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SECTION 500 RAINFALL

501 INTRODUCTION

Presented in this section is the design rainfall data to be used with the Colorado Urban Hydrograph Procedure (CUHP) and the Rational Method. All hydrological analysis within the jurisdiction of this MANUAL shall utilize the rainfall data presented herein for calculating storm runoff.

The rainfall data published by the National Oceanic and Atmospheric Administration (NOAA) in the "Precipitation-Frequency Atlas of the Western United States, Volume III - Colorado" (Reference-16) was used to develop 1-hour and 6-hour point rainfall values for Boulder County. The County was divided into four rainfall zones to reflect the variation in precipitation amounts. These point values were then used to develop 2-hour and 3-hour design rainfall distributions as well as time-intensity-frequency curves for three of the rainfall zones. The design storms were defined using the procedures developed by the Urban Drainage and Flood Control District (UD&FCD) (Reference-17). The calculations for the design storms have been published in a technical memorandum (Reference-18) on file with Boulder County and City of Longmont.

502 BOULDER COUNTY RAINFALL ZONES

502.1 Description of the Zones

A review of the isopluvial maps presented in the NOAA Atlas for Colorado (Reference-16) showed that Boulder County can be divided into four rainfall zones. Within each zone, the precipitation values for various return periods and duration storms were found to have either minimal variation (i.e., less than 0.10-inches) or were found to vary significantly (i.e., up to 0.8-inches) within a small area of the County. These zones were delineated on Figure-501 and are discussed below:

Zone 1: Covers the area from the east county line to the 6000-foot contour just west of the City of Boulder. The point rainfall values in this zone vary less than 0.10-inches for return periods from 2-year to 100-year and for storm durations from 1-hour to 6-hour.

Zone 2: Covers the area from the 6000-foot contour to the 8000-foot contour and generally represent the foothills of the front range. The point rainfall values in this zone decrease from east to west by as much as 0.8-inches for the storm durations and return periods noted.

Zone 3: Covers the area from the 8000-foot contour to the 10,000-foot contour in the foothills. The point rainfall values in this zone vary by less than 0.10-inches.

Zone 4: Covers the area from the 8000-foot contour to the continental divide. The point rainfall values also decrease from east to west in this zone by as much as 0.6-inches. Data has not been provided for this zone as developed is not permitted above 8000-feet.

The county was divided into the four zones for the purpose of developing uniform design storms and intensity data for use with the CUHP and Rational Method (Section 600). The 1-hour design point rainfall values for each zone, which were obtained from the NOAA Atlas for Colorado, are presented in Table-501.

502.2 Selecting the Rainfall Zone

Since some of the drainage basins will include areas from more than one zone, the following criteria shall be used to select the design rainfall and intensity data. Basin area refers to the actual basin or sub-basin for which storm runoff information is being calculated and not necessarily the entire watershed area.

a. If 40% or more of the basin area lies in Zone 1, then Zone 1 data shall be used.

b. If 60% or more of the basin lies within Zone 2, then Zone 2 data shall be used.

c. If 40% or more of the basin lies within Zone 3, then Zone 3 data shall be used.

d. If 60% or more of the basin lies within Zone 4, then Zone 3 data shall be used.

503 CUHP DESIGN STORMS

503.1 Basis of Design Storm Distributions

Rainfall in the Boulder County area is influenced by the orographic effects of the Rocky Mountains, the topography of the high plains and the semi-arid climatology of the region. Rainstorms can often have an "upslope" character where easterly flow of moisture settles against the mountains. These types of rainstorms have durations that can exceed 6-hours and produce large amount of total precipitation. However, these storms are rarely intense and seldom result in urban flooding problems.

Very intense rainfall in the Boulder area results from convection storms or frontal stimulated convective storms. These types of storms are often less than 1-hour or 2-hours in duration and can produce brief periods of high rainfall intensities. These short duration intense rainstorms appear to cause most of the urban flooding problems (Reference-17).

Analysis of a 73 year record of rainfall at the Denver rain gage by the UD&FCD reveals that an overwhelming majority of the intense rainstorms produce their greatest intensities in the first hour of the storm. In fact, of the 73 most intense storms analyzed, 68 had the most intense period begin and end within the first hour of the storm and 52 had the most intense period begin and end within the first half hour of the storm. The data clearly shows that the leading intensity storms predominate among the "non-upslope" type storms in the Denver Region (Reference-17).

