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Model Documentation for Relations Between Continuous Real-Time and Discrete Water-Quality Constituents in the North Fork Ninnescah River Upstream from Cheney Reservoir, South-Central Kansas, 1999–2009

Open-File Report 2013–1014

U.S. Department of the Interior
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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
milliliter (mL)	0.0338	ounce, fluid (oz)
cubic foot (ft^3)	28.32	cubic decimeter (dm^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
milligram per liter (mg/L)	1	parts per million (ppm)
	Mass	
milligram (mg)	0.001	gram (g)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$°F=(1.8\times°C)+32$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$°C=(°F-32)/1.8$

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

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

Abbreviations

adjr^2	adjusted R^2
C_p	Mallow's C_p
cooksD	Cook's distance
Df	degrees of freedom
dfits	change in fitted values
F-statistic	ratio of the mean square of the regression to the estimated variance
F Value	explained variance divided by unexplained variance
Max	maximum
Mean Sq	mean square
Min	minimum
Nvars	number of explanatory variables
p-value	probability of observing a test statistic that is as extreme or more extreme than currently observed assuming that the null hypothesis is true
Pr(F)	probability of observing a test statistic that is as extreme or more extreme than currently observed assuming that the null hypothesis is true
Pr(>|t|)	probability of observing a test statistic that is as extreme or more extreme than currently observed assuming that the null hypothesis is true
press	prediction error sum of squares
R-squared	coefficient of determination (R^2)
resids	residuals
Std. Error	standard error
Stderr	standard error
stnd.res	standardized residuals
stud.res	studentized residuals
Sum of Sq	sum of squares
t value	coefficient divided by its standard error
yhat	predicted values
1Q	first quartile
3Q	third quartile

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Abstract

Cheney Reservoir in south-central Kansas is one of the primary sources of water for the city of Wichita. The North Fork Ninnescah River is the largest contributing tributary to Cheney Reservoir. The U.S. Geological Survey has operated a continuous real-time water-quality monitoring station since 1998 on the North Fork Ninnescah River. Continuously measured water-quality physical properties include streamflow, specific conductance, pH, water temperature, dissolved oxygen, and turbidity. Discrete water-quality samples were collected during 1999 through 2009 and analyzed for sediment, nutrients, bacteria, and other water-quality constituents. Regression models were developed to establish relations between discretely sampled constituent concentrations and continuously measured physical properties to estimate concentrations of those constituents of interest that are not easily measured in real time because of limitations in sensor technology and fiscal constraints.

Regression models were published in 2006 that were based on a different dataset collected during 1997 through 2003. This report updates those models using discrete and continuous data collected during January 1999 through December 2009. Models also were developed for five new constituents, including additional nutrient species and indicator bacteria. The water-quality information in this report is important to the city of Wichita because it allows the concentrations of many potential pollutants of interest, including nutrients and sediment, to be estimated in real time and characterized over conditions and time scales that would not be possible otherwise.

Introduction

Cheney Reservoir (fig. 1), located in south-central Kansas, was constructed between 1962 and 1965 by the Bureau of Reclamation, U.S. Department of the Interior, to provide a municipal water supply for the city of Wichita, downstream flood control, wildlife habitat, and recreational areas. From 1995 through 2010, water from Cheney Reservoir contributed between 51 and 69 percent of Wichita's water supply (Ziegler and others, 2010). Water-supply needs and reliance on Cheney Reservoir will continue to increase with ongoing population growth and urban development.

The U.S. Geological Survey (USGS), in cooperation with the city of Wichita, continuously has monitored water quality on the North Fork Ninnescah River upstream from Cheney Reservoir (USGS station 07144780; fig. 1) since October 1998. Streamflow has been measured continuously on the North Fork Ninnescah River above Cheney Reservoir since July 1965. Water budget analysis during 1997 through 2003 indicated that the North Fork Ninnescah River contributes about 70 percent of the water flowing into the reservoir (Christensen and others, 2006). Water-quality monitoring on the North Fork Ninnescah River provides continuous measures of specific conductance, pH, water temperature, dissolved oxygen, and turbidity. Dozens of discrete water-quality samples have been collected at this site by USGS personnel and used to develop regression models establishing relations between continuously monitored water-quality physical properties and water-quality constituents of interest that are not monitored continuously.

Purpose and Scope

The purpose of this report is to update and document regression models that establish relations between continuous and discrete water-quality data collected from the North Fork Ninnescah River upstream from Cheney Reservoir (USGS station 07144780; fig. 1). Regression models originally were published by Christensen and others (2006) using data collected during 1997 through 2003 for 15 water-quality constituents, including total suspended solids, suspended sediment, dissolved solids and major ions, total Kjeldahl nitrogen, total phosphorus, orthophosphate, and fecal coliform bacteria. In this report, those regression models are updated using data collected through 2009, and additional models are developed for nitrate, organic nitrogen, *Escherichia coli* (*E. coli*) bacteria, and total organic carbon. Models were updated to be more representative of water-quality conditions at this site and to evaluate whether relations have changed. The updated models are intended to replace existing models. These models are useful for evaluating concentrations of water-quality constituents to compare with water-quality criteria, evaluating variability during rapidly changing conditions, computing loads and yields to assess constituent transport through the watershed, and for providing more accurate load estimates compared to the original models published in 2006. The water-quality information in this report is important to the city of Wichita because it allows many potential pollutant concentrations of interest, including sediment and nutrient inputs, to be estimated in real time and characterized over conditions and time scales that would not otherwise be possible.

Description of Study Area

The Cheney Reservoir watershed is located in south-central Kansas (fig. 1) and has a contributing drainage area of 933 square miles (mi^2). The North Fork Ninnescah River is the largest tributary to Cheney Reservoir. The North Fork Ninnescah River above Cheney Reservoir (USGS station 07144780), where continuous water-quality data have been collected since October 1998, has a drainage area of 734 mi^2.

Land use in the Cheney Reservoir watershed predominately is rural (fig. 1); less than 1 percent of the land use in the watershed is classified as urban. All agricultural crops, including wheat, comprise about 55 percent of land use in the watershed above the North Fork Ninnescah River site. About 25 percent of the North Fork Ninnescah River site's watershed is grassland and about 18 percent is conservation reserve program land (Peterson and others, 2005).

Methods

Continuous and discrete water-quality data were collected at one inflow site on the North Fork Ninnescah River (fig. 1; USGS station 07144780, North Fork Ninnescah River above Cheney Reservoir), hereinafter referred to as the inflow site. The North Fork Ninnescah River is the largest contributing tributary to Cheney Reservoir, and thus one of the main contributors to reservoir water quality. Discrete water-quality samples routinely have been collected since February 1996. Continuous and discrete water-quality data collected by the USGS at the inflow site from January 1999 through December 2009 were used to develop updated and new site-specific regression models.

Continuous Water-Quality Monitoring

Continuous water-quality data were collected from the inflow site and were recorded hourly. Streamflow was measured using standard USGS methods (Turnipseed and Sauer, 2010). The inflow site was equipped with a YSI 6600 Extended Deployment System water-quality monitor that measured specific conductance, pH, water temperature, dissolved oxygen (YSI Clark cell or optical dissolved oxygen sensors), and turbidity (YSI model 6026 turbidity sensor). The YSI Clark cell dissolved-oxygen sensor was used from November 1998 through March 2008 and was replaced by the YSI optical dissolved-oxygen sensor in March 2008. The monitor was installed near the centroid of streamflow to best represent conditions across the width of the stream and was maintained in accordance with standard USGS procedures (Wilde, 2008; Wagner and others, 2006). Continuous streamflow and water-quality data were recorded hourly and are available on the USGS website at *http://nrtwq.usgs.gov/ks*.

The specific conductance, pH, water temperature, and dissolved oxygen sensors have wide ranges of operation (Wagner and others, 2006) that were not exceeded in this study. The YSI model 6026 turbidity sensor instrument maximum (1,700 formazin nephelometric units, FNU) was not exceeded during 1999 through 2009 and the maximum reading recorded at this site during the study period was 1,700 FNU. Continuous data during the study period generally required corrections of less than 10 percent, which classifies the data quality rating as good according to established guidelines (Wagner and others, 2006). Time-series measurements occasionally were missing or deleted from the dataset because of equipment malfunction or excessive fouling caused by environmental conditions. During 1999 through 2009, less than 1 percent of the discharge record, 6 percent of the specific conductance record, 4 percent of the pH record, 3 percent of the temperature record, 8 percent of the dissolved oxygen record, and 7 percent of the turbidity record were missing or deleted. Missing and deleted data were because of issues with calibration of the Clark cell dissolved oxygen sensor, sensors becoming submerged in sand, sensors not having enough water to be submerged during low flow conditions, sensor fouling, data corrections greater than the maximum allowable 20 percent, and extremely cold temperatures causing icy conditions.

Discrete Water-Quality Samples

Discrete water-quality samples were collected over a range of streamflow conditions during January 1999 through December 2009 using depth- and width-integrating sample-collection techniques (Wilde, 2008; U.S. Geological Survey, 2006). Samples collected using this approach are representative of the average chemical composition of the stream cross-sectional area. All water samples were analyzed for dissolved solids and major ions, alkalinity, suspended solids and sediment, nutrients (nitrogen and phosphorus species), indicator

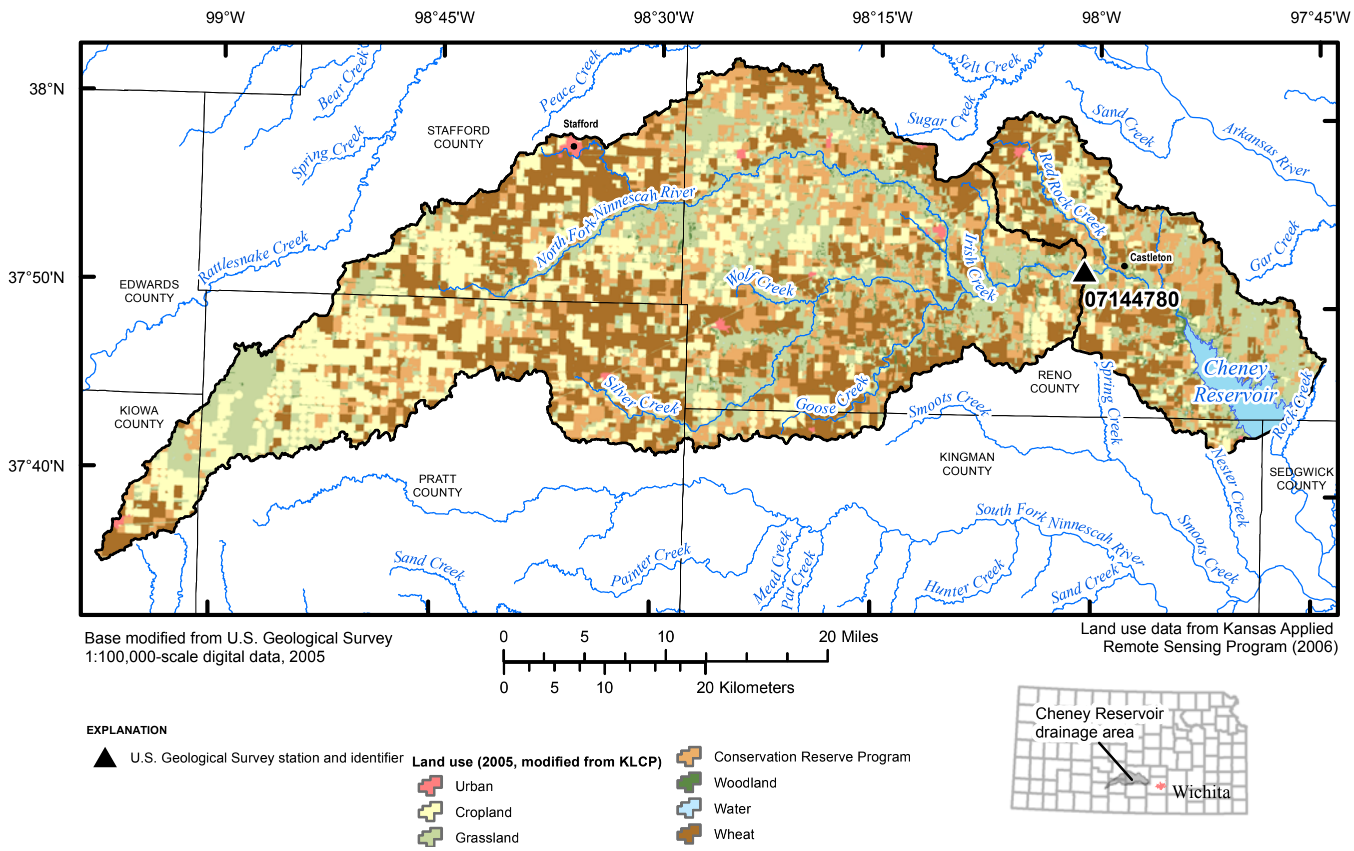

Figure 1. Location of continuous real-time water-quality monitoring station and land use in the Cheney Reservoir watershed.

bacteria, and organic carbon. Dissolved and suspended solids, major ions, alkalinity, nutrients (except for total Kjeldahl nitrogen), fecal coliform bacteria, and organic carbon were analyzed by the Wichita Municipal Water and Wastewater Laboratory in Wichita, Kansas according to standard methods (American Public Health Association and others, 1995). An incremental equivalence method was used for the alkalinity titrations. Bicarbonate concentrations were calculated by multiplying the alkalinity concentrations by 0.8202 (Rounds, 2012). Selected replicate samples were sent to the USGS National Water Quality Laboratory in Lakewood, Colorado and analyzed according to methods presented in Fishman and Friedman (1989). *E. coli* bacteria was analyzed at the USGS Wichita Field Office in Wichita, Kansas using methods described by Wilde (2008). Suspended sediment was analyzed at the USGS Iowa Sediment Laboratory in Iowa City, Iowa according to methods described in Guy (1969).

Quality Assurance and Quality Control

Replicate, standard reference, and blank samples were collected over a range of streamflow conditions as part of quality assurance/quality control (QA/QC). About 8 percent of discrete water-quality samples were QA/QC samples. Approximately 180 sequential replicate constituent pairs were collected during 1999 through 2009 for the inflow site. Replicate samples were analyzed to identify variability in sampling and analysis methods (Wilde, 2008). Relative percentage difference (RPD) was used to evaluate differences in analyte concentrations detected in replicate water samples. The RPD was calculated using the following equation:

$$RPD = \left[\left| A - B \right| / \left(\frac{A+B}{2} \right) \right] \times 100 \quad (1)$$

where A and B are concentrations in each replicate pair. Replicate pairs with an RPD within 10 percent were considered acceptable for inorganic constituents (Ziegler and Combs, 1997). Replicate pairs with an RPD within 20 percent were considered acceptable for organic constituents (including total phosphorus), and RPDs within 50 percent were considered acceptable for bacterial analysis. The median RPD between all constituent replicate pairs was less than their respective acceptability limits. All constituent replicate pairs had median RPDs that were less than 5 percent, except for total Kjeldahl nitrogen (12 percent), total phosphorus (15 percent), *E. coli* (25 percent), and suspended sediment (6 percent). Larger RPDs generally occurred when the values were near the method detection limit.

Approximately 65 sequential constituent replicate pairs were analyzed by the Wichita Municipal Water and Wastewater Laboratory and the USGS National Water Quality Laboratory. The median RPD between laboratories for ions was 6 percent. The median RPD between laboratories for nutrients was 12 percent. Larger nutrient RPDs generally occurred because of differences in laboratory method reporting levels and when the values were at or near the method reporting level.

Blank sample analysis included approximately 210 constituent concentrations. All constituents were below the method reporting level with the exception of ammonia. One ammonia value was 0.01 milligrams per liter (mg/L) above the method reporting level. Median blank bicarbonate concentration was 2.4 mg/L. Median blank alkalinity concentration was 2.0 mg/L.

Standard reference samples were analyzed by the Wichita Municipal Water and Wastewater Laboratory at least annually and submitted to the USGS Branch of Quality Systems for sample analysis and evaluation of laboratory performance. Median major ion constituent RPDs ranged from 1 to 6 percent and median nutrient constituent RPDs ranged from 3 to 5 percent during this study. Results are available at *http://bqs.usgs.gov/srs/*.

Cross-sectional measurements were compared to the continuous measurements to provide verification that minimum bias occurred as a result of water-quality monitor location within the stream cross-section. The median RPD between cross-sectional and continuous monitor measurements was approximately 2 percent for all measurements. Larger differences (greater than 5 percent RPD) between cross-sectional and continuous monitor measurements occurred during stormwater runoff events when conditions were changing rapidly.

Development of Regression Models to Compute Constituent Concentrations

Models were developed using simple linear (ordinary least squares) regression analyses to relate discrete sample concentrations or densities of water-quality constituents to continuously measured water-quality physical properties (Helsel and Hirsch, 2002; Rasmussen and others, 2008). The methods used for the development of these models and quantifying uncertainty are described in detail in Rasmussen and others (2009). All data for this report were analyzed using TIBCO Spotfire S+® 8.1 for Windows® statistical software (TIBCO Software, Inc., 2008).

To avoid false-positive quantification of a constituent, low concentrations are left-censored and reported as "less than" values by the laboratory (Childress and others, 1999). Two constituents had left-censored data: organic nitrogen (15 percent of samples) and orthophosphate (33 percent of samples). The left-censored data arbitrarily were assigned a value of one-half of the censoring level.

Although Christensen and others (2006) included discrete data collected in 1997 and 1998 in their regression analyses, these data were not included in the current analysis. Christensen and others (2006) used cross-sectional means of continuously measured physical properties as explanatory variables, whereas this current analysis uses continuously measured water-quality data after the Rasmussen and others (2009) protocol. Christensen and others (2006) also included discrete data collected by autosamplers as response variables; this report did not use autosampled data because the autosamples represented a relatively small part of the dataset and may not be representative of the average chemical composition of the stream cross-sectional area (Christensen and others, 2006; Rasmussen and others, 2008). Original models had numbers of discrete samples ranging from 20 to 127, with a median of 27 (Christensen and others, 2006). The numbers of discrete samples for models in this report range from 22 to 61, with a median of 54.

All continuously measured variables and seasonal components (sine and cosine variables) were tested for significance (*p*-value less than 0.05) for each response variable. Concomitant in-stream continuous measurements were used to correspond with discrete measurements as described in Rasmussen and others (2009). In-stream continuous data corresponding to each discrete sample were determined from time-series datasets by using time-weighted averages of continuous data values recorded immediately before, during, and after the discrete sample collection.

Outliers were identified and removed as described in Rasmussen and others (2009). Outliers in discrete samples primarily were removed when there was large heterogeneity in corresponding physical properties of cross-sectional data recorded during discrete sampling and when there were issues with nutrient laboratory analysis (such as an orthophosphate concentration being higher than the concomitant total phosphorus concentration). Overall, approximately 5 percent of the discrete-sample data were considered outliers and were removed from regression models. Three percent of the discrete-sample data was removed because of large heterogeneity in corresponding physical properties of cross-sectional data recorded during discrete sampling. One percent of the discrete-sample data was removed because of a large specific conductance value likely affected by road salt application. One percent of the discrete-sample data was removed because of laboratory analysis issues. Uncertainty in regression model predictions is unknown when the cross-sectional measurements vary greatly from the in situ measurements and when road salt is applied.

Regression models were evaluated based on diagnostic statistics (R^2, coefficient of determination; Mallow's C_p; *RMSE*, root mean square error; *PRESS*, prediction error sum of squares), patterns in residual plots, and the range and distribution of discrete and continuous data (Helsel and Hirsch, 2002). All linear models were considered for each constituent, and the best model for each constituent was selected to maximize the amount of variance in the response variable that is explained by the model (multiple R^2 for models with one explanatory variable and adjusted R^2 for models with more than one explanatory variable), that best fits the data (Mallow's C_p), and that minimized heteroscedasticity (irregular scatter) in the residual plots and uncertainty associated with computed values (*RMSE* and *PRESS*). Model simplicity also was considered for model selection because, as more variables are included, the likelihood increases that the variability of the system is not described by the sampling dataset. A second significant explanatory variable was added to the model when doing so substantially increased R^2 and decreased Mallow's C_p.

Mean square error (*MSE*) and *RMSE* were calculated for each model to assess the variance between predicted and observed values (Helsel and Hirsch, 2002). The model standard percentage error (*MSPE*) was calculated as a percentage of the *RMSE* (Hardison, 1969). Because transformation of estimates back into original units results in a low biased estimate (Helsel and Hirsch, 2002), a bias correction factor (*BCF*) was calculated for models with logarithmically transformed response variables (Duan, 1983). Uncertainty associated with regression-computed constituent concentrations was quantified using 90-percent prediction intervals (Helsel and Hirsch, 2002).

Results of Regression Analysis for Selected Constituents

Regression models for 15 constituents developed from data collected during 1997 through 2003 (Christensen and others, 2006) were updated and new models were developed for 5 additional constituents not described in Christensen and others (2006). The updated models were for dissolved solids, calcium, magnesium, sodium, chloride, potassium, sulfate, alkalinity, bicarbonate, total suspended solids, suspended sediment, total Kjeldahl nitrogen, total phosphorus, orthophosphate, and fecal coliform bacteria. The newly developed models were for the nutrient species total nitrogen, organic nitrogen, and nitrate; *E. coli* bacteria; and total organic carbon. Additional streamflow-based models of select constituents of interest were developed to allow computation of constituent concentrations when concomitant initial model real time data are unavailable. Streamflow-based models were developed for dissolved solids, sodium, chloride, sulfate, total suspended solids, suspended sediment, total nitrogen, nitrate, total phosphorus, and *E. coli* bacteria. Updated and newly developed models were developed from data collected during 1999 through 2009. Models are shown in table 1. Model datasets are presented in tables 2–15 and TIBCO Spotfire S+® model (S+®) statistical output is presented in figures 2–61 (see the Abbreviations list in the front of this report for definitions of abbreviations used in the figures).

Graphical S+® statistical output includes plots of the regression analysis for regression equations with one explanatory variable, computed versus measured ("actual") concentrations, a comparison of estimated ("fitted") concentrations and regression residuals ("residuals"), and a standard normal quantiles versus regression residuals plot. The plot of the fitted values and regression residuals indicates unexplained structure left in the residuals (TIBCO Software, Inc., 2008). The standard normal quantiles versus regression residuals plots the normal quantiles ("quantiles of standard normal") against the regression residuals ("residuals") and provides a visual test of the assumption that the model's errors are normally distributed (TIBCO Software, Inc., 2008).

In general, model forms and the amount of variance explained by the models was similar between the original (Christensen and others, 2006) and updated models (table 1). The model forms for most updated models remained unchanged. Dissolved solids, calcium, magnesium, sodium, chloride, potassium, and sulfate were strongly positively correlated with specific conductance; the calcium model included streamflow as an additional explanatory variable. On average, the updated ion models explained 9 percent more of the variance in ion concentrations compared to the original models (table 1). Actual (measured) versus computed plots of dissolved solids, sodium, and chloride using streamflow as an explanatory variable indicate that relations may be different at higher concentrations compared to lower concentrations suggesting limitations in the utility of the streamflow-based model for these constituents (figs. 5*B*, 13*B*, 17*B*).

The maximum pH for discrete water-quality samples associated with alkalinity titrations was 8.7. Alkalinity and bicarbonate were positively correlated with streamflow and specific conductance. The updated alkalinity model explained 6 percent more variance in alkalinity concentrations than the original model and the updated bicarbonate model explained 5 percent more variance than the original model (table 1).

Total suspended solids and suspended sediment were strongly positively correlated with turbidity. The updated suspended-sediment model also included streamflow as an explanatory variable and explained 5 percent more variance in suspended-sediment concentrations than the original model (table 1). The total suspended solids model that uses streamflow as an explanatory variable has a larger amount of variability when total suspended solids concentration is greater than about 150 mg/L than when total suspended solids concentration is less than about 150 mg/L (fig. 31*B*).

All nitrogen species and total phosphorus models included turbidity as an explanatory variable. Total nitrogen and nitrate models also included season as an explanatory variable. The updated total Kjeldahl nitrogen model explained 9 percent more variance in total Kjeldahl nitrogen concentrations than the original model (table 1). The organic nitrogen model also included specific conductance as an explanatory variable, and the orthophosphorus model had specific conductance as the explanatory variable. Fecal coliform and *Escherichia coli* bacteria models were positively related to turbidity and negatively related to specific conductance. The total organic carbon model was positively related to turbidity.

Table 1. Christensen and others (2006), updated, and new regression models and summary statistics for continuous concentration computations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

[R^2, coefficient of determination; MSE, mean square error; RMSE, root mean square error; MSPE, model standard percentage error; %, percent; ±, plus or minus; *n*, number of discrete samples; mg/L, milligrams per liter; log, $\log_{10}$; SC, specific conductance in microsiemens per centimeter at 25 degress Celsius; Q, streamflow in cubic feet per second; TBY_{6026}, turbidity from YSI sensor 6026 in formazin nephelometric units; TKN, total Kjeldahl nitrogen in milligrams per liter; NO_3NO_2, nitrate plus nitrate in milligrams per liter; sin, sine; D, day of year; cos, cosine; <, less than; colonies/100 mL, colonies per 100 milliliters]

Regression model	Multiple R^2	Adjusted R^2	MSE	RMSE	MSPE (upper)	MSPE (lower)	Bias correction factor (Duan, 1983)	90% prediction interval, in ± %	Discrete data				
									n	Range of values in variable measurements	Mean	Median	Standard deviation
Dissolved solids (DS), mg/L													
Christensen and others (2006)													
log(DS) = 0.910log(SC) + 0.0101	0.87	0.87	0.0044	0.0663	17	14	1.01	40	127	DS: 140–707	461	472	168
										SC: 198–1,300	821	837	303
Updated													
log(DS) = 0.892log(SC) + 0.0810	0.98	0.98	0.0006	0.0250	6	6	1.00	39	61	DS: 191–798	507	548	172
										SC: 258–1,430	883	976	326
log(DS) = -0.225log(Q) + 3.19	0.68	0.67	0.0107	0.1036	27	21	1.03	40	61	DS: 191–798	507	548	172
										Q: 9.4–3,725	564	223	873
Calcium (Ca), dissolved, mg/L													
Christensen and others (2006)													
log(Ca) = 0.724log(SC) - 0.387	0.76	0.76	0.0048	0.0767	19	16	1.02	40	127	Ca: 19.7–88.7	52.9	50.7	17.8
										SC: 198–1,300	821	837	303
Updated													
log(Ca) = 0.120log(Q) + 0.964log(SC) - 1.37	0.89	0.89	0.0023	0.0478	12	10	1.01	40	61	Ca: 23.2–86.6	53.4	54.7	15.8
										Q: 9.4–3,725	564	223	873
										SC: 258–1,430	883	976	326
Magnesium (Mg), dissolved, mg/L													
Christensen and others (2006)													
Mg = 0.0086(SC) +1.68	0.80	0.80	1.7500	1.3212	15	-15	1.00	39	127	Mg: 3.52–13.8	8.77	9.27	2.93
										SC: 198–1,300	821	837	303
Updated													
log(Mg) = 0.698log(SC) - 1.08	0.92	0.92	0.0017	0.0410	10	9	1.00	40	61	Mg: 3.66–13.0	9.26	10.0	2.63
										SC: 258–1,430	883	976	326

Table 1. Christensen and others (2006), updated, and new regression models and summary statistics for continuous concentration computations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[R^2, coefficient of determination; MSE, mean square error; RMSE, root mean square error; MSPE, model standard percentage error; %, percent; ±, plus or minus; *n*, number of discrete samples; mg/L, milligrams per liter; log, $\log_{10}$; SC, specific conductance in microsiemens per centimeter at 25 degress Celsius; Q, streamflow in cubic feet per second; TBY_{6026}, turbidity from YSI sensor 6026 in formazin nephelometric units; TKN, total Kjeldahl nitrogen in milligrams per liter; NO_3NO_2, nitrate plus nitrate in milligrams per liter; sin, sine; D, day of year; cos, cosine; <, less than; colonies/100 mL, colonies per 100 milliliters]

Regression model	Multiple R^2	Adjusted R^2	MSE	RMSE	MSPE (upper)	MSPE (lower)	Bias correction factor (Duan, 1983)	90% prediction interval, in ± %	Discrete data: *n*	Range of values in variable measurements	Mean	Median	Standard deviation
Sodium (Na), dissolved, mg/L													
Christensen and others (2006)													
log(Na) = 1.17log(SC) - 1.41	0.89	0.89	0.0061	0.0784	20	17	1.02	40	127	Na: 19.5–180	104	101	46.5
										SC: 198–1,300	821	837	303
Updated													
log(Na) = 1.33log(SC) - 1.86	0.99	0.98	0.0011	0.0330	8	7	1.00	40	61	Na: 22.8–185	117	130	53.4
										SC: 258–1,430	883	976	326
log(Na) = -0.351log(Q) + 2.81	0.74	0.74	0.0187	0.1367	37	27	1.05	41	61	Na: 22.8–185	117	130	53.4
										Q: 9.4–3,725	564	223	873
Chloride (Cl), dissolved, mg/L													
Christensen and others (2006)													
log(Cl) = 1.37log(SC) - 1.82	0.97	0.97	0.0018	0.0420	10	9	1.00	41	27	Cl: 34.0–289	155	159	71.0
										SC: 322–1,250	844	903	297
Updated													
log(Cl) = 1.39log(SC) - 1.90	0.96	0.96	0.0035	0.0591	15	13	1.01	40	48	Cl: 30.8–289	147	139	82.7
										SC: 258–1,430	822	837	339
log(Cl) = -0.401log(Q) + 3.06	0.77	0.76	0.0212	0.1457	40	29	1.05	42	48	Cl: 30.8–289	147	139	82.7
										Q: 15–3,725	697	321	942
Potassium (K), dissolved, mg/L													
Christensen and others (2006)													
log(K) = -0.0003(SC) + 0.944	0.54	0.54	0.0084	0.0917	24	19	1.02	40	127	K: 2.53–8.16	4.94	4.85	1.48
										SC: 198–1,300	821	837	303
Updated													
log(K) = -0.0011(SC) + 1.17log(SC) -1.80	0.73	0.72	0.0055	0.0740	19	16	1.01	40	61	K: 2.89–8.41	4.93	5.00	1.56
										SC: 258–1,430	883	976	326

Table 1. Christensen and others (2006), updated, and new regression models and summary statistics for continuous concentration computations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[R^2, coefficient of determination; MSE, mean square error; RMSE, root mean square error; MSPE, model standard percentage error; %, percent; ±, plus or minus; *n*, number of discrete samples; mg/L, milligrams per liter; log, $\log_{10}$; SC, specific conductance in microsiemens per centimeter at 25 degress Celsius; Q, streamflow in cubic feet per second; TBY_{6026}, turbidity from YSI sensor 6026 in formazin nephelometric units; TKN, total Kjeldahl nitrogen in milligrams per liter; NO_3NO_2, nitrate plus nitrate in milligrams per liter; sin, sine; D, day of year; cos, cosine; <, less than; colonies/100 mL, colonies per 100 milliliters]

Regression model	Multiple R^2	Adjusted R^2	MSE	RMSE	MSPE (upper)	MSPE (lower)	Bias correction factor (Duan, 1983)	90% prediction interval, in ± %	Discrete data: *n*	Range of values in variable measurements	Mean	Median	Standard deviation
Sulfate (SO_4), dissolved, mg/L													
Christensen and others (2006)													
$\log(SO_4) = 0.961\log(SC) - 1.26$	0.85	0.85	0.0059	0.0765	19	16	1.01	41	27	SO_4: 11.0–61.0	35.8	37.9	13.7
										SC: 322–1,250	844	903	297
Updated													
$SO_4 = 0.0408(SC) - 0.002$	0.87	0.87	29.56	5.4369	16	-16	1.00	40	48	SO_4: 8.5–61.0	33.6	29.0	18.9
										SC: 258–1,430	822	837	339
$SO_4 = -20.1\log(Q) + 82.6$	0.77	0.76	51.89	7.2035	21	-21	1.00	40	48	SO_4: 8.5–61.0	33.6	29.0	18.9
										Q: 15–3,725	697	321	942
Alkalinity (ALK), mg/L													
Christensen and others (2006)													
$\log(ALK) = 0.659\log(SC) + 0.241$	0.81	0.80	0.0038	0.0614	15	13	1.01	41	27	ALK: 74–222	147	153	42
										SC: 322–1,250	844	903	297
Updated													
$\log(ALK) = 0.114\log(Q) + 0.810\log(SC) - 0.447$	0.87	0.86	0.0022	0.0464	11	10	1.01	40	48	ALK: 74–215	149	156	38
										Q: 15–3,725	697	321	942
										SC: 258–1,430	822	837	339
Bicarbonate (HCO_3), mg/L													
Christensen and others (2006)													
$\log(HCO_3) = 0.669\log(SC) + 0.296$	0.81	0.80	0.0038	0.0617	15	13	1.01	41	27	HCO_3: 86–271	179	187	51
										SC: 322–1,250	844	903	297
Updated													
$\log(HCO_3) = 0.113\log(Q) + 0.813\log(SC) - 0.368$	0.86	0.85	0.0023	0.0479	12	10	1.01	40	48	HCO_3: 86–260	181	190	47
										Q: 15–3,725	697	321	942
										SC: 258–1,430	822	837	339

Table 1. Christensen and others (2006), updated, and new regression models and summary statistics for continuous concentration computations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[R^2, coefficient of determination; MSE, mean square error; RMSE, root mean square error; MSPE, model standard percentage error; %, percent; ±, plus or minus; *n*, number of discrete samples; mg/L, milligrams per liter; log, $\log_{10}$; SC, specific conductance in microsiemens per centimeter at 25 degress Celsius; Q, streamflow in cubic feet per second; TBY_{6026}, turbidity from YSI sensor 6026 in formazin nephelometric units; TKN, total Kjeldahl nitrogen in milligrams per liter; NO_3NO_2, nitrate plus nitrate in milligrams per liter; sin, sine; D, day of year; cos, cosine; <, less than; colonies/100 mL, colonies per 100 milliliters]

