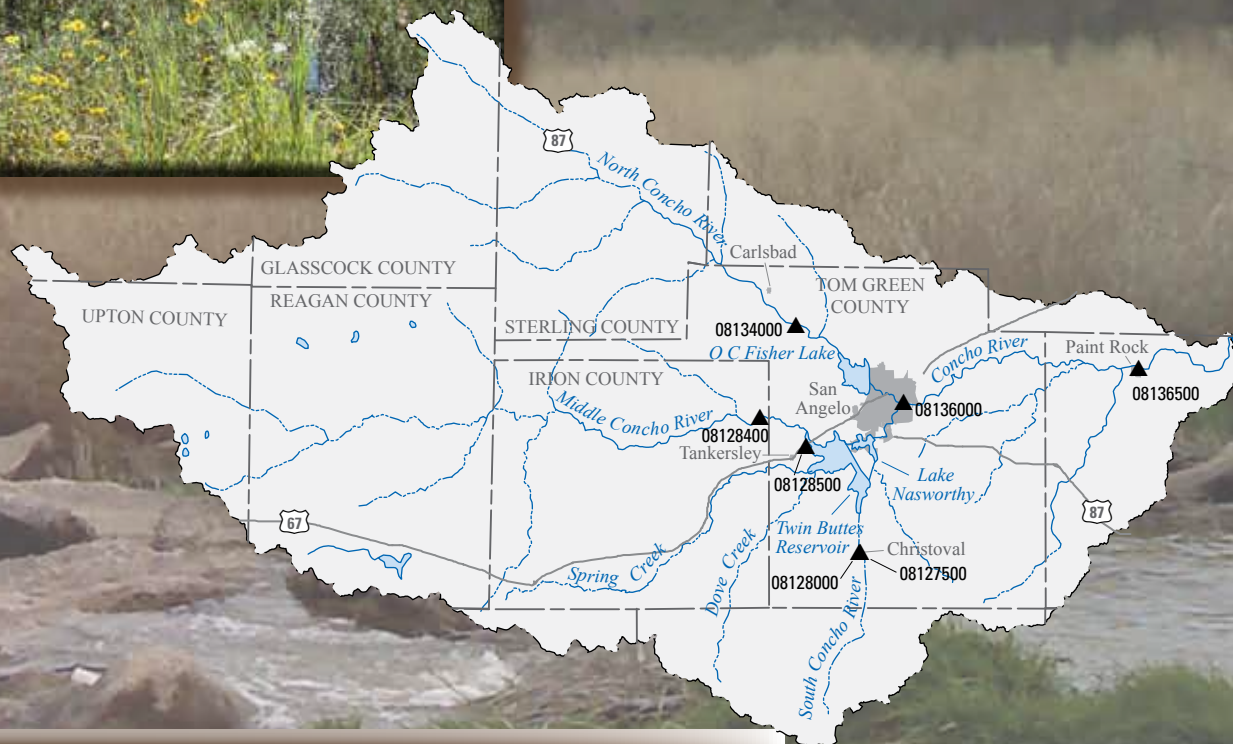# USGS
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Analysis of Trends in Selected Streamflow Statistics for the Concho River Basin, Texas, 1916–2009

Scientific Investigations Report 2012–5193

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

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By Dana L. Barbie, Loren L. Wehmeyer, and Jayne E. May

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
Length		
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
Flow rate		
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Analysis of Trends in Selected Streamflow Statistics for the Concho River Basin, Texas, 1916–2009

By Dana L. Barbie, Loren L. Wehmeyer, and Jayne E. May

Abstract

The Concho River Basin is part of the upper Colorado River Basin in west-central Texas. Monotonic trends in streamflow statistics during various time intervals from 1916–2009 were analyzed to determine whether substantial changes in selected streamflow statistics have occurred within the Concho River Basin. Two types of U.S. Geological Survey streamflow data comprise the foundational data for this report: (1) daily mean discharge (daily discharge) and (2) annual instantaneous peak discharge. Trend directions are reported for the following streamflow statistics: (1) annual mean daily discharge, (2) annual 1-day minimum discharge, (3) annual 7-day minimum discharge, (4) annual maximum daily discharge, and (5) annual instantaneous peak discharge.

The South Concho, Middle Concho, and North Concho Rivers drain the upper part of the Concho River Basin. The North and South Concho Rivers converge in San Angelo, Tex., to form the Concho River. The Concho River flows east from San Angelo to its confluence with the Colorado River east of Paint Rock, Tex. The trend analyses principally focused on application of the nonparametric Kendall's Tau statistical test to detect monotonic trends (dependency) in streamflow with time; in other words, Kendall's Tau is a test of temporal independence of streamflow with time. A positive Tau indicates an upward monotonic streamflow trend; conversely, a negative Tau indicates a downward monotonic streamflow trend. Hence, the trend analysis reported here is limited to direction and not magnitude of streamflow change.

Six U.S. Geological Survey streamflow-gaging stations were selected for analysis. Streamflow-gaging station 08128000 South Concho River at Christoval has downward trends for annual maximum daily discharge and annual instantaneous peak discharge for the combined period 1931–95, 2002–9. Streamflow-gaging station 08128400 Middle Concho River above Tankersley has downward trends for annual maximum daily discharge and annual instantaneous peak discharge for the combined period 1962–95, 2002–9. Streamflow-gaging station 08128500 Middle Concho River near Tankersley has no significant trends in the streamflow statistics considered for the period 1931–60. Streamflow-gaging station 08134000 North Concho River near Carlsbad has downward trends for annual mean daily discharge, annual 7-day minimum daily discharge, annual maximum daily discharge, and annual instantaneous peak discharge for the period 1925–2009. Streamflow-gaging stations 08136000 Concho River at San Angelo and 08136500 Concho River at Paint Rock have downward trends for 1916–2009 for all streamflow statistics calculated, but streamflow-gaging station 08136000 Concho River at San Angelo has an upward trend for annual maximum daily discharge during 1964–2009. The downward trends detected during 1916–2009 for the Concho River at San Angelo are not unexpected because of three reservoirs impounding and profoundly regulating streamflow.