The recommended design storm distribution takes into account the observed "leading intensity" nature of the convection storms. In addition, the temporal distributions were designed to be used with the 1982 version of the CUHP (Section 600), the published NOAA 1-hour precipitation values (Reference-16), and the

Horton's infiltration loss equation. They were developed to approximate the recurrence frequency of peak flows and volumes (i.e., 2- through 100-years) that were estimated for the watersheds for which rainfall/runoff data was collected. The procedure for the development of these design storm distributions and the preliminary results were reported at the 1979 International Symposium on Urban Storm Runoff. The recommendations contained in this MANUAL are the result of refinements to the work by the UD&FCD.

503.2 Basins Less Than Five Square Miles

For drainage basins less than 5 square miles, a 2-hour storm distribution without area adjustment of the point rainfall values shall be used for CUHP. The incremental rainfall distribution for each zone is presented in Table-502.

503.3 Basin Between Five and Ten Square Miles

For drainage basins between 5 and 10 square miles, a 2-hour storm distribution is used but the incremental rainfall values are adjusted for the large basin area in accordance with suggested procedures in the NOAA Atlas for Colorado (Reference-16). The adjustment is an attempt to relate the average of all point values for a given duration and frequency within a basin to the average depth over the basin for the same duration and frequency (Reference-16). The incremental rainfall distribution for each zone is presented in Table-503.

503.4 Basins Between Ten and Twenty Square Miles

For drainage basins between 10 and 20 square miles, a 3-hour storm duration with adjustment for area shall be used. The distribution for the last hour was obtained by uniformly distributing the difference between the 2- and 3-hour point rainfall values. The adjustment for area was obtained from the NOAA Atlas for Colorado (Reference-16). The incremental rainfall distribution for each zone is presented in Table-504.

504 TIME-INTENSITY-FREQUENCY CURVES

The Time-Intensity-Frequency curves for each zone were developed by distributing the 1-hour point rainfall values (Table-501) using the factors obtained from the NOAA Atlas presented below:

FACTORS FOR DURATIONS OF LESS THAN 1-HOUR

Duration (minutes)	5	10	15	30
Ratio to 1-hour Depth	0.29	0.45	0.57	0.79

Source: NOAA Atlas 2, Vol. III, Colorado 1973

The point values were then converted to intensities and plotted on Figures-502 to -504. The data are also presented in Table-505 for each zone.

DESIGN POINT - RAINFALL VALUES

ZONE	ONE-HOUR POINT RAINFALL (IN.)				
	2-YEAR	5-YEAR	10-YEAR	50-YEAR	100-YEAR
I	1.01	1.43	1.73	2.40	2.70
II	0.93	1.30	1.56	2.17	2.44
III	0.77	1.10	1.34	1.89	2.14

TWO-HOUR DESIGN STORM FOR BASINS LESS THAN FIVE SQUARE MILES

	INCREMENTAL RAINFALL DEPTH/RETURN PERIOD														
	ZONE I					ZONE II					ZONE III				
TIME (MIN)	2-YR (IN)	5-YR (IN)	10-YR (IN)	50-YR (IN)	100-YR (IN)	2-YR (IN)	5-YR (IN)	10-YR (IN)	50-YR (IN)	100-YR (IN)	2-YR (IN)	5-YR (IN)	10-YR (IN)	50-YR (IN)	100-YR (IN)
5	.02	.03	.03	.03	.03	.02	.02	.03	.03	.02	.02	.02	.03	.02	.02
10	.04	.05	.06	.08	.08	.03	.05	.06	.08	.07	.03	.04	.05	.07	.06
15	.09	.13	.14	.12	.12	.07	.11	.13	.11	.11	.06	.10	.11	.09	.10
20	.16	.22	.26	.19	.22	.15	.20	.23	.17	.20	.12	.17	.20	.15	.17
25	.25	.36	.43	.36	.38	.23	.32	.39	.33	.34	.19	.28	.34	.28	.30
30	.14	.19	.21	.60	.68	.13	.17	.19	.54	.61	.11	.14	.16	.47	.53
35	.07	.09	.10	.29	.38	.06	.07	.09	.26	.34	.05	.06	.08	.23	.30
40	.05	.06	.07	.19	.22	.04	.06	.07	.17	.19	.04	.05	.06	.15	.17
45	.03	.05	.07	.12	.17	.03	.05	.06	.11	.15	.02	.04	.05	.10	.13
50	.03	.05	.06	.12	.14	.03	.05	.05	.11	.12	.02	.04	.04	.09	.11
55	.03	.04	.06	.08	.11	.03	.04	.05	.09	.10	.02	.03	.04	.07	.09
60	.03	.04	.06	.08	.11	.03	.04	.05	.08	.10	.02	.03	.04	.07	.08
65	.03	.04	.06	.08	.11	.03	.04	.05	.07	.10	.02	.03	.04	.06	.07
70	.02	.04	.06	.06	.05	.02	.04	.05	.05	.05	.02	.03	.04	.04	.04
75	.02	.04	.06	.06	.05	.02	.03	.05	.05	.05	.02	.03	.04	.04	.04
80	.02	.03	.04	.05	.03	.02	.03	.04	.04	.04	.02	.02	.03	.03	.03
85	.02	.03	.03	.05	.03	.02	.03	.03	.04	.04	.02	.02	.03	.03	.03
90	.02	.03	.03	.03	.03	.02	.03	.03	.03	.03	.02	.02	.03	.03	.03
95	.02	.03	.03	.03	.03	.02	.03	.03	.03	.03	.02	.02	.03	.03	.03
100	.02	.02	.03	.03	.03	.02	.02	.03	.03	.03	.01	.02	.03	.03	.03
105	.02	.02	.03	.03	.03	.02	.02	.03	.03	.03	.01	.02	.02	.03	.03
110	.02	.02	.03	.03	.03	.02	.02	.03	.03	.03	.01	.02	.02	.03	.03
115	.01	.02	.03	.03	.03	.01	.02	.02	.02	.02	.01	.02	.02	.03	.03
120	.01	.02	.02	.03	.03	.01	.01	.02	.02	.02	.01	.02	.02	.02	.02
TOTAL	1.17	1.65	2.00	2.77	3.12	1.08	1.50	1.81	2.51	2.82	0.89	1.27	1.55	2.19	2.47

