

Occurrence of Dissolved Solids, Nutrients, Atrazine, and Fecal Coliform Bacteria During Low Flow in the Cheney Reservoir Watershed, South-Central Kansas, 1996

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
acre	4,047	square meter
acre-foot	1,233	cubic meter
microgram per liter	1.0	part per billion
mile	1.609	kilometer
milligram per liter	1.0	part per million
square mile	2.590	square kilometer
ton	907.2	kilogram

Temperature can be converted to degrees Celsius (°C) or degrees Fahrenheit (°F) by the equations:

$$^{\circ}\text{C} = 5/9 (^{\circ}\text{F} - 32)$$

$$^{\circ}\text{F} = 9/5 (^{\circ}\text{C}) + 32.$$

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By Victoria G. Christensen and Larry M. Pope

Abstract

A network of 34 stream sampling sites was established in the 1,005-square-mile Cheney Reservoir watershed, south-central Kansas, to evaluate spatial variability in concentrations of selected water-quality constituents during low flow. Land use in the Cheney Reservoir watershed is almost entirely agricultural, consisting of pasture and cropland. Cheney Reservoir provides 40 to 60 percent of the water needs for the city of Wichita, Kansas.

Sampling sites were selected to determine the relative contribution of point and nonpoint sources of water-quality constituents to streams in the watershed and to identify areas of potential water-quality concern. Water-quality constituents of interest included dissolved solids and major ions, nitrogen and phosphorus nutrients, atrazine, and fecal coliform bacteria.

Water from the 34 sampling sites was sampled once in June and once in September 1996 during Phase I of a two-phase study to evaluate water-quality constituent concentrations and loading characteristics in selected subbasins within the watershed and into and out of Cheney Reservoir. Information summarized in this report pertains to Phase I and was used in the selection of six long-term monitoring sites for Phase II of the study.

The average low-flow constituent concentrations in water collected during Phase I from all sampling sites was 671 milligrams per liter for dissolved solids, 0.09 milligram per liter for dissolved ammonia as nitrogen, 0.85 milligram per liter for dissolved nitrite plus nitrate as nitrogen, 0.19 milligram per liter for total phosphorus, 0.20 microgram per liter for dissolved atrazine, and 543 colonies per 100 milliliters of water for fecal coliform bacteria. Generally, these constituents were of nonpoint-source origin and, with the exception of dissolved solids, probably were related to agricultural activities. Dissolved solids probably occur naturally as the result of the dissolution of rocks and ancient marine sediments containing large salt deposits. Nutrients also may have resulted from point-source discharges from wastewater-treatment plants.

An examination of water-quality characteristics during low flow in the Cheney Reservoir watershed provided insight into the spatial variability of water-quality constituents and allowed for between-site comparisons under stable-flow conditions; identified areas of the watershed that may be of particular water-quality concern; provided a preliminary evaluation of contributions from point and nonpoint sources of contamination; and identified areas of the watershed where long-term monitoring may be appropriate to quantify perceived water-quality problems.

INTRODUCTION

Maintaining acceptable surface-water quality in the Cheney Reservoir watershed (fig. 1) is important because of its use for domestic and municipal water supplies, irrigation, livestock watering, and recreation. Additionally, surface-water quality needs to be maintained to prevent detrimental effects on aquatic organisms, disruption of fish populations, or interference with the natural life cycles of plants and animals relying on surface water for their growth and reproduction.

In an attempt to identify and alleviate sources of contamination in the Cheney Reservoir watershed, the Cheney Reservoir Task Force was formed in 1992 to prepare a plan to manage documented or potential contamination within the watershed. This task force was comprised of members from the city of Wichita, Reno and Sedgwick Counties, several Kansas and Federal agencies, and a committee of landowners (Citizen's Management Committee) from within the watershed. The management plan developed from this partnership of private and governmental interests contained provi-

sions for long-term water-quality monitoring at selected sites within the watershed. This monitoring program will help document the existence and extent of water-quality problems within the Cheney Reservoir watershed and evaluate the effectiveness of efforts to alleviate these problems.

Cheney Reservoir was constructed by the Bureau of Reclamation, U.S. Department of the Interior, between 1962 and 1965 to serve as a water-supply source, to provide for downstream flood control, to allow recreational activities such as boating and fishing, and to provide wildlife benefits. The reservoir has a conservation-pool storage of 151,780 acre-feet, with an additional flood-control pool capacity of 80,860 acre-feet. The city of Wichita acquires about 40 to 60 percent of its daily water supply from Cheney Reservoir (Jerry Blain, city of Wichita, Kansas, Water and Sewer Department, oral commun., 1997).

Algal blooms in Cheney Reservoir have occurred frequently during the summer months over the past several years. These blooms have caused taste and odor

