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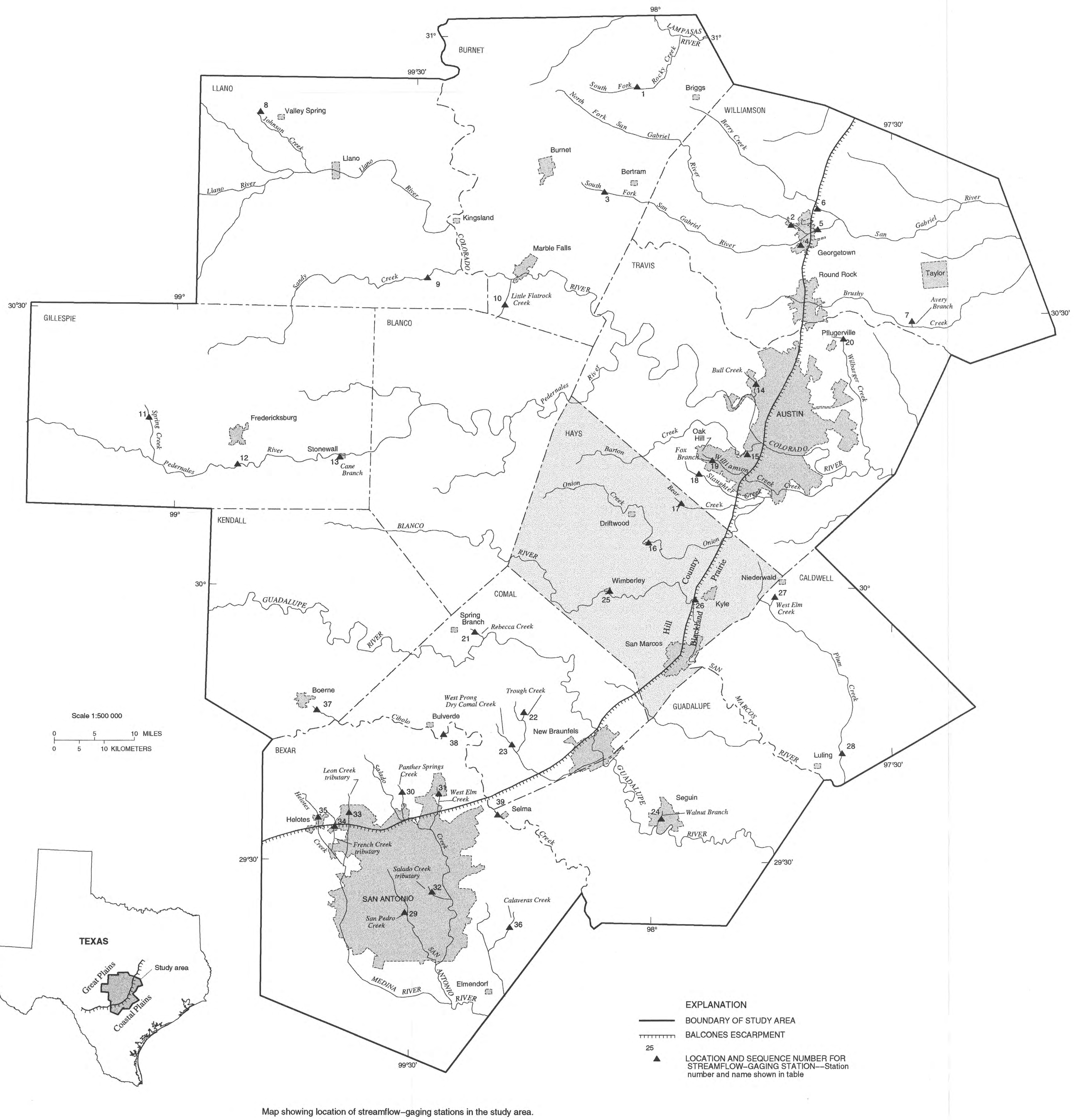
Multiple-regression equations to estimate peak-flow
frequency from streams in Hays County, Texas



Map showing location of streamflow–gaging stations in the study area.

