

NOAA Technical Memorandum NWS WR-130

FLASH-FLOOD PROCEDURE

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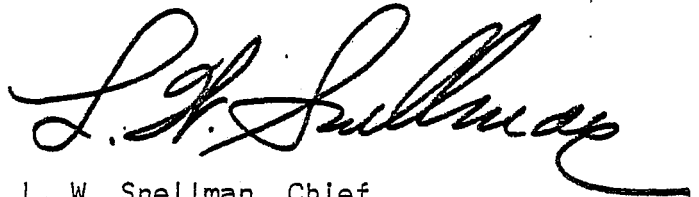
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This Technical Memorandum has been reviewed and is approved for publication by Scientific Services Division, Western Region.

A handwritten signature in black ink, appearing to read "L. W. Snellman". The signature is written in a cursive style with a long, sweeping tail that extends to the right.

L. W. Snellman, Chief
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Salt Lake City, Utah

I. INTRODUCTION

A self-help procedure is a method by which streamflow forecasts can be made by a local user with input data collected by the user or in cooperation with other agencies including the National Weather Service. Many types of procedures are available. This particular procedure was developed for use under circumstances where limited data may be available and estimates may be required. The results received from this procedure are based on defined 100-year 24-hour return period precipitation amounts from many years of data.

In using this procedure the user must input the amount of precipitation that has fallen, the time duration in which the precipitation fell, and the basin area (or the contributing portion of the basin) over which the precipitation occurred. When these data are known, the user can employ the self-help procedure effectively.

II. PURPOSE

The purpose of this study was to develop a self-help procedure that could be quickly and easily used in estimating runoff from thunderstorms in small basins (generally less than 200 square miles). Generally in these small basins there are very little hydrological data to work with, and a considerable number of flash floods that occur in the western United States happen in these small data-sparse basins.

III. DESCRIPTION OF PROCEDURE

This procedure is made up of three parts: A storm rainfall/duration graph, an area graph, and a total flow chart.

The storm rainfall/duration graph was developed by plotting the total rainfall (inches) against the return period (years) and drawing a family of curves depicting specific storm durations ranging from 5 minutes to 24 hours. Precipitation return periods (Miller, et al, 1973) for durations from 195 stations, in the Salt Lake City River Forecast Center area of responsibility, were computed and analyzed.

The area graph was calculated by plotting return periods against peak-flow per-unit area. A family of curves showing basin areas ranging from 1 square mile to 500 square miles was produced. This particular graph, developed by the Agricultural Research Service (Osborn and Laursen, 1973), has been portrayed by Williams (1975) in "A Study of Flash Flood Susceptibility--A Basin in Southern Arizona".

The total flow chart (Table I) is simply a chart delineating contributing area against peak-flow per-unit area. This gives the total peak

flow expected from a thunderstorm, for a basin or a defined area, with a given amount of precipitation, for a known duration.

In order to use this procedure properly and to get the best results, the user should use extreme care in defining the contributing area and the duration of storm as well as mean areal precipitation amount.

The contributing area and duration can be estimated with the aid of radar. Observer reports will also help in estimating the three needed variables.

An analysis of the return periods for the 24-hour, one-hundred-year precipitation amounts was plotted for the area (Figure 1). Three distinct subareas were recognized; therefore, a separate duration graph was drawn for each subarea. Basically the subareas divided themselves into three geographical sections: 1) The southern desert of Arizona which showed 4.0 inches of precipitation or greater, 2) The mountainous areas of Utah, northern Arizona, and southern Nevada, which had 3.0 to 4.0 inches, and 3) The Upper Colorado River Basin and the Humboldt River Basin which were calculated to be less than 3.0 inches.

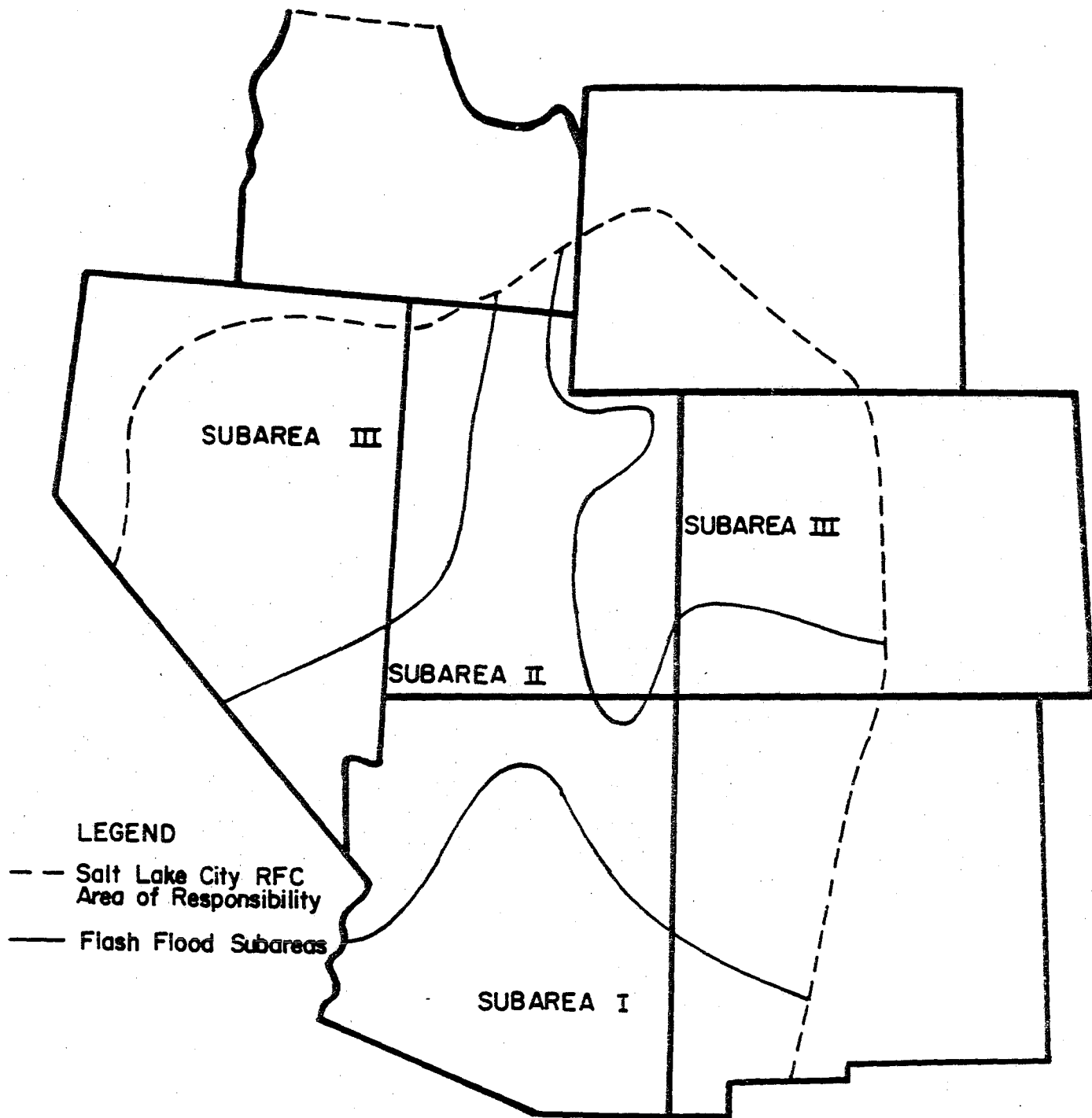
IV. PROCEDURE

Precipitation amounts are entered in the left-hand column of Figure 2. Then it is horizontally moved to the right until the correct duration curve is reached. This value is then used by dropping vertically until the storm contributing area curve is reached. Moving horizontally to the left margin, the peak-flow per-unit area is obtained. The user then obtains the total expected maximum flow by referring to the flow chart (Table I) which is a linear relationship used to obtain total flow from flow per-unit area. The total flow is given in cubic feet per second and is the expected peak flow for a storm of the given duration and rainfall amount over the calculated contributing area. (See Appendix A.)

In using this procedure it must be remembered that in basins, where only a portion of the basin is contributing to the runoff, that the calculated total maximum flow applies only to affected portion of the basin, not the entire basin. If the contributing portion of the basin is in the headwater area and measurements are made downstream, the flow from the contributing area must be routed downstream to the measuring station. The routing of a peak flow downstream usually results in a lower crest unless additional contributing areas add significantly to the flow.

