TEXAS
Floods and Droughts

Texas, bounded on the southeast by the Gulf of Mexico and on the west by arid and semiarid regions characteristic of the Southwestern United States, is a land of climatic diversity. Although the average July maximum temperature differs little across the State, the average January minimum temperature ranges from less than 20 °F (degrees Fahrenheit) in the northwestern part of the Texas panhandle to almost 50 °F in parts of the Rio Grande valley. The terrain is equally as diverse, ranging from the featureless coastal plains along the gulf coast to the spectacular features of western Texas, which include the Guadalupe Mountains, the canyons of Big Bend, and the Cap Rock Escarpment of the High Plains (fig. 1).

The average annual precipitation differs little from north to south, but greatly from west to east. El Paso receives an average annual precipitation of less than 8 inches. More than 770 miles to the east, the average annual precipitation in the lower Sabine River valley of extreme eastern Texas exceeds 56 inches. The precipitation varies seasonally as well as geographically. Although spring and fall are the wettest seasons, intense rainfall can occur in late summer during the tropical storm and hurricane season. For most of the State, however, the average precipitation during summer is only slightly greater than that during the winter.

Such climatic and geographic diversity increases the State's vulnerability to two persistent hydrologic conditions—floods and droughts. These two weather-related phenomena, representing opposite ends of the hydrologic spectrum, have plagued Texas throughout its history, causing hardship and economic loss. Floods occur regularly in Texas, and destructive floods occur somewhere in the State every year. In the 1900's, Texas has suffered droughts in every decade, including two long and severe droughts in the 1950's and 1960's.

Floods and droughts have a major effect on the water resources within the State. Surface-water resources are replenished by intense rains and the resultant floods. Ground-water resources also are recharged by rainfall from storms. When rainfall and surface-water resources are adequate, the demand for ground water decreases. When these conditions are reversed and rainfall is deficient, streamflows decrease and lake and reservoir levels are adversely affected. Ground-water resources are affected by decreased recharge to the aquifers and by increased withdrawals from the aquifers.

Floods and droughts can substantially affect the State and its people. Hundreds of lives have been lost because of flooding and other weather-related conditions, and the economic loss has been substantial. Although droughts generally do not cause loss of human lives, they cause large economic losses and disrupt normal use of the State's water resources.

Planning and management responsibilities for floods and droughts within the State are dealt with on an individual basis. No single government body has complete responsibility for planning and management activities, which are mostly conducted on the local level. All natural flow in Texas streams is considered to be the property of the State, and the water is controlled through an appropriative system. Most of the major streams are controlled by river authorities or agencies created by the State.

Flood and drought management is enhanced by a network of lakes and reservoirs across the State. Controlled storage of surface water throughout the State is a management practice that can compensate for the onset of less than normal streamflow—that is, drought conditions.

Flood-plain management programs are in effect all across Texas. Many cities and counties participate in the National Flood Insurance Program through local ordinances that conform to minimum criteria established by the Federal Emergency Management Agency for development in flood-hazard areas.

Flood warnings generally are issued by the National Weather Service (NWS) through its various forecast offices. The need for additional data and more accurate local flood warnings has caused some local communities to establish their own flood-warning systems.

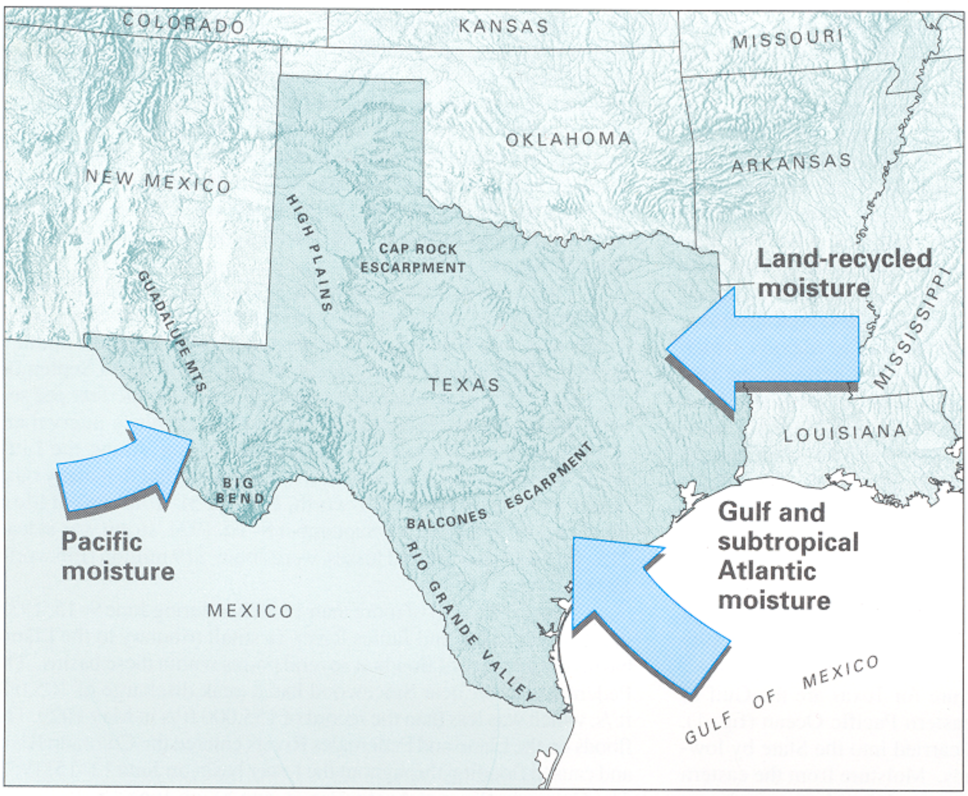


Figure 1. Principal sources and patterns of delivery of moisture into Texas. Size of arrow implies relative contribution of moisture from source shown. (Source: Data from Douglas R. Clark and Andrea Lage, Wisconsin Geological and Natural History Survey.)

