APPENDIX A

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APPENDIX A. ANALYSIS OF EXTREME RAINFALL EVENTS AT AUSTIN, TEXAS

ANALYSIS OF EXTREME RAINFALL EVENTS OCCURRING AT AUSTIN, TEXAS

FOR
THE CITY OF AUSTIN, TEXAS
THE COMPREHENSIVE DRAINAGE PLAN AND STUDY
CIP PROJECT NO. 7029 0

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1.0 PURPOSE

The purpose of this report is to define extreme rainfall intensities at Austin, Texas for storms of predetermined length and return period. The results of this analysis will be used to establish design flows for the City of Austin Master Drainage Plan.

Initial work in conjunction with this phase of the Master Drainage Plan revealed the existence of data that were not included in the results of the U.S. Weather Bureau analyses presented in Technical Papers No. 25 and 40. The magnitude and number of these events dictated that a new analysis be performed to obtain accurate rainfall intensities for Austin, Texas.

Section 2.0 of this report describes the statistical techniques employed to derive the results displayed in section 3.0.

2.0 METHODOLOGY

The approach used in analyzing the data of extreme events was developed by Fisher and Tippett in 1928 which resulted from their investigation of the distribution of extreme values. One of the first published hydrological applications of the Fisher-Tippett work was by E.J. Gumbel in 1941. To apply the technique a series of N observations of a random variable y is divided into n subsamples each of size m, so that N = mn. The largest occurrence in each subsample is selected, thus creating a set of random variables X i, i - 1,2, ..., n, which can be described by a Gumbel distribution.

The probability density function takes the form

$$f_X(x) = a \exp [-a(x- ß) - e^{-a (x- ß)}]$$
(1)

where - a £X £a

and the cumulative distribution function is given by

$$f_X(x) = \exp [- e^{-a (x- ß)}] \quad (2)$$

The two parameters that locate and shape the distribution (band a) are the mode and a measure of the dispersion of the data, respectively. The mean (m) standard deviation (s), and the median (M) are defined by,

m= b+ g/a; s= p/ (aÖ6; M = b+ 0.3665/a

where gis Euler's constant (0.577). The skewness of a Gumbel distribution has a constant value of 1.1396.

As the raze of the sample approaches infinity, the sample mean and standard deviation approach the population mean and standard deviation, therefore,

a= 1.281/ sand b= m- 0.45 s

Because our samples are not infinite, the sample mean and standard deviation (m, s) are used for the population statistics resulting in

a= *a*/sand b= m- b/a

Table I is a set of values for a and b obtained by least square analysis that was done by Gumbel (1954).

Table I		
Years	**b**	**a**
20	0.52	1.06
30	0.54	1.11
40	0.54	1.14
50	0.55	1.16
60	0.55	1.17
70	0.55	1.19
80	0.56	1.19
90	0.56	1.20
100	0.56	1.21
150	0.56	1.23
200	0.57	1.24
¥	0.57	1.28

The Gumbel distribution has been widely used to analyze extremes in hydrological events, e.g., flood discharge, wind gust, rainfall, etc.

3.0 ANALYSIS

Table II is a listing of the rainfall durations and their corresponding period of record that was analyzed.

Table II

Duration (Min.)	Period of Record	Length of Record (Yrs.)
5	1927-1948, 1951-1973	45
10	1927-1948, 1951-1973	45
15	1927-1948, 1951-1973	45
30	1927-1948, 1951-1973	45
60	1927-1948, 1951-1973	45
120	1927-1948, 1951-1973	45
180	1951-1973	23
1440	1900-1973	74

Table III shows the sample mean and standard deviation for the different durations of annual maximum rainfall.