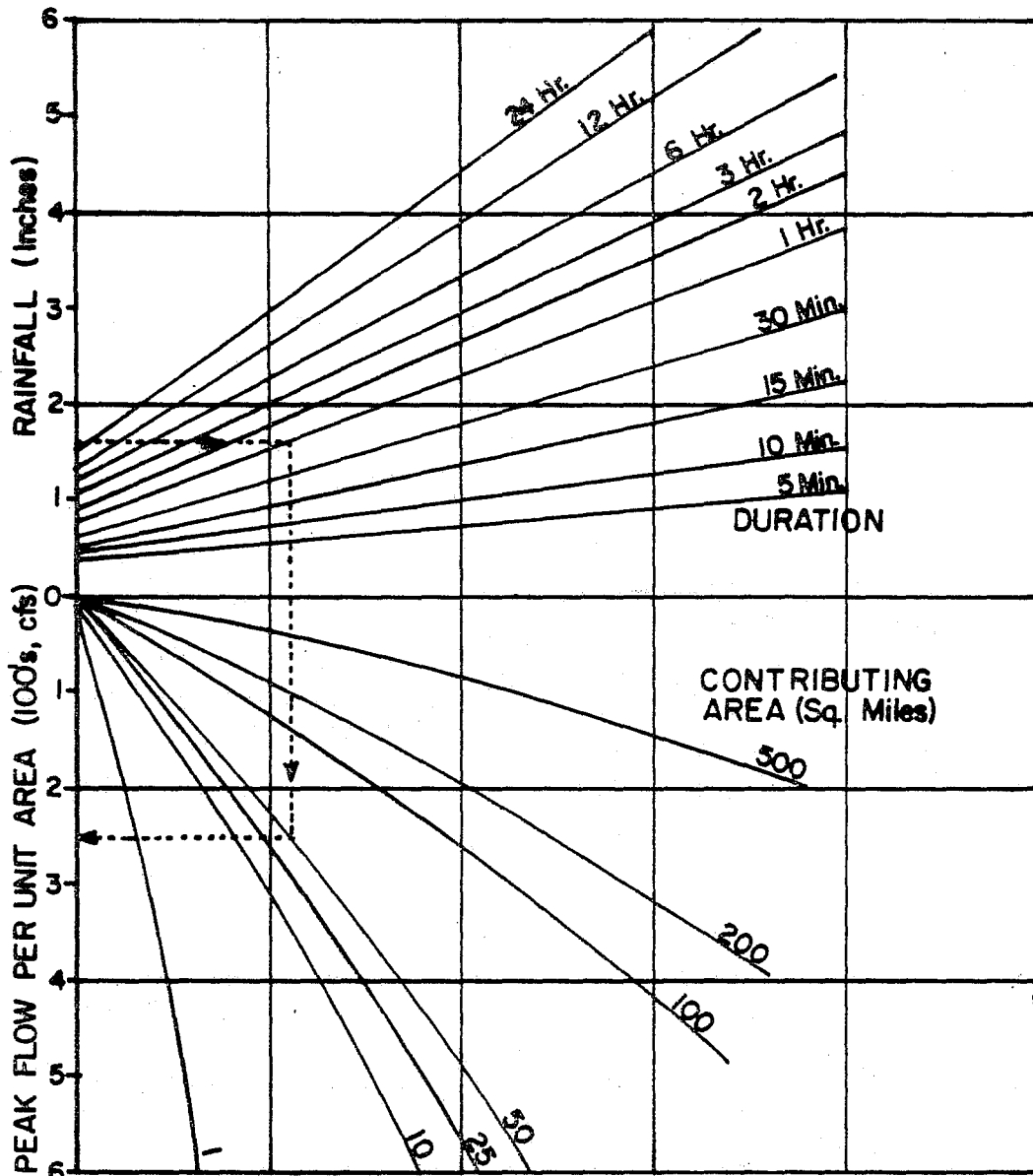
V. TEST RESULTS

Tests were made on a number of storms. However when adequate storm duration periods were lacking, many problems were encountered. On storms tested where the three variables were available, the results were very encouraging. A good example would be the September 2, 1960, storm over Farm Creek near Hanna, Utah. Rainfall totaling 1.27 inches fell in less than one hour at Hanna. The Farm Creek Basin area is 8.1 square miles. It is estimated from the available data that about 1.25 inches of precipitation fell over Farm Creek Basin in 60 minutes.



Flash Flood Subarea

Figure 1



Rainfall Duration Curve

FIGURE 2

PEAK FLOW PER UNIT AREA (100s, cfs)	TOTAL FLOW (100s, cfs)								
	10	20	30	40	50	60	70	80	90
2.1	21	42	63	84	105	126	147	168	189
2.2	22	44	66	88	110	132	154	176	198
2.3	23	46	69	92	115	138	161	184	207
2.4	24	48	72	96	120	144	168	192	216
2.5	25	50	75	100	125	150	175	200	225
2.6	26	52	78	104	130	156	182	208	234
2.7	27	54	81	108	135	162	189	216	243
2.8	28	56	84	112	140	168	196	224	252
2.9	29	58	87	116	145	174	203	232	261
3.0	30	60	90	120	150	180	210	240	270
	10	20	30	40	50	60	70	80	90
	TOTAL AREA (Sq. Miles)								

Area Curve

Putting this data into the procedure, a total peak flow of 3650 CFS is realized. The measured maximum discharge was 4300 CFS; however, research data and logic indicate the duration may have been smaller which would yield a higher peak flow than was forecast.

In using this self-help procedure it is very important that caution be used since the variables employed are sensitive and an error in the data can result in significant changes in the forecast. Data listed in Table II and plotted on Figure 3 are the test data used in the study development.

VI. CONCLUSION

This self-help procedure should be an effective tool to aid meteorologists in alerting communities when time from rainfall to flood peak is relatively short. To effectively use this procedure, it is very beneficial for personnel from each office to review hydrology in as many drainages as possible. Since the procedure provides a reasonable estimate of the peak flow from the contributing area, it is necessary that a review of high flows be made to determine the extent of the damages for each basin of concern; hopefully, a similar type procedure can be automated for use in AFOS.

- NOTE: 1) Most of the test data used to develop these charts were obtained from subarea I. Consequently, additional test data verified best using subarea-I charts. However, it is suggested that for specific areas charts corresponding to that area be used. But it is felt that if data are limited for any area and questions exist with the results obtained in subareas II or III, the subarea-I chart may be used as an adequate backup.
- 2) These procedures are drawn in scale to fit most flash-flood events. This was done to facilitate clarity and accurate use of the figures. The flows of record for entire regions such as El Dorado, Nevada; Tonto Creek, Arizona (Arizona Labor Day storm 1970); Bruneo Wash, Arizona; Big Thompson, Colorado; Rapid City, South Dakota; and Heppner, Oregon; extend beyond the curves. Flows of these magnitudes are extremely difficult to measure adequately and errors tend to cause erratic plotting points.

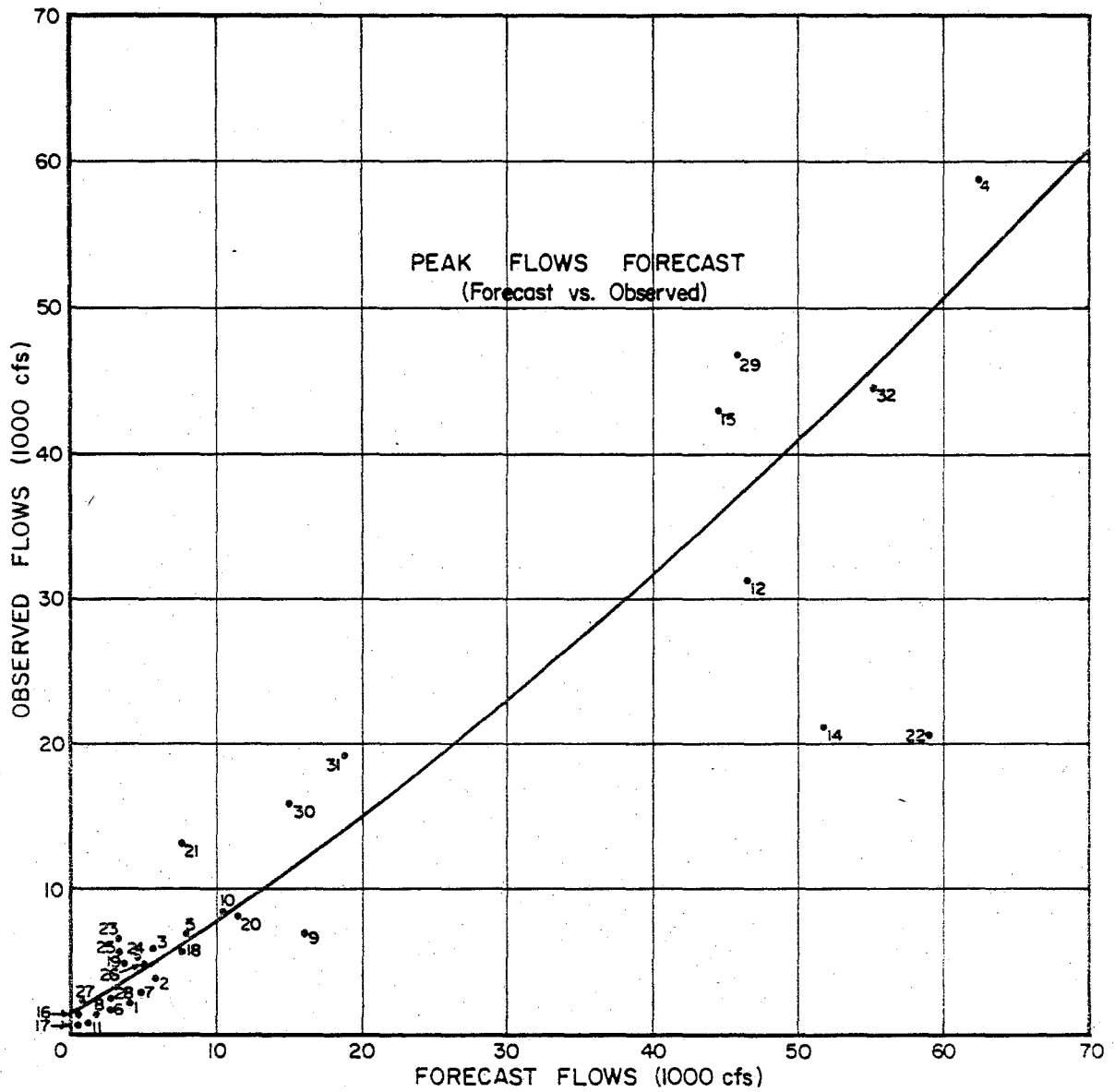
However, peak-flow per-unit area on them is generally very high and approaching 1000 - 2000 CFS/square mile. When values obtained in the procedure extend beyond the curve, peak flows may be approaching record crests and immediate action should be considered.