Introduction

The Concho River Basin is part of the upper Colorado River Basin in west-central Texas, principally in Tom Green, Irion, Reagan, and Sterling Counties and to a lesser degree in Coke, Concho, Crockett, Glasscock, Howard, Midland, Runnels, Schleicher, and Upton Counties (fig. 1). The population of the Concho River Basin is approximately 120,000, and most of the residents (approximately 93,200 in 2010) live in San Angelo (fig. 1) (U.S. Census Bureau, 2012). The major water demands (withdrawals) in the basin are for public (municipal) supply, ranching, irrigated agriculture, and oil and gas production. Public water supply in San Angelo historically has been provided by streamflow stored in O.H. Ivie and Twin Buttes Reservoirs, Lakes Nasworthy and E.V. Spence, and O.C. Fisher Lake (fig. 1). Although streamflow supplies some water for irrigation, most agriculture land is irrigated with groundwater. Tom Green County has the largest area under irrigation (about 40,000 acres in 2007) (Region F Water Planning Group, 2009). Groundwater is the predominant water source for the rural population, ranching, and oil and gas production in the study area. Because the Concho River Basin provides water stored for public water supply for most residents in the study area, trends in streamflow in the Concho River Basin are of interest to water managers in this part of west Texas. Accordingly, the U.S. Geological Survey (USGS), in cooperation with the Texas Water Development Board,
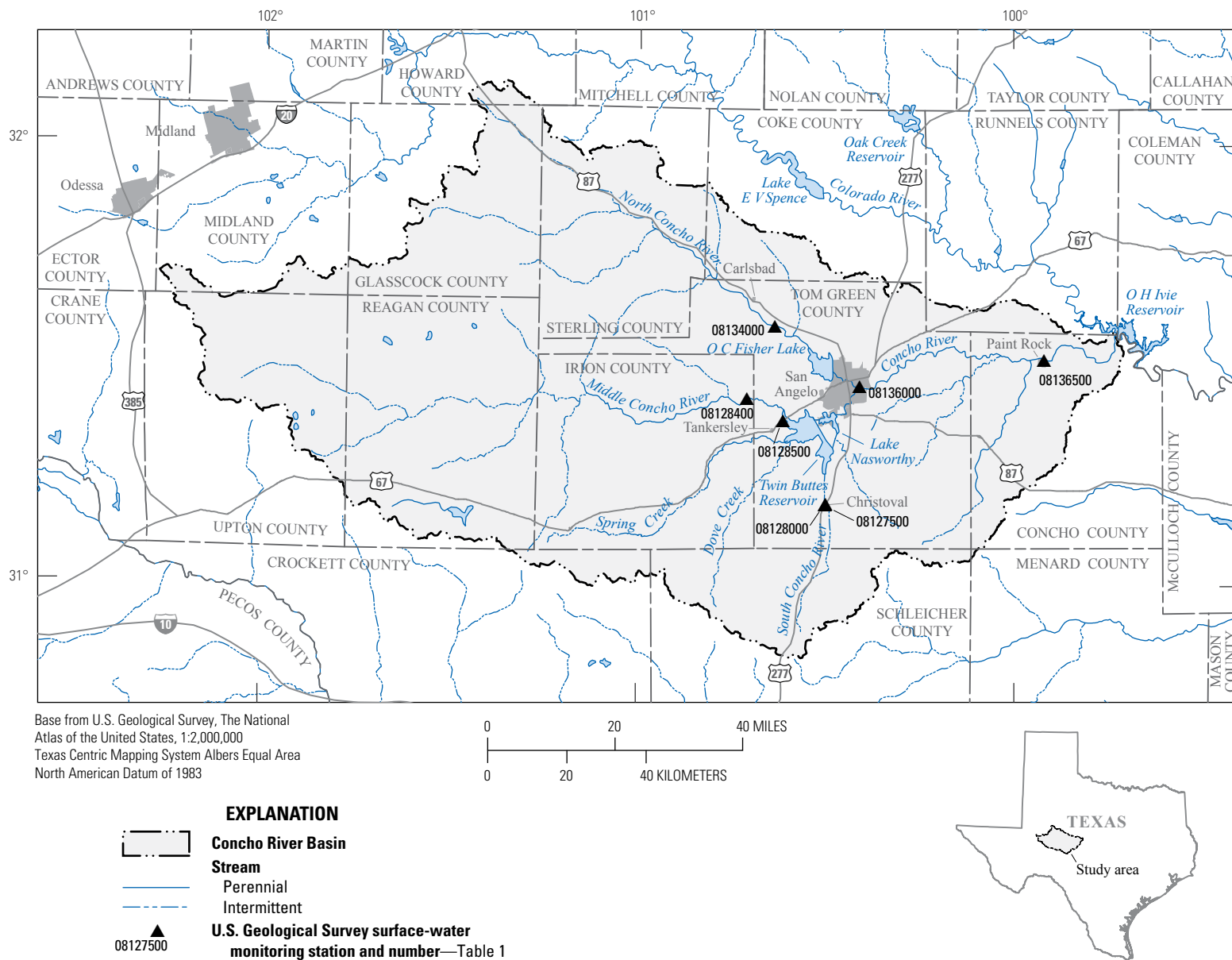
Figure 1. Selected U.S. Geological Survey surface-water monitoring stations in the Concho River Basin, Texas.

evaluated trends during 1916–2009 in selected streamflow statistics for the Concho River Basin. Six USGS streamflow-gaging stations were selected for analysis: 08128000 South Concho River at Christoval, Tex.; 08128400 Middle Concho River above Tankersley, Tex.; 08128500 Middle Concho River near Tankersley, Tex.; 08134000 North Concho River near Carlsbad, Tex.; 08136000 Concho River at San Angelo, Tex.; and 08136500 Concho River at Paint Rock, Tex. (fig. 1, table 1). In addition to the six streamflow-gaging stations listed in table 1, a USGS surface-water monitoring station used to monitor discharge in a canal is listed (station 08127500 South Concho Irrigation Company Canal at Christoval, Tex.). The use of the discharge data for this station and how it interacts with the analyses presented in this report is described in the section "Analysis of Trends in Selected Streamflow Statistics" pertaining to the South Concho River Basin.

The USGS has published statistical and historical summaries of streamflow data in Texas with great emphasis on visualization of streamflow data and statistics (Asquith and others, 2007a, b; Asquith and Heitmuller, 2008). These previous reports include similar and complementary statistical and graphical presentations of streamflow data for the six streamflow-gaging stations analyzed in this report. Lastly, the periods of annual instantaneous peak discharge for the six streamflow-gaging stations contribute to the regression equations by Asquith and Roussel (2009) that estimate peak-streamflow frequency in Texas.

Purpose and Scope

Monotonic trends in selected streamflow statistics in the Concho River Basin were evaluated for using a nonparametric test (Kendall's Tau) at selected USGS streamflow-gaging stations. Two types of USGS streamflow data comprise the foundational data for this report: (1) daily mean discharge (daily discharge) and (2) annual instantaneous peak discharge. Trends are reported for the following streamflow statistics: (1) annual mean daily discharge, (2) annual 1-day minimum discharge, (3) annual 7-day minimum discharge, (4) annual maximum daily discharge, and (5) annual instantaneous peak discharge. The scope of this report does not include an analysis of how possible changes in precipitation, land use, or groundwater withdrawals might have affected streamflow trends.

Concho River Basin Description

The South Concho, Middle Concho, and North Concho Rivers drain the upper part of the Concho River Basin. The Concho River and its tributaries generally flow from west to east with the exception of the South Concho River, which flows from south to north (fig. 1). Middle and South Concho Rivers join at Twin Buttes Reservoir (fig. 1) and continue downstream as the South Concho River. The Concho River is formed by the confluence of the South Concho and North Concho Rivers in San Angelo. From where it rises in San Angelo, the Concho River flows east about 60 miles (mi) to its confluence with the Colorado River, east of Paint Rock (fig. 1). Although the published drainage area of the Concho River Basin is about 6,765 square miles (mi^2) (U.S. Geological Survey, 2012), approximately 1,130 mi^2 of the basin are characterized by playas or other natural depressions that do not contribute runoff to the Concho River (Tovar and Maldonado, 1981). The contributing drainage area of the Concho River is about 5,634 mi^2 (Tovar and Maldonado, 1981).

Table 1. Selected U.S. Geological Survey surface-water monitoring stations in the Concho River Basin, Texas, 1915–2009.