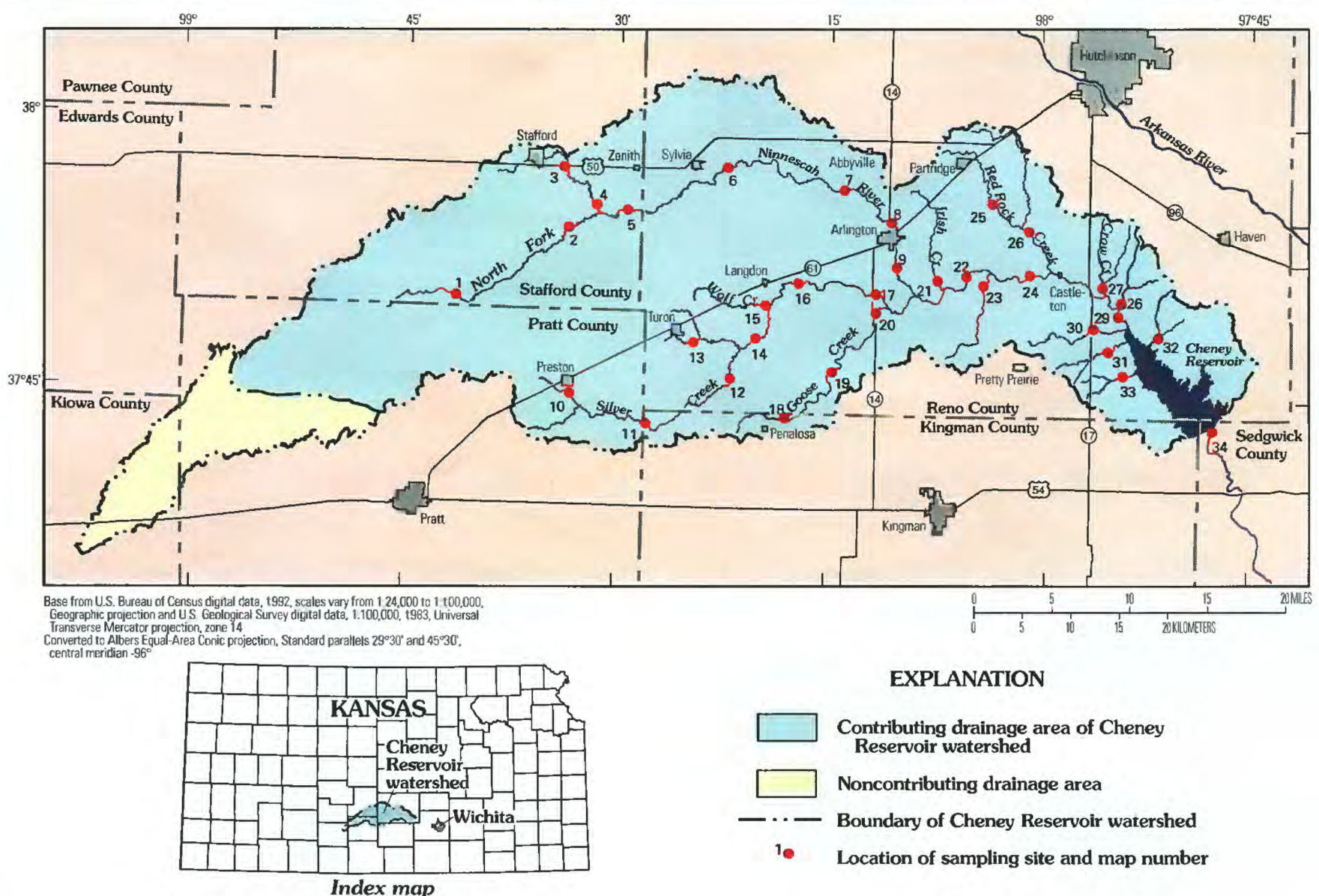


Figure 1. Location of Cheney Reservoir watershed and sampling sites for Phase I of study.

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problems in water withdrawn from Cheney Reservoir by the city of Wichita for use as public supplies. Excessive nutrient concentrations may be causing these blooms. Sporadic, historical water-quality data also indicate that sedimentation and occurrence of pesticides may constitute additional water-quality problems for Cheney Reservoir.

In 1996, the U.S. Geological Survey entered into a cooperative study with the city of Wichita, with technical assistance provided by the Bureau of Reclamation, to define the water quality of the Cheney Reservoir watershed. The purposes of the study are to:

(1) describe spatial differences in concentrations and loading characteristics for selected water-quality constituents within the watershed; (2) evaluate annual loadings of selected constituents into and out of Cheney Reservoir; and (3) evaluate long-term changes in reservoir sediment quality. In this study, loading refers to the mass transport of water-quality constituents expressed as a unit of weight such as pounds or kilograms. Information collected during this study will be used by the Citizen's Management Committee to evaluate the effectiveness of implemented watershed management practices in reducing the loadings of selected water-quality constituents such as nutrients, sediment, and pesticides. Also, this information may have transferability to similar watersheds in Kansas and the Nation.

The Cheney Reservoir watershed study consists of two general phases. Phase I components included a short-term, basinwide preliminary evaluation of low-flow water-quality conditions to document spatial variability in water-quality constituents and to assist in selection of long-term monitoring sites. Phase II consists of a 3-year, data-collection effort to quantify water-quality constituent concentrations and loading characteristics in selected subbasins within the watershed and into and out of Cheney Reservoir.

This report (1) describes the spatial variability of selected water-quality constituent concentrations during stable, low-flow conditions in the Cheney Reservoir watershed and (2) discusses the potential causal factors related to the documented water-quality conditions and possible implications for Cheney Reservoir. Low-flow (nonrunoff-affected) sampling provides a view of water-quality conditions as they exist simultaneously over a broad geographical area (Cheney Reservoir watershed). The low-flow sampling conducted during this study was done at many sites over a short period of time (2 days in both June and September

1996) to minimize variation in water-quality conditions from natural (rainfall) or human-related causes (point-source discharges or irrigation return flow).

Results of low-flow sampling can identify areas of the watershed that may be of potential water-quality concern and, because of the near simultaneous collection of samples, allow site-to-site comparison for a selected set of water-quality constituents. However, results of only low-flow sampling are not adequate for calculation of total annual loads of water-quality constituents nor will low-flow results provide meaningful information for suspended sediment because sediment is not transported in environmentally significant quantities during low flow. Suspended-sediment concentrations and loads will be determined in Phase II of this study.

STUDY AREA

The Cheney Reservoir watershed has a drainage area of about 1,005 square miles (643,000 acres) in parts of five south-central Kansas counties (fig. 1). It is believed that at least 72 square miles (46,000 acres) of the drainage area is noncontributing. Noncontributing drainage does not supply surface runoff or shallow ground-water discharge to the hydrologically contiguous streams in the watershed. The study area for this report includes only the 933-square-mile (597,000 acres) contributing drainage area of the Cheney Reservoir watershed and consists of the North Fork Ninnescah River and associated tributary streams. The study area also includes Cheney Reservoir and its outflow to the North Fork Ninnescah River immediately downstream from the Cheney Reservoir dam.

The total drainage area (1,005 square miles) used in this report is based on a 1996 hydrologic revision of the Cheney Reservoir watershed boundary and is substantially larger than the 901-square-mile area previously published in Putnam and others (1996). The revision was conducted by the U.S. Natural Resources Conservation Service using the latest available information and was limited mainly to the topographically flat southwest part of the watershed. Review of the revised watershed boundary was provided by the U.S. Geological Survey.

The North Fork Ninnescah River Valley and the surrounding plains are underlain by consolidated rocks of Permian age (230–280 million years old) covered by unconsolidated fluvial and windblown deposits of Pleistocene age (less than 1.5 million years old). The

Permian rocks in south-central Kansas include what are known as the “red beds” for their distinctive red color. Thin beds of marine sediments (dolomite and limestone) occur within the “red beds,” but subsurface rocks are mainly sandstone, shale, and siltstone. Some of the lower Permian formations, including the Ninnescah Shale, Wellington, and Salt Plain Formations, contain thick deposits of salt (Zeller, 1968). The subsurface rocks are faulted, but these faults are not known to reach the surface in the North Fork Ninnescah River Valley.

Land use in the Cheney Reservoir watershed (fig. 2) is extensively agricultural, and livestock and crop production are a major part of the economy in the watershed. It was estimated that about 76,000 cattle (as of January 1, 1996) and 14,000 hogs and pigs (as of December 1, 1995) were in the watershed. Most of the cattle are pastured; however, many small dairies and feedlots operate within the watershed. In 1995 (latest data available), there were about 27,000 acres of corn, 51,000 acres of grain sorghum, 5,000 acres of soybeans, and 200,000 acres of wheat harvested in the watershed. Livestock and crop-acreage data were esti-

mated from county data presented in Kansas Department of Agriculture and U.S. Department of Agriculture (1996).