TABLE II.

TEST DATA USED IN VERIFYING CURVE

(Much more data were used to develop curves.)

LOCATION	Contributing Area (Miles)	BASIN	DURATION	DATE
1. Las Vegas, NV	12.0	Tropicanna Wash	4.5 hours	July 3, 1975
2. Las Vegas, NV	12.0	Flamingo Wash	4.5 hours	July 3, 1975
3. Las Vegas, NV	32.0	Las Vegas Wash	4.5 hours	July 3, 1975
4. Wickenburg, AZ	417.0	Hassayampa River	24.0 hours	Sept 5, 1970
5. Tucson, AZ	35.5	Sabino Canyon	30 minutes	Sept 12, 1966
6. Tucson, AZ	35.5	Sabino Canyon	15.0 hours	Sept 26, 1962
7. Tucson, AZ	35.5	Sabino Canyon	5 minutes	Aug 15-16, 1963
8. Tucson, AZ	35.5	Sabino Canyon	10 minutes	Sept 14-15, 1964
9. Tucson, AZ	35.5	Sabino Canyon	15 minutes	Sept 12-13, 1966
10. Tucson, AZ	35.5	Sabino Canyon	10 minutes	Sept 6, 1970
11. Tucson, AZ	35.5	Sabino Canyon	30 minutes	July 17, 1967
12. Drake, CO	70.0	Big Thompson Canyon	4.5 hours	Jul 31-Aug 1, 1975
13. Las Vegas, NV	22.0	Eldorado Canyon	50 minutes	Sept 14, 1974
14. Blanding, UT	205.0	Cottonwood Wash	24.0 hours	Aug 1, 1968
15. Bluff, UT	340.0	Cottonwood Wash	24.0 hours	Aug 1, 1968
16. Fielding, UT	0.5	Sleepy Hollow	50 minutes	July 30, 1958
17. Morgan, UT	0.2	Weber Canyon	50 minutes	Aug 16, 1958
18. Escalante, UT	53.0	Upper Valley Creek	24. hours	Aug 2, 1959
19. Hanna, UT	8.1	Farm Creek	50 minutes	Sept 2, 1960
20. Hite, UT	12.5	Farley Canyon	15 minutes	Sept 8, 1961
21. Mexican Hat, UT	33.0	Twin Wash	30 minutes	Aug 30, 1963
22. Green River, UT	179.0	Iron Wash	1.0 hour	Aug 19, 1965
23. Richfield, UT	16.6	Flat Canyon	15 minutes	July 23, 1967
24. Annabelle, UT	2.6	Twist Canyon	1.0 hour	Aug 17, 1965
25. Cedar City, UT	28.0	Fiddlers Canyon	30 minutes	Aug 17, 1965
26. Rifle, CO	201.0	Rifle Creek	2.0 hours	Aug , 1963
27. Reno, NV	17.1	Whites Creek	2.5 hours	Aug 15, 1965
28. Reno, NV	19.5	Galena Creek	2.5 hours	Aug 15, 1965
29. Whitlow Dam, AZ	100.0	Queens Creek	6.0 hours	Aug 19, 1954
30. Phoenix, AZ	83.0	Indianbend Wash	3.0 hours	June 22, 1972
31. Scottsdale, AZ	142.0	Indianbend Wash	3.0 hours	June 22, 1972
32. Gisela, AZ	90.0	Tonto Creek	45 minutes	Sept 4-6, 1970