[USGS, U.S. Geological Survey; mi^2, square miles; NA, not applicable]

USGS station number	USGS station name	Gaging station type	Total drainage area (mi^2)	Contributing drainage area (mi^2)	Period of continuous daily mean discharge record	Water years statistically evaluated
08127500	South Concho Irrigation Company Canal at Christoval, Tex.	canal	NA	NA	Dec. 1939–Oct. 1983	none
08128000	South Concho River at Christoval, Tex.	stream	413	354	Mar. 1930–Sept. 1995; May 2001–Sept. 2009	1931–95, 2002–9
08128400	Middle Concho River above Tankersley, Tex.	stream	2,084	1,116	Apr. 1961–Sept. 1995; Apr. 2001–Sept. 2009	1962–95, 2002–9
08128500	Middle Concho River near Tankersley, Tex.	stream	2,653	1,685	Mar. 1930–Mar. 1961	1931–60
08134000	North Concho River near Carlsbad, Tex.	stream	1,266	1,191	Apr. 1924–Sept. 2009	1925–2009
08136000	Concho River at San Angelo, Tex.	stream	5,542	4,411	Oct. 1915–Sept. 2009	1916–2009
08136500	Concho River at Paint Rock, Tex.	stream	6,572	5,443	Oct. 1915–Sept. 2009	1916–2009

The USGS has collected streamflow data in the Concho River Basin since October 1915. Since then and at various time intervals, up to 24 daily surface water stations (19 streamflow-gaging stations, 3 lake or reservoir stations, and 2 canal stations) have collected data in the basin through the present (2012). Two streamflow-gaging stations (the oldest in the basin) were installed in 1915 (Concho River at San Angelo and Concho River at Paint Rock), one was installed in 1924 (North Concho River near Carlsbad), and two were installed in 1930 (South Concho River at Christoval and Middle Concho River near Tankersley). The canal gage was installed in 1939 and discontinued in 1983. The South Concho River at Christoval, Middle Concho River near Tankersley, and Middle Concho River above Tankersley streamflow-gaging stations are upstream from Twin Buttes Reservoir and Lake Nasworthy. The North Concho River near Carlsbad streamflow-gaging station is upstream from O.C. Fisher Lake. The Concho River at San Angelo and Concho River at Paint Rock streamflow-gaging stations are downstream from the three identified impoundments.

Methods

Trend analysis used in this study is based on application of the nonparametric Kendall's Tau statistical test to detect monotonic trends in streamflow with time (Helsel and Hirsch, 2002). A positive Tau indicates an upward monotonic streamflow trend; conversely, a negative Tau indicates a downward monotonic streamflow trend. The p-value of Kendall's Tau is a measure of the statistical significance of the trend. For this study, a p-value of less than 0.05 indicates a significant trend, whereas a p-value of 0.05 or greater indicates no significant trend. The trend analysis reported here is limited to direction and not magnitude of streamflow change.

Annual mean daily discharge is computed as the average of daily mean discharges during a water year (a water year is defined as the 12-month period from October 1 to September 30). The annual 1-day minimum discharge is the discharge on the day of lowest daily mean discharge in a given water year. Similarly, the annual 7-day minimum discharge is the lowest daily mean discharge during 7 consecutive days in a given water year. The annual maximum daily discharge is the discharge on the day of highest annual daily mean discharge in a given water year. The annual instantaneous peak discharge is the discharge associated with the highest instantaneous streamflow computed in a given water year; this statistic is fundamentally different from the other four streamflow statistics because there is no time averaging involved. The date of the annual instantaneous peak discharge is not constrained to occur on the same day as the annual maximum daily discharge. To conduct the trend analysis, the software package Statistica (StatSoft, 2009) was used to perform the Kendall's Tau test. For each of the six streamflow-gaging stations, Kendall's Tau statistics were computed for the five

streamflow statistics; the precise period of records evaluated by streamflow-gaging station are listed in table 1.

There is an important limitation of the Kendall's Tau statistical test when applied to streamflow time series data that might contain a substantial number of years with no flow for annual 1-day (or 7-day) minimum discharge. The Tau and the attendant p-value become highly unreliable and direct interpretation of their numerical meaning can become tenuous because of ties. In many nonparametric statistical tests, considerable accommodation of ties in the data set can be made but are only approximations. For this study, the trend analysis of annual 1-day and 7-day minimum daily discharge for streamflow-gaging stations 08128400 Middle Concho River above Tankersley and 08128500 Middle Concho River near Tankersley yield Tau and p-values that are difficult to interpret and hence specially noted when the trends analysis is presented in tabular form.

Analysis of Trends in Selected Streamflow Statistics

South Concho River Basin

The headwaters of the South Concho River are in north Schleicher County (fig. 1) approximately 40 mi south of San Angelo. The river flows north into Twin Buttes Reservoir. The South Concho Irrigation Company Canal diverts water upstream from the South Concho River at Christoval streamflow-gaging station and returns water to the river downstream from the streamflow-gaging station. The canal gaging station was operated from December 1939 through October 1983 (table 1) and the South Concho River at Christoval streamflow-gaging station was operated from March 1930 through September 1995 and reactivated from May 2001 to the present (2012). The return discharge from the canal into the river is less than the discharge diverted into the canal upstream because of withdrawals for irrigation and evaporation losses (Sauer, 1972). The sum of the discharge in the canal and the discharge at the nearby streamflow-gaging station can be used as an estimate for the total South Concho River discharge during the period of mutual operation. The three time series of annual mean discharges shown in figure 2 indicate that the estimated combined annual mean streamflow does not materially vary or diverge from patterns seen in the South Concho River at Christoval annual mean streamflow. Hence, for this report, the five statistics of South Concho River at Christoval streamflow were evaluated for monotonic trends, and a benefit of this decision is that a longer period of record (blue line in fig. 2) is available for analysis without inclusion of the streamflow in the canal.

