USGS

science for a changing world

In cooperation with the Texas Department of Transportation

Synthesis of Rainfall and Runoff Data Used for Texas Department of Transportation Research Projects 0–4193 and 0–4194

Open-File Report 2004–1035
(TxDOT Research Reports 0–4193–2 and 0–4194–2)

U.S. Department of the Interior
U.S. Geological Survey

1. Report No. FHWA/TX–04/0–4193–2 FHWA/TX–04/0–4194–2	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle SYNTHESIS OF RAINFALL AND RUNOFF DATA USED FOR TEXAS DEPARTMENT OF TRANSPORTATION RESEARCH PROJECTS 0–4193 AND 0–4194		5. Report Date June 2004	
		6. Performing Organization Code	
7. Author(s) William H. Asquith, David B. Thompson, Theodore G. Cleveland, and Xing Fang		8. Performing Organization Report No. OFR 2004–1035	

9. Performing Organization Name and Address
  U.S. Geological Survey
  Water Resources Division
  8027 Exchange Drive
  Austin, Texas 78754
		10. Work Unit No. (TRAIS)	

		11. Contract or Grant No. Project 0–4193	
12. Sponsoring Agency Name and Address Texas Department of Transportation U.S. Geological Survey Research and Technology Implementation Office Water Resources Division 4000 Jackson Ave., Bldg. 1 8027 Exchange Drive P.O. Box 5080 Austin, Texas 78754 Austin, TX 78731		13. Type of Report and Period Covered Research from 2001 to 2004	
		14. Sponsoring Agency Code	

15. Supplementary Notes

Project conducted in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

16. Abstract

In the early 2000s, the Texas Department of Transportation funded several research projects to examine the unit hydrograph and rainfall hyetograph techniques for hydrologic design in Texas for the estimation of design flows for stormwater drainage systems. A research consortium comprised of Lamar University, Texas Tech University, the University of Houston, and the U.S. Geological Survey (USGS), was chosen to examine the unit hydrograph and rainfall hyetograph techniques. Rainfall and runoff data collected by the USGS at 91 streamflow-gaging stations in Texas formed a basis for the research. These data were collected as part of USGS small-watershed projects and urban watershed studies that began in the late 1950s and continued through most of the 1970s; a few gages were in operation in the mid-1980s. Selected hydrologic events from these studies were available in the form of over 220 printed reports, which offered the best aggregation of hydrologic data for the research objectives. Digital versions of the data did not exist. Therefore, a significant effort was undertaken by the research consortium to manually enter the data into a digital database from the printed record. The rainfall and runoff data for over 1,650 storms were entered. To enhance data integrity, considerable quality-control and quality-assurance efforts were conducted as the database was assembled and after assembly to enhance data integrity. This report documents the database and informs interested parties on its usage.

17. Key Words Precipitation, Rainfall, Runoff, Rainfall hyetograph, Unit hydrograph, Small watershed, Texas		18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161, www.ntis.gov	
19. Security Classif. (of report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages 1,050	22. Price

Form DOT F 1700.7 (8-72)   Reproduction of completed page authorized

Synthesis of Rainfall and Runoff Data Used for Texas Department of Transportation Research Projects 0–4193 and 0–4194

William H. Asquith, David B. Thompson, Theodore G. Cleveland, and Xing Fang

In cooperation with the Texas Department of Transportation

Open-File Report 2004–1035
(TxDOT Research Reports 0–4193–2 and 0–4194–2)

U.S. Department of the Interior
U.S. Geological Survey

U.S. DEPARTMENT OF THE INTERIOR

Gale A. Norton, Secretary

U.S. GEOLOGICAL SURVEY

Charles G. Groat, Director

Austin, Texas: June 2004

CONTENTS

FIGURES

TABLES

ACKNOWLEDGMENTS

SYNTHESIS OF RAINFALL AND RUNOFF DATA USED FOR TEXAS DEPARTMENT OF TRANSPORTATION RESEARCH PROJECTS 0–4193 AND 0–4194

By William H. Asquith[1], David B. Thompson[2], Theodore G. Cleveland[3], and Xing Fang[4]

ABSTRACT

In the early 2000s, the Texas Department of Transportation funded several research projects to examine the unit hydrograph and rainfall hyetograph techniques for hydrologic design in Texas for the estimation of design flows for stormwater drainage systems. A research consortium comprised of Lamar University, Texas Tech University, the University of Houston, and the U.S. Geological Survey (USGS), was chosen to examine the unit hydrograph and rainfall hyetograph techniques. Rainfall and runoff data collected by the USGS at 91 streamflow-gaging stations in Texas formed a basis for the research. These data were collected as part of USGS small-watershed projects and urban watershed studies that began in the late 1950s and continued through most of the 1970s; a few gages were in operation in the mid-1980s. Selected hydrologic events from these studies were available in the form of over 220 printed reports, which offered the best aggregation of hydrologic data for the research objectives. Digital versions of the data did not exist. Therefore, significant effort was undertaken by the consortium to manually enter the data into a digital database from the printed record. The rainfall and runoff data for over 1,650 storms were entered. To enhance data integrity, considerable quality-control and quality-assurance efforts were conducted as the database was assembled and after assembly to enhance data integrity. This report documents the database and informs interested parties on its usage.

INTRODUCTION

The U.S. Geological Survey (USGS) in collaborative peer-to-peer research projects with Lamar University, Texas Tech University, and the University of Houston, has developed a digital database of rainfall and runoff values for selected watersheds in Texas. The research was sponsored by Texas Department of Transportation research (TxDOT) projects 0–4139 and 0–4194. These projects are hereafter referred to as the "TxDOT research projects." The database is an aggregation of previously published sources and requires documentation in the context of the TxDOT research projects.

The data were derived from over 220 historical USGS data reports that occupy approximately 8 linear feet of bookshelf space. In total, the database contains more than 1,650 storms for 91 mostly small rural and urban watersheds in Texas. A small watershed is considered to have a drainage area of less than about 20 square miles. Each storm is

---

[1] U.S. Geological Survey, Austin, Texas
[2] Texas Tech University, Lubbock, Texas
[3] University of Houston, Houston, Texas
[4] Lamar University, Beaumont, Texas

recorded by rainfall and runoff for USGS streamflow-gaging stations in the watersheds. The locations of the stations are shown in figure 1. Detailed location maps of the respective study areas are available in each of the original reports, referenced in figures 14–29. Finally, a comprehensive citation list for the reports is provided in the "References" section of this report. The cited reports are organized by database module and are listed in chronological order.
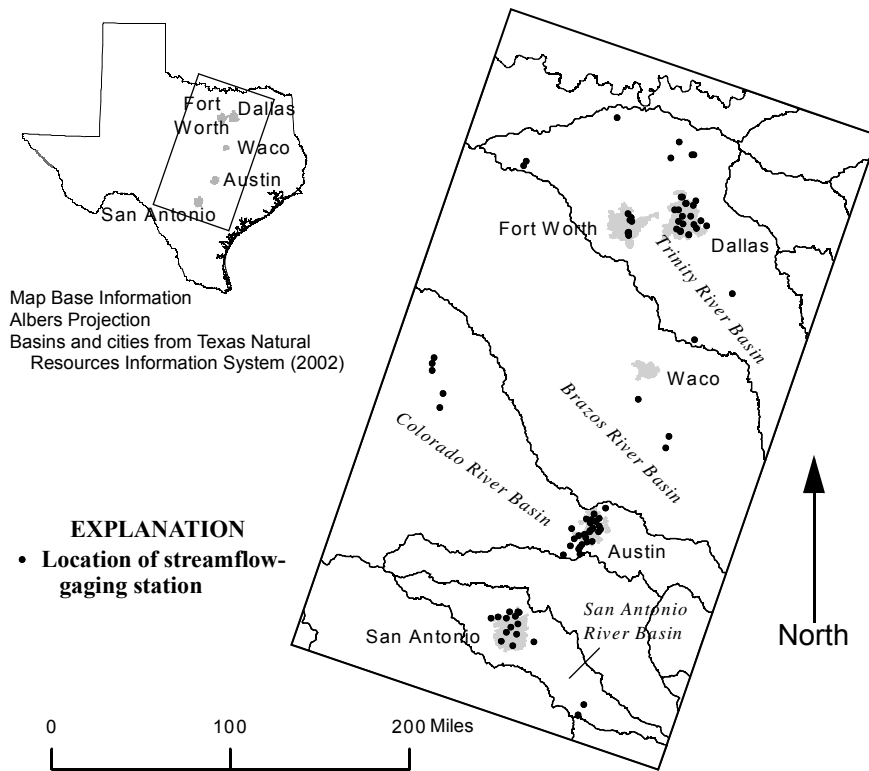
Figure 1. Locations of USGS streamflow-gaging stations represented in the database.

The purpose of this report is to document the database used by the investigators as part of the TxDOT research projects. The documentation of the database includes: (1) a basic description, (2) a listing of the original data sources, (3) the methods for converting data from original sources to the digital form used for the projects, (4) quality-assurance and quality-control measures implemented by the investigators, (5) description of limitations and caveats of the data, and (6) a complete listing of the data at the request of TxDOT.

RAINFALL-RUNOFF DATABASE

Overview

An overview of the database and its structure is described before details of the data are provided. The database contains rainfall and runoff values for watersheds in Texas. The database is separated into five "modules": `austin`, `fortworth`, `dallas`, `sanantonio`, and `smallruralsheds`. These modules correspond to a natural cataloging of the data reports.

The `austin`, `dallas`, `fortworth`, and `sanantonio` modules contain rainfall-runoff data for watersheds within or near the cities of Austin, Dallas, Fort Worth, and San Antonio, Texas, respectively. The data collection activities in these cities are known as the USGS "urban studies." [The USGS also has conducted investigations and published data reports for the Houston area. These data were not used for the TxDOT research projects because of time and funding constraints and in part because of the contemporary publication of Liscum (2001).] The drainage network for each watershed generally comprises first to third order tributaries (see detailed location maps in "References" section). The land use included in the urban studies ranges from fully developed urban to natural or rural watersheds.

The `smallruralsheds` module contains rainfall-runoff data for 12 intensively studied watershed units in rural regions of central to north-central Texas. The drainage network for each watershed generally comprises first to third order tributaries. The 12 watershed study units were studied in part by the historical development of the approximately 3,500 U.S. Soil Conservation Service (SCS) flood and soil-erosion control structures built in Texas between the period beginning in 1951–62 and ending in 1970–79. The USGS and SCS cooperatively collected data on a small fraction of these control structures and proximal watersheds.

The `smallruralsheds` module is further divided into four components: watersheds within the Brazos, Colorado, San Antonio, and Trinity River Basins. The Brazos River section contains four watershed study units: Cow Bayou, Green Creek, and Little Pond and North Elm Creeks watersheds. (Little Pond and North Elm Creeks neighbor one another, and data for these creeks were published together.) The Colorado River section contains two watershed study units: Deep Creek and Mukewater Creek. The San Antonio River section contains two watershed study units: Calaveras Creek and Escondido Creek. Finally, the Trinity River section contains five watershed study units: Elm Fork Trinity River, Honey Creek, Little Elm Creek, North Creek, and Pin Oak Creek.

The rainfall and runoff components of the database are described in separate sections of this report. Each "storm event" is recorded in the database by two data files. One file for the rainfall of the storm, and a second data file for the storm runoff. The storm events were chosen by the previous USGS analysts; the events are not inclusive of all rainfall-runoff events for the watersheds. Factors influencing whether an event was published in the original data reports include: instrument operation (data integrity), significance or magnitude of the storm, time of year, or simply the desire to have the data for a few storms per year published. The stations, for which incremental values of concomitant streamflow and rainfall for storm events are available, are listed in tables 1–5.

Table 1. U.S. Geological Survey streamflow–gaging stations within the `austin` database module.

[mi^2, square miles; Approx., approximate; SH, State Highway; U.S., U.S. Highway; FM, Farm to Market Road; IH, Interstate Highway. 1 mi^2 equals 2.59 square kilometers (km^2)]

Station no.	Station name	Latitude	Longitude	Drainage area (mi^2)	Approx. period of record
08154700	Bull Creek at Loop 360, Austin, Texas	30°22'19"	97°47'04"	22.3	1978–86
08155200	Barton Creek at SH 71, Oak Hill, Texas	30°17'46"	97°55'31"	89.7	1978–82
08155300	Barton Creek at Loop 360, Austin, Texas	30°14'40"	97°48'07"	116.0	1979–86
08155550	West Bouldin Creek at Riverside Drive, Austin, Texas	30°15'49"	97°45'17"	3.12	1977–85
08156650	Shoal Creek at Steck Avenue, Austin, Texas	30°21'55"	97°44'11"	2.79	1975–82
08156700	Shoal Creek at Northwest Park, Austin, Texas	30°20'50"	97°44'41"	7.03	1976–83
08156750	Shoal Creek at White Rock Drive, Austin, Texas	30°20'21"	97°44'50"	7.56	1976–80
08156800	Shoal Creek at 12th Street, Austin, Texas	30°16'35"	97°45'00"	12.3	1975–86
08157000	Waller Creek at 38th Street, Austin, Texas	30°17'49"	97°43'36"	2.31	1967–80
08157500	Waller Creek at 23rd Street, Austin, Texas	30°17'08"	97°44'01"	4.13	1967–80
08158050	Boggy Creek at U.S. 183, Austin, Texas	30°15'47"	97°40'20"	13.1	1976–85
08158100	Walnut Creek at FM 1325, Austin, Texas	30°24'35"	97°42'41"	12.6	1976–86
08158200	Walnut Creek at Dessau Road, Austin, Texas	30°22'30"	97°39'37"	26.2	1976–86
08158380	Little Walnut Creek at Georgian Drive Austin, Texas	30°21'15"	97°41'52"	5.22	1985–86
08158400	Little Walnut Creek at IH 35, Austin, Texas	30°20'57"	97°41'34"	5.57	1976–81
08158500	Little Walnut Creek at Manor Road, Austin, Texas	30°18'34"	97°40'04"	12.1	1976–81
08158600	Walnut Creek at Webberville Road, Austin, Texas	30°16'59"	97°39'17"	51.3	1974–86
08158700	Onion Creek near Driftwood, Texas	30°04'59"	98°00'29"	124	1980–87
08158800	Onion Creek at Buda, Texas	30°05'09"	97°50'52"	166	1980–83
08158810	Bear Creek below FM 1826, Driftwood, Texas	30°09'19"	97°56'23"	12.2	1980–86
08158820	Bear Creek at FM 1626, Manchaca, Texas	30°08'25"	97°50'50"	24.0	1980–83
08158825	Little Bear Creek at FM 1626, Manchaca, Texas	30°07'31"	97°51'43"	21.0	1980–83
08158840	Slaughter Creek at FM 1826, Austin, Texas	30°12'32"	97°54'11"	8.24	1979–86
08158860	Slaughter Creek at FM 2304, Austin, Texas	30°09'43"	97°49'55"	23.1	1981–82
08158880	Boggy Creek (south) at Circle "S" Road, Austin, Texas	30°10'50"	97°46'55"	3.58	1976–86
08158920	Williamson Creek at Oak Hill, Texas	30°14'06"	97°51'36"	6.3	1979–84
08158930	Williamson Creek at Manchaca Road, Austin, Texas	30°13'16"	97°47'36"	19.0	1976–84
08158970	Williamson Creek at Jimmy Clay Road, Austin, Texas	30°11'21"	97°43'56"	27.6	1976–86
08159150	Wilbarger Creek near Pflugerville, Texas	30°27'16"	97°36'02"	4.61	1967–77

Table 2. U.S. Geological Survey streamflow–gaging stations within the `dallas` database module.

[mi^2, square miles; Approx., approximate; U.S., U.S. Highway; IH, Interstate Highway; SH, State Highway. 1 mi^2 equals 2.59 square kilometers (km^2)]

Station no.	Station name	Latitude	Longitude	Drainage area (mi^2)	Approx. period of record
08055580	Joes Creek at Royal Lane, Dallas, Texas	32°53'43"	96°41'36"	1.94	1974–79
08055600	Joes Creek, Dallas, Texas	32°51'41"	96°52'27"	7.51	1973–79
08055700	Bachman Branch, Dallas, Texas	32°51'37"	96°50'13"	10.0	1964–79
08056500	Turtle Creek, Dallas, Texas	32°48'26"	96°48'08"	7.98	1964–79
08057020	Coombs Creek at Sylvan Avenue, Dallas, Texas	32°46'01"	96°50'07"	4.75	1965–79
08057050	Cedar Creek at Bonnie View Road, Dallas, Texas	32°44'50"	96°47'44"	9.42	1974–79
08057120	Spanky Branch at McCallum Lane, Dallas, Texas	32°57'58"	96°48'11"	6.77	1973–78
08057130	Rush Branch at Arapaho Road, Dallas, Texas	32°57'45"	96°47'44"	1.22	1973–79
08057140	Cottonwood Creek at Forest Lane, Dallas, Texas	32°54'33"	96°45'54"	8.5	1973–78
08057160	Floyd Branch at Forest Lane, Dallas, Texas	32°54'33"	96°45'34"	4.17	1974–79
08057320	Ash Creek at Highland Road, Dallas, Texas	32°48'18"	96°43'04"	6.92	1973–78
08057415	Elam Creek at Seco Boulevard, Dallas, Texas	32°44'14"	96°41'36"	1.25	1973–79
08057418	Fivemile Creek at Kiest Boulevard, Dallas, Texas	32°42'19"	96°51'32"	7.65	1976–79
08057420	Fivemile Creek at U.S. 77, Dallas, Texas	32°41'15"	96°49'22"	13.2	1973–79
08057425	Woody Branch at U.S. 77, Dallas, Texas	32°40'58"	96°49'22"	11.5	1973–79
08057435	Newton Creek at IH 635, Dallas, Texas	32°39'19"	96°44'41"	5.91	1976–79
08057440	Whites Branch at IH 635, Dallas Texas	32°39'26"	96°44'25"	2.53	1976–79
08057445	Prairie Creek at U.S. 175, Dallas, Texas	32°42'17"	96°40'11"	9.03	1976–79
08061620	Duck Creek at Buckingham Road, Garland, Texas	32°55'53"	96°39'55"	8.05	1973–79
08061920	South Mesquite Creek at SH 352, Mesquite, Texas	32°46'09"	96°37'18"	13.4	1973–79
08061950	South Mesquite Creek at Mercury Road, Mesquite, Texas	32°43'32"	96°34'12"	23.0	1969–79

Table 3. U.S. Geological Survey streamflow–gaging stations within the `fortworth` database module.

[mi^2, square miles; Approx., approximate; --, not available; IH, Interstate Highway; W, West. 1 mi^2 equals 2.59 square kilometers (km^2)]

Station no.	Station name	Latitude	Longitude	Drainage area (mi^2)	Approx. period of record
--	Seminary South Shopping Center, Fort Worth, Texas	--	--	0.38	1970–76
08048520	Sycamore Creek at IH 35–W, Fort Worth, Texas	32°39'55"	97°19'16"	17.7	1970–77
08048530	Sycamore Creek tributary above Seminary South Shopping Center, Fort Worth, Texas	32°41'08"	97°19'44"	0.97	1970–77
08048540	Sycamore Creek tributary at IH 35–W, Fort Worth, Texas	32°41'18"	97°19'11"	1.35	1970–76
08048550	Dry Branch at Blandin Street, Fort Worth, Texas	32°47'19"	97°18'22"	1.08	1969–76
08048600	Dry Branch at Fain Street, Fort Worth, Texas	32°46'34"	97°17'18"	2.15	1969–77
08048820	Little Fossil Creek at IH 820, Fort Worth, Texas	32°50'22"	97°19'22"	5.64	1969–77
08048850	Little Fossil Creek at Mesquite Street, Fort Worth, Texas	32°48'33"	97°17'28"	12.3	1969–77

Table 4. U.S. Geological Survey streamflow–gaging stations within the `sanantonio` database module.

[mi^2, square miles; Approx., approximate; FM, Farm to Market Road. 1 mi^2 equals 2.59 square kilometers (km^2)]

Station no.	Station name	Latitude	Longitude	Drainage area (mi^2)	Approx. period of record
08177600	Olmos Creek tributary at FM 1535, Shavano Park, Texas	29°34'35"	98°32'45"	0.33	1970–81
08177700	Olmos Creek at Dresden Drive, San Antonio, Texas	29°29'56"	98°30'36"	21.2	1969–78
08178300	Alazan Creek at St. Cloud Street, San Antonio, Texas	29°27'29"	98°32'59"	3.26	1969–79
08178555	Harlendale Creek at West Harding Street, San Antonio, Texas	29°21'05"	98°29'32"	2.43	1977–80
08178600	Panther Springs Creek at FM 2696 near San Antonio, Texas	29°37'31"	98°31'06"	9.54	1969–75
08178620	Lorence Creek at Thousand Oaks Boulevard, San Antonio, Texas	29°35'24"	98°27'47"	4.05	1981–81
08178640	West Elm Creek at San Antonio, Texas	29°37'23"	98°26'29"	2.45	1976–79
08178645	East Elm Creek at San Antonio, Texas	29°37'04"	98°25'41"	2.33	1976–79
08178690	Salado Creek tributary at Bitters Road, San Antonio, Texas	29°31'36"	98°26'25"	0.26	1969–81
08178736	Salado Creek tributary at Bee Street, San Antonio, Texas	29°26'38"	98°27'13"	0.45	1972–76
08181000	Leon Creek tributary at FM 1604, San Antonio, Texas	29°35'14"	98°37'40"	5.57	1970–79
08181400	Helotes Creek at Helotes, Texas	29°34'42"	98°41'29"	15.0	1969–81
08181450	Leon Creek tributary at Kelly Air Force Base, Texas	29°23'12"	98°36'00"	1.19	1969–79

Description of the database layout is provided for clarity. A listing of the directory nomenclature of the data hierarchy for each module is shown in figures 2–6. In each figure the "/" symbol is an individual directory separator. The parent module is shown at the beginning of each line, such as `austin`. For the four urban databases (figs. 2–5), the second entry in the line is the local watershed name, such as `ShoalCreek`. For the `smallruralsheds` module (fig. 6), the second entry in the line is a major river basin in Texas, such as `BrazosBasin`. The specific station is identified by `sta#######_d`, where # represents a single digit in the USGS eight-digit station number. Following the station number component are two subdirectories: `hyetos` and `hydros`. These directories contain the actual data files. The `hyetos` directory contains the rainfall or hyetograph data files, and the `hydros` directory contains the runoff data files.