TABLE 502

WRC ENG.

REFERENCE: WRC TM-1 NOV. 1983

TWO-HOUR DESIGN STORM FOR BASINS BETWEEN FIVE AND TEN SQUARE MILES

TIME (MIN)	INCREMENTAL RAINFALL DEPTH/RETURN PERIOD														
	ZONE I					ZONE II					ZONE III				
	2-YR (IN)	5-YR (IN)	10-YR (IN)	50-YR (IN)	100-YR (IN)	2-YR (IN)	5-YR (IN)	10-YR (IN)	50-YR (IN)	100-YR (IN)	2-YR (IN)	5-YR (IN)	10-YR (IN)	50-YR (IN)	100-YR (IN)
5	.02	.03	.03	.03	.03	.02	.02	.03	.03	.02	.02	.02	.03	.02	.02
10	.04	.05	.06	.08	.08	.03	.05	.06	.08	.07	.03	.04	.05	.07	.06
15	.09	.13	.14	.12	.12	.07	.11	.13	.11	.11	.06	.10	.11	.09	.10
20	.16	.21	.25	.19	.22	.14	.19	.22	.17	.20	.12	.16	.19	.15	.17
25	.24	.34	.42	.35	.36	.22	.31	.37	.31	.33	.18	.26	.32	.27	.29
30	.14	.18	.20	.58	.65	.12	.16	.18	.52	.59	.10	.14	.15	.45	.51
35	.07	.09	.10	.28	.36	.06	.07	.09	.25	.33	.05	.06	.08	.22	.29
40	.05	.06	.07	.19	.22	.04	.06	.07	.17	.19	.04	.05	.06	.15	.17
45	.03	.05	.07	.12	.17	.03	.05	.06	.11	.15	.02	.04	.05	.09	.13
50	.03	.05	.06	.12	.14	.03	.05	.06	.11	.12	.02	.04	.04	.09	.10
55	.03	.04	.06	.09	.11	.03	.04	.05	.08	.10	.02	.03	.04	.07	.08
60	.03	.04	.06	.09	.09	.03	.04	.05	.08	.10	.02	.03	.04	.07	.08
65	.03	.04	.06	.08	.09	.03	.04	.05	.07	.10	.02	.03	.04	.06	.08
70	.02	.04	.06	.07	.07	.02	.04	.05	.05	.05	.02	.03	.04	.04	.04
75	.02	.04	.06	.07	.07	.02	.03	.05	.05	.05	.02	.03	.04	.04	.04
80	.02	.03	.04	.04	.04	.02	.03	.03	.03	.03	.02	.02	.03	.03	.03
85	.02	.03	.04	.04	.04	.02	.03	.03	.03	.03	.02	.02	.03	.03	.03
90	.02	.03	.03	.03	.03	.02	.03	.03	.03	.03	.02	.02	.03	.03	.03
95	02	.03	.03	.03	.03	.02	.03	.03	.03	.03	.02	.02	.03	.03	.03
100	.02	.02	.03	.03	.03	.02	.02	.03	.03	.03	.01	.02	.03	.03	.03
105	02	02	.03	.03	.03	.02	.02	.03	.03	.03	.01	.02	.02	.03	.03
110	.02	.02	.03	.03	.03	.02	.02	.03	.03	.03	.01	.02	.02	.03	.03
115	.01	.02	.02	.02	.02	.01	.02	.02	.03	.03	.01	.02	.02	.03	.03
120	.01	.02	.02	.02	.02	.01	.01	.02	.03	.03	.01	.02	.02	.03	.0
TOTAL	1.16	1.61	1.97	2.73	3.05	1.05	1.47	1.77	2.46	2.78	.87	1.24	1.51	2.15	

TABLE 503

WRC ENG.

