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MEAN ANNUAL PRECIPITATION AND PRECIPITATION DEPTH-DURATION-FREQUENCY DATA FOR THE SAN FRANCISCO BAY REGION, CALIFORNIA

By

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ABSTRACT

This report presents precipitation data for the San Francisco Bay region in a form suitable for use as criteria for both drainage design and the study of the stability of land slopes. The data presented include (1) an isohyetal map showing long-term mean annual precipitation and (2) a table of storm precipitation depths, corresponding to various durations and frequencies, that are applicable to any site in the region. The regimen of precipitation in the region is such that depth-duration-frequency characteristics for a site are closely related to the mean annual precipitation for that site.

INTRODUCTION

Precipitation-frequency data are commonly used in engineering design, and the most frequently used sources of such data are the highly generalized precipitation maps in U.S. Weather Bureau Technical Papers 28 (1956), 40 (1961), and 49 (1964). The maps in Technical Paper 28 are at an approximate scale of 1:5,500,000, and those in Technical Papers 40 and 49 are at an approximate scale of 1:10,000,000. The lack of refinement in those small-scale maps is acknowledged in the text of the Weather Bureau reports in such statements as the following:

"Even this relatively dense network (of precipitation stations in the United States), cannot reveal very accurately the fine structure of the isopluvial pattern in the mountainous regions of the West." (U.S. Weather Bureau Technical Paper 40, p. 5)

"Where orographic (mountain) influences are important, and where local agencies have prepared maps of detail scale, users are urged to refer to these and other available maps and diagrams." (U.S. Weather Bureau Technical Paper 28, p. 7)

In response to the need for more refined precipitation-frequency data for drainage design and other engineering studies in the San Francisco Bay region, a method was developed whereby such data could be computed with reasonable accuracy for any site in the region. The derivation of the method is explained in an earlier report by Rantz (1971).

Purpose and Scope

The purpose of this report is to present precipitation data for the San Francisco Bay region in a form suitable for use as criteria for both drainage design and the study of the stability of land slopes. The region of primary concern is the 7,416 square miles in the nine counties shown in figure 1, but the data obtained are applicable to the entire trapezoidal study area delineated in the figure. The precipitation data presented include (1) an isohyetal map of mean annual precipitation and (2) a table showing precipitation values for durations ranging from 5 minutes to 60 consecutive days and for recurrence intervals ranging from 2 to 100 years. Data for the shorter durations are required for local drainage design and for the study of soil-erosion potential; data for the longer durations are required for the study of land-slippage potential. The isohyetal map, useful in itself for climatological and water-resources studies, is a necessary adjunct to the table for obtaining depth-duration-frequency data for any site in the study area.

Acknowledgments

This report was prepared by the U.S. Geological Survey, in cooperation with the U.S. Department of Housing and Urban Development. The work was done during 1970 under the overall direction of R. E. Wallace, project director of the San Francisco Bay region environment and resources planning study, and under the general supervision of R. Stanley Lord, district chief in charge of water-resources investigations in California.

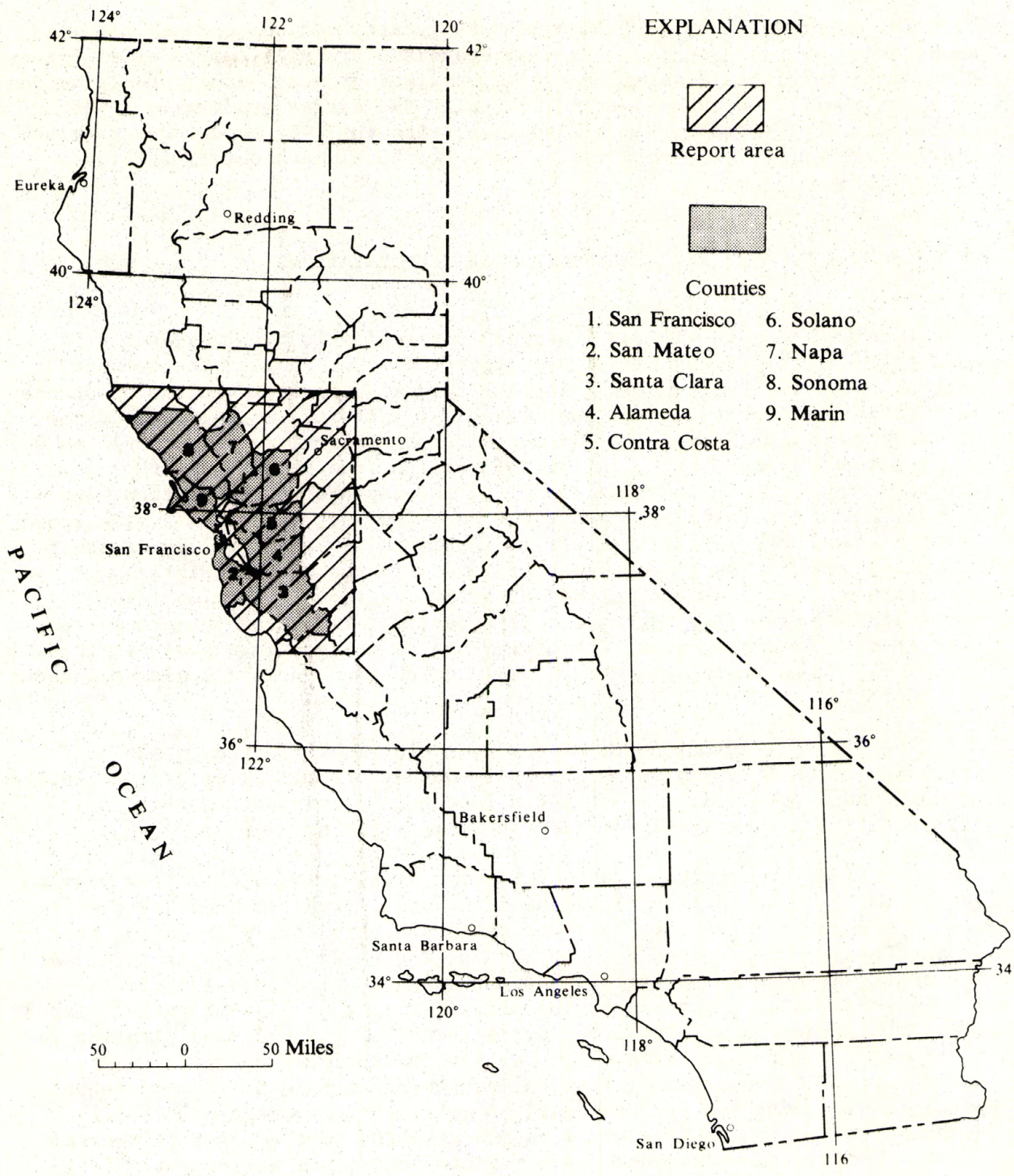

FIGURE 1.--Location of report area.

The labor involved in this study was greatly reduced through the cooperation of two agencies. The San Francisco District, Corps of Engineers, U.S. Army, furnished a detailed preliminary map of mean annual precipitation, at a scale of 1:250,000, covering virtually the entire study area. The California Department of Water Resources, through J. R. Goodridge, provided statistical arrays of precipitation data for 80 climatological stations.

