DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS REPORT 88-4218
(SHEET 1 OF 2)

PRECIPITATION

PRECIPITATION, STREAMFLOW, AND BASE FLOW IN WEST-CENTRAL TEXAS, DECEMBER 1974 THROUGH MARCH 1977

INTRODUCTION

Precipitation, streamflow, and base-flow data were analyzed for December 1974 through March 1977 as a part of the Edwards-Trinity Regional Aquifer-Systems Analysis (RASA) project (Bush, 1986). These data are key components in water-budget calculations for estimating recharge in the area underlain by the Edwards-Trinity aquifer system in west-central Texas (fig. 1). The period of record analyzed corresponds to the calibration period of a digital ground-water flow model currently (1988) being constructed. In a simple system the appropriate equations for several components of the water budget are:

$$R = P - ET - SRO, \qquad (1)$$
$$R = BF + DR, \text{ and} \qquad (2)$$
$$TS = BF + SRO \qquad (3)$$

where R is shallow recharge, in inches;
P is precipitation, in inches;
ET is evaportanspiration, in inches;
SRO is surface runoff, in inches;
BF is base flow, in inches;
DR is deep recharge, in inches; and
TS is total streamflow, in inches.

Precipitation and the precipitation departure from normal (1895-1985) (Karl and Knight, 1985a, b, c, d) are presented on sheet 1. Information about total streamflow and base flow is presented on sheet 2.

PHYSIOGRAPHY AND HYDROLOGIC SETTING

The Edwards-Trinity aquifer system in west-central Texas is bounded on the south and east by the Balcones fault zone along the southern and eastern edge of the Hill Country physiographic region (fig. 1). The Hill Country region is characterized by rolling terrain ranging in altitude from 400 to 2,400 ft (Ashworth, 1983, p. 2). The center of the study area is in the Edwards Plateau physiographic region, characterized by "***rolling plains to flat tableland and rugged, steep-walled canyons and draws ***" ranging in altitude from 1,000 to 3,300 ft (Walker, 1979, p. 7). To the west, the Edwards-Trinity aquifer system is bounded by a series of mountain ranges at the center of the Trans-Pecos physiographic region. The Trans-Pecos region is characterized by the flat alluvial valley of the Pecos River in the north and east, the extensively dissected flat plateaus and mesas in the south, and the rugged, high-relief terrain of the Davis Mountains on the west. Altitudes in the Trans-Pecos region range from 1,200 ft in the south to 8,000 ft in the Davis Mountains (Rees, Rhys, and Buckner, 1980, p. 2).

The northwestern part of the study area is in the southern part of the High Plains physiographic region. The High Plains region is flat with few streams. Altitudes in the southern High Plains range from 2,600 ft in the east to 3,300 ft in the west. The northeastern part of the study area is in the Central Minerals physiographic region. The Central Minerals region is hilly with high relief and deeply incised streams. The Central Minerals region is lower in altitude than the Edwards Plateau with altitudes ranging from 1,000 ft near the Colorado and Llano Rivers to 1,800 ft near the Edwards Plateau.

The climate varies from subhumid in the east to arid in the west. There are two rainy seasons, one in spring and one in fall, in the eastern part of the study area. Intense storms may occur in spring, summer, and fall (March through November). In winter (December through February), storms are less intense. Storms in the eastern part of the area usually are widespread. In the western part of the study area, precipitation usually occurs in the summer. These summer storms may be intense, but are local in extent. Precipitation has the greatest spatial variability and the least frequency in the west. Mean annual precipitation (1951-80) throughout the study area varies from 32 inches in the east to 10 inches in the west (fig. 2).

Potential evapotranspiration is a theoretical value representing the maximum quantity of water that could be used by plants if precipitation were sufficient to supply this quantity of water to the soil. Potential evapotranspiration commonly is a mathematical function of temperature and number of daylight hours. In the study area potential evapotranspiration ranges from 36 to 48 in/yr (Geraghty and others, 1973, pl. 13). Actual evapotranspiration is much less than the theoretical value for potential evapotranspiration in the study area because precipitation is much less than potential evapotranspiration. Potential evapotranspiration can be as much as 18 to 38 in/yr greater than precipitation from east to west, respectively.

Four major river basins drain the study area: The Colorado, the Guadalupe, the Nueces, and the Rio Grande. Mean annual streamflow (1951-80) in these basins ranges from 5 in/yr on the Balcones fault zone in the east to less than 0.1 in/yr in the Rio Grande basin in the west (Walter Lear, U.S. Geological Survey, written commun., 1986).

The major aquifers of the Edwards-Trinity system occur in rocks of Cretaceous age. In the Balcones fault zone, the principal aquifer is the Edwards. In the Hill Country, the principal aquifer is the Trinity. In the Edwards Plateau and the Trans-Pecos, the principal aquifer is the Edwards-Trinity. Lithologically, these aquifers are predominantly carbonate with some basal sand formations. In the Trans-Pecos region, the Edwards-Trinity is overlain by and hydraulically connected to the alluvial aquifer near the Pecos River that consists of sediment of Cenozoic age. The High Plains aquifer to the northwest of the Edwards-Trinity aquifer consists of sand of Cenozoic age that is adjacent to and hydraulically connected to the sand of the Edwards-Trinity in the Edwards Plateau. In the Central Minerals region, the Hickory Sandstone and Ellenburger-San Saba (limestone) aquifers consist of older rocks ranging in age from Cambrian to Ordovician. Precambrian rocks of eroded, faulted, and fractured granite also crop out in the region (Walker, 1979, table 2).

Throughout the Central Minerals, Edwards Plateau, Trans-Pecos, and northwestern part of the Hill Country physiographic regions, the Edwards-Trinity aquifer is unconfined to semiconfined. The water table varies from near land surface adjacent to some of the streams to as much as 800 ft below land surface in the mountains. In general, the water table is 100 to 200 ft below the land surface throughout most of the Edwards Plateau. Gradients of the water table indicate ground-water movement toward the headwaters of streams in the Hill Country and toward all streams in the Central Minerals, Edwards Plateau, and Trans-Pecos physiographic regions (Walker, 1979, fig. 15; Rees, Rhys, and Buckner, 1980, fig. 7). In the Edwards aquifer along the Balcones fault zone, water-table conditions exist in a narrow strip of outcrop adjacent to the Hill Country and confined conditions exist downdip from the outcrop. Gradients indicate flow from southwest to northeast along the strike of the fault zone (Maclay and Small, 1986, fig. 23).

PRECIPITATION

The Edwards-Trinity aquifer system in west-central Texas underlies all or part of several climatic divisions. The major divisions are the High Plains, the Trans-Pecos, the Edwards Plateau, and the South Central (fig. 3). Total precipitation was computed using National Weather Service rain-gage data. Thiessen polygons were constructed using monthly data; the data were summed for the 28-month calibration period and divided by 2.333 to convert the values to inches per year. Precipitation ranged from 30 to 45 in/yr in the South Central division within the study area, 13 to 41 in/yr in the Edwards Plateau division, 6 to 21 in/yr in the Trans-Pecos division within the study area, and 16 to 22 in/yr at the two stations in the High Plains division within the study area. Areas of equal 28-month mean precipitation are shown in figure 3.

Precipitation departure from normal (1951-80) was computed for the calibration period by subtracting the mean annual precipitation (fig. 2) for the 30-year period from the areas of equal 28-month mean precipitation, in inches per year (fig. 3). Precipitation ranged from 6 in/yr less than normal to 15 in/yr greater than normal in the major divisions (fig. 4). Because the calibration period is 28 months starting in December, the 28-month mean is biased by an extra winter season.

Seasonal and monthly precipitation departure from normal (1895-1985) has been determined for 344 climatic divisions for the contiguous United States by Karl and Knight (1985a, b, c, d). They analyzed precipitation data for each division and fit the data to a three-parameter Pearson Type III distribution, also known as the gamma distribution.