Forecast Flow vs. Observed Flow

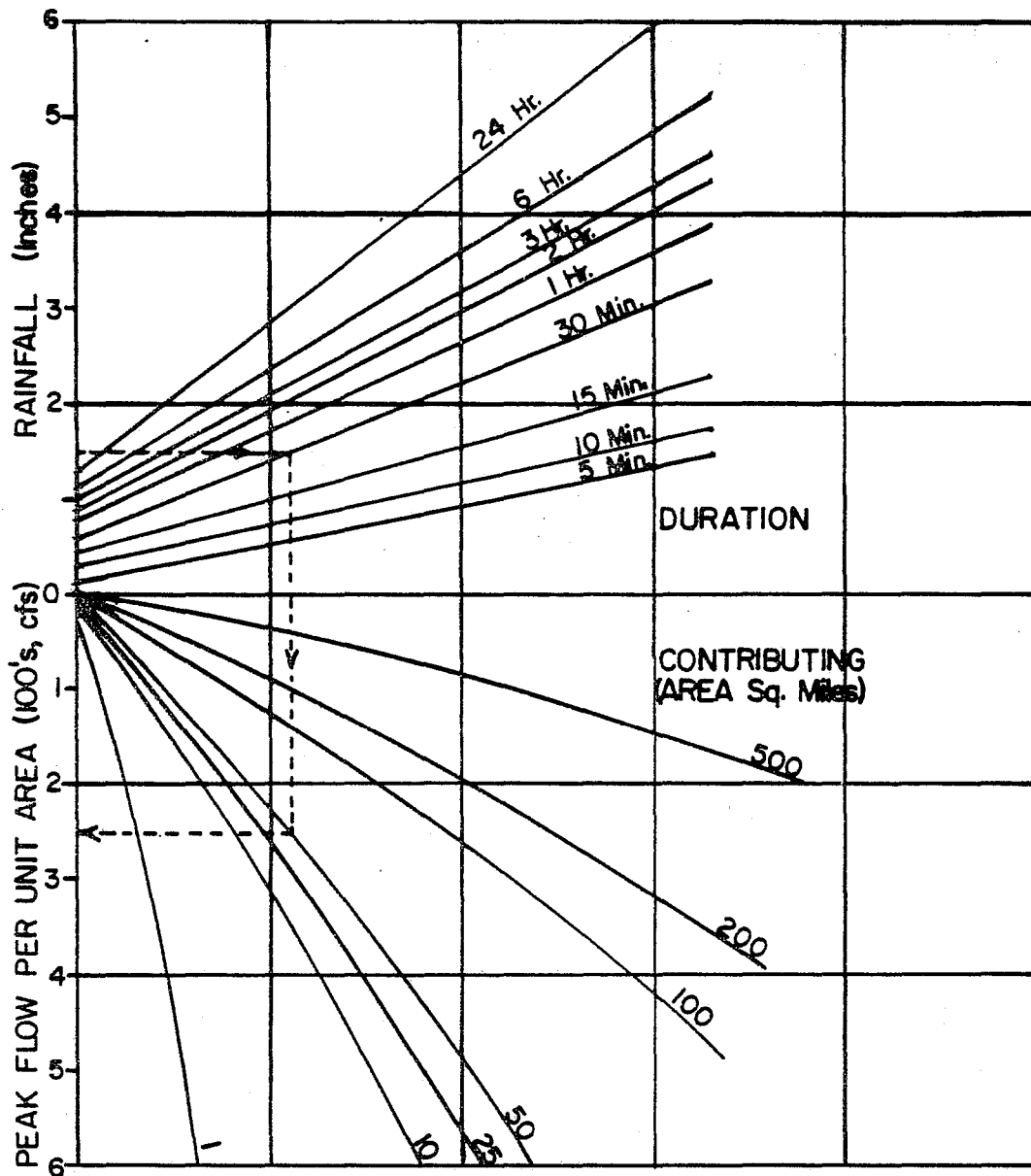
FIGURE 3

VII. REFERENCES

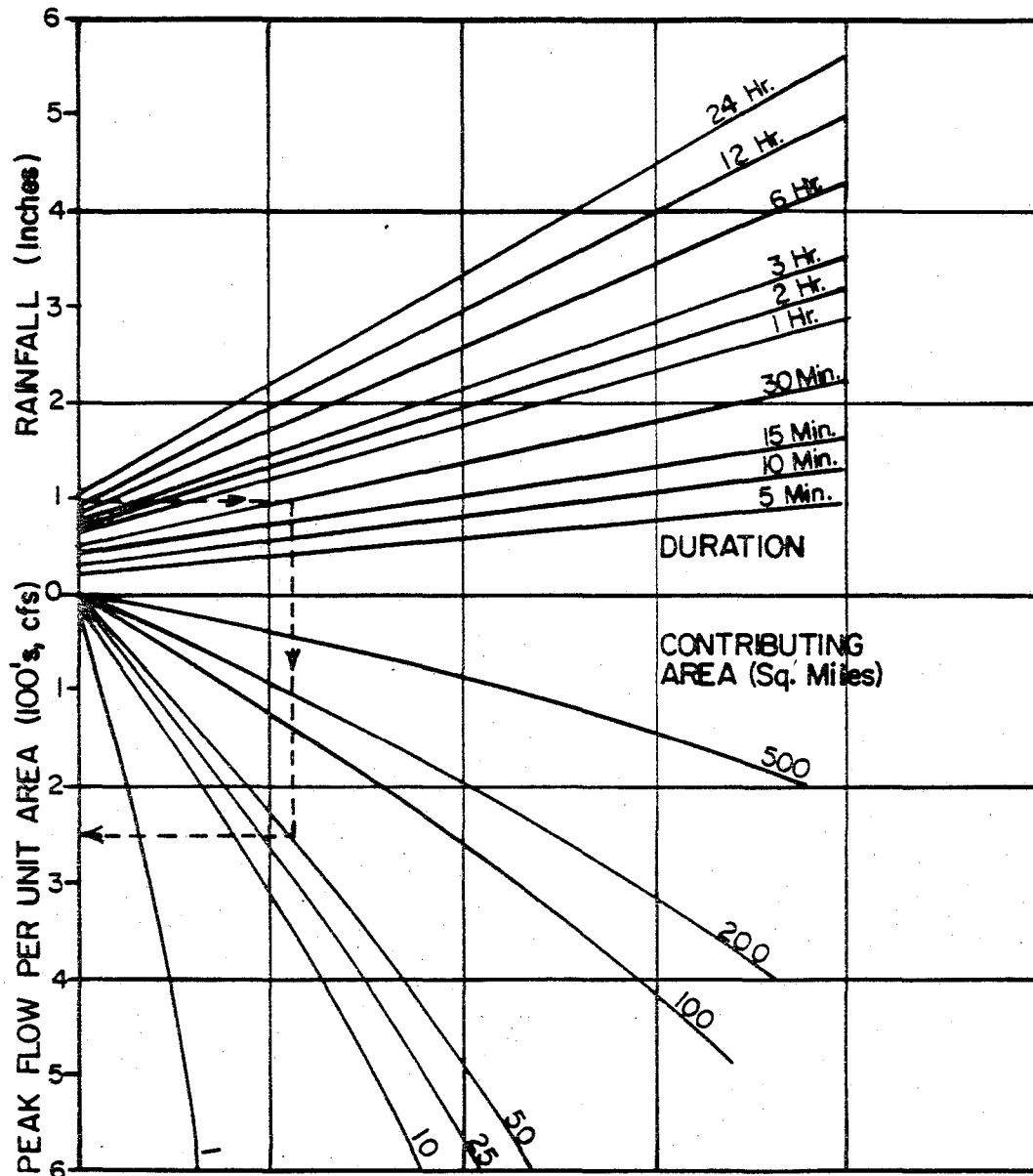
- Miller, J. F., R. H. Frederick, and R. J. Tracey, 1973: Precipitation-Frequency Atlas of Western United States, NOAA Atlas 2, Vol. VIII, Arizona; Vol. VI, Utah; Vol. II, Wyoming; Vol. III, Colorado; Vol. VIII, Nevada.
- Osborn, H. B., and E. M. Laursen, 1973: Thunderstorm Runoff in Southern Arizona. J. Hydraul. Div. Proc., ASCE 99 (HY 7): 1129-1145.
- Williams, G., 1975: A Study of Flash-Flood Susceptibility - A Basin in Southern Arizona. NOAA Technical Memorandum NWS WR-99, 6 p.

APPENDIX A

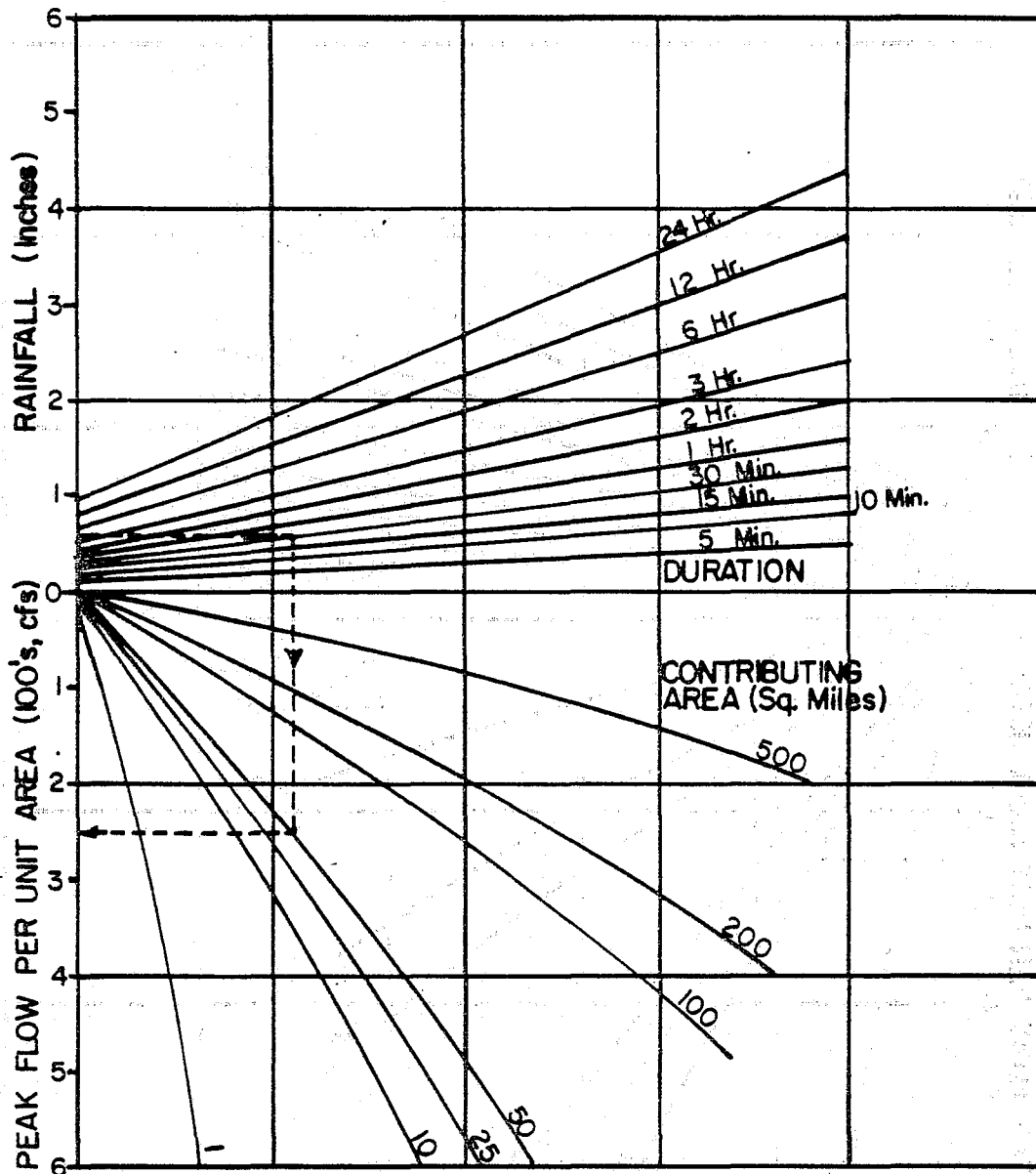
Rainfall duration curves for Areas 1, 2, and 3, as well as total flow charts for 10 to 1000 CFS/square mile.



