Water-Quality Assessment of the South Platte River Basin, Colorado, Nebraska, and Wyoming--Analysis of Available Nutrient, Suspended-Sediment, and Pesticide Data, Water Years 1980-92

by Kevin F. Dennehy, David W. Litke, Peter B. McMahon, Janet S. Heiny, and Cathy M. Tate

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
million gallons per day (Mgal/d)	0.04387	cubic meter per second
ounce (oz)	0.0283	kilogram
pound (lb)	0.4536	kilogram
pound per acre (lb/acre)	0.000112	kilogram per square meter
square mile (mi^2)	2.590	square kilometer
ton	0.9022	megagram
ton per year (ton/yr)	0.9022	megagram per year

Temperature in degree Celsius (°C) can be converted to degree Fahrenheit (°F) as follows:

$$°F = 1.8 (°C) + 32$$

Temperature in degree Fahrenheit (°F) can be converted to degree Celsius (°C) as follows:

$$°C = (°F - 32)/1.8$$

ADDITIONAL ABBREVIATIONS

mg/L	milligram per liter	MCL	Maximum Contaminant Level
µg/L	microgram per liter	µg/g	microgram per gram

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Seal Level Datum of 1929.

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ABSTRACT

In 1991, a water-quality investigation of the South Platte River Basin was initiated as part of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) program. One of the first tasks of the assessment was a compilation, screening, and interpretation of available nutrient, suspended-sediment, and pesticide data collected from surface- and ground-water sites in the basin. The data used in the analysis were from water years 1980–92. The analysis of existing water-quality data provides a perspective on recent water-quality conditions in the South Platte River Basin, evaluations of the strengths and weaknesses of available data, and implications for water-quality issues and future study priorities and design.

Most of the data used in the analysis were retrieved from the U.S. Geological Survey National Water Information System and U.S. Environmental Protection Agency Storage and Retrieval data bases. Data collected from three local agencies not contained in either data base were also used in the analysis. A total of 3,484 samples from 54 surface-water sites and 107 wells were used in the analysis. The quantity of data available from these sites and wells varied considerably with respect to constituent sampled.

The areal distribution of nutrient samples collected from surface-water and ground-water sites were sufficient in number and areal distribution to describe current water-quality conditions throughout the basin, but data were not sufficient to analyze factors and processes affecting water quality. However, suspended-sediment and pesticide data were sparse in their distribution with respect to time, space, and flow regime, and were sufficient only to provide a preliminary description of conditions in the basin.

Data indicate that nutrient concentrations (nitrogen and phosphorus) in surface-water samples were elevated downstream of point source discharges, especially wastewater treatment plants, in urban and mixed urban and agricultural areas. Concentrations of dissolved nitrite plus nitrate were substantially higher during the winter (low-flow) season than at other times of the year. Only two surface-water samples equaled or exceeded the U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Level (MCL) (10 milligrams per liter (mg/L) as nitrogen). The composition of the nitrogen load was mostly as organic nitrogen plus ammonia in the urban areas, whereas nitrite plus nitrate was most of the load in the downstream agricultural areas. Nitrogen concentrations in ground-water samples were generally highest in samples from the alluvial aquifer collected from wells completed in agricultural areas. Forty-six percent of the dissolved nitrite plus nitrate analyses from wells completed in the alluvium underlying agricultural areas equaled or exceeded the MCL for nitrate.

Generally, suspended-sediment concentrations were larger at the downstream sites in the basin. Water-management practices, especially in the lower basin, affect and control the sediment transport along the river. Suspended sediment concentrations varied by month, with the highest loads being transported during snowmelt runoff.

Most pesticide concentrations were less than laboratory reporting levels. The pesticides with the highest percent detections in surface water among the six land uses studied were atrazine in agricultural areas and picloram in mixed agricultural and urban land use. Only one surface-water site, located in the mixed agricultural and urban land-use area, had a pesticide (parathion) concentration that exceeded a water-quality

criteria. All but one of the detectable concentration of pesticides in ground-water samples occurred in alluvial wells, and all detections were from agricultural land-use areas. None of the pesticide concentrations in ground water exceeded State and Federal water-quality criteria.

INTRODUCTION

In 1991, the U.S. Geological Survey (USGS) began a full-scale National Water-Quality Assessment (NAWQA) program. The long-term goals of the NAWQA program are to describe the status and trends in the quality of a large 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. In meeting these goals, the program will produce a wealth of water-quality information that will be useful to policy makers and managers at the national, State, and local levels.

A major design feature of the NAWQA program is the integration of water-quality information at different areal scales. The principal building blocks of the program are the study-unit investigations on which the national-level assessments are based (Jones and Sylvester, 1992). The 60 study-unit investigations that make up the program are hydrologic systems that include parts of the Nation's major river basins and aquifer systems. These study units include areas ranging from about 600 mi^2 (Oahu Study Unit) to about 67,000 mi^2 (Central High Plains Study Unit) and incorporate about 60 to 70 percent of the Nation's water use and population served by public water supply. In 1991, the South Platte River Basin was among the first 20 NAWQA study units selected for study.

A diverse group of local, State, and Federal agencies and organizations have collected water-quality data throughout the South Platte River Basin for a variety of purposes. One of the first activities to be undertaken by this study was a compilation, screening, and analysis of available water-quality data. This preliminary water-quality assessment will help establish priorities and help formulate plans for the intensive data collection activities.

Purpose and Scope

This report presents the analysis of available nutrient, suspended-sediment, and pesticide information for the South Platte River Basin in Colorado, Nebraska, and Wyoming for water years 1980–92. More specifically, the purposes of this report are to: (1) Describe recent water-quality conditions for these selected constituents to the extent possible in the South Platte River Basin; (2) provide information on strengths and weaknesses of the available data; and (3) assess implications of findings to relevant water-quality issues in the basin and to future study priorities and design.

A total of 3,484 samples from 54 surface-water sites and 107 wells were used in this analysis. Nutrient constituents examined included: total nitrogen, total organic nitrogen plus ammonia (for surface-water sites), dissolved organic nitrogen plus ammonia (for ground-water sites), dissolved ammonia, dissolved nitrite, dissolved nitrite plus nitrate, dissolved phosphorus, dissolved orthophosphate, and total phosphorus. All nitrogen species are reported as nitrogen, and all phosphorus species are reported as phosphorus. Suspended-sediment constituents examined included suspended-sediment concentration and suspended-sediment particle size distribution. Pesticide constituents examined included these compound classes: carbamates, chlorophenoxy acid herbicides, organochlorine and organophosphorus insecticides, and triazine and other nitrogen-containing herbicides.

Acknowledgments

The authors wish to thank the various Federal and State agencies and members of the South Platte River Basin Liaison Committee for their cooperation in providing information and data that were used in preparing this report. Specifically, the authors are grateful to the U.S. Environmental Protection Agency, Region VIII; Colorado Department of Health; Denver Regional Council of Governments; Denver Water Department; Metro Wastewater Reclamation District; and Northern Front Range Water Quality Planning Association for their assistance during the preparation of this report. We would also like to thank James E. Paschal (U.S. Geological Survey) for compiling the database for this report and Sharon L. Qi (U.S. Geological Survey) for preparing the report graphics and tables.

DESCRIPTION OF THE SOUTH PLATTE RIVER BASIN

This section gives a brief synopsis of the natural and anthropogenic features in the South Platte River Basin that may affect water quality. For a more detailed description of the environmental setting and its implications for water quality, the reader may refer to Dennehy and others (1993).

Physical Setting

The South Platte River Basin has a drainage area of about 24,300 mi^2 (Dennehy, 1991) and is located in parts of three States (fig. 1): Colorado (79 percent of the basin), Nebraska (15 percent of the basin), and Wyoming (6 percent of the basin). The South Platte River originates in the mountains of central Colorado at the Continental Divide and flows about 450 mi northeast across the Great Plains to its confluence with the North Platte River at North Platte, Nebraska. Altitude in the basin ranges from 14,286 ft at Mt. Lincoln on the Continental Divide to 2,750 ft at the confluence of the South Platte and North Platte Rivers. The basin includes two physiographic provinces, the Front Range Section of the Southern Rocky Mountain Province and the Colorado Piedmont Section of the Great Plains Province.

The basin has a continental-type climate modified by topography, in which there are large temperature ranges and irregular seasonal and annual precipitation. Mean temperatures increase from west to east and on the plains from north to south (Gaggiani and others, 1987). Areas along the Continental Divide average 30 in. or more of precipitation annually, which includes snowfall in excess of 300 in. In contrast, the annual precipitation on the plains east of Denver, Colorado, and in the South Park area in the southwest part of the basin, ranges from 7 to 15 in (fig. 2). Most of the precipitation on the plains occurs as rain, which falls between April and September, while most of the precipitation in the mountains occurs as snow, which falls during the winter.

The three-State area of the South Platte River Basin has about 2.4 million people, over 95 percent of whom live in Colorado. The basin contains the most concentrated population density in the Rocky Mountain region (fig. 3) located along the Front Range urban corridor in Colorado where the mountains meet the plains. Population densities outside the urban corridor are small, centered in small towns located along the principal streams. The principal economy in the mountainous headwaters is based on tourism and recreation; the economy in the urbanized south-central region mostly is related to manufacturing, service and trade industries, and government services; and the economy of the basin downstream from Denver is based on agriculture and livestock production.

Land use and land cover in the South Platte River Basin (fig. 4) during the period 1975–80 (Feagas, and others, 1983) is divided into: 41 percent rangeland, 37 percent agricultural land, 16 percent forest land, 3 percent urban or built-up land, and 3 percent other land. Rangeland is present across all areas of the basin except over the high mountain forests. Agricultural land is somewhat more restricted to the plains and the South Park area near Fairplay, Colorado. Forest land occurs in a north-south band in the mountains. Urban or built-up land is present primarily in the Front Range urban corridor. The 'other land' category includes: water (110 mi^2), barren lands (160 mi^2), tundra (400 mi^2), and perennial snow and ice (1 mi^2). Barren lands primarily are areas under construction or are areas of strip mining, quarries, or gravel pits.

Hydrologic Setting

The South Platte River and its major tributaries (Clear Creek, St. Vrain Creek, Big Thompson River, and Cache la Poudre River) originate in the Rocky Mountains and maintain perennial flow generated primarily by snowmelt runoff. Prairie streams, on the other hand, are ephemeral and intermittent and contribute little to South Platte River flows except during rainfall events. Mean annual-runoff patterns (fig. 5) mirror precipitation patterns, with runoff greater than 20 in. in the mountains and runoff less than 2 in. in the plains. Annual mean streamflow and mean monthly streamflow for a typical mountain stream (Big Thompson River at Estes Park, Colorado, station number 06733000) and a typical plains stream (Bijou Creek at Wiggins, Colorado, station number 06759000) are shown in figure 6. Although the drainage area of the Bijou Creek station is 1,310 mi^2, its mean annual streamflow was only 9.2 cubic feet per second (ft^3/s), compared to the Big Thompson station with a drainage area of 137 mi^2 and a mean annual streamflow of 127 ft^3/s. Annual flows on Bijou Creek are small for most years, but infrequently can be extremely large; annual variability on the Big Thompson River is less. Monthly flow on Bijou Creek occurs only during the summer rainstorm season, while on the Big Thompson there is an annual baseflow in addition to the spring snowmelt runoff. Many of the streams in the South Platte River Basin originate in the mountains, and then flow through the plains, and have streamflow characteristics that are a mixture of the two types. Among the water-quality sites examined in this report there are 20 sites that have at least 10 years of streamflow data; streamflow statistics for these sites are listed in table 27 in the "Supplemental Data" section at the back of this report.

There are three primary aquifers in the South Platte River Basin (fig. 7): the unconsolidated alluvial aquifer along the South Platte River and its tributaries, which includes about 4,000 mi^2 of gravel, sand, silt, and clay (hereinafter referred to in this report as the

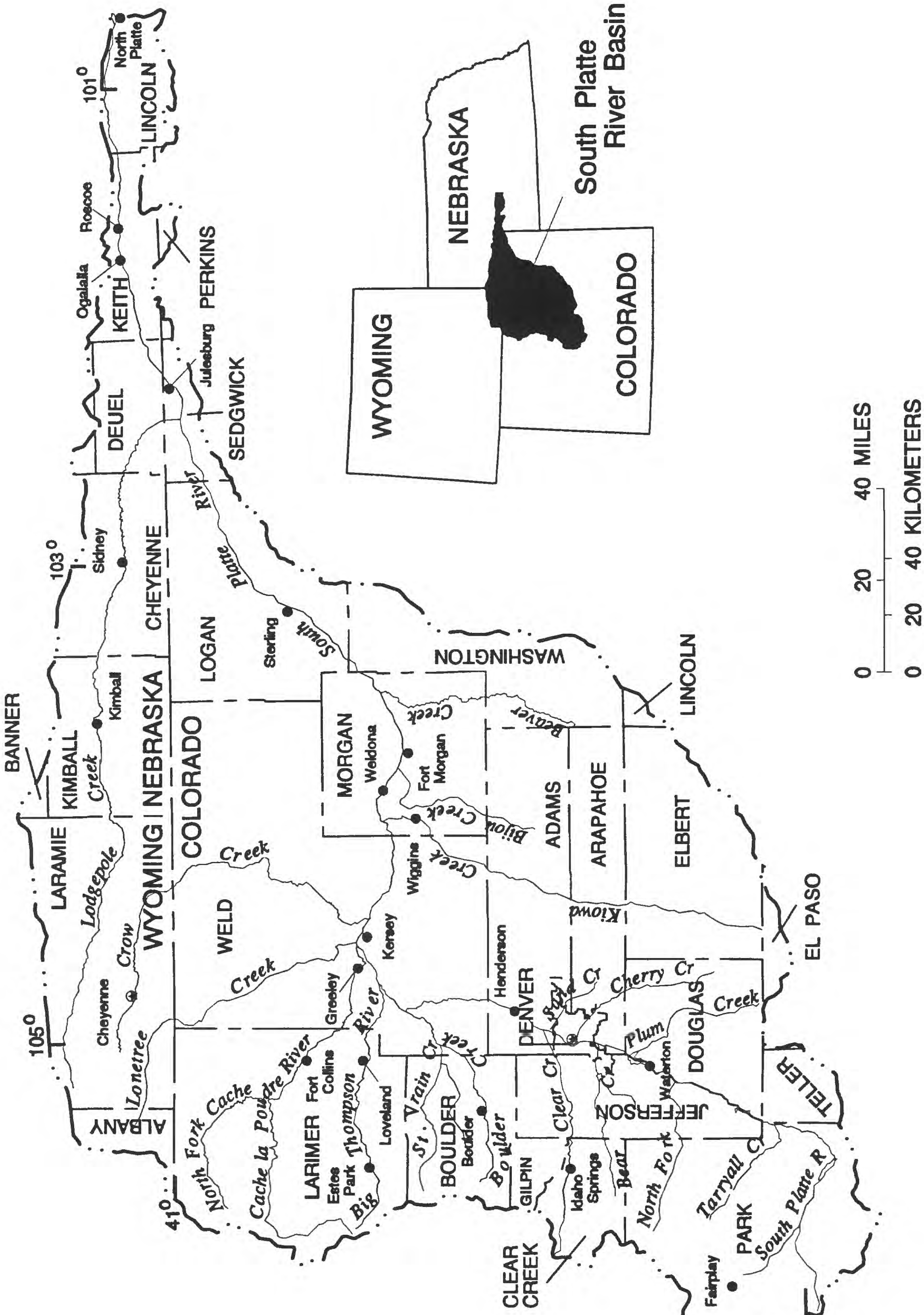

Figure 1. Location of the study unit and selected cities and streams in the South Platte River Basin.

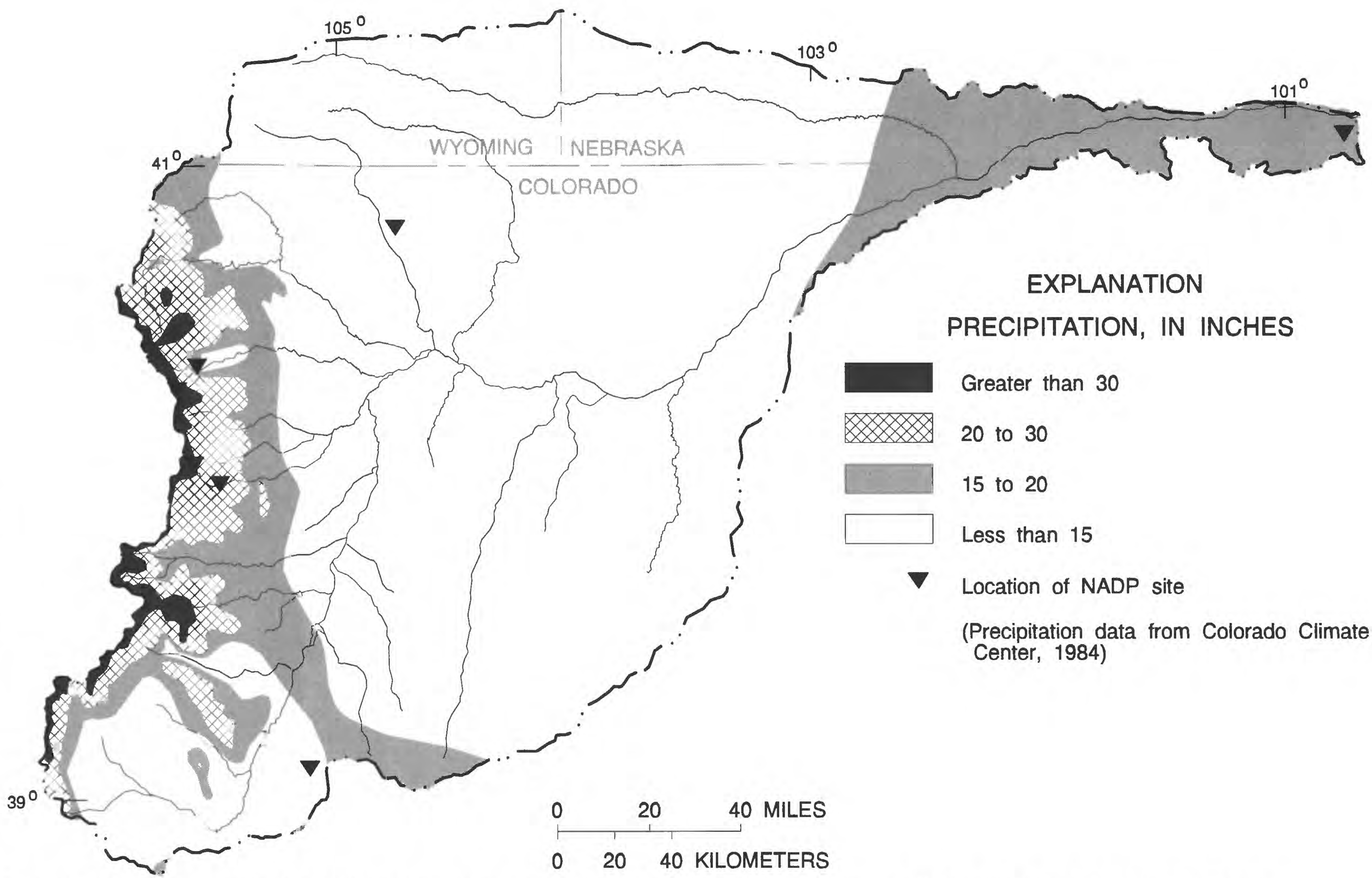

Figure 2. Average annual precipitation (1951–80) and location of National Atmospheric Deposition Program (NADP) sites in the South Platte River Basin.

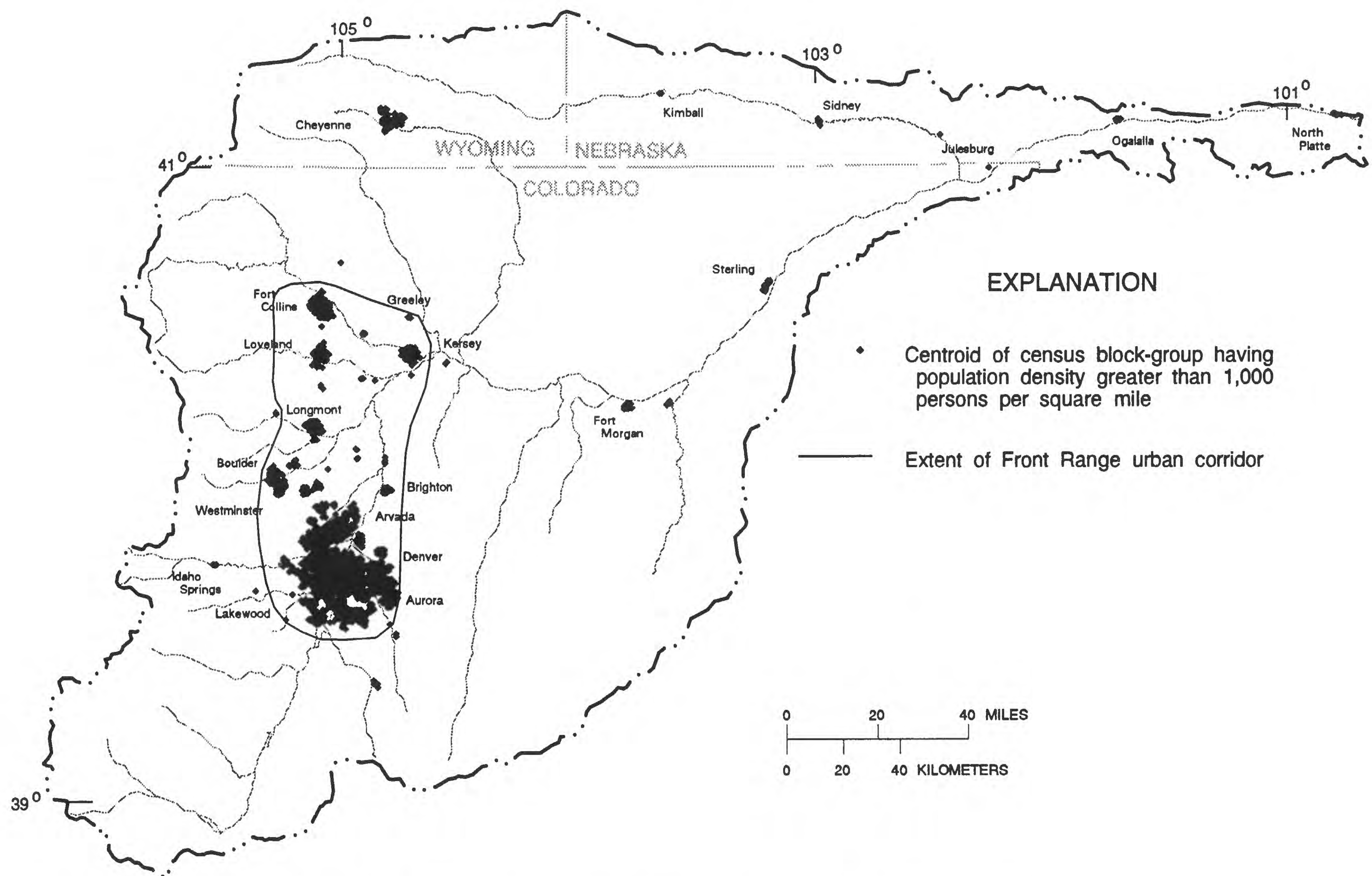

Figure 3. Population density in the South Platte River Basin (data from U.S. Department of Commerce, Bureau of Census, 1991).

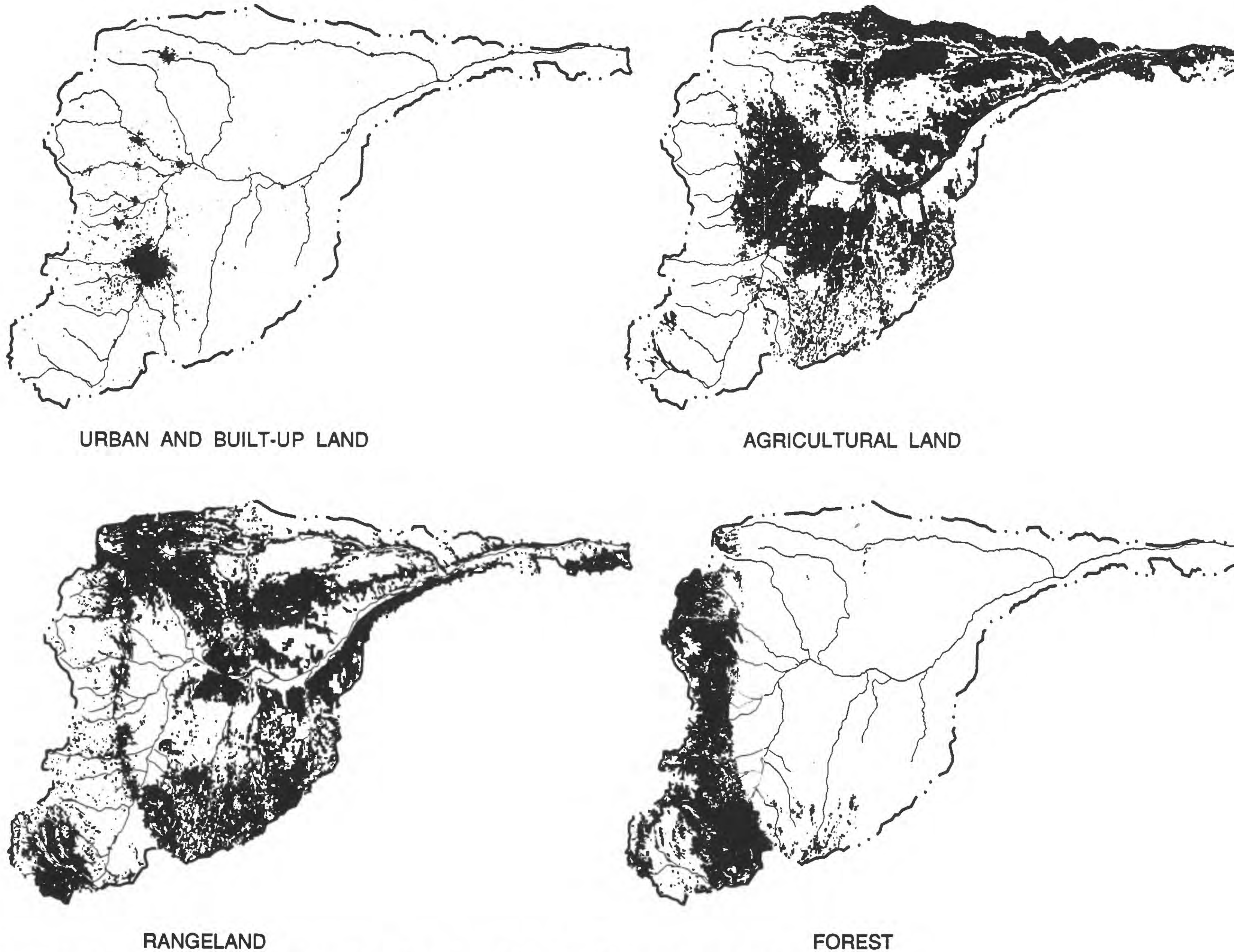

Figure 4. Major land uses, 1975–80, in the South Platte River Basin (from Feagas and others, 1983).

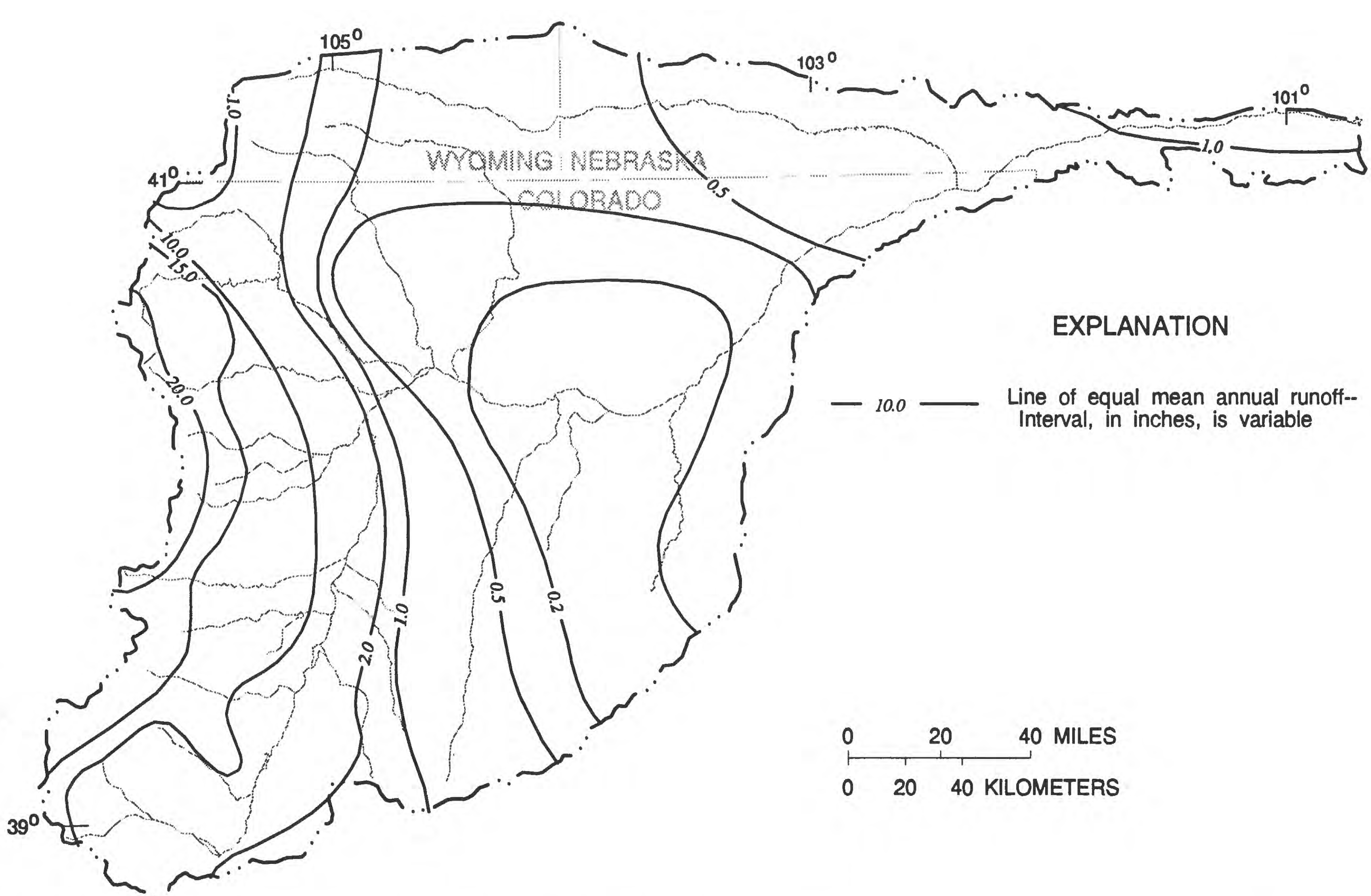

Figure 5. Mean annual runoff (1951–80) in the South Platte River Basin (Gerbert and others, 1987)

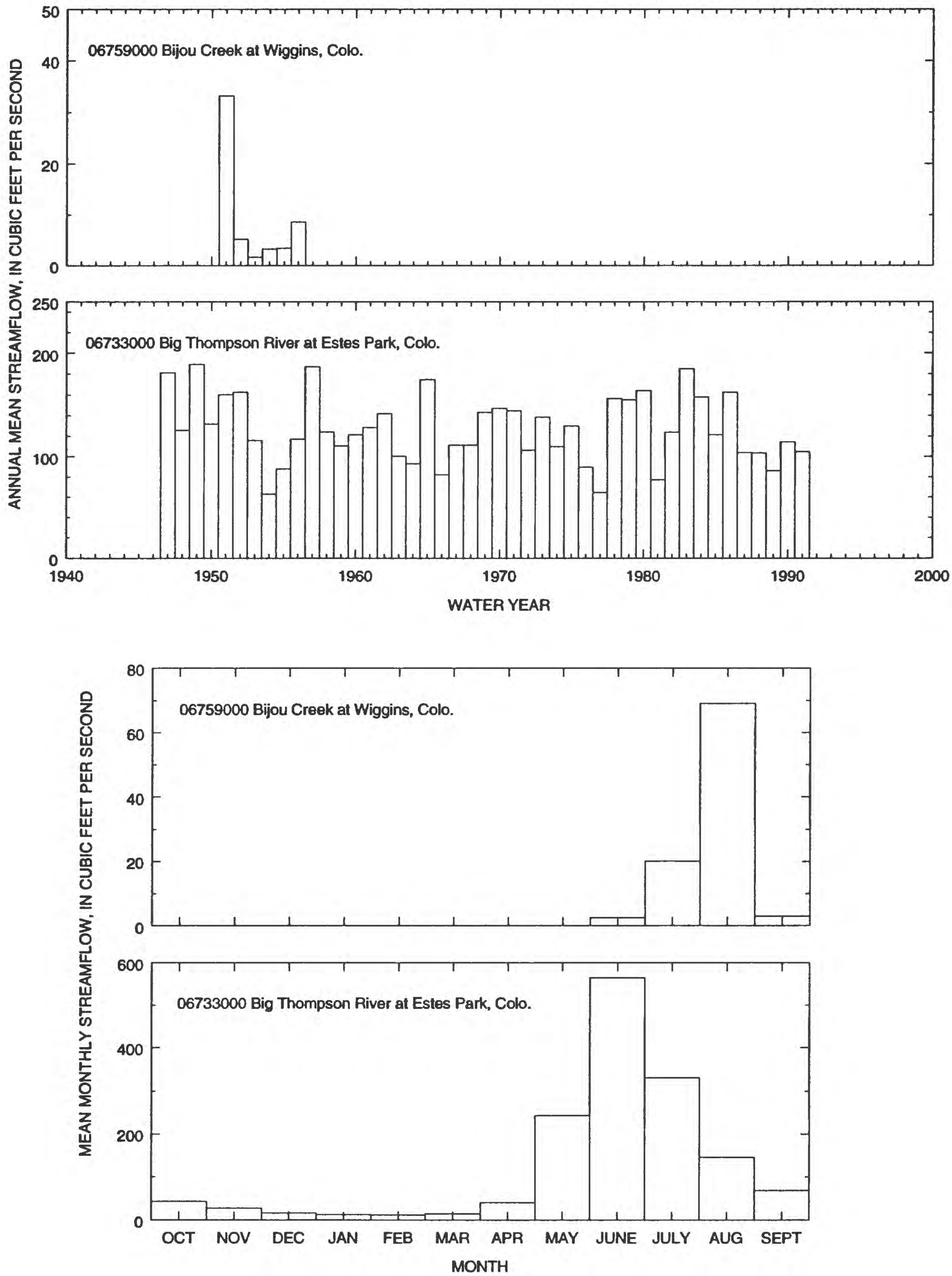

Figure 6. Annual mean streamflow and mean monthly streamflow at Bijou Creek at Wiggins, Colorado, and Big Thompson River at Estes Park, Colorado.