Seasonal departures from normal for all of Texas are shown in figure 5 for December 1974 through May 1977. Class limits, or ranges, for each category of precipitation are listed in table 1. The probability of occurrence, in percent, shown for each category in figure 5 indicates that seasonal precipitation in either the extremely wet or the extremely dry category has a less than 5-percent chance of occurrence; precipitation in either the very wet or the very dry category has a 10-percent chance of occurrence; precipitation in either the moderately wet or the moderately dry category has a 15-percent chance of occurrence; and near-normal precipitation has a 40-percent chance of occurrence. In the study area during the calibration period, precipitation ranged from near normal to extremely dry from September 1975 through February 1976. Precipitation ranged from near normal to extremely wet from March 1976 through May 1976 and from September 1976 through November 1976 (fig. 5). Winter is the dryest season for the climatic divisions in the study area. During winter 1976-77, the extra season in the 28-month mean, conditions were near normal over most of the study area.

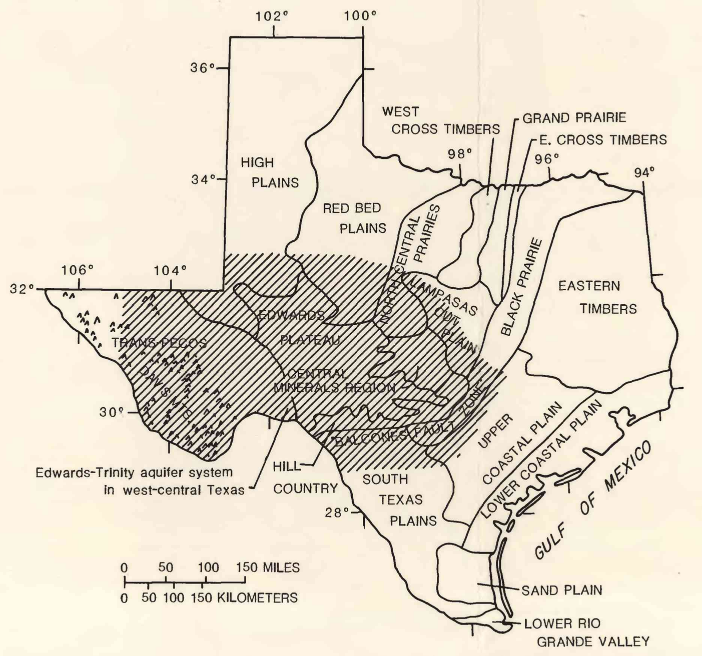


Figure 1.--Physiographic regions of Texas and location of the Edwards-Trinity aquifer system in west-central Texas. (Modified from Kier and others, 1977)

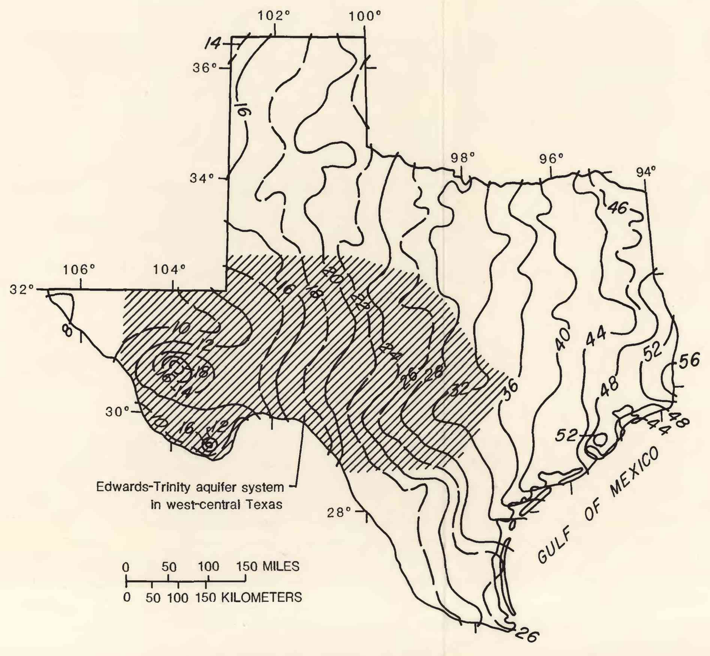


Figure 2.--Mean annual precipitation in inches, 1951-80. (From Riggio and others, 1987, fig. 11)

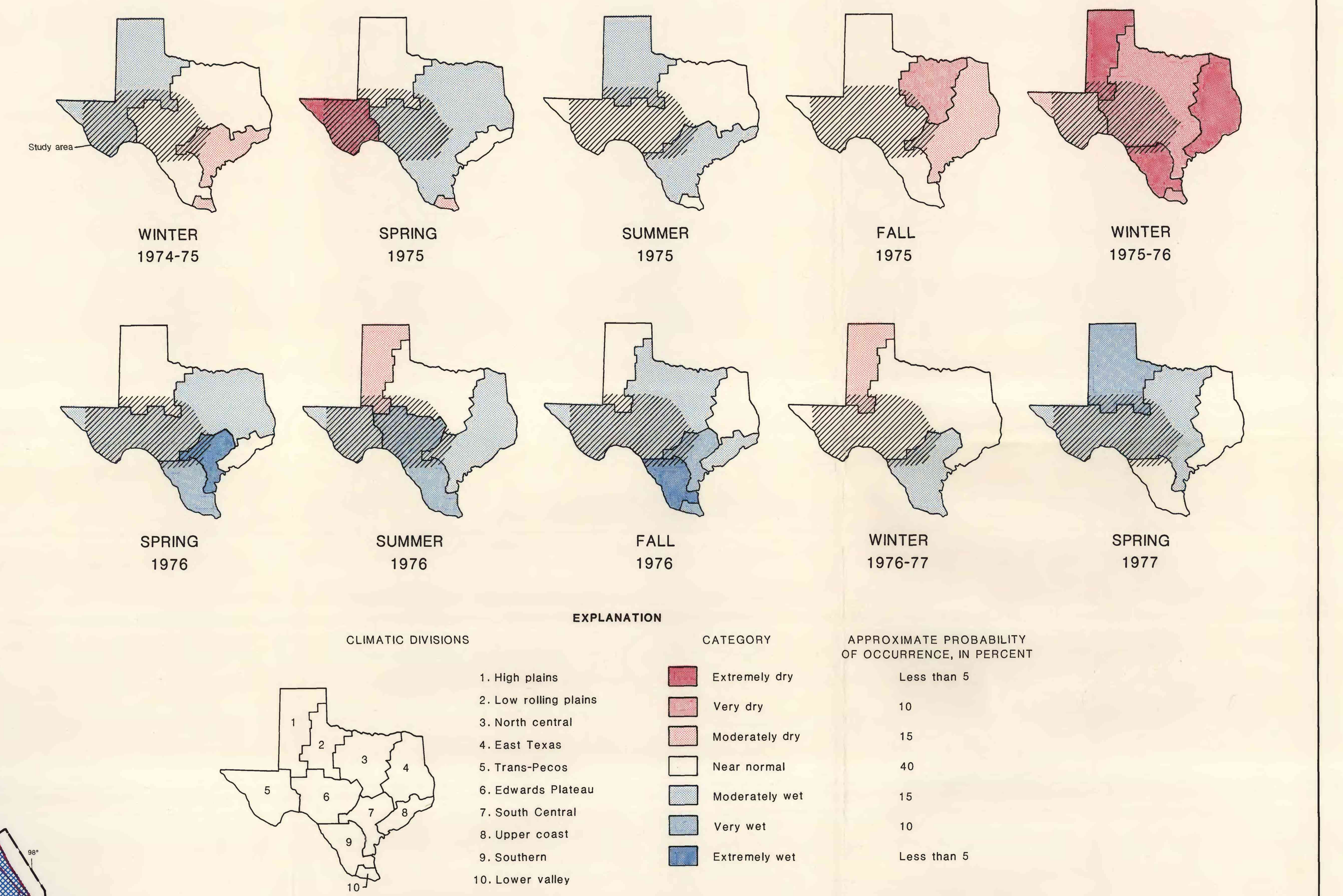


Figure 5.--Seasonal precipitation departures from normal (1895-1985) for the climatic divisions of Texas, December 1974 through May 1977 (Karl and Knight, 1985 a,b,c,d).

