U.S. Geological Survey
Water-Resources Investigations Report 01-4199

Prepared in cooperation with the
CITY OF WICHITA, KANSAS

Occurrence of Phosphorus, Nitrate, and Suspended Solids in Streams of the Cheney Reservoir Watershed, South-Central Kansas, 1997-2000

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Unnamed tributary to Cheney Reservoir, April 26, 2001, photo by C.R. Milligan.

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second (ft /s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
gallon (gal)	3.785	liter
micrometer (mm)	0.00003937	inch
mile (mi)	1.609	kilometer
milligram per liter (mg/L)	1.0	part per million
pound (lb)	453.6	gram
pound per acre (lb/acre)	1.121	kilogram per hectare
square mile (miî)	2.590	square kilometer

The use of brand, trade, or firm names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Abstract

Improving water quality of Cheney Reservoir in south-central Kansas is an important objective of State and local water managers. The reservoir serves as a water supply for about 350,00 people in the Wichita area and an important recreational resource for the area. In 1992, a task force was formed to study and prepare a plan to identify and mitigate potential sources of stream contamination in the Cheney Reservoir watershed. This task force was established to develop stream-water-quality goals to aid in the development and implementation of best-management practices in the watershed. In 1996, the U.S. Geological Survey entered into a cooperative study with the city of Wichita to assess the water quality in the Cheney Reservoir watershed. Water-quality constituents of particular concern in the Cheney Reservoir watershed are phosphorus, nitrate, and total suspended solids. Water-quality samples were collected at five streamflow-gaging sites upstream from the reservoir and at the outflow of the reservoir. The purpose of this report is to present the results of a 4-year (1997-2000) data-collection effort to quantify the occurrence of phosphorus, nitrate, and suspended solids during base-flow, runoff, and long-term streamflow conditions (all available data for 1997-2000) and to compare these results to stream-water-quality goals established by the Cheney Reservoir Task Force.

Mean concentrations of each of the constituents examined during this study exceeded the Cheney Reservoir Task Force stream-water-quality goal for at least one of the streamflow conditions evaluated. Most notably, mean base-flow and mean long-term concentrations of total phosphorus and mean base-flow concentrations of dissolved nitrate exceeded the goals of 0.05, 0.10, and 0.25 milligram per liter, respectively, at all five sampling sites upstream from the reservoir. Additionally, the long-term stream-water-quality goal for dissolved nitrate was exceeded by the mean concentration at one upstream sampling site, and the base-flow total suspended solids goal (20 milligrams per liter) and long-term total suspended solids goal (100 milligrams per liter) were each exceeded by mean concentrations at three upstream sampling sites. Generally, it seems unlikely that water-quality goals for streams in the Cheney Reservoir watershed will be attainable for mean base-flow and mean long-term total phosphorus and total suspended solids concentrations and for mean base-flow dissolved nitrate concentrations as long as current (2001) watershed conditions and practices persist. However, future changes in these conditions and practices that mitigate the transport of these consitutents may modify this conclusion.

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BACKGROUND

Cheney Reservoir, located on the North Fork Ninnescah River in south-central Kansas (fig. 1), was constructed between 1962 and 1965 to provide downstream flood control, wildlife habitat, recreational opportunities, and a reliable municipal water supply for the city of Wichita, Kansas. Currently (2001), the city obtains 60 to 70 percent of its daily water supply for about 350,000 people from Cheney Reservoir (Jerry Blain, city of Wichita Water and Sewer Department, oral commun., 2000).

In 1992, a task force was formed to study and prepare a plan to identify and mitigate potential sources of stream contamination in the Cheney Reservoir watershed. The Cheney Reservoir Task Force, consisting of members of the Reno and Sedgwick County Conservation Districts, Reno County Health Department, Wichita Water and Sewer Department, and other local, State and Federal agencies, was established to study contamination problems, develop stream-water-quality goals, and, with the assistance of cooperating agencies, implement and maintain best-management practices (BMPs) throughout the Cheney Reservoir watershed (Cheney Reservoir Task Force Committee, written commun., 1996). BMPs include, but are not limited to, terracing, stubble mulch, grassed waterways, and efficient fertilizer application.

The Cheney Reservoir Task Force prepared a water-quality plan to, in part, mitigate the transport of nutrients, such as phosphorus and nitrate, and suspended solids to Cheney Reservoir. It was believed that decreasing the transport of nutrients and suspended solids would reduce the potential for reservoir eutrophication (nutrient enrichment) and excessive sedimentation that could decrease the useful life of the reservoir. The plan was implemented in July 1994 and is overseen by the Citizen's Management Committee, a committee of landowners in the Cheney Reservoir watershed, and a subcommittee of the Reno County Conservation District.

In 1996, the U.S. Geological Survey (USGS) entered into a cooperative study with the city of Wichita, Kansas, with technical assistance provided by the Bureau of Reclamation, U.S. Department of Interior. The purposes of the study were to describe spatial occurrence and transport of selected water-quality constituents in the streams of the Cheney Reservoir watershed and into and out of Cheney Reservoir. This information will be used by the city of Wichita and the Citizen's Management Committee to evaluate the overall effectiveness of implemented BMPs in mitigating surface-water contamination and to determine areas of the watershed where additional BMPs may be needed. Results of this study also will support Federal, State, and local goals toward implementing watershed strategies to improve water quality and may have transferability to other watersheds in Kansas or the Nation, especially those with similar land-use and land-management characteristics.

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Constituents of Concern

Previous studies indicated that phosphorus is a primary constituent of concern that may limit the useful lifespan of Cheney Reservoir (Pope and Christensen, 1997; Pope, 1998; Pope and Milligan, 2000). Nutrients, such as phosphorus, are essential for plant growth, so much so, that in some biological reactions, phosphorus is the limiting nutrient determining the rate of plant growth (Hem, 1992). However, excessive phosphorus concentrations in the aquatic environment may produce eutrophication of streams and reservoirs. Eutrophication (nutrient enrichment) generally is characterized by an abundance of nutrients, decreases in dissolved oxygen, and dense algal growth (Christensen and Pope, 1997). Many of the chemical constituents associated with eutrophication may cause taste-and-odor problems in finished drinking water, as has been experienced in Wichita. Additionally, rooted aquatic vegetation may grow dense in shallow water with excessive phosphorus, thus reducing the recreational value of the water body. These rooted plants also may uptake phosphorus that is held in the bottom sediment and subsequently release it into the aquatic environment (Mitchell and Stapp, 1996). Sources of phosphorus in the Cheney Reservoir watershed include inorganic phosphates added to agricultural soils as fertilizer, manure from confined animal-feeding operations, and treated human sewage discharged directly into receiving streams.

Inorganic ions of nitrogen, such as nitrite and nitrate, also are essential nutrients required for plant growth. In most oxygen-rich water bodies, nitrate is the most common ion due to the ease of oxidation of the nitrite ion. Nitrate is the form of nitrogen most easily used by rooted green plants and algae. Nitrate usually occurs in relatively small concentrations in uncontaminated surface water with a world average of 0.30 mg/L (Reid and Wood, 1976, p. 235). Larger concentrations may stimulate the growth of rooted plants or accelerate algal production to an extent that it may produce a taste-and-odor problem in finished drinking water. Additionally, when large algal blooms die, decomposition of the blooms consumes large amounts of dissolved oxygen, further stressing the aquatic environment.