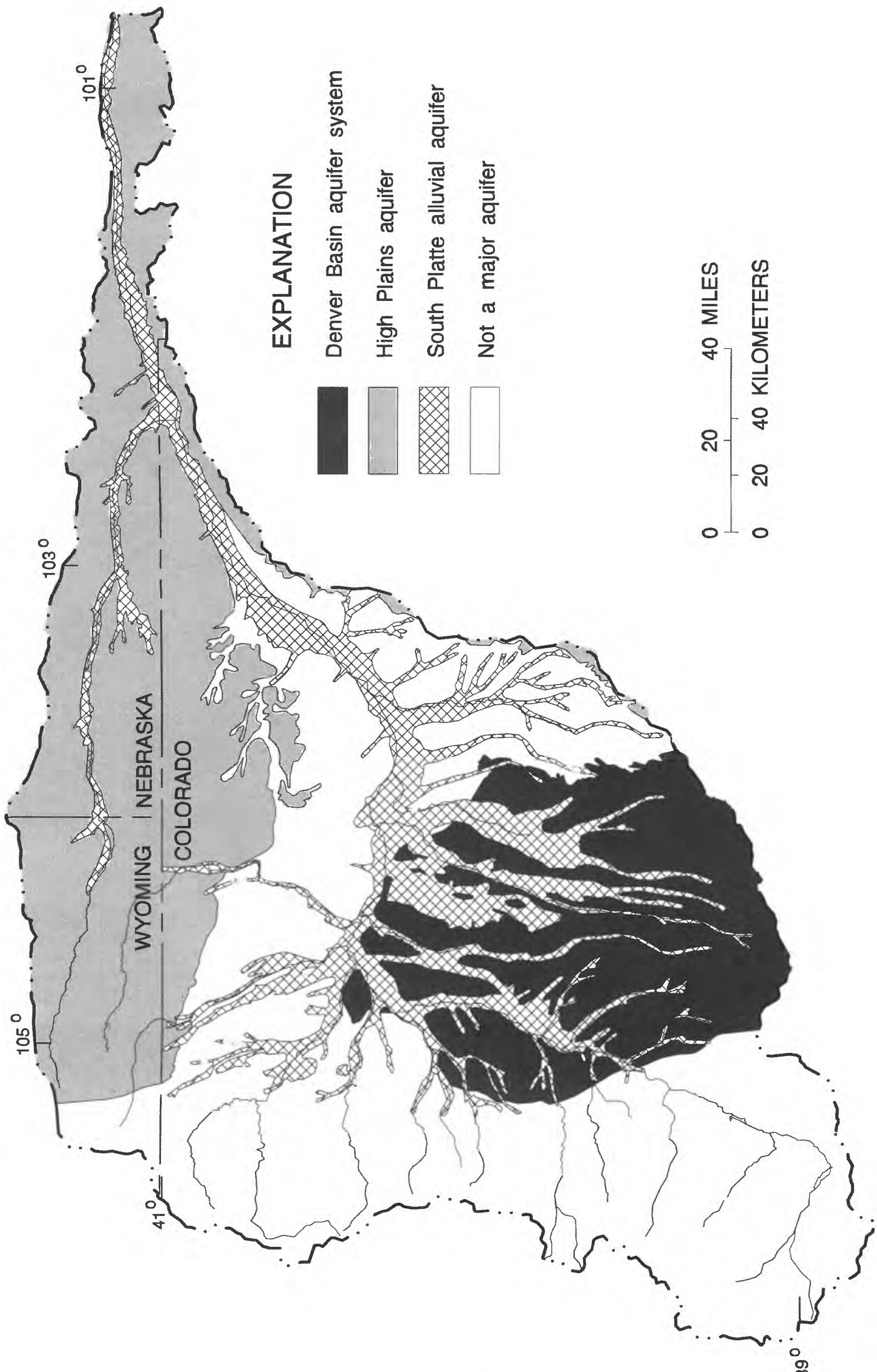

Figure 7. Major aquifers of the South Platte River Basin.

'alluvial aquifer' or 'alluvium'); the unconsolidated High Plains aquifer in eastern Colorado, southeastern Wyoming, and western Nebraska; and the consolidated rocks of the Denver Basin aquifer system in the Front Range urban corridor area. The Denver Basin aquifer system includes four named units, which, from stratigraphicaly lowest to highest are: the Laramie-Fox Hills, Arapahoe, Denver, and Dawson aquifers. The unconfined alluvial aquifer is hydraulically connected with the South Platte River along its main stem and major perennial tributaries and is recharged by precipitation, by leakage from streams, reservoirs, and ditches, and by percolation of applied irrigation water. The High Plains aquifer generally is unconfined, but is confined locally by lenses of silt and clay. The Denver Basin aquifer system consists of consolidated rocks, which underlie the South Platte River Basin; this aquifer system is recharged in outcrop areas by rainfall, snowmelt, and streamflow. Discharge from all three primary aquifers occurs through wells, seeps, springs, streams, and evapotranspiration.

The natural hydrology of the South Platte River Basin has been altered considerably by water development. The quantity of water in the basin has been increased an average of 400,000 acre-ft/yr through interbasin transfers of water from the Colorado, Arkansas, and North Platte River Basins (Litke and Appel, 1989). Occurrence of water has been modified in both space and time through a complex network of ditches and reservoirs (fig. 8 and table 1); the South Platte River is one of the most regulated rivers in the United States. Flows in the river during fall and winter (low flow) since the early 1900's have been maintained primarily by ground-water return flows from agricultural lands (Boyd, 1897; Hurr and others, 1975, p. 17), whereas flows during spring and summer (high flow) are dominated by a snowmelt runoff that is attenuated by reservoir storage and irrigation diversions.

An examination of flow conditions during water year 1991 gives a general picture of water routing along the South Platte River, although flows during the 1991 water year were about 25 percent below average. The South Platte River upstream from Denver is regulated by water-supply reservoirs, and most of the water is diverted via pipelines to water-treatment plants; the mean flow downstream from these diversions at South Platte River at Waterton (fig. 1) was 75 ft^3/s. The river next flows into Chatfield Reservoir, which is a flood-control reservoir whose releases generally match inflows; mean flow downstream from the dam was 74 ft^3/s. In the Chatfield to Henderson reach of the river, water is added by two major tributaries (Bear Creek, mean flow of 51 ft^3/s; Clear Creek, mean flow of 84 ft^3/s) and by wastewater-treatment-plant discharges (8 plants contribute about 275 ft^3/s), but more than 100 ft^3/s is removed by the Burlington Ditch and other irrigation ditches for irrigation downstream from this reach; mean flow downstream from Denver at South Platte River at Henderson was 393 ft^3/s. In the Henderson to Kersey reach of the river, three major tributaries enter the river: the St. Vrain River (mean flow of 208 ft^3/s), the Big Thompson River (mean flow of 64 ft^3/s), and the Cache la Poudre River (mean flow of 119 ft^3/s); mean flow at South Platte River at Kersey was 808 ft^3/s. Although the inputs to this reach (total of 780 ft^3/s) are about equal to the flow at Kersey, this balance masks the process of irrigation diversions and irrigation return flows (primarily ground-water return flows); several hundred cubic feet per second of water are diverted for irrigation through this reach. Flows on the South Platte River reach their maximum at Kersey. There are no major tributaries to the South Platte downstream from Kersey; the large prairie drainages (Bijou Creek, Kiowa Creek, Lodgepole Creek) flow only during large rainfall events or from irrigation return flows. From Kersey to North Platte, water is primarily removed by irrigation diversions and added by ground-water return flows from irrigation. At several locations, almost the entire river flow can be diverted. During 1991, mean flow was 470 ft^3/s at Weldona, 365 ft^3/s at Julesburg, 311 ft^3/s at Roscoe, Nebraska, and 216 ft^3/s at North Platte, Nebraska.

Water Use

The estimated total offstream water use in the South Platte River Basin in 1990 was 3,900 Mgal/d (4.4 million acre-ft). Of this amount, 71 percent is surface water, and 29 percent is ground water. Ground water is withdrawn primarily from the alluvial aquifer. The principal uses were irrigation (70.8 percent), power generation (14.6 percent), and domestic use (8.4 percent). Large instream uses of water include hydroelectric use (1,600 Mgal/d) and reservoir evaporation (220 Mgal/d). Water use is discussed in detail by Dennehy and others (1993).

Irrigation is the largest water use throughout the basin, except in the lower South Platte River in Nebraska where power generation is the largest use. Most of the domestic water use in the basin is present along the Front Range urban corridor; about 40 percent of this domestic use is for lawn watering (Litke and Appel, 1989). The remaining five water-use categories

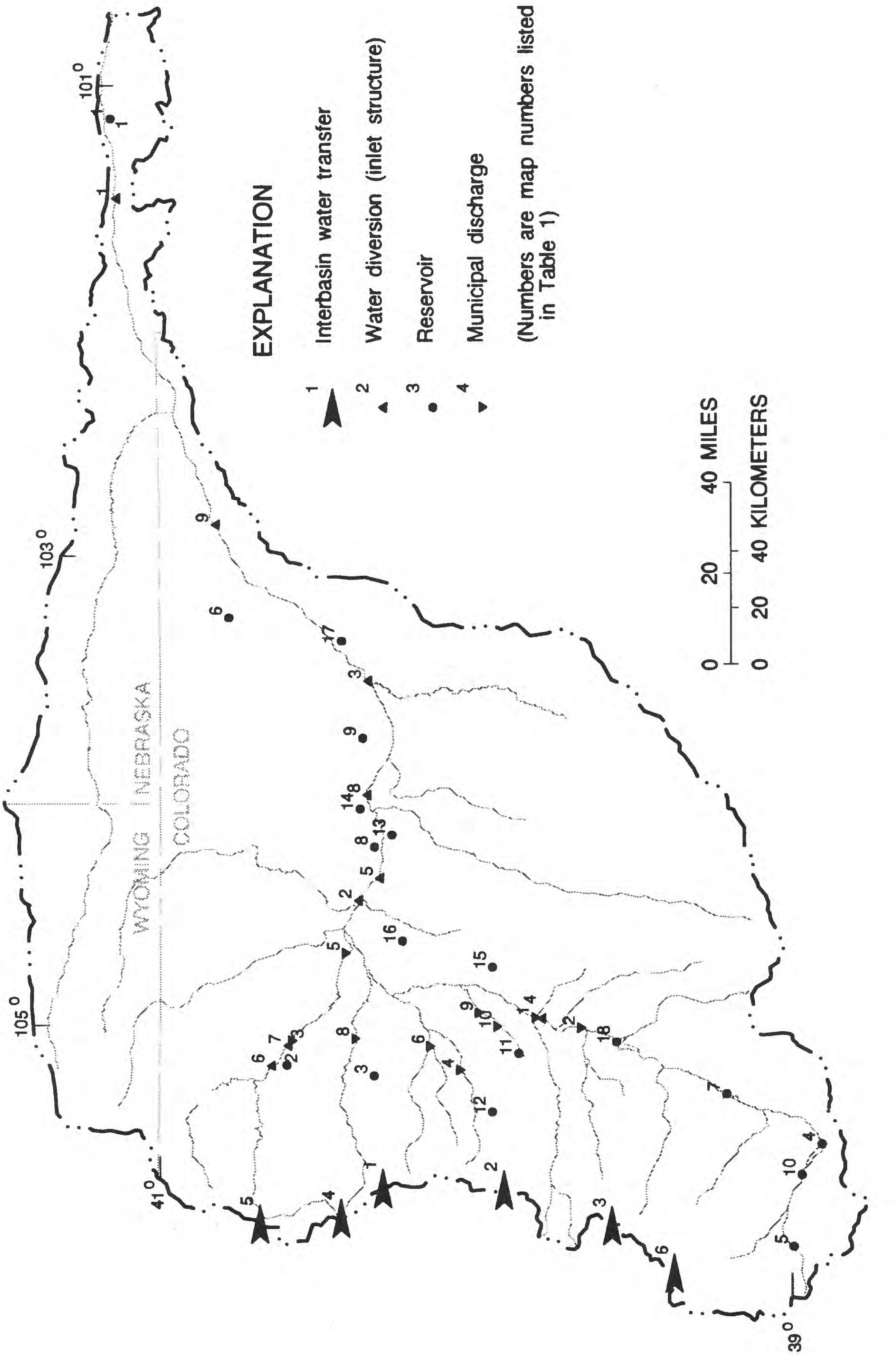

Figure 8. Major interbasin water transfers, water diversions, reservoirs, and municipal discharges in the South Platte River Basin.

Table 1. Major interbasin water transfers, water diversions, reservoirs, and municipal discharges in the South Platte River Basin

Map number (fig. 8)	Structure name	Water quantity (acre-feet per year)
	Interbasin Water Transfers[1]	
1	Alva B. Adams Tunnel	285,000
2	Moffat Water Tunnel	77,500
3	Harold D. Roberts	59,600
4	Grand River Ditch	20,800
5	Laramie-Poudre Tunnel	13,800
6	Hoosier Pass Tunnel	7,400
	Water Diversions[2]	
1	Korty Canal	211,000
2	Riverside Inlet Ditch	128,000
3	North Sterling Ditch	117,000
4	Burlington Ditch	96,400
5	Bijou Ditch	66,100
6	Larimer County Canal	63,900
7	Larimer and Weld Counties Canal	62,800
8	Fort Morgan Canal	61,700
9	Harmony No. 1 Ditch	61,700
	Reservoirs[3]	
1	Sutherland Reservoir	181,500
2	Horsetooth Reservoir	151,800
3	Carter Lake	112,200
4	Eleven Mile Canyon Reservoir	97,800
5	Antero Reservoir	85,600
6	North Sterling Reservoir	80,600
7	Cheesman Reservoir	79,100
8	Riverside Reservoir	65,000
9	Wildcat Reservoir (approved but not built)	64,000
10	Spinney Mountain Reservoir	54,500
11	Standley Reservoir	42,400
12	Gross Reservoir	43,100
13	Empire Reservoir	37,700
14	Jackson Lake	35,600
15	Barr Lake	32,200
16	Milton Lake Reservoir	29,700
17	Prewitt Reservoir	28,800
18	Chatfield Lake	26,600

Table 1. Major interbasin water transfers, water diversions, reservoirs, and municipal discharges in the South Platte River Basin--Continued

Map number (fig. 8)	Structure name	Water quantity (acre-feet per year)
	Municipal Discharges[4]	
1	Metro Wastewater Reclamation District	164,000
2	Cities of Littleton and Englewood	24,000
3	City of Fort Collins	18,000
4	City of Boulder—75th St. Plant	16,900
5	City of Greeley	8,900
6	City of Longmont	8,000
7	Publ. Util. Board of Cheyenne, Wyo.—Dry Cr	6,100
8	City of Loveland	5,900
9	City of Northglenn	5,400
10	City of Westminster	4,200

[1]Interbasin transfers conveying greater than 5,000 acre-feet are listed. Data are for 1985, except for Harold D. Roberts Tunnel. This tunnel was closed during most of 1985 and delivered only 299 acre-feet, so the more representative value of 59,600 acre-feet for 1990 was used.

[2]Diversions greater than 50,000 acre-feet are listed. Data are for 1990.

[3]Reservoirs having normal capacity greater than 25,000 acre-feet are listed.

[4]Municipal discharges greater than 4,000 acre-feet are listed. Data are for 1990.

(commercial, industrial, livestock, mining, and other) account for only 6.2 percent of total offstream water use. Commercial and industrial uses primarily occur in the Front Range urban corridor in Colorado. Mining water use includes sand and gravel operations, hard-rock mining, and oil and gas production. However, most the water used in the basin is returned to the hydrologic system; only 44 percent of the water withdrawn is consumptively used. Irrigation-return flows amount to 1,200 Mgal/d, primarily as ground-water return flows.

Urban Practices

Urban and built-up areas comprise only 3 percent of the total land use in the South Platte River Basin, but because of the variety and intensity of urban activities, there can be a disproportionate effect on water quality. Urban practices can lead to both point source and non-point source effects on water quality. For example, a study on urban storm runoff in the Denver Metropolitan area (Ellis and others, 1984), reported that point sources were substantial contributors to nutrient loads in the South Platte River, while storm runoff was a major contributor of suspended solids, total organic carbon, lead, and zinc.

Point sources to surface water are permitted by the U.S. Environmental Protection Agency (USEPA) National Pollution Discharge Elimination System (NPDES) program. The ten largest wastewater-treatment plants in the study unit, which discharge at least 4,200 acre-ft (6 ft^3/s), are listed in table 1. Effluent discharges from these plants can make up a substantial part of the streamflow downstream from their discharge points. For example, the largest discharger in the basin, Metro Wastewater Reclamation District (MWRD), on an annual basis can account for about 69 percent of the flow and as much as 100 percent on a given day in the South Platte River downstream from the discharge point. In addition to wastewater-treatment plants there are other point dischargers; in Colorado in 1990 there were 253 facility discharge permits of which 142 were wastewater-treatment plants. Other urban-area dischargers include drinking water-treatment plants (25), breweries (3), meat-packing plants (2), and sugar-beet plants (3). Industrial dischargers generally recycle their water in-plant and pre-treat their effluent prior to discharging to a stream or sewer system.

Point sources to ground water include landfills, gasoline-storage tanks, and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) sites. There are nine USEPA Superfund CERCLA sites in the South Platte River Basin. They include Lowery Landfill in Arapahoe County, Marshall Landfill in Boulder County, Martin Marietta site and Rocky Flats site in Jefferson County, and the Sand Creek site and Rocky Mountain Arsenal in Denver and Adams Counties.

Non-point urban sources include urban storm runoff and urban lawn and turf irrigation return flows. Storm runoff currently is being investigated in urban areas to prepare for discharge permit applications. Cultivation of turf in urban lawns, parks, and golf courses is a widespread activity. It has been estimated that 42 percent of the total water demand by Denver Water Department customers is for summer seasonal use (U.S. Army Corps of Engineers, 1986, p.40); if this ratio is applied to the total water demand in the Denver metropolitan area for 1992, then it can be estimated that about 125,000 acre-ft are used in this area primarily to grow lawns. Since about 2 ft of water are needed to grow turf in a year, about 60,000 acres of turf may be grown. Turf-growing professionals recommend (Follett and others, 1991) that about 60 lbs/acre of nitrogen fertilizer be applied annually to lawns at four times throughout the growing season: late April–mid May, mid–late June, late August–early September, and October–early November, but actual application rates may vary widely. Pesticides also are applied to this acreage; however, there are little available data with which to characterize urban pesticide use.

Agricultural Practices

Agriculture accounts for about 37 percent of the land use in the South Platte River Basin. Essentially all of this acreage is located in the Plains east of the Rocky Mountains (fig. 4). Agriculture in the plains is located primarily in two areas: on the alluvial deposits of the South Platte River and its major tributaries and on the terrace deposits and bench lands above and adjacent to the alluvial deposits. The total amount of land in crops in counties in the basin is about 4.1 million acres (see table 28 in the "Supplemental Data" section at the back of this report). Of this acreage, about 1.4 million acres are irrigated, 1.6 million acres are non-irrigated, and the remaining acreage is partially irrigated.

Irrigated farming predominates on the alluvial deposits, whereas non-irrigated (dryland) farming predominates on the terrace deposits and bench lands. Corn (57 percent of all irrigated acreage), hay (26 percent of irrigated acreage), dry beans (7 percent of irrigated acreage), winter wheat (6 percent of irrigated acreage), and barley (3 percent of irrigated acreage) represent the major irrigated crops in the basin (table 28). The leading counties in the basin, in terms of irrigated-crop production, are Weld, Colorado; Lincoln, Nebraska; Morgan, Colorado; Perkins, Nebraska; and Logan, Nebraska. Table 2 lists the estimated net monthly irrigation requirements for selected crops in the Greeley, Colorado area. Alfalfa hay has the largest irrigation requirement, followed by sugar beets and corn. Most of the irrigation water is applied in July and August.

Winter wheat is the major non-irrigated crop grown in the basin (80 percent of all non-irrigated acreage). In terms of acres harvested, non-irrigated winter wheat represents the most important crop grown in the basin. The leading counties in the basin, in terms of non-irrigated-crop production, are Washington, Weld, Lincoln, Adams, and Logan, all of which are in Colorado.

In addition to field-crop production, cattle feedlot operations are an important form of agriculture on the alluvial deposits. Recent work by the U.S. Department of Agriculture, Agricultural Research Service (ARS) (Schuff, 1992), has indicated that ground water in aquifers in the vicinity of large feedlot operations along the South Platte River typically has elevated concentrations of dissolved nitrate. One possible source of the nitrate in ground water suggested in the ARS study is the leaching of nitrogen from manure after the manure has been applied to fields.

Table 29, in the "Supplemental Data" section in the back of the report, lists approximate planting dates, days to harvest, and rates and timing of application of common fertilizers and pesticides (herbicides and insecticides) for the crops referred to above. Most of the crops are planted between the middle of April and the end of May, and most fertilizer and pesticide applications occur around planting time. The rates and timing of fertilizer and pesticide application varies depending on numerous factors, including soil nutrient content and the kind of weed and insect problems encountered.

The most commonly applied pesticides in the South Platte River Basin are listed in table 3. Herbicide application data by county are available and are listed in table 30 in the "Supplemental Data" section at the back of this report. Insecticide application data by county are not available. The common names, trade names, compound classes, and typical applications of the pesticides are listed in table 31 in the "Supplemental Data" section at the back of this report. The most commonly applied herbicides were 2,4-D, EPTC, atrazine, alachlor, and butylate. Counties with the greatest herbicide applications were Weld, Colorado; Lincoln, Nebraska; Morgan, Colorado; Perkins, Nebraska; and Logan, Colorado. The herbicide 2,4-D is the most applied herbicide in the basin. Its primary uses are for broadleaf control in winter wheat and rangeland. Because most of the acreage associated with wheat and rangeland is located on the terrace deposits and bench lands, the potential effect of 2,4-D on surface-water quality may be smaller than that of pesticides applied predominantly on irrigated crops on the alluvial deposits. For example, EPTC, which is the second most applied herbicide in the basin, is used on irrigated crops like corn, dry beans, and sugar beets. Because most of the irrigated acreage is located on the alluvial deposits, EPTC can potentially have a greater effect on surface-water quality than 2,4-D. The most applied insecticides, in terms of pounds of active ingredient applied, were terbufos, chlorpyrifos, propargite, disulfoton, and carbofuran. Although the pesticides listed in table 3 represent some of the more important compounds used in the basin, they are only a few of the possible pesticides that could be applied.

Nitrogen was the most commonly applied fertilizer in the South Platte River Basin, followed by phosphorus (as P_2O_5) and potassium (as K_2O). Estimated fertilizer use by county for 1991 is listed in table 32 in the "Supplemental Data" section at the back of this report. The leading counties for fertilizer applications were Weld, Colorado; Lincoln, Nebraska; Perkins, Nebraska; Washington, Colorado; and Keith, Nebraska.

Water-Quality Issues in the Basin

Water-quality issues in the South Platte River Basin have been summarized by the Colorado Department of Health (1990). Standards have not been met in surface water for dissolved oxygen and un-ionized ammonia. Nutrient concentrations were determined to be elevated (but within standard limits) downstream from wastewater-treatment plants. Of 40 stream segments identified by the Colorado Department of Health as impaired, 14 were impaired by un-ionized ammonia, 3 by nutrients, and 2 by suspended sediment. Of 68 lakes and reservoirs in the basin, 33 have been assessed to date, and of these, 21 were categorized by the Colorado Department of Health as eutrophic. Ground water in shallow alluvial aquifers has been determined in some areas to contain concentrations of nitrate in excess of the drinking-water standard. Effected areas include the area around Greeley, Colorado (Schuff, 1992), and in southeast Deuel County, Nebraska (Rod Horn, South Platte Natural Resources District, personal commun., 1993). There are little data on pesticide concentrations in water of the South Platte River Basin, which is in itself a concern.

Table 2. Estimated monthly net irrigation requirements for selected crops in the Greeley, Colorado area, 1988

[Values in inches of water; data from U.S. Department of Agriculture, Soil Conservation Service, 1988]

Crop	Average growing season	Days	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Alfalfa	4/1 to 10/10	193	0	0	0	1.1	2.5	4.9	6.7	5.7	3.1	0.4	0	0	24.4
Corn, silage	4/30 to 9/16	139	0	0	0	0	0.2	2.5	6.0	5.7	1.3	0	0	0	15.7
Dry beans	5/20 to 9/2	105	0	0	0	0	0	3.1	6.5	4.7	0	0	0	0	14.3
Sugar beets	4/7 to 10/7	183	0	0	0	0	0.7	3.7	7.0	6.8	3.7	0.3	0	0	22.2

Table 3. Most common pesticides applied annually in the South Platte River Basin

[Herbicide data for 1987 to 1989 from Gianessi and Puffer (1990); insecticide data for 1989 from Bohmont (1991)

Pesticides	Active ingredient in pounds
Insecticides	
Terbufos	298,000
Chlorpyrifos	206,536
Propargite	166,000
Disulfoton	89,116
Carbofuran	46,494
Carbaryl	32,372
Parathion-ethyl	32,250
Phorate	31,068
Dimethoate	27,454
Diazinon	14,800
Herbicides	
2,4-D	568,965
EPTC	560,778
Atrazine	547,625
Alachlor	466,481
Butylate	317,674
Dicamba	209,909
Cyanazine	152,884
Metolachlor	137,587
Picloram	44,493
Cycloate	44,100

SOURCES AND CHARACTERISTICS OF AVAILABLE WATER-QUALITY DATA

In late 1991, a telephone survey was conducted to establish the availability of water-quality data in the South Platte River Basin. Information collected included: data availability, format, and storage medium (paper or computer); years of record; constituents analyzed; and methods and frequency of data collection. Additionally, during the first South Platte River Basin Liaison Committee meeting (July 1991), members of the Liaison Committee were polled as to the nature and availability of similar water-quality data. The Liaison Committee is composed of representatives from local, State, and national agencies concerned with water resources within the study basin. Organizations contacted as potential sources for water-quality data are listed in table 4. These agencies were asked to provide water-quality data that could be used in an analysis of available nutrient, suspended-sediment, and pesticide data. Data available on magnetic media were requested because of ease of data transfer; data available only on hard copy were not included in this analysis.

The available data across the study unit were not ideal for conducting a basin-wide water-quality assessment. For example, each agency has sampled for different purposes and, accordingly, has analyzed different constituents using different sampling techniques and analytical methods. The lack of consistency in these two factors makes it difficult to combine data from different agencies. Additionally, sites with long-term monthly data are rare in the basin and lack necessary areal distribution to characterize differences in water quality as it might relate to various land uses. Furthermore, few sites had complete nutrient species analyses, and most sites lacked suspended-sediment and pesticide data.

The analysis of available data presented here is not meant to be an exhaustive analysis of all possible data collected within the study unit. The philosophy adopted here is that after evaluating the most easily obtainable data, gaps in space, time, flow regime, and other characteristics will be recognized. Data more difficult to obtain can be used to fill these gaps when the additional information is worth the extra effort. Other agencies' data were used when their data collection and laboratory analysis methods were documented and appropriate.