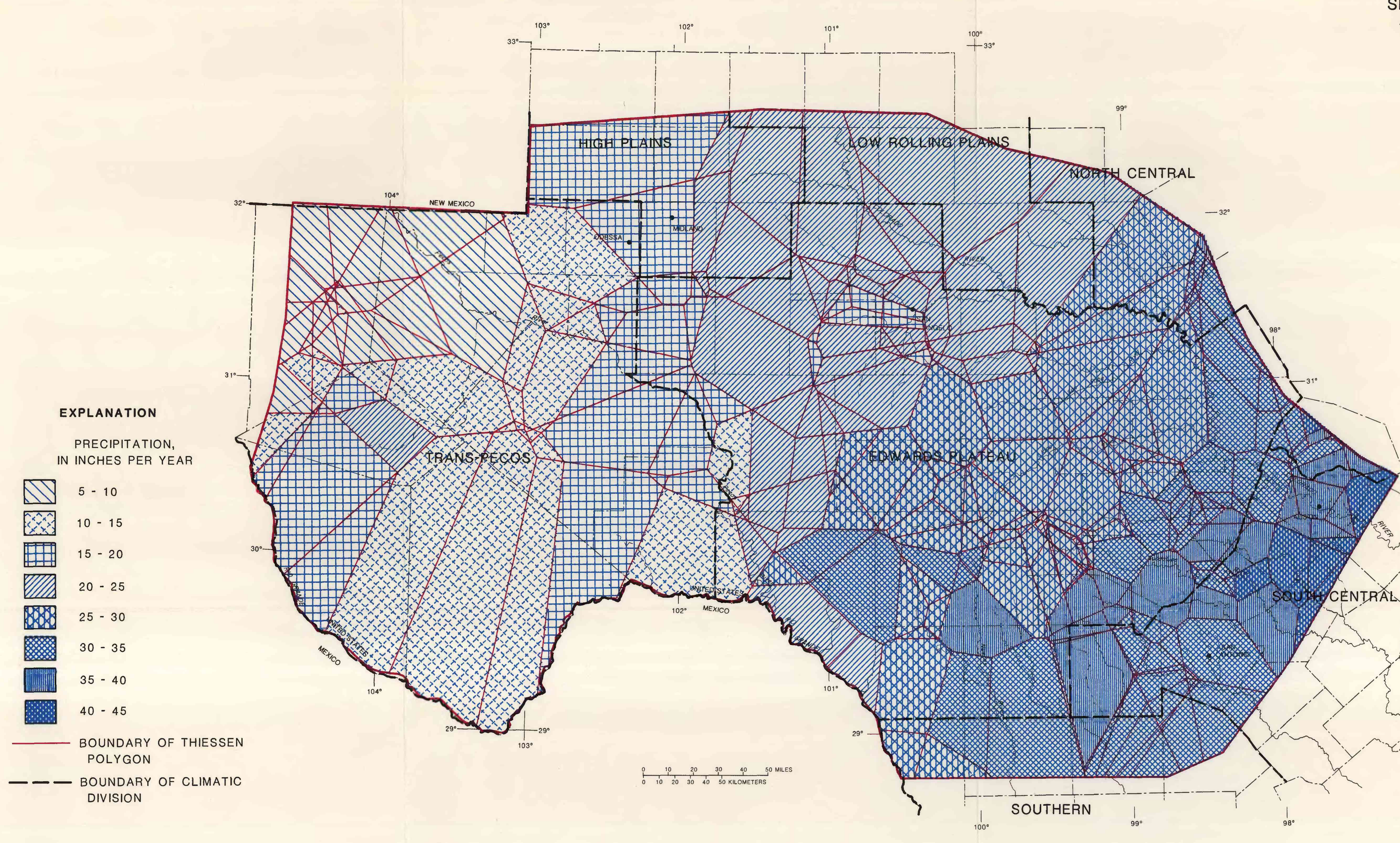
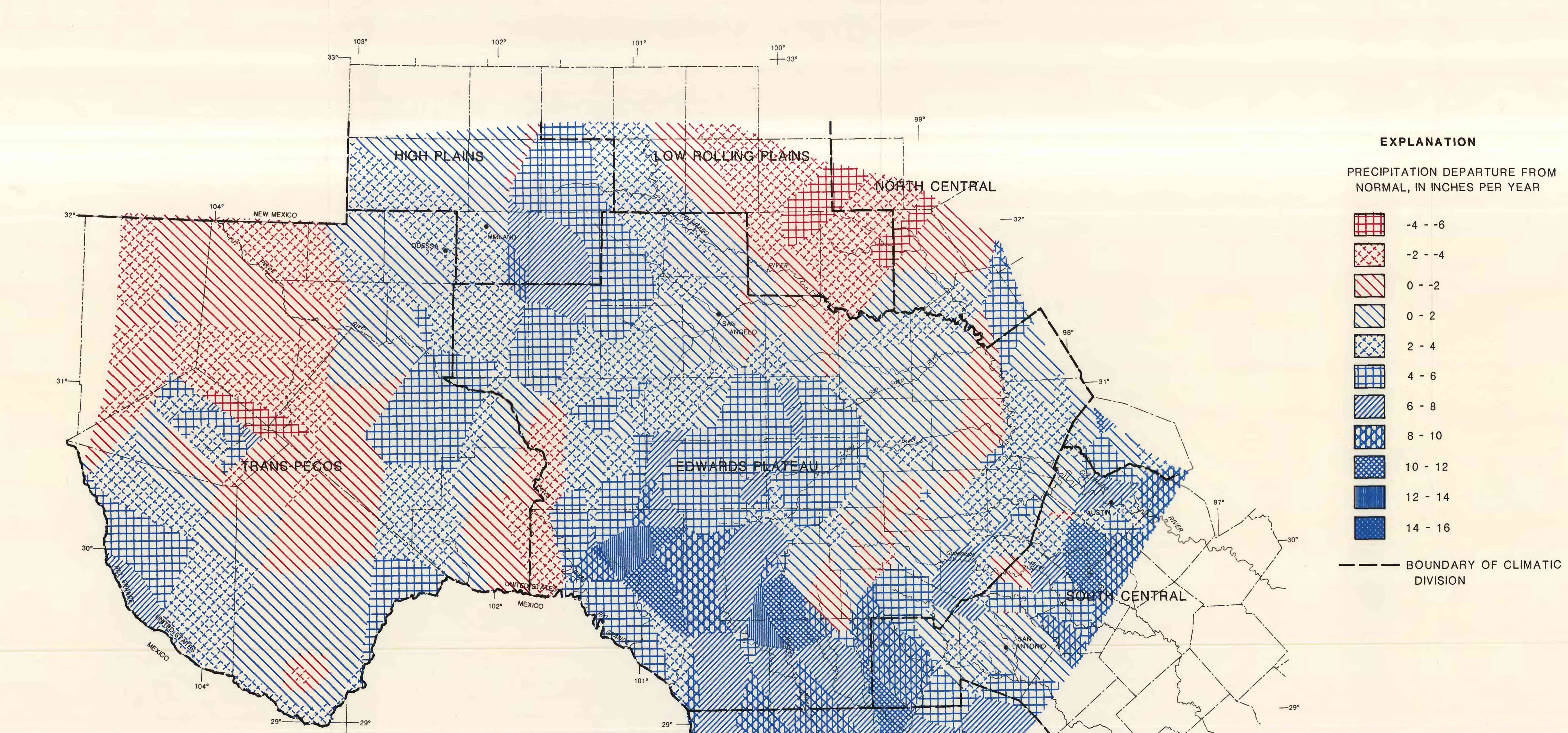


Figure 3.--Areas of equal 28-month mean precipitation in west-central Texas, December 1974 through March 1977.