GENERAL CLIMATOLOGY

Texas has a climate as diverse as the land—10 climatic divisions and 4 physiographic regions. Because of its great areal extent and long coastline along the Gulf of Mexico, the weather conditions in various parts of the State differ greatly. Temperatures are most diverse in the winter. Northern parts of the State may have snow and ice and daily high temperatures that do not rise above freezing, while southern parts have daily high temperatures that may be well above freezing. This temperature range in winter can be attributed in part to the large north-to-south extent of Texas—about 800 miles from the northwest corner of the panhandle to the southern tip of the State on the Rio Grande downstream from Brownsville (fig. 2). Temperatures are most stable in the summer. Daily maximum temperatures in July and August in most of the State are in the high 90's and low 100's.

Temperatures vary more in the spring and fall than in the summer but less than in the winter. This variation is caused by the changing of the seasons and the large distance from north to south in the State. Early fall frontal systems, which typically are cold fronts, tend to stall or diminish before reaching the southern part of the State, thus creating a sizable temperature difference between northern and southern parts. This pattern in late winter and early spring is about the same as in the fall. As cold fronts begin to lose their ability to move southward, each successive frontal system affects a smaller part of the State.

Jetstreams (upper atmospheric winds) greatly affect the large-scale weather patterns over Texas (Bomar, 1983). The polar jetstream, which generally crosses Texas from the late fall to mid-spring, affects the movement of cold, arctic airmasses through the State in December, January, and February. As spring arrives, the subtropical jetstream, which is most prevalent during fall and spring and consists of moist, subtropical air, enters the State from the southwest and carries moisture from the eastern Pacific Ocean.

The average annual precipitation ranges from less than 8 inches at El Paso in the extreme western part of the State to about 56 inches in the extreme southeastern part. More than one-half of the State receives less than 30 inches of precipitation per year.

Spring is the wettest season in most of Texas, with April and May being the wettest months. Summers are dry in most of the State. In late summer and early fall (September and October), a secondary peak of rainfall is received. This pattern of rainfall can be attributed to thunderstorms in spring and tropical cyclones, which include hurricanes and tropical storms, in late summer or early fall. The spring thunderstorms generally are caused by successive weak frontal systems that attempt to move through the State. These cool airmasses are overtopped by warm, moist air from the Gulf of Mexico, which causes thunderstorms along the line of contact between the two systems. Tropical cyclones originate in weather systems that have their beginning in the Caribbean Sea or the Gulf of Mexico. Rainfall quantities that result from tropical cyclones can differ greatly because of the different conditions in each storm. Remnants of some hurricanes reaching landfall have produced large quantities of rainfall over wide areas of the State.

Droughts are caused mainly by activities of the extensive subtropical high-pressure cell (the Bermuda High) that drifts latitudinally with the passing of the seasons. When the Bermuda High becomes entrenched over the southern United States, the possibility of drought becomes more likely.

The principal sources of moisture for Texas are the Gulf of Mexico and, to a lesser extent, the eastern Pacific Ocean (fig. 1). Moisture from the Gulf of Mexico is carried into the State by low-level southerly and southeasterly winds. Moisture from the eastern Pacific is carried into the State from the southwest by tropical continental airmasses. In addition to the oceans, important moisture sources include local and upwind land surfaces, as well as lakes and reservoirs, from which moisture evaporates into the atmosphere. Typically, as a moisture-laden ocean airmass moves inland, it is modified to include some water that has been recycled one or more times through the land-vegetation-air interface.

MAJOR FLOODS AND DROUGHTS

Major floods and droughts described herein are those having significant areal extent and recurrence intervals greater than 25 years for floods and greater than 10 years for droughts. The evaluation of floods and droughts, determined from streamflow records, is limited to the period starting in the early 1900's when the collection of systematic streamflow records was just beginning. Streamflow data are collected, stored, and reported by water year (a water year is the 12-month period from October 1 through September 30 and is identified by the calendar year in which it ends). The most significant floods and droughts in Texas are listed chronologically in table 1; rivers and cities are shown in figure 2.

Eleven streamflow-gaging stations were selected from the statewide network to show floods (fig. 3) and droughts (fig. 4) in Texas in the 1900's. Selection was based on areal distribution, climatologic division, hydrologic setting, and degree of regulation. The gaging stations chosen are on streams in river basins that receive runoff entirely from within the State.

FLOODS

The flood data shown in figure 3 indicate the areal extent and the severity of five floods, as determined from the statewide network of gaging stations. Annual peak discharges and the discharge having 10-year and 100-year recurrence intervals for six selected gaging stations are shown by graphs.

During September 8–10, 1921, record floods occurred in an area of south-central Texas from San Antonio to just north of Temple. During September 7–11, rainfall ranged from 5 to 10 inches in most of the area; one area northeast of Thrall received an unofficial total of 38.2 inches in 24 hours during September 9–10. San Antonio received more than 6 inches of rainfall in 24 hours during September 9–10 and as much as 17 inches in the northern part of the city for the entire storm (September 8–10). A total of 52 lives were lost in San Antonio and vicinity. Total damage there exceeded $3.7 million (Ellsworth, 1923).

The largest of the September 8–10, 1921, floods occurred in the northern part of the storm area, on the Little and San Gabriel Rivers and their tributaries in an area north of Austin and south of Temple. The Little River at Cameron (fig. 3, site 6) on September 10, 1921, had a peak discharge of 647,000 ft^3/s (cubic feet per second), which greatly exceeded the 100-year recurrence interval and is the maximum of record at this gaging station. Along the Little River, at least 159 lives were lost, with the possibility that many other bodies were never found (Ellsworth, 1923, p. 5). Total loss of life in south-central Texas for the September 8–10, 1921, storm was at least 215. Property damage and losses were about $19 million (Ellsworth, 1923).