Data-Selection Criteria and Screening Procedures

The data set of available water-quality data was refined by selecting constituents of interest and a time period of interest. Nutrient constituents selected were: total nitrogen, total organic nitrogen plus ammonia (for surface-water sites), dissolved organic nitrogen plus ammonia (for ground-water sites), dissolved ammonia, dissolved nitrite, dissolved nitrite plus nitrate, dissolved phosphorus, dissolved orthophosphate, and total phosphorus. All nitrogen species are reported as nitrogen, and all phosphorus species are reported as phosphorus. Suspended-sediment constituents selected were: suspended-sediment concentration and suspended-sediment particle size distribution. Pesticide constituents selected consisted of the following com-

Table 4. Organizations contacted as potential sources of water-quality data in the South Platte River Basin

Organizations	
Central Colorado Water Conservancy District	Northern Front Range Water Quality Planning Association
Colorado Division of Wildlife	Twin Platte Natural Resources District
Colorado Department of Health, Water Quality Control Division	Urban Drainage and Flood Control District
Colorado State Engineer Office	U.S. Army Corps of Engineers
Colorado State University	U.S. Bureau of Land Management
Colorado Water Resources Research Institute	U.S. Bureau of Reclamation
Denver Regional Council of Governments	U.S. Department of Agriculture, Soil Conservation Service
Denver Water Department	U.S. Environmental Protection Agency
Lower South Platte Water Conservancy District	U.S. Fish and Wildlife Service, Division of Environmental Contaminants
Metro Wastewater Reclamation District	U.S. Forest Service
Northern Colorado Water Conservancy District	

pound classes: carbamates, chlorophenoxy acid herbicides, organochlorine and organophosphorus insecticides, and triazine and other nitrogen-containing herbicides. The time period selected was water years 1980–92. This 12-year span is of sufficient length to detect trends while minimizing variability due to changes in analytical techniques.

The data set was next screened in several ways to ensure only appropriate data were included:

1. Data were screened by medium, such as water or sediment; and by site type, such as surface water or ground water.
2. Data were screened to remove replicate samples, blanks, quality-control samples, and the like.
3. Where more than one sample was collected in a given month at a site, only the first sample of the month was retained, in order to remove temporal bias.
4. Data that were affected by changes in laboratory methods or otherwise determined to be biased were not used. For example, from 1980–82, the National Water Quality Laboratory (NWQL) of the USGS had ammonia contamination that caused a positive bias for concentrations of ammonia species; and in May 1990, the NWQL changed method protocols for total phosphorus determinations (U.S. Geological Survey, written commun., 1992). Consequently, for trend analyses, the following data were used in this retrospective report: (a) for total organic nitrogen plus ammonia, dissolved organic nitrogen plus ammonia, and dissolved ammonia, only data for water years 1982–92; and, (b) for total phosphorus, only data for water years 1980–90.
5. After the above data screening, sites were accepted only if there were at least six data observations over a period of at least 2 years.

Next, sampling sites were screened and selected:

1. Where sites were closely spaced, for example due to a site-specific water-quality study, only one site was selected from the cluster.
2. Well sites were used only if they had aquifer and well-depth information available.
3. Where surface-water sites were closely spaced, sites having daily streamflow records were preferentially selected.

As a result of data selection and screening, data were assembled for 54 surface-water sites and 107 wells (figs. 9 and 10). The agency source of data for selected surface-water sites is listed in table 5. Surface-water data primarily came from the USGS National Water Information System (NWIS) database (36 sites), which contains data collected for a variety of purposes by USGS personnel and their cooperators. Data from 12 surface-water sites originated in USEPA Storage and Retrieval (STORET) data base; these data were collected by the Denver Water Department, the U.S. Army Corps of Engineers, the Colorado Department of Health, and the USEPA. Data from four sites were collected by the Denver Regional Council of Governments (DRCOG), as part of the Bear Creek Reservoir Clean Lakes Study. Data for two sites were collected by the MWRD as part of their monitoring activities near their discharge point.

The agency source of data for selected ground-water sites is listed in table 6. Ground-water data (75 sites) primarily came from the USGS NWIS database. Data from 32 ground-water sites were collected by the Northern Front Range Water Quality Planning Association (NFRWQPA) as part of a nitrates-in-ground-water monitoring effort.

Quality Assurance of Data

To document the quality of the data used in this report, information was collected about the quality-assurance programs for each agency source of data. Ideally, for comparisons of data, samples should have comparable collection, storage, preservation, analysis, and quality-control methods.

The USGS collects equal-discharge-increment (EDI) or equal-width-increment (EWI) composite surface-water samples to ensure a representative sample is taken of the entire stream (Edwards and Glysson, 1988). The collection methods used by agencies contributing data to the USEPA STORET database often could not be ascertained. DRCOG samples were grab samples. Some of the MWRD samples were grab samples collected just below the surface in flowing water (Roy Zimmerman, Metro Wastewater Reclamation District, written commun., 1992); however, the majority of samples collected were EWI composites. The USGS has protocols for ground-water sampling such as purging of wells, placement of pumps in wells, and equipment and collection methods for sample parameters (Wood, 1976), but the protocols used by other agencies are unknown.

For this report, laboratory analyses were considered reliable if they were performed by the USEPA or

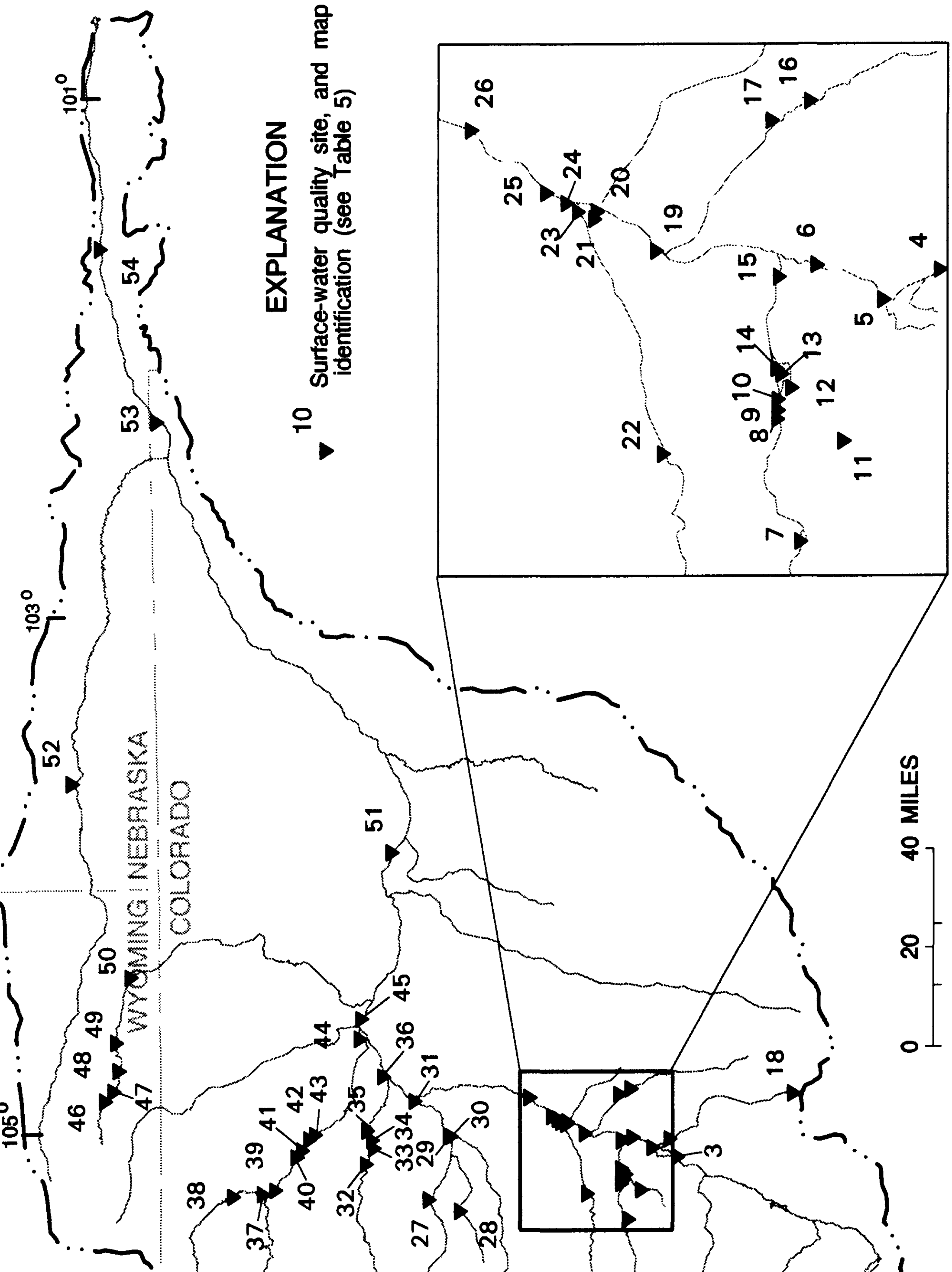

Figure 9. Locations of selected surface-water-quality sites in the South Platte River Basin, water years 1980–92.

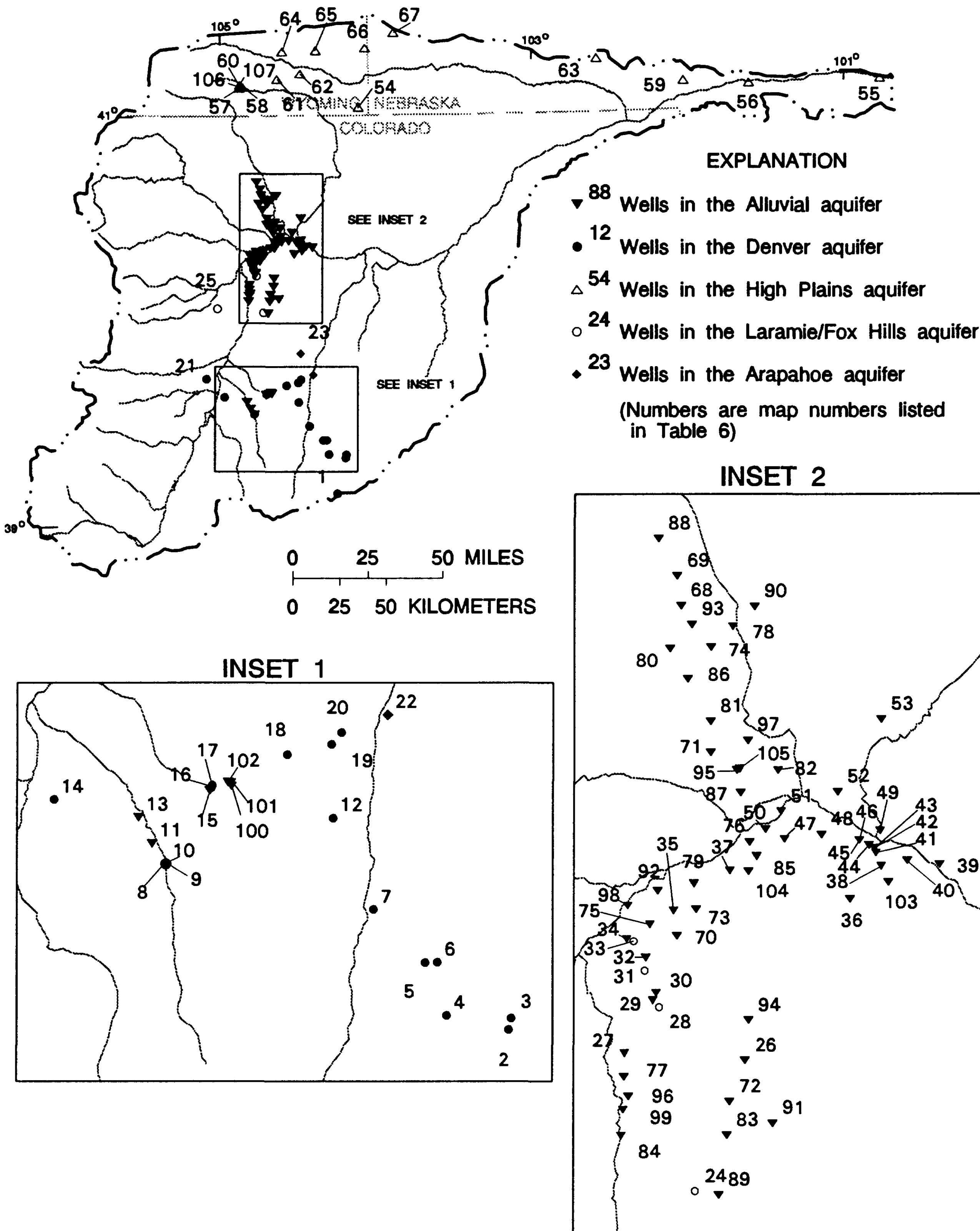

Figure 10. Locations of selected ground-water-quality sites in the South Platte River Basin, water years 1980–92.

Table 5. Characteristics of selected surface-water-quality sites in the South Platte River Basin, water years 1980–92

[Latitude and longitude = degrees, minutes, and seconds; no., number; mi^2, square miles; WWTP, wastewater-treatment plant; --, not determined; DWD, Denver Water Department; USGS, U.S. Geological Survey; COE, Corps of Engineers; DRCOG, Denver Regional Council of Governments; USEPA, U.S. Environmental Protection Agency; MWRD, Metro Wastewater Reclamation District; N, nutrients; P, Pesticides; S, sediment]

Site no. (fig. 9)	Site name	Station number	Latitude	Longitude	Drainage area (mi^2)	Agency source of data	Strata			Type of data
							Geology	Land use	Significant WWTP discharges	
1	Antero Reservoir Outlet at South Platte River, Colorado	001102	38 59 40	105 53 45	--	DWD	sedimentary bedrock	rangeland	no	N
2	Tarryall Creek near Jefferson, Colorado	06698500	39 17 42	105 43 05	183	USGS	sedimentary bedrock	rangeland	no	N
3	South Platte River above Chatfield Reservoir, Colorado	08CHI1	39 29 18	105 05 32	2,620	COE	sedimentary bedrock	forest	no	N, P
4	Plum Creek above Chatfield Reservoir, Colorado	08CHI2	39 30 42	105 01 28	320	COE	alluvium	built-up	no	N, P
5	Chatfield Reservoir release, Colorado	08CHR1	39 33 40	105 03 30	3,020	COE	alluvium	built-up	no	N, P
6	South Platte River at Littleton, Colorado	06710000	39 37 08	105 01 07	3,069	USGS	alluvium	urban	yes	N, S
7	Upper Bear Creek near Evergreen Reservoir, Colorado	BCU	39 37 58	105 19 59	104	DRCOG	crystalline bedrock	built-up	no	N
8	Bear Creek at Morrison, Colorado	06710500	39 39 11	105 11 43	164	USGS	sedimentary bedrock	built-up	yes	N
9	Bear Creek above Harriman Ditch confluence, Colorado	080000	39 39 08	105 11 07	175	COE	sedimentary bedrock	built-up	yes	N, P
10	Lower Bear Creek near Bear Creek Reservoir, Colorado	BCL	39 39 08	105 10 23	176	DRCOG	sedimentary bedrock	built-up	yes	N
11	Upper Turkey Creek near Twin Forks, Colorado	TCU	39 35 43	105 13 10	--	DRCOG	crystalline bedrock	built-up	no	N

Table 5. Characteristics of selected surface-water-quality sites in the South Platte River Basin, water years 1980–92--Continued

Site no. (fig. 9)	Site name	Station number	Latitude	Longitude	Drainage area (mi^2)	Agency source of data	Strata: Geology	Strata: Land use	Strata: Significant WWTP discharges	Type of data
12	Lower Turkey Creek near Bear Creek Reservoir, Colorado	TCL	39 38 27	105 09 34	51	DRCOG	sedimentary bedrock	built-up	yes	N
13	Turkey Creek above Bear Creek confluence, Colorado	080003	39 38 58	105 08 39	52	COE	sedimentary bedrock	built-up	yes	N, P
14	Bear Creek at Bear Creek Reservoir release, Colorado	08BCR1	39 39 14	105 08 15	236	COE	alluvium	built-up	no	P
15	Bear Creek at mouth at Sheridan, Colorado	06711500	39 39 08	105 01 57	260	USGS	alluvium	urban	no	N
16	Cherry Creek Reservoir inflow, Colorado	080005	39 37 30	104 50 00	360	COE	alluvium	built-up	no	N, P
17	Cherry Creek Lake release, Colorado	08CCR1	39 39 30	104 51 20	385	COE	alluvium	built-up	no	P
18	Cherry Creek at Denver, Colorado	06712990	39 09 03	104 51 13	409	USGS	alluvium	urban	yes	N
19	South Platte River at Denver, Colorado	06714000	39 45 35	105 00 10	3,861	USGS	alluvium	urban	yes	N
20	South Platte River near 64th Avenue, Denver, Colorado	12070	39 48 43	104 57 30	3,880	MWRD	alluvium	urban	yes	N
21	South Platte River at Denver Metro Wastewater Plant, Colorado	CO-0026638-1	39 48 50	104 58 00	--	USEPA	alluvium	urban	yes	P
22	Clear Creek at Golden, Colorado	06719505	39 45 11	105 14 05	400	USGS	sedimentary bedrock	built-up	no	N

Table 5. Characteristics of selected surface-water-quality sites in the South Platte River Basin, water years 1980–92--Continued

Site no. (fig. 9)	Site name	Station number	Latitude	Longitude	Drainage area (mi^2)	Agency source of data	Strata: Geology	Strata: Land use	Strata: Significant WWTP discharges	Type of data
23	Clear Creek near York Street, Denver, Colorado	000034	39 49 42	104 57 30	--	CDH	alluvium	urban	no	P
24	South Platte River near 78th Avenue, Denver, Colorado	ERCO-SP-3	39 50 19	104 56 55	4,650	USEPA	alluvium	urban	yes	N, P
25	South Platte River near 88th Avenue, Denver, Colorado	12020	39 51 22	104 56 14	--	MWRD	alluvium	urban	yes	N
26	South Platte River at Henderson, Colorado	06720500	39 55 19	104 52 00	4,713	USGS	alluvium	agricultural and urban	yes	N, S, P
27	St Vrain Creek at Lyons, Colorado	06724000	40 13 05	105 15 34	212	USGS	sedimentary bedrock	built-up	no	N, P
28	Left Hand Creek near Boulder, Colorado	06724500	40 07 32	105 18 12	52	USGS	crystalline bedrock	forest	no	N, P
29	St Vrain Creek below Longmont, Colorado	06725450	40 09 29	105 00 53	424	USGS	alluvium	agricultural and urban	yes	N, P
30	Boulder Creek at mouth near Longmont, Colorado	06730500	40 09 08	105 00 52	439	USGS	alluvium	agricultural and urban	yes	N
31	St Vrain Creek at mouth near Platteville, Colorado	06731000	40 15 29	104 52 45	976	USGS	alluvium	agricultural and urban	yes	N
32	Big Thompson River above Loveland, Colorado	06741480	40 24 02	105 07 20	525	USGS	alluvium	built-up	no	N
33	Big Thompson River at Loveland, Colorado	06741510	40 22 43	105 03 38	535	USGS	alluvium	urban	no	N

Table 5. Characteristics of selected surface-water-quality sites in the South Platte River Basin, water years 1980–92--Continued

Site no. (fig. 9)	Site name	Station number	Latitude	Longitude	Drainage area (mi^2)	Agency source of data	Strata: Geology	Strata: Land use	Strata: Significant WWTP discharges	Type of data
34	Big Thompson River below Loveland, Colorado	06741520	40 23 00	105 01 45	540	USGS	alluvium	urban	yes	N
35	Big Thompson River at Interstate Highway-25, Colorado	06741530	40 23 51	104 59 32	571	USGS	alluvium	agricultural and urban	yes	N
36	Big Thompson River at mouth near La Salle, Colorado	06744000	40 21 00	104 47 04	830	USGS	alluvium	agricultural and urban	yes	N
37	Cache la Poudre River near Fort Collins, Colorado	06749500	40 42 04	105 14 27	484	USGS	crystalline bedrock	forest	no	N, P
38	North Fork Cache la Poudre River at Livermore, Colorado	06751490	40 47 15	105 15 06	539	USGS	sedimentary bedrock	rangeland	no	N, S
39	Cache la Poudre River at Mouth of Canyon, Colorado	06752000	40 39 52	105 13 26	1,056	USGS	crystalline bedrock	forest	no	N
40	Cache la Poudre River at Shields Street, Fort Collins, Colorado	06752258	40 36 11	105 05 43	1,119	USGS	alluvium	built-up	no	N, P
41	Cache la Poudre River at Fort Collins, Colorado	06752260	40 35 17	105 04 08	1,127	USGS	alluvium	urban	no	N, P
42	Cache la Poudre River below Fort Collins, Colorado	06752270	40 34 01	105 01 36	1,240	USGS	alluvium	urban	yes	N, P

Table 5. Characteristics of selected surface-water-quality sites in the South Platte River Basin, water years 1980–92--Continued

Site no. (fig. 9)	Site name	Station number	Latitude	Longitude	Drainage area (mi^2)	Agency source of data	Strata			Type of data
							Geology	Land use	Significant WWTP discharges	
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	06752280	40 32 56	105 00 28	1,245	USGS	alluvium	agricultural and urban	yes	N, P
44	Cache la Poudre River near Greeley, Colorado	06752500	40 25 04	104 38 22	1,877	USGS	alluvium	agricultural and urban	yes	N
45	South Platte River at Kersey, Colorado	06754000	40 24 44	104 33 46	9,654	USGS	alluvium	agricultural and urban	yes	N, P
46	Crow Creek at Roundtop Road near Cheyenne, Wyoming	06755800	41 09 30	104 52 44	229	USGS	alluvium	rangeland	no	P
47	Crow Creek at Warren Air Force Base, Wyoming	06755950	41 08 02	104 50 25	--	USGS	alluvium	urban	no	N, P
48	Crow Creek near Cheyenne, Wyoming	06756000	41 07 09	104 45 33	297	USGS	alluvium	urban	no	N, P
49	Crow Creek near Archer, Wyoming	06756060	41 07 35	104 39 04	--	USGS	alluvium	agricultural and urban	yes	N, P
50	Crow Creek near Carpenter, Wyoming	06756100	41 04 58	104 23 56	415	USGS	alluvium	agricultural	no	P
51	South Platte River near Weldona, Colorado	06758500	40 19 19	103 55 17	13,245	USGS	alluvium	agricultural	no	N, S, P
52	Lodgepole Creek near Kimball, Nebraska	06762550	41 14 50	103 38 32	--	USGS	alluvium	agricultural	no	N
53	South Platte River at Julesburg, Colorado	06764000	40 58 46	102 15 15	23,193	USGS	alluvium	agricultural	no	N, S, P
54	South Platte River at Roscoe, Nebraska	06764880	41 07 33	101 34 35	24,000	USGS	alluvium	agricultural	no	N, P

Table 6. Characteristics of selected ground-water-quality sites in the South Platte River Basin, water years 1980–92

[Latitude and longitude = degrees, seconds, and minutes; units for open intervals and well depth in feet below land surface; NA; not applicable; --, no data; USGS, U.S. Geological Survey; NRFPA, Northern Front Range Water Quality Planning Association; agri., agricultural; N, nutrients; P, pesticides]

Site no. (fig 10)	Station number	Latitude	Longitude	Aquifer name	Land use	Top of open interval	Bottom of open interval	Well depth	Reporting agency	Primary use of water	Type of data
1	390917104154201	39 09 17	104 15 42	Denver	NA	--	--	227.00	USGS	stock	N
2	391938104123301	39 19 38	104 12 33	Denver	NA	--	--	200.00	USGS	stock	N
3	392031104121801	39 20 31	104 12 18	Denver	NA	--	--	174.00	USGS	stock	N
4	392045104184601	39 20 45	104 18 46	Denver	NA	--	--	275.00	USGS	domestic	N
5	392451104205401	39 24 51	104 20 54	Denver	NA	--	--	479.00	USGS	domestic	N
6	392453104194101	39 24 53	104 19 41	Denver	NA	--	--	307.00	USGS	stock	N
7	392903104260501	39 29 03	104 26 05	Denver	NA	--	--	155.00	USGS	stock	N
8	393234104465601	39 32 34	104 46 56	Alluvium	agri.	40.00	57.00	57.00	USGS	public supply	N
9	393240104465501	39 32 40	104 46 55	Laramie/ Fox Hills	NA	2,020.00	2,100.00	2,220.00	USGS	public supply	N
10	393240104465701	39 32 40	104 46 57	Denver	NA	1,020.00	1,040.00	1,110.00	USGS	public supply	N
11	393416104481701	39 34 16	104 48 17	Alluvium	agri.	12.00	52.00	52.00	USGS	observation	N
12	393610104300601	39 36 10	104 30 06	Denver	NA	--	--	156.00	USGS	stock	N
13	393617104493901	39 36 17	104 49 39	Alluvium	range	27.50	67.50	67.50	USGS	observation	N
14	393740104580701	39 37 40	104 58 07	Denver	NA	414.00	666.00	666.00	USGS	domestic	N
15	393819104423001	39 38 19	104 42 30	Alluvium	agri.	40.00	--	53.00	USGS	observation	N
16	393832104422103	39 38 32	104 42 21	Denver	NA	241.00	--	244.00	USGS	observation	N
17	393844104421501	39 38 44	104 42 15	Denver	NA	160.00	163.00	163.00	USGS	observation	N
18	394104104344201	39 41 04	104 34 42	Denver	NA	--	--	575.00	USGS	--	N
19	394152104301501	39 41 52	104 30 15	Denver	NA	--	--	755.00	USGS	domestic	N
20	394245104291501	39 42 45	104 29 15	Denver	NA	--	--	515.00	USGS	domestic	N
21	394259105045600	39 42 59	105 04 56	Denver	NA	--	--	40.00	USGS	--	N
22	394405104243301	39 44 05	104 24 33	Arapahoe	NA	--	--	260.00	USGS	domestic	N
23	395025104292101	39 50 25	104 29 21	Arapahoe	NA	--	--	200.00	USGS	domestic	N
24	400219104432501	40 02 19	104 43 25	Laramie/ Fox Hills	NA	325.00	425.00	740.00	USGS	observation	N
25	400331105005201	40 03 31	105 00 52	Laramie/ Fox Hills	NA	350.00	595.00	595.00	USGS	domestic	N

Table 6. Characteristics of selected ground-water-quality sites in the South Platte River Basin, water years 1980–92--Continued

Site no. (fig 10)	Station number	Latitude	Longitude	Aquifer name	Land use	Top of open interval	Bottom of open interval	Well depth	Reporting agency	Primary use of water	Type of data
26	401000104393602	40 10 00	104 39 36	Alluvium	agri.	39.50	54.50	54.50	USGS	observation	N, P
27	401026104484503	40 10 26	104 48 45	Alluvium	agri.	11.00	16.00	16.00	USGS	observation	N, P
28	401306104460801	40 13 06	104 46 08	Laramie/ Fox Hills	NA	--	--	270.00	USGS	stock	N
29	401330104363702	40 13 30	104 46 37	Alluvium	agri.	19.10	20.40	35.00	USGS	observation	N
30	401356104462201	40 13 56	104 46 22	Alluvium	agri.	24.00	29.00	29.90	USGS	observation	N
31	401513104471401	40 15 13	104 47 14	Laramie/ Fox Hills	NA	--	--	346.00	USGS	domestic	N
32	401559104470901	40 15 59	104 47 09	Alluvium	agri.	--	--	52.00	USGS	irrigation	N
33	401656104480401	40 16 56	104 48 04	Laramie/ Fox Hills	NA	--	--	331.00	USGS	domestic	N
34	401704104483601	40 17 04	104 48 36	Alluvium	agri.	22.00	37.00	37.00	USGS	observation	N, P
35	401844104450103	40 18 44	104 45 01	Alluvium	agri.	32.50	37.50	37.50	USGS	observation	N, P
36	401925104313701	40 19 25	104 31 37	Alluvium	agri.	--	--	60.00	USGS	irrigation	N
37	402104104404501	40 21 04	104 40 45	Alluvium	agri.	5.00	20.00	20.00	USGS	observation	N, P
38	402118104291401	40 21 18	104 29 14	Alluvium	agri.	--	--	90.00	USGS	stock	N
39	402123104244701	40 21 23	104 24 47	Alluvium	agri.	--	--	120.00	USGS	domestic	N
40	402137104271501	40 21 37	104 27 15	Alluvium	agri.	30.00	--	100.00	USGS	irrigation	N
41	402206104293601	40 22 05	104 29 37	Alluvium	agri.	48.00	68.00	68.00	USGS	observation	N
42	402221104294301	40 22 21	104 29 45	Alluvium	agri.	93.70	97.70	98.70	USGS	observation	N
43	402221104294303	40 22 21	104 29 45	Alluvium	agri.	41.50	45.50	45.50	USGS	observation	N
44	402231104300903	40 22 31	104 30 09	Alluvium	agri.	40.50	44.50	44.50	USGS	observation	N
45	402249104305301	40 22 49	104 30 53	Alluvium	agri.	118.00	122.00	123.00	USGS	observation	N
46	402249104305304	40 22 49	104 30 53	Alluvium	agri.	56.00	60.00	60.00	USGS	observation	N
47	402254104363401	40 22 54	104 36 34	Alluvium	agri.	--	--	68.90	USGS	irrigation	N
48	402310104334701	40 23 10	104 33 47	Alluvium	urban	--	--	42.00	USGS	domestic	N
49	402322104291801	40 23 22	104 29 18	Alluvium	agri.	--	--	5.00	USGS	irrigation	N
50	402328104380105	40 23 28	104 38 01	Alluvium	agri.	5.00	15.00	15.00	USGS	observation	N, P
51	402430104365001	40 24 30	104 36 50	Alluvium	agri.	--		25.00	USGS	irrigation	N
52	402538104323301	40 25 38	104 32 33	Alluvium	range	--	--	50.00	USGS	irrigation	N
53	402948104291201	40 29 48	104 29 12	Alluvium	agri.	--	--	107.00	USGS	irrigation	N

Table 6. Characteristics of selected ground-water-quality sites in the South Platte River Basin, water years 1980–92--Continued

Site no. (fig 10)	Station number	Latitude	Longitude	Aquifer name	Land use	Top of open interval	Bottom of open interval	Well depth	Reporting agency	Primary use of water	Type of data
54	410230104065501	41 02 30	104 06 55	High Plains	NA	--	--	100.00	USGS	irrigation	N, P
55	410652100454401	41 06 52	100 45 44	High Plains	NA	--	--	75.00	USGS	irrigation	N,P
56	410708101360801	41 07 08	101 36 08	High Plains	NA	--	--	62.00	USGS	public supply	N, P
57	410806104524801	41 08 06	104 52 48	High Plains	NA	13.00	33.00	--	USGS	observation	N
58	410827104512401	41 08 27	104 51 24	High Plains	NA	7.00	27.00	--	USGS	observation	N
59	410836102010901	41 08 36	102 01 09	High Plains	NA	--	--	362.00	USGS	irrigation	N
60	410859104523601	41 08 59	104 52 36	High Plains	NA	72.00	102.00	--	USGS	observation	N
61	411048104381601	41 10 48	104 38 16	High Plains	NA	--	--	280.00	USGS	--	N
62	411222104291701	41 12 34	104 29 19	High Plains	NA	125.00	225.00	225.00	USGS	irrigation	N, P
63	411538102343801	41 15 38	102 34 38	High Plains	NA	--	--	205.00	USGS	irrigation	N
64	411851104362001	41 18 51	104 36 20	High Plains	NA	180.00 240.00	200.00 350.00	350.00	USGS	irrigation	N, P
65	411905104231801	41 19 05	104 23 18	High Plains	NA	--	--	25.00	USGS	irrigation	N
66	411941104041401	41 19 41	104 04 14	High Plains	NA	165.00	451.00	451.00	USGS	irrigation	N, P
67	412406103531001	41 24 06"	103 53 10	High Plains	NA	--	--	396.00	USGS	irrigation	N
68	000031D	40 36 34	104 44 27	Alluvium	agri.	--	--	53.00	NFRPA	irrigation	N
69	000121D	40 38 19	104 44 44	Alluvium	agri.	--	--	28.00	NFRPA	irrigation	N
70	000221R	40 17 15	104 44 46	Alluvium	agri.	--	--	94.00	NFRPA	irrigation	N