**Rainfall Duration Curve
{Area I}**



**Rainfall Duration Curve
{Area 2}**



**Rainfall Duration Curve
{Area 3}**

PEAK FLOW
PER
UNIT AREA
(100 CFS)

TOTAL FLOW
(CFS)

TOTAL AREA (SQ MILES)

	10	20	30	40	50	60	70	80	90	100
0.1	100.	200.	300.	400.	500.	600.	700.	800.	900.	1000.
0.2	200.	400.	600.	800.	1000.	1200.	1400.	1600.	1800.	2000.
0.3	300.	600.	900.	1200.	1500.	1800.	2100.	2400.	2700.	3000.
0.4	400.	800.	1200.	1600.	2000.	2400.	2800.	3200.	3600.	4000.
0.5	500.	1000.	1500.	2000.	2500.	3000.	3500.	4000.	4500.	5000.
0.6	600.	1200.	1800.	2400.	3000.	3600.	4200.	4800.	5400.	6000.
0.7	700.	1400.	2100.	2800.	3500.	4200.	4900.	5600.	6300.	7000.
0.8	800.	1600.	2400.	3200.	4000.	4800.	5600.	6400.	7200.	8000.
0.9	900.	1800.	2700.	3600.	4500.	5400.	6300.	7200.	8100.	9000.
1.0	1000.	2000.	3000.	4000.	5000.	6000.	7000.	8000.	9000.	10000.
1.1	1100.	2200.	3300.	4400.	5500.	6600.	7700.	8800.	9900.	11000.
1.2	1200.	2400.	3600.	4800.	6000.	7200.	8400.	9600.	10800.	12000.
1.3	1300.	2600.	3900.	5200.	6500.	7800.	9100.	10400.	11700.	13000.
1.4	1400.	2800.	4200.	5600.	7000.	8400.	9800.	11200.	12600.	14000.
1.5	1500.	3000.	4500.	6000.	7500.	9000.	10500.	12000.	13500.	15000.
1.6	1600.	3200.	4800.	6400.	8000.	9600.	11200.	12800.	14400.	16000.
1.7	1700.	3400.	5100.	6800.	8500.	10200.	11900.	13600.	15300.	17000.
1.8	1800.	3600.	5400.	7200.	9000.	10800.	12600.	14400.	16200.	18000.
1.9	1900.	3800.	5700.	7600.	9500.	11400.	13300.	15200.	17100.	19000.
2.0	2000.	4000.	6000.	8000.	10000.	12000.	14000.	16000.	18000.	20000.
2.1	2100.	4200.	6300.	8400.	10500.	12600.	14700.	16800.	18900.	21000.
2.2	2200.	4400.	6600.	8800.	11000.	13200.	15400.	17600.	19800.	22000.
2.3	2300.	4600.	6900.	9200.	11500.	13800.	16100.	18400.	20700.	23000.
2.4	2400.	4800.	7200.	9600.	12000.	14400.	16800.	19200.	21600.	24000.
2.5	2500.	5000.	7500.	10000.	12500.	15000.	17500.	20000.	22500.	25000.

TOTAL FLOW
(CFS)

PEAK FLOW
PER
UNIT AREA
(100 CFS)

TOTAL AREA (SQ MILES)

	10	20	30	40	50	60	70	80	90	100
2.6	2600.	5200.	7800.	10400.	13000.	15600.	18200.	20800.	23400.	26000.
2.7	2700.	5400.	8100.	10800.	13500.	16200.	18900.	21600.	24300.	27000.
2.8	2800.	5600.	8400.	11200.	14000.	16800.	19600.	22400.	25200.	28000.
2.9	2900.	5800.	8700.	11600.	14500.	17400.	20300.	23200.	26100.	29000.
3.0	3000.	6000.	9000.	12000.	15000.	18000.	21000.	24000.	27000.	30000.
3.1	3100.	6200.	9300.	12400.	15500.	18600.	21700.	24800.	27900.	31000.
3.2	3200.	6400.	9600.	12800.	16000.	19200.	22400.	25600.	28800.	32000.
3.3	3300.	6600.	9900.	13200.	16500.	19800.	23100.	26400.	29700.	33000.
3.4	3400.	6800.	10200.	13600.	17000.	20400.	23800.	27200.	30600.	34000.
3.5	3500.	7000.	10500.	14000.	17500.	21000.	24500.	28000.	31500.	35000.
3.6	3600.	7200.	10800.	14400.	18000.	21600.	25200.	28800.	32400.	36000.
3.7	3700.	7400.	11100.	14800.	18500.	22200.	25900.	29600.	33300.	37000.
3.8	3800.	7600.	11400.	15200.	19000.	22800.	26600.	30400.	34200.	38000.
3.9	3900.	7800.	11700.	15600.	19500.	23400.	27300.	31200.	35100.	39000.
4.0	4000.	8000.	12000.	16000.	20000.	24000.	28000.	32000.	36000.	40000.
4.1	4100.	8200.	12300.	16400.	20500.	24600.	28700.	32800.	36900.	41000.
4.2	4200.	8400.	12600.	16800.	21000.	25200.	29400.	33600.	37800.	42000.
4.3	4300.	8600.	12900.	17200.	21500.	25800.	30100.	34400.	38700.	43000.
4.4	4400.	8800.	13200.	17600.	22000.	26400.	30800.	35200.	39600.	44000.
4.5	4500.	9000.	13500.	18000.	22500.	27000.	31500.	36000.	40500.	45000.
4.6	4600.	9200.	13800.	18400.	23000.	27600.	32200.	36800.	41400.	46000.
4.7	4700.	9400.	14100.	18800.	23500.	28200.	32900.	37600.	42300.	47000.
4.8	4800.	9600.	14400.	19200.	24000.	28800.	33600.	38400.	43200.	48000.
4.9	4900.	9800.	14700.	19600.	24500.	29400.	34300.	39200.	44100.	49000.
5.0	5000.	10000.	15000.	20000.	25000.	30000.	35000.	40000.	45000.	50000.

PEAK FLOW
PER
UNIT AREA
(100 CFS)

TOTAL FLOW
(CFS)

TOTAL AREA (SQ MILES)

151

	10	20	30	40	50	60	70	80	90	100
5.1	5100.	10200.	15300.	20400.	25500.	30600.	35700.	40800.	45900.	51000.
5.2	5200.	10400.	15600.	20800.	26000.	31200.	36400.	41600.	46800.	52000.
5.3	5300.	10600.	15900.	21200.	26500.	31800.	37100.	42400.	47700.	53000.
5.4	5400.	10800.	16200.	21600.	27000.	32400.	37800.	43200.	48600.	54000.
5.5	5500.	11000.	16500.	22000.	27500.	33000.	38500.	44000.	49500.	55000.
5.6	5600.	11200.	16800.	22400.	28000.	33600.	39200.	44800.	50400.	56000.
5.7	5700.	11400.	17100.	22800.	28500.	34200.	39900.	45600.	51300.	57000.
5.8	5800.	11600.	17400.	23200.	29000.	34800.	40600.	46400.	52200.	58000.
5.9	5900.	11800.	17700.	23600.	29500.	35400.	41300.	47200.	53100.	59000.
6.0	6000.	12000.	18000.	24000.	30000.	36000.	42000.	48000.	54000.	60000.
6.1	6100.	12200.	18300.	24400.	30500.	36600.	42700.	48800.	54900.	61000.
6.2	6200.	12400.	18600.	24800.	31000.	37200.	43400.	49600.	55800.	62000.
6.3	6300.	12600.	18900.	25200.	31500.	37800.	44100.	50400.	56700.	63000.
6.4	6400.	12800.	19200.	25600.	32000.	38400.	44800.	51200.	57600.	64000.
6.5	6500.	13000.	19500.	26000.	32500.	39000.	45500.	52000.	58500.	65000.
6.6	6600.	13200.	19800.	26400.	33000.	39600.	46200.	52800.	59400.	66000.
6.7	6700.	13400.	20100.	26800.	33500.	40200.	46900.	53600.	60300.	67000.
6.8	6800.	13600.	20400.	27200.	34000.	40800.	47600.	54400.	61200.	68000.
6.9	6900.	13800.	20700.	27600.	34500.	41400.	48300.	55200.	62100.	69000.
7.0	7000.	14000.	21000.	28000.	35000.	42000.	49000.	56000.	63000.	70000.
7.1	7100.	14200.	21300.	28400.	35500.	42600.	49700.	56800.	63900.	71000.
7.2	7200.	14400.	21600.	28800.	36000.	43200.	50400.	57600.	64800.	72000.
7.3	7300.	14600.	21900.	29200.	36500.	43800.	51100.	58400.	65700.	73000.
7.4	7400.	14800.	22200.	29600.	37000.	44400.	51800.	59200.	66600.	74000.
7.5	7500.	15000.	22500.	30000.	37500.	45000.	52500.	60000.	67500.	75000.

PEAK FLOW
PER
UNIT AREA
(100 CFS)

TOTAL FLOW
(CFS)

TOTAL AREA (SQ MILES)

	10	20	30	40	50	60	70	80	90	100
7.6	7600.	15200.	22800.	30400.	38000.	45600.	53200.	60800.	68400.	76000.
7.7	7700.	15400.	23100.	30800.	38500.	46200.	53900.	61600.	69300.	77000.
7.8	7800.	15600.	23400.	31200.	39000.	46800.	54600.	62400.	70200.	78000.
7.9	7900.	15800.	23700.	31600.	39500.	47400.	55300.	63200.	71100.	79000.
8.0	8000.	16000.	24000.	32000.	40000.	48000.	56000.	64000.	72000.	80000.
8.1	8100.	16200.	24300.	32400.	40500.	48600.	56700.	64800.	72900.	81000.
8.2	8200.	16400.	24600.	32800.	41000.	49200.	57400.	65600.	73800.	82000.
8.3	8300.	16600.	24900.	33200.	41500.	49800.	58100.	66400.	74700.	83000.
8.4	8400.	16800.	25200.	33600.	42000.	50400.	58800.	67200.	75600.	84000.
8.5	8500.	17000.	25500.	34000.	42500.	51000.	59500.	68000.	76500.	85000.
8.6	8600.	17200.	25800.	34400.	43000.	51600.	60200.	68800.	77400.	86000.
8.7	8700.	17400.	26100.	34800.	43500.	52200.	60900.	69600.	78300.	87000.
8.8	8800.	17600.	26400.	35200.	44000.	52800.	61600.	70400.	79200.	88000.
8.9	8900.	17800.	26700.	35600.	44500.	53400.	62300.	71200.	80100.	89000.
9.0	9000.	18000.	27000.	36000.	45000.	54000.	63000.	72000.	81000.	90000.
9.1	9100.	18200.	27300.	36400.	45500.	54600.	63700.	72800.	81900.	91000.
9.2	9200.	18400.	27600.	36800.	46000.	55200.	64400.	73600.	82800.	92000.
9.3	9300.	18600.	27900.	37200.	46500.	55800.	65100.	74400.	83700.	93000.
9.4	9400.	18800.	28200.	37600.	47000.	56400.	65800.	75200.	84600.	94000.
9.5	9500.	19000.	28500.	38000.	47500.	57000.	66500.	76000.	85500.	95000.
9.6	9600.	19200.	28800.	38400.	48000.	57600.	67200.	76800.	86400.	96000.
9.7	9700.	19400.	29100.	38800.	48500.	58200.	67900.	77600.	87300.	97000.
9.8	9800.	19600.	29400.	39200.	49000.	58800.	68600.	78400.	88200.	98000.
9.9	9900.	19800.	29700.	39600.	49500.	59400.	69300.	79200.	89100.	99000.
10.0	10000.	20000.	30000.	40000.	50000.	60000.	70000.	80000.	90000.	100000.