REFERENCE: WRC TM-1 NOV. 1983

TABLE 504

THREE-HOUR DESIGN STORM FOR BASINS BETWEEN TEN AND TWENTY SQUARE MILES

	INCREMENTAL RAINFALL DEPTH/RETURN PERIOD														
	ZONE I					ZONE II					ZONE III				
TIME (MIN)	2-YR (IN)	5-YR (IN)	10-YR (IN)	50-YR (IN)	100-YR (IN)	2-YR (IN)	5-YR (IN)	10-YR (IN)	50-YR (IN)	100-YR (IN)	2-YR (IN)	5-YR (IN)	10-YR (IN)	50-YR (IN)	100-YR (IN)
5	.02	.03	.03	.03	.03	.02	.02	.03	.03	.02	.02	.02	.03	.02	.02
10	.04	.05	.06	.08	.08	.03	.05	.06	.08	.07	.03	.04	.05	.07	.06
15	.09	.13	.14	.12	.12	.07	.11	.13	.11	.11	.06	.10	.11	.09	.10
20	.15	.20	.23	.19	.22	.13	.18	.21	.17	.20	.11	.15	.18	.15	.17
25	.23	.32	.39	.32	.34	.21	.29	.35	.29	.31	.17	.25	.30	.26	.27
30	.13	.17	.19	.54	.61	.12	.15	.17	.49	.55	.10	.13	.14	.43	.48
35	.07	.09	.10	.26	.34	.06	.07	.09	.23	.31	.05	.06	.08	.20	.27
40	.05	.06	.07	.19	.22	.04	.06	.07	.17	.19	.04	.05	.06	.15	.17
45	.03	.05	.07	.12	.17	.03	.05	.06	.11	.15	.02	.04	.05	.09	.13
50	.03	.05	.06	.12	.14	.03	.05	.05	.11	.12	.02	.04	.04	.09	.11
55	.03	.04	.06	.09	.11	.03	.04	.05	.07	.10	.02	.03	.04	.07	.09
60	.03	.04	.06	.09	.11	.03	.04	.05	.07	.10	.02	.03	.04	.07	.09
65	.03	.04	.06	.09	.11	.03	.04	.05	.07	.10	.02	.03	.04	.07	.08
70	.02	.04	.06	.06	.06	.02	.04	.05	.05	.05	.02	.03	.04	.05	.05
75	.02	.04	.06	.06	.06	.02	.03	.05	.05	.05	.02	.03	.04	.05	.05
80	.02	.03	.04	.04	.04	.02	.03	.04	.04	.04	.02	.02	.03	.03	.03
85	.02	.03	.03	.03	.03	.02	.03	.03	.04	.04	.02	.02	.03	.03	.03
90	.02	.03	.03	.03	.03	.02	.03	.03	.03	.03	.02	.02	.03	.03	.03
95	.02	.03	.03	.03	.03	.02	.03	.03	.03	.03	.01	.02	.03	.03	.03
100	.02	.02	.03	.03	.03	.02	.02	.03	.03	.03	.01	.02	.03	.03	.03
105	.02	.02	.03	.03	.03	.02	.02	.03	.03	.03	.01	.02	.02	.03	.03
110	.02	.02	.03	.03	.03	.02	.02	.03	.03	.03	.01	.02	.02	.02	.02
115	.02	.02	.03	.03	.03	.01	.02	.02	.03	.03	.01	.02	.02	.02	.02
120	.01	.02	.02	.03	.03	.01	.02	.02	.03	.03	.01	.02	.02	.02	.02
125	.01	.02	.02	.02	.02	.01	.02	.02	.02	.03	.01	.02	.02	.02	.02
130	.01	.02	.02	.02	.02	.01	.02	.02	.02	.02	.01	.02	.02	.02	.02
135	.01	.02	.02	.02	.02	.01	.01	.02	.02	.02	.01	.01	.02	.02	.02
140	.01	.02	.02	.02	.02	.01	.01	.02	.02	.02	.01	.01	.01	.02	.02
145	.01	.01	.02	.02	.02	.01	.01	.02	.02	.02	.01	.01	.01	.02	.02
150	.01	.01	.01	.02	.02	.01	.01	.02	.02	.02	.01	.01	.01	.02	.02
155	.01	.01	.01	.02	.02	.01	.01	.01	.02	.02	.01	.01	.01	.02	.02
160	.01	.01	.01	.02	.02	.01	.01	.01	.02	.02	.01	.01	.01	.01	.01
165	.01	.01	.01	.02	.02	.01	.01	.01	.02	.02	.01	.01	.01	.01	01
170	.01	.01	.01	.02	.02	.01	.01	.01	.02	.02	.01	.01	.01	.01	01
175	.01	.01	.01	.02	.02	.01	.01	.01	.02	.02	.01	.01	.01	.01	01
180	.01	.01	.01	.01	.02	.01	.01	.01	.02	.02	.01	.01	.01	.01	01
TOTAL	1.26	1.73	2.08	2.87	3.24	1.15	1.58	1.91	2.63	2.97	.96	1.35	1.62	2.29	57

