# SOURCES AND LOADS OF NUTRIENTS IN THE SOUTH PLATTE RIVER, COLORADO AND NEBRASKA, 1994–95

**By David W. Litke**

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# FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for a specific contamination problem; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional and national policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 study units, and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Chief Hydrologist

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## CONVERSION FACTORS AND ABBREVIATIONS

| Multiply | By | To obtain |
|---|---|---|
| acre | 0.4047 | hectare |
| cubic foot per second ($ft^3/s$) | 0.02832 | cubic meter per second |
| cubic foot per second per mile [$(ft^3/s)/mi$] | 0.01676 | cubic meter per second per kilometer |
| mile (mi) | 1.609 | kilometer |
| million gallons per day (Mgal/d) | 0.04381 | cubic meter per second |
| pound (lb) | 0.4536 | kilogram |
| pound per day (lb/d) | 0.1826 | ton per year |
| square mile ($mi^2$) | 2.59 | square kilometer |
| ton | 0.9072 | megagram |
| ton per year (ton/yr) | 0.9072 | megagram per year |

Degree Celsius (°C) may be converted to degree Fahrenheit (°F) by using the following equation:

$$°F = 9/5\,(°C) + 32.$$

## ADDITIONAL ABBREVIATIONS

| | | | |
|---|---|---|---|
| mg/L | milligram per liter | MCL | maximum contaminant level |

# Sources and Loads of Nutrients in the South Platte River, Colorado and Nebraska, 1994–95

*By* David W. Litke

## ABSTRACT

The South Platte River Basin was one of 20 river basins selected in 1991 for investigation as part of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program. Nationwide, nutrients have been identified as one of the primary nationwide water-quality concerns and are of particular interest in the South Platte River Basin where nutrient concentrations are large compared to concentrations in other NAWQA river basins. This report presents estimates of the magnitude of nutrient-source inputs to the South Platte River Basin, describes nutrient concentrations and loads in the South Platte River during different seasons, and presents comparisons of nutrient inputs to instream nutrient loads.

Annual nutrient inputs to the basin were estimated to be 306,000 tons of nitrogen and 41,000 tons of phosphorus. The principal nutrient sources were wastewater-treatment plants, fertilizer and manure applications, and atmospheric deposition.

To characterize nutrient concentrations and loads in the South Platte River during different seasons, five nutrient synoptic samplings were conducted during 1994 and 1995. Upstream from Denver, Colorado, during April 1994 and January 1995, total nitrogen concentrations were less than 2 milligrams per liter (mg/L), and total phosphorus concentrations were less than 0.2 mg/L. The water in the river at this point was derived mostly from forested land in the mountains west of Denver. Total nutrient concentrations increased through the Denver metropolitan area, and concentration peaks occurred just downstream from each of Denver's largest wastewater-treatment plants with maximum concentrations of 13.6 mg/L total nitrogen and 2.4 mg/L total phosphorus. Nutrient concentrations generally decreased downstream from Denver.

Upstream from Denver during April 1994 and January 1995, total nitrogen loads were less than 1,000 pounds per day (lb/d), and total phosphorus loads were less than 125 lb/d. Total nutrient loads increased through the Denver metropolitan area, and load peaks occurred just downstream from each of Denver's largest wastewater-treatment plants, with a maximum load of 14,000 lb/d total nitrogen and 2,300 lb/d total phosphorus. In April 1994, nutrient loads generally decreased from Henderson, Colorado, to North Platte, Nebraska. In January 1995, however, nutrient loads increased from Henderson to Kersey, Colorado (maximum loads of 31,000 lb/d total nitrogen and 3,000 lb/d total phosphorus), and then decreased from Kersey to North Platte.

Seasonal nutrient loads primarily were dependent on streamflow. Total nitrogen loads were largest in June 1994 and January 1995 when streamflows also were largest. During June, streamflow was large, but nitrogen concentrations were small, which indicated that snowmelt runoff diluted the available supply of nitrogen. Total phosphorus loads were largest in June, when streamflow and phosphorus concentrations were large, which indicated an additional source of phosphorus during snowmelt runoff. Streamflow along the South Platte River was smallest in April and August 1994, and nutrient loads also were smallest during these months.

The downstream pattern for nutrient loads did not vary much by season. Loads were large at Henderson, decreased between Henderson and Kersey, and usually were largest at Kersey. The magnitude of the decrease in loads between Henderson and Kersey varied between synoptics and was dependent on the amount of water removed by irrigation ditches. Nutrient loads leaving the basin were very small compared to the estimated total nutrient inputs to the basin.

Streamflow balances indicated that the South Platte River is a gaining river throughout much of its length; streamflow-balance residuals were as large as 15 cubic feet per second per mile. Nutrient-load balances indicated that increases in river nitrate loads were, in some places, due to nitrification and, elsewhere, were due to the influx of nitrate-enriched ground water to the river. Nutrient-load balances also indicated that the South Platte River was effluent-dominated from Denver to about 60 miles downstream from Denver.

# INTRODUCTION

In 1991, the U.S. Geological Survey (USGS) began to implement the full-scale National Water-Quality Assessment (NAWQA) Program. The goals of the NAWQA Program are to describe the status and trends in the quality of a large, representative part of the Nation's surface- and ground-water resources and to provide a sound, scientific understanding of the primary natural and human factors affecting the quality of these resources (Leahy and others, 1990). The South Platte River Basin was among the first 20 NAWQA study units selected for study under the full-scale implementation plan (Dennehy, 1991).

Nutrients are essential substances for plant growth and were identified as one of the primary water-quality concerns in the Nation. Nutrients are of particular interest in the South Platte River Basin because they occur in large concentrations; a comparison of historical nutrient-concentration data determined that nitrate and phosphorus concentrations in the South Platte River Basin were among the largest in the first 20 NAWQA study units (Mueller and others, 1995).

In water, nutrients are dissolved or can be attached to suspended sediment, suspended organic matter, and bottom materials. Because dissolved nutrients can be rapidly assimilated by plants, their concentrations in natural water usually are small. Nutrients can be adsorbed to or released from sediment or organic matter. Excessive concentrations of nutrients in rivers, lakes, and reservoirs can accelerate the growth of algae and other aquatic plants, causing problems such as clogged pipelines, fishkills, and restricted recreation. Phosphorus generally is the controlling factor for reservoir eutrophication, and the U.S. Environmental Protection Agency (USEPA) has recommended that total phosphorus concentrations be less than 0.1 mg/L in rivers and less than 0.05 mg/L where rivers enter lakes and reservoirs (U.S. Environmental Protection Agency, 1986). The USEPA also has set a maximum contaminant level (MCL) of 10 mg/L for nitrate, as nitrogen, in drinking water (U.S. Environmental Protection Agency, 1990).

## Purpose and Scope

This report presents estimates of the magnitude of nutrient-source inputs to the South Platte River Basin, describes nutrient concentrations and loads in the South Platte River during different seasons, and presents comparisons of nutrient inputs to instream nutrient loads. Nutrient samples were collected before the irrigation season (April 1994), during the irrigation season (May, June, and August 1994), and after the irrigation season (January 1995). Samples were collected from among 41 sites located on the South Platte River and its tributaries from Denver, Colorado, to North Platte, Nebraska. Nitrogen and phosphorus species are the nutrients discussed in this report and include dissolved ammonium, dissolved nitrite, dissolved nitrite plus nitrate, dissolved organic nitrogen, total organic nitrogen, dissolved phosphorus, and total phosphorus. In this report, all nitrogen species are reported as nitrogen, and all phosphorus species are reported as phosphorus.

## Acknowledgments

The author would like to thank the USGS employees who assisted in the collection of the nutrient water samples for this study, particularly Robert A. Kimbrough and Dennis E. Smits. The author also thanks Martha A. Crawford, Denis F. Healy, and Gerhard Kuhn of the USGS for their thorough and thoughtful reviews of this report.

# DESCRIPTION OF BASIN

The South Platte River Basin (fig. 1) has a drainage area of about 24,300 mi$^2$; 79 percent of the basin is in Colorado, 15 percent is in Nebraska, and 6 percent is in Wyoming (Dennehy, 1991). The South Platte River originates in the mountains of central Colorado and flows about 450 mi northeast across the Great Plains to the confluence with the North Platte River at North

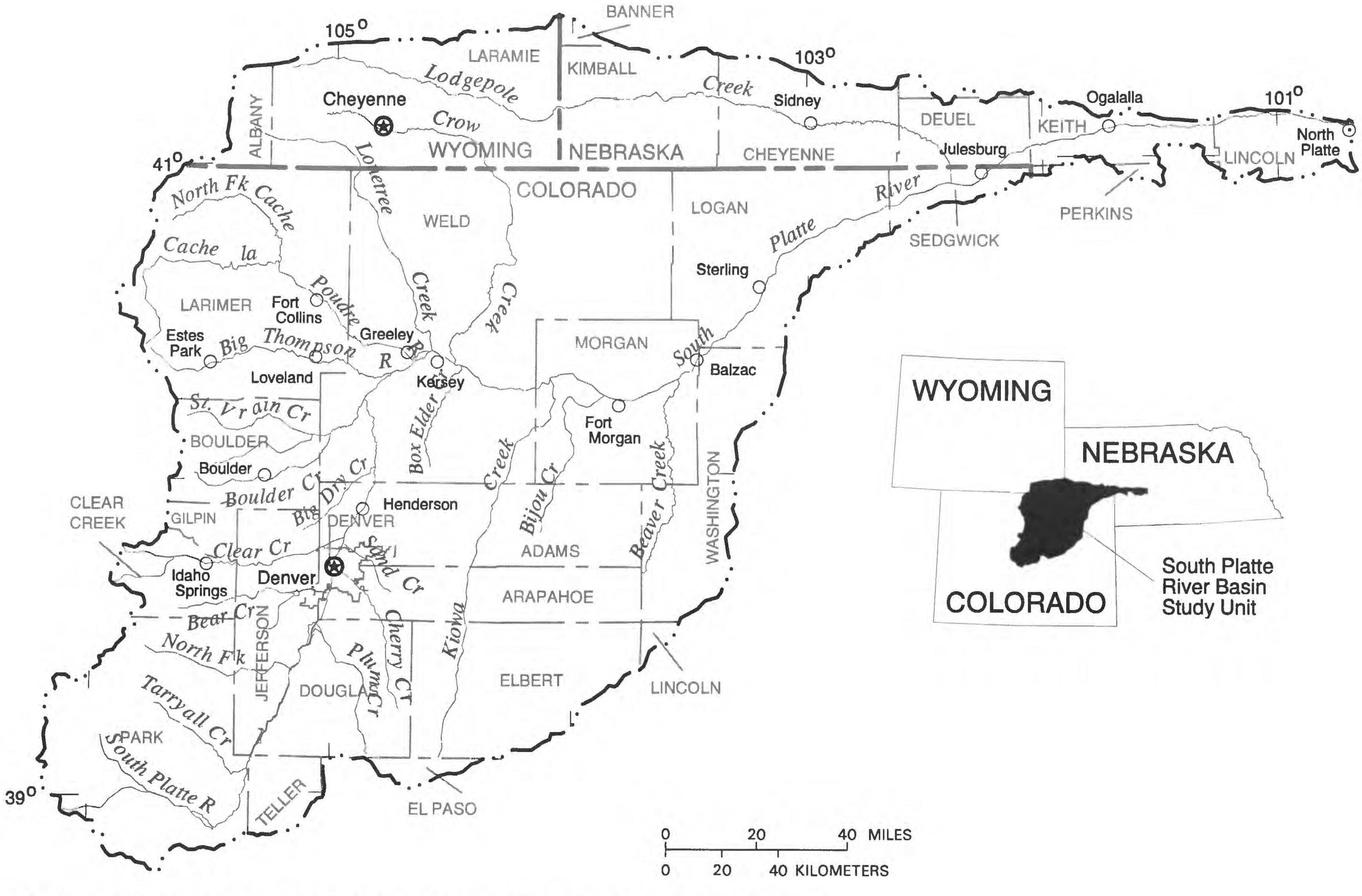


**Figure 1.** Location of the study unit and selected cities and streams in the South Platte River Basin.

Platte, Nebraska. The major tributaries of the South Platte River (Clear Creek, St. Vrain Creek, Big Thompson River, and Cache La Poudre River) are perennial streams that originate in the Rocky Mountains; plains streams (Kiowa Creek, Bijou Creek, Beaver Creek, and Lodgepole Creek) are ephemeral and contribute little water to the South Platte River during most years. The South Platte alluvial-aquifer system, which is 4,000 $mi^2$ in area and is located in the alluvial valley and benchlands of the South Platte River and its tributaries, is hydraulically connected to the river and contributes substantially to streamflow in the river. The South Platte River has become a drain for ground-water irrigation return flows from adjacent agricultural lands, and the return flow affects water quality in the river (Dennehy and others, 1993). In a study of available water-quality data in the basin during 1980–92, Dennehy and others (1995) determined that nutrient concentrations were largest in urban and agricultural land-use areas. Information about the water-quality effects of other basin characteristics, such as physiography, climate, geology, soils, land use, and water use, is included in Dennehy and others (1993).

## NUTRIENT SOURCES

To manage nutrients in rivers, sources of nutrients to rivers need to be identified and quantified. Since the passage of the Federal Water Pollution Control Act Amendments of 1972 [also referred to as the Clean Water Act (Public Law 92-500)], much effort has been directed toward controlling point sources of nutrients to rivers. Point sources are sources that exist at a specific location, such as the discharge of municipal wastewater-treatment-plant effluent into a river. However, the importance of nonpoint sources of nutrients also is recognized. Nonpoint sources are diffuse sources that cannot be assigned a single location, such as storm runoff into rivers and ground-water discharge into rivers. Nonpoint sources generally carry nutrients that are present on the land surface. Human activities have become an important contributor of nutrients to the land surface; for example, the use of nitrogen fertilizers in the United States increased twentyfold between 1945 and 1993, and phosphorus use tripled (Puckett, 1995). The atmosphere also contributes nutrients (natural and anthropogenic) to the land surface through wet and dry deposition. Annual inputs of nutrients from urban, agricultural, and atmospheric sources are estimated in the following sections. The inputs are based on data sets collected from 1980 to 1993, and the estimates are assumed to be representative for the study period (1994–95).

