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Methods for Estimating Low-Flow Frequency Statistics, Mean Monthly and Annual Flow, and Flow-Duration Curves for Ungaged Locations in Kansas

Scientific Investigations Report 2021–5100

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

Cover: Photograph showing 1.02 cubic feet per second (ft^3/s) over riffle control at Saline River near Wakeeny, Kansas (U.S. Geological Survey [USGS] station 06866900), taken August 25, 2021, by Tyler Saryerwinnie, USGS.

Back cover: Left: Photograph showing 0.64 ft^3/s over riffle control at Kill Creek at 95th Street near De Soto, Kans. (USGS station 06892360), taken September 21, 2018, by Sami Milk, USGS.

Top, right: Photograph showing 0.85 ft^3/s over riffle control at Stranger Creek at Easton, Kans. (USGS station 06891850), taken October 1, 2018, by Bradley Lukasz, USGS.

Bottom right: Photograph showing observed zero flow at South Fork Republican River near Colorado-Kansas State Line (USGS station 06827000), taken September 7, 2021, by Lori Marintzer, USGS.

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
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)

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

Elevation, as used in this report, refers to distance above the vertical datum.

Supplemental Information

A water year begins on October 1 of the previous calendar year and ends on September 30 of the year of interest; thus, the water year ending September 30, 2011, is called the “2011 water year.”

A climatic year begins on April 1 and ends on March 31 of the following year. A climatic year is designated by the calendar year during which most of the 12 months occur.

Abbreviations

BFI	base-flow index
CONTDA	contributing drainage area
DAR	drainage-area ratio
GIS	geographic information system
MLE	maximum-likelihood estimation
NWIS	National Water Information System
p	probability
PRECIPfull	mean annual precipitation for 1895–2017
RMSE	root mean square error
SE	standard error
USGS	U.S. Geological Survey
7Q5	annual minimum 7-day mean low flow with 5-year recurrence interval
7Q10	annual minimum 7-day mean flow with 10-year recurrence interval

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By Bradley S. Lukasz

Abstract

Knowledge of the magnitude, frequency, and duration of low flows is critical for water-supply management; reservoir design; waste-load allocation; and the preservation of water quality and quantity for irrigation, recreation, and ecological conservation purposes. The U.S. Geological Survey (USGS), in cooperation with the Kansas Water Office, completed a statewide study to develop regression equations for selected low-flow frequency and flow-duration statistics for ungaged streams in Kansas.

The low-flow statistics included the annual and monthly 1-, 7-, and 30-day mean low flow for a recurrence interval of 10 years; flow-duration exceedance probabilities of 0.01, 0.1, 2, 5, 10, 25, 50, 75, 90, 95, 99, 99.9, and 99.99 percent; and mean annual flow. Data used in this analysis were from 254 USGS continuous-record streamgages using data through March 31, 2017, for the regression equation analysis and using data through September 30, 2017, for the flow-duration curve analysis. The streamgages used in the regression analysis of this report are in Kansas and 50 miles beyond the borders of the State. A trend analysis was done because trends can introduce bias into results. Some trends were detected; however, no streamgage was omitted from the analysis because of the presence of a trend. Geographic-information-system software was used to compute 13 basin characteristics for each streamgage.

The State of Kansas was divided into two study areas for the regional regression analysis. Logistic and left-censored regression techniques were used to develop the equations because of the presence of zero flows in the datasets. A collection of performance metrics is provided to estimate the accuracy of each equation. These equations are only applicable to streams in Kansas that are not substantially affected by diversion, regulation, or urbanization. Basin characteristics of these ungaged locations also need to be within the range of the basin characteristics used to develop these equations.

The drainage-area ratio (DAR) method was tested against the regional regression equations using 19 pairs of streamgages. The 7-day annual mean low-flow statistic was estimated using the regression equations and the DAR method. The absolute difference, in percent, was calculated using the observed 7-day annual mean low flow for both methods. The results of the Wilcoxon signed-rank test indicated that the difference between the absolute differences, in percent, for the groups tested was not statistically significant. Previous USGS studies state it is preferable to use the DAR method when the ratio is between 0.5 and 1.5. Some studies offer no scientific basis for these guidelines, whereas other studies have developed different guidelines. In Kansas, the DAR method produced the smallest absolute difference, in percent, when the ratio of drainage areas was between 0.5 and 1.5. The results of this study indicate that the DAR method is appropriate for use in Kansas when estimating streamflow at an ungaged location if there is a nearby streamgage on the same river or stream where the DAR is between 0.5 and 1.5 and the low-flow statistic at the nearby streamgage is not zero.

The regression equations developed in this report will be incorporated into the USGS StreamStats web-based geographic-information-system tool. This will allow users to click on any ungaged location within StreamStats and compute estimates of the selected low-flow frequency and flow-duration statistics. The low-flow frequency and flow-duration statistics for streamgages in Kansas also will be available in StreamStats.

Introduction

Knowledge of the magnitude, frequency, and duration of low flows is critical for water-supply management; reservoir design; waste-load allocation; and the preservation of water quality and quantity for irrigation, recreation, and ecological conservation purposes. Flow-duration curves and low-flow statistics, including *n*-day flow frequency, are used by Federal, State, and local entities for setting regulatory standards and establishing water-quality and water-supply management goals, particularly during dry periods when demand often exceeds the supply of water (Ries, 2006). Historically, the Kansas Department of Health and Environment has used the annual minimum 7-day mean streamflow with a 10-year recurrence interval statistic (often referred to as “7Q10”) to determine critical flow levels to maintain established water-quality criteria for Kansas streams. The U.S. Geological Survey (USGS) operates a monitoring network of streamgages in Kansas and throughout the Nation where water-resources information, collected in near-real time, is used for computing long-term (30 or more years) low-flow statistics and developing flow-duration curves. However, the USGS cannot operate streamgages at every location, so methods are needed to estimate low-flow frequency statistics and flow-duration curves at ungaged stream locations (Eash and Barnes, 2017; Gotvald, 2017; Painter and others, 2017).

Determination of low-flow statistics, mean annual and monthly flows, and flow durations for ungaged locations, using various statistical methods, is often needed to provide the necessary information to effectively manage water resources throughout the State. Thus, the USGS, in cooperation with the Kansas Water Office, completed a statewide study to develop regression equations for selected low-flow frequency and flow-duration statistics for ungaged streams in Kansas. Regionalization, a commonly used regression technique, includes the development of regression equations for a hydrologic region to estimate flow statistics at ungaged locations based on the relation of computed statistics at gaged locations to various physical and climate characteristics of that region. Alternative methods, including the drainage-area ratio (DAR) method, have been used to estimate flow statistics at ungaged locations on gaged streams for regulated and unregulated flows (Perry and others, 2004a). Other uses for low-flow frequency statistics are establishing minimum flow requirements for streams and rivers, permitting for wastewater discharges (Gotvald, 2017),making management and design decisions for hydroelectric facilities, fish passage (Williams-Sether and Gross, 2016), irrigation; recreation, and wildlife conservation (Ziegeweid and others, 2015).

Purpose and Scope

The purpose of this report is to present the results of the study to update low-flow frequency statistics and flow-duration curves for gaged locations in Kansas with data available through 2017 and regression equations used to estimate low-flow frequency statistics, mean annual flow, and flow-duration curves for ungaged locations in Kansas.

Regression equations will be incorporated into the StreamStats program, a web-based tool developed by the USGS (Ries and others, 2017) to automatically compute various streamflow statistics at user-specified locations on Kansas streams. The scope of this report includes stream locations that are not substantially affected by regulation, diversion, or urbanization. Streamflow statistics at streamgages affected by the previously mentioned activities were computed for completeness. Nationally, the methods and results presented in this report offer guidance and perspective for future studies concerned with estimating low-flow statistics at ungaged locations.

Description of Study Area

The study area (fig. 1) consists of the State of Kansas and neighboring areas within a 50-mile (mi) buffer of Kansas in the bordering States of Colorado, Missouri, Nebraska, and Oklahoma. The physical and climatic characteristics differ substantially across the study area, which results in a varied hydrologic streamflow response (Painter and others, 2017). Rivers, streams, and creeks in Kansas generally flow from west to east, following the topography of the landscape (Painter and others, 2017).

Land-surface elevations within Kansas range from about 700 feet (ft) above the North American Vertical Datum of 1988 at the Oklahoma State line in southeastern Kansas to about 4,135 ft above the North American Vertical Datum of 1988 near the Colorado border in western Kansas—a difference of about 3,435 ft (Rasmussen and Perry, 2000; Perry and others, 2004a, b; U.S. Geological Survey, 2019; fig. 2). Mean basin slope for the 254 streamgages in Kansas and the surrounding States used in the regression analysis is about 3.8 percent (fig. 3; U.S. Geological Survey, 2010).

Land use in Kansas is mainly agricultural, with pasture plus grassland (48.9 percent) and cropland (43.2 percent) accounting for much of the land use in the State (Fry and others, 2011; Painter and others, 2017; fig. 4). Forest cover and urban land use account for about 3.8 and 1.5 percent of the State, respectively (Fry and others, 2011; Painter and others, 2017).

A large precipitation gradient, from west to east, is typical in Kansas, as well as other regions in the central United States (Goodin and others, 2004; Painter and others, 2017). This mean annual precipitation gradient in Kansas is shown in figure 5. Mean annual precipitation ranges from about 18 inches (in.) in the far west to more than 44 in. in the southeastern corner of the State. The Rocky Mountains (not shown) cause a rain shadow effect, which can yield semidry to dry conditions in western Kansas, whereas moist air from the Gulf of Mexico, predominantly in the spring and summer months, produces more precipitation in the eastern part of the State (Goodin and others, 2004; Painter and others, 2017). Irrigation associated with groundwater withdrawals is common in the area west of the 28-in. precipitation contour line (fig. 5), which approximately splits the State in half (Painter and others, 2017). These withdrawals are substantial and are likely responsible for reduced flow conditions in the western part of Kansas (Juracek and Eng, 2017).

The west-to-east gradient in elevation and precipitation characteristics across the State also results in a west-to-east increase in mean annual surface-water runoff across Kansas (Painter and others, 2017). Mean annual runoff ranges from about 0.2 in. near the western Kansas border to around 8 in. near the eastern Kansas border (Gebert and others, 1987; Painter and others, 2017). Flows at streamgages in central and eastern Kansas have a typical temporal hydrologic distribution

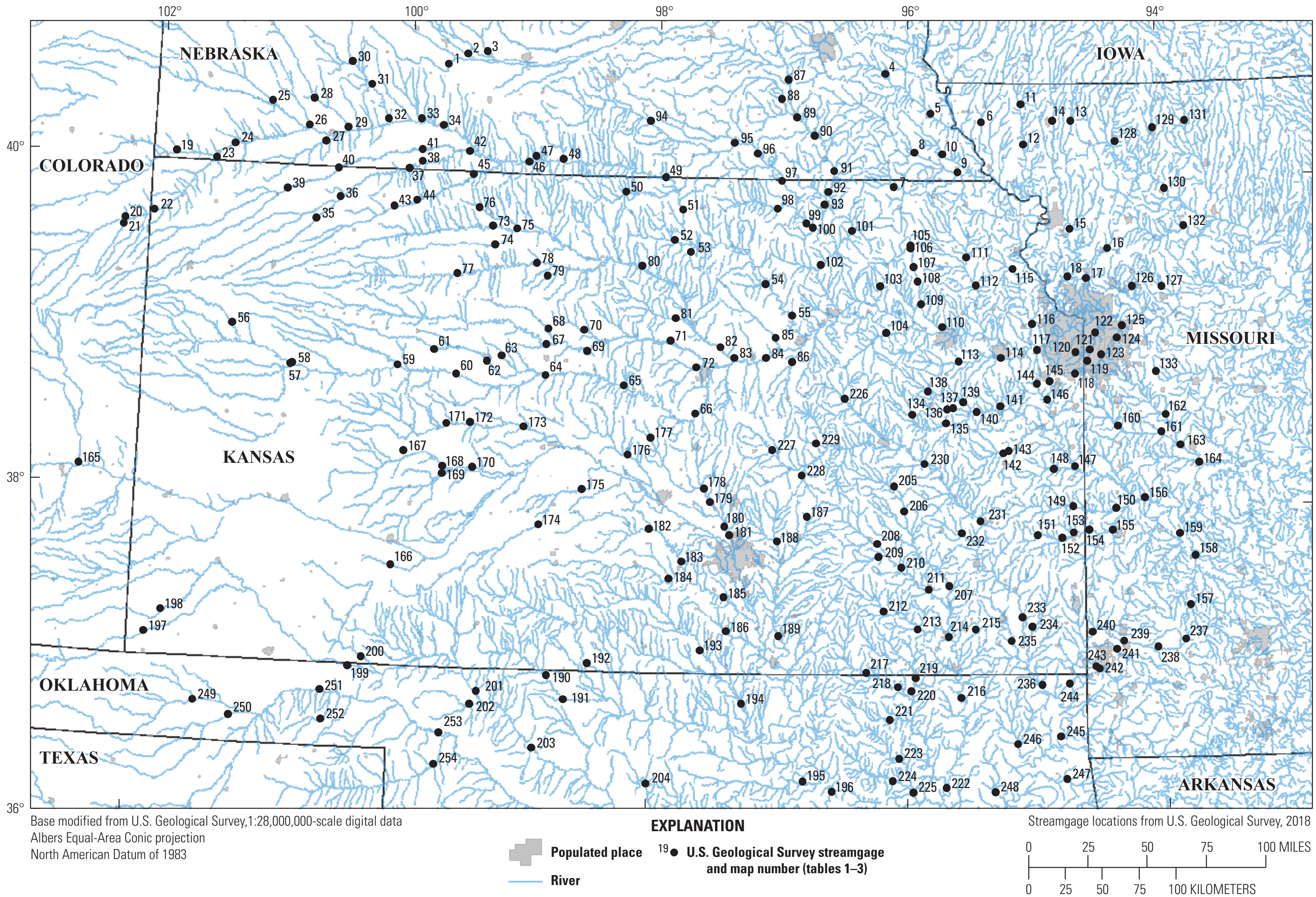


Figure 1. Locations of U.S. Geological Survey streamgages in Kansas and parts of surrounding States that were used to develop regression equations.

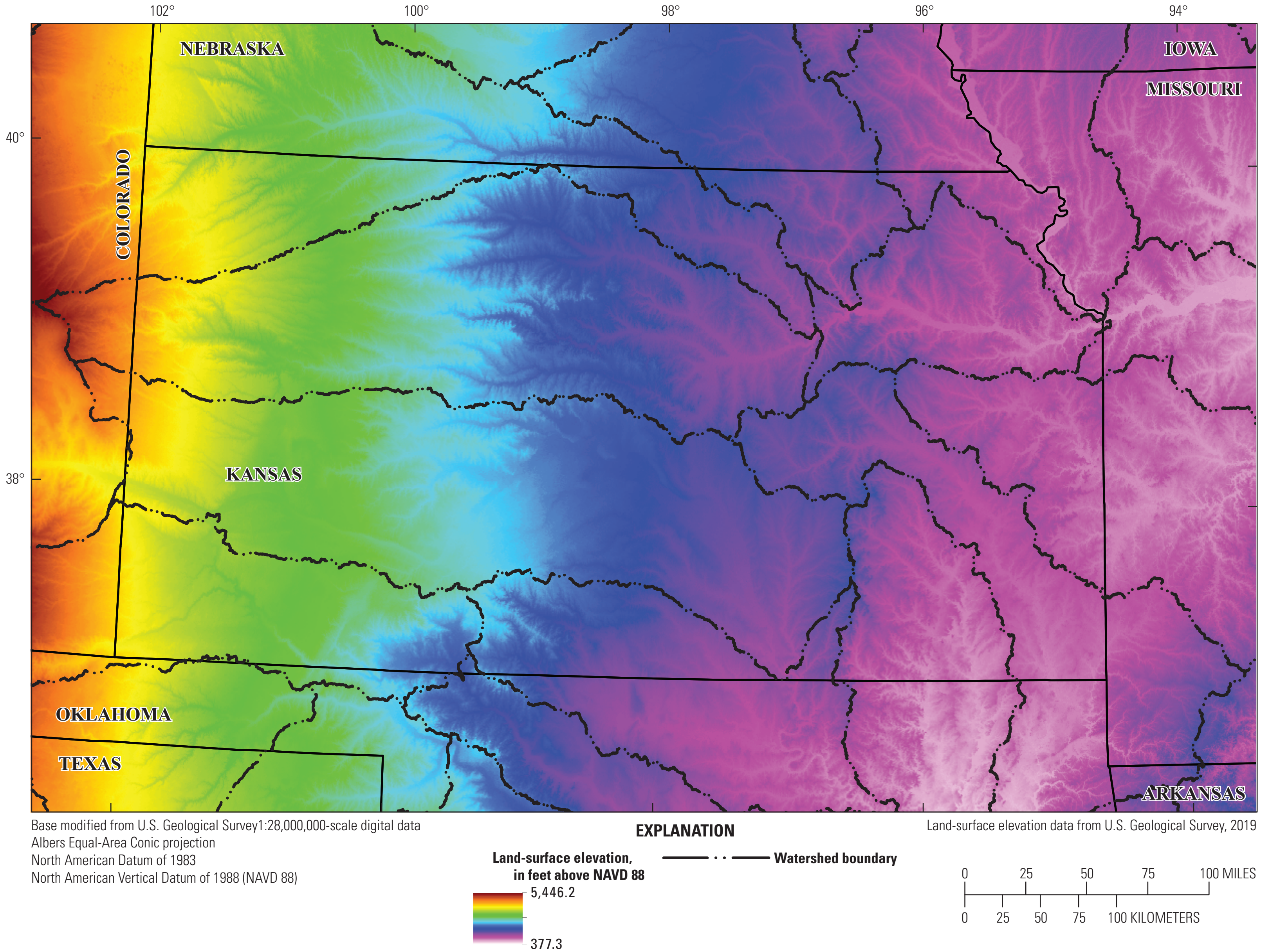


Figure 2. Land-surface elevation in Kansas and parts of surrounding States.

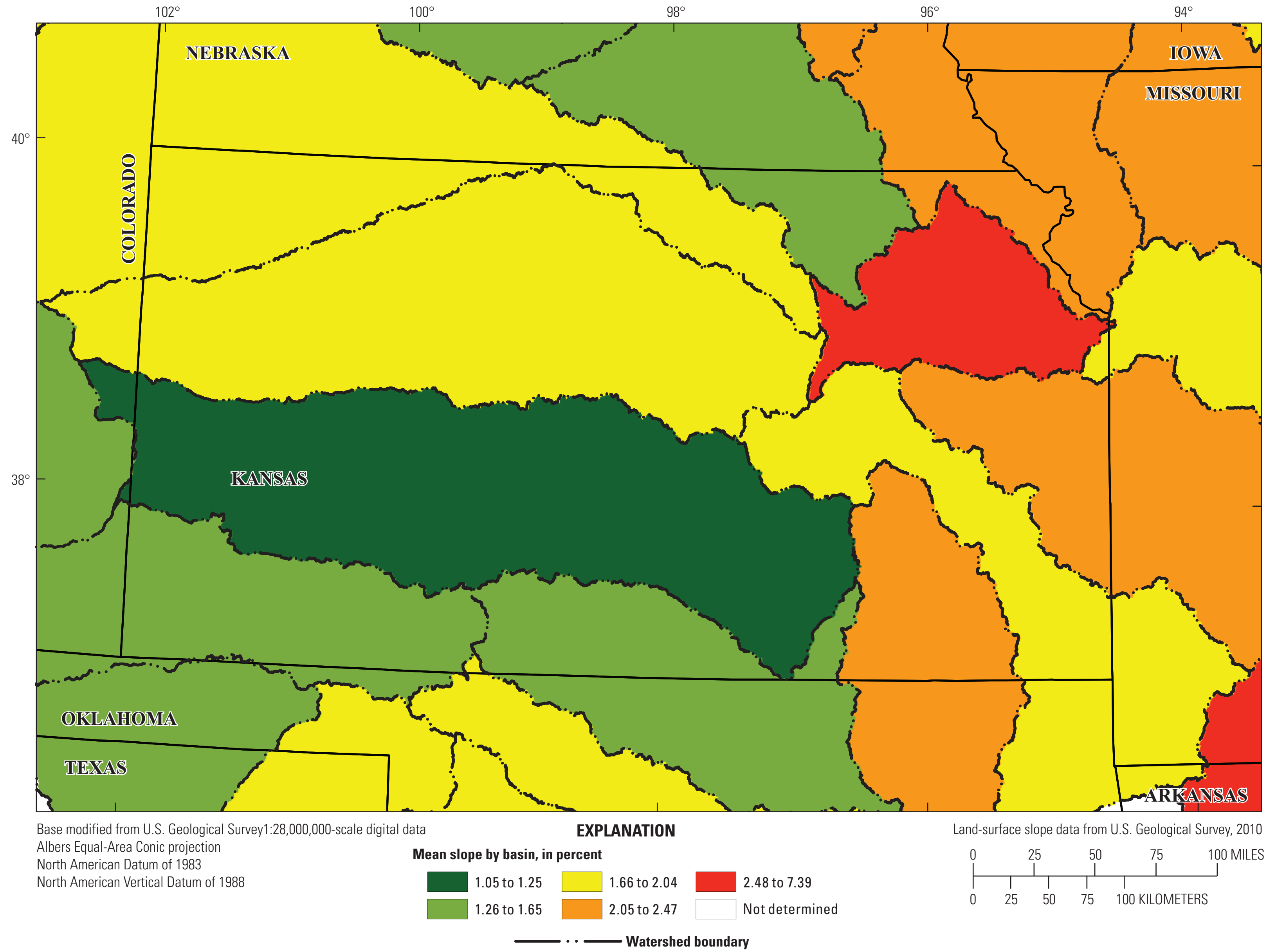


Figure 3. Land-surface slope in Kansas and parts of surrounding States.

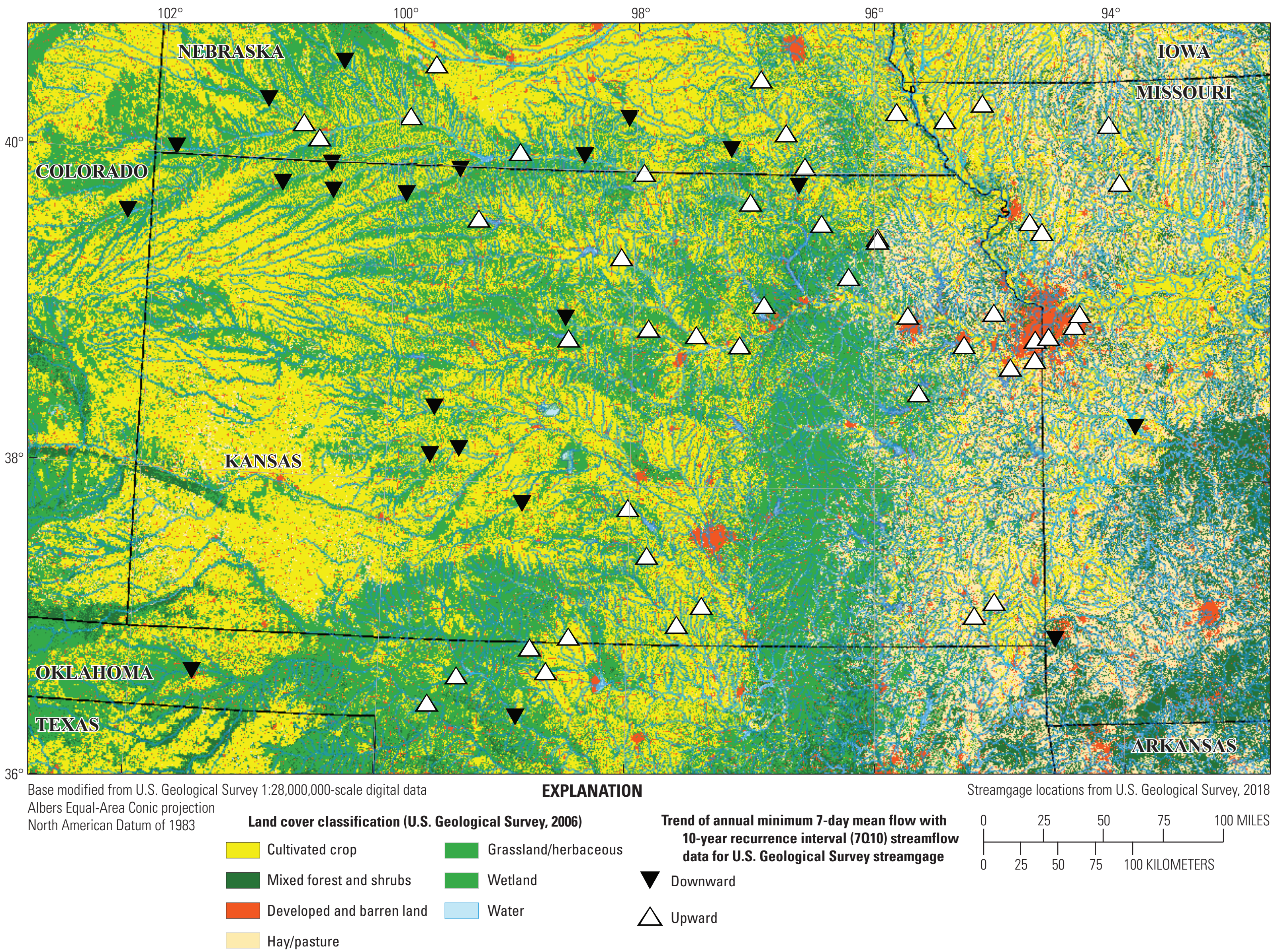
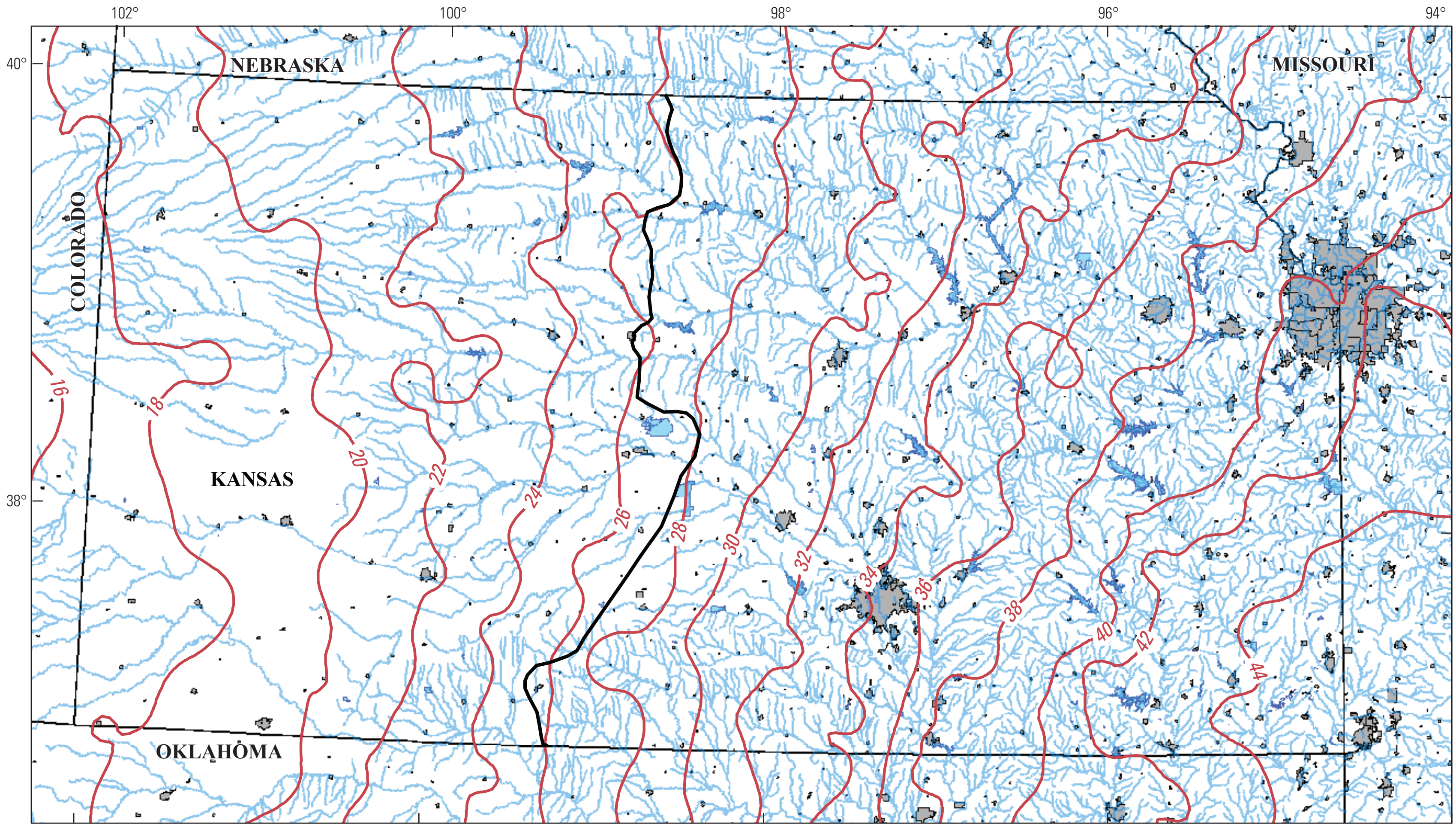


Figure 4. Land use in Kansas and parts of surrounding States with annual minimum 7-day streamflow trends.