INTRODUCTION

Equations were developed to estimate peak-flow frequencies for streams in an area encompassing Hays County, Tex., and 11 other counties immediately adjacent to or one county away from Hays County (see map). The study area and Hays County are intersected by the Balcones escarpment, a line of low hills that divides the vast Great Plains physiographic province (locally, the Hill Country in Hays County) from the Coastal Plains (locally, the Blackland Prairie in Hays County). Northwest of the escarpment, the landscape is characterized by plateau uplands and ruggedly dissected limestone hills covered by thin, stoney soils. Southeast of the escarpment, the terrain changes to rolling prairies and broad river bottoms with thick, clayey soils (Abbott and Woodruff, 1986, preface).

The mean annual precipitation for 1951–80 ranges from about 26 in. at the western edge of Gillespie County to about 36 in. at the eastern edge of Caldwell County (Riggio and others, 1987, p. 23). Most of the streamflow-gaging stations used for this investigation, however, are along the Balcones escarpment, where the mean annual precipitation ranges from about 29 to about 34 in. The entire study area is within a homogeneous meteorologic region and is subject to large storms—the cause for large floods in the region (Baker, 1975, p. 1–2).

The purpose of this report is to present and qualify equations to estimate peak-flow frequency for large streams with natural drainage basins in Hays County. The study was made in cooperation with the Federal Emergency Management Agency and the U.S. Army Corps of Engineers. In this report, peak-flow frequency represents the peak discharges for recurrence intervals of 2, 5, 10, 25, 50, and 100 years. A large stream is defined as having a drainage area of at least 0.3 mi^2; and a natural drainage basin is a basin for which the annual peak discharges are not affected by reservoirs, regulations, diversions, urbanization, or other human-related activities.

Many large storms and catastrophic floods have occurred along the Balcones escarpment (Caran and Baker, 1986; and Slade, 1986). About a dozen storms, with precipitation depths exceeding 15 in. in a few days or less, have been documented in this area during the past 60 years. Some of these storms have produced world-record precipitation depths for durations less than 48 hours. One large storm, in May 1929, contributed more than 15 in. of rain, mostly in 2 days, on much of Hays County (Slade, 1986). Only one station, Blanco River near Kyle. (sequence no. 26, see map), was in operation in Hays County during the 1929 flood; therefore, the storm's peak discharge is documented for only one station in the county. The documentation of this and other large storms indicates that they are not uniformly distributed temporally or areally; therefore, the recurrence intervals for these storms cannot be verified (Slade, 1986, p. 17). These large storms in the study area can cause some flood peaks which would exceed those that can be predicted accurately by analyses of available precipitation or flood data.

APPROACH

The peak-flow frequency was estimated for each qualified streamflow-gaging station in the study area. Equations to estimate peak-flow frequency then were developed based on the mathematical relation between values for the peak-flow frequency and the basin characteristics for the stations. Only four of the stations are in Hays County—an insufficient number of stations for this analysis. Therefore, a larger study area including 39 stations was selected to provide sufficient data for the approach.

Qualified streamflow-gaging stations are those with at least 8 years of data from natural basins of less than 500 mi^2 (see map, table). Stations with drainage areas exceeding 500 mi^2 were excluded from the investigation because there are no streams with basins exceeding that size in Hays County. The entire available period of systematic record was used for each station except for the stations North Fork San Gabriel River near Georgetown (sequence no. 2); Plum Creek near Luling (sequence no. 28); Cibolo Creek near Boerne (sequence no. 37); and Cibolo Creek at Selma (sequence no. 39). One or more reservoirs completed in the basin of each of these stations during the period of systematic record caused the annual peak discharges to become regulated. The regulated annual peak discharges for these stations were excluded from this analysis (see table).