For brevity, a listing of the data file names are not provided in this section. However, the entire contents of the database are provided at the end of this report, and the data file names are shown in the header of the data files (see next two sections). The rainfall data files are named according to the following example: `rain_sta08156800_1981_0523.dat`. The station number follows the "`sta`" component, the next four digits represent the year (1981) and the following four digits represent the month (May) and day (23rd) of the storm. If multiple storms occurred on the same day for the same station, then another underscore and four digits representing the hour and minute of the start of the storm follows. Single digit values for month, day, hour, and minute are always prepended with a leading 0; this practice conveniently ensures that sorted lists of file names are in chronological order.

Table 5. U.S. Geological Survey streamflow-gaging stations within the `smallruralsheds` database module.

[mi^2, square miles; Approx., approximate; Sub., Subwatershed; The * notes that two different drainage areas have been published for this station. 1 mi^2 equals 2.59 square kilometers (km^2)]

Station no.	Station name	Latitude	Longitude	Drainage area (mi^2)	Approx. period of record
TRINITY RIVER BASIN					
08042650	North Creek Sub. 28A near Jermyn, Texas	33°14'52"	98°19'19"	6.82	1973–79
08042700	North Creek near Jacksboro, Texas	33°16'57"	98°17'53"	21.6	1959–79
08050200	Elm Fork Trinity River Sub. 6 near Muenster, Texas	33°37'13"	97°24'15"	.77	1961–70
08052630	Little Elm Creek Sub. 10 near Gunter, Texas	33°24'33"	96°48'41"	2.10	1966–76
08052700	Little Elm Creek near Aubrey, Texas	33°17'00"	96°53'33"	75.5	1959–76
08057500	Honey Creek Sub. 11 near McKinney, Texas	33°18'12"	96°41'22"	2.14	1960–70
08058000	Honey Creek Sub.12 near McKinney, Texas	33°18'20"	96°40'12"	1.26	1959–70
08063200	Pin Oak Creek near Hubbard, Texas	31°48'01"	96°43'02"	17.6	1959–71
BRAZOS RIVER BASIN					
08094000	Green Creek Sub. 1 near Dublin, Texas	32°10'00"	98°20'30"	*3.18/ 4.19	1959–71
08096800	Cow Bayou Sub. 4 near Bruceville, Texas	31°19'59"	97°16'02"	*5.25/ 5.04	1959–75
08098300	Little Pond Creek near Burlington, Texas	31°01'35"	96°59'17"	22.2	1964–72
08108200	North Elm Creek near Cameron, Texas	30°55'52"	97°01'13"	48.6	1964–72
COLORADO RIVER BASIN					
08136900	Mukewater Creek Sub. 10A near Trickham, Texas	31°39'01"	99°13'30"	21.8	1966–73
08137000	Mukewater Creek Sub. 9 near Trickham, Texas	31°41'40"	99°12'18"	4.02	1961–73
08137500	Mukewater Creek at Trickham, Texas	31°35'24"	99°13'36"	70.4	1959–61
08139000	Deep Creek Sub. 3 near Placid,Texas	31°17'25"	99°09'22"	3.42	1960–71
08140000	Deep Creek Sub. 8 near Mercury, Texas	31°24'08"	99°07'17"	*4.32/ 5.41	1960–71
SAN ANTONIO RIVER BASIN					
08182400	Calaveras Creek Sub. 6 near Elmendorf, Texas	29°22'49"	98°17'33"	7.01	1961–71
08187000	Escondido Creek Sub. 1 near Kenedy, Texas	28°46'41"	97°53'41"	3.29	1959–71
08187900	Escondido Creek Sub. 11 near Kenedy, Texas	28°51'39"	97°50'39"	8.43	1962–70

The runoff data files are named similarly except `unit` instead of `rain` begins the file name: `unit_sta08156800_1981_0523.dat`. A special note is needed concerning the runoff data file name; the date-time values of the runoff data file name exactly match those in the rainfall file. The beginning of the storm rainfall dictated the date-time value in both rainfall and runoff file names.

```
austin/BartonCreek/sta08155200_d/hydros          austin/SlaughterCreek/sta08158840_d/hyetos
austin/BartonCreek/sta08155200_d/hyetos          austin/SlaughterCreek/sta08158860_d/hydros
austin/BartonCreek/sta08155300_d/hydros          austin/SlaughterCreek/sta08158860_d/hyetos
austin/BartonCreek/sta08155300_d/hyetos          austin/WallerCreek/sta08157000_d/hydros
austin/BearCreek/sta08158810_d/hydros            austin/WallerCreek/sta08157000_d/hyetos
austin/BearCreek/sta08158810_d/hyetos            austin/WallerCreek/sta08157500_d/hydros
austin/BearCreek/sta08158820_d/hydros            austin/WallerCreek/sta08157500_d/hyetos
austin/BearCreek/sta08158820_d/hyetos            austin/WalnutCreek/sta08158100_d/hydros
austin/BearCreek/sta08158825_d/hydros            austin/WalnutCreek/sta08158100_d/hyetos
austin/BearCreek/sta08158825_d/hyetos            austin/WalnutCreek/sta08158200_d/hydros
austin/BoggyCreek/sta08158050_d/hydros           austin/WalnutCreek/sta08158200_d/hyetos
austin/BoggyCreek/sta08158050_d/hyetos           austin/WalnutCreek/sta08158400_d/hydros
austin/BoggyCreekSouth/sta08158880_d/            austin/WalnutCreek/sta08158400_d/hyetos
hydros                                            austin/WalnutCreek/sta08158500_d/hydros
austin/BoggyCreekSouth/sta08158880_d/            austin/WalnutCreek/sta08158500_d/hyetos
hyetos                                            austin/WalnutCreek/sta08158600_d/hydros
austin/BullCreek/sta08154700_d/hydros            austin/WalnutCreek/sta08158600_d/hyetos
austin/BullCreek/sta08154700_d/hyetos            austin/WestBouldinCreek/sta08155550_d/
austin/LittleWalnutCreek/sta08158380_d/          hydros
hydros                                            austin/WestBouldinCreek/sta08155550_d/
austin/LittleWalnutCreek/sta08158380_d/          hyetos
hyetos                                            austin/WilbargerCreek/sta08159150_d/hydros
austin/OnionCreek/sta08158700_d/hydros           austin/WilbargerCreek/sta08159150_d/hyetos
austin/OnionCreek/sta08158700_d/hyetos           austin/WilliamsonCreek/sta08158920_d/
austin/OnionCreek/sta08158800_d/hydros           hydros
austin/OnionCreek/sta08158800_d/hyetos           austin/WilliamsonCreek/sta08158920_d/
austin/ShoalCreek/sta08156650_d/hydros           hyetos
austin/ShoalCreek/sta08156650_d/hyetos           austin/WilliamsonCreek/sta08158930_d/
austin/ShoalCreek/sta08156700_d/hydros           hydros
austin/ShoalCreek/sta08156700_d/hyetos           austin/WilliamsonCreek/sta08158930_d/
austin/ShoalCreek/sta08156750_d/hydros           hyetos
austin/ShoalCreek/sta08156750_d/hyetos           austin/WilliamsonCreek/sta08158970_d/
austin/ShoalCreek/sta08156800_d/hydros           hydros
austin/ShoalCreek/sta08156800_d/hyetos           austin/WilliamsonCreek/sta08158970_d/
austin/SlaughterCreek/sta08158840_d/hydros       hyetos
```

Figure 2. Directory structure of the `austin` database module.

```
dallas/AshCreek/sta08057320_d/hydros          dallas/JoesCreek/sta08055580_d/hyetos
dallas/AshCreek/sta08057320_d/hyetos          dallas/JoesCreek/sta08055600_d/hydros
dallas/BachmanBranch/sta08055700_d/hydros     dallas/JoesCreek/sta08055600_d/hyetos
dallas/BachmanBranch/sta08055700_d/hyetos     dallas/NewtonCreek/sta08057435_d/hydros
dallas/CedarCreek/sta08057050_d/hydros        dallas/NewtonCreek/sta08057435_d/hyetos
dallas/CedarCreek/sta08057050_d/hyetos        dallas/PrairieCreek/sta08057445_d/hydros
dallas/CoombsCreek/sta08057020_d/hydros       dallas/PrairieCreek/sta08057445_d/hyetos
dallas/CoombsCreek/sta08057020_d/hyetos       dallas/RushBranch/sta08057130_d/hydros
dallas/CottonwoodCreek/sta08057140_d/hydros   dallas/RushBranch/sta08057130_d/hyetos
dallas/CottonwoodCreek/sta08057140_d/hyetos   dallas/SouthMesquite/sta08061920_d/hydros
dallas/DuckCreek/sta08061620_d/hydros         dallas/SouthMesquite/sta08061920_d/hyetos
dallas/DuckCreek/sta08061620_d/hyetos         dallas/SouthMesquite/sta08061950_d/hydros
dallas/ElamCreek/sta08057415_d/hydros         dallas/SouthMesquite/sta08061950_d/hyetos
dallas/ElamCreek/sta08057415_d/hyetos         dallas/SpankyCreek/sta08057120_d/hydros
dallas/FivemileCreek/sta08057418_d/hydros     dallas/SpankyCreek/sta08057120_d/hyetos
dallas/FivemileCreek/sta08057418_d/hyetos     dallas/TurtleCreek/sta08056500_d/hydros
dallas/FivemileCreek/sta08057420_d/hydros     dallas/TurtleCreek/sta08056500_d/hyetos
dallas/FivemileCreek/sta08057420_d/hyetos     dallas/WhitesBranch/sta08057440_d/hydros
dallas/FloydBranch/sta08057160_d/hydros       dallas/WhitesBranch/sta08057440_d/hyetos
dallas/FloydBranch/sta08057160_d/hyetos       dallas/WoodyBranch/sta08057425_d/hydros
dallas/JoesCreek/sta08055580_d/hydros         dallas/WoodyBranch/sta08057425_d/hyetos
```

Figure 3. Directory structure of the `dallas` **database module.**

```
fortworth/DryBranch/sta08048550_d/hydros      fortworth/Sycamore/sta08048520_d/hydros
fortworth/DryBranch/sta08048550_d/hyetos      fortworth/Sycamore/sta08048520_d/hyetos
fortworth/DryBranch/sta08048600_d/hydros      fortworth/Sycamore/sta08048530_d/hydros
fortworth/DryBranch/sta08048600_d/hyetos      fortworth/Sycamore/sta08048530_d/hyetos
fortworth/LittleFossil/sta08048820_d/hydros   fortworth/Sycamore/sta08048540_d/hydros
fortworth/LittleFossil/sta08048820_d/hyetos   fortworth/Sycamore/sta08048540_d/hyetos
fortworth/LittleFossil/sta08048850_d/hydros   fortworth/Sycamore/staSSSC_d/hydros
fortworth/LittleFossil/sta08048850_d/hyetos   fortworth/Sycamore/staSSSC_d/hyetos
```

Figure 4. Directory structure of the `fortworth` **database module.**

```
sanantonio/AlazanCreek/sta08178300_d/hydros   sanantonio/SaladoCreek/sta08178600_d/hydros
sanantonio/AlazanCreek/sta08178300_d/hyetos   sanantonio/SaladoCreek/sta08178600_d/hyetos
sanantonio/LeonCreek/sta08181000_d/hydros     sanantonio/SaladoCreek/sta08178620_d/hydros
sanantonio/LeonCreek/sta08181000_d/hyetos     sanantonio/SaladoCreek/sta08178620_d/hyetos
sanantonio/LeonCreek/sta08181400_d/hydros     sanantonio/SaladoCreek/sta08178640_d/hydros
sanantonio/LeonCreek/sta08181400_d/hyetos     sanantonio/SaladoCreek/sta08178640_d/hyetos
sanantonio/LeonCreek/sta08181450_d/hydros     sanantonio/SaladoCreek/sta08178645_d/hydros
sanantonio/LeonCreek/sta08181450_d/hyetos     sanantonio/SaladoCreek/sta08178645_d/hyetos
sanantonio/OlmosCreek/sta08177600_d/hydros    sanantonio/SaladoCreek/sta08178690_d/hydros
sanantonio/OlmosCreek/sta08177600_d/hyetos    sanantonio/SaladoCreek/sta08178690_d/hyetos
sanantonio/OlmosCreek/sta08177700_d/hydros    sanantonio/SaladoCreek/sta08178736_d/hydros
sanantonio/OlmosCreek/sta08177700_d/hyetos    sanantonio/SaladoCreek/sta08178736_d/hyetos
sanantonio/OlmosCreek/sta08178555_d/hydros
sanantonio/OlmosCreek/sta08178555_d/hyetos
```

Figure 5. Directory structure of the `sanantonio` **database module.**

```
smallruralsheds/BrazosBasin/CowBayou/          smallruralsheds/SanAntonioBasin/Escondido/
sta08096800_d/hydros                           sta08187000_d/hydros

smallruralsheds/BrazosBasin/CowBayou/          smallruralsheds/SanAntonioBasin/Escondido/
sta08096800_d/hyetos                           sta08187000_d/hyetos

smallruralsheds/BrazosBasin/Green/             smallruralsheds/SanAntonioBasin/Escondido/
sta08094000_d/hydros                           sta08187900_d/hydros

smallruralsheds/BrazosBasin/Green/             smallruralsheds/SanAntonioBasin/Escondido/
sta08094000_d/hyetos                           sta08187900_d/hyetos

smallruralsheds/BrazosBasin/Pond-Elm/
sta08098300_d/hydros
                                               smallruralsheds/TrinityBasin/ElmFork/
smallruralsheds/BrazosBasin/Pond-Elm/          sta08050200_d/hydros
sta08098300_d/hyetos
                                               smallruralsheds/TrinityBasin/ElmFork/
smallruralsheds/BrazosBasin/Pond-Elm/          sta08050200_d/hyetos
sta08108200_d/hydros
                                               smallruralsheds/TrinityBasin/Honey/
smallruralsheds/BrazosBasin/Pond-Elm/          sta08057500_d/hydros
sta08108200_d/hyetos
                                               smallruralsheds/TrinityBasin/Honey/
                                               sta08057500_d/hyetos

smallruralsheds/ColoradoBasin/Deep/            smallruralsheds/TrinityBasin/Honey/
sta08139000_d/hydros                           sta08058000_d/hydros

smallruralsheds/ColoradoBasin/Deep/            smallruralsheds/TrinityBasin/Honey/
sta08139000_d/hyetos                           sta08058000_d/hyetos

smallruralsheds/ColoradoBasin/Deep/            smallruralsheds/TrinityBasin/LittleElm/
sta08140000_d/hydros                           sta08052630_d/hydros

smallruralsheds/ColoradoBasin/Deep/            smallruralsheds/TrinityBasin/LittleElm/
sta08140000_d/hyetos                           sta08052630_d/hyetos

smallruralsheds/ColoradoBasin/Mukewater/       smallruralsheds/TrinityBasin/LittleElm/
sta08136900_d/hydros                           sta08052700_d/hydros

smallruralsheds/ColoradoBasin/Mukewater/       smallruralsheds/TrinityBasin/LittleElm/
sta08136900_d/hyetos                           sta08052700_d/hyetos

smallruralsheds/ColoradoBasin/Mukewater/       smallruralsheds/TrinityBasin/North/
sta08137000_d/hydros                           sta08042650_d/hydros

smallruralsheds/ColoradoBasin/Mukewater/       smallruralsheds/TrinityBasin/North/
sta08137000_d/hyetos                           sta08042650_d/hyetos

smallruralsheds/ColoradoBasin/Mukewater/       smallruralsheds/TrinityBasin/North/
sta08137500_d/hydros                           sta08042700_d/hydros

smallruralsheds/ColoradoBasin/Mukewater/       smallruralsheds/TrinityBasin/North/
sta08137500_d/hyetos                           sta08042700_d/hyetos

                                               smallruralsheds/TrinityBasin/PinOak/
                                               sta08063200_d/hydros
smallruralsheds/SanAntonioBasin/Calaveras/
sta08182400_d/hydros                           smallruralsheds/TrinityBasin/PinOak/
                                               sta08063200_d/hyetos
smallruralsheds/SanAntonioBasin/Calaveras/
sta08182400_d/hyetos
```

Figure 6. Directory structure of the `smallruralsheds` database module.

Rainfall Data—Hyetographs

Each storm within the database is represented by a single rainfall data or hyetograph file. There are 1,657 hyetograph files in the database; these files contain approximately 57,900 lines of data. Three standard components of an hyetograph data file are provided in figure 7. The three main components of the file are the header, the column titles, and the data records. The header of the file is identified by the lines containing the leading # sign. A single field line containing the label or column titles follows the header. This line is delimited by one or more spaces. Finally, the data records, which also are one or more space delimited, make up the remainder of the file. A part of the data lines have been removed from the figure because of limited space.

```
# HYETOGRAPH FILE
# Filename=rain_sta08156800_1981_0523.dat
# site=08156800 Shoal Creek at 12th Street, Austin, Texas.
# latitude=30()16'35"
# longitude=97()45'00"
# drainagearea (mi2)=12.3
# DATE_TIME=date and time in MM/DD/YYYY@HH:MM
# PRECIP1=1SHL raw recorded data
# PRECIP2=2SHL raw recorded data
# ACCUM_WTD_PRECIP=accumulated weighted precipitation in inches
DATE_TIME         HOURS_PASSED    PRECIP1      PRECIP2     ACCUM_WTD_PRECIP
05/23/1981@00:00:00     0.0000     0.0000     0.0000     0.0000
05/23/1981@23:30:00    23.5000     0.0700     0.0000     0.0200
05/23/1981@23:45:00    23.7500     0.5700     0.1900     0.2800
05/24/1981@00:00:00    24.0000     0.7400     0.5700     0.6100
05/24/1981@00:30:00    24.5000     1.0400     0.9200     0.9500
05/24/1981@01:00:00    25.0000     1.1300     1.0700     1.0800
              ... portion cut for brevity ...
05/25/1981@00:15:00    48.2500     8.5100     7.8800     8.0300
05/25/1981@00:30:00    48.5000     8.5700     7.9800     8.1200
05/25/1981@00:45:00    48.7500     8.6500     8.0200     8.1700
05/25/1981@01:00:00    49.0000     8.7300     8.0700     8.2300
05/25/1981@01:30:00    49.5000     8.7500     8.0800     8.2400
05/25/1981@02:00:00    50.0000     8.7900     8.1400     8.3000
```

Figure 7. Example hyetograph data file `austin/ShoalCreek/sta08156800_d/hyetos/` `rain_sta08156800_1981_0523.dat` **from the** `austin` **database module.**

Some other aspects of the data file in figure 7 that need description are the values for `PRECIP1`, `PRECIP2`, and `ACCUM_WTD_PRECIP`. The `ACCUM_WTD_PRECIP` (accumulated weighted precipitation) is the best available estimate of rainfall for the entire watershed and was derived from the `PRECIP1` and `PRECIP2` values. For example, two rain gages, labeled `PRECIP1` and `PRECIP2`, were operating during the May 1981 storm event in the Shoal Creek watershed. If additional rain gages were available during the event, then the labeling follows the `PRECIP#` convention. Often, but not always, one of the rain gages was coincident with the streamflow-gaging station. The raw data are shown in the `PRECIP#` fields. Sometimes the rainfall data collected for a watershed might include one or more weighing or volumetric rain gages, which previous authors determined more accurate data about total rainfall than the recording charts or tipping bucket rain gages. Volumetric rain gage data are not reported in the file, and hence are not explicitly represented in the database. The `ACCUM_WTD_PRECIP` values were computed by previous USGS analysts by amalgamated weighting of partial areas on the watershed and adjustments to the volumetric values when available. The partial area weight factors and volumetric adjustments are not reported for each rain gage for each storm in the database; the original data report is required to extract the appropriate weight and adjustment factors to convert the `PRECIP#` data to the `ACCUM_WTD_PRECIP` data.

The 1,657 hyetographs for the five database modules are shown in figures 8–12. In each of the five figures, the values composing each hyetograph are plotted against the concomitant time values in the top graphs (graphs A). The period of record available in each module is seen in graphs A. The separate watersheds within each database module are not differentiated. It is evident in graphs A that the number of storms represented per year is relatively uniform for the four urban database modules (figs. 8–11). Some minor clustering of events on a yearly basis is exhibited; this reflects concepts of "wet" and "dry" years. The `smallruralsheds` module (fig. 12) exhibits a marked reduction in the

number of storm events per year starting about 1972 as the study units were decommissioned. The last storms available in the database occur in 1987 for the `austin` module. Although the USGS and numerous collaborating agencies continue to collect data in rural and urban areas in Texas, compilation and publication of both rainfall and runoff data for individual storms immediately applicable to the TxDOT research projects are not available after about 1987 (outside of the Houston area).