### Urban

Urban land use (fig. 2) is a source of nutrients primarily through point-source discharges from municipal wastewater-treatment plants. There are more than 100 municipal wastewater-treatment plants in the South Platte River Basin. The locations of the 29 largest wastewater-treatment plants, which discharge at least 1.0 Mgal/d, are shown in figure 2. Together, these plants discharge 277 Mgal/d of effluent, which is about 95 percent of the total wastewater-treatment-plant discharge in the basin. Effluent discharges from individual plants can make up a substantial part of the streamflow downstream from the discharge points. For example, Metro Wastewater Reclamation District annually contributes about 69 percent of the flow and as much as 100 percent of the flow on a given day in the South Platte River downstream from the discharge point (Dennehy and others, 1995).

Nutrient inputs from the 29 largest wastewater-treatment plants in the basin were estimated by using available data from the USEPA National Pollution Discharge Elimination System data base and by using data collected directly from the wastewater-treatment plants. Inputs were estimated by multiplying the 1993 median wastewater-treatment-plant discharge by 1993 median nutrient-constituent concentrations. Discharge data were available from wastewater-treatment plants, but only limited nutrient-concentration data (primarily ammonium data) were available. Using the available data, methods were developed to estimate nutrient concentrations for sites that had no data (Matthew Pocernich, Colorado State University, written commun., 1995). The estimated nitrogen input to the basin from the 29 wastewater-treatment plants for 1993 was 7,000 tons, and the estimated phosphorus input was 1,200 tons (table 1). The nitrogen input was 38 percent ammonium, 36 percent nitrite plus nitrate, and 26 percent total organic nitrogen. The phosphorus input predominantly was dissolved orthophosphate.

The wastewater-treatment-plant inputs, summed by the reach of the South Platte River in which they are located, are shown in figure 3; the reach sums include wastewater-treatment-plant inputs located on tributary streams in each reach. However, not all wastewater-

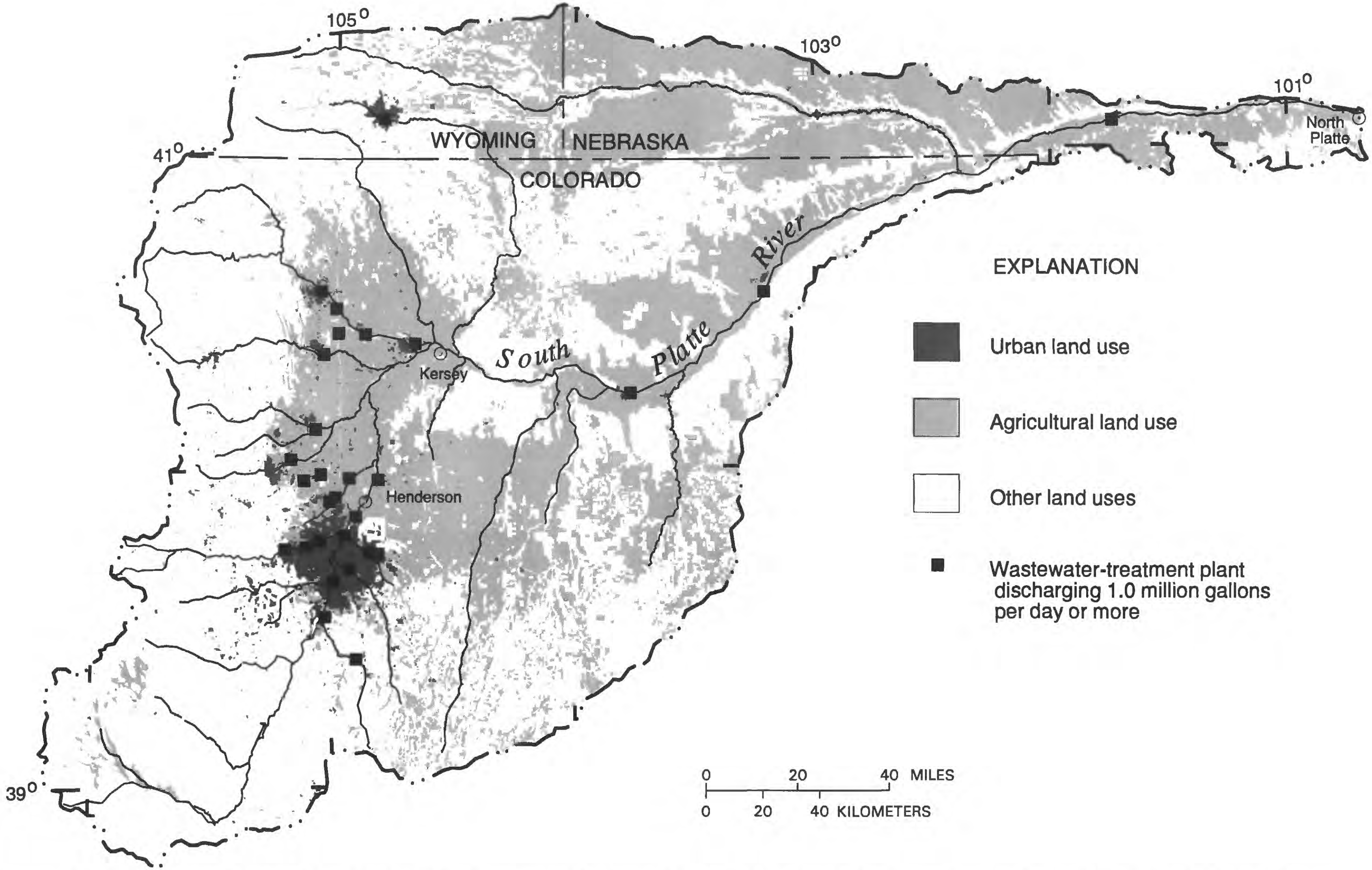


**Figure 2.** Urban and agricultural land use (modified from Fegeas and others, 1983) and the location of major wastewater-treatment plants in the South Platte River Basin.

**Table 1.** Estimated annual nutrient inputs to the South Platte River Basin

[Inputs are in tons per year; --, no data]

| Source | Nitrogen | Phosphorus | Method of calculation and source of data |
|---|---|---|---|
| Urban | | | |
| Wastewater-treatment plants | 7,000 | 1,200 | Based on 1993 data collected from wastewater-treatment plants. |
| Turf fertilizer application | 7,000 | -- | Use rate of 30 pounds of nitrogen per urbanized acre and an urbanized area of 470,000 acres. |
| Agricultural | | | |
| Fertilizer | 132,000 | 14,000 | Sum of county data from Battaglin and Goolsby (1995). |
| Manure | 94,000 | 26,000 | Sum of county data from Richard Alexander (U.S. Geological Survey, written commun., 1992). |
| Atmospheric | 66,000 | -- | Based on precipitation-chemistry data for 1980–91 from National Atmospheric Deposition Program (NRSP-3)/National Trends Network (1992). |
| Total (rounded) | 306,000 | 41,000 | |

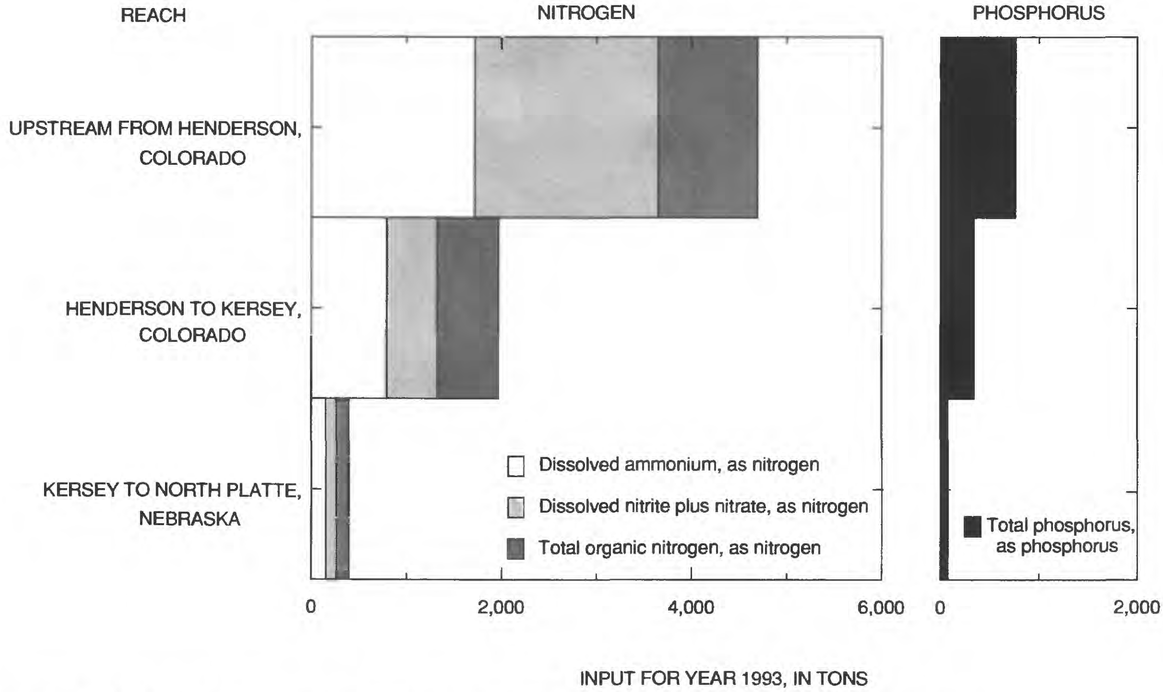


**Figure 3.** Estimated nutrient inputs for 1993 from the 29 largest wastewater-treatment plants.

treatment-plant inputs are discharged into rivers; some plants have the option of discharging into irrigation ditches. In addition, a part of the wastewater-treatment-plant inputs on tributary streams might be removed from tributary streams by irrigation ditches and might not be delivered to the South Platte River. About 67 percent of the total estimated wastewater-treatment-plant input is in the South Platte River upstream from Henderson, Colorado, where the river flows through the Denver metropolitan area. Another 28 percent of the total estimated input is in the Henderson to Kersey, Colorado, reach of the South Platte River. This part of the input originates from the St. Vrain Creek, the Big Thompson River, and the Cache La Poudre River drainages. From Kersey to North Platte, Nebraska, there are few wastewater-treatment-plant inputs (5 percent of the total).

Nutrients also are input to the basin in urban areas from the application of fertilizer to lawns and turf. About 30 lb of nitrogen is applied each year per acre of urbanized area in three cities (Greeley, Fort Collins, and Loveland, Colorado) in the South Platte River Basin (David DuBois, Northern Front Range Water Quality Planning Association, written commun., 1995). This rate would amount to an input of 7,000 tons of nitrogen per year (table 1) over the total urban land-use area (470,000 acres) (fig. 2) in the basin. Part of this land-based nutrient input might be conveyed to rivers via storm runoff or ground-water discharge. Urban storm runoff in the Denver metropolitan area contains elevated concentrations of nitrogen and phosphorus, but storms are of short duration so that annual storm-runoff contributions to instream nutrient loads are small. Ellis and others (1984) estimated that storm runoff contributed 5 percent (80 tons) of the total nitrogen load and 6 percent (22 tons) of the total phosphorus load at a site on the South Platte River downstream from the Denver metropolitan area during the April through September 1981 storm season. These data indicated that nutrient loads from urban storm runoff were substantially smaller than nutrient loads from wastewater-treatment plants.

### Agricultural

Agricultural land use (fig. 2) is a source of nutrients primarily through fertilizer and manure that are applied to crops, which were estimated to be 226,000 tons/yr of nitrogen and 40,000 tons/yr of phosphorus for all counties in the South Platte River Basin (table 1). These estimates represent an upper limit for actual applications because the estimates are the sum of county applications even though some parts of a county might not be completely in the South Platte River Basin. The county fertilizer inputs were calculated based on fertilizer sales data from the U.S. Department of Agriculture for 1991 (Battaglin and Goolsby, 1995); the county manure inputs were calculated based on county animal populations from the U.S. Department of Agriculture for 1987 (Richard Alexander, U.S. Geological Survey, written commun., 1992). The fertilizer and manure nitrogen inputs, when averaged over the total agricultural land area of the basin, equaled about 80 lb of nitrogen per acre. However, much of the agricultural inputs are concentrated in the irrigated alluvial lands where corn is grown for silage and feedlots are common. Fertilizer and manure inputs in these lands most likely are substantially larger than the overall average. Large quantities of nutrients in manure are generated at cattle feedlots, but feedlots are designed to retain these nutrients (Borman, 1981). Feedlot manure generally is trucked to nearby farms for land application. In the United States, farmers are estimated to apply from 24 to 38 percent more fertilizer than crops need (Trachtenberg and Ogg, 1994), so some excess nutrients might be available in the soil and might be transported to streams by storm runoff or ground-water discharge. In an area near Greeley, elevated nitrate concentrations in ground water have been detected in agricultural areas surrounding feedlots (Schuff, 1992).

### Atmospheric

Atmospheric deposition was estimated to contribute 66,000 tons of nitrogen to the basin annually (table 1). This estimate was based on nitrate- and ammonium-concentration data for 1980–91 from five National Atmospheric Deposition Program/National Trend Network (NADP/NTN) precipitation sites in the basin [National Atmospheric Deposition Program (NRSP-3)/National Trends Network, 1992]; phosphorus-concentration data were not available. The nitrogen estimate was calculated by assigning volume-weighted annual average nitrogen concentrations from the five NADP/NTN sites to nearby parts of the basin and, then, by multiplying the assigned concentrations by the long-term average annual precipitation for each part of the basin. The NADP/NTN site concentrations were assumed to be representative of the nearby parts of the basin. Small areas of the basin (such as urban areas) might have substantially different nitrogen concentrations in precipitation, but the size of these anomalous areas was assumed to be small enough so that the basin estimate was not affected. About 70 percent of the atmospheric nitrogen input occurs over the forested or rangeland parts of the basin. However, streams in forested and rangeland areas have significantly smaller nitrogen concentrations than streams in urban and agricultural land-use areas (Dennehy and others, 1995), which indicates that large nutrient concentrations in streams are more a result of fertilizer, manure, and wastewater-treatment-plant inputs than of atmospheric inputs.

## NUTRIENT LOADS

Instream nutrient loads are the product of streamflow and nutrient concentrations in the water. To characterize nutrient loads in the South Platte River during different seasons, streamflow and nutrient-concentration data were collected as part of five nutrient synoptic samplings during 1994 and 1995.