PEAK-FLOW FREQUENCY FOR STREAMFLOW-GAGING STATIONS

Peak-streamflow discharges are monitored at each of the qualified stations in the study area. The stations have various periods of systematic record, as identified on the table. The systematic record represents the data collected from the time the station is established until it is discontinued. The peak discharges used in this investigation include the largest peak discharge for each year of systematic record (annual peak discharge) and all known historical peak discharges. A historical peak discharge—documented by newspaper articles, personal recollections, or other historical sources—represents the largest peak discharge since a known date preceding the beginning of the systematic record. The historical record is the number of years represented by the historical peaks. For example, 30 years of systematic record (from 1963–1992) exist for the station South Fork Rocky Creek near Briggs (sequence no. 1 on table). However, the 1976 peak discharge is the highest since 1904 or before, according to a local resident. Thus, that peak is the largest in at least 89 years (1904–92). The minimum length for the historical record, therefore, is 89 years. Historical peak discharges can occur before or within the systematic record.

The annual and historical peak discharges for each station were used, together with U.S. Geological Survey computer program J–407 (U.S. Geological Survey, 1979, p. C1–C57), to estimate peak discharges for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals (see table). The computer program follows the procedures established by the IACWD (Interagency Advisory Committee on Water Data, 1982). The length of the historical record used in the calculations (see table) represents the minimum length as described above.

A different analysis of peak-flow frequency was done for the station Blanco River near Kyle (sequence no. 26 see table) because the station is in Hays County (the subject county) and has limited years of systematic record compared to a nearby station on the same river (Blanco River at Wimberley, sequence no. 25). The station near Wimberley has 66 years of systematic record (1925–26, 1929–92), and the station near Kyle has only 36 years of systematic record (1957–92). Historical peak discharges in 1929 and 1952 also are available for each station. Linear regression was used to relate the 38 annual peak discharges for the common years for the two stations. The correlation coefficient for the regression is 0.99; and the mean error of prediction is about 14 percent for one-half of the annual peak discharges—those with the largest values. The annual peak discharges for the two stations, therefore, are highly correlated. The regression was used to estimate the Kyle station annual peak discharges for the years of record available for the Wimberley station but not available for the Kyle station (1925–26, 1929–56). The estimated annual peak discharges were used, with the systematic and historical peak discharges, to estimate peak-flow frequency for the station Blanco River near Kyle (see table).

An analysis was done for the generalized skew coefficients of the distribution for the annual peak discharges, based on the data for the stations with long-term systematic records in the study area. A skew coefficient was calculated for each of 13 stations in the study area—those with at least 20 years of systematic record. The mean value for the skew coefficients is -0.25, which approximates, for the study area, the values for the generalized skew coefficients presented by the IACWD—about -0.22 to about -0.26. The generalized skew coefficients from the IACWD, therefore, were used as the generalized skew coefficients in the calculations for the peak-flow frequency for the stations in the study area. A generalized skew coefficient was used for each station, along with a calculated skew coefficient, to determine a weighted skew coefficient as described by the IACWD. A weighted skew coefficient then was used in the calculations of the peak-flow frequency for each station.

SELECTED BASIN CHARACTERISTICS FOR STREAMFLOW-GAGING STATIONS

Selected basin characteristics were aggregated for each station (see table). Only those characteristics considered pertinent to estimate peak-flow frequency were used—contributing drainage area, stream length, stream slope, and shape factor. These characteristics were identified as being pertinent during a previous investigation of peak-discharge frequency in Texas (Schroeder and Massey, 1977). The contributing drainage area is expressed in square miles. The stream length represents the length, in miles, of the longest mapped channel from the gaging station to the drainage divide at the headwaters, based on quadrangle maps prepared by the U.S. Geological Survey (scale, 1:100,000). The stream slope is the ratio (1) of change in elevation of the longest mapped channel from the station to the drainage divide to (2) the length of the longest mapped channel. The shape factor is the ratio of the square of the stream length to the drainage area, which mathematically represents the ratio of the longest stream length to the mean width of the basin.