Base modified from U.S. Geological Survey 1:28,000,000-scale digital data
Albers Equal-Area Conic projection
North American Datum of 1983

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https://prism.oregonstate.edu
Map created March 9, 2020

EXPLANATION

U.S. Army Corps of Engineers reservoir

Populated place

River

Division of hydrologic regions (Painter and others, 2017)

16 Line of equal mean annual precipitation (1981–2010)—Interval 2 inches

0 25 50 75 100 MILES

0 25 50 75 100 KILOMETERS

Figure 5. Distribution of mean annual precipitation (1981–2010) in Kansas and parts of surrounding States and the hydrologic region boundary used in this study.

with greater mean monthly streamflows in the spring and early summer months (Moody and others, 1986; Painter and others, 2017).

Because of the west-to-east gradients in elevation and precipitation, land cover differences, and the use of different hydrologic regions in Painter and others (2017), this report divides Kansas into two hydrologic regions. Region 1 encompasses the eastern part of the State, whereas region 2 consists of the western part of Kansas. The boundary of these regions is near the 26-in. and 28-in. precipitation contour lines, shown in figure 5 (Painter and others, 2017). As mentioned before, irrigation associated with groundwater withdrawals is common in the area west of this boundary, and it is likely that these withdrawals affect surface water (Juracek and Eng, 2017).

Previous Studies in Kansas

Several low-flow and flow-duration studies have been completed for Kansas. An investigation by Furness (1959) developed a method for estimating flow-duration curves for ungaged locations in Kansas for the period of 1921–56 (Perry and others, 2004b). Jordan (1983) revised the maps developed by Furness by including additional streamgages and data for the period of 1957–76 (Perry and others, 2004b). Two studies completed by Studley (2000, 2001) assessed the use of the Furness method to estimate flow-duration curves for ungaged stream locations in Kansas using information from nearby streamgages. The findings of the studies by Studley concluded that the Furness method was a beneficial tool for estimating flow-duration curves at ungaged locations with small drainage areas, less than 100 square miles (mi^2) (Perry and others, 2004b). Two studies by Perry and others (2004a, b) estimated median flows, flow-duration curves, and peak streamflow for streamgages on the 1999 Kansas Surface Water Register. The Perry and others (2004a) report provided regression equations for mean annual flow; 10-, 25-, 50-, 75-, and 90-percent flow durations; and 2-, 5-, 10-, 25-, 50-, and 100-year (50-, 20-, 10-, 4-, 2-, and 1-percent annual exceedance intervals) peak streamflow flows for drainage areas ranging from 0.17 to 9,100 mi^2.

Methods for Streamgage Selection

The data for the initial dataset used for regression equation development in this report were compiled from a total of 351 active and inactive continuous-record streamgages, of which 212 were in Kansas and 139 were from a 50-mi buffer of the neighboring States of Nebraska, Missouri, Oklahoma, and Colorado (fig. 1 and tables 1–3). Streamgages with at least 10 years of record, or 3,650 daily values of discharge, initially were selected for evaluation in this study. Streamgages from neighboring States were used to improve the calculation of selected low-flow frequency statistics for streamgages near the Kansas border. The annual period used in this report for the calculation of annual low-flow frequency statistics was defined as the climatic year (April 1 through March 31). The climatic year is used for low-flow frequency studies because low-flow events in Kansas normally occur during the late summer through winter months. Daily mean streamflow data collected through climatic year 2017 (through March 31, 2017) were used for the regression equation analysis. Daily mean streamflow data collected through water year 2017 (through September 30, 2017) were used for the flow-duration curve analysis in this report. A water year begins on October 1 of the previous calendar year and ends on September 30 of the year of interest. The data for the streamgages in this study were retrieved from the USGS National Water Information System (NWIS) database, which is available at https://doi.org/10.5066/F7P55KJN (U.S. Geological Survey, 2018). These data were used to compute selected low-flow frequency and flow-duration statistics.

Peak streamflow data were retrieved from the USGS NWIS database and reviewed to exclude data affected by diversions, regulations, and urbanization. This was done so the computations of selected low-flow and flow-duration statistics would not be biased. The criteria for including a streamgage for the regression equations in this study were location within the study area and a minimum of 10 years of daily streamflow data that were not affected by regulation, diversion, or urbanization. Streamgages with long periods of record sometimes have parts of record that are marked as being affected by regulation, diversion, or urbanization and other parts that are not. If the earlier part of the record period had at least 10 years of daily streamflow data that were not marked as being affected by regulation, diversion, or urbanization, then that part of the record was included in this study. Information about a streamgage being affected by regulation, diversion, or urbanization may be limited or unavailable. It is possible that some data that were affected by one of those activities could have been included in the dataset for this report; however, the overall effect on the computation of the low-flow and flow-duration curve statistics and the development of regression equations is believed to be minimal. Streamgages that lacked basin characteristic data were removed from the regression equation analysis. Streamgages that contained basin characteristic data that were calculated to be zero also were removed from the regression analysis. These streamgages were removed because of the complications that occur when log transforming zero values. Four streamgages were removed from the regression analysis because the base-flow index (BFI) basin characteristic was calculated to be zero, and three streamgages were removed because the reservoir storage basin characteristic was calculated to be zero.

Streamflow data from streamgages on the Kansas and Arkansas Rivers were not included in the development of the regression equations in this study. The streamflow for the Kansas River streamgages is heavily regulated by upstream reservoirs (fig. 6 and table 4). Factors such as local changes in land and water use, and groundwater withdrawals, are responsible for streamflow alteration along the western reaches

Table 1. Active and inactive U.S. Geological Survey streamgages used for regression analysis within the study area (map numbers 1–85). U.S. Geological Survey streamgage information is from U.S. Geological Survey (2018).

[no., number; USGS, U.S. Geological Survey; NE, Nebraska; MO, Missouri; C, Creek; NR, near; KS, Kansas; CO, Colorado; SF, South Fork; R, River; ST, State; AB, above; NF, North Fork; BL, below; RE, Reservoir]

Map no. (fig. 1)	USGS station number	USGS station name	Latitude	Longitude	No. annual series	Hydrologic region
1	06767500	PLUM CREEK NEAR SMITHFIELD, NE	40.64138889	−99.71055556	55	West
2	06768020	SPRING CREEK NEAR OVERTON, NE	40.70723067	−99.5598289	21	West
3	06769525	ELM CREEK NEAR ELM CREEK, NE	40.7288988	−99.3989885	21	West
4	06810500	LITTLE NEMAHA RIVER NEAR SYRACUSE, NE	40.6325	−96.179444	17	East
5	06811500	LITTLE NEMAHA RIVER AT AUBURN, NE	40.39277778	−95.8127778	67	East
6	06813000	TARKIO RIVER AT FAIRFAX, MO	40.3391833	−95.4059056	95	East
7	06814000	TURKEY C NR SENECA, KS	39.9477773	−96.1086149	68	East
8	06814500	NORTH FORK BIG NEMAHA RIVER AT HUMBOLDT, NE	40.15694485	−95.9447206	64	East
9	06815000	BIG NEMAHA RIVER AT FALLS CITY, NE	40.0355577	−95.5960957	73	East
10	06815500	MUDDY CREEK AT VERDON, NE	40.14555556	−95.72027778	19	East
11	06817500	NODAWAY RIVER NEAR BURLINGTON JUNCTION, MO	40.44488056	−95.0888972	95	East
12	06817700	NODAWAY RIVER NEAR GRAHAM, MO	40.2024722	−95.0695556	34	East
13	06818900	PLATTE RIVER AT RAVENWOOD, MO	40.3449905	−94.6863546	12	East
14	06819500	ONE HUNDRED AND TWO RIVER AT MARYVILLE, MO	40.3455	−94.8321944	84	East
15	06820500	PLATTE RIVER NEAR AGENCY, MO	39.68802778	−94.7026111	92	East
16	06821080	LITTLE PLATTE RIVER NEAR PLATTS-BURG, MO	39.56777778	−94.407	17	East
17	06821150	LITTLE PLATTE RIVER AT SMITHVILLE, MO	39.38805536	−94.5791215	10	East
18	06821190	PLATTE RIVER AT SHARPS STATION, MO	39.4009722	−94.7268333	38	East
19	06823500	BUFFALO CREEK NEAR HAIGLER, NE	40.03944444	−101.8666667	76	West
20	06825000	SOUTH FORK REPUBLICAN RIVER NEAR IDALIA, CO	39.6163822	−102.2426918	20	West
21	06825500	LANDSMAN CREEK NEAR HALE, CO	39.575549	−102.2521363	25	West
22	06827000	SF REPUBLICAN R NR CO-KS ST LINE, KS	39.67193827	−102.0135164	71	West
23	06827500	SOUTH FORK REPUBLICAN RIVER NEAR BENKELMAN, NE	40.01027778	−101.5419444	80	West

Table 1. Active and inactive U.S. Geological Survey streamgages used for regression analysis within the study area (map numbers 1–85). U.S. Geological Survey streamgage information is from U.S. Geological Survey (2018).—Continued

[no., number; USGS, U.S. Geological Survey; NE, Nebraska; MO, Missouri; C, Creek; NR, near; KS, Kansas; CO, Colorado; SF, South Fork; R, River; ST, State; AB, above; NF, North Fork; BL, below; RE, Reservoir]

Map no. (fig. 1)	USGS station number	USGS station name	Latitude	Longitude	No. annual series	Hydrologic region
24	06828000	REPUBLICAN RIVER AT MAX, NE	40.1016622	−101.3998866	15	West
25	06835000	STINKING WATER CREEK NEAR PALISADE, NE	40.373056	−101.116944	44	West
26	06836000	BLACKWOOD CREEK NEAR CULBERTSON, NE	40.23611111	−100.8111111	39	West
27	06836500	DRIFTWOOD CREEK NEAR MCCOOK, NE	40.14583655	−100.6732083	71	West
28	06837300	RED WILLOW CREEK ABOVE HUGH BUTLER LAKE, NE	40.4013948	−100.7837665	33	West
29	06838000	RED WILLOW CREEK NEAR RED WILLOW, NE	40.2347222	−100.5008333	21	West
30	06840000	FOX CREEK AT CURTIS, NE	40.634722	−100.490278	40	West
31	06841000	MEDICINE CREEK ABOVE HARRY STRUNK LAKE, NE	40.500556	−100.322778	44	West
32	06843000	MEDICINE CREEK AT CAMBRIDGE, NE	40.298333	−100.176944	12	West
33	06844000	MUDDY CREEK AT ARAPAHOE, NE	40.305833	−99.911667	42	West
34	06844210	TURKEY CREEK AT EDISON, NE	40.2708411	−99.7337279	15	West
35	06844900	SF SAPPA C NR ACHILLES, KS	39.6769485	−100.7220931	49	West
36	06845000	SAPPA C NR OBERLIN, KS	39.8130606	−100.5343122	77	West
37	06845110	SAPPA C NR LYLE, KS	40.0016726	−99.9929055	21	West
38	06845200	SAPPA CREEK NEAR BEAVER CITY, NE	40.04584	−99.8904005	64	West
39	06846000	BEAVER C AT LUDELL, KS	39.8480579	−100.9615446	81	West
40	06846500	BEAVER C AT CEDAR BLUFFS, KS	39.98500557	−100.560148	70	West
41	06847000	BEAVER CREEK NEAR BEAVER CITY, NE	40.1200068	−99.8934566	79	West
42	06847500	SAPPA CREEK NEAR STAMFORD, NE	40.1183333	−99.5169444	71	West
43	06847900	PRAIRIE DOG C AB KEITH SEBELIUS LAKE, KS	39.769727	−100.1006875	54	West
44	06848000	PRAIRIE DOG C AT NORTON, KS	39.8100055	−99.9220683	19	West
45	06848500	PRAIRIE DOG C NR WOODRUFF, KS	39.9787043	−99.4786584	34	West
46	06850500	REPUBLICAN RIVER NEAR BLOOMINGTON, NE	40.066389	−99.036389	20	West
47	06851000	CENTER CREEK AT FRANKLIN, NE	40.103333	−98.980278	45	West

Table 1. Active and inactive U.S. Geological Survey streamgages used for regression analysis within the study area (map numbers 1–85). U.S. Geological Survey streamgage information is from U.S. Geological Survey (2018).—Continued

[no., number; USGS, U.S. Geological Survey; NE, Nebraska; MO, Missouri; C, Creek; NR, near; KS, Kansas; CO, Colorado; SF, South Fork; R, River; ST, State; AB, above; NF, North Fork; BL, below; RE, Reservoir]

Map no. (fig. 1)	USGS station number	USGS station name	Latitude	Longitude	No. annual series	Hydrologic region
48	06851500	THOMPSON CREEK AT RIVERTON, NE	40.0891807	−98.7609064	46	West
49	06853500	REPUBLICAN R NR HARDY, NE	39.992513	−97.932543	46	East
50	06853800	WHITE ROCK C NR BURR OAK, KS	39.89918	−98.2503276	59	East
51	06854500	REPUBLICAN R AT SCANDIA, KS	39.79873	−97.7931266	31	East
52	06855800	BUFFALO C NR JAMESTOWN, KS	39.6145692	−97.8568182	30	East
53	06855900	WOLF C NR CONCORDIA, KS	39.5437887	−97.723024	19	East
54	06856600	REPUBLICAN R AT CLAY CENTER, KS	39.3555515	−97.1275203	33	East
55	06857000	REPUBLICAN R AT MILFORD, KS	39.1647189	−96.9158446	57	East
56	06858500	NF SMOKY HILL R NR MCALLASTER, KS	39.01787498	−101.3479109	37	West
57	06859500	LADDER C BL CHALK C NR SCOTT CITY, KS	38.7889022	−100.8698688	28	West
58	06860000	SMOKY HILL R AT ELKADER, KS	38.7947354	−100.8584796	77	West
59	06861000	SMOKY HILL R NR ARNOLD, KS	38.8077898	−100.0226243	67	West
60	06862500	SMOKY HILL R NR ELLIS, KS	38.76862365	−99.560034	71	West
61	06863300	BIG C NR OGALLAH, KS	38.9106938	−99.7433365	12	West
62	06863500	BIG C NR HAYS, KS	38.852234	−99.3181589	71	West
63	06863900	NF BIG C NR VICTORIA, KS	38.8866783	−99.2062101	25	West
64	06864000	SMOKY HILL R NR RUSSELL, KS	38.7766781	−98.8548066	10	West
65	06864500	SMOKY HILL R AT ELLSWORTH, KS	38.72667589	−98.2336684	54	East
66	06866000	SMOKY HILL R AT LINDSBORG, KS	38.56380659	−97.6664947	41	East
67	06867000	SALINE R NR RUSSELL, KS	38.96584479	−98.8545276	71	West
68	06867500	PARADISE C NR PARADISE, KS	39.05919167	−98.8422917	71	West
69	06868000	SALINE R NR WILSON, KS	38.9333444	−98.53368	33	East
70	06868400	WOLF C NR LUCAS, KS	39.0576803	−98.5597071	11	East
71	06869500	SALINE R AT TESCOTT, KS	39.0038923	−97.8739316	43	East
72	06869950	MULBERRY C NR SALINA, KS	38.8444476	−97.6683699	15	East
73	06871000	NF SOLOMON R AT GLADE, KS	39.6730652	−99.3095409	64	West
74	06871500	BOW C NR STOCKTON, KS	39.5594542	−99.2859298	66	West
75	06871800	NF SOLOMON R AT KIRWIN, KS	39.6600106	−99.115644	34	West
76	06871900	DEER C NR PHILLIPSBURG, KS	39.7810731	−99.4221617	14	West

Table 1. Active and inactive U.S. Geological Survey streamgages used for regression analysis within the study area (map numbers 1–85). U.S. Geological Survey streamgage information is from U.S. Geological Survey (2018).—Continued

[no., number; USGS, U.S. Geological Survey; NE, Nebraska; MO, Missouri; C, Creek; NR, near; KS, Kansas; CO, Colorado; SF, South Fork; R, River; ST, State; AB, above; NF, North Fork; BL, below; RE, Reservoir]

Map no. (fig. 1)	USGS station number	USGS station name	Latitude	Longitude	No. annual series	Hydrologic region
77	06873000	SF SOLOMON R AB WEBSTER RE, KS	39.37667456	−99.5801096	72	West
78	06873500	SF SOLOMON R AT ALTON, KS	39.4543049	−98.9483529	37	West
79	06873700	KILL C NR BLOOMINGTON, KS	39.379177	−98.8595249	18	West
80	06876000	SOLOMON R AT BELOIT, KS	39.45450957	−98.1098985	25	East
81	06876700	SALT C NR ADA, KS	39.13916876	−97.8369849	57	East
82	06876900	SOLOMON R AT NILES, KS	38.9691663	−97.4772513	56	East
83	06877000	SMOKY HILL R AT SOLOMON, KS	38.9051028	−97.3683676	15	East
84	06877600	SMOKY HILL R AT ENTERPRISE, KS	38.90638906	−97.1177952	11	East
85	06878000	CHAPMAN C NR CHAPMAN, KS	39.031109	−97.0402922	63	East

Table 2. Active and inactive U.S. Geological Survey streamgages used for regression analysis within the study area (map numbers 86–170). U.S. Geological Survey streamgage information is from U.S. Geological Survey (2018).

[no., number; USGS, U.S. Geological Survey; C, Creek; NR, near; KS, Kansas; NE, Nebraska; R, River; L, Little; ST., Saint; ST, Street; BLVD, Boulevard; EXT, Exit; KC, Kansas City; MO, Missouri; CO, Colorado]

Map no. (fig. 1)	USGS station number	USGS station name	Latitude	Longitude	No. annual series	Hydrologic region
86	06878500	LYON C NR WOODBINE, KS	38.8847238	−96.9100115	20	East
87	06881000	BIG BLUE RIVER NEAR CRETE, NE	40.59666667	−96.9605556	63	East
88	06881200	TURKEY CREEK NEAR WILBER, NE	40.480004	−97.0122523	34	East
89	06881380	TURKEY CREEK NEAR DEWITT, NE	40.3672222	−96.8894444	14	East
90	06881500	BIG BLUE R AT BEATRICE, NE	40.256667	−96.746944	83	East
91	06882000	BIG BLUE RIVER AT BARNESTON, NE	40.0447222	−96.5872222	84	East
92	06882500	BIG BLUE R AT HULL, KS	39.9166688	−96.6336319	20	East
93	06882510	BIG BLUE R AT MARYSVILLE, KS	39.8419463	−96.6622425	32	East
94	06883000	LITTLE BLUE RIVER NEAR DEWEESE, NE	40.3325	−98.0669444	64	East
95	06883570	LITTLE BLUE RIVER NEAR ALEXANDRIA (GILEAD), NE	40.206944	−97.388611	32	East
96	06884000	LITTLE BLUE RIVER NEAR FAIRBURY, NE	40.1464722	−97.2007222	107	East
97	06884025	LITTLE BLUE RIVER AT HOLLENBERG, KS	39.98027778	−97.0047222	43	East
98	06884200	MILL C AT WASHINGTON, KS	39.81361476	−97.0375267	57	East
99	06884400	L BLUE R NR BARNES, KS	39.72583518	−96.8047432	58	East
100	06884500	L BLUE R AT WATERVILLE, KS	39.7004873	−96.7545251	35	East
101	06885500	BLACK VERMILLION R NR FRANKFORT, KS	39.68194349	−96.4427888	63	East
102	06886000	BIG BLUE R AT RANDOLPH, KS	39.4765097	−96.6887196	41	East
103	06888000	VERMILLION C NR WAMEGO, KS	39.34777386	−96.2174979	80	East
104	06888500	MILL C NR PAXICO, KS	39.06472106	−96.1691605	63	East
105	06889120	SOLDIER C NR BANCROFT, KS	39.59476	−95.97391908	24	East
106	06889140	SOLDIER C NR SOLDIER, KS	39.5768743	−95.9756814	34	East
107	06889160	SOLDIER C NR CIRCLEVILLE, KS	39.4631449	−95.9505944	37	East
108	06889180	SOLDIER C NR ST. CLERE, KS	39.3758289	−95.9183232	17	East
109	06889200	SOLDIER C NR DELIA, KS	39.23833024	−95.8885992	58	East
110	06889500	SOLDIER C NR TOPEKA, KS	39.0994439	−95.7249828	87	East
111	06890100	DELAWARE R NR MUSCOTAH, KS	39.5213873	−95.532756	47	East

Table 2. Active and inactive U.S. Geological Survey streamgages used for regression analysis within the study area (map numbers 86–170). U.S. Geological Survey streamgage information is from U.S. Geological Survey (2018).—Continued

[no., number; USGS, U.S. Geological Survey; C, Creek; NR, near; KS, Kansas; NE, Nebraska; R, River; L, Little; ST., Saint; ST, Street; BLVD, Boulevard; EXT, Exit; KC, Kansas City; MO, Missouri; CO, Colorado]

Map no. (fig. 1)	USGS station number	USGS station name	Latitude	Longitude	No. annual series	Hydrologic region
112	06890500	DELAWARE R AT VALLEY FALLS, KS	39.3508317	−95.4546974	44	East
113	06891260	WAKARUSA R NR RICHLAND, KS	38.89194444	−95.5944444	14	East
114	06891500	WAKARUSA R NR LAWRENCE, KS	38.9113923	−95.261084	51	East
115	06891810	STRANGER C NR POTTER, KS	39.4477753	−95.162191	11	East
116	06892000	STRANGER C NR TONGANOXIE, KS	39.1163912	−95.0108006	87	East
117	06892360	KILL C AT 95TH ST NR DESOTO, KS	38.95666667	−94.9736111	14	East
118	06893080	BLUE R NR STANLEY, KS	38.8125082	−94.6757906	42	East
119	06893150	BLUE RIVER AT BLUE RIDGE BLVD EXT IN KC, MO	38.88941667	−94.5806667	14	East
120	06893300	INDIAN C AT OVERLAND PARK, KS	38.9405621	−94.6713469	16	East
121	06893500	BLUE RIVER AT KANSAS CITY, MO	38.957	−94.5588889	77	East
122	06893578	BLUE RIVER AT STADIUM DRIVE IN KANSAS CITY, MO	39.0583384	−94.5118983	14	East
123	06893793	LITTLE BLUE RIVER BELOW LONGVIEW DAM AT KC, MO	38.925917	−94.468583	17	East
124	06893890	EAST FORK LITTLE BLUE RIVER NEAR BLUE SPRINGS, MO	39.02556175	−94.3438385	42	East
125	06894000	LITTLE BLUE RIVER NEAR LAKE CITY, MO	39.1005609	−94.3005038	69	East
126	06894500	EAST FORK FISHING RIVER AT EXCEL-SIOR SPRINGS, MO	39.338781	−94.213183	19	East
127	06895000	CROOKED RIVER NEAR RICHMOND, MO	39.33266389	−93.98	69	East
128	06896500	THOMPSON BRANCH NEAR ALBANY, MO	40.213964	−94.332111	16	East
129	06897000	EAST FORK BIG CREEK NEAR BETHA-NY, MO	40.2972222	−94.0262222	83	East
130	06897500	GRAND RIVER NEAR GALLATIN, MO	39.9269517	−93.9427225	95	East
131	06898100	THOMPSON RIVER AT MOUNT MORIAH, MO	40.336333	−93.7685	16	East
132	06899700	SHOAL CREEK NEAR BRAYMER, MO	39.699525	−93.7958722	59	East
133	06907500	SOUTH FORK BLACKWATER RIVER NEAR ELM, MO	38.818956	−94.035864	24	East

Table 2. Active and inactive U.S. Geological Survey streamgages used for regression analysis within the study area (map numbers 86–170). U.S. Geological Survey streamgage information is from U.S. Geological Survey (2018).—Continued

[no., number; USGS, U.S. Geological Survey; C, Creek; NR, near; KS, Kansas; NE, Nebraska; R, River; L, Little; ST., Saint; ST, Street; BLVD, Boulevard; EXT, Exit; KC, Kansas City; MO, Missouri; CO, Colorado]

Map no. (fig. 1)	USGS station number	USGS station name	Latitude	Longitude	No. annual series	Hydrologic region
134	06910800	MARAIS DES CYGNES R NR READING, KS	38.56695524	−95.961657	47	East
135	06911000	MARAIS DES CYGNES R AT MELVERN, KS	38.5161111	−95.6961111	32	East
136	06911490	SALT C AT LYNDON, KS	38.60139907	−95.6847068	17	East
137	06911500	SALT C NR LYNDON, KS	38.6088989	−95.6383168	59	East
138	06911900	DRAGOON C NR BURLINGAME, KS	38.7091737	−95.8383205	57	East
139	06912500	HUNDRED AND TEN MILE C NR QUENEMO, KS	38.6450089	−95.5597037	23	East
140	06913000	MARAIS DES CYGNES R NR POMONA, KS	38.5841777	−95.4535902	14	East
141	06913500	MARAIS DES CYGNES R NR OTTAWA, KS	38.61806669	−95.2683071	60	East
142	06914000	POTTAWATOMIE C NR GARNETT, KS	38.333631	−95.2488634	77	East
143	06914100	POTTAWATOMIE C NR SCIPIO, KS	38.348889	−95.203333	15	East
144	06914950	BIG BULL C NR EDGERTON, KS	38.75334168	−94.977188	23	East
145	06914990	L BULL C NR SPRING HILL, KS	38.7675084	−94.8794073	23	East
146	06915000	BIG BULL C NR HILLSDALE, KS	38.6563999	−94.8963521	21	East
147	06916000	MARAIS DES CYGNES R AT TRADING POST, KS	38.2486687	−94.686432	29	East
148	06916500	BIG SUGAR C AT FARLINVILLE, KS	38.2353027	−94.8538516	41	East
149	06917000	L OSAGE R AT FULTON, KS	38.00892428	−94.7041264	68	East
150	06917060	LITTLE OSAGE RIVER AT HORTON, MO	37.99480556	−94.3693056	28	East
151	06917240	MARMATON R NR UNIONTOWN, KS	37.83559565	−94.981361	16	East
152	06917380	MARMATON R NR MARMATON, KS	37.81754116	−94.7919095	36	East
153	06917500	MARMATON R NR FORT SCOTT, KS	37.848929	−94.7027392	95	East
154	06917560	MARMATON RIVER NEAR RICHARDS, MO	37.8647222	−94.5822222	11	East
155	06918060	MARMATON RIVER NEAR NEVADA, MO	37.86202778	−94.39925	13	East
156	06918070	OSAGE RIVER ABOVE SCHELL CITY, MO	38.0558611	−94.1454167	29	East
157	06918460	TURNBACK CREEK ABOVE GREENFIELD, MO	37.4023611	−93.8020278	51	East

Table 2. Active and inactive U.S. Geological Survey streamgages used for regression analysis within the study area (map numbers 86–170). U.S. Geological Survey streamgage information is from U.S. Geological Survey (2018).—Continued

[no., number; USGS, U.S. Geological Survey; C, Creek; NR, near; KS, Kansas; NE, Nebraska; R, River; L, Little; ST., Saint; ST, Street; BLVD, Boulevard; EXT, Exit; KC, Kansas City; MO, Missouri; CO, Colorado]

Map no. (fig. 1)	USGS station number	USGS station name	Latitude	Longitude	No. annual series	Hydrologic region
158	06919000	SAC RIVER NEAR STOCKTON, MO	37.70105278	−93.7567806	46	East
159	06919500	CEDAR CREEK NEAR PLEASANT VIEW, MO	37.83420277	−93.8754918	93	East
160	06921590	SOUTH GRAND RIVER AT ARCHIE, MO	38.49158056	−94.3442444	47	East
161	06921600	SOUTH GRAND RIVER AT URICH, MO	38.45223976	−94.0043859	56	East
162	06921720	BIG CREEK NEAR BLAIRSTOWN, MO	38.55497778	−93.9653528	56	East
163	06921760	SOUTH GRAND RIVER NEAR CLINTON, MO	38.370139	−93.858111	21	East
164	06922000	SOUTH GRAND RIVER NEAR BROWN-INGTON, MO	38.263611	−93.714444	49	East
165	07134100	BIG SANDY CREEK NEAR LAMAR, CO	38.11417565	−102.4838023	49	West
166	07139800	MULBERRY C NR DODGE CITY, KS	37.5977599	−100.0153544	22	West
167	07140700	GUZZLERS GULCH NR NESS CITY, KS	38.2922532	−99.951842	18	West
168	07140850	PAWNEE R NR BURDETT, KS	38.2066829	−99.6434539	35	West
169	07141175	BUCKNER C NR BURDETT, KS	38.1625166	−99.6428988	17	West
170	07141200	PAWNEE R AT ROZEL, KS	38.2075145	−99.4062247	92	West

Table 3. Active and inactive U.S. Geological Survey streamgages used for regression analysis within the study area (map numbers 171–254). U.S. Geological Survey streamgage information is from U.S. Geological Survey (2018).