It is important to note that the total number of visually distinct hyetographs in graphs A does not equal the number of events seen in the other graphs (B and C) or indicated in the figure title. This difference in count exists because numerous events typically occur simultaneously; a single storm system often affects many stations in the area surrounding and along the path of the system. This has the effect of causing many hyetographs to become masked in graphs A. Because many of the hyetographs occur on the same day or other intervals of time, the observed hyetographs are not each independent. Therefore, meteorological mechanisms generating each hyetograph are not random or statistically independent—the database does not contain as much *independent information* as suggested by the total number of hyetographs.

In order to visualize seasonal differences in the magnitude and the number of events, the year was converted to a common base (on a leap year) for the middle graphs (graphs B) in figures 8–12. A strong seasonal clustering of events is seen for the `austin` module (fig. 8). One cluster occurs between the middle of April and the middle of June, and a secondary cluster occurs in October. The `dallas` module (fig. 9) also exhibits a primary event cluster between the middle of April and the middle of June. Distinct clusters are harder to visualize in the `fortworth` module (fig. 10); although a weak cluster near the end of May might exist. The `sanantonio` module (fig. 11) exhibits a strong primary cluster between the middle of April and the middle of June. This is consistent with the `austin` module. A secondary cluster for the `sanantonio` module is less distinct and much longer lasting than that for the `austin` module. The cluster begins at the beginning of August and gradually tapers off towards the end of the year. The `smallruralsheds` module, which has the greatest range in geographic location of the five modules and includes areas proximate to the other four modules, exhibits two or three event clusters. One cluster occurs between the middle of April and the middle of June; a possible cluster near the end of July; and a final cluster between the end of August to the middle of October.

In the bottom graphs (graphs C) in figures 8–12, each hyetograph is plotted against the `HOURS_PASSED` field. A substantial variation in the temporal distribution of relative rainfall intensity (slope or first derivative of the lines) exists.
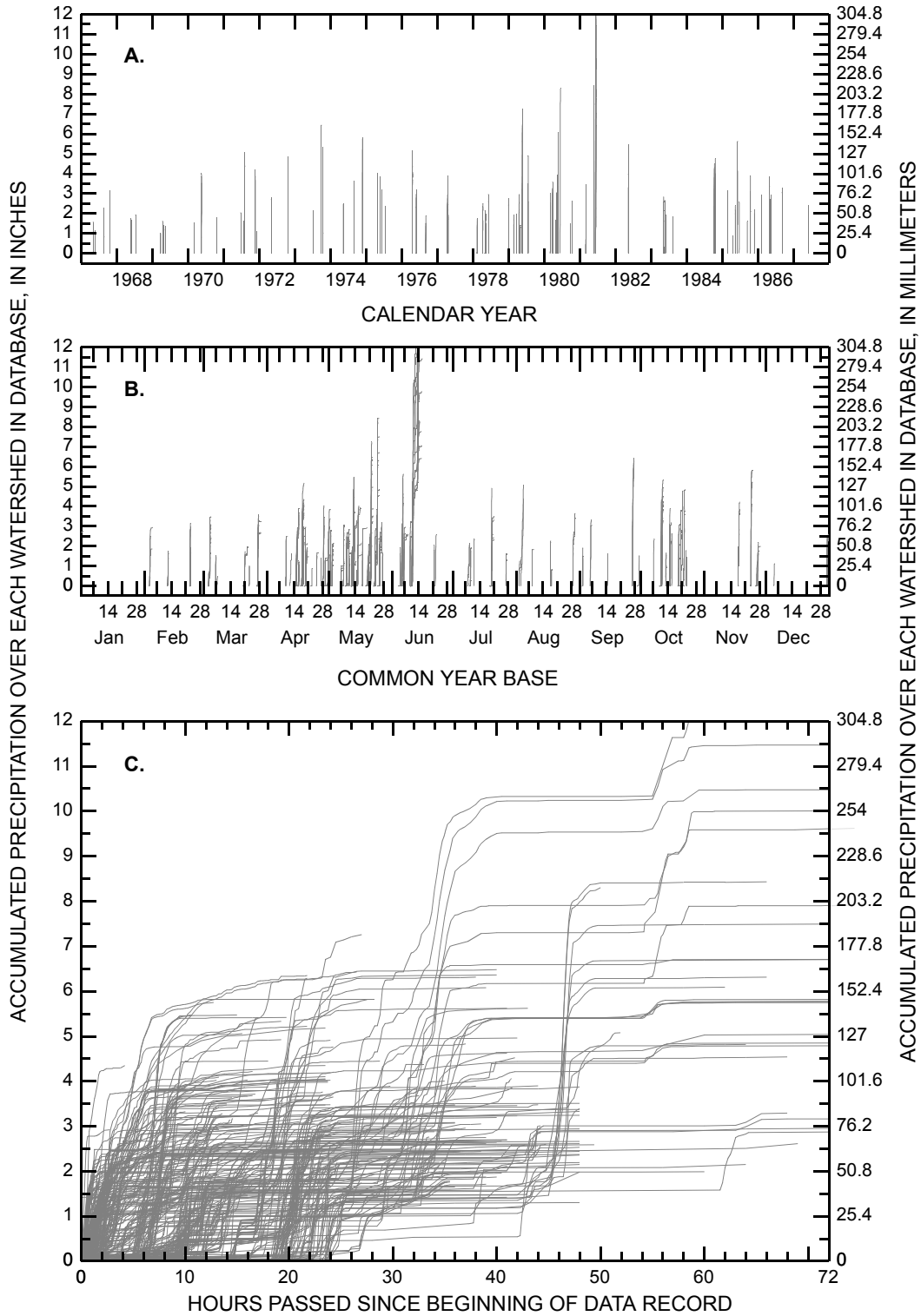
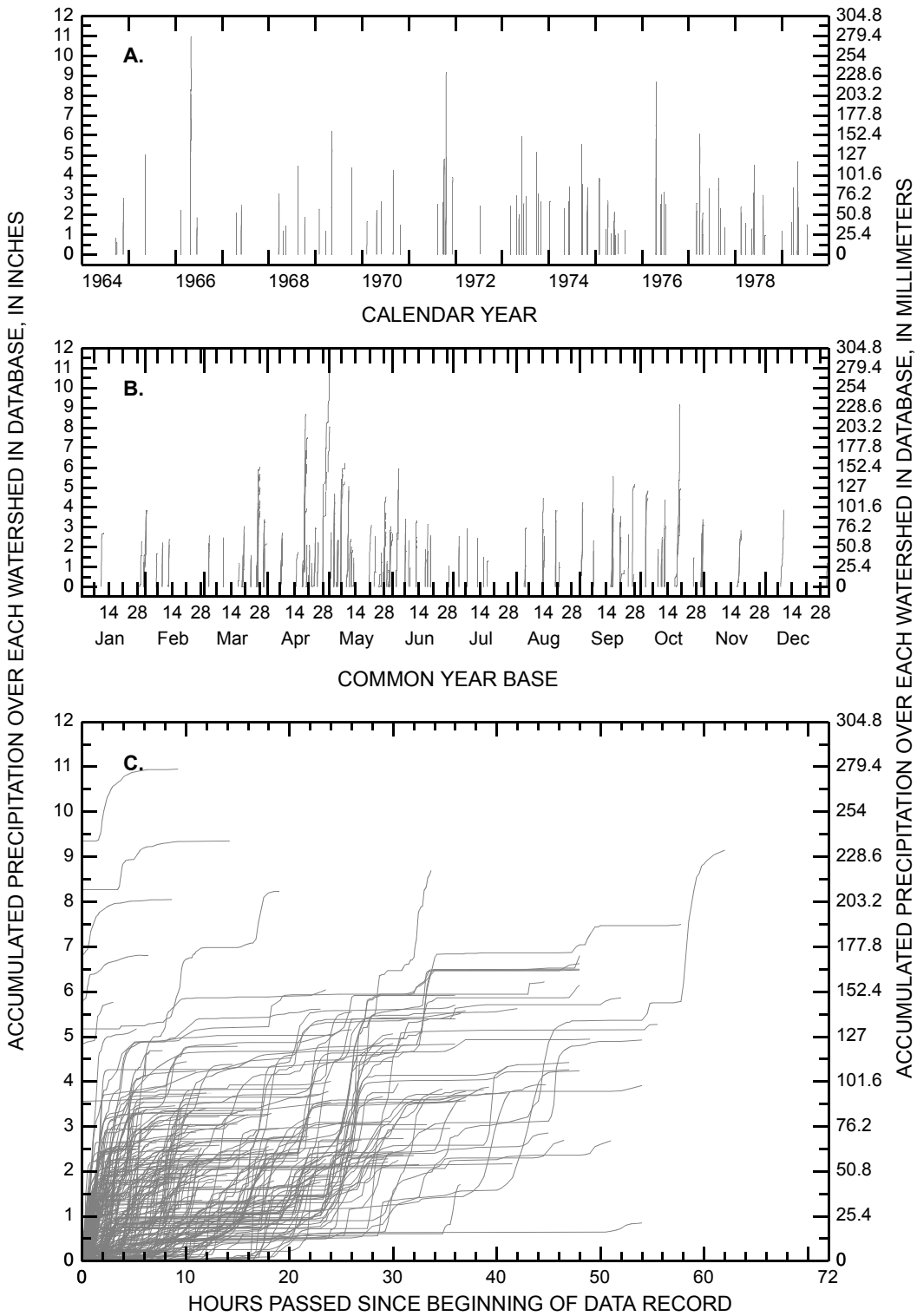Figure 8. Hyetographs for austin database module—401 storm events represented.

Figure 9. Hyetographs for `dallas` database module—240 storm events represented.
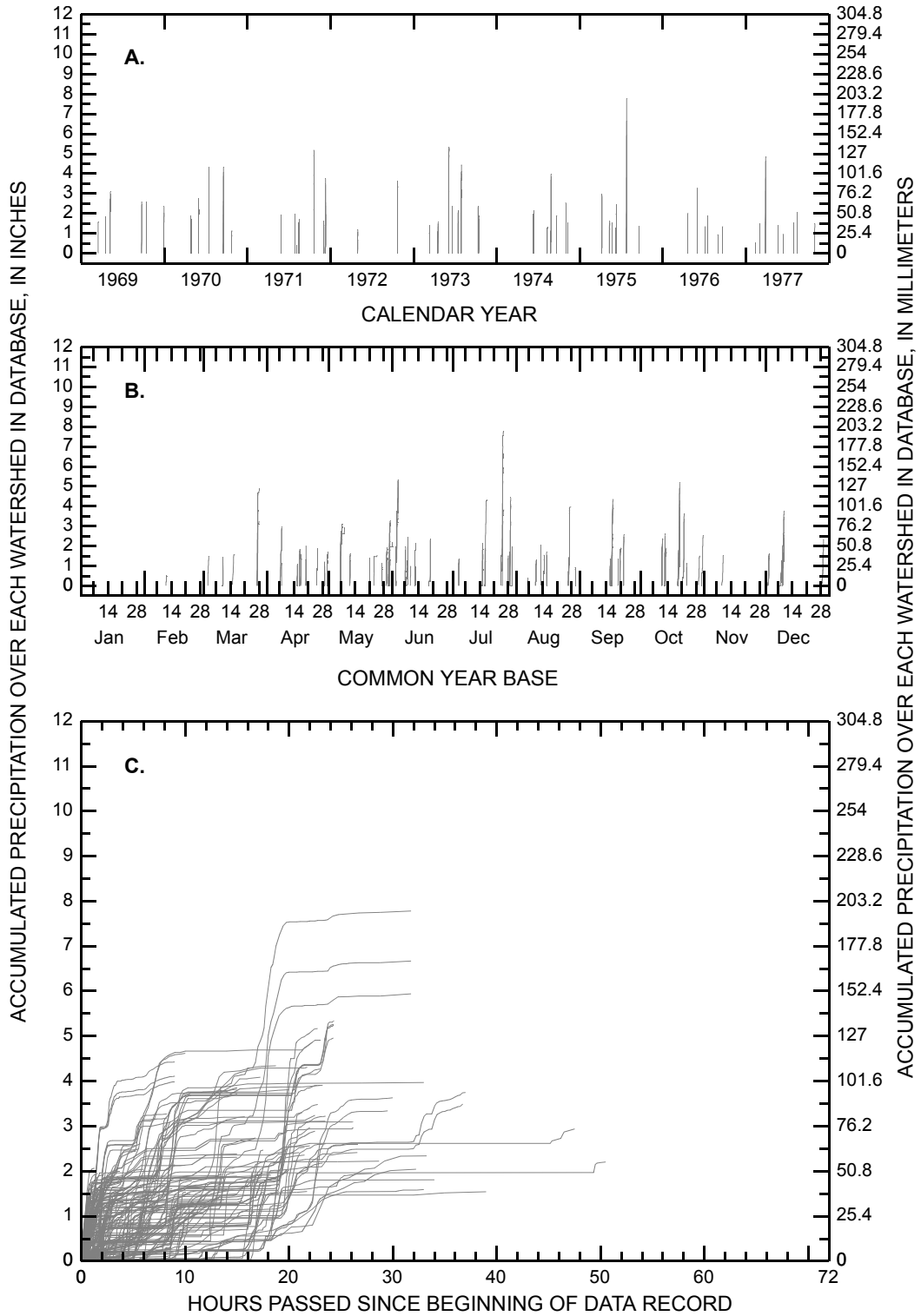
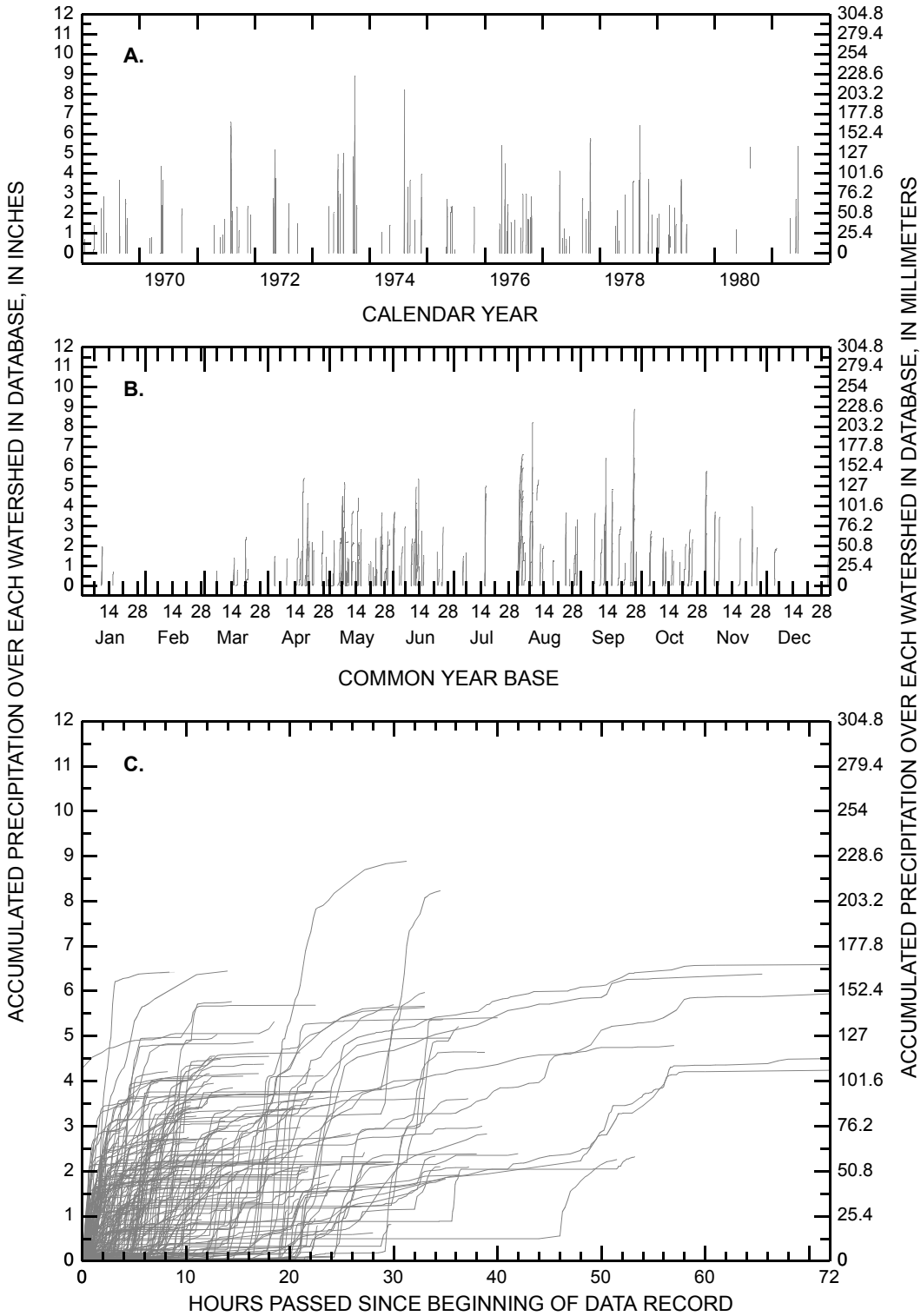**Figure 10. Hyetographs for fortworth database module—194 storm events represented.**

Figure 11. Hyetographs for sanantonio database module—215 storm events represented.
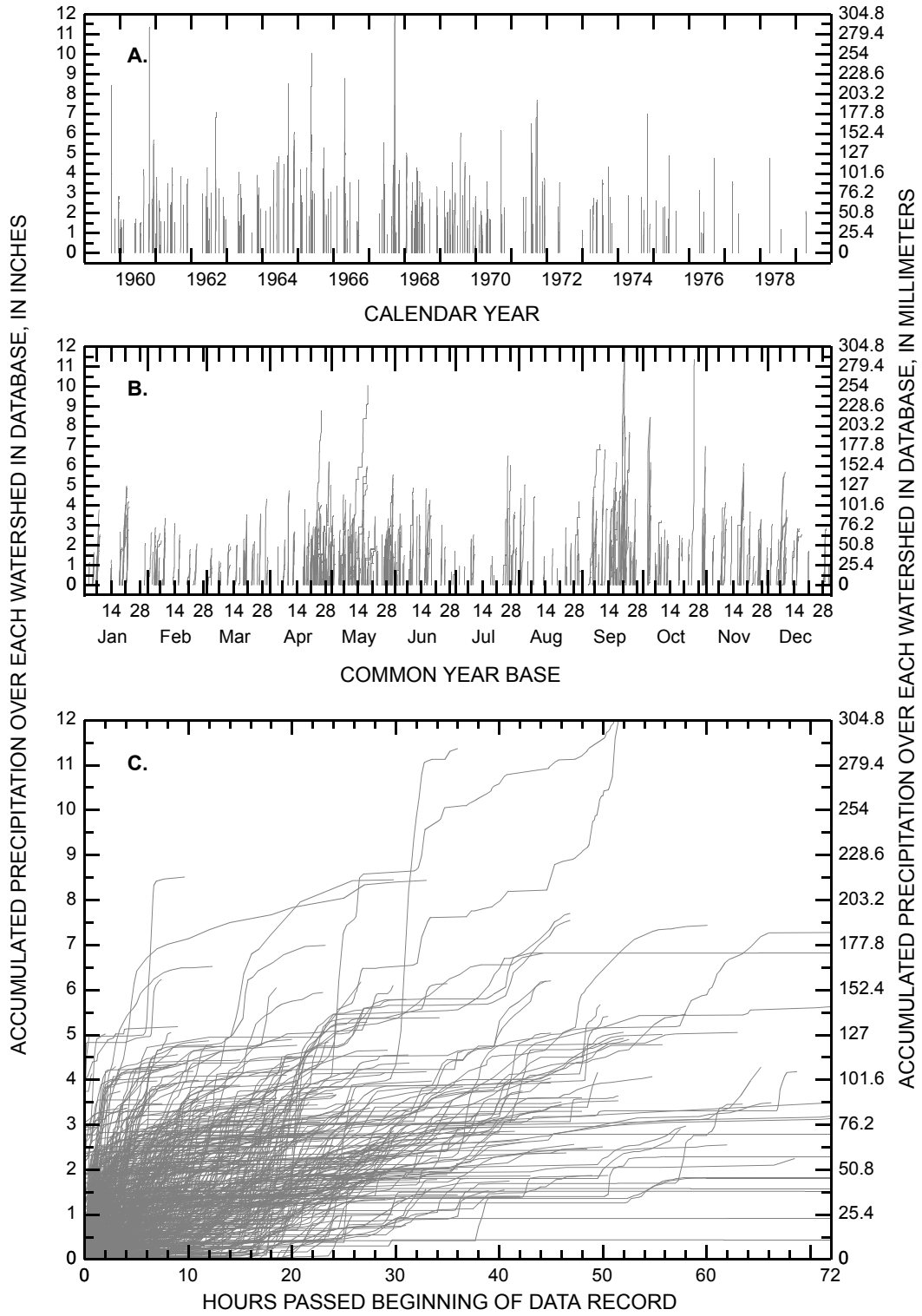
Synthesis of Rainfall and Runoff Data Used for Texas Department of Transportation Research Projects 0–4193 and 0–4194

Figure 12. Hyetographs for `smallruralsheds` database module—607 storm events represented.