Regression model	Multiple R^2	Adjusted R^2	MSE	RMSE	MSPE (upper)	MSPE (lower)	Bias correction factor (Duan, 1983)	90% prediction interval, in ± %	Discrete data				
									n	Range of values in variable measurements	Mean	Median	Standard deviation
Total suspended solids (TSS), mg/L													
Christensen and others (2006)													
$\log(TSS) = 0.893\log(TBY_{6026}) + 0.253$	0.92	0.92	0.0233	0.1525	42	30	1.06	43	29	TSS: 8–696	156	55	186
										TBY_{6026}: 7.9–575	154	40	188
$\log(TSS) = 0.682\log(Q) + 0.431$	0.61	0.59	0.1190	0.3454	122	55	1.34	54	29	TSS: 8–696	156	55	186
										Q: 9.3–3,460	406	106	775
Updated													
$\log(TSS) = 0.903\log(TBY_{6026}) + 0.252$	0.87	0.87	0.0295	0.1718	49	33	1.08	42	57	TSS: 8–696	153	119	144
										TBY_{6026}: 13–600	136	110	138
$\log(TSS) = 0.575\log(Q) + 0.624$	0.64	0.63	0.0810	0.2846	93	48	1.25	49	57	TSS: 8–696	153	119	144
										Q: 9.4–3,725	600	238	892
Suspended-sediment concentration (SSC), mg/L													
Christensen and others (2006)													
$\log(SSC) = 1.10\log(TBY_{6026}) +0.0037$	0.85	0.85	0.0589	0.2426	75	43	1.18	48	22	SSC: 22–2,150	385	93	625
										TBY_{6026}: 15–575	170	60.8	194
$\log(SSC) = 0.934\log(Q) +0.043$	0.76	0.78	0.0959	0.3097	104	51	1.26	51	22	SSC: 22–2,150	385	93	625
										Q: 20–3,460	482	120	870
Updated													
$\log(SSC) = 0.540\log(Q) + 0.559\log(TBY_{6026}) - 0.110$	0.90	0.90	0.0347	0.1862	54	35	1.09	43	52	SSC: 19–2,690	439	208	596
										Q: 15–3,725	645	263	919
										TBY_{6026}: 13–600	146	113	139
$\log(SSC) = 0.861\log(Q) + 0.209$	0.82	0.81	0.0622	0.2494	78	44	1.18	47	52	SSC: 19–2,690	439	208	596
										Q: 15–3,725	645	263	919

Table 1. Christensen and others (2006), updated, and new regression models and summary statistics for continuous concentration computations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[R^2, coefficient of determination; MSE, mean square error; RMSE, root mean square error; MSPE, model standard percentage error; %, percent; ±, plus or minus; *n*, number of discrete samples; mg/L, milligrams per liter; log, $\log_{10}$; SC, specific conductance in microsiemens per centimeter at 25 degress Celsius; Q, streamflow in cubic feet per second; TBY_{6026}, turbidity from YSI sensor 6026 in formazin nephelometric units; TKN, total Kjeldahl nitrogen in milligrams per liter; NO_3NO_2, nitrate plus nitrate in milligrams per liter; sin, sine; D, day of year; cos, cosine; <, less than; colonies/100 mL, colonies per 100 milliliters]

Regression model	Multiple R^2	Adjusted R^2	MSE	RMSE	MSPE (upper)	MSPE (lower)	Bias correction factor (Duan, 1983)	90% prediction interval, in ± %	Discrete data: *n*	Range of values in variable measurements	Mean	Median	Standard deviation
Nitrogen, total (TN), mg/L (TKN + NO_3NO_2)													
New													
$\log(TN) = 0.0218\sin(2\pi D/365) + 0.112\cos(2\pi D/365) + 0.182\log(TBY_{6026}) - 0.0012$	0.63	0.60	0.0077	0.0876	22	18	1.02	40	54	TN: 0.99–4.43	2.18	2.02	0.72
										TBY_{6026}: 12–600	141	113	140
$\log(TN) = 0.0209\sin(2\pi D/365) + 0.105\cos(2\pi D/365) + 0.0822\log(Q) + 0.150$	0.38	0.34	0.0127	0.1129	30	23	1.03	41	54	TN: 0.99-4.43	2.18	2.02	0.72
										Q: 15–3,725	632	256	906
Nitrogen, ammonia plus organic (TKN), total, mg/L													
Christensen and others (2006)													
$TKN = -0.0004(Q) + 0.0054(TBY_{6026}) + 0.790$	0.92	0.91	0.0881	0.2968	20	-20	1.00	41	20	TKN: 0.48–3.5	1.45	1.24	0.91
										Q: 20–2,360	367	108	590
										TBY_{6026}: 15–532	151	41	177
Updated													
$\log(TKN) = 0.426\log(TBY_{6026}) - 0.700$	0.83	0.83	0.0079	0.0888	23	18	1.02	40	50	TKN: 0.48–3.40	1.57	1.55	0.69
										TBY_{6026}: 13–600	155	121	141
Organic Nitrogen (ON), mg/L (TKN - ammonia)													
New													
$ON = 1.58\log(TBY_{6026}) + 1.04\log(SC) - 4.65$	0.82	0.81	0.0870	0.2950	21	-21	1.00	40	54	ON: <0.07–3.26	1.40	1.38	0.68
										TBY_{6026}: 12–600	140	113	140
										SC: 258–1,430	857	935	337
Nitrate (NO_3), mg/L													
New													
$NO_3 = 0.0519\sin(2\pi D/365) + 0.619\cos(2\pi D/365) - 0.389\log(TBY_{6026}) + 1.63$	0.63	0.61	0.0954	0.3088	45	-45	1.00	39	61	NO_3: 0.03–2.38	0.69	0.52	0.49
										TBY_{6026}: 12–600	129	92	136
$NO_3 = 0.0903\sin(2\pi D/365) + 0.652\cos(2\pi D/365) - 0.278\log(Q) + 1.55$	0.60	0.58	0.1028	0.3206	46	-46	1.00	39	61	NO_3: 0.03–2.38	0.69	0.52	0.49
										Q: 9.40–3,725	564	223	873

Table 1. Christensen and others (2006), updated, and new regression models and summary statistics for continuous concentration computations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[R^2, coefficient of determination; MSE, mean square error; RMSE, root mean square error; MSPE, model standard percentage error; %, percent; ±, plus or minus; *n*, number of discrete samples; mg/L, milligrams per liter; log, log_{10}; SC, specific conductance in microsiemens per centimeter at 25 degress Celsius; Q, streamflow in cubic feet per second; TBY_{6026}, turbidity from YSI sensor 6026 in formazin nephelometric units; TKN, total Kjeldahl nitrogen in milligrams per liter; NO_3NO_2, nitrate plus nitrate in milligrams per liter; sin, sine; D, day of year; cos, cosine; <, less than; colonies/100 mL, colonies per 100 milliliters]

Regression model	Multiple R^2	Adjusted R^2	MSE	RMSE	MSPE (upper)	MSPE (lower)	Bias correction factor (Duan, 1983)	90% prediction interval, in ± %	Discrete data: *n*	Discrete data: Range of values in variable measurements	Discrete data: Mean	Discrete data: Median	Discrete data: Standard deviation
Phosphorus, total (TP), mg/L													
Christensen and others (2006)													
$TP = 0.0001(Q) + 0.0008(TBY_{6026}) + 0.0863$	0.84	0.83	0.0661	0.0661	33	-33	1.00	40	26	TP: 0.03–0.58	0.20	0.13	0.16
										Q: 9.3–2,360	293	103	533
										TBY_{6026}: 7.9–532	125	39.0	163
Updated													
$log(TP) = 0.611log(TBY_{6026}) -1.829$	0.83	0.82	0.0189	0.1375	37	27	1.05	42	55	TP: 0.04–0.58	0.27	0.26	0.16
										TBY_{6026}: 13–600	137	110	139
$TP = 0.191log(Q) - 0.174$	0.57	0.56	0.0115	0.1073	39	-39	1.00	40	55	TP: 0.04–0.58	0.27	0.26	0.16
										Q: 9.4–3,725	596	238	904
Orthophosphate, filtered (OP), mg/L as phosphate													
Christensen and others (2006)													
$OP = -0.0002(SC) + 0.237$	0.84	0.83	0.0007	0.0263	66	-66	1.00	40	25	OP: <0.01–0.19	0.04	0.01	0.06
										SC: 322–1,250	966	1,087	288
Updated													
$OP = -0.0002(SC) + 0.224$	0.74	0.73	0.0011	0.0339	56	-56	1.00	40	54	OP: 0.01–0.23	0.06	0.03	0.07
										SC: 317–1,430	907	977	311
Fecal coliform bacteria (FC), colonies/100 mL													
Christensen and others (2006)													
$log(FC) = 0.714log(TBY_{6026}) - 0.0016(SC) + 3.10$	0.78	0.76	0.2230	0.4691	195	66	1.52	61	30	FC: 8–36,000	4,888	500	8,646
										TBY_{6026}: 7.9–575	152	41	185
										SC: 322–1,250	944	1,070	292
Updated													
$log(FC) = 0.761log(TBY_{6026}) - 0.0013(SC) + 2.73$	0.72	0.71	0.2367	0.4865	207	67	1.71	67	60	FC: 8–65,000	6,207	880	11,736
										TBY_{6026}: 13–600	138	120	134
										SC: 200–1,430	843	896	333

Table 1. Christensen and others (2006), updated, and new regression models and summary statistics for continuous concentration computations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[R^2, coefficient of determination; MSE, mean square error; RMSE, root mean square error; MSPE, model standard percentage error; %, percent; ±, plus or minus; *n*, number of discrete samples; mg/L, milligrams per liter; log, log_{10}; SC, specific conductance in microsiemens per centimeter at 25 degress Celsius; Q, streamflow in cubic feet per second; TBY_{6026}, turbidity from YSI sensor 6026 in formazin nephelometric units; TKN, total Kjeldahl nitrogen in milligrams per liter; NO_3NO_2, nitrate plus nitrate in milligrams per liter; sin, sine; D, day of year; cos, cosine; <, less than; colonies/100 mL, colonies per 100 milliliters]

Regression model	Multiple R^2	Adjusted R^2	MSE	RMSE	MSPE (upper)	MSPE (lower)	Bias correction factor (Duan, 1983)	90% prediction interval, in ± %	Discrete data				
									n	Range of values in variable measurements	Mean	Median	Standard deviation
Escherichia coli bacteria (EC), colonies/100 mL													
New													
$\log(EC) = 0.0032(TBY_{6026}) - 0.0016(SC) + 4.01$	0.87	0.85	0.0965	0.3106	104	51	1.20	49	22	EC: 17–30,000	5,086	1,400	8,319
										TBY_{6026}: 13–280	130	121	87.3
										SC: 200–1,430	797	755	347
$\log(EC) = 0.977\log(Q) + 0.650$	0.73	0.71	0.1902	0.4361	173	63	1.45	59	22	EC: 17–30,000	5,086	1,400	8,319
										Q: 15–4,780	993	402	1,321
Total organic carbon (TOC), mg/L													
New													
$\log(TOC) = 0.485\log(TBY_{6026}) + 0.0080$	0.73	0.72	0.0183	0.1353	37	27	1.04	41	45	TOC: 2.5–20.5	11.2	12.6	5.3
										TBY_{6026}: 13–600	161	123	144

Table 2. Dissolved solids, calcium, magnesium, sodium, and potassium simple linear regression model datasets for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

[hh, hours; mm, minutes]

Date	Time, in hhmm	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Streamflow, in cubic feet per second	Dissolved solids, in milligrams per liter	Calcium, in milligrams per liter	Magnesium, in milligrams per liter	Sodium, in milligrams per liter	Potassium, in milligrams per liter
January 26, 1999	1150	1,195	106	677	84.9	11.7	164	2.89
April 16, 1999	1255	973	684	468	54.9	9.53	111	5.34
May 13, 1999	1025	1,138	98	654	78.0	13.0	173	3.03
May 24, 1999	1045	974	158	545	68.6	10.9	129	3.91
June 10, 1999	1200	1,125	86	641	59.8	12.3	155	2.92
June 25, 1999	1115	896	237	548	63.9	9.33	118	5.59
July 14, 1999	1120	1,078	63	618	56.3	11.1	159	3.47
July 29, 1999	0955	1,148	60	640	59.5	11.9	160	4.02
August 12, 1999	1035	1,150	43	658	55.9	11.8	171	3.56
August 26, 1999	1050	1,080	34	620	50.7	11.2	168	3.04
September 22, 1999	1120	1,165	49	657	66.2	10.6	161	3.18
December 2, 1999	1035	1,230	62	684	69.0	10.8	163	3.28
February 25, 2000	1040	841	256	486	54.4	9.00	104	6.34
April 27, 2000	1045	1,180	110	658	75.8	12.0	147	2.99
May 25, 2000	1020	1,190	60	656	65.4	11.9	163	3.14
June 21, 2000	1200	1,120	47	642	50.6	10.2	155	3.41
July 26, 2000	1150	896	117	532	54.7	8.67	130	6.36
August 29, 2000	1100	1,080	9.4	581	45.9	11.1	162	3.83
September 28, 2000	1030	1,058	20	608	47.5	10.3	154	3.33
October 26, 2000	1050	342	2,663	194	26.2	3.66	30.0	6.07
June 6, 2001	1135	342	1,753	198	29.1	4.54	31.0	5.61
September 4, 2001	1105	1,080	19	605	43.1	10.8	167	3.44
September 19, 2001[1]	1025	343	188	359	40.9	6.15	81.2	5.51
June 12, 2002[1]	1110	187	478	211	21.9	4.38	39.4	6.49
August 14, 2002	1135	398	347	239	30.2	4.70	45.0	6.29
March 18, 2003	1200	678	396	392	47.3	8.25	79.7	4.37
March 19, 2003	1220	342	2,245	224	27.6	4.99	34.5	5.81
April 21, 2003	1130	833	551	517	55.3	9.27	111	6.55
March 5, 2004	1210	445	1,968	355	35.1	5.79	50.1	5.91
May 14, 2004	1035	407	579	243	34.6	5.65	45.9	7.21
June 14, 2004	0945	576	238	331	39.3	6.64	63.4	8.41
September 8, 2004	1025	1,240	39	677	60.4	11.5	182	3.61
March 24, 2005	1015	1,060	381	621	69.0	12.4	144	5.17
May 16, 2005	1140	518	524	306	42.6	5.78	53.2	6.53
June 10, 2005	1055	258	1,100	191	23.2	4.43	22.8	6.00
June 13, 2005	0925	311	3,150	216	27.9	5.25	23.1	6.55
August 29, 2005	0935	707	256	420	52.2	6.68	83.0	8.05
March 2, 2006	0950	1,250	92	697	80.3	12.3	173	3.17

Table 2. Dissolved solids, calcium, magnesium, sodium, and potassium simple linear regression model datasets for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[hh, hours; mm, minutes]

Date	Time, in hhmm	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Streamflow, in cubic feet per second	Dissolved solids, in milligrams per liter	Calcium, in milligrams per liter	Magnesium, in milligrams per liter	Sodium, in milligrams per liter	Potassium, in milligrams per liter
March 22, 2006[2]	1130	1,665	144	952	100	16.8	238	5.45
May 1, 2006	1115	1,243	85	725	74.7	12.0	170	3.26
May 12, 2006	1030	1,120	156	639	73.0	11.3	149	5.28
June 5, 2006	1015	1,173	39	630	51.3	11.6	174	3.74
July 31, 2006	1030	1,150	15	637	41.5	11.8	185	3.95
September 7, 2006	1050	1,280	39	697	56.4	10.6	185	3.58
September 21, 2006	1000	1,230	24	667	56.1	11.1	174	3.77
January 9, 2007	1030	1,430	70	798	86.6	12.2	184	3.84
March 14, 2007	1020	1,280	67	696	71.8	11.8	174	2.93
March 22, 2007	1000	1,120	98	682	73.9	11.5	162	3.00
March 26, 2007	1040	976	295	597	60.4	9.46	139	5.00
March 31, 2007	1230	637	1,370	375	47.3	7.82	66.1	7.00
April 16, 2007	1215	724	751	437	54.5	8.54	85.7	6.00
May 7, 2007	1030	317	3,725	202	25.7	4.32	27.8	7.00
June 29, 2007	1025	701	401	427	54.9	8.44	74.5	7.00
September 4, 2007	1126	1,140	28	622	51.0	11.1	163	3.00
April 24, 2008	1140	569	269	335	43.8	8.09	61.8	6.00
May 9, 2008	1135	353	3,103	210	25.5	5.01	34.3	6.00
June 19, 2008	0945	978	223	527	65.4	9.65	114	5.00
September 15, 2008	1055	831	404	480	56.4	8.33	106	7.00
October 16, 2008	1010	589	839	362	43.5	6.96	71.0	7.00
March 31, 2009	1120	897	721	524	60.6	11.3	121	6.00
April 27, 2009	1215	478	2,150	306	39.5	8.37	47.6	6.00
June 17, 2009	1040	785	349	436	53.5	8.30	99.3	5.00
August 20, 2009	1050	1,095	103	632	65.6	9.97	149	5.00
September 10, 2009	1130	464	482	278	38.9	5.43	48.7	7.00

[1]Data point removed from final analysis because of atypically large heterogeneity in channel cross-sectional data during sample collection.

[2]Data point removed from final analysis because of the large specific conductance value likely affected by road salt application.

Table 3. Chloride and sulfate simple linear regression model datasets for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

[hh, hours; mm, minutes]

Date	Time, in hhmm	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Streamflow, in cubic feet per second	Chloride, in milligrams per liter	Sulfate, in milligrams per liter
April 16, 1999	1255	973	684	127	29.0
June 10, 1999	1200	1,125	86	211	49.0
June 25, 1999	1115	896	237	164	29.0
July 29, 1999	0955	1,148	60	235	61.0
September 22, 1999	1120	1,165	49	254	52.8
December 2, 1999	1035	1,230	62	289	54.8
February 25, 2000	1040	841	256	159	41.2
October 26, 2000	1050	342	2,663	40.0	17.0
June 6, 2001	1135	342	1,753	34.0	11.0
September 4, 2001	1105	1,080	19	228	47.0
September 19, 2001[1]	1025	343	188	116	39.2
June 12, 20021	1110	187	478	58.0	16.0
August 14, 2002	1135	398	347	59.0	23.0
March 18, 2003	1200	678	396	110	29.0
March 19, 2003	1220	342	2,245	46.0	14.0
April 21, 2003	1130	833	551	150	28.0
March 5, 2004	1210	445	1,968	64.0	26.0
May 14, 2004	1035	407	579	58.0	22.0
June 14, 2004	0945	576	238	92.0	32.0
September 8, 2004	1025	1,240	39	237	54.0
March 24, 2005	1015	1,060	381	185	41.8
May 16, 2005	1140	518	524	75.7	21.6
June 10, 2005	1055	258	1,100	31.3	12.8
June 13, 2005	0925	311	3,150	30.8	14.3
August 29, 2005	0935	707	256	109	27.7
March 2, 2006	0950	1,250	92	237	49.4
March 22, 2006[2]	1130	1,665	144	239	52.1
May 1, 2006	1115	1,243	85	242	45.8
May 12, 2006	1030	1,120	156	193	46.8
June 5, 2006	1015	1,173	39	237	48.2
July 31, 2006	1030	1,150	15	253	50.2
September 7, 2006	1050	1,280	39	288	49.9
September 21, 2006	1000	1,230	24	263	47.8
January 9, 2007	1030	1,430	70	274	58.8
March 22, 2007	1000	1,120	98	230	49.0
March 26, 2007	1040	976	295	210	39.0
March 31, 2007	1230	637	1,370	81.0	24.0
April 16, 2007	1215	724	751	110	28.0
May 7, 2007	1030	317	3,725	50.0	8.50
June 29, 2007	1025	701	401	100	22.0

Table 3. Chloride and sulfate simple linear regression model datasets for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[hh, hours; mm, minutes]

Date	Time, in hhmm	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Streamflow, in cubic feet per second	Chloride, in milligrams per liter	Sulfate, in milligrams per liter
September 4, 2007	1126	1,140	28	240	46.0
April 24, 2008	1140	569	269	76.0	25.0
May 9, 2008	1135	353	3,103	40.0	12.0
June 19, 2008	0945	978	223	120	24.0
September 15, 2008	1055	831	404	150	30.0
October 16, 2008	1010	589	839	96.0	21.0
March 31, 2009	1120	897	721	150	38.0
April 27, 2009	1215	478	2,150	48.0	16.0
June 17, 2009	1040	785	349	120	22.0
August 20, 2009	1050	1,095	103	210	52.0
September 10, 2009	1130	464	482	63.0	19.0

[1]Data point removed from final analysis because of atypically large heterogeneity in channel cross-sectional data during sample collection.

[2]Data point removed from final analysis because of the large specific conductance value likely affected by road salt application.

Table 4. Alkalinity and bicarbonate simple linear regression model datasets for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

[hh, hours; mm, minutes]

Date	Time, in hhmm	Streamflow, in cubic feet per second	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Alkalinity, in milligrams per liter	Bicarbonate, in milligrams per liter
April 16, 1999	1255	684	973	179	220
June 10, 1999	1200	86	1,125	176	220
June 25, 1999	1115	237	896	196	240
July 29, 1999	0955	60	1,148	172	210
September 22, 1999	1120	49	1,165	182	220
December 2, 1999	1035	62	1,230	192	230
February 25, 2000	1040	256	841	153	190
October 26, 2000	1050	2,663	342	74.0	86.0
June 6, 2001	1135	1,753	342	102	120
September 4, 2001	1105	19	1,080	132	160
September 19, 2001[1]	1025	188	343	104	130
June 12, 2002[1]	1110	478	187	74.0	90.0
August 14, 2002	1135	347	398	80.0	98.0
March 18, 2003	1200	396	678	143	170
March 19, 2003	1220	2,245	342	89.0	110
April 21, 2003	1130	551	833	174	210
March 5, 2004	1210	1,968	445	98.0	120
May 14, 2004	1035	579	407	104	130
June 14, 2004	0945	238	576	120	150
September 8, 2004	1025	39	1,240	172	210
March 24, 2005	1015	381	1,060	209	260
May 16, 2005	1140	524	518	126	150
June 10, 2005	1055	1,100	258	81.0	99.0
June 13, 2005	0925	3,150	311	101	120
August 29, 2005	0935	256	707	162	200
March 2, 2006	0950	92	1,250	202	250
March 22, 2006[2]	1130	144	1,665	230	280
May 1, 2006	1115	85	1,243	200	240
May 12, 2006	1030	156	1,120	195	240
June 5, 2006	1015	39	1,173	144	180
July 31, 2006	1030	15	1,150	121	150
September 7, 2006	1050	39	1,280	152	180
September 21, 2006	1000	24	1,230	159	190
January 9, 2007	1030	70	1,430	215	260
March 22, 2007	1000	98	1,120	196	240
March 26, 2007	1040	295	976	160	200
March 31, 2007	1230	1,370	637	149	180
April 16, 2007	1215	751	724	164	200
May 7, 2007	1030	3,725	317	90.0	110

Table 4. Alkalinity and bicarbonate simple linear regression model datasets for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[hh, hours; mm, minutes]

Date	Time, in hhmm	Streamflow, in cubic feet per second	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Alkalinity, in milligrams per liter	Bicarbonate, in milligrams per liter
June 29, 2007	1025	401	701	170	210
September 4, 2007	1126	28	1,140	158	190
April 24, 2008	1140	269	569	136	170
May 9, 2008	1135	3,103	353	92.0	110
June 19, 2008	945	223	978	186	230
September 15, 2008	1055	404	831	144	180
October 16, 2008	1010	839	589	132	160
March 31, 2009	1120	721	897	174	210
April 27, 2009	1215	2,150	478	140	170
June 17, 2009	1040	349	785	166	200
August 20, 2009	1050	103	1,095	162	200
September 10, 2009	1130	482	464	104	130

[1]Data point removed from final analysis because of atypically large heterogeneity in channel cross-sectional data during sample collection.

[2]Data point removed from final analysis because of the large specific conductance value likely affected by road salt application.

Table 5. Total suspended solids simple linear regression model dataset for the North Fork Ninnescah River above Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

[hh, hours; mm, minutes]

Date	Time, in hhmm	Turbidity, in formazin nephelometric units	Streamflow, in cubic feet per second	Total suspended solids, in milligrams per liter
January 26, 1999	1150	21	106	17
April 16, 1999	1255	128	684	309
May 13, 1999	1025	15	98	55
May 24, 1999	1045	138	158	119
June 10, 1999	1200	32	86	61
June 25, 1999	1115	120	237	148
July 29, 1999	0955	56	60	48
August 12, 1999	1035	51	43	35
August 26, 1999	1050	27	34	21
September 22, 1999	1120	22	49	30
December 2, 1999	1035	18	62	25
February 25, 2000	1040	272	256	422
April 27, 2000	1045	13	110	27
May 25, 2000	1020	27	60	38
June 21, 2000	1200	45	47	55
July 26, 2000	1150	123	117	142
August 29, 2000	1100	13	9.4	15
September 28, 2000	1030	22	20	8
October 26, 2000	1050	320	2,663	162
June 6, 2001	1135	250	1,753	212
September 19, 2001[1]	1025	1,335	188	357
June 12, 2002[1]	1110	965	478	582
August 14, 2002	1135	435	347	264
March 18, 2003	1200	600	396	696
March 19, 2003	1220	580	2,245	476
April 21, 2003	1130	130	551	124
March 5, 2004	1210	475	1,968	375
May 14, 2004	1035	210	579	100
June 14, 2004	0945	120	238	162
March 24, 2005	1015	105	381	120
May 16, 2005	1140	115	524	128
June 10, 2005	1055	240	1,100	250
June 13, 2005	0925	125	3,150	145
August 29, 2005	0935	140	256	172
March 2, 2006	0950	14	92	21
March 22, 2006	1130	71	144	87
June 5, 2006	1015	48	39	75
July 31, 2006	1030	31	15	24
September 7, 2006	1050	25	39	29
September 21, 2006	1000	13	24	15

Table 5. Total suspended solids simple linear regression model dataset for the North Fork Ninnescah River above Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[hh, hours; mm, minutes]

Date	Time, in hhmm	Turbidity, in formazin nephelometric units	Streamflow, in cubic feet per second	Total suspended solids, in milligrams per liter
January 9, 2007	1030	22	70	30
March 14, 2007	1020	15	67	23
March 22, 2007	1000	39	98	74
March 26, 2007	1040	190	295	316
March 31, 2007	1230	220	1,370	459
April 16, 2007	1215	65	751	94
May 7, 2007	1030	170	3,725	211
June 29, 2007	1025	68	401	92
September 4, 2007	1126	15	28	22
April 24, 2008	1140	123	269	136
May 9, 2008	1135	253	3,103	283
June 19, 2008	0945	92	223	67
September 15, 2008	1055	74	404	146
October 16, 2008	1010	110	839	112
March 31, 2009	1120	220	721	364
April 27, 2009	1215	270	2,150	318
June 17, 2009	1040	140	349	201
August 20, 2009	1050	220	103	278
September 10, 2009	1130	280	482	258

[1]Data point removed from final analysis because of atypically large heterogeneity in channel cross-sectional data during sample collection.

Table 6. Suspended-sediment concentration simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

[hh, hours; mm, minutes]

Date	Time, in hhmm	Turbidity, in formazin nephelometric units	Streamflow, in cubic feet per second	Suspended-sediment concentration, in milligrams per liter
May 13, 1999	1025	15	98	67
May 24, 1999	1045	138	158	233
June 10, 1999	1200	32	86	28
June 25, 1999	1115	120	237	180
July 8, 1999	1400	90	76	62
July 29, 1999	0955	56	60	43
December 2, 1999	1035	18	62	22
April 27, 2000	1045	13	110	32
May 25, 2000	1020	27	60	44
June 21, 2000	1200	45	47	65
October 26, 2000	1050	320	2,663	2,100
June 6, 2001	1135	250	1,753	303
June 27, 2001	1155	48	77	94
September 19, 2001[1]	1025	1,335	188	547
January 8, 2002	1120	50	81	93
May 13, 2002	1040	245	318	226
May 15, 2002	1100	66	130	91
June 12, 2002[1]	1110	965	478	801
August 14, 2002	1135	435	347	468
March 18, 2003	1200	600	396	1,090
March 19, 2003	1220	580	2,245	2,150
April 21, 2003	1130	130	551	208
March 5, 2004	1210	475	1,968	2,690
May 14, 2004	1035	210	579	219
June 14, 2004	0945	120	238	187
March 24, 2005	1015	105	381	174
May 16, 2005	1140	115	524	295
June 10, 2005	1055	240	1,100	673
June 13, 2005	0925	125	3,150	747
August 29, 2005	0935	140	256	227
March 2, 2006	0950	14	92	51
March 22, 2006	1130	71	144	99
June 5, 2006	1015	48	39	52
July 31, 2006	1030	31	15	23
September 7, 2006	1050	25	39	46
September 21, 2006	1000	13	24	19
January 9, 2007	1030	22	70	82
March 14, 2007	1020	15	67	38
March 22, 2007	1000	39	98	72
March 26, 2007	1040	190	295	333

Table 6. Suspended-sediment concentration simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[hh, hours; mm, minutes]

Date	Time, in hhmm	Turbidity, in formazin nephelometric units	Streamflow, in cubic feet per second	Suspended-sediment concentration, in milligrams per liter
March 31, 2007	1230	220	1,370	1,240
April 16, 2007	1215	65	751	288
May 7, 2007	1030	170	3,725	1,390
June 29, 2007	1025	68	401	149
April 24, 2008	1140	123	269	208
May 9, 2008	1135	253	3,103	1,110
June 19, 2008	0945	92	223	139
September 15, 2008	1055	74	404	229
October 16, 2008	1010	110	839	1,060
March 31, 2009	1120	220	721	859
April 27, 2009	1215	270	2,150	967
June 17, 2009	1040	140	349	858
August 20, 2009	1050	220	103	292
September 10, 2009	1130	280	482	420

[1]Data point removed from final analysis because of atypically large heterogeneity in channel cross-sectional data during sample collection.

Table 7. Total nitrogen simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

[hh, hours; mm, minutes; sin, sine; D, day of year; cos, cosine; <, less than]

Date	Time, in hhmm	sin(2πD/365)	cos(2πD/365)	Turbidity, in formazin nephelometric units	Streamflow, in cubic feet per second	Total Kjeldahl nitrogen, in milligrams per liter	Nitrate plus nitrite, in milligrams per liter	Total nitrogen (Total Kjeldahl nitrogen plus nitrate plus nitrite), in milligrams per liter
January 26, 1999	1150	0.433	0.902	21	106	0.48	2.17	2.65
April 16, 1999	1255	0.968	-0.251	128	684	1.60	0.02	1.62
May 13, 1999	1025	0.753	-0.658	15	98	0.79	1.18	1.97
May 24, 1999	1045	0.615	-0.788	138	158	1.20	1.34	2.54
June 10, 1999	1200	0.362	-0.932	32	86	1.20	0.40	1.60
June 25, 1999	1115	0.112	-0.994	120	237	1.70	0.32	2.02
July 14, 1999	1120	-0.214	-0.977	28	63	1.20	0.38	1.58
July 29, 1999	0955	-0.456	-0.890	56	60	1.30	0.40	1.70
December 2, 1999	1035	-0.479	0.878	18	62	0.50	2.38	2.88
February 25, 2000	1040	0.821	0.570	272	256	3.00	0.99	3.99
April 27, 2000	1045	0.896	-0.444	13	110	0.58	1.10	1.68
May 25, 2000	1020	0.588	-0.809	27	60	0.88	0.70	1.58
June 21, 2000	1200	0.163	-0.987	45	47	0.91	0.52	1.43
October 26, 2000	1050	-0.900	0.437	320	2,663	1.70	0.32	2.02
June 6, 2001	1135	0.425	-0.905	250	1,753	1.40	0.28	1.68
September 4, 2001	1105	-0.896	-0.444	39	19	1.20	0.34	1.54
September 19, 2001[1]	1025	-0.980	-0.201	1,335	188	3.40	0.93	4.33
June 12, 2002[1]	1110	0.329	-0.944	965	478	3.50	0.47	3.97
August 14, 2002	1135	-0.681	-0.732	435	347	2.60	0.53	3.13
March 18, 2003	1200	0.970	0.243	600	396	3.40	1.03	4.43
March 19, 2003	1220	0.974	0.226	580	2,245	2.40	0.55	2.95
April 21, 2003	1130	0.943	-0.333	130	551	1.40	0.47	1.87
March 5, 2004	1210	0.900	0.437	475	1,968	3.00	0.75	3.75
May 14, 2004	1035	0.730	-0.684	210	579	1.70	0.47	2.17
June 14, 2004	0945	0.280	-0.960	120	238	1.50	0.44	1.94
September 8, 2004	1025	-0.931	-0.366	12	39	0.45	0.92	1.37
March 24, 2005	1015	0.990	0.142	105	381	1.40	0.78	2.18
May 16, 2005	1140	0.718	-0.696	115	524	1.40	0.10	1.50
June 10, 2005	1055	0.362	-0.932	240	1,100	1.80	0.32	2.12

Table 7. Total nitrogen simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[hh, hours; mm, minutes; sin, sine; D, day of year; cos, cosine; <, less than]

Date	Time, in hhmm	sin(2πD/365)	cos(2πD/365)	Turbidity, in formazin nephelometric units	Streamflow, in cubic feet per second	Total Kjeldahl nitrogen, in milligrams per liter	Nitrate plus nitrite, in milligrams per liter	Total nitrogen (Total Kjeldahl nitrogen plus nitrate plus nitrite), in milligrams per liter
June 13, 2005	0925	0.313	-0.950	125	3,150	1.30	0.16	1.46
August 29, 2005	0935	-0.845	-0.534	140	256	1.60	0.40	2.00
March 2, 2006[2]	0950	0.867	0.498	14	92	<0.1	1.90	1.95
March 22, 2006	1130	0.984	0.176	71	144	1.30	1.64	2.94
May 1, 2006	1115	0.872	-0.490	24	85	0.73	0.39	1.12
May 12, 2006	1030	0.764	-0.645	45	156	1.30	0.66	1.96
June 5, 2006	1015	0.441	-0.898	48	39	1.60	0.18	1.78
July 31, 2006	1030	-0.486	-0.874	31	15	1.20	0.03	1.23
September 7, 2006	1050	-0.918	-0.398	25	39	0.72	0.68	1.40
September 21, 2006	1000	-0.986	-0.167	13	24	0.49	0.50	0.99
January 9, 2007	1030	0.154	0.988	22	70	0.64	1.87	2.51
March 14, 2007	1020	0.951	0.309	15	67	0.55	1.17	1.72
March 22, 2007	1000	0.984	0.176	39	98	0.84	1.03	1.87
March 26, 2007	1040	0.994	0.107	190	295	2.10	0.63	2.73
March 31, 2007	1230	1.000	0.022	220	1,370	2.60	0.40	3.00
April 16, 2007	1215	0.968	-0.251	65	751	1.00	0.43	1.43
May 7, 2007	1030	0.817	-0.577	170	3,725	2.00	0.37	2.37
June 29, 2007	1025	0.043	-0.999	68	401	1.40	0.66	2.06
April 24, 2008	1140	0.918	-0.398	123	269	1.60	0.88	2.48
May 9, 2008	1135	0.786	-0.619	253	3,103	2.20	0.36	2.56
June 19, 2008	0945	0.197	-0.980	92	223	2.30	0.16	2.46
September 15, 2008	1055	-0.968	-0.251	74	404	1.50	0.34	1.84
October 16, 2008	1010	-0.961	0.276	110	839	1.60	0.72	2.32
March 31, 2009	1120	1.000	0.022	220	721	2.10	1.19	3.29
April 27, 2009	1215	0.903	-0.429	270	2,150	2.20	0.43	2.63
June 17, 2009	1040	0.247	-0.969	140	349	1.60	0.51	2.11
August 20, 2009	1050	-0.753	-0.658	220	103	2.10	0.85	2.95
September 10, 2009	1130	-0.937	-0.350	280	482	1.90	0.58	2.48

[1]Data point removed from final analysis because of atypically large heterogeneity in channel cross-sectional data during sample collection.