[no., number; USGS, U.S. Geological Survey; C, Creek; NR, near; KS, Kansas; L, Little; R, River; HWY, Highway; NF, North Fork; AB, above; RE, Reservoir; SF, South Fork; OK, Oklahoma; CLEV, Cleveland; BLW, below; M, Middle; MO, Missouri]

Map no. (fig. 1)	USGS station number	USGS station name	Latitude	Longitude	No. annual series	Hydrologic region
171	07141770	WALNUT C NR ALEXANDER, KS	38.4647369	−99.6226162	18	West
172	07141780	WALNUT C AT NEKOMA, KS	38.47723614	−99.4381656	47	West
173	07141900	WALNUT C AT ALBERT, KS	38.46167948	−99.014817	58	West
174	07142300	RATTLESNAKE C NR MACKSVILLE, KS	37.8716826	−98.8762067	57	West
175	07142575	RATTLESNAKE C NR ZENITH, KS	38.0936248	−98.5461894	43	East
176	07143300	COW C NR LYONS, KS	38.3083438	−98.1920045	79	East
177	07143600	L ARKANSAS R NR LITTLE RIVER, KS	38.41329	−98.0173439	11	East
178	07143665	L ARKANSAS R AT ALTA MILLS, KS	38.1122326	−97.591987	38	East
179	07143672	L ARKANSAS R AT HWY 50 NR HALSTEAD, KS	38.0286223	−97.540597	21	East
180	07144100	L ARKANSAS R NR SEDGWICK, KS	37.88306739	−97.4244864	23	East
181	07144200	L ARKANSAS R AT VALLEY CENTER, KS	37.83223425	−97.3889317	94	East
182	07144780	NF NINNESCAH R AB CHENEY RE, KS	37.8625129	−98.0139449	51	East
183	07144800	NF NINNESCAH R NR CHENEY, KS	37.6675828	−97.7559865	13	East
184	07145200	SF NINNESCAH R NR MURDOCK, KS	37.561683	−97.8531094	66	East
185	07145500	NINNESCAH R NR PECK, KS	37.4569636	−97.4239353	25	East
186	07145700	SLATE C AT WELLINGTON, KS	37.24946707	−97.4036569	48	East
187	07146570	COLE C NR DEGRAFF, KS	37.9478819	−96.7819805	19	East
188	07147070	WHITEWATER R AT TOWANDA, KS	37.79612785	−97.0144806	51	East
189	07147800	WALNUT R AT WINFIELD, KS	37.22391557	−96.9961475	59	East
190	07148350	SALT FORK ARKANSAS RIVER NR WINCHESTER, OK	36.9616959	−98.7823116	33	East
191	07148400	SALT FORK ARKANSAS RIVER NR ALVA, OK	36.81503056	−98.6481395	79	East
192	07149000	MEDICINE LODGE R NR KIOWA, KS	37.03891547	−98.4709092	79	East
193	07151500	CHIKASKIA R NR CORBIN, KS	37.12891225	−97.6019945	66	East
194	07152000	CHIKASKIA RIVER NEAR BLACKWELL, OK	36.8114211	−97.277265	41	East
195	07153000	BLACK BEAR CREEK AT PAWNEE, OK	36.34366537	−96.7994788	22	East
196	07153100	RANCH CREEK AT CLEV DAM NR CLEVELAND, OK	36.2833984	−96.5766931	23	East
197	07155590	CIMARRON R NR ELKHART, KS	37.12196746	−101.8979456	39	West

Table 3. Active and inactive U.S. Geological Survey streamgages used for regression analysis within the study area (map numbers 171–254). U.S. Geological Survey streamgage information is from U.S. Geological Survey (2018).—Continued

[no., number; USGS, U.S. Geological Survey; C, Creek; NR, near; KS, Kansas; L, Little; R, River; HWY, Highway; NF, North Fork; AB, above; RE, Reservoir; SF, South Fork; OK, Oklahoma; CLEV, Cleveland; BLW, below; M, Middle; MO, Missouri]

Map no. (fig. 1)	USGS station number	USGS station name	Latitude	Longitude	No. annual series	Hydrologic region
198	07156010	NF CIMARRON R AT RICHFIELD, KS	37.25835665	−101.7754438	14	West
199	07157000	CIMARRON RIVER NEAR MOCANE, OK	36.9758611	−100.3143115	22	West
200	07157500	CROOKED C NR ENGLEWOOD, KS	37.032528	−100.2112531	74	West
201	07157950	CIMARRON RIVER NEAR BUFFALO, OK	36.85197484	−99.315387	57	West
202	07157960	BUFFALO CREEK NEAR LOVEDALE, OK	36.7705872	−99.3670537	26	West
203	07158000	CIMARRON RIVER NEAR WAYNOKA, OK	36.51725644	−98.8795366	40	East
204	07159000	TURKEY CREEK NEAR DRUMMOND, OK	36.31809	−98.001172	22	East
205	07165700	VERDIGRIS R NR MADISON, KS	38.1349719	−96.1033057	20	East
206	07165750	VERDIGRIS R NR VIRGIL, KS	37.98252814	−96.0238817	27	East
207	07166500	VERDIGRIS R NR ALTOONA, KS	37.5297764	−95.674703	20	East
208	07167000	FALL R NR EUREKA, KS	37.7850551	−96.2348096	29	East
209	07167500	OTTER C AT CLIMAX, KS	37.70808736	−96.2236107	70	East
210	07168500	FALL R NR FALL RIVER, KS	37.6445207	−96.0570703	10	East
211	07169500	FALL R AT FREDONIA, KS	37.50838374	−95.8335924	50	East
212	07169800	ELK R AT ELK FALLS, KS	37.37559729	−96.185548	44	East
213	07170000	ELK R NR ELK CITY, KS	37.2664504	−95.918041	30	East
214	07170500	VERDIGRIS R AT INDEPENDENCE, KS	37.22368014	−95.6777573	52	East
215	07170700	BIG HILL C NR CHERRYVALE, KS	37.2667325	−95.469144	59	East
216	07171000	VERDIGRIS RIVER NEAR LENAPAH, OK	36.85119615	−95.5860882	10	East
217	07172000	CANEY R NR ELGIN, KS	37.00393886	−96.3166638	77	East
218	07173000	CANEY RIVER NEAR HULAH, OK	36.9184044	−96.0710968	12	East
219	07174000	LITTLE CANEY RIVER NEAR COPAN, OK	36.9709077	−95.9349807	14	East
220	07174200	LITTLE CANEY RIVER BLW COTTON CR, NR COPAN, OK	36.8950786	−95.9694266	21	East
221	07174600	SAND CREEK AT OKESA, OK	36.7195235	−96.1324935	33	East
222	07176000	VERDIGRIS RIVER NEAR CLAREMORE, OK	36.3075	−95.6997222	13	East
223	07176500	BIRD CREEK AT AVANT, OK	36.48508798	−96.0602743	31	East
224	07177000	HOMINY CREEK NEAR SKIATOOK, OK	36.348697	−96.1100024	37	East
225	07177500	BIRD CREEK NEAR SPERRY, OK	36.27842534	−95.954162	45	East
226	07179500	NEOSHO R AT COUNCIL GROVE, KS	38.66584085	−96.493614	25	East

Table 3. Active and inactive U.S. Geological Survey streamgages used for regression analysis within the study area (map numbers 171–254). U.S. Geological Survey streamgage information is from U.S. Geological Survey (2018).—Continued

[no., number; USGS, U.S. Geological Survey; C, Creek; NR, near; KS, Kansas; L, Little; R, River; HWY, Highway; NF, North Fork; AB, above; RE, Reservoir; SF, South Fork; OK, Oklahoma; CLEV, Cleveland; BLW, below; M, Middle; MO, Missouri]

Map no. (fig. 1)	USGS station number	USGS station name	Latitude	Longitude	No. annual series	Hydrologic region
227	07180000	COTTONWOOD R NR MARION, KS	38.35140376	−97.0586349	29	East
228	07180500	CEDAR C NR CEDAR POINT, KS	38.19640618	−96.8244648	78	East
229	07181500	M CREEK NR ELMDALE, KS	38.39321704	−96.7185648	11	East
230	07182400	NEOSHO R AT STRAWN, KS	38.2698522	−95.8660774	14	East
231	07183000	NEOSHO R NR IOLA, KS	37.92225778	−95.4277596	55	East
232	07183100	OWL C NR PIQUA, KS	37.8489051	−95.5742718	10	East
233	07183500	NEOSHO R NR PARSONS, KS	37.34005866	−95.1099687	40	East
234	07184000	LIGHTNING C NR MCCUNE, KS	37.2811711	−95.0327428	78	East
235	07184500	LABETTE C NR OSWEGO, KS	37.19379589	−95.1924979	78	East
236	07185000	NEOSHO RIVER NEAR COMMERCE, OK	36.92868144	−94.9574574	22	East
237	07185500	STAHL CREEK NEAR MILLER, MO	37.19321	−93.84496	25	East
238	07185700	SPRING RIVER AT LA RUSSELL, MO	37.15027778	−94.0613889	59	East
239	07185765	SPRING RIVER AT CARTHAGE, MO	37.18863889	−94.3259167	50	East
240	07186000	SPRING RIVER NEAR WACO, MO	37.2456111	−94.5664167	92	East
241	07186400	CENTER CREEK NEAR CARTERVILLE, MO	37.1406145	−94.3827238	28	East
242	07187000	SHOAL CREEK ABOVE JOPLIN, MO	37.02316667	−94.5165556	75	East
243	07187500	SHOAL CREEK NEAR JOPLIN, MO	37.0347844	−94.5418911	17	East
244	07188000	SPRING RIVER NEAR QUAPAW, OK	36.93451148	−94.7471711	45	East
245	07189500	NEOSHO RIVER NEAR GROVE, OK	36.6125757	−94.8238434	14	East
246	07191000	BIG CABIN CREEK NEAR BIG CABIN, OK	36.56841789	−95.1521891	38	East
247	07191222	BEATY CREEK NEAR JAY, OK	36.35535924	−94.7763388	18	East
248	07192000	PRYOR CREEK NEAR PRYOR, OK	36.281206	−95.3258024	15	East
249	07232500	BEAVER RIVER NEAR GUYMON, OK	36.721415	−101.4896047	39	West
250	07233000	COLDWATER CREEK NEAR HARDESTY, OK	36.6439157	−101.210993	24	West
251	07234000	BEAVER RIVER AT BEAVER, OK	36.82224819	−100.5193158	41	West
252	07234100	CLEAR CREEK NEAR ELMWOOD, OK	36.6450279	−100.5023688	14	West
253	07234500	BEAVER RIVER NEAR FORT SUPPLY, OK	36.5917013	−99.5920598	13	West
254	07236000	WOLF CREEK NEAR FARGO, OK	36.3992044	−99.6231707	33	West

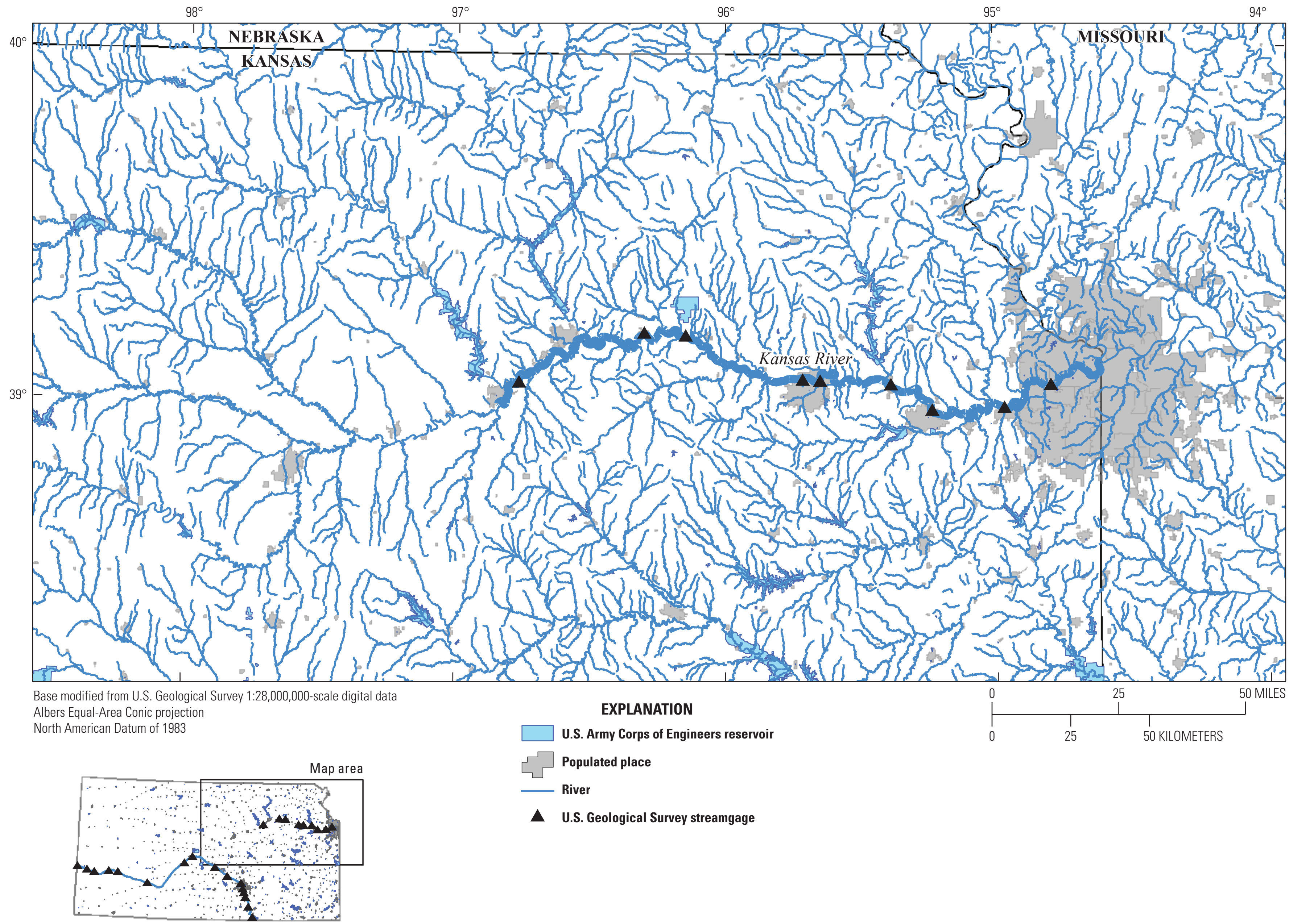

Figure 6. Active Kansas River U.S. Geological Survey streamgages and U.S. Army Corps of Engineers reservoirs that regulate the flow in the Kansas River.

Table 4. List of active U.S. Geological Survey streamgages on the Kansas and Arkansas Rivers.

[USGS, U.S. Geological Survey; R, River; KS, Kansas; NR, near; HWY, Highway]

USGS station number	USGS station name	Latitude	Longitude	Hydrologic region
06879100	Kansas R at Fort Riley, KS	39.06166457	−96.76639630	East
06887500	Kansas R at Wamego, KS	39.19833014	−96.30555320	East
06888350	Kansas R nr Belvue, KS	39.19305265	−96.14749450	East
06888990	Kansas R at Topeka Water Plant, KS	39.07194435	−95.71637150	East
06889000	Kansas R at Topeka, KS	39.06666660	−95.64970280	East
06891000	Kansas R at Lecompton, KS	39.05111157	−95.38636330	East
06891080	Kansas R at Lawrence, KS	38.97327778	−95.23211110	East
06892350	Kansas R at De Soto, KS	38.98333750	−94.96468930	East
06892518	Kansas R nr Lake Quivira, KS	39.04611110	−94.78944440	East
07137500	Arkansas R nr Coolidge, KS	38.02751290	−102.01157060	West
07138000	Arkansas R at Syracuse, KS	37.96612410	−101.75683870	West
07138020	Arkansas R at Kendall, KS	37.93001500	−101.54933710	West
07138070	Arkansas R at Deerfield, KS	37.96974420	−101.12877940	West
07139000	Arkansas R at Garden City, KS	37.95585650	−100.87738440	West
07139500	Arkansas R at Dodge City, KS	37.74474270	−100.03291260	West
07141220	Arkansas R nr Larned, KS	38.20362484	−99.00231980	West
07141300	Arkansas R at Great Bend, KS	38.35306787	−98.76425190	West
07142680	Arkansas R nr Nickerson, KS	38.14501130	−98.11116900	East
07143330	Arkansas R nr Hutchinson, KS	37.94640028	−97.77504880	East
07143375	Arkansas R nr Maize, KS	37.78140109	−97.38976650	East
07144300	Arkansas R at Wichita, KS	37.64334849	−97.33532270	East
07144550	Arkansas R at Derby, KS	37.54418457	−97.27559990	East
07144570	Arkansas R at Mulvane, KS	37.47550278	−97.26127220	East
07145600	Arkansas R on HWY 160 at Oxford, KS	37.27440556	−97.16226390	East
07146500	Arkansas R at Arkansas City, KS	37.03750830	−97.03921940	East

of the Arkansas River (Juracek and others, 2017). Data for selected low-flow and flow-duration statistics were included from these streamgages for completeness (table 5). The final dataset to develop the regression equations consisted of 254 streamgages from within Kansas and a 50-mi buffer of the neighboring States of Nebraska, Missouri, Oklahoma, and Colorado.

Basin Characteristics

"Low-flow characteristics of streams are related to the physical, geologic, and climatic properties of drainage basins" (Eash and Barnes, 2017, p. 13). In many studies, drainage area is an important variable in explaining low-flow variability (Kroll and others, 2004; Funkhouser and others, 2008; Eash and Barnes, 2017). Basin characteristics investigated in this study as possible independent variables in the regression analysis were chosen based on their theoretic relation to low flows, findings of previous studies in similar hydrologic areas, and the capability to compute the basin characteristics using geographic-information-system (GIS) technology and digital datasets. "The use of GIS enables the automation of the basin characteristic measurements and solution of the regional regression equations using StreamStats" (Eash and Barnes, 2017, p. 13).

Using GIS technology and other sources, 13 basin characteristics were measured for each of the 254 streamgages used in the regression analysis for this report. A brief explanation of each basin characteristic and the data source used to measure it are included in table 6.

Basic Statistics

Daily mean streamflow data were downloaded from the USGS NWIS database using the USGS Surface-Water Toolbox (SWToolbox) version 1.0.4 software (Kiang and

Table 5. Annual low-flow frequency statistics for active U.S. Geological Survey streamgages on the Kansas and Arkansas Rivers.

[USGS, U.S. Geological Survey; KS, Kansas; nr, near; HWY, Highway]

USGS station number	USGS station name	Parameter (days)	Recurrence interval (years)			
			50	20	10	5
06879100	Kansas River at Fort Riley, KS	1	122	141	164	202
06879100	Kansas River at Fort Riley, KS	7	132	154	180	221
06879100	Kansas River at Fort Riley, KS	30	174	196	224	269
06887500	Kansas River at Wamego, KS	1	205	267	336	442
06887500	Kansas River at Wamego, KS	7	262	327	399	507
06887500	Kansas River at Wamego, KS	30	306	383	469	601
06888350	Kansas River nr Belvue, KS	1	401	441	489	569
06888350	Kansas River nr Belvue, KS	7	446	486	534	616
06888350	Kansas River nr Belvue, KS	30	491	546	611	719
06888990	Kansas River at Topeka Water Plant, KS	1	706	772	831	902
06888990	Kansas River at Topeka Water Plant, KS	7	882	918	952	994
06888990	Kansas River at Topeka Water Plant, KS	30	979	993	1,010	1,050
06889000	Kansas River at Topeka, KS	1	235	307	388	512
06889000	Kansas River at Topeka, KS	7	280	358	445	578
06889000	Kansas River at Topeka, KS	30	328	421	525	685
06891000	Kansas River at Lecompton, KS	1	268	348	439	580
06891000	Kansas River at Lecompton, KS	7	302	391	491	647
06888350	Kansas River at Lecompton, KS	30	380	481	595	773
06888990	Kansas River at Lawrence, KS	1	662	674	690	720
06891080	Kansas River at Lawrence, KS	7	812	838	865	903
06891080	Kansas River at Lawrence, KS	30	829	854	888	948
06892350	Kansas River at De Soto, KS	1	281	365	458	602
06892350	Kansas River at De Soto, KS	7	339	435	541	703
06892350	Kansas River at De Soto, KS	30	430	541	665	856
06892518	Kansas River nr Lake Quivira, KS	1	1,110	1,130	1,150	1,190
06892518	Kansas River nr Lake Quivira, KS	7	1,180	1,190	1,210	1,240
06892518	Kansas River nr Lake Quivira, KS	30	1,190	1,260	1,320	1,410
07137500	Arkansas River nr Coolidge, KS	1	0	0.197	0.768	2.38
07137500	Arkansas River nr Coolidge, KS	7	0	0.356	1.23	3.49
07137500	Arkansas River nr Coolidge, KS	30	0.402	1.11	2.57	6.52
07138000	Arkansas River at Syracuse, KS	1	0.047	0.224	0.623	1.83
07138000	Arkansas River at Syracuse, KS	7	0.065	0.291	0.787	2.26
07138000	Arkansas River at Syracuse, KS	30	0.133	0.457	1.25	3.81
07138020	Arkansas River at Kendall, KS	1	0	0	0	0.038
07138020	Arkansas River at Kendall, KS	7	0	0	0	0.326
07138020	Arkansas River at Kendall, KS	30	0	0	0	1.32
07138070	Arkansas River at Deerfield, KS	1	0	0	0	0
07138070	Arkansas River at Deerfield, KS	7	0	0	0	0
07138070	Arkansas River at Deerfield, KS	30	0	0	0	0
07139000	Arkansas River at Garden City, KS	1	0	0	0	0
07139000	Arkansas River at Garden City, KS	7	0	0	0	0
07139000	Arkansas River at Garden City, KS	30	0	0	0	0

Table 5. Annual low-flow frequency statistics for active U.S. Geological Survey streamgages on the Kansas and Arkansas Rivers.—Continued

[USGS, U.S. Geological Survey; KS, Kansas; nr, near; HWY, Highway]

USGS station number	USGS station name	Parameter (days)	Recurrence interval (years)			
			50	20	10	5
07139500	Arkansas River at Dodge City, KS	1	0	0	0	0
07139500	Arkansas River at Dodge City, KS	7	0	0	0	0
07139500	Arkansas River at Dodge City, KS	30	0	0	0	0
07141220	Arkansas River nr Larned, KS	1	0	0	0	0
07141220	Arkansas River nr Larned, KS	7	0	0	0	0
07141220	Arkansas River nr Larned, KS	30	0	0	0	0
07141300	Arkansas River at Great Bend, KS	1	0	0	0.01	0.528
07141300	Arkansas River at Great Bend, KS	7	0	0	0.084	0.75
07141300	Arkansas River at Great Bend, KS	30	0.005	0.066	0.277	1.15
07142680	Arkansas River nr Nickerson, KS	1	14.5	19	24.3	32.8
07142680	Arkansas River nr Nickerson, KS	7	14.8	19.6	25.1	34.2
07142680	Arkansas River nr Nickerson, KS	30	16	21.4	27.7	37.9
07143330	Arkansas River nr Hutchinson, KS	1	24.6	32	40.4	53.3
07143330	Arkansas River nr Hutchinson, KS	7	27.1	35.4	44.7	59
07143330	Arkansas River nr Hutchinson, KS	30	32.2	42.2	53.4	70.6
07143375	Arkansas River nr Maize, KS	1	0.516	2.22	6.69	20.2
07143375	Arkansas River nr Maize, KS	7	0.72	2.91	8.4	24.3
07143375	Arkansas River nr Maize, KS	30	1.46	5.17	13.5	34.9
07144300	Arkansas River at Wichita, KS	1	8.41	15.3	25	43.1
07144300	Arkansas River at Wichita, KS	7	10.7	19.1	30.9	52.7
07144300	Arkansas River at Wichita, KS	30	17.9	29.9	45.9	74.1
07144550	Arkansas River at Derby, KS	1	69.7	83.2	97.3	118
07144550	Arkansas River at Derby, KS	7	76.3	92.2	109	133
07144550	Arkansas River at Derby, KS	30	90.8	112	134	167
07144570	Arkansas River at Mulvane, KS	1	68.9	91.3	114	145
07144570	Arkansas River at Mulvane, KS	7	152	164	176	191
07144570	Arkansas River at Mulvane, KS	30	205	225	244	270
07145600	Arkansas River on HWY 160 at Oxford, KS	1	218	230	243	264
07145600	Arkansas River on HWY 160 at Oxford, KS	7	221	240	260	287
07145600	Arkansas River on HWY 160 at Oxford, KS	30	338	345	356	377
07146500	Arkansas River at Arkansas City, KS	1	23.8	43.3	70	117
07146500	Arkansas River at Arkansas City, KS	7	30.7	53.4	83.6	137
07146500	Arkansas River at Arkansas City, KS	30	53	83.2	121	185

others, 2018; U.S. Geological Survey, 2018). SWToolbox is a Windows-based desktop computer application that provides a set of procedures for statistical analysis of streamflow time series, which includes the computation of low-flow frequency statistics (Kiang and others, 2018). It combines the functionality of the USGS SWSTAT and the U.S. Environmental Protection Agency DFLOW software programs (Kiang and others, 2018). The basic statistics for all the streamgages mentioned in this study were computed using a utility within SWToolbox. The minimum, maximum, mean, standard deviation, and count of all daily mean streamflows are provided in tables 7–8.

Table 6. Basin characteristics tested for significance during the regression analysis.

[E, denotes exponentiation; NA, not applicable]

Basin characteristic and abbreviation	Unit	Source	Range	Website
Contributing drainage area—CONTDA	Square miles	U.S. Geological Survey, 2018	3.86 to 24,900	https://doi.org/10.5066/F7P55KJN
Mean annual precipitation for 1895–2017—PRECIPfull	Inches	PRISM Climate Group, 2020	14.6 to 44.4	https://www.prism.oregonstate.edu/explorer/
Mean annual precipitation for 1961–90—PRECIP 1961–90	Inches	PRISM Climate Group, 2020	13.7 to 44.4	https://www.prism.oregonstate.edu/
Mean annual precipitation for 1971–2000—PRECIP 1971–2000	Inches	PRISM Climate Group, 2020	14.6 to 46.4	https://www.prism.oregonstate.edu/
Mean annual precipitation for 1981–2010—PRECIP 1981–2010	Inches	PRISM Climate Group, 2020	14.9 to 47.0	https://www.prism.oregonstate.edu/
Saturated hydraulic conductivity—KSAT	Micrometers per second	Wieczorek, 2014	1.21 to 89.3	https://doi.org/10.3133/tm3B10
Drainage basin slope—SLOPE	Percent	ArcGIS slope tool on National Elevation Dataset	0.82 to 12.2	NA
Base-flow index—BFI	Dimensionless	Barlow and others, 2015	4.00E−03 to 0.82	https://www.usgs.gov/software/groundwater-toolbox-a-graphical-and-mapping-interface-analysis-hydrologic-data
Reservoir storage—STORAGE	Percent	U.S. Geological Survey, 2006	0.02 to 9.25	https://www.usgs.gov/centers/eros/science/national-land-cover-database?qt-science_center_objects=0#qt-science_center_objects
Forest land cover—FOREST	Percent	U.S. Geological Survey, 2006	1.00E−03 to 35.5	https://www.usgs.gov/centers/eros/science/national-land-cover-database?qt-science_center_objects=0#qt-science_center_objects
Shrub land cover—LC06SHRUB	Percent	U.S. Geological Survey, 2006	6.42E−05 to 35.8	https://www.usgs.gov/centers/eros/science/national-land-cover-database?qt-science_center_objects=0#qt-science_center_objects
Pasture land cover—LC06PAST	Percent	U.S. Geological Survey, 2006	3.37E−03 to 83.7	https://www.usgs.gov/centers/eros/science/national-land-cover-database?qt-science_center_objects=0#qt-science_center_objects
Crop land cover—LC06CROP	Percent	U.S. Geological Survey, 2006	0.17 to 85.9	https://www.usgs.gov/centers/eros/science/national-land-cover-database?qt-science_center_objects=0#qt-science_center_objects

Table 7. Basic statistics for daily mean streamflows of U.S. Geological Survey streamgages used in the regression analysis (map numbers 1–126), computed using SWToolbox (Kiang and others, 2018).