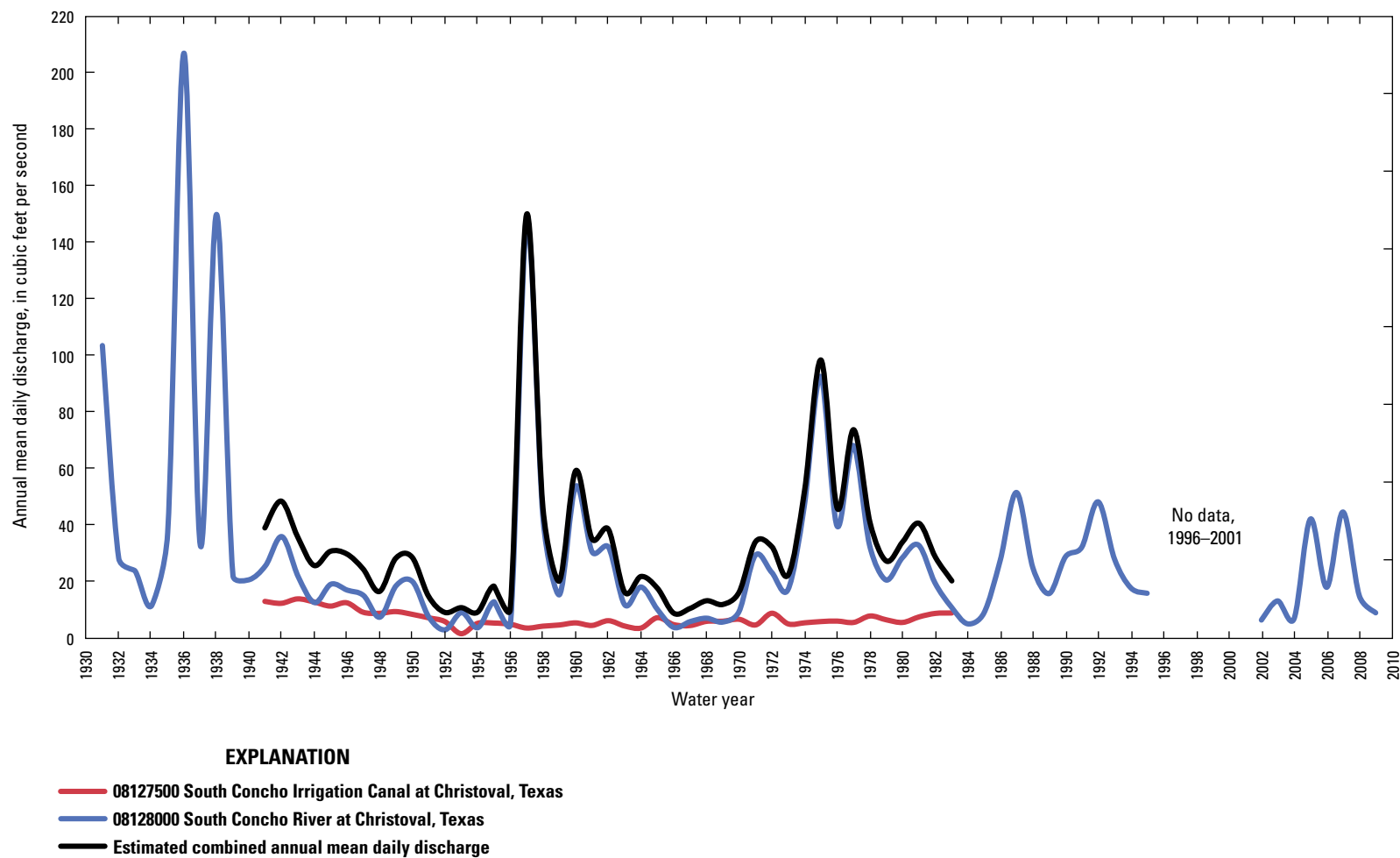For the South Concho River at Christoval streamflow-gaging station, statistically significant downward trends

Figure 2. Annual mean daily discharge for U.S. Geological Survey surface-water monitoring stations 08128000 South Concho River near Christoval, Texas and 08127500 South Concho Irrigation Canal at Christoval, Tex., along with the estimated combined annual mean daily discharge.

in streamflow for the combined period 1931–95 and 2002–9 were detected for annual maximum daily discharge and annual instantaneous peak discharge (table 2). No statistically significant trends were detected for the other three streamflow statistics.

Middle Concho River Basin

The headwaters of the Middle Concho River are approximately 90 mi west of San Angelo. The river flows east into Twin Buttes Reservoir (fig. 1). The two Middle Concho River streamflow-gaging stations were not operated concurrently (table 1), visually indicated by the plotted annual mean daily discharges for the streamflow-gaging stations shown in figure 3. The upstream streamflow-gaging station 08128400 Middle Concho River above Tankersley, Tex., (drainage area 1,116 mi[2]) was a replacement for streamflow-gaging station 08128500 Middle Concho River near Tankersley, Tex. (drainage area 1,685 mi[2]). The Middle Concho River near Tankersley streamflow-gaging station was discontinued on March 31, 1961, in order to accommodate the construction of Twin Buttes Reservoir. The Middle Concho River above Tankersley streamflow-gaging station began operating April 1, 1961. This streamflow-gaging station transition occurred at the beginning of a multi-year period of unusually low streamflow. For example in 1962, the annual mean discharge was no flow (fig. 3).

For the Middle Concho River above Tankersley streamflow-gaging station, statistically significant downward trends in streamflow for the combined period 1962–95 and 2002–9 were detected for annual maximum daily discharge and annual instantaneous peak discharge at (table 3a). No statistically significant trends were detected for the other three streamflow statistics. For the Middle Concho River near Tankersley streamflow-gaging station, no statistically significant trends were detected for all five streamflow statistics for the period 1931–60 (table 3b).

North Concho River Basin

The headwaters of the North Concho River are approximately 70 mi northwest of San Angelo. The North Concho River flows from northwest to southeast into O.C. Fisher Lake (fig. 1). The North Concho River near Carlsbad streamflow-gaging station is a particularly important sentinel for streamflow conditions for much of the greater Concho River Basin. Specifically, the streamflow at this streamflow-gaging station is considered natural to the extent that the upstream watershed has effectively no diversions or regulation during the 85 years of record (April 1924–September 2009). The annual mean discharge for the North Concho River near Carlsbad is shown in figure 4.

For the North Concho River near Carlsbad streamflow-gaging station, statistically significant downward trends for the period 1925–2009 were detected for annual mean daily discharge (fig. 4), annual 7-day minimum discharge, annual maximum daily discharge, and annual instantaneous peak discharge (table 4).

Lower Concho River Basin

Three impoundments regulate streamflow in the Concho River Basin: Lake Nasworthy (since 1930), O.C. Fisher Lake (since 1952), and Twin Buttes Reservoir (since 1963) (Dowell, 1964; U.S. Geological Survey, 2012). These impoundments are upstream from the Concho River mainstem that originates just downstream from the reservoirs at San Angelo. These impoundments then substantially regulate low to high streamflows observed at the Concho River at San Angelo and Concho River at Paint Rock streamflow-gaging stations. Both O.C. Fisher Lake and Twin Buttes Reservoir did not initially yield the public water supply anticipated from the reservoir designs that were based on the existing streamflow records in Concho River Basin (Sauer, 1972). Since impoundment began in 1952, the only time the conservation pool level in

Table 2.   Results of Kendall's Tau statistical test for detection of monotonic trends in select streamflow statistics for U.S. Geological Survey streamflow-gaging station 08128000 South Concho River at Christoval, Texas.

[p-value, probability value; <, less than]