WRC ENG.

REFERENCE: WRC TM-1 NOV. 1983

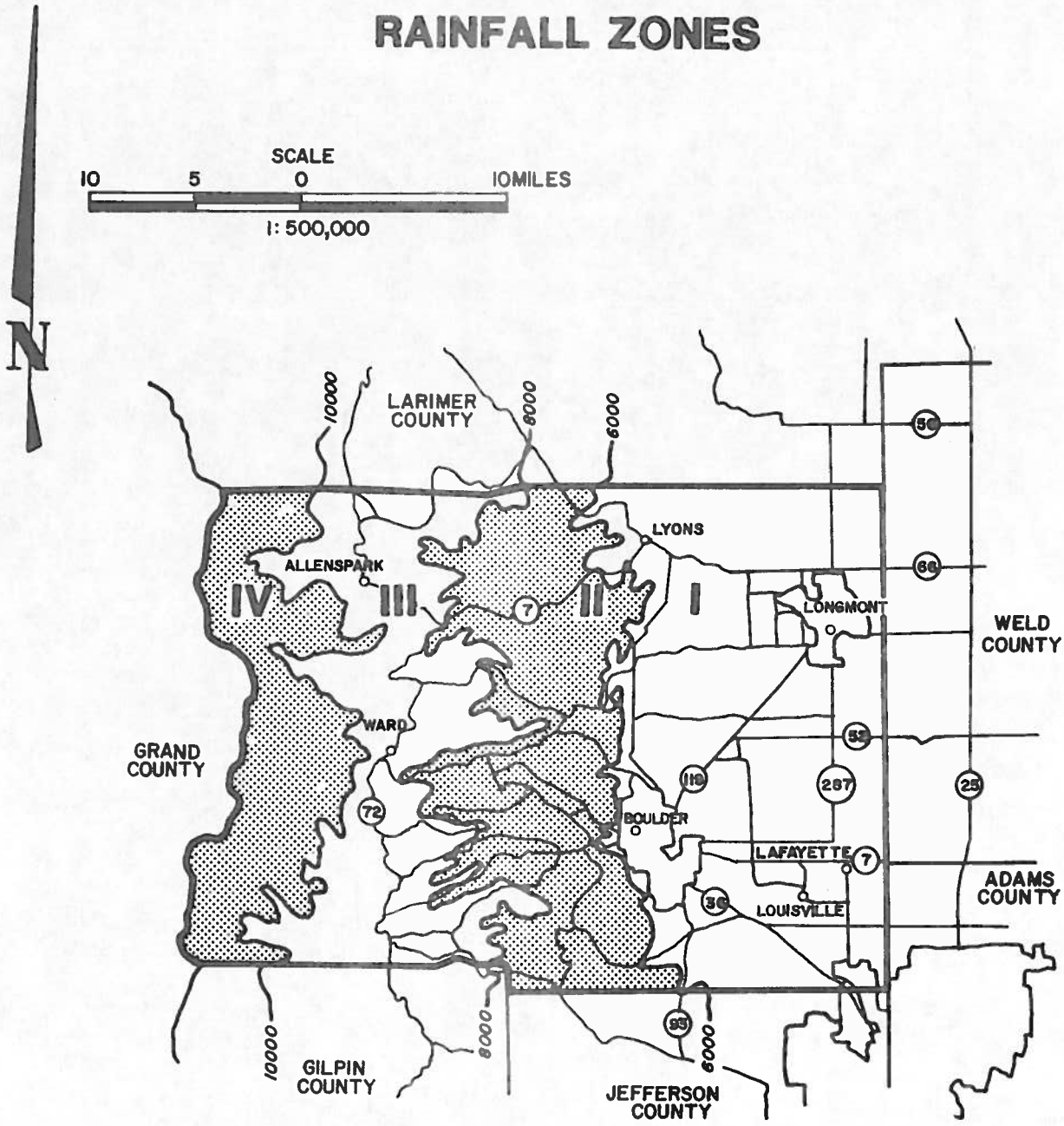
TIME - INTENSITY - FREQUENCY TABULATION

ZONE	FREQ.	RAINFALL INTENSITY (IN/HR)/DURATION				
		5 MIN	10 MIN	15 MIN	30 MIN	60 MIN
I	2-YR	3.51	2.73	2.30	1.60	1.01
	5-YR	4.98	3.86	3.26	2.26	1.43
	10-YR	6.02	4.67	3.94	2.73	1.73
	50-YR	8.35	6.48	5.47	3.79	2.40
	100-YR	9.40	7.29	6.16	4.27	2.70
II	2-YR	3.24	2.51	2.12	1.47	0.93
	5-YR	4.52	3.51	2.96	2.05	1.30
	10-YR	5.43	4.21	3.56	2.46	1.56
	50-YR	7.55	5.86	4.95	3.43	2.17
	100-YR	8.49	6.59	5.56	3.86	2.44
III	2-YR	2.68	2.08	1.76	1.22	0.77
	5-YR	3.83	2.97	2.51	1.74	1.10
	10-YR	4.66	3.62	3.06	2.12	1.34
	50-YR	6.58	5.10	4.31	2.99	1.89
	100-YR	7.45	5.78	4.88	3.38	2.14

See Figures-502, -503, and -504 for plot of data.