[no., number; USGS, U.S. Geological Survey; NE, Nebraska; MO, Missouri; C, Creek; NR, near; KS, Kansas; CO, Colorado; R, River; SF, South Fork; ST, State; AB, above; NF, North Fork; BL, below; RE, Reservoir; L, Little; ST., Saint; ST, Street; BLVD, Boulevard; EXT, Exit; KC, Kansas City]

Map no. (fig. 1)	USGS station number	USGS station name	Minimum	Maximum	Mean	Standard deviation	Count
1	06767500	PLUM CREEK NEAR SMITHFIELD, NE	0	1,850	9.67	47.931	7,120
2	06768020	SPRING CREEK NEAR OVERTON, NE	0	464	26.1	35.879	7,670
3	06769525	ELM CREEK NEAR ELM CREEK, NE	0	893	4.1	20.911	7,670
4	06810500	LITTLE NEMAHA RIVER NEAR SYRACUSE, NE	0	14,500	63.4	336.37	6,209
5	06811500	LITTLE NEMAHA RIVER AT AUBURN, NE	0.87	70,400	325	1,337.90	24,472
6	06813000	TARKIO RIVER AT FAIRFAX, MO	0	11,100	235	609.92	28,677
7	06814000	TURKEY C NR SENECA, KS	0	16,700	123	514.85	24,837
8	06814500	NORTH FORK BIG NEMAHA RIVER AT HUMBOLDT, NE	0.07	30,000	214	950.76	16,985
9	06815000	BIG NEMAHA RIVER AT FALLS CITY, NE	0.69	57,600	599	2,029.50	26,663
10	06815500	MUDDY CREEK AT VERDON, NE	1	14,300	67.2	303.15	6,940
11	06817500	NODAWAY RIVER NEAR BURLINGTON JUNCTION, MO	1.1	34,500	589	1,476.80	23,116
12	06817700	NODAWAY RIVER NEAR GRAHAM, MO	22	52,000	1,010	2,240.20	12,419
13	06818900	PLATTE RIVER AT RAVENWOOD, MO	2.4	9,950	268	805.92	4,383
14	06819500	ONE HUNDRED AND TWO RIVER AT MARYVILLE, MO	0	25,500	262	890.07	26,947
15	06820500	PLATTE RIVER NEAR AGENCY, MO	0	57,500	1,030	2,710	32,961
16	06821080	LITTLE PLATTE RIVER NEAR PLATTSBURG, MO	0	7,730	47.2	247.03	5,854
17	06821150	LITTLE PLATTE RIVER AT SMITHVILLE, MO	0	21,100	161	683.08	3,653
18	06821190	PLATTE RIVER AT SHARPS STATION, MO	12	41,200	1,760	3,271.40	13,880
19	06823500	BUFFALO CREEK NEAR HAIGLER, NE	0	90	5.83	4.0813	27,759
20	06825000	SOUTH FORK REPUBLICAN RIVER NEAR IDALIA, CO	0	6,640	32.8	120.83	7,305
21	06825500	LANDSMAN CREEK NEAR HALE, CO	0	1,800	3.77	36.73	9,132
22	06827000	SF REPUBLICAN R NR CO-KS ST LINE, KS	0	2,000	20.2	46.517	9,253
23	06827500	SOUTH FORK REPUBLICAN RIVER NEAR BENKELMAN, NE	0	5,500	73	208.38	4,383
24	06828000	REPUBLICAN RIVER AT MAX, NE	0	85,000	191	1,256.10	5,479
25	06835000	STINKING WATER CREEK NEAR PALISADE, NE	4.9	1,640	37.1	34.473	16,071
26	06836000	BLACKWOOD CREEK NEAR CULBERTSON, NE	0	1,270	5.89	28.804	14,245
27	06836500	DRIFTWOOD CREEK NEAR MCCOOK, NE	0	3,950	8.05	54.122	25,933
28	06837300	RED WILLOW CREEK ABOVE HUGH BUTLER LAKE, NE	3.1	734	26.2	24.257	12,053
29	06838000	RED WILLOW CREEK NEAR RED WILLOW, NE	2	5,730	42.9	107.77	7,670
30	06840000	FOX CREEK AT CURTIS, NE	0.71	1,560	7.05	22.133	7,669

Table 7. Basic statistics for daily mean streamflows of U.S. Geological Survey streamgages used in the regression analysis (map numbers 1–126), computed using SWToolbox (Kiang and others, 2018).—Continued

[no., number; USGS, U.S. Geological Survey; NE, Nebraska; MO, Missouri; C, Creek; NR, near; KS, Kansas; CO, Colorado; R, River; SF, South Fork; ST, State; AB, above; NF, North Fork; BL, below; RE, Reservoir; L, Little; ST., Saint; ST, Street; BLVD, Boulevard; EXT, Exit; KC, Kansas City]

Map no. (fig. 1)	USGS station number	USGS station name	Minimum	Maximum	Mean	Standard deviation	Count
31	06841000	MEDICINE CREEK ABOVE HARRY STRUNK LAKE, NE	9.1	5,900	62.6	115	16,071
32	06843000	MEDICINE CREEK AT CAMBRIDGE, NE	6	28,500	93.1	513.56	4,047
33	06844000	MUDDY CREEK AT ARAPAHOE, NE	0	4,570	14.8	81.188	13,514
34	06844210	TURKEY CREEK AT EDISON, NE	0.01	330	7.61	13.002	5,479
35	06844900	SF SAPPA C NR ACHILLES, KS	0	3,060	2.48	35.171	17,897
36	06845000	SAPPA C NR OBERLIN, KS	0	5,100	14.2	114.03	15,350
37	06845110	SAPPA C NR LYLE, KS	0	877	7.12	23.149	7,670
38	06845200	SAPPA CREEK NEAR BEAVER CITY, NE	0	4,700	38	157.76	12,875
39	06846000	BEAVER C AT LUDELL, KS	0	2,000	9.41	58.043	9,404
40	06846500	BEAVER C AT CEDAR BLUFFS, KS	0	4,560	10.1	74.087	25,568
41	06847000	BEAVER CREEK NEAR BEAVER CITY, NE	0	5,130	19	87.125	21,549
42	06847500	SAPPA CREEK NEAR STAMFORD, NE	0	16,600	37	184.64	25,933
43	06847900	PRAIRIE DOG C AB KEITH SEBELIUS LAKE, KS	0	3,150	7.61	55.974	19,724
44	06848000	PRAIRIE DOG C AT NORTON, KS	0	9,650	42.4	258.7	6,939
45	06848500	PRAIRIE DOG C NR WOODRUFF, KS	0	9,700	57.5	291.15	7,721
46	06850500	REPUBLICAN RIVER NEAR BLOOMINGTON, NE	6.8	116,000	720	2,111.50	7,305
47	06851000	CENTER CREEK AT FRANKLIN, NE	0	839	8.04	20.663	11,320
48	06851500	THOMPSON CREEK AT RIVERTON, NE	8.1	3,230	32.3	91.766	11,687
49	06853500	REPUBLICAN R NR HARDY, NE	0	117,000	867	2,057.30	10,190
50	06853800	WHITE ROCK C NR BURR OAK, KS	0	6,000	26.2	134.98	21,550
51	06854500	REPUBLICAN R AT SCANDIA, KS	0	115,000	827	1,988.90	7,992
52	06855800	BUFFALO C NR JAMESTOWN, KS	0	19,900	70.2	342.39	10,957
53	06855900	WOLF C NR CONCORDIA, KS	0	2,320	10.9	58.977	6,940
54	06856600	REPUBLICAN R AT CLAY CENTER, KS	1	103,000	1,140	2,244	12,053
55	06857000	REPUBLICAN R AT MILFORD, KS	57	71,000	1,610	3,800.70	4,414
56	06858500	NF SMOKY HILL R NR MCALLASTER, KS	0	2,360	3.67	45.371	11,415
57	06859500	LADDER C BL CHALK C NR SCOTT CITY, KS	0	6,580	11.6	115.66	10,227
58	06860000	SMOKY HILL R AT ELKADER, KS	0	13,700	19.3	193.21	28,124
59	06861000	SMOKY HILL R NR ARNOLD, KS	0	14,200	38.5	307.41	24,472
60	06862500	SMOKY HILL R NR ELLIS, KS	0	8,960	133	461.45	3,862

Table 7. Basic statistics for daily mean streamflows of U.S. Geological Survey streamgages used in the regression analysis (map numbers 1–126), computed using SWToolbox (Kiang and others, 2018).—Continued

[no., number; USGS, U.S. Geological Survey; NE, Nebraska; MO, Missouri; C, Creek; NR, near; KS, Kansas; CO, Colorado; R, River; SF, South Fork; ST, State; AB, above; NF, North Fork; BL, below; RE, Reservoir; L, Little; ST., Saint; ST, Street; BLVD, Boulevard; EXT, Exit; KC, Kansas City]

Map no. (fig. 1)	USGS station number	USGS station name	Minimum	Maximum	Mean	Standard deviation	Count
61	06863300	BIG C NR OGALLAH, KS	0	6,720	22.7	166.86	4,383
62	06863500	BIG C NR HAYS, KS	0	10,600	28	179.97	25,933
63	06863900	NF BIG C NR VICTORIA, KS	0	4,380	3.33	56.222	9,131
64	06864000	SMOKY HILL R NR RUSSELL, KS	0	12,500	189	662.26	3,652
65	06864500	SMOKY HILL R AT ELLSWORTH, KS	1	41,800	212	794.35	13,952
66	06866000	SMOKY HILL R AT LINDSBORG, KS	0	24,000	241	764.67	9,693
67	06867000	SALINE R NR RUSSELL, KS	0.06	23,400	85.5	391.59	23,863
68	06867500	PARADISE C NR PARADISE, KS	0	8,350	18.4	147.84	8,075
69	06868000	SALINE R NR WILSON, KS	2	16,200	169	623.92	12,053
70	06868400	WOLF C NR LUCAS, KS	0.13	3,090	14.9	99.334	4,017
71	06869500	SALINE R AT TESCOTT, KS	0	47,600	250	881.41	15,660
72	06869950	MULBERRY C NR SALINA, KS	0	15,400	32.5	316.7	5,479
73	06871000	NF SOLOMON R AT GLADE, KS	0	10,900	25.6	152.84	23,376
74	06871500	BOW C NR STOCKTON, KS	0	4,990	15.1	93.238	24,107
75	06871800	NF SOLOMON R AT KIRWIN, KS	0	12,000	85.4	390.67	7,824
76	06871900	DEER C NR PHILLIPSBURG, KS	0	1,850	4.06	47.073	5,114
77	06873000	SF SOLOMON R AB WEBSTER RE, KS	0	35,000	47.1	365.6	26,208
78	06873500	SF SOLOMON R AT ALTON, KS	0	52,900	97.5	744.12	8,733
79	06873700	KILL C NR BLOOMINGTON, KS	0	685	1.93	17.412	6,575
80	06876000	SOLOMON R AT BELOIT, KS	0	113,000	456	2,156.20	9,131
81	06876700	SALT C NR ADA, KS	0	10,400	61.6	276.39	20,819
82	06876900	SOLOMON R AT NILES, KS	1	157,000	623	2,317.10	15,400
83	06877000	SMOKY HILL R AT SOLOMON, KS	25	18,400	958	1,834.60	5,113
84	06877600	SMOKY HILL R AT ENTERPRISE, KS	45	32,000	1,400	2,764.40	4,018
85	06878000	CHAPMAN C NR CHAPMAN, KS	0.2	12,600	86	350.86	23,011
86	06878500	LYON C NR WOODBINE, KS	0	17,200	105	529.99	7,305
87	06881000	BIG BLUE RIVER NEAR CRETE, NE	6	21,400	391	984.61	23,011
88	06881200	TURKEY CREEK NEAR WILBER, NE	0	13,100	95.4	393.34	12,418
89	06881380	TURKEY CREEK NEAR DEWITT, NE	−11.2	21,000	133	627.73	5,114
90	06881500	BIG BLUE R AT BEATRICE, NE	5	44,400	792	1,900.70	8,475

Table 7. Basic statistics for daily mean streamflows of U.S. Geological Survey streamgages used in the regression analysis (map numbers 1–126), computed using SWToolbox (Kiang and others, 2018).—Continued

[no., number; USGS, U.S. Geological Survey; NE, Nebraska; MO, Missouri; C, Creek; NR, near; KS, Kansas; CO, Colorado; R, River; SF, South Fork; ST, State; AB, above; NF, North Fork; BL, below; RE, Reservoir; L, Little; ST., Saint; ST, Street; BLVD, Boulevard; EXT, Exit; KC, Kansas City]

Map no. (fig. 1)	USGS station number	USGS station name	Minimum	Maximum	Mean	Standard deviation	Count
91	06882000	BIG BLUE RIVER AT BARNESTON, NE	1	50,000	842	2,084.60	30,681
92	06882500	BIG BLUE R AT HULL, KS	2	14,800	475	1,003.70	6,175
93	06882510	BIG BLUE R AT MARYSVILLE, KS	16.1	35,000	1,020	2,252.90	11,688
94	06883000	LITTLE BLUE RIVER NEAR DEWEESE, NE	2	14,300	135	414.26	22,645
95	06883570	LITTLE BLUE RIVER NEAR ALEXANDRIA (GILEAD), NE	2.9	16,300	234	626.3	11,119
96	06884000	LITTLE BLUE RIVER NEAR FAIRBURY, NE	14	43,700	365	1,110.60	34,150
97	06884025	LITTLE BLUE RIVER AT HOLLENBERG, KS	24.2	39,300	472	1,334.70	15,706
98	06884200	MILL C AT WASHINGTON, KS	0	10,000	98.3	382.96	20,819
99	06884400	L BLUE R NR BARNES, KS	21.1	46,100	653	1,657.50	21,185
100	06884500	L BLUE R AT WATERVILLE, KS	27	45,300	621	1,734.20	11,652
101	06885500	BLACK VERMILLION R NR FRANKFORT, KS	0	28,800	168	716.07	23,011
102	06886000	BIG BLUE R AT RANDOLPH, KS	42	75,000	1,670	3,975.90	14,976
103	06888000	VERMILLION C NR WAMEGO, KS	0	13,200	83.9	373.82	15,672
104	06888500	MILL C NR PAXICO, KS	0	21,700	184	692.69	23,011
105	06889120	SOLDIER C NR BANCROFT, KS	0	672	6.83	34.351	8,766
106	06889140	SOLDIER C NR SOLDIER, KS	0	1,920	10.6	55.544	12,418
107	06889160	SOLDIER C NR CIRCLEVILLE, KS	0.03	5,830	32.3	155.52	13,514
108	06889180	SOLDIER C NR ST. CLERE, KS	0.11	4,410	50	199.28	6,209
109	06889200	SOLDIER C NR DELIA, KS	0	24,900	92.3	412.93	21,185
110	06889500	SOLDIER C NR TOPEKA, KS	0	30,600	155	657.27	30,747
111	06890100	DELAWARE R NR MUSCOTAH, KS	0	26,000	257	995.87	17,167
112	06890500	DELAWARE R AT VALLEY FALLS, KS	0.1	55,200	383	1,598.90	16,071
113	06891260	WAKARUSA R NR RICHLAND, KS	0	15,800	91	420.34	5,114
114	06891500	WAKARUSA R NR LAWRENCE, KS	0	22,600	192	796.07	18,628
115	06891810	STRANGER C NR POTTER, KS	0.07	16,300	104	486.83	4,017
116	06892000	STRANGER C NR TONGANOXIE, KS	0	23,000	248	832.52	31,777
117	06892360	KILL C AT 95TH ST NR DESOTO, KS	0	2,450	35.1	134.61	5,114
118	06893080	BLUE R NR STANLEY, KS	0	5,520	36.4	169.21	15,341
119	06893150	BLUE RIVER AT BLUE RIDGE BLVD EXT IN KC, MO	1.1	5,920	85.7	275.36	4,863
120	06893300	INDIAN C AT OVERLAND PARK, KS	0	1,970	23.1	98.71	5,844

Table 7. Basic statistics for daily mean streamflows of U.S. Geological Survey streamgages used in the regression analysis (map numbers 1–126), computed using SWToolbox (Kiang and others, 2018).—Continued

[no., number; USGS, U.S. Geological Survey; NE, Nebraska; MO, Missouri; C, Creek; NR, near; KS, Kansas; CO, Colorado; R, River; SF, South Fork; ST, State; AB, above; NF, North Fork; BL, below; RE, Reservoir; L, Little; ST., Saint; ST, Street; BLVD, Boulevard; EXT, Exit; KC, Kansas City]

Map no. (fig. 1)	USGS station number	USGS station name	Minimum	Maximum	Mean	Standard deviation	Count
121	06893500	BLUE RIVER AT KANSAS CITY, MO	0	20,000	177	622.98	28,124
122	06893578	BLUE RIVER AT STADIUM DRIVE IN KANSAS CITY, MO	19.6	18,800	300	830.58	5,114
123	06893793	LITTLE BLUE RIVER BELOW LONGVIEW DAM AT KC, MO	0	3,940	39.5	163.82	6,210
124	06893890	EAST FORK LITTLE BLUE RIVER NEAR BLUE SPRINGS, MO	0	4,850	29.3	82.654	11,753
125	06894000	LITTLE BLUE RIVER NEAR LAKE CITY, MO	0	27,700	163	468.13	25,202
126	06894500	EAST FORK FISHING RIVER AT EXCELSIOR SPRINGS, MO	0	3,890	13.2	90.581	6,940

Table 8. Basic statistics for daily mean streamflows of U.S. Geological Survey streamgages used in the regression analysis (map numbers 127–254), computed using SWToolbox (Kiang and others, 2018).

[no., number; USGS, U.S. Geological Survey; MO, Missouri; R, River; NR, near; KS, Kansas; C, Creek; L, Little; CO, Colorado; HWY, Highway; NF, North Fork; AB, above; RE, Reservoir; SF, South Fork; OK, Oklahoma]

Map no. (fig. 1)	USGS station number	USGS station name	Minimum	Maximum	Mean	Standard deviation	Count
127	06895000	CROOKED RIVER NEAR RICHMOND, MO	0	17,900	120	488.54	11,687
128	06896500	THOMPSON BRANCH NEAR ALBANY, MO	0	400	2.91	16.064	5,844
129	06897000	EAST FORK BIG CREEK NEAR BETHANY, MO	0	6,200	54.8	214.49	21,182
130	06897500	GRAND RIVER NEAR GALLATIN, MO	2	85,500	1,310	3,913.80	34,699
131	06898100	THOMPSON RIVER AT MOUNT MORIAH, MO	8	18,100	519	1,198	5,844
132	06899700	SHOAL CREEK NEAR BRAYMER, MO	0	22,000	278	859.48	10,695
133	06907500	SOUTH FORK BLACKWATER RIVER NEAR ELM, MO	0	2,250	11.8	64.501	8,766
134	06910800	MARAIS DES CYGNES R NR READING, KS	0	25,000	103	508.97	17,167
135	06911000	MARAIS DES CYGNES R AT MELVERN, KS	0	39,400	195	925.66	11,688
136	06911490	SALT C AT LYNDON, KS	0	11,800	52.4	316.63	6,209
137	06911500	SALT C NR LYNDON, KS	0	17,600	65.4	338.76	21,549
138	06911900	DRAGOON C NR BURLINGAME, KS	0	14,800	65.5	350.27	20,819
139	06912500	HUNDRED AND TEN MILE C NR QUENEMO, KS	0	27,700	182	899.2	8,400
140	06913000	MARAIS DES CYGNES R NR POMONA, KS	0	29,500	328	1,434.50	5,114
141	06913500	MARAIS DES CYGNES R NR OTTAWA, KS	0	134,000	621	2,539.10	17,172
142	06914000	POTTAWATOMIE C NR GARNETT, KS	0	33,400	236	979.46	22,462
143	06914100	POTTAWATOMIE C NR SCIPIO, KS	0	58,700	234	1,222	5,479
144	06914950	BIG BULL C NR EDGERTON, KS	0	2,520	21.2	106.91	8,401
145	06914990	L BULL C NR SPRING HILL, KS	0	930	8.87	38.146	8,401
146	06915000	BIG BULL C NR HILLSDALE, KS	0	18,000	96.6	501.72	7,671
147	06916000	MARAIS DES CYGNES R AT TRADING POST, KS	0	141,000	1,600	4,848.20	10,592
148	06916500	BIG SUGAR C AT FARLINVILLE, KS	0	16,400	120	589.97	8,728
149	06917000	L OSAGE R AT FULTON, KS	0	51,800	237	966.68	24,837
150	06917060	LITTLE OSAGE RIVER AT HORTON, MO	0	43,700	364	1,197.50	6,210
151	06917240	MARMATON R NR UNIONTOWN, KS	0	8,710	68.4	279.91	5,844
152	06917380	MARMATON R NR MARMATON, KS	0	67,900	280	1,281.80	13,149
153	06917500	MARMATON R NR FORT SCOTT, KS	0	30,200	293	1,151.10	19,730
154	06917560	MARMATON RIVER NEAR RICHARDS, MO	0.11	35,300	470	1,438	4,018
155	06918060	MARMATON RIVER NEAR NEVADA, MO	0.03	33,800	944	2,232.40	4,748

Table 8. Basic statistics for daily mean streamflows of U.S. Geological Survey streamgages used in the regression analysis (map numbers 127–254), computed using SWToolbox (Kiang and others, 2018).—Continued

[no., number; USGS, U.S. Geological Survey; MO, Missouri; R, River; NR, near; KS, Kansas; C, Creek; L, Little; CO, Colorado; HWY, Highway; NF, North Fork; AB, above; RE, Reservoir; SF, South Fork; OK, Oklahoma]

Map no. (fig. 1)	USGS station number	USGS station name	Minimum	Maximum	Mean	Standard deviation	Count
156	06918070	OSAGE RIVER ABOVE SCHELL CITY, MO	0	153,000	5,240	9,698.70	9,329
157	06918460	TURNBACK CREEK ABOVE GREENFIELD, MO	4.48	23,700	259	554.58	18,628
158	06919000	SAC RIVER NEAR STOCKTON, MO	0	79,800	986	2,308.40	16,802
159	06919500	CEDAR CREEK NEAR PLEASANT VIEW, MO	0	28,300	329	1,040.20	25,931
160	06921590	SOUTH GRAND RIVER AT ARCHIE, MO	0	25,500	298	1,133.80	9,628
161	06921600	SOUTH GRAND RIVER AT URICH, MO	0	27,200	448	1,473.20	4,087
162	06921720	BIG CREEK NEAR BLAIRSTOWN, MO	0	20,800	342	1,060.90	8,533
163	06921760	SOUTH GRAND RIVER NEAR CLINTON, MO	2.02	59,900	1,070	3,291.50	7,075
164	06922000	SOUTH GRAND RIVER NEAR BROWNINGTON, MO	0	60,300	1,050	2,806.30	17,897
165	07134100	BIG SANDY CREEK NEAR LAMAR, CO	0	1,460	13.3	27.249	13,213
166	07139800	MULBERRY C NR DODGE CITY, KS	0	666	0.64	12.772	8,035
167	07140700	GUZZLERS GULCH NR NESS CITY, KS	0	1,020	2.08	26.35	6,940
168	07140850	PAWNEE R NR BURDETT, KS	0	3,830	9	87.74	12,784
169	07141175	BUCKNER C NR BURDETT, KS	0	2,750	13.6	91.146	6,209
170	07141200	PAWNEE R AT ROZEL, KS	0	14,300	54.6	354.09	33,575
171	07141770	WALNUT C NR ALEXANDER, KS	0	1,550	14.5	62.052	6,575
172	07141780	WALNUT C AT NEKOMA, KS	0	5,690	21.8	135.76	17,167
173	07141900	WALNUT C AT ALBERT, KS	0	10,300	43.7	224.44	21,185
174	07142300	RATTLESNAKE C NR MACKSVILLE, KS	0	7,330	20	85.207	20,819
175	07142575	RATTLESNAKE C NR ZENITH, KS	0	13,600	39	176.91	15,706
176	07143300	COW C NR LYONS, KS	0	16,800	76	354.84	25,157
177	07143600	L ARKANSAS R NR LITTLE RIVER, KS	0	1,190	9.09	53.982	4,017
178	07143665	L ARKANSAS R AT ALTA MILLS, KS	0	15,300	200	792.31	13,880
179	07143672	L ARKANSAS R AT HWY 50 NR HALSTEAD, KS	0	10,800	201	745.53	7,670
180	07144100	L ARKANSAS R NR SEDGWICK, KS	0.56	17,600	351	1,239.30	8,401
181	07144200	L ARKANSAS R AT VALLEY CENTER, KS	1.1	28,600	315	1,110.20	34,334
182	07144780	NF NINNESCAH R AB CHENEY RE, KS	0	39,700	139	516.96	18,628
183	07144800	NF NINNESCAH R NR CHENEY, KS	0	10,300	165	451.11	4,749
184	07145200	SF NINNESCAH R NR MURDOCK, KS	7.9	18,000	204	422.94	22,366
185	07145500	NINNESCAH R NR PECK, KS	0.2	33,700	555	1,287.50	9,131

Table 8. Basic statistics for daily mean streamflows of U.S. Geological Survey streamgages used in the regression analysis (map numbers 127–254), computed using SWToolbox (Kiang and others, 2018).—Continued

[no., number; USGS, U.S. Geological Survey; MO, Missouri; R, River; NR, near; KS, Kansas; C, Creek; L, Little; CO, Colorado; HWY, Highway; NF, North Fork; AB, above; RE, Reservoir; SF, South Fork; OK, Oklahoma]

Map no. (fig. 1)	USGS station number	USGS station name	Minimum	Maximum	Mean	Standard deviation	Count
186	07145700	SLATE C AT WELLINGTON, KS	0	10,600	75.7	356.35	17,532
187	07146570	COLE C NR DEGRAFF, KS	0	6,000	17.1	119.15	6,940
188	07147070	WHITEWATER R AT TOWANDA, KS	0.3	49,400	206	975.14	18,628
189	07147800	WALNUT R AT WINFIELD, KS	0	77,100	792	2,799.80	21,550
190	07148350	SALT FORK ARKANSAS RIVER NR WINCHESTER, OK	0	12,100	93.6	391.64	12,053
191	07148400	SALT FORK ARKANSAS RIVER NR ALVA, OK	0	17,000	125	435.86	18,627
192	07149000	MEDICINE LODGE R NR KIOWA, KS	0	9,660	146	338.56	25,994
193	07151500	CHIKASKIA R NR CORBIN, KS	0	27,800	256	841.86	20,454
194	07152000	CHIKASKIA RIVER NEAR BLACKWELL, OK	0	69,500	485	2,069.50	14,975
195	07153000	BLACK BEAR CREEK AT PAWNEE, OK	0	25,400	164	779.59	8,035
196	07153100	RANCH CREEK AT CLEV DAM NR CLEVELAND, OK	0	4,840	10.4	88.99	6,574
197	07155590	CIMARRON R NR ELKHART, KS	0	6,190	7.46	103.63	15,341
198	07156010	NF CIMARRON R AT RICHFIELD, KS	0	6,100	5.25	103.79	5,479
199	07157000	CIMARRON RIVER NEAR MOCANE, OK	0	17,900	97	316.42	8,036
200	07157500	CROOKED C NR ENGLEWOOD, KS	0	12,700	25.4	167.41	26,977
201	07157950	CIMARRON RIVER NEAR BUFFALO, OK	0	12,500	155	454.03	5,844
202	07157960	BUFFALO CREEK NEAR LOVEDALE, OK	0	3,830	12.9	85.981	9,497
203	07158000	CIMARRON RIVER NEAR WAYNOKA, OK	0	51,600	346	1,437.70	14,610
204	07159000	TURKEY CREEK NEAR DRUMMOND, OK	0	10,400	50.1	276.2	8,035
205	07165700	VERDIGRIS R NR MADISON, KS	0	11,900	129	470.87	7,305
206	07165750	VERDIGRIS R NR VIRGIL, KS	0	8,440	190	579.47	4,747
207	07166500	VERDIGRIS R NR ALTOONA, KS	0	57,000	665	2,486.90	7,305
208	07167000	FALL R NR EUREKA, KS	0	31,300	194	810.09	10,593
209	07167500	OTTER C AT CLIMAX, KS	0	21,700	85.6	488.59	25,568
210	07168500	FALL R AT FALL RIVER, KS	0	54,000	464	2248.5	4,170
211	07169500	FALL R AT FREDONIA, KS	0	39,300	536	1,944.40	3,653
212	07169800	ELK R AT ELK FALLS, KS	0	47,500	153	717.31	18,263
213	07170000	ELK R NR ELK CITY, KS	0	56,200	307	1,513.50	10,958

Table 8. Basic statistics for daily mean streamflows of U.S. Geological Survey streamgages used in the regression analysis (map numbers 127–254), computed using SWToolbox (Kiang and others, 2018).—Continued

[no., number; USGS, U.S. Geological Survey; MO, Missouri; R, River; NR, near; KS, Kansas; C, Creek; L, Little; CO, Colorado; HWY, Highway; NF, North Fork; AB, above; RE, Reservoir; SF, South Fork; OK, Oklahoma]

Map no. (fig. 1)	USGS station number	USGS station name	Minimum	Maximum	Mean	Standard deviation	Count
214	07170500	VERDIGRIS R AT INDEPENDENCE, KS	0	106,000	1,570	4,823.30	12,416
215	07170700	BIG HILL C NR CHERRYVALE, KS	0	10,700	27.3	183.33	7,670
216	07171000	VERDIGRIS RIVER NEAR LENAPAH, OK	0	134,000	2,720	7,465.10	3,653
217	07172000	CANEY R NR ELGIN, KS	0	79,200	282	1,180.40	28,124
218	07173000	CANEY RIVER NEAR HULAH, OK	0	31,900	398	1,578.80	4,383
219	07174000	LITTLE CANEY RIVER NEAR COPAN, OK	0	22,500	246	1,072.80	5,113
220	07174200	LITTLE CANEY RIVER BLW COTTON CR, NR COPAN, OK	0	22,000	278	943.3	7,671
221	07174600	SAND CREEK AT OKESA, OK	0	13,200	82.6	407.7	12,053
222	07176000	VERDIGRIS RIVER NEAR CLAREMORE, OK	0	181,000	4,020	10,398	4,748
223	07176500	BIRD CREEK AT AVANT, OK	0	28,500	197	959.41	11,323
224	07177000	HOMINY CREEK NEAR SKIATOOK, OK	0	30,000	179	842.23	13,500
225	07177500	BIRD CREEK NEAR SPERRY, OK	0	62,800	488	2,039.80	16,437
226	07179500	NEOSHO R AT COUNCIL GROVE, KS	0	34,000	123	848.84	9,132
227	07180000	COTTONWOOD R NR MARION, KS	0	30,600	115	654.39	10,593
228	07180500	CEDAR C NR CEDAR POINT, KS	0	10,900	59.9	284.08	28,490
229	07181500	M CREEK NR ELMDALE, KS	0	5,510	42.2	234.35	4,018
230	07182400	NEOSHO R AT STRAWN, KS	0	274,000	1,360	5,702.70	5,113
231	07183000	NEOSHO R NR IOLA, KS	0	344,000	1,600	5,292.50	18,443
232	07183100	OWL C NR PIQUA, KS	0	15,600	112	592.74	3,652
233	07183500	NEOSHO R NR PARSONS, KS	0	366,000	2,490	6,930.10	14,610
234	07184000	LIGHTNING C NR MCCUNE, KS	0	42,400	171	804.63	23,741
235	07184500	LABETTE C NR OSWEGO, KS	0	13,400	196	790.98	4,018
236	07185000	NEOSHO RIVER NEAR COMMERCE, OK	0	251,000	3,730	8,862.50	8,035
237	07185500	STAHL CREEK NEAR MILLER, MO	0	422	2.87	14.153	9,132
238	07185700	SPRING RIVER AT LA RUSSELL, MO	17	19,900	268	552.81	12,298
239	07185765	SPRING RIVER AT CARTHAGE, MO	12.1	28,700	409	918.95	10,743
240	07186000	SPRING RIVER NEAR WACO, MO	4.5	108,000	958	2,684.40	33,603
241	07186400	CENTER CREEK NEAR CARTERVILLE, MO	9.7	10,000	209	449.2	10,227
242	07187000	SHOAL CREEK ABOVE JOPLIN, MO	15	36,700	426	826.9	27,394

Table 8. Basic statistics for daily mean streamflows of U.S. Geological Survey streamgages used in the regression analysis (map numbers 127–254), computed using SWToolbox (Kiang and others, 2018).—Continued

[no., number; USGS, U.S. Geological Survey; MO, Missouri; R, River; NR, near; KS, Kansas; C, Creek; L, Little; CO, Colorado; HWY, Highway; NF, North Fork; AB, above; RE, Reservoir; SF, South Fork; OK, Oklahoma]

Map no. (fig. 1)	USGS station number	USGS station name	Minimum	Maximum	Mean	Standard deviation	Count
243	07187500	SHOAL CREEK NEAR JOPLIN, MO	16	12,000	398	673.78	6,209
244	07188000	SPRING RIVER NEAR QUAPAW, OK	5.8	169,000	2,010	4,923.90	16,436
245	07189500	NEOSHO RIVER NEAR GROVE, OK	34	130,000	6,250	12,135	5,113
246	07191000	BIG CABIN CREEK NEAR BIG CABIN, OK	0.1	46,300	325	1,465.60	13,879
247	07191222	BEATY CREEK NEAR JAY, OK	0	6,890	51.4	212.34	6,575
248	07192000	PRYOR CREEK NEAR PRYOR, OK	0	26,600	138	695.89	5,478
249	07232500	BEAVER RIVER NEAR GUYMON, OK	0	14,700	25.5	249.24	14,245
250	07233000	COLDWATER CREEK NEAR HARDESTY, OK	0	11,300	16.2	203.42	8,766
251	07234000	BEAVER RIVER AT BEAVER, OK	0	39,900	103	708.73	14,975
252	07234100	CLEAR CREEK NEAR ELMWOOD, OK	0	5,480	7.47	98.423	5,114
253	07234500	BEAVER RIVER NEAR FORT SUPPLY, OK	0	24,200	193	844.92	4,748
254	07236000	WOLF CREEK NEAR FARGO, OK	0	21,800	65.8	399.39	12,054

Flow-Duration Statistics

The flow-duration curve is a cumulative frequency curve that indicates the percentage of time a specified streamflow was equaled or exceeded during a given period (Searcy, 1959). Flow durations are first calculated by sorting individual flows for a period of record from the largest to the smallest value. Next, the frequencies of exceedance are then calculated using the Weibull formula for computing plotting position (Helsel and others, 2020):

$$P = 100 \cdot \left[\frac{M}{n+1}\right], \quad (1)$$

where

- P is the probability that a given flow will be equaled or exceeded (percentage),
- M is the ranked position (dimensionless), and
- n is the number of events for the period of record (dimensionless).