Table 6. Characteristics of selected ground-water-quality sites in the South Platte River Basin, water years 1980–92--Continued

Site no. (fig 10)	Station number	Latitude	Longitude	Aquifer name	Land use	Top of open interval	Bottom of open interval	Well depth	Reporting agency	Primary use of water	Type of data
71	000268N	40 27 55	104 42 13	Alluvium	agri	--	--	57.00	NFRPA	stock	N
72	000812R	40 07 35	104 40 47	Alluvium	agri.	--	--	81.00	NFRPA	irrigation	N
73	001586R	40 18 50	104 43 19	Alluvium	agri.	--	--	80.00	NFRPA	irrigation	N
74	001634R	40 34 08	104 42 09	Alluvium	agri.	--	--	63.00	NFRPA	irrigation	N
75	001960R	40 17 55	104 46 50	Alluvium	agri.	--	--	78.00	NFRPA	irrigation	N
76	004131F	40 22 44	104 39 14	Alluvium	agri.	--	--	76.00	NFRPA	irrigation	N
77	004490R	40 09 04	104 48 48	Alluvium	agri.	--	--	57.00	NFRPA	irrigation	N
78	005165F	40 35 20	104 40 29	Alluvium	agri.	--	--	11.00	NFRPA	irrigation	N
79	005412F	40 20 20	104 43 29	Alluvium	agri.	--	--	36.00	NFRPA	--	N
80	008668R	40 34 02	104 45 17	Alluvium	agri.	--	--	44.00	NFRPA	irrigation	N
81	008671R	40 29 43	104 42 12	Alluvium	agri.	--	--	61.00	NFRPA	irrigation	N
82	010244R	40 26 52	104 37 04	Alluvium	agri.	--	--	72.00	NFRPA	irrigation	N
83	011193R	40 05 37	104 41 00	Alluvium	agri.	--	--	70.00	NFRPA	irrigation	N
84	012175R	40 05 36	104 49 02	Alluvium	urban	--	--	52.00	NFRPA	irrigation	N
85	012196R	40 21 54	104 38 42	Alluvium	agri.	--	--	60.00	NFRPA	irrigation	N
86	012317R	40 32 13	104 43 56	Alluvium	agri.	--	--	60.00	NFRPA	irrigation	N
87	012713R	40 25 36	104 39 54	Alluvium	agri.	--	--	50.00	NFRPA	irrigation	N
88	012746R	40 40 29	104 46 09	Alluvium	agri.	--	--	36.00	NFRPA	irrigation	N
89	012838R	40 02 06	104 41 37	Alluvium	agri.	--	--	52.00	NFRPA	irrigation	N
90	012908R	40 36 31	104 38 49	Alluvium	agri.	--	--	27.00	NFRPA	irrigation	N
91	013157F	40 06 19	104 37 31	Alluvium	agri.	--	--	63.00	NFRPA	irrigation	N
92	013430R	40 19 57	104 46 14	Alluvium	agri.	--	--	63.00	NFRPA	irrigation	N
93	013665F	40 35 29	104 43 36	Alluvium	agri.	--	--	32.00	NFRPA	irrigation	N
94	014101R	40 12 20	104 39 20	Alluvium	agri.	--	--	81.00	NFRPA	irrigation	N
95	014958R	40 26 53	104 40 13	Alluvium	agri.	--	--	71.00	NFRPA	irrigation	N
96	016381R	40 07 57	104 48 29	Alluvium	agri.	--	--	50.00	NFRPA	irrigation	N
97	019372R	40 28 37	104 39 22	Alluvium	agri.	--	--	70.00	NFRPA	irrigation	N
98	020461R	40 19 02	104 48 31	Alluvium	agri.	--	--	30.00	NFRPA	irrigation	N
99	020843R	40 07 08	104 48 52	Alluvium	agri.	--	--	48.00	NFRPA	irrigation	N
100	393841104401901	39 38 41	104 40 19	Alluvium	agri.	--	--	18.30	USGS	observation	P
101	393855104402401	39 38 55	104 40 24	Alluvium	agri.	30.00	--	33.00	USGS	observation	P

Table 6. Characteristics of selected ground-water-quality sites in the South Platte River Basin, water years 1980–92--Continued

Site no. (fig 10)	Station number	Latitude	Longitude	Aquifer name	Land use	Top of open interval	Bottom of open interval	Well depth	Reporting agency	Primary use of water	Type of data
102	393859104404001	39 38 59	104 40 40	Alluvium	range	--	--	19.60	USGS	observation	P
103	402023104284202	40 20 23	104 28 42	Alluvium	agri.	3.50	14.50	14.50	USGS	observation	P
104	402103104391801	40 21 03	104 39 18	Alluvium	agri.	4.00	19.00	19.00	USGS	observation	P
105	402658104400001	40 26 58	104 40 00	Alluvium	agri.	27.00	42.00	42.00	USGS	observation	P
106	410827104523101	41 08 27	104 52 31	High Plains	NA	27.00	32.00	--	USGS	observation	P
107	410904104522901	41 09 04	104 52 29	High Plains	NA	9.00	24.00	--	USGS	observation	P

a laboratory certified by the USEPA or were done by the USGS or by a laboratory participating in the standard-reference-sample quality-control program of the USGS. The MWRD analyzes samples internally; their laboratory follows USEPA guidelines, and they successfully passed the USGS audit (Carl Calkins, Metro Wastewater Reclamation District, personal commun., 1992). Samples collected for NFRWQPA by the Weld and Larimer County Health Departments in Colorado were sent to the Colorado State University Soils Laboratory for analysis. Duplicate samples were collected from randomly selected wells and were analyzed by the Colorado Department of Health and the Weld County Health Department. There were no significant differences in the results from the three laboratories (Dave Dubois, Northern Front Range Water Quality Planning Association, personal commun., 1992). All of the agencies used similar quality-control methods that included standards, blanks, replicates, and spikes; and all of the agencies had quality-assurance programs.

SITE CHARACTERIZATION

When using water-quality data from selected sites to assess basin-wide conditions, it is useful to characterize each site relative to environmental factors that affect water quality. Geology, land use, and significance of wastewater-treatment-plant discharges were selected as important surface-water-site characteristics for this analysis (table 5). Typically, surface-water sites are characterized by selecting the predominant type for each environmental factor within a site's entire drainage basin. For example, land use for the 3,861-mi^2 drainage basin for the South Platte River at Denver (site 19) consists of 44% forest, 32% rangeland, 8% agricultural, 8% urban, and 8% other land uses; therefore, this might be characterized as a forested site. Closer examination of this site, however, reveals that water contributed from the forested portion of this basin is diverted out of the stream before it reaches Denver, and water at the site consists of wastewater-treatment-plant discharges and urban runoff. Therefore, this site is more correctly characterized as urban. The characterization of sites for this analysis takes into account the hydrologic modifications, which affect the source of water at each site.

Geology was characterized for surface-water sites as crystalline bedrock for sites in the mountains, alluvium for sites in the plains, or sedimentary bedrock for sites in the transition zone between the mountains and plains. This geologic grouping is paralleled to some degree by other site characteristics such as physiographic province and ecoregion (for more details, see Dennehy and others, 1993). Land use was characterized as forest, rangeland, urban, built-up, agricultural, or mixed agricultural and urban. Built-up land use is a subcategory of urban land use but was separated out for this analysis. Built-up areas consist of low-density housing and other development, often located along stream valleys, as compared with urban land use, which consists of high-density housing and commercial and industrial development encompassing quite large population centers. The mixed agricultural and urban land use was assigned to locations along the Front Range corridor downstream from Denver where agriculture and population centers are commingled. The importance of point discharges was evaluated by the proportion of streamflow contributed by a point discharge at a site and by the proximity of those point discharges to the site.

Geology, land use, well depth, and primary use of well were selected as important characteristics for ground-water sites for this analysis (table 6). For ground-water sites, the geology is defined by the aquifer (fig. 7) from which water is withdrawn. The wells were distributed between five aquifers: the alluvial aquifer of the South Platte River and its tributaries, the High Plains aquifer, the Denver aquifer, the Arapahoe aquifer, and the Laramie/Fox Hills aquifer. Land use at ground-water sites was assigned by overlying the land-use map with a map of well locations, under the assumption that water in shallow wells can be affected by recharge from the overlying land surface. However, this assumption cannot be made for deeper wells, so land use was not assigned to wells in the deeper aquifers, like the High Plains aquifer and the Denver Basin aquifer system. Ground-water sites also were characterized by well depth; where available, the location of the open interval is listed in table 6, but for most wells only the well depth was known. Ground-water sites also were characterized according to the primary use of the water, which was stock wells, domestic use, public supply, irrigation, or observation wells.

DATA-ANALYSIS METHODS

Various methods were used to summarize and analyze data in this report. Non-parametric statistical techniques, such as boxplots, primarily were used because such methods require few assumptions about the statistical properties of a data set and are suited for data sets having few observations that might not be normally distributed.

Boxplots were drawn to compare constituent concentrations in water (Helsel and Hirsch, 1992); boxplots (fig. 11) graphically display the median or 50th percentile (the center line of the box), interquartile range (the box representing the range between the 25th and 75th percentiles), the 10th and 90th percentiles (the lines to the boundary points of the boxplot), and the quartile skew (the relative position of the median to the 25th and 75th percentiles). For nutrient- and sediment-data groups that had five to nine data values, only the individual data values were plotted, and only the medians were reported in tables. For pesticides, all values were plotted, but statistical comparisons were not done for groups that had less than five values, and only the medians were reported in tables. For data groups that had 10 to 14 values, the boxes and median line were drawn for boxplots, and the 25th and 75th percentiles were added to the tables. For data groups that had 15 or more values, boxplots and boundary lines were drawn, and the 10th and 90th percentiles of the data distributions were added to tables. Where appropriate, a line was drawn on boxplots to indicate the USEPA Maximum Contaminant Level (MCL) for each constituent.

The Kruskal-Wallis test was used to compare the means of different groups of data. This is a non-parametric test that compares real and chance differences in groups of data; the null hypothesis states that no real difference exists. For this study, this test was done at the 0.05 level of significance, which represents the maximum probability of rejecting the null hypothesis when it is actually true. Multiple-stage tests (as described in Helsel and Hirsch, 1992) were performed to detect differences between various combinations of groups.

The LOWESS, or LOcally WEighted Scatterplot Smoothing method (Cleveland, 1979) was used to highlight trends or patterns of selected nutrient concentrations over time. To test for statistically-significant trends, the Seasonal Kendall test (Hirsch and others, 1982) was done at the 0.05 level of significance. Water-quality trends were only analyzed for sites with: (1) instantaneous flow data and at least one nutrient sample per month during 1980–92 and (2) at least one-half of the data present in the first and last thirds of the record. Concentrations were flow-adjusted to remove the variability due to differences in streamflow (Lanfear and Alexander, 1990).

Nutrient loads were estimated using nutrient-transport models. Models were based on data collected during water years 1980–92. Data requirements for load calculation were as follows: (1) 35 or more observations for a nutrient constituent from the period 1980 to 1992; (2) at least 3 of these observations from samples collected during the top decile of flow; and (3) daily streamflow data available for years of interest. Models were developed by multiple regression of nutrient-constituent load on independent variables including: (1) streamflow, because constituent concentrations often are related to streamflow; (2) time, to compensate for long-term trends; and (3) sine and cosine of time to compensate for seasonal variations. Censored data were modified using the adjusted maximum likelihood estimator (Cohn and Gilroy, 1992).

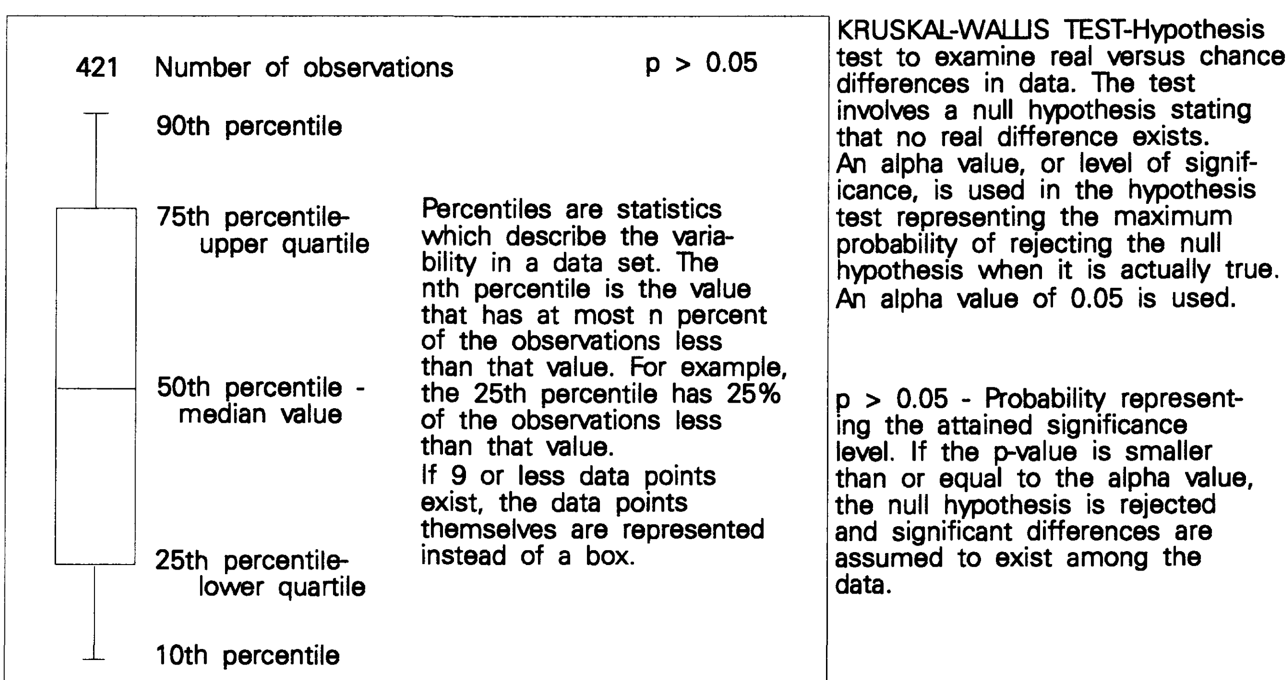

Figure 11. Description of components of a boxplot and related statistical tests.

The significance of variables as explanatory variables was evaluated using the minimum variance unbiased estimator (Gilroy and others, 1989). De-transformation bias due to the log-log form of the regression was corrected using the Duan smearing estimate (Duan, 1983). Regression assumptions (linearity, variance of residuals, independence of residuals, and normality of residuals) were verified for each regression.

Atmospheric loadings of ammonia and nitrate to the basin were estimated using data from National Atmospheric Deposition Program (NADP) sites in the basin (fig. 2). There are seven NADP sites in the basin (Dennehy and others, 1993). However, data from two of these sites were not used in this analysis, because the data did not pass the Data Completeness Criterion established by the NADP Technical Committee, which provides a measure of whether the data available are representative of annual deposition characteristics (Carrol Simmons, NADP/NTN Coordination Office, written commun., 1992). Precipitation concentration data were available from the five remaining sites for all or part of 1980–91. Average annual loadings were calculated by assigning volume-weighted annual average concentrations from the five NADP sites to geographically similar sub-areas of the basin, and then multiplying the assigned concentrations by the long-term average annual precipitation for each subarea.

NUTRIENTS

Nitrogen and phosphorus species are called nutrients because they are essential for plant growth. Nutrients occur dissolved in water and attached to suspended sediment, suspended organic matter, and bottom materials. Dissolved nutrients can be rapidly assimilated by plants, and consequently their concentrations in natural water usually are small. Nutrients can be adsorbed to or released from suspended and bed sediment. Excessive concentrations of nutrients in water can cause eutrophication in reservoirs--blooms of nuisance algae and other aquatic plants. Phosphorus generally is the controlling factor for reservoir eutrophication, and dissolved orthophosphate is the species most readily available for growth of algae.

Direct or indirect sources of nitrogen in surface water and ground water include: (1) synthetic fertilizers, such as anhydrous ammonia; (2) precipitation containing nitrogen oxides, which result from the combustion of fossil fuel; (3) discharges from wastewater-treatment facilities; (4) animal waste; and (5) nitrogen-fixing algae (Hem, 1989). Sources of phosphorus in water include: (1) phosphate fertilizers, (2) discharges from wastewater-treatment facilities, (3) animal waste, and (4) erosion of sediments to which phosphorus is bound in surface water (Hem, 1989).

The only nutrient species regulated for drinking water is nitrate, for which the MCL is 10 mg/L. However, antidegradation standards for stream waters based on their historical use have been established for various nutrient species as mandated by the Clean Water Act. Stream segments used for domestic water supply are limited to 0.5 mg/L ammonia, 10 mg/L nitrate, and 1.0 mg/L nitrite. Stream segments used for support of aquatic life are limited to 0.02 mg/L unionized ammonia for cold water biota (0.06 mg/L for warm water biota), and 0.05 mg/L nitrite. Stream segments used for agriculture are limited to 100 mg/L nitrate and 10 mg/L nitrite. Segment-specific standards also have been set by the Colorado Water Quality Control Commission to address specific stream-segment water-quality concerns. For example, a phosphorus limit of 0.027 mg/L has been established for Chatfield Reservoir near Waterton, Colorado in an effort to control nuisance algal blooms.

Description of Surface-Water Data

There are 48 surface-water sites for which nutrient data were selected (sites with an 'N' in the 'Type of Data' column in table 5). Thirteen sites are located on the South Platte River, and the remaining 35 sites are located on tributaries. In an upstream to downstream direction, tributary sites include: one site on Tarryall Creek, one site on Plum Creek, eight sites in the Bear Creek basin, two sites on Cherry Creek, one site in the Clear Creek basin, five sites in the St. Vrain Creek basin, five sites on Big Thompson River, eight sites in the Cache la Poudre River basin, three sites on Crow Creek, and one site on Lodgepole Creek. There were a total of 2,427 samples collected at these sites.

The amount of data available at surface-water sites varies (table 7); only 27 of the 48 sites have 25 or greater nutrient samples collected over the 1980–92 water year period. Nine sites have more than 100 samples each; eight of these sites are monitoring sites on Boulder Creek, Big Thompson River, and Cache la Poudre River, which were established to examine the effects of point discharges. Sites and samples are most abundant for the built-up and urban land uses (figure 12), and sampling is most intense at urban sites. Data for agricultural, forest, and rangeland land uses are relatively scarce. Sites where point sources are important and sites where point sources are not important are about equally represented. Among the geology types, data for alluvial sites predominates; crystalline bedrock and sedimentary bedrock each account for only about 15 percent of the data.

Table 7. Summary of selected nutrient data for surface-water sites in the South Platte River Basin, water years 1980–92

[no., number; TN, total nitrogen; TON plus NH_3, total organic nitrogen plus ammonia, as nitrogen; DNH_3, dissolved ammonia, as nitrogen; DNO_2, dissolved nitrite, as nitrogen; DNO_{2-3}, dissolved nitrite plus nitrate, as nitrogen; DP, dissolved phosphorus, as phosphorus; DPO_4, dissolved orthophosphate, as phosphorus; TP, total phosphorus, as phosphorus; N, non-parametric analysis; T, trend analysis; L, load estimates; --, no data]

Site no. (fig. 9)	Site name	Data used in report	Period of water-discharge record	Period of water-quality record	Frequency (no. per year)	Number of observations (after filtering)							
						TN	TON plus NH_3	DNH_3	DNO_2	DNO_{2-3}	DP	DPO_4	TP
1	Antero Reservoir Outlet at South Platte River, Colorado	N	--	1979–82	2	0	0	0	0	0	0	0	7
2	Tarryall Creek near Jefferson, Colorado	N	1980–81	1979–81	7	22	22	0	0	0	23	0	22
3	South Platte River above Chatfield Reservoir, Colorado	N	1980–83	1980–90	6	0	55	0	0	0	0	0	55
4	Plum Creek above Chatfield Reservoir, Colorado	N	--	1982–90	6	0	44	0	0	0	0	0	44
5	Chatfield Reservoir release, Colorado	N	--	1980–90	6	0	55	0	0	0	0	0	55
6	South Platte River at Littleton, Colorado	N,L	1980–86	1979–86	6	47	47	45	7	45	45	28	45
7	Upper Bear Creek near Evergreen Reservoir, Colorado	N	1984–92	1988–89	6	0	0	0	0	12	12	12	12
8	Bear Creek at Morrison, Colorado	N	1980–92	1980–81	4	0	7	0	0	0	0	0	8
9	Bear Creek above Harriman Ditch confluence, Colorado	N	--	1980–90	6	0	54	0	0	0	0	0	55
10	Lower Bear Creek near Bear Creek Reservoir, Colorado	N	1986–92	1988–89	6	0	0	0	0	12	12	12	12
11	Upper Turkey Creek near Twin Forks, Colorado	N	--	1988–89	5	0	0	0	0	9	10	10	10
12	Lower Turkey Creek near Bear Creek Reservoir, Colorado	N	1986–89	1988–89	6	0	0	0	0	12	12	12	12
13	Turkey Creek above Bear Creek confluence, Colorado	N	--	1980–90	6	0	55	0	0	0	0	0	55

Table 7. Summary of selected nutrient data for surface-water sites in the South Platte River Basin, water years 1980–92--Continued

Site no. (fig. 9)	Site name	Data used in report	Period of water-discharge record	Period of water-quality record	Frequency (no. per year)	Number of observations (after filtering)							
						TN	TON plus NH_3	DNH_3	DNO_2	$DNO_{2\text{-}3}$	DP	DPO_4	TP
15	Bear Creek at mouth at Sheridan, Colorado	N	1980–92	1980–84	2	7	8	0	0	0	0	0	4
16	Cherry Creek Reservoir inflow, Colorado	N	--	1980–90	6	0	51	0	0	0	0	0	51
18	Cherry Creek at Denver, Colorado	N	1986–92	1980–81	4	0	2	0	0	0	0	0	8
19	South Platte River at Denver, Colorado	N	1980–92	1980–84	1	7	6	0	0	0	0	0	2
20	South Platte River near 64th Avenue, Denver, Colorado	N	1982–92	1987–92	12	0	62	0	62	0	0	62	0
22	Clear Creek at Golden, Colorado	N	1980–92	1981–86	2	15	15	0	0	15	15	0	15
24	South Platte River near 78th Avenue, Denver, Colorado	N	--	1987–92	12	0	59	0	60	0	0	59	0
25	South Platte River near 88th Avenue, Denver, Colorado	N	--	1987–90	4	0	14	0	15	0	0	14	0
26	South Platte River at Henderson, Colorado	N	1980–92	1988–92	6	25	25	25	25	25	24	25	24
27	St Vrain Creek at Lyons, Colorado	N	1980–92	1979–81	5	0	0	17	0	17	1	0	17
28	Left Hand Creek near Boulder, Colorado	N	--	1979–81	5	0	0	17	0	17	1	0	17
29	St Vrain Creek below Longmont, Colorado	N	1980–92	1979–81	5	0	0	17	0	17	0	0	17
30	Boulder Creek at mouth near Longmont, Colorado	N,L	1980–92	1979–90	10	11	11	11	11	105	104	12	12
31	St. Vrain Creek at mouth near Platteville, Colorado	N,L	1980–92	1979–82	12	0	0	0	0	37	37	0	0
32	Big Thompson River above Loveland, Colorado	N,T	--	1979–92	12	45	83	136	136	99	95	18	1
33	Big Thompson River at Loveland, Colorado	N,T,L	1980–92	1979–92	12	44	82	137	137	98	91	21	1

Table 7. Summary of selected nutrient data for surface-water sites in the South Platte River Basin, water years 1980–92--Continued

Site no. (fig. 9)	Site name	Data used in report	Period of water-discharge record	Period of water-quality record	Frequency (no. per year)	Number of observations (after filtering)							
						TN	TON plus NH_3	DNH_3	DNO_2	$DNO_{2\text{-}3}$	DP	DPO_4	TP
34	Big Thompson River below Loveland, Colorado	N,T	--	1979–92	12	44	84	136	136	90	94	21	2
35	Big Thompson River at Interstate Highway-25, Colorado	N	--	1987–92	12	0	0	50	50	49	11	16	0
36	Big Thompson River at mouth near La Salle, Colorado	N	1980–83	1979–82	12	0	0	0	0	37	37	0	0
37	Cache la Poudre River near Fort Collins, Colorado	N	--	1979–84	12	58	58	59	59	59	59	1	0
38	North Fork Cache la Poudre River at Livermore, Colorado	N	1986–92	1986–92	12	57	58	57	57	56	36	36	58
39	Cache la Poudre River at mouth of Canyon, Colorado	N	1980–92	1979–82	12	0	0	2	0	36	35	0	2
40	Cache la Poudre River at Shields Street, Fort Collins, Colorado	N,T	--	1979–92	12	46	88	142	142	101	101	17	0
41	Cache la Poudre River at Fort Collins, Colorado	N,T,L	1980–92	1979–92	12	46	88	138	138	96	99	16	0
42	Cache la Poudre River below Fort Collins, Colorado	N,T	--	1979–92	12	48	89	143	142	100	100	16	0
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	N,T,L	1980–92	1979–92	12	49	90	143	143	103	102	17	0
44	Cache la Poudre River near Greeley, Colorado	N,L	1980–92	1979–89	4	0	0	0	0	39	37	0	0
45	South Platte River at Kersey, Colorado	N	1980–92	1979–91	1	1	1	1	1	14	13	1	1
47	Crow Creek at Warren Air Force Base, Wyoming	N	--	1986–92	3	19	19	0	0	2	0	0	19

Table 7. Summary of selected nutrient data for surface-water sites in the South Platte River Basin, water years 1980–92--Continued

Site no. (fig. 9)	Site name	Data used in report	Period of water-discharge record	Period of water-quality record	Frequency (no. per year)	Number of observations (after filtering)							
						TN	TON plus NH_3	DNH_3	DNO_2	DNO_{2-3}	DP	DPO_4	TP
48	Crow Creek near Cheyenne, Wyoming	N	--	1987–90	4	16	17	0	0	0	0	0	17
49	Crow Creek near Archer, Wyoming	N	--	1990–92	2	7	7	0	0	0	0	0	7
51	South Platte River near Wel-dona, Colorado	N,T,L	1980–92	1979–92	9	13	13	13	13	113	110	13	14
52	Lodgepole Creek near Kim-ball, Nebraska	N	--	1979–80	5	11	11	0	0	3	3	0	11
53	South Platte River at Jules-burg, Colorado	N,T,L	1980–92	1979–92	6	68	68	68	28	68	67	42	68
54	South Platte River at Roscoe, Nebraska	N,L	1983–92	1979–83	12	48	48	0	0	17	16	1	48

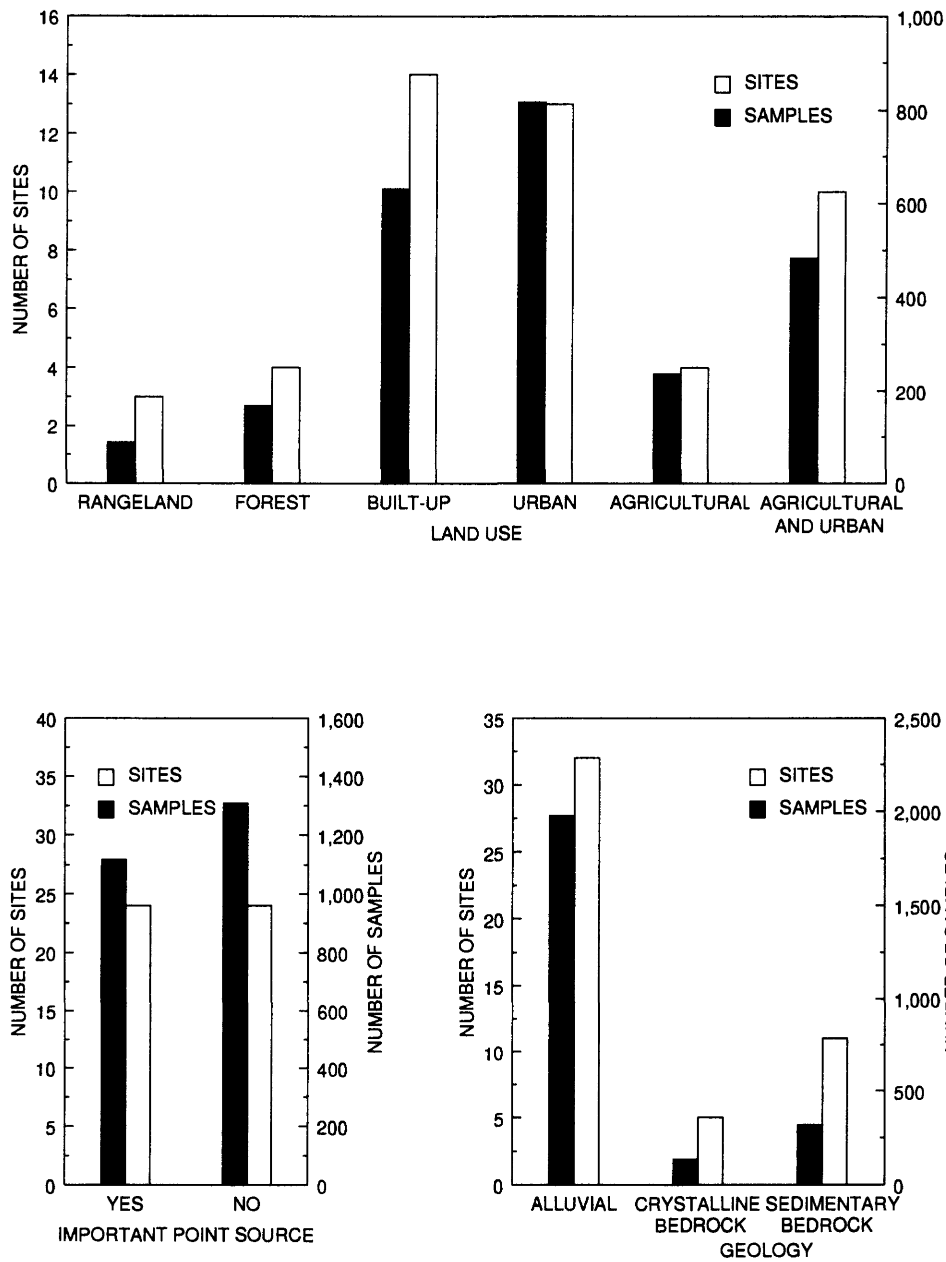

Figure 12. Distribution of nutrient sites and samples by site characteristics.