Intense rainfall of more than 18 inches during June 9–15, 1935, in the South Llano and James River (a small tributary to the Llano) basins created record floods at several points within these basins. The Pedernales River near Spicewood had a peak discharge of 105,000 ft^3/s, which was less than the record of 155,000 ft^3/s in May 1929. The floods on the Llano and Pedernales Rivers entered the Colorado River and caused flooding throughout the lower basin on June 13–15, 1935. The Colorado River at Austin (fig. 3, site 5), on June 15, 1935, had a peak discharge of 481,000 ft^3/s, which exceeded the discharge with a 100-year recurrence interval. The stage of 42.0 feet on June 15

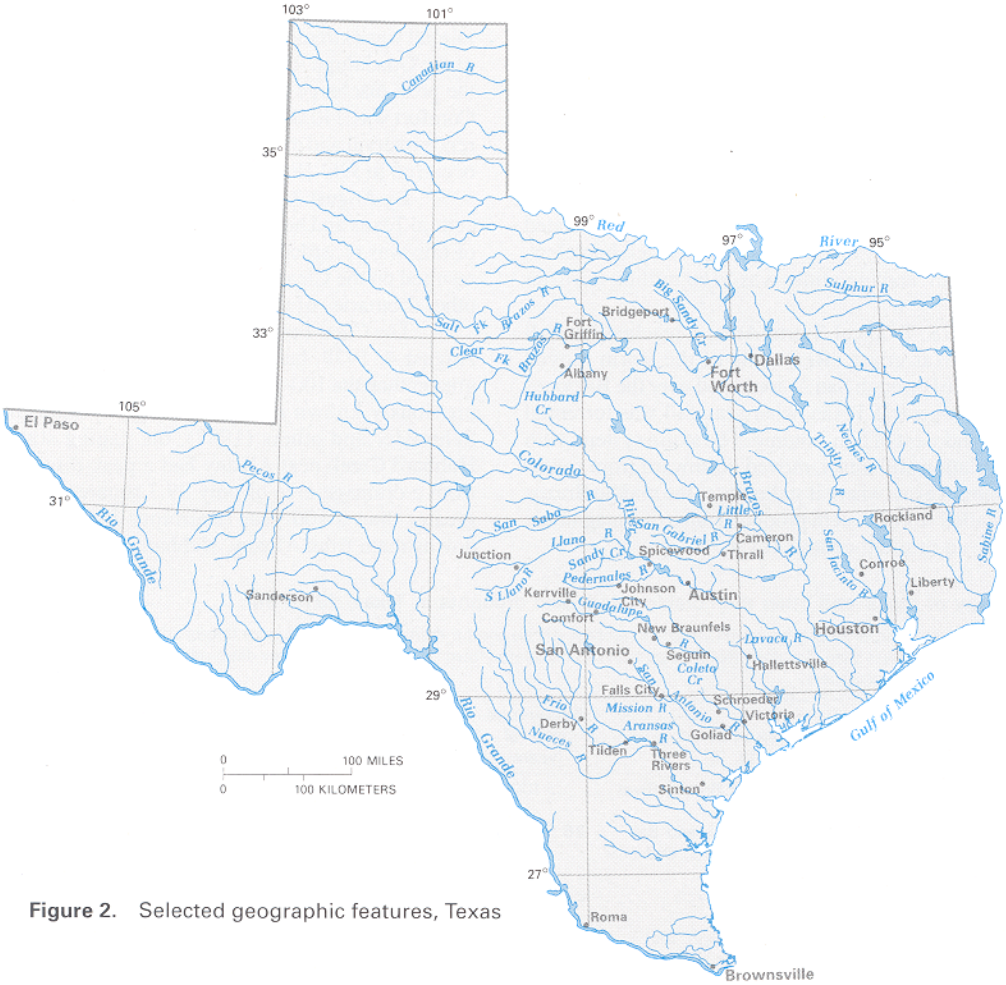


Figure 2. Selected geographic features, Texas

was 1.0 foot less than the maximum stage of the July 1869 flood (Dalrymple and others, 1937).

Floods of September 9–11, 1952, greatly exceeded the previous floods at many points on streams in the Guadalupe and lower Colorado River basins in the hill country of central Texas. Discharges were especially large in the basins of the San Saba, lower Llano, and Pedernales Rivers and Sandy Creek—all tributaries to the Colorado River. Discharges were also large on tributaries of the Guadalupe River to the west and southwest of Austin. These floods were the result of intense rain during September 9–11, 1952. Rainfall was as much as 26 inches in an area near the divide between the Colorado and Guadalupe River basins (Breeding and Montgomery, 1954).

On September 11, 1952, the Pedernales River near Johnson City (fig. 3, site 4) had a peak discharge of 441,000 ft^3/s which greatly exceeded the 100-year recurrence interval. The gage height of 42.5 feet was 9.5 feet above the 33-foot stage reported in July 1869, which was the previous highest on record. As a result of the floods of September 9–11, 1952, 5 people lost their lives and 454 homes were damaged. Total damage in the Colorado and Guadalupe River basins was about $12 million (Breeding and Montgomery, 1954).

The September–October 1967 floods in southern Texas were the direct result of Hurricane Beulah, which reached landfall near Brownsville on September 20 and dissipated in the mountains of northern Mexico on September 22. Unofficial rainfall measurements during September 19–25 were as large as 34 inches in the Nueces River basin in Texas and as large as 35 inches in the Rio Alamo basin in Mexico. The largest rainfall total measured at an official U.S. Weather Bureau rainfall station was 25.5 inches near Falls City (Schroeder and others, 1974).