REGIONAL REGIMEN OF PRECIPITATION

Precipitation in the San Francisco Bay region is highly seasonal; almost 90 percent of the annual precipitation occurs during the 6-month period November through April. The great bulk of that precipitation occurs in a series of general storms that reach all parts of the region, but the storm centers usually pass to the north of the region, and the result is a general tendency for precipitation to decrease from north to south. Altitude has a strong local influence on the depth of precipitation, and because altitudes range from sea level to 4,400 feet, there is a wide range in mean annual precipitation--from 10 inches in low-lying valley areas in the east to 80 inches in some mountain areas in the north. Winter precipitation often occurs as snow at altitudes above 2,000 feet, but snowfalls are generally light, and snow does not remain on the ground for more than a few days. Snow, therefore, has an insignificant role in the hydrology of the region. Intense local convective storms are almost unknown in the region.

The seasonal distribution of precipitation is reflected in the following table 1, which shows the mean monthly precipitation, in percentage of the annual total, at five selected long-term precipitation stations. Precipitation is negligible during the summer months.

Annual precipitation at any particular site varies widely from year to year. For example, at Kentfield the mean annual precipitation for the period 1888-1965 is 46.4 inches, but the annual precipitation during that 77-year period ranged from 88.2 inches in 1890 to 22.2 inches in 1924. At San Jose, the mean annual precipitation for the period 1874-1965 is 14.0 inches, but the annual precipitation during that 91-year period ranged from 30.3 inches in 1890 to 4.83 inches in 1877. (Annual precipitation in 1924 was 6.55 inches.) Figure 2 shows the cumulative probability distribution of annual precipitation, expressed as a ratio to mean annual precipitation, for the two stations, as well as the average probability distribution for the entire study region computed on the basis of records for 80 precipitation stations. The regional curve was not computed for exceedence probabilities of more than 50 percent, because the necessary data were not readily available, but it may safely be presumed that the lower end of the regional curve would closely match the lower ends of the curves for Kentfield and San Jose. Although all distributions shown in figure 2 are skewed, the probability of the mean annual precipitation being exceeded in any year is only slightly less than 50 percent.

TABLE 1.--Mean monthly distribution of precipitation at selected stations

Precipitation station	Mean annual precip-itation (inches)	Mean monthly distribution of precipitation, in percentage of mean annual precipitation											
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Healdsburg (Sonoma County)	40.0	22.3	17.8	13.3	6.7	3.5	0.89	0.07	0.14	1.2	4.9	10.8	18.4
Vacaville (Solano County)	25.4	21.7	17.9	13.4	7.0	3.5	.52	0	.08	1.2	4.5	10.1	20.1
Kentfield (Marin County)	46.4	21.9	18.4	13.5	6.1	3.5	.79	.04	.07	1.3	5.3	10.4	18.7
Livermore (Alameda County)	14.6	20.7	16.9	14.9	7.4	3.6	.79	.07	.14	1.9	4.4	10.2	19.0
San Jose (Santa Clara County)	14.0	20.1	17.6	16.4	7.7	3.6	.77	0	.13	1.8	4.6	9.4	17.9

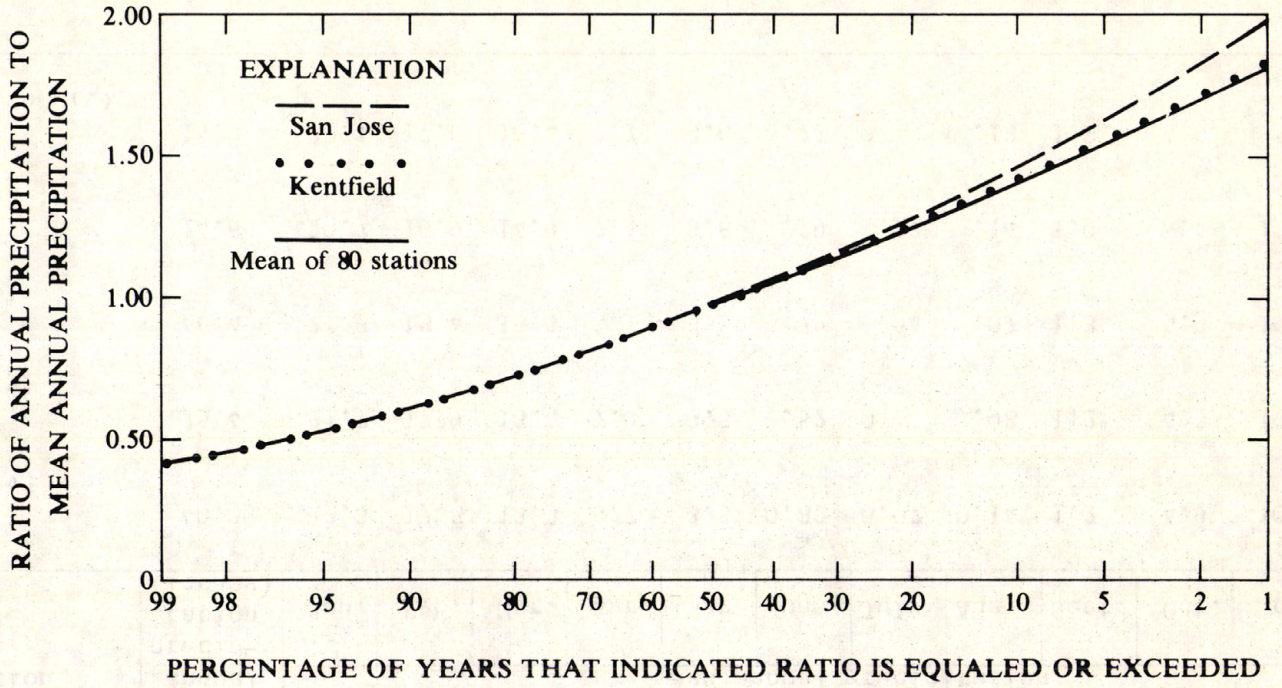

FIGURE 2.--Cumulative probability curves of annual precipitation.

AREAL DISTRIBUTION OF MEAN ANNUAL PRECIPITATION

The most useful single statistic concerning precipitation at a site is the mean annual precipitation; an isohyetal map of mean annual precipitation shows that value for any site in the region. In constructing such a map, the first step is to relate long-term values of mean annual precipitation at climatological stations to such parameters as latitude and altitude of the stations, height of upwind barriers, and distance downwind from the mountain barriers. From the derived relation the mean annual precipitation at ungaged sites is deduced, and the deduced and observed values are used, along with the directional trend of topographic contours, to draw the required isohyets. For this study a preliminary isohyetal map at a scale of 1:250,000 was available from the Corps of Engineers, San Francisco District. The map was based on records for 698 precipitation stations operated by the Weather Bureau, various public agencies, and private companies and individuals.

The Corps of Engineers map was developed in 1957, and all records at that time were adjusted to the common 50-year base period, 1906-56. The adjustment of short-term records to the base period was made by correlating records for the short-term stations with those for nearby long-term stations. Experience has shown that in California the mean annual precipitation for almost any 50-year period provides a close estimate of the long-term mean annual value. For example, comparison of the mean annual precipitation for the entire period of record at representative long-term stations in the San Francisco Bay region with their respective mean values for the period 1906-56, shows that the 50-year mean values are, in general, 2 to 4 percent lower than the long-term mean values. Because this small difference is well within the accuracy of the isohyets on a map of the scale used, no revision of the map was considered. The Corps of Engineers map is consistent with a less-detailed map at a scale of 1:1,000,000 recently compiled by the author for an as-yet unpublished statewide water-resources study. The Corps of Engineers map covers virtually the entire study area; the less-detailed map was used as a basis for extending the isohyets of the Corps of Engineers map to cover the entire area. That expanded isohyetal map of mean annual precipitation is reproduced for this report as plate 1.