The largest towns in the watershed include Arlington, Castleton, Partridge, Preston, Stafford, Sylvia, and Turon. Populations for these towns range from less than 200 people (Castleton and Preston) to just over 1,200 people (Stafford) (Helyar, 1994).

STUDY METHODS

A network of 34 sampling sites (table 1, fig. 1) was established in the Cheney Reservoir watershed to evaluate spatial variability in concentrations of selected water-quality constituents during low flow. Low flow is streamflow originating primarily as springs or ground-water seepage (including irrigation return flow) or from point-source discharges such as wastewater-treatment plants. Low flow does not have a surface-runoff component. The sampling sites were located on the main stem of the North Fork Ninnescah River, major tributary streams, or tributaries that flow

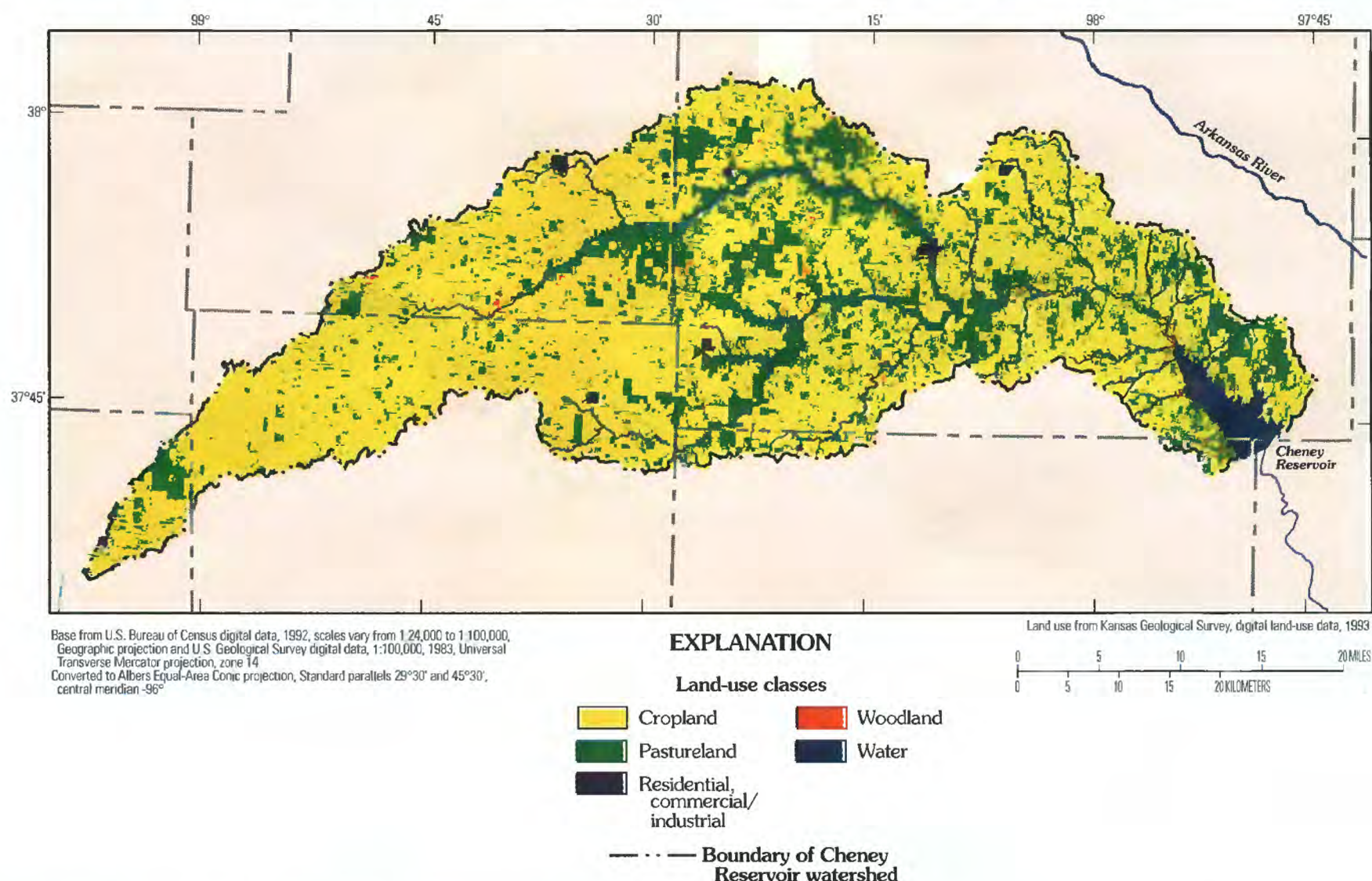


Figure 2. Land use in the Cheney Reservoir watershed.

Table 1. Location and contributing drainage area of sampling sites in the Cheney Reservoir watershed

Map number (fig. 1)	Site name	Contributing drainage area (square miles)
1	North Fork Ninnescah River 10 miles southwest of Stafford, Kansas	104
2	North Fork Ninnescah River 4.8 miles southeast of Stafford, Kansas	185
3	Dooleyville Creek 2.0 miles east of Stafford, Kansas	10.4
4	Dooleyville Creek 5.0 miles southeast of Stafford, Kansas	19.0
5	North Fork Ninnescah River near Zenith, Kansas	239
6	North Fork Ninnescah River near Sylvia, Kansas	308
7	North Fork Ninnescah River near Abbyville, Kansas	389
8	North Fork Ninnescah River north of Arlington, Kansas	401
9	North Fork Ninnescah River south of Arlington, Kansas	412
10	Silver Creek near Preston, Kansas	8.88
11	Silver Creek 6.3 miles southwest of Turon, Kansas	44.0
12	Silver Creek 4.8 miles southeast of Turon, Kansas	69.4
13	Silver Creek tributary near Turon, Kansas	19.5
14	Silver Creek 3.6 miles south of Langdon, Kansas	106
15	Wolf Creek near Langdon, Kansas	26.6
16	Silver Creek 2.0 miles east of Langdon, Kansas	158
17	Silver Creek near Arlington, Kansas	193
18	Goose Creek near Penalosa, Kansas	9.40
19	Goose Creek 7.3 miles southeast of Langdon, Kansas	24.1
20	Goose Creek near Arlington, Kansas	51.8
21	Irish Creek near Arlington, Kansas	12.4
22	North Fork Ninnescah River 5.5 miles southeast of Arlington, Kansas	705
23	North Fork Ninnescah River tributary 6.0 miles southeast of Arlington, Kansas	10.9
24	North Fork Ninnescah River near Pretty Prairie, Kansas	734
25	Red Rock Creek 3.0 miles southeast of Partridge, Kansas	6.96
26	Red Rock Creek near Pretty Prairie, Kansas	53.2
27	Crow Creek 8.0 miles southwest of Haven, Kansas	10.4
28	North Fork Ninnescah River tributary 7.5 miles southwest of Haven, Kansas	8.23
29	North Fork Ninnescah River 8.5 miles southwest of Haven, Kansas	838
30	Tributary to Cheney Reservoir 5.5 miles northeast of Pretty Prairie, Kansas	10.3
31	Tributary to Cheney Reservoir 6.4 miles northeast of Pretty Prairie, Kansas	4.94
32	Tributary to Cheney Reservoir 7.6 miles southwest of Haven, Kansas	5.63
33	Tributary to Cheney Reservoir 7.0 miles east of Pretty Prairie, Kansas	5.17
34	North Fork Ninnescah River at Cheney Dam, Kansas	933

directly into Cheney Reservoir. The sampling sites were selected to help determine the relative contribution of point and nonpoint sources to the streams and to identify areas in the watershed of potential water-quality concern.