Runoff Data—Hydrographs

The runoff for each storm within the database is represented by a single hydrograph file. There are 1,657 hydrograph files in the database; these files contain approximately 72,100 lines of data. Three standard components of a hydrograph file are provided in figure 13. The file format is closely related to the format for the hyetograph files. The three main components of the file are the header, the column titles, and the data records. The header of the file is identified by the lines containing the leading # sign. A single field line containing the label or column titles follows the header. This line is delimited by one or more spaces. Finally, the data records, which also are space delimited, make up the remainder of the file. A part of the data lines have been removed from the figure because of limited space.

```
# HYDROGRAPH FILE
# Filename=unit_sta08156800_1981_0523.dat
# site=08156800 Shoal Creek at 12th Street, Austin, Texas.
# latitude=30()16'35"
# longitude=97()45'00"
# drainagearea (mi2)=12.3
# DATE_TIME=date and time in MM/DD/YYYY@HH:MM
# RUNOFF=runoff in cubic feet per second
# ACCUM_RUNOFF=accumulated runoff in inches
DATE_TIME      HOURS_PASSED      RUNOFF      ACCUM_RUNOFF
05/23/1981@00:00:00    0.0000    1.0000    0.0015
05/23/1981@23:30:00    23.5000   1.0000    0.0030
05/23/1981@23:45:00    23.7500   1.0000    0.0030
05/24/1981@00:00:00    24.0000   1.0000    0.0032
05/24/1981@00:30:00    24.5000   96.0000   0.0092
05/24/1981@01:00:00    25.0000   314.0000  0.0240
              ... portion cut for brevity ...
05/25/1981@08:00:00    56.0000   180.0000  4.2795
05/25/1981@10:00:00    58.0000   140.0000  4.3147
05/25/1981@12:00:00    60.0000   102.0000  4.3404
05/25/1981@14:00:00    62.0000   79.0000   4.3702
05/25/1981@18:00:00    66.0000   47.0000   4.3998
05/26/1981@00:00:00    72.0000   27.0000   4.4100
```

Figure 13. Example hydrograph data file austin/ShoalCreek/sta08156800_d/hyetos/
   unit_sta08156800_1981_0523.dat **from the** austin **database module.**

Some other aspects of the data file in figure 13 that need description are the values for RUNOFF and ACCUM_RUNOFF. The RUNOFF is either inches of runoff between successive date-time stamps, or it is the instantaneous discharge in cubic feet per second for the corresponding date-time stamp. The USGS urban studies report RUNOFF in cubic feet per second; whereas, the reports represented in the smallruralsheds module have RUNOFF values reported in inches. The ACCUM_RUNOFF field contains the cumulative runoff in inches for the storm. An incremental runoff value in inches is computed from streamflow in cubic feet per second by

$$R = 2.58 \times 10^{-5} \times \frac{QT}{A}, \tag{1}$$

where R is runoff in inches, Q is cubic feet per second, T is time in minutes, and A is drainage area in square miles. The T value in eq. 1 is determined by the integration

method; a mid-point method generally is used (see next section). A final note about the ACCUM_RUNOFF data is that base flow has not been removed (see "Cautions" section for further discussion).

Note on Discharge

An important component of the hydrograph data files is the backwards-computation of discharge (RUNOFF in the urban modules) in cubic feet per second from the ACCUM_RUNOFF in inches. All stations, except those with "subwatershed" in the station name, require that discharge is computed by a backwards-runoff centered-time finite difference (eq. 2).

The backwards-runoff centered-time finite difference is

$$Q_i = 645 \times A \times \frac{R_i - R_{i-1}}{0.5 \times (T_{i+1} - T_{i-1})}, \tag{2}$$

where Q_i is the discharge in cubic feet per second for the ith HOURS_PASSED value, R_i is the ACCUM_RUNOFF in inches for the ith time, T_i is the HOURS_PASSED value, and A is the drainage area in square miles. The value 645 accounts for unit conversion.

For those stations that have "subwatershed" in the station name, a backwards-runoff backwards-time finite difference is used (eq. 3). An example subwatershed is station 08094000 Green Creek subwatershed no. 1 near Dublin, Texas (table 5). The reason for the different method is that the subwatersheds had hydrologic data collected on flood-water detention basins; inflow computations (the runoff) were made through change in storage conditions on the basin. Hence, runoff is in inches and not cubic feet per second. The peak discharge of inflow for the subwatersheds is computed by

$$Q_i = 645 \times A \times \frac{R_i - R_{i-1}}{T_i - T_{i-1}}, \tag{3}$$

where Q_i is the discharge in cubic feet per second for the ith HOURS_PASSED value, R_i is the ACCUM_RUNOFF in inches for the ith time, T_i is the HOURS_PASSED value, and A is the drainage area in square miles. The value 645 accounts for unit conversion.

Quality Control and Quality Assurance

The original data sources are in printed format and a range of tabulation styles: handwritten, dot matrix, hand-typed, and modern computer print. The research projects required digitally formatted data. The data were manually entered into an open-source computer text file versioning software system (*http://www.cvshome.org*) on a RedHat™ Linux™ (*http://www.redhat.com*) server over the course of 2 years by approximately 20 individuals scattered between the four research entities. The data were derived from over 220 historical USGS data reports. The USGS provided database administrative support and off premises backup, and TTU administered the server in Lubbock.

Absolute verification of the manually inputted data is not possible given the scale of the database and numerous individuals involved in data entry. However, during the course of database development, numerous custom Perl (*http://www.perl.com* and *http://www.perl.org*) scripts were run to scan each line of data to search for anomalies and enhance data integrity. A summary of functions (not necessarily in order) performed by the scripts follows:

1. The scripts have confirmed that all date-time values are valid—that is the value is for a real date and time. The scripts are based on Perl date-time computation modules, which are publicly available from *http://www.cpan.org*. The scripts are not able to test that the date-time value in the database is actually correct in respect to the original data.

2. The scripts have confirmed that the date-time values within each data file (rainfall and runoff) monotonically increase with time; a condition that is exhibited by the original data.

3. The scripts for each data file have cumulated the RUNOFF data and compared this total to the ACCUM_RUNOFF to identify anomalous data. A check based on explicit equality of the cumulated RUNOFF to the ACCUM_RUNOFF is not possible due to rounding and limited precision in the original data sources.

4. The scripts were used to compute the HOURS_PASSED field. The HOURS_PASSED field was not part of the original data sources.

5. The scripts have assured that the label line of the rainfall data files follow the DATE_TIME, HOURS_PASSED, PRECIP#, and ACCUM_WTD_PRECIP convention.

6. The scripts have assured that the label line of the runoff data files follow the DATE_TIME, HOURS_PASSED, RUNOFF and ACCUM_RUNOFF convention.

7. The scripts have confirmed that cumulative values of rainfall and runoff are valid floating point numbers and that the numbers monotonically increase with time.

8. The data reports, particularly the urban study reports, consider the time value of zero-hundred hours (00:00) and the time value of twenty-four hundred hours (24:00) separately. Unfortunately 24:00 is not a recognized international standard in date-time computations. The time 24:00 is best considered as 00:00 of the next day. Scripts were necessary to remove 24:00 time stamps from the data files; careful manipulation of the rainfall and runoff values was required to maintain data integrity. However, the treatment of midnight varies from report to report, which influences the reliability of the ACCUM_RUNOFF values originally entered into the database. Interested readers can consult the data reports for further clarification.

Furthermore, during the TxDOT research projects, the investigators each independently developed data-processing software to fulfill research objectives. These software programs frequently required digital comparison of the date-time values between the rainfall and runoff data files in the context of hydrologic research. Errors in the date-time stamps values were occasionally discovered. The data files then were compared to the original data sources and corrections applied. Others errors or inconsistencies were discovered in processing the data; when these errors were found, corrections were applied. Most error correction was completed by USGS staff in Austin.

A final script was run (May 2004) that recomputed the ACCUM_RUNOFF values using a mid-point integration method (half-width intervals were used for the initial and final RUNOFF values) from the RUNOFF values for the austin, dallas, fortworth, and sanantonio data modules. Such recomputation was deemed necessary to compensate for various original integration methods, data and intermediate computation precision (hand and early computer programs), various methods for the midnight transition, drainage area revisions (see "Cautions" section) and the fact that some original computations were hand made—erroneous ACCUM_RUNOFF values often were detected.

Cautions

Several cautions regarding the database are listed in this section. These cautions influence how the data are processed and interpreted.

1. **Drainage Area**—The drainage areas for some of the stations particularly in the smallruralsheds module are known to have more than one published value. This influences the values for RUNOFF and smallruralsheds. These are identified in table 5. RUNOFF in the smallruralsheds database is in inches. Inches of RUNOFF for a watershed is dependent on drainage area. The values in the smallruralsheds module are those available in the original data reports, and thus the drainage area used for the runoff calculations is the area available at the time that the original data were collected. The research team has explicitly chosen to leave the data in original values for the smallruralsheds module. However, the urban study modules have RUNOFF in cubic feet per second. Therefore, correction of the ACCUM_RUNOFF for revisions in drainage area was performed.

2. **Latitude and Longitude**—The latitude and longitude for some of the stations particularly in the smallruralsheds module are known to have been revised (typos or errors in the reports) slightly over the course of the original data collection. The physical locations of the stations did not change. The research team believes that most accurate values are reflected in the tables. Exact location of the stations has little ramification on analysis objectives for the TxDOT research projects—unlike the changes in drainage area.

3. **Rounding and Significant Figures**—The data files were reformatted during quality-control and quality-assurance processing to assure file consistency. The reformatting included fixing decimal places to four. Four decimal places are necessary to maintain accuracy for the HOURS_PASSED values, which could have included data recorded as frequently as 5 minutes ($5/60 = 0.08\overline{3}$). The RUNOFF values, when given in inches, were frequently recorded to but never greater than

four decimal places. However, when RUNOFF values are in cubic feet per second, the original data were reported with various significant figures, but the values (discharge in cubic feet per second) are never more accurate than two decimal places. The ACCUM_RUNOFF values generally were reported to but never better than four decimal places. Users of the database should be aware that false precision is reflected in the data files. Users should also be aware that discharge computed using equations 2 or 3 in circumstances in which the difference between successive ACCUM_RUNOFF values is one or two significant figures (for example, 0.0001 inch) will only approximate the discharge reported in either the data files or the original reports.

4. **Runoff as a Concept**—The runoff data files in the database report total flow at the gaging station. Base flow was not removed from the data prior to recording in the original data reports, and hence, base flow is still a component of the data in this database. However, the majority of the stations represented are on small ephemeral streams; base flow represents a small component of the total flow at the station. The flow for the watershed frequently is zero at the beginning of the storms in the database.

5. **Beginning and Ending of Runoff**—The beginning of runoff data for a specific storm event report can be large relative to the peak discharge or total storm runoff. Likewise, the ending of the runoff data also can be large. Therefore uncertainty related to the actual beginning and ending of runoff exists for some storms.

6. **Separate Files for Rainfall and Runoff**—Several reasons exist for the use of two separate data files for each storm event in the database. The major reasons are:

   a. The original data reports represented in the smallruralsheds database module generally have separate tables for rainfall and runoff—logistically separate files made data entry easier.

   b. The second reason is related to the first, which is that the original data reports represented in the smallruralsheds database module do not necessarily have matching date-time stamps for rainfall and runoff. For example, during peak rainfall intensities the time interval could be a low as 5 minutes, while the runoff occurring at the same time might be in hourly intervals. If multiple date-time stamps were used, data file structure would be considerably more complicated and it would be more difficult to perform quality-control and quality-assurance tests. Sophisticated computer algorithms for date-time mathematics are required for some applications of concurrent processing of the rainfall and runoff data.

   c. The beginning and ending times of rainfall hyetographs are not coincident with the beginning and ending times of a runoff hydrograph. Rainfall must occur before the runoff. Runoff hydrographs occur over a longer period of time relative to the rainfall; this is evidenced by the larger number of records of runoff data than rainfall data in the database.

   d. TxDOT research project 0–4194 specifically involves the processing of rainfall data in pursuit of hyetograph definition in Texas.

SUMMARY

The U.S. Geological Survey (USGS), Texas District, in collaborative peer-to-peer research projects with Lamar University, Texas Tech University, and the University of Houston, has developed a digital database of rainfall and runoff values for selected watersheds in Texas. The research was funded by the Texas Department of Transportation.

The data were derived from over 220 historical USGS data reports. The data were transcribed from hard-copy format to digital format over the course of 2 years. In total the database contains 1,657 storms for 91 rural and urban watersheds in Texas. Each storm is recorded by rainfall and runoff for USGS streamflow-gaging stations in the watersheds.

The composite database is divided into five database "modules." These modules are separated into four urban centers and are called `austin`, `dallas`, `fortworth`, and `sanantonio`, for the Austin, Dallas, Fort Worth, and San Antonio areas of Texas, respectively. The fifth module is referred to as the `smallruralsheds` database and contains clusters of intensively monitored small rural watershed study units within the Brazos River, Colorado River, San Antonio River, and Trinity River Basins of Texas.

Each storm event is recorded in the database by two data files. One file for the rainfall of the storm and a second data file for the storm runoff. Each storm within the database is represented by a single rainfall data or hyetograph file. There are 1,657 rainfall or hyetograph files in the database; these files contain approximately 57,900 lines of data. The hyetograph files contain date-time values and corresponding precipitation for one or more rain gages in the watershed; the files also contain the cumulative rainfall for the event. The runoff for each storm within the database is represented by a single hydrograph file. The hydrograph files contain date-time values, corresponding runoff (streamflow or change in reservoir storage), and cumulative runoff for the event. There are 1,657 hydrograph files in the database; these files contain approximately 72,100 lines of data.

An important component of the hydrograph data files is the discharge expressed in cubic feet per second for the event. The discharge is estimated from the cumulative runoff values. One of two types of finite-difference methods for discharge estimation are applicable for a given streamflow station. Each method is described, and a method to determine which discharge estimation type is applicable for a given watershed is described.

Discussion pertinent to the quality-control and quality-assurance method used on the database during the manual data-entry phase is provided. Finally, caveats, limitations, and miscellaneous discussion concerning the contents of the database are presented.

REFERENCES

Liscum, Fred, 2001, Effects of urban development on stormwater runoff characteristics for the Houston, Texas, metropolitan area: U.S. Geological Survey Water-Resources Investigations Report 01–4071, 35 p.

AUSTIN URBAN STUDIES

U.S. Geological Survey, 1967, Basic data for urban hydrology study, Austin, Texas, 1967: U.S. Geological Survey, Texas District, 59 p.

U.S. Geological Survey, 1968, Compilation of hydrologic data, Austin, Texas, 1968: U.S. Geological Survey, Texas District, 68 p.

Robbins, W.D., 1969, Annual compilation and analysis of hydrologic data for urban studies in the Austin, Texas metropolitan area, 1969: U.S. Geological Survey, Texas District, 46 p.

VanZandt, J.K., 1972, Annual compilation and analysis of hydrologic data for urban studies in the Austin, Texas metropolitan area, 1970: U.S. Geological Survey Open-File Report, 70 p.

Tovar, F.H., 1973, Annual compilation and analysis of hydrologic data for urban studies in the Austin, Texas metropolitan area, 1971: U.S. Geological Survey Open-File Report, 73 p.

Wehmeyer, E.E., 1974, Hydrologic data for urban studies in the Austin, Texas metropolitan area, 1972: U.S. Geological Survey Open-File Report, 49 p.

Mitchell, R.N., 1975, Hydrologic data for urban studies in the Austin, Texas metropolitan area, 1973: U.S. Geological Survey Open-File Report, 61 p.

Mitchell, R.N., 1976, Hydrologic data for urban studies in the Austin, Texas metropolitan area, 1974: U.S. Geological Survey Open-File Report, 60 p.

Choffel, K.L., Roddy, W.R., and Mitchell, R.N., 1977, Hydrologic data for urban studies in the Austin, Texas metropolitan area, 1975: U.S. Geological Survey Open-File Report 76–885, 126 p.

Maderak, M.L., Gordon, J.D., and Mitchell, R.N., 1978, Hydrologic data for urban studies in the Austin, Texas metropolitan area, 1976: U.S. Geological Survey Open-File Report 78–457, 263 p.

Slade, R.M., Jr., Gordon, J.D., and Mitchell, R.N., 1979, Hydrologic data for urban studies in the Austin, Texas metropolitan area, 1977: U.S. Geological Survey Open-File Report 79–271, 192 p.

Slade, R.M., Jr., Dorsey, M.E., Gordon, J.D., and Mitchell, R.N., 1980, Hydrologic data for urban studies in the Austin, Texas metropolitan area, 1978: U.S. Geological Survey Open-File Report 80–728, 227 p.

Slade, R.M., Jr., Dorsey, M.E., Gordon, J.D., Mitchell, R.N., and Gaylord, J.L., 1981, Hydrologic data for urban studies in the Austin, Texas metropolitan area, 1979: U.S. Geological Survey Open-File Report 81–628, 281 p.

Slade, R.M., Jr., Gaylord, J.L., Dorsey, M.E., Mitchell, R.N., and Gordon, J.D., 1982, Hydrologic data for urban studies in the Austin, Texas metropolitan area, 1980: U.S. Geological Survey Open-File Report 82–506, 264 p.

Massey, B.C., Reeves, W.E., and Lear, W.A., 1982, Flood of May 24–25, 1981, in the Austin, Texas metropolitan area: U.S. Geological Survey Hydrologic Investigations Atlas HA–656, 2 p.

Slade, R.M., Jr., Veenhuis, J.E., Dorsey, M.E., Gardiner, H., and Smith, A.E., 1983, Hydrologic data for urban studies in the Austin, Texas metropolitan area, 1981: U.S. Geological Survey Open-File Report 83–44, 293 p.

Slade, R.M., Jr., Veenhuis, J.E., Dorsey, M.E., Stewart, S.L., and Ruiz, L.M., 1984, Hydrologic data for urban studies in the Austin, Texas metropolitan area, 1982: U.S. Geological Survey Open-File Report 84–061, 196 p.

Gordon, J.D., Pate, D.L., and Dorsey, M.E., 1985, Hydrologic data for urban studies in the Austin, Texas metropolitan area, 1983: U.S. Geological Survey Open-File Report 85–172, 154 p.

Gordon, J.D., Pate, D.L., and Dorsey, M.E., 1986, Hydrologic data for urban studies in the Austin metropolitan area, Texas, 1984: U.S. Geological Survey Open-File Report 85–676, 92 p.

Veenhuis, J.E. and Gannett, D.G., 1986, The effects of urbanization on floods in the Austin metropolitan area, Texas: U.S. Geological Survey Water-Resources Investigations Report 86–4069, 65 p.

Gordon, J.D., Pate, D.L., and Dorsey, M.E., 1987, Hydrologic data for urban studies in the Austin metropolitan area, Texas, 1985: U.S. Geological Survey Open-File Report 87–224, 170 p.

Gordon, J.D., Pate, D.L., and Slagle, D.L., 1988, Hydrologic data for urban studies in the Austin metropolitan area, Texas, 1986: U.S. Geological Survey Open-File Report 87–768, 144 p.
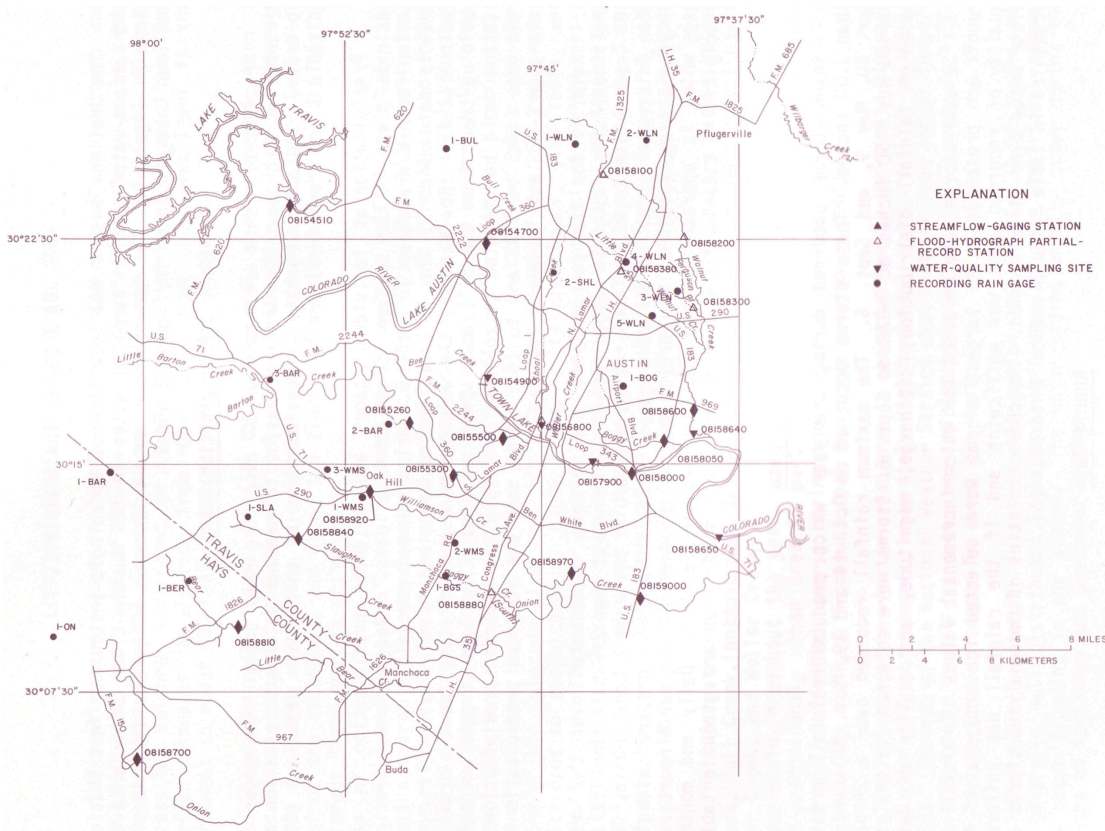
Figure 14. Location map for austin database module adopted from Gordon, Pate, and Slagle, 1988.