There are about 1,400 observations for each of the major nutrient species, but data are more sparse for total nitrogen (753 observations), total phosphorus (808 observations), and dissolved orthophosphate (482 observations). For the DRCOG sites (sites 7, 10, 11, and 12), dissolved nitrate was reported rather than dissolved nitrite plus nitrate; based on available data, which indicated that nitrite generally is small at these sites, dissolved nitrate was assumed to be equivalent to dissolved nitrite plus nitrate. For many sites total nitrogen was reported, but for others, total nitrogen was calculated by summing total organic nitrogen plus ammonia and dissolved nitrite plus nitrate.

To adequately represent surface-water quality, sites need to have data distributed over a range of hydrologic conditions, seasons, and years. The distribution of nutrient data over the range of streamflow was examined at those sites for which daily streamflow data are available (table 7). At the 28 sites with streamflow data, long-term deciles of flow were calculated, and the number of nutrient samples collected within each decile of flow was tabulated (see table 33 in the "Supplemental Data" section at the back of this report). For example, the distribution of nitrite plus nitrate samples (figure 13) at the Big Thompson River at Loveland, Colorado (site 33), is relatively uniform; a total of 97 samples were collected at this site, and the number of samples collected by decile of flow ranged from 6 to 17. If samples were uniformly distributed, 10 percent of the samples would fall in each decile of flow. The total percent departure from a uniform distribution for each site (figure 13) shows that the distribution of samples tends to improve as more samples are collected, especially when the number of samples is greater than about 40. Sites having fewer than 40 samples and no streamflow information comprise only about 15 percent of the data set. These sites are included primarily to improve the geographic distribution of sites and to improve representation of basin characteristics, and data from these sites are used only in the nonparametric tests for differences in means between site characteristics.

The seasonal distribution of nutrient data at each site was examined by tabulating the number of nutrient samples collected during each month of the year (see table 34 in the "Supplemental Data" section at the back of this report). The distribution of samples over the months of the year is excellent, because field work often is conducted on a monthly schedule. Because the monthly distributions of samples is good, other seasonal categorizations, such as irrigation/non-irrigation season, also have good sample distribution. The yearly distribution of samples can be assessed by examining the period of record for each site (figure 14). Sixteen sites were sampled throughout the study period; 19 sites were sampled during the first part of the study period; and 13 sites were sampled during the latter part of the study period.

Description of Ground-Water Data

There are 99 wells from which nutrient data were selected (sites with an 'N' in the 'Type of Data' column in table 6). In general, the areal distribution of wells was poor. There were no wells located in the mountains and almost no wells located in the plains east of Weld County, Colorado. For the most part, wells were clustered in three groups; southeast of Denver, Colorado, in western Arapahoe County, southwest and west-central Weld County, Colorado, and southeast Laramie County, Wyoming.

A total of 272 samples were used in the analysis of nutrient concentrations in ground water. The numbers of ground-water samples for selected dissolved nutrients, by aquifer, well type, and land use in the alluvial aquifer are listed in table 8. In general, the availability of nutrient data by aquifer and land-use area was poor. Data were lacking for all aquifers except the alluvial aquifer, and data were lacking for all land uses except agriculture. The predominant well types sampled were irrigation and observation wells. There were a large number of samples for all of the dissolved species. For example, there were 144 samples analyzed for dissolved organic nitrogen plus ammonia, and 151 samples analyzed for ammonia. Having data available for related nutrient species is useful from a data-analysis standpoint. The lack of nutrient data for unfiltered ground-water samples (total nutrient concentrations) was not seen as a substantial drawback to the data set because ground water generally does not contain high concentrations of suspended material that might contribute to the total concentration of a given nutrient species in ground water.

The number of nutrient samples by year and month are shown in figure 15. Samples were available for each year and each month. The distribution of samples by year and month, however, was not equal. Few samples were available in 1979 and 1983–85. On a monthly basis, most of the samples were collected between May and September. The poor distribution of samples by year and month limited the analysis of nutrient-concentration changes with time. More ground-water nutrient data are needed for the winter and for an additional number of years to do a more complete analysis of changing nutrient concentrations with time. In general, the overall ground-water nutrient database in the South Platte River Basin is limited with

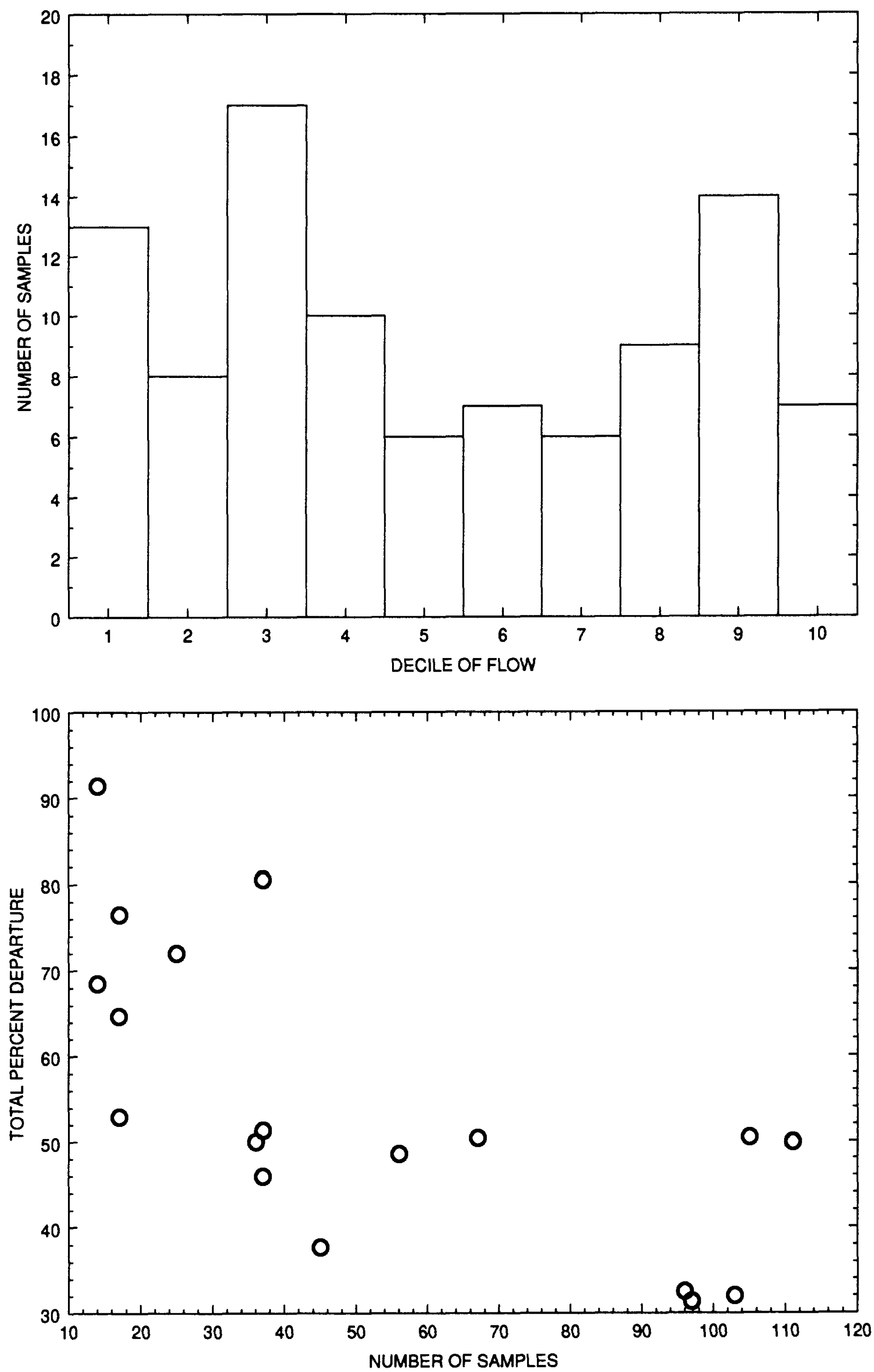

Figure 13. Relation of nitrite plus nitrate samples and streamflow distribution.

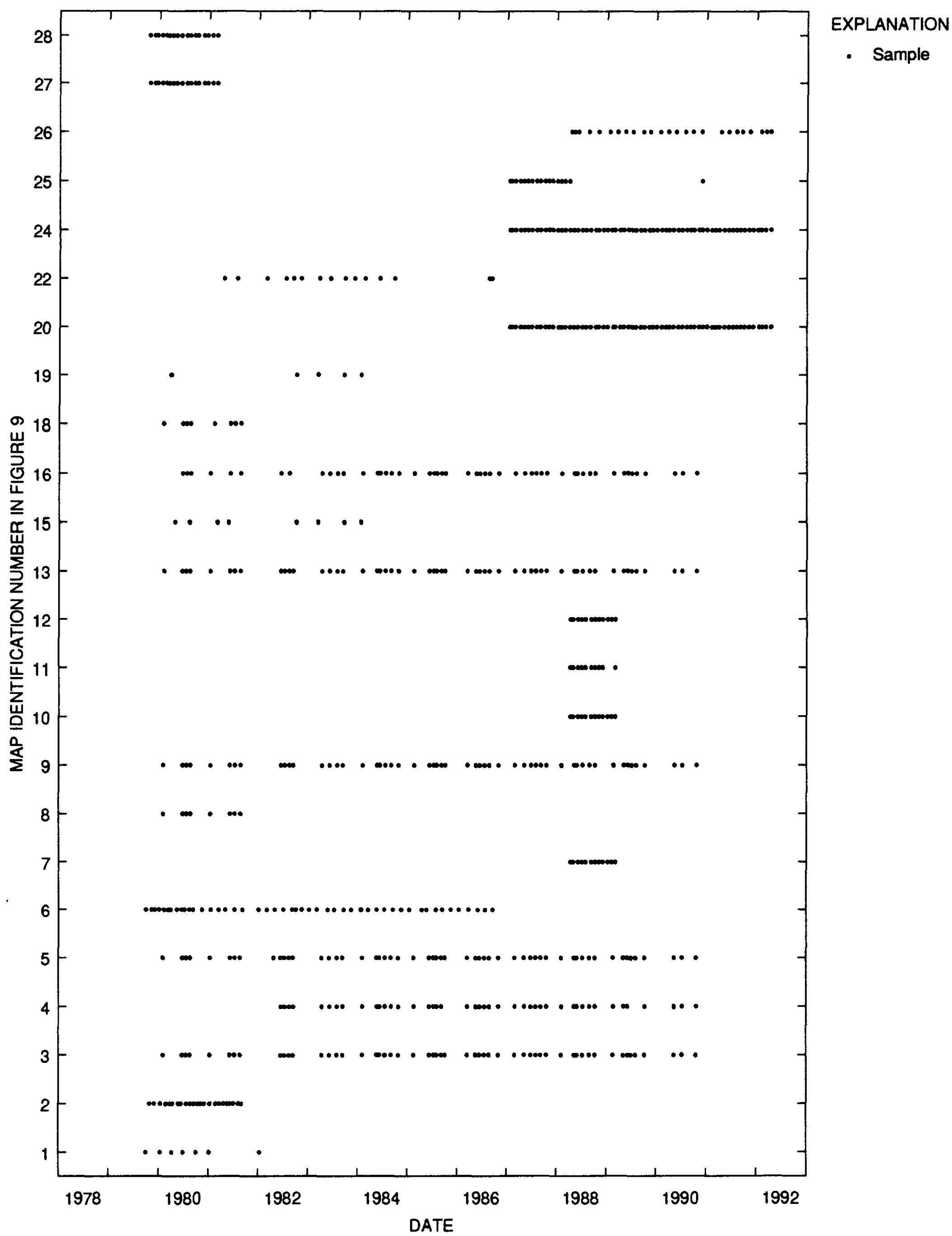

Figure 14. Dates of nutrient sample collection for surface-water sites in the South Platte River Basin.

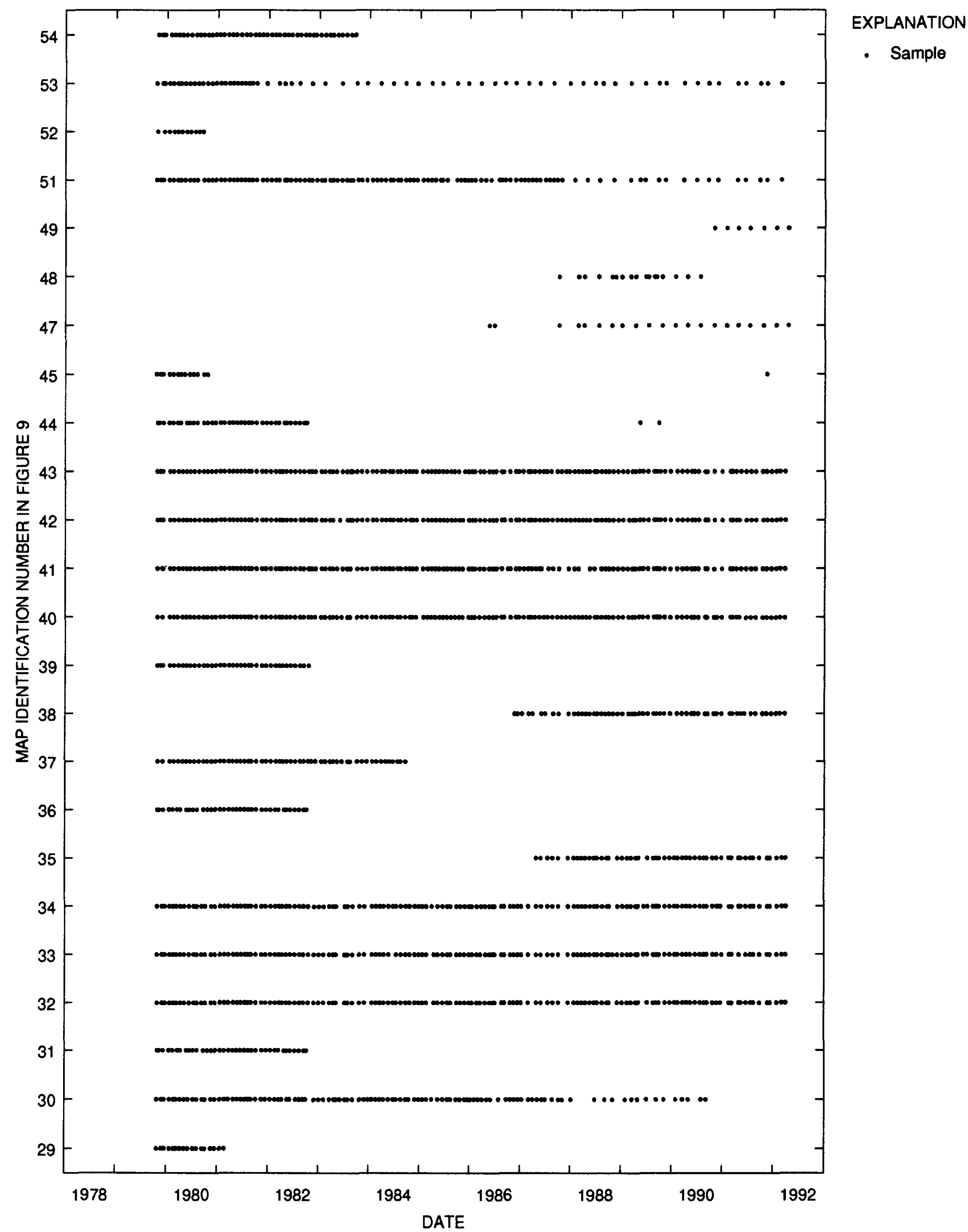

Figure 14. Dates of nutrient sample collection for surface-water sites in the South Platte River Basin--Continued.

Table 8. Summary of statistics for selected dissolved nutrients in ground-water samples by aquifer, well type, and land use in the alluvial aquifer in the South Platte River Basin, water years 1980–92

[nd, not detected; --, not available, concentrations are in milligrams per liter]

Category	Dissolved nitrite plus nitrate, as nitrogen						Dissolved nitrite, as nitrogen					
	Number of samples	Concentration at indicated percentile					Number of samples	Concentration at indicated percentile				
		10	25	50	75	90		10	25	50	75	90
Aquifer												
Alluvial	113	0.91	4.2	8.6	20	31	104	nd	nd	nd	0.01	0.02
Arapahoe	2	0.04	0.04	0.165	0.29	0.29	--	--	--	--	--	--
Denver	16	nd	0.0305	0.1085	0.172	0.182	--	--	--	--	--	--
High Plains	20	1.25	1.8	2.2	3.5	5.5	4	nd	nd	nd	0.005	0.01
Laramie/Fox Hills	34	nd	nd	0.08	0.16	0.37	31	nd	nd	nd	nd	nd
Well Type												
Domestic	40	nd	0.021	0.094	0.2	0.55	33	nd	nd	nd	nd	0.01
Irrigation	30	1.35	2.2	6.65	14.8	22.7	18	nd	nd	nd	0.01	0.03
Observation	94	0.54	4	8.1	19.9	33	81	nd	nd	nd	0.01	0.02
Public Supply	10	nd	1.28	1.8	2.24	2.725	6	nd	nd	nd	nd	0.02
Stock	9	nd	0.11	0.165	0.173	10	1	0.01	0.01	0.01	0.01	0.01
Land Use in the Alluvial Aquifer												
Agricultural	99	0.8	3.6	9	21.7	33	92	nd	nd	nd	0.01	0.02
Rangeland	13	5.8	7.2	7.8	8.95	20	11	nd	nd	nd	0.02	0.03
Urban	1	7.2	7.2	7.2	7.2	7.2	1	0.01	0.01	0.01	0.01	0.01

Table 8. Summary of statistics for selected dissolved nutrients in ground-water samples by aquifer, well type, and land use in the alluvial aquifer in the South Platte River Basin, water years 1980–92--Continued

Category	Dissolved organic nitrogen plus ammonia, as nitrogen						Dissolved ammonia, as nitrogen					
	Number of samples	Concentrations at indicated percentile					Number of samples	Concentrations at indicated percentile				
		10	25	50	75	90		10	25	50	75	90
Aquifer												
Alluvial	110	nd	0.5	0.9	1.3	2	113	nd	nd	0.03	0.09	0.2
Arapahoe	--	--	--	--	--	--	--	--	--	--	--	--
Denver	4	nd	nd	nd	0.5	1	4	0.33	0.345	0.38	0.42	0.44
High Plains	--	--	--	--	--	--	4	nd	0.01	0.03	0.04	0.04
Laramie/Fox Hills	30	nd	0.3	0.55	0.9	1.4	30	nd	0.3	0.5	0.6	0.7
Well Type												
Domestic	32	nd	0.3	0.64	0.9	1.44	32	nd	0.3	0.5	0.6	0.7
Irrigation	16	nd	0.35	1.25	1.7	2.4	18	nd	nd	0.025	0.06	0.1
Observation	90	nd	0.4	0.9	1.3	2	92	nd	nd	0.03	0.11	0.36
Public Supply	5	nd	0.5	0.9	1	1.9	8	nd	0.01	0.04	0.06	0.1
Stock	1	1.1	1.1	1.1	1.1	1.1	1	0.04	0.04	0.04	0.04	0.04
Land Use in the Alluvial Aquifer												
Agricultural	97	nd	0.6	1	1.4	2.2	99	nd	nd	0.03	0.09	0.2
Rangeland	12	nd	nd	0.15	0.7	1.6	13	nd	nd	nd	0.07	0.15
Urban	1	0.78	0.78	0.78	0.78	0.78	1	0.01	0.01	0.01	0.01	0.01

Table 8. Summary of statistics for selected dissolved nutrients in ground-water samples by aquifer, well type, and land use in the alluvial aquifer in the South Platte River Basin, water years 1980–92--Continued

Category	Dissolved phosphorus, as phosphorus						Dissolved orthophosphate, as phosphorus					
	Number of samples	Concentration at indicated percentile					Number of samples	Concentration at indicated percentile				
		10	25	50	75	90		10	25	50	75	90
Aquifer												
Alluvial	80	0.015	0.03	0.05	0.195	0.355	84	nd	nd	0.01	0.05	0.19
Arapahoe	2	nd	nd	0.015	0.03	0.03	--	--	--	--	--	--
Denver	13	0.02	0.03	0.04	0.06	0.07	--	--	--	--	--	--
High Plains	--	--	--	--	--	--	4	nd	nd	nd	0.005	0.01
Laramie/Fox Hills	4	nd	nd	0.005	0.02	0.03	30	nd	nd	nd	nd	0.04
Well Type												
Domestic	10	0.005	0.02	0.025	0.06	0.065	32	nd	nd	nd	0.01	0.04
Irrigation	7	0.01	0.03	0.05	0.09	0.11	18	nd	nd	nd	0.04	0.09
Observation	65	0.01	0.03	0.05	0.2	0.39	63	nd	nd	0.01	0.05	0.25
Public Supply	8	0.02	0.035	0.155	0.23	0.3	4	nd	nd	0.005	0.075	0.14
Stock	9	nd	nd	0.03	0.04	0.08	1	0.03	0.03	0.03	0.03	0.03
Land Use in the Alluvial Aquifer												
Agricultural	66	0.02	0.03	0.045	0.14	0.36	78	nd	nd	0.005	0.04	0.14
Rangeland	13	0.01	0.1	0.18	0.28	0.3	5	0.03	0.05	0.08	0.25	0.36
Urban	1	0.02	0.02	0.02	0.02	0.02	1	0.02	0.02	0.02	0.02	0.02

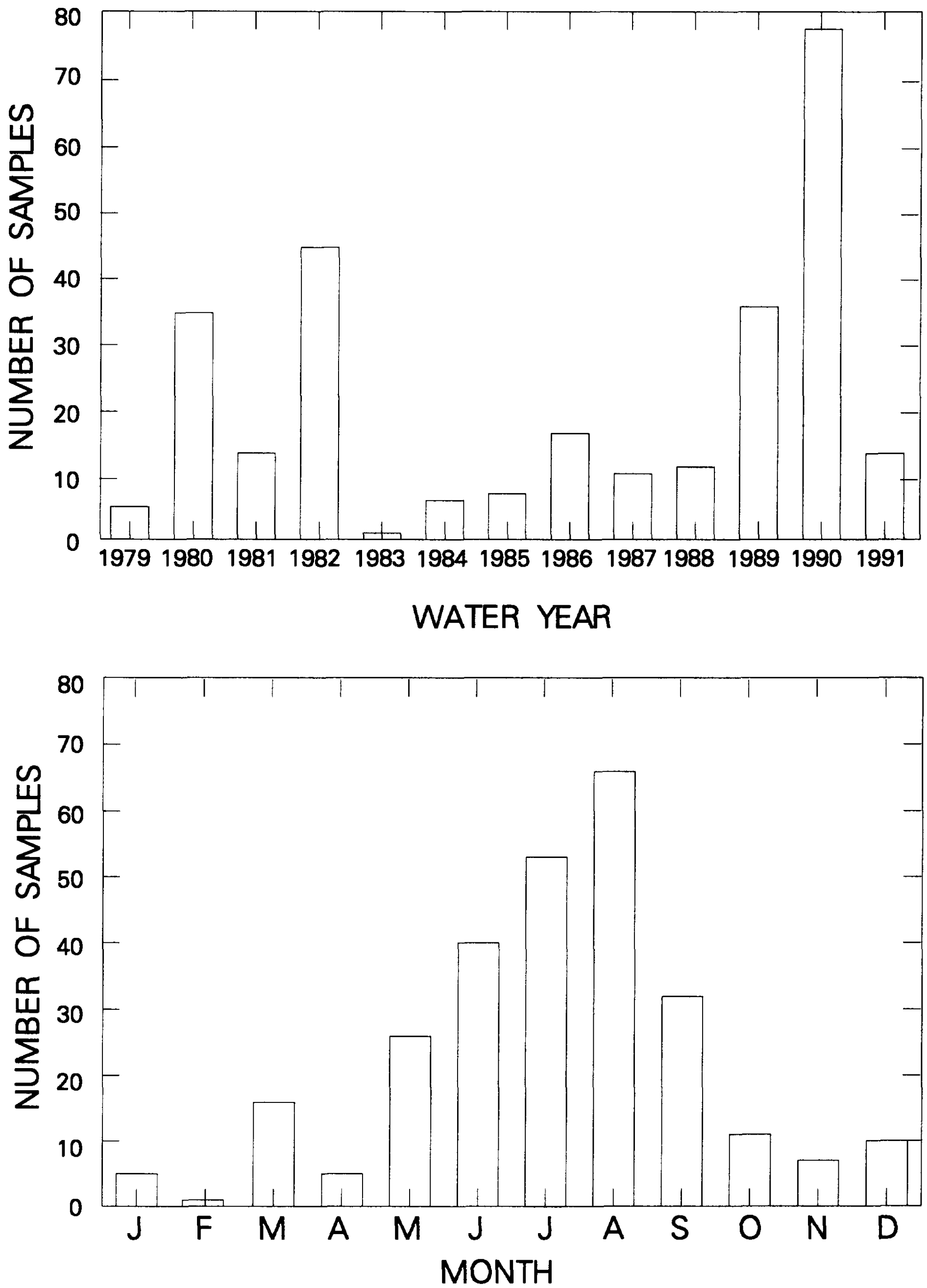

Figure 15. Number of selected ground-water samples, by year and month, in the South Platte River Basin, water years 1980–92.

respect to the number of samples by aquifer, land-use, and timing during the year. Future data-collection activities should be directed toward providing additional samples that fill in these data gaps.

Concentrations in Surface Water

Boxplots of nutrient concentrations in surface water (figure 16) show the general relations between the nutrient species in the South Platte River Basin. Total nitrogen has a median of 1.7 mg/L and total phosphorus has a median of 0.1 mg/L; the range in values is larger for total nitrogen. Total organic nitrogen plus ammonia and dissolved nitrite plus nitrate each have a median concentration about half that of total nitrogen, but dissolved nitrite plus nitrate is more variable. Dissolved ammonia and dissolved nitrite are present at much smaller concentrations, with dissolved ammonia being the more variable of the two. Dissolved phosphorus values are similar to total phosphorus values. Dissolved orthophosphate seems to have the largest concentrations of the phosphorus species, but this is a artifact of the data set because there are much fewer

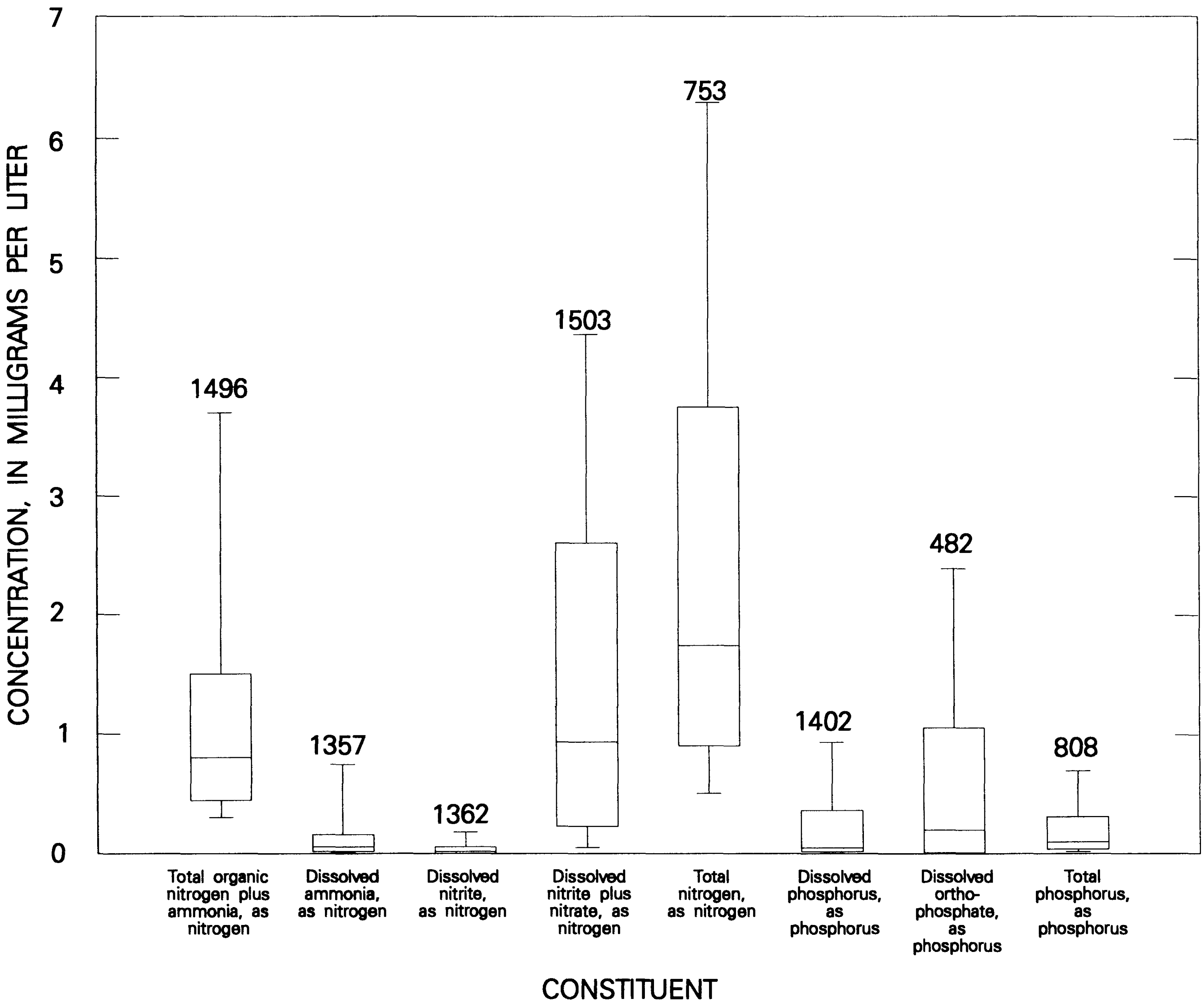

Figure 16. Nutrient concentrations in surface water in the South Platte River Basin, water years 1980–92.

observations for dissolved orthophosphate, and the existing observations are predominantly at sites downstream from wastewater-treatment plants.

No observations in the data set exceeded the drinking-water standard for nitrate, although nitrate concentrations equal to the standard of 10 mg/L occurred at two sites, Boulder Creek at mouth near Longmont, Colorado (site 30) and Big Thompson River below Loveland, Colorado (site 34). At both sites, only about one sample out of 100 reached this maximum value. The maximum observed dissolved nitrite concentration was 1.63 mg/L, and the maximum observed dissolved ammonia concentration was 19 mg/L. These values are in excess of some stream-segment standards; however, it is beyond the scope of this analysis and this data set to determine which stream segments have impaired water quality.