Flow durations summarize past hydrologic events and rank them in order; however, if the streamflow during the period for which the flow-duration curve is based is a suitably long period (at least 10 years, but 30 years or more is desirable), the statistics can be used as an indicator of likely future conditions (Searcy, 1959). Flow durations for this report were calculated using daily mean values of streamflow for complete water years through September 2017. Flow durations in this report were computed for the 0.01-, 0.1-, 2-, 5-, 10-, 25-, 50-, 75-, 90-, 95-, 99-, 99.9-, and 99.99-percent exceedance intervals. An example of a flow-duration curve is shown in figure 7, and in appendix 1, tables 1.1 and 1.2 provide the tabular calculations for all the streamgages used in this report.

Low-Flow Frequency Statistics

To estimate low-flow streamflows for selected recurrence intervals at streamgages in Kansas (for example, the 7Q10), a low-flow frequency analysis was done. For this report, low-flow frequencies were estimated for annual 1-, 7-, and 30-day flows at recurrence intervals of 5, 10, 20, and 50 years. Monthly (January, February, and so on) 1-, 7-, and 30-day flows at recurrence intervals of 5, 10, 20, and 50 years also were estimated. The magnitude and frequency of low flows are computed for a streamgage by relating a specific number of consecutive daily mean streamflows during a selected period (annually or monthly in this report) to a minimum nonexceedance probability or recurrence interval (Eash and Barnes, 2017).

n-Day Analysis

The low-flow frequency statistics in this report are based on the *n*-day, *Y*-year frequency statistic of daily mean streamflow for a climatic year. The climatic year (April 1–March 31) was used as the annual period for computing low-flow statistics. The climatic year is used for low-flow frequency investigation because low-flow events typically happen during the late summer through the winter months in Kansas. Use of the climatic year helps avoid the possibility of using one low-flow event that occurs during the fall months (September, October, and November) and has the potential to cross water years (October 1–September 30).

The mean streamflow for any *n*-day period throughout the climatic year is computed, and the minimum value is used for that period. The recurrence interval (expressed as *Y*-years) indicates the mean number of years between occurrences of a selected low-flow value; for example, the 7Q10 low-flow statistic is the annual minimum mean streamflow for 7 consecutive days that is expected to not be exceeded once during any 10-year period (Southard, 2013). This low-flow statistic naming convention does not indicate that a particular low-flow magnitude occurs on a regular yearly interval at a given streamgage. It can be more accurately described as a probability. The probability is the reciprocal of the annual nonexceedance interval, expressed as $1/Y$ (Southard, 2013); therefore, a 7Q10 is the 7-day annual minimum mean flow that has a 10-percent chance of occurring in any given year and for which the mean time between occurrences is 10 years.

An example of the 7Q10 statistic that shows the annual minimum 7-day mean flows for the USGS streamgage Little Blue River near Barnes, Kansas (06884400), between climatic years 1960 and 2017 is provided in figure 8. Also shown in figure 8 is the 7Q10 that was computed from those data. From figure 8, seven of the annual minimum 7-day mean flows fell to less than the calculated 7Q10. These seven occurrences are not evenly distributed across the time series. The first occurrence happens in 1965, but the second does not occur until 1989. The third occurrence happens shortly after the second (in 1992), but the fourth does not happen until 2007. The final three occurrences then happen consecutively between 2013 and 2015. As shown in figure 8, these statistics (the 7Q10 in this example) do not occur at a regular interval, but they have a probability of occurring each year.

For this report, low-flow frequencies were calculated for annual and monthly *n*-day durations of 1-, 7-, and 30-day intervals. Low-flow recurrence intervals were computed at 5, 10, 20, and 50 years, with the corresponding probabilities being 20, 10, 5, and 2 percent. A frequency examination was done on each *n*-day annual series using a log-Pearson Type III distribution, as indicated by Riggs (1972) and Barnes (1979). The computer program SWToolbox was used to compute the low-flow frequency statistics and fit them to a log-Pearson Type III distribution in this study. More detailed information on the log-Pearson Type III distribution is provided in “Guidelines for Determining Flood Flow Frequency—Bulletin 17C” (England

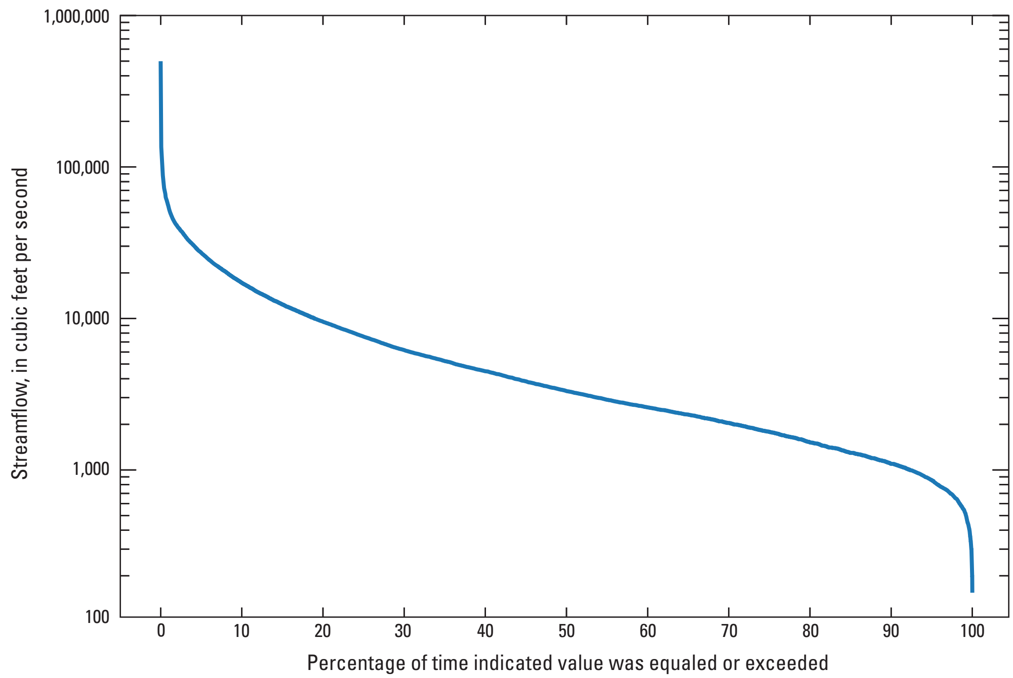

Figure 7. Flow-duration curve for the U.S. Geological Survey streamgage Kansas River at De Soto, Kansas (06892350).

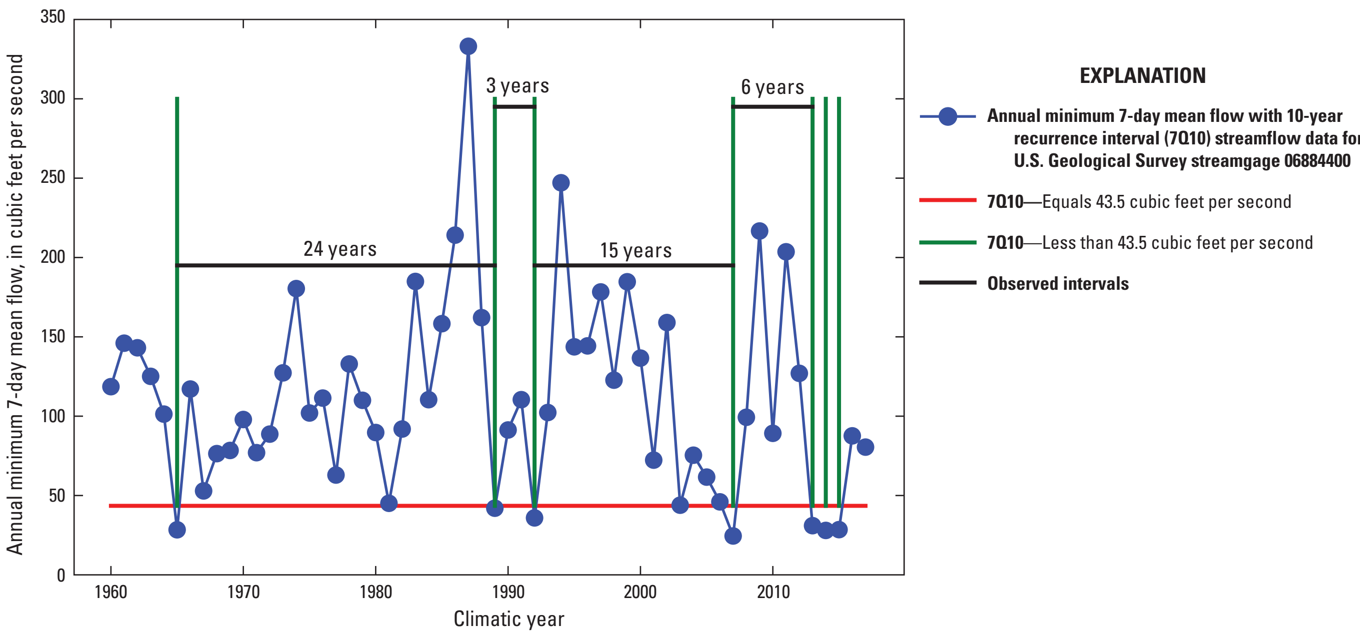

Figure 8. Annual minimum 7-day mean streamflow and calculated 7Q10 at U.S. Geological Survey streamgage Little Blue River near Barnes, Kansas (06884400).

and others, 2019). Data that were output by the software program SWToolbox were reviewed for quality assurance. In appendix 2, table 2.1 provides the low-flow frequency statistics for streamgages that were used in the regression analysis, table 2.2 provides the monthly low-flow frequency statistics for streamgages that were used in the regression analysis, and table 2.3 provides the low-flow frequency statistics for all the active streamgages in the State of Kansas.

Trend Analysis

The SWToolbox software program uses the Mann-Kendall test to test the time-series data for trends (for more information on this test, see Kendall [1938] and Helsel and others [2020]). This feature of SWToolbox was used for the time-series data in this report. The Mann-Kendall test was used to determine statistical significance of monotonic trends in annual 1-day, 7-day, and 30-day mean low flows with time. A trend was considered statistically significant for a probability value (*p*-value) of less than or equal to 0.05. SWToolbox also computes the Kendall's tau statistic to determine correlation. If the datasets indicate perfect positive correlation, then tau=1; if there is perfect negative correlation, then tau=−1; and if there is no correlation, then tau=0 (Gotvald, 2016).

An important limitation of the Mann-Kendall statistical test is when it is used on streamflow data that have a considerable number of days of zero flows. The tau and its corresponding *p*-value become undependable, and interpretation of these numbers becomes weak because of ties in the data (Barbie and others, 2012; Gotvald, 2016). The trend analysis of minimum 1-day mean flows for 17 streamgages, minimum 7-day mean flows for 14 streamgages, and minimum 30-day mean flows for 7 streamgages produced tau and *p*-values that may be difficult to interpret because of the presence of several zero flows. In appendix 2, table 2.4 lists the results of the Mann-Kendall statistical test for trends on the streamgages used in the regression analysis.

When reviewing hydrologic records over short-term periods of a few years to a few decades, trends commonly appear (Lins and others, 2010); however, when these records are reviewed in the context of decades to centuries, short-term trends may be recognized as being part of much longer term fluctuations (Lins and others, 2010). The Mann-Kendall test is more suitable for long-term hydrologic time-series records than short-term records. This test can be applied to shorter hydrologic time-series records; however, tests applied to shorter records may not deliver information that is useful. Mann-Kendall tests that are applied to shorter hydrologic time-series records may not identify a statistically significant trend even if a large increase or decrease in flow has occurred (Gotvald, 2016). Any trend identified by a test applied to a shorter time-series record may not indicate any practical importance (Gotvald, 2016); therefore, long-term hydrologic time-series records are better for trend assessments. Streamgages with 30 or more years of streamflow records are considered long-term streamgages by the USGS (U.S. Geological Survey, 2020); therefore, this study designates long-term streamgages as having at least 30 or more years of streamflow records.

The USGS streamgage Little Blue River near Barnes, Kans. (06884400), is a long-term streamgage that has a record length of 58 years. Although a linear regression curve, which was included to offer a visual representation of possible trends, shows a small downward slope for the annual minimum 7-day mean flow for the period of record from climatic year 1960 to 2017, the Mann-Kendall test indicated no statistically significant trend (table 2.4; fig. 9*A*). The criteria used to determine the significance of the trend was the *p*-value produced by the Mann-Kendall test. A *p*-value of 0.05 or below indicates a significant trend, whereas a *p*-value above 0.05 indicates a nonsignificant trend. To demonstrate how period of record and hydrologic conditions measured in that record can affect the trend assessment, a trend analysis for various subsets of the record was completed. For the 20-year period between 1968 and 1987, the analysis indicated an upward trend (tau=0.4211, *p*-value=0.0104; fig. 9*B*). For the 22-year period between 1994 and 2015, the analysis indicated a downward trend (tau=−0.3853, *p*-value=0.0131; fig. 9*C*). A trend analysis for the 30-year period from 1988 to 2017 indicated no significant trend (tau=−0.2, *p*-value=0.1250; fig. *D*). These results highlight the importance of long-term data-collection programs to accurately measure hydrologic trends.

Of the 254 streamgages used in the regression analysis, 77 indicated a significant trend for the 7-day annual minimum flow. An upward trend was seen at 56 streamgages, whereas a downward trend was observed at 21 streamgages. Of the 77 streamgages that indicated a significant trend, 47 had 30 years or more of streamflow record, whereas 30 had between 10 and 29 years of streamflow record. It is possible the trends observed at these streamgages are affected by changing climatological conditions within the study area. To evaluate the changes in climate in the study area, a Mann-Kendall test was completed on the annual mean air temperature and the annual measured precipitation for the State of Kansas and the National Oceanic and Atmospheric Administration, National Centers for Environmental Information climate divisions that are within or near Kansas.

The datasets for the annual mean air temperature and the annual measured precipitation contained data from 1895 to 2017. The data for air temperature and precipitation were obtained from the National Oceanic and Atmospheric Administration, National Centers for Environmental Information website (National Oceanic and Atmospheric Administration, National Centers for Environmental Information, 2020). There are 20 total climate divisions within the study area (fig. 10). The trend analysis for annual mean air temperature indicated that 17 of the 20 climate divisions indicate a significant upward trend (fig. 10). The Southeast (Kansas), West Ozarks (Missouri), and Northeast (Oklahoma) climate divisions indicated no significant trend in the observed air temperature data. Conversely, the trend analysis for the annual measured precipitation indicated that

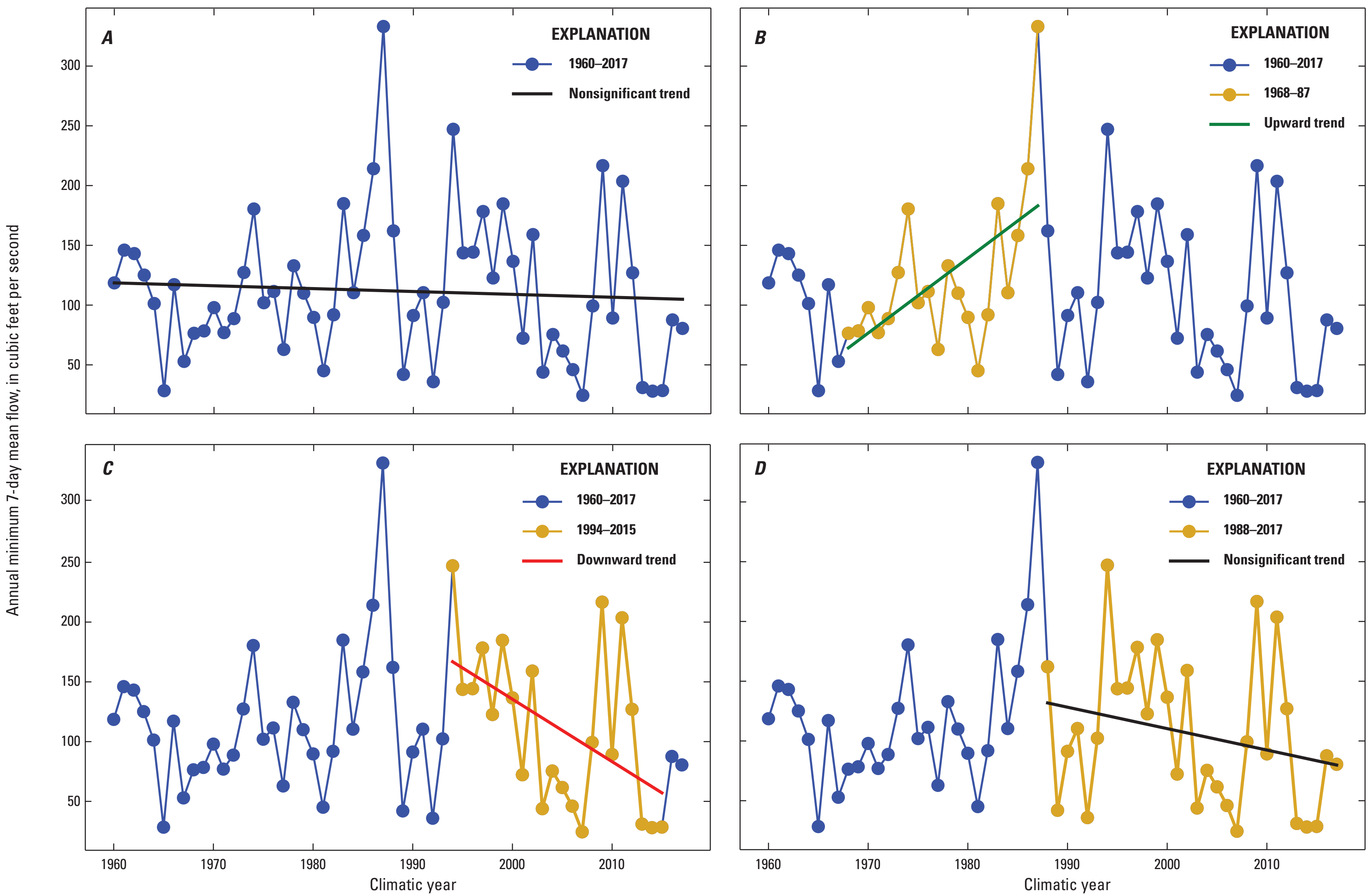

Figure 9. Selected periods of record for U.S. Geological Survey streamgage Little Blue River near Barnes, Kansas (06884400), for which a Mann-Kendall test for detection of trends was assessed. *A*, 1960–2017; *B*, 1968–87; *C*, 1994–2015; *D*, 1988–2017.

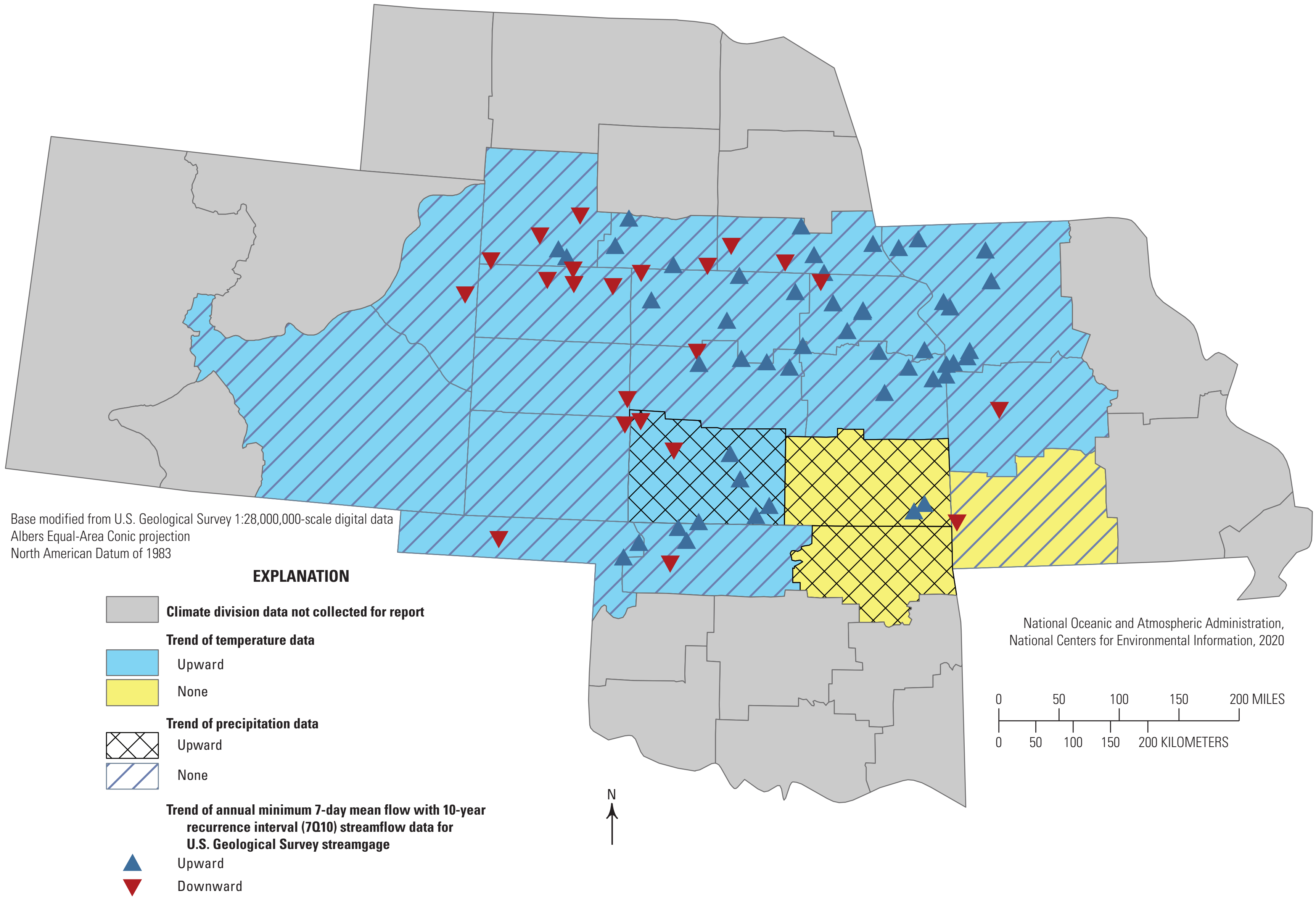

Figure 10. Annual mean temperature and annual mean precipitation trends by National Oceanic and Atmospheric Administration climate divisions within the study area, 1987–2017, and annual minimum 7-day mean flow with 10-year recurrence interval streamflow trends at streamgages for their period of record through 2017.

17 of the 20 climate divisions indicated no significant trend (fig. 10). The South Central (Kansas), Southeast (Kansas), and Northeast (Oklahoma) climate divisions indicated a significant upward trend for the precipitation data.

The upward trends in the climate data could explain the upward trends seen in the streamgages that indicate a similar trend; however, the trends in the climate data do not explain the downward trend observed at other streamgages. One potential source of effect on the streamgages with a downward trend is increased groundwater pumping. Juracek and others (2017) stated that a likely or possible diminished condition for streamflow in the Cimarron River and Rattlesnake Creek Basins, located in the Southwest (Kansas) and Northwest (Oklahoma) climate divisions, was caused by groundwater declines that result from groundwater pumping for irrigated agriculture. Shown in figure 4 are the streamgages in this report that indicate a significant trend for the annual minimum 7-day mean flow and the land uses near those streamgages.

An analysis of the causes of the trends in annual 1-day, 7-day, and 30-day low flows in Kansas is outside the scope of this report. Two recent extensive studies on the factors and trends affecting streamflows in Kansas have been published. Juracek (2015) and Juracek and Eng (2017) concluded that an annual precipitation explanation for changing streamflows in Kansas was not supported because of the lack of a trend in the precipitation data. Both studies also determined that groundwater pumping was the likely reason for lower streamflow conditions occurring in western and central Kansas. Juracek and Eng (2017) also noted that most streamgages that were determined to have a lower streamflow condition are in the western half of Kansas. Because of the presence of numerous zero flows in the dataset and several periods of record being less than 30 years in length, no streamflow data were excluded from this study because of the presence of a significant trend in streamflow.

Regression Equation Development

In a regional regression study, dividing a large study area into subregions that are fairly homogenous in terms of low-flow hydrology can help to reduce error in the regression equations (Eash and Barnes, 2017). Because two flow regions were developed in the Painter and others (2017) study, the same two flow regions were used in this study. Because of the presence of zero flows in the dataset, a multiple linear regression analysis could not be used because of the errors caused by log-transforming zero. Other regression techniques were explored, and the left-censored and logistic regression techniques were chosen as the most appropriate methods to deal with the substantial amount of zero flows in the dataset.

Multiple Linear Regression

Multiple linear regression analysis has been used by the USGS and other researchers throughout the United States and elsewhere to develop equations for estimating streamflow statistics at ungaged locations (Perry and others, 2004a). In a regression analysis, a streamflow statistic, also known as the dependent variable, for a collection of streamgages is correlated statistically to the basin characteristics, also known as the independent variables (Perry and others, 2004a). The result is an equation that can be used to estimate the streamflow statistic for locations where no streamflow data are present. Regression equations can be developed by using several types of multiple linear regression analyses. Choosing one analysis over another depends on the characteristics of the data to be used in the analysis and the assumptions made in that analysis. The multiple linear regression equation is represented by the following general formula:

$$Y_i = b_0 + b_1 X_1 + b_2 X_2 + \ldots + b_n X_n + e_i, \tag{2}$$

where

Y_i is the dependent variable for location i,
b_0 to b_n are the n+1 regression-model coefficients,
X_1 to X_n are the n independent variables, and
e_i is the error for location i (Perry and others, 2004a).

Assumptions for the use of multiple linear regression analyses are as follows:

1. the model adequately describes the linear relation between the dependent and independent variables,
2. the mean of e_i is zero,
3. the variance of e_i is constant and independent of the values of X_n,
4. the values of e_i are normally distributed, and
5. the values of e_i are independent of each other (Iman and Conover, 1983; Eash and Barnes, 2017).

Streamflow and basin characteristics are usually log-normally distributed when used in hydrologic regression analysis (Perry and others, 2004a). Logarithmic transformations of variables is usually required to satisfy regression assumption 4.

Left-Censored Regression

Left-censored regression, which also can be referred to as a Tobit analysis or Tobit regression, can be used to include zero values in an analysis that includes logarithmic transformation (Perry and others, 2004a). Censored data are data values that are less than a threshold value (Perry and other, 2004a) These censored values are then increased to the threshold value so that the data can be logarithmically transformed (Perry and others, 2004a). Left-censored regression is comparable to multiple linear regression, except the regression coefficients are fit via maximum-likelihood estimation (MLE; Eash and Barnes, 2017; Helsel and others, 2020). MLE is similar to a curve-matching procedure, where a probability distribution is best fitted to the observed data (Eash and Barnes, 2017). "MLE assumes that residuals are normally distributed around the regression line for the estimation of the slope and intercept, and the range of predicted values has constant variance" (Eash and Barnes, 2017, p. 26). More information on MLE is provided in Helsel and others (2020) and in Runkel and others (2004).