[2]Data point removed from final analysis because the total Kjeldahl nitrogen value was below the detection limit and likely erroneous.

Table 8. Total Kjeldahl nitrogen simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

[hh, hours; mm, minutes; <, less than]

Date	Time, in hhmm	Turbidity, in formazin nephelometric units	Total Kjeldahl nitrogen, in milligrams per liter
January 26, 1999	1150	21	0.48
April 16, 1999	1255	128	1.60
May 13, 1999	1025	14.5	0.79
May 24, 1999	1045	138	1.20
June 10, 1999	1200	32	1.20
June 25, 1999	1115	120	1.70
July 29, 1999	0955	56	1.30
December 2, 1999	1035	18	0.50
February 25, 2000	1040	272	3.00
April 27, 2000	1045	13	0.58
May 25, 2000	1020	27	0.88
June 21, 2000	1200	45	0.91
October 26, 2000	1050	320	1.70
June 6, 2001	1135	250	1.40
September 19, 2001[1]	1025	1,335	3.40
May 13, 2002	1040	245	2.00
June 12, 2002[1]	1110	965	3.50
August 14, 2002	1135	435	2.60
March 18, 2003	1200	600	3.40
March 19, 2003	1220	580	2.40
April 21, 2003	1130	130	1.40
March 5, 2004	1210	475	3.00
May 14, 2004	1035	210	1.70
June 14, 2004	945	120	1.50
March 24, 2005	1015	105	1.40
May 16, 2005	1140	115	1.40
June 10, 2005	1055	240	1.80
June 13, 2005	0925	125	1.30
August 29, 2005	0935	140	1.60
March 2, 2006[2]	0950	14	<0.1
March 22, 2006	1130	71	1.30
June 5, 2006	1015	48	1.60
July 31, 2006	1030	31	1.20
September 7, 2006	1050	25	0.72
September 21, 2006	1000	13	0.49
January 9, 2007	1030	22	0.64
March 14, 2007	1020	15	0.55
March 22, 2007	1000	39	0.84
March 26, 2007	1040	190	2.10
March 31, 2007	1230	220	2.60
April 16, 2007	1215	65	1.00

Table 8. Total Kjeldahl nitrogen simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[hh, hours; mm, minutes; <, less than]

Date	Time, in hhmm	Turbidity, in formazin nephelometric units	Total Kjeldahl nitrogen, in milligrams per liter
May 7, 2007	1030	170	2.00
June 29, 2007	1025	68	1.40
April 24, 2008	1140	123	1.60
May 9, 2008	1135	253	2.20
June 19, 2008	0945	92	2.30
September 15, 2008	1055	74	1.50
October 16, 2008	1010	110	1.60
March 31, 2009	1120	220	2.10
April 27, 2009	1215	270	2.20
June 17, 2009	1040	140	1.60
August 20, 2009	1050	220	2.10
September 10, 2009	1130	280	1.90

[1]Data point removed from final analysis because of atypically large heterogeneity in channel cross-sectional data during sample collection.

[2]Data point removed from final analysis because the total Kjeldahl nitrogen value was below the detection limit and likely erroneous.

Table 9. Organic nitrogen simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

[hh, hours; mm, minutes; <, less than]

Date	Time, in hhmm	Turbidity, in formazin nephelometric units	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Total Kjeldahl nitrogen, in milligrams per liter	Ammonia, in milligrams per liter	Organic nitrogen (total Kjeldahl nitrogen minus ammonia), in milligrams per liter
January 26, 1999	1150	21	1,195	0.48	0.08	0.40
April 16, 1999	1255	128	973	1.60	0.04	1.56
May 13, 1999	1025	15	1,138	0.79	0.10	0.69
May 24, 1999	1045	138	974	1.20	0.04	1.16
June 10, 1999	1200	32	1,125	1.20	<0.03	1.19
June 25, 1999	1115	120	896	1.70	0.14	1.56
July 14, 1999	1120	28	1,078	1.20	0.07	1.13
July 29, 1999	0955	56	1,148	1.30	0.21	1.09
December 2, 1999	1035	18	1,230	0.50	0.06	0.44
February 25, 2000	1040	272	841	3.00	0.13	2.87
April 27, 2000	1045	13	1,180	0.58	0.07	0.51
May 25, 2000	1020	27	1,190	0.88	0.05	0.83
June 21, 2000	1200	45	1,120	0.91	0.06	0.85
October 26, 2000	1050	320	342	1.70	<0.03	1.69
June 6, 2001	1135	250	342	1.40	0.03	1.37
September 4, 2001	1105	39	1,080	1.20	<0.03	1.19
September 19, 2001[1]	1025	1,335	343	3.40	0.07	3.33
June 12, 2002[1]	1110	965	187	3.50	0.09	3.41
August 14, 2002	1135	435	398	2.60	0.17	2.43
March 18, 2003	1200	600	678	3.40	0.14	3.26
March 19, 2003	1220	580	342	2.40	0.18	2.22
April 21, 2003	1130	130	833	1.40	<0.03	1.39
March 5, 2004	1210	475	445	3.00	0.27	2.73
May 14, 2004	1035	210	407	1.70	0.06	1.64
June 14, 2004	0945	120	576	1.50	0.03	1.47
September 8, 2004	1025	12	1,240	0.45	0.04	0.41
March 24, 2005	1015	105	1,060	1.40	0.12	1.28
May 16, 2005	1140	115	518	1.40	0.04	1.36
June 10, 2005	1055	240	258	1.80	0.10	1.70
June 13, 2005	0925	125	311	1.30	0.07	1.23
August 29, 2005	0935	140	707	1.60	0.06	1.54
March 2, 2006	0950	14	1,250	<0.1	0.03	0.02
March 22, 2006[2]	1130	71	1,665	1.30	0.09	1.21
May 1, 2006	1115	24	1,243	0.73	0.03	0.70
May 12, 2006	1030	45	1,120	1.30	0.03	1.27
June 5, 2006	1015	48	1,173	1.60	0.04	1.56
July 31, 2006	1030	31	1,150	1.20	0.03	1.17

Table 9. Organic nitrogen simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[hh, hours; mm, minutes; <, less than]

Date	Time, in hhmm	Turbidity, in formazin nephelometric units	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Total Kjeldahl nitrogen, in milligrams per liter	Ammonia, in milligrams per liter	Organic nitrogen (total Kjeldahl nitrogen minus ammonia), in milligrams per liter
September 7, 2006	1050	25	1,280	0.72	<0.03	0.71
September 21, 2006	1000	13	1,230	0.49	0.03	0.46
January 9, 2007	1030	22	1,430	0.64	0.04	0.60
March 14, 2007	1020	15	1,280	0.55	0.03	0.52
March 22, 2007	1000	39	1,120	0.84	0.07	0.77
March 26, 2007	1040	190	976	2.10	0.03	2.07
March 31, 2007	1230	220	637	2.60	0.10	2.50
April 16, 2007	1215	65	724	1.00	0.06	0.94
May 7, 2007	1030	170	317	2.00	0.05	1.95
June 29, 2007	1025	68	701	1.40	0.05	1.35
April 24, 2008	1140	123	569	1.60	0.08	1.52
May 9, 2008	1135	253	353	2.20	0.68	1.52
June 19, 2008	0945	92	978	2.30	<0.03	2.29
September 15, 2008	1055	74	831	1.50	0.03	1.47
October 16, 2008	1010	110	589	1.60	0.10	1.50
March 31, 2009	1120	220	897	2.10	0.17	1.93
April 27, 2009	1215	270	478	2.20	0.10	2.10
June 17, 2009	1040	140	785	1.60	<0.03	1.59
August 20, 2009	1050	220	1,095	2.10	0.02	2.07
September 10, 2009	1130	280	464	1.90	0.08	1.82

[1]Data point removed from final analysis because of atypically large heterogeneity in channel cross-sectional data during sample collection.

[2]Data point removed from final analysis because of the large specific conductance value likely affected by road salt application.

Table 10. Nitrate simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

[hh, hours; mm, minutes; sin, sine; D, day of year; cos, cosine]

Date	Time, in hhmm	sin(2πD/365)	cos(2πD/365)	Turbidity, in formazin nephelometric units	Streamflow, in cubic feet per second	Nitrate, in milligrams per liter
January 26, 1999	1150	0.4328	0.9015	21	106	2.17
April 16, 1999	1255	0.9679	-0.2512	128	684	0.44
May 13, 1999	1025	0.7527	-0.6584	15	98	1.18
May 24, 1999	1045	0.6153	-0.7883	138	158	0.87
June 10, 1999	1200	0.3617	-0.9323	32	86	0.40
June 25, 1999	1115	0.1117	-0.9937	120	237	0.32
July 14, 1999	1120	-0.2135	-0.9769	28	63	0.38
July 29, 1999	0955	-0.4559	-0.8900	56	60	0.38
August 12, 1999	1035	-0.6552	-0.7555	51	43	0.63
August 26, 1999	1050	-0.8165	-0.5773	27	34	0.74
September 22, 1999	1120	-0.9887	-0.1500	22	49	1.69
December 2, 1999	1035	-0.4787	0.8780	18	62	2.38
February 25, 2000	1040	0.8215	0.5702	272	256	0.99
April 27, 2000	1045	0.8958	-0.4444	13	110	1.10
May 25, 2000	1020	0.5878	-0.8090	27	60	0.70
June 21, 2000	1200	0.1628	-0.9867	45	47	0.52
July 26, 2000	1150	-0.4250	-0.9052	123	117	0.11
August 29, 2000	1100	-0.8543	-0.5197	13	9.4	0.37
September 28, 2000	1030	-0.9995	-0.0301	22	20	1.07
October 26, 2000	1050	-0.8996	0.4367	320	2,663	0.32
June 6, 2001	1135	0.4250	-0.9052	250	1,753	0.28
September 4, 2001	1105	-0.8958	-0.4444	39	19	0.34
September 19, 2001[1]	1025	-0.9796	-0.2009	1,335	188	0.47
June 12, 2002[1]	1110	0.3294	-0.9442	965	478	1.03
August 14, 2002	1135	-0.6808	-0.7325	435	347	0.55
March 18, 2003	1200	0.9701	0.2428	600	396	0.47
March 19, 2003	1220	0.9741	0.2261	580	2,245	0.75
April 21, 2003	1130	0.9428	-0.3335	130	551	0.47
March 5, 2004	1210	0.8996	0.4366	475	1,968	0.44
May 14, 2004	1035	0.7296	-0.6839	210	579	0.92
June 14, 2004	0945	0.2802	-0.9599	120	238	0.78
September 8, 2004	1025	-0.9307	-0.3657	12	39	0.10
March 24, 2005	1015	0.9899	0.1415	105	381	0.32
May 16, 2005	1140	0.7177	-0.6964	115	524	0.16
June 10, 2005	1055	0.3617	-0.9323	240	1,100	0.40
June 13, 2005	0925	0.3131	-0.9497	125	3,150	1.90
August 29, 2005	0935	-0.8453	-0.5344	140	256	0.39
March 2, 2006	0950	0.8675	0.4975	14	92	0.66
March 22, 2006[2]	1130	0.9845	0.1755	71	144	0.18
May 1, 2006	1115	0.8717	-0.4900	24	85	0.03
May 12, 2006	1030	0.7639	-0.6454	45	156	0.68

Table 10. Nitrate simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[hh, hours; mm, minutes; sin, sine; D, day of year; cos, cosine]

Date	Time, in hhmm	sin(2πD/365)	cos(2πD/365)	Turbidity, in formazin nephelometric units	Streamflow, in cubic feet per second	Nitrate, in milligrams per liter
June 5, 2006	1015	0.4405	-0.8977	48	39	0.50
July 31, 2006	1030	-0.4863	-0.8738	31	15	1.87
September 7, 2006	1050	-0.9176	-0.3975	25	39	1.17
September 21, 2006	1000	-0.9859	-0.1670	13	24	1.03
January 9, 2007	1030	0.1543	0.9880	22	70	0.63
March 14, 2007	1020	0.9511	0.3090	15	67	0.40
March 22, 2007	1000	0.9845	0.1755	39	98	0.43
March 26, 2007	1040	0.9942	0.1074	190	295	0.37
March 31, 2007	1230	0.9998	0.0215	220	1,370	0.66
April 16, 2007	1215	0.9679	-0.2512	65	751	0.82
May 7, 2007	1030	0.8165	-0.5773	170	3,725	0.85
June 29, 2007	1025	0.0430	-0.9991	68	401	0.35
September 4, 2007	1126	-0.8958	-0.4444	15	28	0.14
April 24, 2008	1140	0.9176	-0.3975	123	269	0.34
May 9, 2008	1135	0.7856	-0.6187	253	3,103	0.70
June 19, 2008	0945	0.1967	-0.9805	92	223	1.18
September 15, 2008	1055	-0.9679	-0.2512	74	404	0.42
October 16, 2008	1010	-0.9611	0.2761	110	839	0.51
March 31, 2009	1120	0.9998	0.0215	220	721	0.83
April 27, 2009	1215	0.9034	-0.4289	270	2,150	0.56
June 17, 2009	1040	0.2470	-0.9690	140	349	0.51
August 20, 2009	1050	-0.7527	-0.6584	220	103	0.83
September 10, 2009	1130	-0.9369	-0.3496	280	482	0.56

[1]Data point removed from final analysis because of atypically large heterogeneity in channel cross-sectional data during sample collection.

[2]Data point removed from final analysis because of the large specific conductance value likely affected by road salt application.

Table 11. Total phosphorus simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

[hh, hours; mm, minutes]

Date	Time, in hhmm	Turbidity, in formazin nephelometric units	Streamflow, in cubic feet per second	Total phosphorus, in milligrams per liter
January 26, 1999	1150	21	106	0.07
April 16, 1999	1255	128	684	0.21
May 13, 1999	1025	15	98	0.05
May 24, 1999	1045	138	158	0.24
June 10, 1999	1200	32	86	0.13
June 25, 1999	1115	120	237	0.26
July 29, 1999	0955	56	60	0.19
August 12, 1999	1035	51	43	0.13
August 26, 1999	1050	27	34	0.09
September 22, 1999	1120	22	49	0.09
December 2, 1999	1035	18	62	0.07
February 25, 2000	1040	272	256	0.58
April 27, 2000	1045	13	110	0.06
May 25, 2000	1020	27	60	0.07
June 21, 2000	1200	45	47	0.11
July 26, 2000	1150	123	117	0.26
August 29, 2000	1100	13	9.4	0.08
September 28, 2000[1]	1030	22	20	0.03
October 26, 2000	1050	320	2,663	0.48
June 6, 2001	1135	250	1,753	0.44
September 19, 2001[2]	1025	1,335	188	0.57
May 13, 2002	1040	245	318	0.45
June 12, 20022	1110	965	478	0.38
August 14, 2002	1135	435	347	0.52
March 18, 2003	1200	600	396	0.45
March 19, 2003	1220	580	2,245	0.51
April 21, 2003	1130	130	551	0.33
March 5, 2004	1210	475	1,968	0.51
May 14, 2004[1]	1035	210	579	0.08
June 14, 2004	0945	120	238	0.34
March 24, 2005	1015	105	381	0.19
May 16, 2005	1140	115	524	0.23
June 10, 20051	1055	240	1,100	0.09
June 13, 2005	0925	125	3,150	0.18
August 29, 2005	0935	140	256	0.27
March 2, 2006	0950	14	92	0.04
March 22, 2006	1130	71	144	0.23
June 5, 2006	1015	48	39	0.26
July 31, 2006	1030	31	15	0.14
September 7, 2006	1050	25	39	0.13
September 21, 2006	1000	13	24	0.09

Table 11. Total phosphorus simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[hh, hours; mm, minutes]

Date	Time, in hhmm	Turbidity, in formazin nephelometric units	Streamflow, in cubic feet per second	Total phosphorus, in milligrams per liter
January 9, 2007	1030	22	70	0.07
March 14, 2007	1020	15	67	0.10
March 22, 2007	1000	39	98	0.12
March 26, 2007	1040	190	295	0.49
March 31, 2007	1230	220	1,370	0.48
April 16, 2007	1215	65	751	0.31
May 7, 2007	1030	170	3,725	0.51
June 29, 2007	1025	68	401	0.45
September 4, 2007	1126	15	28	0.11
April 24, 2008	1140	123	269	0.34
May 9, 2008	1135	253	3,103	0.47
June 19, 2008	0945	92	223	0.31
September 15, 2008	1055	74	404	0.41
October 16, 2008	1010	110	839	0.45
March 31, 2009	1120	220	721	0.39
April 27, 2009	1215	270	2,150	0.42
June 17, 2009	1040	140	349	0.38
August 20, 2009	1050	220	103	0.31
September 10, 2009	1130	280	482	0.40

[1]Data point removed from final analysis because of laboratory issues with phosphorus analysis. Dissolved phosphorus was greater than total phosphorus.

[2]Data point removed from final analysis because of atypically large heterogeneity in channel cross-sectional data during sample collection.

Table 12. Orthophosphate simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

[hh, hours; mm, minutes]

Date	Time, in hhmm	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Orthophosphate, in milligrams per liter
January 26, 1999	1150	1,195	0.02
April 16, 1999	1255	973	0.05
May 13, 1999	1025	1,138	<0.01
May 24, 1999	1045	974	0.02
June 10, 1999	1200	1,125	<0.01
June 25, 1999	1115	896	0.06
July 14, 1999	1120	1,078	0.02
July 29, 1999	0955	1,148	0.02
August 12, 1999	1035	1,150	<0.01
August 26, 1999	1050	1,080	<0.01
December 2, 1999	1035	1,230	<0.01
February 25, 2000	1040	841	<0.01
April 27, 2000	1045	1,180	0.01
May 25, 2000	1020	1,190	<0.01
June 21, 2000	1200	1,120	<0.01
July 26, 2000	1150	896	<0.01
August 29, 2000	1100	1,080	<0.01
September 28, 2000[1]	1030	1,058	<0.01
October 26, 2000	1050	342	0.18
June 6, 2001	1135	342	0.18
September 4, 2001	1105	1,080	<0.01
September 19, 2001[2]	1025	343	0.04
June 12, 2002[2]	1110	187	0.19
August 14, 2002	1135	398	0.11
March 18, 2003	1200	678	0.05
March 19, 2003	1220	342	0.14
April 21, 2003	1130	833	0.07
March 5, 2004	1210	445	0.15
May 14, 2004[1]	1035	407	0.16
June 14, 2004[3]	0945	576	0.12
September 8, 2004	1025	1,240	0.02
March 24, 2005	1015	1,060	0.05
May 16, 2005	1140	518	0.04
June 10, 2005[3]	1055	258	0.17
June 13, 20053	0925	311	0.16
August 29, 2005	0935	707	0.11
March 2, 2006	0950	1,250	0.02
March 22, 2006[4]	1130	1,665	0.08
May 1, 2006	1115	1,243	0.02
May 12, 2006[3]	1030	1,120	0.13

Table 12. Orthophosphate simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[hh, hours; mm, minutes]

Date	Time, in hhmm	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Orthophosphate, in milligrams per liter
June 5, 2006	1015	1,173	0.02
July 31, 2006	1030	1,150	<0.01
September 7, 2006	1050	1,280	<0.01
September 21, 2006	1000	1,230	<0.01
January 9, 2007	1030	1,430	<0.01
March 14, 2007	1020	1,280	<0.01
March 22, 2007	1000	1,120	<0.01
March 26, 2007	1040	976	0.03
March 31, 2007	1230	637	0.14
April 16, 2007	1215	724	0.11
May 7, 2007	1030	317	0.21
June 29, 2007	1025	701	0.23
September 4, 2007	1126	1,140	<0.01
April 24, 2008	1140	569	0.14
May 9, 2008	1135	353	0.16
June 19, 2008	0945	978	0.04
September 15, 2008	1055	831	0.09
October 16, 2008	1010	589	0.19
March 31, 2009	1120	897	0.09
April 27, 2009	1215	478	0.13
June 17, 2009	1040	785	0.12
August 20, 2009	1050	1,095	0.04
September 10, 2009	1130	464	0.11

[1]Data point removed from final analysis because of laboratory issues with phosphorus analysis. Dissolved phosphorus was greater than total phosphorus.

[2]Data point removed from final analysis because of atypically large heterogeneity in channel cross-sectional data during sample collection.

[3]Data point removed from final analysis because of laboratory issues with phosphorus analysis. Orthophosphorus was larger than dissolved phosphorus.

[4]Data point removed from final analysis because of the large specific conductance value likely affected by road salt application.

Table 13. Fecal coliform bacteria simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

[hh, hours; mm, minutes]

Date	Time, in hhmm	Turbidity, in formazin nephelometric units	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Fecal coliform bacteria, in colonies per 100 milligrams
January 26, 1999	1150	21	1,195	8.0
February 1, 1999	1055	120	1,060	200
April 15, 1999	1125	180	629	65,000
April 16, 1999	1255	128	973	5,700
May 13, 1999	1025	15	1,138	100
May 24, 1999	1045	138	974	760
June 10, 1999	1200	32	1,125	280
June 25, 1999	1115	120	896	780
July 29, 1999	0955	56	1,148	190
August 12, 1999	1035	51	1,150	1,000
August 26, 1999	1050	27	1,080	470
September 22, 1999	1120	22	1,165	320
December 2, 1999	1035	18	1,230	80
February 25, 2000	1040	272	841	13,000
April 27, 2000	1045	13	1,180	240
May 25, 2000	1020	27	1,190	100
June 21, 2000	1200	45	1,120	300
July 26, 2000	1150	123	896	700
August 29, 2000	1100	13	1,080	530
September 28, 2000	1030	22	1,058	330
October 26, 2000	1050	320	342	36,000
June 6, 2001	1135	250	342	5,900
September 19, 2001[1]	1025	1,335	343	22,000
June 12, 2002[1]	1110	965	187	6,700
August 14, 2002	1135	435	398	21,000
March 18, 2003	1200	600	678	10,000
March 19, 2003	1220	580	342	20,000
April 21, 2003	1130	130	833	2,500
March 5, 2004	1210	475	445	3,900
May 14, 2004	1035	210	407	11,000
June 14, 2004	0945	120	576	1,700
March 24, 2005	1015	105	1,060	3,200
May 16, 2005	1140	115	518	1,300
June 10, 2005	1055	240	258	810
June 13, 2005	0925	125	311	3,300
August 29, 2005	0935	140	707	590
March 2, 2006	0950	14	1,250	27
March 22, 2006[2]	1130	71	1,665	220
June 5, 2006	1015	48	1,173	19
July 31, 2006	1030	31	1,150	400

Table 13. Fecal coliform bacteria simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[hh, hours; mm, minutes]

Date	Time, in hhmm	Turbidity, in formazin nephelometric units	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Fecal coliform bacteria, in colonies per 100 milligrams
September 7, 2006	1050	25	1,280	520
September 21, 2006	1000	13	1,230	330
January 9, 2007	1030	22	1,430	24
March 14, 2007	1020	15	1,280	95
March 22, 2007	1000	39	1,120	300
March 26, 2007	1040	190	976	1,100
March 31, 2007	1230	220	637	2,000
April 1, 2007	1600	120	572	11,000
April 16, 2007	1215	65	724	1,800
May 7, 2007	1030	170	317	20,000
May 24, 2007	1200	150	200	15,000
June 29, 2007	1025	68	701	710
September 4, 2007	1126	15	1,140	170
April 24, 2008	1140	123	569	6,700
May 9, 2008	1135	253	353	35,000
June 19, 2008	0945	92	978	900
September 15, 2008	1055	74	831	590
October 16, 2008	1010	110	589	8,700
March 31, 2009	1120	220	897	3,500
April 27, 2009	1215	270	478	35,000
June 17, 2009	1040	140	785	1,400
August 20, 2009	1050	220	1,095	860
September 10, 2009	1130	280	464	15,000

[1]Data point removed from final analysis because of atypically large heterogeneity in channel cross-sectional data during sample collection.

[2]Data point removed from final analysis because of the large specific conductance value likely affected by road salt application.

Table 14. *Escherichia coli* bacteria simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

[hh, hours; mm, minutes]

Date	Time, in hhmm	Turbidity, in formazin nephelometric units	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Streamflow, in cubic feet per second	*Escherichia coli,* in colonies per 100 milliliters
July 31, 2006	1030	31	1,150	15	340
September 7, 2006	1050	25	1,280	39	250
September 21, 2006	1000	13	1,230	24	140
January 9, 2007	1030	22	1,430	70	17
March 14, 2007	1020	15	1,280	67	82
March 26, 2007	1040	190	976	295	1,300
March 31, 2007	1230	220	637	1,370	6,000
April 1, 2007	1600	120	572	1,660	6,100
April 16, 2007	1215	65	724	751	1,500
May 7, 2007	1030	170	317	3,725	12,000
May 24, 2007	1200	150	200	4,780	6,700
June 29, 2007	1025	68	701	401	680
April 24, 2008	1140	123	569	269	2,600
May 9, 2008	1135	253	353	3,103	28,000
June 19, 2008	0945	92	978	223	670
September 15, 2008	1055	74	831	404	620
October 16, 2008	1010	110	589	839	6,300
March 31, 2009	1120	220	897	721	3,900
April 27, 2009	1215	270	478	2,150	30,000
June 17, 2009	1040	140	785	349	1,200
August 20, 2009	1050	220	1,095	103	800
September 10, 2009	1130	280	464	482	2,700

Table 15. Total organic carbon simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

[hh, hours; mm, minutes]

Date	Time, in hhmm	Turbidity, in formazin nephelometric units	Total organic carbon, in milligrams per liter
April 16, 1999	1255	128	10.7
June 10, 1999	1200	32	3.40
June 25, 1999	1115	120	7.60
July 29, 1999	0955	56	4.60
September 22, 1999	1120	22	3.00
December 2, 1999	1035	18	2.50
February 25, 2000	1040	272	9.70
October 26, 2000	1050	320	6.70
June 6, 2001	1135	250	7.40
September 19, 2001[1]	1025	1,335	6.30
June 12, 2002[1]	1110	965	22.5
August 14, 2002	1135	435	19.4
March 18, 2003	1200	600	15.9
March 19, 2003	1220	580	18.9
April 21, 2003	1130	130	13.7
March 5, 2004	1210	475	20.5
May 14, 2004	1035	210	12.9
June 14, 2004	0945	120	12.6
March 24, 2005	1015	105	9.90
May 16, 2005	1140	115	9.50
June 10, 2005	1055	240	15.4
June 13, 2005	0925	125	15.6
August 29, 2005	0935	140	12.6
March 2, 2006	0950	14	2.80
March 22, 2006	1130	71	9.00
June 5, 2006	1015	48	6.90
July 31, 2006	1030	31	5.70
September 7, 2006	1050	25	4.90
September 21, 2006	1000	13	4.20
January 9, 2007	1030	22	4.50
March 22, 2007	1000	39	5.50
March 26, 2007	1040	190	15.7
March 31, 2007	1230	220	18.7
April 16, 2007	1215	65	10.5
May 7, 2007	1030	170	16.4
June 29, 2007	1025	68	12.7
September 4, 2007	1126	15	4.21
April 24, 2008	1140	123	13.0
May 9, 2008	1135	253	15.3
June 19, 2008	0945	92	11.2
September 15, 2008	1055	74	12.9

Table 15. Total organic carbon simple linear regression model dataset for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.—Continued

[hh, hours; mm, minutes]

Date	Time, in hhmm	Turbidity, in formazin nephelometric units	Total organic carbon, in milligrams per liter
October 16, 2008	1010	110	13.5
March 31, 2009	1120	220	17.4
April 27, 2009	1215	270	19.7
June 17, 2009	1040	140	15.5
August 20, 2009	1050	220	14.3
September 10, 2009	1130	280	16.4

[1]Data point removed from final analysis because of atypically large heterogeneity in channel cross-sectional data during sample collection.

```
      *** Linear Model ***

Call: lm(formula = LOGDS ~ LOGSC, data = DS, na.action = na.exclude)
Residuals:
      Min       1Q     Median       3Q    Max
 -0.07485 -0.01183 -0.0008959 0.009746 0.1077

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  0.0810  0.0469     1.7274  0.0893
      LOGSC  0.8916  0.0161    55.4096  0.0000

Residual standard error: 0.02496 on 59 degrees of freedom
Multiple R-Squared: 0.9811      Adjusted R-squared: 0.9808
F-statistic: 3070 on 1 and 59 degrees of freedom, the p-value is 0

Correlation of Coefficients:
      (Intercept)
LOGSC -0.9977

Analysis of Variance Table

Response: LOGDS

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
    LOGSC  1  1.913515 1.913515 3070.229     0
Residuals 59  0.036772 0.000623

      model.formula nvars     stderr    adjr2       Cp      press
     LOGDS ~ LOGSC     1 0.02496494 98.08259 2.792865 0.04052048

Test criteria
 leverage cooksD dfits
   0.0984  0.798 0.362
       Observations exceeding at least one test criterion
   LOGDS yhat  resids stnd.res stud.res leverage cooksD  dfits
 2  2.67 2.75 -0.0748    -3.03    -3.27   0.0191 0.0893 -0.456
20  2.29 2.34 -0.0520    -2.16    -2.24   0.0744 0.1880 -0.634
21  2.30 2.34 -0.0439    -1.83    -1.87   0.0741 0.1339 -0.528
27  2.55 2.44  0.1077     4.41     5.35   0.0441 0.4498  1.149
33  2.28 2.23  0.0506     2.16     2.23   0.1187 0.3138  0.818
34  2.33 2.30  0.0315     1.32     1.33   0.0879 0.0843  0.413
```

Figure 2. S+® output of regression model development using specific conductance (SC) as an explanatory variable for dissolved solids (DS) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

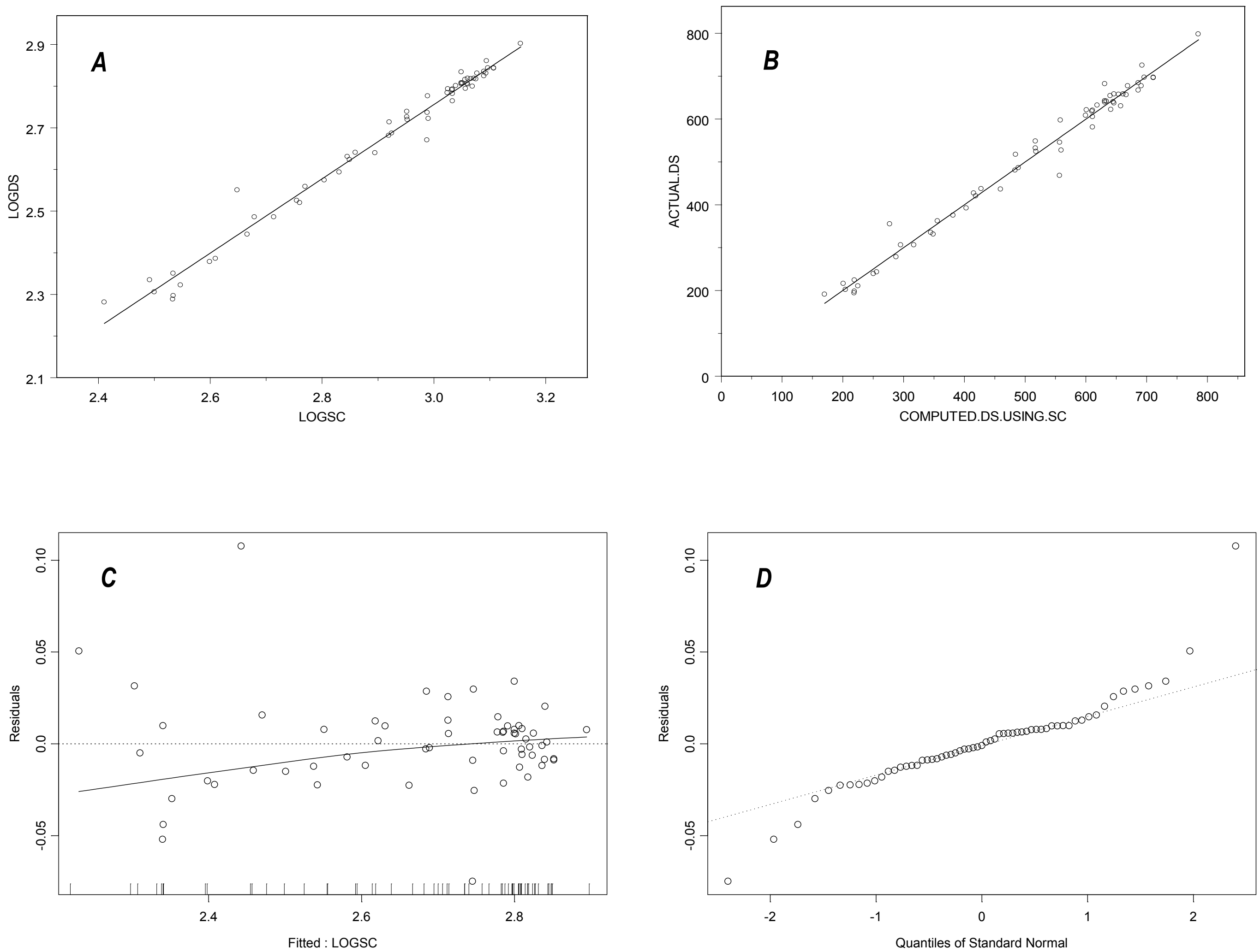

Figure 3. S+® output graphs from simple linear regression analysis showing *A*, log-transformed specific conductance (SC) versus log-transformed dissolved solids (DS) concentrations; *B*, computed versus actual DS concentrations; *C*, computed log-transformed DS concentrations versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = LOGDS ~ LOGQ, data = DS, na.action = na.exclude)
Residuals:
     Min       1Q  Median      3Q    Max
 -0.2396 -0.08065 0.01697 0.08353 0.1845