Nutrient concentrations between specific sites can be compared where there is sufficient data to assure good representation of conditions at a site, as discussed in the "Description of Surface-Water Data" section of this report. Comparison of data at representative sites (sites with at least 40 observations, table 9) gives an indication of the factors that affect nutrient concentrations, as well as a picture of the geographic distribution of data. Concentration boxplots of the major nutrient species for eight sites along the South Platte River are shown in figure 17 along with land-use designations. Upstream from site 3, the land use is forest; built-up land use surrounds site 5; land use is urban from site 6 to site 24, which encompasses the Denver metropolitan area; between site 24 and 51, where there is no data, the land use is mixed agricultural and urban; and from site 51 to site 54, the land use is agricultural.

Data for total organic nitrogen plus ammonia are available at seven of the eight sites shown in figure 17; median concentrations are less than 1.0 mg/L upstream from Denver (sites 3 and 5) but increase greatly through the urban area due primarily to wastewater-treatment-plant discharges which enter the river between sites 6 and 20 and between sites 20 and 24. There is a gap in data for a 300-mi reach of river between South Platte River near 78th Avenue, Denver, Colorado (site 24) and South Platte River at Julesburg, Colorado (site 53), wherein the median organic nitrogen plus ammonia concentration changes from 7.70 mg/L to 1.40 mg/L; along this reach the South Platte traverses mixed agricultural and urban land along the Front Range and then primarily agricultural land in eastern Colorado. This decrease in concentration may be due to conversion to nitrate, or because water is removed from the river for irrigation and replaced with water from other sources. Concentrations are about the same near the mouth of the South Platte River at South Platte River at Roscoe, Nebraska (site 54) as at the South Platte River at Julesburg, Colorado (site 53). The river flows through agricultural land between these sites. Total organic nitrogen plus ammonia data also are available at sites along the Big Thompson and Cache la Poudre Rivers (table 9). Concentrations also increase downstream from treatment plants on these streams (between sites 33 and 34 and between sites 41 and 42), although the increases are not as pronounced as on the South Platte River where the treatment-plant discharges contribute a greater proportion of the total streamflow. Median dissolved ammonia concentrations are less than 10 percent of the median total organic nitrogen plus ammonia concentrations on the South Platte River sites as indicated in table 9; however, they comprise from 10 to 25 percent at three tributary sites (sites 34, 42, and 43) downstream from wastewater-treatment plants.

Nitrite plus nitrate data are available for only three of the eight sites depicted in figure 17. The median concentration upstream from Denver at South Platte River at Littleton, Colorado (site 6) is 0.30 mg/L; 100 mi downstream at South Platte River at Weldona, Colorado (site 51), the median concentration is 4.30 mg/L. This increase probably is related to urban and agricultural land uses. At the next site downstream, South Platte at Julesburg, Colorado (site 53), after flowing through agricultural areas, the median nitrite plus nitrate concentration is smaller (2.25 mg/L). At sites on the Big Thompson and Cache la Poudre Rivers, nitrite plus nitrate concentrations increase downstream from the wastewater-treatment plants. Median dissolved nitrite concentrations are less than the detection limit of 0.01 mg/L except at sites downstream from wastewater-treatment plants (sites 20, 24 on the South Platte River, sites 34 and 35 on the Big Thompson River, and sites 42 and 43 on the Cache la Poudre River); its proportion is greatest at site 34 where it is 6 percent as large as the median dissolved nitrite plus nitrate concentration.

Total nitrogen concentration data are available for three of the eight sites depicted in figure 17. Median total nitrogen concentration is 1.24 mg/L at Littleton, 3.60 mg/L at Julesburg, and 3.20 mg/L at Roscoe. Total nitrogen concentrations likely peak at other locations on the river however, since the greatest observed median organic nitrogen plus ammonia concentration (7.70 mg/L) occurs at 78th Avenue at Denver (site 24), while the greatest observed median nitrite plus nitrate concentration (4.30 mg/L) occurs at Weldona (site 51).

Phosphorus data are scarce on the South Platte River sites. Only the South Platte River at Julesburg, Colorado (site 53) has data for all three phosphorus

Table 9. Statistical summary of nutrient concentrations at selected surface-water sites with at least 40 observations in the South Platte River Basin, water years 1980–92

[no., number; N, number of observations; <, less than]

Site no. (fig 9)	Site name	N	Concentration at indicated percentile, in milligrams per liter				
			10	25	50	75	90
	Total organic nitrogen plus ammonia, as nitrogen						
3	South Platte River above Chatfield Reservoir, Colorado	55	0.06	0.10	0.20	0.34	0.50
4	Plum Creek above Chatfield Reservoir, Colorado	44	.20	.30	.41	.77	1.60
5	Chatfield Reservoir release, Colorado	55	.20	.30	.40	.50	.94
6	South Platte River at Littleton, Colorado	47	.38	.50	.74	.60	.75
9	Bear Creek above Harriman Ditch confluence, Colorado	54	.10	.22	.40	.60	.75
13	Turkey Creek above Bear Creek confluence, Colorado	55	.20	.30	.44	.70	1.30
16	Cherry Creek Reservoir inflow, Colorado	51	.30	.40	.68	.96	1.58
20	South Platte River near 64th Avenue, Denver, Colorado	62	1.10	1.40	2.20	3.62	5.40
24	South Platte River near 78th Avenue, Denver, Colorado	59	2.30	4.60	7.70	13.20	16.20
32	Big Thompson River above Loveland, Colorado	83	.33	.40	.61	.93	1.16
33	Big Thompson River at Loveland, Colorado	82	.30	.40	.69	.90	1.20
34	Big Thompson River below Loveland, Colorado	84	.88	1.10	1.70	2.85	4.75
37	Cache la Poudre River near Fort Collins, Colorado	58	.20	.30	.50	.74	1.31
38	North Fork Cache la Poudre River at Livermore, Colorado	58	<.01	.28	.50	.60	1.10
40	Cache la Poudre River at Shields Street, Fort Collins, Colorado	88	.20	.39	.59	.75	.91
41	Cache la Poudre River at Fort Collins, Colorado	88	.30	.40	.60	.90	1.21
42	Cache la Poudre River below Fort Collins, Colorado	89	.50	.80	1.00	1.40	1.90
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	90	.60	.90	1.20	1.52	2.00
53	South Platte River at Julesburg, Colorado	68	.60	.92	1.40	1.90	2.31
54	South Platte River at Roscoe, Nebraska	48	.91	1.12	1.60	2.07	2.55
	Dissolved ammonia, as nitrogen						
6	South Platte River at Littleton, Colorado	45	<.01	.03	.07	.11	.16
32	Big Thompson River above Loveland, Colorado	136	.01	.02	.04	.08	.13
33	Big Thompson River at Loveland, Colorado	137	.01	.03	.05	.09	.19
34	Big Thompson River below Loveland, Colorado	136	.02	.09	.43	1.37	3.10
35	Big Thompson River at Interstate Highway-25, Colorado	50	<.01	.02	.06	.36	1.38
37	Cache la Poudre River near Fort Collins, Colorado	59	<.01	.01	.03	.08	.13

Table 9. Statistical summary of nutrient concentrations at selected surface-water sites with at least 40 observations in the South Platte River Basin, water years 1980–92--Continued

Site no. (fig 9)	Site name	N	Concentration at indicated percentile, in milligrams per liter				
			10	25	50	75	90
	Dissolved ammonia, as nitrogen—Continued						
38	North Fork Cache la Poudre River at Livermore, Colorado	57	<.01	<.01	.02	.02	.04
40	Cache la Poudre River at Shields Street, Fort Collins, Colorado	142	<.01	.02	.03	.06	.10
41	Cache la Poudre River at Fort Collins, Colorado	138	<.01	.02	.03	.06	.11
42	Cache la Poudre River below Fort Collins, Colorado	143	.02	.04	.10	.29	1.06
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	143	.04	.08	.16	.24	.68
53	South Platte River at Julesburg, Colorado	68	.01	.04	.09	.20	.49
	Dissolved nitrite, as nitrogen						
20	South Platte River near 64th Avenue, Denver, Colorado	62	.05	.08	.13	.21	.26
24	South Platte River near 78th Avenue, Denver, Colorado	60	.08	.11	.16	.25	.45
32	Big Thompson River above Loveland, Colorado	136	<.01	<.01	<.01	.01	.02
33	Big Thompson River at Loveland, Colorado	137	<.01	<.01	<.01	.01	.02
34	Big Thompson River below Loveland, Colorado	136	.02	.04	.12	.22	.38
35	Big Thompson River at Interstate Highway-25, Colorado	50	<.01	.02	.05	.18	.27
37	Cache la Poudre River near Fort Collins, Colorado	59	<.01	<.01	<.01	<.01	.01
38	North Fork Cache la Poudre River at Livermore, Colorado	57	<.01	<.01	<.01	<.01	<.01
40	Cache la Poudre River at Shields Street, Fort Collins, Colorado	142	<.01	<.01	<.01	.01	.02
41	Cache la Poudre River at Fort Collins, Colorado	138	<.01	<.01	<.01	.01	.02
42	Cache la Poudre River below Fort Collins, Colorado	142	<.01	.02	.03	.07	.14
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	143	.01	.02	.03	.05	.08
	Dissolved nitrite plus nitrate, as nitrogen						
6	South Platte River at Littleton, Colorado	45	.03	.13	.30	.63	.79
30	Boulder Creek at mouth near Longmont, Colorado	105	.58	.83	1.40	2.40	3.24
32	Big Thompson River above Loveland, Colorado	99	.07	.15	.30	.63	1.60
33	Big Thompson River at Loveland, Colorado	98	.06	.15	.34	.61	1.00
34	Big Thompson River below Loveland, Colorado	90	.39	1.00	2.10	4.50	7.15
35	Big Thompson River at Interstate Highway-25, Colorado	49	.70	1.05	3.00	4.80	5.90
37	Cache la Poudre River near Fort Collins, Colorado	59	<.01	<.01	.02	.11	.15

Table 9. Statistical summary of nutrient concentrations at selected surface-water sites with at least 40 observations in the South Platte River Basin, water years 1980–92--Continued

Site no. (fig 9)	Site name	N	Concentration at indicated percentile, in milligrams per liter				
			10	25	50	75	90
	Dissolved nitrite plus nitrate, as nitrogen--Continued						
38	North Fork Cache la Poudre River at Livermore, Colorado	56	<.01	<.01	<.01	.15	.25
40	Cache la Poudre River at Shields Street, Fort Collins, Colorado	101	.03	.12	.37	.90	1.28
41	Cache la Poudre River at Fort Collins, Colorado	96	.04	.15	.50	.89	1.30
42	Cache la Poudre River below Fort Collins, Colorado	100	.22	.52	1.70	2.37	3.28
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	103	.24	.57	1.60	2.50	3.40
51	South Platte River near Weldona, Colorado	113	2.10	2.80	4.30	5.35	5.90
53	South Platte River at Julesburg, Colorado	68	.80	1.50	2.25	3.97	4.61
	Total nitrogen, as nitrogen						
6	South Platte River at Littleton, Colorado	47	.66	.83	1.24	1.50	1.95
32	Big Thompson River above Loveland, Colorado	45	.77	.90	1.36	2.32	4.90
33	Big Thompson River at Loveland, Colorado	44	.66	.92	1.42	1.90	2.79
34	Big Thompson River below Loveland, Colorado	44	1.29	1.75	3.65	6.40	8.30
37	Cache la Poudre River near Fort Collins, Colorado	58	.20	.31	.50	.80	1.38
38	North Fork Cache la Poudre River at Livermore, Colorado	57	.15	.40	.50	.81	1.10
40	Cache la Poudre River at Shields Street, Fort Collins, Colorado	46	.60	.73	1.04	1.51	2.04
41	Cache la Poudre River at Fort Collins, Colorado	46	.70	.81	1.24	1.72	2.03
42	Cache la Poudre River below Fort Collins, Colorado	48	.99	1.68	2.98	4.15	5.10
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	49	1.19	2.02	3.5	4.60	5.60
53	South Platte River at Julesburg, Colorado	68	2.18	2.85	3.6	5.55	6.10
54	South Platte River at Roscoe, Nebraska	48	1.50	2.25	3.2	4.65	6.30
	Dissolved phosphorus, as phosphorus						
6	South Platte River at Littleton, Colorado	45	<.01	.01	.02	.03	.04
30	Boulder Creek at mouth near Longmont, Colorado	104	.15	.25	.70	1.10	2.00
32	Big Thompson River above Loveland, Colorado	95	<.01	.01	.02	.03	.05
33	Big Thompson River at Loveland, Colorado	91	<.01	.01	.02	.04	.06
34	Big Thompson River below Loveland, Colorado	94	.13	.36	1.00	2.03	3.05
37	Cache la Poudre River near Fort Collins, Colorado	59	<.01	.01	.01	.02	.04
40	Cache la Poudre River at Shields Street, Fort Collins, Colorado	101	<.01	<.01	.01	.02	.03
41	Cache la Poudre River at Fort Collins, Colorado	99	<.01	.01	.02	.03	.04

Table 9. Statistical summary of nutrient concentrations at selected surface-water sites with at least 40 observations in the South Platte River Basin, water years 1980–92--Continued

Site no. (fig 9)	Site name	N	Concentration at indicated percentile, in milligrams per liter				
			10	25	50	75	90
	Dissolved phosphorus, as phosphorus--Continued						
42	Cache la Poudre River below Fort Collins, Colorado	100	.02	.03	.09	.28	.57
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	102	.01	.03	.07	.17	.70
51	South Platte River near Weldona, Colorado	110	.09	.19	.37	.73	.95
53	South Platte River at Julesburg, Colorado	67	.03	.06	.15	.34	.45
	Dissolved orthophosphate, as phosphorus						
20	South Platte River near 64th Avenue, Denver, Colorado	62	.24	.42	.61	.97	1.32
24	South Platte River near 78th Avenue, Denver, Colorado	59	.45	1.44	2.21	2.98	3.59
53	South Platte River at Julesburg, Colorado	42	.01	.05	.13	.30	.38
	Total phosphorus, as phosphorus						
3	South Platte River above Chatfield Reservoir, Colorado	55	.01	.02	.03	.05	.06
4	Plum Creek above Chatfield Reservoir, Colorado	44	.08	.10	.18	.30	.48
5	Chatfield Reservoir release, Colorado	55	.01	.02	.04	.06	.08
6	South Platte River at Littleton, Colorado	45	.02	.02	.04	.07	.11
9	Bear Creek above Harriman Ditch confluence, Colorado	55	.08	.10	.15	.30	.53
13	Turkey Creek above Bear Creek confluence, Colorado	55	.04	.10	.20	.46	.88
16	Cherry Creek Reservoir inflow, Colorado	51	.15	.18	.28	.40	.50
38	North Fork Cache la Poudre River at Livermore, Colorado	58	<.01	.01	.02	.04	.07
53	South Platte River at Julesburg, Colorado	68	.08	.11	.28	.51	.79
54	South Platte River at Roscoe, Nebraska	48	.12	.17	.27	.47	.70

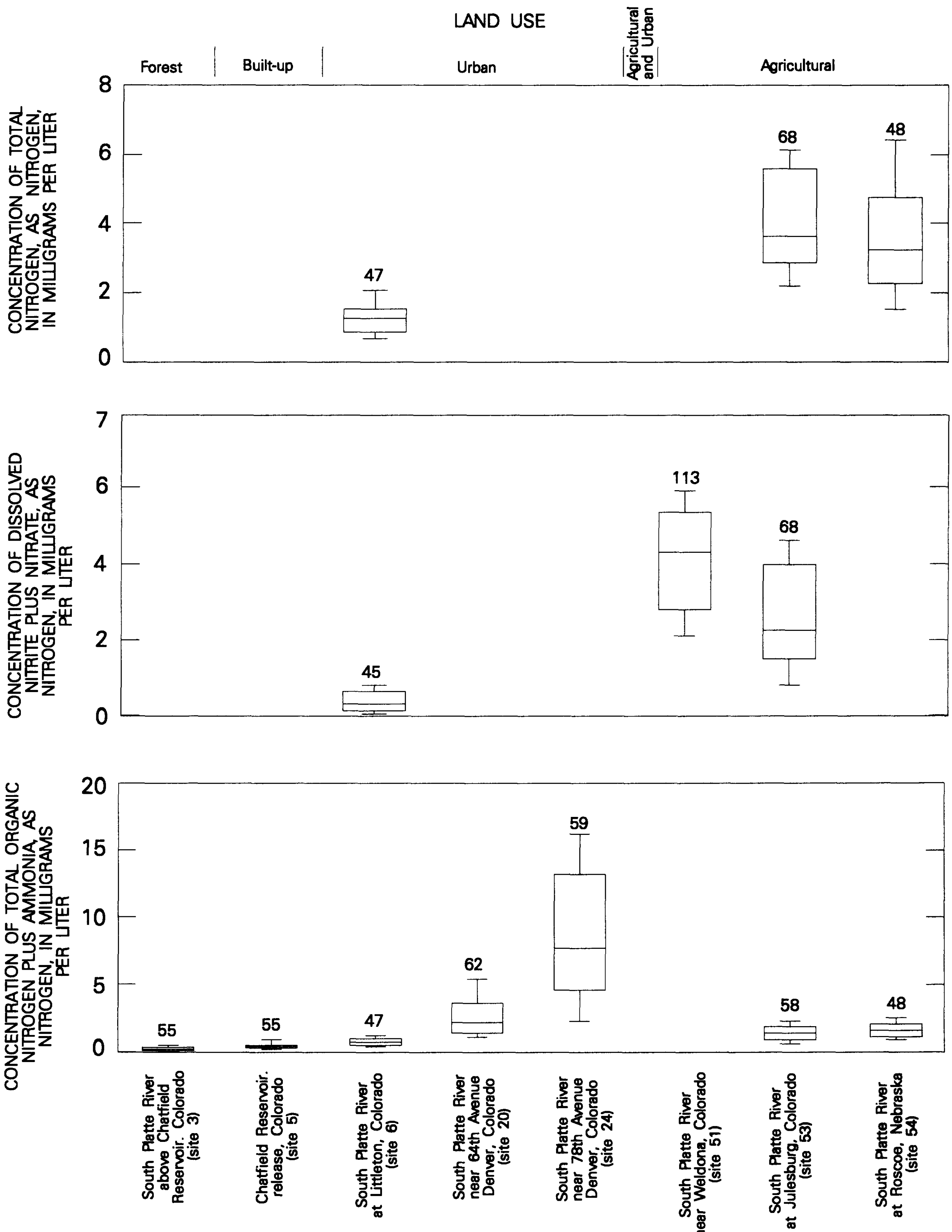

Figure 17. Nutrient concentrations at selected sites along the South Platte River, water years 1980–92.

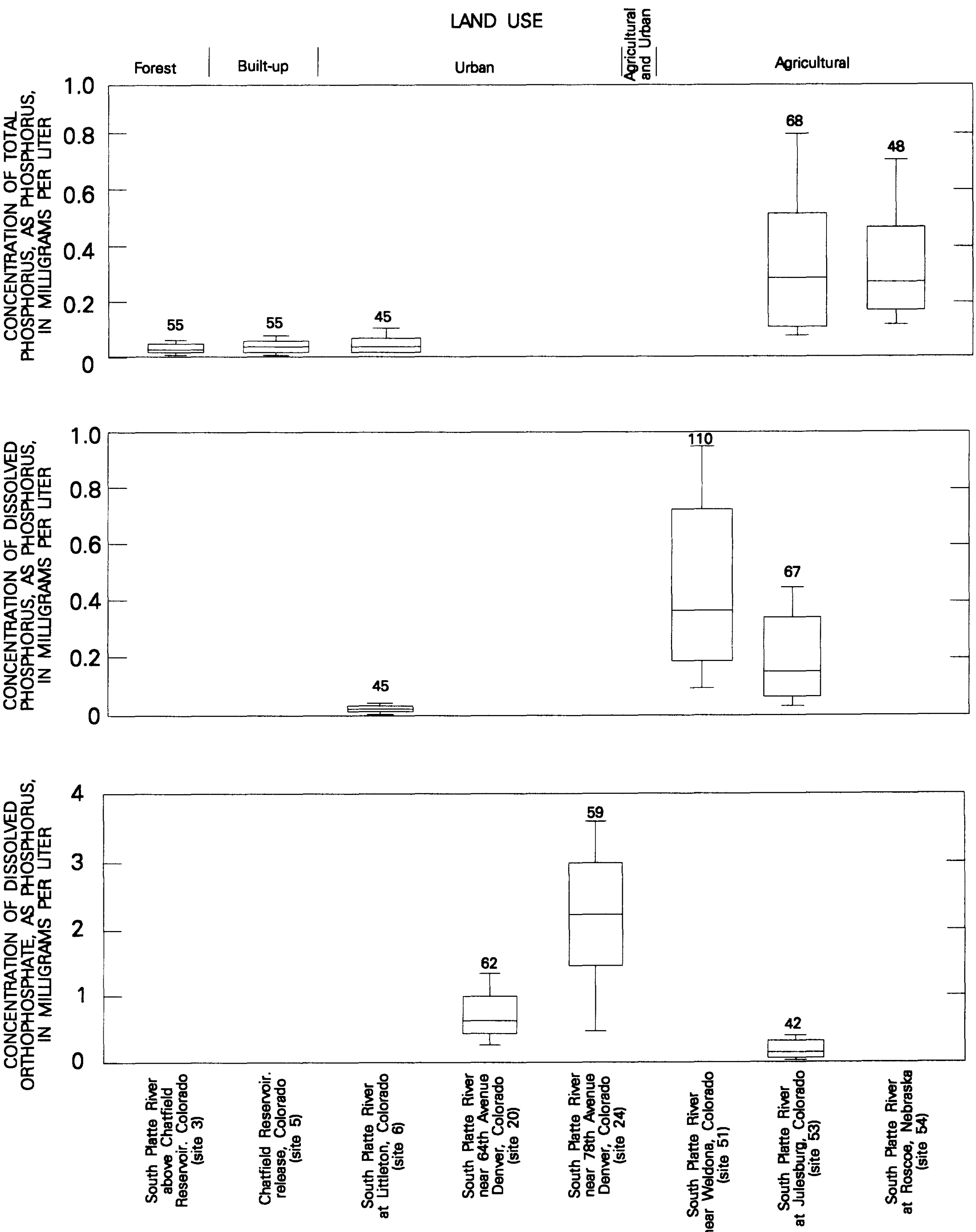

Figure 17. Nutrient concentrations at selected sites along the South Platte River, water years 1980–92--Continued

species; at this site the median orthophosphate concentration is about the same as the median dissolved phosphorus concentration, and the median dissolved phosphorus concentration is about half as large as the median total phosphorus concentration. Median concentrations of phosphorus species are less than 0.04 mg/L at sites upstream from the Denver urban area but are large at sites 20 and 24 downstream from Denver wastewater-treatment plants. At Weldona (site 51), median dissolved phosphorus concentration is back down to 0.37 mg/L. Median dissolved phosphorus concentration is smaller at Julesburg than at Weldona, and median total phosphorus concentrations are similar at Julesburg and at Roscoe; suspended phosphorus appears to be more substantial in the lower agricultural reaches of the river than in the upper urban reaches. Median total phosphorus concentrations also are as large as 0.28 mg/L at tributary sites in the built-up areas upstream from Denver (sites 4, 9, 13, 16).

These observed patterns in nutrient concentrations indicate that land use and the location of wastewater-treatment plants are important factors affecting nutrient concentrations. The land-use patterns were tested for statistical significance using multiple-stage Kruskal-Wallis tests (Helsel and Hirsch, 1992). The results of these tests are shown in figure 18, wherein

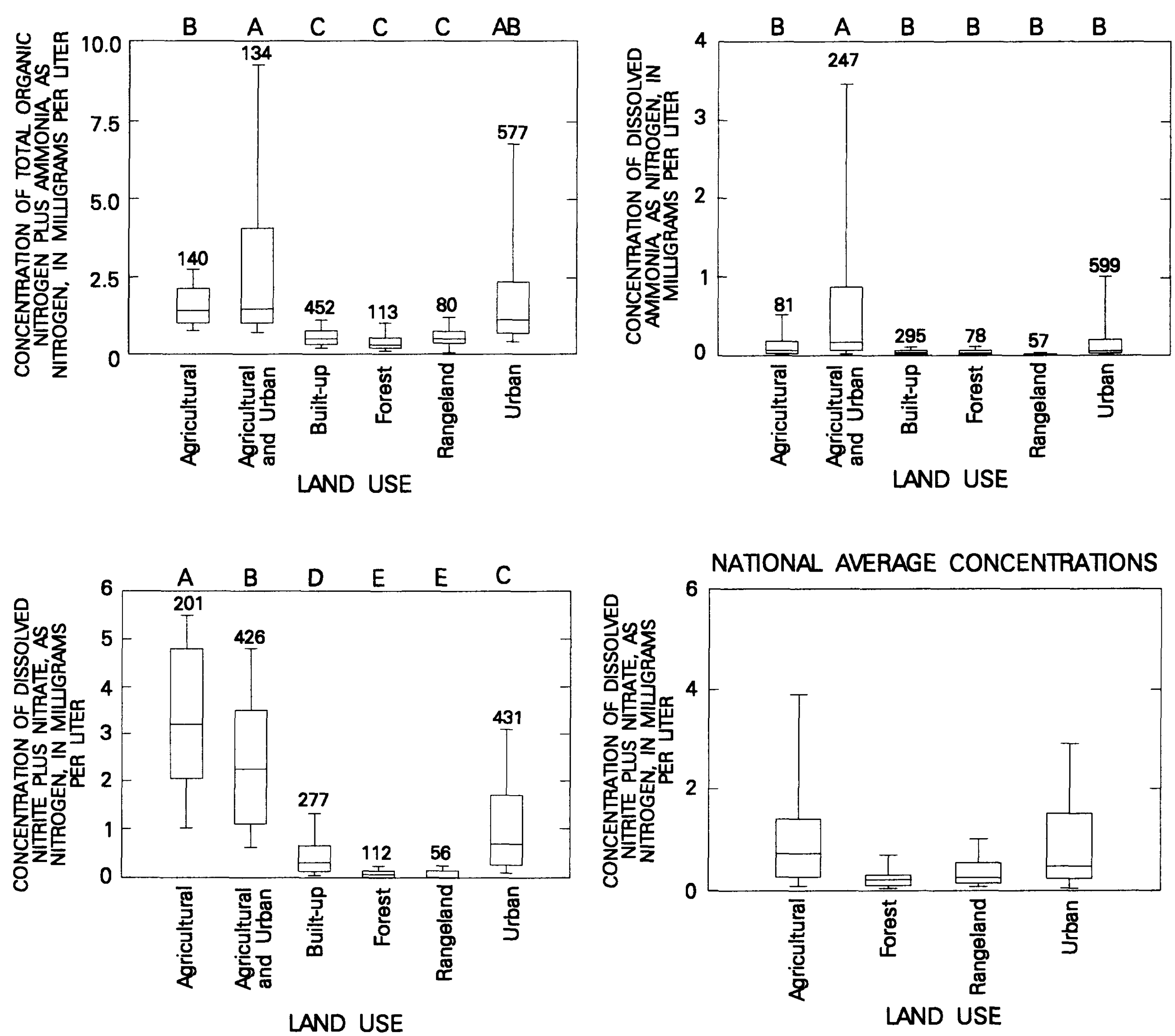

Figure 18. Relations of land use to concentrations of selected nutrients in the South Platte River Basin, water years 1980–92. [Boxplots with the same letter within a nutrient constituent indicate medians are not significantly different, Kruskal-Wallis test (Helsel and Hirsch, 1992), p<0.05 for all cases; numbers indicate the number of samples represented in each boxplot; National average concentration data from U.S. Geological Survey, 1993].

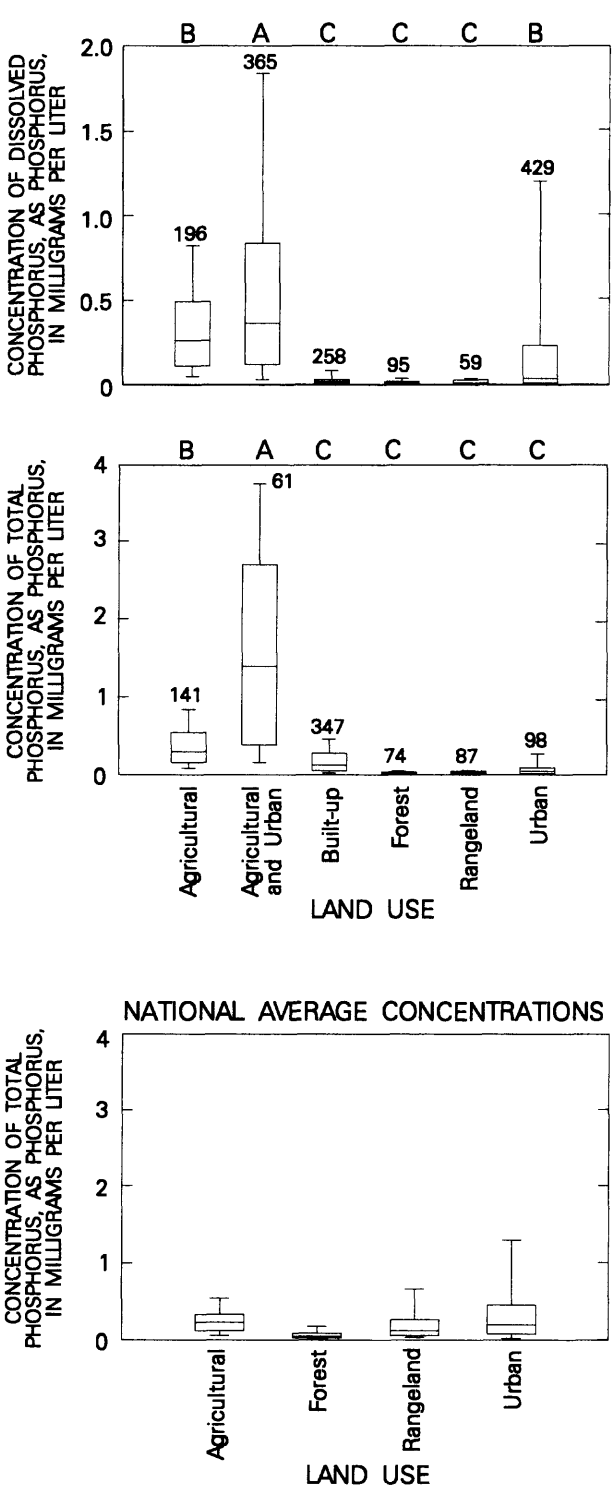

Figure 18. Relations of land use to concentrations of selected nutrients in the South Platte River Basin, water years 1980–92. [Boxplots with the same letter within a nutrient constituent indicate medians are not significantly different, Kruskal-Wallis test (Helsel and Hirsch, 1992), p<0.05 for all cases; numbers indicate the number of samples represented in each boxplot; National average concentration data from U.S. Geological Survey, 1993] --Continued.

land-use groups with statistically different median concentrations are assigned different letters, with the 'A' groups having the greatest median concentrations. For total organic nitrogen plus ammonia, urban and mixed agricultural and urban land use had the greatest median concentration, followed by agricultural land use. Built-up, forest, and rangeland had the smallest concentrations and were indistinguishable. For dissolved ammonia, mixed agricultural and urban land use had the highest median concentration, and the remaining land-use classes were indistinguishable. This pattern probably is related to land use and to the location of water-quality sites downstream from wastewater-treatment plants, which are a major source of ammonia. Agricultural land use had the greatest median concentrations of dissolved nitrite plus nitrate, followed by mixed agricultural and urban, urban, and built-up land use. Dissolved phosphorus concentrations were greatest in the mixed agricultural and urban, agricultural, and urban land uses, while total phosphorus concentrations seem to be more related to agricultural land use. The low concentrations for all nitrogen and phosphorus species in the forest land use probably is due to the minimum anthropogenic effect at those sites.