Base from U.S. Geological Survey State base map, 1985. Lambert conformal conic projection based on standard parallels 33° and 45°

Figure 4.--Areas of equal 28-month mean precipitation departure from normal (1951-80) in west-central Texas, December 1974 through March 1977.

Table 1.--Class limits of seasonal precipitation for the climatic divisions of Texas, in inches
[<, less than; >, more than. Karl and Knight, 1985 a,b,c,d]

Climatic division	Category	Winter Dec.-Feb.	Spring March-May	Summer June-Aug.	Fall Sept.-Nov.
High Plains	Extremely dry	< 0.468	< 2.755	< 3.834	<1.713
	Very dry	0.468- 0.771	2.755- 3.068	3.834- 5.023	1.713- 2.414
	Moderately dry	.772- 1.118	3.069- 3.538	5.024- 6.096	2.415- 3.166
	Near normal	1.119- 2.129	3.539- 5.297	6.097- 8.489	3.167- 5.225
	Moderately wet	2.130- 2.796	5.298- 6.652	8.490- 9.764	5.226- 6.522
	Very wet	2.797- 3.753	6.653- 8.767	9.765- 11.367	6.523- 8.335
	Extremely wet	> 3.753	> 8.767	>11.367	> 8.335
Low Rolling Plains	Extremely dry	> .487	< 4.446	< 2.622	< 2.371
	Very dry	.487- 1.201	4.446- 4.807	2.622- 4.213	2.371- 3.669
	Moderately dry	1.202- 1.901	4.808- 5.357	4.214- 5.575	3.670- 4.855
	Near normal	1.902- 3.637	5.358- 7.435	5.576- 8.410	4.856- 7.544
	Moderately wet	3.638- 4.649	7.436- 9.046	8.411- 9.826	7.545- 8.998
	Very wet	4.650- 5.997	9.047- 11.568	9.827- 11.527	8.999- 10.843
	Extremely wet	> 5.997	>11.568	>11.527	>10.843
North Central	Extremely dry	< 2.418	< 7.208	<2.729	< 3.615
	Very dry	2.418- 3.555	7.208- 7.694	2.729- 4.412	3.615- 5.283
	Moderately dry	3.556- 4.691	7.695- 8.449	4.413- 5.863	5.284- 6.816
	Near normal	4.692- 7.568	8.454- 11.352	5.864- 8.912	6.817- 10.319
	Moderately wet	7.569- 9.275	11.353- 13.620	8.913- 10.448	10.320- 12.226
	Very wet	9.276- 11.575	13.621- 17.190	10.449- 12.304	12.227- 14.657
	Extremely wet	>11.575	>17.190	>12.304	>14.657
East Texas	Extremely dry	< 6.388	< 7.257	< 4.409	< 5.722
	Very dry	6.388- 7.976	7.257- 9.102	4.409- 6.241	5.722- 7.094
	Moderately dry	7.977- 9.532	9.103- 10.838	6.242- 7.840	7.095- 8.569
	Near normal	9.533- 13.383	10.839- 14.927	7.841- 11.263	8.570- 12.628
	Moderately wet	13.384- 15.625	14.928- 17.212	11.264- 13.017	12.629- 15.192
	Very wet	15.626- 18.611	17.213- 20.174	13.018 15.163	15.193- 18.782
	Extremely wet	>18.611	>20.174	>15.163	>18.782
Trans-Pecos	Extremely dry	< .181	< 1.222	< 2.776	< 1.147
	Very dry	.181- .562	1.222- 1.233	2.776- 3.503	1.147- 1.630
	Moderately dry	.563- .933	1.234- 1.321	3.504- 4.157	1.631- 2.268
	Near normal	.934- 1.841	1.322- 2.050	4.158- 5.612	2.269- 4.406
	Moderately wet	1.842- 2.365	2.051- 2.833	5.613- 6.385	4.407- 5.950
	Very wet	2.366- 3.061	2.834- 4.262	6.386- 7.356	5.951- 8.282
	Extremely wet	> 3.061	> 4.262	>7.356	> 8.282
Edwards Plateau	Extremely dry	< .796	< 3.883	< 2.660	< 2.469
	Very dry	.796- 1.794	3.883- 4.450	2.660- 3.913	2.469- 3.909
	Moderately dry	1.795- 2.727	4.451- 5.190	3.914- 5.125	3.910- 5.260
	Near normal	2.748- 5.031	5.191- 7.653	5.126- 8.072	5.261- 8.429
	Moderately wet	5.032- 6.326	7.654- 9.423	8.073- 9.765	8.430- 10.193
	Very wet	6.327- 8.023	9.424- 12.089	9.766- 12.000	10.194- 12.477
	Extremely wet	> 8.023	>12.089	>12.000	>12.477
South Central	Extremely dry	< 2.904	< 3.905	< 3.711	< 4.011
	Very dry	2.904- 4.129	3.905- 5.409	3.711- 5.057	4.011- 5.757
	Moderately dry	4.130- 5.286	5.410- 6.851	5.058- 6.436	5.798- 7.480
	Near normal	5.287- 8.030	6.852- 10.321	6.437- 10.029	7.481- 11.457
	Moderately wet	8.031- 9.571	10.322- 12.297	10.030- 12.209	11.458- 13.683
	Very wet	9.572- 11.576	12.298- 14.890	12.210- 15.186	13.684- 16.575
	Extremely wet	>11.576	>14.890	>15.186	>16.575
Upper Coast	Extremely dry	< 5.912	< 4.133	< 5.983	< 5.802
	Very dry	5.912- 7.417	4.133- 6.100	5.983- 7.920	5.802- 8.030
	Moderately dry	7.418- 8.822	6.101- 7.933	7.921- 9.913	8.031- 10.147
	Near normal	8.823- 12.103	7.934- 12.197	9.914- 15.133	10.148- 15.191
	Moderately wet	12.104- 13.922	12.198- 14.554	15.134- 18.312	15.192- 18.037
	Very wet	13.923- 16.270	14.555- 17.590	18.313- 22.664	18.038- 21.752
	Extremely wet	>16.270	>17.590	>22.664	>21.752
Southern	Extremely dry	< 1.226	< 2.569	< 2.581	<3.021
	Very dry	1.226- 1.731	2.569- 3.473-	2.581- 3.809	3.021- 3.773
	Moderately dry	1.732- 2.322	3.474- 4.405	3.180- 5.006	3.774- 4.736
	Near normal	2.323- 4.090	4.406- 6.848	5.007- 7.948	4.737- 7.889
	Moderately wet	4.091- 5.276	6.849- 8.339	7.949- 9.651	7.890- 10.131
	Very wet	5.277- 6.995	8.340- 10.382	9.652- 11.912	10.132- 13.487
	Extremely wet	> 6.995	>10.382	>11.912	>13.487
Lower Valley	Extremely dry	< 1.541	< 2.278	< 2.461	< 4.186
	Very dry	1.541- 1.885	2.278- 2.896	2.461- 3.947	4.186- 4.899
	Moderately dry	1.886- 2.445	2.897- 3.653	3.948- 5.313	4.900- 5.938
	Near normal	2.446- 4.676	3.654- 6.032	5.314- 8.438	5.939- 9.741
	Moderately wet	4.677- 6.454	6.033- 7.679	8.439- 10.140	9.742- 12.632
	Very wet	6.455- 9.279	7.680- 10.111	10.141- 12.312	12.633- 17.117
	Extremely wet	> 9.279	>10.111	>12.312	>17.117

PRECIPITATION, STREAMFLOW, AND BASE FLOW IN WEST-CENTRAL TEXAS, DECEMBER 1974 THROUGH MARCH 1977

By
EVE L. KUNIANSKY

1989

STREAMFLOW

Total streamflow equals precipitation that runs off the land surface plus precipitation that infiltrates into the ground and eventually seeps into a stream. Streamflow is gaged at streamflow-gaging stations located throughout the study area (fig. 6). Diversions and effects of regulations by dams are not represented in these gaged discharges. Footnotes for the streamflow-gaging stations described in table 2, indicate that few streams in Texas are unregulated. The total-streamflow column (table 2) includes the volume of known diversions from the stream upstream from the gage. The basins shaded in dark blue (fig. 6) are those upstream from the most upstream gage on each stream. The streamflow shown in these basins matches the computed annual flow given in table 2. The basins shaded in light blue (fig. 6) represent intervening basins between gages on streams. The numbers shown in these basins represents the gain (+) or loss (-) in streamflow between the gages. The accuracy of the numbers in figure 6 and table 2 is variable, depending on the volume of unknown diversions. The uncolored basins in figure 6 represent basins for which evaporation from large reservoirs or large unknown diversions or both preclude meaningful estimates of total streamflow.