MULTIPLE-REGRESSION EQUATIONS TO ESTIMATE PEAK-FLOW FREQUENCY

A generalized least-squares multiple-regression analysis (Tasker and Stedinger, 1989) was done for the values represented by the peak discharges for the recurrence intervals and the basin characteristics. The 2-, 5-, 10-, 25-, 50-, and 100-year peak discharges, respectively, were used as the dependent variable, and the basin characteristics were used as the independent variables. The dependent and independent variables were transformed to their common (base 10) logarithms before the analysis. Empirical equations (G.D. Tasker, U.S. Geological Survey, oral commun., 1994) were used to calculate a weight factor for weighting the value of the record length for each station based on the number of years of systematic record, the number of historical peaks, and the number of years of historical record (see table). Mathematical correlations between the stations were determined (based on the common logarithms of their annual peak discharges) and a relation of these correlations and distance between stations was used in the regression analysis in order to minimize the effects of the stations with related data.

Equations were developed to estimate 2-, 5-, 10-, 25-, 50-, and 100-year peak discharges. The independent variable "stream length" was excluded from the analysis because it is highly correlated with the variable "contributing drainage area," which had the largest correlation coefficient with the dependent variables. Many equations were developed for each recurrence interval using various combinations of the three remaining independent variables (contributing drainage area, stream slope, and shape factor). All equations chosen have only 1 or 2 independent variables; and, except for the 2-year equation, are those that produced the lowest mean standard error of prediction. The equations are shown below, along with each mean standard error of prediction.

Equation for indicated T-year peak discharge (cubic feet per second)	Mean standard error of prediction (percent)
$Q_2 = 252\,(CDA)^{0.721}(SF)^{-0.326}$	51
$Q_5 = 525\,(CDA)^{0.648}$	34
$Q_{10} = 732\,(CDA)^{0.667}$	30
$Q_{25} = 1034\,(CDA)^{0.686}$	30
$Q_{50} = 408\,(CDA)^{0.768}(SS)^{0.281}$	30
$Q_{100} = 416\,(CDA)^{0.788}(SS)^{0.325}$	31

Where Q_T = discharge, for given (T-year) recurrence interval, in cubic feet per second;
CDA = contributing drainage area, in square miles;
SF = shape factor; and
SS = stream slope, in feet per mile.

The equations reveal the relation between the independent variables and peak discharges for the various recurrence intervals. For example, the exponent for the shape factor is -0.326 for the equation estimating the 2-year peak discharge and is approximately 0 (and therefore not used) in the equations for the 5-year and longer recurrence intervals. Large values for the shape factor result in large estimated values for the 2-year peak discharges, but the shape factor is not important in estimating peak discharges for recurrence intervals exceeding 2 years. The stream slope is not needed in the equations for the 25-year and smaller recurrence intervals, which indicates that the stream slope is not important for estimating peak discharges with smaller recurrence intervals. Stream slope influences estimated peak discharges with larger recurrence intervals and thus appears in the 50- and the 100-year equations.

These equations can be used to estimate peak-flow frequency for streams with natural basins in Hays County, except for two specific reaches on the Blanco River. The two reaches that are exceptions are in the vicinity of the stations Blanco River at Wimberley and Blanco River near Kyle (sequence no. 25 and 26). Many years of peak-discharge data and two or more historical peak discharges exist for each of these stations, and the peak-discharge frequency (see table) can be used with greater confidence than those derived from the regression equations. Two other stations, Onion Creek near Driftwood, and Bear Creek below FM Road 1826 near Driftwood (sequence no. 16 and 17), are also in Hays County and were included in this investigation. Only 13 years of annual peak discharges exist for each of these stations; therefore, the regression equations are more appropriate to estimate peak-flow frequency for these streams.