Nitrate concentrations in drinking water can have adverse health effects on the human population as well. Concentrations in excess of 10 mg/L may result in methemoglobinemia (blue-baby syndrome) in infants-a condition in which the nitrate ion attaches to the oxygen-transporting hemoglobin, essentially blocking the site required for adequate oxygen transport and resulting in subsequent suffocation of the exposed individual. Accordingly, a Maximum Contaminant Level (MCL) of 10 mg/L has been established for Kansas drinking water (Kansas Department of Health and Environment, 1994). Sources of nitrate in the Cheney Reservoir watershed are similar to those for phosphorus and include manure from confined animal-feeding operations, application of synthetic fertilizers, discharged human waste, and atmospheric contributions.

Suspended solids may be organic or inorganic materials originating from sources such as decaying vegetation, algae, solids discharged by industries and municipalities, urban and agricultural runoff, and physical degradation of geological formations (Mays, 1996). Excessive suspended solids can shorten the useful life of a reservoir by increasing the rate of sedimentation, smothering rooted vegetation, and adversely affecting the ecosystem of aquatic benthic (bottom-dwelling) organisms. Also, increased suspended solids in reservoir water increase turbidity, restrict the available sunlight that reaches aquatic plants and organisms, and inhibit photosynthesis and primary productivity. Furthermore, suspended solids can serve as a heat sink by absorbing solar radiation, which ultimately may increase water temperatures, stress aquatic organisms, and potentially may create conditions favorable to disease in fish populations. Suspended solids also are a transport mechanism for constituents of water-quality concern such as phosphorus and pesticides.

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Purpose and Scope

Maintaining acceptable surface-water quality in the Cheney Reservoir watershed is important because of reservoir use for municipal water supplies, wildlife habitat, and recreation. The transport of phosphorus, nitrate, and suspended solids into Cheney Reservoir is a main concern in efforts to maintain a quality water supply. BMPs have been implemented in the Cheney Reservoir watershed to limit the transport of these constituents, and the Cheney Reservoir Task Force has established stream-water-quality goals to determine the overall effectiveness of the BMPs.

The purpose of this report is to present the results of a 4-year (1997-2000) data-collection effort to quantify the occurrence of total phosphorus, dissolved nitrate, and total suspended solids during base-flow, runoff, and long-term streamflow conditions in the Cheney Reservoir watershed and to compare these results to the stream-water-quality goals established by the Cheney Reservoir Task Force. In this report, base flow is defined as streamflow that originates generally as ground-water inflow to the stream channel. Runoff is that part of precipitation, snowmelt, or irrigation that flows over and through the soil and eventually ends up in a stream channel (Ward and Elliot, 1995). Long-term streamflow conditions refer to a combination of base-flow and runoff conditions as reflected by all available data collected for 1997-2000.

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Description of Study Area

The Cheney Reservoir watershed consists of 933 miî of contributing drainage area of the North Fork Ninnescah River and associated tributary streams (fig. 1). The noncontributing drainage is 72 miî and is located in the extreme upstream part of the watershed.

Land use in the watershed is predominantly agricultural with about 52 percent of the land used for major crop production (corn, grain sorghum, soybean, and wheat) (fig. 2). Estimated cropland acreage for 1995 included about 27,000 acres of corn, 51,000 acres of grain sorghum, 5,000 acres of soybeans, and 200,000 acres of wheat. Livestock inventories included about 76,000 cattle and 14,000 hogs and pigs. Most of the cattle were pastured; however, many small dairies and feedlots operate within the watershed (Christensen and Pope, 1997).

The population of the watershed is less than 4,000 people, many of whom are associated with the approximately 1,000 farms in the watershed (Cheney Reservoir Task Force Committee, written commun., 1996). The populations of the six largest towns in 1992 ranged from less than 200 people in Castleton and Preston to slightly more than 1,200 in Stafford (Heylar, 1994).

The North Fork Ninnescah River Valley and the surrounding plains are underlain by consolidated rocks (mainly shale with thin layers of limestone, dolomite, siltstone, sandstone, gypsum, and salt) of Permian age (230 to 280 million years old) covered by unconsolidated fluvial (mainly sand and gravel) and windblown (mainly silt and clay) deposits of Pleistocene age (less than 1.5 million years old) (Zeller, 1968). The unconsolidated deposits are a source of water for domestic supply, irrigation, and livestock and range in thickness from little or no saturated thickness in the eastern part of the Red Rock Creek subwatershed (fig. 1) to more than 160 ft in the northern part of Pratt County (Hansen, 1991).

Soils in the Cheney Reservoir watershed generally are classified as clayey loam on the uplands to sand or sandy loam on low-lying areas or where slopes are less than about 3 percent. Many of the soils in the watershed are subject to erosion by wind and rainfall runoff (Rockers and others, 1966).

Topography in the Cheney Reservoir watershed ranges from flat to gently sloping hills. Total topographic relief is about 550 ft, with maximum local relief (within 1 mi) of about 50 ft.

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STUDY METHODS

A network of six streamflow-gaging/water-quality sampling sites (fig. 1, table 1) was established in the Cheney Reservoir watershed in the fall of 1996 to define the water-quality characteristics of the North Fork Ninnescah River and associated tributary streams. These sites were established to define water-quality characteristics of the North Fork Ninnescah River and selected tributary streams and to evaluate spatial variability in concentrations of selected water-quality constituents within the watershed and into and out of Cheney Reservoir.

Table 1. Streamflow-gaging/water-quality sampling sites in Cheney Reservoir watershed, south-central Kansas

Map index number (fig. 1)	U.S. Geological Survey site identification number	Sampling-site name	Contributing drainage area (square miles)
1	07144601	North Fork Ninnescah River at Arlington, Kansas	403
2	07144660	Silver Creek near Arlington, Kansas	193
3	07144680	Goose Creek near Arlington, Kansas	51.8
4	07144780	North Fork Ninnescah River above Cheney Reservoir, Kansas	734
5	07144730	Red Rock Creek near Pretty Prairie, Kansas	53.2
6	07144795	North Fork Ninnescah River at Cheney Dam, Kansas	933

For this study, water-quality samples were analyzed for total phosphorus, dissolved nitrite plus nitrate as nitrogen (hereinafter referred to as nitrate), and total suspended solids. In this report, with respect to constituent concentrations, the term "total" is operationally defined as an unfiltered sample, whereas the term "dissolved" refers to that part of a water sample that passes through a 0.45-mm pore-size filter. These constituents will be discussed relative to stream-water-quality goals established by the Cheney Reservoir Task Force (Cheney Reservoir Task Force Committee, written commun., 1996).