### Data Collection

Synoptic sampling is designed to characterize water quality in a large area by collecting a large number of samples during a short time period. To ensure that data along a river system are comparable, sampling schedules are designed to follow a parcel of water as it flows downstream through the system. For this study, the timing of sampling was approximate because detailed information about time of travel was not available for the entire South Platte River. Where time-of-travel data were lacking, sites were sampled within a few days of each other; the total time of travel between Denver and North Platte, Nebraska, was estimated to be 10 days.

Synoptic sampling occurred at a total of 41 sites (fig. 4 and table 3 in the "Supplemental Data" section at the back of the report). The April 1994 and January 1995 synoptic samplings were designed to occur before and after the irrigation season to enable calculation of mass balances while minimizing the effect of irrigation inputs and outputs. The May, June, and August 1994 synoptic samplings were designed to examine variability in nutrient loads during the irrigation season.

Thirty-six sites (26 main-stem sites and 10 tributary sites) were sampled during the April synoptic sampling (April 12–May 3, 1994); 15 sites (10 main-stem sites and 5 tributary sites) were sampled during the May synoptic sampling (May 9–11, 1995); 15 sites (10 main-stem sites and 5 tributary sites) were sampled during the June synoptic sampling (May 31–June 2, 1994); 18 sites (10 main-stem sites and 8 tributary sites) were sampled during the August synoptic sampling (August 29–31, 1994); and 38 sites (26 main-stem sites and 12 tributary sites) were sampled during the January synoptic sampling (January 9–20, 1995).

Water samples were collected using standard USGS depth- and width-integrating procedures (Edwards and Glysson, 1988; Shelton, 1994). Field parameters measured at the time of sampling included streamflow, specific conductance, hydrogen-ion activity (pH), water temperature, and dissolved-oxygen concentration. Raw and filtered samples were preserved with mercuric chloride (except for the January 1995 synoptic sampling because use of mercuric chloride as a preservative was discontinued by the USGS in October 1994), chilled, and sent to the USGS National Water-Quality Laboratory in Arvada, Colorado, for analysis. Water samples were analyzed for dissolved ammonium, dissolved nitrite, dissolved nitrite plus nitrate, dissolved organic nitrogen plus ammonium, total organic nitrogen plus ammonium, dissolved orthophosphate, dissolved phosphorus, and total phosphorus, using methods documented in Patton and Truitt (1992) and Fishman (1993). All nitrogen species concentrations were reported as nitrogen, and all phosphorus species concentrations were reported as phosphorus. The nutrient data are summarized in table 3 in the "Supplemental Data" section at the back of the report. Nutrient species concentrations discussed in this report can be calculated based on the data in table 3. Total organic nitrogen is calculated by subtracting ammonium from total organic nitrogen plus ammonium. Total nitrogen is calculated as the sum of total organic nitrogen plus ammonium and dissolved nitrite plus nitrate. Suspended phosphorus is calculated by subtracting dissolved phosphorus from total phosphorus.

Quality-control data (table 2) indicated that the nutrient results were reliable. Analyses of 14 field blanks resulted in 24 detections out of 112 analyses, but these detections were all within 0.02 mg/L of the minimum reporting level. Dissolved ammonium was detected in 10 of the 14 blanks, and total phosphorus

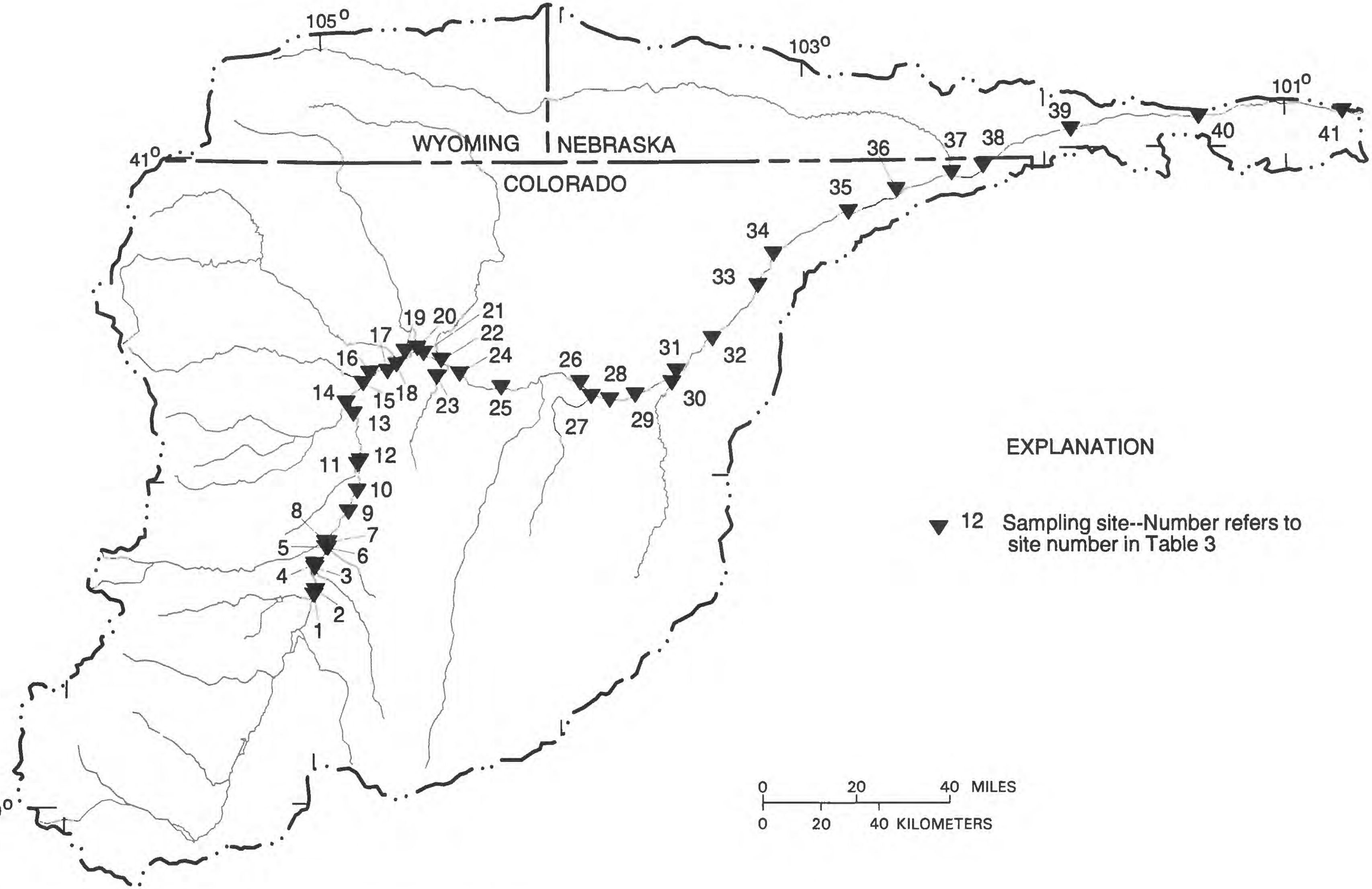


**Figure 4.** Location of nutrient synoptic-sampling sites, 1994–95.

**Table 2.** Summary of quality-control data

[mg/L, milligram per liter; nitrogen species reported as nitrogen; phosphorus species reported as phosphorus; --, not applicable]

| Constituent | Minimum reporting level (mg/L) | Field blanks[1] | | Replicates[2] | |
|---|---|---|---|---|---|
| | | Number with detections | Median value of detections (mg/L) | Maximum difference (percent) | Median difference (percent) |
| Dissolved ammonium | 0.01 | 10 | 0.02 | 34 | 6 |
| Dissolved nitrite | .01 | 1 | .01 | 3 | 1 |
| Dissolved nitrite plus nitrate | .05 | 0 | -- | 3 | 2 |
| Dissolved organic nitrogen plus ammonium | .2 | 0 | -- | 19 | 8 |
| Total organic nitrogen plus ammonium | .2 | 0 | -- | 11 | 3 |
| Dissolved orthophosphate | .01 | 2 | .01 | 11 | 2 |
| Dissolved phosphorus | .01 | 4 | .02 | 9 | 2 |
| Total phosphorus | .01 | 7 | .02 | 20 | 4 |

[1]Analyses done on 14 field blanks.

[2]Analyses done on 16 sets of replicates.

was detected in 7 of the 14 blanks; the concentrations detected were small (table 2), but the data indicated that a small positive bias might exist in the dissolved-ammonium and total phosphorus data. The median field-blank concentration for ammonium was 10 percent of the median environmental-sample concentration, and the median field-blank concentration for total phosphorus was 1 percent of the median environmental-sample concentration. Analyses of 16 sets of replicates indicated that reproducibility of results was good; the median difference between replicates ranged from 1 percent for dissolved nitrite to 8 percent for dissolved organic nitrogen plus ammonium.

## Concentration Variation

The April 1994 (fig. 5) and January 1995 (fig. 6) synoptic samplings provided detailed information about nutrient-concentration patterns in the South Platte River. Data for tributary sites are not shown in these figures but are listed in table 3.

Dissolved-ammonium concentrations in the South Platte River were large downstream from wastewater-treatment plants in the Denver area (figs. 5*B* and 6*B*), but decreased downstream as ammonium was used by biota or converted to nitrate by bacteria (nitrification). Ammonium concentrations in the South Platte River and in tributary streams (table 3) generally were largest in January. These large concentrations might be due to decreased rates of biotic uptake and nitrification in the winter; also, some wastewater-treatment plants discharge more ammonium in the winter in accordance with their discharge permits (Matthew Pocernich, Colorado State University, written commun., 1995). Un-ionized ammonia concentrations, which were calculated based on pH, water temperature, and dissolved-ammonium concentrations, were less than the State of Colorado chronic standards for un-ionized ammonia for segments of the South Platte River (Colorado Department of Health, 1993) during the five synoptic samplings, except during April when the un-ionized ammonia concentration at South Platte River at Henderson (0.11 mg/L) was larger than the chronic standard for that segment (0.10 mg/L).

Dissolved nitrite plus nitrate was the predominant nitrogen species in the South Platte River (figs. 5*B* and 6*B*). Although the South Platte River is not classified for water-supply use downstream from Big Dry Creek (river mile 61.8), the drinking water MCL of 10 mg/L for nitrate is a useful point of reference for nitrate concentrations; and nowhere on the South Platte River during the five synoptic samplings did the concentration of nitrate exceed 10 mg/L. The largest nitrite plus nitrate concentrations in the South Platte River (figs. 5*B* and 6*B*) occurred in Denver, downstream from a wastewater-treatment plant that includes nitrification in its wastewater treatment. Nitrite plus

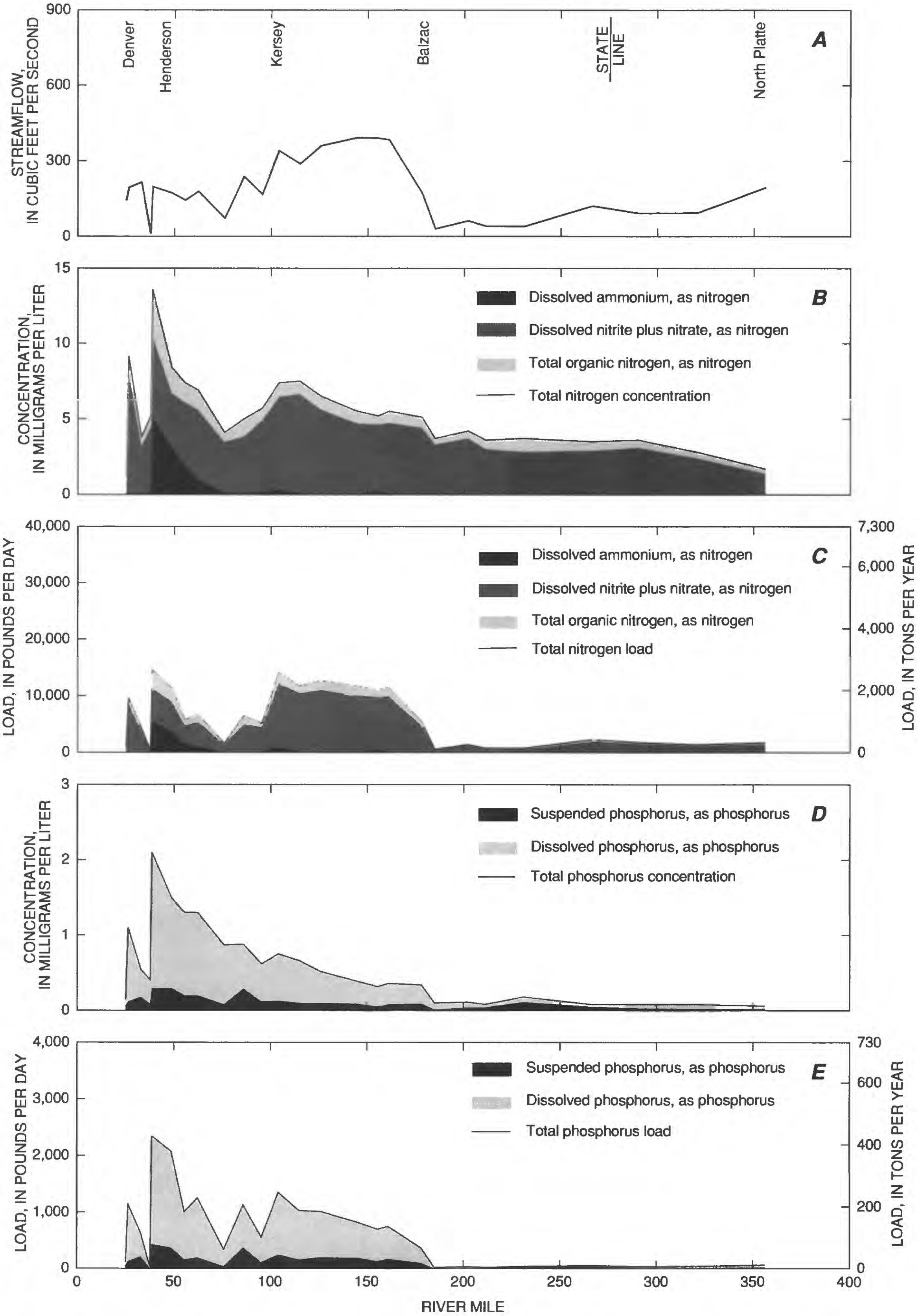


**Figure 5.** Streamflow and nutrient species concentrations and loads in the South Platte River during the April 1994 synoptic sampling: *A*, streamflow; *B*, nitrogen species concentrations; *C*, nitrogen species loads; *D*, phosphorus species concentrations; and *E*, phosphorus species loads.