Each of the 34 sampling sites were sampled once during June 11–12, 1996, and again during September 10–11, 1996. Five sampling sites during the June period and six sampling sites during the September period were not sampled because the streams at those sites were either dry or had no streamflow (contained only isolated pools). Physical determinations made onsite included streamflow, specific conductance, pH, air and water temperatures, barometric pressure, and dissolved-oxygen concentration. Samples collected for subsequent laboratory determination included dissolved solids and major ions, nutrients (nitrogen and phosphorus species), atrazine, and fecal coliform bacteria. All samples were collected according to methods presented in Horowitz and others (1994).

Samples for all constituents except atrazine were analyzed at the city of Wichita laboratory. Atrazine samples were analyzed at the U.S. Geological Survey laboratory in Lawrence, Kansas, using relatively new enzyme-linked immunosorbent assay (ELISA) procedures similar to those presented in Thurman and others (1990) and used previously in a surface-water study of atrazine in northeast Kansas (Pope and others, 1997). During this study, 12 atrazine samples were analyzed by both the ELISA and the more traditional gas chromatography/mass spectrometry (GC/MS) methods. The average difference between ELISA- and GC/MS-determined concentrations was 0.15 µg/L (microgram per liter) after first assuming all reported less-than-analytical-detection-limit concentrations to be one-half of the detection limit (0.05 µg/L).

An examination of the June and September 1996 low-flow data indicated no substantial or environmentally significant differences in concentrations for water-quality constituents presented in this report; therefore, for purposes of site-to-site comparison, the June and September concentrations were averaged except for site 25, which was not sampled in September because of no streamflow. For each water-quality constituent discussed in this report, an average concentration for the Cheney Reservoir watershed also is presented. This watershed average was calculated from all samples collected in June and September at all sampling sites (a total of 57 samples).

DISSOLVED SOLIDS AND MAJOR IONS

Dissolved solids in surface water are the result of natural dissolution of rocks and minerals or of discharges from municipal or industrial sources. The major constituents of dissolved solids are the cations (positively charged ions) calcium, magnesium, sodium, and potassium, and the anions (negatively charged ions) bicarbonate, carbonate, sulfate, and chloride. Excessively large concentrations of dissolved solids are objectionable in drinking water because of possible physiological effects, unpalatable mineral tastes, and greater costs because of corrosion or the necessity for additional treatment (U.S. Environmental Protection Agency, USEPA, 1986). The Secondary Maximum Contaminant Level (SMCL) for dissolved solids in drinking water is 500 mg/L (milligrams per liter) (USEPA, 1995). SMCLs are not enforceable water-quality standards.

Dissolved solids occur naturally in all surface water at varying concentrations. This natural variability in concentration depends on chemical characteristics of drainage-basin soils, composition of alluvial material, and in some situations the minerals in deeper geologic strata. Larger dissolved-solids concentrations in surface water may be expected in areas underlain by ancient marine sediments containing large salt deposits (Bevans, 1989; Gillespie and Hargadine, 1994). Ground water may dissolve these salts and eventually discharge into surface water. Point-source discharge,

such as from wastewater-treatment plants, also may increase dissolved-solids concentrations in surface water.

The average concentration of dissolved solids for samples collected in June and September 1996 from the Cheney Reservoir watershed was 671 mg/L. Water from all sites sampled on the main stem North Fork Ninnescah River (sites 2, 5, 6, 7, 8, 9, 22, 24, and 29) had average dissolved-solids concentrations greater than the 500-mg/L SMCL for drinking water during low flow (fig. 3). Overall, water from 19 of the 29 sites sampled had average dissolved-solids concentrations greater than the SMCL. The largest of these were in the Silver Creek drainage where the average concentration of dissolved solids in all samples of water from sampling sites 12–17 was 1,120 mg/L. This relatively large average concentration of dissolved solids was the result, in part, of large average concentrations of sodium and chloride of 288 and 478 mg/L, respectively, in water from sampling sites 12–17. These concentrations of sodium and chloride are in contrast to the average concentrations of 106 and 138 mg/L, respectively, in water collected from all other sampling sites. These relatively large sodium and chloride concentrations probably are the result of seepage of ground water affected by dissolution of the Salt Plain Formation or the “Ninnescah salt” in the Ninnescah Shale, which underlie the south-central part of the study area (Gillespie and Hargadine, 1994). The SMCL