With regard to the accuracy of the map on plate 1, it should be realized that a considerable amount of subjectivity goes into the construction of an isohyetal map and the contours are drawn to fit virtually all observed data. Consequently there are no "degrees of freedom" left, in the statistical sense, for estimating the probable error of the contours. Although objective mathematical procedures exist for constructing the isohyetal map--for example, trend-surface analysis techniques--the procedures are as yet unproven for use in rugged terrain, such as in the report region. At the present state of the art, many uncertainties exist in preparing maps for areas of rugged relief, and it can be said only that the map on plate 1 represents the best estimate of mean annual precipitation available for the region in general. The standard error of the contours probably ranges from 15 percent for the large values of mean annual precipitation to 20 percent for the small values. Highly detailed study of smaller areas within the study region may have produced maps of greater precision for those areas, but the few that the author has seen--isohyetal maps for parts of San Mateo and Marin Counties, compilers unknown--have not differed significantly from plate 1.

PRECIPITATION DEPTH-DURATION-FREQUENCY RELATIONS

The principal product of this study is a set of precipitation depth-duration-frequency relations for use at any site within the San Francisco Bay region. The 80 precipitation stations used in the frequency analysis are listed, along with pertinent information concerning them, in tables 2 and 3, and the station locations are shown with identifying number in figure 3. The method of analyzing the precipitation data, described by Rantz (1971), is based on the fact that the regimen of precipitation in the San Francisco Bay region is such that depth-duration-frequency characteristics for a site are closely related to the mean annual precipitation for that site.

In the previously cited report by Rantz (p. 238), a description is given of an adjustment made to the derived precipitation relations to ensure internal consistency among them. It is pointed out in that discussion that if the adjusted relations give a family of smooth consistent frequency curves for precipitation depths corresponding to a mean annual precipitation of 80 inches--the greatest such value in the study region--all frequency curves corresponding to lesser precipitation depths will likewise be smooth and consistent. Figures 4-6 that follow, show the frequency curves obtained for durations ranging from 1 hour to 60 consecutive days that are appropriate for sites having a mean annual precipitation of 80 inches.

TABLE 2.--Recording precipitation stations used in depth-duration-frequency analysis

Number (fig. 3)	Station name	Latitude (north)		Longitude (west)		Altitude (feet)	Number of years of record used in analysis	Mean annual precipitation for years used in analysis (inches)
		Degrees	Minutes	Degrees	Minutes			
(1)	(2)	(3)		(4)		(5)	(6)	(7)
199S	Berkeley	37	52	122	15	299	[1] 11, 24	[2] 22.91
204S	Brentwood 6 SW	37	53	121	46	325	[1] 11, 17	[2] 14.81
205S	Brooks Farnham Ranch	38	46	122	09	300	[1] 11, 27	[2] 19.32
215S	Davis 2 WSW	38	32	121	45	51	[1] 11, 26	[2] 16.12
234S[3]	Hopland 8 NE	39	01	123	00	2,510	[1] 11, 24	[2] 37.85
241S	Mahnke	38	51	122	47	2,380	11	48.57
252S	Pacheco Pass	37	04	121	11	850	[1] 11, 18	[2] 13.21
279S	Walnut Creek 2 ENE	37	53	122	02	245	11	18.25
290S[3]	Clearlake Highlands	38	58	122	39	1,320	[1] 11, 27	[2] 23.64
296S	Freedom 8 NNW	37	03	121	49	1,495	[1] 11, 28	[2] 41.79
297S	Gilroy 8 NE	37	02	121	26	1,050	[1] 11, 24	[2] 19.29
306S[3]	Modesto No. 2	37	38	121	00	92	[1] 11, 26	[2] 10.63
308S	Palo Alto City Hall	37	27	122	08	23	11	14.08
311S	San Juan Bautista 3 SSE	36	49	121	31	615	11	17.44
313S	So. East Farallon	37	42	123	00	27	11	14.55
314S	Sunset Beach State Park	36	54	121	50	85	11	18.16
316S	Venado	38	37	123	01	1,260	11	59.78
324S	Cloverdale 11 W	38	46	123	13	1,820	[1] 10, 23	[2] 62.39
326S	Corralitos	36	59	121	49	730	[1] 11, 22	[2] 24.49
331S	Sacramento Airport	38	31	121	30	17	[1] 11, 28	[2] 17.24
332S	Stockton Disposal Plant	37	56	121	20	11	[1] 11, 27	[2] 14.13
334S	The Geysers	38	48	122	49	1,600	[1] 11, 28	[2] 55.23
337S	Tracy 2 SSE	37	43	121	25	108	[1] 11, 28	[2] 9.09
339S	Upper San Leandro Filters	37	46	122	10	395	24	21.29
363S	Atlas Road	38	25	122	15	1,735	24	36.63
375S	Hayward 6 ESE	37	39	121	58	925	27	25.83
381S	Oakland Airport	37	44	122	12	3	[1] 11, 28	[2] 18.61
386S	St. Helena 7 NE	38	34	122	22	1,050	[1] 11, 24	[2] 36.50
388S	San Francisco	37	47	122	25	52	79	20.56
389S	San Jose	37	21	121	54	70	60	13.42
406S	Boulder Creek-Locatelli	37	08	122	12	2,200	24	58.28
411S[3]	Hernandez 7 SE	36	18	120	42	2,765	[1] 11, 27	[2] 19.23
412S[3]	La Panza Ranch	35	23	120	10	1,560	[1] 11, 27	[2] 10.04
415S	Novato 8 WNW	38	08	122	43	350	[1] 11, 24	[2] 29.34
420S	Sacramento City WB	38	35	121	29	25	66	16.70

[1]The same length of record was not used for all durations studied; usually the shorter period of years shown was used with durations of 2, 3, and 12 hours, and the longer period of years shown was used with durations of 1, 6, and 24 hours.

[2]Mean annual precipitation is associated with the longer period of years shown in column 6.

[3]Station is located outside the area shown in figure 3.

TABLE 3.--Nonrecording precipitation stations used in depth-duration-frequency analysis