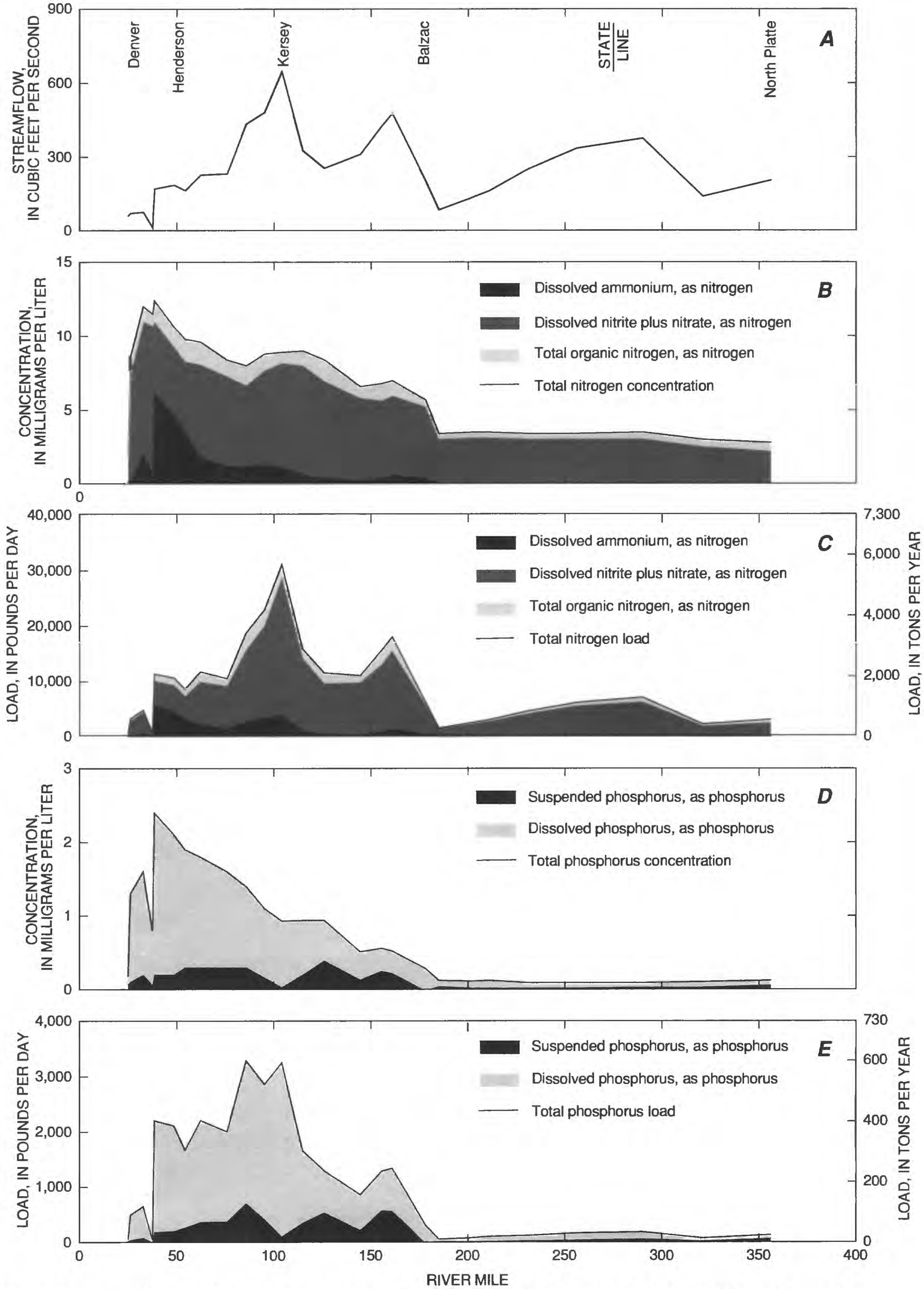


**Figure 6.** Streamflow and nutrient species concentrations and loads in the South Platte River during the January 1995 synoptic sampling: *A*, streamflow; *B*, nitrogen species concentrations; *C*, nitrogen species loads; *D*, phosphorus species concentrations; and *E*, phosphorus species loads.

nitrate concentrations also were large and increased from Henderson to Kersey. Agricultural nonpoint sources of nitrate occur in this area; the largest concentrations of nitrite plus nitrate measured as part of this sampling occurred in small agricultural tributary streams [23.0 mg/L at site 17, Lower Latham Drain at La Salle, Colorado; 16.0 mg/L at site 22, Crow Creek at mouth at Kuner, Colorado (table 3)]. These large concentrations occurred in January 1995 when water in these streams consisted primarily of ground-water discharge from the underlying aquifer.

Dissolved nitrite averaged only 3 percent of the concentration of dissolved nitrite plus nitrate at sites in the South Platte River. Nitrite concentrations in the South Platte River were largest downstream from wastewater-treatment plants and decreased quickly downstream as nitrite was oxidized to nitrate. Nitrite concentrations in the South Platte River were smaller than State of Colorado stream-segment standards during the five synoptic samplings.

Total organic nitrogen composed an average of 14 percent of the total nitrogen concentration at sites along the South Platte River (figs. 5*B* and 6*B*). Concentrations were largest at Henderson and gradually decreased downstream.

Dissolved-phosphorus concentrations in the South Platte River (figs. 5*D* and 6*D*) generally were larger from Denver to Balzac than the USEPA recommended limit for control of eutrophication (0.1 mg/L). Dissolved orthophosphate composed an average of 90 percent of the dissolved-phosphorus concentration. Suspended-phosphorus concentrations were small and composed an average of 20 percent of the total phosphorus concentration.

Upstream from Denver, total nitrogen concentrations (figs. 5*B* and 6*B*) were less than 2 mg/L, and total phosphorus concentrations (figs. 5*D* and 6*D*) were less than 0.2 mg/L. The water in the river upstream from Denver was derived mostly from forested land in the mountains. Total nutrient concentrations increased through the Denver metropolitan area with concentration peaks just downstream from each of Denver's largest wastewater-treatment plants, and maximum concentrations were 13.6 mg/L total nitrogen and 2.4 mg/L total phosphorus. Total nitrogen concentrations then decreased from Henderson to Balzac, except for a local peak near Kersey; total phosphorus concentrations decreased from Henderson to Balzac. From Balzac to North Platte, Nebraska, nutrient concentrations varied little. Concentrations generally were similar for the April 1994 and January 1995 synoptic samplings, except that concentrations upstream from Balzac were larger in January than in April.

## Load Variation

Total nitrogen and phosphorus loads in the South Platte River during April 1994 are shown in figures 5*C* and 5*E*, and loads for January 1995 are shown in figures 6*C* and 6*E*. Loads calculated from a single sample are instantaneous loads because they represent a single point in time. In most of the river, conditions do not change greatly in the course of a day, so loads can be extrapolated to pounds per day (lb/d), which is the unit used in figures 5 and 6. A scale for tons per year (tons/yr) also is depicted in figures 5 and 6 so that instream loads can be compared to nutrient-source inputs, but extrapolation to this time scale is very approximate.

Upstream from Denver, total nitrogen loads (figs. 5*C* and 6*C*) were less than 1,000 lb/d, and total phosphorus loads (figs. 5*E* and 6*E*) were less than 125 lb/d. Total nutrient loads increased through the Denver metropolitan area, and load peaks occurred just downstream from each of Denver's largest wastewater-treatment plants, with a maximum load of 14,000 lb/d total nitrogen and 2,300 lb/d total phosphorus. In April 1994, nutrient loads generally decreased from Henderson to North Platte. In January 1995, however, nutrient loads increased from Henderson to Kersey (maximum loads of 31,000 lb/d total nitrogen and 3,000 lb/d total phosphorus) and then decreased from Kersey to North Platte.

Nutrient loads are the product of concentration and streamflow, and streamflow variations were large during April 1994 and January 1995 synoptics (figs. 5*A* and 6*A*). Surface-water inputs to the river were similar during both synoptics: wastewater-treatment plants in the Denver area added about 200 $ft^3/s$ to the river, and three large tributary streams added about 400 $ft^3/s$ to the river between Henderson and Kersey. The streamflow patterns depended primarily on which irrigation diversions were active. Thirty-nine irrigation ditches were active during April 1994 and removed a total of 2,000 $ft^3/s$ of water from the river. These small diversion ditches were in operation primarily to saturate the water table beneath ditches and to wet the soil profile in fields. Most diversions were small (average of 52 $ft^3/s$) and occurred all along the river. The river maintains streamflow due to ground-water discharge into the river. During January 1995, only nine ditches were active, and they removed a total of 1,400 $ft^3/s$ of water from the river. Most of the large ditches are located downstream from Kersey and generally operate from November through April to fill offstream irrigation reservoirs. During January, no ditches were in operation from Henderson to Kersey, so streamflow increased throughout the reach.

Nitrogen-load patterns had the same general shape as the streamflow patterns, which indicated that water inputs to the river had nitrogen concentrations similar to nitrogen concentrations already in the river. However, the composition of the nitrogen load in the river changed from equal proportions of ammonium and nitrate near Henderson to a nitrate-dominated load at and downstream from Kersey. Phosphorus-load patterns did not match streamflow patterns as well, especially downstream from Kersey, where phosphorus loads did not increase as streamflow increased. This lack of increase indicated that water inputs to the river have smaller phosphorus concentrations than the concentrations already in the river.

Seasonal nutrient loads primarily also were dependent on streamflow as indicated by data from the five synoptic samplings conducted during 1994–95 (fig. 7). In this figure, loads are shown only for the 10 main-stem sites that were sampled during all five synoptic samplings. Total nitrogen loads were largest in June 1994 and January 1995 when streamflows also were largest. During January, streamflow was moderately large, whereas nitrogen concentrations were large. During June, streamflow was large, whereas nitrogen concentrations were small, which indicated that snowmelt runoff diluted the available supply of nitrogen. Total phosphorus loads were largest in June, when streamflow and phosphorus concentrations were both large, which indicated an additional source of phosphorus during snowmelt runoff, most likely from overland runoff or resuspension of bed material. This conclusion is supported by the fact that, at Kersey during June, about 70 percent of the phosphorus was in the suspended phase, whereas in January, only 3 percent was in the suspended phase. Data from NAWQA monitoring sites in agricultural areas in the South Platte River Basin (Ugland and others, 1994, 1995) also indicated that particulate nutrients (suspended organic nitrogen and suspended phosphorus) increased as streamflow increased during runoff. Streamflow and nutrient loads in the South Platte River generally were smallest in April and August 1994.

The downstream pattern of nutrient loads did not vary much between the five synoptic samplings (fig. 7). During each of the five synoptic samplings, loads were large at Henderson, decreased between Henderson and Kersey, and usually were largest at Kersey. The magnitude of the decrease in loads between Henderson and Kersey varied between synoptic samplings and was dependent on the amount of water removed by irrigation ditches. During each of the five synoptic samplings, loads decreased to low levels downstream from Kersey. Nutrient loads at North Platte, Nebraska, did not vary much between the five synoptic samplings compared to loads at other sites. The median nitrogen load at North Platte was 1,800 lb/d, which is equivalent to 340 tons/yr; and the median phosphorus load was 66 lb/d, or 12 tons/yr. These annual nutrient loads leaving the basin were very small compared to the estimated total nutrient inputs to the basin and were even small compared to the wastewater-treatment-plant inputs.

## Sources of Instream Loads

The source of nutrient loads in the South Platte River can be estimated through the use of nutrient-load balances, which can be calculated for reaches along the South Platte River by using the data collected during the April 1994 and January 1995 synoptic samplings. As a first step, streamflow balances for reaches along the South Platte River were calculated by summing surface-water outputs along a reach and subtracting surface-water inputs along that same reach. Positive streamflow-balance residuals were attributed to ground-water discharge from the alluvial aquifer to the river. Streamflow balances were only calculated for the river downstream from river mile 80. Hourly flow variability in the river upstream from this point was large due to fluctuating wastewater-treatment-plant discharges. These fluctuating discharges cause ground-water-discharge rates to change in magnitude and in direction of flow during the course of a day (McMahon and others, 1995). Also, during January 1995, the river was affected by ice cover and ice jams downstream from river mile 260, which caused channel storage so that streamflow balances could not be computed for the affected reaches.