Logistic Regression

The response variable in a logistic regression is categorical or binary. In this study, a response value of zero was given to streamgages with no flow, and a response value of one was given to streamgages with flow. The probability of the response variable falling into one category or the other is examined to determine if it varies as a function of continuous independent variables (Eash and Barnes, 2017; Helsel and others, 2020). Computations from logistic regression will be between zero and one and are known as the probability (p) of observing a response of one, or predicting flow at an ungaged location to be greater than zero (Eash and Barnes, 2017); thus, $(1-p)$ is the probability of observing a response of zero or predicting zero flow at an ungaged location (Eash and Barnes, 2017). The form of the logistic regression equation to predict zero flow is as follows:

$$P_{zero} = 1 - (e^{a_0 + c_1V_1 + \ldots + c_nV_n} / 1 + e^{a_0 + c_1V_1 + \ldots + c_nV_n}), \qquad (3)$$

where

P_{zero} is the probability of the low-flow frequency statistic being zero;

a_0 is the regression-model constant;

e is the base of the natural logarithm value, approximately 2.7183;

c_1 to c_n are the regression-model coefficients; and

V_1 to V_n are the independent variables, or basin characteristics (Eash and Barnes, 2017).

Current applications of logistic regression that pertain to low-flow studies are provided in Funkhouser and others (2008), Martin and Arihood (2010), and Eash and Barnes (2017).

Final Regression Equations

Logistic and left-censored regression techniques were chosen for this study because several of the flow-duration and low-flow statistic values were calculated or estimated to be zero. The left-censored regression equations in this study were weighted based on the number of years of record available (Lorenz, 2014; Gotvald, 2017). Censored and uncensored values were used in the left-censored regression analyses. When datasets do not have censored values, weighted left-censored regression delivers the same results as weighted least squares regression (Gotvald, 2017; Helsel and others, 2020). Because of the ability of a streamgage to report continuous data lower than 0.1 cubic foot per second (ft^3/s), the censoring threshold used to develop the left-censored regression equations was set at 0.1 ft^3/s (Gotvald, 2017). Seven basin characteristics were used as independent variables in the final regression equations (table 6). These include contributing drainage area (CONTDA), BFI, crop land cover, mean soil permeability or saturated hydraulic conductivity of soil, reservoir storage, mean annual precipitation for 1895–2017 (PRECIPfull), and drainage basin slope. GIS software was required to measure most of the basin characteristics used as independent variables in the final regression equations in this report. The basin characteristics that were not measured with GIS software were BFI (Barlow and others, 2015) and PRECIPfull (PRISM Climate Group, 2020).

Final regression equations for the east and west regions of Kansas are listed in tables 9 and 10, along with the number of streamgages used in the regression analysis and select performance metrics. Explanations of the variables and their corresponding units of measure are listed in table 6. Most of the independent variables included in the final regression equations were statistically significant at the 95-percent confidence level and were not correlated with other independent variables used in the same equation. The only variable that was allowed outside of the 95-percent confidence interval was the CONTDA. This was done because including the CONTDA lowered the standard error (SE) of the equations when it was included. Because left-censored and logistic regression techniques were used to develop final equations, performance metrics are reported differently for each type of regression.

For the 17 logistic regression equations in the east region and the 43 logistic regression equations in the west region of Kansas, classification is reported, in percent, and the number of streamgages used to develop the equation also is listed. Classification is the predictive accuracy of streamgages correctly estimated to have zero flow. For the 53 left-censored regression equations in the east region and the 53 left-censored regression equations in the west region of Kansas, the SE, the SE range, and the pseudocoefficient of determination are reported, in percent. The number of streamgages censored in each analysis and the number of streamgages used to develop the equation also are listed.

The logistic regression equations in the east and west regions of Kansas (tables 9 and 10) should be used first to determine the probability of a specific low-flow statistic or flow-duration exceedance interval equaling zero for an ungaged location before the left-censored regression equation is used to estimate a specific low-flow statistic or flow-duration exceedance interval. If the resulting probability is greater than or equal to 0.5, then the value for that low-flow

Table 9. Regression equations for estimating selected low-flow frequency statistics for unregulated streams in the east region of Kansas.

[classification, percentage of time equation correctly predicts zero flow; SE, standard error; %, percent; RMSE, root mean square error; pseudo-R^2, pseudocoefficient of determination; 1Q10, 1-day mean flow with 10-year recurrence interval; Q, flow; Ann, annual; P_{zero}, probability of zero flow; *e*, base of natural logarithm, approximately equal to 2.7183; ln, natural logarithm; *CONTDA*, contributing drainage area; *BFI*, base-flow index; *LC06CROP*, percentage of crop land cover; NA, not applicable; 7Q10, 7-day mean flow with 10-year recurrence interval; 30Q10, 30-day mean flow with 10-year recurrence interval; *KSAT*, saturated hydraulic conductivity; *STORAGE*, percentage of reservoir storage; FD, flow duration; 99.99, 99.99% interval; 99.90, 99.90% interval; 99, 99% interval; 95, 95% interval; 90, 90% interval; 75, 75% interval; 50, 50% interval; 25, 25% interval; *PRECIPfull*, mean annual precipitation for 1895–2017; 10, 10% interval; 5, 5% interval; 2, 2% interval; 0.1, 0.1% interval; 0.01, 0.01% interval]

East (region 1) flow statistic	Regression model	Regression type	Performance metrics					
			Classification	SE (%)	RMSE	Pseudo-R^2	Number censored	Number of streamgages
1Q10_Ann_P_{zero}*	$1-(e^{1.27+0.04\ln(CONTDA)+2.59\ln(BFI)+0.75\ln(LC06CROP)}/1+e^{1.27+0.04\ln(CONTDA)+2.59\ln(BFI)+0.75\ln(LC06CROP)})$	Logistic	75.3	NA	NA	NA	NA	181
7Q10_Ann_P_{zero}*	$1-(e^{0.97+0.06\ln(CONTDA)+2.42\ln(BFI)+0.82\ln(LC06CROP)}/1+e^{0.97+0.06\ln(CONTDA)+2.42\ln(BFI)+0.82\ln(LC06CROP)})$	Logistic	79.2	NA	NA	NA	NA	181
30Q10_Ann_P_{zero}*	$1-(e^{1.30+0.23\ln(CONTDA)+2.10\ln(BFI)+0.51\ln(LC06CROP)}/1+e^{1.30+0.23\ln(CONTDA)+2.10\ln(BFI)+0.51\ln(LC06CROP)})$	Logistic	87.6	NA	NA	NA	NA	181
1Q10_Ann	$0.42+0.96\ln(CONTDA)-0.81\ln(KSAT)+5.06\ln(BFI)$	Left censored	NA	1,485	2.32	0.7229	100	181
7Q10_Ann	$-0.16+1.01\ln(CONTDA)-0.73\ln(KSAT)+4.55\ln(BFI)$	Left censored	NA	1,133	2.20	0.7229	94	181
30Q10_Ann	$0.20+0.81\ln(CONTDA)-0.77(KSAT)+4.10\ln(BFI)+0.40\ln(LC06CROP)$	Left censored	NA	556.9	1.86	0.7518	75	181
1Q10_January	$-0.62+0.79\ln(CONTDA)+2.37\ln(BFI)$	Left censored	NA	200.6	1.27	0.7753	34	181
7Q10_January	$-0.73+0.82\ln(CONTDA)+2.28\ln(BFI)$	Left censored	NA	193.4	1.25	0.7814	30	181
30Q10_January	$-0.54+0.81\ln(CONTDA)+1.99(BFI)$	Left censored	NA	175.5	1.19	0.7737	20	181
1Q10_February	$-0.75+0.79\ln(CONTDA)+2.04\ln(BFI)$	Left censored	NA	204.4	1.28	0.7462	29	181
7Q10_February	$-0.68+0.81\ln(CONTDA)+1.98\ln(BFI)$	Left censored	NA	193.3	1.25	0.7547	25	181
30Q10_February	$-0.29+0.77\ln(CONTDA)+1.54\ln(BFI)$	Left censored	NA	161.3	1.13	0.7413	9	181
1Q10_March	$-0.65+0.82\ln(CONTDA)+1.89\ln(BFI)$	Left censored	NA	194.9	1.25	0.7477	22	181

Table 9. Regression equations for estimating selected low-flow frequency statistics for unregulated streams in the east region of Kansas.—Continued

[classification, percentage of time equation correctly predicts zero flow; SE, standard error; %, percent; RMSE, root mean square error; pseudo-R^2, pseudocoefficient of determination; 1Q10, 1-day mean flow with 10-year recurrence interval; Q, flow; Ann, annual; P_{zero}, probability of zero flow; *e*, base of natural logarithm, approximately equal to 2.7183; ln, natural logarithm; *CONTDA*, contributing drainage area; *BFI*, base-flow index; *LC06CROP*, percentage of crop land cover; NA, not applicable; 7Q10, 7-day mean flow with 10-year recurrence interval; 30Q10, 30-day mean flow with 10-year recurrence interval; *KSAT*, saturated hydraulic conductivity; *STORAGE*, percentage of reservoir storage; FD, flow duration; 99.99, 99.99% interval; 99.90, 99.90% interval; 99, 99% interval; 95, 95% interval; 90, 90% interval; 75, 75% interval; 50, 50% interval; 25, 25% interval; *PRECIPfull*, mean annual precipitation for 1895–2017; 10, 10% interval; 5, 5% interval; 2, 2% interval; 0.1, 0.1% interval; 0.01, 0.01% interval]

East (region 1) flow statistic	Regression model	Regression type	Performance metrics					
			Classification	SE (%)	RMSE	Pseudo-R^2	Number censored	Number of streamgages
7Q10_March	−0.56+0.82ln(*CONTDA*) +1.78ln(*BFI*)	Left censored	NA	177.3	1.19	0.7573	17	181
30Q10_March	−0.70+0.80ln(*CONTDA*) +1.10ln(*BFI*)	Left censored	NA	153.9	1.10	0.7189	6	181
1Q10_April	−0.83+0.81ln(*CONTDA*) +1.63ln(*BFI*)	Left censored	NA	196.7	1.29	0.7204	19	181
7Q10_April	−0.80+0.81ln(*CONTDA*) +1.38ln(*BFI*)	Left censored	NA	149.3	1.08	0.7552	8	181
30Q10_April	−0.27+0.71ln(*CONTDA*) +0.57ln(*BFI*)+0.39ln (*STORAGE*)	Left censored	NA	123.5	0.96	0.6917	2	177
1Q10_May	0.34+0.88ln(*CONTDA*) +1.74ln(*BFI*)−0.45ln(*KSAT*) −0.20ln(*LC06CROP*)	Left censored	NA	163.3	1.14	0.7478	15	181
7Q10_May	0.37+0.90ln(*CONTDA*) +1.54ln(*BFI*)−0.45ln(*KSAT*) −0.22ln(*LC06CROP*)	Left censored	NA	132.7	1.01	0.7791	11	181
30Q10_May	−0.27+0.72ln(*CONTDA*) +0.41ln(*BFI*)+0.40ln (*STORAGE*)	Left censored	NA	113.7	0.91	0.7037	3	177
1Q10_June	−0.23+0.93ln(*CONTDA*) +2.17ln(*BFI*)−0.67ln(*KSAT*)	Left censored	NA	190.7	1.24	0.7654	24	181
7Q10_June	0.01−0.90ln(*CONTDA*) +1.90ln(*BFI*)−0.63ln(*KSAT*)	Left censored	NA	138.3	1.03	0.8019	13	181
30Q10_June	0.17+0.85ln(*CONTDA*) +0.86ln(*BFI*)−0.47ln(*KSAT*) +0.25ln(*STORAGE*)	Left censored	NA	80.17	0.71	0.8373	1	177
1Q10_July_P_{zero}	$1-(e^{0.69+0.33\ln(CONTDA)+1.89\ln(BFI)+0.44\ln(LC06CROP)}/1+e^{0.69+0.33\ln(CONTDA)+1.89\ln(BFI)+0.44\ln(LC06CROP)})$	Logistic	89.4	NA	NA	NA	NA	177

Table 9. Regression equations for estimating selected low-flow frequency statistics for unregulated streams in the east region of Kansas.—Continued

[classification, percentage of time equation correctly predicts zero flow; SE, standard error; %, percent; RMSE, root mean square error; pseudo-R^2, pseudocoefficient of determination; 1Q10, 1-day mean flow with 10-year recurrence interval; Q, flow; Ann, annual; P_{zero}, probability of zero flow; *e*, base of natural logarithm, approximately equal to 2.7183; ln, natural logarithm; *CONTDA*, contributing drainage area; *BFI*, base-flow index; *LC06CROP*, percentage of crop land cover; NA, not applicable; 7Q10, 7-day mean flow with 10-year recurrence interval; 30Q10, 30-day mean flow with 10-year recurrence interval; *KSAT*, saturated hydraulic conductivity; *STORAGE*, percentage of reservoir storage; FD, flow duration; 99.99, 99.99% interval; 99.90, 99.90% interval; 99, 99% interval; 95, 95% interval; 90, 90% interval; 75, 75% interval; 50, 50% interval; 25, 25% interval; *PRECIPfull*, mean annual precipitation for 1895–2017; 10, 10% interval; 5, 5% interval; 2, 2% interval; 0.1, 0.1% interval; 0.01, 0.01% interval]

East (region 1) flow statistic	Regression model	Regression type	Performance metrics					
			Classification	SE (%)	RMSE	Pseudo-R^2	Number censored	Number of streamgages
7Q10_July_P_{zero}	$1-(e^{-0.84+0.77\ln(CONTDA)+1.99\ln(BFI)+0.49\ln(LC06CROP)}/1+e^{-0.84+0.77\ln(CONTDA)+1.99\ln(BFI)+0.49\ln(LC06CROP)})$	Logistic	97.1	NA	NA	NA	NA	176
1Q10_July	$0.06+1.00\ln(CONTDA)+3.64\ln(BFI)-0.86\ln(KSAT)$	Left censored	NA	508.9	1.81	0.7362	67	181
7Q10_July	$-0.86+1.06\ln(CONTDA)+2.97\ln(BFI)-0.80\ln(KSAT)$	Left censored	NA	427.4	1.72	0.7243	56	181
30Q10_July	$-0.61+1.01\ln(CONTDA)+1.91\ln(BFI)-0.62\ln(KSAT)$	Left censored	NA	138.3	1.03	0.8262	15	181
1Q10_August_P_{zero}*	$1-(e^{0.63+0.21\ln(CONTDA)+2.15\ln(BFI)+0.62\ln(LC06CROP)}/1+e^{0.63+0.21\ln(CONTDA)+2.15\ln(BFI)+0.62\ln(LC06CROP)})$	Logistic	82.2	NA	NA	NA	NA	181
7Q10_August_P_{zero}	$1-(e^{-0.81+0.51\ln(CONTDA)+1.93\ln(BFI)+0.62\ln(LC06CROP)}/1+e^{-0.81+0.51\ln(CONTDA)+1.93\ln(BFI)+0.62\ln(LC06CROP)})$	Logistic	88.6	NA	NA	NA	NA	181
1Q10_August	$-0.22+1.05\ln(CONTDA)+4.33\ln(BFI)-0.78\ln(KSAT)$	Left censored	NA	873	2.08	0.7359	87	181
7Q10_August	$-2.48+0.79\ln(CONTDA)+2.79\ln(BFI)+0.42\ln(LC06CROP)$	Left censored	NA	562.7	1.87	0.689	68	181
30Q10_August	$-1.17+1.03\ln(CONTDA)+2.33\ln(BFI)-0.47\ln(KSAT)$	Left censored	NA	223.3	1.34	0.7667	31	177
1Q10_September_P_{zero}	$1-(e^{0.38+0.31\ln(CONTDA)+2.27\ln(BFI)+0.56\ln(LC06CROP)}/1+e^{0.38+0.31\ln(CONTDA)+2.27\ln(BFI)+0.56\ln(LC06CROP)})$	Logistic	84.8	NA	NA	NA	NA	181
7Q10_September_P_{zero}	$1-(e^{0.70+0.47\ln(CONTDA)+1.67\ln(BFI)}/1+e^{0.70+0.47\ln(CONTDA)+1.67\ln(BFI)})$	Logistic	91.1	NA	NA	NA	NA	181
1Q10_September	$-0.38+0.87\ln(CONTDA)+4.32\ln(BFI)-0.72\ln(KSAT)+0.37\ln(LC06CROP)$	Left censored	NA	928.4	2.11	0.726	84	181
7Q10_September	$-0.74+0.95\ln(CONTDA)+3.80\ln(BFI)-0.77\ln(KSAT)+0.32\ln(LC06CROP)$	Left censored	NA	577.8	1.88	0.746	73	181

Table 9. Regression equations for estimating selected low-flow frequency statistics for unregulated streams in the east region of Kansas.—Continued

[classification, percentage of time equation correctly predicts zero flow; SE, standard error; %, percent; RMSE, root mean square error; pseudo-R^2, pseudocoefficient of determination; 1Q10, 1-day mean flow with 10-year recurrence interval; Q, flow; Ann, annual; P_{zero}, probability of zero flow; *e*, base of natural logarithm, approximately equal to 2.7183; ln, natural logarithm; *CONTDA*, contributing drainage area; *BFI*, base-flow index; *LC06CROP*, percentage of crop land cover; NA, not applicable; 7Q10, 7-day mean flow with 10-year recurrence interval; 30Q10, 30-day mean flow with 10-year recurrence interval; *KSAT*, saturated hydraulic conductivity; *STORAGE*, percentage of reservoir storage; FD, flow duration; 99.99, 99.99% interval; 99.90, 99.90% interval; 99, 99% interval; 95, 95% interval; 90, 90% interval; 75, 75% interval; 50, 50% interval; 25, 25% interval; *PRECIPfull*, mean annual precipitation for 1895–2017; 10, 10% interval; 5, 5% interval; 2, 2% interval; 0.1, 0.1% interval; 0.01, 0.01% interval]

East (region 1) flow statistic	Regression model	Regression type	Performance metrics					
			Classification	SE (%)	RMSE	Pseudo-R^2	Number censored	Number of streamgages
30Q10_September	$-1.00+1.06\ln(CONTDA)+2.62\ln(BFI)-0.60\ln(KSAT)$	Left censored	NA	266.6	1.45	0.7561	37	177
1Q10_October_P_{zero}*	$1-(e^{0.33+0.27\ln(CONTDA)+2.10\ln(BFI)+0.60\ln(LC06CROP)}/1+e^{0.33+0.27\ln(CONTDA)+2.10\ln(BFI)+0.60\ln(LC06CROP)})$	Logistic	82.4	NA	NA	NA	NA	181
7Q10_October_P_{zero}	$1-(e^{0.48+0.33\ln(CONTDA)+2.08\ln(BFI)+0.56\ln(LC06CROP)}/1+e^{0.48+0.33\ln(CONTDA)+2.08\ln(BFI)+0.56\ln(LC06CROP)})$	Logistic	87.4	NA	NA	NA	NA	181
1Q10_October	$0.17+0.74\ln(CONTDA)+4.44\ln(BFI)-0.61\ln(KSAT)+0.53\ln(LC06CROP)$	Left censored	NA	756	2.02	0.7462	82	181
7Q10_October	$-0.05+0.83\ln(CONTDA)+4.12\ln(BFI)-0.72\ln(KSAT)+0.47\ln(LC06CROP)$	Left censored	NA	573.8	1.88	0.7589	74	181
30Q10_October	$0.37+0.78\ln(CONTDA)+3.36\ln(BFI)-0.55\ln(KSAT)+0.32\ln(LC06CROP)$	Left censored	NA	320.8	1.56	0.7683	51	181
1Q10_November_P_{zero}*	$1-(e^{2.56+0.20\ln(CONTDA)+2.53\ln(BFI)+0.53\ln(LC06CROP)}/1+e^{2.56+0.20\ln(CONTDA)+2.53\ln(BFI)+0.53\ln(LC06CROP)})$	Logistic	92.4	NA	NA	NA	NA	181
7Q10_November_P_{zero}	$1-(e^{1.47+0.43\ln(CONTDA)+2.27\ln(BFI)+0.43\ln(LC06CROP)}/1+e^{1.47+0.43\ln(CONTDA)+2.27\ln(BFI)+0.43\ln(LC06CROP)})$	Logistic	94.3	NA	NA	NA	NA	181
1Q10_November	$0.27+0.54\ln(CONTDA)+3.31\ln(BFI)+0.43\ln(LC06CROP)$	Left censored	NA	377.6	1.65	0.7328	61	181
7Q10_November	$0.38+0.57\ln(CONTDA)+3.29\ln(BFI)+0.43\ln(LC06CROP)$	Left censored	NA	334.3	1.58	0.754	55	181
30Q10_November	$-0.69+0.73\ln(CONTDA)+2.42\ln(BFI)+0.28\ln(LC06CROP)$	Left censored	NA	242.3	1.39	0.7536	31	181

Table 9. Regression equations for estimating selected low-flow frequency statistics for unregulated streams in the east region of Kansas.—Continued

[classification, percentage of time equation correctly predicts zero flow; SE, standard error; %, percent; RMSE, root mean square error; pseudo-R^2, pseudocoefficient of determination; 1Q10, 1-day mean flow with 10-year recurrence interval; Q, flow; Ann, annual; P_{zero}, probability of zero flow; *e*, base of natural logarithm, approximately equal to 2.7183; ln, natural logarithm; *CONTDA*, contributing drainage area; *BFI*, base-flow index; *LC06CROP*, percentage of crop land cover; NA, not applicable; 7Q10, 7-day mean flow with 10-year recurrence interval; 30Q10, 30-day mean flow with 10-year recurrence interval; *KSAT*, saturated hydraulic conductivity; *STORAGE*, percentage of reservoir storage; FD, flow duration; 99.99, 99.99% interval; 99.90, 99.90% interval; 99, 99% interval; 95, 95% interval; 90, 90% interval; 75, 75% interval; 50, 50% interval; 25, 25% interval; *PRECIPfull*, mean annual precipitation for 1895–2017; 10, 10% interval; 5, 5% interval; 2, 2% interval; 0.1, 0.1% interval; 0.01, 0.01% interval]

East (region 1) flow statistic	Regression model	Regression type	Performance metrics					
			Classification	SE (%)	RMSE	Pseudo-R^2	Number censored	Number of streamgages
1Q10_December	$-0.38+0.68\ln(CONTDA)+2.62\ln(BFI)+0.21\ln(LC06CROP)$	Left censored	NA	221.1	1.33	0.7696	41	181
7Q10_December	$-0.66+0.72\ln(CONTDA)+2.52\ln(BFI)+0.25\ln(LC06CROP)$	Left censored	NA	224.5	1.34	0.7704	37	181
30Q10_December	$-0.92+0.79\ln(CONTDA)+2.09\ln(BFI)+0.15\ln(LC06CROP)$	Left censored	NA	194.4	1.25	0.7537	22	175
FD_99.99_P_{zero}	$1-(e^{-0.13+0.30\ln(CONTDA)+1.89\ln(BFI)}/1+e^{-0.13+0.30\ln(CONTDA)+1.89\ln(BFI)})$	Logistic	56.4	NA	NA	NA	NA	181
FD_99.90_P_{zero}*	$1-(e^{0.47+0.07\ln(CONTDA)+2.38\ln(BFI)+0.59\ln(LC06CROP)}/1+e^{0.47+0.07\ln(CONTDA)+2.38\ln(BFI)+0.59\ln(LC06CROP)})$	Logistic	69.2	NA	NA	NA	NA	181
FD_99_P_{zero}	$1-(e^{1.69+0.28\ln(CONTDA)+2.01\ln(BFI)}/1+e^{1.69+0.28\ln(CONTDA)+2.01\ln(BFI)})$	Logistic	78.6	NA	NA	NA	NA	181
FD_95_P_{zero}	$1-(e^{2.99+0.34\ln(CONTDA)+2.92\ln(BFI)+0.44\ln(LC06CROP)}/1+e^{2.99+0.34\ln(CONTDA)+2.92\ln(BFI)+0.44\ln(LC06CROP)})$	Logistic	94.2	NA	NA	NA	NA	181
FD_99.99	$-3.35+0.99\ln(CONTDA)+5.05\ln(BFI)$	Left censored	NA	13,270	3.13	0.6274	130	181
FD_99.90	$-0.43+1.09\ln(CONTDA)+6.24\ln(BFI)-0.86\ln(KSAT)$	Left censored	NA	6,074	2.87	0.6925	116	176
FD_99	$-1.44+0.66\ln(CONTDA)+3.76\ln(BFI)+0.58\ln(LC06CROP)$	Left censored	NA	1,079	2.18	0.6845	83	181
FD_95	$-1.46+0.75\ln(CONTDA)+2.73\ln(BFI)+0.36\ln(LC06CROP)$	Left censored	NA	372.5	1.64	0.7241	53	181
FD_90	$-0.36+0.85\ln(CONTDA)+2.61\ln(BFI)-0.39\ln(KSAT)+0.20\ln(LC06CROP)$	Left censored	NA	229.4	1.35	0.754	30	175

Table 9. Regression equations for estimating selected low-flow frequency statistics for unregulated streams in the east region of Kansas.—Continued

[classification, percentage of time equation correctly predicts zero flow; SE, standard error; %, percent; RMSE, root mean square error; pseudo-R^2, pseudocoefficient of determination; 1Q10, 1-day mean flow with 10-year recurrence interval; Q, flow; Ann, annual; P_{zero}, probability of zero flow; *e*, base of natural logarithm, approximately equal to 2.7183; ln, natural logarithm; *CONTDA*, contributing drainage area; *BFI*, base-flow index; *LC06CROP*, percentage of crop land cover; NA, not applicable; 7Q10, 7-day mean flow with 10-year recurrence interval; 30Q10, 30-day mean flow with 10-year recurrence interval; *KSAT*, saturated hydraulic conductivity; *STORAGE*, percentage of reservoir storage; FD, flow duration; 99.99, 99.99% interval; 99.90, 99.90% interval; 99, 99% interval; 95, 95% interval; 90, 90% interval; 75, 75% interval; 50, 50% interval; 25, 25% interval; *PRECIPfull*, mean annual precipitation for 1895–2017; 10, 10% interval; 5, 5% interval; 2, 2% interval; 0.1, 0.1% interval; 0.01, 0.01% interval]

East (region 1) flow statistic	Regression model	Regression type	Performance metrics					
			Classification	SE (%)	RMSE	Pseudo-R^2	Number censored	Number of streamgages
FD_75	0.36+0.82ln(*CONTDA*) +1.65ln(*BFI*)−0.33ln(*KSAT*)	Left censored	NA	93.43	0.79	0.8447	2	176
FD_50	1.22+0.77ln(*CONTDA*) +1.06ln(*BFI*)−0.46ln(*KSAT*) +0.21ln(*STORAGE*)	Left censored	NA	73.63	0.66	0.8557	1	181
FD_25	−16.20+0.94ln(*CONTDA*) +4.27ln(*PRECIPfull*)	Left censored	NA	55.17	0.52	0.8953	0	181
FD_10	−16.12+0.90ln(*CONTDA*) +0.11ln(*STORAGE*) +4.61ln(*PRECIPfull*)	Left censored	NA	39.62	0.36	0.9395	0	181
FD_5	−15.09+0.86ln(*CONTDA*) +0.15ln(*STORAGE*) +4.61ln(*PRECIPfull*)	Left censored	NA	36.93	0.36	0.9432	0	181
FD_2	−10.19+0.70ln(*CONTDA*) +0.08ln(*STORAGE*) +3.91ln(*PRECIPfull*)	Left censored	NA	37.41	0.36	0.9116	0	177
FD_0.1	−6.24+0.64ln(*CONTDA*) +3.22ln(*PRECIPfull*)	Left censored	NA	38.21	0.37	0.8867	0	181
FD_0.01	−3.70+0.58ln(*CONTDA*) +0.11ln(*STORAGE*) +2.80ln(*PRECIPfull*)	Left censored	NA	42.58	0.41	0.8456	0	178
Mean_Ann_Q	−14.2+0.82ln(*CONTDA*) +4.08ln(*PRECIPfull*)	Left censored	NA	33.19	0.32	0.944	0	181

**CONTDA* was not statistically significant but was included in the model.

Table 10. Regression equations for estimating selected low-flow frequency statistics for unregulated streams in the west region of Kansas.