The September–October 1967 floods were widespread in southern Texas and ranged from minor to maximum of record. Flooding was severe on the main and tributary streams in the Guadalupe, San Antonio, Mission, Aransas, and Nueces River basins; on many of the small coastal basins in Texas; on the Rio Grande and its floodways; and on the Rio Alamo and Rio San Juan in Mexico. Parts of the lower Guadalupe River basin received extremely intense rainfall in September. The gaging station on Coleto Creek near Schroeder on September 21 recorded a peak discharge of 122,000 ft^3/s, which exceeded the 100-year recurrence interval and is the largest peak discharge recorded at this site since 1872. The San Antonio River at Goliad (fig. 3, site 1) had a peak discharge of 138,000 ft^3/s, which was more than four times the previously maximum recorded in 1869 and exceeded the discharge having a 100-year recurrence interval.

The lower Nueces River basin also had severe flooding in September 1967. At the gaging station near Tilden, the stage was the highest since 1902, and the peak discharge had a recurrence interval greater than 50 years. At Nueces River near Three Rivers (fig. 3, site 2), the peak discharge was 141,000 ft^3/s on September 23. This peak, which had a recurrence interval of greater than 50 years, was greater than the previous maximum, which occurred in 1919.

Record streamflow during late September 1967 created flooding on the Rio Grande in the reach downstream from Falcon Dam near Roma. Some of the floodwaters originated in the United

States, where rainfall quantities were 12 to 24 inches during September 19–25. However, most of the floodwaters originated in Mexico, where Hurricane Beulah left extremely large rainfall quantities before dissipating in the mountains of northeastern Mexico. Rainfall totals for September 19–25 exceeded 20 inches in the San Juan River basin and about 35 inches in the Rio Alamo basin, both in northern Mexico. Recurrence intervals were not determined, but the flooding exceeded previously known maximum discharges at many locations. As a result of Hurricane Beulah and the associated flooding, 44 people lost their lives, and thousands were left homeless. Damage from wind, rain, and high tides was $160 million (Grozier and others, 1968).

On July 31, 1978, Tropical Storm Amelia reached landfall along the southern Texas coast. Remnants of the storm moved westward and northward through San Antonio and over the Balcones Escarpment into south-central Texas, where rainfall was torrential in an area just north and west of San Antonio. The storm system, with its upper-level circulation still intact, moved northward from south-central to north-central Texas, where it stalled over the middle Brazos River basin. The stalled storm system produced rains of a magnitude equal to those received in south-central Texas.

On the night of August 1 and the morning of August 2, 1978, rainfall was extremely intense just west of Kerrville in the headwaters of the Guadalupe River (Schroeder and others, 1979). On August 2, the peak discharge at the gaging station on the Guadalupe River at Comfort was 240,000 ft^3/s, which had greater than a 100-year recurrence interval and exceeded the previously known maximum, which occurred in July 1869.

By August 3, 1978, the storm system had moved into north-central Texas and had stalled. During the next 24 hours, 29.0 inches of rain was recorded by the NWS at Albany. Record-setting floods resulted on the Clear Fork Brazos River and on Hubbard Creek and other tributaries of the Clear Fork Brazos River.

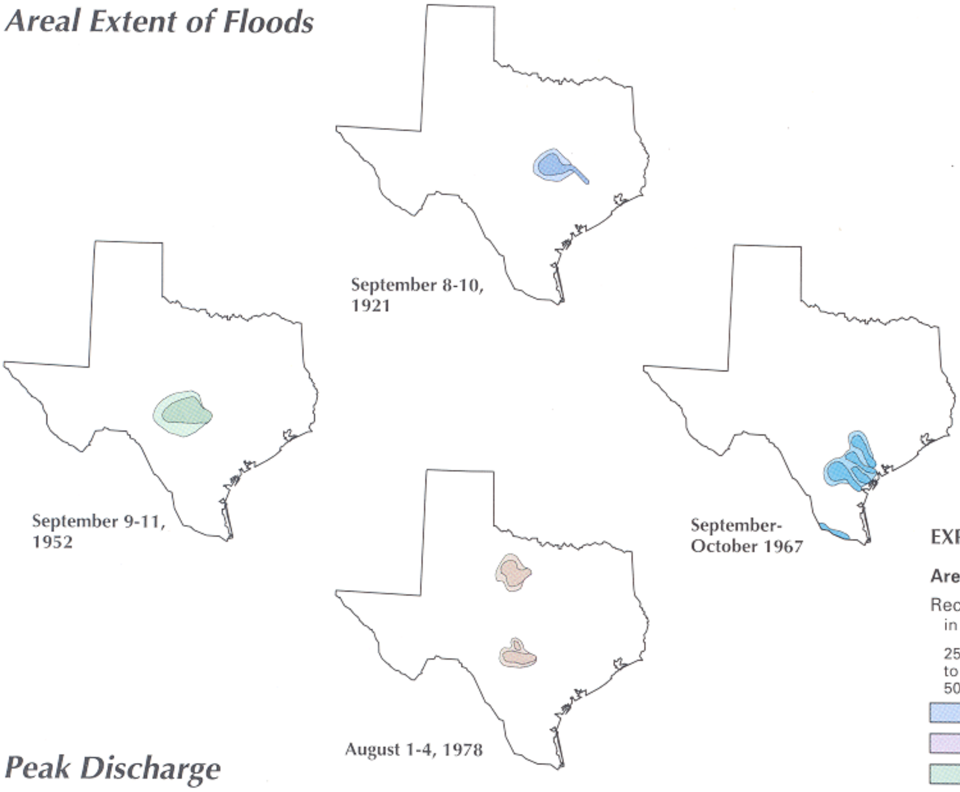
The Clear Fork Brazos River at Fort Griffin (fig. 3, site 3) on August 4, 1978, had a peak discharge of 149,000 ft^3/s, which is greater than the 100-year recurrence interval and which exceeded the previously known maximum stage by 0.88 foot. According to Schroeder and others (1987), the gaging station on North Fork Hubbard Creek near Albany had a peak discharge of 103,000 ft^3/s from a drainage area of only 39.3 square miles; the discharge had greater than a 100-year recurrence interval. At a gaging station downstream from Albany, Hubbard Creek had a peak discharge of