Number (fig. 3)	Station name	Latitude (north)		Longitude (west)		Altitude (feet)	Number of years of record used in analysis	Mean annual precipitation for years used in analysis (inches)
		Degrees	Minutes	Degrees	Minutes			
(1)	(2)	(3)		(4)		(5)	(6)	(7)
22S	Cazadero	38	52	123	07	1,040	26	72.05
32S[1]	Colfax	39	06	120	57	2,418	62	45.51
55S	Folsom	38	41	121	11	252	67	23.58
59S	Galt	38	15	121	18	47	67	17.04
70S	Hobergs	38	51	122	43	2,960	38	57.14
86S	Livermore	37	39	121	47	545	66	14.08
95S	Montezuma Hills	38	05	121	48	20	42	12.76
114S	Plainfield Heinz	38	35	121	48	63	68	16.68
131S	Stockton	37	58	121	18	11	70	14.14
139S	Tracy Carbona	37	42	121	25	137	34	9.25
145S	Vacaville	38	22	122	00	175	65	24.65
156S	Winters 3 NE	38	32	121	56	116	41	18.27
158S	Woodland	38	41	121	48	69	55	16.64
172S	Gerber Ranch	37	22	121	29	2,140	53	17.67
173S	Gilroy	37	00	121	34	194	94	20.43
192S[1]	Turlock	37	29	120	51	115	75	11.70
245S	Millberry	37	07	121	55	1,750	25	44.45
262S	Saratoga Gap	37	16	122	07	2,600	26	55.29
282S	Willow Glen	37	18	121	54	155	34	14.20
283S	Alma College	37	11	122	00	900	48	34.82
288S	Capay 4 W	38	42	122	07	290	80	22.61
325S	Cobb	38	50	122	43	2,520	12	73.18
343S	Chabot Reservoir	37	44	122	07	245	40	21.73
349S	Lodi	38	07	121	17	40	77	16.92
357S	San Pablo Reservoir	37	56	122	16	330	17	26.39
360S	Upper San Leandro Filters	37	46	122	10	395	17	26.09
362S	Youngstown	38	11	121	14	65	30	16.18
377S	Lodi 4 NNE Devinny Ranch	38	10	121	15	61	21	16.06
379S	Marshall Ranch	38	06	121	13	60	38	15.68
385S	Pinole Creek	37	57	122	14	215	25	20.14
395S	Crystal Springs Cottage	37	33	122	20	400	22	24.53
396S[1]	Denair	37	32	120	48	124	61	11.08
400S	Lower Crystal Springs	37	32	122	22	450	21	25.11
401S	Pilarcitos	37	33	122	25	625	21	38.02
403S	San Andreas Lake	37	35	122	24	377	21	30.60
405S	Antioch	38	00	121	47	46	69	12.61
407S[1]	Brush Creek Ranger Station	39	41	121	20	3,560	34	73.30
408S	Calaveras Reservoir	37	29	121	49	805	21	20.50
409S	Davis 2 WSW	38	32	121	45	51	69	16.33
410S[1]	Fresno WB	36	47	119	42	331	44	9.33
413S	Meganos Pump	37	51	121	40	172	37	12.13
414S[1]	Montpelier	37	33	120	42	225	27	12.44
417S[1]	Pinnacles	36	29	121	11	1,307	32	17.00
418S[1]	Placerville	38	44	120	48	1,890	71	38.57
419S	Rio Vista	38	09	121	41	22	65	16.30

[1]Station is located outside the area shown in figure 3.

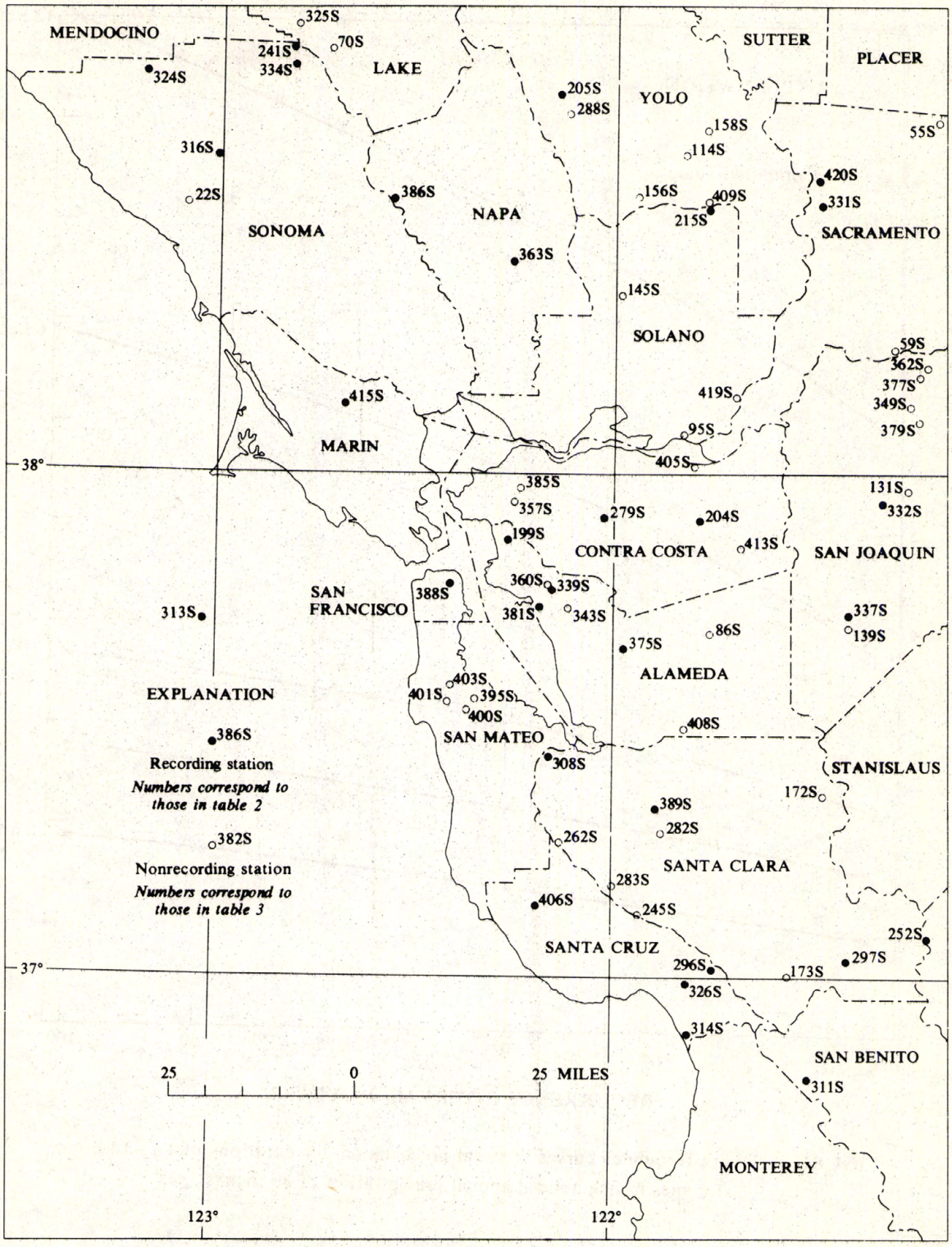

FIGURE 3.--Precipitation stations used in depth-duration-frequency analysis.