Table III

Duration (Min.)	Mean Depth (in.)	Standard Deviation (in.)
5	.493	.133
10	.795	.225
15	1.04	.298
30	1.48	.493
60	1.91	.665
120	2.22	.823
180	2.47	.793
1440	4.14	2.49

Taking twice the logarithm of Eq. (2) yields

$$a(x - b) = -1n [-1nF_X(x)] \quad (3)$$

where

$$F_X(x) = 1 \quad p [X^3x]$$

therefore

$$x = \{-1n (-1n(1 \quad P[X^3x]\} (s/a) + m- (bs/a)$$

Letting $k = -1n(-1n(1-P\{X^3x]))$

gives $x = s/a (k \quad b) + m$ (4)

For a given return period, i.e., T_R=1/P[X≥x], and the mean and standard deviation for a particular duration, a depth of rainfall can easily be calculated from Eq. (4). Work done by the U.S. Weather Bureau and published in Technical Paper 40(1961) indicates a needed correction for return periods of less than or equal to 10 years. This manipulation of data is to account for the divergence between the partial and annual series which propagates in the realm of small return periods. The calculated x value from Eq. (4) for return periods of 10, 5, and 2 years were increased by 1, 4, and 13.6 percent, respectively. Figure 1 depicts duration of rainfall as a function of intensity and return period for the historical data as outlined in Table II.

In an effort to obtain one consistent set of data, a correlation analysis was performed on the data for the common period of record. The correlation coefficients are displayed in Table IV. Events of 180 minutes duration were not considered further in this analysis because of the limited amount of data.

Table IV

Duration/ Duration	**5**	**10**	**15**	**30**	**60**	**120**	**1440**
5	1.0	.920	.878	.716	.489	.397	.246
10		1.0	.963	.799	.587	.496	.260
15			1.0	.900	.703	.600	.277
30				1.0	.870	.740	.329
60					1.0	.910	.492
120						1.0	.649
1440							1.0

In accordance with the technique described by Beard (1962). Eq. (5) and (6) are used with the data presented in Tables III and IV to calculate means and standard deviations that reflect the influence of the additional record available for the 24 hour event.

$$s_i - s_i = (s_{24} - s_{24})\, r_{i,24}\, s_i / s_{24} \qquad (5)$$

$$m_i - m_i = (m_{24} - m_{24})\, r_{i,\,24}\, s_i / s_{24} \qquad (6)$$

where

i = 5, 10, 15, 30, 60, 120 minutes

The primes represent values for the longer period of record. The length of record for the durations with adjusted statistics is changed by an amount equivalent to the quantity of information contained in the additional period or record and is defined by Eq. (7).

$$N_i = \frac{N_i}{1 \quad \frac{N_{24} \quad N_i}{N_{24}} r^2_{i,24}} \qquad (7)$$

where r is given by

$$1 \quad r^2_{i,\,24} = (1 \quad r^2_{i,\,24}) \frac{N_i - 1}{N_i - 2}$$

and r is the correlation coefficient given in Table IV.

Table V presents the adjusted statistics for the 5, 10, 15, 30, 60, 120 minute durations.

Table V

D	m	s	N	r	b	a
120	2.33	1.06	53.5	.638	.550	1.16
60	1.98	.77	49.3	.474	.549	1.16
30	1.51	.53	46.6	.296	.547	1.15
15	1.06	.31	46.0	.235	.546	1.15
10	.81	.24	45.8	.214	.546	1.15
5	.50	.14	45.7	.200	.546	1.15

Table VI is a comparison of EH&A precipitation depth for various return periods and durations, with the comparable values in Technical Paper 40 (1961), and Technical Paper 25 (1955). Figure 2 is a graphical representation of EH&A rainfall intensities vs. duration for different return periods. Figures 3 and 4 are graphical comparison of rainfall intensities vs. duration obtained from Technical Paper 40 (1960), Technical Paper 25 (1955) and the analysis described above.

Table VI							
D/TR		**2**	**5**	**10**	**25**	**50**	**100**
5	TP 40	NA	.74	,87	1.00	1.17	1.25
	EH&A	.54	.64	.72	.82	.91	.99
	TP 25	.46	.56	.63	.71	.78	.83
10	TP 40	NA	1.15	1.33	1.54	1.76	1.95
	EH&A	.87	1.05	1.18	1.36	1.51	1.67
	TP 25	.75	.95	1.07	1.22	1.33	1.45
15	TP 40	NA	1.45	1.69	1.94	2.21	2.44
	EH&A	1.15	1.37	1.54	1.78	1.96	2.15
	TP 25	.98	1.25	1.48	1.68	1.90	1.98
30	TP 40	1.60	2.01	2.34	2.70	3.07	3.38
	EH&A	1.62	2.03	2.31	2.73	3.06	3.38
	TP 25	1.40	1.90	2.20	2.60	2.85	3.15
60	TP 40	2.00	2.56	2.95	3.45	3.87	34.30
	EH&A	2.11	2.71	3.14	3.74	4.21	4.67
	TP 25	1.85	2.50	3.00	3.50	4.00	4.50
120	TP 40	2.30	3.10	3.65	4.30	4.30	4.75
5.35	EH&A	2.46	3.33	3.92	4.75	5.39	6.03
	TP 25	2.20	3.00	3.60	4.30	5.00	5.60
1440	TP 40	4.10	5.60	6.70	7.90	8.90	10.00
	EH&A	4.32	6.24	7.68	9.60	11.04	12.48
	TP 25	3.35	4.80	6.00	7.20	8.15	9.10