PEAK FLOW
PER
UNIT AREA
(100 CFS)

TOTAL FLOW
(CFS)

TOTAL AREA (SQ MILES)

	110	120	130	140	150	160	170	180	190	200
0.1	1100.	1200.	1300.	1400.	1500.	1600.	1700.	1800.	1900.	2000.
0.2	2200.	2400.	2600.	2800.	3000.	3200.	3400.	3600.	3800.	4000.
0.3	3300.	3600.	3900.	4200.	4500.	4800.	5100.	5400.	5700.	6000.
0.4	4400.	4800.	5200.	5600.	6000.	6400.	6800.	7200.	7600.	8000.
0.5	5500.	6000.	6500.	7000.	7500.	8000.	8500.	9000.	9500.	10000.
0.6	6600.	7200.	7800.	8400.	9000.	9600.	10200.	10800.	11400.	12000.
0.7	7700.	8400.	9100.	9800.	10500.	11200.	11900.	12600.	13300.	14000.
0.8	8800.	9600.	10400.	11200.	12000.	12800.	13600.	14400.	15200.	16000.
0.9	9900.	10800.	11700.	12600.	13500.	14400.	15300.	16200.	17100.	18000.
1.0	11000.	12000.	13000.	14000.	15000.	16000.	17000.	18000.	19000.	20000.
1.1	12100.	13200.	14300.	15400.	16500.	17600.	18700.	19800.	20900.	22000.
1.2	13200.	14400.	15600.	16800.	18000.	19200.	20400.	21600.	22800.	24000.
1.3	14300.	15600.	16900.	18200.	19500.	20800.	22100.	23400.	24700.	26000.
1.4	15400.	16800.	18200.	19600.	21000.	22400.	23800.	25200.	26600.	28000.
1.5	16500.	18000.	19500.	21000.	22500.	24000.	25500.	27000.	28500.	30000.
1.6	17600.	19200.	20800.	22400.	24000.	25600.	27200.	28800.	30400.	32000.
1.7	18700.	20400.	22100.	23800.	25500.	27200.	28900.	30600.	32300.	34000.
1.8	19800.	21600.	23400.	25200.	27000.	28800.	30600.	32400.	34200.	36000.
1.9	20900.	22800.	24700.	26600.	28500.	30400.	32300.	34200.	36100.	38000.
2.0	22000.	24000.	26000.	28000.	30000.	32000.	34000.	36000.	38000.	40000.
2.1	23100.	25200.	27300.	29400.	31500.	33600.	35700.	37800.	39900.	42000.
2.2	24200.	26400.	28600.	30800.	33000.	35200.	37400.	39600.	41800.	44000.
2.3	25300.	27600.	29900.	32200.	34500.	36800.	39100.	41400.	43700.	46000.
2.4	26400.	28800.	31200.	33600.	36000.	38400.	40800.	43200.	45600.	48000.
2.5	27500.	30000.	32500.	35000.	37500.	40000.	42500.	45000.	47500.	50000.

PEAK FLOW
PER
UNIT AREA
(100 CFS)

TOTAL FLOW
(CFS)

TOTAL AREA (SQ MILES)

	110	120	130	140	150	160	170	180	190	200
2.6	28600.	31200.	33800.	36400.	39000.	41600.	44200.	46800.	49400.	52000.
2.7	29700.	32400.	35100.	37800.	40500.	43200.	45900.	48600.	51300.	54000.
2.8	30800.	33600.	36400.	39200.	42000.	44800.	47600.	50400.	53200.	56000.
2.9	31900.	34800.	37700.	40600.	43500.	46400.	49300.	52200.	55100.	58000.
3.0	33000.	36000.	39000.	42000.	45000.	48000.	51000.	54000.	57000.	60000.
3.1	34100.	37200.	40300.	43400.	46500.	49600.	52700.	55800.	58900.	62000.
3.2	35200.	38400.	41600.	44800.	48000.	51200.	54400.	57600.	60800.	64000.
3.3	36300.	39600.	42900.	46200.	49500.	52800.	56100.	59400.	62700.	66000.
3.4	37400.	40800.	44200.	47600.	51000.	54400.	57800.	61200.	64600.	68000.
3.5	38500.	42000.	45500.	49000.	52500.	56000.	59500.	63000.	66500.	70000.
3.6	39600.	43200.	46800.	50400.	54000.	57600.	61200.	64800.	68400.	72000.
3.7	40700.	44400.	48100.	51800.	55500.	59200.	62900.	66600.	70300.	74000.
3.8	41800.	45600.	49400.	53200.	57000.	60800.	64600.	68400.	72200.	76000.
3.9	42900.	46800.	50700.	54600.	58500.	62400.	66300.	70200.	74100.	78000.
4.0	44000.	48000.	52000.	56000.	60000.	64000.	68000.	72000.	76000.	80000.
4.1	45100.	49200.	53300.	57400.	61500.	65600.	69700.	73800.	77900.	82000.
4.2	46200.	50400.	54600.	58800.	63000.	67200.	71400.	75600.	79800.	84000.
4.3	47300.	51600.	55900.	60200.	64500.	68800.	73100.	77400.	81700.	86000.
4.4	48400.	52800.	57200.	61600.	66000.	70400.	74800.	79200.	83600.	88000.
4.5	49500.	54000.	58500.	63000.	67500.	72000.	76500.	81000.	85500.	90000.
4.6	50600.	55200.	59800.	64400.	69000.	73600.	78200.	82800.	87400.	92000.
4.7	51700.	56400.	61100.	65800.	70500.	75200.	79900.	84600.	89300.	94000.
4.8	52800.	57600.	62400.	67200.	72000.	76800.	81600.	86400.	91200.	96000.
4.9	53900.	58800.	63700.	68600.	73500.	78400.	83300.	88200.	93100.	98000.
5.0	55000.	60000.	65000.	70000.	75000.	80000.	85000.	90000.	95000.	100000.

PEAK FLOW
PER
UNIT AREA
(100 CFS)

TOTAL FLOW
(CFS)

TOTAL AREA (SQ MILES)

	110	120	130	140	150	160	170	180	190	200
5.1	56100.	61200.	66300.	71400.	76500.	81600.	86700.	91800.	96900.	102000.
5.2	57200.	62400.	67600.	72800.	78000.	83200.	88400.	93600.	98800.	104000.
5.3	58300.	63600.	68900.	74200.	79500.	84800.	90100.	95400.	100700.	106000.
5.4	59400.	64800.	70200.	75600.	81000.	86400.	91800.	97200.	102600.	108000.
5.5	60500.	66000.	71500.	77000.	82500.	88000.	93500.	99000.	104500.	110000.
5.6	61600.	67200.	72800.	78400.	84000.	89600.	95200.	100800.	106400.	112000.
5.7	62700.	68400.	74100.	79800.	85500.	91200.	96900.	102600.	108300.	114000.
5.8	63800.	69600.	75400.	81200.	87000.	92800.	98600.	104400.	110200.	116000.
5.9	64900.	70800.	76700.	82600.	88500.	94400.	100300.	106200.	112100.	118000.
6.0	66000.	72000.	78000.	84000.	90000.	96000.	102000.	108000.	114000.	120000.
6.1	67100.	73200.	79300.	85400.	91500.	97600.	103700.	109800.	115900.	122000.
6.2	68200.	74400.	80600.	86800.	93000.	99200.	105400.	111600.	117800.	124000.
6.3	69300.	75600.	81900.	88200.	94500.	100800.	107100.	113400.	119700.	126000.
6.4	70400.	76800.	83200.	89600.	96000.	102400.	108800.	115200.	121600.	128000.
6.5	71500.	78000.	84500.	91000.	97500.	104000.	110500.	117000.	123500.	130000.
6.6	72600.	79200.	85800.	92400.	99000.	105600.	112200.	118800.	125400.	132000.
6.7	73700.	80400.	87100.	93800.	100500.	107200.	113900.	120600.	127300.	134000.
6.8	74800.	81600.	88400.	95200.	102000.	108800.	115600.	122400.	129200.	136000.
6.9	75900.	82800.	89700.	96600.	103500.	110400.	117300.	124200.	131100.	138000.
7.0	77000.	84000.	91000.	98000.	105000.	112000.	119000.	126000.	133000.	140000.
7.1	78100.	85200.	92300.	99400.	106500.	113600.	120700.	127800.	134900.	142000.
7.2	79200.	86400.	93600.	100800.	108000.	115200.	122400.	129600.	136800.	144000.
7.3	80300.	87600.	94900.	102200.	109500.	116800.	124100.	131400.	138700.	146000.
7.4	81400.	88800.	96200.	103600.	111000.	118400.	125200.	133200.	140600.	148000.
7.5	82500.	90000.	97500.	105000.	112500.	120000.	127500.	135000.	142500.	150000.

