41	42	44	45	47	48	50	52	53	55	57
21	30	32	33	34	35	36	38	39	40	42	43	44	46	47	49	51	52	54	56	58	60
22	32	33	34	35	37	38	39	41	42	43	45	46	48	49	51	53	55	56	58	60	62
23	33	34	36	37	38	39	40	42	44	45	47	48	50	52	53	55	57	59	61	63	65
24	34	36	37	38	40	41	42	44	45	47	48	50	52	54	56	57	60	61	63	65	68
25	36	37	38	40	41	43	44	46	47	49	50	52	54	56	58	60	62	64	66	68	70
26	37	38	40	41	43	44	46	47	49	50	52	54	56	58	60	62	64	66	68	70	73
27	38	40	41	43	44	46	47	49	51	52	54	56	58	60	62	64	66	68	71	73	75
28	39	41	42	44	45	47	49	50	52	54	56	58	60	62	64	66	68	70	73	75	78
29	41	42	44	45	47	49	50	52	54	56	57	60	62	64	66	68	70	73	75	78	80
30	42	43	45	47	48	50	52	54	55	57	59	61	64	66	68	70	73	75	78	80	83
31	43	45	46	48	50	51	53	55	57	59	61	63	65	68	70	72	75	77	80	83	85
32	44	46	48	49	51	53	55	57	59	61	63	65	67	69	72	74	77	79	82	85	88
33	45	47	49	51	52	54	56	58	60	62	64	67	69	71	74	77	79	82	84	87	90
34	47	48	50	52	54	56	58	60	62	64	66	69	71	73	76	79	81	84	87	90	93
35	48	50	51	53	55	57	59	61	64	66	68	70	73	75	78	81	83	86	89	92	95
36	49	51	53	55	56	59	61	63	65	67	70	72	75	77	80	83	85	88	91	94	97
37	50	52	54	56	58	60	62	64	67	69	71	74	76	79	82	85	88	90	94	97	100
38	51	53	55	57	59	61	63	66	68	70	73	75	78	81	84	87	90	92	96	99	102
39	52	54	56	58	60	63	65	67	70	72	74	77	80	83	86	89	92	95	98	101	105
40	53	55	57	60	62	64	66	69	71	73	76	79	82	84	87	90	94	97	100	103	107
41	54	56	59	61	63	65	68	70	73	75	78	81	83	86	89	92	96	99	102	106	109
42	56	58	60	62	64	67	69	72	74	77	79	82	85	88	91	94	98	101	104	108	112
43	57	59	61	63	66	68	70	73	76	78	81	84	87	90	93	96	100	103	107	110	114
44	58	60	62	64	67	69	72	74	77	80	82	85	88	92	94	98	102	105	109	112	116
45	59	61	63	66	68	71	73	76	79	81	84	87	90	93	97	100	104	107	111	114	118
46	60	62	64	67	69	72	74	77	80	83	86	89	92	95	98	102	105	109	113	117	121
47	61	63	65	68	70	73	76	78	81	84	87	90	93	97	100	104	107	111	115	119	123
48	62	64	67	69	72	74	77	80	83	86	89	92	95	98	102	106	109	113	117	121	125
49	63	65	68	70	73	76	78	81	84	87	90	93	97	100	104	107	111	115	119	123	127
50	64	66	69	71	74	77	80	82	86	88	92	95	98	102	105	109	113	117	121	125	129
55	69	71	74	77	80	83	86	89	92	95	99	103	106	110	114	118	122	127	131	135	140
60	73	76	79	82	85	89	98	95	99	102	106	110	114	118	122	127	131	136	141	145	150
65	78	81	84	87	91	94	97	101	105	109	113	117	121	125	130	135	140	145	150	155	160
70	82	85	88	92	95	99	103	107	111	115	119	124	128	133	138	143	148	153	159	164	170
75	86	89	93	96	100	104	108	112	117	121	125	130	135	140	145	150	156	161	167	173	179
80	89	93	97	101	105	109	113	117	122	126	131	136	141	146	152	157	163	169	176	182	188
85	93	97	101	105	109	113	118	122	127	132	137	142	147	153	159	164	171	177	184	190	197
90	96	100	104	109	113	117	122	127	132	137	142	148	153	159	165	171	178	184	191	198	205
95	99	103	108	112	117	121	126	131	137	142	147	153	159	165	171	178	184	191	198	206	213
100	102	107	111	116	120	125	130	135	141	146	152	158	164	170	177	184	191	198	206	213	221
105	105	109	114	119	124	129	134	139	145	151	157	163	169	176	183	190	197	204	212	220	228
110	108	112	117	122	127	132	138	143	149	155	161	168	174	181	188	195	203	211	219	227	235
115	110	115	120	125	130	135	141	147	153	159	165	172	179	186	193	201	209	217	225	233	242
120	112	117	122	127	133	139	144	150	157	163	169	176	183	190	198	206	214	222	231	240	249
125	115	119	125	130	136	141	147	154	160	166	173	180	187	195	203	211	219	228	237	246	255
130	116	122	127	133	138	144	150	157	163	170	177	184	191	199	207	215	224	233	242	251	261
135	118	124	129	135	141	147	153	159	166	173	180	188	198	203	212	220	229	238	248	257	267
140	120	125	131	137	143	149	156	162	169	176	183	191	199	207	216	224	233	243	253	262	273
145	122	127	133	139	145	151	158	165	172	179	186	194	202	211	220	228	238	247	257	267	278
150	123	129	135	141	147	153	160	167	174	182	189	197	206	214	223	232	242	252	262	272	283
155	125	130	136	142	149	155	162	169	177	184	192	200	209	217	227	236	246	256	266	277	288
160	126	132	138	144	151	157	164	172	179	187	195	203	212	220	230	239	249	260	271	281	293
165	127	133	139	145	152	159	166	174	181	189	197	206	214	223	233	243	253	263	275	285	297
170	128	134	140	147	154	161	168	175	183	191	199	208	217	226	236	246	256	267	278	289	301
175	129	135	142	148	155	162	169	177	185	193	202	210	219	229	239	249	260	270	282	293	305
180	130	136	143	149	156	163	171	179	187	195	204	212	222	231	242	252	263	274	285	297	309
185	131	137	144	150	158	165	172	180	189	197	205	214	224	234	244	255	265	277	289	300	313
190	132	138	145	151	159	166	174	182	190	198	207	216	226	236	247	257	268	280	292	304	317
195	132	139	145	152	160	167	175	183	191	200	209	218	228	238	249	259	271	282	295	307	320
200	133	139	146	153	161	168	176	184	193	201	210	220	230	240	251	262	273	285	297	310	323
205	134	140	147	154	161	168	177	185	194	203	212	221	231	242	253	264	275	287	300	313	326
210	134	141	148	155	162	170	178	186	195	204	213	223	233	243	255	266	278	290	303	315	329
215	135	141	148	155	163	171	179	187	196	205	214	224	234	245	257	268	280	292	305	318	332
220	135	142	149	156	164	171	180	188	197	206	216	225	236	246	258	269	282	294	307	320	334
225	136	142	149	156	164	172	180	190	198	207	217	227	237	248	260	271	283	296	309	322	337
230	136	142	150	157	165	173	181	190	199	208	218	228	238	249	261	273	285	298	311	325	339
235	136	143	150	157	165	173	182	190	200	209	219	229	239	250	262	274	287	299	313	327	341
240	136	143	150	158	166	174	182	191	200	209	219	230	240	251	264	275	288	301	315	329	343
245	137	143	151	158	166	174	183	192	201	210	220	230	241	252	265	277	289	303	316	330	345
250	137	144	151	158	166	175	183	192	201	211	221	231	242	253	266	278	291	304	318	332	347