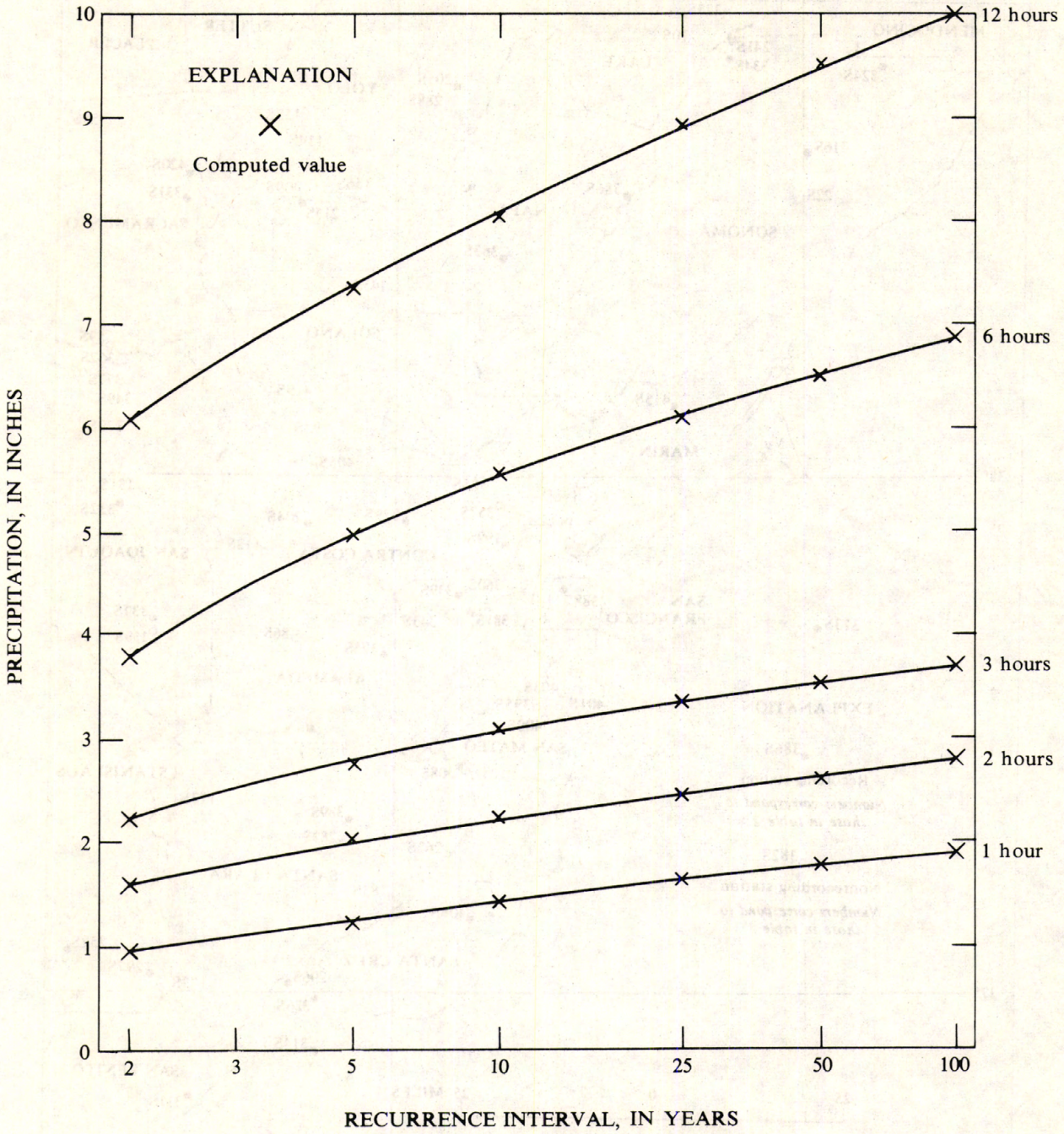

FIGURE 4.--Depth-frequency curves of storm precipitation, for durations of 1 to 12 hours, for sites having a mean annual precipitation of 80 inches.

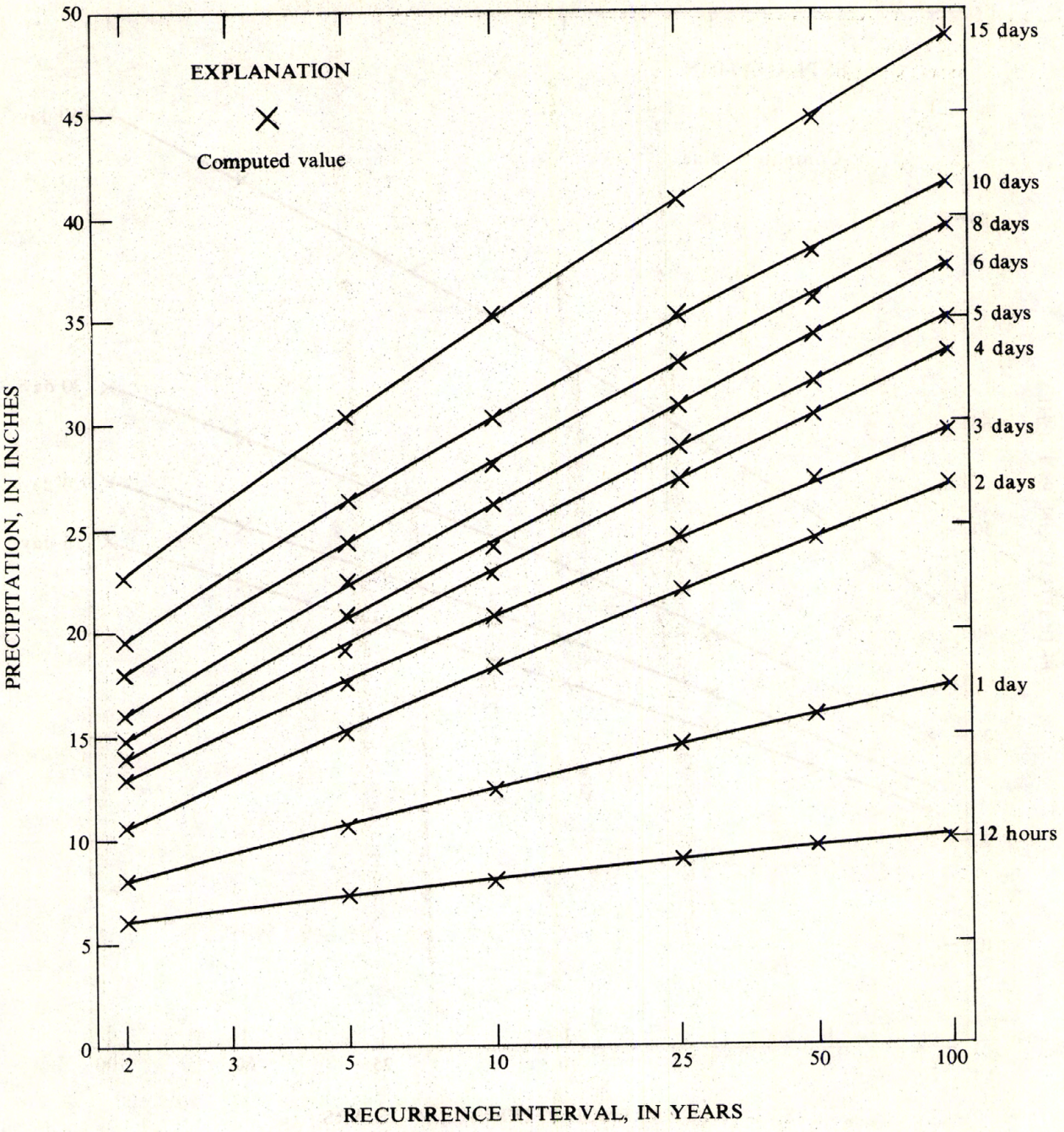

FIGURE 5.--Depth-frequency curves of storm precipitation, for durations of 12 hours to 15 days, for sites having a mean annual precipitation of 80 inches.