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Sample Collection and Analysis

Samples of streamflow were collected either manually (manual samples) (Horowitz and others, 1994) or with automatic samplers (automatic samples). All samples collected at sampling site 6, the outflow from Cheney Reservoir, were collected manually. Automatic samplers were installed at all sampling sites upstream from Cheney Reservoir (sampling sites 1-5, fig. 1). The automatic samplers used in this study were capable of collecting four 1-gal samples before service was required. Water-quality samples were collected from sampling sites 1-5 during low-flow (base-flow) and high-flow (runoff) conditions. Outflow from Cheney Reservoir (sampling site 6) is completely regulated, and therefore, no distinction was made between base-flow and runoff conditions for this site.

Base-flow samples were collected on a routine basis throughout the year (monthly), with an increased sampling frequency during the growing season, April-August, when samples were collected about every 2 weeks. Due to the unpredictable nature of runoff and the potential difficulty in collecting samples during runoff, automatic samplers were installed to collect multiple samples during runoff periods. The automatic samplers were programmed to initiate a sampling routine when the stream stage (stream water-surface elevation) reached a predetermined level. Streamflow samples were collected at time intervals that would represent a complete runoff period, typically collecting four to eight samples per runoff period.

By definition, samples of base flow were collected during low-streamflow conditions. Low streamflow, however, does not imply a static flow rate. Base flow can vary seasonally, annually, and before and after runoff. Because base flow is sustained primarily by ground-water discharge to stream channels, factors that affect ground-water levels can affect base flow. Precipitation, or the lack of precipitation, is a primary factor affecting ground-water levels (Heath, 1983). Seasons or years with greater precipitation may result in increased ground-water levels and, ultimately, ground-water discharge to stream channels. Because of this ground-water/precipitation relation, base flow also may be larger after runoff than it was before the runoff.

Samples of runoff were collected when streams received surface-water flow as a direct result of precipitation. During this study, runoff samples were collected as streams rose, near peak runoff (maximum streamflow), and as streams receded. Runoff conditions were easily discernable during most of a runoff period. However, the separation between cessation of runoff and the reestablishment of base-flow conditions was somewhat subjective. Generally, the area of the recession hydrograph where rate of change in stage was minimal and the hydrograph approached a straight line was considered to be the separation between runoff and base flow.

All base-flow and some runoff samples were collected manually from sampling sites 1-5. Most runoff samples from these sites were collected with automatic samplers. Manual samples were collected to provide a depth- and width-integrated composite sample representative of the stream average cross-sectional chemical composition. Automatic samples were collected from a single point in the stream cross-sectional area and, therefore, may not be representative of the stream average cross-sectional chemical composition at the time of sample collection.

Water-quality samples were collected by USGS personnel and delivered to the Wichita Water and Sewer Department Laboratory for analysis. Total phosphorus was analyzed using U.S. Environmental Protection Agency (USEPA) method 365.2 (U.S. Environmental Protection Agency, 1983), dissolved nitrite plus nitrate using USEPA method 300.0 (U.S. Environmental Protection Agency, 1993), and total suspended solids using USEPA method 160.2 (U.S. Environmental Protection Agency, 1983) (Vernon Strasser, city of Wichita Water and Sewer Department, oral commun., 2001).

In a previous study of phosphorus transport in the Cheney Reservoir watershed (Pope and Milligan, 2000), total phosphorus concentrations in automatic samples from sites 1-5 were adjusted to approximate concentrations in the manual samples. This was done by relating pairs of concurrently collected manual and automatic samples using linear-regression analysis to produce an adjustment coefficient (slope of regression line) of 0.854. This coefficient then was used to adjust all automatic sample concentrations at sampling sites 1-5 (fig. 1). However, for the present study (described in this report), total phosphorus and total suspended solids concentrations from automatic samples were adjusted using coefficients determined by linear-regression analysis (table 2) for individual subwatersheds (sampling sites 1-5, fig. 1). Regression relations were forced through the graphical origin to honor the assumption that a zero concentration in a manually collected sample would equate to a zero concentration in an automatically collected sample.

Regression relations presented in table 2 are all statistically significant at a level of significance (p value) of less than 0.0001. However, the coefficients of determination for total phosphorus and total suspended solids relations at sampling site 1 were relatively small. The concentrations in the automatic samples explained 40 percent or less of the variation in the concentrations in the manual samples. It is believed that these small coefficients are a result of a combination of the placement of the water-sample intake of the automatic sampler and the geomorphology of the stream channel at sampling site 1.

Table 2. Results of regression analysis relating total phosphorus and total suspended solids concentrations determined for manually and automatically collected, concurrent samples from sampling sites 1-5 in Cheney Reservoir watershed, south-central Kansas, 1997-2000

[M, concentration in manually collected samples, in milligrams per liter; A, concentration in automatically collected samples, in milligrams per liter; Rî, coefficient of determination; SEE, standard error of estimate, in milligrams per liter. Level of significance (p value) for all relations is less than 0.0001]

	Total phosphorus			Total suspended solids		
Map index number (fig. 1)	**Regression equation (M=)**	**Rî**	**SSE**	**Regression equation (M=)**	**Rî**	**SSE**
1	0.73A	0.21	0.09	0.45A	0.40	63
2	093A	.92	.02	.95A	.78	16
3	1.02A	.90	.03	.94A	.90	16
4	.94A	.76	.05	.89A	.60	50
5	.96A	.91	.09	.99A	.99	21

The water-sample intake for the automatic sampler at sampling site 1 was located on the left bridge abutment at the left streambank, at the extreme edge of streamflow, unlike the other sampling sites where the intakes were located closer to the center of the stream channel. During low-flow conditions, streamflow at sampling site 1 generally was braided (several flow channels), and during runoff conditions, streamflow combined into one relatively wide, shallow channel. In retrospect, a sample collected from the edge of flow during either flow condition might not result in a water sample representative of the mean water-quality, cross-sectional composition. Because of the placement of the sampler intake and stream-channel characteristics, concentrations of total suspended solids in water from automatic samples were always larger than concentrations from manual samples. This difference was most pronounced when concentrations of total suspended solids were larger than 500 mg/L in automatic samples. On the basis of concurrently collected automatic and manual samples from sampling site 1, mean percentage differences between the two types of samples were 52 percent when total suspended solids in the automatic samples exceeded 500 mg/L and 24 percent when concentrations were less than 500 mg/L. Percentage differences between concentrations of total suspended solids in concurrently collected automatic and manual samples were calculated as the absolute value of 100 multiplied by the difference in concurrent concentrations divided by the summation of concurrent concentrations.

Because of the fluctuations in variability of total suspended solids concentrations in water from automatic and manual samples, a statistically significant relation, initially, did not exist between the two types of samples at sampling site 1. Most of the streamflow samples collected during runoff were automatic samples. The necessity of estimating mean cross-sectional concentrations for total constituents examined during this study required that concentrations from automatic samples be adjusted to approximate the mean cross-sectional concentration provided by a manual sample. Therefore, to develop a statistically significant relation between total suspended solids concentrations in water from automatic and manual samples collected at sampling site 1, concurrent sample pairs were deleted from the data set used for regression analysis when the total suspended solids concentration in water from the automatic sample exceeded 500 mg/L. Regression analysis using this modified data set produced a statistically significant relation, as presented in table 2. Because of this modified regression relation, all total suspended solids concentrations in water from automatic samples used to estimate concentrations in water from manual samples (mean stream cross-sectional concentration) at sampling site 1, likewise, were deleted from the 1997-2000 data set.