DALLAS URBAN STUDIES

U.S. Geological Survey, 1965, Basic data for urban hydrology study, Dallas, Texas, 1965: U.S. Geological Survey, Texas District, 80 p.

U.S. Geological Survey, 1966, Basic data for urban hydrology study, Dallas, Texas, 1966: U.S. Geological Survey, Texas District, 198 p.

U.S. Geological Survey, 1967, Basic data for urban hydrology study, Dallas, Texas, 1967: U.S. Geological Survey, Texas District, 80 p.

U.S. Geological Survey, 1968, Basic data for urban hydrology study, Dallas, Texas, 1968: U.S. Geological Survey, Texas District, 103 p.

Dempster, G.R., Jr. and Massey, B.C., 1971, Annual compilation and analysis of hydrologic data for urban studies in the Dallas, Texas metropolitan area, 1969: U.S. Geological Survey, Texas District, 136 p.

Dempster, G.R., Jr. and Massey, B.C., 1972, Annual compilation and analysis of hydrologic data for urban studies in the Dallas, Texas metropolitan area, 1970: U.S. Geological Survey, Texas District, 122 p.

Massey, B.C., 1973, Annual compilation and analysis of hydrologic data for urban studies in the Dallas, Texas metropolitan area, 1971: U.S. Geological Survey, Texas District, 84 p.

Massey, B.C. and Wood, C.M., 1974, Hydrologic data for urban studies in the Dallas, Texas metropolitan area, 1972: U.S. Geological Survey Open-File Report, 136 p.

Dempster, G.R., Jr., 1974, Effects of urbanization on floods in the Dallas, Texas metropolitan area: U.S. Geological Survey Water-Resources Investigations Report 60–73, 51 p.

Hampton, B.B., 1975, Hydrologic data for urban studies in the Dallas, Texas metropolitan area, 1973: U.S. Geological Survey Open-File Report, 146 p.

Hampton, B.B., 1976, Hydrologic data for urban studies in the Dallas, Texas metropolitan area, 1974: U.S. Geological Survey Open-File Report, 182 p.

Hampton, B.B. and Wood, C.M.,1977, Hydrologic data for urban studies in the Dallas, Texas metropolitan area, 1975: U.S. Geological Survey Open-File Report 77–381, 209 p.

Hampton, B.B. and Wood, C.M., 1978, Hydrologic data for urban studies in the Dallas, Texas metropolitan area, 1976: U.S. Geological Survey Open-File Report 78–437, 161 p.

Hampton, B.B. and Wood, C.M., 1979, Hydrologic data for urban studies in the Dallas, Texas metropolitan area, 1977: U.S. Geological Survey Open-File Report 79–562, 146 p.

Hampton, B.B. and Wood, C.M., 1980, Hydrologic data for urban studies in the Dallas, Texas metropolitan area, 1978: U.S. Geological Survey Open-File Report 80–1004, 114 p.

Wood, C.M., Butler, H.S., and Benton, J.D., 1981, Hydrologic data for urban studies in the Dallas, Texas metropolitan area, 1979: U.S. Geological Survey Open-File Report 81–491, 147 p.

Land, L.F., Schroeder, E.E., and Hampton, B.B., 1982, Techniques for estimating the magnitude and frequency of floods in the Dallas-Fort Worth metropolitan area, Texas: U.S. Geological Survey Water-Resources Investigations Report 82–18, 55 p.
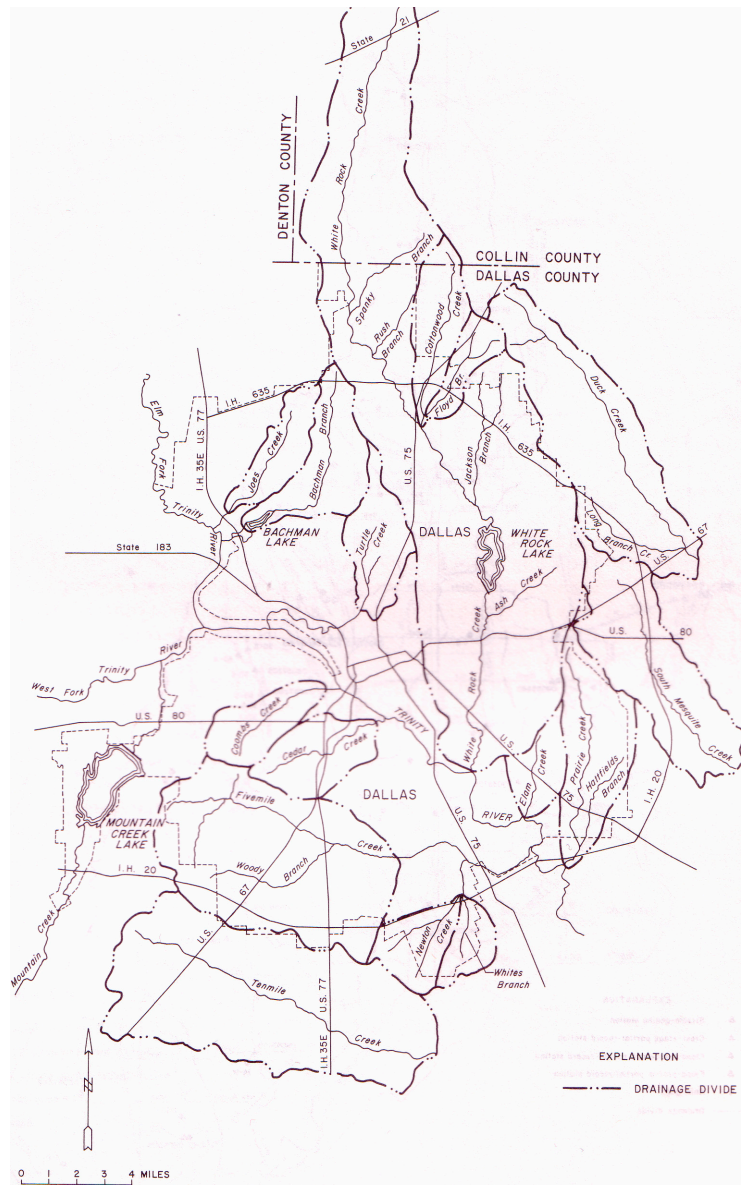
Figure 15. Location map for `dallas` **database module adopted from Wood, Butler, and Benton, 1981.**

FORT WORTH URBAN STUDIES

Dempster, G.R., Jr., and Massey, B.C., 1969, Annual compilation and analysis of
hydrologic data for urban studies in the Fort Worth, Texas metropolitan area, 1969:
U.S. Geological Survey Open-File Report, 50 p.

Dempster, G.R., Jr., and Massey, B.C., 1972, Annual compilation and analysis of
hydrologic data for urban studies in the Fort Worth, Texas metropolitan area, 1970:
U.S. Geological Survey Open-File Report, 89 p.

Hampton, B.B., 1973, Annual compilation and analysis of hydrologic data for urban studies in the Fort Worth, Texas metropolitan area, 1971: U.S. Geological Survey Open-File Report, 77 p.

Hampton, B.B., 1974, Hydrologic data for urban studies in the Fort Worth, Texas metropolitan area, 1972: U.S. Geological Survey Open-File Report, 123 p.

Hampton, B.B., 1975, Hydrologic data for urban studies in the Fort Worth, Texas metropolitan area, 1973: U.S. Geological Survey Open-File Report, 129 p.

Slade, R.M., Jr., and Taylor, J.M., 1976, Hydrologic data for urban studies in the Fort Worth, Texas metropolitan area, 1974: U.S. Geological Survey Open-File Report, 100 p.

Slade, R.M., Jr., and Taylor, J.M., 1977, Hydrologic data for urban studies in the Fort Worth, Texas metropolitan area, 1975: U.S. Geological Survey Open-File Report 77–266, 96 p.

Slade, R.M., Jr., and Taylor, J.M., 1978, Hydrologic data for urban studies in the Fort Worth, Texas metropolitan area, 1976: U.S. Geological Survey Open-File Report 77–770, 84 p.

Slade, R.M., Jr., Taylor, J.M., and Haynes, D.L., 1979, Hydrologic data for urban studies in the Fort Worth, Texas metropolitan area, 1977: U.S. Geological Survey Open-File Report 79–216, 39 p.

Land, L.F., Schroeder, E.E., and Hampton, B.B., 1982, Techniques for estimating the magnitude and frequency of floods in the Dallas-Fort Worth metropolitan area, Texas: U.S. Geological Survey Water-Resources Investigations Report 82–18, 55 p. [also listed in DALLAS URBAN STUDIES section]
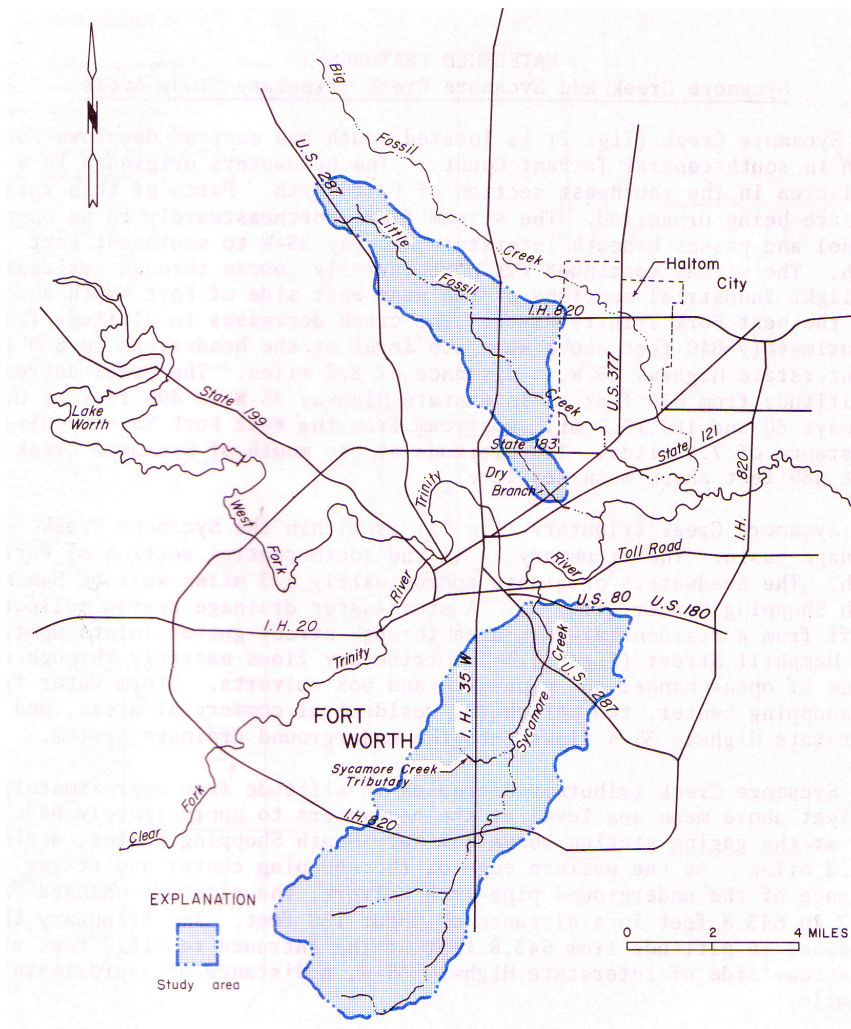
Figure 16. Location map for `fortworth` database module adopted from Slade, Taylor, and Haynes, 1979.

SAN ANTONIO URBAN STUDIES

Land, L.F., 1971, Annual compilation and analysis of hydrologic data for urban studies in the San Antonio, Texas metropolitan area, 1969: U.S. Geological Survey 109 p.

Land, L.F., 1972, Annual compilation and analysis of hydrologic data for urban studies in the San Antonio, Texas metropolitan area, 1970: U.S. Geological Survey, Texas District, 178 p.

Steger, R.D., 1973, Annual compilation and analysis of hydrologic data for urban studies in the San Antonio, Texas metropolitan area, 1971: U.S. Geological Survey, Texas District, 109 p.

Steger, R.D., 1974, Hydrologic data for urban studies in the San Antonio, Texas metropolitan area, 1972: U.S. Geological Survey Open-File Report, 102 p.

Steger, R.D., 1975, Hydrologic data for urban studies in the San Antonio, Texas metropolitan area, 1973: U.S. Geological Survey Open-File Report, 127 p.

Gonzalez, Victor, 1976, Hydrologic data for urban studies in the San Antonio, Texas metropolitan area, 1974: U.S. Geological Survey Open-File Report, 109 p.

Harmsen, Lynn, 1977, Hydrologic data for urban studies in the San Antonio, Texas metropolitan area, 1975: U.S. Geological Survey Open-File Report 77–221, 91 p.

Harmsen, Lynn, 1978, Hydrologic data for urban studies in the San Antonio, Texas metropolitan area, 1976: U.S. Geological Survey Open-File Report 78–164, 132 p.

Perez, Roberto, 1980, Hydrologic data for urban studies in the San Antonio, Texas metropolitan area, 1977: U.S. Geological Survey Open-File Report 80–743, 100 p.

Perez, Roberto, 1981, Hydrologic data for urban studies in the San Antonio, Texas metropolitan area, 1978: U.S. Geological Survey Open-File Report 81–922, 91 p.

Perez, Roberto, 1982, Hydrologic data for urban studies in the San Antonio, Texas metropolitan area, 1979–80: U.S. Geological Survey Open-File Report 82–158, 125 p.

Perez, Roberto, 1983, Hydrologic data for urban studies in the San Antonio, Texas metropolitan area, 1981: U.S. Geological Survey Open-File Report 83–35, 58 p.
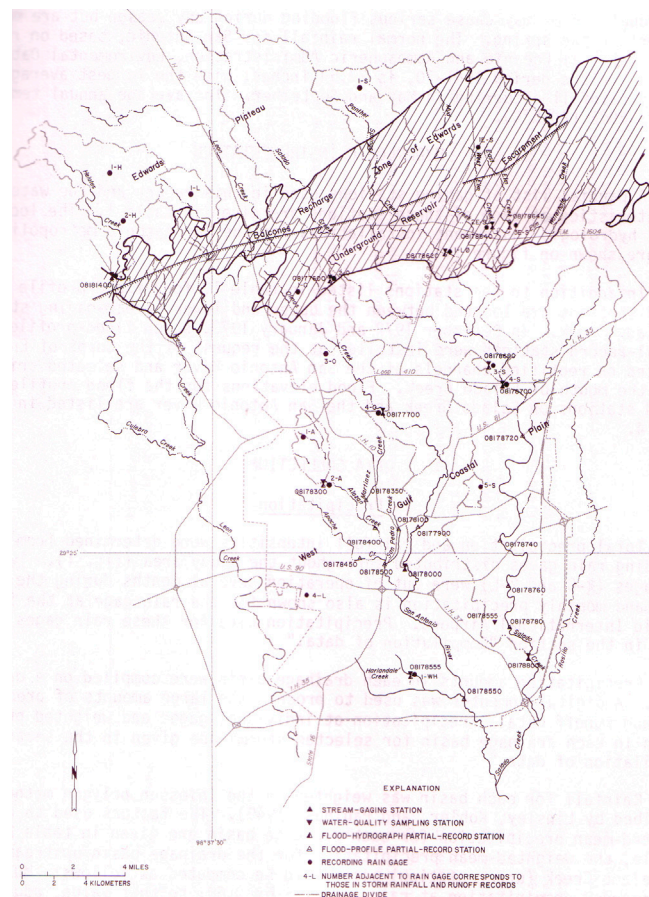
Figure 17. Location map for `sanantonio` **database module adopted from Perez, 1983.**

BRAZOS RIVER BASIN: Cow Bayou Watershed Studies

U.S. Geological Survey, 1960, Hydrologic studies of small watersheds, Cow Bayou Basin, Texas: U.S. Geological Survey, Texas District, 52 p.

U.S. Geological Survey, 1961, Hydrologic studies of small watersheds, Cow Bayou Basin, Texas: U.S. Geological Survey, Texas District, 17 p.

U.S. Geological Survey, 1962, Hydrologic data of Cow Bayou, Brazos River Basin, Texas, 1962: U.S. Geological Survey, Texas District, 68 p.

U.S. Geological Survey, 1963, Compilation of hydrologic data, Cow Bayou, Brazos River Basin, Texas, 1963: U.S. Geological Survey, Texas District, 40 p.

U.S. Geological Survey, 1964, Compilation of hydrologic data, Cow Bayou, Brazos River Basin, Texas, 1964: U.S. Geological Survey, Texas District, 55 p.

U.S. Geological Survey, 1965, Compilation of hydrologic data, Cow Bayou, Brazos River Basin, Texas, 1965: U.S. Geological Survey, Texas District, 64 p.

U.S. Geological Survey, 1966, Compilation of hydrologic data, Cow Bayou, Brazos River Basin, Texas, 1966: U.S. Geological Survey, Texas District, 72 p.

U.S. Geological Survey, 1967, Compilation of hydrologic data, Cow Bayou, Brazos River Basin, Texas, 1967: U.S. Geological Survey, Texas District, 62 p.

U.S. Geological Survey, 1968, Compilation of hydrologic data, Cow Bayou, Brazos River Basin, Texas, 1968: U.S. Geological Survey, Texas District, 80 p.

U.S. Geological Survey, 1969, Hydrologic studies of small watersheds, Cow Bayou, Brazos River Basin, Texas, 1955–64: U.S. Geological Survey, Texas District, 66 p.

Sansom, J.N., 1969, Annual compilation and analysis of hydrologic data for Cow Bayou, Brazos River Basin, Texas, 1969: U.S. Geological Survey, Texas District, 76 p.

Watson, J.A., 1970, Annual compilation and analysis of hydrologic data for Cow Bayou, Brazos River Basin, Texas, 1970: U.S. Geological Survey, Texas District, 85 p.

Watson, J.A., 1971, Annual compilation and analysis of hydrologic data for Cow Bayou, Brazos River Basin, Texas, 1971: U.S. Geological Survey, Texas District, 63 p.

VanZandt, J.K., 1972, Hydrologic data for Cow Bayou, Brazos River Basin, Texas, 1972: U.S.Geological Survey Open-File Report, 72 p.

VanZandt, J.K., 1973, Hydrologic data for Cow Bayou, Brazos River Basin, Texas, 1973: U.S.Geological Survey Open-File Report, 74 p.

VanZandt, J.K., 1974, Hydrologic data for Cow Bayou, Brazos River Basin, Texas, 1974: U.S.Geological Survey Open-File Report, 63 p.

Mitchell, R.N., and Wehmeyer, E.E., 1977, Hydrologic data for Cow Bayou, Brazos River Basin, Texas, 1975: U.S.Geological Survey Open-File Report 76–723, 81 p.
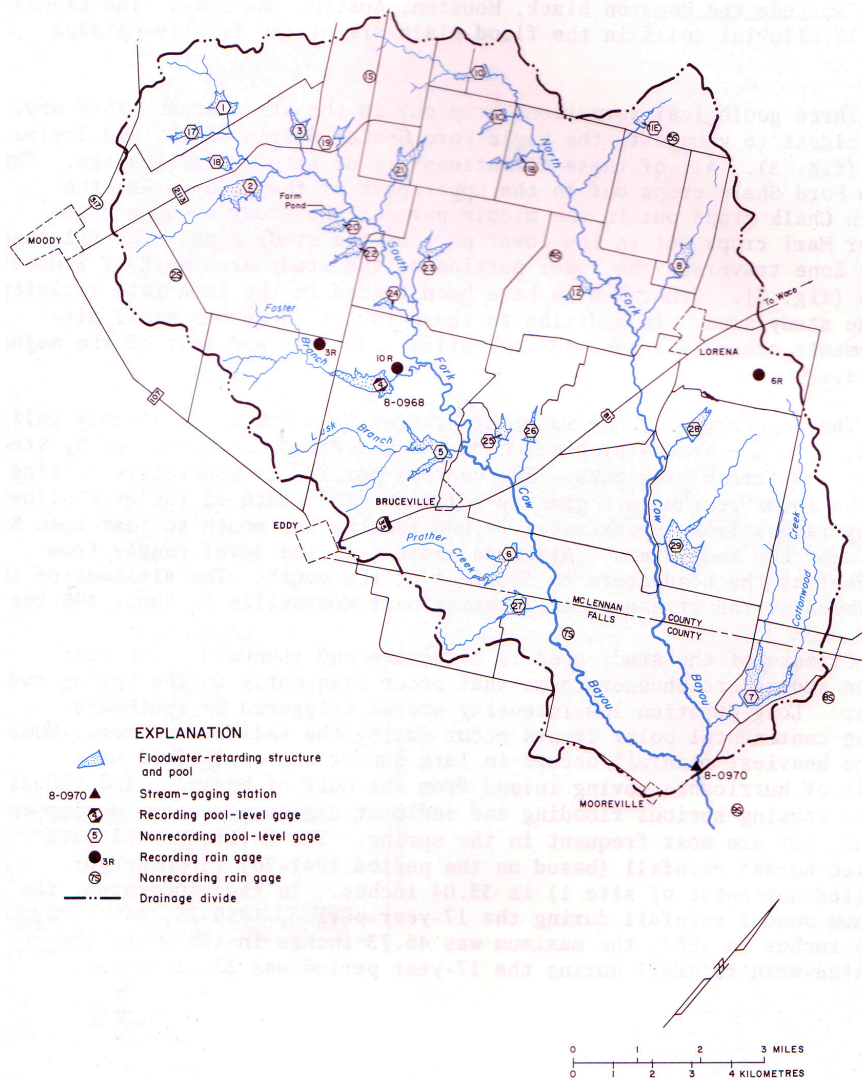
Figure 18. Location map for `smallruralsheds` database module for Cow Bayou watershed adopted from Mitchell and Wehmeyer, 1977.