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)   3.1891   0.0484    65.8379   0.0000
       LOGQ  -0.2249   0.0203   -11.0809   0.0000

Residual standard error: 0.1036 on 59 degrees of freedom
Multiple R-Squared: 0.6754      Adjusted R-squared: 0.6699
F-statistic: 122.8 on 1 and 59 degrees of freedom, the p-value is 4.441e-016

Correlation of Coefficients:
     (Intercept)
LOGQ -0.9618

Analysis of Variance Table

Response: LOGDS

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq F Value         Pr(F)
     LOGQ  1  1.317310 1.317310 122.787 4.440892e-016
Residuals 59  0.632977 0.010728

       model.formula nvars     stderr    adjr2       Cp    press
       LOGDS ~ LOGQ     1 0.10357807 66.99434 6.949271 0.680932

Test criteria
 leverage cooksD dfits
   0.0984  0.798 0.362
       Observations exceeding at least one test criterion
   LOGDS yhat resids stnd.res stud.res leverage cooksD  dfits
18  2.76 2.97 -0.206    -2.08    -2.14   0.0834 0.1960 -0.645
21  2.30 2.46 -0.163    -1.62    -1.64   0.0509 0.0700 -0.379
33  2.28 2.51 -0.224    -2.21    -2.28   0.0377 0.0954 -0.452
```

Figure 4. S+® output of regression model development using streamflow (Q) as an explanatory variable for dissolved solids (DS) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

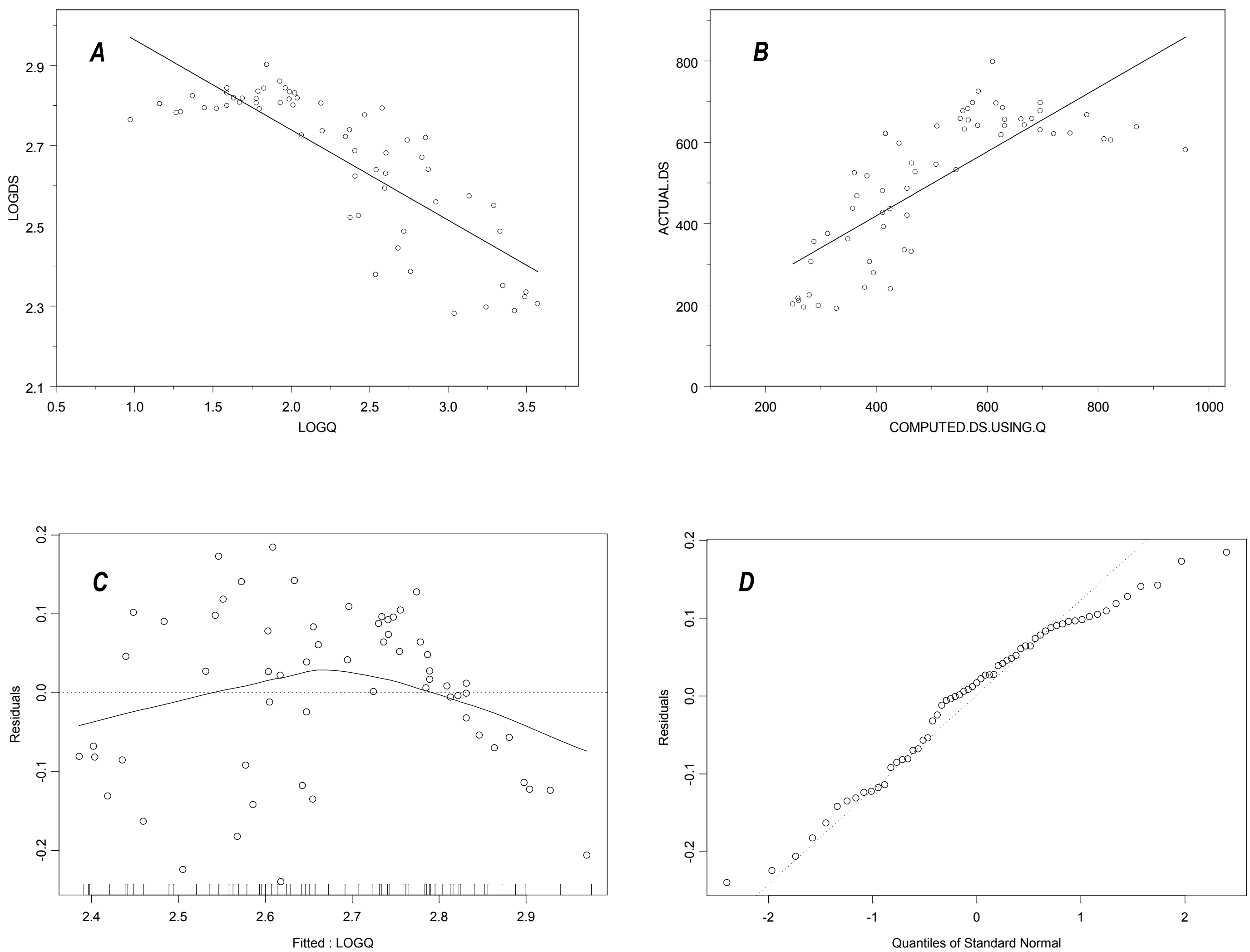

Figure 5. S+® output graphs from simple linear regression analysis showing *A*, log-transformed streamflow (Q) versus log-transformed dissolved solids (DS) concentrations; *B*, computed versus actual DS concentrations; *C*, computed log-transformed DS concentrations versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
      *** Linear Model ***

Call: lm(formula = LOGCA ~ LOGQ + LOGSC, data = CA, na.action = na.exclude)
Residuals:
     Min       1Q   Median      3Q     Max
 -0.1095 -0.02992 -0.00139 0.04099 0.09087

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  -1.3710   0.1981    -6.9211   0.0000
       LOGQ   0.1197   0.0171     6.9865   0.0000
      LOGSC   0.9641   0.0564    17.1014   0.0000

Residual standard error: 0.04779 on 58 degrees of freedom
Multiple R-Squared: 0.8907      Adjusted R-squared: 0.887
F-statistic: 236.4 on 2 and 58 degrees of freedom, the p-value is 0

Correlation of Coefficients:
      (Intercept)    LOGQ
 LOGQ -0.8915
LOGSC -0.9936      0.8375

Analysis of Variance Table

Response: LOGCA

Terms added sequentially (first to last)
          Df Sum of Sq   Mean Sq  F Value Pr(F)
     LOGQ  1 0.4117400 0.4117400 180.2895     0
    LOGSC  1 0.6679043 0.6679043 292.4566     0
Residuals 58 0.1324588 0.0022838

Variance inflation factors
    LOGQ   LOGSC
 3.34962 3.34962

        model.formula nvars     stderr    adjr2       Cp     press
 LOGCA ~ LOGQ + LOGSC     2 0.04778883 88.69516  3.00000 0.1492417

Test criteria
 leverage cooksD dfits
    0.148  0.849 0.444
      Observations exceeding at least one test criterion
   LOGCA yhat  resids stnd.res stud.res leverage cooksD  dfits
 2  1.74 1.85 -0.1095    -2.41    -2.52   0.0939 0.2002 -0.810
22  1.63 1.71 -0.0707    -1.54    -1.56   0.0825 0.0714 -0.469
33  1.37 1.32  0.0482     1.11     1.11   0.1683 0.0825  0.498
40  1.62 1.72 -0.1007    -2.21    -2.29   0.0912 0.1634 -0.725
53  1.41 1.50 -0.0962    -2.09    -2.16   0.0756 0.1193 -0.617
```

Figure 6. S+® output of regression model development using streamflow (Q) and specific conductance (SC) as explanatory variables for calcium (CA) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

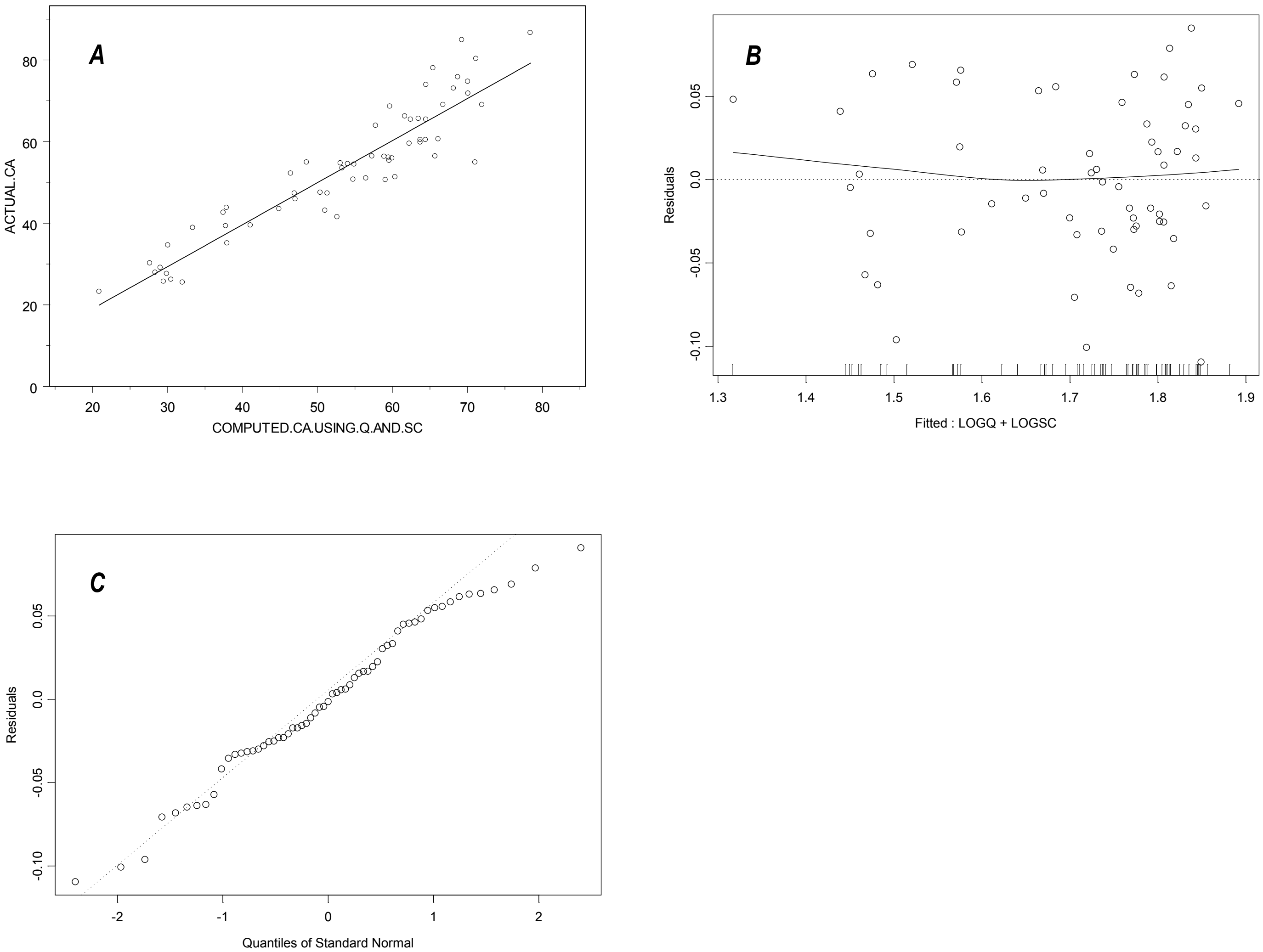

Figure 7. S+® output graphs from simple linear regression analysis using streamflow (Q) and specific conductance (SC) as explanatory variables for calcium (CA) showing *A*, computed versus actual CA concentrations; *B*, computed log-transformed CA concentrations versus regression residuals; and *C*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = LOGMG ~ LOGSC, data = MG, na.action = na.exclude)
Residuals:
     Min       1Q   Median      3Q    Max
 -0.1213 -0.02679 0.003214 0.01909 0.1361

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  -1.0822   0.0770   -14.0606   0.0000
      LOGSC   0.6975   0.0264    26.4042   0.0000

Residual standard error: 0.04098 on 59 degrees of freedom
Multiple R-Squared: 0.922      Adjusted R-squared: 0.9207
F-statistic: 697.2 on 1 and 59 degrees of freedom, the p-value is 0

Correlation of Coefficients:
      (Intercept)
LOGSC -0.9977

Analysis of Variance Table

Response: LOGMG

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq F Value Pr(F)
    LOGSC  1  1.170948 1.170948 697.183     0
Residuals 59  0.099093 0.001680

      model.formula nvars     stderr    adjr2       Cp     press
     LOGMG ~ LOGSC     1 0.04098222 92.06541 2.706622 0.1079854

Test criteria
 leverage cooksD dfits
   0.0984  0.798 0.362
       Observations exceeding at least one test criterion
   LOGMG  yhat  resids stnd.res stud.res leverage cooksD  dfits
20 0.563 0.685 -0.1213    -3.08    -3.33   0.0744  0.380 -0.943
33 0.646 0.599  0.0472     1.23     1.23   0.1187  0.101  0.452
34 0.720 0.656  0.0642     1.64     1.67   0.0879  0.130  0.517
58 0.923 0.787  0.1361     3.39     3.74   0.0379  0.226  0.742
```

Figure 8. S+® output of regression model development using specific conductance (SC) as an explanatory variable for magnesium (MG) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

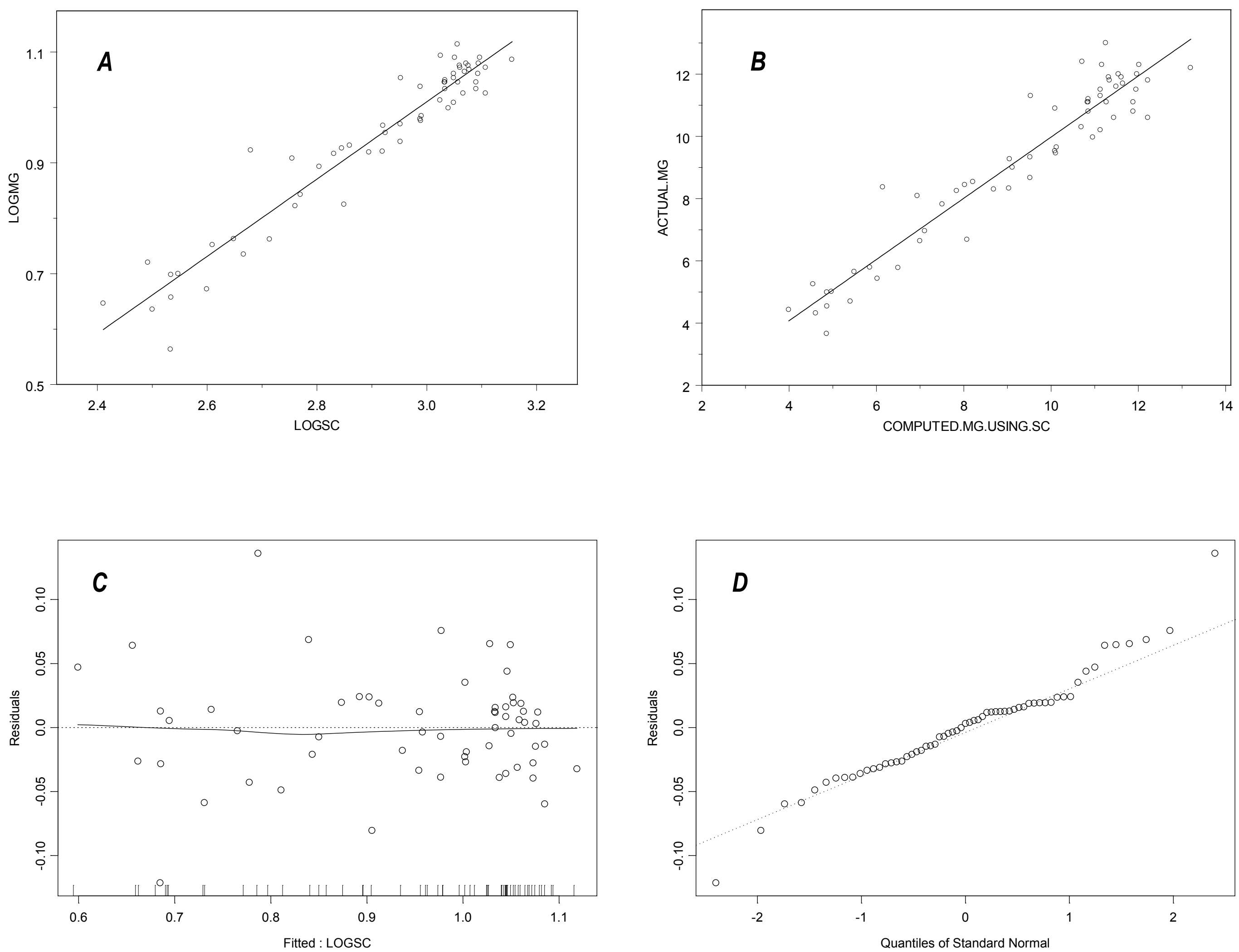

Figure 9. S+® output graphs from simple linear regression analysis showing *A*, log-transformed specific conductance (SC) versus log-transformed magnesium (MG) concentrations; *B*, computed versus actual MG concentrations; *C*, computed log-transformed MG concentrations versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = LOGNA ~ LOGSC, data = NA, na.action = na.exclude)
Residuals:
      Min       1Q    Median      3Q     Max
 -0.08809 -0.01781 -0.002292 0.02416 0.05946

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  -1.8615   0.0620   -30.0234   0.0000
      LOGSC   1.3295   0.0213    62.4796   0.0000

Residual standard error: 0.03301 on 59 degrees of freedom
Multiple R-Squared: 0.9851      Adjusted R-squared: 0.9849
F-statistic: 3904 on 1 and 59 degrees of freedom, the p-value is 0

Correlation of Coefficients:
      (Intercept)
LOGSC -0.9977

Analysis of Variance Table

Response: LOGNA

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
    LOGSC  1  4.254731 4.254731 3903.701     0
Residuals 59  0.064305 0.001090

      model.formula nvars     stderr    adjr2       Cp      press
     LOGNA ~ LOGSC     1 0.03301397 98.48588 6.550423 0.06965938

Test criteria
 leverage cooksD dfits
   0.0984  0.798 0.362
       Observations exceeding at least one test criterion
   LOGNA yhat  resids stnd.res stud.res leverage cooksD  dfits
23  1.65 1.59  0.0589    1.836    1.874   0.0557 0.0994  0.455
28  1.66 1.61  0.0538    1.676    1.703   0.0531 0.0788  0.403
33  1.36 1.34  0.0143    0.461    0.458   0.1187 0.0143  0.168
34  1.36 1.45 -0.0881   -2.794   -2.974   0.0879 0.3762 -0.923
43  2.26 2.33 -0.0687   -2.126   -2.194   0.0420 0.0992 -0.460
```

Figure 10. S+® output of regression model development using specific conductance (SC) as an explanatory variable for sodium (NA) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

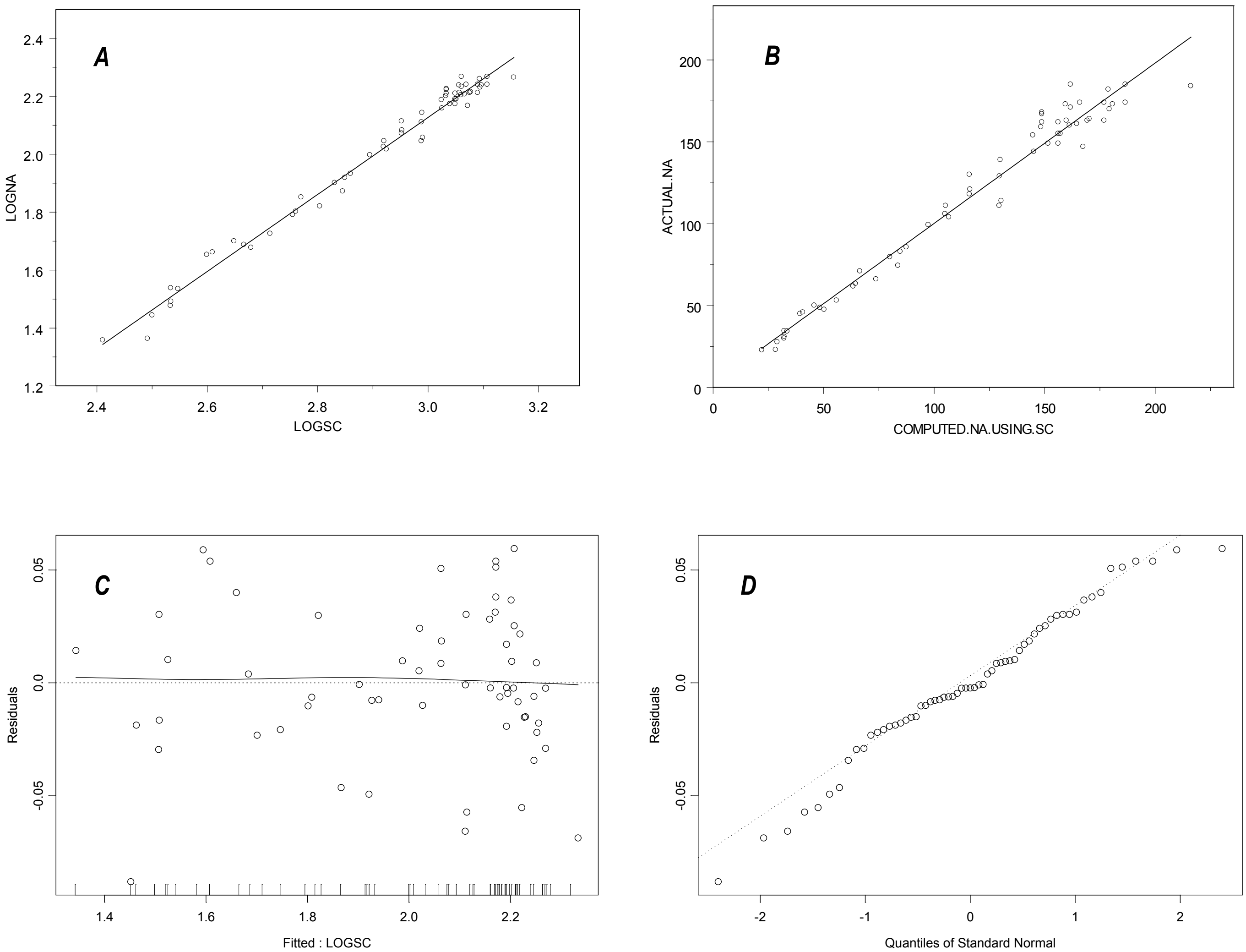

Figure 11. S+® output graphs of simple linear regression analysis showing *A*, log-transformed specific conductance (SC) versus log-transformed sodium (NA) concentrations; *B*, computed versus actual NA concentrations; *C*, computed log-transformed NA concentrations versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = LOGNA ~ LOGQ, data = Na, na.action = na.exclude)
Residuals:
     Min      1Q Median      3Q   Max
 -0.3833 -0.0946 0.0231 0.09604 0.277

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)   2.8099   0.0639    43.9399   0.0000
       LOGQ  -0.3514   0.0268   -13.1139   0.0000

Residual standard error: 0.1367 on 59 degrees of freedom
Multiple R-Squared: 0.7446      Adjusted R-squared: 0.7402
F-statistic: 172 on 1 and 59 degrees of freedom, the p-value is 0

Correlation of Coefficients:
     (Intercept)
LOGQ -0.9618

Analysis of Variance Table

Response: LOGNA

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
     LOGQ  1  3.215783 3.215783 171.9742     0
Residuals 59  1.103254 0.018699

       model.formula nvars    stderr    adjr2       Cp    press
       LOGNA ~ LOGQ      1 0.1367451 74.02307 5.067156 1.187213

Test criteria
 leverage cooksD dfits
   0.0984  0.798 0.362
       Observations exceeding at least one test criterion
   LOGNA yhat resids stnd.res stud.res leverage cooksD  dfits
18  2.21 2.47 -0.258    -1.97    -2.02   0.0834 0.1768 -0.610
33  1.36 1.74 -0.383    -2.86    -3.05   0.0377 0.1602 -0.605
34  1.36 1.58 -0.217    -1.65    -1.67   0.0719 0.1053 -0.466
57  2.08 1.81  0.277     2.06     2.12   0.0285 0.0621  0.363
```

Figure 12. S+® output of regression model development using streamflow (Q) as an explanatory variable for sodium (NA) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

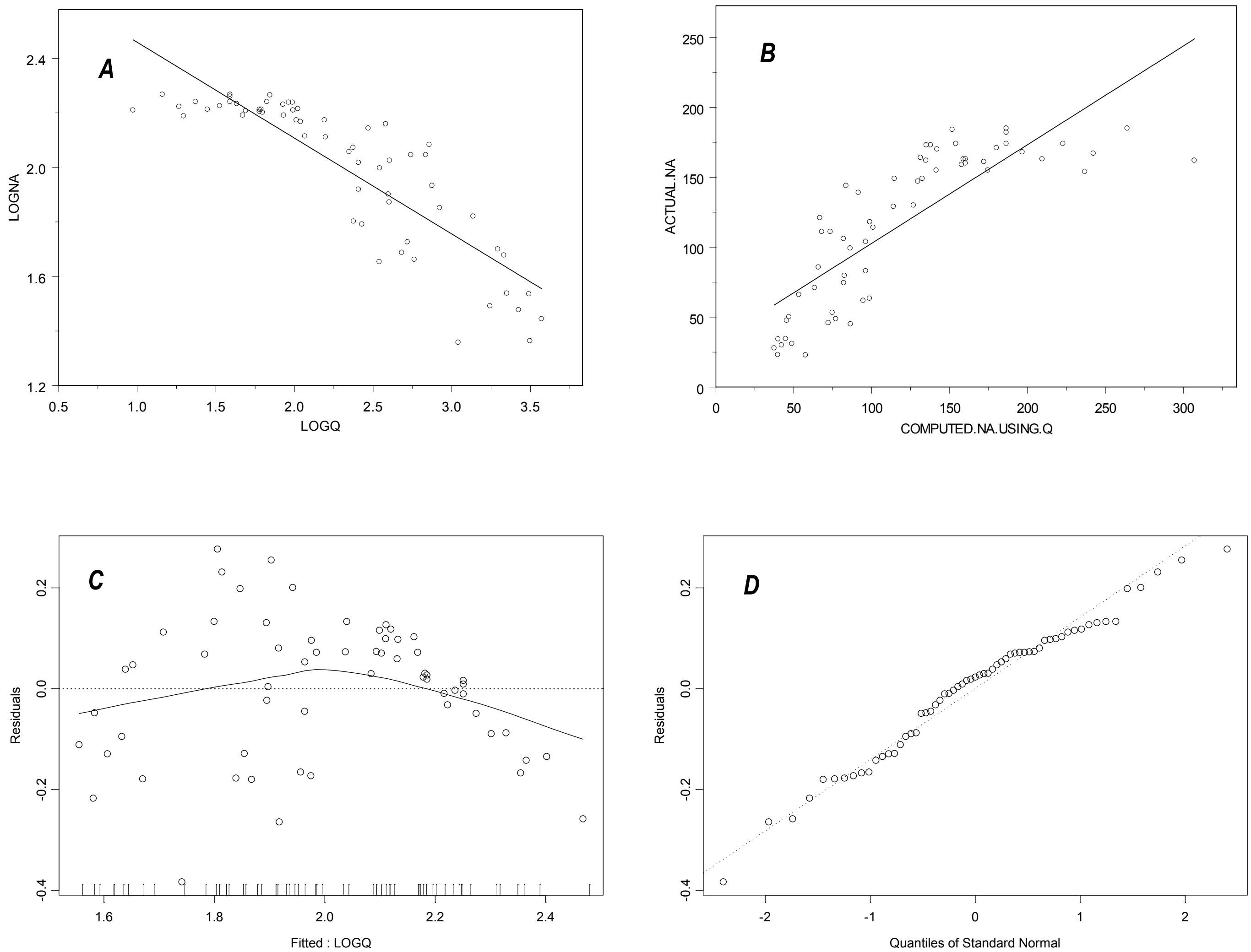

Figure 13. S+® output graphs from simple linear regression analysis showing *A*, log-transformed streamflow (Q) versus log-transformed sodium (NA) concentrations; *B*, computed versus actual NA concentrations; *C*, computed log-transformed NA concentrations versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 071447800), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = LOGCL ~ LOGSC, data = CL, na.action = na.exclude)
Residuals:
     Min       1Q  Median      3Q    Max
 -0.1695 -0.03047 0.01382 0.04013 0.1298

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  -1.8984   0.1180   -16.0909   0.0000
      LOGSC   1.3868   0.0410    33.8255   0.0000

Residual standard error: 0.05914 on 46 degrees of freedom
Multiple R-Squared: 0.9613      Adjusted R-squared: 0.9605
F-statistic: 1144 on 1 and 46 degrees of freedom, the p-value is 0

Correlation of Coefficients:
      (Intercept)
LOGSC -0.9974

Analysis of Variance Table

Response: LOGCL

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
    LOGSC  1  4.001980 4.001980 1144.166     0
Residuals 46  0.160895 0.003498

      model.formula nvars     stderr    adjr2      Cp     press
     LOGCL ~ LOGSC     1 0.05914158 96.05097 1.53727 0.1765017

Test criteria
 leverage cooksD dfits
    0.125    0.8 0.408
       Observations exceeding at least one test criterion
   LOGCL yhat  resids stnd.res stud.res leverage cooksD  dfits
 1  2.10 2.25 -0.1416    -2.43    -2.57   0.0275 0.0834 -0.433
 9  1.53 1.62 -0.0848    -1.49    -1.51   0.0750 0.0901 -0.430
36  1.70 1.57  0.1298     2.30     2.41   0.0865 0.2498  0.743
41  2.08 2.25 -0.1695    -2.91    -3.18   0.0278 0.1207 -0.538
45  1.68 1.82 -0.1362    -2.35    -2.48   0.0383 0.1099 -0.494
```

Figure 14. S+® output of regression model development using specific conductance (SC) as an explanatory variable for chloride (CL) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

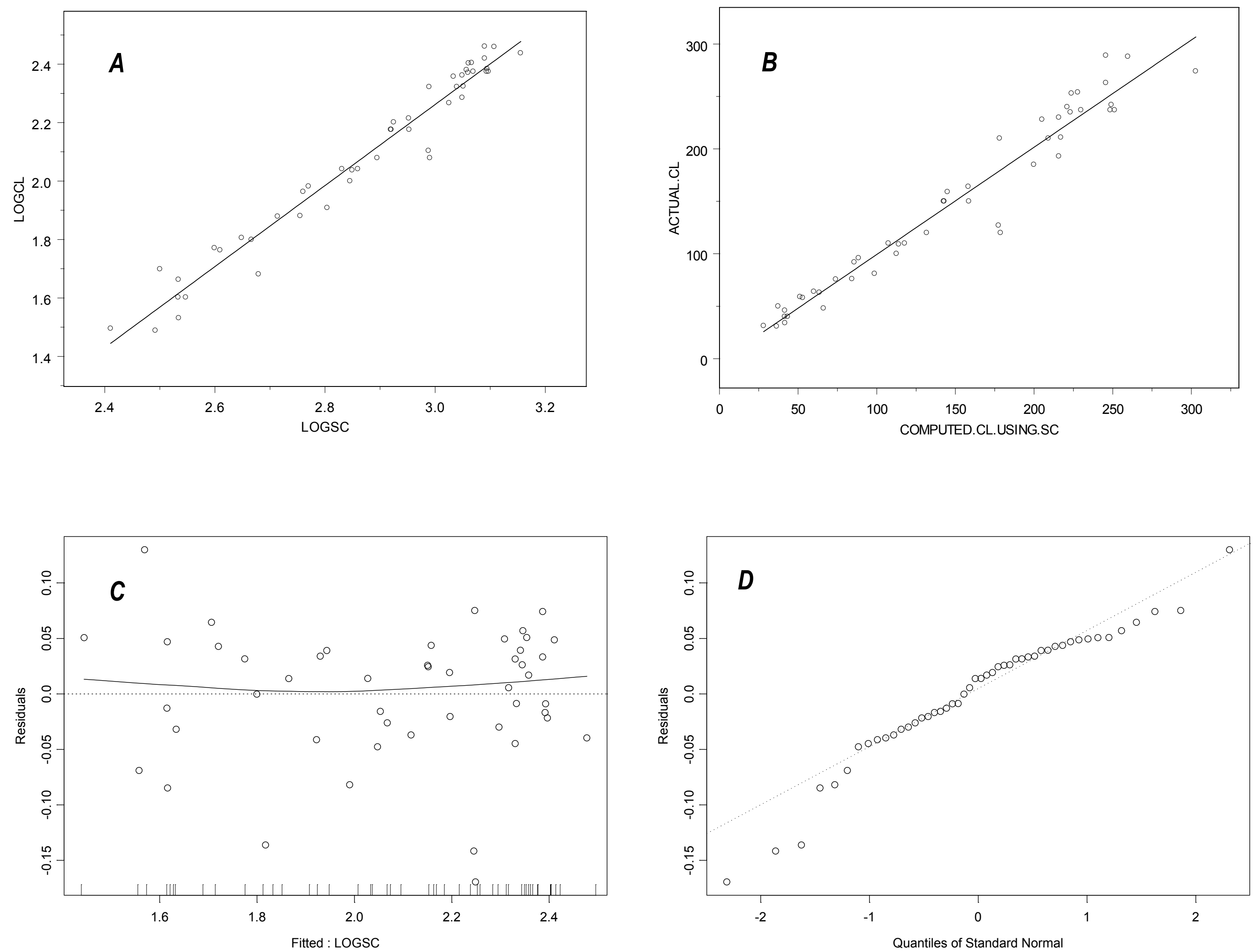

Figure 15. S+® output graphs from simple linear regression showing *A*, log-transformed specific conductance (SC) versus log-transformed chloride (CL) concentrations; *B*, computed versus actual CL concentrations; *C*, computed log-transformed CL concentrations versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = LOGCL ~ LOGQ, data = CL, na.action = na.exclude)
Residuals:
    Min       1Q  Median     3Q   Max
 -0.346 -0.09134 0.02241 0.1038 0.261