Concentrations of nitrate in automatically collected streamflow samples were not adjusted for this study. Unlike phosphorus and suspended solids that are transported mainly in the particulate phase, nitrate is transported as a dissolved water-quality constituent (Hem, 1992) and, potentially, is less subject to stream cross-sectional variability. To verify this characterization, regression analysis was performed that related all dissolved nitrate concentrations in concurrently collected manual and automatic samples from sampling sites 1-5 (fig. 1). Results of this analysis (fig. 3) indicated little difference between dissolved nitrate concentrations in manually and automatically collected samples. The slope of the regression line (y = 0.99x) and high coefficient of determination (Rî) of 0.99 indicated an almost one-to-one relation between the two concentrations, and thus, streamflow at sampling sites 1-5 tended to be well mixed with respect to dissolved water-quality constituents such as nitrate.

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Quality Control

Analytical quality control consisted of analysis of replicate stream samples, analysis of standard reference samples, and analysis of blank-water (highly purified water, free of contamination) samples. Laboratory analytical precision and reproducibility were evaluated by the analysis of replicate subsamples from selected stream-water samples. These replicate subsamples were withdrawn from a USGS sample churn containing a flow-weighted composite sample of a stream cross section. The USGS sample churn has provisions for sample agitation during the subsample withdrawal procedure, thereby assuring that each subsample was equivalent and representative of the original composite sample in regard to water-quality constituent concentrations. Therefore, analytical variability between replicate samples would indicate the degree of precision and reproducibility of the methods and techniques used to analyze for selected water-quality constituents.

A statistical summary of the relative analytical variation between analyses of replicate samples of total phosphorus, dissolved nitrate, and total suspended solids is presented in table 3. The variation, as a percentage, was calculated as the absolute value of 100 multiplied by the quotient of the difference in replicate concentrations divided by the summation of replicate concentrations. Analytical variation was not calculated if one or both analyses for a replicate pair were less than the analytical method reporting limits.

Table 3. Statistical summary of analytical variation between analyses of replicate samples for total phosphorus, dissolved nitrate, and total suspended solids, Cheney Reservoir watershed, 1997-2000

		Percentage of analytical variation		
Water-quality constituent	**Number of replicate analyses**	**Minimum**	**Median**	**Maximum**
Total phosphorus	29	0	3.7	14.3
Dissolved nitrate as nitrogen	26	0	.4	53.8
Total suspended solids	23	0	3.6	30.3

For the three constituents of concern-total phosphorus, dissolved nitrate, and total suspended solids-the median analytical variations were 3.7, 0.4, and 3.6 percent, respectively (table 3). The analytical variation for about one-third (36 percent) of all total phosphorus and suspended solids analyses exceeded 5.0 percent, possibly indicating greater variability in laboratory precision and reproducibility among these constituents. However, the median analytical variation of replicate pairs indicated an acceptable degree of laboratory precision and reproducibility.

The accuracy of laboratory analyses for total phosphorus and dissolved nitrate was evaluated on the basis of variation between the analyses of standard reference samples and the most-probable values (MPV) for those constituents (table 4). The MPV of each standard reference sample is determined by sending reference samples to laboratories that are involved in an interlaboratory analytical evaluation program in conjunction with the USGS National Water Quality Laboratory (NWQL) Branch of Quality Service (BQS) in Denver, Colorado. Each laboratory analyzes the samples and then submits the results to BQS. BQS then statistically analyzes the combined results to derive the MPV, which is the median value calcluated from the reported results (Connor and others, 2001). Percentage variation between the MPV and analytical results of the standard reference samples was determined by calculating the absolute value of 100 multiplied by the quotient of the difference between the MPV and the analytical result of the standard reference sample divided by the MPV. The median percentage variations for analyses of total phosphorus and dissolved nitrate were 6.3 and 7.6 percent, respectively (table 4), indicating an acceptable degree of accuracy.

Table 4. Statistical summary of percentage variations between analyses of standard reference samples and most-probable analytical values for total phosphorus and dissolved nitrate, Cheney Reservoir watershed, 1997-2000

		Percentage of analytical variation
Water-quality	**Number of reference**	

constituent	samples	Minimum	Median	Maximum
Total phosphorus	21	0.4	6.3	50.9
Dissolved nitrate as nitrogen	22	0	7.6	66.7

The possibility of sample contamination from equipment or methods used to collect and process samples was examined through the analysis of blank-water samples processed as either an equipment blank or a churn blank. An equipment blank is a sample of blank water that has been processed through the same procedures as an environmental sample and includes passing the blank water through the sample-collection device, compositing in the churn, and subsampling into separate bottles with the appropriate sample preservatives. In effect, an equipment blank represents all possible sources of contamination of a sample. A churn blank is processed the same as an equipment blank except that the blank water is not passed through the sampling device.

A total of 35 blank-water samples were analyzed for this study. Three of these samples were equipment blanks, and 32 samples were churn blanks. In 105 analyses of blank-water samples, only three, one for each of the three constituents of concern-total phosphorus, dissolved nitrate, and total suspended solids-were equal to the analytical method detection limit; all other samples were less than the method detection limit. Therefore, sample-collection and processing procedures were not a substantial source of contamination for the environmental samples collected during this study.

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STREAMFLOW CONDITIONS

Annual mean streamflow in the Cheney Reservoir watershed varied substantially among the years 1997, 1998, 1999, 2000 and also in comparison to longer term average streamflow. Annual mean streamflow at sampling site 4 (fig. 1) was larger during 1998 (162 ft /s) (fig. 4) than during 1997, 1999, or 2000, and was 9 percent larger than the average streamflow of 149 ft /s for the period of record (1965-2000).

In February 1996, sampling site 4 was moved to its present location from a site about 4 mi downstream. The average streamflow for 1965-2000 at sampling site 4 was calculated, in part, from data collected at this downstream location (at the Kansas Highway 17 bridge, fig. 1. To make comparisons of annual mean streamflow at sampling site 4 for 1997-2000 to a longer term average streamflow, it was necessary to adjust the 1997-2000 annual mean values to account for the relocation of the station. The adjustment was made by summing the annual mean streamflow at sampling sites 4 and 5 and an estimate of annual mean streamflow for the approximately 20 miî ungaged area downstream from sampling sites 4 and 5 and upstream from the discontinued gaging-station site at Highway 17. Annual mean streamflow at sampling site 4 was estimated for 2000, due to the discontinuance of stream-gaging activities in October of that year. The adjusted annual mean streamflow at sampling site 4 is shown in figure 4 and is included in the calculation of the longer term average streamflow at sampling site 4.