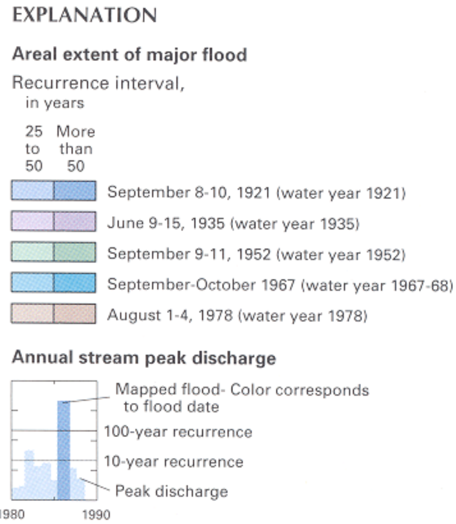
Table 1. Chronology of major and other memorable floods and droughts in Texas, 1913–88

[Recurrence interval: The average interval of time within which streamflow will be greater than a particular value for floods or less than a particular value for droughts. Symbols: >, greater than; <, less than. Sources: Recurrence intervals calculated from U.S. Geological Survey data; other information from U.S. Geological Survey, State and local reports, and newspapers]

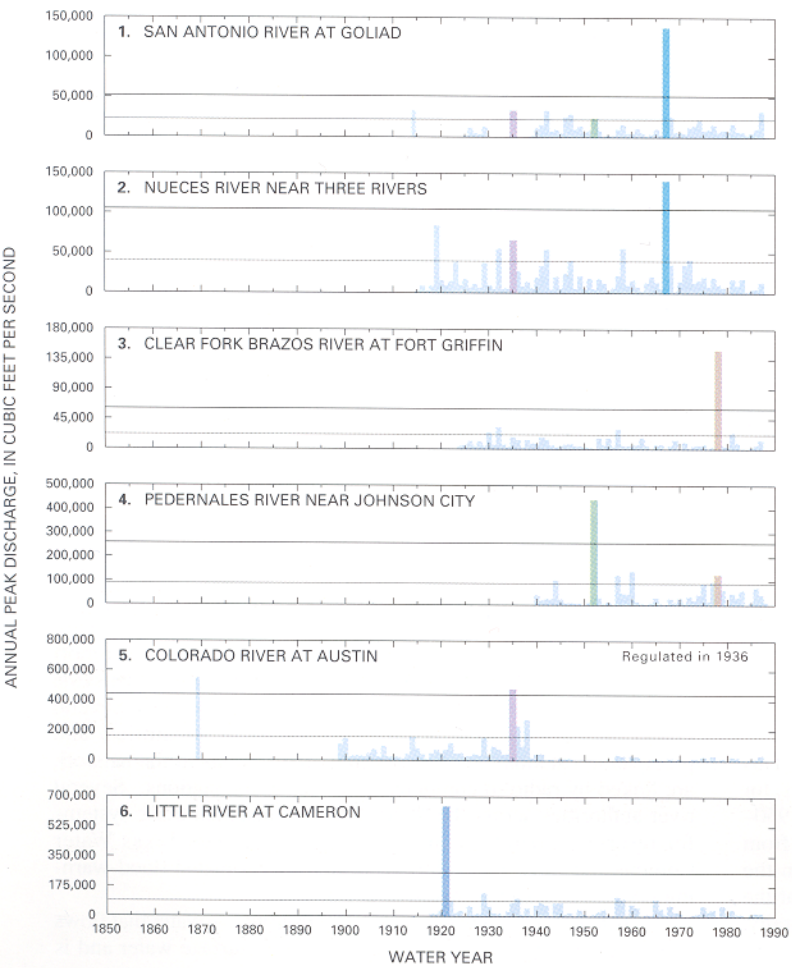
Flood or drought	Date	Area affected (fig. 2)	Recurrence interval (years)	Remarks
Flood	Dec. 1–5, 1913	Middle and lower Brazos River basins.	>100	Record to date in some areas. Deaths, 177; damage, $8.5 million.
Flood	Sept. 8–10, 1921	Lower Brazos, Little, and San Gabriel River basins, and city of San Antonio.	25 to >100	Exceeded 1913 flood in some areas. Deaths, 215; damage, $19 million.
Drought	1932–34	Statewide	<10 to >25	Duration 1–2 years. Recurrence interval 10–25 years for 60–70 percent of State and >25 years for 5 percent.
Flood	June 9–15, 1935	Lower Colorado, Llano, and Pedernales River basins.	25 to >100	Intense rainfall in upper Llano and Pedernales River basins.
Drought	1938–40	Statewide	<10 to >25	Duration about 2 years. Recurrence interval 10–25 years for 50 percent of State and >25 years for 10 percent.
Drought	1947–48	Statewide	<10 to 25	Duration 18–21 months. Recurrence interval 10–25 years for 40 percent of State.
Drought	1950–57	Statewide	>25	Duration about 7 years. Recurrence interval 50–80 years for entire State. Worst drought of 1900's.
Flood	Sept. 9–11, 1952	Lower Colorado, Llano, Guadalupe, San Saba, and Pedernales River basins.	25 to >100	Intense rainfall in Llano and Pedernales River basins. Deaths, 5; damage, $12 million.
Drought	1960–67	Statewide	10 to >25	Recurrence interval 10–25 years for 40 percent of State and >25 years for 60 percent.
Flood	Sept. 21–23, 1964	Upper Trinity River, Big Fossil Creek, and White Rock Creek basins.	Unknown	Intense rainfall along Big Fossil Creek in Fort Worth and White Rock Creek in north Dallas. Damage, $3 million.
Flood	June 11, 1965	Middle Rio Grande, Sanderson Creek, and Dry Creek basins; city of Sanderson.	Unknown	Flash flood caused 26 deaths and $2.7 million in damage.
Flood	Apr. 22–29, 1966	Sulphur, Trinity, and Sabine River basins.	<100	Intense rainfall caused 19 deaths and $12 million in damage.
Flood	Apr. 28, 1966	Gulf Coast, Trinity River basin.	>100	Flash flood in Dallas caused 14 deaths and $15 million in damage.
Flood	Sept.–Oct. 1967	Guadalupe River, Nueces River, Rio Grande, and Lower Rio Grande basins.	25 to >100	Intense rainfall from Hurricane Beulah. Deaths, 44; damage, $160 million.
Drought	1970–72	Statewide	<10	Duration 6 months to 2 years; shortest duration in southern Texas. Some breaks for short periods.
Flood	May 11–12, 1972	Guadalupe River basin; cities of New Braunfels and Seguin.	>100	Intense rainfall downstream from retention dam. Deaths, 17; damage, $17.5 million.
Flood	June 12–13, 1973	Trinity and San Jacinto River basins.	Unknown	Massive rainstorm in area of Houston, Liberty, and Conroe. Deaths, 10; damage, $50 million.
Flood	June 15, 1976	Trinity and San Jacinto River basins.	Unknown	Houston and surrounding area. Deaths, 8; damage, $25 million.
Flood	Aug. 1–4, 1978	Middle Brazos River, Clear Fork Brazos River, Hubbard Creek, North Fork Hubbard Creek, and Guadalupe River basins.	25 to >100	Intense rainfall from Tropical Storm Amelia. Deaths, 33; damage, $110 million.
Flood	May 24, 1981	Gulf Coast, lower Colorado River, and Shoal Creek basins.	>100	Flash flood in Austin caused by intense rainfall on Shoal Creek basin. Deaths, 13; damage, $40 million.