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)   3.0610   0.0826    37.0506   0.0000
       LOGQ  -0.4010   0.0327   -12.2547   0.0000

Residual standard error: 0.1457 on 46 degrees of freedom
Multiple R-Squared: 0.7655      Adjusted R-squared: 0.7604
F-statistic: 150.2 on 1 and 46 degrees of freedom, the p-value is 4.441e-016

Correlation of Coefficients:
     (Intercept)
LOGQ -0.9671

Analysis of Variance Table

Response: LOGCL

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq F Value         Pr(F)
     LOGQ  1  3.186761 3.186761 150.178 4.440892e-016
Residuals 46  0.976115 0.021220

       model.formula nvars    stderr    adjr2       Cp    press
       LOGCL ~ LOGQ     1 0.1456705 76.04216 3.316772 1.056413

Test criteria
 leverage cooksD dfits
    0.125    0.8 0.408
       Observations exceeding at least one test criterion
   LOGCL yhat resids stnd.res stud.res leverage cooksD  dfits
10  2.36 2.55 -0.195    -1.40    -1.42   0.0905 0.0979 -0.447
21  1.50 1.84 -0.346    -2.42    -2.57   0.0390 0.1190 -0.517
28  2.40 2.60 -0.192    -1.39    -1.41   0.1036 0.1122 -0.479
```

Figure 16. S+® output of regression model development using streamflow (Q) as the explanatory variable for chloride (CL) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

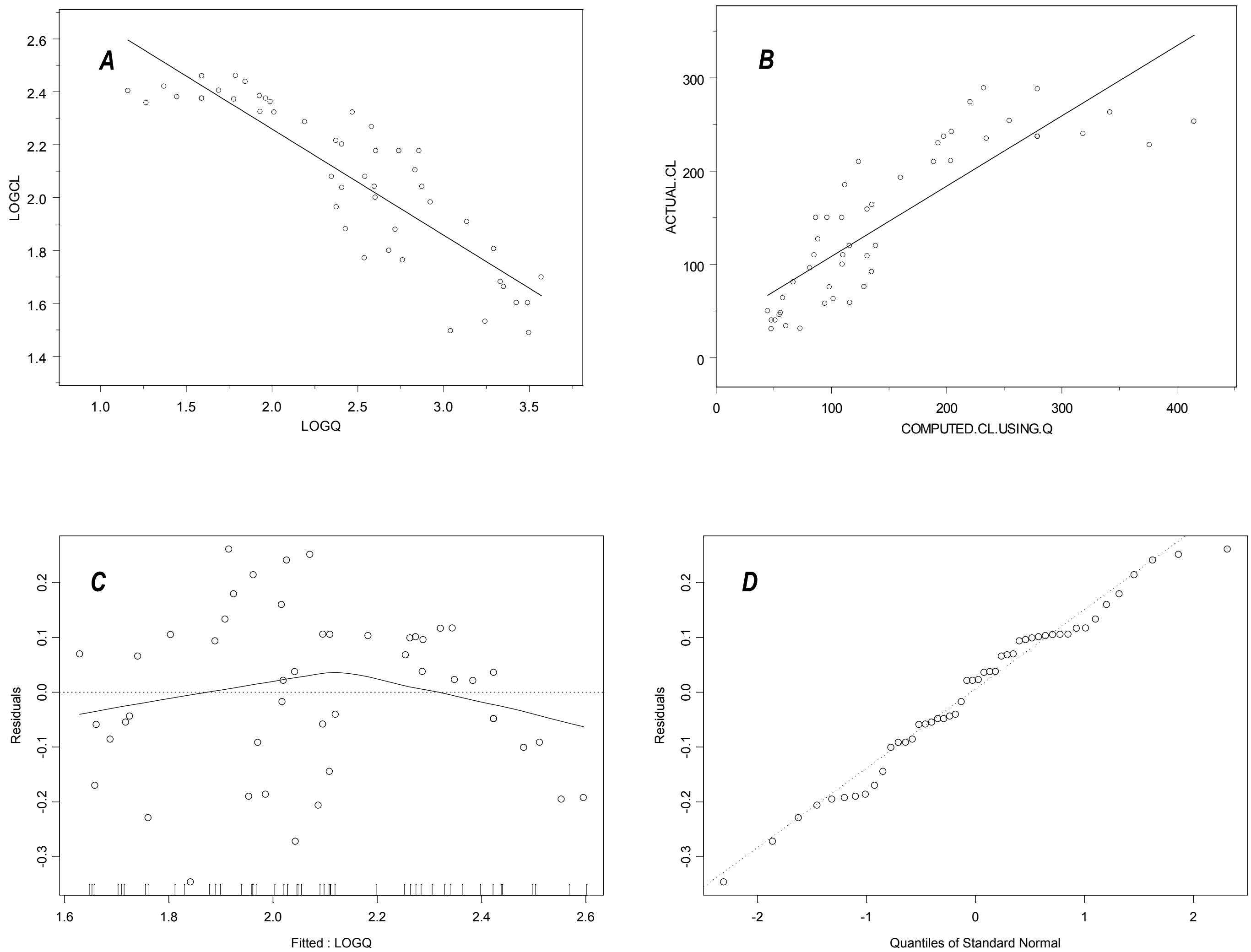

Figure 17. S+® output graphs from simple linear regression analysis showing *A*, log-transformed streamflow (Q) versus log-transformed chloride (CL) concentrations; *B*, computed versus actual CL concentrations; *C*, computed log-transformed CL concentrations versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
      *** Linear Model ***

Call: lm(formula = LOGK ~ SC + LOGSC, data = K, na.action = na.exclude)
Residuals:
     Min       1Q    Median      3Q    Max
 -0.1576 -0.05541 -0.003193 0.05333 0.1994

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -1.7980  0.6242    -2.8806  0.0056
         SC -0.0011  0.0002    -6.5201  0.0000
      LOGSC  1.1690  0.2627     4.4495  0.0000

Residual standard error: 0.07405 on 58 degrees of freedom
Multiple R-Squared: 0.7329      Adjusted R-squared: 0.7237
F-statistic: 79.58 on 2 and 58 degrees of freedom, the p-value is 0

Correlation of Coefficients:
      (Intercept)      SC
   SC  0.9749
LOGSC -0.9990     -0.9834

Analysis of Variance Table

Response: LOGK

Terms added sequentially (first to last)
          Df Sum of Sq   Mean Sq  F Value         Pr(F)
       SC  1 0.7641589 0.7641589 139.3684 0.00000000000
    LOGSC  1 0.1085549 0.1085549  19.7984 0.00003959515
Residuals 58 0.3180148 0.0054830

Variance inflation factors
       SC    LOGSC
 30.30338 30.30338

      model.formula nvars     stderr    adjr2       Cp     press
 LOGK ~ SC + LOGSC     2 0.07404738 72.37146  3.00000 0.3558819

Test criteria
 leverage cooksD dfits
    0.148  0.849 0.444
       Observations exceeding at least one test criterion
    LOGK  yhat resids stnd.res stud.res leverage cooksD  dfits
24 0.640 0.798 -0.158   -2.186    -2.26   0.0521 0.0875 -0.530
33 0.778 0.749  0.029    0.453     0.45   0.2537 0.0233  0.262
43 0.584 0.385  0.199    2.918     3.13   0.1488 0.4963  1.310
```

Figure 18. S+® output of regression model development using specific conductance (SC) as an explanatory variable for potassium (K) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

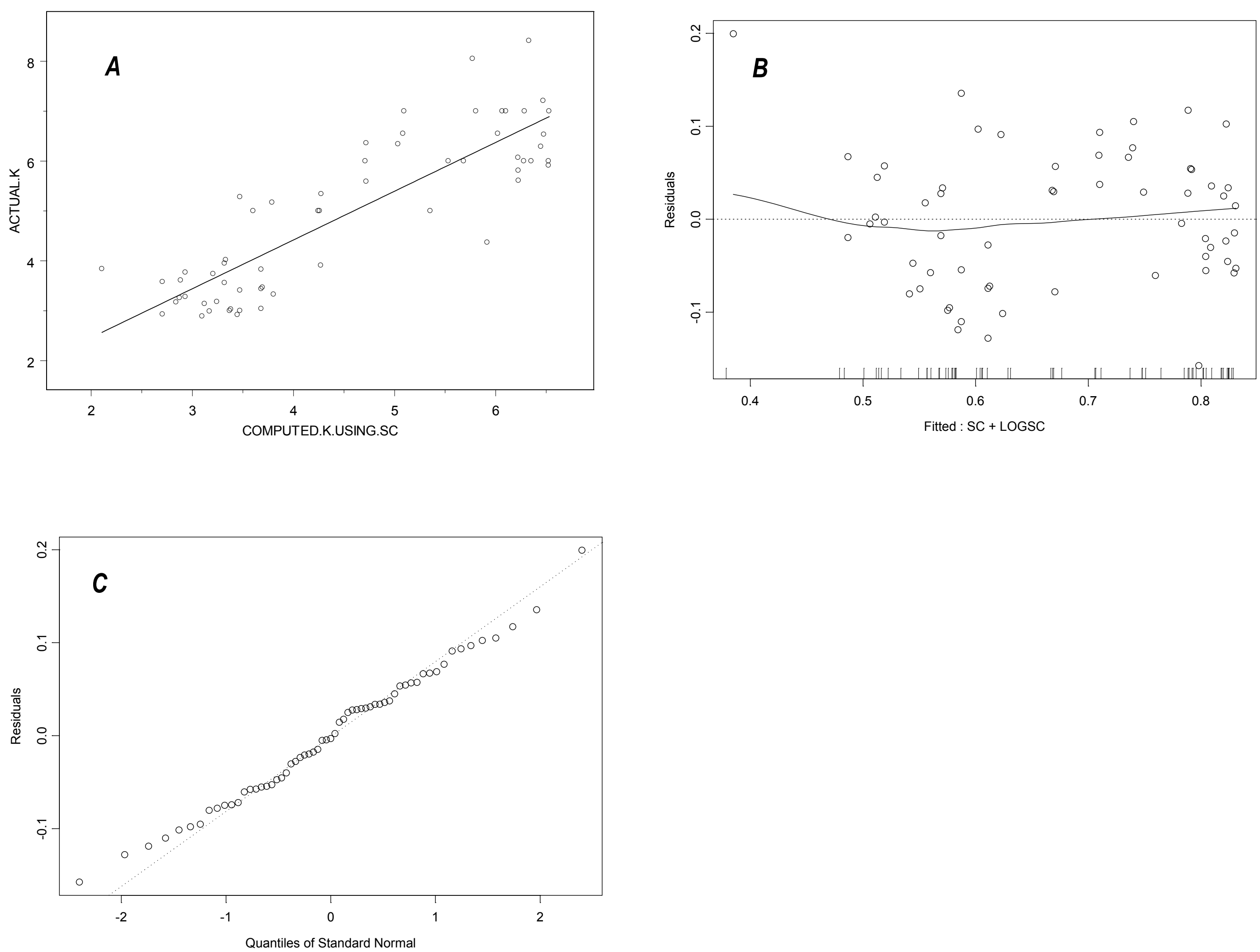

Figure 19. S+® output graphs from simple linear regression analysis using specific conductance (SC) and log-transformed SC as explanatory variables for potassium (K) concentrations showing *A*, computed versus actual K concentrations; *B*, computed log-transformed K concentrations versus regression residuals; and *C*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
      *** Linear Model ***

Call: lm(formula = SO4 ~ SC, data = SO4, na.action = na.exclude)
Residuals:
    Min      1Q Median    3Q   Max
 -15.94 -2.564 0.1872 3.105 14.14

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  -0.0020   2.0754    -0.0009   0.9992
         SC   0.0408   0.0023    17.4635   0.0000

Residual standard error: 5.437 on 46 degrees of freedom
Multiple R-Squared: 0.8689      Adjusted R-squared: 0.8661
F-statistic: 305 on 1 and 46 degrees of freedom, the p-value is 0

Correlation of Coefficients:
   (Intercept)
SC -0.9258

Analysis of Variance Table

Response: SO4

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
       SC  1  9015.111 9015.111 304.9746     0
Residuals 46  1359.769   29.560

     model.formula nvars   stderr    adjr2       Cp    press
         SO4 ~ SC     1 5.436929 86.60872 2.835275 1457.633

Test criteria
 leverage cooksD dfits
    0.125    0.8 0.408
       Observations exceeding at least one test criterion
   SO4 yhat resids stnd.res stud.res leverage cooksD  dfits
 4  61 46.9   14.1     2.66     2.85   0.0405  0.149  0.586
41  24 39.9  -15.9    -2.97    -3.27   0.0254  0.115 -0.527
```

Figure 20. S+® output of regression model development using specific conductance (SC) as an explanatory variable for sulfate (SO4) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

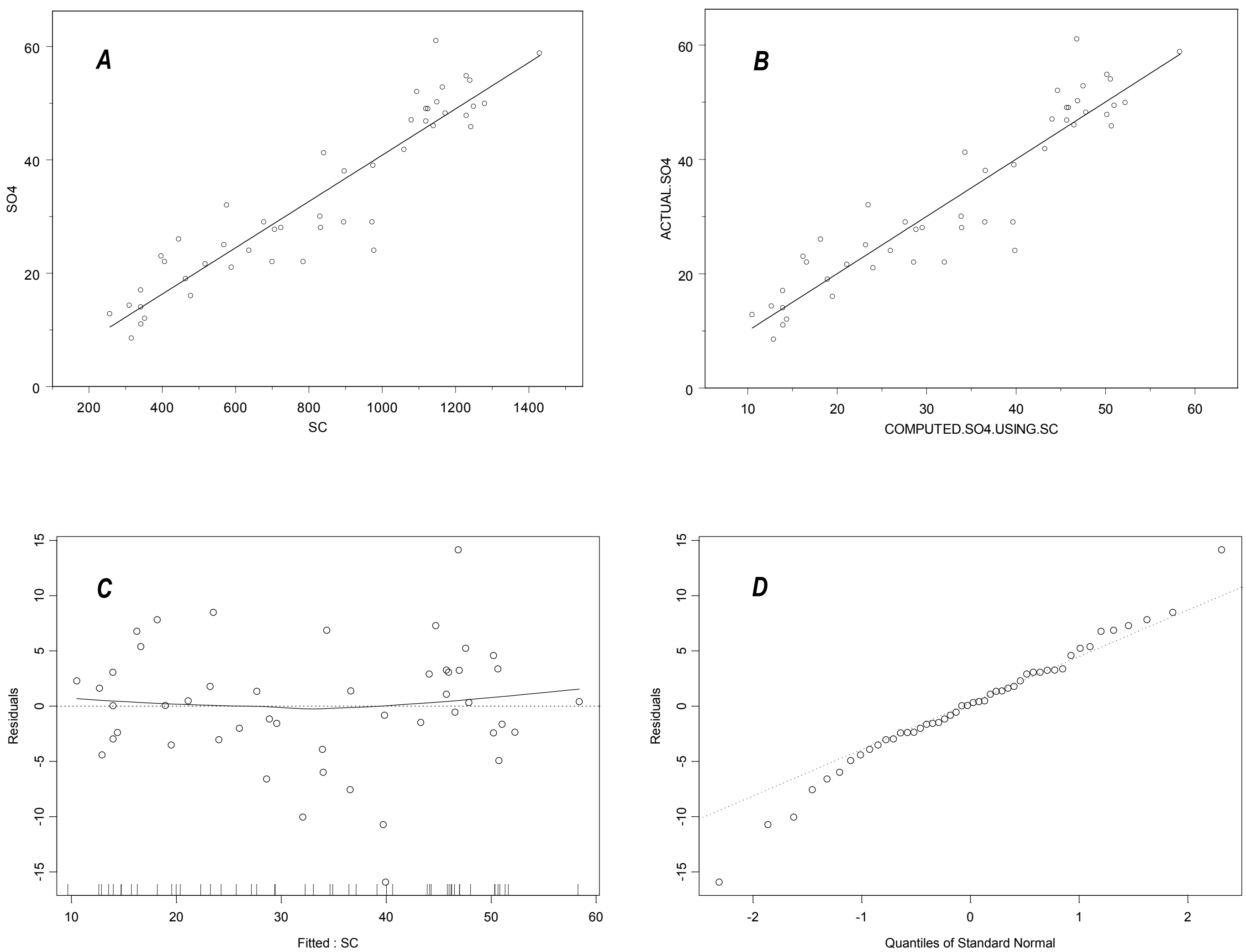

Figure 21. S+® output graphs from simple linear regression analysis showing *A*, specific conductance (SC) versus sulfate (SO4) concentrations; *B*, computed versus actual SO4 concentrations; *C*, computed SO4 concentrations versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
      *** Linear Model ***

Call: lm(formula = SO4 ~ LOGQ, data = SO4, na.action = na.exclude)
Residuals:
    Min     1Q  Median    3Q   Max
 -11.43 -6.472 -0.3668 5.413 14.13

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  82.5695   4.0854    20.2107   0.0000
       LOGQ -20.0745   1.6180   -12.4071   0.0000

Residual standard error: 7.204 on 46 degrees of freedom
Multiple R-Squared: 0.7699      Adjusted R-squared: 0.7649
F-statistic: 153.9 on 1 and 46 degrees of freedom, the p-value is 3.331e-016

Correlation of Coefficients:
     (Intercept)
LOGQ -0.9671

Analysis of Variance Table

Response: SO4

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value         Pr(F)
     LOGQ  1  7987.909 7987.909 153.9373 3.330669e-016
Residuals 46  2386.971   51.891

     model.formula nvars   stderr    adjr2       Cp    press
       SO4 ~ LOGQ     1 7.203518 76.49263 1.189501 2587.379

Test criteria
 leverage cooksD dfits
    0.125    0.8 0.408
       Observations exceeding at least one test criterion
    SO4 yhat resids stnd.res stud.res leverage cooksD  dfits
 4 61.0 46.9  14.13     2.00     2.08   0.0431 0.0904  0.440
10 47.0 57.1 -10.13    -1.47    -1.49   0.0905 0.1081 -0.471
28 50.2 59.3  -9.06    -1.33    -1.34   0.1036 0.1018 -0.455
```

Figure 22. S+® output of regression model development using streamflow (Q) as an explanatory variable for sulfate (SO4) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

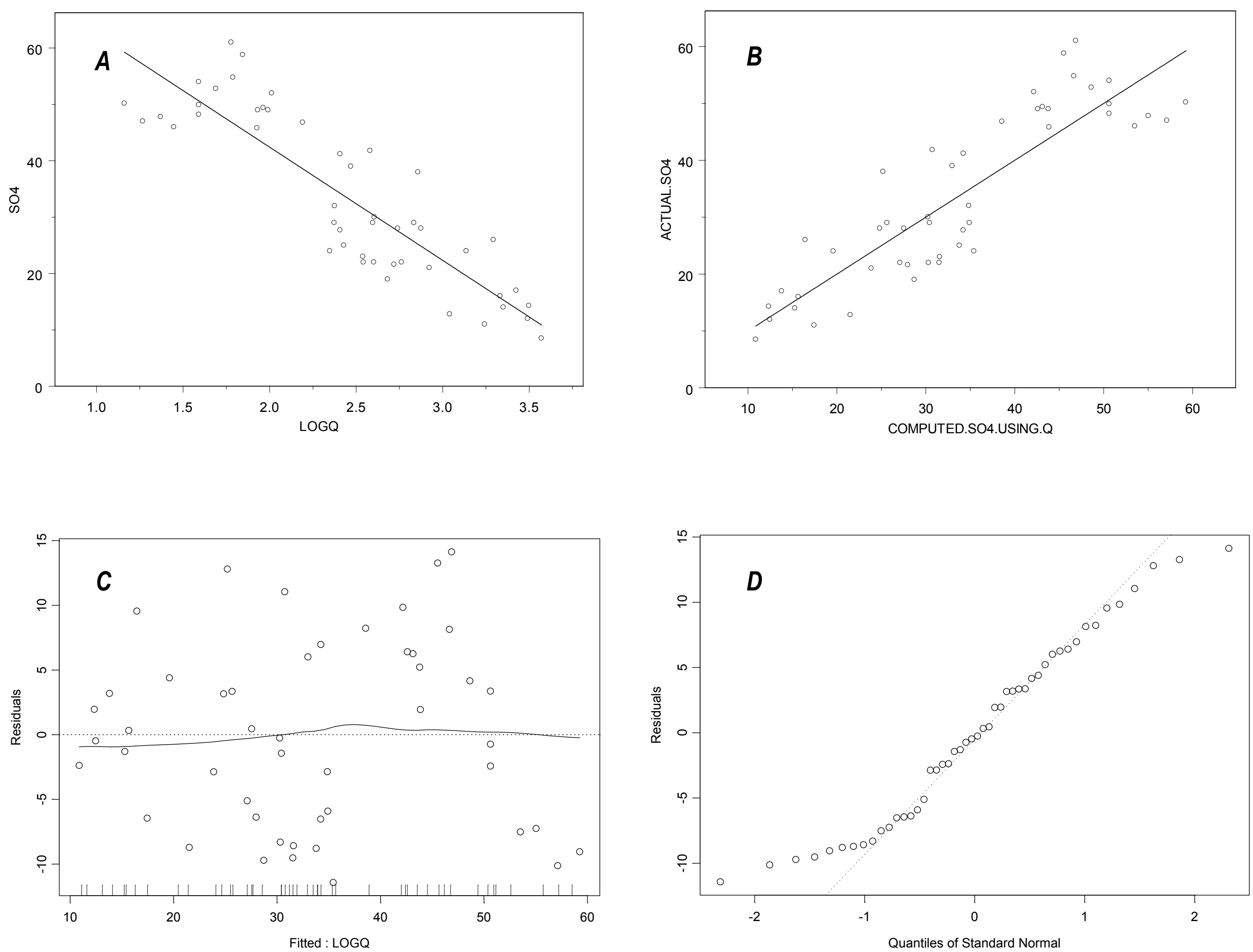

Figure 23. S+® output graphs from simple linear regression analysis showing *A*, log-transformed streamflow (Q) versus sulfate (SO4) concentrations; *B*, computed versus actual SO4 concentrations; *C*, computed SO4 concentrations versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
      *** Linear Model ***

Call: lm(formula = LOGALK ~ LOGQ + LOGSC, data = ALK, na.action = na.exclude)
Residuals:
     Min       1Q   Median      3Q     Max
 -0.1253 -0.03398 0.007513 0.03147 0.07802

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  -0.4469   0.2121   -2.1064   0.0408
       LOGQ   0.1136   0.0193    5.8909   0.0000
      LOGSC   0.8101   0.0595   13.6066   0.0000

Residual standard error: 0.0464 on 45 degrees of freedom
Multiple R-Squared: 0.8661      Adjusted R-squared: 0.8601
F-statistic: 145.5 on 2 and 45 degrees of freedom, the p-value is 0

Correlation of Coefficients:
      (Intercept)    LOGQ
 LOGQ -0.8998
LOGSC -0.9923      0.8415

Analysis of Variance Table

Response: LOGALK

Terms added sequentially (first to last)
          Df Sum of Sq   Mean Sq  F Value         Pr(F)
     LOGQ  1 0.2278944 0.2278944 105.8508 2.118306e-013
    LOGSC  1 0.3985991 0.3985991 185.1386 0.000000e+000
Residuals 45 0.0968839 0.0021530

Variance inflation factors
     LOGQ    LOGSC
 3.425637 3.425637

          model.formula nvars     stderr    adjr2       Cp     press
 LOGALK ~ LOGQ + LOGSC     2 0.04640018 86.01147  3.00000 0.1119638

Test criteria
 leverage cooksD dfits
    0.188  0.852   0.5
       Observations exceeding at least one test criterion
   LOGALK yhat  resids stnd.res stud.res leverage cooksD  dfits
 8   1.87 1.99 -0.1253    -2.81    -3.06   0.0774  0.221 -0.887
21   1.91 1.85  0.0569     1.36     1.37   0.1831  0.137  0.648
28   2.08 2.16 -0.0817    -1.90    -1.96   0.1449  0.205 -0.808
```

Figure 24. S+® output of regression model development using streamflow (Q) and specific conductance (SC) as explanatory variables for alkalinity (ALK) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

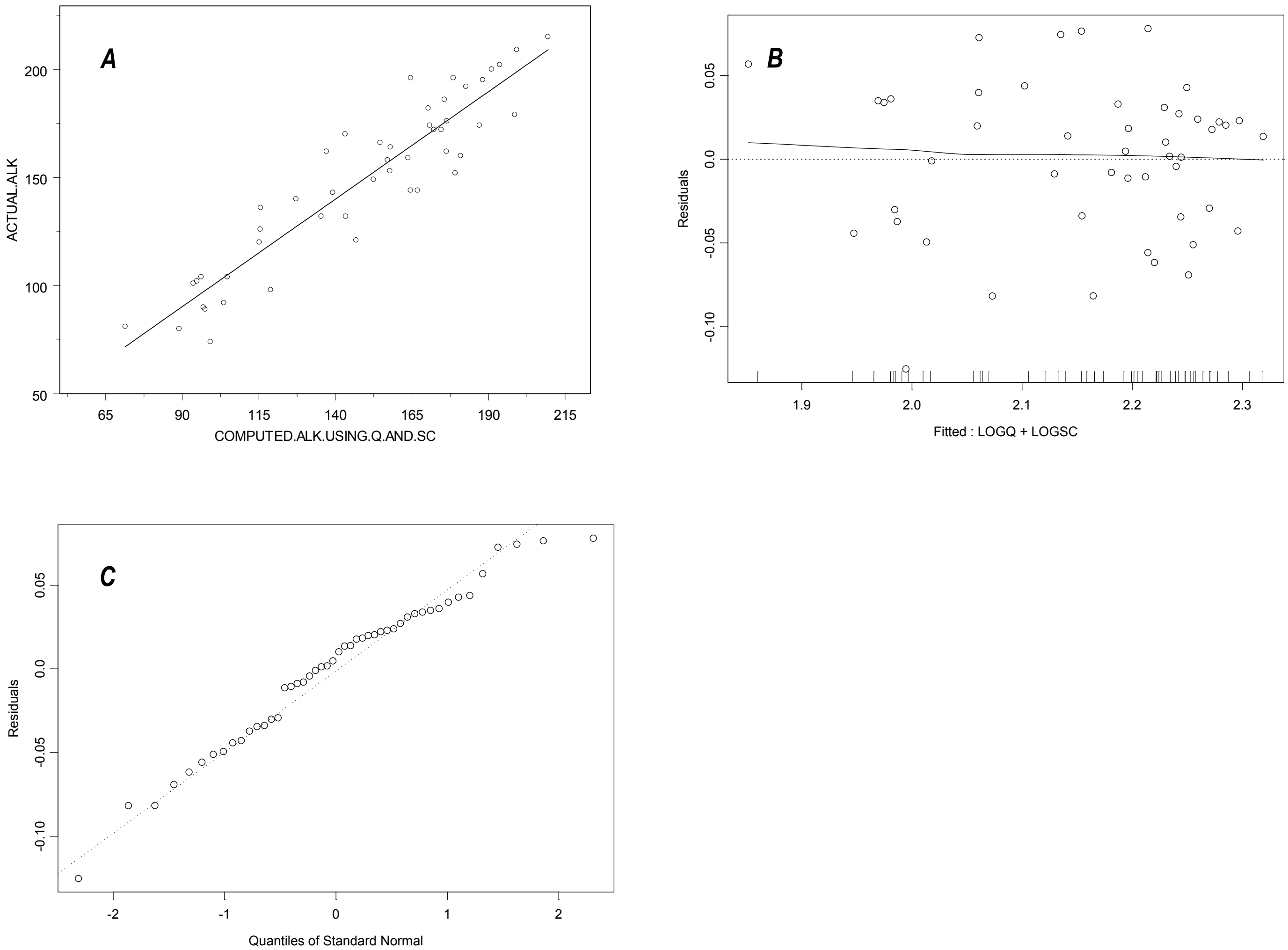

Figure 25. S+® output graphs from simple linear regression analysis using streamflow (Q) and specific conductance (SC) as explanatory variables for alkalinity (ALK) concentrations showing *A*, computed versus actual ALK concentrations; *B*, computed log-transformed ALK concentrations versus regression residuals; and *C*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = LOGHCO3 ~ LOGQ + LOGSC, data = HCO3, na.action = na.exclude)
Residuals:
     Min       1Q   Median      3Q     Max
 -0.1443 -0.03119 0.006959 0.02818 0.08358

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  -0.3677   0.2190    -1.6792   0.1001
       LOGQ   0.1126   0.0199     5.6560   0.0000
      LOGSC   0.8134   0.0614    13.2375   0.0000

Residual standard error: 0.04789 on 45 degrees of freedom
Multiple R-Squared: 0.8608      Adjusted R-squared: 0.8546
F-statistic: 139.1 on 2 and 45 degrees of freedom, the p-value is 0

Correlation of Coefficients:
      (Intercept)    LOGQ
 LOGQ -0.8998
LOGSC -0.9923      0.8415

Analysis of Variance Table

Response: LOGHCO3

Terms added sequentially (first to last)
          Df Sum of Sq   Mean Sq  F Value         Pr(F)
     LOGQ  1 0.2362125 0.2362125 102.9856 3.274048e-013
    LOGSC  1 0.4019175 0.4019175 175.2308 0.000000e+000
Residuals 45 0.1032141 0.0022936

Variance inflation factors
     LOGQ    LOGSC
 3.425637 3.425637

           model.formula nvars     stderr    adjr2      Cp     press
 LOGHCO3 ~ LOGQ + LOGSC     2 0.04789203 85.45866  3.0000 0.1192452

Test criteria
 leverage cooksD dfits
    0.188  0.852   0.5
       Observations exceeding at least one test criterion
   LOGHCO3 yhat  resids stnd.res stud.res leverage cooksD  dfits
 8    1.93 2.08 -0.1443    -3.14    -3.51   0.0774  0.275 -1.016
21    2.00 1.94  0.0598     1.38     1.40   0.1831  0.143  0.661
28    2.18 2.25 -0.0767    -1.73    -1.77   0.1449  0.169 -0.730
```

Figure 26. S+® output of regression model development using streamflow (Q) and specific conductance (SC) as explanatory variables for bicarbonate (HCO3) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

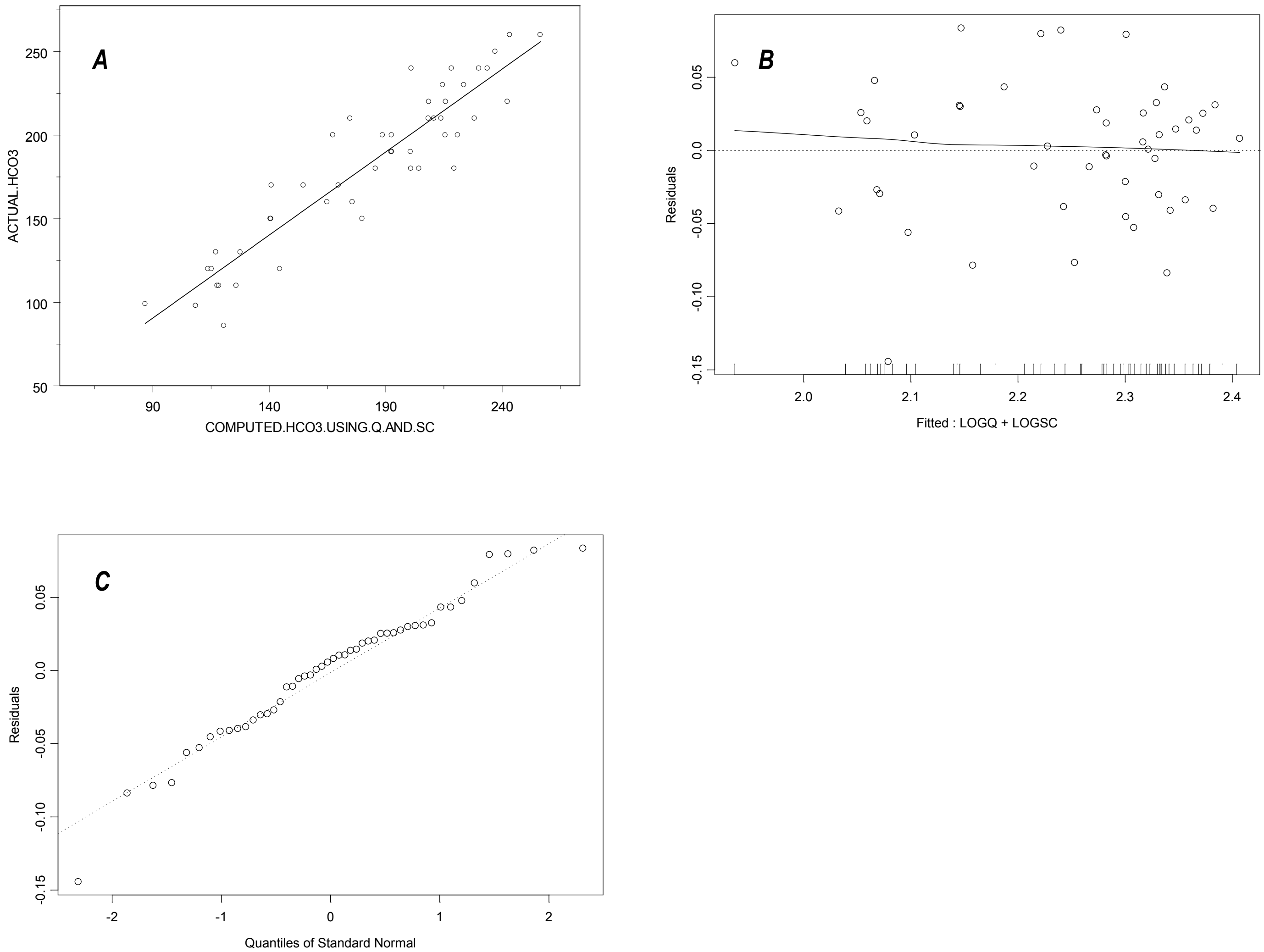

Figure 27. S+® output graphs from simple linear regression analysis using streamflow (Q) and specific conductance (SC) as explanatory variables for bicarbonate (HCO3) concentrations showing *A*, computed versus actual HCO3 concentrations; *B*, computed log-transformed HCO3 concentrations versus regression residuals, and *C*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = LOGTSS ~ LOGTBY, data = TSS, na.action = na.exclude)
Residuals:
     Min       1Q  Median      3Q   Max
 -0.5663 -0.08246 0.01373 0.07905 0.439