Annual mean streamflow from Cheney Reservoir (sampling site 6, fig. 1) was largest in 1999 (180 ft /s) (fig. 4) and was 49 percent larger than the average of 121 ft /s for the period of record (1965-2000). Annual mean streamflow in 2000 (61 ft /s) was 50 percent of the 1965-2000 average. Much of the streamflow from Cheney Reservoir during 1999 was due to a lowering of the reservoir level for dam maintenance. Conversely, much of the smaller streamflow in 2000 was due to storage of water to return the reservoir to the conservation-pool level. No long-term streamflow data are available for sampling sites 1, 2, 3, and 5 because these sites were established during this study.

Annual mean streamflow is dependent, to a large extent, on annual precipitation and precipitation characteristics such as seasonal distribution (timing) and intensity of precipitation. Therefore, a comparison of annual mean streamflows among years may or may not help to describe annual variability in water-quality characteristics. Conceivably, years of near-equal annual mean streamflows may have substantial differences in water-quality characteristics because of differences in annual precipitation characteristics. However, a detailed analysis of precipitation characteristics during the 4-year period (1997-2000) associated with sampling sites in the Cheney Reservoir watershed is beyond the purpose and scope of this report.

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OCCURRENCE OF PHOSPHORUS, NITRATE, AND SUSPENDED SOLIDS

Mean concentrations of total phosphorus, dissolved nitrate, and total suspended solids were calculated for streamflow samples collected during base-flow and runoff conditions at sampling sites 1-5 (fig. 1). Additionally, mean long-term concentrations were calculated using all available data (both base flow and runoff for 1997-2000) from each of the six sampling sites. Site-to-site comparisons of mean concentrations were made as well as comparisons to stream-water-quality goals established by the Cheney Reservoir Task Force (written commun., 1996) to reduce the potential for reservoir eutrophication and accelerated sedimentation.

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Total Phosphorus

Mean concentrations of total phosphorus in 183 samples collected during base-flow conditions at sampling sites 1-5 did not vary substantially among the sampling sites (fig. 5A). Mean base-flow concentrations ranged from 0.10 mg/L at sampling site 4 (fig. 1) to 0.14 mg/L at sampling sites 2 and 5 (table 5) and were at least twice the base-flow water-quality goal of 0.05 mg/L established by the Cheney Reservoir Task Force (table 6). Additionally, at least 82 percent of total phosphorus concentrations in samples collected during base flow from each of the five sampling sites upstream from Cheney Reservoir exceeded this goal (table 7).

Table 5. Mean concentrations of total phosphorus, dissolved nitrate, and total suspended solids in streamflow during base-flow, runoff, and long-term streamflow conditions at sampling sites 1-6 in Cheney Reservoir watershed, south-central Kansas, 1997-2000

[Shading indicates mean concentrations that exceeded stream-water-quality goals established by the Cheney Reservoir Task Force (written commun., 1996); all concentrations are in milligrams per liter; --, not applicable]

	Total phosphorus			Dissolved nitrate as nitrogen			Total suspended solids		
Map index number (fig. 1)	**Base flow**	**Runoff**	**Long term (1997-2000)**	**Base flow**	**Runoff**	**Long term (1997-2000)**	**Base flow**	**Runoff**	**Long term (1997-2000)**
1	0.13	0.29	0.25	1.6	0.90	1.1	69	170	130
2	.14	.28	.23	.43	.43	.43	23	120	89
3	.11	.48	.36	1.5	.95	1.2	16	140	100
4	.10	.38	.30	1.0	.71	.80	41	280	210
5	.14	.62	.50	2.4	1.3	1.6	10	220	170
6	--	--	.10	--	--	.24	9.8	--	--

Table 6. Mean stream-water-quality goals established by Cheney Reservoir Task Force for total phosphorus, dissolved nitrate, and total suspended solids in streams of Cheney Reservoir watershed, south-central Kansas, during base-flow, runoff, and long-term streamflow conditions

	Mean water-quality goal, in milligrams per liter		
Water-quality constituent	**Base flow**	**Runoff**	**Long term**
Total phosphorus	0.05	0.40	0.10
Dissolved nitrate as nitrogen	.25	6.6	1.2
Total suspended solids	20	550	100

Table 7. Number of samples analyzed and percentage of analyses that exceeded stream-water-quality goals for total phosphorus, dissolved nitrate, and total suspended solids from base-flow, runoff, and long-term streamflow conditions at sampling sites 1-6 in Cheney Reservoir watershed, south-central Kansas, 1997-2000

[N, number of samples analyzed; %, percentage of analyses that exceeded stream-water-quality goals; --, not applicable]

	Total phosphorus	Dissolved nitrate as nitrogen	Total suspended solids
Map			

index number (fig. 1)	Base flow		Runoff		Long term (1997-2000)		Base flow		Runoff		Long term (1997-2000)		Base flow		Runoff		Long term (1997-2000)	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
1	36	92	92	22	128	86	36	97	93	0	129	35	36	94	57	0	93	59
2	38	82	78	19	116	83	38	50	80	0	118	2.5	38	26	80	1.2	118	30
3	40	90	78	53	118	76	40	90	80	0	120	39	39	28	80	2.5	119	27
4	32	94	85	30	117	78	32	94	86	0	118	16	32	75	86	10	118	59
5	37	92	106	83	143	90	37	100	108	0	145	57	37	8	105	6.6	142	52
6	--	--	--	--	97	44	--	--	--	--	99	1.0	--	--	--	--	99	1.0

Mean concentrations of total phosphorus in 439 samples collected during runoff at sampling sites 1-5 (fig. 5B) were substantially larger and varied more among the sampling sites than mean concentrations in samples of base flow (fig. 5A). Mean runoff concentrations of total phosphorus ranged from 0.28 (sampling site 2) to 0.62 mg/L (sampling site 5) (table 5). However, in contrast to mean base-flow concentrations of total phosphorus that exceeded the stream-water-quality goal (0.05 mg/L, table 6) at all five upstream sampling sites (fig. 5A), only mean runoff concentrations of total phosphorus from sampling sites 3 and 5 (fig. 5B) exceeded the runoff stream-water-quality goal of 0.40 mg/L (table 6). Accordingly, sampling sites 3 and 5 were the only sites where a substantial percentage of runoff samples had total phosphorus concentrations larger than the runoff stream-water-quality goal. Fifty-three and 83 percent of all total phosphorus concentrations in runoff samples collected at sampling sites 3 and 5, respectively, exceeded the runoff stream-water-quality goal. This contrasts to an average of 24 percent for sampling sites 1, 2, and 4 (table 7).

Mean long-term concentrations of total phosphorus (fig. 5C) varied among sampling sites in a manner similar to that for mean runoff concentrations of total phosphorus (fig. 5B). Mean long-term concentrations of total phosphorus for sampling sites 1-5 ranged from 0.23 (sampling site 2) to 0.36 and 0.50 mg/L (sampling sites 3 and 5, respectively) (table 5). Mean long-term concentrations of total phosphorus from all sampling sites upstream from Cheney Reservoir (sites 1-5) were at least twice to as much as five times the stream-water-quality goal of 0.10 mg/L (table 6). The mean long-term concentration in the outflow of Cheney Reservoir (sampling site 6) equalled this goal.