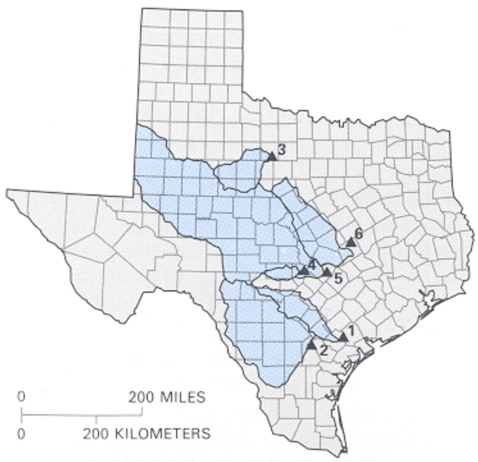
Areal Extent of Floods





Peak Discharge





U.S. Geological Survey streamflow-gaging stations and corresponding drainage basins — Numbers refer to graphs

Figure 3. Areal extent of major floods with a recurrence interval of 25 years or more in Texas, and annual peak discharge for selected sites, water years 1869–1988. (Source: Data from U.S. Geological Survey files.)

330,000 ft³/s, which also is greater than that expected once every 100 years.

Floods caused by rainfall associated with Tropical Storm Amelia caused severe and widespread damage in 17 counties in central Texas. Eight of these counties were declared flood-disaster areas by the Federal Government. In south-central Texas, 27 people drowned, about 150 people were injured, and property damage and losses were about $50 million. In north-central Texas, six people drowned, four were injured, and property damage and losses exceeded $60 million. In the total area affected by the storm, 33 people lost their lives, 154 were injured, and property damage and losses were estimated at $110 million (Schroeder and others, 1987).

DROUGHTS

Drought occurs in Texas on a relatively regular basis. Scorched pastureland, dry stock ponds, crop failures, decreased supplies of surface and ground water, increased food prices, and water rationing are but a few of the effects of drought. Indeed, drought has created immeasurable hardship and economic loss, either statewide or to parts of the State, in every decade of this century.

Major droughts in Texas, as determined from streamflow records collected since the early 1900's, occurred during the 1920's, 1930's, 1940's, 1950's, 1960's, and 1970's (Riggio and others, 1987). Although some of the streamflow records used in this analysis start as early as 1900–20, most start in the 1930's. Because of the limited quantity of data for the early 1900's, the discussion of droughts is limited to the period after 1930. Five major droughts have occurred in Texas since the early 1930's. These droughts were statewide but differed among areas with respect to duration and intensity. The areal extent and severity of these droughts, as determined from 22 long-term streamflow records from a statewide network, are shown on the maps in figure 4. The period of drought was composited from streamflow records at many gaging stations in each drought area. In basins upstream from any one gaging station, the drought may have begun or ended at dates that were different from the composited period of drought. The graphs in figure 4 show annual departure from average streamflow at six selected gaging stations. Streamflow records at some stations indicate essentially a continuous below-average discharge throughout a given drought period, while records at other stations indicate small periods of greater than normal streamflow. This pattern differed from station to station and from drought to drought. Drought recurrence intervals were computed with no consideration given to the small periods of greater than normal flow.

The droughts of 1932–34, 1938–40, and 1947–48, although statewide in extent, were considerably less severe than the droughts of 1950–57 and 1960–67. At most gaging stations, the recurrence interval of the earlier droughts was less than 25 years. Drought periods are not easily defined for some stations. Data from the Llano River near Junction (fig. 4, site 4) indicate a continuous period of drought lasting from the end of the 1938–40 drought through the 1947–48 drought. Data from the Clear Fork Brazos River at Fort Griffin (site 2) indicate continuous streamflow deficits from the 1947–48 drought through the 1950–57 drought. The streamflow record for the Frio River near Derby (fig. 4, site 6) indicates that 6 years of deficient streamflow preceded the 1947–48 drought and that the annual deficits continued into the 1950–57 drought.