| Streamflow statistic	Interval analyzed	Kendall's Tau	p-value	Trend
Annual mean daily discharge	1931–95, 2002–9	-0.07	0.40	not significant
Annual 1-day minimum discharge	1931–95, 2002–9	0.14	0.08	not significant
Annual 7-day minimum discharge	1931–95, 2002–9	0.12	0.13	not significant
Annual maximum daily discharge	1931–95, 2002–9	-0.19	<0.05	downward
Annual instantaneous peak discharge	1931–95, 2002–9	-0.22	<0.05	downward
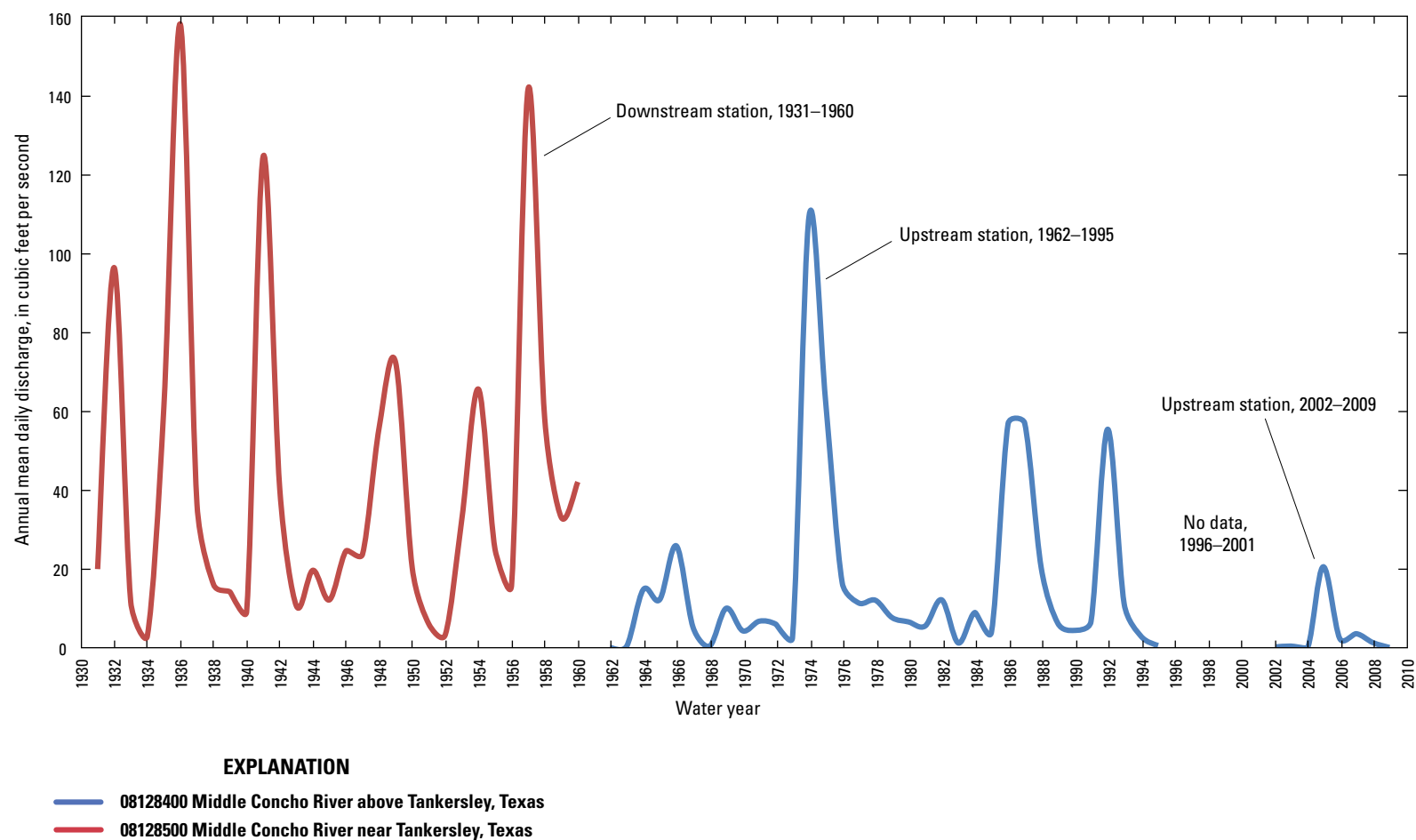
Figure 3. Annual mean daily discharge for U.S. Geological Survey streamflow-gaging stations 08128400 Middle Concho River above Tankersley, Texas, and 08128500 Middle Concho River near Tankersley, Tex.

Table 3.   Results of Kendall's Tau statistical test for detection of monotonic trends in select streamflow statistics for *A*, U.S. Geological Survey streamflow-gaging station 08128400 Middle Concho River above Tankersley, Texas, and *B*, U.S. Geological Survey streamflow-gaging station 08128500 Middle Concho River near Tankersley, Tex.

[USGS, U.S. Geological Survey; p-value, probability value; <, less than]

A, **USGS streamflow-gaging station 08128400 Middle Concho River above Tankersley, Tex.**

Streamflow statistic	Interval analyzed	Kendall's Tau	p-value	Trend
Annual mean daily discharge	1962–95, 2002–9	-0.17	0.10	not significant
Annual 1-day minimum discharge	1962–95, 2002–9	[1]0.75	0.2	not significant
Annual 7-day minimum discharge	1962–95, 2002–9	[1]0.67	0.1	not significant
Annual maximum daily discharge	1962–95, 2002–9	-0.25	<0.05	downward
Annual instantaneous peak discharge	1962–95, 2002–9	-0.24	<0.05	downward

B, **USGS streamflow-gaging station 08128500 Middle Concho River near Tankersley, Tex.**

Annual mean daily discharge	1931–60	0.10	0.44	not significant
Annual 1-day minimum discharge	1931–60	0.04	0.5	not significant
Annual 7-day minimum discharge	1931–60	0.04	0.5	not significant
Annual maximum daily discharge	1931–60	0.10	0.45	not significant
Annual instantaneous peak discharge	1931–60	0.07	0.57	not significant

[1]The numerical values for Kendall's Tau and attendant p-value are considered approximate and difficult to interpret because of substantial number of zero flow values for the annual 1-day and 7-day minimum discharges.

O.C. Fisher Lake was attained occurred in 1957 (U.S. Army Corps of Engineers, 2005). Water levels in Twin Buttes Reservoir did not reach the conservation pool elevation until 1974 (approximately 11 years after completion) (Zuniga, 1999). Controlled releases, or lack thereof, from the impoundments have significantly reduced flood peaks at the Concho River streamflow-gaging stations. The two Concho River streamflow-gaging stations were analyzed for their period of record (1916–2009) and for the period in which of all three impoundments provided regulation (1964–2009).

Concho River at San Angelo

The Concho River at San Angelo streamflow-gaging station is 0.4 mi downstream from the confluence of the North and South Concho Rivers in the eastern part of the city of San Angelo. The streamflow-gaging station is approximately 6 mi downstream from Lake Nasworthy, approximately 5 mi downstream from O.C. Fisher Lake, and approximately 60 mi upstream from the mouth (fig. 1). The annual mean discharge for the Concho River at San Angelo is shown in figure 5.

For the Concho River at San Angelo streamflow-gaging station, statistically significant downward trends for the period 1916–2009 were detected for all five streamflow

statistics (table 5). No statistically significant trends for the period 1964–2009 were detected except that annual maximum daily discharge has an upward trend (table 5). The downward trends detected for the period 1916–2009 are not unexpected because of three reservoirs impounding and controlling streamflow.

Concho River at Paint Rock, Texas

The Concho River at Paint Rock streamflow-gaging station is 20 mi upstream from the mouth of Concho River (fig. 1) and is approximately 42 mi downstream from San Angelo. The streamflow-gaging station represents the terminal streamflow data collection point in the Concho River Basin. The annual mean daily discharge for the Concho River at Paint Rock is shown in figure 6.