In general, streamflow increases in the downstream direction; therefore, the difference in streamflow at successive downstream gages represents a gain in streamflow throughout most of the study area. Where streams cross faulted, fractured surfaces and the water table is below the streambed, such as along the Balcones fault zone, water from the stream flows directly into the ground (see footnotes for total-streamflow column in table 2). This results in streamflow losses between successive downstream gages (the negative values shown in fig. 6) along several streams in the Balcones fault zone.

Precipitation is the major factor in the variation of streamflow from year to year. Areas of equal precipitation departure from normal (1951-80) are shown in figure 4. In general, precipitation was near normal in the northern and eastern parts of the study area and was greater than normal in the southeastern part of the study area. Total streamflow varied from about 13 in/yr in the Balcones fault zone to less than 1 in/yr in the western part of the study area (table 2; fig. 6). In the Balcones fault zone in the southeastern part of the study area, the streamflow was as much as 8 in/yr greater than normal (1951-80).

STREAMFLOW

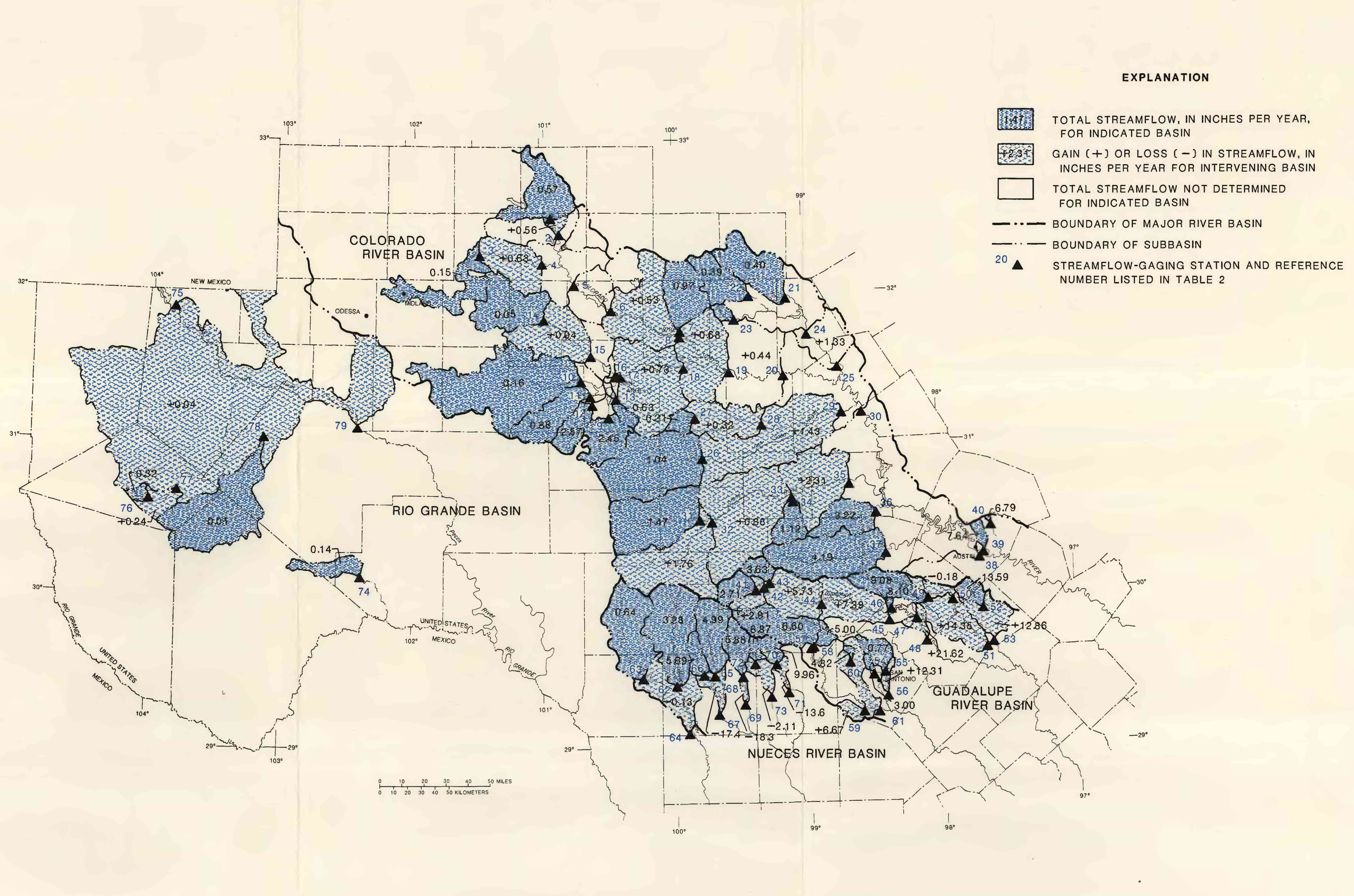


Figure 6.--Total 28-month mean streamflow values by drainage basin, December 1974 through March 1977.

Table 2.--Streamflow-gaging stations in west-central Texas used to determine total runoff, December 1974 through March 1977

[mi², square miles; acre-ft, acre-feet; ft³/s, cubic feet per second; in, inches; in/yr, inches per year. Total volume--amounts are from stations not regulated by a lake or a reservoir larger than 25,000 acre-ft, but flow may be affected by small reservoirs, unless otherwise indicated.]