As shown in figure 18, nutrient concentrations for land uses in the South Platte River Basin differ from those in the National Water Summary (NWS) report (U.S. Geological Survey, 1993). Dissolved nitrite plus nitrate concentrations are higher in the basin than in the NWS report for agricultural land use, similar for urban land use, and lower for rangeland and forest. Similarly, total-phosphorus concentrations in the basin are higher than in the NWS report for agricultural and urban land uses, but lower for forest and rangeland land uses. Differences between the agricultural land use in the South Platte River Basin and the NWS report could be because of differences in land use definition. An agricultural-land use site reported in the NWS had to have more than 40 percent of its upstream area in crop or pasture, less than 40 percent in forest, less than 10 percent in urban-land use, and have a drainage area of 1,000 to 3,000 mi^2. An agricultural-land use site in the South Platte River Basin was defined by its location on a land-use map and by site-specific knowledge about water sources at each site. The land-use percentage of drainage area was ignored because it would overestimate the percentages of land-use categories that do not have a direct effect on water quality at a given site.

The significance of point sources on nutrient concentrations also was statistically tested (figure 19) using the Kruskal-Wallis test and a level of significance of 0.05 (see "Data-Analysis Methods" section for more details). A p-value less than 0.05 (fig. 19) indicates that

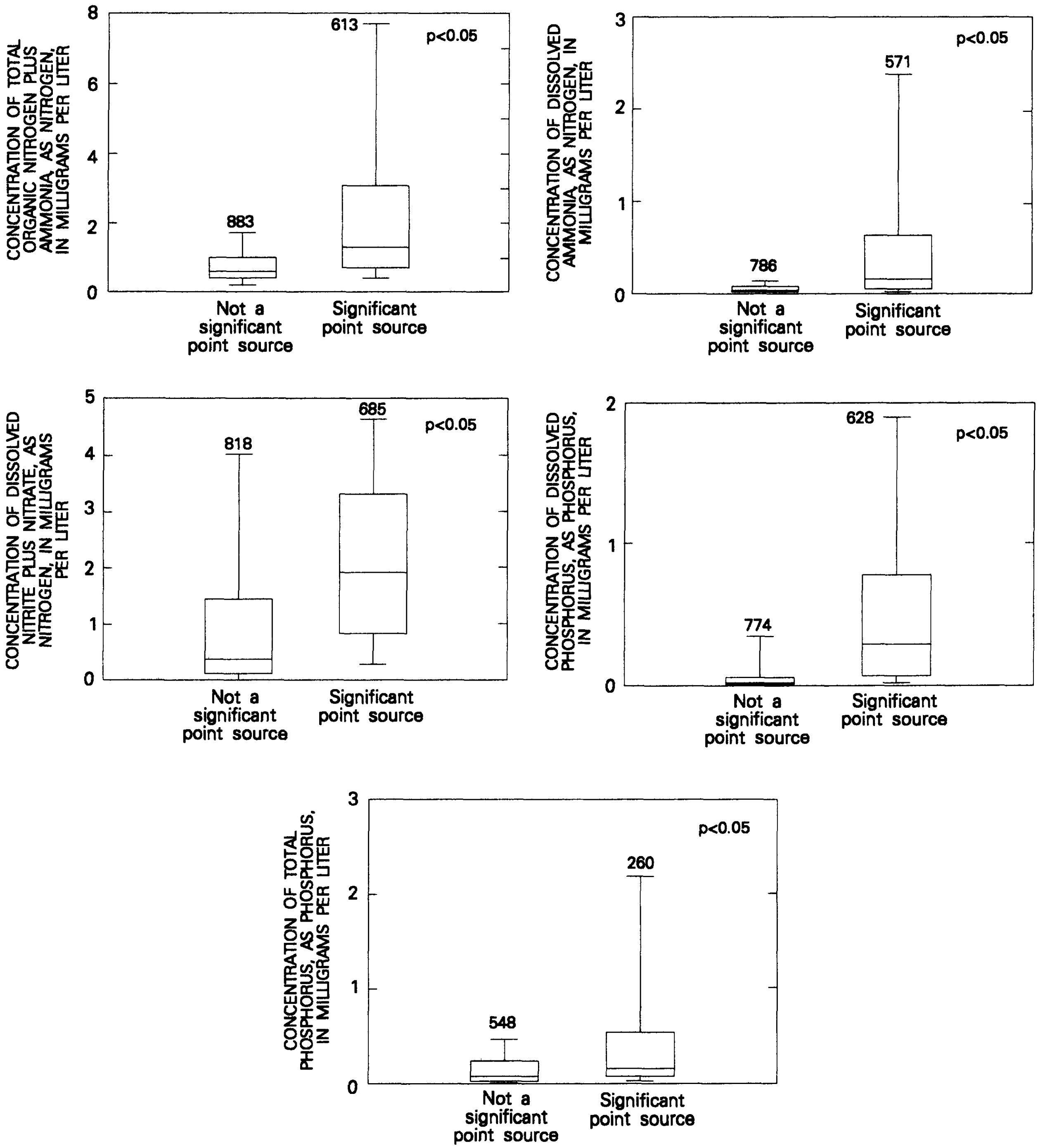

Figure 19. Statistical relations of wastewater-treatment-plant discharges to concentrations of selected nutrients in the South Platte River Basin, water years 1980–92.

groups are statistically different; a p-value greater than 0.05 indicates that groups are not significantly different. Sites characterized as being affected by significant wastewater-treatment-plant discharges (table 5) were determined to have greater median concentrations of nutrients than sites without significant wastewater-treatment-plant discharges. Statistically significant differences were determined for total organic nitrogen plus ammonia, dissolved ammonia, dissolved nitrite plus nitrate, dissolved phosphorus, and total phosphorus. The largest differences in medians occurred for dissolved ammonia, dissolved nitrite plus nitrate, and dissolved phosphorus. The effects of treatment plants vary from site to site, due to treatment practices at each plant and due to distances of sites downstream from plants, because conversions between nutrient species can occur within short distances.

Geology was used as a site-characterization theme for surface-water sites (table 5). However, due to insufficient distribution of sites and related groupings for geology and land use at selected sites, geology was not useful in characterizing nutrient water quality. For example, there are no forest or rangeland sites in the alluvium, while all urban, agricultural, and mixed agricultural and urban land-use sites are located in the alluvium. Built-up sites are distributed among the three geology types, but there was insufficient information to detect differences in concentrations due to geology within this land-use stratum. Because of the large effect of urban and agricultural land use and of point sources on nutrient concentrations, it is likely that the nutrient concentration differences due to geology could only be examined at undeveloped sites.

Because agricultural land use is an important factor for nutrient concentrations, it was tested to see whether seasonality was an important factor in nutrient concentrations, where months were grouped into two seasons--an irrigation season for April through September, and a non-irrigation season comprising the remainder of the year. When grouped this way, all nitrogen species and dissolved phosphorus were determined to have greater concentrations during the non-irrigation season. Similarly, when grouped by land use and season (fig. 20), concentrations generally were greater in the non-irrigation season. Because this pattern is independent of land use, the smaller April-through-September nutrient concentrations might better be explained by factors in addition to irrigation such as dilution of water by snowmelt runoff. Nutrient concentrations also might be higher during the non-irrigation season compared to the irrigation season because of decrease of biological activity during the cold temperatures of the non-irrigation season. Higher nitrate concentrations have been reported during the fall-winter season compared to spring-summer season in prairie streams in Kansas; the higher nitrate concentrations were attributed to dormant terrestrial vegetation along with decreased instream biological activity during the fall-winter season (Tate, 1990). In addition to biological activity, higher nutrient concentrations in the non-irrigation season compared to irrigation season could also be a function of ground-water inputs during low flow and surface-water dilution during high flow. In contrast to other nutrients, total phosphorus concentrations were higher during the irrigation season than the non-irrigation season for the forest land use; phosphorus might be on sediment particles carried by spring runoff, an effect not shown for dissolved phosphorus.

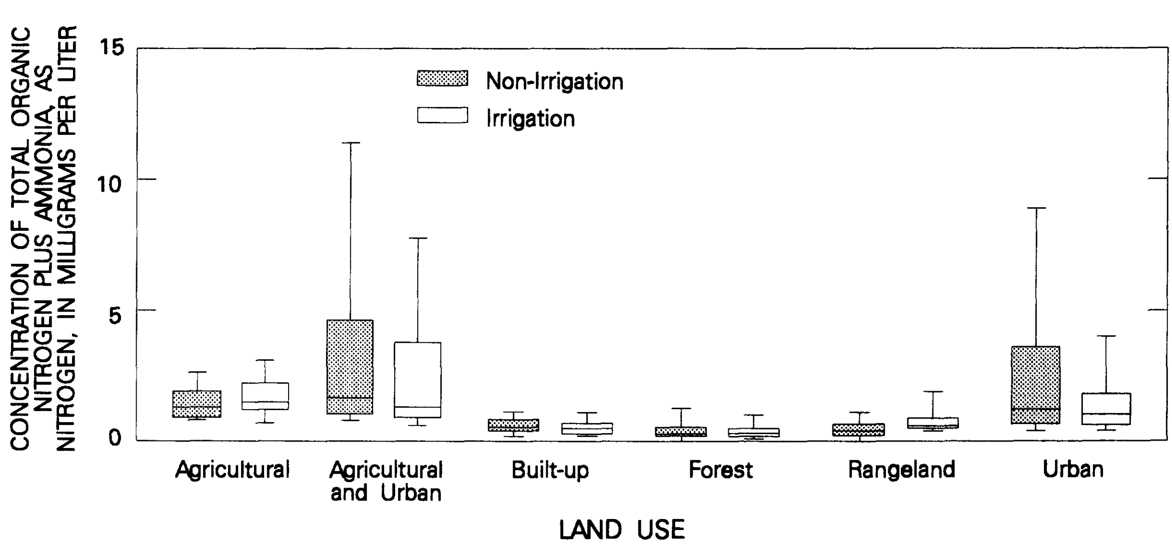

Figure 20. Relations of land use and concentrations of total organic nitrogen plus ammonia, as nitrogen, by season, in the South Platte River Basin, water years 1980–92.

Trends in Surface Water

Nutrient concentrations were tested for time trends at sites having sufficient data to meet the statistical requirements discussed in the "Data-Analysis Methods" section of this report. Some of the variability in nutrient concentrations often seems to be related to the date of sample collection. LOWESS smooth lines are used to dampen some of the variability in the data so as to make trends more evident. Nutrient concentrations for the South Platte River at Julesburg, Colorado (figure 21) seem to have some trend with time amongst a more prevalent seasonal variability. The seasonal variability generally is attributed to seasonal variability in streamflow, which can affect nutrient concentrations. Streamflow also varies from year to year; for example at the South Platte River at Julesburg, Colorado, water years 1980–82 had relatively small annual mean discharges, water years 1983–87 had large annual mean discharges, and water years 1988–92 were relatively small again. Concentrations of dissolved nitrite plus nitrate and dissolved phosphorus at this site seem to mirror these streamflow patterns; that is, concentrations increase with increasing streamflow. These patterns could be due to flow regulation, rather than patterns in natural streamflow. To remove the effects of streamflow in the statistical analysis of trends, concentrations were first flow adjusted. However, flow adjustment on data sets from regulated streams could remove variability due to flow regulation as well as variability due to natural streamflow, making interpretation of results somewhat tenuous.

Results of trend analysis using the seasonal Kendall test (Helsel and Hirsch, 1992) are presented in table 10. Among the constituents presented in figure 21 for the South Platte River at Julesburg, Colorado, only dissolved ammonia had a statistically-significant trend. All sites in the Big Thompson River and Cache la Poudre River also had decreasing trends in dissolved ammonia concentrations. Dissolved nitrite plus nitrate concentrations decreased at two sites along the Big Thompson River (sites 32 and 33) but increased at the Big Thompson River below Loveland, Colorado (site 34). For the Cache la Poudre River, site 41 had no trend, and sites 42 and 43 had a decrease in dissolved nitrite plus nitrate concentrations. Two sites on the South Platte River (sites 51 and 53) had no significant trend in dissolved nitrite plus nitrate concentrations. No trends were determined for dissolved phosphorus for any site on the Big Thompson River or the South Platte River. The Cache la Poudre River below Fort Collins, Colorado (site 42) had a decreasing trend in dissolved phosphorus concentration. Nutrient trends downstream from wastewater-treatment plants might be related to changes in treatment processes at those plants. Trends elsewhere might be related to land-use effects or to changes in flow regulation. More data about wastewater-treatment-plant discharges, changes in land use, and water-regulation practices, as well as more complete data on instream nutrient concentrations, are needed to evaluate trends in the South Platte River Basin.

Relation of Concentration to Streamflow

The relation between nutrient concentrations and streamflow can provide some information on processes affecting nutrient concentrations. Streamflow can be standardized between sites by converting each discharge value to a flow percentile. The relation between nitrite plus nitrate concentrations and percentile of flow and between dissolved phosphorus and percentile of flow is shown for selected sites in figure 22. Nitrite plus nitrate concentrations are small for all flows at the South Platte River at Littleton, Colorado (site 6); this site is downstream from Chatfield Reservoir. Nitrite plus nitrite concentrations also are small at the Cache la Poudre River at Fort Collins, Colorado (site 41), which is upstream from urban and agricultural areas. Concentrations decrease with increasing streamflow; this decrease may be due to dilution. Concentrations are much higher at the Cache la Poudre River near Greeley, Colorado (site 44) and South Platte River at Julesburg, Colorado (site 53). The large concentrations at Greeley are consistently large, probably due to upstream urban and agricultural land uses. The curve is slightly convex, indicating that mid-range flows contribute increasing amounts of nitrite plus nitrate, while some dilution occurs at very high flows. The concentration curve for Julesburg also shows concentrations increasing with streamflow (as discussed in the previous section), with dilution beginning to occur only at very high flows. Among sites examined, it seems that the range in flow at which dilution begins to occur increases downstream from the Greeley area. Patterns for dissolved phosphorus (fig. 22) are similar to the nitrite plus nitrate patterns, although dilution of concentrations at high flows at site 44 does not occur. Concentration patterns for total ammonia plus organic nitrogen also are similar to the nitrite plus nitrate and dissolved phosphorus patterns.

Total phosphorus was plotted against flow percentile (fig. 23) for the South Platte River at Littleton, Colorado (site 6) and the South Platte River at Julesburg, Colorado (site 53). Concentrations at Littleton are highest at low flows, which probably indicates the presence of a small wastewater-treatment plant upstream from the site. Concentrations decrease as flow increases. Concentrations at Julesburg increase across the flow range. The relation between sus-

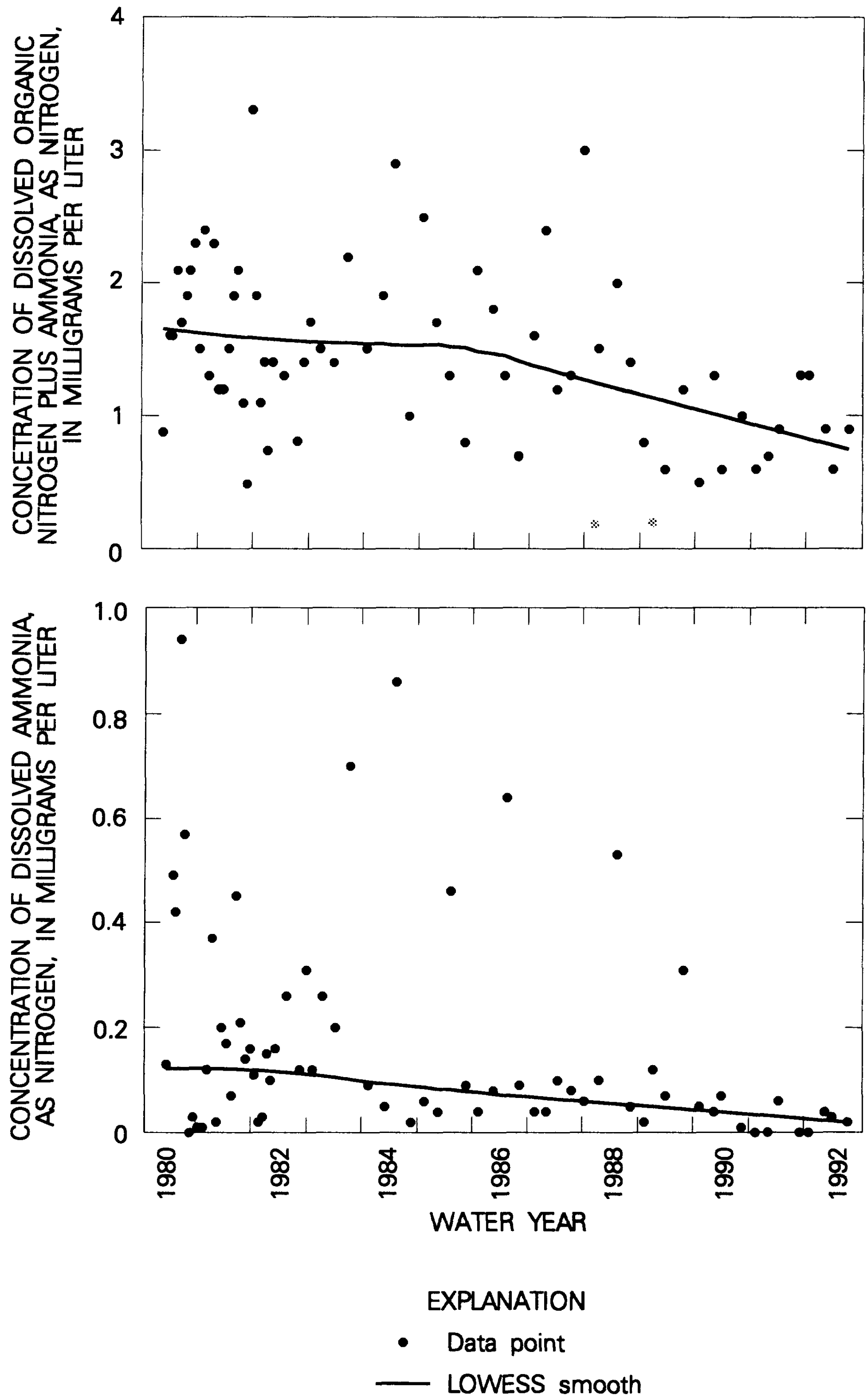

Figure 21. Relations of selected nutrient concentrations and time at the South Platte River at Julesburg, Colorado, water years 1980–92.

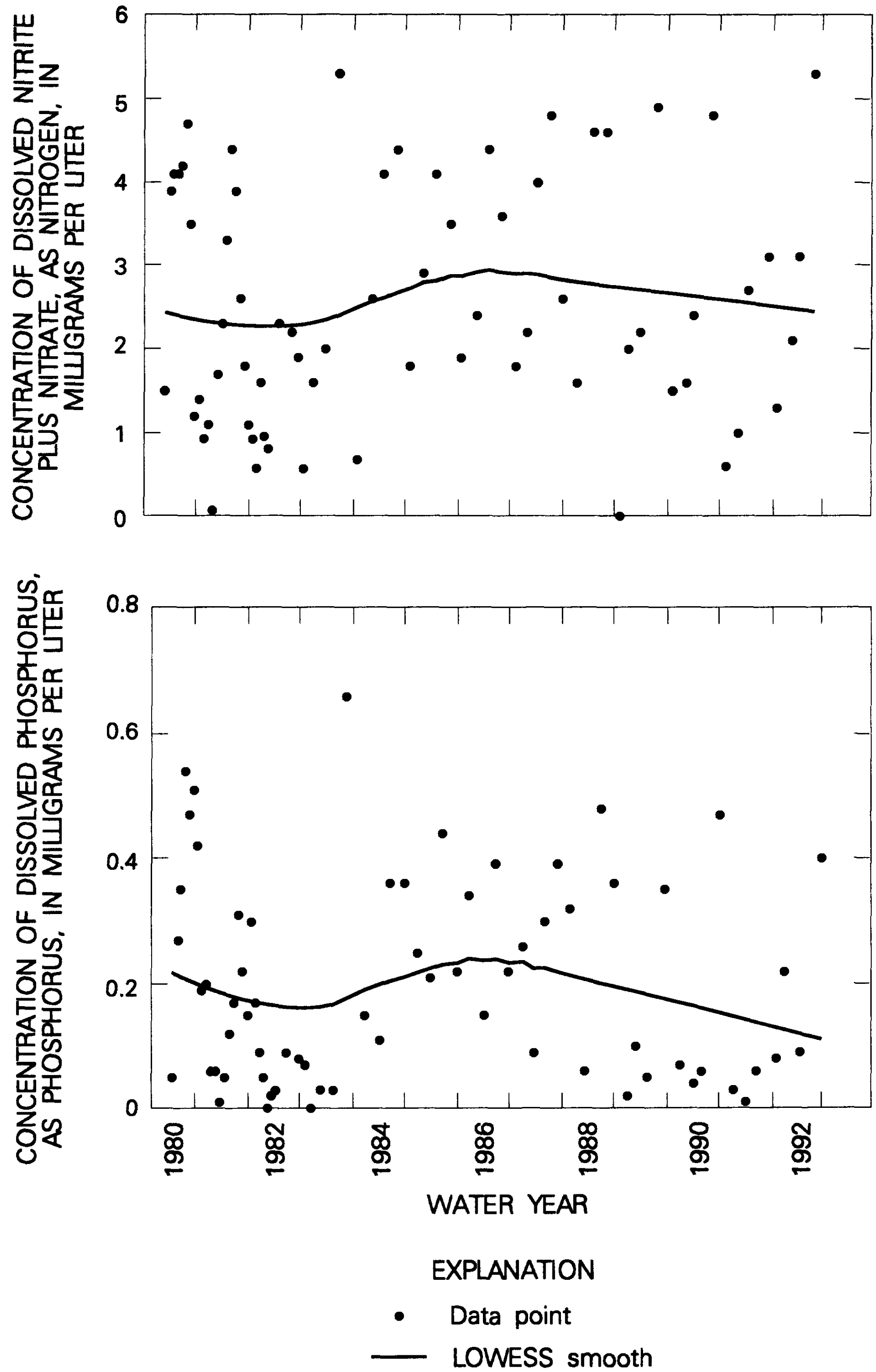

Figure 21. Relations of selected nutrient concentrations and time at the South Platte River at Julesburg, Colorado, water years 1980–92--Continued.

Table 10. Results of seasonal Kendall tests for time trends for flow adjusted concentrations of selected nutrients at selected surface-water sites in the South Platte River Basin

[no., number; bolded values, significant at 0.1 probability level; <, less than].

Site no. (fig. 9)	Site name	Inclusive water years	No. of years	Probability level	Slopes	Trend
	Total organic nitrogen plus ammonia, as nitrogen					
53	South Platte River at Julesburg, Colorado	1982–89	8	0.320	-0.0288	No trend
	Dissolved ammonia, as nitrogen					
32	Big Thompson River above Loveland, Colorado	1982–89	8	<0.001	-0.0088	Downward
33	Big Thompson River at Loveland, Colorado	1982–89	8	<0.001	-0.0128	Downward
34	Big Thompson River below Loveland, Colorado	1982–89	8	<0.001	-0.0783	Downward
41	Cache la Poudre River at Fort Collins, Colorado	1982–89	8	<0.001	-0.0093	Downward
42	Cache la Poudre River below Fort Collins, Colorado	1982–89	8	0.008	-0.0208	Downward
43	Cache la Poudre River above Box Elder Creek, Colorado	1982–89	8	0.025	-0.0118	Downward
53	South Platte River at Julesburg, Colorado	1982–89	8	0.014	-0.0108	Downward
	Dissolved nitrite plus nitrate, as nitrogen					
32	Big Thompson River above Loveland, Colorado	1980–89	10	<0.001	-0.0696	Downward
33	Big Thompson River at Loveland, Colorado	1980–89	10	<0.001	-0.0528	Downward
34	Big Thompson River below Loveland, Colorado	1980–89	10	0.001	+0.2567	Upward
41	Cache la Poudre River at Fort Collins, Colorado	1980–89	10	0.214	-0.0150	No trend
42	Cache la Poudre River below Fort Collins, Colorado	1980–89	10	0.009	-0.0841	Downward
43	Cache la Poudre River above Box Elder Creek, Colorado	1980–89	10	<0.001	-0.1513	Downward
51	South Platte River near Weldona, Colorado	1980–89	10	0.690	+0.0231	No trend
53	South Platte River at Julesburg, Colorado	1980–89	10	0.136	+0.0689	No trend

Table 10. Results of seasonal Kendall tests for time trends for flow adjusted concentrations of selected nutrients at selected surface-water sites in the South Platte River Basin--Continued

Site no. (fig. 9)	Site name	Inclusive water years	No. of years	Probability level	Slopes	Trend
		Dissolved phosphorus, as phosphorus				
32	Big Thompson River above Loveland, Colorado	1980–89	10	0.698	-0.0001	No trend
33	Big Thompson River at Loveland, Colorado	1980–89	10	0.667	+0.0003	No trend
34	Big Thompson River below Loveland, Colorado	1980–89	10	0.747	-0.0282	No trend
40	Cache la Poudre River at Shields Street, Fort Collins, Colorado	1980–89	10	0.272	-0.0004	No trend
41	Cache la Poudre River at Fort Collins, Colorado	1980–89	10	1.000	-0.0000	No trend
42	Cache la Poudre River below Fort Collins, Colorado	1980–89	10	0.019	-0.0206	Downward
43	Cache la Poudre River above Box Elder Creek, Colorado	1980–89	10	0.138	-0.0058	No trend
51	South Platte River near Weldona, Colorado	1980–89	10	0.402	-0.0056	No trend
53	South Platte River at Julesburg, Colorado	1980–89	10	0.810	+0.0024	No trend

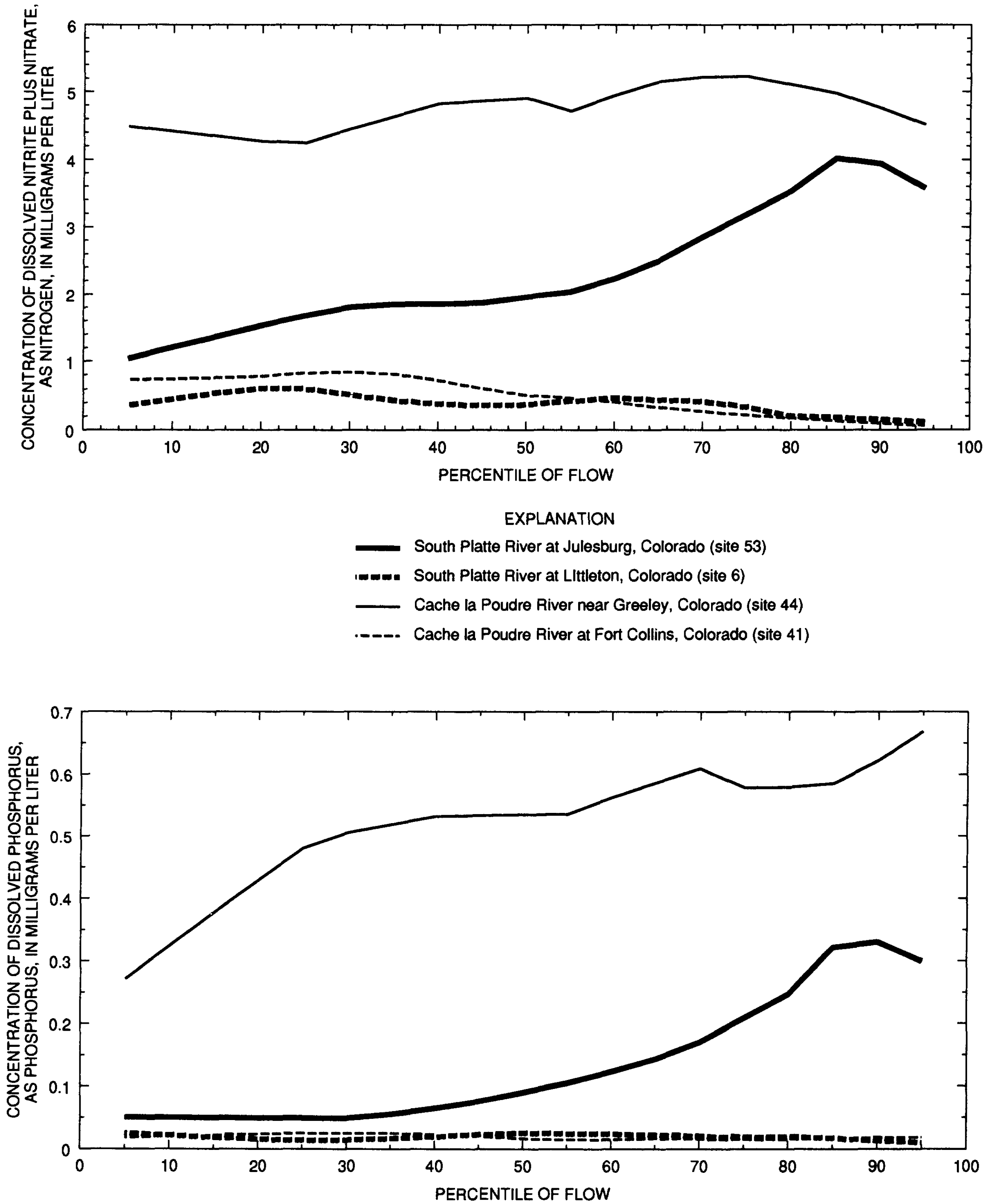

Figure 22. Relations between nutrient concentrations and percentiles of flow at selected surface-water sites in the South Platte River Basin, water years 1980–92. (Lines on graph are LOWESS smooth lines).