For the Concho River at Paint Rock streamflow-gaging station, statistically significant downward trends for the period 1916–2009 were detected for all five streamflow statistics (table 6). No statistically significant trends were detected for the period 1964–2009 for all five statistics (table 6). The downward trends detected for the period 1916–2009 are not unexpected because of three reservoirs impounding and controlling streamflow.
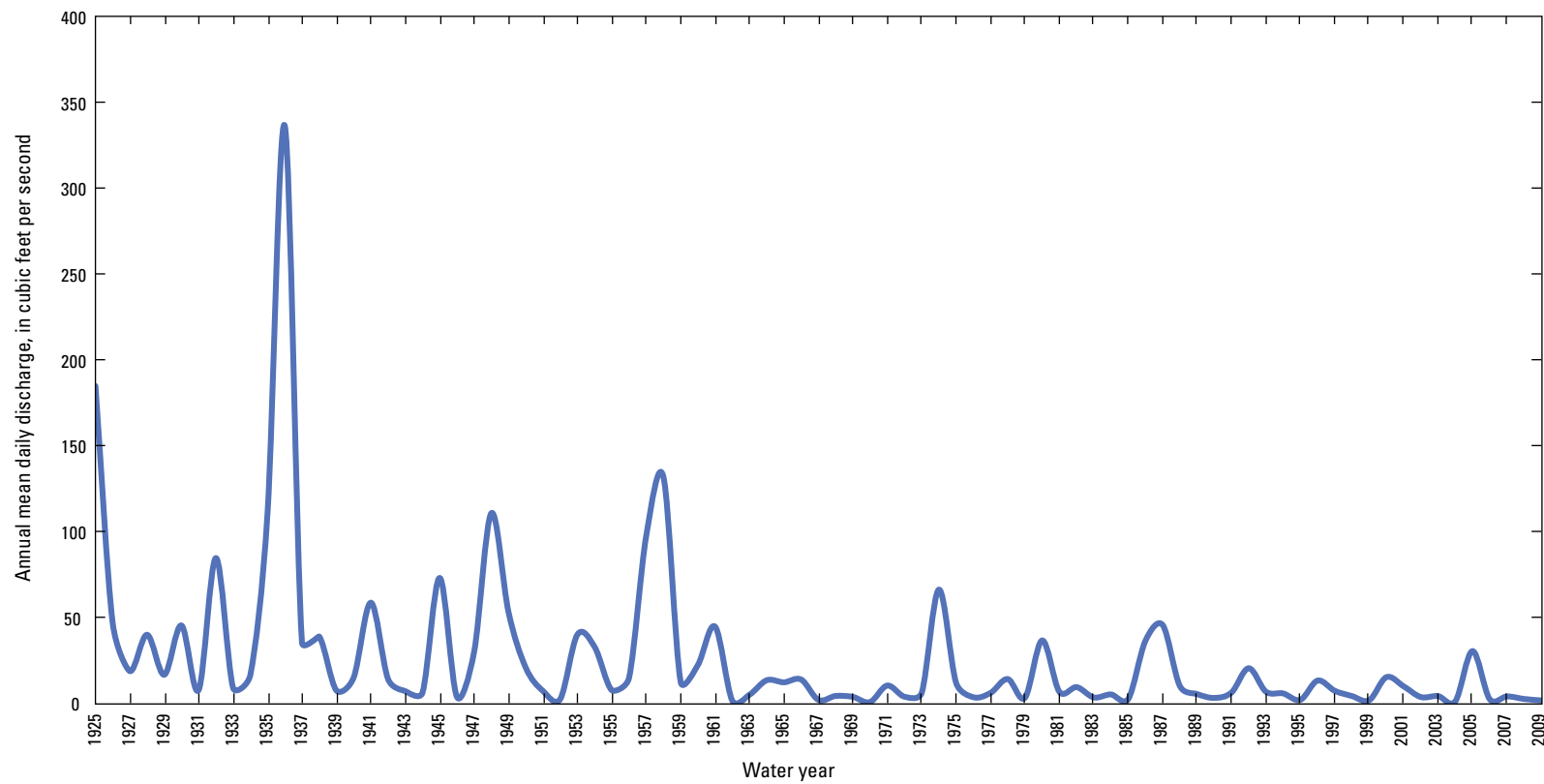
Figure 4. Annual mean daily discharge for U.S. Geological Survey streamflow-gaging station 08134000 North Concho River near Carlsbad, Texas.

Table 4.   Results of Kendall's Tau statistical test for detection of monotonic trends in select streamflow statistics for U.S. Geological Survey streamflow-gaging station 08134000 North Concho River near Carlsbad, Texas.

[p-value, probability value; <, less than]

| Streamflow statistic	Interval analyzed	Kendall's Tau	p-value	Trend
Annual mean daily discharge	1925–2009	-0.39	<0.05	downward
Annual 1-day minimum discharge	1925–2009	0.14	0.06	not significant
Annual 7-day minimum discharge	1925–2009	-0.17	<0.05	downward
Annual maximum daily discharge	1925–2009	-0.35	<0.05	downward
Annual instantaneous peak discharge	1925–2009	-0.36	<0.05	downward
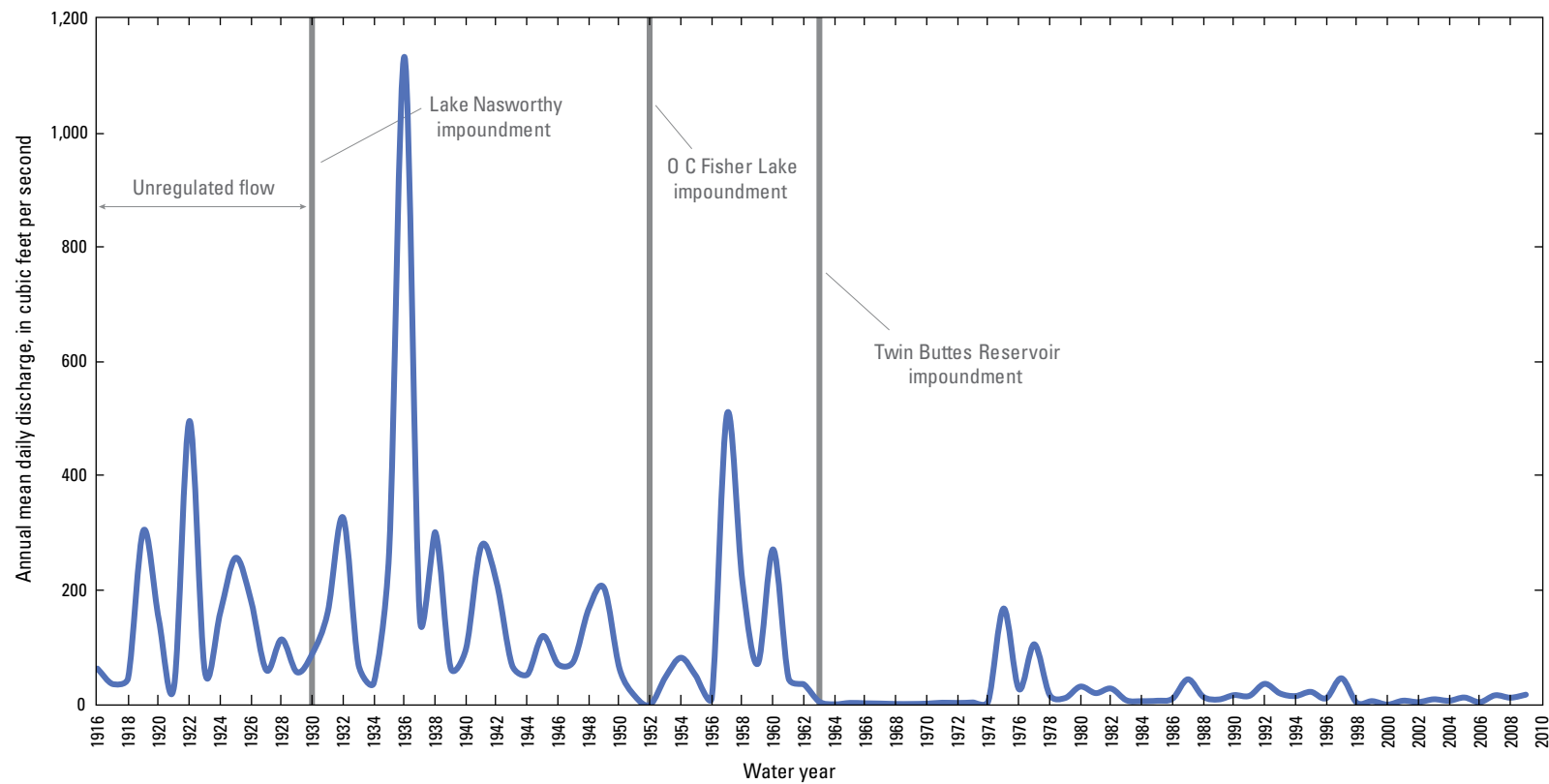
Figure 5.   Annual mean daily discharge for U.S. Geological Survey streamflow-gaging station 08136000 Concho River at San Angelo, Texas.