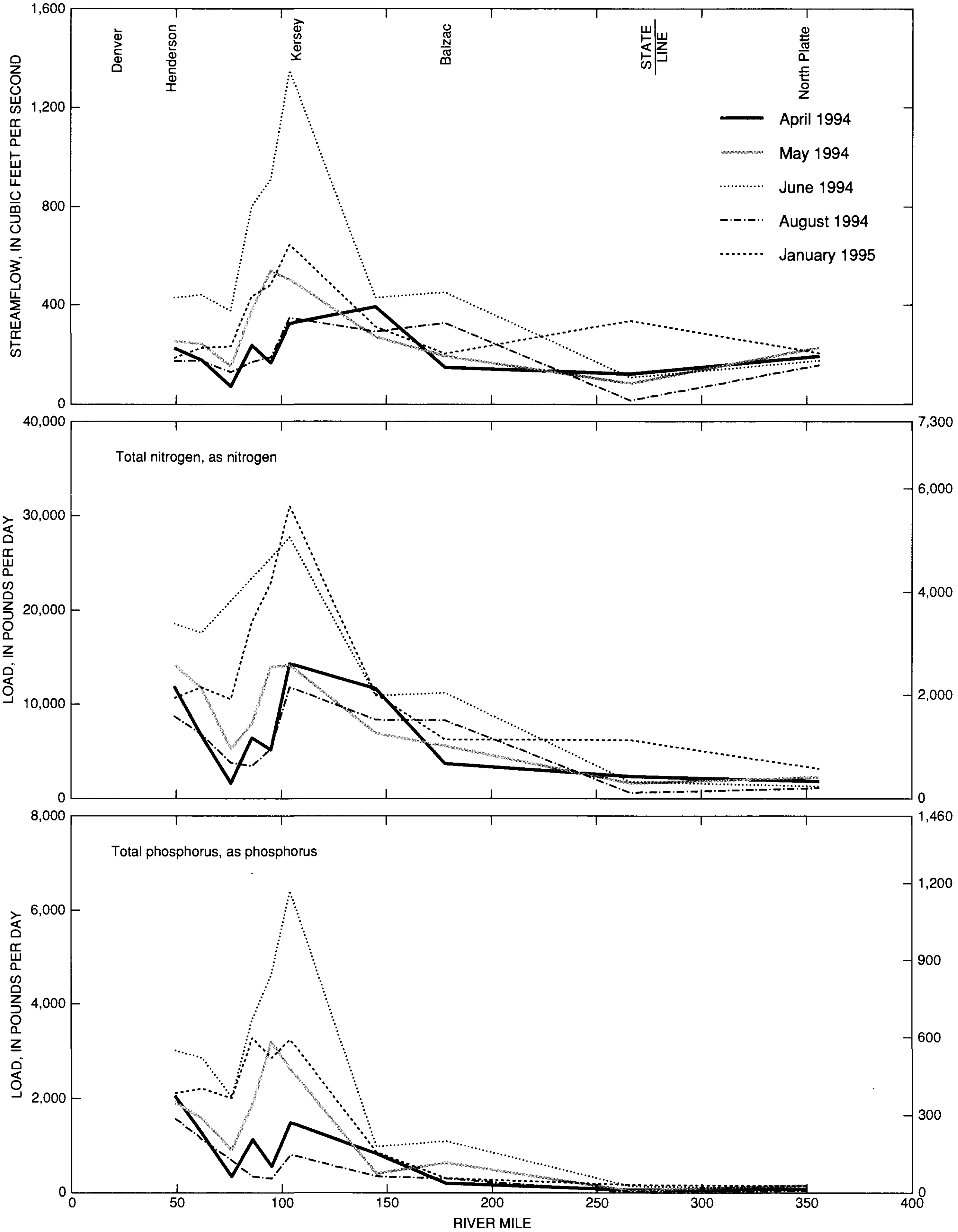


**Figure 7.** Seasonal variability in nutrient loads for 10 main-stem sites along the South Platte River, 1994–95.

Streamflow-balance residuals were positive during both synoptic samplings (fig. 8). Residuals generally were similar in April 1994 and January 1995. Near Kersey, the median residual was about 3 [($ft^3$/s)/mi]. Median residuals increased to about 15 [($ft^3$/s)/mi] just downstream from Kersey and then generally decreased in a downstream direction to about 1 [($ft^3$/s)/mi]. In April 1994, residuals increased to about 6 [($ft^3$/s)/mi] near North Platte. The residuals were consistent with existing literature estimates for ground-water discharge to the river (Hurr and others, 1975; Ruddy, 1984; Wind, 1994). The downstream variability in streamflow residuals could be due to aquifer morphology and the proximity of irrigation canals, irrigation reservoirs, and ground-water augmentation ponds to the river. These large streamflow residuals indicated that the South Platte River downstream from Kersey is essentially a recycled river—a substantial part of the water that is removed from the river for irrigation infiltrates into the aquifer and eventually returns to the river. Surface water diverted out of the river downstream from Kersey during April 1994 (1,485 $ft^3$/s) was replaced by a similar amount of ground water discharged to the river (1,430 $ft^3$/s).

Nutrient-load balances also were calculated for reaches of the river downstream from river mile 80. Nitrate-load residuals generally were large, nitrite- and organic-nitrogen-load residuals were small, and ammonium-load residuals were small and negative. Dividing load residuals, in pounds per day, by streamflow residuals, in cubic feet per second, provided a residual concentration, in milligrams per liter, for comparing reaches; residual concentrations for nitrate and ammonium during the April 1994 and January 1995 synoptic samplings are shown in figure 9. Near Kersey, large positive residual concentrations for nitrate and smaller negative residual concentrations for ammonium were calculated. These residual concentrations indicated that ammonium was being converted to nitrate (nitrification). However, farther downstream from Kersey, residual concentrations for ammonium were small and residual concentrations for nitrate remained large, which indicated that most of the nitrate-load increases in this part of the river were due to nitrate in ground water discharging to the river. Nitrate concentrations in alluvial ground water along the South Platte River were larger than the estimated residual concentrations for nitrate (Breton W. Bruce, U.S. Geological Survey, written commun., 1995), indi-

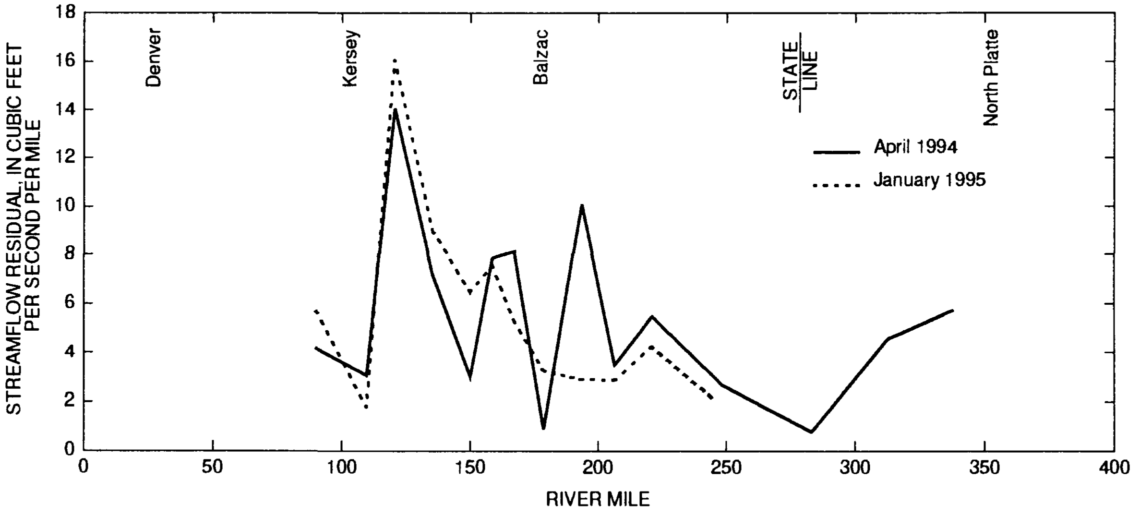


**Figure 8.** Streamflow residuals along the South Platte River during the April 1994 and January 1995 synoptic samplings.

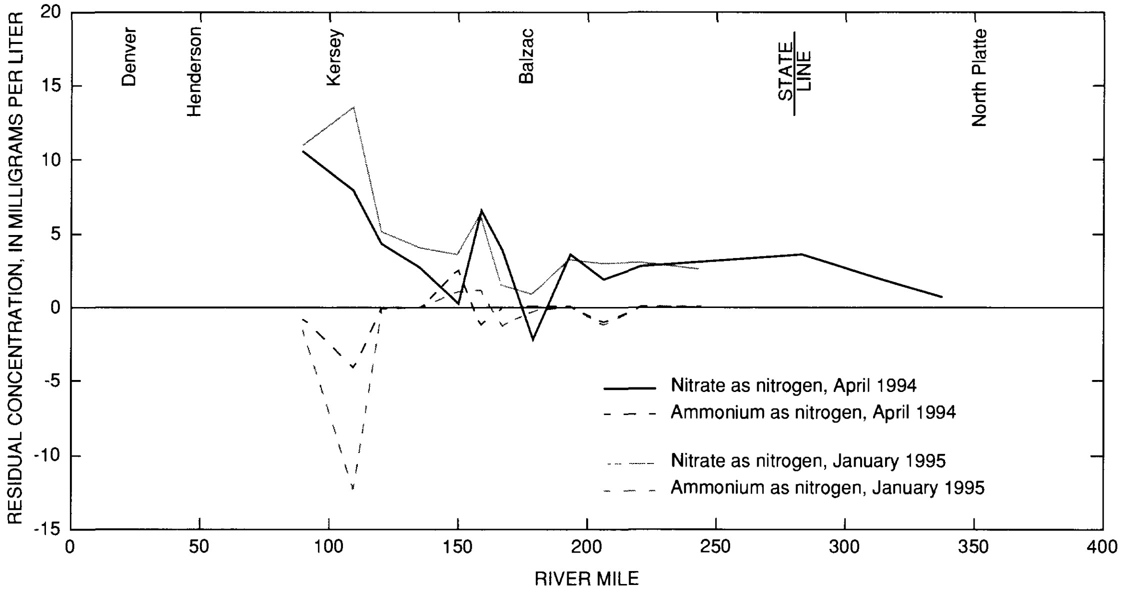


**Figure 9.** Residual concentrations of nitrate and ammonium for reaches of the South Platte River during the April 1994 and January 1995 synoptic samplings.

cating that denitrification of incoming ground water is an important process throughout the length of the river. Other USGS data (Peter B. McMahon, U.S. Geological Survey, oral commun., 1995) indicated that denitrifying bacteria removed from 15 to 30 percent of nitrate in ground water as it moved from its source beneath agricultural fields to where it discharged into the South Platte River and that denitrification continued in the river environment as surface water migrated in and out of the riverbed sediments as the water traveled downstream.

Phosphorus-load residuals were small along the river, which indicated that ground water was not an important source of phosphorus to the river. Phosphorus concentrations generally were small in alluvial ground water along the South Platte River—30 wells sampled by the USGS as part of the NAWQA Program had a median dissolved-phosphorus concentration of 0.05 mg/L (Breton W. Bruce, written commun., 1995).

Nutrient-load data from the April 1994 and January 1995 synoptic samplings also were used to estimate the proportional contribution to river nitrogen loads from wastewater-treatment plants. For each reach, measured contributions from wastewater-treatment plants were accrued. Removal of water from the river did not change the source proportion. Ground-water nutrient input into a reach was assumed to consist of nonpoint-source nitrogen and, therefore, was assumed to decrease the wastewater-treatment-plant proportion. Nitrogen loads in the river at Henderson (fig. 10*A*) were almost entirely due to wastewater-treatment-plant discharges. From Henderson to Balzac, the wastewater-treatment-plant proportion steadily decreased as water that was removed from the river was replaced by ground water. About 60 mi downstream from Denver (river mile 100), the proportion of the nitrogen load attributable to wastewater-treatment plants made up less than 50 percent of the total nitrogen load in the river. Nitrogen loads from wastewater-treatment plants remained in the river farther downstream in January 1995 than in April 1994 because irrigation diversions between Henderson and Kersey were smaller in January.

A second measure of wastewater-treatment-plant contribution to river water is the concentration ratio of nitrogen to phosphorus in the water. The concentration ratio for effluent from wastewater-treatment plants in the South Platte River Basin was 6, whereas the ratio in nonpoint-source-dominated water generally is greater than 10 (Sharpley and others, 1994). Based

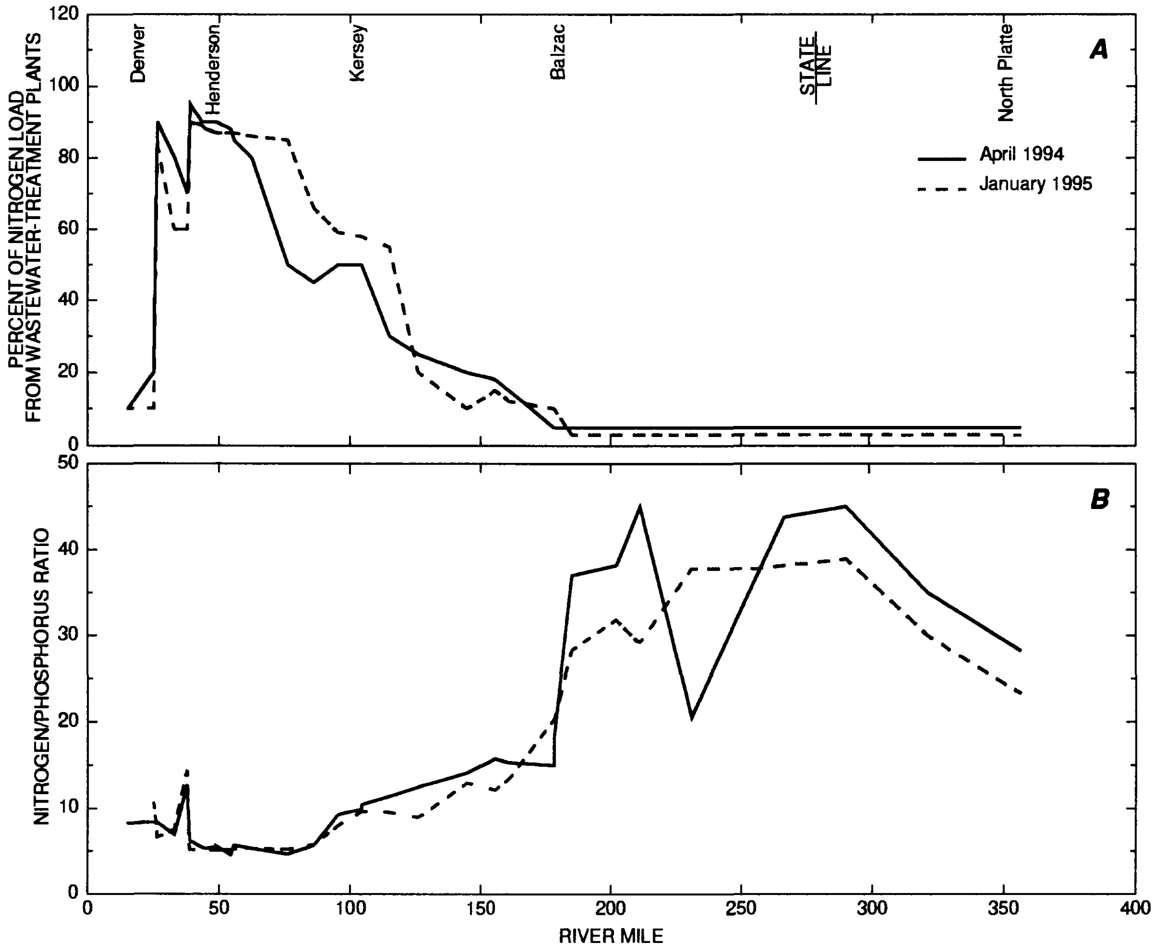


**Figure 10.** Measures of wastewater-treatment-plant contributions to river nutrient loads during the April 1994 and January 1995 synoptic samplings: *A*, mass-balance estimate of nitrogen-load source; and *B*, nitrogen/phosphorus ratio.

on this measure, the river becomes nonpoint-source dominated (fig. 10*B*) at about river mile 100, which also is where nutrient-load-balance data indicated that the proportion of wastewater-treatment-plant loads was less than 50 percent.