The equations are based on streams in or near Hays County for which the annual peak discharges are not affected by reservoirs, regulations, diversions, urbanization, or other human-related activities. The equations, therefore, are applicable for similarly characterized streams in Hays County. Also, the equations are not applicable for streams with basins that have values for contributing drainage area, channel slope, or shape factor outside the range of the values for the stations used in the equations. The contributing drainage areas for the stations range from 0.18 to 412 mi^2, but only one station has a basin smaller than 0.3 mi^2. Thus the equations can be used for streams with drainage areas between 0.3 and 412 mi^2. Likewise, the stream slopes range from 12.56 to about 155 ft/mi. Therefore the equations apply to streams with stream slopes within that range. The shape factors for the stations range from 0.45 to 16.45. However, the factors for 31 of the 39 stations are between 1.8 and 11.0; therefore, the equations can be used for streams with shape factors within that range.

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CONVERSION FACTORS

Multiply	By	To obtain
cubic foot (ft^3)	0.0283	cubic meter
cubic foot per second (ft^3/s)	0.0283	cubic meter per second
foot (ft)	0.3048	meter
foot per mile (ft/mi)	1.89	meter per kilometer
inch (in.)	25.40	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Table Selected basin characteristics and peak-flow frequency for streamflow-gaging stations in Hays County and adjacent area, Texas

[mi^2, square miles; mi, mile; ft/mi, feet per mile; yr, years; ft^3/s, cubic feet per second; FM, Farm to Market; trib., tributary]