[classification, percentage of time equation correctly predicts zero flow; SE, standard error; %, percent; RMSE, root mean square error; pseudo-R^2, pseudocoefficient of determination; 1Q10, 1-day mean flow with 10-year recurrence interval; Q, flow; Ann, annual; P_{zero}, probability of zero flow; *e*, base of natural logarithm, approximately equal to 2.7183; ln, natural logarithm; *CONTDA*, contributing drainage area; *BFI*, base-flow index; *SLOPE*, mean basin slope; NA, not applicable; 7Q10, 7-day mean flow with 10-year recurrence interval; 30Q10, 30-day mean flow with 10-year recurrence interval; *KSAT*, saturated hydraulic conductivity; FD, flow duration; 99.99, 99.99% interval; 99.90, 99.90% interval; 99, 99% interval; 95, 95% interval; 90, 90% interval; 75, 75% interval; 50, 50% interval; 25, 25% interval; 10, 10% interval; 5, 5% interval; *PRECIPfull*, mean annual precipitation for 1895–2017; 2, 2% interval; 0.1, 0.1% interval; 0.01, 0.01% interval]

West (region 2) flow statistic	Regression model	Regression type	Performance metrics					
			Classification	SE (%)	RMSE	Pseudo-R^2	Number censored	Number of streamgages
1Q10_Ann_P_{zero}*	$1-(e^{-2.09+0.10\ln(CONTDA)+5.08\ln(BFI)+3.75\ln(SLOPE)}/1+e^{-2.09+0.10\ln(CONTDA)+5.08\ln(BFI)+3.75\ln(SLOPE)})$	Logistic	62.5	NA	NA	NA	NA	71
7Q10_Ann_P_{zero}*	$1-(e^{-1.12+0.16\ln(CONTDA)+3.43\ln(BFI)+2.08\ln(SLOPE)}/1+e^{-1.12+0.16\ln(CONTDA)+3.43\ln(BFI)+2.08\ln(SLOPE)})$	Logistic	63.6	NA	NA	NA	NA	73
30Q10_Ann_P_{zero}*	$1-(e^{1.38+0.17\ln(CONTDA)+3.24\ln(BFI)}/1+e^{1.38+0.17\ln(CONTDA)+3.24\ln(BFI)})$	Logistic	65.4	NA	NA	NA	NA	73
1Q10_Ann*	$1.76-0.52\ln(CONTDA)+7.56\ln(BFI)+2.32\ln(SLOPE)$	Left censored	NA	2,649	2.56	0.819	53	66
7Q10_Ann*	$0.40-0.36\ln(CONTDA)+6.43\ln(BFI)+2.44\ln(SLOPE)$	Left censored	NA	3,022	2.61	0.7652	49	66
30Q10_Ann*	$-1.44+0.001\ln(CONTDA)+5.34\ln(BFI)+2.20\ln(SLOPE)$	Left censored	NA	3,581	2.68	0.8348	46	68
1Q10_January_P_{zero}*	$1-(e^{5.07+0.17\ln(CONTDA)+5.08\ln(BFI)}/1+e^{5.07+0.17\ln(CONTDA)+5.08\ln(BFI)})$	Logistic	92.9	NA	NA	NA	NA	72
7Q10_January_P_{zero}*	$1-(e^{3.22+0.38\ln(CONTDA)+4.65\ln(BFI)}/1+e^{3.22+0.38\ln(CONTDA)+4.65\ln(BFI)})$	Logistic	88.4	NA	NA	NA	NA	73
30Q10_January_P_{zero}*	$1-(e^{2.60+0.46\ln(CONTDA)+4.25\ln(BFI)}/1+e^{2.60+0.46\ln(CONTDA)+4.25\ln(BFI)})$	Logistic	89.1	NA	NA	NA	NA	73
1Q10_January	$-2.68+0.53\ln(CONTDA)+4.88\ln(BFI)+0.88\ln(KSAT)$	Left censored	NA	418.8	1.71	0.9105	34	73
7Q10_January	$-2.50+0.54\ln(CONTDA)+4.84\ln(BFI)+0.92\ln(KSAT)$	Left censored	NA	395.4	1.68	0.9126	31	73
30Q10_January	$-3.47+0.63\ln(CONTDA)+4.69\ln(BFI)+1.16\ln(KSAT)$	Left censored	NA	590.1	1.89	0.8897	29	73
1Q10_February_P_{zero}*	$1-(e^{5.23+0.19\ln(CONTDA)+5.12\ln(BFI)}/1+e^{5.23+0.19\ln(CONTDA)+5.12\ln(BFI)})$	Logistic	90.9	NA	NA	NA	NA	73
7Q10_February_P_{zero}	$1-(e^{1.40+0.65\ln(CONTDA)+3.94\ln(BFI)}/1+e^{1.40+0.65\ln(CONTDA)+3.94\ln(BFI)})$	Logistic	93.9	NA	NA	NA	NA	73

Table 10. Regression equations for estimating selected low-flow frequency statistics for unregulated streams in the west region of Kansas.—Continued

[classification, percentage of time equation correctly predicts zero flow; SE, standard error; %, percent; RMSE, root mean square error; pseudo-R^2, pseudocoefficient of determination; 1Q10, 1-day mean flow with 10-year recurrence interval; Q, flow; Ann, annual; P_{zero}, probability of zero flow; *e*, base of natural logarithm, approximately equal to 2.7183; ln, natural logarithm; *CONTDA*, contributing drainage area; *BFI*, base-flow index; *SLOPE*, mean basin slope; NA, not applicable; 7Q10, 7-day mean flow with 10-year recurrence interval; 30Q10, 30-day mean flow with 10-year recurrence interval; *KSAT*, saturated hydraulic conductivity; FD, flow duration; 99.99, 99.99% interval; 99.90, 99.90% interval; 99, 99% interval; 95, 95% interval; 90, 90% interval; 75, 75% interval; 50, 50% interval; 25, 25% interval; 10, 10% interval; 5, 5% interval; *PRECIPfull*, mean annual precipitation for 1895–2017; 2, 2% interval; 0.1, 0.1% interval; 0.01, 0.01% interval]

West (region 2) flow statistic	Regression model	Regression type	Performance metrics					
			Classification	SE (%)	RMSE	Pseudo-R^2	Number censored	Number of streamgages
30Q10_February_P_{zero}*	$1-(e^{3.94+0.56\ln(CONTDA)+4.92\ln(BFI)}/1+e^{3.94+0.56\ln(CONTDA)+4.92\ln(BFI)})$	Logistic	96.2	NA	NA	NA	NA	73
1Q10_February	$-2.97+0.56\ln(CONTDA)+4.57\ln(BFI)+0.98\ln(KSAT)$	Left censored	NA	451.9	1.75	0.8974	31	73
7Q10_February	$-3.53+0.61\ln(CONTDA)+4.53\ln(BFI)+1.17\ln(KSAT)$	Left censored	NA	493	1.8	0.8934	29	73
30Q10_February	$-2.44+0.58\ln(CONTDA)+4.02\ln(BFI)+0.93\ln(KSAT)$	Left censored	NA	596.4	1.9	0.8551	23	73
1Q10_March_P_{zero}*	$1-(e^{5.06+0.14\ln(CONTDA)+4.16\ln(BFI)}/1+e^{5.06+0.14\ln(CONTDA)+4.16\ln(BFI)})$	Logistic	89.8	NA	NA	NA	NA	73
7Q10_March_P_{zero}*	$1-(e^{3.94+0.56\ln(CONTDA)+4.92\ln(BFI)}/1+e^{3.94+0.56\ln(CONTDA)+4.92\ln(BFI)})$	Logistic	96.2	NA	NA	NA	NA	73
30Q10_March_P_{zero}*	$1-(e^{3.68+0.56\ln(CONTDA)+4.60\ln(BFI)}/1+e^{3.68+0.56\ln(CONTDA)+4.60\ln(BFI)})$	Logistic	94.4	NA	NA	NA	NA	73
1Q10_March	$0.96+0.48\ln(CONTDA)+4.77\ln(BFI)$	Left censored	NA	373.2	1.64	0.9053	25	73
7Q10_March	$1.11+0.49\ln(CONTDA)+4.74\ln(BFI)$	Left censored	NA	528.2	1.83	0.884	24	73
30Q10_March	$0.60+0.63\ln(CONTDA)+4.69\ln(BFI)$	Left censored	NA	505.2	1.81	0.8866	21	73
1Q10_April_P_{zero}*	$1-(e^{4.21+0.25\ln(CONTDA)+3.92\ln(BFI)}/1+e^{4.21+0.25\ln(CONTDA)+3.92\ln(BFI)})$	Logistic	94.0	NA	NA	NA	NA	72
7Q10_April_P_{zero}*	$1-(e^{4.64+0.40\ln(CONTDA)+4.79\ln(BFI)}/1+e^{4.64+0.40\ln(CONTDA)+4.79\ln(BFI)})$	Logistic	96.1	NA	NA	NA	NA	71
30Q10_April_P_{zero}*	$1-(e^{3.12+0.49\ln(CONTDA)+3.87\ln(BFI)}/1+e^{3.12+0.49\ln(CONTDA)+3.87\ln(BFI)})$	Logistic	98.1	NA	NA	NA	NA	71
1Q10_April	$0.74+0.55\ln(CONTDA)+5.22\ln(BFI)$	Left censored	NA	356.7	1.62	0.9223	26	73
7Q10_April	$1.13+0.49\ln(CONTDA)+4.74\ln(BFI)$	Left censored	NA	376	1.65	0.9041	23	73

Table 10. Regression equations for estimating selected low-flow frequency statistics for unregulated streams in the west region of Kansas.—Continued

[classification, percentage of time equation correctly predicts zero flow; SE, standard error; %, percent; RMSE, root mean square error; pseudo-R^2, pseudocoefficient of determination; 1Q10, 1-day mean flow with 10-year recurrence interval; Q, flow; Ann, annual; P_{zero}, probability of zero flow; *e*, base of natural logarithm, approximately equal to 2.7183; ln, natural logarithm; *CONTDA*, contributing drainage area; *BFI*, base-flow index; *SLOPE*, mean basin slope; NA, not applicable; 7Q10, 7-day mean flow with 10-year recurrence interval; 30Q10, 30-day mean flow with 10-year recurrence interval; *KSAT*, saturated hydraulic conductivity; FD, flow duration; 99.99, 99.99% interval; 99.90, 99.90% interval; 99, 99% interval; 95, 95% interval; 90, 90% interval; 75, 75% interval; 50, 50% interval; 25, 25% interval; 10, 10% interval; 5, 5% interval; *PRECIPfull*, mean annual precipitation for 1895–2017; 2, 2% interval; 0.1, 0.1% interval; 0.01, 0.01% interval]

West (region 2) flow statistic	Regression model	Regression type	Performance metrics					
			Classification	SE (%)	RMSE	Pseudo-R^2	Number censored	Number of streamgages
30Q10_April	$0.89+0.56\ln(CONTDA)+4.42\ln(BFI)$	Left censored	NA	342	1.59	0.8994	20	73
1Q10_May_P_{zero}*	$1-(e^{11.05-0.43\ln(CONTDA)+6.75\ln(BFI)}/1+e^{11.05-0.43\ln(CONTDA)+6.75\ln(BFI)})$	Logistic	90.2	NA	NA	NA	NA	71
7Q10_May_P_{zero}*	$1-(e^{4.85+0.21\ln(CONTDA)+4.46\ln(BFI)}/1+e^{4.85+0.21\ln(CONTDA)+4.46\ln(BFI)})$	Logistic	87.2	NA	NA	NA	NA	71
1Q10_May	$3.86+0.20\ln(CONTDA)+5.94\ln(BFI)-0.42\ln(KSAT)$	Left censored	NA	487.6	1.79	0.829	29	69
7Q10_May	$2.74+0.18\ln(CONTDA)+4.94\ln(BFI)$	Left censored	NA	359.8	1.62	0.8367	25	70
30Q10_May	$0.48+0.57\ln(CONTDA)+3.86\ln(BFI)$	Left censored	NA	236.5	1.4	0.9021	16	73
1Q10_June_P_{zero}*	$1-(e^{2.87+0.19\ln(CONTDA)+4.49\ln(BFI)}/1+e^{2.87+0.19\ln(CONTDA)+4.49\ln(BFI)})$	Logistic	80.6	NA	NA	NA	NA	73
7Q10_June_P_{zero}*	$1-(e^{4.90+0.02\ln(CONTDA)+3.79\ln(BFI)}/1+e^{4.90+0.02\ln(CONTDA)+3.79\ln(BFI)})$	Logistic	88.9	NA	NA	NA	NA	73
1Q10_June*	$2.11+0.17\ln(CONTDA)+6.90\ln(BFI)$	Left censored	NA	2,762	2.58	0.804	40	67
7Q10_June*	$1.50+0.15\ln(CONTDA)+4.33\ln(BFI)$	Left censored	NA	818.6	2.05	0.7108	30	70
30Q10_June	$-0.93+0.66\ln(CONTDA)+3.00\ln(BFI)$	Left censored	NA	294.6	1.51	0.8344	13	73
1Q10_July_P_{zero}*	$1-(e^{0.006-0.01\ln(CONTDA)+3.67\ln(BFI)+2.49\ln(SLOPE)}/1+e^{0.006-0.01\ln(CONTDA)+3.67\ln(BFI)+2.49\ln(SLOPE)})$	Logistic	72.0	NA	NA	NA	NA	71
7Q10_July_P_{zero}*	$1-(e^{2.94-0.02\ln(CONTDA)+2.94\ln(BFI)}/1+e^{2.94-0.02\ln(CONTDA)+2.94\ln(BFI)})$	Logistic	75.0	NA	NA	NA	NA	73
30Q10_July_P_{zero}*	$1-(e^{2.67+0.22\ln(CONTDA)+2.03\ln(BFI)}/1+e^{2.94+0.22\ln(CONTDA)+2.03\ln(BFI)})$	Logistic	96.5	NA	NA	NA	NA	73
1Q10_July*	$-3.21+0.17\ln(CONTDA)+6.34\ln(BFI)+2.63\ln(SLOPE)$	Left censored	NA	22,090	3.29	0.661	48	65

Table 10. Regression equations for estimating selected low-flow frequency statistics for unregulated streams in the west region of Kansas.—Continued

[classification, percentage of time equation correctly predicts zero flow; SE, standard error; %, percent; RMSE, root mean square error; pseudo-R^2, pseudocoefficient of determination; 1Q10, 1-day mean flow with 10-year recurrence interval; Q, flow; Ann, annual; P_{zero}, probability of zero flow; *e*, base of natural logarithm, approximately equal to 2.7183; ln, natural logarithm; *CONTDA*, contributing drainage area; *BFI*, base-flow index; *SLOPE*, mean basin slope; NA, not applicable; 7Q10, 7-day mean flow with 10-year recurrence interval; 30Q10, 30-day mean flow with 10-year recurrence interval; *KSAT*, saturated hydraulic conductivity; FD, flow duration; 99.99, 99.99% interval; 99.90, 99.90% interval; 99, 99% interval; 95, 95% interval; 90, 90% interval; 75, 75% interval; 50, 50% interval; 25, 25% interval; 10, 10% interval; 5, 5% interval; *PRECIPfull*, mean annual precipitation for 1895–2017; 2, 2% interval; 0.1, 0.1% interval; 0.01, 0.01% interval]

West (region 2) flow statistic	Regression model	Regression type	Performance metrics					
			Classification	SE (%)	RMSE	Pseudo-R^2	Number censored	Number of streamgages
7Q10_July*	$-1.84+0.09\ln(CONTDA)+5.32\ln(BFI)+2.42\ln(SLOPE)$	Left censored	NA	4,426	2.75	0.6636	42	68
30Q10_July	$-0.11+0.31\ln(CONTDA)+2.65\ln(BFI)$	Left censored	NA	919.8	2.11	0.47	21	70
1Q10_August_P_{zero}*	$1-(e^{-1.16+0.17\ln(CONTDA)+3.48\ln(BFI)+2.09\ln(SLOPE)}/1+e^{-1.16+0.17\ln(CONTDA)+3.48\ln(BFI)+2.09\ln(SLOPE)})$	Logistic	66.7	NA	NA	NA	NA	73
7Q10_August_P_{zero}*	$1-(e^{-1.66+0.22\ln(CONTDA)+2.78\ln(BFI)+2.09\ln(SLOPE)}/1+e^{-1.66+0.22\ln(CONTDA)+2.78\ln(BFI)+2.09\ln(SLOPE)})$	Logistic	71.4	NA	NA	NA	NA	73
30Q10_August_P_{zero}*	$1-(e^{3.35-0.007\ln(CONTDA)+2.27\ln(BFI)}/1+e^{3.35-0.007\ln(CONTDA)+2.27\ln(BFI)})$	Logistic	89.1	NA	NA	NA	NA	73
1Q10_August*	$1.69-0.06\ln(CONTDA)+6.16\ln(BFI)$	Left censored	NA	13,790	3.14	0.6879	47	67
7Q10_August*	$1.36-0.44\ln(CONTDA)+5.55\ln(BFI)+2.35\ln(SLOPE)$	Left censored	NA	2,029	2.45	0.7487	42	64
30Q10_August*	$-4.29+0.56\ln(CONTDA)+3.55\ln(BFI)+1.90\ln(SLOPE)$	Left censored	NA	3,318	2.65	0.5036	30	68
1Q10_September_P_{zero}*	$1-(e^{-1.04+0.15\ln(CONTDA)+3.32\ln(BFI)+1.78\ln(SLOPE)}/1+e^{-1.04+0.15\ln(CONTDA)+3.32\ln(BFI)+1.78\ln(SLOPE)})$	Logistic	57.1	NA	NA	NA	NA	73
7Q10_September_P_{zero}*	$1-(e^{-0.06+0.12\ln(CONTDA)+3.71\ln(BFI)+1.72\ln(SLOPE)}/1+e^{-0.06+0.12\ln(CONTDA)+3.71\ln(BFI)+1.72\ln(SLOPE)})$	Logistic	70.8	NA	NA	NA	NA	72
30Q10_September_P_{zero}*	$1-(e^{-0.19+0.28\ln(CONTDA)+3.02\ln(BFI)+1.78\ln(SLOPE)}/1+e^{-0.19+0.28\ln(CONTDA)+3.02\ln(BFI)+1.78\ln(SLOPE)})$	Logistic	87.8	NA	NA	NA	NA	73
1Q10_September*	$1.07-0.40\ln(CONTDA)+6.32\ln(BFI)+2.09\ln(SLOPE)$	Left censored	NA	3,674	2.68	0.7431	48	65
7Q10_September*	$-1.55-0.01\ln(CONTDA)+5.64\ln(BFI)+2.06\ln(SLOPE)$	Left censored	NA	11,780	3.09	0.6312	46	65

Table 10. Regression equations for estimating selected low-flow frequency statistics for unregulated streams in the west region of Kansas.—Continued

[classification, percentage of time equation correctly predicts zero flow; SE, standard error; %, percent; RMSE, root mean square error; pseudo-R^2, pseudocoefficient of determination; 1Q10, 1-day mean flow with 10-year recurrence interval; Q, flow; Ann, annual; P_{zero}, probability of zero flow; *e*, base of natural logarithm, approximately equal to 2.7183; ln, natural logarithm; *CONTDA*, contributing drainage area; *BFI*, base-flow index; *SLOPE*, mean basin slope; NA, not applicable; 7Q10, 7-day mean flow with 10-year recurrence interval; 30Q10, 30-day mean flow with 10-year recurrence interval; *KSAT*, saturated hydraulic conductivity; FD, flow duration; 99.99, 99.99% interval; 99.90, 99.90% interval; 99, 99% interval; 95, 95% interval; 90, 90% interval; 75, 75% interval; 50, 50% interval; 25, 25% interval; 10, 10% interval; 5, 5% interval; *PRECIPfull*, mean annual precipitation for 1895–2017; 2, 2% interval; 0.1, 0.1% interval; 0.01, 0.01% interval]

West (region 2) flow statistic	Regression model	Regression type	Performance metrics					
			Classification	SE (%)	RMSE	Pseudo-R^2	Number censored	Number of streamgages
30Q10_September*	$-2.40+0.36\ln(CONTDA)+4.20\ln(BFI)+1.55\ln(SLOPE)$	Left censored	NA	1,332	2.28	0.8139	38	76
1Q10_October_P_{zero}*	$1-(e^{-0.18+0.26\ln(CONTDA)+4.25\ln(BFI)+1.56\ln(SLOPE)}/1+e^{-0.18+0.26\ln(CONTDA)+4.25\ln(BFI)+1.56\ln(SLOPE)})$	Logistic	73.1	NA	NA	NA	NA	72
7Q10_October_P_{zero}*	$1-(e^{3.22+0.18\ln(CONTDA)+4.95\ln(BFI)}/1+e^{3.22+0.18\ln(CONTDA)+4.95\ln(BFI)})$	Logistic	80	NA	NA	NA	NA	73
30Q10_October_P_{zero}*	$1-(e^{2.22+0.28\ln(CONTDA)+3.67\ln(BFI)}/1+e^{2.22+0.28\ln(CONTDA)+3.67\ln(BFI)})$	Logistic	86.8	NA	NA	NA	NA	73
1Q10_October*	$-0.76+0.07\ln(CONTDA)+6.07\ln(BFI)+1.82\ln(SLOPE)$	Left censored	NA	3,555	2.67	0.7166	42	65
7Q10_October*	$-1.82+0.45\ln(CONTDA)+6.83\ln(BFI)+1.56\ln(SLOPE)$	Left censored	NA	1,504	2.33	0.9122	45	73
30Q10_October*	$1.20+0.32\ln(CONTDA)+5.78\ln(BFI)$	Left censored	NA	1,110	2.2	0.8842	38	73
1Q10_November_P_{zero}*	$1-(e^{2.60+0.36\ln(CONTDA)+4.94\ln(BFI)}/1+e^{2.60+0.36\ln(CONTDA)+4.94\ln(BFI)})$	Logistic	91.4	NA	NA	NA	NA	73
7Q10_November_P_{zero}*	$1-(e^{2.39+0.47\ln(CONTDA)+5.36\ln(BFI)}/1+e^{2.39+0.47\ln(CONTDA)+5.36\ln(BFI)})$	Logistic	91.7	NA	NA	NA	NA	73
30Q10_November_P_{zero}*	$1-(e^{1.99-0.44\ln(CONTDA)+4.16\ln(BFI)}/1+e^{1.99-0.44\ln(CONTDA)+4.16\ln(BFI)})$	Logistic	87.8	NA	NA	NA	NA	73
1Q10_November	$0.05+0.56\ln(CONTDA)+6.76\ln(BFI)$	Left censored	NA	1,430	2.31	0.9059	42	73
7Q10_November	$0.09+0.64\ln(CONTDA)+6.83\ln(BFI)$	Left censored	NA	1,042	2.17	0.9183	39	73
30Q10_November	$0.59+0.59\ln(CONTDA)+6.35\ln(BFI)$	Left censored	NA	992.2	2.14	0.9084	35	73
1Q10_December_P_{zero}*	$1-(e^{3.42+0.34\ln(CONTDA)+5.54\ln(BFI)}/1+e^{3.42+0.34\ln(CONTDA)+5.54\ln(BFI)})$	Logistic	91.7	NA	NA	NA	NA	73
7Q10_December_P_{zero}*	$1-(e^{3.55+0.28\ln(CONTDA)+4.85\ln(BFI)}/1+e^{3.55+0.28\ln(CONTDA)+4.85\ln(BFI)})$	Logistic	89.7	NA	NA	NA	NA	73

Table 10. Regression equations for estimating selected low-flow frequency statistics for unregulated streams in the west region of Kansas.—Continued

[classification, percentage of time equation correctly predicts zero flow; SE, standard error; %, percent; RMSE, root mean square error; pseudo-R^2, pseudocoefficient of determination; 1Q10, 1-day mean flow with 10-year recurrence interval; Q, flow; Ann, annual; P_{zero}, probability of zero flow; *e*, base of natural logarithm, approximately equal to 2.7183; ln, natural logarithm; *CONTDA*, contributing drainage area; *BFI*, base-flow index; *SLOPE*, mean basin slope; NA, not applicable; 7Q10, 7-day mean flow with 10-year recurrence interval; 30Q10, 30-day mean flow with 10-year recurrence interval; *KSAT*, saturated hydraulic conductivity; FD, flow duration; 99.99, 99.99% interval; 99.90, 99.90% interval; 99, 99% interval; 95, 95% interval; 90, 90% interval; 75, 75% interval; 50, 50% interval; 25, 25% interval; 10, 10% interval; 5, 5% interval; *PRECIPfull*, mean annual precipitation for 1895–2017; 2, 2% interval; 0.1, 0.1% interval; 0.01, 0.01% interval]

West (region 2) flow statistic	Regression model	Regression type	Performance metrics					
			Classification	SE (%)	RMSE	Pseudo-R^2	Number censored	Number of streamgages
30Q10_December_P_{zero}*	$1-(e^{5.15+0.11\ln(CONTDA)+4.52\ln(BFI)}/1+e^{5.15+0.11\ln(CONTDA)+4.52\ln(BFI)})$	Logistic	91.1	NA	NA	NA	NA	73
1Q10_December	$0.70+0.50\ln(CONTDA)+6.50\ln(BFI)$	Left censored	NA	826.2	2.06	0.9177	39	73
7Q10_December	$0.93+0.52\ln(CONTDA)+6.66\ln(BFI)$	Left censored	NA	927.9	2.11	0.9174	38	73
30Q10_December	$0.69+0.60\ln(CONTDA)+6.13\ln(BFI)$	Left censored	NA	873.4	2.09	0.9075	32	73
FD_99.99_P_{zero}*	$1-(e^{-1.10+0.16\ln(CONTDA)+13.55\ln(BFI)+5.14\ln(SLOPE)}/1+e^{-1.10+0.16\ln(CONTDA)+13.55\ln(BFI)+5.14\ln(SLOPE)})$	Logistic	71.4	NA	NA	NA	NA	67
FD_99.90_P_{zero}*	$1-(e^{1.72-0.51\ln(CONTDA)+6.67\ln(BFI)+4.00\ln(SLOPE)}/1+e^{1.72-0.51\ln(CONTDA)+6.67\ln(BFI)+4.00\ln(SLOPE)})$	Logistic	69.2	NA	NA	NA	NA	71
FD_99_P_{zero}*	$1-(e^{-0.67+0.11\ln(CONTDA)+3.48\ln(BFI)+1.70\ln(SLOPE)}/1+e^{-0.67+0.11\ln(CONTDA)+3.48\ln(BFI)+1.70\ln(SLOPE)})$	Logistic	60.0	NA	NA	NA	NA	73
FD_95_P_{zero}*	$1-(e^{0.79-0.50\ln(CONTDA)+4.69\ln(BFI)}/1+e^{0.79-0.50\ln(CONTDA)+4.69\ln(BFI)})$	Logistic	83.3	NA	NA	NA	NA	73
FD_90_P_{zero}*	$1-(e^{2.82+0.27\ln(CONTDA)+4.08\ln(BFI)}/1+e^{2.82+0.27\ln(CONTDA)+4.08\ln(BFI)})$	Logistic	87.2	NA	NA	NA	NA	73
FD_75_P_{zero}*	$1-(e^{2.88+0.64\ln(CONTDA)+4.79\ln(BFI)}/1+e^{2.88+0.64\ln(CONTDA)+4.79\ln(BFI)})$	Logistic	94.1	NA	NA	NA	NA	73
FD_99.99*	$2.55+0.41\ln(CONTDA)+20.29\ln(BFI)$	Left censored	NA	171,500	3.86	0.9385	62	70
FD_99.90*	$2.68+0.07\ln(CONTDA)+11.40\ln(BFI)$	Left censored	NA	5,140	2.81	0.901	57	70
FD_99*	$2.37-0.59\ln(CONTDA)+6.65\ln(BFI)+2.21\ln(SLOPE)$	Left censored	NA	8,111	2.97	0.7357	46	64
FD_95*	$0.65-0.04\ln(CONTDA)+6.74\ln(BFI)+1.92\ln(SLOPE)$	Left censored	NA	1,254	2.25	0.8193	38	64

Table 10. Regression equations for estimating selected low-flow frequency statistics for unregulated streams in the west region of Kansas.—Continued

[classification, percentage of time equation correctly predicts zero flow; SE, standard error; %, percent; RMSE, root mean square error; pseudo-R^2, pseudocoefficient of determination; 1Q10, 1-day mean flow with 10-year recurrence interval; Q, flow; Ann, annual; P_{zero}, probability of zero flow; *e*, base of natural logarithm, approximately equal to 2.7183; ln, natural logarithm; *CONTDA*, contributing drainage area; *BFI*, base-flow index; *SLOPE*, mean basin slope; NA, not applicable; 7Q10, 7-day mean flow with 10-year recurrence interval; 30Q10, 30-day mean flow with 10-year recurrence interval; *KSAT*, saturated hydraulic conductivity; FD, flow duration; 99.99, 99.99% interval; 99.90, 99.90% interval; 99, 99% interval; 95, 95% interval; 90, 90% interval; 75, 75% interval; 50, 50% interval; 25, 25% interval; 10, 10% interval; 5, 5% interval; *PRECIPfull*, mean annual precipitation for 1895–2017; 2, 2% interval; 0.1, 0.1% interval; 0.01, 0.01% interval]

West (region 2) flow statistic	Regression model	Regression type	Performance metrics					
			Classification	SE (%)	RMSE	Pseudo-R^2	Number censored	Number of streamgages
FD_90*	2.27+0.16ln(*CONTDA*) +5.59ln(*BFI*)	Left censored	NA	998.1	2.15	0.7892	35	70
FD_75	0.68+0.57ln(*CONTDA*) +4.77ln(*BFI*)	Left censored	NA	460.2	1.76	0.8945	25	73
FD_50	−1.89+0.68ln(*CONTDA*) +2.62ln(*BFI*)+0.56ln(*KSAT*)	Left censored	NA	175	1.18	0.8765	12	73
FD_25	−0.07+0.68ln(*CONTDA*) +1.94ln(*BFI*)	Left censored	NA	120.6	0.95	0.7641	5	68
FD_10	−0.03+0.68ln(*CONTDA*) +1.07ln(*BFI*)	Left censored	NA	116.5	0.93	0.6207	1	70
FD_5	−22.44+0.87ln(*CONTDA*) +6.69ln(*PRECIPfull*)	Left censored	NA	88.72	0.76	0.743	0	71
FD_2	−15.98+0.83ln(*CONTDA*) +5.22ln(*PRECIPfull*)	Left censored	NA	64.59	0.59	0.8033	0	71
FD_0.1	−6.96+0.65ln(*CONTDA*) +3.25ln(*PRECIPfull*)	Left censored	NA	62.01	0.57	0.716	0	71
FD_0.01	−3.53+0.57ln(*CONTDA*) +2.61ln(*PRECIPfull*)	Left censored	NA	74.42	0.66	0.5878	0	71
Mean_Ann_Q	−14.59+0.65ln(*CONTDA*) +4.34ln(*PRECIPfull*)	Left censored	NA	86.34	0.69	0.5324	0	71

**CONTDA* was not statistically significant but was included in the model.

frequency statistic or flow-duration exceedance interval is estimated to be zero, and the corresponding left-censored regression equation does not need to be used (Eash and Barnes, 2017). If the resulting probability is less than 0.5, the matching left-censored regression equation should be used to estimate the value for the low-flow frequency statistic or flow-duration exceedance interval.