Reference number	Station number	Station name	Contributing drainage area (mi²)	Total volume (acre-ft)	Mean flow (ft³/s)	Total runoff (in)	28-Month mean runoff (in/yr)
1	08120700	Colorado River near Cuthbert	a/ 549.0	b/ 38,894.0	23.0	1.328	0.569
2	08121000	Colorado River at Colorado City	a/ 600.0	b/ c/ 42,443.6	25.1	1.326	.568
3	08123650	Beals Creek above Big Springs	a/ 486.0	b/ c/ 9,001.6	5.3	.347	.149
4	08123800	Beals Creek near Westbrook	a/ 959.0	d/ 43,822.0	26.0	.856	.367
5	08123850	Colorado River above Silver	a/ 2,161.0	b/ d/ 85,802.0	50.8	.744	.319
6	08124000	Colorado River at Robert Lee	a/ 33.0	b/ d/ 2,768.0	1.6	1.529	.612
7	08126500	Colorado River at Ballinger	a/ 903.0	b/ d/ 60,184.0	35.7	1.248	.532
8	08127000	Elm Creek et Ballinger	450.0	c/ 54,268.6	32.2	2.260	.969
9	08128000	South Concho River at Christoval	344.0	c/104,918.0	62.2	5.716	2.450
10	08128400	Middle Concho River above Tankersley	1,644.0	33,529.0	19.9	.382	.164
11	08129300	Spring Creek above Tankersley	405.0	e/ 44,200.0	26.2	2.045	.876
12	08130500	Dove Creek at Knickerbocker	218.0	e/ 69,830.0	41.4	6.003	2.573
13	08131400	Pecan Creek near San Angelo	81.1	6,312.0	3.7	1.459	.625
14	08133500	North Concho River at Sterling City	568.0	e/ 3,144.6	1.9	.104	.045
15	08134000	North Concho River near Carlsbed	1,191.0	d/ 6,291.0	3.7	.099	.042
16	08135000	North Concho River at San Angelo	a/ 20.0	b/ 3,245.9	1.9	3.045	1.305
17	08136000	Concho River at San Angelo	4,411.0	b/ c/ 153,660.4	91.0	.653	.280
18	08136500	Concho River at Paint Rock	a/ 1,109.0	b/ d/ 217,492.0	128.9	3.676	1.575
19	08136700	Colorado River near Stacy	a/ 3,234.0	b/ d/ 394,380.0	233.6	2.284	.978
20	08138000	Colorado River at Winchell	a/ 4,231.0	b/ d/ 448,930.0	266.0	1.993	.850
21	08140700	Pecan Bayou near Cross Cut	532.0	e/ 26,549.0	15.7	.935	.401
22	08140800	Jim Ned Creek near Coleman	333.0	b/ c/ 16,142.0	9.6	.908	.389
23	08141500	Hords Creek near Valera	54.2	b/ 2,717.9	1.6	.940	.403
24	08143500	Pecan Bayou at Brownwood	1,660.0	b/ c/ 109,906.0	65.1	12.407	5.317
25	08143600	Pecen Bayou near Mullin	2,073.0	b/ 135,952.0	80.5	1.229	.527
26	08144500	San Saba River at Menard	1,128.0	c/ 145,744.0	86.3	2.421	1.038
27	08144800	Brady Creek near Eden	101.0	2,610.0	1.5	.484	.207
28	08145000	Brady Creek at Brady	588.0	b/ 22,006.3	13.0	.701	.300
29	08146000	San Saba River at San Saba	3,039.0	b/ d/ 381,570.0	226.1	2.353	1.008
30	08147000	Colorado River near San Seba	a/ 9,379.0	b/ d/ 1,106,810.0	655.7	2.213	.948
31	08148500	North Llano River near Junction	914.0	e/ 167,440.0	99.2	3.433	1.471
32	08150000	Llano River near Junction	1,849.0	e/ 372,970.0	221.0	3.780	1.620
33	08150700	Llano River near Mason	3,342.0	537,140.0	318.2	3.012	1.291
34	08150800	Beaver Creek near Meson	215.0	29,861.0	17.7	2.603	1.116
35	08151500	Llano River at Llano	4,192.0	e/ f/ 749,930.0	444.3	3.353	1.437
36	08152000	Sandy Creek near Kingsland	346.0	138,521.0	82.1	7.503	3.216
37	08153500	Pedernales River near Johnson City	901.0	d/ 470,080.0	278.5	9.777	4.190
38	08158000	Coloredo River at Austin	a/ 17,166.0	b/ d/ 3,604,560.0	2 135.5	3.937	1.687
39	08158600	Walnut Creek at Webberville Rd., Austin,	51.3	48,773.0	28.9	17.817	7.636
40	08159150	Wilbarger Creek near Pflugerville	4.6	3,894.9	2.3	15.833	6.786
41	08165300	North Fork Guedalupe River near Hunt	168.0	56,654.0	33.6	6.321	2.709
42	08165500	Guedalupe River at Hunt	288.0	d/ 100,170.0	59.3	6.519	2.794
43	08166000	Johnson Creek near Ingram	114.0	e/ 51,530.0	30.5	8.473	3.632
44	08167000	Guadalupe River at Comfort	838.0	e/ 462,900.0	274.2	10.354	4.438
45	08167500	Guedelupe River near Spring Brench	1,315.0	e/ 902,320.0	534.6	12.862	5.513
46	08167600	Rebecce Creek near Spring Branch	10.9	10,987.0	6.5	18.894	8.098
47	08167800	Guadelupe River at Settler	1,436.0	b/ e/ 989,330.0	586.1	12.914	5.535
48	08168500	Guadalupe Ri. above Comal Ri. at New Brenfels,	1,518.0	b/ e/ 1,210,220.0	717.0	14.944	6.405
49	08171000	Blenco River at Wimberly	355.0	e/ 400,990.0	237.6	21.172	9.075
50	08171300	Blenco River near Kyle	412.0	e/ f/ 399,700.0	236.8	18.184	7.794
51	08172000	San Mercus River at Luling	838.0	1,161,230.0	688.0	25.974	1.133
52	08172400	Plum Creek at Locknart	112.0	189,395.0	112.2	31.697	3.586
53	08173000	Plum Creek near Luling	309.0	505,150.0	299.3	30.643	3.135
54	08177700	Olmos Creek at Oresden Or., San Antonio,	21.2	7,926.0	4.7	7.008	3.004
55	08178700	Selado Creek (upper station) et Sen Antonio,	137.0	13,172.0	7.8	1.802	.772
56	08178800	Salado Creek (lower station) at San Antonio,	189.0	e/ 92,960.0	55.1	9.219	3.952
57	08179000	Medina River near Pipe Creek	474.0	e/ 389,640.0	230.8	15.408	6.604
58	08179100	Red Bluff Creek near Pipe Creek	56.3	35,050.0	20.8	11.669	5.002
59	08180800	Medina River near Somerset	967.0	b/ c/ 588,871.7	348.9	11.414	4.892
60	08181400	Helotes Creek et Helotes Texas	15.0	e/ f/ 9,001.3	5 3	11.248	4.821
61	08181500	Medina River et San Antonio	1,317.0	b/ d/ 696,460.0	412.6	9.912	4.249
62	08190000	Nueces River at Laguna	764.0	e/ 312,080.0	184.9	7.657	3.281
63	08190500	West Nueces River neer Brackettville	700.0	f/ 55,291.4	32.8	1.481	.635
64	08192000	Nueces River below Uvalde	1,947.0	e/ f/ 359,610.0	213.0	3.462	1.484
65	08195000	Frio River et Concan	405.0	e/ 251,440.0	149.0	11.637	4.987
66	08196000	Ory Frio River near Reagan Wells	117.0	e/ 82,870.0	49.1	13.276	5.690
67	08197500	Frio River below Dry Frio River neer Uvelde	661.0	e/ f/ 32,697.5	19.4	.927	.397
68	08198000	Sabinel River near Sebinal	206.0	e/ 150,840.0	89.4	13.725	5.882
69	08198500	Sebinal River et Sabinal	247.0	e/ f/ 57,323.0	34.0	4.350	1.864
70	08200000	Hondo Creek near Tarpley	86.2	e/ 106,920.0	63.3	23.250	9.964
71	08200700	Hondo Creek at King Weterhole neer Hondo	142.0	e/ f/ 12,095.4	7.2	1.597	.684
72	08201500	Selo Creek at Miller Ranch neer Utopia	43.1	36,884.0	21.9	16.041	6.875
73	08202700	Selo Creek et Rowe Ranch near O'Hanis	168.0	f/ 4,021.4	2.4	.449	.192
74	08376300	Sanderson Canyon at Sanderson	195.0	3,319.0	2.0	.319	.137
75	08412500	Pecos River near Orle	21,210.0	b/ d/ 144,399.0	85.5	.128	.055
76	08431700	Limpia Creek above Fort Davis	52.4	2,101.3	1.2	.752	.322
77	08431800	Limpia Creek below Fort Oavis	227.0	7,238.0	4.3	.598	.256
78	08435800	Coyanosa Draw near Fort Stockton	1,182.0	g/ 1,014.0	0.6	.016	.007
79	08446500	Pecos River near Girvin	29,560.0	b/ c/ 185,311.5	109.8	.118	.051

a/ Contributing dreinage aree less then published because of no reservoir releases.
b/ Flow regulated by lerge lake or reservoir.
c/ All known diversions added into flow upstream of gage.
d/ Oiversions for municipal and industrial use unknown.
e/ Unknown small diversions.
f/ Streamflow disapears into feulted formations upstreem of gage.
g/ Records poor.