Sequence no.	Station no.	Station name	Latitude	Longitude	Available period of systematic record[1]	Contributing drainage area (mi^2)	Stream length (mi)	Stream slope (ft/mi)	Shape factor (dimensionless)	Available systematic record (yr)	No. of historical peaks	Historical record (yr)	Weight factor (yr)	Peak discharge for indicated recurrence interval (ft^3/s): 2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
1	08103900	South Fork Rocky Creek near Briggs, Tex.	30°54'41"	98°02'12"	1963–92	33.30	11.44	36.15	3.93	30	1	89	51	3,060	6,710	9,810	14,400	18,200	22,300
2	08104700	North Fork San Gabriel River near Georgetown, Tex.	30°39'42"	97°42'40"	[2]1969–92	248.00	47.70	16.30	9.17	11	0	11	11	7,080	15,900	24,200	37,800	50,600	65,600
3	08104850	South Fork San Gabriel River near Bertram, Tex.	30°43'14"	98°06'15"	1967–74	8.90	5.42	41.75	3.30	8	0	8	8	686	1,800	3,000	5,190	7,400	10,200
4	08104900	South Fork San Gabriel River at Georgetown, Tex.	30°37'32"	97°41'27"	1968–92	133.00	38.03	19.84	10.88	25	0	25	25	7,380	15,000	21,300	30,300	37,700	45,600
5	08105000	San Gabriel River at Georgetown, Tex.	30°39'14"	97°39'18"	1935–73	405.00	52.23	16.02	6.74	39	2	122	70	12,900	27,000	39,500	58,900	76,100	95,600
6	08105100	Berry Creek near Georgetown, Tex.	30°41'28"	97°39'21"	1968–92	83.10	28.01	16.04	9.44	25	0	25	25	4,351	7,976	10,800	14,790	18,010	21,440
7	08105900	Avery Branch near Taylor, Tex.	30°29'11"	97°27'27"	1967–74	3.52	2.74	13.17	2.13	8	0	8	8	683	1,180	1,590	2,200	2,720	3,310
8	08151300	Johnson Creek near Valley Spring, Tex.	30°51'38"	98°49'52"	1967–74	5.66	5.44	75.95	5.23	8	0	8	8	243	900	1,720	3,360	5,100	7,360
9	08152000	Sandy Creek near Kingsland, Tex.	30°33'30"	98°28'19"	1967–92	346.00	48.34	24.84	6.75	26	1	112	56	8,960	18,800	27,400	40,700	52,200	65,100
10	08152700	Little Flatrock Creek near Marble Falls, Tex.	30°30'52"	98°18'44"	1967–74	3.20	3.98	39.57	4.95	8	0	8	8	226	753	1,370	2,550	3,760	5,280
11	08152800	Spring Creek near Fredericksburg, Tex.	30°18'09"	99°03'23"	1967–74	15.20	6.09	47.40	2.44	8	0	8	8	668	2,030	3,640	6,850	10,300	15,000
12	08152900	Pedernales River near Fredericksburg, Tex.	30°13'13"	98°52'10"	1979–92	369.00	38.81	17.64	4.08	14	1	86	40	8,330	23,000	36,900	58,800	77,800	98,600
13	08153100	Cane Branch at Stonewall, Tex.	30°14'07"	98°39'21"	1966–74	1.37	2.94	64.29	6.31	9	0	9	9	47	134	240	453	692	1,020
14	08154700	Bull Creek at Loop 360 near Austin, Tex.	30°22'19"	97°47'04"	1979–92	22.30	9.40	48.16	3.96	14	0	14	14	3,070	7,880	12,200	18,700	24,200	30,000
15	08155300	Barton Creek at Loop 360, Austin, Tex.	30°14'40"	97°48'07"	1980–92	116.00	43.53	18.92	16.33	13	1	64	32	3,740	13,400	23,700	41,100	56,600	73,900
16	08158700	Onion Creek near Driftwood, Tex.	30°04'59"	98°00'29"	1980–92	124.00	31.99	15.59	8.25	13	0	13	13	3,370	8,480	13,400	21,300	28,600	36,900
17	08158810	Bear Creek below FM 1826 near Driftwood, Tex.	30°09'19"	97°56'23"	1980–92	12.20	5.49	55.55	2.47	13	1	69	34	938	3,420	6,480	12,500	18,800	26,800
18	08158840	Slaughter Creek at FM 1826 near Austin, Tex.	30°12'32"	97°54'11"	1980–92	8.24	4.20	52.32	2.14	13	0	13	13	936	2,620	4,390	7,470	10,400	14,000
19	08158900	Fox Branch near Oak Hill, Tex.	30°14'01"	97°52'29"	1966–74	.18	.40	124.32	.89	9	0	9	9	47	98	145	225	302	394
20	08159150	Wilbarger Creek near Pflugerville, Tex.	30°27'16"	97°36'02"	1964–80	4.61	2.99	38.44	1.94	17	1	87	42	573	962	1,240	1,620	1,900	2,190