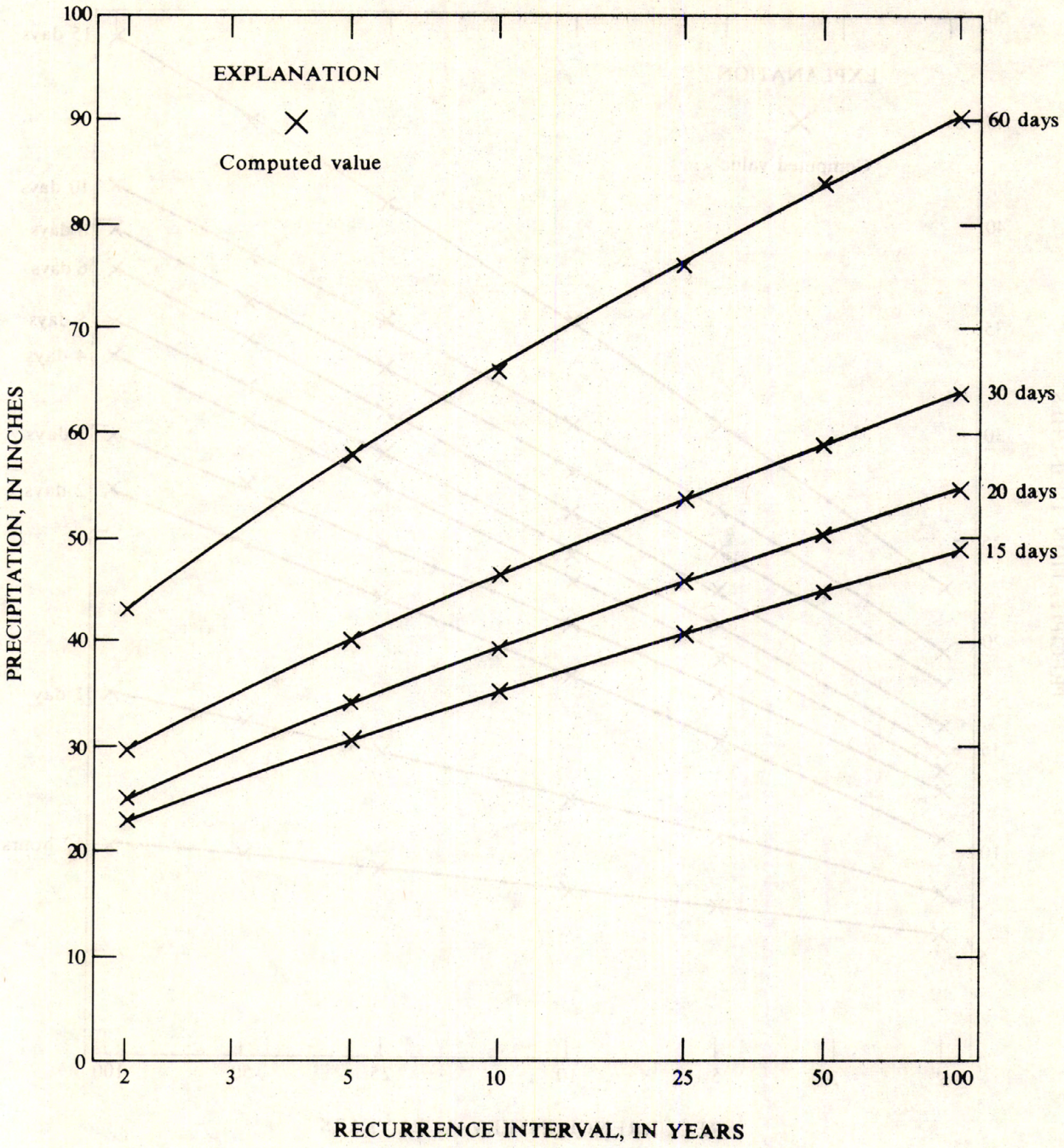

FIGURE 6.--Depth-frequency curves of storm precipitation, for durations of 15 to 60 days, for sites having a mean annual precipitation of 80 inches.

The results of the analysis have been summarized in table 4, which is a tabulation of precipitation depths for selected durations and recurrence intervals corresponding to various values of mean annual precipitation. The durations range from 5 minutes to 60 consecutive days; the recurrence intervals, which are the reciprocals of the exceedence probabilities, range from 2 to 100 years; the values of mean annual precipitation range from 10 to 80 inches.

Table 4 is used with the isohyetal map on plate 1, to obtain depth-duration-frequency data for any site in the San Francisco Bay region. This is done by first obtaining the mean annual precipitation from plate 1 for the site under consideration. Table 4 is then entered with that value and the precipitation corresponding to the required duration and frequency is obtained. Where necessary, straight-line interpolation is used between tabular values.

Evaluation of the precipitation depth-duration-frequency relations (Rantz, 1971, p. 240) showed the graphical standard error of estimate to range from 10 to 20 percent, the greater percentages being associated with the greater recurrence intervals and the shorter durations. It was also stated earlier that the standard error of the isohyetal map probably ranges from 15 percent for the large values of mean annual precipitation to 20 percent for the small values. If we combine statistically the standard errors for the frequency relations and the isohyetal map, we find that the standard error of estimate for the precipitation obtained at a given site for a given duration and frequency, ranges from about 18 to 28 percent, and for all practical purposes may be assumed to be 25 percent.

SUMMARY

Precipitation depth-duration-frequency relations have been derived for the San Francisco Bay region. The regimen of precipitation in the region is such that depth-duration-frequency characteristics for a site are closely related to the mean annual precipitation for that site. The derived precipitation-frequency data are given in table 4, and that table, when used in conjunction with the detailed isohyetal map on plate 1, gives the storm precipitation for any site in the region, for any duration between 5 minutes and 60 consecutive days, and any recurrence interval between 2 and 100 years.

TABLE 4.--Depth-duration-frequency data for the San Francisco Bay region

Duration	Recurrence interval (years) \ P_{MA}	Storm precipitation, in inches, corresponding to indicated values of mean annual precipitation (P_{MA}), in inches											
		10	12	14	16	18	20	30	40	50	60	70	80
5 minutes	2	0.08	0.10	0.11	0.12	0.13	0.14	0.16	0.19	0.21	0.23	0.26	0.28
	5	.12	.14	.15	.16	.17	.18	.21	.24	.27	.30	.33	.36
	10	.15	.17	.18	.19	.20	.21	.24	.28	.31	.35	.38	.41
	25	.17	.19	.21	.23	.24	.25	.29	.32	.36	.40	.44	.48
	50	.19	.21	.23	.24	.26	.27	.31	.35	.39	.43	.47	.51
	100	.21	.23	.25	.26	.28	.29	.33	.38	.42	.46	.51	.55
10 minutes	2	.13	.15	.17	.18	.20	.22	.25	.29	.32	.36	.40	.43
	5	.19	.21	.23	.25	.26	.27	.32	.37	.41	.46	.51	.56
	10	.23	.26	.28	.30	.32	.33	.38	.43	.49	.54	.58	.64
	25	.27	.30	.33	.35	.37	.39	.45	.50	.56	.62	.68	.74
	50	.30	.33	.36	.38	.40	.42	.48	.54	.61	.67	.73	.80
	100	.32	.36	.38	.41	.43	.45	.52	.58	.65	.72	.79	.86
15 minutes	2	.16	.19	.21	.23	.26	.27	.32	.36	.41	.46	.50	.55
	5	.25	.27	.29	.31	.33	.35	.41	.47	.52	.59	.65	.71
	10	.30	.32	.35	.38	.40	.42	.48	.55	.62	.68	.74	.81
	25	.34	.38	.42	.44	.47	.49	.56	.64	.71	.79	.86	.93
	50	.38	.42	.45	.48	.51	.53	.61	.69	.77	.85	.93	1.01
	100	.41	.45	.48	.52	.55	.57	.66	.74	.83	.91	1.00	1.08

TABLE 4.--Depth-duration-frequency data for the San Francisco Bay region--Continued