Figure 1 Historical Rainfall Intensities

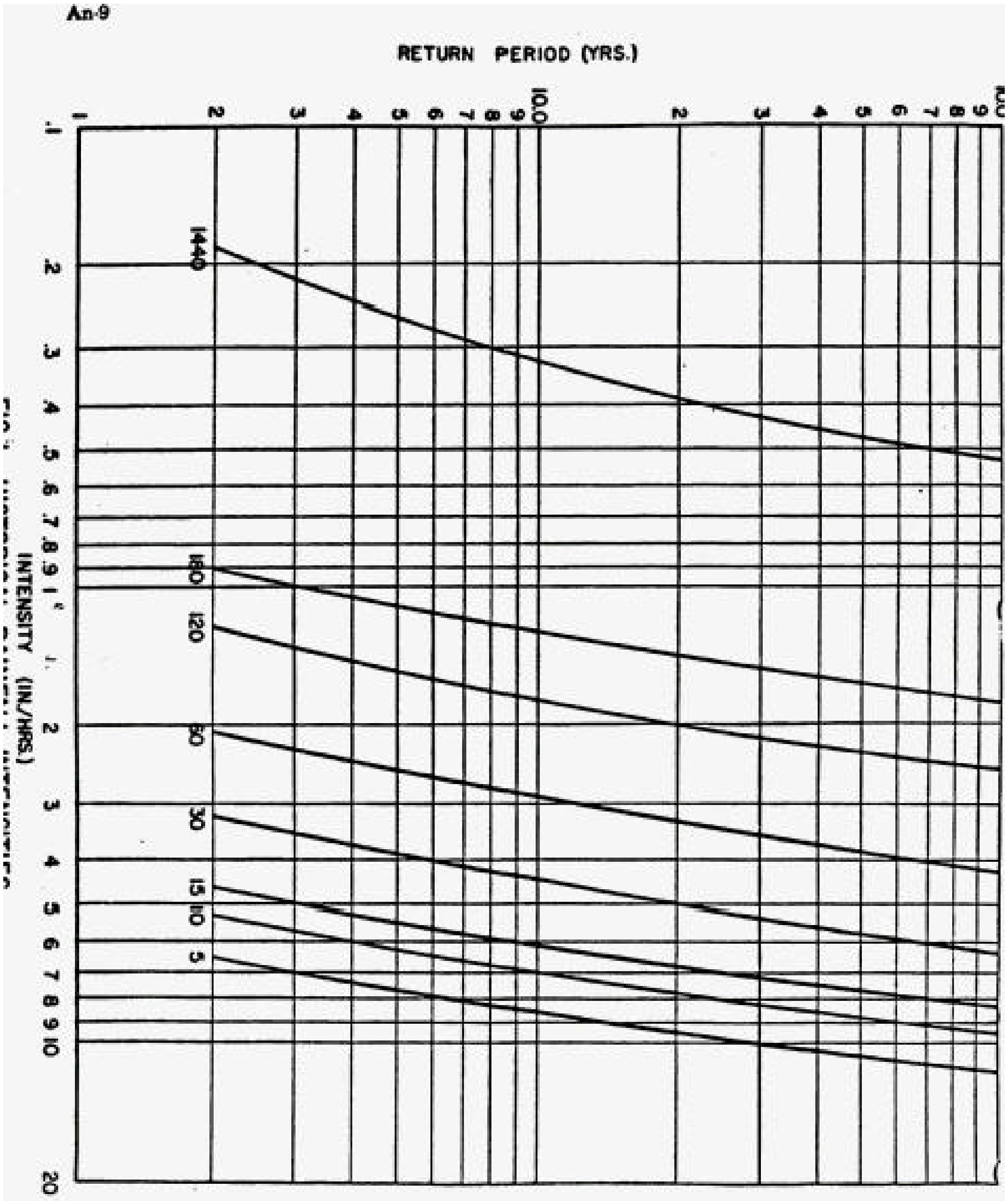


Figure 2 Rainfall Curves for Austin, Texas