Table 5. Results of Kendall's Tau statistical test for detection of monotonic trends in select streamflow statistics for U.S. Geological Survey streamflow-gaging station 08136000 Concho River at San Angelo, Texas.

[p-value, probability value; <, less than]

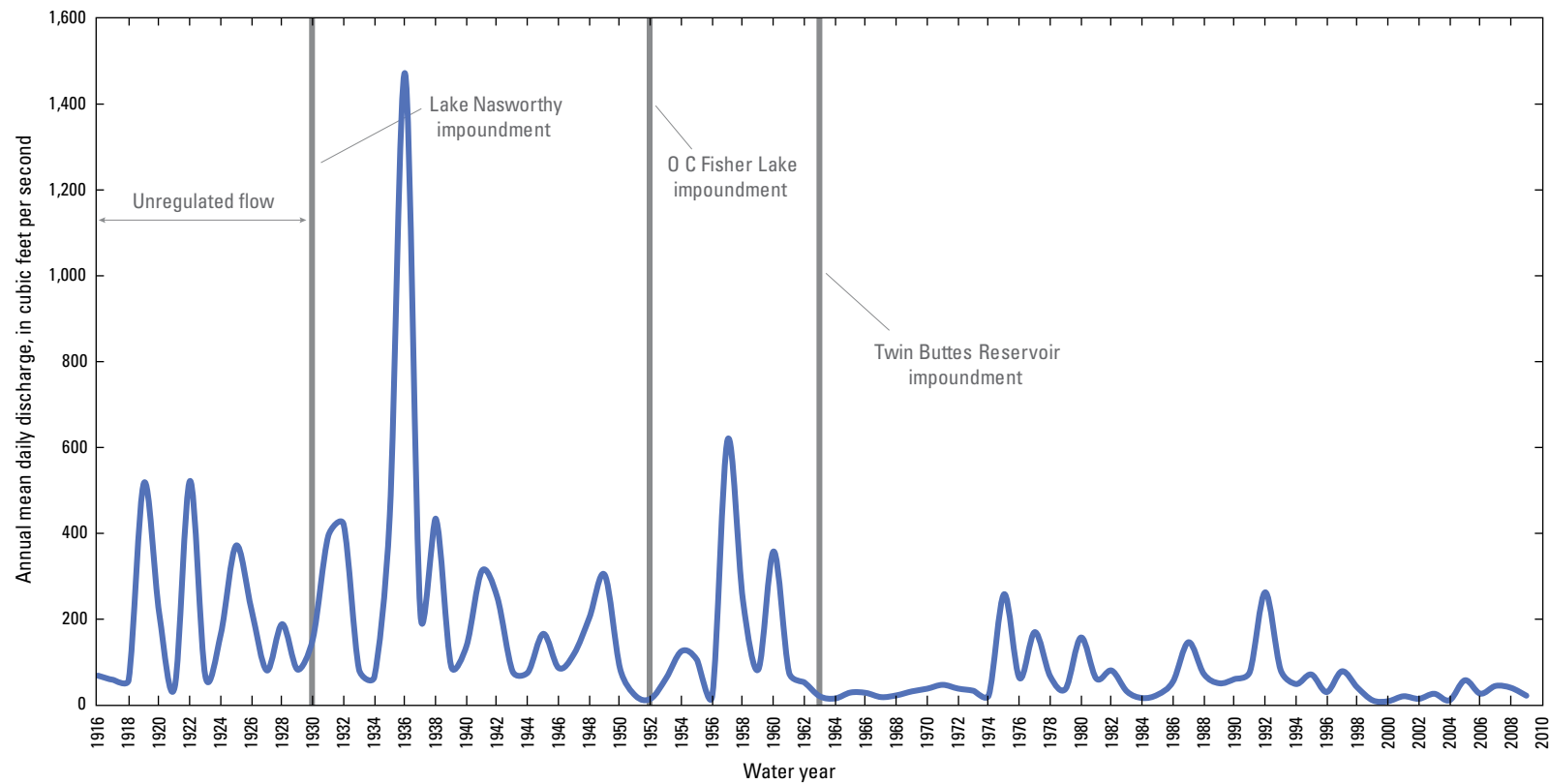| Streamflow statistic	Interval analyzed	Kendall's Tau	p-value	Trend
Annual mean daily discharge	1916–2009	-0.41	<0.05	downward
Annual 1-day minimum discharge	1916–2009	-0.35	<0.05	downward
Annual 7-day minimum discharge	1916–2009	-0.25	<0.05	downward
Annual maximum daily discharge	1916–2009	-0.37	<0.05	downward
Annual instantaneous peak discharge	1916–2009	-0.42	<0.05	downward
Annual mean daily discharge	1964–2009	0.20	0.05	not significant
Annual 1-day minimum discharge	1964–2009	-0.13	0.20	not significant
Annual 7-day minimum discharge	1964–2009	-0.10	0.34	not significant
Annual maximum daily discharge	1964–2009	0.24	<0.05	upward
Annual instantaneous peak discharge	1964–2009	0.06	0.54	not significant

Figure 6. Annual mean daily discharge for U.S. Geological Survey streamflow-gaging station 08136500 Concho River at Paint Rock, Texas.

Table 6. Results of Kendall's Tau statistical test for detection of monotonic trends in select streamflow statistics for U.S. Geological Survey streamflow-gaging station 08136500 Concho River at Paint Rock, Texas.

[p-value, probability value; <, less than]

Streamflow statistic	Interval analyzed	Kendall's Tau	p-value	Trend
Annual mean daily discharge	1916–2009	-0.37	<0.05	downward
Annual 1-day minimum discharge	1916–2009	0.14	<0.05	downward
Annual 7-day minimum discharge	1916–2009	0.14	<0.05	downward
Annual maximum daily discharge	1916–2009	-0.41	<0.05	downward
Annual instantaneous peak discharge	1916–2009	-0.43	<0.05	downward
Annual mean daily discharge	1964–2009	-0.03	0.77	not significant
Annual 1-day minimum discharge	1964–2009	-0.12	0.22	not significant
Annual 7-day minimum discharge	1964–2009	-0.07	0.45	not significant
Annual maximum daily discharge	1964–2009	-0.03	0.75	not significant
Annual instantaneous peak discharge	1964–2009	-0.06	0.58	not significant