Duration	P_{MA} / Recurrence interval (years)	Storm precipitation, in inches, corresponding to indicated values of mean annual precipitation (P_{MA}), in inches											
		10	12	14	16	18	20	30	40	50	60	70	80
30 minutes	2	0.22	0.26	0.29	0.32	0.36	0.38	0.44	0.51	0.57	0.63	0.70	0.76
	5	.34	.37	.40	.43	.46	.48	.57	.65	.73	.81	.90	.98
	10	.41	.45	.49	.52	.55	.58	.66	.76	.85	.94	1.03	1.12
	25	.47	.53	.58	.62	.65	.68	.78	.88	.99	1.09	1.19	1.30
	50	.52	.58	.62	.66	.70	.73	.85	.96	1.07	1.18	1.29	1.40
	100	.57	.62	.67	.72	.76	.79	.91	1.03	1.15	1.26	1.38	1.50
1 hour	2	.28	.33	.37	.41	.45	.48	.56	.64	.72	.80	.88	.96
	5	.43	.47	.51	.55	.58	.61	.72	.82	.92	1.03	1.14	1.24
	10	.52	.57	.62	.66	.70	.73	.84	.96	1.08	1.19	1.30	1.42
	25	.60	.67	.73	.78	.82	.86	.99	1.12	1.25	1.38	1.51	1.64
	50	.66	.73	.79	.84	.89	.93	1.07	1.21	1.35	1.49	1.63	1.77
	100	.72	.79	.85	.91	.96	1.00	1.15	1.30	1.45	1.60	1.75	1.90
2 hours	2	.45	.51	.56	.61	.66	.70	.85	1.00	1.15	1.30	1.45	1.60
	5	.67	.72	.76	.80	.84	.88	1.07	1.26	1.45	1.64	1.83	2.02
	10	.74	.79	.84	.89	.93	.97	1.18	1.39	1.60	1.81	2.02	2.23
	25	.90	.94	.99	1.03	1.08	1.12	1.34	1.56	1.78	2.00	2.22	2.44
	50	.98	1.03	1.07	1.12	1.16	1.21	1.44	1.67	1.90	2.13	2.36	2.59
	100	1.05	1.10	1.15	1.20	1.25	1.30	1.55	1.80	2.05	2.30	2.55	2.80

TABLE 4.--Depth-duration-frequency data for the San Francisco Bay region--Continued

Duration	Recurrence interval (years) \ P_{MA}	Storm precipitation, in inches, corresponding to indicated values of mean annual precipitation (P_{MA}), in inches											
		10	12	14	16	18	20	30	40	50	60	70	80
3 hours	2	0.63	0.68	0.72	0.77	0.81	0.86	1.09	1.32	1.55	1.78	2.01	2.24
	5	.78	.84	.89	.95	1.00	1.06	1.34	1.62	1.90	2.18	2.46	2.74
	10	.91	.97	1.03	1.10	1.16	1.22	1.53	1.84	2.15	2.46	2.77	3.08
	25	1.03	1.10	1.16	1.23	1.29	1.36	1.69	2.02	2.35	2.68	3.01	3.34
	50	1.14	1.21	1.28	1.34	1.41	1.48	1.82	2.16	2.50	2.84	3.18	3.52
	100	1.25	1.32	1.39	1.46	1.53	1.60	1.95	2.30	2.65	3.00	3.35	3.70
6 hours	2	.91	.99	1.07	1.16	1.24	1.32	1.73	2.14	2.55	2.96	3.37	3.78
	5	1.14	1.25	1.36	1.46	1.57	1.68	2.22	2.76	3.30	3.84	4.38	4.92
	10	1.30	1.42	1.54	1.66	1.78	1.90	2.50	3.10	3.70	4.30	4.90	5.50
	25	1.46	1.59	1.72	1.86	1.99	2.12	2.78	3.44	4.10	4.76	5.42	6.08
	50	1.60	1.74	1.88	2.02	2.16	2.30	3.00	3.70	4.40	5.10	5.80	6.50
	100	1.73	1.88	2.02	2.17	2.31	2.46	3.19	3.92	4.65	5.38	6.11	6.84
12 hours	2	1.04	1.18	1.33	1.47	1.62	1.76	2.48	3.20	3.92	4.64	5.36	6.08
	5	1.44	1.61	1.78	1.94	2.11	2.28	3.12	3.96	4.80	5.64	6.48	7.32
	10	1.70	1.88	2.06	2.24	2.42	2.60	3.50	4.40	5.30	6.20	7.10	8.00
	25	1.90	2.10	2.30	2.50	2.70	2.90	3.90	4.90	5.90	6.90	7.90	8.90
	50	2.15	2.36	2.57	2.78	2.99	3.20	4.25	5.30	6.35	7.40	8.45	9.50
	100	2.35	2.57	2.79	3.01	3.23	3.45	4.55	5.65	6.75	7.85	8.95	10.05

TABLE 4.--Depth-duration-frequency data for the San Francisco Bay region--Continued

Duration	Recurrence interval (years) \ P_{MA}	Storm precipitation, in inches, corresponding to indicated values of mean annual precipitation (P_{MA}), in inches											
		10	12	14	16	18	20	30	40	50	60	70	80
1 day	2	1.20	1.40	1.60	1.80	2.00	2.20	3.20	4.20	5.20	6.20	7.20	8.20
	5	1.60	1.86	2.12	2.38	2.64	2.90	4.20	5.50	6.80	8.10	9.40	10.70
	10	1.90	2.20	2.50	2.80	3.10	3.40	4.90	6.40	7.90	9.40	10.90	12.40
	25	2.25	2.60	2.95	3.30	3.65	4.00	5.75	7.50	9.25	11.00	12.75	14.50
	50	2.60	2.98	3.36	3.74	4.12	4.50	6.40	8.30	10.20	12.10	14.00	15.90
	100	2.85	3.26	3.67	4.08	4.49	4.90	6.95	9.00	11.05	13.10	15.15	17.20
2 days	2	1.52	1.78	2.05	2.31	2.58	2.84	4.16	5.48	6.80	8.12	9.44	10.76
	5	2.00	2.38	2.76	3.14	3.52	3.90	5.80	7.70	9.60	11.50	13.40	15.30
	10	2.30	2.76	3.22	3.68	4.14	4.60	6.90	9.20	11.50	13.80	16.10	18.40
	25	2.75	3.30	3.85	4.40	4.95	5.50	8.25	11.00	13.75	16.50	19.25	22.00
	50	3.05	3.66	4.27	4.88	5.49	6.10	9.15	12.20	15.25	18.30	21.35	24.40
	100	3.40	4.08	4.76	5.44	6.12	6.80	10.20	13.60	17.00	20.40	23.80	27.20
3 days	2	1.60	1.92	2.24	2.56	2.88	3.20	4.80	6.40	8.00	9.60	11.20	12.80
	5	2.20	2.64	3.08	3.52	3.96	4.40	6.60	8.80	11.00	13.20	15.40	17.60
	10	2.60	3.12	3.64	4.16	4.68	5.20	7.80	10.40	13.00	15.60	18.20	20.80
	25	3.06	3.67	4.28	4.90	5.51	6.12	9.18	12.24	15.30	18.36	21.42	24.48
	50	3.40	4.08	4.76	5.44	6.12	6.80	10.20	13.60	17.00	20.40	23.80	27.20
	100	3.70	4.44	5.18	5.92	6.66	7.40	11.10	14.80	18.50	22.20	25.90	29.60

TABLE 4.--Depth-duration-frequency data for the San Francisco Bay region--Continued