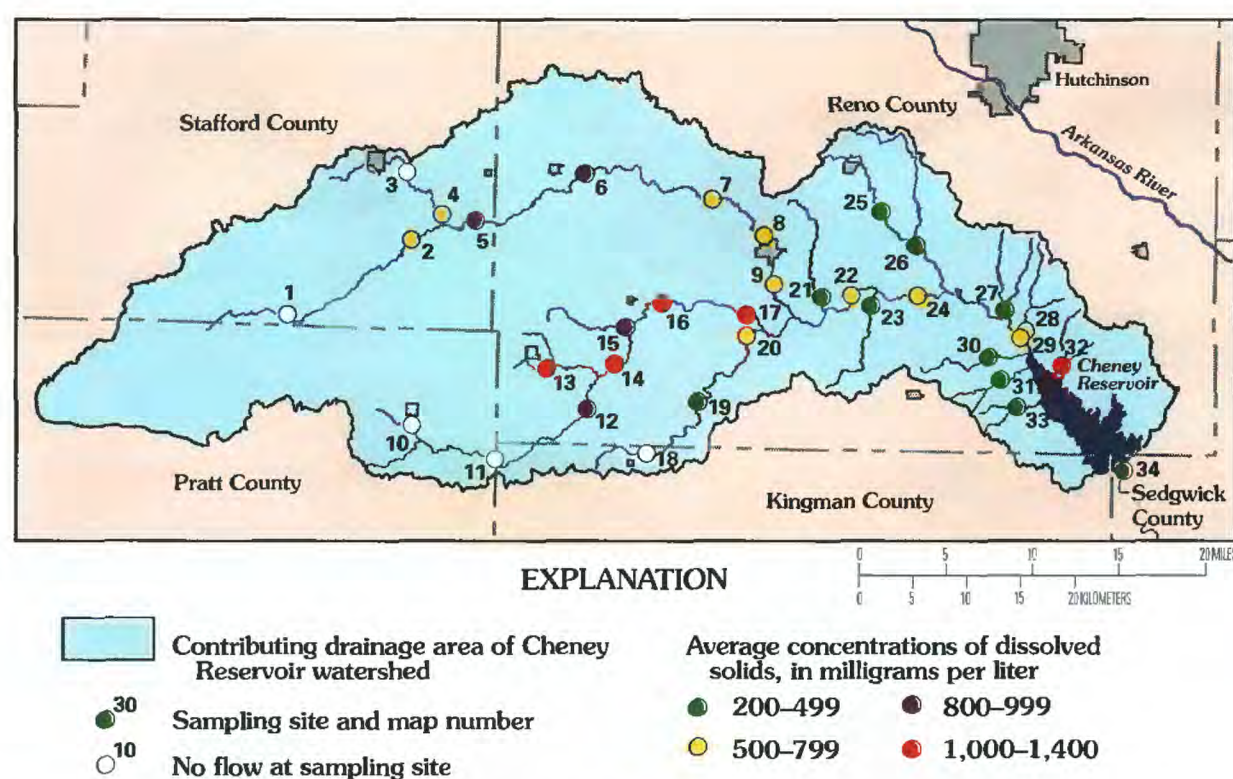


Figure 3. Distribution of average dissolved-solids concentrations in June and September 1996 samples.

for chloride in drinking water is 250 mg/L (USEPA, 1995).

The average dissolved-solids concentration (1,090 mg/L) in water from sampling site 32 was unusually large relative to nearby sampling sites and was due in part to large sulfate concentrations, which averaged 425 mg/L. The source of this sulfate is not known, but it may originate from the dissolution of evaporite sediment, such as calcium sulfate (gypsum), or the oxidation of metal sulfides, such as pyrite. The SMCL for sulfate in drinking water is 250 mg/L (USEPA, 1995).

NUTRIENTS

The elements nitrogen and phosphorus are essential for the growth and reproduction of plants. Rooted aquatic plants and algae, for instance, require dissolved forms of nitrogen and phosphorus as nutrients. Compounds of nitrogen such as ammonia, nitrite, and nitrate are the basic building blocks for protein synthesis. Phosphorus serves as an energy source in cellular chemical reactions. However, large inputs of nitrogen compounds and phosphorus into the aquatic environment can cause excessive algal growth. This may produce taste and odor problems in drinking water, reduce the aesthetic and recreational value of water, and stress aquatic organisms resulting from depleted dissolved-oxygen concentrations when algal blooms die. Large nutrient concentrations in drinking water may have adverse physiological effects on humans and may interfere with growth and reproduction of aquatic organisms. Therefore, it is desirable to prevent or mitigate the introduction of excessive nutrient concentrations into surface water used as public supplies or where sensitive aquatic organisms may be present.

Major sources of nutrients include agricultural activities such as the application of synthetic fertilizers and the pasturing and confined feeding of livestock. Synthetic fertilizers include, among others, anhydrous ammonia, ammonium nitrate, urea, and mono- and diammonium phosphates. The amount of synthetic fertilizer applied in Kansas has increased greatly in the last four decades. In 1950, about 180,000 tons of fertilizer (Kansas State Board of Agriculture and U.S. Department of Agriculture, 1985) were applied in Kansas, whereas by 1994, application was about 1,800,000 tons (Kansas Department of Agriculture and U.S. Department of Agriculture, 1996). It is likely that

this statewide trend in increased use of synthetic fertilizers also has occurred in the Cheney Reservoir watershed. Additionally, farm livestock can produce considerable amounts of nitrogenous organic waste (urine and manure) that can concentrate in areas where large numbers of animals are pastured or confined. The decomposition of large amounts of synthetic fertilizers and manure can release nutrients to surface runoff or to the shallow ground-water system with the potential for discharge to nearby streams.

A less significant nonpoint source of nutrients is the bacterial decomposition of plant and animal protein and possible leaching from septic systems. Also, nutrients, particularly ammonia and nitrate, may be components of rainfall; however, because of the predominate agricultural land use in the watershed and the associated potential for distribution of nutrients, it is presumed that rainfall is a relatively minor contributor of nutrients to the watershed. The most substantial point sources of nutrients in the Cheney Reservoir watershed probably are the municipal wastewater discharges from several small towns within the watershed.

Ammonia

Concentrations of ammonia as nitrogen ranging from 0.44 to 18.7 mg/L (uncorrected for pH) were shown to be acutely toxic to 19 freshwater invertebrate species, whereas acute toxicity among 29 fish species ranged from 0.068 to 3.78 mg/L, uncorrected for pH (USEPA, 1986). Concentrations of ammonia acutely toxic to fish may cause increases in respiratory activity, oxygen uptake, and heart rate; reductions in hatching success and growth and morphological development; and injury to gills, liver, and kidneys. At larger concentrations, fish may experience convulsions, coma, or death (USEPA, 1986).

The average concentration of dissolved ammonia as nitrogen for samples collected in June and September 1996 from the Cheney Reservoir watershed was 0.09 mg/L. Most average dissolved ammonia as nitrogen concentrations in water from sampling sites in the Cheney Reservoir watershed were less than 0.06 mg/L (fig. 4). Of the 29 sites sampled in June and September 1996, water from 17 (59 percent) had average concentrations less than 0.06 mg/L, 10 (34 percent) had average concentrations ranging between 0.06 and 0.50 mg/L, and 2 (7 percent) had average concentrations greater than 0.51 mg/L. None of the dissolved ammonia as nitrogen concentrations determined for either June or September 1996 exceeded Kansas Department of Health and Environment (KDHE, 1994)

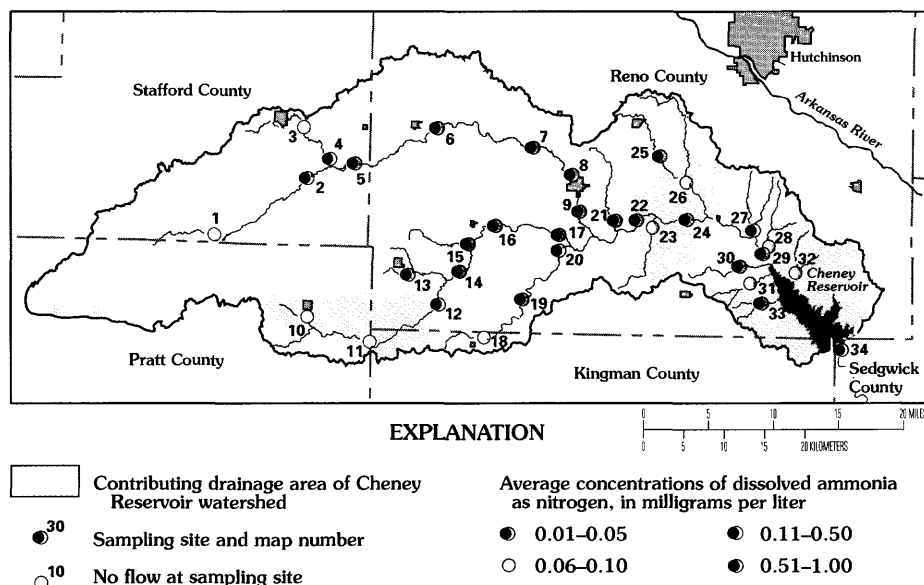


Figure 4. Distribution of average dissolved ammonia as nitrogen concentrations in June and September 1996 samples.

chronic water-quality criteria, which vary depending on water temperature and pH.