The documentation that sampling sites 3 and 5 had the largest mean long-term concentrations of total phosphorus is consistent with a previous investigation of the Cheney Reservoir watershed (Pope and Milligan, 2000) that quantified phosphorus yields for 1997-98 from the subwatershed areas represented by sampling sites 1-5 (fig. 1). The largest phosphorus yields were from the Goose Creek subwatershed (sampling site 3, about 0.30 lb/acre) and the Red Rock Creek subwatershed (sampling site 5, about 0.37 lb/acre). The reasons for differences in phosphorus concentrations and yields among sampling sites and subwatershed areas are not definitively known but probably is a combination of many factors that may include variations in (1) naturally occurring phosphorus; (2) precipitation; (3) soil types and characteristics such as particle size, porosity, and erodibility; (4) topography; and (5) agricultural activities that include the widespread use of phosphorus-containing fertilizers or livestock production (pastured and confined) and resulting distribution of manure.

As expected from long-term data presented in table 5, sampling sites 1-5 (fig. 1) had a substantial percentage of total phosphorus analyses that exceeded the long-term stream-water-quality goal of 0.10 mg/L (table 6). On average for the five sites, 83 percent of the samples exceeded this goal (table 7). In contrast, 44 percent of total phosphorus samples from the outflow of Cheney Reservoir (sampling site 6, fig. 1) exceeded the long-term goal. These data attest to the trapping efficiency of Cheney Reservoir for water-quality constituents transported to the reservoir in the suspended or particulate phase. A previous investigation (Pope and Milligan, 2000) estimated that, on average, about 62 percent of the phosphorus load to the reservoir was retained in the reservoir.

On the basis of data presented in tables 5 and 7, it seems unlikely that mean concentrations of total phosphorus in base flow and under long-term streamflow conditions at sampling sites 1-5 (fig. 1) will meet the Cheney Reservoir Task Force stream-water-quality goals of 0.05 and 0.10 mg/L, respectively, as long as current (2001) watershed conditions and management practices persist. Furthermore, if watershed conditions become more conducive to phosphorus transport, such as increased soil erosion and increased distribution of phosphorus fertilizers and livestock manure, the long-term mean concentration of total phosphorus in the outflow of Cheney Reservoir (sampling site 6, fig. 1) also may exceed the long-term stream-water-quality goal of 0.10 mg/L.

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Dissolved Nitrate

Mean concentrations of dissolved nitrate in 183 samples collected during base-flow conditions at sampling sites 1-5 varied substantially among the sampling sites (fig. 6A). Mean base-flow concentrations ranged from 0.43 mg/L at sampling site 2 (fig. 1) to 2.4 mg/L at sampling site 5 (table 5) and were nearly twice to more than nine times the base-flow stream-water-quality goal of 0.25 mg/L established by the Cheney Reservoir Task Force (table 6). Additionally, on average, 86 percent of all dissolved nitrate concentrations in samples collected at sampling sites 1-5 during base flow exceeded this goal (table 7).

Mean concentrations of dissolved nitrate in 447 samples collected during runoff at sampling sites 1-5 (fig. 6B)were substantially less than mean concentrations in base flow (fig. 6A). However, the variability in mean sample concentrations among sampling sites was similar to that for base flow. Mean runoff concentrations of dissolved nitrate ranged from 0.43 (sampling site 2) to 1.3 mg/L (sampling site 5) (table 5). However, in contrast to mean base-flow concentrations of dissolved nitrate that exceeded the stream-water-quality goal (0.25 mg/L, table 6) at all five sampling sites (fig. 6A), no mean runoff concentrations of dissolved nitrate (fig. 6B) exceeded the stream-water-quality goal of 6.6 mg/L (table 6) at any of the five sampling sites upstream from Cheney Reservoir. Furthermore, no dissolved nitrate concentration in any sample collected during runoff exceeded this runoff stream-water-quality goal. This is in contrast to a sampling-site average of 86 percent for dissolved nitrate concentrations in samples collected during base flow that exceeded the stream-water-quality goal of 0.25 mg/L (table 7).

Mean long-term concentrations of dissolved nitrate (fig. 6C) had a distribution among sampling sites similar to that for mean base-flow (fig. 6A) and mean runoff (fig. 6B) nitrate concentrations. Mean long-term concentrations of dissolved nitrate ranged from 0.24 (sampling site 6) to 1.6 mg/L (sampling site 5) (table 5); however, only the mean runoff concentration of dissolved nitrate from sampling site 5 (fig. 6C) exceeded the runoff stream-water-quality goal of 1.2 mg/L (table 6). Accordingly, sampling site 5 was the only site where a substantial number, 57 percent, of long-term samples had dissolved nitrate concentrations larger than the long-term stream-water-quality goal. This contrasts with an average of 19 percent for the remaining sampling sites (table 7).

On the basis of data presented in tables 5 and 7, it seems unlikely that mean concentrations of dissolved nitrate in base flow at sampling sites 1-5 (fig. 1) will meet the stream-water-quality goal of 0.25 mg/L (table 6) as long as current (2001) watershed conditions and management practices persist. However, with the exception of the mean long-term dissolved nitrate concentration in samples from sampling site 5, mean runoff and long-term concentrations at all other sampling sites were less than stream-water-quality goals.

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Total Suspended Solids

Mean concentrations of total suspended solids in 182 samples collected during base flow at sampling sites 1-5 varied substantially among the sampling sites (fig. 7A). Mean base-flow concentrations of total suspended solids ranged from 10 mg/L at sampling site 5 (fig. 1) to 69 mg/L at sampling site 1 (table 5). Mean concentrations of total suspended solids for samples collected during base flow exceeded the stream-water-quality goal of 20 mg/L (table 6) at three of the five upstream sampling sites (sites 1, 2, and 4), ranging from just exceeding the goal to nearly 3.5 times larger than the goal. The percentage of total suspended solids concentrations in samples of base flow that exceeded the 20-mg/L goal ranged from 8 percent at sampling site 5 to 94 percent at sampling site 1, with an average of 46 percent for sites 1-5 (table 7).

Mean concentrations of total suspended solids in 408 samples collected during runoff at sampling sites 1-5 (fig. 7B) were substantially larger than mean concentrations from base flow. Mean runoff concentrations of total suspended solids ranged from 120 mg/L at sampling site 2 (fig. 1) to 280 mg/L at sampling site 4 (table 5). However, mean runoff concentrations of total suspended solids did not exceed the stream-water-quality goal of 550 mg/L (table 6) in samples from any of the five sampling sites upstream from Cheney Reservoir. This is in contrast to mean base-flow concentrations of total suspended solids that exceeded the stream-water-quality goal in samples from three of the five upstream sampling sites. On average, about 4 percent of the runoff samples collected at sampling sites 1-5 had total suspended solids concentrations that exceeded the stream-water-quality goal of 550 mg/L (table 7).