PEAK FLOW
PER
UNIT AREA
(100 CFS)

TOTAL FLOW
(CFS)

TOTAL AREA (SQ MILES)

	110	120	130	140	150	160	170	180	190	200
7.6	83600.	91200.	98800.	106400.	114000.	121600.	129200.	136800.	144400.	152000.
7.7	84700.	92400.	100100.	107800.	115500.	123200.	130900.	138600.	146300.	154000.
7.8	85800.	93600.	101400.	109200.	117000.	124800.	132600.	140400.	148200.	156000.
7.9	96900.	94800.	102700.	110600.	118500.	126400.	134300.	142200.	150100.	158000.
8.0	88000.	96000.	104000.	112000.	120000.	128000.	136000.	144000.	152000.	160000.
8.1	89100.	97200.	105300.	113400.	121500.	129600.	137700.	145800.	153900.	162000.
8.2	90200.	98400.	106600.	114800.	123000.	131200.	139400.	147600.	155800.	164000.
8.3	91300.	99600.	107900.	116200.	124500.	132800.	141100.	149400.	157700.	166000.
8.4	92400.	100800.	109200.	117600.	126000.	134400.	142800.	151200.	159600.	168000.
8.5	93500.	102000.	110500.	119000.	127500.	136000.	144500.	153000.	161500.	170000.
8.6	94600.	103200.	111800.	120400.	129000.	137600.	146200.	154800.	163400.	172000.
8.7	95700.	104400.	113100.	121800.	130500.	139200.	147900.	156600.	165300.	174000.
8.8	96800.	105600.	114400.	123200.	132000.	140800.	149600.	158400.	167200.	176000.
8.9	97900.	106800.	115700.	124600.	133500.	142400.	151300.	160200.	169100.	178000.
9.0	99000.	108000.	117000.	126000.	135000.	144000.	153000.	162000.	171000.	180000.
9.1	100100.	109200.	118300.	127400.	136500.	145600.	154700.	163800.	172900.	182000.
9.2	101200.	110400.	119600.	128800.	138000.	147200.	156400.	165600.	174800.	184000.
9.3	102300.	111600.	120900.	130200.	139500.	148800.	158100.	167400.	176700.	186000.
9.4	103400.	112800.	122200.	131600.	141000.	150400.	159800.	169200.	178600.	188000.
9.5	104500.	114000.	123500.	133000.	142500.	152000.	161500.	171000.	180500.	190000.
9.6	105600.	115200.	124800.	134400.	144000.	153600.	163200.	172800.	182400.	192000.
9.7	106700.	116400.	126100.	135800.	145500.	155200.	164900.	174600.	184300.	194000.
9.8	107800.	117600.	127400.	137200.	147000.	156800.	166600.	176400.	186200.	196000.
9.9	108900.	118800.	128700.	138600.	148500.	158400.	168300.	178200.	188100.	198000.
10.0	110000.	120000.	130000.	140000.	150000.	160000.	170000.	180000.	190000.	200000.

PEAK FLOW
PER
UNIT AREA
(100 CFS)

TOTAL FLOW
(CFS)

TOTAL AREA (SQ MILES)

	210	220	230	240	250	260	270	280	290	300
0.1	2100.	2200.	2300.	2400.	2500.	2600.	2700.	2800.	2900.	3000.
0.2	4200.	4400.	4600.	4800.	5000.	5200.	5400.	5600.	5800.	6000.
0.3	6300.	6600.	6900.	7200.	7500.	7800.	8100.	8400.	8700.	9000.
0.4	8400.	8800.	9200.	9600.	10000.	10400.	10800.	11200.	11600.	12000.
0.5	10500.	11000.	11500.	12000.	12500.	13000.	13500.	14000.	14500.	15000.
0.6	12600.	13200.	13800.	14400.	15000.	15600.	16200.	16800.	17400.	18000.
0.7	14700.	15400.	16100.	16800.	17500.	18200.	18900.	19600.	20300.	21000.
0.8	16800.	17600.	18400.	19200.	20000.	20800.	21600.	22400.	23200.	24000.
0.9	18900.	19800.	20700.	21600.	22500.	23400.	24300.	25200.	26100.	27000.
1.0	21000.	22000.	23000.	24000.	25000.	26000.	27000.	28000.	29000.	30000.
1.1	23100.	24200.	25300.	26400.	27500.	28600.	29700.	30800.	31900.	33000.
1.2	25200.	26400.	27600.	28800.	30000.	31200.	32400.	33600.	34800.	36000.
1.3	27300.	28600.	29900.	31200.	32500.	33800.	35100.	36400.	37700.	39000.
1.4	29400.	30800.	32200.	33600.	35000.	36400.	37800.	39200.	40600.	42000.
1.5	31500.	33000.	34500.	36000.	37500.	39000.	40500.	42000.	43500.	45000.
1.6	33600.	35200.	36800.	38400.	40000.	41600.	43200.	44800.	46400.	48000.
1.7	35700.	37400.	39100.	40800.	42500.	44200.	45900.	47600.	49300.	51000.
1.8	37800.	39600.	41400.	43200.	45000.	46800.	48600.	50400.	52200.	54000.
1.9	39900.	41800.	43700.	45600.	47500.	49400.	51300.	53200.	55100.	57000.
2.0	42000.	44000.	46000.	48000.	50000.	52000.	54000.	56000.	58000.	60000.
2.1	44100.	46200.	48300.	50400.	52500.	54600.	56700.	58800.	60900.	63000.
2.2	46200.	48400.	50600.	52800.	55000.	57200.	59400.	61600.	63800.	66000.
2.3	48300.	50600.	52900.	55200.	57500.	59800.	62100.	64400.	66700.	69000.
2.4	50400.	52800.	55200.	57600.	60000.	62400.	64800.	67200.	69600.	72000.
2.5	52500.	55000.	57500.	60000.	62500.	65000.	67500.	70000.	72500.	75000.

PEAK FLOW
PER
UNIT AREA
(100 CFS)

TOTAL FLOW
(CFS)

TOTAL AREA (SQ MILES)

	210	220	230	240	250	260	270	280	290	300
2.6	54600.	57200.	59800.	62400.	65000.	67600.	70200.	72800.	75400.	78000.
2.7	56700.	59400.	62100.	64800.	67500.	70200.	72900.	75600.	78300.	81000.
2.8	58800.	61600.	64400.	67200.	70000.	72800.	75600.	78400.	81200.	84000.
2.9	60900.	63800.	66700.	69600.	72500.	75400.	78300.	81200.	84100.	87000.
3.0	63000.	66000.	69000.	72000.	75000.	78000.	81000.	84000.	87000.	90000.
3.1	65100.	68200.	71300.	74400.	77500.	80600.	83700.	86800.	89900.	93000.
3.2	67200.	70400.	73600.	76800.	80000.	83200.	86400.	89600.	92800.	96000.
3.3	69300.	72600.	75900.	79200.	82500.	85800.	89100.	92400.	95700.	99000.
3.4	71400.	74800.	78200.	81600.	85000.	88400.	91800.	95200.	98600.	102000.
3.5	73500.	77000.	80500.	84000.	87500.	91000.	94500.	98000.	101500.	105000.
3.6	75600.	79200.	82800.	86400.	90000.	93600.	97200.	100800.	104400.	108000.
3.7	77700.	81400.	85100.	88800.	92500.	96200.	99900.	103600.	107300.	111000.
3.8	79800.	83600.	87400.	91200.	95000.	98800.	102600.	106400.	110200.	114000.
3.9	81900.	85800.	89700.	93600.	97500.	101400.	105300.	109200.	113100.	117000.
4.0	84000.	88000.	92000.	96000.	100000.	104000.	108000.	112000.	116000.	120000.
4.1	86100.	90200.	94300.	98400.	102500.	106600.	110700.	114800.	118900.	123000.
4.2	88200.	92400.	96600.	100800.	105000.	109200.	113400.	117600.	121800.	126000.
4.3	90300.	94600.	98900.	103200.	107500.	111800.	116100.	120400.	124700.	129000.
4.4	92400.	96800.	101200.	105600.	110000.	114400.	118800.	123200.	127600.	132000.
4.5	94500.	99000.	103500.	108000.	112500.	117000.	121500.	126000.	130500.	135000.
4.6	96600.	101200.	105800.	110400.	115000.	119600.	124200.	128800.	133400.	138000.
4.7	98700.	103400.	108100.	112800.	117500.	122200.	126900.	131600.	136300.	141000.
4.8	100800.	105600.	110400.	115200.	120000.	124800.	129600.	134400.	139200.	144000.
4.9	102900.	107800.	112700.	117600.	122500.	127400.	132300.	137200.	142100.	147000.
5.0	105000.	110000.	115000.	120000.	125000.	130000.	135000.	140000.	145000.	150000.