FIGURE 501

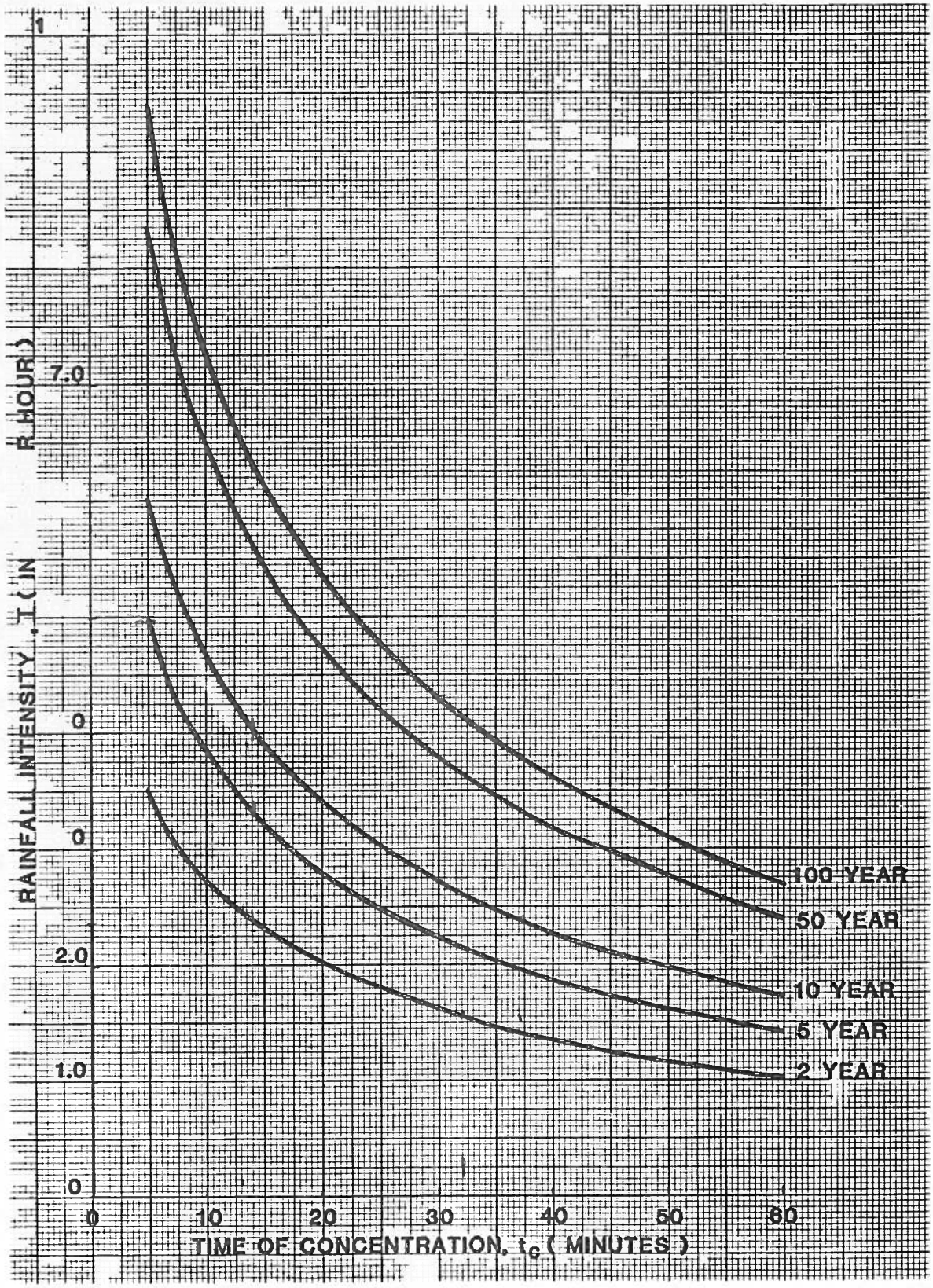
RAINFALL ZONES



WRC ENG.	REFERENCE: Base map from USGS map for State of