The drought Texans remember most is that of 1950–57. This drought was the most intense and longest, on a statewide basis, for the entire 20th century to date. The recurrence intervals for the 1950–57 drought exceeded 25 years for the entire State and ranged from 50 to 80 years in most areas. Data from gaging stations on the Guadalupe and Frio Rivers (fig. 4, sites 5 and 6) indicate that the drought began several years earlier at those locations. Generally, streamflow remained deficient in most areas of the State for the entire period. At some gaging stations, short periods of average to greater than average flow occurred between longer periods of deficient flow.

The drought of 1960–67 was less severe than the 1950–57 drought in most areas of the State. Nonetheless, the drought recurrence interval at five of the six gaging stations exceeded 25 years (fig. 4). Recurrence intervals exceeded 60 years at sites 4 and 6 and 80 years at site 3.

Many other floods and droughts have occurred in Texas since the early 1900's. Although many were locally severe, they generally affected much smaller areas than those described in this report.

WATER MANAGEMENT

Surface-water resources are managed by the State and by the various river authorities. Many reservoirs and lakes have been built for conservation and flood control on most of the major rivers in Texas. No statutes authorize direct State regulation of flood-plain areas, and the State does not require that local governments adopt and administer such regulations. Local governments are the first to deal with drought conditions in their areas. Most cities and towns enact special, limited water-control measures to meet their individual needs. The State may become involved as a coordinator for statewide, severe drought.

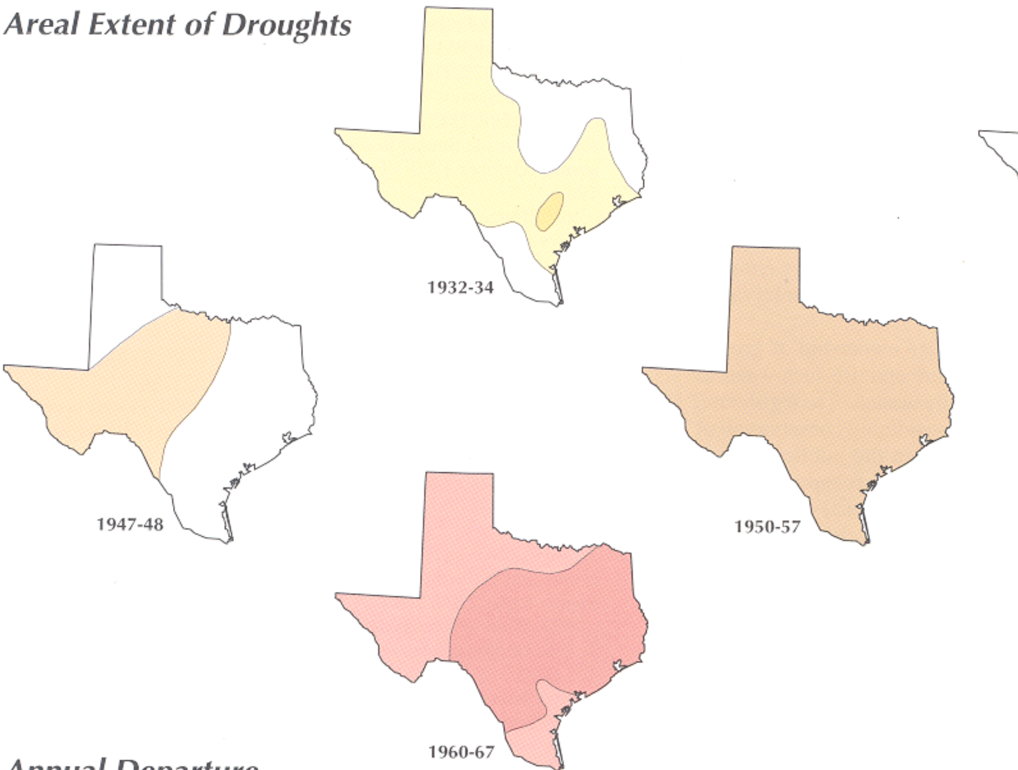
Flood-Plain Management.—Flood-plain-management programs in Texas have been implemented by local governments (cities and counties), pursuant to the Texas Flood Control and Insurance Act of 1969 (Section 16.315 of the Texas Water Code), for the purpose of participating in the National Flood Insurance Program. Local ordinances establishing such programs need to conform, at a minimum, to the criteria established by the Federal Emergency Management Agency for development in special flood-hazard areas.

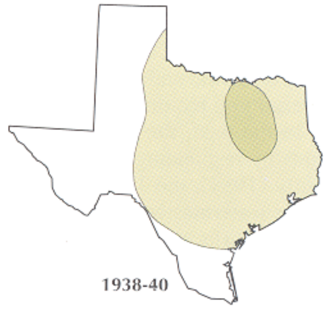
As of January 1, 1988, 1,257 communities in Texas have been designated by the Federal Emergency Management Agency as having special flood-hazard areas. Maps identifying these special flood-hazard areas have been published for 1,127 of these communities. To date (1989), 829 cities, counties, and special-purpose districts in Texas are participating in the flood-insurance program. To encourage sound flood-plain management and to promote the flood-insurance program, the State of Texas, through the Texas Water Commission, is a participant in the Community Assistance Program of the Federal Emergency Management Agency. Under this program, the Commission performs community assistance visits, provides ordinance and technical assistance, and conducts flood-plain-management workshops and seminars across the State. A quarterly Floodplain Management Newsletter also is published as part of this activity.