Accuracy and Limitations of Regression Equations

The accuracy of the logistic regression equations is described in the classification column; classification being the percentage that the equation correctly predicts zero flow and flow. The logistic regression equations in the east region have a classification range from 56.4 to 97.1 percent, and the mean is 84.1 percent. The classification range of the west region is from 57.1 to 98.1 percent, and the mean is 83.6 percent. The SE and the root mean square error (RMSE) for the regression equations are listed in tables 9 and 10. The SE and the RMSE have fairly large ranges in tables 9 and 10, and the values measured in the west region of the State (table 10) are greater than the values measured in the east region of the State (table 9). The smallest SE and RMSE values occur in the late spring (March–May) and early summer (June–August) months, whereas the greatest values occur during the midsummer and early fall (September–November) months. The reason for the large error values in some of the regression equations is the large percentage of censored values used to create the equations, which are in tables 9 and 10. Flows of 0.1 ft^3/s and less are not uncommon in Kansas, especially in the summer and fall months.

The following list describes limitations for using the final regional regression equations developed in this report.

1. Using the equations on locations where the independent variables are outside the ranges of those in this study may generate errors that are greater than the errors listed in tables 9 and 10. The ranges of the independent variables are listed in table 6 of this report.

2. The regional regression equations in this report are not suitable for streams where flow is substantially affected by regulation, diversion, or urbanization.

3. The basin characteristic computations at ungaged locations should be calculated using the same GIS and other datasets and calculation approaches used in this study. References for basin characteristics are in table 6 and appendix 3, tables 3.1 and 3.2.

4. Special consideration is warranted for censored values and the number of significant figures used. Because of the ability of streamgages to provide continuous data at streamflows of less than 0.1 ft^3/s, the censoring threshold used to develop the left-censored regression equations in this report was set at 0.1 ft^3/s; therefore, any regression estimates of less than 0.1 ft^3/s should be reported as “less than 0.1 ft^3/s.”

Example Calculations

Approaches for applying the regional regression equations listed in tables 9 and 10 are detailed in the following examples.

Example 1.—This example is a calculation of the April 7Q10 (April 7-day low flow with a recurrence interval of 10 years [7Q10_April]) for a streamgage in the east region. Shown in figure 1 is the location of USGS streamgage Stranger Creek near Tonganoxie, Kans. (06892000), as map number 115. This drainage basin is located entirely within the east region. Estimating the selected low-flow frequency statistic is a one-step process using the equation in table 9. Using the StreamStats web-based GIS tool (https://streamstats.usgs.gov/ss/) or the “StreamStats Gage page” link, CONTDA is measured as 406 mi^2 and BFI is measured as 0.172 (dimensionless). Because both basin characteristic values are within the range provided in table 6, the left-censored regression equation is applicable for estimating the April 7Q10. The April 7Q10 left-censored regression equation is as follows:

$$7Q10\_April = -0.80 + 0.81\ln(CONTDA) + 1.38\ln(BFI), \quad (4)$$

$$7Q10\_April = -0.80 + 0.81\ln(406) + 1.38\ln(0.172),$$

$$7Q10\_April = -0.80 + 4.8651 - 2.4292,$$

$$7Q10\_April = 1.64 \text{ ft}^3\text{/s},$$

where

CONTDA	is contributing drainage area and
BFI	is base-flow index.

Example 2.—This example is a calculation of the 95-percent flow-duration exceedance interval (streamflow that is equaled or exceeded 95 percent of the time) for a streamgage in the west region. Shown in figure 1 is the location of USGS streamgage Smoky Hill River at Elkader, Kans. (06860000), as map number 58. This drainage basin is located entirely within the west region. Estimating the selected low-flow frequency statistic is a one- or two-step process. Step 1 is to estimate the probability of zero flow using the logistic regression equation listed in table 10. Using the StreamStats web-based GIS tool or the “StreamStats Gage page” link, CONTDA is measured as 3,555 mi^2 and BFI is measured as 0.202 (dimensionless). Because both basin characteristic values are within the range provided in table 6, the logistic

regression and left-censored regression equations are applicable for estimating the 95-percent flow-duration exceedance interval. The 95-percent flow-duration exceedance interval ($FD\_95\_P_{zero}$) logistic regression equation is as follows:

$$FD\_95\_P_{zero}=1-[(e^{0.79+0.50\ln(CONTDA)+4.69\ln(BFI)})/(1-(e^{0.79+0.50\ln(CONTDA)+4.69\ln(BFI)}))], \quad (5)$$

$$FD\_95\_P_{zero}=1-[(e^{0.79}\cdot 3{,}555^{0.50}\cdot 0.202^{4.69})/(1-(e^{0.79}\cdot 3{,}555^{0.50}\cdot 0.202^{4.69}))],$$

$$FD\_95\_P_{zero}=1-[(7.25\times10^{-2})/(1-(7.25\times10^{-2}))],$$

$$FD\_95\_P_{zero}=1-[(7.25\times10^{-2})/(9.28\times10^{-1})],$$

$$FD\_95\_P_{zero}=0.92,$$

where

e is the base of natural logarithm, approximately equal to 2.7183.

Because the estimate for the $FD\_95\_P_{zero}$ is greater than the probability threshold of 0.5 used for this study, the estimate for the $FD\_95\_P_{zero}$ is zero flow, making step 2 unnecessary. If step 2 were necessary, the FD_95 equation in table 10 would be applied in the same fashion as example 1.

Example 3.—This example is a calculation of the mean annual flow for a streamgage in the east region. Shown in figure 1 is the location of USGS streamgage Turkey Creek near Seneca, Kans. (06814000), as map number 7. This drainage basin is located entirely within the east region. Estimating the selected low-flow frequency statistic is a one-step process using the left-censored regression equation in table 9. Using the StreamStats web-based GIS tool or the "StreamStats Gage page" link, CONTDA is measured as 276 mi². Using table 3.1, in appendix 3, PRECIPfull is measured as 32.2 in. Because all the basin characteristic values are within the range provided in table 6, the left-censored regression equation is applicable for estimating the mean annual flow. The mean annual flow (Mean_Ann_Q) left-censored regression equation is as follows:

$$Mean\_Ann\_Q=-14.2+0.82\ln(CONTDA)+4.08\ln(PRECIPfull), \quad (6)$$

$$Mean\_Ann\_Q=-14.2+0.82\ln(276)+4.08\ln(32.2),$$

$$Mean\_Ann\_Q=-14.2+4.6087+14.1656,$$

$$Mean\_Ann\_Q=4.57\ ft^3/s,$$

where

PRECIPfull is the mean annual precipitation for 1895–2017.

Drainage-Area Ratio Method

Another method to estimate selected low-flow statistics for an ungaged location is the DAR method. The DAR method assumes that streamflow at an ungaged location is the same per unit area as that for a streamgage upstream or downstream from the ungaged location (Southard, 2013; Eash and Barnes, 2017). Low-flow frequency statistics computed for the streamgage are multiplied by the DAR of the ungaged location to estimate low-flow frequency statistics at the ungaged location. This method is appropriate for streams with a streamgage and is not dependent on how many streamgages are on the same stream (Southard, 2013). "The accuracy of the DAR method depends on similarities in drainage area and other basin characteristics (such as soils, geology, precipitation) between the two locations" (Eash and Barnes, 2017, p. 37). The DAR method usually is applied when the ungaged location is on the same stream as a streamgage and the DAR of the two locations is between 0.5 and 1.5 (Hortness, 2006; Eash and Barnes, 2017). Other studies have examined DARs to verify the range for which the DAR method offers estimates of low-flow statistics that are higher quality than estimates determined using regional regression equations (Eash and Barnes, 2017). Koltun and Schwartz (1987) recommended a DAR range from 0.85 to 1.15 for estimating low-flow statistics in Ohio, whereas Ries and Friesz (2000) concluded that a range from 0.3 to 1.5 was appropriate for low-flow statistics in Massachusetts (Eash and Barnes, 2017). The studies mentioned previously recommend using regression equations for ungaged locations outside of their published DAR ranges. The following equation is the DAR method computation:

$$Q_{DARu}=(DA_u/DA_g)Q_{og}, \quad (7)$$

where

Q_{DARu} is the low-flow frequency estimate of the ungaged location,

DA_u is the drainage area of the ungaged location,

DA_g is the drainage area of the streamgage on the same stream, and

Q_{og} is the computed low-flow frequency estimate from the observed streamgage record.

Comparison to Regression Model

To evaluate which method, DAR or regional regression equations, is most applicable for Kansas and to determine what range is appropriate for either method, 20 pairs of streamgages were selected for testing estimates of the 7Q10 statistic following a process described by Ries and Friesz (2000) and Eash and Barnes (2017). A set of 26 streamgages composed the 20 pairs, which are listed in table 11. Each pair of streamgages is on the same stream. Of the streams, 8 had only 2 streamgages that could be used for the comparison, 2 had 3 streamgages for comparison, and 1 had 4 streamgages available for comparison. More streamgage pairs are desirable for this analysis, but streamgages with only partial records of flow not affected by regulation, diversion, or urbanization were omitted from this analysis because these streamgages could introduce bias into the results. Two streamgages had observed 7Q10 values of zero; these were changed to less than 0.1 ft^3/s so the mathematical computations would be valid and a comparison could be made. The period of record used to compute the 7Q10 statistic for each streamgage ranged from 11 to 107 years. Drainage area size ranged from 218 to 4,777 mi^2. Two pairs of streamgages are in the west region of the study area, whereas the other 18 pairs are in the east region.

Using the DAR method and the regional regression equations, 20 pairs of the 7Q10 statistic were calculated. In each pair, it was assumed that one of the locations was ungaged, whereas the other was used as a streamgage. The absolute difference, in percent, was calculated from the observed 7Q10 value and the estimations computed from the DAR method and the regional regression equations for each streamgage that was assumed to be an ungaged location. The results of the absolute differences were then split into four groups; these groups were as follows:

1. DAR estimates with DARs of less than 0.5 and greater than 1.5,
2. DAR estimates with DARs between 0.5 and 1.5,
3. regional regression estimates with DARs of less than 0.5 and greater than 1.5, and
4. regional regression estimates with DARs between 0.5 and 1.5.

Medians and standard deviations of the absolute differences, in percent, are provided in table 12, and the medians and standard deviations for all the DAR and regional regression equation estimates.

As listed in table 12, the median absolute differences, in percent, for the DAR methods are much lower than the median absolute differences for the regional regression equations, and the standard deviations for the DAR method are much greater than the standard deviations for the regional regression equations. The Wilcoxon signed-rank test was completed using R statistical software to determine the statistical difference between the medians of the groups in this analysis (R Core Team, 2020). The results indicated that the DAR method estimates are not significantly different from the regional regression equations. The p-value equaled 0.44 when the DAR was less than 0.5 and greater than 1.5. The p-value equaled 0.56 when the DAR was between 0.5 and 1.5. To summarize, based on the Wilcoxon signed-rank test, either the DAR method or the regional regression equations can be used to estimate flow statistics for ungaged locations in Kansas. Other studies have published guidelines indicating what DARs are acceptable before the use of regression equations is preferred. Several studies have reported that the DAR is ideal when the ratio is between 0.5 and 1.5 (Ries and Friesz, 2000). Many of the studies that published this guideline did not offer any scientific basis for how it was set (Ries and Friesz, 2000). This analysis concludes the DAR method or regional regression equations can be used to estimate flow statistics in Kansas based on the results of the Wilcoxon signed-rank test. It should be noted that the median absolute difference, in percent, is significantly lower for the DAR method when the ratios are between 0.5 and 1.5.

Example Calculation

Example 4.—This example is a calculation of a DAR for the annual 7-day mean low flow with a recurrence interval of 5 years (7Q5) statistic for a stream location in the east region. The USGS streamgage Stranger Creek near Potter, Kans. (06891810), is shown in figure 1 as map number 115. This streamgage was assumed to be an ungaged location for this example. Another streamgage, Stranger Creek near Tonganoxie, Kans. (06892000), also is shown in figure 1 as map number 116. This streamgage will be used as the streamgage in this example. This drainage basin is located entirely within the east region of the study area. Using the StreamStats web-based GIS tool or the “StreamStats Gage page” link, CONTDA is measured as 184 mi^2 for the ungaged location and 406 mi^2 for the streamgage. Listed in appendix table 2.1 is the computed 7Q5 statistic for the streamgage as 0.30 ft^3/s. The DAR method equation for the 7Q5 low-flow frequency statistic is as follows:

$$Q_{DARu}=(DA_u/DA_g)Q_{og}, \qquad (8)$$

$$Q_{DARu}=(184\ mi^2/406\ mi^2)0.30\ ft^3/s,$$

$$Q_{DARu}=(0.45)0.30\ ft^3/s,$$

$$Q_{DARu}=0.14\ ft^3/s.$$

Table 11. Pairs of U.S. Geological Survey streamgages for drainage-area ratio versus regional regression equations analysis.

[USGS, U.S. Geological Survey; CONTDA, contributing drainage area; DAR, drainage-area ratio; 7Q10, minimum 7-day annual low flow with a 10-year recurrence interval; %, percent; NE, Nebraska; MO, Missouri; C, Creek; NR, near; KS, Kansas; R, River; OK, Oklahoma]

Pair number	Map number	USGS station number	USGS station name	CONTDA	DAR	Observed 7Q10	DAR method		Regional regression equations	
							Estimate	Absolute difference (%)	Estimate	Absolute difference (%)
1	4	06810500	LITTLE NEMAHA RIVER NEAR SYRACUSE, NE	218	0.28	0.41	3.11	660.7	0.10	75.6
	5	06811500	LITTLE NEMAHA RIVER AT AUBURN, NE	792	3.63	11.3	1.49	86.9	1.37	87.8
2	11	06817500	NODAWAY RIVER NEAR BURLINGTON JUNCTION, MO	1,240	0.82	6.91	24.7	257.8	0.53	92.3
	12	06817700	NODAWAY RIVER NEAR GRAHAM, MO	1,520	1.23	30.3	8.47	72.0	2.30	92.4
3	15	06820500	PLATTE RIVER NEAR AGENCY, MO	1,760	0.74	3.39	16.7	393.1	0.10	97.1
	18	06821190	PLATTE RIVER AT SHARPS STATION, MO	2,371	1.35	22.5	4.57	79.7	1.75	92.2
4	36	06845000	SAPPA C NR OBERLIN, KS*	923	0.62	0.10	0.01	87.6	0.10	0.0
	37	06845110	SAPPA C NR LYLE, KS	1,488	1.61	0.02	0.16	706.1	0.10	400.0
5	86	06881000	BIG BLUE RIVER NEAR CRETE, NE	2,716	0.62	26.3	26.9	2.2	2.61	90.1
	90	06882000	BIG BLUE RIVER AT BARNESTON, NE	4,370	1.61	43.3	42.3	2.1	2.10	95.1
6	86	06881000	BIG BLUE RIVER NEAR CRETE, NE	2,716	0.57	26.3	29.6	12.4	2.61	90.1
	92	06882510	BIG BLUE R AT MARYSVILLE, KS	4,777	1.76	52.0	46.3	11.0	2.96	94.3
7	90	06882000	BIG BLUE RIVER AT BARNESTON, NE	4,370	0.91	43.3	47.6	10.0	2.10	95.1
	92	06882510	BIG BLUE R AT MARYSVILLE, KS	4,777	1.09	52.0	47.3	9.1	2.96	94.3

Table 11. Pairs of U.S. Geological Survey streamgages for drainage-area ratio versus regional regression equations analysis.—Continued

[USGS, U.S. Geological Survey; CONTDA, contributing drainage area; DAR, drainage-area ratio; 7Q10, minimum 7-day annual low flow with a 10-year recurrence interval; %, percent; NE, Nebraska; MO, Missouri; C, Creek; NR, near; KS, Kansas; R, River; OK, Oklahoma]

Pair number	Map number	USGS station number	USGS station name	CONTDA	DAR	Observed 7Q10	DAR method		Regional regression equations	
							Estimate	Absolute difference (%)	Estimate	Absolute difference (%)
8	87	06881200	TURKEY CREEK NEAR WILBER, NE	461	0.64	0.19	1.27	580.7	0.10	46.5
	88	06881380	TURKEY CREEK NEAR DEWITT, NE	724	1.57	2.00	0.29	85.3	0.10	95.0
9	93	06883000	LITTLE BLUE RIVER NEAR DEWEESE, NE	984	0.42	8.09	16.6	105.5	1.97	75.6
	95	06884000	LITTLE BLUE RIVER NEAR FAIRBURY, NE	2,350	2.39	39.7	19.3	51.3	2.16	94.6
10	93	06883000	LITTLE BLUE RIVER NEAR DEWEESE, NE	984	0.36	8.09	14.8	83.6	1.97	75.6
	96	06884025	LITTLE BLUE RIVER AT HOLLENBERG, KS	2,752	2.80	41.5	22.6	45.5	2.03	95.1
11	93	06883000	LITTLE BLUE RIVER NEAR DEWEESE, NE	984	0.29	8.09	12.8	57.9	1.97	75.6
	98	06884400	LITTLE BLUE R NR BARNES, KS	3,351	3.41	43.5	27.5	36.7	2.09	95.2
12	95	06884000	LITTLE BLUE RIVER NEAR FAIRBURY, NE	2,350	0.85	39.7	35.5	10.6	2.16	94.6
	96	06884025	LITTLE BLUE RIVER AT HOLLENBERG, KS	2,752	1.17	41.5	46.5	11.9	2.03	95.1
13	95	06884000	LITTLE BLUE RIVER NEAR FAIRBURY, NE	2,350	0.70	39.7	30.5	23.2	2.16	94.6
	98	06884400	LITTLE BLUE R NR BARNES, KS	3,351	1.43	43.5	56.6	30.2	2.09	95.2
14	96	06884025	LITTLE BLUE RIVER AT HOLLENBERG, KS	2,752	0.82	41.5	35.7	14.0	2.03	95.1
	98	06884400	LITTLE BLUE R NR BARNES, KS	3,351	1.22	43.5	50.6	16.3	2.09	95.2

Table 11. Pairs of U.S. Geological Survey streamgages for drainage-area ratio versus regional regression equations analysis.—Continued

[USGS, U.S. Geological Survey; CONTDA, contributing drainage area; DAR, drainage-area ratio; 7Q10, minimum 7-day annual low flow with a 10-year recurrence interval; %, percent; NE, Nebraska; MO, Missouri; C, Creek; NR, near; KS, Kansas; R, River; OK, Oklahoma]

Pair number	Map number	USGS station number	USGS station name	CONTDA	DAR	Observed 7Q10	DAR method		Regional regression equations	
							Estimate	Absolute difference (%)	Estimate	Absolute difference (%)
15	110	06890100	DELAWARE R NR MUSCOTAH, KS	431	0.47	0.21	0.43	108.5	0.10	51.5
	111	06890500	DELAWARE R AT VAL-LEY FALLS, KS	922	2.14	0.92	0.44	52.0	0.10	89.1
16	152	06917500	MARMATON R NR FORT SCOTT, KS	388	0.85	0.17	0.32	91.6	0.10	39.8
	153	06917560	MARMATON RIVER NEAR RICHARDS, MO	455	1.17	0.37	0.19	47.8	0.10	73.2
17	152	06917500	MARMATON R NR FORT SCOTT, KS	388	0.36	0.17	0.39	132.9	0.10	39.8
	154	06918060	MARMATON RIVER NEAR NEVADA, MO	1,074	2.77	1.07	0.46	57.1	0.10	90.7
18	153	06917560	MARMATON RIVER NEAR RICHARDS, MO	455	0.42	0.37	0.45	21.5	0.10	73.2
	154	06918060	MARMATON RIVER NEAR NEVADA, MO	1,074	2.36	1.07	0.88	17.7	0.10	90.7
19	196	07155590	CIMARRON R NR ELKHART, KS*	2,416	0.56	0.10	3.33	3,233.6	0.10	0.0
	198	07157000	CIMARRON RIVER NEAR MOCANE, OK	4,305	1.78	5.94	0.18	97.0	0.10	98.3
20	236	07185700	SPRING RIVER AT LA RUSSELL, MO	306	0.72	26.8	21.3	20.5	1.52	94.3
	237	07185765	SPRING RIVER AT CARTHAGE, MO	425	1.39	29.6	37.3	25.8	1.52	94.9

*Reported values are zero, used 0.1 cubic foot per second for analysis.

Table 12. Medians and standard deviations of the absolute differences between annual mean 7-day low flow with a recurrence interval of 10 years (7Q10) using observed streamflow, the drainage-area ratio method, and regional regression equations.

[<, less than; >, greater than]

Group	Drainage-area ratio range	Number in group	Median absolute difference (percent)	Standard deviation
All estimates	All	80	87.2	373.1
Drainage-area ratio method	All	40	51.7	523.4
	<0.5 and >1.5	19	57.9	199.3
	0.5 to 1.5	21	25.8	701.5
Regional regression equations	All	40	92.4	56.1
	<0.5 and >1.5	19	90.7	74.4
	0.5 to 1.5	21	94.3	30.6

StreamStats Implementation

StreamStats is a USGS web-based GIS tool that permits users to find streamflow statistics, basin characteristics, and other information for user-selected locations on streams. “The StreamStats home page (https://streamstats.usgs.gov/ss/) provides links to a more detailed description of the program, a user's manual, descriptions of the outputs, definitions of basin characteristics and streamflow statistics, limitations for use of the application, and other information” (U.S. Geological Survey, 2021). It is recommended that users read the user's manual before trying to use the application.

“StreamStats makes the process of computing streamflow statistics for ungaged locations much faster, more accurate, and more consistent than previously used manual methods” (Eash and Barnes, 2017, p. 43). Another advantage of StreamStats is that it makes streamflow statistics for streamgages readily available and more easily accessed (Eash and Barnes, 2017). Streamflow statistics can be needed at any location alongside a stream and can aid with water-resources planning and management; the design of facilities such as wastewater-treatment plants; and the design of structures such as roads, bridges, culverts, and levees (Eash and Barnes, 2017). Also, planners, regulators, and others often need to recognize the physical and climatic characteristics (basin characteristics) of the drainage basins upstream from places of interest to support them in understanding the processes that affect water availability and quality at these locations (Eash and Barnes, 2017).

The regression equations provided in this report will be implemented in the USGS StreamStats web-based GIS tool. StreamStats will provide users the ability to estimate selected low-flow frequency and flow-duration statistics for ungaged streams in Kansas.

Summary

Knowledge of the magnitude, frequency, and duration of low flows is critical for water-supply management; reservoir design; waste-load allocation; and the preservation of water quality and quantity for irrigation, recreation, and ecological conservation purposes. Because of the importance of low-flow statistics, the U.S. Geological Survey (USGS), in cooperation with the Kansas Water Office, began a statewide study in 2018 to develop regression equations to estimate selected low-flow frequency and flow-duration statistics for ungaged stream locations in Kansas.

Major components of this study included (1) streamgage selection; (2) computation of selected low-flow statistics at 254 continuous-record streamgages within Kansas and the surrounding States with at least 10 years of record through September 30, 2017; (3) measurement of 13 basin characteristics for each streamgage within the study area; (4) development of 167 regression equations to estimate selected statistics at ungaged stream locations based on basin characteristics; (5) explanation of the drainage-area ratio (DAR) method and instances when it is appropriate to be used instead of regression equations; and (6) incorporation of the regression equations published in this report into the USGS StreamStats application.

A Mann-Kendall test was completed on each streamgage included in the regression analysis for this study because trends in the *n*-day data can introduce bias in the results of the low-flow frequency analysis. Of the streamgages tested, 77 indicated a significant trend for the 7-day annual minimum flow. An upward trend was seen at 56 streamgages, whereas a decreasing trend was observed at 21 streamgages. The trend analysis of minimum 1-day mean flows for 17 streamgages, minimum 7-day mean flows for 14 streamgages, and minimum 30-day mean flows for 7 streamgages produced tau and probability values that may be difficult to interpret because of the presence of several zero flows. When reviewing streamgage records over periods of a few years to a few decades, trends commonly appear; however, when these records are reviewed in the context of decades to centuries, short-term trends can be recognized as being part of much longer term fluctuations. No streamgage was omitted from this study because of the presence of a positive or negative trend in its dataset.

Methods described in the report for estimating selected flow-duration and low-flow frequency statistics are applicable to streams in Kansas that are not substantially affected by diversion, regulation, or urbanization by using regression equations. Regression equations were developed to estimate the annual and monthly 1-, 7-, and 30-day mean low flows with a recurrence interval of 10 years at ungaged stream locations. Regression equations were developed to estimate the flow-duration of 0.01-, 0.1-, 2-, 5-, 10-, 25-, 50-, 75-, 90-, 95-, 99-, 99.9-, and 99.99-percent exceedance intervals. Regression equations were developed for the mean annual flows as well.

For this study, Kansas was split into an east and west region and different regression equations were developed for each region. Logistic and left-censored regression techniques were used in this report because of the presence of several zero flows in the record periods. These techniques are recommended when zero flows are present and significant in a dataset. The threshold for censored data was set at 0.1 cubic foot per second (ft^3/s) because of the ability of a streamgage to provide continuous data during extreme low-flow conditions. A variety of performance metrics is provided to estimate the accuracy of each equation. These equations are only appropriate for streams in Kansas that are not substantially affected by diversion, regulation, or urbanization. Basin characteristics of these ungaged locations also need to be within the range of the basin characteristics used to develop these equations. The large amount of zero flows in some datasets are believed to be the cause of large errors in some of the previously published equations. Any equation that yields a result of less than 0.1 ft^3/s should be reported as “less than 0.1 ft^3/s.”

The DAR method was described, and instances when it is appropriate to be used instead of regression equations were presented. Previous studies indicated that it is preferable to have a ratio of drainage areas that is between 0.5 and 1.5 for the DAR method although no scientific basis for this guideline has been provided. The results of the Wilcoxon signed-rank test for this analysis of Kansas indicated that the absolute differences, in percent, were not significantly different when comparing the DAR method to the regional regression equations, regardless of what the DAR was. The DAR method had the smallest median absolute difference, in percent, when the ratio was between 0.5 and 1.5. Therefore, the results of this study indicate the DAR method is appropriate for use in Kansas when estimating streamflow at an ungaged location if there is a nearby streamgage on the same river or stream where the DAR is between 0.5 and 1.5 and the low-flow statistic at the nearby streamgage is not zero.

The regional regression equations developed in this study are not intended for use at ungaged stream locations where the basin characteristics are outside the ranges of those used to develop the equations published in this study. Geographic-information-system software is required to measure the basin characteristics included as independent variables in the regression equations. All the regression equations developed for this study will be incorporated into the USGS StreamStats web-based geographic-information-system tool. StreamStats will provide users with a set of annual and monthly low-flow frequency statistics, as well as flow-duration and mean annual flow estimates for ungaged stream locations within Kansas. StreamStats also will provide users with the basin characteristics for the locations.

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Appendixes 1–3

Appendix 1. Flow-Duration Curve Information

This appendix contains two tables with flow-duration curve information. Flow-duration curve information for the streamgages used in the regression analysis in this report is provided in table 1.1, and flow-duration curve information for all active streamgages in the State of Kansas is provided in table 1.2 (tables 1.1 and 1.2 are available for download at https://doi.org/10.3133/sir20215100). Statistics provided in tables 1.1 and 1.2 were computed using data from the U.S. Geological Survey National Water Information System database (U.S. Geological Survey, 2018).

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Appendix 2. Low-Flow Frequency Statistics Information

This appendix contains four tables with low-flow frequency statistics information. Annual low-flow frequency statistics for the streamgages used in the regression analysis in this report are provided in table 2.1, monthly low-flow frequency statistics for the streamgages used in the regression analysis in this report are provided in table 2.2, annual low-flow frequency statistics for the active streamgages in the State of Kansas are provided in table 2.3, and the results of the Mann-Kendall test for trends for the streamgages used in the regression analysis in this report are provided in table 2.4 (tables 2.1–2.4 are available for download at https://doi.org/10.3133/sir20215100). Statistics provided in tables 2.1–2.4 were computed using data from the U.S. Geological Survey National Water Information System database (U.S. Geological Survey, 2018).

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Appendix 3. Basin Characteristic Information

This appendix contains two tables with basin characteristic information. The basin characteristics considered for use in the regression analysis in this report for the streamgages within region 1 of the study area (east region) are listed in table 3.1, and the basin characteristics considered for use in the regression analysis in this report for the streamgages located within region 2 (west region) of the study area are listed in table 3.2 (tables 3.1 and 3.2 are available for download at https://doi.org/10.3133/sir20215100).

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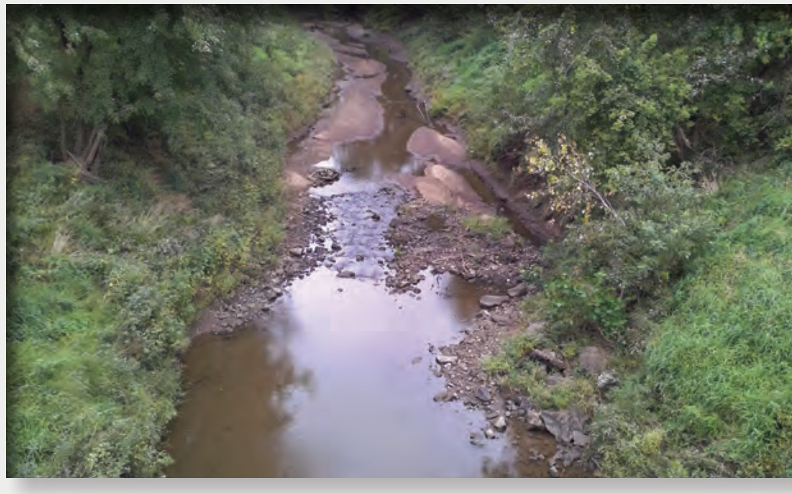

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