Mean long-term concentrations of total suspended solids (fig. 7C) varied among sampling sites in a manner similar to that for runoff concentrations (fig. 7B). Although mean long-term concentrations of total suspended solids were less than mean runoff concentrations in samples from all sampling sites (table 5), the mean long-term concentrations in samples from sampling sites 1, 4, and 5 exceeded the long-term stream-water-quality goal of 100 mg/L (table 6). Overall, mean long-term concentrations ranged from 9.8 (sampling site 6) to 210 mg/L (sampling site 4).

As expected from long-term data presented in table 5, sampling sites 1-5 (fig. 1) had a substantial percentage of samples with total suspended solids concentrations that exceeded the long-term stream-water-quality goal of 100 mg/L (table 7). On average for samples from sites 1-5, 45 percent of the total suspended solids concentrations exceeded the long-term goal. In contrast, only 1 percent of the samples from site 6 (fig. 1), the outflow to Cheney Reservoir, had total suspended solids concentrations that exceeded the long-term goal. These data attest to the trapping efficiency of Cheney Reservoir in regards to total suspended solids and other water-quality constituents, such as total phosphorus, that may be transported in the suspended or particulate phase.

On the basis of data presented in tables 5 and 7 relative to stream-water-quality goals (table 6), and under current (2001) watershed conditions and management practices, water-quality concerns with regard to total suspended solids are evident at three sampling sites (sites 1, 4, and 5) during base-flow conditions and at three sampling sites (sites 1, 4, and 5) during long-term streamflow conditions. It seems unlikely that either the base-flow stream-water-quality goal of 20 mg/L for total suspended solids at sampling sites 1, 4, and 5 or the 100-mg/L long-term stream-water-quality goal at sampling sites 1, 4, and 5 will be met under present conditions and management practices. This conclusion is reinforced by the fact that average streamflow conditions in the watershed during the 4 years of this study (1997-2000) approximated average conditions for the period of record (1965-2000). Annual mean streamflow (fig. 4) at sampling site 4 (fig. 1) for 1997-2000 was 146 ft3/s, just slightly less than the 1965-2000 average of 149 ft /s.

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COMPARISON TO PREVIOUS INVESTIGATION

In a previous investigation of phosphorus transport in the Cheney Reservoir watershed, Pope and Milligan (2000) estimated annual phosphorus loads for 1997 and 1998 (table 8) at sampling sites 1-6 (fig. 1). By utilizing these data and total streamflow data from Putnam and others (1998-2000) (table 8), an estimate of annual total phosphorus concentration (in milligrams per liter) was determined. This estimate was calculated by multiplying annual total phosphorus load (pounds) by total streamflow (acre-feet) by an appropriate unit conversion factor. A mean phosphorus concentration was calculated for 1997-98 and compared to the mean long-term (1997-2000) total phosphorus concentrations presented in this report (table 8).

Table 8. Comparison of mean total phosphorus concentrations calculated from previously estimated annual phosphorus loads, 1997-98, to mean long-term, 1997-2000, total phosphorus concentrations from all available total phosphorus concentration data for sampling sites 1-6 in Cheney Reservoir watershed, south-central Kansas

[mg/L, milligrams per liter]

	1997			1998				
Map index number (fig. 1)	**Estimated annual phosphorus load— (pounds)**	**Total stream-flowî (acre-feet)**	**Calculated mean total phosphorus concentration (mg/L)**	**Estimated annual phosphorus load— (pounds)**	**Total stream-flowî (acre-feet)**	**Calculated mean total phosphorus concentration (mg/L)**	**Calculated mean total phosphorus concentration, 1997-98 (mg/L)**	**Long-term mean total phosphorus concentration, 1997-2000 (mg/L)**
1	28,900	40,500	0.26	40,020	46,200	0.32	0.29	0.25
2	14,700	22,200	.24	17,700	24,400	.27	.25	.23
3	7,040	7,300	.35	11,800	9,700	.45	.40	.36
4	56,500	81,600	.25	95,700	104,000	.34	.30	.30
5	6,770	5,160	.48	18,500	9,930	.68	.58	.50
6	33,400	68,200	.18	54,000	117,000	.17	.18	.10

Estimated mean annual phosphorus concentrations for 1997-98 (Pope and Milligan, 2000) compared well with mean long-term 1997-2000 phosphorus concentrations presented in this report (table 8). Sampling-site mean total phosphorus concentrations differed by no more than 0.08 mg/L. This small variability has a two-fold implication: (1) it provides a validation of phosphorus load estimates in the previous investigation (Pope and Milligan, 2000), and (2) it provides an assurance that calculations of mean long-term concentrations of total phosphorus presented in this report are reasonable.

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SUMMARY AND CONCLUSIONS

Land use and human activities can have substantial effects on the water quality in a downstream reservoir. Water-quality constituents such as nutrients (species of phosphorus and nitrogen) and suspended solids may have detrimental effects on reservoir water quality through accelerated eutrophication, increased sedimentation, and reduced light penetration. Improving water quality of Cheney Reservoir in south-central Kansas is an important objective of State and local water managers. This reservoir serves as a water-supply source for about 350,000 people in the Wichita area and an important recreational resource for the area.

In 1992, a task force was formed to study and prepare a plan to identify and mitigate potential sources of stream contamination in the Cheney Reservoir watershed. This task force was established to study contamination problems and to develop stream-water-quality goals to aid in the development and implementation of best-management practices (BMPs) to mitigate the transport of nutrients and suspended solids. Stream-water-quality goals were established for selected water-quality constituents during various streamflow conditions. In 1996, the U.S. Geological Survey entered into a cooperative study with the city of Wichita, Kansas, to describe the spatial occurrence and transport of selected water-quality constituents within the Cheney Reservoir watershed.

Water-quality samples were collected from 1997-2000 at five streamflow-gaging sites upstream from Cheney Reservoir and from the outflow of the reservoir. Samples were analyzed for total phosphorus, dissolved nitrate, and total suspended solids and evaluated on the basis of mean concentrations during base-flow, runoff, and long-term (all available data for period of record, in this case 1997-2000) streamflow conditions at the upstream sampling sites. Mean concentrations were evaluated only for long-term streamflow conditions at the outflow of Cheney Reservoir.

The stream-water-quality goals for base-flow conditions of 0.05 mg/L (milligrams per liter) and for long-term streamflow conditions of 0.10 mg/L established for mean total phosphorus concentrations by the Cheney Reservoir Task Force were exceeded at all five upstream sampling sites. Mean base-flow total phosphorus concentrations ranged from 0.10 to 0.14 mg/L, and mean long-term total phosphorus concentrations ranged from 0.23 to 0.50 mg/L for the five upstream sampling sites. The mean long-term total phosphorus concentration in outflow of Cheney Reservoir was 0.10 mg/L, which equalled the stream-water-quality goal established by the Cheney Reservoir Task Force. Mean runoff total phosphorus concentrations ranged from 0.28 to 0.62 mg/L and exceeded the stream-water-quality goal of 0.40 mg/L at two upstream sampling sites. At least 82 percent of total phosphorus concentrations in samples collected during base flow and 26 percent of concentrations in samples collected during long-term streamflow conditions at each of the five upstream sampling sites exceeded the respective stream-water-quality goals.