BRAZOS RIVER BASIN: Green Creek Watershed Studies

U.S. Geological Survey, 1960, Hydrologic studies of small watersheds, Green Creek Basin, Texas: U.S. Geological Survey, Texas District, 42 p.

U.S. Geological Survey, 1961, Hydrologic studies of small watersheds, Green Creek study area, Texas, 1961: U.S. Geological Survey, Texas District, [variously paged].

U.S. Geological Survey, 1962, Hydrologic data of Green Creek, Brazos River Basin, Texas, 1962: U.S. Geological Survey, Texas District, [variously paged].

U.S. Geological Survey, 1963, Compilation of hydrologic data, Green Creek, Brazos River Basin, Texas, 1963: U.S. Geological Survey, Texas District, 52 p.

U.S. Geological Survey, 1964, Compilation of hydrologic data, Green Creek, Brazos River Basin, Texas, 1964: U.S. Geological Survey, Texas District, 58 p.

U.S. Geological Survey, 1965, Compilation of hydrologic data, Green Creek, Brazos River Basin, Texas, 1965: U.S. Geological Survey, Texas District, 44 p.

U.S. Geological Survey, 1966, Compilation of hydrologic data, Green Creek, Brazos River Basin, Texas, 1966: U.S. Geological Survey, Texas District, 109 p.

U.S. Geological Survey, 1967, Compilation of hydrologic data, Green Creek, Brazos River Basin, Texas, 1967: U.S. Geological Survey, Texas District, 34 p.

U.S. Geological Survey, 1968, Compilation of hydrologic data, Green Creek, Brazos River Basin, Texas, 1968: U.S. Geological Survey, Texas District, 66 p.

Massey, B.C., 1969, Annual compilation and analysis of hydrologic data for Green Creek, Brazos River Basin, Texas, 1969: U.S. Geological Survey, Texas District, 44 p.

U.S. Geological Survey, 1969, Preparation of hydrologic data small watersheds project: U.S. Geological Survey, Texas District, 43 p.

Hampton, B.B., 1970, Annual compilation and analysis of hydrologic data for Green Creek, Brazos River Basin, Texas, 1970: U.S. Geological Survey Open-File Report, 42 p.

Hampton, B.B., 1971, Annual compilation and analysis of hydrologic data for Green Creek, Brazos River Basin, Texas, 1971: U.S. Geological Survey Open-File Report, 30 p.

U.S. Geological Survey, 1972, Hydrologic studies of small watersheds, Green Creek, Brazos River Basin, Texas, 1955–66: U.S. Geological Survey, Texas District, 55 p.

BRAZOS RIVER BASIN: Little Pond Creek and North Elm Creek Watershed Studies

Slade, R.M., Jr., 1970, Annual compilation and analysis of hydrologic data for Little Pond Creek and North Elm Creek, Brazos River Basin, Texas, 1970: U.S. Geological Survey Open-File Report, 44 p.

Hawkinson, R.O., 1972, Hydrologic studies of Little Pond Creek and North Elm Creek watersheds, Brazos River Basin, Texas, 1963–69: U.S. Geological Survey, Texas District, 137 p.

VanZandt, J.K., 1973, Annual compilation and analysis of hydrologic data for Little Pond Creek and North Elm Creek, Brazos River Basin, Texas, 1971: U.S. Geological Survey Open-File Report, 52 p.

Mitchell, R.N., 1974, Hydrologic data for Little Pond Creek and North Elm Creek, Brazos River Basin, Texas, 1972: U.S. Geological Survey Open-File Report, 37 p.
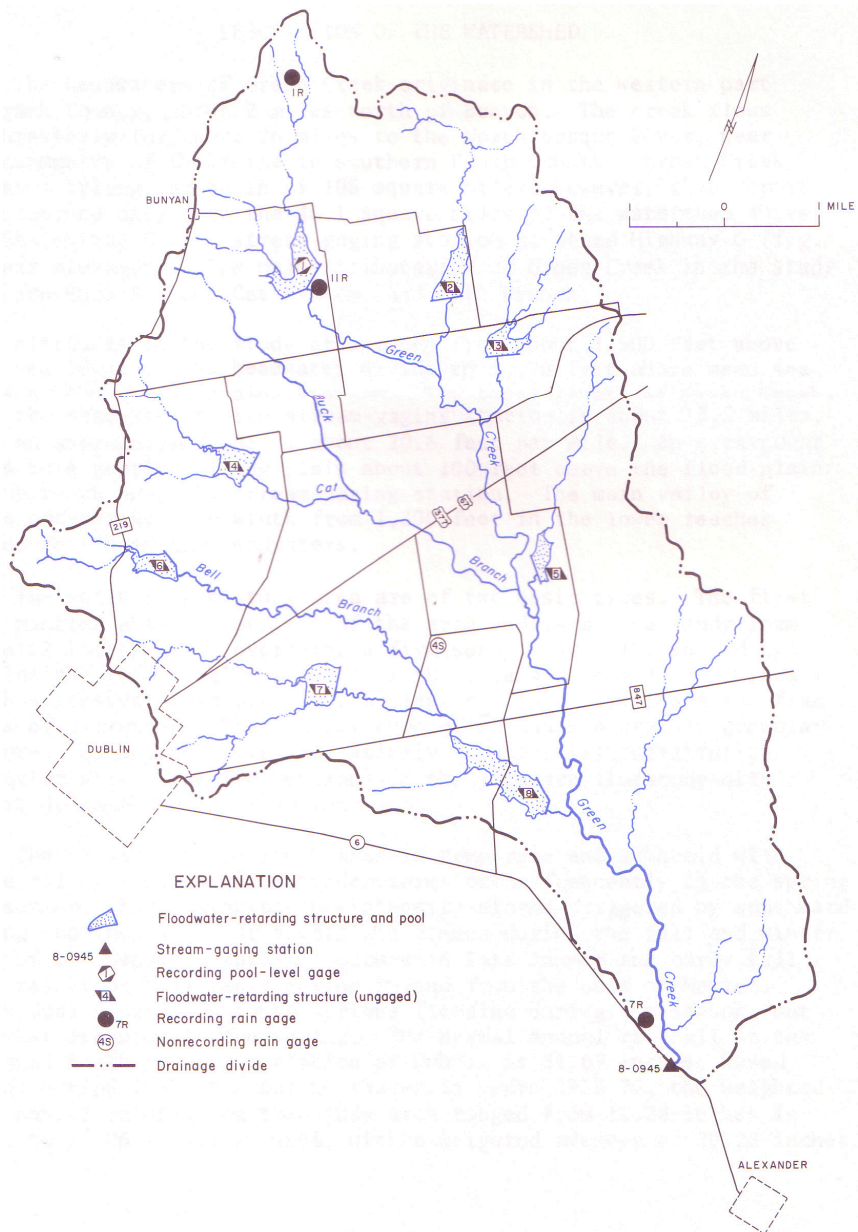
EXPLANATION

⬛ Floodwater-retarding structure and pool

▲ Stream-gaging station
8-0945

◐ Recording pool-level gage

4 Floodwater-retarding structure (ungaged)

● 7R Recording rain gage

4S Nonrecording rain gage

Drainage divide

Figure 19. Location map for smallruralsheds **database module for Green Creek watershed adopted from Hampton, 1971.**

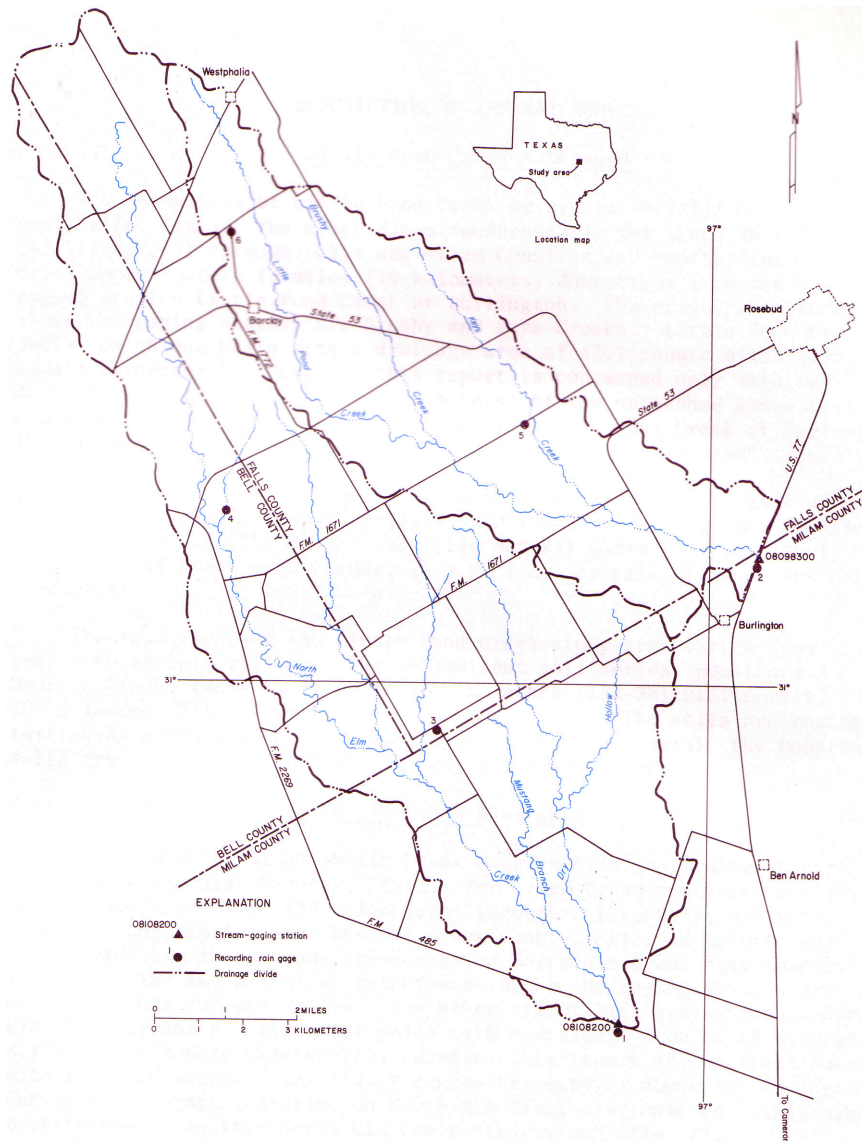**Figure 20. Location map for `smallruralsheds` database module for Little Pond and North Elm Creek watersheds adopted from Mitchell, 1974.**

COLORADO RIVER BASIN: Deep Creek Watershed Studies

U.S. Geological Survey, 1960, Hydrologic studies of small watersheds, Deep Creek Basin, Texas: U.S. Geological Survey, Texas District, 58 p.

U.S. Geological Survey, 1961, Hydrologic studies of small watersheds, Deep Creek study area, Texas, 1961: U.S. Geological Survey, Texas District, 111 p.

U.S. Geological Survey, 1962, Hydrologic data of Deep Creek, Colorado River Basin, Texas, 1962: U.S. Geological Survey, Texas District, 51 p.

U.S. Geological Survey, 1963, Hydrologic data of Deep Creek, Colorado River Basin, Texas, 1963: U.S. Geological Survey, Texas District, 153 p.

U.S. Geological Survey, 1964, Compilation of hydrologic data, Deep Creek, Colorado River Basin, Texas, 1964: U.S. Geological Survey, Texas District, 78 p.

U.S. Geological Survey, 1965, Hydrologic studies of small watersheds, Deep Creek, Colorado River Basin, Texas, 1951–61: U.S. Geological Survey, Texas District, 123 p.

U.S. Geological Survey, 1965, Compilation of hydrologic data, Deep Creek, Colorado River Basin, Texas, 1965: U.S. Geological Survey, Texas District, 72 p.

U.S. Geological Survey, 1966, Compilation of hydrologic data, Deep Creek, Colorado River Basin, Texas, 1966: U.S. Geological Survey, Texas District, 55 p.

U.S. Geological Survey, 1967, Compilation of hydrologic data, Deep Creek, Colorado River Basin, Texas, 1967: U.S. Geological Survey, Texas District, 87 p.

U.S. Geological Survey, 1968, Compilation of hydrologic data, Deep Creek, Colorado River Basin, Texas, 1968: U.S. Geological Survey, Texas District, 86 p.

Hejl, H.R., 1971, Annual compilation and analysis of hydrologic data for Deep Creek, Colorado River Basin, Texas, 1969: U.S. Geological Survey, Texas District, 73 p.

Hejl, H.R., 1972, Annual compilation and analysis of hydrologic data for Deep Creek, Colorado River Basin, Texas, 1970: U.S. Geological Survey, Texas District, 35 p.

Lee, J.N., 1973, Annual compilation and analysis of hydrologic data for Deep Creek, Colorado River Basin, Texas, 1971: U.S. Geological Survey, Texas District, 76 p.

COLORADO RIVER BASIN: Mukewater Creek Watershed Studies

U.S. Geological Survey, 1960, Hydrologic studies of small watersheds Mukewater Creek Basin, Texas: U.S. Geological Survey, Texas District, 30 p.

U.S. Geological Survey, 1961, Hydrologic studies of small watersheds Mukewater Creek study area, Texas, 1961: U.S. Geological Survey, Texas District, 47 p.

U.S. Geological Survey, 1962, Hydrologic data of Mukewater Creek, Colorado River Basin, Texas, 1962: U.S. Geological Survey, Texas District, 60 p.

U.S. Geological Survey, 1963, Compilation of hydrologic data of small watersheds Mukewater Creek, Colorado River Basin, Texas, 1963: U.S. Geological Survey, Texas District, 80 p.

U.S. Geological Survey, 1964, Compilation of hydrologic data of small watersheds Mukewater Creek, Colorado River Basin, Texas, 1964: U.S. Geological Survey, Texas District, 56 p.
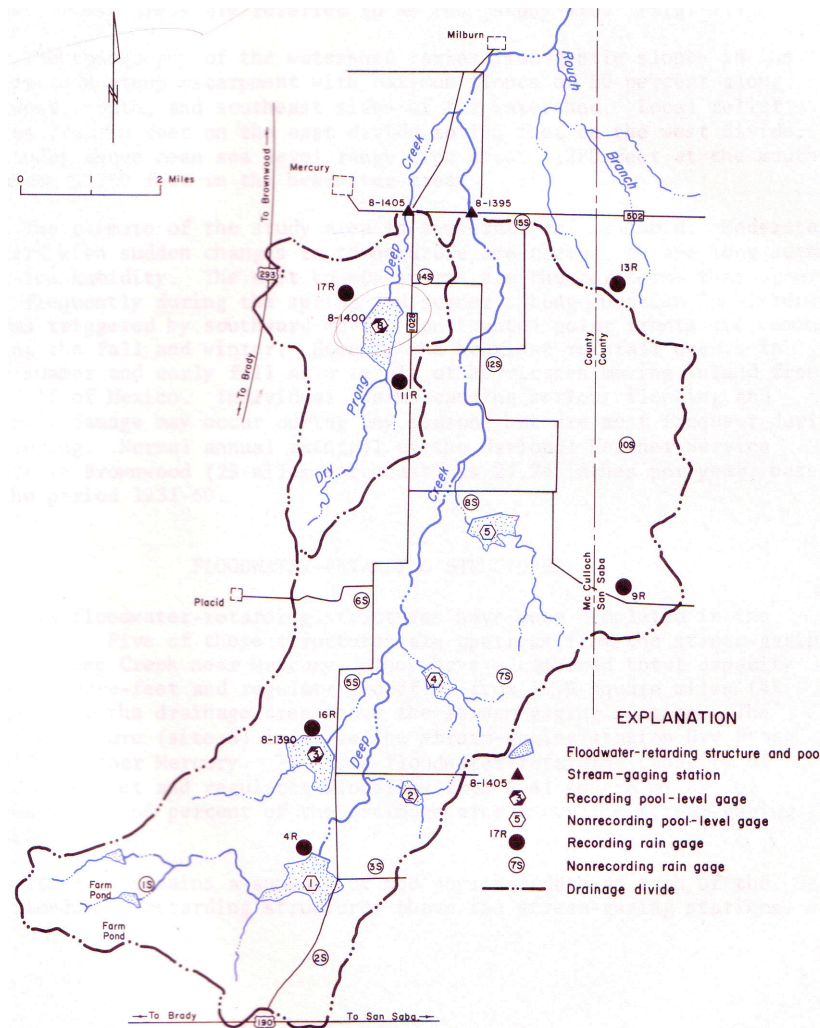
U.S. Geological Survey, 1965, Hydrologic studies of small watersheds Mukewater Creek, Colorado River Basin, Texas, 1952–60: U.S. Geological Survey, Texas District, 70 p.

U.S. Geological Survey, 1965, Compilation of hydrologic data of small watersheds Mukewater Creek, Colorado River Basin, Texas, 1965: U.S. Geological Survey, Texas District, 67 p.

Figure 21. Location map for `smallruralsheds` database module for Deep Creek watershed adopted from Hejl, 1972.

U.S. Geological Survey, 1966, Compilation of hydrologic data of small watersheds Mukewater Creek, Colorado River Basin, Texas, 1966: U.S. Geological Survey, Texas District, 56 p.

U.S. Geological Survey, 1967, Compilation of hydrologic data of small watersheds Mukewater Creek, Colorado River Basin, Texas, 1967: U.S. Geological Survey, Texas District, 87 p.

U.S. Geological Survey, 1968, Compilation of hydrologic data of small watersheds Mukewater Creek, Colorado River Basin, Texas, 1968: U.S. Geological Survey, Texas District, 81 p.

Hejl, H.R., 1969, Annual compilation and analysis of hydrologic data for Mukewater Creek, Colorado River Basin, Texas, 1969: U.S. Geological Survey, Texas District, 84 p.

Hejl, H.R., 1972, Annual compilation and analysis of hydrologic data for Mukewater
   Creek, Colorado River Basin, Texas, 1970: U.S. Geological Survey Open-File Report,
   69 p.

Lee, J.N., 1973, Annual compilation and analysis of hydrologic data for Mukewater
   Creek, Colorado River Basin, Texas, 1971: U.S. Geological Survey Open-File Report,
   89 p.

Lee, J.N., 1974, Hydrologic data for Mukewater Creek, Colorado River Basin, Texas,
   1972: U.S. Geological Survey Open-File Report, 67 p.

Lee, J.N., 1975, Hydrologic data for Mukewater Creek, Colorado River Basin, Texas,
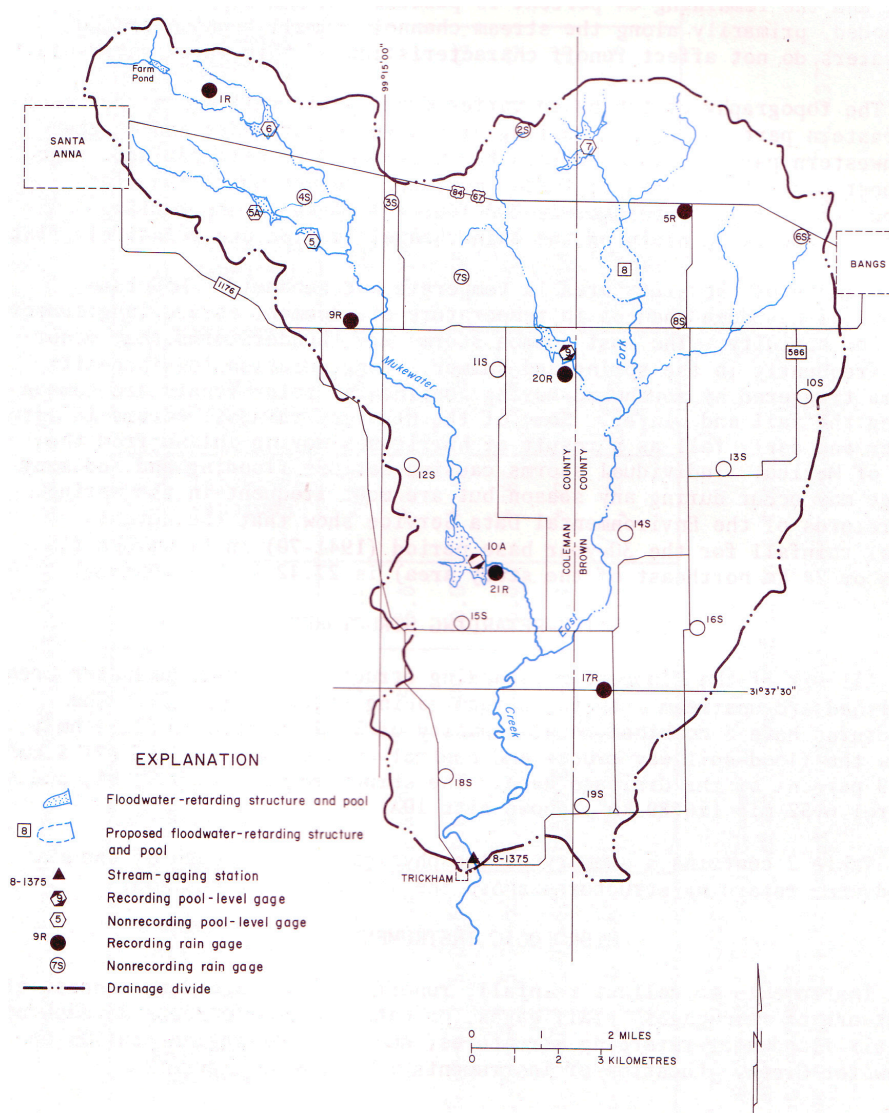   1973: U.S. Geological Survey Open-File Report, 65 p.