BASE FLOW

Base flow is that part of precipitation recharged at topographically high areas that is discharged to streams at topographically low areas. Base flow also can be defined as the part of total streamflow that is not direct surface runoff. In general, direct surface runoff occurs quickly after a storm, whereas base flow is slowly released to a stream. It is this time delay in the appearance of base flow in a stream that allows the base-flow contribution to streamflow to be graphically separated from the surface-runoff contribution on a discharge hydrograph. Hydrographs were separated in this manner for selected streamflow-gaging stations; an example of this separation on a daily discharge hydrograph is shown in figure 7. Monthly mean base flow was determined and averaged for the 28-month calibration period. These base flows are tabulated in table 3.

Generally, streams with sustained base flows will have larger ratios of base flow to total streamflow. These ratios for the stations analyzed, expressed in percent in table 3, ranged from 24.6 to 89.5 percent. The largest base-flow values, from about 4 to 6 in/yr, are for basins in the southeastern part of the study area where precipitation is greatest. In the Rio Grande basin and in the upper Colorado River basin, base-flow values are not shown because they are less than 0.1 in/yr (fig. 8). As in figure 6, a distinction in values is made in figure 8 between basins in which the labeled number is the base flow for the entire contributing area upstream from the gage (dark blue basins) and basins in which the labeled number is the base flow for only the intervening basin between successive gages (light blue basins).

In other parts of the United States, base flow has been related to flow-duration statistics. Flow-duration statistics are determined by ranking gaged daily discharges by magnitude and computing the percentage of time a discharge of a specific magnitude is equaled or exceeded. A flow-duration curve is the resulting cumulative frequency distribution of the daily discharges. Examples of flow-duration curves at two of the stations where base flow was determined are shown in figure 9.

In the Delmarva Peninsula of Maryland and Delaware, Cushing and others (1973) determined that mean annual base flow was approximately equal to the discharge exceeded 50 percent of the time (Q50). In the outcrop area of the sand aquifers of the southeast coastal plain in Mississippi, Alabama, Georgia, and South Carolina, Stricker (1983) determined that mean annual base flow was approximately equal to the discharge exceeded 60 to 65 percent of the time. However, no such relation could be established for the streams in west-central Texas because there was no correlation between any one flow-duration statistic and mean annual base flow (plots of mean base flow versus any one flow-duration statistic had considerable scatter rather than plotting in a band or a line).

The flow-duration index, defined as the square root of the ratio of the discharge equaled or exceeded 25 percent of the time to the discharge equaled or exceeded 75 percent of the time, $\sqrt{Q_{25}/Q_{75}}$, is shown in column 7 of table 3. This index is used as an indication of the shape of the flow-duration curve. The greater the index, the steeper the curve, and the lesser the index, the flatter the curve (fig. 9). A steep flow-duration curve indicates a stream in which discharge decreases rapidly after a storm. A flat flow-duration curve indicates a stream with well-sustained base flow. Generally, the eight stations that have an index greater than 2 are on streams in which base flow is a smaller percentage of gaged flow. The average base flow for these eight stations is 45 percent of the gaged flow. The 29 stations that have an index less than 2 are on streams that have an average base flow of 65 percent of the gaged flow.

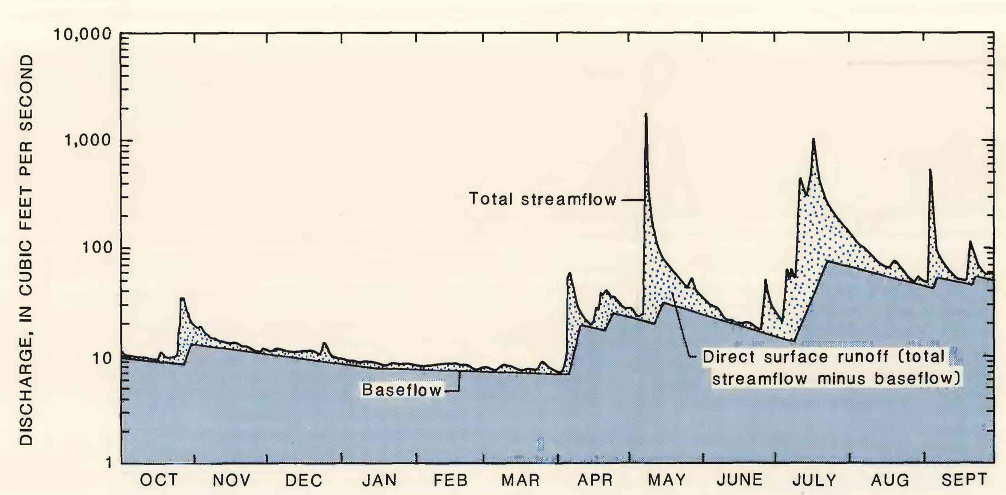


Figure 7.--Daily discharge hydrograph showing base-flow separation, station 66 (08196000), Dry Frio River near Reagan Wells, water year 1976.

Table 3.--Streamflow-gaging stations in west-central Texas used to determine base flow, December 1974 through March 1977

[mi², square miles; ft³/s, cubic feet per second; $\sqrt{(Q25/Q75)}$, the square root of flow with 25-percent duration divided by flow with 75-percent duration; in, inches; in/yr, inches per year. Note: Refer to table 1 for remarks about the streamflow-gaging stations.]

Reference number	Station number	Station name	Contributing drainage area (mi²)	Mean base flow (ft³/s)	Percent of total flow	Duration curve indices $\sqrt{(Q25/Q75)}$	Base flow runoff (in)	28-month mean base flow runoff (in/yr)
8	08127000	Elm Creek at Ballinger	450.0	12.4	38.4	2.485	0.870	0.373
9	08128000	South Concho River at Christoval	344.0	55.7	89.5	1.355	5.123	2.195
10	08128400	Middle Concho River above Tankersley	1,644.0	14.0	70.4	1.653	.269	.115
11	08129300	Spring Creek above Tankersley	405.0	17.2	65.7	1.337	1.345	.576
12	08130500	Dove Creek at Knickerbocker	218.0	34.7	83.9	1.170	5.043	2.161
13	08131400	Pecan Creek near San Angelo	81.1	2.5	67.2	2.974	.970	.416
18	a/08136500	Concho River at Paint Rock	1,109.0	57.1	44.3	1.488	1.629	.697
19	a/08136700	Colorado River near Stacy	3,234.0	116.1	49.7	1.644	1.136	.487
20	a/08138000	Colorado River at Winchell	4,231.0	102.4	38.5	1.897	.766	.329
26	08144500	San Saba River at Menard	1,128.0	64.4	74.6	1.281	1.806	.774
27	08144800	Brady Creek near Eden	101.0	.8	53.3	1.526	.250	.107
29	a/08146000	San Saba River at San Saba	3,039.0	165.7	73.3	1.406	1.726	.740
30	a/08147000	Colorado River near San Saba	9,379.0	356.9	54.4	1.802	1.205	.516
31	08148500	North Llano near Junction	914.0	68.8	69.4	1.368	2.382	1.021
32	08150000	Llano River near Junction	1,849.0	180.2	81.6	1.180	3.084	1.322
33	08150700	Llano River near Mason	3,342.0	229.6	72.2	1.247	2.174	.932
34	08150800	Beaver Creek near Mason	215.0	4.4	24.6	1.646	.641	.275
35	08151500	Llano River at Llano	4,192.0	274.6	61.8	1.327	2.073	.888
36	08152000	Sandy Creek near Kingsland	346.0	32.5	39.6	2.088	2.973	1.274
37	08153500	Pedernales River near Johnson City	901.0	153.4	55.1	1.725	5.386	2.308
39	08158600	Walnut Creek at Webberville Rd., Austin	51.3	10.4	36.1	2.408	6.438	2.759
40	08159150	Wilbarger Creek near Pflugervilla	4.6	.6	28.0	7.071	4.423	1.895
41	08165300	North Fork Guadalupe River near Hunt	168.0	27.7	82.5	1.276	5.219	2.237
42	08165500	Guadalupe River at Hunt	288.0	46.2	78.0	1.280	5.081	2.178
43	08166000	Johnson Creek near Ingram	114.0	24.3	79.6	1.264	6.740	2.889
44	08167000	Guadalupe River at Comfort	838.0	178.4	65.1	1.419	6.735	2.886
45	08167500	Guadalupe River near Spring Branch	1,315.0	330.3	61.8	1.601	7.952	3.408
49	08171000	Blanco River at Wimberly	355.0	140.1	59.0	1.664	12.487	5.352
56	08178800	Salado Creek (lower station) at San Antonio	189.0	26.9	48.9	1.420	4.508	1.932
57	08179000	Medina River near Pipe Creek	474.0	157.8	68.4	1.648	10.532	4.514
58	08179100	Red Bluff Creek near Pipe Creek	56.3	6.5	31.2	51.961	3.653	1.566
62	08190000	Nueces River at Laguna	764.0	146.5	79.2	1.507	6.067	2.600
65	08195000	Frio River at Concan	405.0	107.9	72.4	1.352	8.429	3.612
66	08196000	Dry Frio River near Reagan Wells	117.0	27.9	56.7	1.820	7.533	3.228
68	08198000	Sabinal River near Sabinal	206.0	56.1	62.7	1.715	8.612	3.691
70	08200000	Hondo Creek near Tarpley	86.2	37.9	59.9	2.088	13.908	5.961
72	08201500	Selo Creek at Miller Ranch near Utopia	43.1	13.6	61.9	2.059	9.948	4.263