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  0.2523  0.0927     2.7205  0.0087
     LOGTBY  0.9033  0.0473    19.1125  0.0000

Residual standard error: 0.1718 on 55 degrees of freedom
Multiple R-Squared: 0.8691      Adjusted R-squared: 0.8668
F-statistic: 365.3 on 1 and 55 degrees of freedom, the p-value is 0

Correlation of Coefficients:
       (Intercept)
LOGTBY -0.9694

Analysis of Variance Table

Response: LOGTSS

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
   LOGTBY  1  10.77767 10.77767 365.2859     0
Residuals 55   1.62276  0.02950

         model.formula nvars    stderr    adjr2       Cp     press
      LOGTSS ~ LOGTBY     1 0.1717695 86.67574 1.202253  1.752887

Test criteria
 leverage cooksD dfits
    0.105  0.799 0.375
       Observations exceeding at least one test criterion
   LOGTSS yhat resids stnd.res stud.res leverage cooksD  dfits
 3  1.740 1.30  0.439     2.63     2.79   0.0591 0.2181  0.700
18  0.903 1.47 -0.566    -3.37    -3.74   0.0409 0.2414 -0.773
19  2.210 2.52 -0.306    -1.82    -1.86   0.0450 0.0782 -0.404
26  2.000 2.35 -0.350    -2.07    -2.14   0.0309 0.0683 -0.381
```

Figure 28. S+® output of regression model development using turbidity (TBY) as an explanatory variable for total suspended solids (TSS) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

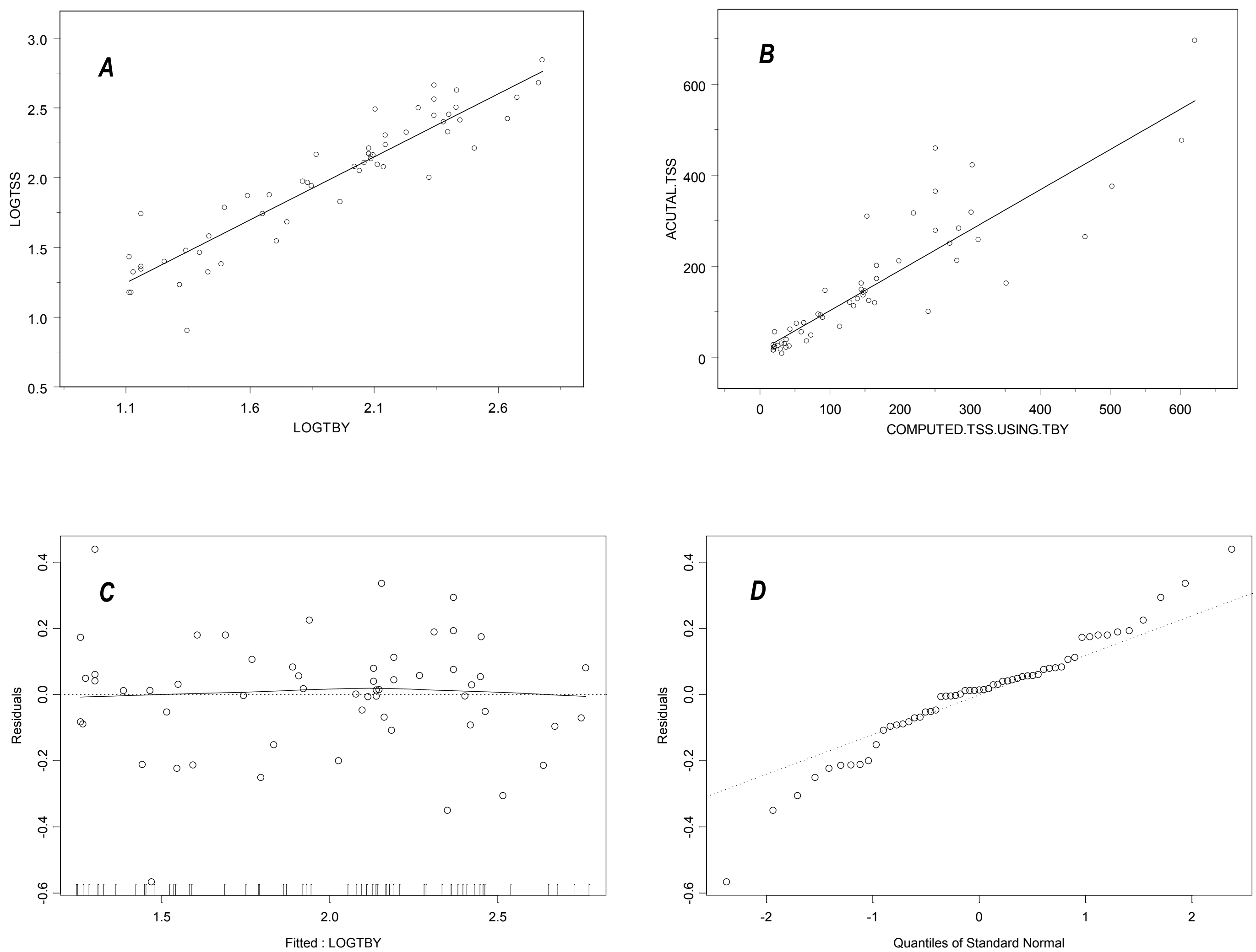

Figure 29. S+® output graphs from simple linear regression analysis showing *A*, log-transformed turbidity (TBY) versus log-transformed total suspended solids (TSS) concentrations; *B*, computed versus actual TSS concentrations; *C*, computed log-transformed TSS concentrations versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = LOGTSS ~ LOGQ, data = TSS, na.action = na.exclude)
Residuals:
     Min      1Q   Median     3Q    Max
 -0.5578 -0.1812 -0.01994 0.1864 0.7242

Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) 0.6243 0.1411     4.4240  0.0000
       LOGQ 0.5753 0.0581     9.9018  0.0000

Residual standard error: 0.2846 on 55 degrees of freedom
Multiple R-Squared: 0.6406      Adjusted R-squared: 0.6341
F-statistic: 98.05 on 1 and 55 degrees of freedom, the p-value is 7.938e-014

Correlation of Coefficients:
     (Intercept)
LOGQ -0.9636

Analysis of Variance Table

Response: LOGTSS

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value         Pr(F)
     LOGQ  1  7.944119 7.944119 98.04663 7.938095e-014
Residuals 55  4.456314 0.081024

        model.formula nvars    stderr    adjr2      Cp    press
       LOGTSS ~ LOGQ     1 0.2846469 63.40984 30.6069 4.761309

Test criteria
 leverage cooksD dfits
    0.105  0.799 0.375
       Observations exceeding at least one test criterion
   LOGTSS yhat resids stnd.res stud.res leverage cooksD  dfits
18  0.903 1.37 -0.467    -1.69    -1.72   0.0630 0.0964 -0.447
19  2.210 2.59 -0.385    -1.40    -1.41   0.0666 0.0700 -0.378
22  2.843 2.12  0.724     2.57     2.72   0.0203 0.0684  0.391
31  2.161 2.64 -0.475    -1.74    -1.77   0.0734 0.1192 -0.498
45  2.324 2.68 -0.354    -1.30    -1.31   0.0806 0.0740 -0.387
```

Figure 30. S+® output of regression model development using streamflow (Q) as an explanatory variable for total suspended solids (TSS) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

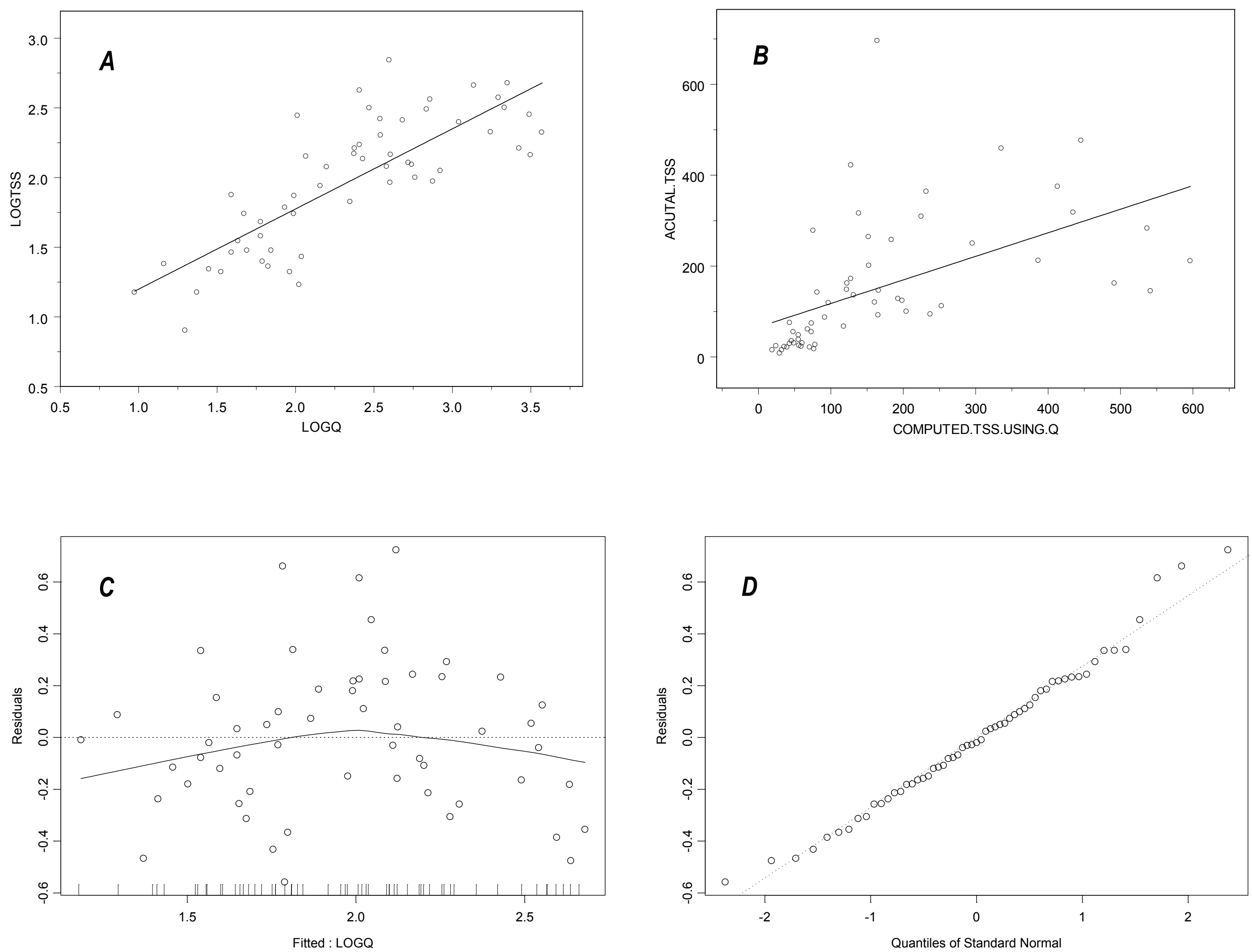

Figure 31. S+® output graphs from simple linear regression analysis showing *A*, log-transformed streamflow (Q) versus log-transformed total suspended solids (TSS) concentrations; *B*, computed versus actual TSS concentrations; *C*, computed log-transformed TSS concentrations versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = LOGSSC ~ LOGQ + LOGTBY, data = SSC, na.action = na.exclude)
Residuals:
     Min       1Q    Median     3Q    Max
 -0.4998 -0.08841 -0.002607 0.1056 0.4714

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -0.1103  0.1187    -0.9292  0.3573
       LOGQ  0.5400  0.0663     8.1439  0.0000
     LOGTBY  0.5589  0.0877     6.3748  0.0000

Residual standard error: 0.1862 on 49 degrees of freedom
Multiple R-Squared: 0.8993      Adjusted R-squared: 0.8952
F-statistic: 218.8 on 2 and 49 degrees of freedom, the p-value is 0

Correlation of Coefficients:
       (Intercept)    LOGQ
  LOGQ -0.2530
LOGTBY -0.4221     -0.7587

Analysis of Variance Table

Response: LOGSSC

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value         Pr(F)
     LOGQ  1  13.77122 13.77122 397.0356 0.000000e+000
   LOGTBY  1   1.40951  1.40951  40.6375 6.172674e-008
Residuals 49   1.69957  0.03469

 Variance inflation factors
     LOGQ   LOGTBY
 2.356401 2.356401

           model.formula nvars    stderr    adjr2       Cp    press
 LOGSSC ~ LOGQ + LOGTBY     2 0.1862393 89.52069  3.00000 1.888522

Test criteria
 leverage cooksD dfits
    0.173  0.851  0.48
       Observations exceeding at least one test criterion
   LOGSSC yhat resids stnd.res stud.res leverage cooksD  dfits
12   2.48 2.98 -0.500    -2.76    -2.98   0.0560 0.1510 -0.725
47   3.03 2.61  0.416     2.28     2.39   0.0425 0.0771  0.504
```

Figure 32. S+® output of regression model development using streamflow (Q) and turbidity (TBY) as explanatory variables for suspended-sediment concentrations (SSC) for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

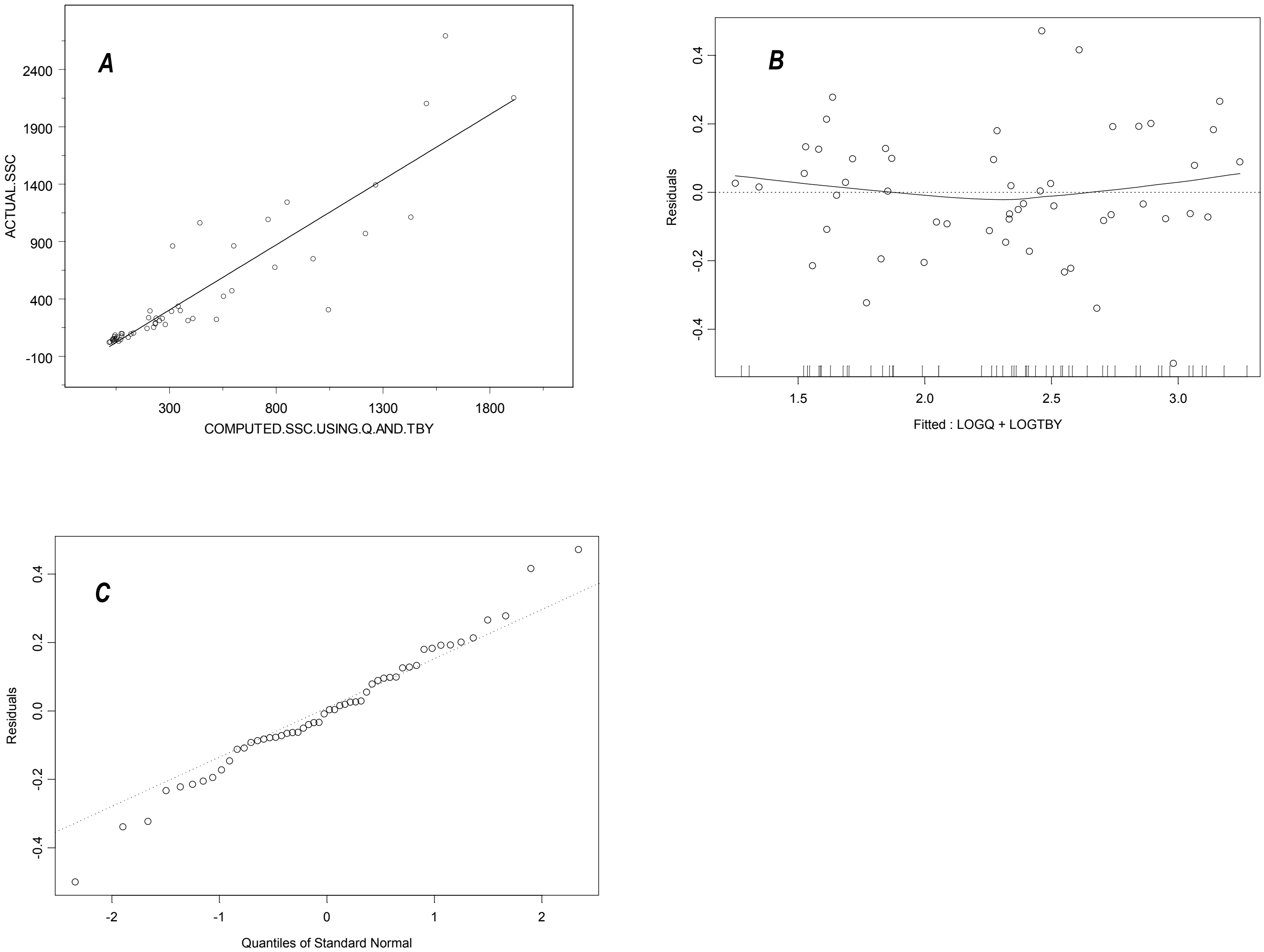

Figure 33. S+® output graphs from simple linear regression analysis using streamflow (Q) and turbidity (TBY) as explanatory variables for suspended-sediment concentrations (SSC) showing *A*, computed versus actual SSC concentrations; *B*, computed log-transformed SSC versus regression residuals; and *C*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = LOGSSC ~ LOGQ, data = SSC, na.action = na.exclude)
Residuals:
     Min      1Q   Median     3Q    Max
 -0.5193 -0.1469 -0.02211 0.1559 0.5931

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  0.2092  0.1441     1.4515  0.1529
       LOGQ  0.8606  0.0578    14.8818  0.0000

Residual standard error: 0.2494 on 50 degrees of freedom
Multiple R-Squared: 0.8158      Adjusted R-squared: 0.8121
F-statistic: 221.5 on 1 and 50 degrees of freedom, the p-value is 0

Correlation of Coefficients:
     (Intercept)
LOGQ -0.9708

Analysis of Variance Table

Response: LOGSSC

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
     LOGQ  1  13.77122 13.77122 221.4674     0
Residuals 50   3.10908  0.06218

        model.formula nvars    stderr    adjr2       Cp    press
       LOGSSC ~ LOGQ     1 0.2493625 81.21322 31.73686 3.353123

Test criteria
 leverage cooksD dfits
    0.115    0.8 0.392
       Observations exceeding at least one test criterion
   LOGSSC yhat resids stnd.res stud.res leverage cooksD  dfits
12   2.48 3.00 -0.519    -2.14    -2.23   0.0558 0.1357 -0.541
21   3.43 3.04  0.386     1.60     1.62   0.0604 0.0818  0.411
27   2.87 3.22 -0.347    -1.45    -1.47   0.0818 0.0938 -0.438
```

Figure 34. S+® output of regression model development using streamflow (Q) as an explanatory variable for suspended-sediment concentrations (SSC) for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

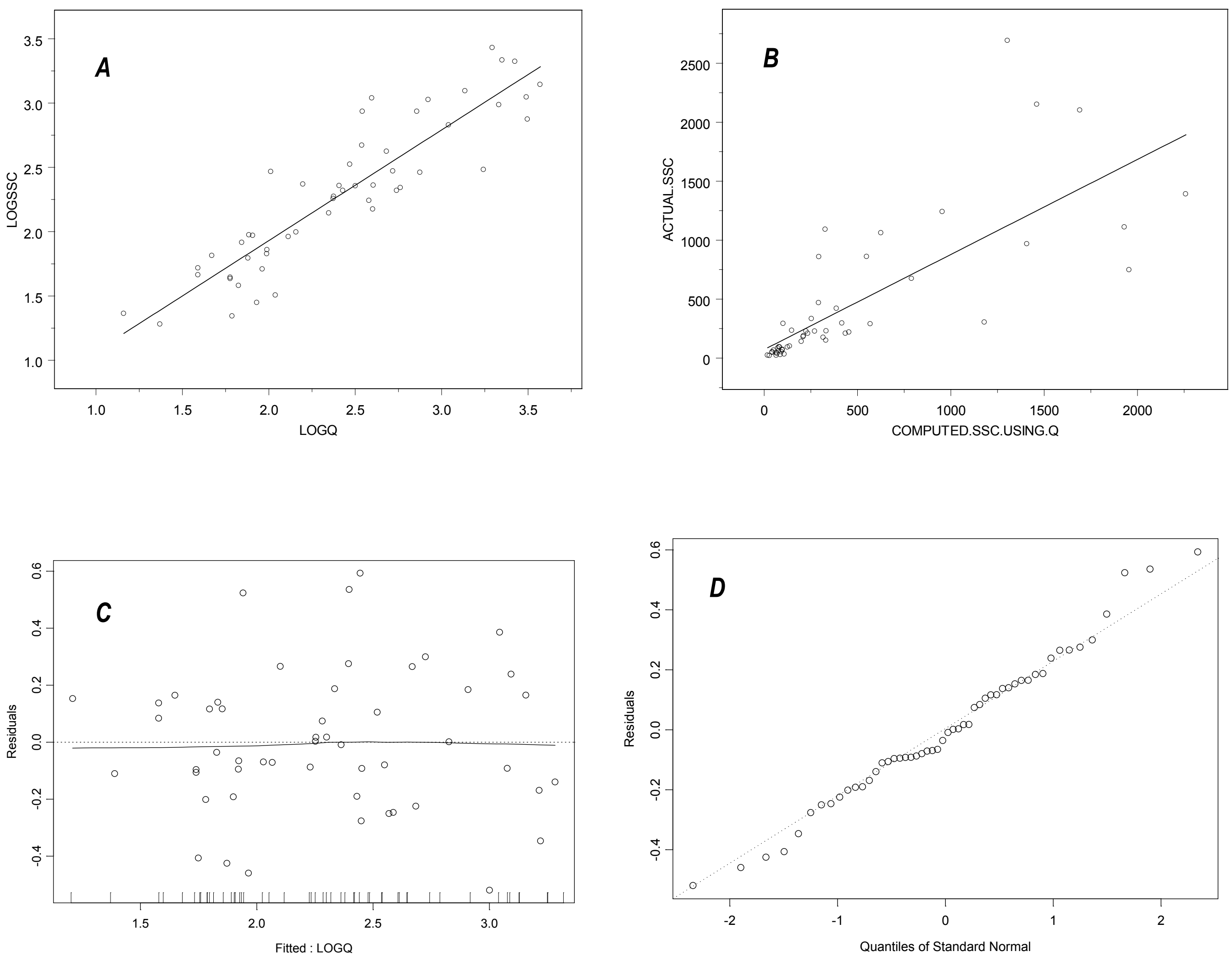

Figure 35. S+® output graphs from simple linear regression analysis showing *A*, log-transformed streamflow (Q) versus log-transformed suspended-sediment concentrations (SSC); *B*, computed versus actual SSC concentrations; *C*, computed log-transformed SSC versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
      *** Linear Model ***

Call: lm(formula = LOGTN ~ SIN + COS + LOGTBY, data = TN, na.action = na.exclude)
Residuals:
     Min       1Q  Median      3Q    Max
 -0.1782 -0.04105 0.01431 0.05001 0.1447

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -0.0012  0.0513    -0.0235  0.9814
        SIN  0.0218  0.0173     1.2584  0.2141
        COS  0.1118  0.0220     5.0822  0.0000
     LOGTBY  0.1818  0.0260     7.0011  0.0000

Residual standard error: 0.08755 on 50 degrees of freedom
Multiple R-Squared: 0.6254      Adjusted R-squared: 0.6029
F-statistic: 27.82 on 3 and 50 degrees of freedom, the p-value is 1.003e-010

Correlation of Coefficients:
       (Intercept)     SIN     COS
   SIN  0.0792
   COS  0.1375     -0.1148
LOGTBY -0.9546     -0.1946  0.0271

Analysis of Variance Table

Response: LOGTN

Terms added sequentially (first to last)
          Df Sum of Sq   Mean Sq  F Value       Pr(F)
      SIN  1 0.0803847 0.0803847 10.48781 0.002137292
      COS  1 0.1836119 0.1836119 23.95589 0.000010690
   LOGTBY  1 0.3756877 0.3756877 49.01608 0.000000006
Residuals 50 0.3832291 0.0076646

Variance inflation factors
     SIN      COS   LOGTBY
 1.05247 1.013377 1.039364

              model.formula nvars     stderr    adjr2        Cp     press
 LOGTN ~ SIN + COS + LOGTBY     3 0.08754760 60.28766  4.000000 0.4586760

Test criteria
 leverage cooksD dfits
    0.222  0.882 0.544
      Observations exceeding at least one test criterion
      LOGTN  yhat resids stnd.res stud.res leverage cooksD  dfits
 3  0.29447 0.153  0.142     1.70     1.74   0.0961 0.0770  0.566
 9  0.45939 0.315  0.145     1.82     1.86   0.1729 0.1726  0.851
14  0.30535 0.484 -0.178    -2.23    -2.33   0.1694 0.2542 -1.052
31  0.04922 0.214 -0.165    -1.95    -2.01   0.0688 0.0703 -0.546
36 -0.00436 0.161 -0.166    -2.02    -2.08   0.1204 0.1392 -0.771
```

Figure 36. S+® output of regression model development using season (SIN and COS) and turbidity (TBY) as explanatory variables for total nitrogen (TN) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

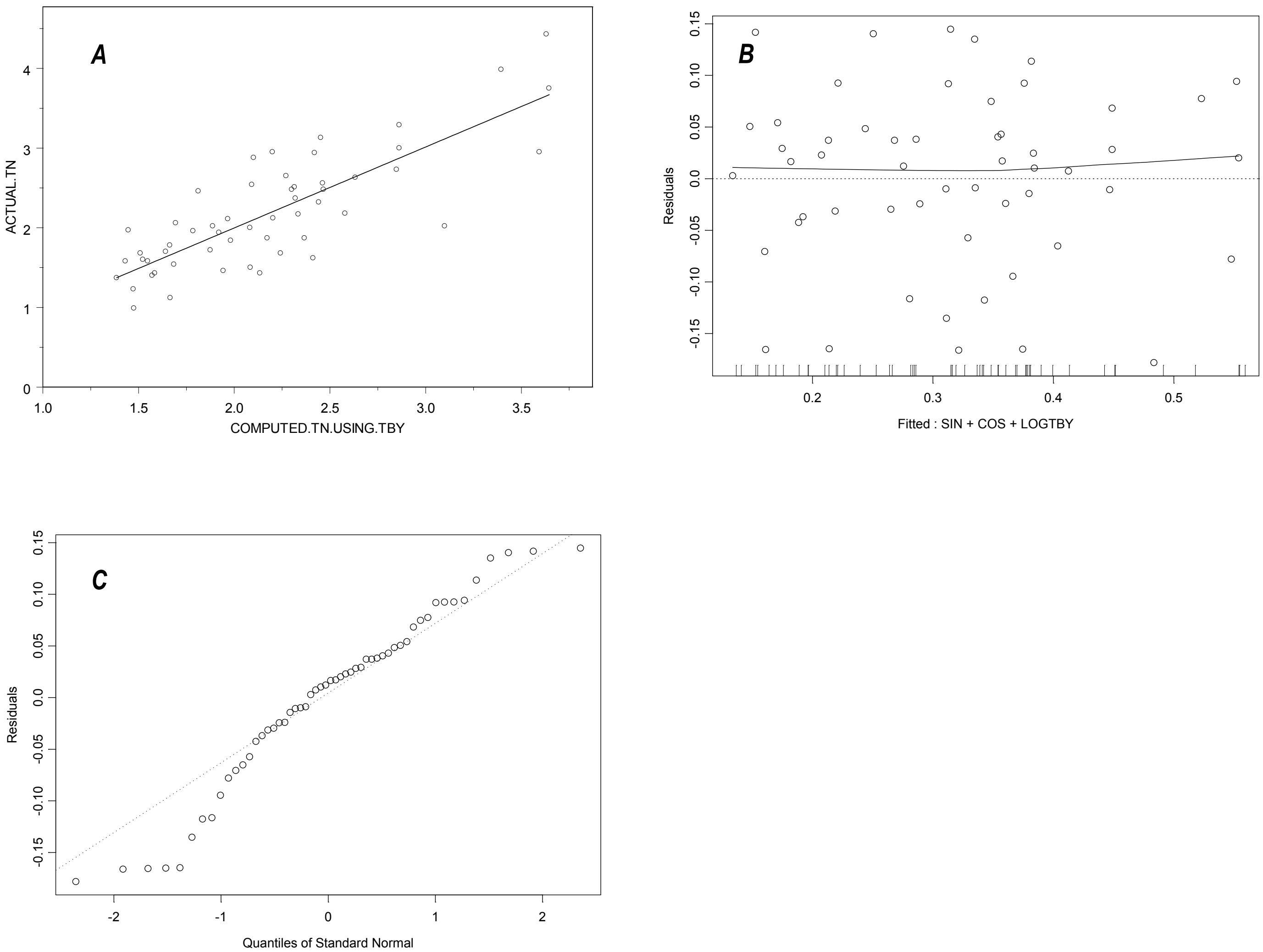

Figure 37. S+® output graphs from simple linear regression analysis using season (SIN and COS) and turbidity (TBY) as explanatory variables for total nitrogen (TN) concentrations showing *A*, computed versus actual TN concentrations; *B*, computed log-transformed TN concentrations versus regression residuals; and *C*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
      *** Linear Model ***

Call: lm(formula = LOGTN ~ SIN + COS + LOGQ, data = TN, na.action = na.exclude)
Residuals:
     Min       1Q  Median      3Q    Max
 -0.2292 -0.06353 0.01046 0.05958 0.2388

Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) 0.1503 0.0650     2.3109  0.0250
        SIN 0.0209 0.0233     0.8990  0.3730
        COS 0.1049 0.0284     3.6985  0.0005
       LOGQ 0.0822 0.0266     3.0923  0.0032

Residual standard error: 0.1129 on 50 degrees of freedom
Multiple R-Squared: 0.3772      Adjusted R-squared: 0.3398
F-statistic: 10.09 on 3 and 50 degrees of freedom, the p-value is 0.00002619

Correlation of Coefficients:
     (Intercept)     SIN     COS
 SIN  0.2196
 COS  0.1957     -0.0945
LOGQ -0.9529     -0.3395 -0.0310

Analysis of Variance Table

Response: LOGTN

Terms added sequentially (first to last)
          Df Sum of Sq   Mean Sq  F Value      Pr(F)
      SIN  1 0.0803847 0.0803847  6.30888 0.01528828
      COS  1 0.1836119 0.1836119 14.41053 0.00039846
     LOGQ  1 0.1218415 0.1218415  9.56256 0.00324482
Residuals 50 0.6370753 0.0127415

  Variance inflation factors
      SIN      COS     LOGQ
 1.144573 1.013607 1.135441

             model.formula nvars    stderr    adjr2        Cp     press
 LOGTN ~ SIN + COS + LOGQ     3 0.1128783 33.98270  4.000000 0.7442692

 Test criteria
 leverage cooksD dfits
    0.222  0.882 0.544
      Observations exceeding at least one test criterion
      LOGTN  yhat resids stnd.res stud.res leverage cooksD  dfits
14  0.30535 0.459 -0.154    -1.54    -1.56   0.2215 0.1692 -0.834
17  0.49554 0.268  0.227     2.09     2.16   0.0685 0.0802  0.587
28  0.16435 0.345 -0.181    -1.69    -1.73   0.1090 0.0878 -0.604
36 -0.00436 0.225 -0.229    -2.15    -2.23   0.1076 0.1393 -0.776
53  0.46982 0.231  0.239     2.18     2.27   0.0610 0.0774  0.579
```

Figure 38. S+® output of regression model development using season (SIN and COS) and streamflow (Q) as explanatory variables for total nitrogen (TN) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