Duration	P_{MA} / Recurrence interval (years)	Storm precipitation, in inches, corresponding to indicated values of mean annual precipitation (P_{MA}), in inches											
		10	12	14	16	18	20	30	40	50	60	70	80
4 days	2	1.75	2.10	2.45	2.80	3.15	3.50	5.25	7.00	8.75	10.50	12.25	14.00
	5	2.40	2.88	3.36	3.84	4.32	4.80	7.20	9.60	12.00	14.40	16.80	19.20
	10	2.85	3.42	3.99	4.56	5.13	5.70	8.55	11.40	14.25	17.10	19.95	22.80
	25	3.40	4.08	4.76	5.44	6.12	6.80	10.20	13.60	17.00	20.40	23.80	27.20
	50	3.80	4.56	5.32	6.08	6.84	7.60	11.40	15.20	19.00	22.80	26.60	30.40
	100	4.20	5.04	5.88	6.72	7.56	8.40	12.60	16.80	21.00	25.20	29.40	33.60
5 days	2	1.85	2.22	2.59	2.96	3.33	3.70	5.55	7.40	9.25	11.10	12.95	14.80
	5	2.60	3.12	3.64	4.16	4.68	5.20	7.80	10.40	13.00	15.60	18.20	20.80
	10	3.00	3.60	4.20	4.80	5.40	6.00	9.00	12.00	15.00	18.00	21.00	24.00
	25	3.60	4.32	5.04	5.76	6.48	7.20	10.80	14.40	18.00	21.60	25.20	28.80
	50	4.00	4.80	5.60	6.40	7.20	8.00	12.00	16.00	20.00	24.00	28.00	32.00
	100	4.40	5.28	6.16	7.04	7.92	8.80	13.20	17.60	22.00	26.40	30.80	35.20
6 days	2	2.00	2.40	2.80	3.20	3.60	4.00	6.00	8.00	10.00	12.00	14.00	16.00
	5	2.80	3.36	3.92	4.48	5.04	5.60	8.40	11.20	14.00	16.80	19.60	22.40
	10	3.25	3.90	4.55	5.20	5.85	6.50	9.75	13.00	16.25	19.50	22.75	26.00
	25	3.85	4.62	5.39	6.16	6.93	7.70	11.55	15.40	19.25	23.10	26.95	30.80
	50	4.30	5.16	6.02	6.88	7.74	8.60	12.90	17.20	21.50	25.80	30.10	34.40
	100	4.70	5.64	6.58	7.52	8.46	9.40	14.10	18.80	23.50	28.20	32.90	37.60

TABLE 4.--Depth-duration-frequency data for the San Francisco Bay region--Continued

Duration	P_{MA} / Recurrence interval (years)	Storm precipitation, in inches, corresponding to indicated values of mean annual precipitation (P_{MA}), in inches											
		10	12	14	16	18	20	30	40	50	60	70	80
8 days	2	2.25	2.70	3.15	3.60	4.05	4.50	6.75	9.00	11.25	13.50	15.75	18.00
	5	3.05	3.66	4.27	4.88	5.49	6.10	9.15	12.20	15.25	18.30	21.35	24.40
	10	3.50	4.20	4.90	5.60	6.30	7.00	10.50	14.00	17.50	21.00	24.50	28.00
	25	4.10	4.92	5.74	6.56	7.38	8.20	12.30	16.40	20.50	24.60	28.70	32.80
	50	4.50	5.40	6.30	7.20	8.10	9.00	13.50	18.00	22.50	27.00	31.50	36.00
	100	4.90	5.88	6.86	7.84	8.82	9.80	14.70	19.60	24.50	29.40	34.30	39.20
10 days	2	2.45	2.94	3.43	3.92	4.41	4.90	7.35	9.80	12.25	14.70	17.15	19.60
	5	3.30	3.96	4.62	5.28	5.94	6.60	9.90	13.20	16.50	19.80	23.10	26.40
	10	3.80	4.56	5.32	6.08	6.84	7.60	11.40	15.20	19.00	22.80	26.60	30.40
	25	4.40	5.28	6.16	7.04	7.92	8.80	13.20	17.60	22.00	26.40	30.80	35.20
	50	4.80	5.76	6.72	7.68	8.64	9.60	14.40	19.20	24.00	28.80	33.60	38.40
	100	5.20	6.24	7.28	8.32	9.36	10.40	15.60	20.80	26.00	31.20	36.40	41.60
15 days	2	2.85	3.42	3.99	4.56	5.13	5.70	8.55	11.40	14.25	17.10	19.95	22.80
	5	3.80	4.56	5.32	6.08	6.84	7.60	11.40	15.20	19.00	22.80	26.60	30.40
	10	4.40	5.28	6.16	7.04	7.92	8.80	13.20	17.60	22.00	26.40	30.80	35.20
	25	5.10	6.12	7.14	8.16	9.18	10.20	15.30	20.40	25.50	30.60	35.70	40.80
	50	5.60	6.72	7.84	8.96	10.08	11.20	16.80	22.40	28.00	33.60	39.20	44.80
	100	6.10	7.32	8.54	9.76	10.98	12.20	18.30	24.40	30.50	36.60	42.70	48.80

TABLE 4.--Depth-duration-frequency data for the San Francisco Bay region--Continued

Duration	P_{MA} / Recurrence interval (years)	Storm precipitation, in inches, corresponding to indicated values of mean annual precipitation (P_{MA}), in inches											
		10	12	14	16	18	20	30	40	50	60	70	80
20 days	2	3.10	3.72	4.34	4.96	5.58	6.20	9.30	12.40	15.50	18.60	21.70	24.80
	5	4.25	5.10	5.95	6.80	7.65	8.50	12.75	17.00	21.25	25.50	29.75	34.00
	10	4.90	5.88	6.86	7.84	8.82	9.80	14.70	19.60	24.50	29.40	34.30	39.20
	25	5.70	6.84	7.98	9.12	10.26	11.40	17.10	22.80	28.50	34.20	39.90	45.60
	50	6.30	7.56	8.82	10.08	11.34	12.60	18.90	25.20	31.50	37.80	44.10	50.40
	100	6.80	8.16	9.52	10.88	12.24	13.60	20.40	27.20	34.00	40.80	47.60	54.40
30 days	2	3.70	4.44	5.18	5.92	6.66	7.40	11.10	14.80	18.50	22.20	25.90	29.60
	5	5.00	6.00	7.00	8.00	9.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00
	10	5.80	6.96	8.12	9.28	10.44	11.60	17.40	23.20	29.00	34.80	40.60	46.40
	25	6.70	8.04	9.38	10.72	12.06	13.40	20.10	26.80	33.50	40.20	46.90	53.60
	50	7.35	8.82	10.29	11.76	13.23	14.70	22.05	29.40	36.75	44.10	51.45	58.80
	100	8.00	9.60	11.20	12.80	14.40	16.00	24.00	32.00	40.00	48.00	56.00	64.00
60 days	2	5.30	6.36	7.42	8.48	9.54	10.60	15.90	21.20	26.50	31.80	37.10	42.40
	5	7.20	8.64	10.08	11.52	12.96	14.40	21.60	28.80	36.00	43.20	50.40	57.60
	10	8.25	9.90	11.55	13.20	14.85	16.50	24.75	33.00	41.25	49.50	57.75	66.00
	25	9.50	11.40	13.30	15.20	17.10	19.00	28.50	38.00	47.50	57.00	66.50	76.00
	50	10.50	12.60	14.70	16.80	18.90	21.00	31.50	42.00	52.50	63.00	73.50	84.00
	100	11.30	13.56	15.82	18.08	20.34	22.60	33.90	45.20	56.50	67.80	79.10	90.40

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