## SUMMARY

The South Platte River Basin was 1 of 20 river basins selected in 1991 for investigation as part of the U.S. Geological Survey's National Water-Quality Assessment Program. Nutrient concentrations in surface water of the South Platte River are large compared to concentrations in other NAWQA river basins. Therefore, the source of nutrients to the surface-water system is of particular interest in the South Platte River Basin. This report presents estimates of the magnitude of nutrient-source inputs to the South Platte River Basin, describes nutrient concentrations and loads in the South Platte River during different seasons, and presents comparisons of these inputs to estimated instream nutrient loads.

The South Platte River Basin has a drainage area of about 24,300 $mi^2$. The South Platte River originates in the mountains of central Colorado and flows about 450 mi northeast across the Great Plains to the confluence with the North Platte River at North Platte, Nebraska. The South Platte alluvial-aquifer system, located in the alluvial valley and benchlands of the

South Platte River and its tributaries, is hydraulically connected to the river and contributes substantially to streamflow in the river.

Nutrient sources from urban land use include wastewater-treatment-plant discharges and urban fertilizer applications. Discharges from the 29 largest wastewater-treatment plants in the basin were estimated for 1993 to total 7,000 tons of nitrogen and 1,200 tons of phosphorus. Urban lawn fertilization was estimated to total 7,000 tons of nitrogen per year applied to the urban lands in the basin. A part of the urban fertilizer input can reach streams through storm runoff or ground-water discharge; however, a previous study indicated that storm runoff in the Denver, Colorado, metropolitan area contributed only 5 percent of the total instream nutrient load downstream from Denver.

Nutrient sources from agricultural land use primarily are through fertilizer and manure that are applied to fields and were estimated to be 226,000 tons/yr of nitrogen and 40,000 tons/yr of phosphorus for all counties in the South Platte River Basin. Excess nutrients from these applications can be available in the soil and might be transported to streams by storm runoff or ground-water discharge. In an area near Greeley, Colorado, previous studies have detected elevated nitrate concentrations in ground water in agricultural areas surrounding feedlots.

Atmospheric deposition was estimated to contribute 66,000 tons of nitrogen to the basin annually. About 70 percent of the atmospheric nitrogen input occurs over the forested or rangeland parts of the basin. However, previous studies have determined that streams in forested and rangeland areas have significantly smaller nitrogen concentrations than streams in urban and agricultural land-use areas. These smaller nitrogen concentrations indicated that large nutrient concentrations in streams are more dependent on fertilizer, manure, and wastewater-treatment-plant inputs than on atmospheric inputs.

To characterize nutrient concentrations and loads in the South Platte River during different seasons, five nutrient synoptic samplings were conducted during 1994 and 1995. Synoptic sampling occurred at a total of 41 sites. April 1994 and January 1995 synoptic samplings were designed to occur before and after the irrigation season to enable calculation of mass balances while minimizing the effect of irrigation inputs and outputs. May, June, and August 1994 synoptic samplings were designed to examine variability in nutrient loads during the irrigation season.

Upstream from Denver during April 1994 and January 1995, total nitrogen concentrations were less than 2 mg/L, and total phosphorus concentrations were less than 0.2 mg/L. The water in the river at this point was derived mostly from forested land in the mountains west of Denver. Total nutrient concentrations increased through the Denver metropolitan area, and concentration peaks occurred just downstream from each of Denver's largest wastewater-treatment plants with maximum concentrations of 13.6 mg/L total nitrogen and 2.4 mg/L total phosphorus. Total nitrogen concentrations then decreased from Henderson, Colorado, to Balzac, Colorado, except for a local peak near Kersey, Colorado. Total phosphorus concentrations decreased from Henderson to Balzac. From Balzac to North Platte, Nebraska, nutrient concentrations varied little. Dissolved nitrite plus nitrate was the predominant nitrogen species in the South Platte River.

Upstream from Denver during April 1994 and January 1995, total nitrogen loads were less than 1,000 lb/d, and total phosphorus loads were less than 125 lb/d. Total nutrient loads increased through the Denver metropolitan area, and load peaks occurred just downstream from each of Denver's largest wastewater-treatment plants, with a maximum load of 14,000 lb/d total nitrogen and 2,300 lb/d total phosphorus. In April 1994, nutrient loads generally decreased from Henderson to North Platte. In January 1995, however, nutrient loads increased from Henderson to Kersey (maximum loads of 31,000 lb/d total nitrogen and 3,000 lb/d total phosphorus), and then decreased from Kersey to North Platte.

Nitrogen-load patterns had the same general shape as the streamflow patterns, which indicated that water inputs to the river had nitrogen concentrations similar to nitrogen concentrations already in the river. However, the composition of the nitrogen load in the river changed from equal proportions of ammonium and nitrate near Henderson to a nitrate-dominated load at and downstream from Kersey. Phosphorus-load patterns did not match streamflow patterns as well, especially downstream from Kersey, where phosphorus-load increases did not match streamflow increases. This lack of increase indicated that water inputs to the river had smaller phosphorus concentrations than the concentrations already in the river.

Seasonal nutrient loads also primarily were dependent on streamflow. Total nitrogen loads were largest in June 1994 and January 1995 when streamflows also were largest. During January, streamflow was moderately large, whereas nitrogen concentrations were large. During June, streamflow was large, whereas nitrogen concentrations were small, which indicated that snowmelt runoff diluted the available supply of nitrogen. Total phosphorus loads were largest in June, when streamflow and phosphorus concentrations were both large, which indicated an additional source of phosphorus during snowmelt runoff, most likely from overland runoff or resuspension of bed material. Streamflow in the South Platte River was small in April and August 1994, and nutrient loads also were small during these months.

The downstream pattern of nutrient loads did not vary much between the five nutrient synoptic samplings. Loads were large at Henderson, decreased between Henderson and Kersey, and usually were largest at Kersey. The magnitude of the decrease in loads between Henderson and Kersey varied between synoptic samplings and was dependent on the amount of water removed by irrigation ditches. The median nitrogen load at North Platte was 340 tons/yr, and the median phosphorus load was 12 tons/yr. These annual nutrient loads leaving the basin were very small compared to the estimated total nutrient inputs to the basin.

Streamflow-balance and nutrient-load-balance residuals were calculated by using the data collected during the April 1994 and January 1995 synoptic samplings. Near Kersey, streamflow-balance residuals were about 3 [($ft^3$/s)/mi]. Residuals increased to about 15 [($ft^3$/s)/mi] just downstream from Kersey and then generally decreased in a downstream direction to about 1 [($ft^3$/s)/mi]. The large residuals indicated that the South Platte River downstream from Kersey is essentially a recycled river; a substantial part of the water that is removed from the river for irrigation infiltrates into the aquifer and eventually returns to the river. Surface water diverted out of the river downstream from Kersey during April 1994 (1,485 $ft^3$/s) was replaced by a similar amount of ground water discharged to the river (1,430 $ft^3$/s).

For reaches on the South Platte River, nitrate-load residuals were large, nitrite- and organic-nitrogen-load residuals were small, and ammonium-load residuals primarily were small and negative. Near Kersey, large positive residual concentrations for nitrate and smaller negative residual concentrations for ammonium were calculated, which indicated that ammonium was being converted to nitrate (nitrification). However, farther downstream from Kersey, residual concentrations of ammonium were small, and residual concentrations of nitrate remained large, which indicated that most of the nitrate-load increases in this part of the river were due to nitrate in ground water discharging to the river. Phosphorus-load residuals were small along the river, which indicated that ground water was not an important source of phosphorus to the river.

Nutrient-load data from the April 1994 and January 1995 synoptic samplings also were used to estimate the proportional contribution to river nitrogen loads from wastewater-treatment plants. Nitrogen loads in the river at Henderson were almost entirely due to wastewater-treatment-plant discharges. From Henderson to Balzac, the wastewater-treatment-plant proportion steadily decreased as water that was removed from the river was replaced by ground water. About 60 mi downstream from Denver, the proportion of the nitrogen load attributable to wastewater-treatment plants made up less than 50 percent of the total nitrogen load in the river. Nitrogen loads from wastewater-treatment plants remained in the river farther downstream in January 1995 than in April 1994 because irrigation diversions between Henderson and Kersey were smaller in January.

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# SUPPLEMENTAL DATA

**Table 3**. Water-quality data collected as part of the nutrient synoptic sampling, April 1994 through January 1995

[$ft^3/s$, cubic foot per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; mg/L, milligram per liter; N, nitrogen; P, phosphorus; --, no data; <, less than; E, estimated; ns, no sample taken]

| Site number (fig. 4) | River mile[1] | Station name | Date | Time | Streamflow ($ft^3/s$) | Specific conductance (µS/cm) | pH (standard units) | Water temperature (°C) | Oxygen, dissolved (mg/L) | Nitrogen, ammonia, dissolved (mg/L as N) | Nitrogen, nitrite, dissolved (mg/L as N) | Nitrogen, nitrite plus nitrate, dissolved (mg/L as N) | Nitrogen, ammonia plus organic, dissolved (mg/L as N) | Nitrogen, ammonia plus organic, total (mg/L as N) | Phosphorus, ortho, dissolved (mg/L as P) | Phosphorus, dissolved (mg/L as P) | Phosphorus, total (mg/L as P) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 25.1 | South Platte River at Englewood, Colo. | 04-12-94 | 1100 | 145 | 580 | 8.2 | 7.0 | 13.4 | 0.04 | 0.03 | 0.75 | <0.2 | 0.5 | 0.09 | 0.09 | 0.15 |
| | | | 01-09-95 | 0800 | 60 | 697 | 7.5 | 1.5 | 10.5 | .17 | .04 | 1.4 | .4 | .5 | .11 | .11 | .18 |
| 2 | 26.3 | South Platte River at East Evans, at Denver, Colo. | 04-12-94 | 1005 | 193 | 700 | 8.1 | 8.0 | 12.0 | .06 | .04 | 8.1 | .6 | 1.1 | .89 | .98 | 1.1 |
| | | | 01-09-95 | 0800 | 70 | 808 | 7.6 | 4.5 | 10.7 | .21 | .05 | 7.3 | .8 | 1.3 | 1.1 | 1.20 | 1.3 |
| 3 | 32.4 | Cherry Creek at Denver, Colo. | 04-12-94 | 1505 | 27 | 1,080 | 8.6 | 16.0 | 8.8 | .05 | .03 | 2.1 | .4 | .7 | .19 | .19 | .23 |
| | | | 01-09-95 | 1025 | 7.9 | 2,370 | 8.4 | 7.5 | 11.7 | .03 | .03 | 4.7 | .3 | .4 | .37 | .36 | .39 |
| 4 | 32.8 | South Platte River at Denver, Colo. | 04-12-94 | 1545 | 215 | 740 | 8.1 | 11.0 | 10.2 | .07 | .04 | 3.2 | .5 | .6 | .36 | .37 | .55 |
| | | | 01-09-95 | 1300 | 69 | 984 | 7.9 | 7.0 | 10.1 | 2.0 | .31 | 9.0 | 3.1 | 3.0 | 1.30 | 1.40 | 1.6 |
| 5 | 37.6 | South Platte River at 64th Avenue, at Commerce City, Colo. | 04-12-94 | 1730 | 8.8 | 1,320 | 7.5 | 16.5 | 11.4 | .09 | .08 | 4.4 | .6 | .8 | .29 | .32 | .41 |
| | | | 01-09-95 | 1515 | 11 | 1,490 | 7.9 | 9.5 | 10.6 | .71 | .18 | 10.0 | 1.4 | 1.5 | .66 | .74 | .8 |
| 6 | 37.9 | Sand Creek at mouth, near Commerce City, Colo. | 04-13-94 | 1005 | 24 | 1,400 | 8.3 | 10.0 | 10.8 | .31 | .08 | 2.2 | 0.7 | 1.0 | .23 | .23 | .34 |
| | | | 01-09-95 | 1520 | 16 | 1,760 | 8.3 | 8.5 | 10.8 | 1.5 | .11 | 3.4 | 2.0 | 2.3 | .69 | .76 | .89 |

**Table 3**. Water-quality data collected as part of the nutrient synoptic sampling, April 1994 through January 1995--Continued

| Site number (fig. 4) | River mile[1] | Station name | Date | Time | Streamflow ($ft^3$/s) | Specific conductance (µS/cm) | pH (standard units) | Water temperature (°C) | Oxygen, dissolved (mg/L) | Nitrogen, ammonia, dissolved (mg/L as N) | Nitrogen, nitrite, dissolved (mg/L as N) | Nitrogen, nitrite plus nitrate, dissolved (mg/L as N) | Nitrogen, ammonia plus organic, dissolved (mg/L as N) | Nitrogen, ammonia plus organic, total (mg/L as N) | Phosphorus, ortho, dissolved (mg/L as P) | Phosphorus, dissolved (mg/L as P) | Phosphorus, total (mg/L as P) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 38.6 | South Platte River above Clear Creek, near Commerce City, Colo. | 04-13-94 | 0855 | 197 | 1,030 | 7.3 | 14.5 | 7.3 | 5.1 | 0.24 | 5.4 | 6.7 | 8.2 | 1.7 | 1.8 | 2.2 |
| | | | 01-09-95 | 1700 | 170 | 990 | 7.2 | 14.5 | 7.1 | 6.2 | .37 | 4.8 | 7.8 | 7.6 | 2.0 | 2.2 | 2.4 |
| 8 | 39.0 | Clear Creek at mouth, near Derby, Colo. | 04-13-94 | 1030 | 87 | 670 | 8.4 | 11.5 | 10.3 | .15 | .04 | .62 | .5 | 1.5 | .16 | .15 | .39 |
| | | | 01-09-95 | 1330 | 20 | 1,110 | 8.8 | 5.5 | -- | .47 | .11 | 2.00 | 1.6 | 2.2 | .74 | .80 | .98 |
| 9 | 48.7 | South Platte River at Henderson, Colo. | 04-13-94 | 1720 | 225 | 970 | 8.1 | 17.0 | 8.1 | 3.0 | .34 | 4.3 | 4.3 | 5.0 | 1.3 | 1.4 | 1.7 |
| | | | 05-09-94 | 0830 | 253 | 834 | 7.9 | 16.0 | 7.1 | 3.6 | .35 | 4.9 | 4.8 | 5.5 | .96 | 1.1 | 1.4 |
| | | | 05-31-94 | 0950 | 430 | 673 | 7.6 | 17.5 | 6.7 | 2.2 | .37 | 4.3 | 2.9 | 3.7 | 1.1 | 1.1 | 1.3 |
| | | | 08-29-94 | 0845 | 173 | 883 | 7.7 | 20.0 | 5.8 | 2.6 | .93 | 5.6 | 4.0 | 3.8 | 1.4 | 1.8 | 1.7 |
| | | | 01-10-95 | 0710 | 186 | 1,040 | 7.7 | 9.0 | 7.6 | 4.6 | .42 | 4.7 | 5.7 | 5.9 | 1.6 | 1.9 | 2.1 |
| 10 | 54.4 | South Platte River at 160th Street, at Brighton, Colo. | 04-14-94 | 1345 | 11 | 1,010 | 7.7 | 16.0 | 7.1 | 2.3 | .32 | 3.9 | 3.3 | 3.8 | 1.1 | 1.1 | 1.4 |
| | | | 01-10-95 | 1305 | 163 | 1,060 | 8.0 | 10.0 | 10.1 | 3.5 | .35 | 4.8 | 4.5 | 5.0 | 1.5 | 1.6 | 1.9 |
| 11 | 61.8 | Big Dry Creek at mouth, near Fort Lupton, Colo. | 04-14-94 | 1505 | 36 | 1,170 | 8.1 | 16.5 | 9.7 | .88 | .16 | 5.8 | 1.6 | 2.1 | 1.1 | 1.2 | 1.4 |
| | | | 01-10-95 | 1500 | 23 | 1,350 | 8.3 | 6.0 | 10.2 | 1.8 | .12 | 6.2 | 2.6 | 2.7 | 1.8 | 1.9 | 1.9 |