Figure 22. Location map for `smallruralsheds` **database module for Mukewater Creek watershed
   adopted from Lee, 1975.**

SAN ANTONIO RIVER BASIN: Calaveras Creek Watershed Studies

U.S. Geological Survey, 1960, Hydrologic studies of small watersheds, Calaveras Creek Basin, Texas, 1960: U.S. Geological Survey, Texas District, 36 p.

U.S. Geological Survey, 1961, Hydrologic studies of small watersheds, Calaveras Creek study area, Texas, 1961: U.S. Geological Survey, Texas District, [variously paged].

U.S. Geological Survey, 1962, Hydrologic data of Calaveras Creek, San Antonio River Basin, Texas, 1962: U.S. Geological Survey, Texas District, 41 p.

U.S. Geological Survey, 1963, Compilation of hydrologic data, Calaveras Creek, San Antonio River Basin, Texas, 1963: U.S. Geological Survey, Texas District, 41 p.

U.S. Geological Survey, 1964, Compilation of hydrologic data, Calaveras Creek, San Antonio River Basin, Texas, 1964: U.S. Geological Survey, Texas District, 50 p.

U.S. Geological Survey, 1965, Compilation of hydrologic data, Calaveras Creek, San Antonio River Basin, Texas, 1965: U.S. Geological Survey, Texas District, 62 p.

U.S. Geological Survey, 1966, Compilation of hydrologic data, Calaveras Creek, San Antonio River Basin, Texas, 1966: U.S. Geological Survey, Texas District, 34 p.

U.S. Geological Survey, 1967, Compilation of hydrologic data, Calaveras Creek, San Antonio River Basin, Texas, 1967: U.S. Geological Survey, Texas District, 47 p.

U.S. Geological Survey, 1968, Compilation of hydrologic data, Calaveras Creek, San Antonio River Basin, Texas, 1968: U.S. Geological Survey, Texas District, 66 p.

Alexander, J.M., 1969, Annual compilation and analysis of hydrologic data for Calaveras Creek, San Antonio River Basin, Texas, 1969: U.S. Geological Survey, Texas District, 56 p.

Reddy, D.R., 1971, Annual compilation and analysis of hydrologic data for Calaveras Creek, San Antonio River Basin, Texas, 1970: U.S. Geological Survey Open-File Report, 63 p.

U.S. Geological Survey, 1972, Hydrologic studies of small watersheds, Calaveras Creek, San Antonio River Basin, Texas, 1955–68: U.S. Geological Survey, Texas District, 109 p.

Steger, R.D., 1973, Annual compilation and analysis of hydrologic data for Calaveras and Escondido Creeks, San Antonio River Basin, Texas, 1971: U.S. Geological Survey Open-File Report, 74 p.
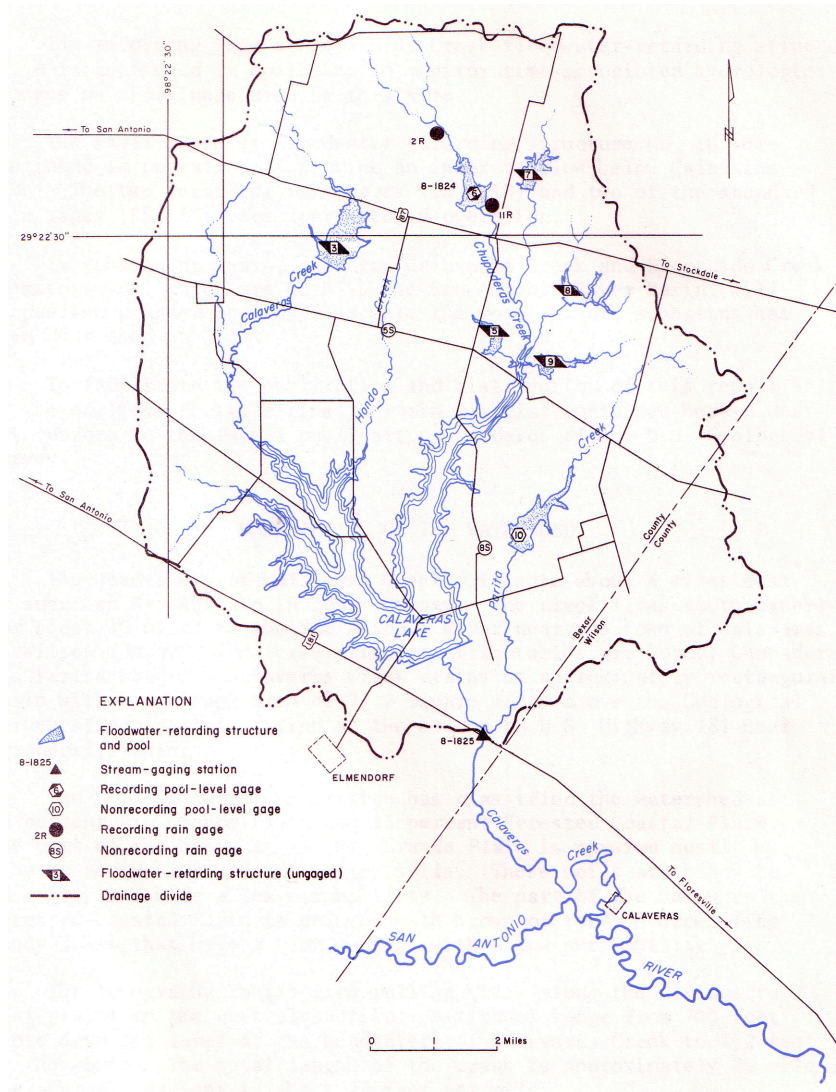
Figure 23. Location map for `smallruralsheds` **database module for Calaveras Creek watershed adopted from Reddy, 1971.**

SAN ANTONIO RIVER BASIN: Escondido Creek Watershed Studies

U.S. Geological Survey, 1960, Hydrologic studies of small watersheds, Escondido Creek Basin, Texas, 1960: U.S. Geological Survey, Texas District, 45 p.

U.S. Geological Survey, 1961, Hydrologic studies of small watersheds, Escondido Creek Basin, Texas, 1961: U.S. Geological Survey, Texas District, 70 p.

U.S. Geological Survey, 1962, Hydrologic data of Escondido Creek, San Antonio River Basin, Texas, 1962: U.S. Geological Survey, Texas District, 43 p.

U.S. Geological Survey, 1963, Compilation of hydrologic data, Escondido Creek, San Antonio River Basin, Texas, 1963: U.S. Geological Survey, Texas District, 85 p.

U.S. Geological Survey, 1964, Compilation of hydrologic data, Escondido Creek, San Antonio River Basin, Texas, 1964: U.S. Geological Survey, Texas District, 86 p.

U.S. Geological Survey, 1965, Compilation of hydrologic data, Escondido Creek, San Antonio River Basin, Texas, 1965: U.S. Geological Survey, Texas District, 72 p.

U.S. Geological Survey, 1966, Compilation of hydrologic data, Escondido Creek, San Antonio River Basin, Texas, 1966: U.S. Geological Survey, Texas District, 44 p.

U.S. Geological Survey, 1967, Hydrologic studies of small watersheds, Escondido Creek, San Antonio River Basin, Texas, 1955–63: U.S. Geological Survey, Texas District, 123 p.

U.S. Geological Survey, 1967, Compilation of hydrologic data, Escondido Creek, San Antonio River Basin, Texas, 1967: U.S. Geological Survey, Texas District, 73 p.

U.S. Geological Survey, 1968, Compilation of hydrologic data, Escondido Creek, San Antonio River Basin, Texas, 1968: U.S. Geological Survey, Texas District, 73 p.

Reddy, D.R., 1971, Annual compilation and analysis of hydrologic data for Escondido Creek, San Antonio River Basin Texas, 1969: U.S. Geological Survey, Texas District, 62 p.

Reddy, D.R., 1971, Annual compilation and analysis of hydrologic data for Escondido Creek, San Antonio River Basin, Texas, 1970: U.S. Geological Survey Open-File Report, 65 p.

Steger, R.D., 1973, Annual compilation and analysis of hydrologic data for Calaveras and Escondido Creeks, San Antonio River Basin, Texas, 1971: U.S. Geological Survey Open-File Report, 74 p.
[also listed in SAN ANTONIO RIVER BASIN: Calaveras Creek Watershed Studies section]

TRINITY RIVER BASIN: Elm Fork Trinity River Watershed Studies

U.S. Geological Survey, 1961, Hydrologic studies of small watersheds, Elm Fork Trinity River study area, Texas, 1961: U.S. Geological Survey, Texas District, 43 p.

U.S. Geological Survey, 1962, Hydrologic studies of small watersheds, Elm Fork Trinity River Basin, Montague and Cooke Counties, Texas 1956–60: U.S. Geological Survey, Texas District, 77 p.

U.S. Geological Survey, 1962, Hydrologic data of Elm Fork Trinity River, Trinity River Basin, Texas, 1962: U.S. Geological Survey, Texas District, 60 p.

U.S. Geological Survey, 1963, Compilation of hydrologic data, Elm Fork Trinity River, Trinity River Basin, Texas, 1963: U.S. Geological Survey, Texas District, 60 p.

U.S. Geological Survey, 1965, Compilation of hydrologic data, Elm Fork Trinity River, Trinity River Basin, Texas, 1964–65: U.S. Geological Survey, Texas District, 135 p.
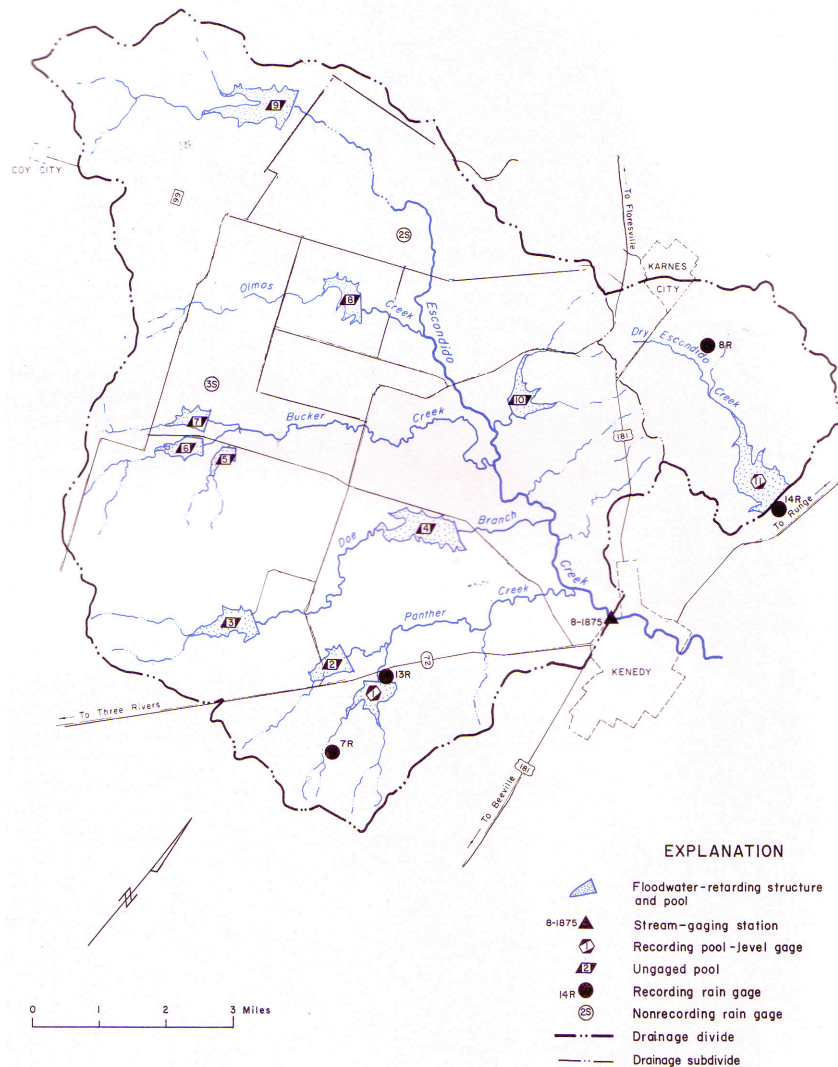
Figure 24. Location map for `smallruralsheds` **database module for Escondido Creek watershed adopted from Steger, 1973.**

U.S. Geological Survey, 1966, Compilation of hydrologic data, Elm Fork Trinity River, Trinity River Basin, Texas, 1966: U.S. Geological Survey, Texas District, 60 p.

U.S. Geological Survey, 1967, Compilation of hydrologic data, Elm Fork Trinity River, Trinity River Basin, Texas, 1967: U.S. Geological Survey, Texas District, 54 p.

U.S. Geological Survey, 1968, Compilation of hydrologic data, Elm Fork Trinity River, Trinity River Basin, Texas, 1968: U.S. Geological Survey, Texas District, 84 p.

Sansom, J.N., 1969, Annual compilation and analysis of hydrologic data for Elm Fork Trinity River, Trinity River Basin, Texas, 1969: U.S. Geological Survey, Texas District, 47 p.

Sansom, J.N., 1972, Annual compilation and analysis of hydrologic data for Elm Fork
    Trinity River, Trinity River Basin, Texas, 1970: U.S. Geological Survey Open-File
    Report, 47 p.

Lucero, E.D., 1973, Annual compilation and analysis of hydrologic data for Elm Fork
    Trinity River, Trinity River Basin, Texas, 1971: U.S. Geological Survey Open-File
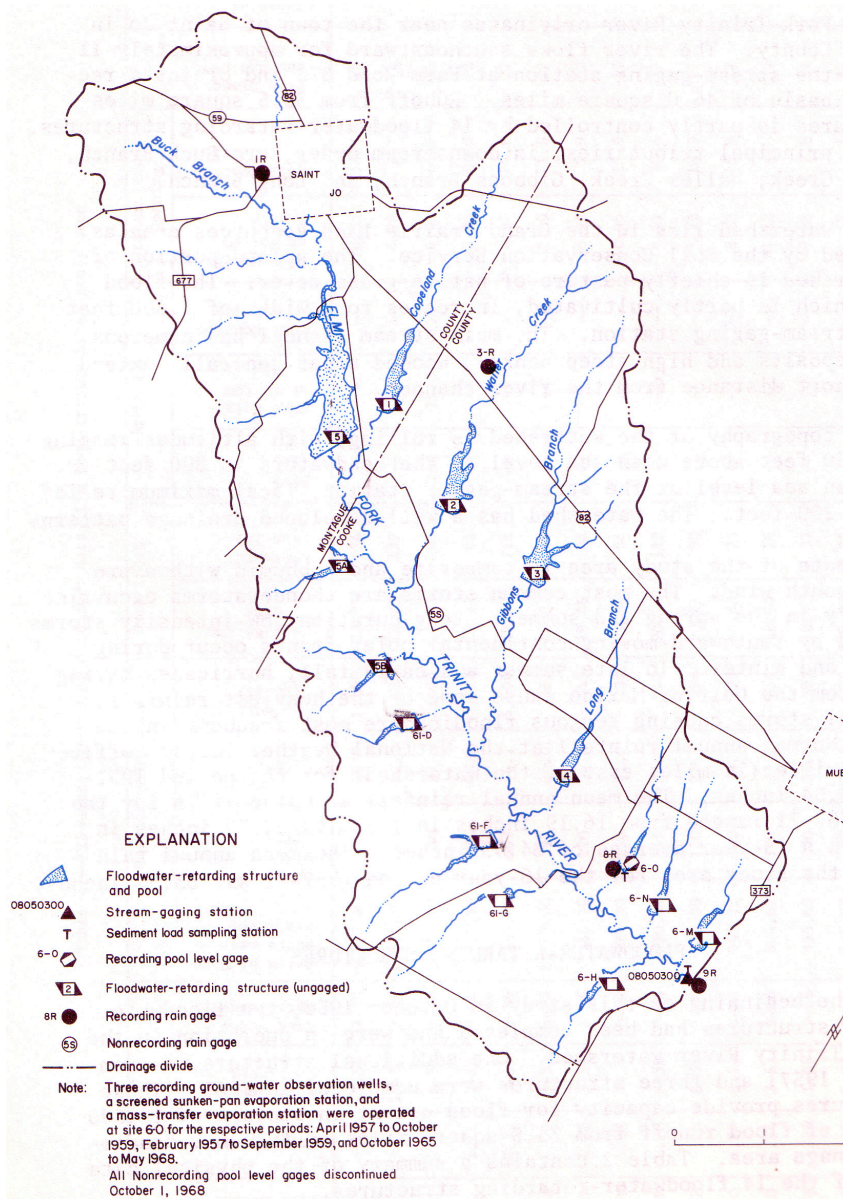   Report, 27 p.

Figure 25. Location map for `smallruralsheds` **database module for Elm Fork Trinity River watershed adopted from Lucero, 1973.**

TRINITY RIVER BASIN: Honey Creek Watershed Studies

U.S. Geological Survey, 1960, Hydrologic studies of small watersheds, Honey Creek Basin, Texas, 1960: U.S. Geological Survey, Texas District, 89 p.

U.S. Geological Survey, 1961, Hydrologic studies of small watersheds, Honey Creek Basin, Texas, 1961: U.S. Geological Survey, Texas District, 73 p.

U.S. Geological Survey, 1962, Hydrologic studies of small watersheds, Honey Creek Basin, Collin and Grayson Counties, Texas, 1953–59: U.S. Geological Survey, Texas District, 102 p.

U.S. Geological Survey, 1962, Hydrologic data of Honey Creek, Trinity River Basin, Texas, 1962: U.S. Geological Survey, Texas District, 148 p.

U.S. Geological Survey, 1963, Compilation of hydrologic data, Honey Creek, Trinity River Basin, Texas, 1963: U.S. Geological Survey, Texas District, 83 p.

U.S. Geological Survey, 1964, Compilation of hydrologic data, Honey Creek, Trinity River Basin, Texas, 1964: U.S. Geological Survey, Texas District, 77 p.

U.S. Geological Survey, 1965, Compilation of hydrologic data, Honey Creek, Trinity River basin Texas, 1965: U.S. Geological Survey, Texas District, 79 p.

U.S. Geological Survey, 1966, Compilation of hydrologic data, Honey Creek, Trinity River Basin, Texas, 1966: U.S. Geological Survey, Texas District, 126 p.

U.S. Geological Survey, 1967, Compilation of hydrologic data, Honey Creek, Trinity River Basin, Texas, 1967: U.S. Geological Survey, Texas District, 68 p.

U.S. Geological Survey, 1968, Compilation of hydrologic data, Honey Creek, Trinity River Basin, Texas, 1968: U.S. Geological Survey, Texas District, 78 p.

Sansom, J.N., 1969, Annual compilation and analysis of hydrologic data, Honey Creek, Trinity River Basin, Texas, 1969: U.S. Geological Survey Open-File Report, 85 p.

Sansom, J.N., 1972, Annual compilation and analysis of hydrologic data, Honey Creek, Trinity River Basin, Texas, 1970: U.S. Geological Survey Open-File Report, 66 p.