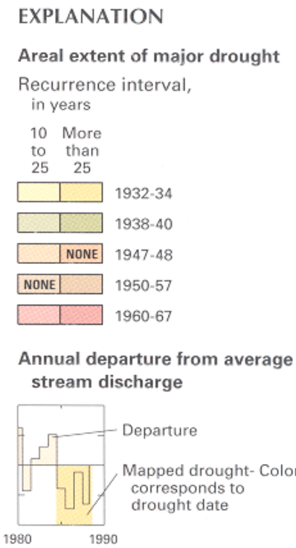
Flood-Warning Systems.—The NWS, through its various forecast offices, has the primary responsibility for issuing flood forecasts and warnings in the State. Recognizing the need for additional data and more accurate local flood warnings, many communities have established their own flood-warning systems. For some, this may be a network of volunteer rainfall observers. Through use of rainfall data and headwater tables developed by the NWS, runoff rates and volumes are predicted. The cities of Sinton and Hallettsville have installed automated flood sensors and alarm systems. Several other communities have installed a network of streamflow and precipitation stations in critical basins; the stations in the network are linked by radio to computer-based receiving stations. Several river authorities across the State also have installed these systems for reservoir operation and flood warnings. The Texas Water Commission currently (1989) is promoting automated flood-warning systems to lessen nonstructural flood loss.

Water-Use Management During Droughts.—Water that flows in a watercourse in Texas is considered to be surface water and is

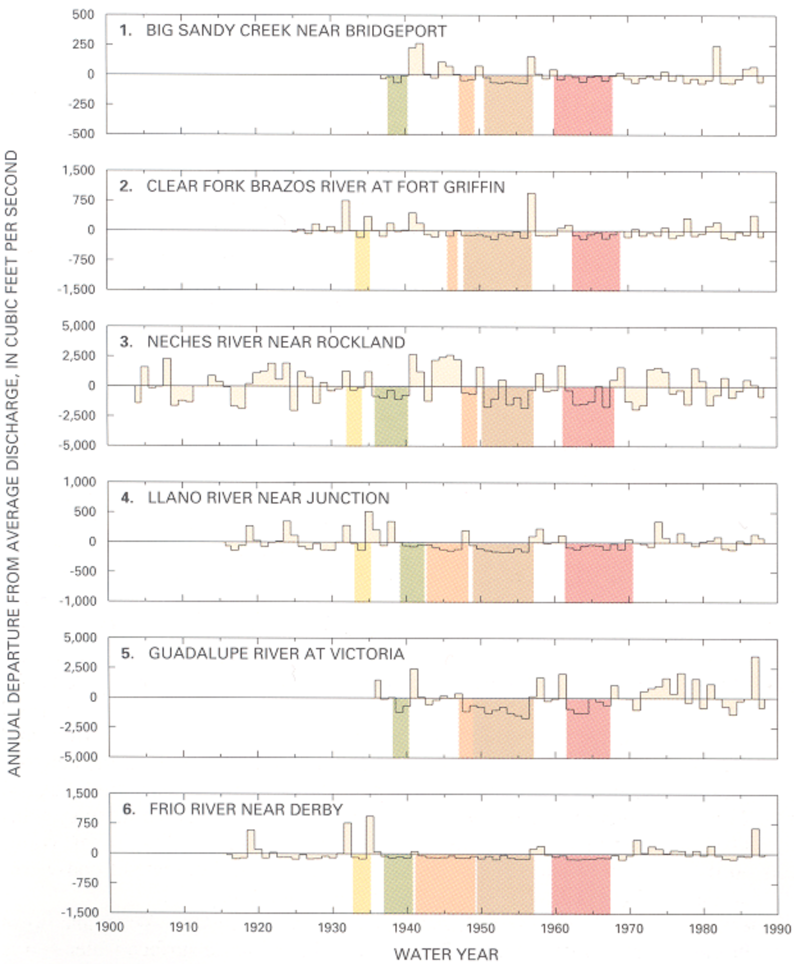
Areal Extent of Droughts

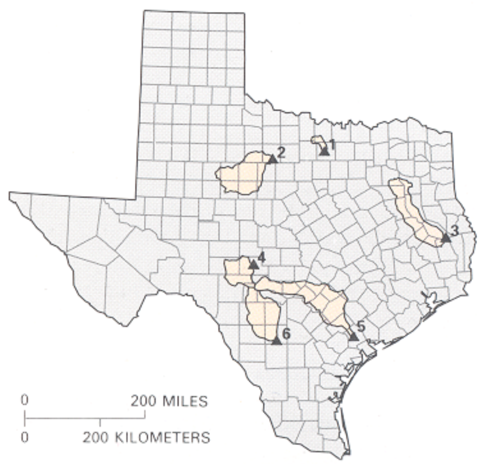






Annual Departure





U.S. Geological Survey streamflow-gaging stations and corresponding drainage basins— Numbers refer to graphs

Figure 4. Areal extent of major droughts with a recurrence interval of 10 years or more in Texas, and annual departure from average stream discharge for selected sites, water years 1904–88. (Source: Data from U.S. Geological Survey files.)

the property of the State. The use of surface water is administered by the Texas Water Commission through an appropriation system. Riparian domestic and livestock users of surface water are exempt from permitting requirements.

In the past, the State has managed surface water during droughts by responding to problem areas as they become known. Presently (1989), the Texas Water Commission is establishing a statewide watermaster program that will permit day-to-day management of surface waters within established water divisions. Although a watermaster operation will basically be an active enforcement program, it also will be a mechanism to encourage conservation of the State's surface-water resources.

Texas follows the doctrine of private ownership of ground water. It is the landowner's right to capture and use such water as long as the water is not wantonly or willfully wasted. The legislature, recognizing private ownership but also considering conservation of water in underground reservoirs as being in the public interest, adopted Chapter 52 of the Texas Water Code. That chapter provides for management of ground water by local or regional underground water conservation districts. No State agency has clear authority to regulate ground-water use. However, the Texas Water Commission has ground-water protection responsibilities, and has taken an active role in working with existing districts and encouraging the creation of new districts to promote the conservation of ground water.

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Prepared by B.D. Jones

FOR ADDITIONAL INFORMATION: District Chief, U.S. Geological Survey, 8011 Cameron Rd., Austin, TX 78753