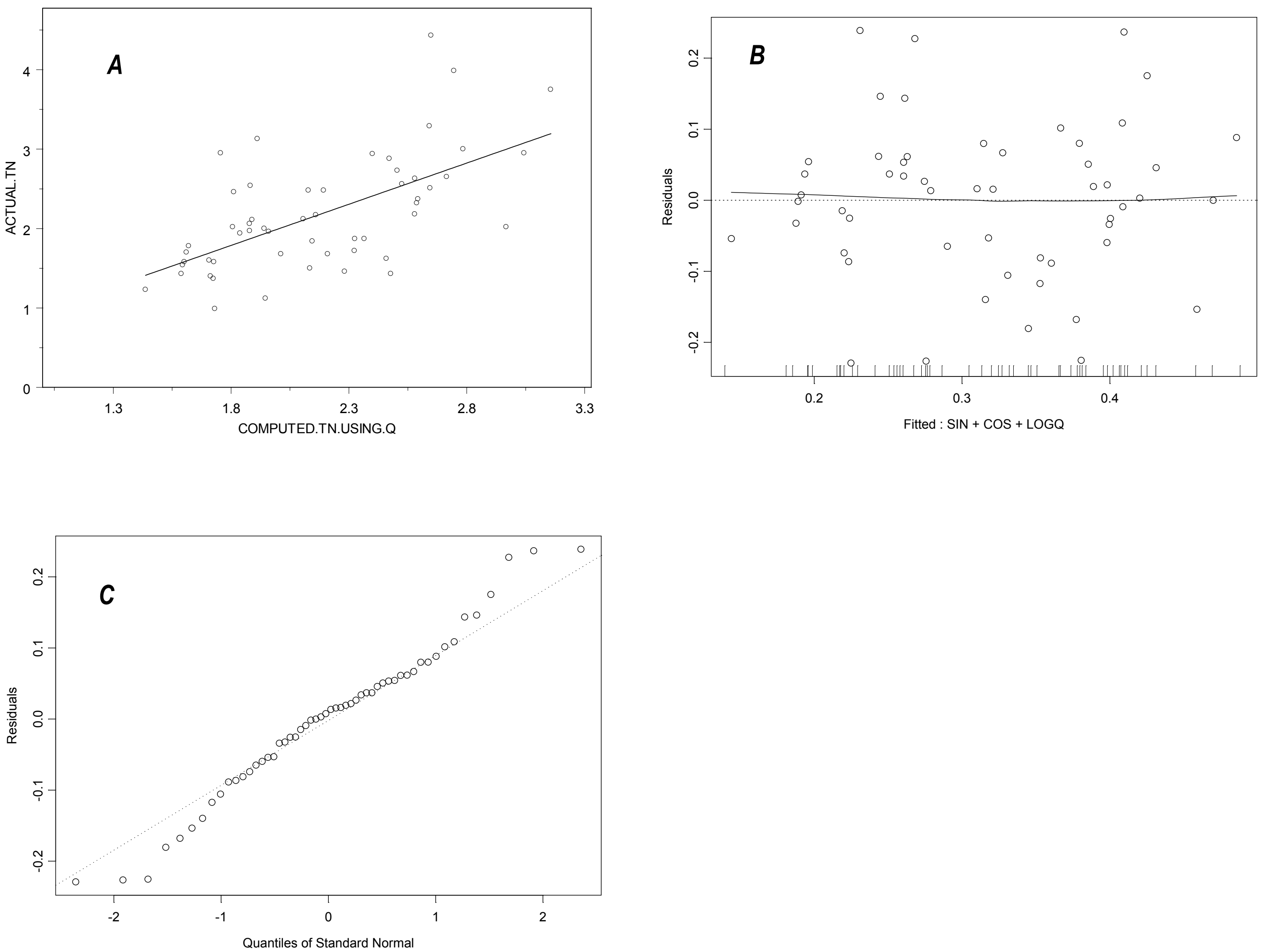

Figure 39. S+® output graphs from simple linear regression analysis using season (SIN and COS) and streamflow (Q) as explanatory variables for total nitrogen (TN) concentrations showing *A*, computed versus actual TN concentrations; *B*, computed log-transformed TN concentrations versus regression residuals; and *C*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
      *** Linear Model ***

Call: lm(formula = LOGTKN ~ LOGTBY, data = TKN, na.action = na.exclude)
Residuals:
     Min       1Q    Median      3Q    Max
 -0.1799 -0.05763 -0.009309 0.04722 0.2251

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  -0.6997   0.0562   -12.4495   0.0000
     LOGTBY   0.4259   0.0275    15.4685   0.0000

Residual standard error: 0.08875 on 48 degrees of freedom
Multiple R-Squared: 0.8329      Adjusted R-squared: 0.8294
F-statistic: 239.3 on 1 and 48 degrees of freedom, the p-value is 0

Correlation of Coefficients:
       (Intercept)
LOGTBY -0.9747

Analysis of Variance Table

Response: LOGTKN

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value Pr(F)
   LOGTBY  1  1.884674 1.884674 239.2752     0
Residuals 48  0.378077 0.007877

         model.formula nvars    stderr    adjr2      Cp     press
      LOGTKN ~ LOGTBY     1 0.0887502 82.94318 1.01267 0.4118841

Test criteria
 leverage cooksD dfits
     0.12    0.8   0.4
       Observations exceeding at least one test criterion
   LOGTKN   yhat resids stnd.res stud.res leverage cooksD  dfits
 1 -0.319 -0.139 -0.180    -2.09    -2.17   0.0636 0.1490 -0.567
 8 -0.301 -0.165 -0.136    -1.59    -1.62   0.0719 0.0979 -0.450
14  0.146  0.321 -0.175    -2.01    -2.08   0.0360 0.0757 -0.402
```

Figure 40. S+® output of regression model development using turbidity (TBY) as an explanatory variable for total Kjeldahl nitrogen (TKN) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

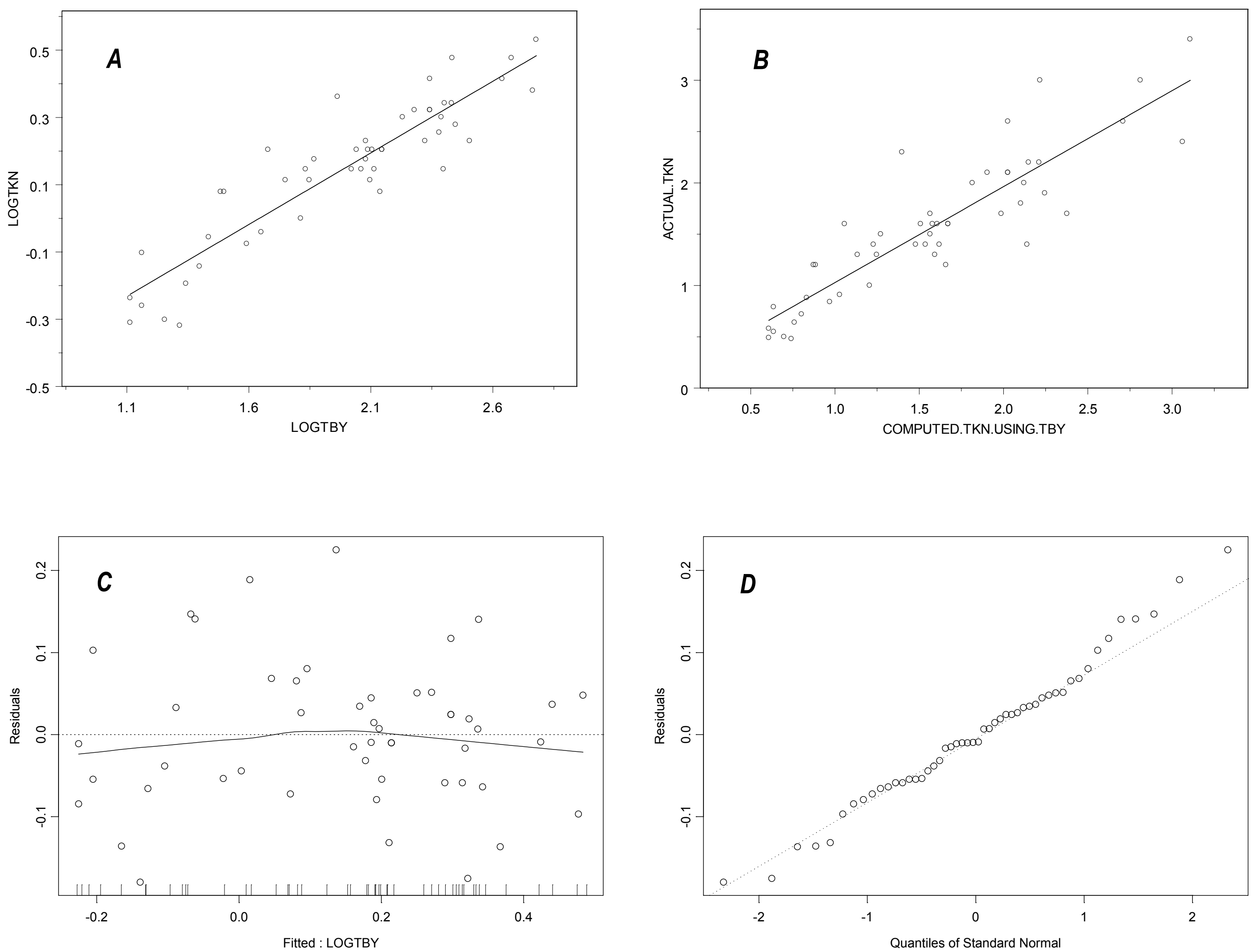

Figure 41. S+® output graphs from simple linear regression analysis showing *A*, log-transformed turbidity (TBY) versus log-transformed total Kjeldahl nitrogen (TKN) concentrations; *B*, computed versus actual TKN concentrations; *C*, computed log-transformed TKN concentrations versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = ON ~ LOGTBY + LOGSC, data = ON, na.action = na.exclude)
Residuals:
     Min      1Q  Median     3Q    Max
 -0.6905 -0.2012 -0.0441 0.1487 0.7088

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  -4.6450   1.0758    -4.3177   0.0001
     LOGTBY   1.5834   0.1293    12.2472   0.0000
      LOGSC   1.0406   0.3024     3.4416   0.0012

Residual standard error: 0.295 on 51 degrees of freedom
Multiple R-Squared: 0.8204      Adjusted R-squared: 0.8134
F-statistic: 116.5 on 2 and 51 degrees of freedom, the p-value is 0

Correlation of Coefficients:
       (Intercept)  LOGTBY
LOGTBY -0.8498
 LOGSC -0.9881      0.7623

Analysis of Variance Table

Response: ON

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value       Pr(F)
   LOGTBY  1  19.24951 19.24951 221.1226 0.000000000
    LOGSC  1   1.03110  1.03110  11.8444 0.001162786
Residuals 51   4.43973  0.08705

Variance inflation factors
   LOGTBY    LOGSC
 2.387615 2.387615

        model.formula nvars    stderr    adjr2      Cp    press
 ON ~ LOGTBY + LOGSC     2 0.2950484 81.33586  3.0000 5.038485

Test criteria
 leverage cooksD dfits
    0.167   0.85 0.471
       Observations exceeding at least one test criterion
     ON yhat resids stnd.res stud.res leverage cooksD  dfits
 4 1.16 1.85 -0.690    -2.40    -2.53   0.0527 0.1071 -0.596
10 2.87 2.25  0.618     2.19     2.27   0.0830 0.1442  0.684
18 3.26 2.70  0.560     2.03     2.10   0.1293 0.2049  0.810
43 1.95 1.49  0.461     1.66     1.69   0.1137 0.1180  0.606
47 2.28 1.58  0.709     2.44     2.57   0.0325 0.0668  0.472
```

Figure 42. S+® output of regression model development using turbidity (TBY) and specific conductance (SC) as explanatory variables for organic nitrogen (ON) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

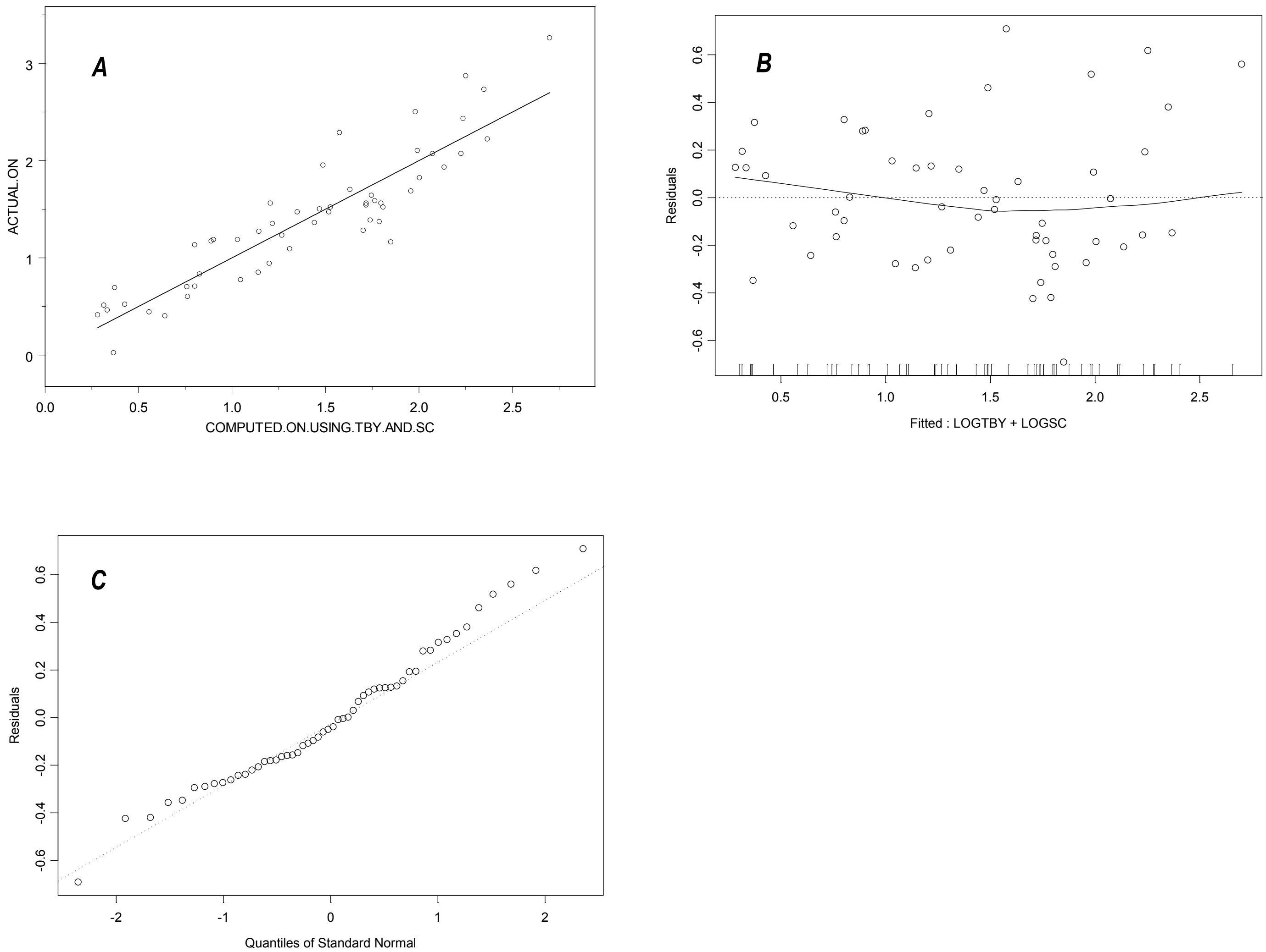

Figure 43. S+® output graphs from simple linear regression analysis using turbidity (TBY) and specific conductance (SC) as explanatory variables for organic nitrogen (ON) concentrations showing *A*, computed versus actual ON concentrations; *B*, computed ON concentrations versus regression residuals; and *C*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
      *** Linear Model ***

Call: lm(formula = NO3 ~ SIN + COS + LOGTBY, data = NO3, na.action = na.exclude)
Residuals:
     Min      1Q   Median     3Q    Max
 -0.5598 -0.2033 -0.02083 0.1656 0.7258

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)   1.6308   0.1618    10.0789   0.0000
        SIN   0.0519   0.0557     0.9304   0.3561
        COS   0.6194   0.0753     8.2222   0.0000
     LOGTBY  -0.3892   0.0853    -4.5632   0.0000

Residual standard error: 0.3088 on 57 degrees of freedom
Multiple R-Squared: 0.6277      Adjusted R-squared: 0.6081
F-statistic: 32.04 on 3 and 57 degrees of freedom, the p-value is 2.877e-012

Correlation of Coefficients:
       (Intercept)     SIN     COS
   SIN  0.2178
   COS  0.0921     -0.1429
LOGTBY -0.9523     -0.2992  0.0876

Analysis of Variance Table

Response: NO3

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
      SIN  1  0.035685 0.035685  0.37418 0.5431685
      COS  1  7.144058 7.144058 74.90901 0.0000000
   LOGTBY  1  1.985835 1.985835 20.82247 0.0000273
Residuals 57  5.436079 0.095370

Variance inflation factors
      SIN      COS LOGTBY
 1.115139 1.023158 1.1008

             model.formula nvars    stderr    adjr2        Cp     press
 NO3 ~ SIN + COS + LOGTBY     3 0.3088200 60.81138  4.000000  6.441167

Test criteria
 leverage cooksD dfits
    0.197  0.881 0.512
       Observations exceeding at least one test criterion
    NO3  yhat resids stnd.res stud.res leverage cooksD  dfits
 1 2.17 1.699  0.471     1.63     1.66   0.1295 0.0993  0.640
11 1.69 0.964  0.726     2.43     2.55   0.0663 0.1050  0.679
12 2.38 1.661  0.719     2.51     2.64   0.1393 0.2545  1.060
20 0.32 0.880 -0.560    -1.98    -2.03   0.1588 0.1843 -0.882
42 0.50 1.043 -0.543    -1.83    -1.87   0.0795 0.0724 -0.550
60 0.83 0.272  0.558     1.88     1.92   0.0734 0.0696  0.540
```

Figure 44. S+® output of regression model development using season (SIN and COS) and turbidity (TBY) as explanatory variables for nitrate (NO3) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

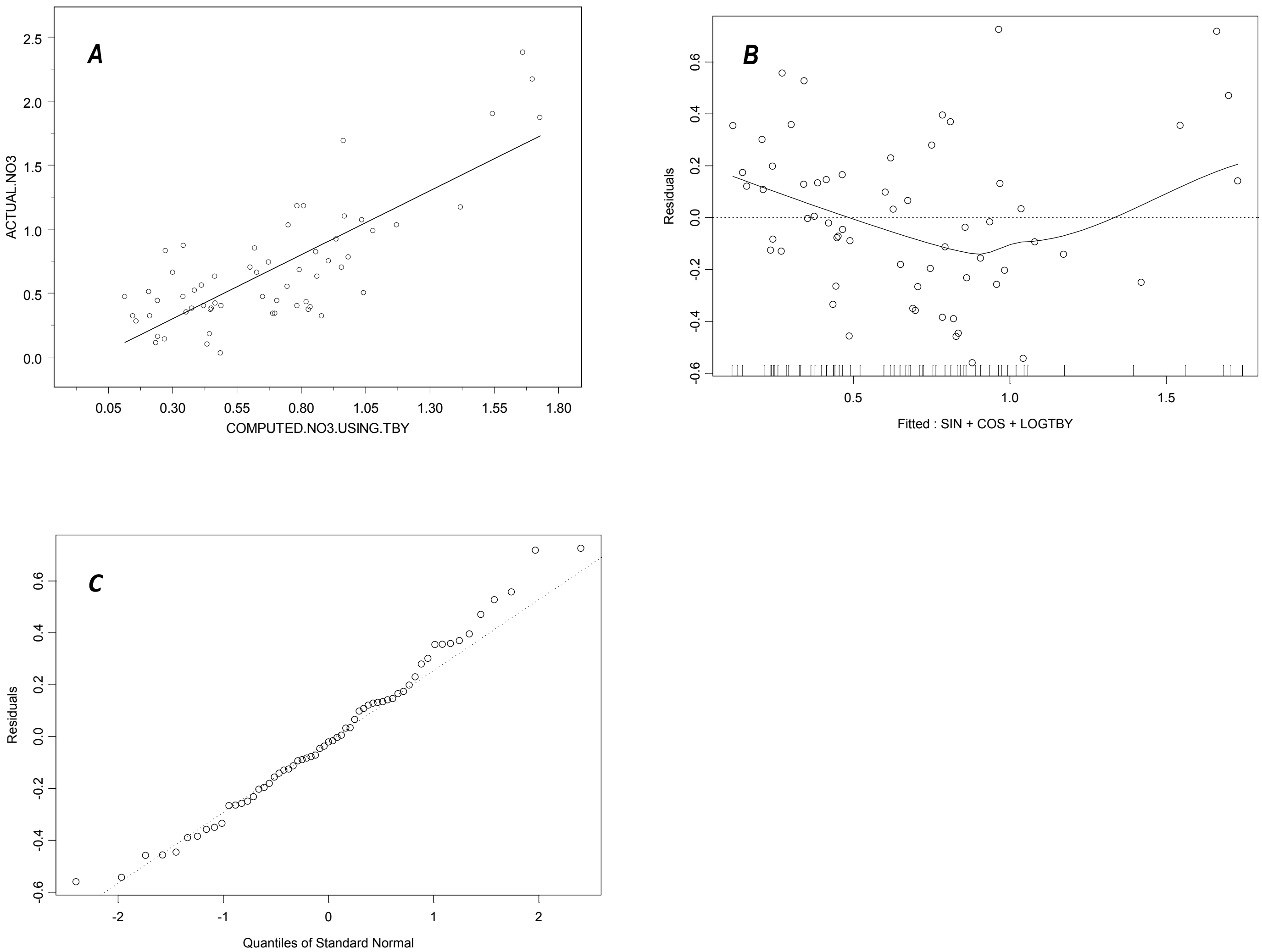

Figure 45. S+® output graphs from simple linear regression analysis using season (SIN and COS) and turbidity (TBY) as explanatory variables for nitrate (NO3) concentrations showing *A*, computed versus actual NO3 concentrations; *B*, computed NO3 concentrations versus regression residuals; and *C*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = NO3 ~ SIN + COS + LOGQ, data = NO3, na.action = na.exclude)
Residuals:
     Min      1Q    Median     3Q   Max
 -0.5831 -0.2364 -0.004877 0.1657 0.798

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  1.5501  0.1676     9.2518  0.0000
        SIN  0.0903  0.0625     1.4444  0.1541
        COS  0.6524  0.0779     8.3741  0.0000
       LOGQ -0.2782  0.0713    -3.9020  0.0003

Residual standard error: 0.3206 on 57 degrees of freedom
Multiple R-Squared: 0.5989      Adjusted R-squared: 0.5777
F-statistic: 28.36 on 3 and 57 degrees of freedom, the p-value is 2.361e-011

Correlation of Coefficients:
     (Intercept)     SIN     COS
 SIN  0.3848
 COS  0.1855     -0.1040
LOGQ -0.9520     -0.4695 -0.0094

Analysis of Variance Table

Response: NO3

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
      SIN  1  0.035685 0.035685  0.34727 0.5579937
      COS  1  7.144058 7.144058 69.52146 0.0000000
     LOGQ  1  1.564567 1.564567 15.22538 0.0002545
Residuals 57  5.857348 0.102760

Variance inflation factors
      SIN      COS     LOGQ
 1.302438 1.015401 1.288456

           model.formula nvars    stderr     adjr2        Cp     press
 NO3 ~ SIN + COS + LOGQ     3 0.3205628 57.774461  4.000000  6.944896

Test criteria
 leverage cooksD dfits
    0.197  0.881 0.512
       Observations exceeding at least one test criterion
    NO3  yhat resids stnd.res stud.res leverage cooksD  dfits
 1 2.17 1.614  0.556     1.85     1.89   0.1180 0.1139  0.690
11 1.69 0.893  0.797     2.57     2.71   0.0612 0.1073  0.690
12 2.38 1.582  0.798     2.67     2.83   0.1310 0.2689  1.099
20 0.32 0.801 -0.481    -1.69    -1.72   0.2154 0.1967 -0.902
36 1.90 1.407  0.493     1.61     1.64   0.0894 0.0638  0.513
40 0.03 0.613 -0.583    -1.89    -1.94   0.0774 0.0753 -0.562
```

Figure 46. S+® output of regression model development using season (SIN and COS) and streamflow (Q) as explanatory variables for nitrate (NO3) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

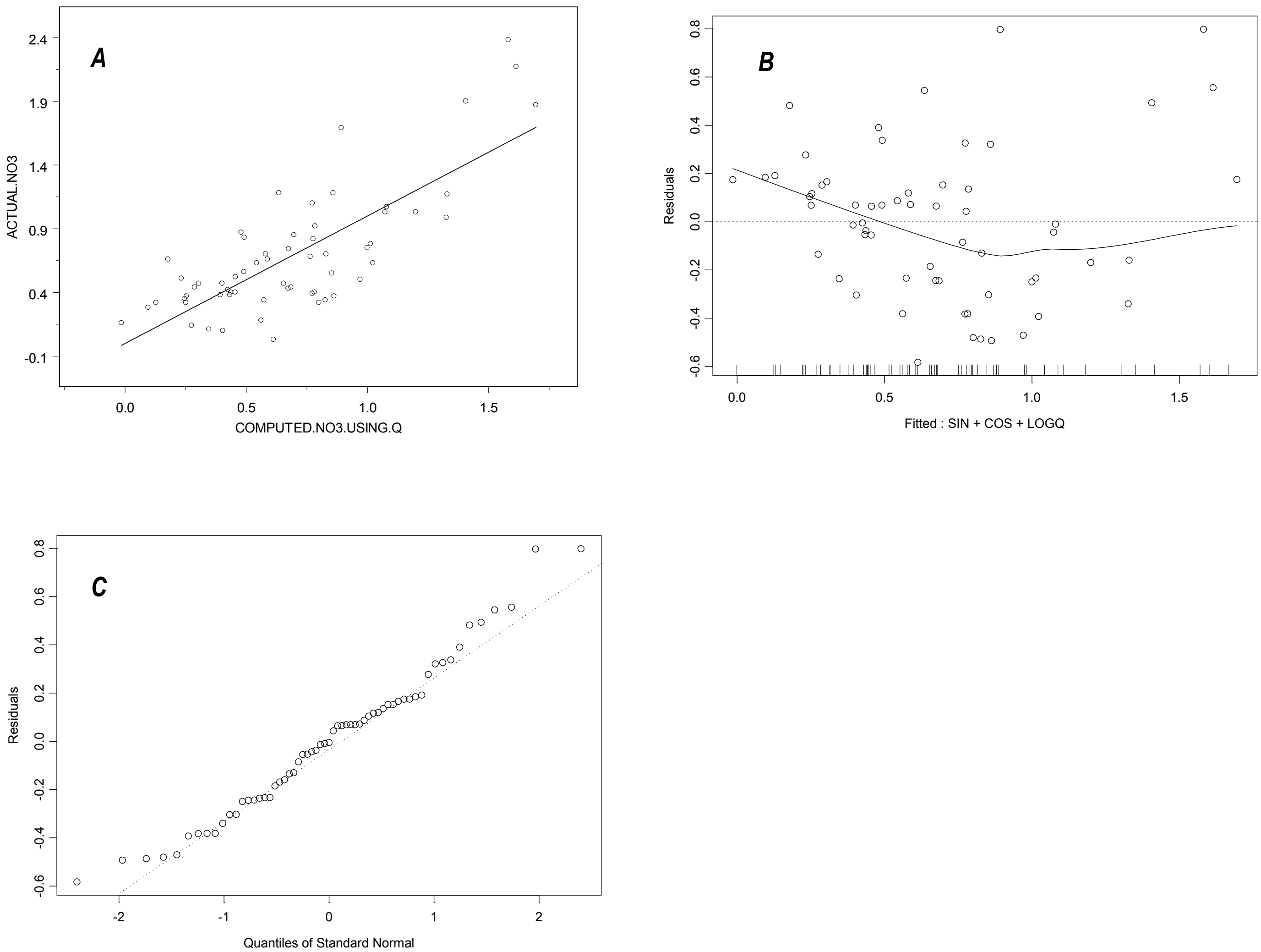

Figure 47. S+® output graphs from simple linear regression analysis using season (SIN and COS) and streamflow (Q) as explanatory variables for nitrate (NO3) concentrations showing *A*, computed versus actual NO3 concentrations; *B*, computed NO3 concentrations versus regression residuals; and *C*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = LOGTP ~ LOGTBY, data = TP, na.action = na.exclude)
Residuals:
    Min       1Q   Median      3Q    Max
 -0.281 -0.09675 -0.01903 0.08665 0.3666

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  -1.8294   0.0757   -24.1638   0.0000
     LOGTBY   0.6106   0.0385    15.8472   0.0000

Residual standard error: 0.1375 on 53 degrees of freedom
Multiple R-Squared: 0.8257      Adjusted R-squared: 0.8224
F-statistic: 251.1 on 1 and 53 degrees of freedom, the p-value is 0

Correlation of Coefficients:
       (Intercept)
LOGTBY -0.9696

Analysis of Variance Table

Response: LOGTP

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq F Value Pr(F)
   LOGTBY  1  4.747262 4.747262 251.133     0
Residuals 53  1.001879 0.018903

        model.formula nvars    stderr    adjr2       Cp      press
      LOGTP ~ LOGTBY     1 0.1374896 82.24461 1.397491   1.077901

Test criteria
 leverage cooksD dfits
    0.109  0.799 0.381
       Observations exceeding at least one test criterion
    LOGTP   yhat resids stnd.res stud.res leverage cooksD  dfits
22 -0.347 -0.133 -0.214    -1.62    -1.65   0.0781 0.1110 -0.479
31 -1.420 -1.139 -0.281    -2.11    -2.19   0.0653 0.1562 -0.578
44 -0.344 -0.710  0.367     2.69     2.87   0.0186 0.0686  0.395
```

Figure 48. S+® output of regression model development using turbidity (TBY) as an explanatory variable for total phosphorus (TP) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

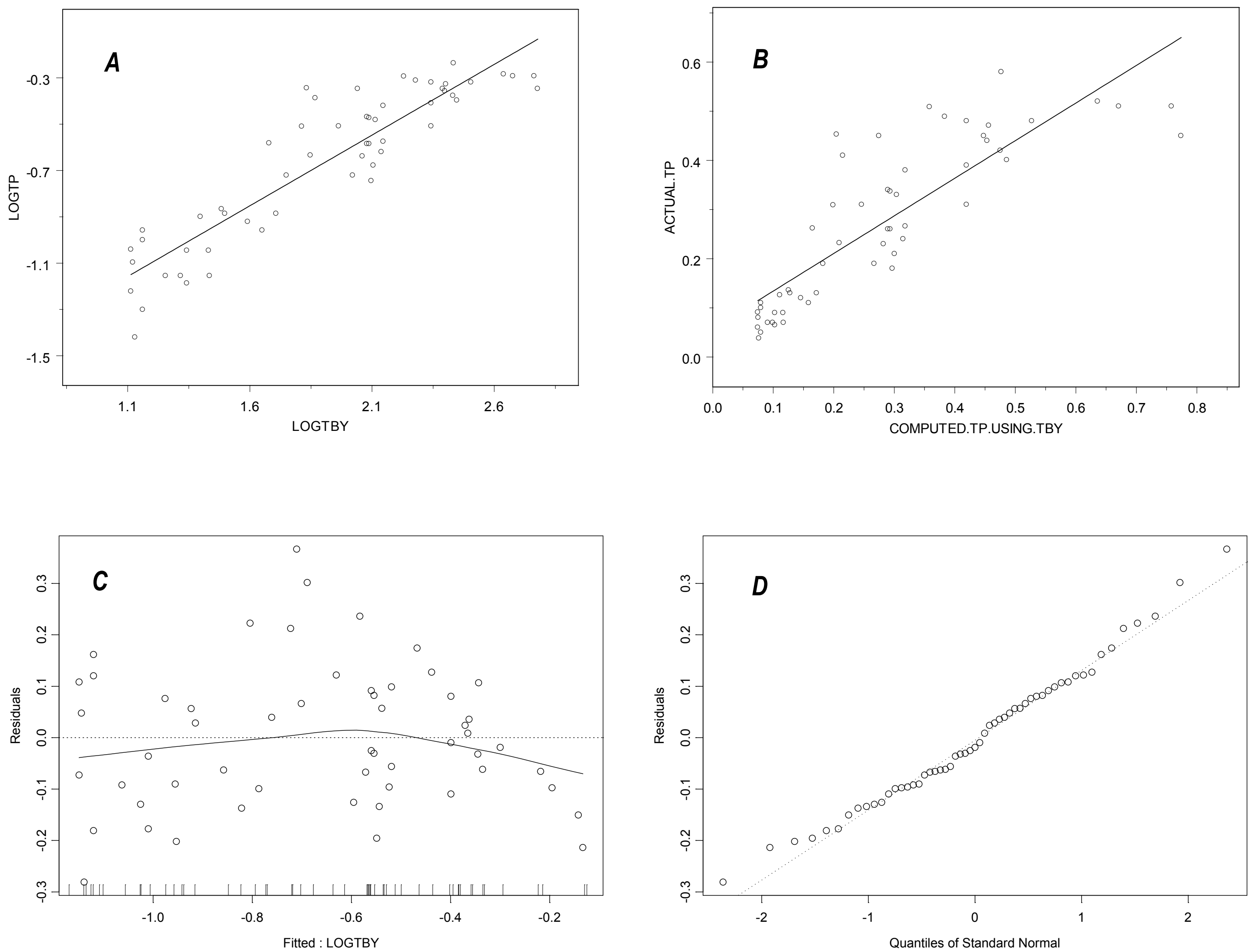

Figure 49. S+® output graphs from simple linear regression analysis showing *A*, log-transformed turbidity (TBY) versus log-transformed total phosphorus (TP) concentrations; *B*, computed versus actual TP concentrations; *C*, computed log-transformed TP concentrations versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = TP ~ LOGQ, data = TP, na.action = na.exclude)
Residuals:
     Min       1Q    Median      3Q   Max
 -0.3131 -0.06473 -0.003157 0.06227 0.295

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -0.1744  0.0552    -3.1612  0.0026
       LOGQ  0.1908  0.0227     8.3927  0.0000

Residual standard error: 0.1073 on 53 degrees of freedom
Multiple R-Squared: 0.5706      Adjusted R-squared: 0.5625
F-statistic: 70.44 on 1 and 53 degrees of freedom, the p-value is 2.653e-011

Correlation of Coefficients:
     (Intercept)
LOGQ -0.965

Analysis of Variance Table

Response: TP

Terms added sequentially (first to last)
          Df Sum of Sq   Mean Sq  F Value         Pr(F)
     LOGQ  1 0.8107083 0.8107083 70.43751 2.653244e-011
Residuals 53 0.6100093 0.0115096

   model.formula nvars    stderr    adjr2       Cp      press
      TP ~ LOGQ     1 0.1072829 56.25317 1.293694   0.654852

Test criteria
 leverage cooksD dfits
    0.109  0.799 0.381
       Observations exceeding at least one test criterion
     TP  yhat resids stnd.res stud.res leverage cooksD  dfits
12 0.58 0.285  0.295     2.78     2.97   0.0184 0.0721  0.407
29 0.18 0.493 -0.313    -3.04    -3.31   0.0782 0.3919 -0.965
```

Figure 50. S+® output of regression model development using streamflow (Q) as an explanatory variable for total phosphorus (TP) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