Hampton, B.B., 1973, Annual compilation and analysis of hydrologic data for Honey Creek, Trinity River Basin, Texas, 1971: U.S. Geological Survey Open-File Report, 28 p.
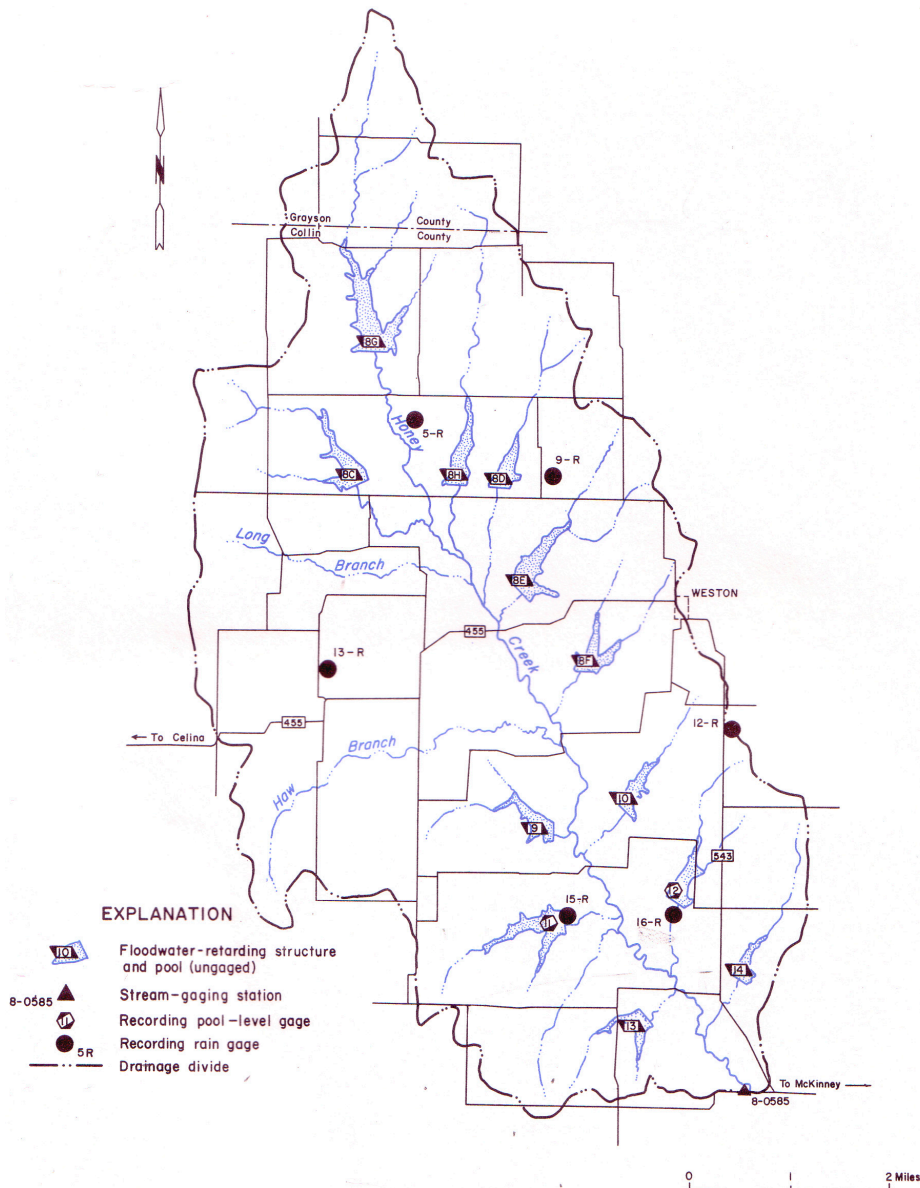
Figure 26. Location map for `smallruralsheds` database module for Honey Creek watershed adopted from Hampton, 1973.

TRINITY RIVER BASIN: Little Elm Creek Watershed Studies

U.S. Geological Survey, 1960, Hydrologic studies of small watersheds, Little Elm Creek Basin, Texas, 1960: U.S. Geological Survey, Texas District, 27 p.

U.S. Geological Survey, 1961, Hydrologic studies of small watersheds, Little Elm Creek study area, Trinity River Basin, Texas, 1961: U.S. Geological Survey, Texas District, 23 p.

U.S. Geological Survey, 1962, Hydrologic data of Little Elm Creek, Trinity River Basin, Texas, 1962: U.S. Geological Survey, Texas District, 35 p.

U.S. Geological Survey, 1963, Compilation of hydrologic data, Little Elm Creek, Trinity River Basin, Texas, 1963: U.S. Geological Survey, Texas District, 34 p.

U.S. Geological Survey, 1964, Compilation of hydrologic data, Little Elm Creek, Trinity River Basin, Texas, 1964: U.S. Geological Survey, Texas District, 28 p.

U.S. Geological Survey, 1965, Compilation of hydrologic data, Little Elm Creek, Trinity River Basin, Texas, 1965: U.S. Geological Survey, Texas District, 28 p.

U.S. Geological Survey, 1966, Hydrologic studies of small watersheds, Little Elm Creek, Trinity River Basin, Texas, 1956–62: U.S. Geological Survey, Texas District, 59 p.

U.S. Geological Survey, 1966, Compilation of hydrologic data, Little Elm Creek, Trinity River Basin, Texas, 1966: U.S. Geological Survey, Texas District, 69 p.

U.S. Geological Survey, 1967, Compilation of hydrologic data, Little Elm Creek, Trinity River Basin, Texas, 1967: U.S. Geological Survey, Texas District, 81 p.

U.S. Geological Survey, 1968, Compilation of hydrologic data, Little Elm Creek, Trinity River Basin, Texas, 1968: U.S. Geological Survey, Texas District, 83 p.

Hampton, B.B., 1971, Annual compilation and analysis of hydrologic data for Little Elm Creek, Trinity River Basin, Texas, 1969: U.S. Geological Survey, Texas District, 68 p.

Hampton, B.B., 1972, Annual compilation and analysis of hydrologic data for Little Elm Creek, Trinity River Basin, Texas, 1970: U.S. Geological Survey, Texas District, 100 p.

Hampton, B.B., 1973, Annual compilation and analysis of hydrologic data for Little Elm Creek, Trinity River Basin, Texas, 1971: U.S. Geological Survey, Texas District, 47 p.

Hampton, B.B., 1974, Hydrologic data for Little Elm Creek, Trinity River Basin, Texas, 1972: U.S. Geological Survey Open-File Report, 74 p.

Slade, R.M., Jr., and Taylor, J.M., 1975, Hydrologic data for Little Elm Creek, Trinity River Basin, Texas, 1973: U.S. Geological Survey Open-File Report, 74 p.

Slade, R.M., Jr., and Taylor, J.M., 1976, Hydrologic data for Little Elm Creek, Trinity River Basin, Texas, 1974: U.S. Geological Survey Open-File Report, 73 p.

Slade, R.M., Jr., and Taylor, J.M., 1977, Hydrologic data for Little Elm Creek, Trinity River Basin, Texas, 1975: U.S. Geological Survey Open-File Report 77–83, 108 p.

Slade, R.M., Jr., and Taylor, J.M., 1978, Hydrologic data for Little Elm Creek, Trinity River Basin, Texas, 1976: U.S. Geological Survey Open-File Report 78–100, 78 p.

TRINITY RIVER BASIN: North Creek Watershed Studies

U.S. Geological Survey, 1960, Hydrologic studies of small watersheds, North Creek Basin, Texas: U.S. Geological Survey, Texas District, 19 p.

U.S. Geological Survey, 1961, Hydrologic studies of small watersheds, North Creek study area, Texas: U.S. Geological Survey, Texas District, [variously paged].
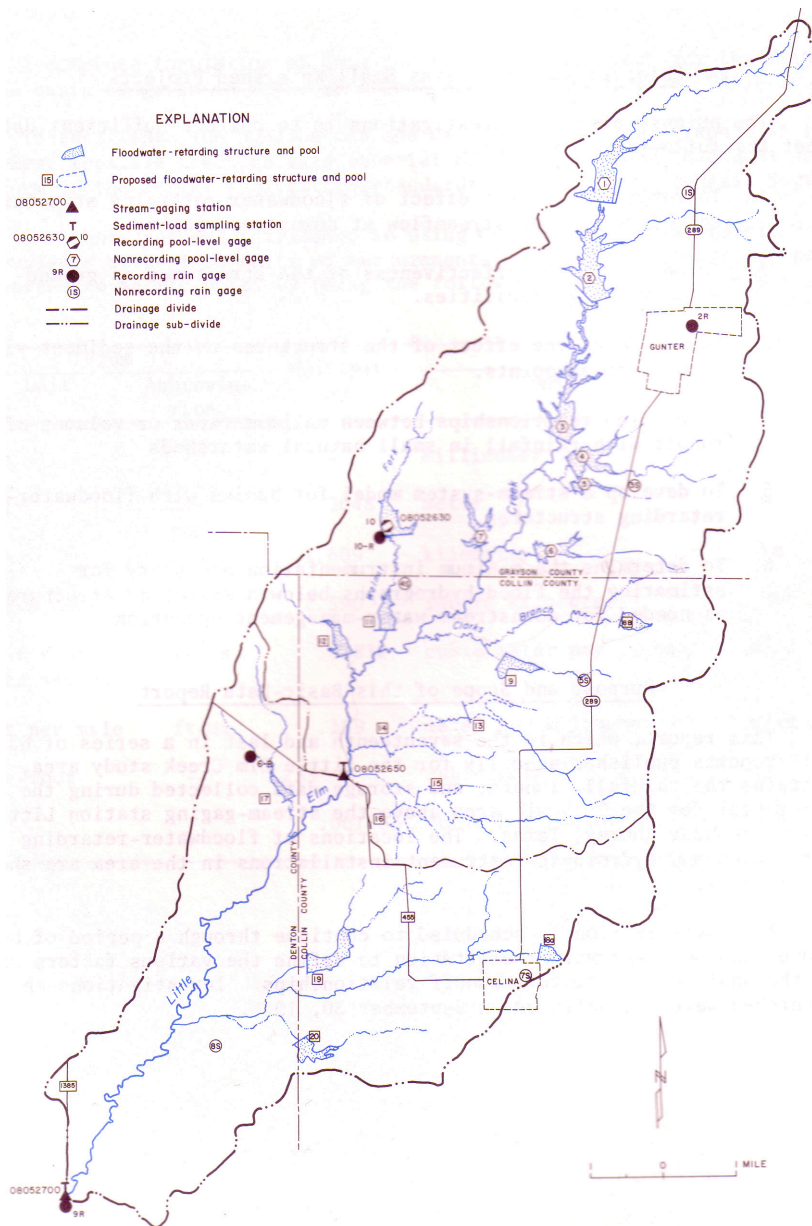
Figure 27. Location map for `smallruralsheds` **database module for Little Elm Creek watershed adopted from Slade and Taylor, 1978.**

U.S. Geological Survey, 1963, Compilation of hydrologic data, North Creek, Trinity River Basin, Texas, 1962–63: U.S. Geological Survey, Texas District, 47 p.

U.S. Geological Survey, 1964, Compilation of hydrologic data, North Creek, Trinity River Basin, Texas, 1964: U.S. Geological Survey, Texas District, 19 p.

U.S. Geological Survey, 1965, Compilation of hydrologic data, North Creek, Trinity River Basin, Texas, 1965: U.S. Geological Survey, Texas District, 30 p.

U.S. Geological Survey, 1966, Compilation of hydrologic data, North Creek, Trinity River Basin, Texas, 1966: U.S. Geological Survey, Texas District, 28 p.

U.S. Geological Survey, 1967, Compilation of hydrologic data, North Creek, Trinity River Basin, Texas, 1967: U.S. Geological Survey, Texas District, 27 p.

U.S. Geological Survey, 1968, Compilation of hydrologic data, North Creek, Trinity River Basin, Texas, 1968: U.S. Geological Survey, Texas District, 36 p.

Kidwell, C.C., 1969, Annual compilation and analysis of hydrologic data for North Creek, Trinity River Basin, Texas, 1969: U.S. Geological Survey, Texas District, 32 p.

Maderak, M.L. and Lucero, E.D., 1971, Annual compilation and analysis of hydrologic data for North Creek, Trinity River Basin, Texas, 1970: U.S. Geological Survey Open-File Report, 32 p.

Lucero, E.D., 1973, Annual compilation and analysis of hydrologic data for North Creek, Trinity River Basin, Texas, 1971: U.S. Geological Survey Open-File Report, 23 p.

Slade, R.M., Jr., 1974, Hydrologic data for North Creek Trinity River Basin, Texas, 1972: U.S. Geological Survey Open-File Report, 31 p.

Slade, R.M., Jr., 1975, Hydrologic data for North Creek Trinity River Basin, Texas, 1973: U.S. Geological Survey Open-File Report, 44 p.

Slade, R.M., Jr., 1976, Hydrologic data for North Creek Trinity River Basin, Texas, 1974: U.S. Geological Survey Open-File Report, 40 p.

Kidwell, C.C., 1977, Hydrologic data for North Creek Trinity River Basin, Texas, 1975: U.S. Geological Survey Open-File Report 76–724, 50 p.

Kidwell, C.C., 1978, Hydrologic data for North Creek Trinity River Basin, Texas, 1976: U.S. Geological Survey Open-File Report 77–732, 42 p.

Kidwell, C.C., 1979, Hydrologic data for North Creek Trinity River Basin, Texas, 1977: U.S. Geological Survey Open-File Report 79–335, 39 p.

Kidwell, C.C., 1980, Hydrologic data for North Creek Trinity River Basin, Texas, 1978: U.S. Geological Survey Open-File Report 80–573, 44 p.

Kidwell, C.C., 1981, Hydrologic data for North Creek Trinity River Basin, Texas, 1979: U.S. Geological Survey Open-File Report 81–823, 38 p.

TRINITY RIVER BASIN: Pin Oak Creek Watershed Studies

U.S. Geological Survey, 1960, Hydrologic studies of small watersheds, Pin Oak Creek, Trinity River Basin, Texas, 1956–62: U.S. Geological Survey, Texas District, 69 p.

U.S. Geological Survey, 1960, Hydrologic studies of small watersheds, Pin Oak Creek Basin, Texas, 1960: U.S. Geological Survey, Texas District, 44 p.

U.S. Geological Survey, 1961, Hydrologic studies of small watersheds, Pin Oak Creek study area, Texas 1961: U.S. Geological Survey, Texas District, 38 p.
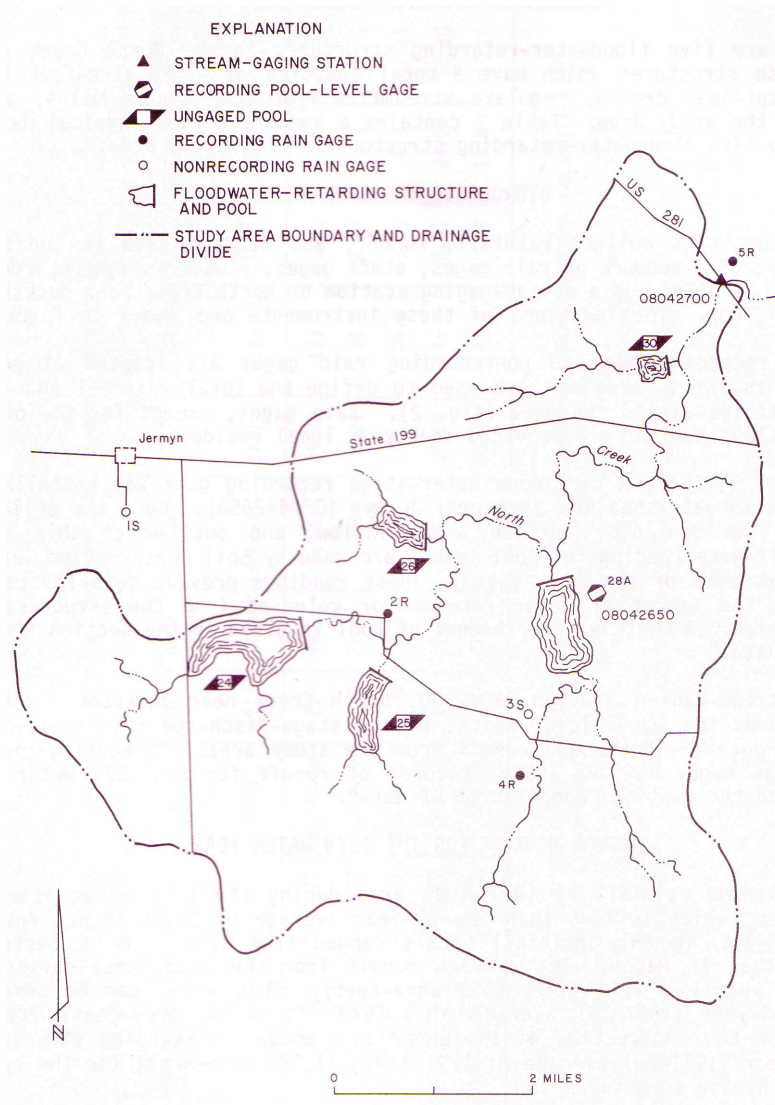
Figure 28. Location map for smallruralsheds database module for North Creek watershed adopted from Kidwell, 1979.

U.S. Geological Survey, 1964, Compilation of hydrologic data, Pin Oak Creek, Trinity River Basin, Texas, 1962–64: U.S. Geological Survey, Texas District, 36 p.

U.S. Geological Survey, 1965, Compilation of hydrologic data, Pin Oak Creek, Trinity River Basin, Texas, 1965: U.S. Geological Survey, Texas District, 30 p.

U.S. Geological Survey, 1966, Compilation of hydrologic data, Pin Oak Creek, Trinity River Basin, Texas, 1966: U.S. Geological Survey, Texas District, 27 p.

U.S. Geological Survey, 1967, Compilation of hydrologic data, Pin Oak Creek, Trinity River Basin, Texas, 1967: U.S. Geological Survey, Texas District, 25 p.

U.S. Geological Survey, 1968, Compilation of hydrologic data, Pin Oak Creek, Trinity River Basin Texas, 1968: U.S. Geological Survey, Texas District, 44 p.

Hampton, B.B., and Myers, D.R., 1969, Annual compilation and analysis of hydrologic data, Pin Oak Creek, Trinity River Basin Texas, 1969: U.S. Geological Survey, Texas District, 28 p.

Hampton, B.B., and Myers, D.R., 1972, Annual compilation and analysis of hydrologic data, Pin Oak Creek, Trinity River Basin Texas, 1970: U.S. Geological Survey Open-File Report, 50 p.

Hampton, B.B., 1973, Annual compilation and analysis of hydrologic data for Pin Oak Creek, Trinity River Basin Texas, 1971: U.S. Geological Survey Open-File Report, 18 p.

Hampton, B.B., 1974, Hydrologic data for Pin Oak Creek, Trinity River Basin Texas, 1972: U.S. Geological Survey Open-File Report, 26 p.
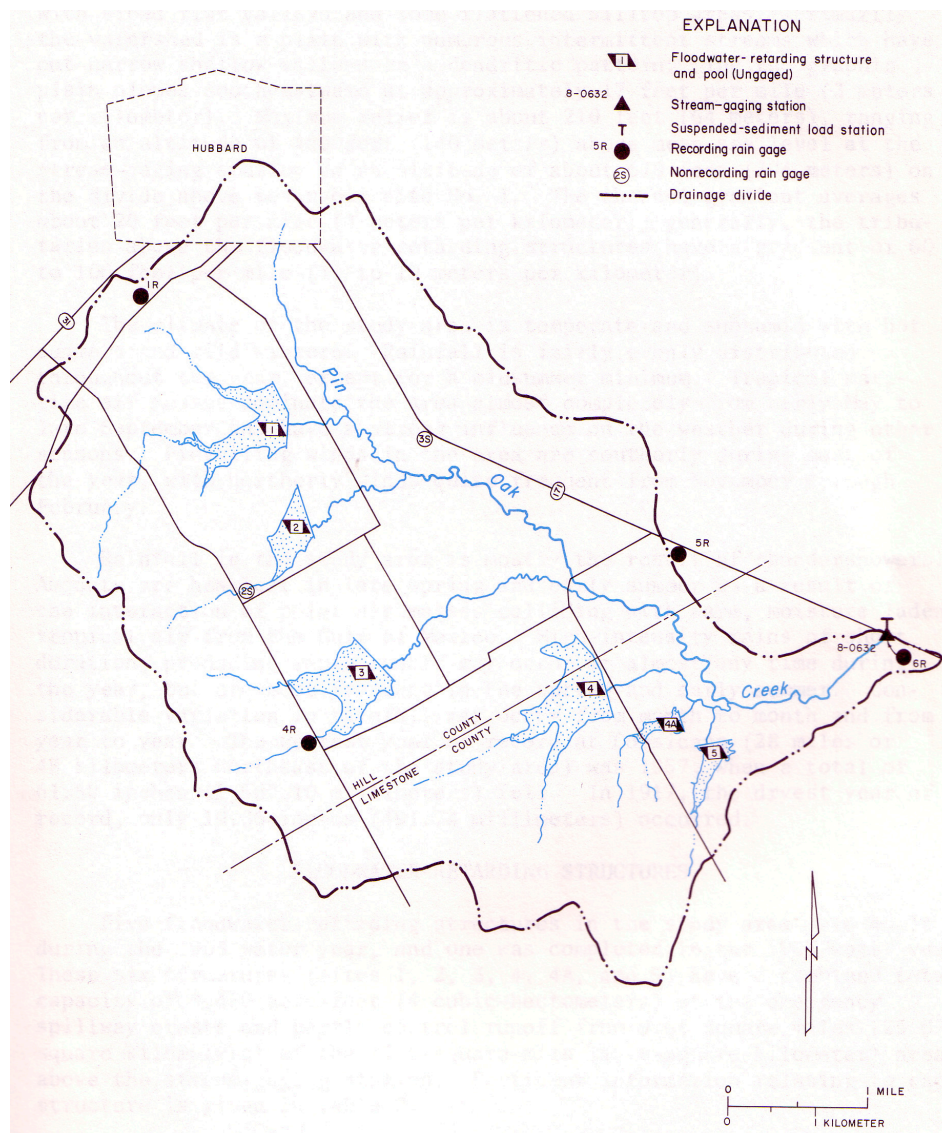
Figure 29. Location map for smallruralsheds database module for Pin Oak Creek watershed adopted from Hampton, 1974.

This page intentionally left blank.