Summary

The Concho River Basin is part of the upper Colorado River Basin in west-central Texas. Streamflow (surface water) supplies some irrigation water and the majority of the public water supply. Public water supply historically has been provided by streamflow stored in O.H. Ivie and Twin Buttes Reservoirs, Lakes Nasworthy and E.V. Spence, and O.C. Fisher Lake. Because the Concho River Basin provides water stored for public water supply for most residents in the study area, trends in streamflow in the Concho River Basin are of interest to water managers in this part of west Texas. Accordingly, the U.S. Geological Survey (USGS), in cooperation with the Texas Water Development Board, evaluated trends during 1916–2009 in selected streamflow statistics for the Concho River Basin. Monotonic trends in streamflow were evaluated using a nonparametric test (Kendall's Tau) to evaluate whether statistically significant changes in the selected streamflow statistics have occurred over time within the Concho River Basin at six USGS streamflow-gaging stations: 08128000 South Concho River at Christoval, Tex.; 08128400 Middle Concho River above Tankersley, Tex.; 08128500 Middle Concho River near Tankersley, Tex.; 08134000 North Concho River near Carlsbad, Tex.; 08136000 Concho River at San Angelo, Tex.; and 08136500 Concho River at Paint Rock, Tex. Two types of USGS streamflow data comprise the foundational data for this report: (1) daily mean discharge (daily discharge) and (2) annual instantaneous peak discharge. Trends are reported for the following streamflow statistics: (1) annual mean daily discharge, (2) annual 1-day minimum discharge, (3) annual 7-day minimum discharge, (4) annual maximum daily discharge, and (5) annual instantaneous peak discharge.

The USGS has collected streamflow data in the Concho River Basin since October 1915. Since then and at various time intervals, as many as 24 daily surface-water monitoring stations (19 streamflow-gaging stations, 3 lake or reservoir stations, and 2 canal stations) have been used to collect data in the basin through the present (2012). Trend analyses used in this study are based on application of the nonparametric Kendall's Tau statistical test to detect monotonic trends in streamflow with time. A positive Tau indicates an upward monotonic streamflow trend; conversely, a negative Tau indicates a downward monotonic streamflow trend. The p-value of Kendall's Tau is a measure of the statistical significance of the trend. For this study, a p-value of less than 0.05 indicates a significant trend, whereas a p-value of 0.05 or greater indicates no significant trend.

For USGS streamflow-gaging station 08128000 South Concho River at Christoval, Tex., statistically significant downward trends in streamflow for the combined period 1931–95 and 2002–9 were detected for annual maximum daily discharge and annual instantaneous peak discharge. For USGS streamflow-gaging station 08128400 Middle Concho River above Tankersley, Tex., statistically significant downward trends in streamflow for the combined period 1962–95 and 2002–9 were detected for annual maximum daily discharge and annual instantaneous peak discharge. For USGS streamflow-gaging station 08128500 Middle Concho River near Tankersley, Tex., no statistically significant trends were detected for all five streamflow statistics for the period
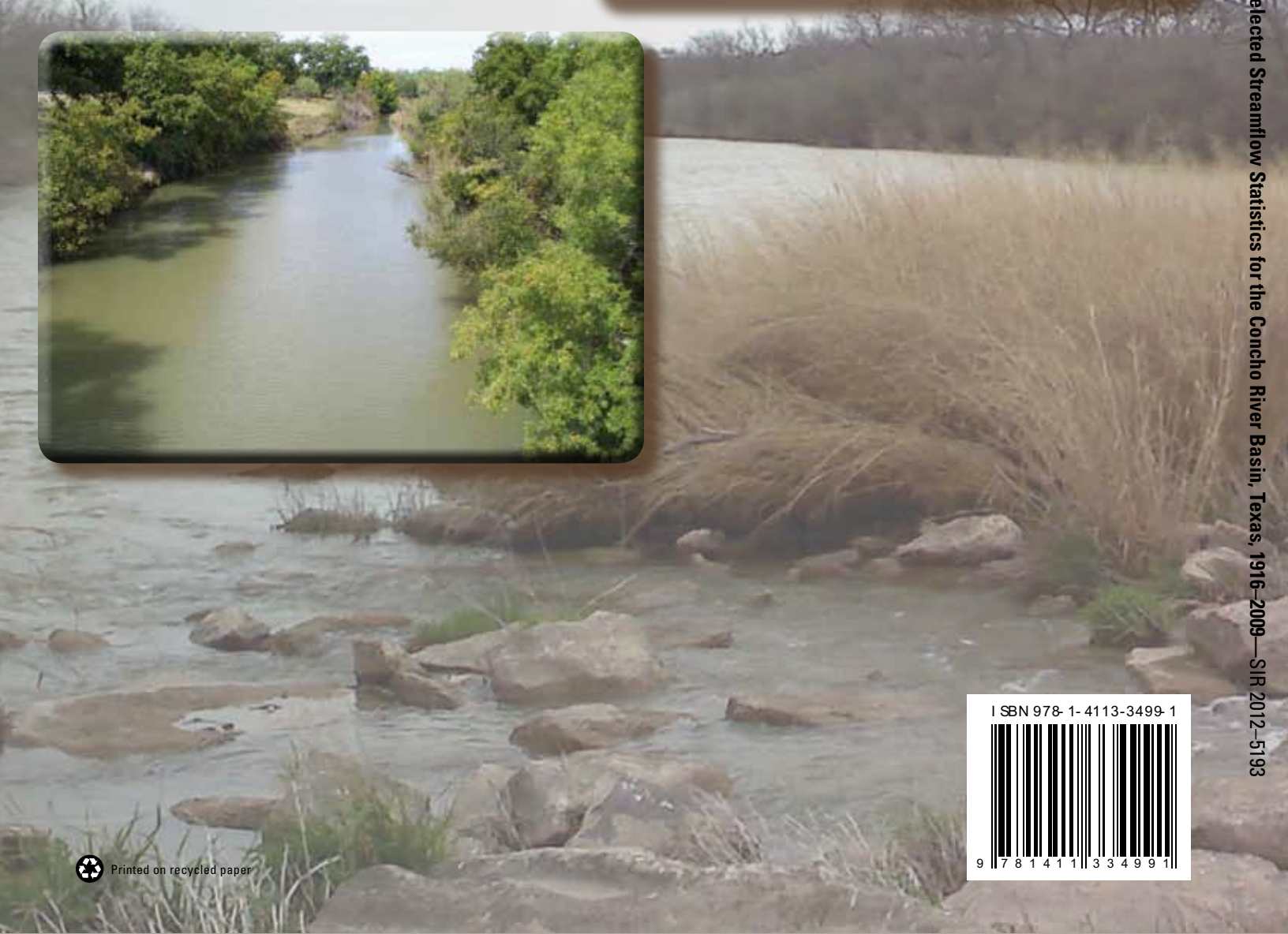
1931–60. For USGS streamflow-gaging station 08134000 North Concho River near Carlsbad, Tex., statistically significant downward trends for the period 1925–2009 were detected for annual mean daily discharge, annual 7-day minimum discharge, annual maximum daily discharge, and annual instantaneous peak discharge. For USGS streamflow-gaging station 08136000 Concho River at San Angelo, Tex., statistically significant downward trends for the period 1916–2009 were detected for all five streamflow statistics. No statistically significant trends for the period 1964–2009 were detected except that annual maximum daily discharge has an upward trend. For USGS streamflow-gaging station 08136500 Concho River at Paint Rock, Tex., statistically significant downward trends for the period 1916–2009 were detected for all five streamflow statistics. No statistically significant trends for the period 1964–2009 were detected. The downward trends detected for the period 1916–2009 are not unexpected because of three reservoirs impounding and controlling streamflow.

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