21	08167600	Rebecca Creek near Spring Branch, Tex.	29°55'06"	98°22'10"	1960–78	10.90	5.57	77.79	2.84	19	0	19	19	1,560	5,100	8,730	14,600	19,800	25,500
22	08168720	Trough Creek near New Braunfels, Tex.	29°46'20"	98°15'58"	1966–74	.48	.70	154.67	1.02	9	1	58	27	76	234	413	746	1,090	1,510
23	08168750	West Prong Dry Comal Creek trib. near New Braunfels, Tex.	29°42'48"	98°17'26"	1966–74	.32	.69	133.14	1.49	9	1	58	27	61	161	265	447	624	841
24	08169750	Walnut Branch at Seguin, Tex.	29°34'47"	97°58'46"	1967–74	5.46	3.80	13.82	2.64	8	0	8	8	727	1,600	2,380	3,600	4,690	5,920
25	08171000	Blanco River at Wimberley, Tex.	29°59'39"	98°05'19"	[3]1925–92	355.00	60.39	19.02	10.27	66	3	124	89	8,170	21,400	34,800	57,800	79,500	106,000
26	08171300	Blanco River near Kyle, Tex.	29°58'45"	97°54'35"	1957–92	412.00	77.08	17.11	14.42	36	2	124	69	9,750	26,400	43,600	73,200	102,000	136,000
27	08172100	West Elm Creek near Niederwald, Tex.	29°59'04"	97°44'39"	1966–74	.44	.57	59.65	.74	9	0	9	9	189	404	588	863	1,100	1,360
28	08173000	Plum Creek near Luling, Tex.	29°41'58"	97°36'12"	[4]1930–92	309.00	42.30	12.56	5.79	34	1	96	56	6,330	15,600	25,400	43,100	61,000	83,800
29	08178500	San Pedro Creek at Furnish St. at San Antonio, Tex.	29°24'22"	98°30'38"	1916–29	2.64	2.66	18.50	2.68	14	0	14	14	591	1,160	1,610	2,260	2,790	3,350
30	08178600	Panther Springs Creek at FM 2696 near San Antonio, Tex.	29°37'31"	98°31'06"	1969–77	9.54	5.09	42.54	2.72	9	0	9	9	763	2,530	4,580	8,400	12,300	17,100
31	08178640	West Elm Creek at San Antonio, Tex.	29°37'23"	98°26'29"	1976–88	2.45	2.52	82.13	2.58	13	0	13	13	297	702	1,080	1,660	2,180	2,770
32	08178736	Salado Creek trib. at Bee St. at San Antonio, Tex.	29°26'37"	98°27'13"	1970–77	.45	.50	64.00	.56	8	0	8	8	284	390	465	564	642	723
33	08181000	Leon Creek trib. at FM 1604, San Antonio, Tex.	29°35'14"	98°37'40"	1969–80	5.57	3.21	71.50	1.85	12	0	12	12	180	808	1,630	3,250	4,920	6,990
34	08181200	French Creek trib. near Helotes, Tex.	29°33'43"	98°39'26"	1966–74	1.08	2.87	82.31	7.63	9	0	9	9	212	466	699	1,070	1,400	1,790
35	08181400	Helotes Creek at Helotes, Tex.	29°34'42"	98°41'29"	1969–92	15.00	8.74	56.70	5.09	24	0	24	24	601	2,783	5,758	11,850	18,360	26,700
36	08182400	Calaveras Creek subwatershed No. 6 near Elmendorf, Tex.	29°22'49"	98°17'33"	1957–77	7.01	3.71	34.45	1.97	21	0	21	21	1,170	2,640	4,000	6,180	8,150	10,400
37	08183900	Cibolo Creek near Boerne, Tex.	29°46'26"	98°41'50"	[5]1963–92	68.40	17.71	35.56	4.59	15	3	101	49	4,590	9,230	13,200	19,100	24,200	29,900
38	08184000	Cibolo Creek near Bulverde, Tex.	29°43'33"	98°25'37"	1946–65	198.00	42.81	22.23	9.25	20	0	20	20	2,330	9,700	18,900	36,300	53,600	74,800
39	08185000	Cibolo Creek at Selma, Tex.	29°35'38"	98°18'39"	[6]1946–92	274.00	67.14	18.47	16.45	35	1	124	65	2,740	13,700	28,000	55,500	82,400	114,000

[1] Stations with available record ending 1992 are still active as of 1994.
[2] Lake Georgetown completed in 1980 within basin. Only peak discharges for 1969–79 used in analysis.
[3] Station discontinued for 2 years during 1927–28.
[4] Many small reservoirs completed in 1964 within basin. Only peak discharges for 1930–63 used in analysis.
[5] Many small reservoirs completed in 1978 within basin. Only peak discharges for 1963–77 used in analysis.
[6] Many small reservoirs completed in 1981 within basin. Only peak discharges for 1946–80 used in analysis.

MULTIPLE-REGRESSION EQUATIONS TO ESTIMATE PEAK-FLOW FREQUENCY FOR STREAMS IN HAYS COUNTY, TEXAS

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