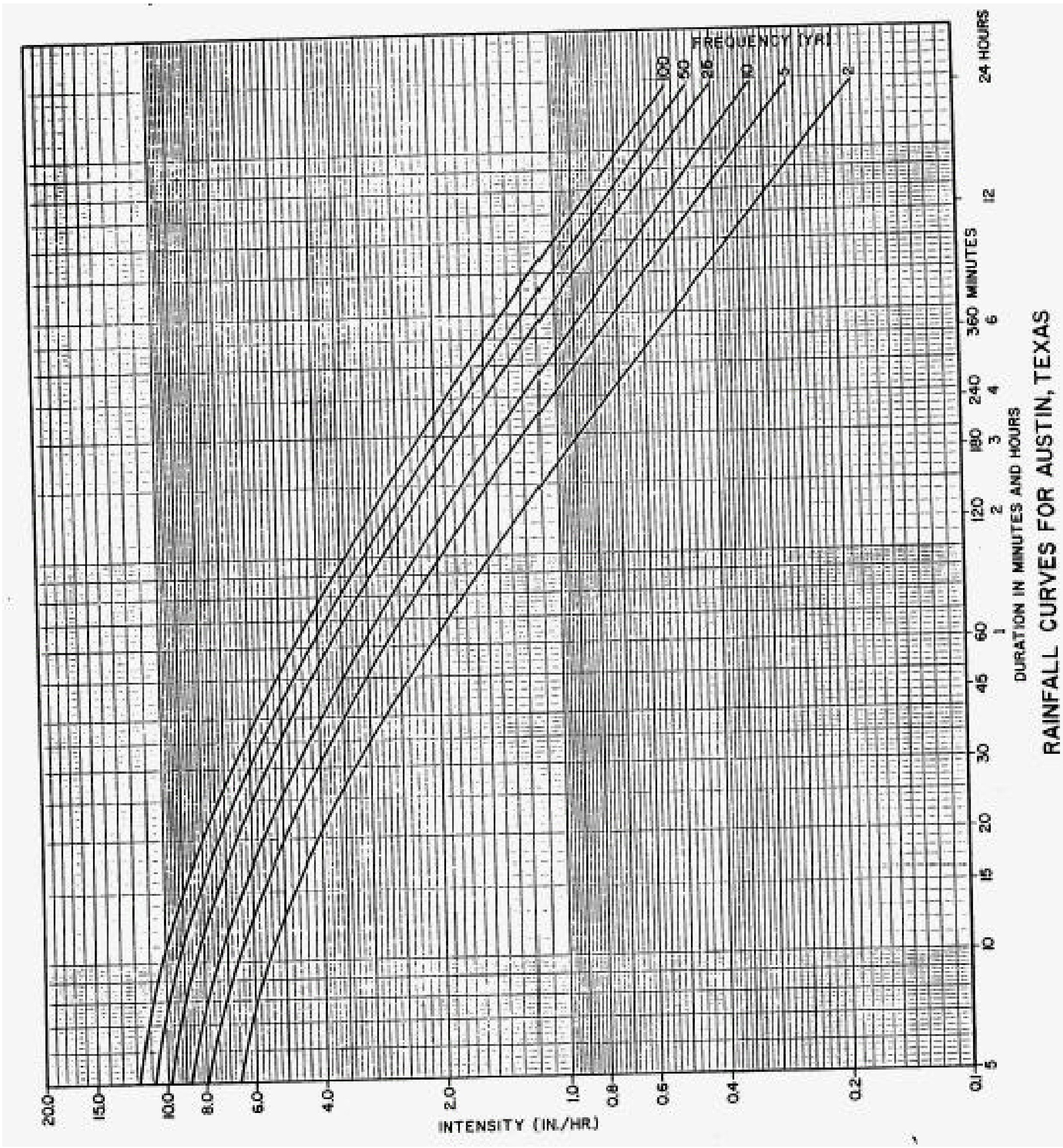


Figure 3 Rainfall Intensity vs. Duration for 25 Year Return Period