For the most part, dissolved ammonia as nitrogen in surface water of the Cheney Reservoir watershed appears to be of nonpoint-source origin, with the larger average concentrations probably related to agricultural activities. Water from site 25 (Red Rock Creek) may be the only sampling site with a relatively substantial point-source discharge effect (wastewater discharge from the town of Partridge). Water from all other sampling sites located downstream from known municipal wastewater discharges had average concentrations less than 0.06 mg/L or the discharges were too small to maintain flow at the sampling site. The reason for the relatively large average concentration at site 19 is not known.

Nitrite Plus Nitrate

The nitrogen cycle is a biogeochemical process whereby elemental nitrogen or organic and inorganic nitrogen compounds are converted by physical or biological actions to other forms of nitrogen. Nitrite and nitrate are inorganic ions produced during various stages of the nitrogen cycle. In most oxygenated surface water, nitrate is by far the most predominate ion because of the rapid oxidation of nitrite.

Nitrate nitrogen is the form of nitrogen most easily used by rooted green plants and algae. Nitrate nitrogen 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 or odor problem in finished drinking water. Because most aquatic organisms can tolerate nitrite plus nitrate concentrations far in excess of what normally might be found even in contaminated surface water, no water-quality criteria have been established for protection of aquatic life.

Adverse human-health effects of large concentrations of nitrates (greater than 10 mg/L) in drinking water include methemoglobinemia (blue-baby syndrome) in infants (USEPA, 1986). Accordingly, a Maximum Contaminant Level (MCL) of 10 mg/L of nitrite plus nitrate as nitrogen has been established for Kansas drinking water by KDHE (1994).

The average concentration of dissolved nitrite plus nitrate as nitrogen for samples collected in June and September 1996 from the Cheney Reservoir watershed was 0.85 mg/L. Of the 29 surface-water sites sampled in June and September 1996, most average concentrations of dissolved nitrite plus nitrate as nitrogen were less than 1.0 mg/L during low flow (fig. 5). The largest average concentrations were in water from sampling sites on the main stem of the North Fork Ninnescah River (sites 5, 6, 7, 8, and 9) and at some downstream tributary sampling sites to either the river (sites 21, 23, and 26) or Cheney Reservoir (sites 28, 30, 31, and 32); however, none of these exceeded the 10-mg/L drinking-water criterion. The smaller concentrations in water from main-stem sampling sites downstream from

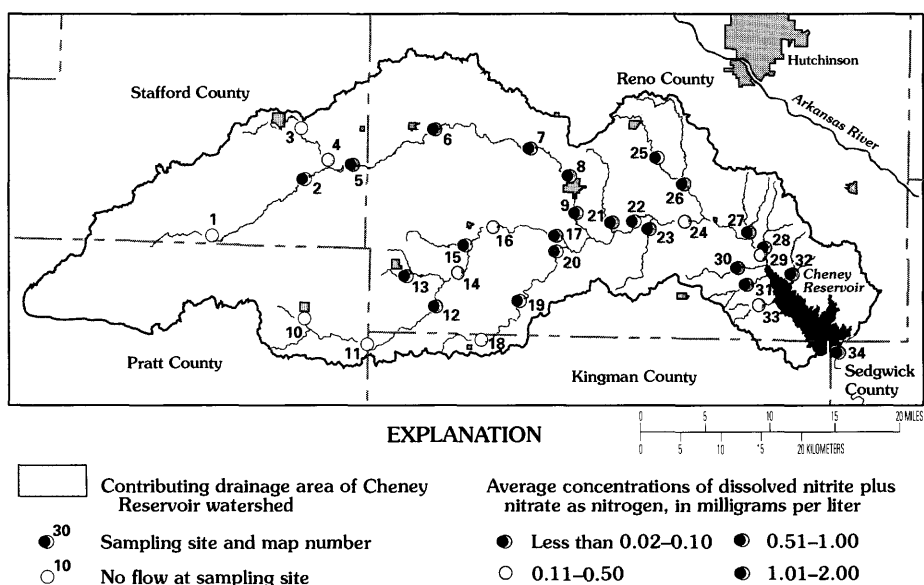


Figure 5. Distribution of average nitrite plus nitrate as nitrogen concentrations in June and September 1996 samples.

site 9 are probably the result of dilution by tributary streams (Silver Creek, for example) and by instream utilization of nitrate by rooted plants and algae between site 9 and Cheney Reservoir. The larger average concentrations in the watershed appear to be of non-point-source origin, presumably from agricultural activities such as livestock production (pasturing or feedlot operations) or fertilizer applications.

Total Phosphorus

Phosphorus is an essential nutrient for plant growth; however, in excess of critical concentrations, it may contribute to the eutrophication of reservoirs. Eutrophication (nutrient enrichment) is characterized by an abundance of nutrients, decreases in dissolved oxygen, dense growth of algae, and an acceleration of the normal rate of ecological succession (Reid and Wood, 1976, p. 293). Phosphorus in its elemental form may be toxic to aquatic organisms and may bioaccumulate in much the same manner as mercury (USEPA, 1986).

To prevent excessive growth of plants and algae and accelerated eutrophication, a goal of 0.10 mg/L of total phosphorus in flowing surface water has been recommended by the USEPA (1986). The average concentration of total phosphorus for samples collected in June and September 1996 from the Cheney Reservoir watershed was 0.19 mg/L. Water from only one sampling site (site 2) in the Cheney Reservoir watershed

had an average total phosphorus concentration less than the recommended goal of 0.10 mg/L (fig. 6). Water from 11 of the 29 sites sampled had average concentrations more than twice this recommended goal.

The widespread occurrence of total phosphorus concentrations greater than the recommended goal of 0.10 mg/L in the Cheney Reservoir watershed probably is the result of nonpoint-source contamination from agricultural activities similar to those presumed responsible for the distribution of nitrite plus nitrate nitrogen. However, the largest average concentration (0.75 mg/L, site 13) may be the result of municipal wastewater discharge from the town of Turon. Primary treatment of sewage removes only about 10 percent of the total phosphorus (Smith, 1980).