Colorado, Rev 1980

FIGURE 502

TIME-INTENSITY-FREQUENCY CURVES ZONE I

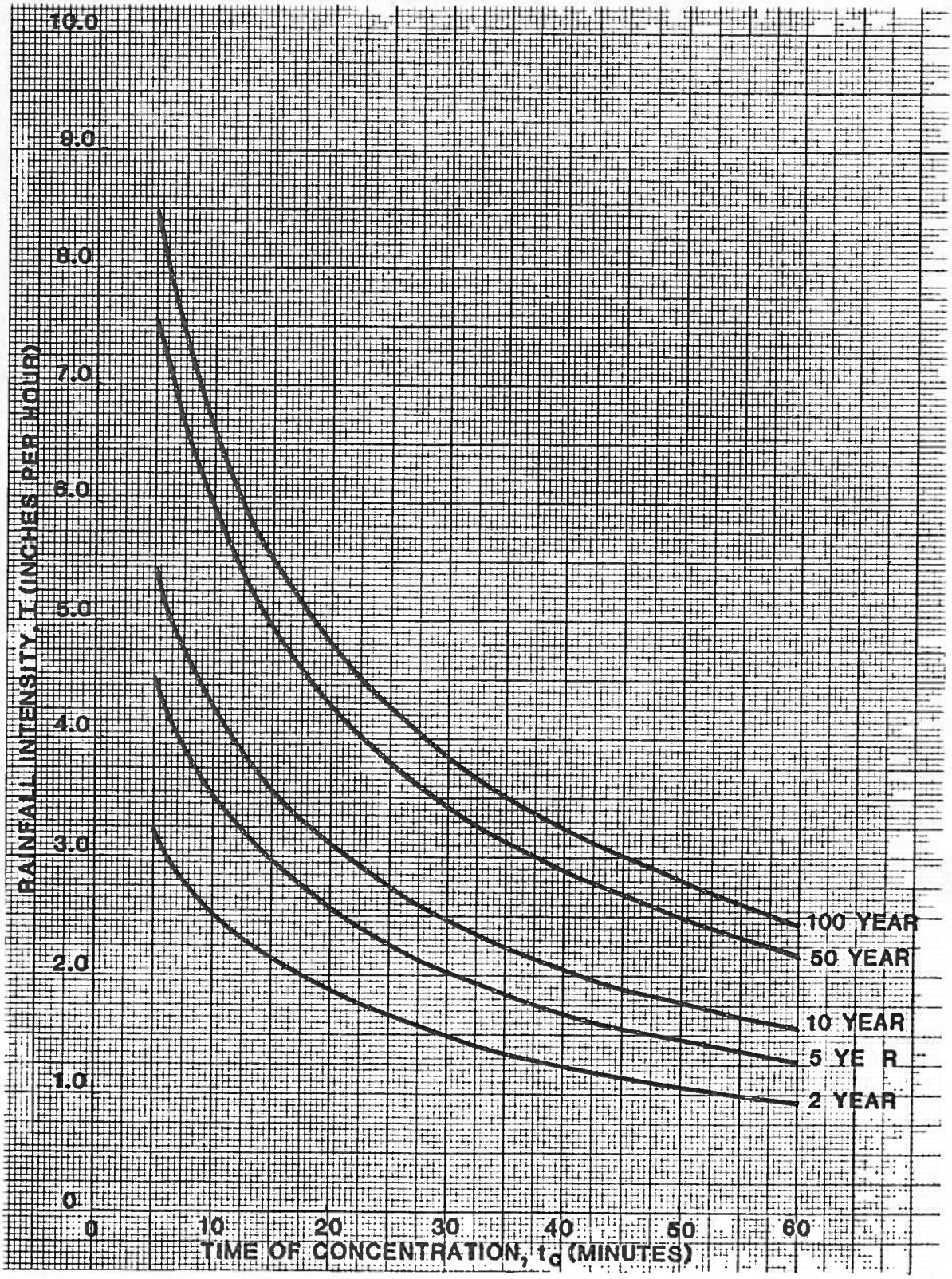


WRC ENG.