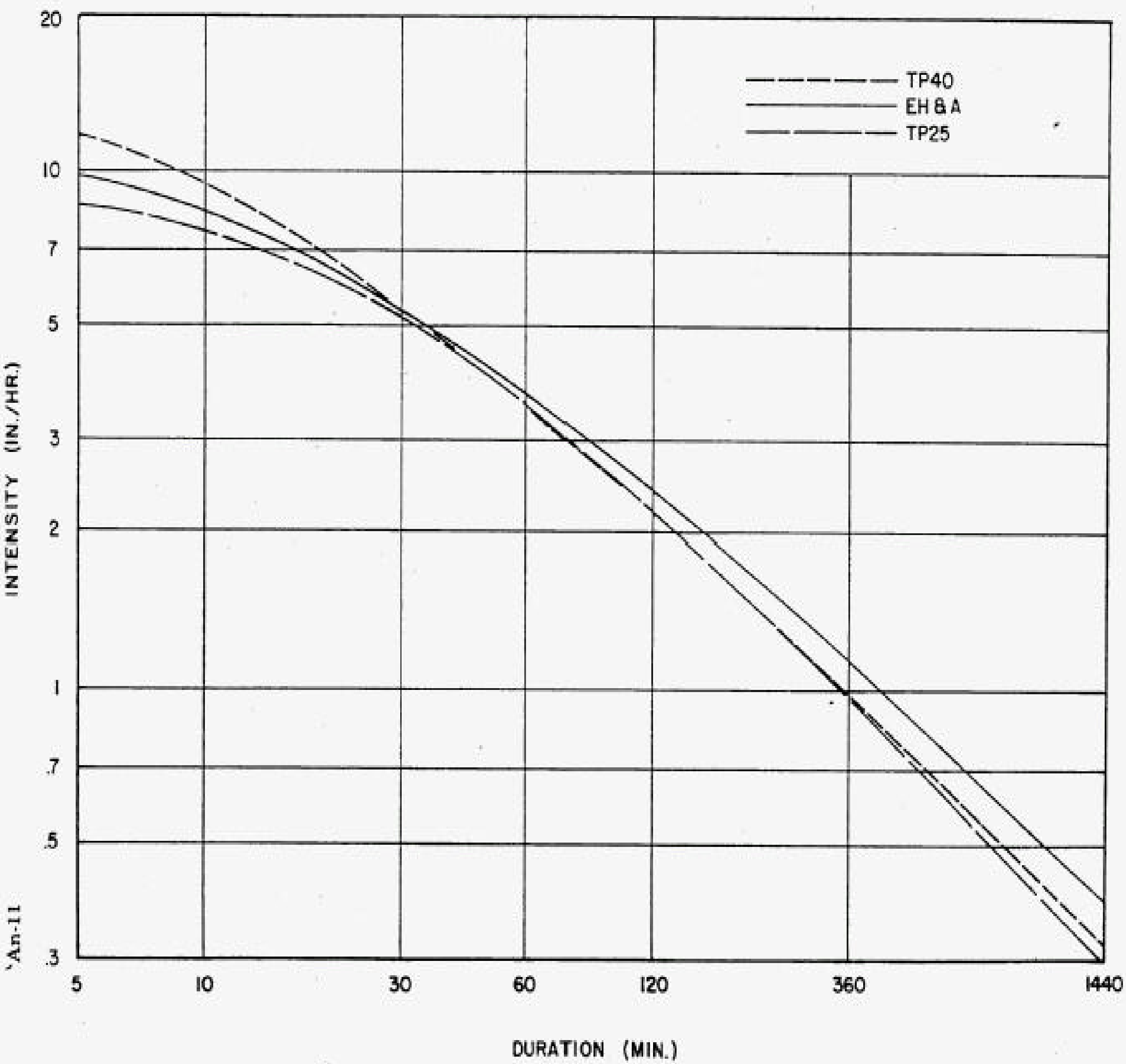
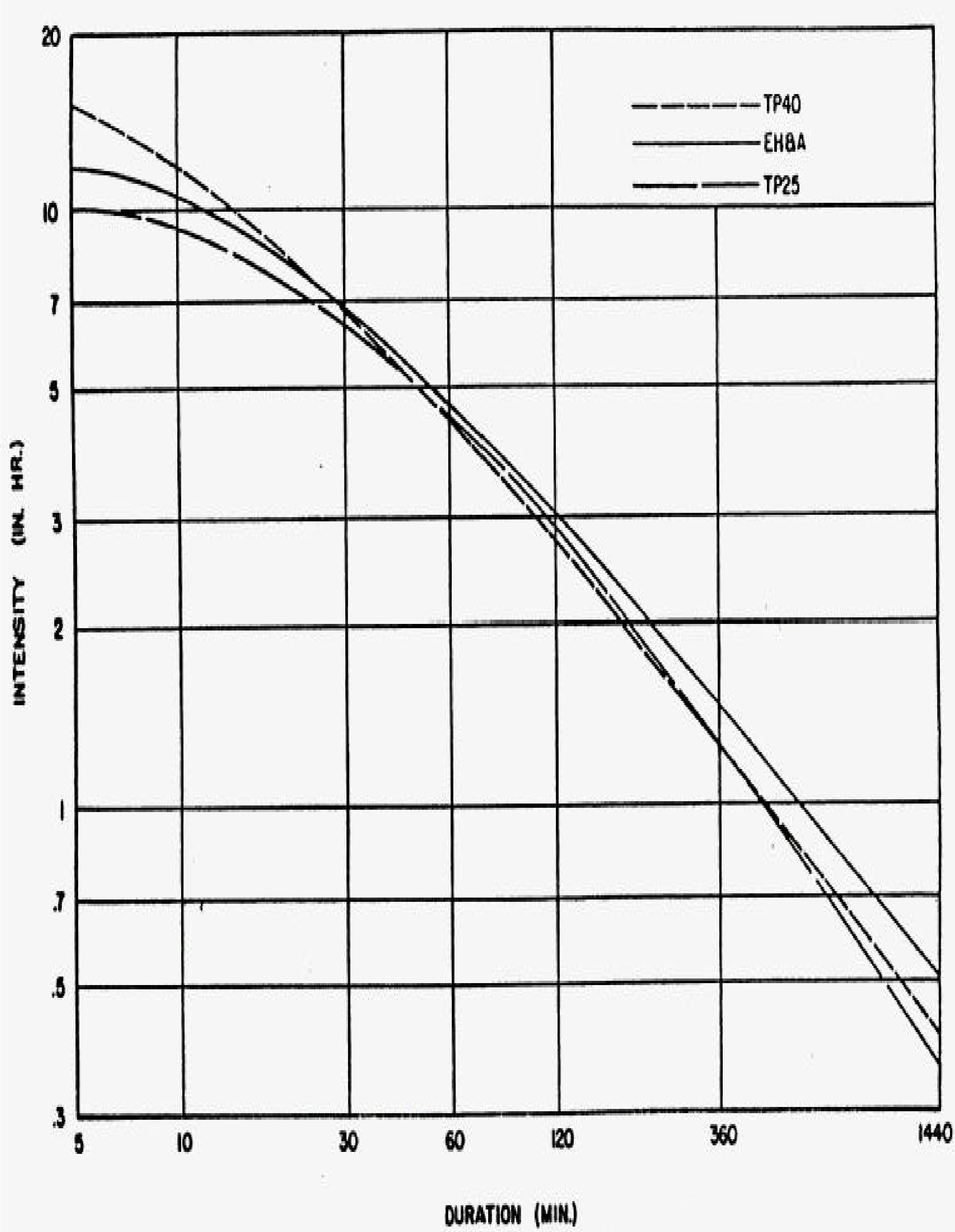


FIG. 3 RAINFALL INTENSITY VS. DURATION FOR 25 YEAR RETURN PERIOD

Figure 4 Rainfall Intensity vs. Duration for 100 Year Return Period



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