ATRAZINE

Atrazine (2-chloro-4-ethylamino-6-isopropylamine-s-triazine), one of the triazine herbicides, is a white, odorless, crystalline solid with a water solubility (at 22 °C) of 70 mg/L (USEPA, 1989). Atrazine is relatively stable in the aquatic medium under environmental pH conditions, and degradation in soil mainly is by photolysis and microbial processes. Its effectiveness lies in its ability to inhibit the photosynthetic reaction and, thus, the cellular production of glucose and adenosine triphosphate, an energy source for other cellular chemical reactions (Kleiner and Orten, 1966). The primary source of atrazine in water in the Cheney Reser-

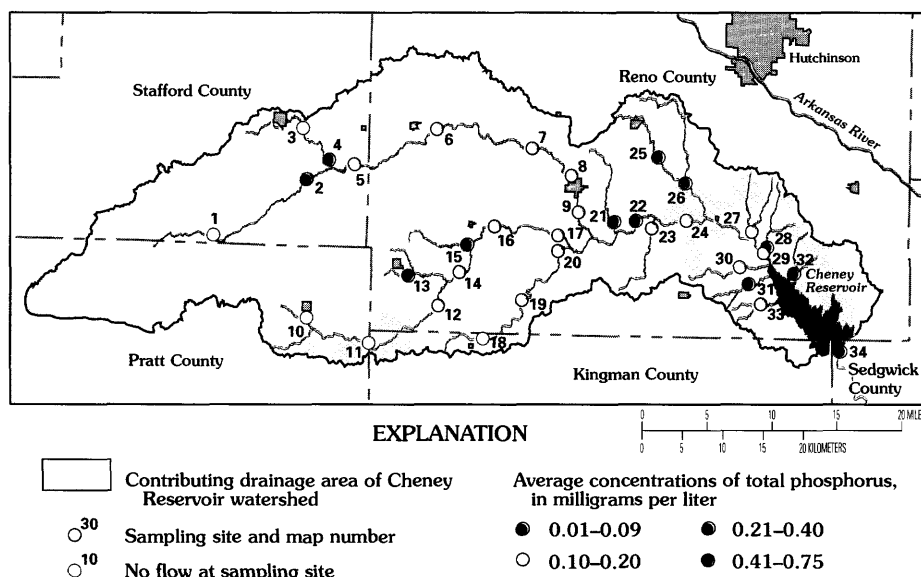


Figure 6. Distribution of average total phosphorus concentrations in June and September 1996 samples.

voir watershed probably is its widespread use as a selective herbicide to control weeds in the production of corn and grain sorghum. A secondary source of atrazine may be its use in controlling weeds along railroad right-of-ways and roads and highways.

Atrazine, where used intensively, may pose a potential threat to public-water supplies because of possible adverse effects on human health and potential toxicity to aquatic life. Currently (1997), KDHE (1994) has established an annual average water-quality criterion of 3.0 µg/L in finished drinking-water supplies.

The average concentration of dissolved atrazine for samples collected in June and September 1996 from the Cheney Reservoir watershed was 0.20 µg/L. In the calculation of this average, sampling sites with average concentrations less than the analytical detection limit (0.10 µg/L) were arbitrarily set at a concentration equal to one-half of this detection limit (0.05 µg/L). Average concentrations of dissolved atrazine did not exceed 1.0 µg/L during low flow at any sampling site in the Cheney Reservoir watershed (fig. 7). Furthermore, average concentrations in water from only two sampling sites (sites 5 and 30) were larger than 0.5 µg/L, whereas average concentrations in water from 11 sampling sites (38 percent) were less than the analytical detection limit of 0.10 µg/L. This indicates that, although atrazine may be used extensively throughout the Cheney Reservoir watershed, average concentrations during low flow are substantially less than the value of the annual average drinking-water criterion.

However, average concentrations during low flow probably are substantially less than those during periods of surface runoff and less than annual averages. In a previous study of atrazine in surface water in northeast Kansas (Pope and others, 1997), it was determined that concentrations of atrazine during surface runoff frequently were as much as 100 times larger than during low flow, and annual averages in a reservoir (Perry Lake) were greatly affected by those runoff concentrations.

FECAL COLIFORM BACTERIA

Fecal coliform bacteria are indigenous to the intestinal tract of warmblooded animals. Therefore, the presence of these organisms in surface water indicate fecal contamination and also may indicate the presence of pathogenic organisms such as reo-, adeno-, and enterovirus; coxsackievirus; and poliovirus. This contamination may come from municipal wastewater discharges, leachate from domestic septic systems, runoff or ground-water seepage from livestock-producing areas (pastures and feedlots) or areas where manure is applied as a fertilizer, or from wildlife populations.

Because of public-health concerns associated with fecal contamination, KDHE (1994) has established a water-quality criterion of 2,000 col/100 mL (colonies per 100 milliliters of water) for noncontact recreation. Noncontact recreation is recreational activities during

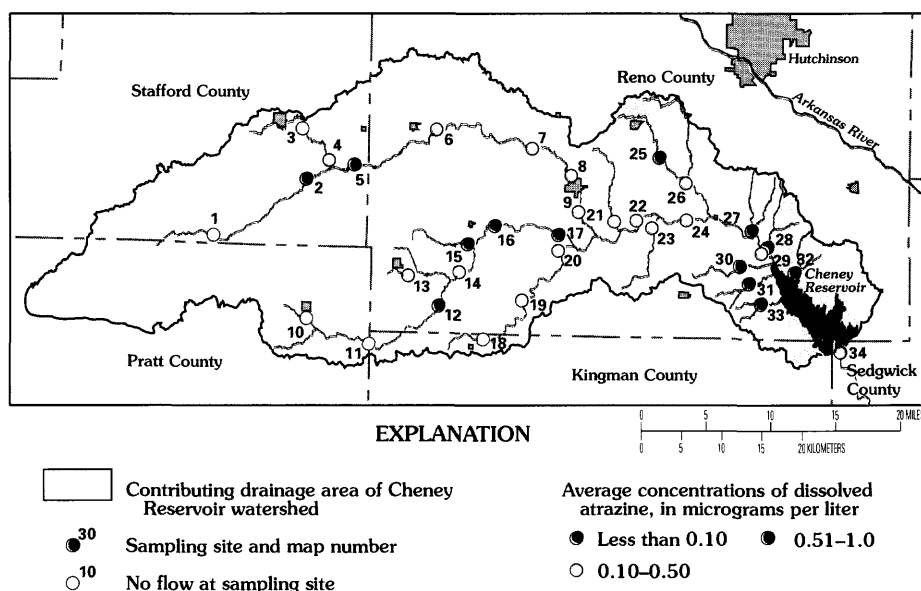


Figure 7. Distribution of average dissolved atrazine concentrations in June and September 1996 samples determined by enzyme-linked immunosorbent assay.

which ingestion of surface water is not probable and includes, but is not limited to, wading, boating, fishing, trapping, and hunting. The North Fork Ninescah River and tributary streams are classified for noncontact recreation. Cheney Reservoir, however, is classified for contact recreation and is subject to the contact-recreational criterion of 200 col/100 mL between April 1 and October 31 of each year.