Appendix C

Table of Precipitable Water (continued)

DEPTH OF PRECIPITABLE WATER (W, .01 in.)
BETWEEN 1000-MB SURFACE AND INDICATED HEIGHT (H, 1000 ft) ABOVE 1000-MB SURFACE,
AS A FUNCTION OF 1000-MB TEMPERATURE (T_{1000}, F),
IN A SATURATED ATMOSPHERE WITH PSEUDOADIABATIC LAPSE RATE

Height 100's ft	Temperature at 1000 mb																				
	60	61	62	62	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
230	136	142	150	157	165	173	181	190	199	208	218	228	238	249	261	273	285	298	311	325	339
235	136	143	150	157	165	173	182	190	200	209	219	229	239	250	262	274	287	299	313	327	341
240	136	143	150	158	166	174	182	191	200	209	219	230	240	251	264	275	288	301	315	329	343
245	137	143	151	158	166	174	183	192	201	210	220	230	241	252	265	277	289	303	316	330	345
250	137	144	151	158	166	175	183	192	201	211	221	231	242	253	266	278	291	304	318	332	347
255	137	144	151	159	167	175	184	192	202	211	221	232	243	254	267	279	292	305	319	334	349
260	137	144	151	159	167	175	184	193	202	212	222	233	244	255	268	280	293	306	321	335	350
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345	138	145	153	161	169	177	186	196	206	216	226	237	249	262	275	288	303	317	333	349	366
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425				161	169	177	187	196	206	216	227	238	250	262	276	289	304	319	335	351	369
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445						177	187	196	206	216	227	238	250	262	276	290	304	319	335	351	369
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535																			335	351	369
540																			335	351	369
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550																			335	351	369

*U.S. GOVERNMENT PRINTING OFFICE:1988-215-175