**Table 3**. Water-quality data collected as part of the nutrient synoptic sampling, April 1994 through January 1995--Continued

| Site number (fig. 4) | River mile[1] | Station name | Date | Time | Streamflow ($ft^3/s$) | Specific conductance (µS/cm) | pH (standard units) | Water temperature (°C) | Oxygen, dissolved (mg/L) | Nitrogen, ammonia, dissolved (mg/L as N) | Nitrogen, nitrite, dissolved (mg/L as N) | Nitrogen, nitrite plus nitrate, dissolved (mg/L as N) | Nitrogen, ammonia plus organic, dissolved (mg/L as N) | Nitrogen, ammonia plus organic, total (mg/L as N) | Phosphorus, ortho, dissolved (mg/L as P) | Phosphorus, dissolved (mg/L as P) | Phosphorus, total (mg/L as P) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 62.3 | South Platte River | 04-14-94 | 1730 | 178 | 1,080 | 7.2 | 16.5 | 6.0 | 1.0 | 0.24 | 4.6 | 1.8 | 2.3 | 1.0 | 1.1 | 1.3 |
| | | at Fort Lupton, | 05-09-94 | 1845 | 243 | 915 | 8.0 | 18.0 | 5.5 | 1.7 | .49 | 5.8 | 2.4 | 3.1 | .97 | .98 | 1.2 |
| | | Colo. | 05-31-94 | 1830 | 441 | 708 | 7.7 | 22.0 | 4.4 | .79 | .40 | 5.3 | 1.3 | 2.1 | .97 | .92 | 1.2 |
| | | | 08-29-94 | 1830 | 175 | 960 | 8.4 | 22.5 | 7.8 | .13 | .28 | 6.2 | .8 | 1.0 | .99 | 1.2 | 1.2 |
| | | | 01-10-95 | 1715 | 227 | 1,080 | 8.2 | 8.5 | 10.6 | 1.8 | .23 | 6.3 | 3.0 | 3.3 | 1.3 | 1.5 | 1.8 |
| 13 | 75.9 | South Platte River | 04-15-94 | 0920 | 71 | 1,150 | -- | 9.0 | 8.0 | .09 | .03 | 3.4 | .5 | .7 | .81 | .79 | .88 |
| | | near Platteville, | 05-10-94 | 0930 | 153 | 983 | 8.1 | 14.5 | 8.8 | .16 | .13 | 5.0 | .7 | 1.3 | .83 | .86 | 1.1 |
| | | Colo. | 06-01-94 | 1025 | 376 | 710 | 7.9 | 20.0 | 8.1 | -- | -- | -- | -- | 1.1 | -- | -- | 1.0 |
| | | | 08-30-94 | 0850 | 128 | 1,070 | 7.7 | 17.0 | 8.1 | .04 | .03 | 4.7 | .6 | .7 | .90 | .95 | .99 |
| | | | 01-11-95 | 0830 | 232 | 1,120 | 7.9 | 5.0 | 9.1 | 1.2 | .11 | 6.1 | 2.0 | 2.3 | 1.2 | 1.3 | 1.6 |
| 14 | 80.6 | St. Vrain Creek at | 04-15-94 | 1040 | 206 | 1,090 | -- | 10.5 | 9.2 | .20 | .14 | 3.6 | .7 | 1.3 | .57 | .59 | .84 |
| | | mouth, near | 05-10-94 | 1100 | 345 | 598 | 8.1 | 13.5 | 7.5 | .18 | .09 | 2.3 | .5 | 1.4 | .24 | .27 | .97 |
| | | Platteville, | 06-01-94 | 1215 | 504 | 500 | 7.9 | 18.5 | 8.5 | .06 | .03 | 1.5 | .4 | 1.2 | .20 | .23 | .60 |
| | | Colo. | 08-30-94 | 1020 | 211 | 1,320 | 8.2 | 18.5 | 7.4 | .05 | .04 | 3.1 | .4 | .5 | .26 | .28 | .32 |
| | | | 01-11-95 | 1000 | 116 | 1,250 | 8.1 | 2.5 | 11.1 | 1.8 | .09 | 3.8 | 2.5 | 3.1 | .67 | .68 | .87 |
| 15 | 85.9 | South Platte River | 04-15-94 | 1730 | 237 | 1,070 | -- | 17.0 | 7.9 | .06 | .06 | 3.8 | .5 | 1.2 | .59 | .59 | .88 |
| | | at Highway 60, | 05-10-94 | 1700 | 376 | 710 | 8.2 | 20.5 | 7.4 | .06 | .04 | 2.9 | .4 | 1.0 | .31 | .34 | .93 |
| | | near Milliken, | 06-01-94 | 1755 | 802 | 597 | 8.0 | 23.5 | 6.6 | -- | -- | -- | -- | 1.4 | -- | -- | .85 |
| | | Colo. | 08-30-94 | 1700 | 170 | 1,270 | 8.5 | 24.0 | 8.9 | .02 | .02 | 3.1 | .4 | .6 | .30 | .33 | .37 |
| | | | 01-11-95 | 1600 | 434 | 1,190 | 8.2 | 6.5 | 10.3 | 1.2 | .10 | 5.5 | 1.9 | 2.5 | 1.0 | 1.1 | 1.4 |

**Table 3**. Water-quality data collected as part of the nutrient synoptic sampling, April 1994 through January 1995--Continued

| Site number (fig. 4) | River mile[1] | Station name | Date | Time | Stream-flow ($ft^3/s$) | Specific conduc-tance (µS/cm) | pH (stan-dard units) | Water tem-pera-ture (°C) | Oxygen, dis-solved (mg/L) | Nitro-gen, ammo-nia, dis-solved (mg/L as N) | Nitro-gen, nitrite, dis-solved (mg/L as N) | Nitro-gen, nitrite plus nitrate, dis-solved (mg/L as N) | Nitro-gen, ammo-nia plus organ-ic, dis-solved (mg/L as N) | Nitro-gen, ammo-nia plus organ-ic, total (mg/L as N) | Phos-phorus, ortho, dis-solved (mg/L as P) | Phos-phorus, dis-solved (mg/L as P) | Phos-phorus, total (mg/L as P) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 90.4 | Big Thompson River at mouth, near La Salle, Colo. | 04-15-94 | 1830 | 55 | 2,150 | -- | 17.5 | 7.2 | 0.86 | 0.35 | 5.0 | 1.6 | 1.8 | 0.37 | 0.40 | 0.49 |
| | | | 05-10-94 | 1500 | 15 | 685 | 8.3 | 23.5 | 8.9 | .53 | .26 | 2.9 | 1.0 | 1.6 | .19 | .21 | .34 |
| | | | 06-01-94 | 1540 | 97 | 880 | 7.8 | 23.0 | 6.8 | -- | -- | -- | -- | 1.0 | -- | -- | .31 |
| | | | 08-30-94 | 1315 | 91 | 1,510 | 8.2 | 21.5 | 7.3 | .22 | .13 | 3.9 | .6 | .6 | .11 | .12 | .16 |
| | | | 01-11-95 | 1400 | 50 | 2,110 | 8.1 | 4.5 | 10.2 | 4.6 | .21 | 3.9 | 6.2 | 5.8 | .33 | .38 | .68 |
| 17 | 93.7 | Lower Latham Drain at La Salle, Colo. | 01-13-95 | 1430 | 12 | 1,600 | 7.9 | 15.0 | 9.7 | .05 | .05 | 23.0 | .3 | .8 | .04 | .04 | .07 |
| 18 | 95.3 | South Platte River at Road 54, near Evans, Colo. | 04-16-94 | 0840 | 166 | 1,330 | -- | 9.5 | 8.2 | .15 | .04 | 4.8 | .6 | .9 | .51 | .50 | .62 |
| | | | 05-11-94 | 0745 | 539 | 780 | 8.1 | 14.5 | 7.5 | .09 | .04 | 3.4 | .5 | 1.4 | .32 | .33 | 1.1 |
| | | | 06-02-94 | 0845 | 910 | 640 | 8.1 | 18.5 | 5.5 | -- | -- | -- | -- | 1.6 | -- | -- | .94 |
| | | | 08-31-94 | 0715 | 189 | 1,460 | 7.6 | 16.5 | 7.2 | .05 | .05 | 4.7 | .3 | .4 | .24 | .24 | .29 |
| | | | 01-12-95 | 0800 | 481 | 1,320 | 7.9 | 2.5 | 1.3 | 1.3 | .11 | 6.4 | 2.1 | 2.4 | .86 | .94 | 1.1 |
| 19 | 101.9 | Cache La Poudre River near Greeley, Colo. | 04-16-94 | 1150 | 86 | 1,830 | -- | 14.0 | 14.2 | .67 | .24 | 7.5 | 1.3 | 2.5 | .85 | .82 | 1.0 |
| | | | 05-11-94 | 1150 | 8.0 | 1,700 | 8.1 | 19.0 | 15.8 | .36 | .19 | 8.5 | .9 | 1.4 | .12 | .13 | .24 |
| | | | 06-02-94 | 1255 | 11 | 460 | 7.9 | 19.0 | 6.5 | -- | -- | -- | -- | 2.5 | -- | -- | 1.1 |
| | | | 08-31-94 | 1025 | 45 | 1,600 | 7.8 | 16.0 | 7.5 | .24 | .15 | 5.9 | .7 | 1.1 | .21 | .23 | .38 |
| | | | 01-12-95 | 1000 | 82 | 1,750 | 7.8 | 4.5 | 12.1 | 1.2 | .11 | 6.9 | 1.7 | 1.8 | .59 | .60 | .63 |
| 20 | 103.0 | Lonetree Creek at mouth, near Greeley, Colo. | 04-16-94 | 1400 | 8.9 | 2,590 | -- | 19.0 | 1.3 | 11.0 | .62 | 7.8 | 12 | 17 | 4.1 | 4.2 | 5.2 |
| | | | 01-12-95 | 1300 | 12 | 2,690 | 7.9 | 5.0 | 10.1 | 13.0 | .63 | 9.9 | 16 | 17 | 5.0 | 5.4 | 5.6 |

**Table 3**. Water-quality data collected as part of the nutrient synoptic sampling, April 1994 through January 1995--Continued