REFERENCE: WRC TM-1 NOV. 1983

BOULDER COUNTY
STORM DRAINAGE CRITERIA MANUAL

TIME-INTENSITY-FREQUENCY CURVES ZONE I

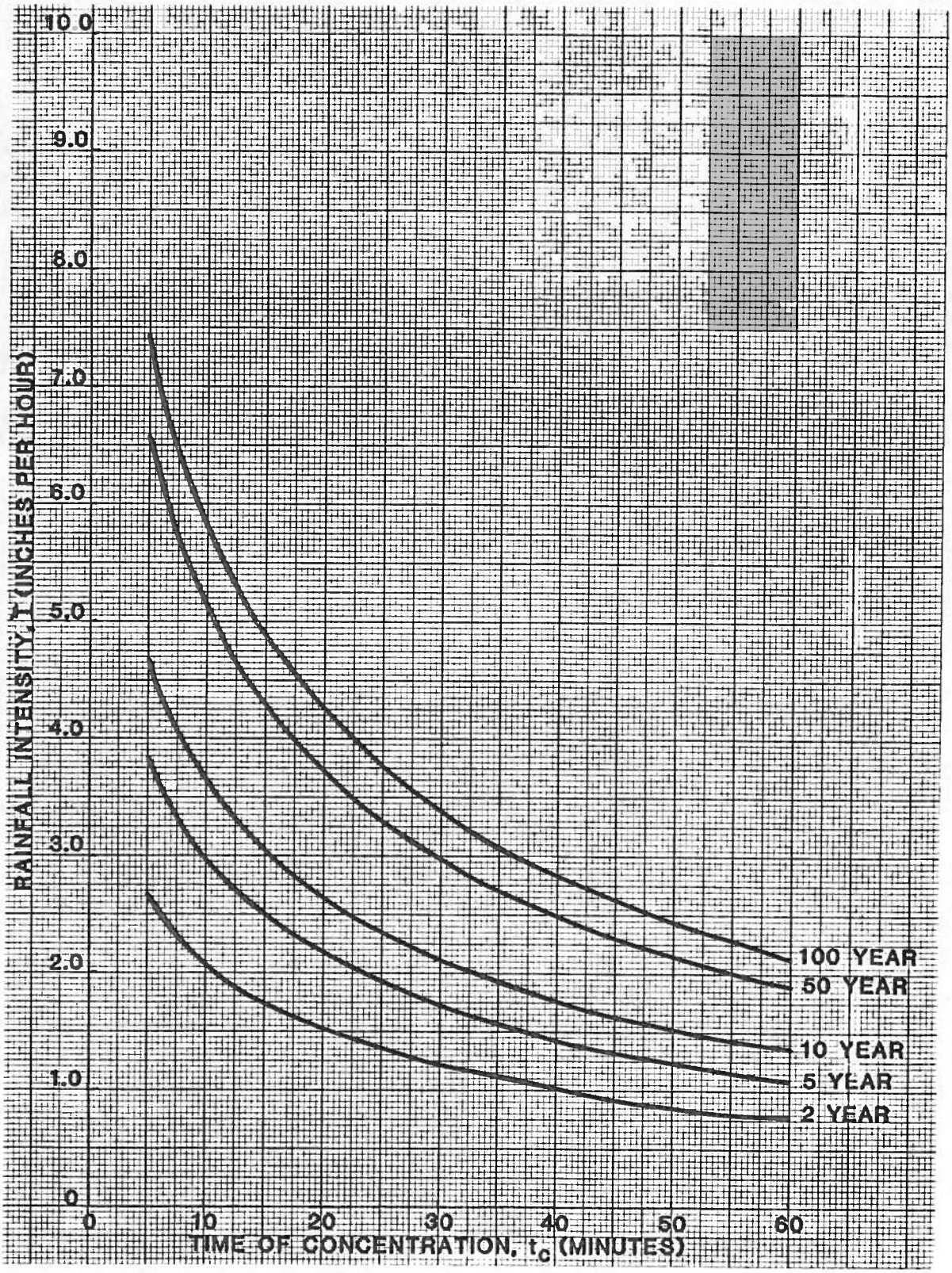


WRC ENG.

REFERENCE: WRC TM-1 NOV. 1983

FIGURE 504

TIME-INTENSITY-FREQUENCY CURVES ZONE III



WRC ENG.	REFERENCE: WRC TM-1 NOV. 1983