a/ Flow at station partly regulated by a reservoir thought to be far enough upstream not to interfere with separation of direct surface runoff from base flow.

BASE FLOW

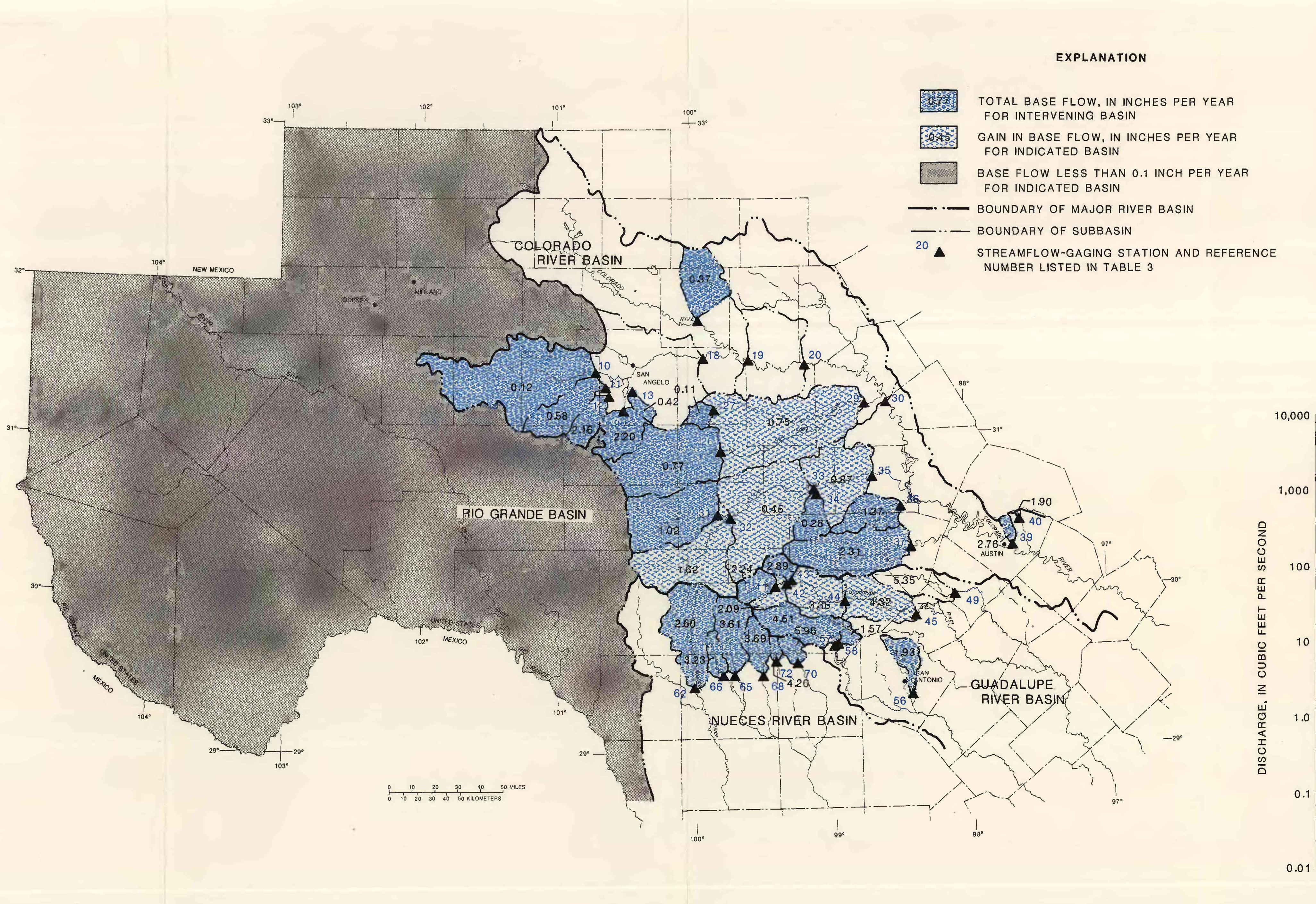


Figure 8.--Twenty eight-month mean base-flow values by drainage basin, December 1977 through March 1977.

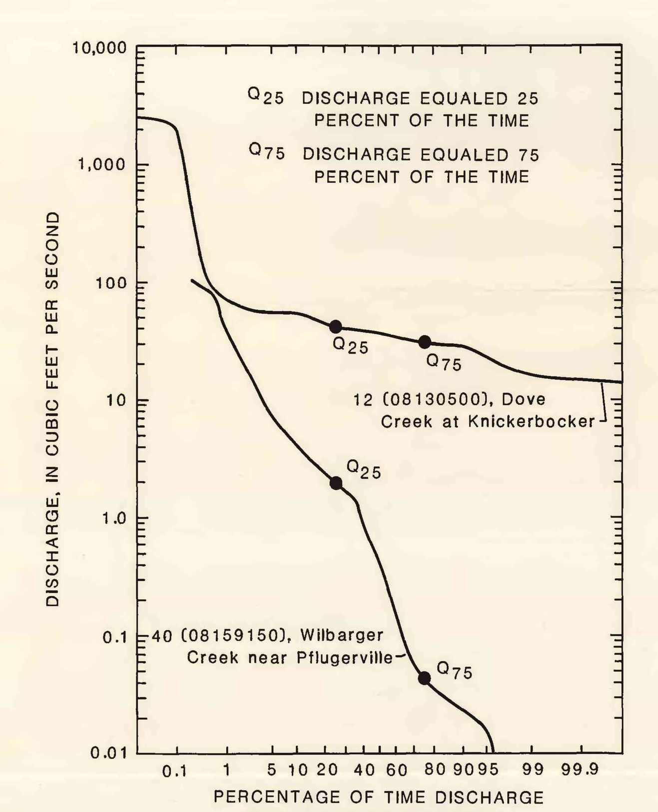


Figure 9.--Flow-duration curves for station 12 (08130500), Dove Creek at Knickerbocker, and station 40 (08159150), Wilbarger Creek near Pflugerville.

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PRECIPITATION, STREAMFLOW, AND BASE FLOW IN WEST-CENTRAL TEXAS, DECEMBER 1974 THROUGH MARCH 1977

By
EVE L. KUNIANSKY

1989