PEAK FLOW
PER
UNIT AREA
(100 CFS)

TOTAL FLOW
(CFS)

TOTAL AREA (SQ MILES)

	210	220	230	240	250	260	270	280	290	300
5.1	107100.	112200.	117300.	122400.	127500.	132600.	137700.	142800.	147900.	153000.
5.2	109200.	114400.	119600.	124800.	130000.	135200.	140400.	145600.	150800.	156000.
5.3	111300.	116600.	121900.	127200.	132500.	137800.	143100.	148400.	153700.	159000.
5.4	113400.	118800.	124200.	129600.	135000.	140400.	145800.	151200.	156600.	162000.
5.5	115500.	121000.	126500.	132000.	137500.	143000.	148500.	154000.	159500.	165000.
5.6	117600.	123200.	128800.	134400.	140000.	145600.	151200.	156800.	162400.	168000.
5.7	119700.	125400.	131100.	136800.	142500.	148200.	153900.	159600.	165300.	171000.
5.8	121800.	127600.	133400.	139200.	145000.	150800.	156600.	162400.	168200.	174000.
5.9	123900.	129800.	135700.	141600.	147500.	153400.	159300.	165200.	171100.	177000.
6.0	126000.	132000.	138000.	144000.	150000.	156000.	162000.	168000.	174000.	180000.
6.1	128100.	134200.	140300.	146400.	152500.	158600.	164700.	170800.	176900.	183000.
6.2	130200.	136400.	142600.	148800.	155000.	161200.	167400.	173600.	179800.	186000.
6.3	132300.	138600.	144900.	151200.	157500.	163800.	170100.	176400.	182700.	189000.
6.4	134400.	140800.	147200.	153600.	160000.	166400.	172800.	179200.	185600.	192000.
6.5	136500.	143000.	149500.	156000.	162500.	169000.	175500.	182000.	188500.	195000.
6.6	138600.	145200.	151800.	158400.	165000.	171600.	178200.	184800.	191400.	198000.
6.7	140700.	147400.	154100.	160800.	167500.	174200.	180900.	187600.	194300.	201000.
6.8	142800.	149600.	156400.	163200.	170000.	176800.	183600.	190400.	197200.	204000.
6.9	144900.	151800.	158700.	165600.	172500.	179400.	186300.	193200.	200100.	207000.
7.0	147000.	154000.	161000.	168000.	175000.	182000.	189000.	196000.	203000.	210000.
7.1	149100.	156200.	163300.	170400.	177500.	184600.	191700.	198800.	205900.	213000.
7.2	151200.	158400.	165600.	172800.	180000.	187200.	194400.	201600.	208800.	216000.
7.3	153300.	160600.	167900.	175200.	182500.	189800.	197100.	204400.	211700.	219000.
7.4	155400.	162800.	170200.	177600.	185000.	192400.	199800.	207200.	214600.	222000.
7.5	157500.	165000.	172500.	180000.	187500.	195000.	202500.	210000.	217500.	225000.

PEAK FLOW
PER
UNIT AREA
(100 CFS)

TOTAL FLOW
(CFS)

TOTAL AREA (SQ MILES)

	210	220	230	240	250	260	270	280	290	300
7.6	159600.	167200.	174800.	182400.	190000.	197600.	205200.	212800.	220400.	228000.
7.7	161700.	169400.	177100.	184800.	192500.	200200.	207900.	215600.	223300.	231000.
7.8	163800.	171600.	179400.	187200.	195000.	202800.	210600.	218400.	226200.	234000.
7.9	165900.	173800.	181700.	189600.	197500.	205400.	213300.	221200.	229100.	237000.
8.0	168000.	176000.	184000.	192000.	200000.	208000.	216000.	224000.	232000.	240000.
8.1	170100.	178200.	186300.	194400.	202500.	210600.	218700.	226800.	234900.	243000.
8.2	172200.	180400.	188600.	196800.	205000.	213200.	221400.	229600.	237800.	246000.
8.3	174300.	182600.	190900.	199200.	207500.	215800.	224100.	232400.	240700.	249000.
8.4	176400.	184800.	193200.	201600.	210000.	218400.	226800.	235200.	243600.	252000.
8.5	178500.	187000.	195500.	204000.	212500.	221000.	229500.	238000.	246500.	255000.
8.6	180600.	189200.	197800.	206400.	215000.	223600.	232200.	240800.	249400.	258000.
8.7	182700.	191400.	200100.	208800.	217500.	226200.	234900.	243600.	252300.	261000.
8.8	184800.	193600.	202400.	211200.	220000.	228800.	237600.	246400.	255200.	264000.
8.9	186900.	195800.	204700.	213600.	222500.	231400.	240300.	249200.	258100.	267000.
9.0	189000.	198000.	207000.	216000.	225000.	234000.	243000.	252000.	261000.	270000.
9.1	191100.	200200.	209300.	218400.	227500.	236600.	245700.	254800.	263900.	273000.
9.2	193200.	202400.	211600.	220800.	230000.	239200.	248400.	257600.	266800.	276000.
9.3	195300.	204600.	213900.	223200.	232500.	241800.	251100.	260400.	269700.	279000.
9.4	197400.	206800.	216200.	225600.	235000.	244400.	253800.	263200.	272600.	282000.
9.5	199500.	209000.	218500.	228000.	237500.	247000.	256500.	266000.	275500.	285000.
9.6	201600.	211200.	220800.	230400.	240000.	249600.	259200.	268800.	278400.	288000.
9.7	203700.	213400.	223100.	232800.	242500.	252200.	261900.	271600.	281300.	291000.
9.8	205800.	215600.	225400.	235200.	245000.	254800.	264600.	274400.	284200.	294000.
9.9	207900.	217800.	227700.	237600.	247500.	257400.	267300.	277200.	287100.	297000.
10.0	210000.	220000.	230000.	240000.	250000.	260000.	270000.	280000.	290000.	300000.

NOAA Technical Memoranda NWSR: (Continued)

- 92 Smoke Management in the Willamette Valley. Earl M. Bates, May 1974. (COM-74-11277/AS)
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- 94 Conditional Probability of Visibility Less than One-Half Mile in Radiation Fog at Fresno, California. John D. Thomas, August 1974. (COM-74-11555/AS)
- 95 Climate of Flagstaff, Arizona. Paul W. Soranson, August 1974. (COM-74-11678/AS)
- 96 Map Type Precipitation Probabilities for the Western Region. Glenn E. Rasch and Alexander E. MacDonald, February 1975. (COM-75-10428/AS)
- 97 Eastern Pacific Cut-off Low of April 21-23, 1974. William J. Alder and George R. Miller, January 1976. (PB-250-711/AS)
- 98 Study on a Significant Precipitation Episode in the Western United States. Ira S. Brenner, April 1975. (COM-75-10719/AS)
- 99 A Study of Flash Flood Susceptibility--A Basin in Southern Arizona. Gerald Williams, August 1975. (COM-75-11360/AS)
- 100 A Study of Flash-Flood Occurrences at a Site Versus Over a Forecast Zone. Gerald Williams, Aug. 1975. (COM-75-11404/AS)
- 102 A Set of Rules for Forecasting Temperatures in Napa and Sonoma Counties. Wesley L. Tuff, Oct. 1975. (PB-246-802/AS)
- 103 Application of the National Weather Service Flash-Flood Program in the Western Region. Gerald Williams, January 1976. (PB-253-853/AS)
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- 113 Winter Season Minimum Temperature Formula for Bakersfield, California, Using Multiple Regression. Michael J. Card, February 1977. (PB-273-694/AS)
- 114 Tropical Cyclone Kathleen. James R. Fors, February 1977. (PB-263-847)
- 116 A Study of Wind Gusts on Lake Mead. Bradley Colman, April 1977. (PB-272-831)
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- 118 Moisture Distribution Modification by Upward Vertical Motion. Ira S. Brenner, April 1977. (PB-273-740)
- 119 Relative Frequency of Occurrence of Warm Season Echo Activity as a Function of Stability Indices Computed from the Yucca Flat, Nevada, Rawinsonde. Darryl Randerson, June 1977. (PB-273-624/AS)
- 121 Climatological Prediction of Cumulonimbus Clouds in the Vicinity of the Yucca Flat Weather Station. R. F. Quiring, June 1977. (PB-273-155/AS)
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- 125 Statistical Guidance on the Prediction of Eastern North Pacific Tropical Cyclone Motion - Part II. Preston W. Leftwich and Charles J. Neumann, August 1977. (PB-273-155/AS)
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