The dissolved nitrate base-flow stream-water-quality goal of 0.25 mg/L established by the Cheney Reservoir Task Force was exceeded by mean base-flow concentrations of dissolved nitrate at all five upstream sampling sites. Mean base-flow dissolved nitrate concentrations ranged from 0.43 to 2.4 mg/L as nitrogen. On average, 86 percent of dissolved nitrate concentrations in samples collected at upstream sampling sites during base flow exceeded the 0.25-mg/L goal. The runoff stream-water-quality goal for dissolved nitrate of 6.6 mg/L was not exceeded at any sampling site. Mean runoff dissolved nitrate concentrations ranged from 0.43 to 1.3 mg/L as nitrogen. The dissolved nitrate long-term stream-water-quality goal of 1.2 mg/L was exceeded at one of the upstream sampling sites. Mean long-term dissolved nitrate concentrations ranged from 0.43 to 1.6 mg/L as nitrogen.

The base-flow stream-water-quality goal of 20 mg/L for total suspended solids established by the Cheney Reservoir Task Force was exceeded by mean base-flow concentrations of total suspended solids in samples from three of the five upstream sampling sites. Mean base-flow total suspended solids concentrations ranged from 10 to 69 mg/L. The percentage of total suspended solids concentrations in samples of base flow that exceeded the 20-mg/L goal ranged from 8 to 94 percent with an average of 46 percent for sampling sites 1-5. The runoff stream-water-quality goal of 550 mg/L for total suspended solids was not exceeded in samples from any sampling site. Mean runoff concentrations of total suspended solids ranged from 120 to 280 mg/L. The long-term stream-water-quality goal of 100 mg/L for total suspended solids was exceeded in samples from three sampling sites, and concentrations ranged from 9.8 to 210 mg/L. On average, 45 percent of the total suspended solids concentrations in long-term samples from the upstream sampling sites exceeded the 100-mg/L goal. In contrast, only 1 percent of the total suspended solids concentrations from the outflow of Cheney Reservoir exceeded the long-term goal. These data attest to the trapping efficiency of Cheney Reservoir in regards to total suspended solids and other water-quality constituents, such as total phosphorus, that may be transported in the suspended or particulate phase.

On the basis of water-quality data collected during 1997-2000, it generally seems unlikely that water-quality goals for streams in the Cheney Reservoir watershed will be attainable for mean base-flow and mean long-term total phosphorus and total suspended solids concentrations and for mean base-flow dissolved nitrate concentrations as long as current (2001) watershed conditions and management practices persist. However, future changes in these conditions and practices that mitigate the transport of these constituents may modify this conclusion.

Mean long-term (all available data for 1997-2000) total phosphorus concentrations compare well with mean phosphorus concentrations estimated from phosphorus loads during a previous investigation of phosphorus transport in the Cheney Reservoir watershed (1997-98). Mean total phosphorus concentrations differed by no more than 0.08 mg/L among the six sampling sites in the Cheney Reservoir watershed.

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REFERENCES

Christensen, V.G., and Pope L.M., 1997, Occurrence of dissolved solids, nutrients, atrazine, and fecal coliform bacteria during low flow in the Cheney Reservoir watershed, south-central Kansas, 1996: U.S. Geological Survey Water-Resources Investigations Report 97-4153, 13 p.

Connor, B.F., Currier, J.P., and Woodworth, M.T., 2001, Results of the U.S. Geological Survey's Analytical Evaluation Program for standard reference samples distributed in October 2000: U.S. Geological Survey Open-File Report 01-137, 116 p.

Hansen, C.V., 1991, Estimates of freshwater storage and potential natural recharge for principal aquifers in Kansas: U.S. Geological Survey Water-Resources Investigations Report 87-4230, 100 p.

Heath, R.C., 1983, Basic ground-water hydrology: U.S. Geological Survey Water-Supply Paper 2220, 84 p.

Hem, J.D., 1992, Study and interpretation of chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Heylar, Thelma, ed., 1994, Kansas statistical abstract 1992-93: Lawrence, University of Kansas Institute for Public Policy and Business Research, 420 p.

Horowitz, A.J., Demas, C.R., Fitzgerald, K.K., Miller, T.L., and Rickert, D.A., 1994, U.S. Geological Survey protocol for the collection and processing of surface-water samples for the subsequent determination of inorganic constituents in filtered water: U.S. Geological Survey Open-File Report 94-539, 57 p.

Kansas Department of Health and Environment, 1994, Kansas register: Topeka, Kansas Secretary of State, v. 13, no. 28, p. 1050-1062.

Mays, L.W., 1996, Water resources handbook: New York, McGraw-Hill Co., variously numbered pages.

Mitchell, M.K., and Stapp, W.B., 1996, Field manual for water quality monitoring-an environmental education program for schools (10th ed.): Dexter, Michigan, Thomson-Shore, Inc., 304 p.

Pope, L.M., 1998, Watershed trend analysis and water-quality assessment using bottom-sediment cores from Cheney Reservoir, south-central Kansas: U.S. Geological Survey Water-Resources Investigations Report 98-4227, 24 p.

Pope, L.M., and Christensen, V.G., 1997, Water-quality study of the Cheney Reservoir watershed, south-central Kansas: U.S. Geological Survey Fact Sheet 14-97, 2 p.

Pope, L.M., and Milligan C.R., 2000, Preliminary assessment of phosphorus transport in the Cheney Reservoir watershed, south-central Kansas, 1997-98: U.S. Geological Survey Water-Resources Investigations Report 00-4023, 29 p.

Putnam, J.E., Lacock, D.L., Schneider, D.R., and Carlson M.D., 1998-2000, Water resources data, Kansas, water years 1997, 1998, 1999: U.S. Geological Survey Water-Data Report KS-97-1, 445 p.; KS-98-1, 447 p.; KS-99-1, 466 p.

Reid, G.K., and Wood, R.D., 1976, Ecology of inland waters and estuaries: New York, D. Van Nostrand Co., 485 p.

Rockers, J.J., Ratcliff, Ivan, Down, L.W., and Bouse, E.F., 1966, Soil survey of Reno County, Kansas: U.S. Department of Agriculture, Soil Conservation Service, 72 p.

U.S. Environmental Protection Agency, 1983, Methods for chemical analysis of water and wastes: U.S. Environmental Protection Agency Report 600/4-79/020, various pagination.

---1993, Methods for the determination of inorganic substances in environmental samples: U.S. Environmental

Protection Agency Report 600/R-93/100, various pagination.

Ward, A.D., and Elliot, W.J., eds., 1995, Environmental hydrology: Boca Raton, Florida, CRC Press LLC, 462 p.

Zeller, D.E., ed., 1968, The stratigraphic succession in Kansas: Kansas Geological Survey Bulletin 189, 81 p.

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