| Site number (fig. 4) | River mile[1] | Station name | Date | Time | Stream-flow (ft³/s) | Specific conduc-tance (µS/cm) | pH (stan-dard units) | Water tem-pera-ture (°C) | Oxygen, dis-solved (mg/L) | Nitro-gen, ammo-nia, dis-solved (mg/L as N) | Nitro-gen, nitrite, dis-solved (mg/L as N) | Nitro-gen, nitrite plus nitrate, dis-solved (mg/L as N) | Nitro-gen, ammo-nia plus organ-ic, dis-solved (mg/L as N) | Nitro-gen, ammo-nia plus organ-ic, total (mg/L as N) | Phos-phorus, ortho, dis-solved (mg/L as P) | Phos-phorus, dis-solved (mg/L as P) | Phos-phorus, total (mg/L as P) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 104.2 | South Platte River near Kersey, Colo. | 04-18-94 | 1015 | 324 | 1,580 | 8.6 | 13.0 | 8.3 | 0.53 | 0.13 | 6.4 | 1.1 | 1.6 | 0.63 | 0.63 | 0.77 |
| | | | 05-11-94 | 1620 | 504 | 860 | 8.3 | 22.0 | 7.7 | .07 | .03 | 3.9 | .4 | 1.3 | .34 | .35 | .96 |
| | | | 06-02-94 | 1600 | 1,350 | 640 | 8.0 | 22.5 | 6.0 | .12 | .03 | 2.4 | .5 | 1.4 | .29 | .29 | .88 |
| | | | 08-31-94 | 1520 | 347 | 1,550 | 8.2 | 17.0 | 8.8 | .15 | .07 | 5.7 | .6 | .6 | .37 | .39 | .43 |
| | | | 01-12-95 | 1715 | 646 | 1,450 | 7.9 | 5.0 | 10.7 | 1.1 | .12 | 7.1 | 1.9 | 1.8 | .85 | .90 | .93 |
| 22 | 109.0 | Crow Creek at mouth, at Kuner, Colo. | 04-18-94 | 1210 | 1.3 | 3,890 | 8.5 | 16.0 | 15.2 | .06 | .25 | 13.0 | 1.1 | 1.6 | <.01 | <.01 | .05 |
| | | | 05-11-94 | 0950 | 27 | 1,460 | 8.5 | 16.5 | 9.3 | 1.4 | .43 | 5.2 | 2.1 | 4.5 | .63 | .65 | 1.2 |
| | | | 06-02-94 | 1045 | 67 | 880 | 7.9 | 20.5 | 6.4 | -- | -- | -- | -- | 1.3 | -- | -- | .39 |
| | | | 08-31-94 | 0850 | 10 | 2,040 | 8.1 | 17.0 | 8.2 | .02 | .29 | 8.9 | .7 | .8 | .37 | .40 | .46 |
| | | | 01-12-95 | 1510 | 1.0 | 3,660 | 8.3 | 0.0 | 20.5 | .03 | .22 | 16.0 | .8 | 1.0 | .01 | .03 | .04 |
| 23 | 111.0 | Box Elder Creek near Kuner, Colo. | 08-30-94 | 0950 | 19 | 1,940 | 8.1 | 18.0 | 7.6 | .03 | .03 | 6.4 | .6 | .6 | .18 | .20 | .22 |
| 24 | 115.0 | South Platte River at Hardin, Colo. | 04-18-94 | 1340 | 288 | 1,610 | 8.5 | 18.0 | 10.0 | .07 | .07 | 6.6 | .5 | .9 | .55 | .56 | .66 |
| | | | 01-13-95 | 0710 | 326 | 1,520 | 8.1 | 2.5 | 10.7 | .63 | .09 | 7.4 | 1.1 | 1.6 | .76 | .74 | .94 |
| 25 | 126.0 | South Platte River at Masters, Colo. | 04-18-94 | 1540 | 360 | 1,560 | 8.6 | 18.0 | 9.9 | .03 | .03 | 5.6 | .4 | .9 | .43 | .42 | .52 |
| | | | 01-13-95 | 1230 | 255 | 1,470 | 8.1 | 1.0 | 11.6 | .38 | .06 | 6.6 | .7 | 1.8 | .58 | .55 | .94 |
| 26 | 144.6 | South Platte River near Weldona, Colo. | 04-18-94 | 1730 | 392 | 1,610 | 8.7 | 18.0 | 10.2 | .01 | .02 | 4.7 | .3 | .8 | .31 | .30 | .39 |
| | | | 05-10-94 | 0945 | 270 | 1,580 | 8.4 | 14.0 | 9.3 | .03 | .03 | 4.0 | .3 | .7 | .20 | .22 | .29 |
| | | | 06-01-94 | 1145 | 430 | 1,440 | 8.2 | 21.5 | 8.0 | .04 | .01 | 3.6 | .5 | 1.1 | .28 | .25 | .42 |
| | | | 08-30-94 | 1305 | 291 | 1,710 | 8.2 | 22.5 | 8.5 | .02 | .02 | 4.9 | .4 | .4 | .18 | .19 | .22 |
| | | | 01-14-95 | 0720 | 311 | 1,540 | 8.1 | .0 | -- | .23 | .03 | 5.6 | .6 | 1.0 | .37 | .38 | .51 |

**Table 3**. Water-quality data collected as part of the nutrient synoptic sampling, April 1994 through January 1995--Continued

| Site number (fig. 4) | River mile[1] | Station name | Date | Time | Streamflow ($ft^3/s$) | Specific conductance (μS/cm) | pH (standard units) | Water temperature (°C) | Oxygen, dissolved (mg/L) | Nitrogen, ammonia, dissolved (mg/L as N) | Nitrogen, nitrite, dissolved (mg/L as N) | Nitrogen, nitrite plus nitrate, dissolved (mg/L as N) | Nitrogen, ammonia plus organic, dissolved (mg/L as N) | Nitrogen, ammonia plus organic, total (mg/L as N) | Phosphorus, ortho, dissolved (mg/L as P) | Phosphorus, dissolved (mg/L as P) | Phosphorus, total (mg/L as P) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 | 152.0 | Bijou Creek near Log Lane Village, Colo. | 08-30-94 | 1445 | 6.9 | 1,610 | 7.4 | 16.5 | 5.4 | 0.04 | 0.06 | 8.4 | <0.2 | 0.3 | <0.01 | 0.02 | 0.02 |
| | | | 01-14-95 | 1640 | 6.4 | 1,620 | 7.6 | 13.5 | 5.6 | <.01 | .05 | 8.0 | .2 | .2 | .03 | .03 | .04 |
| 28 | 155.5 | South Platte River at Fort Morgan, Colo. | 04-19-94 | 0930 | 390 | 1,620 | 8.4 | 13.5 | 9.3 | .24 | .02 | 4.4 | .6 | .8 | .28 | .27 | .33 |
| | | | 01-14-95 | 1020 | 425 | 1,560 | 8.1 | 1.5 | -- | .37 | .03 | 5.3 | .7 | 1.5 | .33 | .31 | .56 |
| 29 | 161.0 | South Platte River at Road 24, near Fort Morgan, Colo. | 04-19-94 | 1110 | 384 | 1,700 | 8.5 | 15.0 | 8.9 | .06 | .04 | 4.7 | .3 | .8 | .28 | .28 | .36 |
| | | | 01-14-95 | 1315 | 477 | 1,630 | 8.3 | 4.0 | -- | .60 | .04 | 5.4 | .9 | 1.6 | .32 | .30 | .52 |
| 30 | 170.0 | Beaver Creek at Hillrose, Colo. | 04-19-94 | 1255 | 8.6 | 1,660 | 8.8 | 17.0 | 15.2 | .02 | .06 | 3.9 | .3 | .8 | .17 | .18 | .27 |
| | | | 08-30-94 | 1635 | 1.2 | 1,710 | 9.0 | 23.0 | 18.7 | .01 | .05 | 2.1 | .4 | .7 | <.01 | .02 | .11 |
| | | | 01-15-95 | 0600 | 0 | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| 31 | 178.2 | South Platte River at Cooper Bridge, near Balzac, Colo. | 04-26-94 | 1255 | 147 | 2,050 | 8.4 | 13.0 | 9.2 | .03 | .03 | 4.0 | .3 | .6 | .17 | .17 | .25 |
| | | | 05-10-94 | 1230 | 193 | 1,980 | 8.2 | 16.5 | 8.2 | .06 | .03 | 3.9 | .4 | 1.4 | .19 | .20 | .61 |
| | | | 06-02-94 | 0830 | 451 | 1,560 | 8.5 | 18.5 | 8.4 | .03 | .02 | 3.2 | .4 | 1.4 | .22 | .22 | .45 |
| | | | 08-31-94 | 0905 | 326 | 1,840 | 8.4 | 16.5 | 8.2 | .01 | .01 | 4.3 | .3 | .4 | .14 | .15 | .17 |
| | | | 01-15-95 | 0720 | 203 | 1,750 | 8.5 | 1.5 | 15.0 | .36 | .04 | 4.9 | .7 | .8 | .26 | .30 | .28 |

**Table 3**. Water-quality data collected as part of the nutrient synoptic sampling, April 1994 through January 1995--Continued

| Site number (fig. 4) | River mile[1] | Station name | Date | Time | Stream-flow ($ft^3/s$) | Specific conduc-tance (µS/cm) | pH (stan-dard units) | Water tem-pera-ture (°C) | Oxygen, dis-solved (mg/L) | Nitro-gen, ammo-nia, dis-solved (mg/L as N) | Nitro-gen, nitrite, dis-solved (mg/L as N) | Nitro-gen, nitrite plus nitrate, dis-solved (mg/L as N) | Nitro-gen, ammo-nia plus organ-ic, dis-solved (mg/L as N) | Nitro-gen, ammo-nia plus organ-ic, total (mg/L as N) | Phos-phorus, ortho, dis-solved (mg/L as P) | Phos-phorus, dis-solved (mg/L as P) | Phos-phorus, total (mg/L as P) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 185.0 | South Platte River at Highway 6, near Merino, Colo. | 04-26-94 | 1700 | 29 | 1,930 | 8.4 | 13.5 | 11.4 | 0.04 | 0.03 | 3.3 | 0.4 | 0.4 | 0.10 | 0.09 | 0.10 |
| | | | 01-15-95 | 1050 | 85 | 1,890 | 8.3 | 6.5 | 13.7 | .06 | .03 | 3.0 | .3 | .4 | .10 | .08 | .12 |
| 33 | 202.0 | South Platte River at Highway 6, at Sterling, Colo. | 04-27-94 | 0910 | 62 | 2,040 | 8.4 | 4.5 | 12.5 | .03 | .04 | 3.7 | .3 | .5 | .07 | .07 | .11 |
| | | | 01-15-95 | 1415 | 134 | 1,910 | 8.4 | 7.5 | -- | .05 | .03 | 3.1 | .2 | .4 | .10 | .09 | .11 |
| 34 | 211.0 | South Platte River at Road 40, near Sterling, Colo. | 04-27-94 | 1050 | 41 | 2,230 | 8.5 | 7.5 | 14.6 | .02 | .04 | 3.0 | .5 | .6 | .04 | .04 | .08 |
| | | | 01-15-95 | 1615 | 162 | 1,990 | 8.5 | 7.0 | -- | .05 | .02 | 3.1 | .3 | .4 | .10 | .10 | .12 |
| 35 | 231.0 | South Platte River near Crook, Colo. | 04-27-94 | 1400 | 38 | 2,350 | 8.6 | 7.5 | 15.2 | .03 | .04 | 2.8 | .5 | .9 | .07 | .07 | .18 |
| | | | 01-16-95 | 0730 | 251 | 2,120 | 8.6 | .0 | 12.1 | .06 | .03 | 3.0 | .3 | .4 | .08 | .07 | .09 |
| 36 | 244.0 | Cottonwood Creek near Sedgwick, Colo. | 01-16-95 | 1145 | 26 | 2,450 | 8.3 | 4.0 | 12.1 | .06 | .03 | 3.0 | .7 | .8 | .05 | .05 | .11 |
| 37 | 257.4 | Lodgepole Creek at Ovid, Colo. | 05-11-94 | 1300 | 30 | 1,960 | 8.5 | 19.5 | 12.6 | .03 | .06 | 1.6 | .3 | .7 | .02 | .04 | .11 |
| | | | 06-02-94 | 1400 | 21 | 2,570 | 8.4 | 22.0 | 7.9 | .05 | .03 | .46 | .9 | 2.3 | .01 | .04 | .50 |
| | | | 08-31-94 | 1510 | 1.1 | 2,390 | 8.4 | 15.0 | 9.7 | .03 | .06 | 5.2 | .4 | .4 | <.01 | <.01 | <.01 |
| | | | 01-16-95 | 0800 | 0 | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |

**Table 3**. Water-quality data collected as part of the nutrient synoptic sampling, April 1994 through January 1995--Continued

| Site number (fig. 4) | River mile[1] | Station name | Date | Time | Streamflow ($ft^3/s$) | Specific conductance (µS/cm) | pH (standard units) | Water temperature (°C) | Oxygen, dissolved (mg/L) | Nitrogen, ammonia, dissolved (mg/L as N) | Nitrogen, nitrite, dissolved (mg/L as N) | Nitrogen, nitrite plus nitrate, dissolved (mg/L as N) | Nitrogen, ammonia plus organic, dissolved (mg/L as N) | Nitrogen, ammonia plus organic, total (mg/L as N) | Phosphorus, ortho, dissolved (mg/L as P) | Phosphorus, dissolved (mg/L as P) | Phosphorus, total (mg/L as P) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 38 | 266.2 | South Platte River | 04-27-94 | 1610 | 121 | 2,220 | 8.4 | 7.5 | 1.8 | 0.02 | 0.04 | 2.9 | 0.4 | 0.6 | 0.03 | 0.03 | 0.08 |
| | | at Julesburg, | 05-11-94 | 1100 | 83 | 2,140 | 8.2 | 18.5 | 10.3 | .03 | .05 | 2.7 | .4 | .8 | <.01 | .02 | .07 |
| | | Colo. | 06-02-94 | 1230 | 107 | 2,180 | 8.4 | 21.5 | 11.0 | .02 | .03 | .85 | .3 | 2.1 | <.01 | <.01 | .23 |
| | | | 08-31-94 | 1345 | 15 | 2,350 | 8.2 | 16.0 | 10.9 | .03 | .07 | 6.6 | .4 | .5 | <.01 | .01 | .02 |
| | | | 01-16-95 | 1020 | 335 | 2,110 | 8.4 | .5 | 12.4 | .07 | .03 | 3.0 | .3 | .4 | .08 | .07 | .09 |
| 39 | 290.2 | South Platte River | 04-28-94 | 0950 | 92 | 2,070 | 8.5 | 5.0 | -- | .02 | .03 | 3.1 | .4 | .5 | .06 | .05 | .08 |
| | | at Brule, Nebr. | 01-19-95 | 1300 | 376 | 1,310 | 8.4 | .0 | 12.3 | .07 | .03 | 3.0 | .5 | .5 | .07 | .06 | .09 |
| 40 | 320.6 | South Platte River | 04-28-94 | 0820 | 93 | 1,940 | 8.5 | 3.0 | 12.0 | .02 | .02 | 2.4 | .3 | .4 | .07 | .06 | .08 |
| | | at Paxton, Nebr. | 01-19-95 | 1530 | 139 | 1,400 | 8.5 | .0 | 11.0 | .03 | .02 | 2.5 | .4 | .5 | .08 | .07 | .10 |
| 41 | 355.9 | South Platte River | 05-03-94 | 1030 | 193 | 1,280 | 8.4 | 10.0 | 10.0 | .02 | <.01 | 1.4 | <.2 | .3 | .04 | .04 | .06 |
| | | at North Platte, | 05-11-94 | 0740 | 228 | 1,170 | 8.3 | 15.0 | 9.4 | .04 | .02 | 1.3 | .2 | .5 | .03 | .05 | .12 |
| | | Nebr. | 06-01-94 | 1000 | 175 | 1,130 | 8.5 | 16.5 | 10.0 | .02 | .02 | .50 | <.2 | .8 | .01 | <.01 | .07 |
| | | | 08-30-94 | 1130 | 157 | 935 | 8.4 | 21.0 | 8.8 | .03 | .01 | .85 | .2 | .4 | .02 | .02 | .05 |
| | | | 01-20-95 | 1030 | 205 | 1,030 | 8.5 | 2.0 | 11.2 | .03 | .01 | 2.2 | .2 | .6 | .06 | .06 | .12 |

[1]River mile is measured downstream from the reference location of the confluence of the North Fork of the South Platte River with the South Platte River. River mile for tributary sites is location of confluence of tributary with the South Platte River.



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