The average density of fecal coliform bacteria for samples collected in June and September 1996 from the Cheney Reservoir watershed was 543 col/100 mL. Water from all but one sampling site (site 25) in the Cheney Reservoir watershed had average fecal coliform bacteria densities less than the 2,000-col/100 mL noncontact-recreational criterion (fig. 8). The 2,900-col/100 mL density in water from site 25 (determined during the June 1996 sampling) may be the result of wastewater discharge from the town of Partridge. The concentration of dissolved ammonia as nitrogen also was relatively large at site 25 (fig. 4). Generally, densities of fecal coliform bacteria in surface water of the Cheney Reservoir watershed appear to be of nonpoint-source origin and presumably associated with livestock production.

IMPLICATIONS FOR CHENEY RESERVOIR

An examination of water-quality characteristics during low flow in the Cheney Reservoir watershed

provided insight into the spatial variability of water-quality constituents and allowed for between-site comparisons under stable-flow conditions; identified areas of the watershed that may be of particular water-quality concern; provided a preliminary evaluation of contributions from point and non-point sources of contamination; and identified areas of the watershed where long-term monitoring may be appropriate to quantify perceived water-quality problems. Results of this study suggest some potential water-quality problems based on a comparison of constituent concentrations to water-quality criteria. For example, relatively large dissolved-solids concentrations may be a local surface-water problem, particularly in the Silver Creek drainage (sites 12-17, fig. 3), and total phosphorus concentrations greater than the USEPA recommended goal of 0.10 mg/L are common throughout the watershed (fig. 6). However, these potential problems under low-flow conditions may or may not be indicators of long-term water-quality problems for Cheney Reservoir.

Water quality in a reservoir is a reflection of the quality of the inflow regime contributing the majority of the impounded water. Reservoirs in Kansas generally receive the majority of annual inflow during periods of high flow resulting from surface runoff in response to rainfall, and therefore, the quality of this high flow probably is the determining factor in the water quality of Cheney Reservoir.

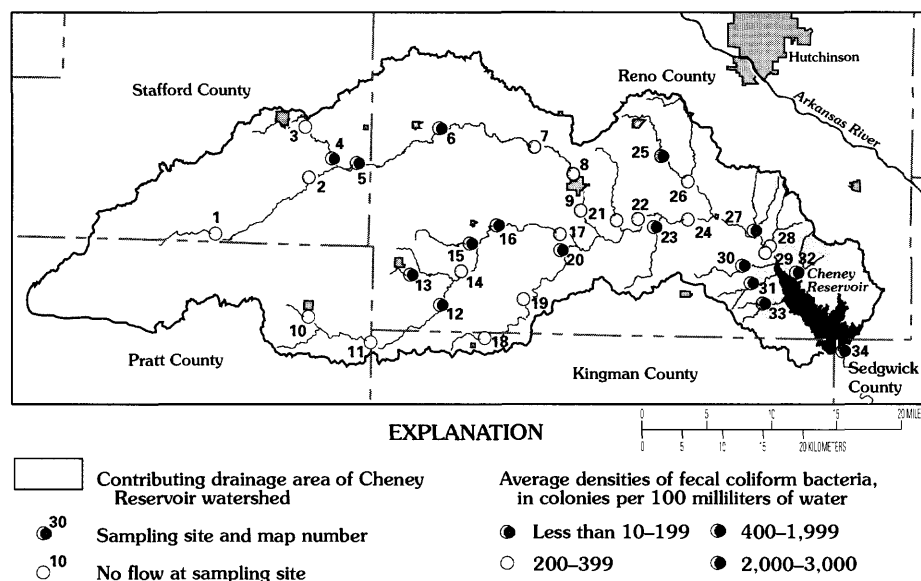


Figure 8. Distribution of average fecal coliform bacteria densities in June and September 1996 samples.

Water-quality constituents may respond differently to increases in streamflow. For example, concentrations of dissolved solids may be largest during low flow when streams are dominated by ground-water discharges containing relatively large concentrations of dissolved minerals. A previous study (Bevans, 1989) showed inverse relationships between dissolved solids and streamflow for the major streams in Sedgwick County. As streamflow increased, dissolved-solids concentrations decreased. Conversely, concentrations of nutrients, atrazine, and fecal coliform bacteria may be largest during high flow when streams are receiving these constituents with runoff from the watershed (Pope, 1995; Pope and others, 1997; Putnam, 1997). The implication of these relations to long-term water quality in Cheney Reservoir are: (1) the average concentration of dissolved solids in the reservoir probably is less than in streams during low flow, and (2) average concentrations of nutrients and atrazine, and average densities of fecal coliform bacteria in the reservoir may be greater than in streams during low flow.

Reservoir processes may obscure some long-term water-quality implications in Cheney Reservoir, particularly for inflow containing nonconservative or hydrophobic constituents such as nutrients and fecal coliform bacteria. These constituents may be transported into the reservoir during high flow, but the evidence of these constituents may be minimal or absent in the outflow (site 34) of the reservoir. For example, inflow concen-

trations of ammonia and nitrite plus nitrate may be reduced or depleted through chemical oxidation and (or) metabolic uptake by the plant and phytoplankton communities within the reservoir, large quantities of phosphorus may be deposited in bottom sediments, and bacteria may die. Therefore, concentrations of these constituents in the outflow of the reservoir may be substantially less than long-term average concentrations in the reservoir as calculated on the basis of the measured constituent load transported into the reservoir. Some of these reservoir processes will be examined in Phase II of the Cheney Reservoir watershed study.

Objectives of Phase I of the Cheney Reservoir watershed study described in this report included the documentation of spatial water-quality variability and identification of areas of potential water-quality concern. This information also assisted in the selection of long-term, water-quality monitoring sites for the watershed. On the basis of information collected during Phase I, six long-term monitoring sites were established: Silver Creek (site 17), Goose Creek (site 20), Red Rock Creek (site 26), two on North Fork Ninnescah River (between sites 8 and 9, and at site 24), and at the outflow from Cheney Dam (site 34). These monitoring sites were selected to provide spatial definition of constituent concentrations and loads within the watershed and into and out of Cheney Reservoir. Additionally, the Silver Creek monitoring site (site 17) is relevant to a concern with dissolved solids (fig. 3), and the monitoring sites on Goose and Red Rock Creeks

are relevant to concerns with relatively large concentrations of ammonia and nitrite plus nitrate (figs. 4 and 5). Determination of water-quality conditions in Cheney Reservoir is planned at several locations within the reservoir during Phase II of this study. Planned activities include collection of water samples at various depths in the reservoir and an evaluation of historical water-quality trends for selected constituents by chemical analyses of reservoir sediment cores.

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