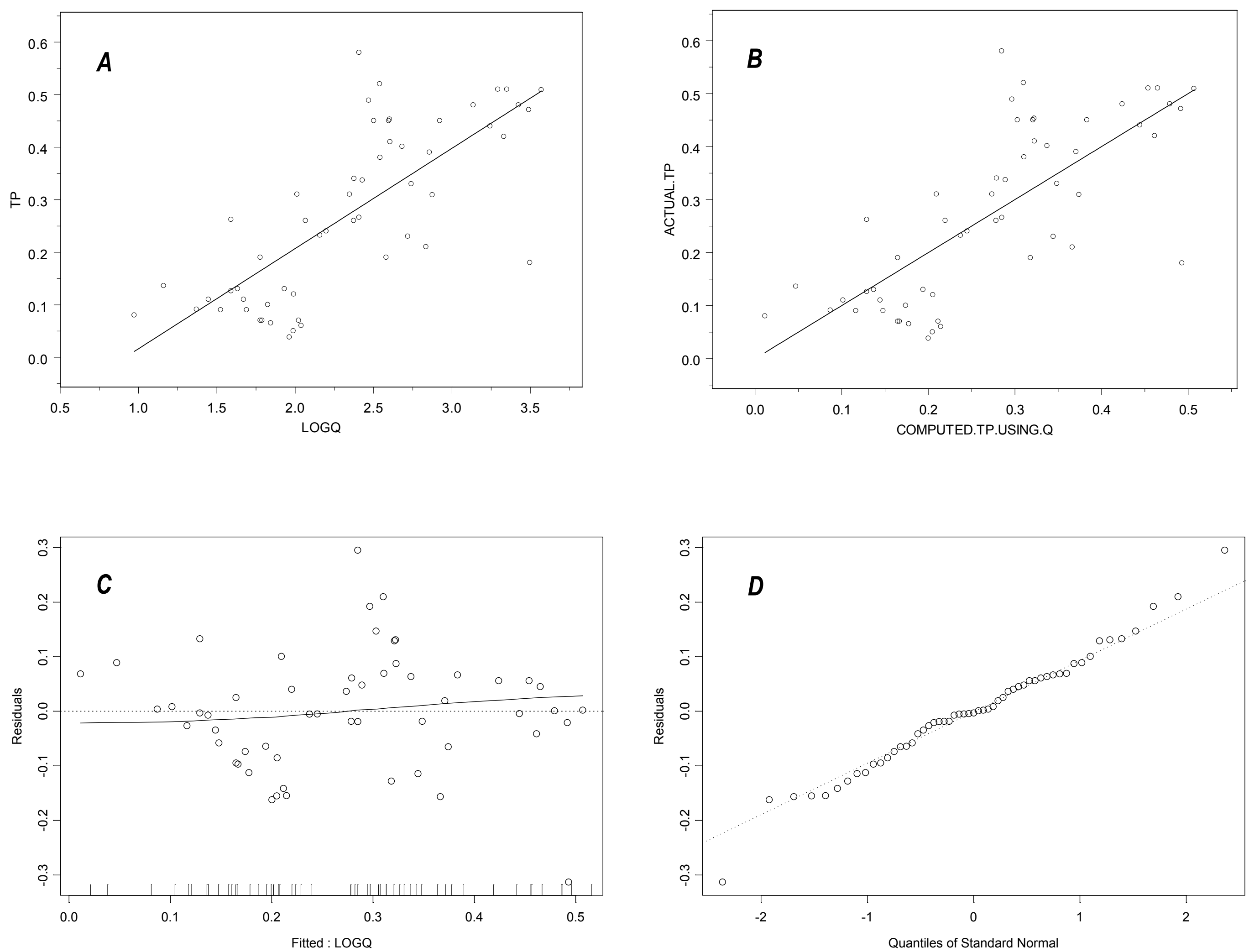

Figure 51. S+® output graphs from simple linear regression analysis showing *A*, log-transformed streamflow (Q) versus total phosphorus (TP) concentrations; *B*, computed versus actual TP concentrations; *C*, computed TP concentrations versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = OP ~ SC, data = OP, na.action = na.exclude)
Residuals:
      Min       1Q    Median      3Q   Max
 -0.09096 -0.01705 0.0003533 0.01675 0.132

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)   0.2243   0.0143    15.6578   0.0000
         SC  -0.0002   0.0000   -12.0588   0.0000

Residual standard error: 0.0339 on 52 degrees of freedom
Multiple R-Squared: 0.7366      Adjusted R-squared: 0.7315
F-statistic: 145.4 on 1 and 52 degrees of freedom, the p-value is 1.11e-016

Correlation of Coefficients:
   (Intercept)
SC -0.9467

Analysis of Variance Table

Response: OP

Terms added sequentially (first to last)
          Df Sum of Sq   Mean Sq  F Value         Pr(F)
       SC  1 0.1670741 0.1670741 145.4137 1.110223e-016
Residuals 52 0.0597458 0.0011490

    model.formula nvars     stderr    adjr2       Cp      press
         OP ~ SC     1 0.03389627 73.15283 1.369267 0.06430480

Test criteria
 leverage cooksD dfits
    0.111  0.799 0.385
       Observations exceeding at least one test criterion
     OP  yhat  resids stnd.res stud.res leverage cooksD  dfits
28 0.04 0.131 -0.0910    -2.75    -2.95   0.0480 0.1908 -0.662
42 0.21 0.167  0.0428     1.32     1.33   0.0864 0.0824  0.409
43 0.23 0.098  0.1320     3.95     4.67   0.0268 0.2147  0.776
49 0.19 0.118  0.0719     2.16     2.25   0.0382 0.0929  0.448
```

Figure 52. S+® output of regression model development using specific conductance (SC) as an explanatory variable for orthophosphate (OP) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

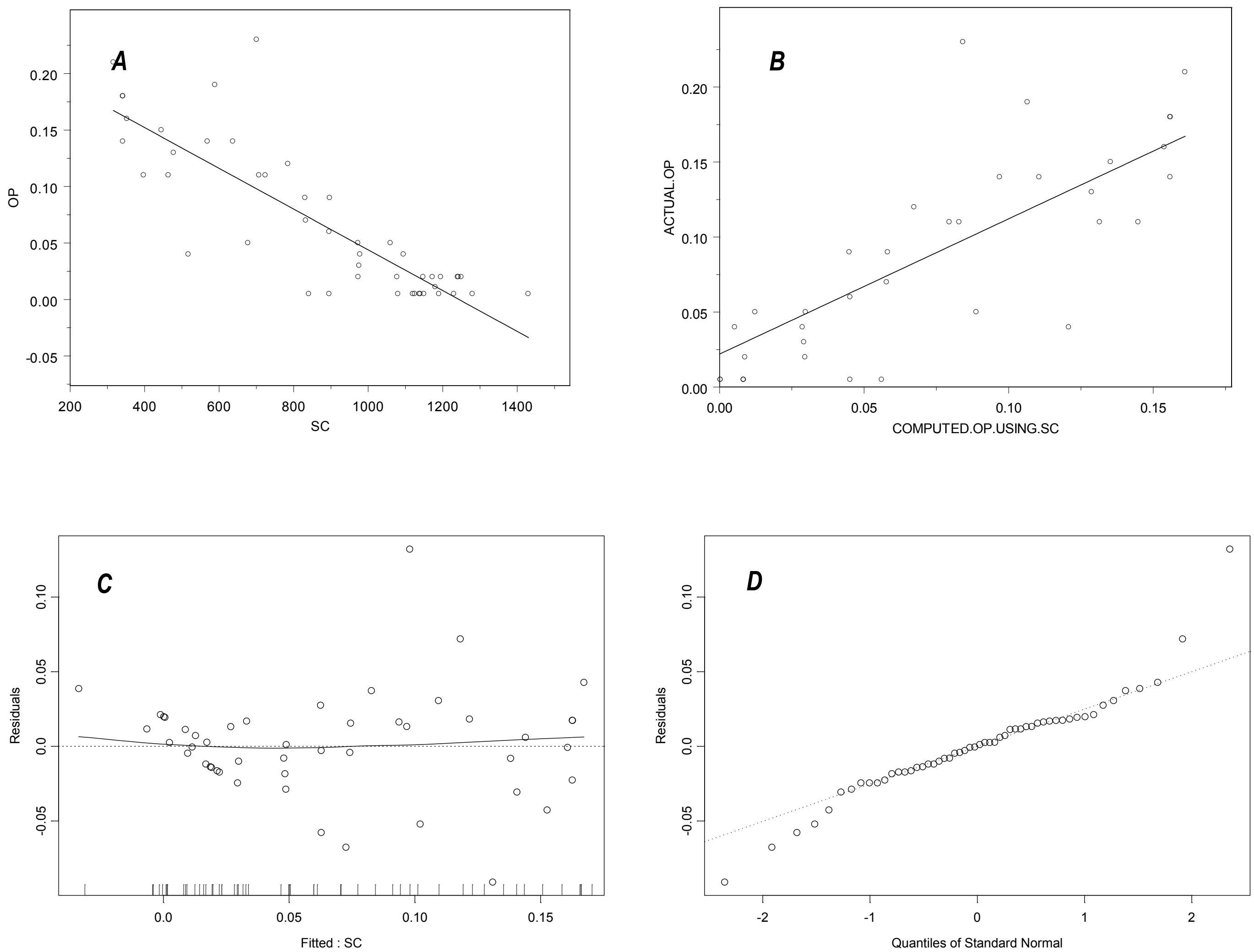

Figure 53. S+® output graphs from simple linear regression analysis showing *A*, specific conductance (SC) versus orthophosphate (OP) concentrations; *B*, computed versus actual OP concentrations; *C*, computed OP concentrations versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = LOGFC ~ LOGTBY + SC, data = FC, na.action = na.exclude)
Residuals:
    Min      1Q Median    3Q   Max
 -1.289 -0.2806 0.0566 0.296 1.202

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  2.7269  0.6447     4.2300  0.0001
     LOGTBY  0.7608  0.2162     3.5193  0.0009
         SC -0.0013  0.0003    -4.2657  0.0001

Residual standard error: 0.4865 on 57 degrees of freedom
Multiple R-Squared: 0.7167      Adjusted R-squared: 0.7067
F-statistic: 72.09 on 2 and 57 degrees of freedom, the p-value is 2.22e-016

Correlation of Coefficients:
       (Intercept)  LOGTBY
LOGTBY -0.9637
    SC -0.9135      0.7896

Analysis of Variance Table

Response: LOGFC

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value         Pr(F)
   LOGTBY  1  29.82038 29.82038 125.9757 0.00000000000
       SC  1   4.30732  4.30732  18.1962 0.00007592688
Residuals 57  13.49277  0.23672

Variance inflation factors
   LOGTBY       SC
 2.655678 2.655678

        model.formula nvars    stderr    adjr2       Cp    press
 LOGFC ~ LOGTBY + SC     2 0.4865339 70.67186  3.00000 14.91702

Test criteria
 leverage cooksD dfits
     0.15  0.849 0.447
       Observations exceeding at least one test criterion
   LOGFC yhat resids stnd.res stud.res leverage cooksD  dfits
 1 0.903 2.15  -1.25    -2.62    -2.77   0.0438 0.1048 -0.593
32 2.908 4.20  -1.29    -2.76    -2.94   0.0770 0.2115 -0.848
36 1.279 2.45  -1.18    -2.46    -2.58   0.0368 0.0771 -0.504
```

Figure 54. S+® output of regression model development using turbidity (TBY) and specific conductance (SC) as explanatory variables for fecal coliform bacteria (FC) densities for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

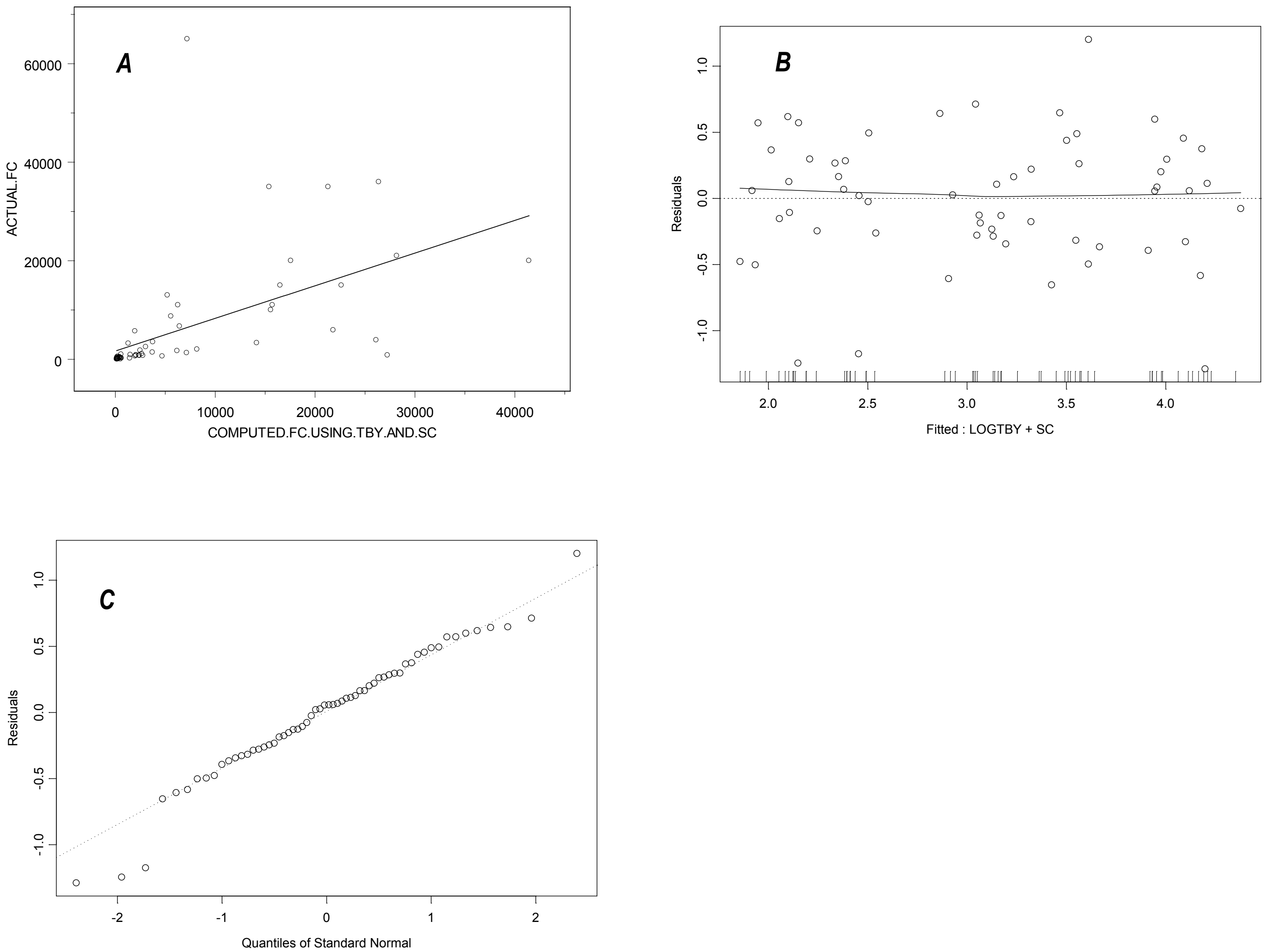

Figure 55. S+® output graphs from simple linear regression analysis using turbidity (TBY) and specific conductance (SC) as explanatory variables for fecal coliform (FC) densities showing *A,* computed versus actual FC densities; *B*, computed log-transformed FC densities versus regression residuals; and *C*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = LOGEC ~ TBY + SC, data = EC, na.action = na.exclude)
Residuals:
     Min      1Q  Median     3Q    Max
 -0.7392 -0.1274 0.04522 0.2341 0.3727

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)   4.0075   0.3063    13.0839   0.0000
        TBY   0.0032   0.0010     3.2199   0.0045
         SC  -0.0016   0.0003    -6.3227   0.0000

Residual standard error: 0.3106 on 19 degrees of freedom
Multiple R-Squared: 0.8681      Adjusted R-squared: 0.8542
F-statistic: 62.54 on 2 and 19 degrees of freedom, the p-value is 4.381e-009

Correlation of Coefficients:
    (Intercept)     TBY
TBY -0.8336
 SC -0.9187      0.6271

Analysis of Variance Table

Response: LOGEC

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value         Pr(F)
      TBY  1  8.207095 8.207095 85.09731 1.899300e-008
       SC  1  3.855518 3.855518 39.97690 4.556139e-006
Residuals 19  1.832429 0.096444

Variance inflation factors
    TBY     SC
 1.6483 1.6483

     model.formula nvars    stderr    adjr2       Cp   press
 LOGEC ~ TBY + SC     2 0.3105538 85.42418  3.00000 2.65851

Test criteria
 leverage cooksD dfits
    0.409   0.87 0.739
       Observations exceeding at least one test criterion
   LOGEC yhat resids stnd.res stud.res leverage cooksD dfits
 4   1.23 1.81 -0.580    -2.10    -2.33    0.205  0.377 -1.18
11   3.83 4.17 -0.346    -1.28    -1.30    0.244  0.176 -0.74
22   3.43 4.17 -0.739    -2.64    -3.23    0.186  0.532 -1.54
```

Figure 56. S+® output of regression model development using turbidity (TBY) and specific conductance (SC) as explanatory variables for *Escherichia coli* bacteria (EC) densities for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

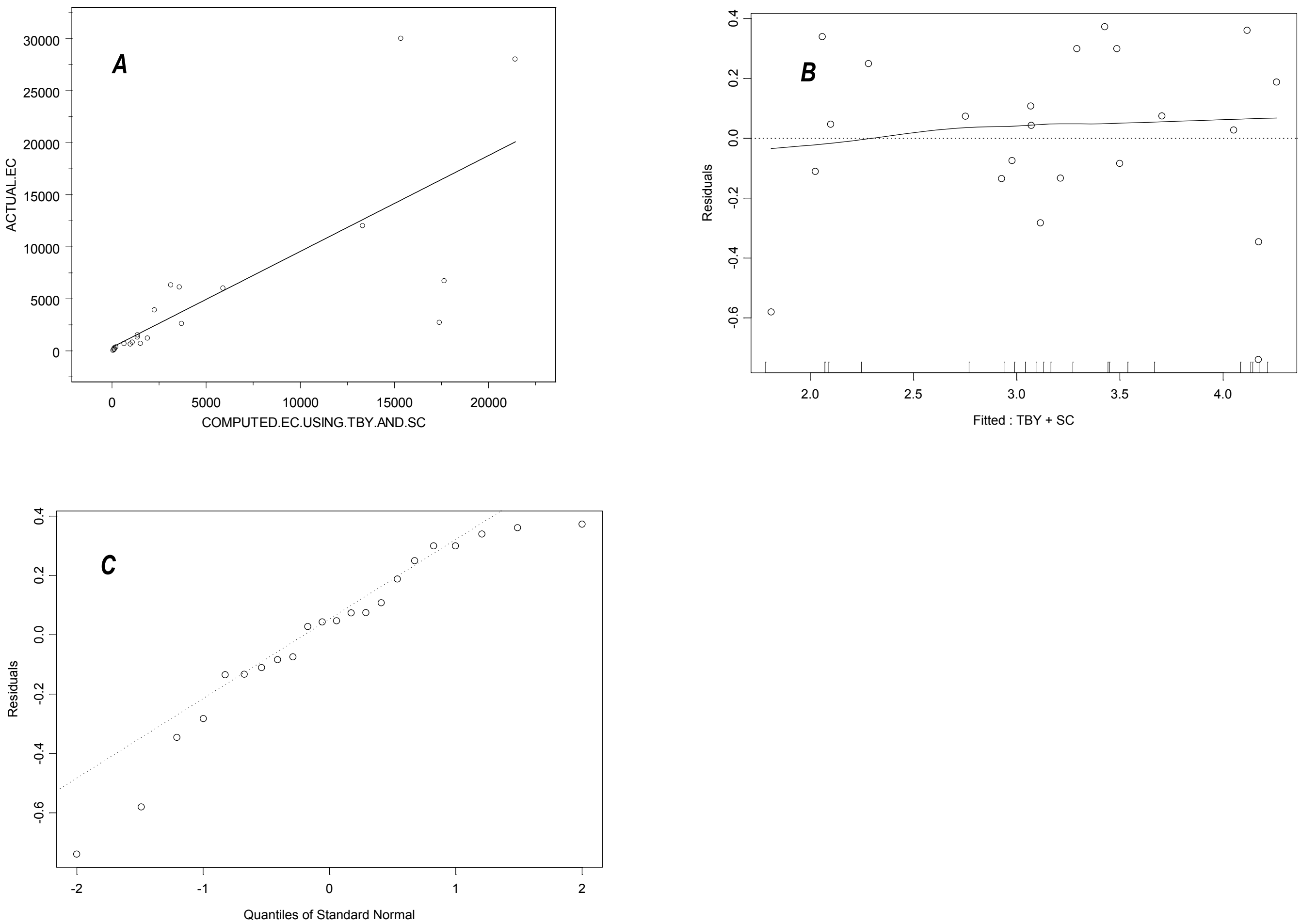

Figure 57. S+® output graphs from simple linear regression analysis using turbidity (TBY) and specific conductance (SC) as explanatory variables for *Escherichia coli* bacteria (EC) densities showing *A*, computed versus actual EC densities; *B*, computed log-transformed EC densities versus regression residuals; and *C*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
      *** Linear Model ***

Call: lm(formula = LOGEC ~ LOGQ, data = EC, na.action = na.exclude)
Residuals:
    Min      1Q  Median     3Q    Max
 -1.222 -0.2419 0.05747 0.2634 0.7469

Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) 0.6500 0.3572     1.8194  0.0839
       LOGQ 0.9769 0.1341     7.2838  0.0000

Residual standard error: 0.4361 on 20 degrees of freedom
Multiple R-Squared: 0.7262      Adjusted R-squared: 0.7125
F-statistic: 53.05 on 1 and 20 degrees of freedom, the p-value is 4.811e-007

Correlation of Coefficients:
     (Intercept)
LOGQ -0.9655

Analysis of Variance Table

Response: LOGEC

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value        Pr(F)
     LOGQ  1  10.09095 10.09095 53.05305 4.81067e-007
Residuals 20   3.80410  0.19020

      model.formula nvars    stderr    adjr2       Cp    press
      LOGEC ~ LOGQ      1 0.4361248 71.25377 7.886898 4.898533

Test criteria
 leverage cooksD dfits
    0.273  0.816 0.603
       Observations exceeding at least one test criterion
  LOGEC yhat resids stnd.res stud.res leverage cooksD dfits
1  2.53 1.78  0.747     1.96     2.12   0.2336  0.583  1.17
4  1.23 2.45 -1.222    -2.95    -3.82   0.0954  0.458 -1.24
```

Figure 58. S+® output of regression model development using streamflow (Q) as an explanatory variable for *Escherichia coli* bacteria (EC) densities for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

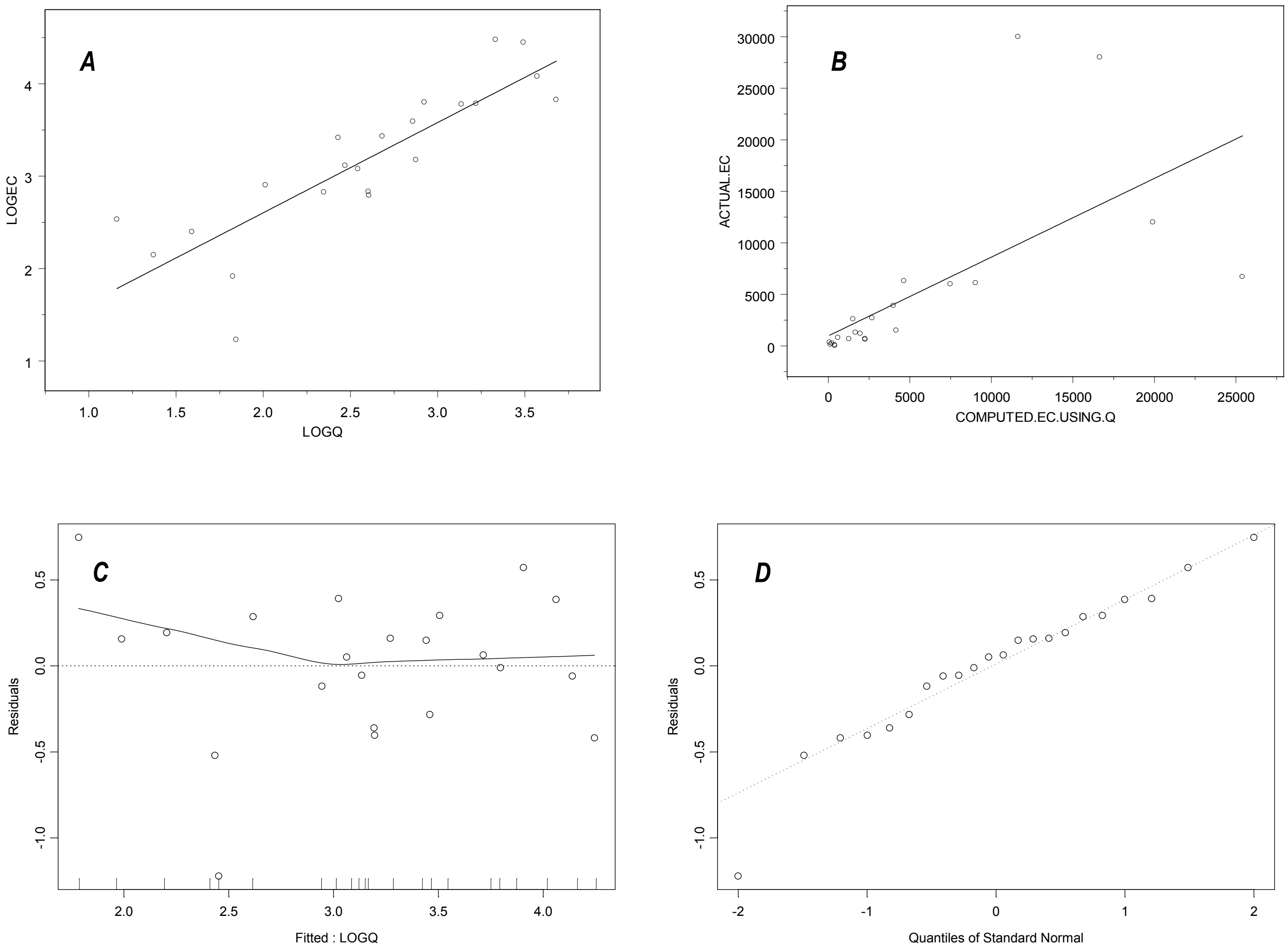

Figure 59. S+® output graphs from simple linear regression analysis showing *A*, log-transformed streamflow (Q) versus log-transformed *Escherichia coli* bacteria (EC) densities; *B*, computed versus actual EC densities; *C*, computed log-transformed EC densities versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

```
       *** Linear Model ***

Call: lm(formula = LOGTOC ~ LOGTBY, data = TOC, na.action = na.exclude)
Residuals:
     Min       1Q  Median      3Q    Max
 -0.3964 -0.03895 0.01692 0.09365 0.2074

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  0.0080  0.0931     0.0856  0.9322
     LOGTBY  0.4848  0.0451    10.7565  0.0000

Residual standard error: 0.1353 on 43 degrees of freedom
Multiple R-Squared: 0.7291      Adjusted R-squared: 0.7228
F-statistic: 115.7 on 1 and 43 degrees of freedom, the p-value is 9.015e-014

Correlation of Coefficients:
       (Intercept)
LOGTBY -0.9763

Analysis of Variance Table

Response: LOGTOC

Terms added sequentially (first to last)
          Df Sum of Sq  Mean Sq  F Value         Pr(F)
   LOGTBY  1  2.116599 2.116599 115.7032 9.015011e-014
Residuals 43  0.786614 0.018293

         model.formula nvars    stderr    adjr2       Cp      press
      LOGTOC ~ LOGTBY     1 0.1352529 72.27529 1.375876  0.8628375

Test criteria
 leverage cooksD dfits
    0.133  0.801 0.422
       Observations exceeding at least one test criterion
  LOGTOC  yhat resids stnd.res stud.res leverage cooksD  dfits
6  0.398 0.617 -0.219    -1.69    -1.73   0.0866  0.136 -0.533
8  0.826 1.222 -0.396    -3.00    -3.34   0.0487  0.231 -0.756
9  0.869 1.170 -0.301    -2.27    -2.39   0.0383  0.103 -0.478
```

Figure 60. S+® output of regression model development using turbidity (TBY) as the explanatory variable for total organic carbon (TOC) concentrations for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

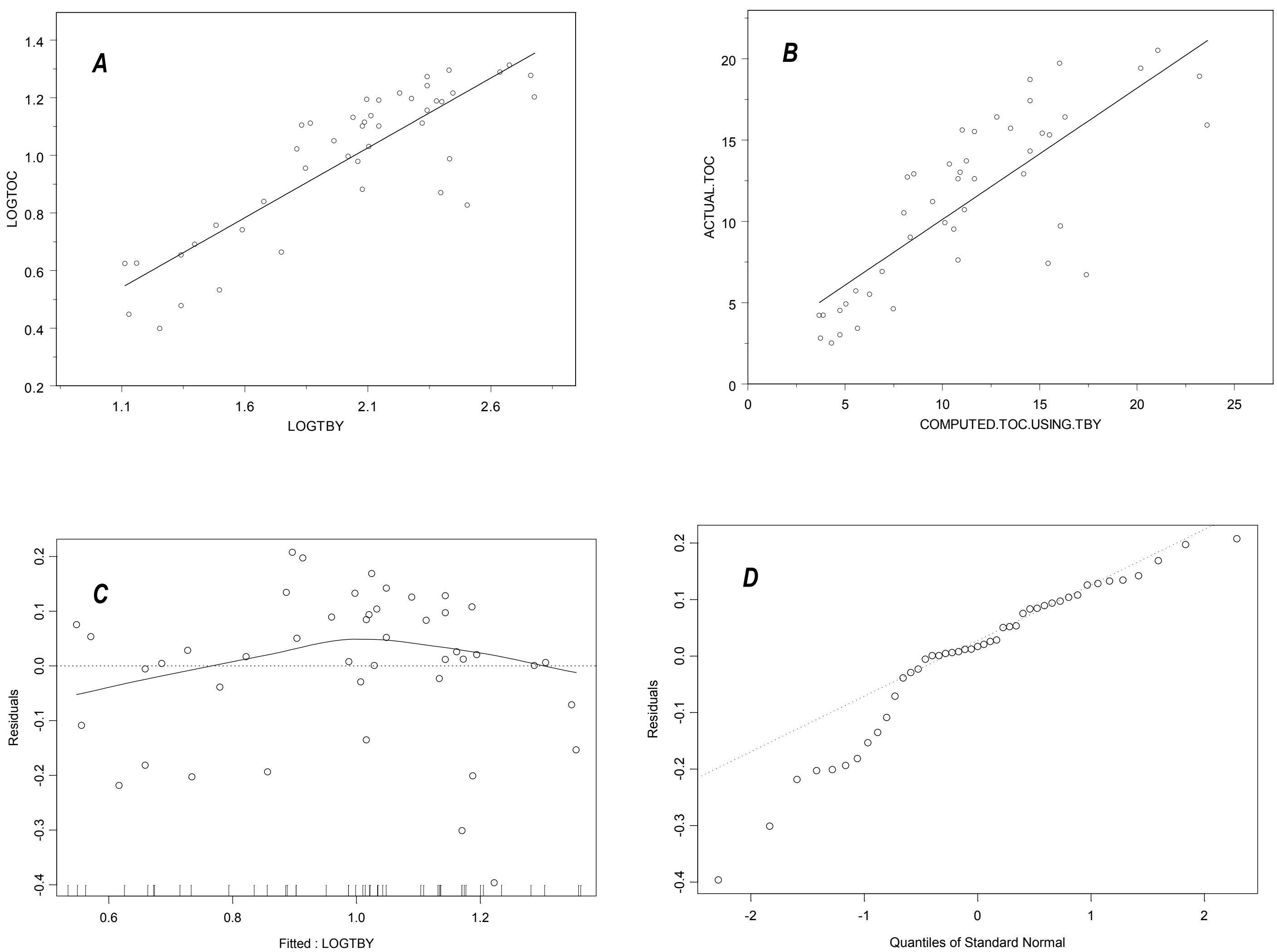

Figure 61. S+® output graphs from simple linear regression analysis showing *A*, log-transformed turbidity (TBY) versus log-transformed total organic carbon (TOC) concentrations; *B*, computed versus actual TOC concentrations; *C*, computed log-transformed TOC concentrations versus regression residuals; and *D*, standard normal quantiles versus regression residuals for the North Fork Ninnescah River upstream from Cheney Reservoir (site 07144780), south-central Kansas, 1999 through 2009.

Summary

Cheney Reservoir in south-central Kansas is one of the primary sources of water for the city of Wichita. The North Fork Ninnescah River is the largest contributing tributary to Cheney Reservoir. The U.S. Geological Survey has operated a continuous real-time water-quality monitoring station since 1998 on the North Fork Ninnescah River. Continuously measured water-quality physical properties include streamflow, specific conductance, pH, water temperature, dissolved oxygen, and turbidity. Discrete water-quality samples were collected during 1999 through 2009 and analyzed for sediment, nutrients, bacteria, and other water-quality constituents.

Regression models were developed to establish relations between discretely sampled constituent concentrations and continuously measured physical properties to estimate concentrations of those constituents of interest that are not easily measured in real time because of limitations in sensor technology and fiscal constraints. The water-quality information in this report is important to the city of Wichita because it allows the concentrations of many potential pollutants of interest, including nutrients and sediment, to be estimated in real time and characterized over conditions and time scales that would not be possible otherwise. Regression models based on data collected during 1997 through 2003 were published in 2006. This report updates those models using discrete and continuous data collected during January 1999 through December 2009. The 2006 models for dissolved solids, sodium, chloride, sulfate, calcium, magnesium, potassium, alkalinity, bicarbonate, total suspended solids, suspended-sediment concentration, total Kjeldahl nitrogen, total phosphorus, orthophosphate, and fecal coliform bacteria were updated. New regression models were developed for total nitrogen, nitrate, organic nitrogen, *Escherichia coli* bacteria, and total organic carbon.

In general, model forms and the amount of variance explained by the models was similar between the original and updated models. The model forms for most updated models remained unchanged. Ions were strongly positively correlated with specific conductance. Sediment was positively correlated with turbidity. Nutrients were generally positively correlated with turbidity. Some nutrient species included either season or specific conductance as explanatory variables. Bacteria was positively correlated to turbidity and negatively correlated with specific conductance.

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