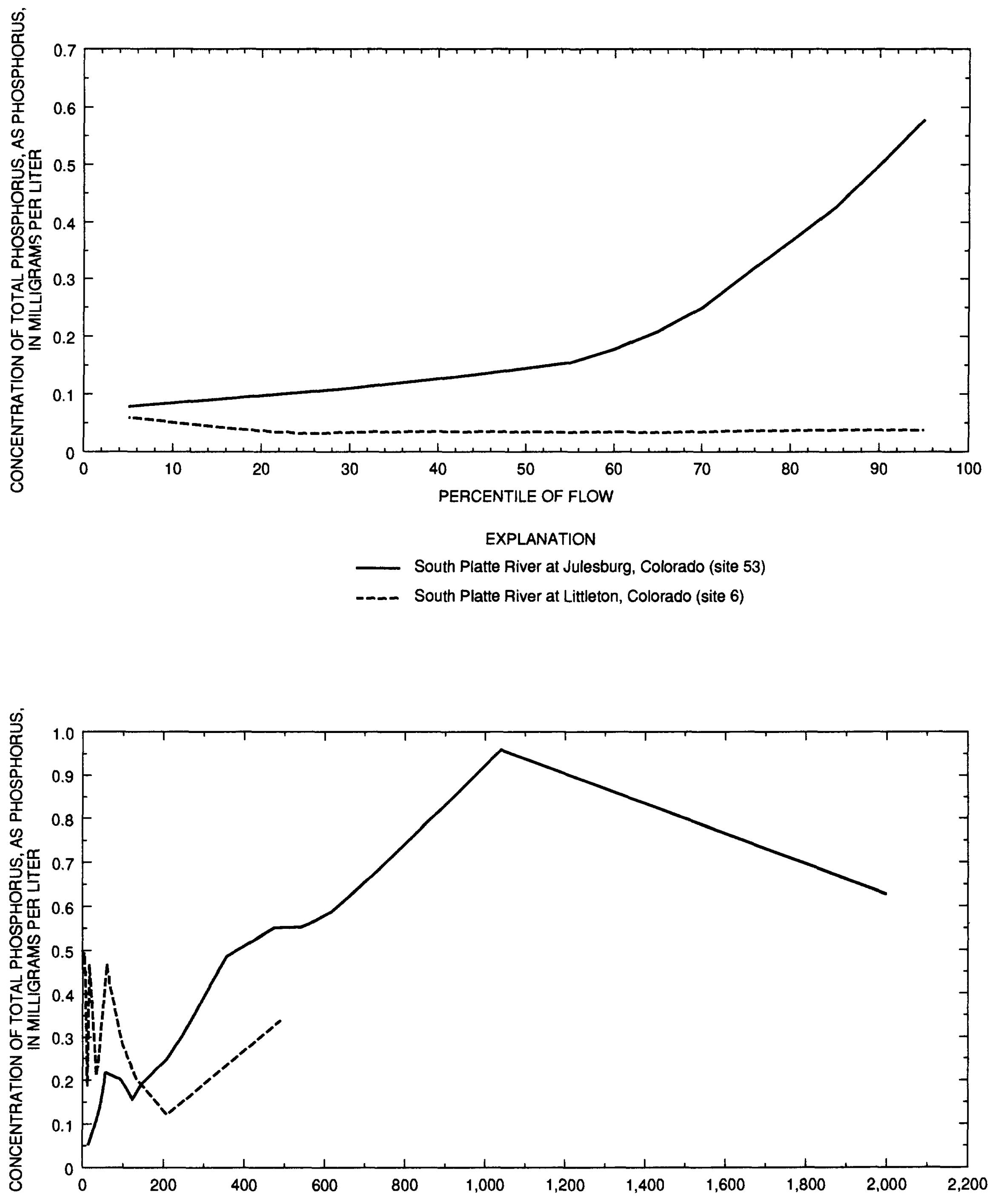

Figure 23. Relations between total phosphorus concentrations, percentile of flow, and suspended-sediment concentrations for selected surface-water sites in the South Platte River Basin, water years 1980–92. (Lines on graph are LOWESS smooth lines).

pended-sediment concentration and total phosphorus concentration at these sites (fig. 23) indicates that the total phosphorus at Julesburg is related to increased suspended-sediment concentrations at higher flows, while at Littleton, suspended-sediment does not increase as releases from Chatfield Reservoir increase.

Loads in Surface Water

Nutrient loads were estimated at ten sites: four sites along the South Platte River (sites 6, 51, 53, and 54), three sites on the Cache la Poudre River (sites 41, 43, and 44), and single sites on Boulder Creek (site 30), St. Vrain Creek (site 31), and the Big Thompson River (site 33). Data requirements and regression models used to estimate loads have been discussed in the "Data-Analysis Methods" section of this report. The regression model coefficients and probability values for each coefficient are listed in table 35 in the "Supplemental Data" section at the back of this report. Mean annual loads were estimated for representative low, median, and high flow years for the following constituents: total organic nitrogen plus ammonia, dissolved ammonia, dissolved nitrite, dissolved nitrite plus nitrate, dissolved phosphorus, dissolved orthophosphate, and total phosphorus (table 11). The standard errors of the estimated loads are about 25 percent of the estimated loads. Median constituent concentrations and mean annual discharges also are listed in table 11 because loads are a multiplicative function of these two factors. Loads generally are increased during higher flow years by a factor somewhat less than the increase in flows because the additional water dilutes constituent concentrations at most sites.

Estimated dissolved ammonia and dissolved nitrite loads were small. Among the sites with load estimates, only Cache la Poudre River above Box Elder Creek near Timnath, Colorado (site 43) is near an upstream wastewater-treatment plant; the increase in dissolved ammonia and dissolved nitrite loads at this site relative to the upstream site (Cache la Poudre River at Fort Collins, Colorado (site 41) is caused by the increase in concentrations downstream from the wastewater-treatment plant; streamflow actually decreases between these two sites. Ammonia and nitrite loads probably increase downstream from other major wastewater-treatment plants in the basin, but these loads can decrease substantially over short distances due to oxidation to nitrate (Paschal and Mueller, 1991). Ammonia and nitrite concentrations are small relative to other nitrogen species, and their contributions to nitrogen loads generally are negligible.

Dissolved nitrite-plus-nitrate loads at three sites on the South Platte River during a median flow year (water year 1986) were small upstream from Denver (47 tons/yr at site 6), much larger downstream from the Front Range mixed agricultural and urban area (3,900 tons/yr at site 51), and then somewhat smaller further downstream (2,900 tons/yr at site 53). The two largest tributaries contribute similar loads, 450 tons/yr from St. Vrain Creek (site 31) and 420 tons/yr from the Cache la Poudre River (site 44). Dissolved nitrite-plus-nitrate loads were calculated for three sites along the Cache la Poudre River, and loads increased in a downstream direction from 11 tons/yr (site 41, water year 1981), to 44 tons/yr (site 43), to 390 tons/yr (site 44). These increases primarily are due to increases in nitrate concentrations. The small increase in loads between sites 41 and 43 most likely is due to a wastewater-treatment-plant discharge, but the large increase between sites 43 and 44 could be due to multiple land uses in this reach, which include a wastewater-treatment plant, an urban area, extensive cropland, and several feedlots.

Total ammonia-plus-organic-nitrogen loads could be estimated for only six sites. Along the South Platte River during a median flow year, loads were small upstream from Denver (110 tons/yr at site 6) and much larger downstream from the Front Range urban-agricultural corridor (1,400 tons/yr at site 53). However, ammonia-plus-organic-nitrogen loads increase between these two sites by about 1,300 tons/yr, while nitrate loads between these two sites increase by about 2,900 tons/yr. Also, nitrate comprises about 30 percent of the total nitrogen load at the upstream site, while it comprises about 67 percent of the total nitrogen load at the downstream site.

The total nitrogen load transported in the South Platte River near the end of the basin at Julesburg (site 53) during a median flow year (water year 1986) was 4,300 tons (2,900 tons of nitrite plus nitrate, as nitrogen, and 1,400 tons of organic nitrogen plus ammonia, as nitrogen); during a high flow year (water year 1983), the total-nitrogen transported was 13,780 tons. Total nonpoint source nitrogen loading to the basin can be estimated as the sum of atmospheric deposition plus fertilizer and manure applications. Estimates of atmospheric-deposition loads indicate that precipitation (wet deposition) contributed about 34,000 tons of nitrate and 12,000 tons of ammonia to the basin, and dry deposition contributed about 15,000 tons of nitrate and 5,000 tons of ammonia (see the "Data-Analysis Methods" section of this report for information on how these loads were estimated). The total atmospheric inputs were 49,000 tons of nitrate and 17,000 tons of ammonia. The estimate for fertilizer contribution was about 132,000 tons of nitrogen, based

Table 11. Estimated annual nutrient loads at selected sites in the South Platte River Basin, for low flow (water year 1981), median flow (water year 1986), and high flow (water year 1983)

[no., number; mg/L, milligrams per liter; ft^3/s, cubic feet per second; --, no data; <, less than]

Site no. (fig. 9)	Site name	Median concern-attrition, in mg/L (water years 1980–92)	Low flow, water year 1981: Mean annual dis-charge (ft^3/s)	Low flow, water year 1981: Estimated annual load (tons per year)	Low flow, water year 1981: Standard error of estimated load (tons per year)	Median flow, water year 1986: Mean annual dis-charge (ft^3/s)	Median flow, water year 1986: Estimated annual load (tons per year)	Median flow, water year 1986: Standard error of estimated load (tons per year)	High flow, water year 1983: Mean annual dis-charge (ft^3/s)	High flow, water year 1983: Estimated annual load (tons per year)	High flow, water year 1983: Standard error of estimated load (tons per year)
				Total organic nitrogen plus ammonia, as nitrogen							
6	South Platte River at Littleton, Colorado	0.74	78	75	7	164	110	13	631	550	68
33	Big Thompson River at Loveland, Colorado	.69	36	32	2	82	37	4	221	120	13
41	Cache la Poudre River at Fort Collins, Colorado	.60	54	46	10	234	180	41	779	590	140
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	1.20	39	49	7	239	190	26	700	700	96
53	South Platte River at Julesburg, Colorado	1.40	322	530	38	886	1,400	110	2,882	7,100	800
54	South Platte River at Roscoe, Nebraska	1.60	--	--	--	942	2,700	600	2,941	7,800	1,100
				Dissolved ammonia, as nitrogen							
6	South Platte River at Littleton, Colorado	.07	78	8	1	164	10	2	631	41	8
33	Big Thompson River at Loveland, Colorado	.05	36	4	<1	82	3	<1	221	10	2
41	Cache la Poudre River at Fort Collins, Colorado	.03	54	4	<1	--	--	--	--	--	--
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	.16	39	11	3	229	40	10	700	180	43
53	South Platte River at Julesburg, Colorado	.09	322	85	19	886	100	20	2,882	250	52

Table 11. Estimated annual nutrient loads at selected sites in the South Platte River Basin, for low flow (water year 1981), median flow (water year 1986), and high flow (water year 1983)--Continued

Site no. (fig. 9)	Site name	Median concern-attrition, in mg/L (water years 1980–92)	Low flow, water year 1981			Median flow, water year 1986			High flow, water year 1983		
			Mean annual dis-charge (ft^3/s)	Estimated annual load (tons per year)	Standard error of estimated load (tons per year)	Mean annual dis-charge (ft^3/s)	Estimated annual load (tons per year)	Standard error of estimated load (tons per year)	Mean annual dis-charge (ft^3/s)	Estimated annual load (tons per year)	Standard error of estimated load (tons per year)
					Dissolved nitrite, as nitrogen						
33	Big Thompson River at Loveland, Colorado	<.01	36	<1	<1	82	<1	<1	221	1	<1
41	Cache la Poudre River at Fort Collins, Colorado	<.01	54	<1	<1	234	2	<1	779	8	1
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	.03	39	1	<1	229	4	<1	700	17	3
					Dissolved nitrite plus nitrate, as nitrogen						
6	South Platte River at Littleton, Colorado	.30	78	37	5	164	47	9	631	100	16
30	Boulder Creek at mouth near Longmont, Colorado	1.40	34	57	7	76	160	16	220	330	53
31	St.Vrain Creek at mouth near Platteville, Colorado	3.00	135	430	17	288	450	110	569	770	100
33	Big Thompson River at Loveland, Colorado	.34	36	14	1	82	13	1	221	35	4
41	Cache la Poudre River at Fort Collins, Colorado	.50	54	11	1	--	--	--	779	65	9
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	1.60	39	44	3	229	62	6	700	210	25
44	Cache la Poudre River near Greeley	4.70	96	390	23	287	420	170	872	1,100	280
51	South Platte River near Weldona, Colorado	4.30	372	1,500	74	976	3,900	160	2,995	8,400	520
53	South Platte River at Julesburg, Colorado	2.25	322	876	91	886	2,900	270	2,882	6,500	770

Table 11. Estimated annual nutrient loads at selected sites in the South Platte River Basin, for low flow (water year 1981), median flow (water year 1986), and high flow (water year 1983)--Continued

Site no. (fig. 9)	Site name	Median concern-attrition, in mg/L (water years 1980–92)	Low flow, water year 1981			Median flow, water year 1986			High flow, water year 1983		
			Mean annual dis-charge (ft^3/s)	Estimated annual load (tons per year)	Standard error of estimated load (tons per year)	Mean annual dis-charge (ft^3/s)	Estimated annual load (tons per year)	Standard error of estimated load (tons per year)	Mean annual dis-charge (ft^3/s)	Estimated annual load (tons per year)	Standard error of estimated load (tons per year)
	Dissolved phosphorus, as phosphorus										
6	South Platte River at Littleton, Colorado	.02	78	1	<1	164	5	<1	631	11	1
30	Boulder Creek at mouth near Longmont, Colorado	.70	34	34	6	76	78	10	220	130	21
31	St.Vrain Creek at mouth near Platteville, Colorado	.39	135	59	3	288	150	47	569	160	26
33	Big Thompson River at Loveland, Colorado	.02	36	1	<1	82	1	<1	221	4	<1
41	Cache la Poudre River at Fort Collins, Colorado	.02	54	1	<1	--	--	--	779	17	3
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	.07	39	7	3	229	39	15	700	180	65
44	Cache la Poudre River near Greeley, Colorado	.53	96	52	4	287	38	22	872	110	41
51	South Platte River near Weldona, Colorado	.37	372	150	17	976	570	62	2,995	1,600	270
53	South Platte River at Julesburg, Colorado	.15	322	68	8	886	260	31	2,882	1,000	170
	Dissolved orthophosphate, as phosphorus										
53	South Platte River at Julesburg, Colorado	.13	322	51	11	886	250	40	2,882	960	240
	Total phosphorus, as phosphorus										
6	South Platte River at Littleton, Colorado	.04	78	3	<1	164	10	2	631	35	8
53	South Platte River at Julesburg, Colorado	.28	322	100	9	886	460	46	2,882	2,500	370
54	South Platte River at Roscoe, Nebraska	.27	--	--	--	942	250	84	2,941	1,500	320

on county-level fertilizer sales data (U.S. Environmental Protection Agency, 1990b). The manure contribution was estimated to be 94,000 tons, based on county animal counts (R.B. Alexander, U.S. Geological Survey, written commun., 1992). Much of the manure load, however, is volatilized over a short time period. The estimated total-nitrogen input is 299,000 tons. Therefore, only about 1 percent of the load applied to the land from precipitation and fertilizer was transported past Julesburg in a median flow year and 5 percent was transported during a high-flow year. Much of the nutrient input to the land surface (atmospheric, fertilizer, and manure loads) does not migrate into the hydrologic system, but rather remains immobile in the unsaturated zone or is taken up by biota.

Dissolved phosphorus loads along the South Platte River follow the same pattern as nitrite plus nitrate loads; they are small upstream from Denver (5 tons/yr at site 6), much larger downstream from the Front Range urban-agricultural area (570 tons/yr at site 51), and then smaller further downstream (260 tons/yr at site 53). Dissolved phosphorus comprises about half the total phosphorus load at sites 6 and 53.

Definitive statements cannot be made relating nutrient loads to land use because most of the sites where loads were estimated have urban and agricultural effects. Three sites near urban areas, but upstream from wastewater-treatment plants and agricultural areas (sites 6, 33, and 41), have the smallest nutrient loads. Sites with mixed urban and agricultural effects (sites 31, 37, 43, 44) have greater nutrient loads. Three sites along the South Platte River (sites 51, 53, and 54) are present in agricultural areas but also are downstream from the Front Range mixed agricultural and urban area; nitrate loads at these sites comprise a greater proportion of the total nitrogen load.

There are 25 wastewater-treatment plants in the study unit, which discharge at least 1 ft^3/s. The estimated proportion of each discharge relative to the discharge of its receiving water ranges from less than one percent to 64 percent. Effluent discharges and nutrient loads have large diurnal and seasonal variations. The USEPA Permit Compliance System database contains few data on major nutrient constituents in wastewater-treatment-plant effluent because these constituents generally are not limited by permits; therefore, the proportion of nutrient loads due to these point sources could not be calculated. The nutrient concentration boxplots for stream reaches presented in this report (fig. 19) illustrate that wastewater-treatment plants have a large effect; quantification of the effect on loadings will require increased data collection.

Nutrient loads and loadings per square mile of drainage area are difficult to interpret because of the complex water-management infrastructure; for example, large irrigation diversions can greatly decrease instream loads. The complexity of the system is typified by downstream changes in instantaneous loads of nitrite plus nitrate on a reach of the Big Thompson River in Colorado from June 19–20, 1991 (fig. 24). On this day, the river emerged from the Big Thompson canyon with a streamflow of 193 ft^3/s. A few miles downstream, transbasin diversion water was added, increasing the streamflow to 420 ft^3/s. In the remaining 30 mi between the mouth of the canyon and the mouth of the Big Thompson River, water was removed from the river by a series of irrigation ditches; only 5.4 ft^3/s was left in the river at its mouth. Concentrations of nitrite plus nitrate in this reach were small downstream from the canyon (0.04 mg/L), increased to 1.2 mg/L downstream from Loveland, Colorado, where the city wastewater-treatment plants discharged into the river, and increased to 1.5 mg/L at the Interstate-25 site. This combination of streamflow and concentration produced a load curve that fluctuated greatly along the reach and loads exiting the reach were about as small as loads entering reach. Similarly complex load patterns occur along almost all river reaches in the basin.

Nutrient loads also are difficult to interpret because there are insufficient data to calculate loads for many important parts of the basin. Data are needed at points on the South Platte River, such as directly downstream from the Denver metropolitan area; at Kersey, Colorado, which is located downstream from the Front Range urban-agricultural area and which has the largest mean annual streamflow on the river; and at points that bracket major instream reservoirs. More complete data along the South Platte River are needed for better estimation of ground-water nutrient inputs along major river reaches. More complete data also are needed at the mouths of the major tributaries to the South Platte River; at points that bracket major offstream reservoirs; and at the mouths of basins representative of a single land use.

Concentrations in Ground Water

Data for seven nutrient species will be presented in this section; however, only three of the seven constituents will be discussed in detail. These three constituents, dissolved nitrite plus nitrate, dissolved organic nitrogen plus ammonia, and dissolved phosphorus, were selected because of their importance within the basin and the quantity and distribution of the data in time and space.

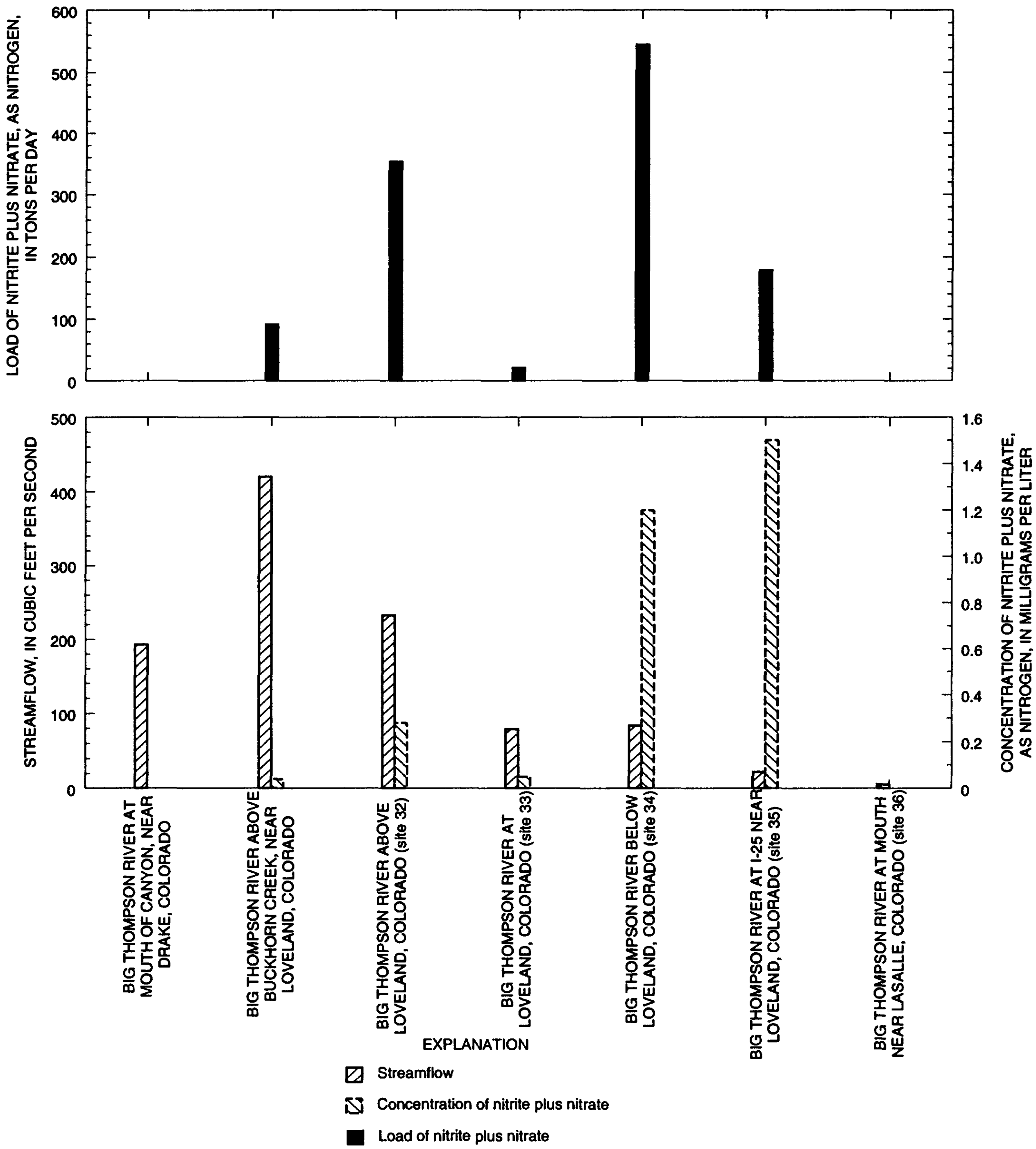

Figure 24. Instantaneous nitrite plus nitrate loads on the Big Thompson River, Colorado, June 19–20, 1991.

The median concentration of dissolved nitrite plus nitrate in ground water varied significantly ($p < 0.05$) between aquifers and well types in the South Platte River Basin; however, none of the median concentrations exceeded the 10 mg/L MCL (fig. 25). The highest median concentrations of dissolved nitrite plus nitrate generally were measured in ground-water samples collected from observation or irrigation wells in the alluvial aquifer. The lowest median concentrations generally were measured in samples collected from domestic wells in the Laramie/Fox Hills or Denver aquifers (fig. 25 and table 8).

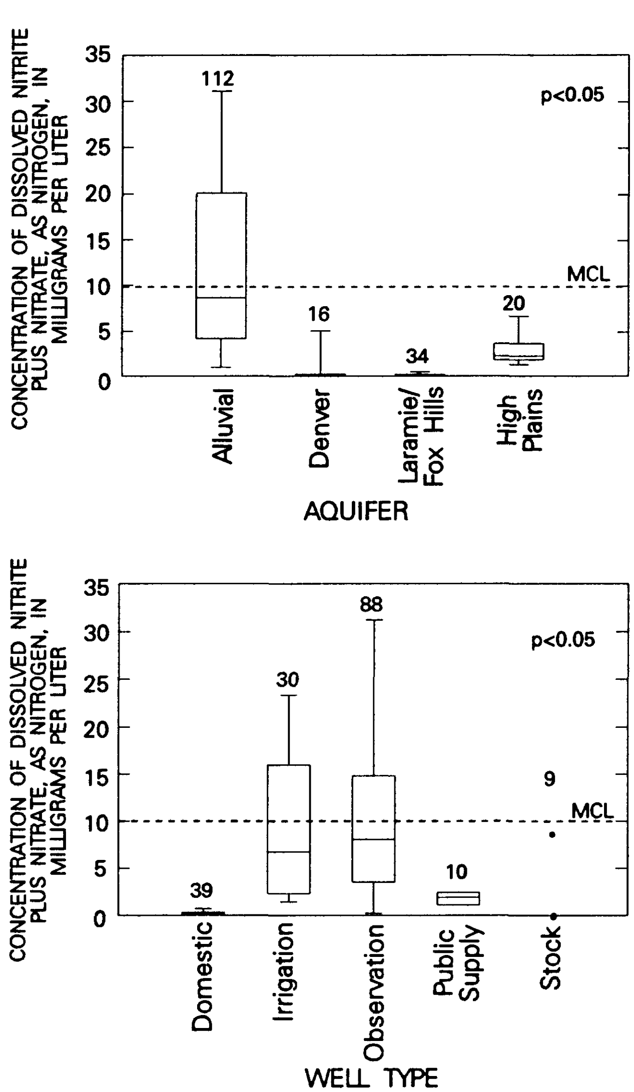

Figure 25. Concentrations of dissolved nitrite plus nitrate, as nitrogen, in ground water from the South Platte River Basin, grouped by aquifer and well type, water years 1980–92.

Ground-water samples from observation and irrigation wells had the highest median concentrations of dissolved nitrite plus nitrate relative to other well types examined. With about 67 percent of the wells being of these two types, the higher median concentrations could indicate the effect of agriculture. Additionally, 46 of the 49 ground-water samples having nitrite plus nitrate concentrations greater than or equal to the 10 mg/L MCL were from wells completed in the alluvium overlain by agricultural land use, indicating that ground water in alluvium underlying agricultural areas might have higher concentrations than ground water from other aquifers (table 12). However, it is not appropriate to relate land use to constituent concentrations obtained from wells completed in these aquifers because some of the wells are completed near the surface, thus being more easily susceptible to human activities, while other wells are completed at depth, which should be minimally affected. This combination does not lend itself to obtaining a clear relation between nutrient concentrations and land use. Therefore, comparisons will only be made between land use and water quality in the near surface, alluvial aquifer, where human activities can have a clear effect on the water resource. Moreover, because of the poor distribution of dissolved nitrite plus nitrate data in time for the alluvial aquifer, relations of this constituent with year of sample or with season (irrigation/nonirrigation) are not possible. About 85 percent of the USGS data collected during 1986 and later for dissolved nitrite plus nitrate is from a single USGS cooperative project located in the Platteville, Colorado, area with the remaining data being from another USGS study in the Greeley, Colorado, area. No other agency data for this constituent were available. This survey of available data indicates the lack of areally-distributed information.

In the mid 1980's, local residents and State regulators realized that there were high concentrations of nitrate within the alluvial aquifer in Weld County, Colorado. This awareness resulted in several studies to look at this perceived problem. The data from these studies became available in about 1989 but was focused in the Greeley area, and total nitrate as nitrogen was the constituent of interest rather than dissolved nitrite plus nitrate. Historical water-quality data from the alluvial aquifer indicate that median concentrations of dissolved nitrite plus nitrate are similar for agricultural and rangeland land uses; there are insufficient data (one well) to test whether dissolved nitrite plus nitrate concentrations are different in the urban land use setting (fig. 26 and table 8).

Table 12. Number of dissolved nitrite plus nitrate, as nitrogen, samples not meeting water-quality criteria in water from selected wells in the South Platte River Basin, water years 1980–92

[Concentrations, in milligrams per liter; MCL, Maximum Contaminant Level in drinking water; MCL for dissolved nitrite plus nitrate is 10 mg/L; lower detection limit is 0.01 mg/L]

Site number (fig. 10)	Total number of samples	Maximum concentration	Number of samples equal to or greater than MCL
11	14	11.2	1
13	12	27.8	2
15	1	15.0	1
21	1	16.0	1
26	1	43.0	1
27	1	20.0	1
29	3	22.0	3
30	17	54.0	17
32	9	24.0	9
34	1	31.0	1
35	1	37.0	1
37	1	26.0	1
38	1	10.0	1
42	6	10.0	1
43	6	12.0	4
46	6	11.0	1
47	1	11.0	1
49	1	13.0	1
53	1	10.0	1

The poor areal distribution of data also was a problem when relating dissolved nitrite plus nitrate concentrations with depth in the alluvial aquifer. The alluvial aquifer is long and narrow (fig. 7) and thickens in a downvalley direction along the axis of the South Platte River. Dissolved nitrite plus nitrate concentrations for 113 samples collected from the alluvial aquifer and well depths are shown in figure 27. A LOWESS smooth line is drawn through the data, which illustrates a decrease of dissolved nitrite plus nitrate concentration with depth. However, plotted on figure 27 are 82 analyses of total nitrate that were analyzed as part of local agencies' investigation of high nitrate concentrations in the Greeley area (Schuff, 1992). These data together with studies being conducted by the USGS (McMahon and others, 1993) agree that in the vicinity of the Greeley area nitrate concentrations show no consistent trend with depth. However, east of the Greeley area the saturated thickness of the alluvial aquifer increases (Hurr, Schneider, and others, 1972) in a downvalley direction, and there are few nitrite plus nitrate analyses from wells completed at depths greater than 100 ft. Therefore, a better distribution of data areally and with depth is needed before a basin-wide relation between nitrate concentrations and well depth can be developed for the South Platte alluvial aquifer. For other aquifers (bedrock) in the basin, well depth seems inversely related to nitrate concentration. These aquifers are deep and not susceptible to contamination from surficial sources as is the alluvial aquifer.

The relative proportions of dissolved organic nitrogen and dissolved ammonia varied between aquifers and well types sampled (table 8). The median concentration of dissolved organic nitrogen plus ammonia was 30 times greater than the median concentration of dissolved ammonia in ground-water samples from the alluvial aquifer, indicating the concentration of organic nitrogen was much higher than the concentration of dissolved ammonia. Furthermore, the median concentration of dissolved ammonia was about the same as the median concentration of dissolved organic nitrogen plus ammonia in ground-water samples from the Laramie/Fox Hills aquifer, indicating the concentration of dissolved ammonia was higher than the concentration of dissolved organic nitrogen. For all well types, the concentration of dissolved ammonia is less than the

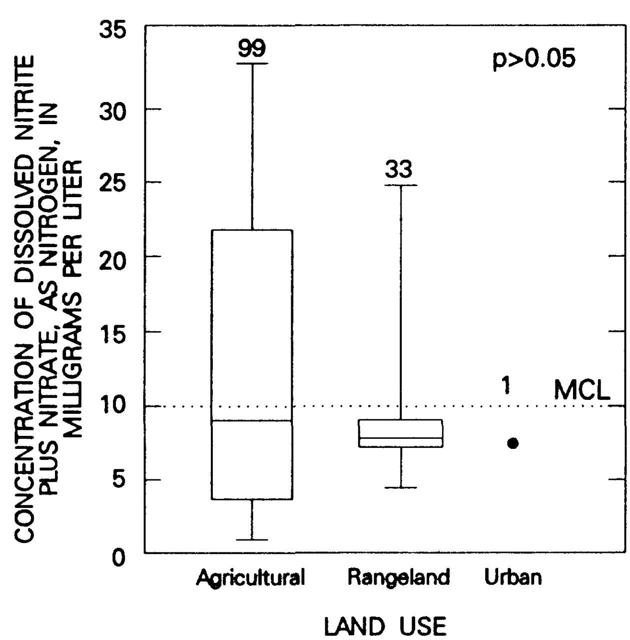

Figure 26. Concentrations of dissolved nitrite plus nitrate, as nitrogen, in ground water from wells completed in the alluvial aquifer from the South Platte River Basin, grouped by land use, water years 1980–92.

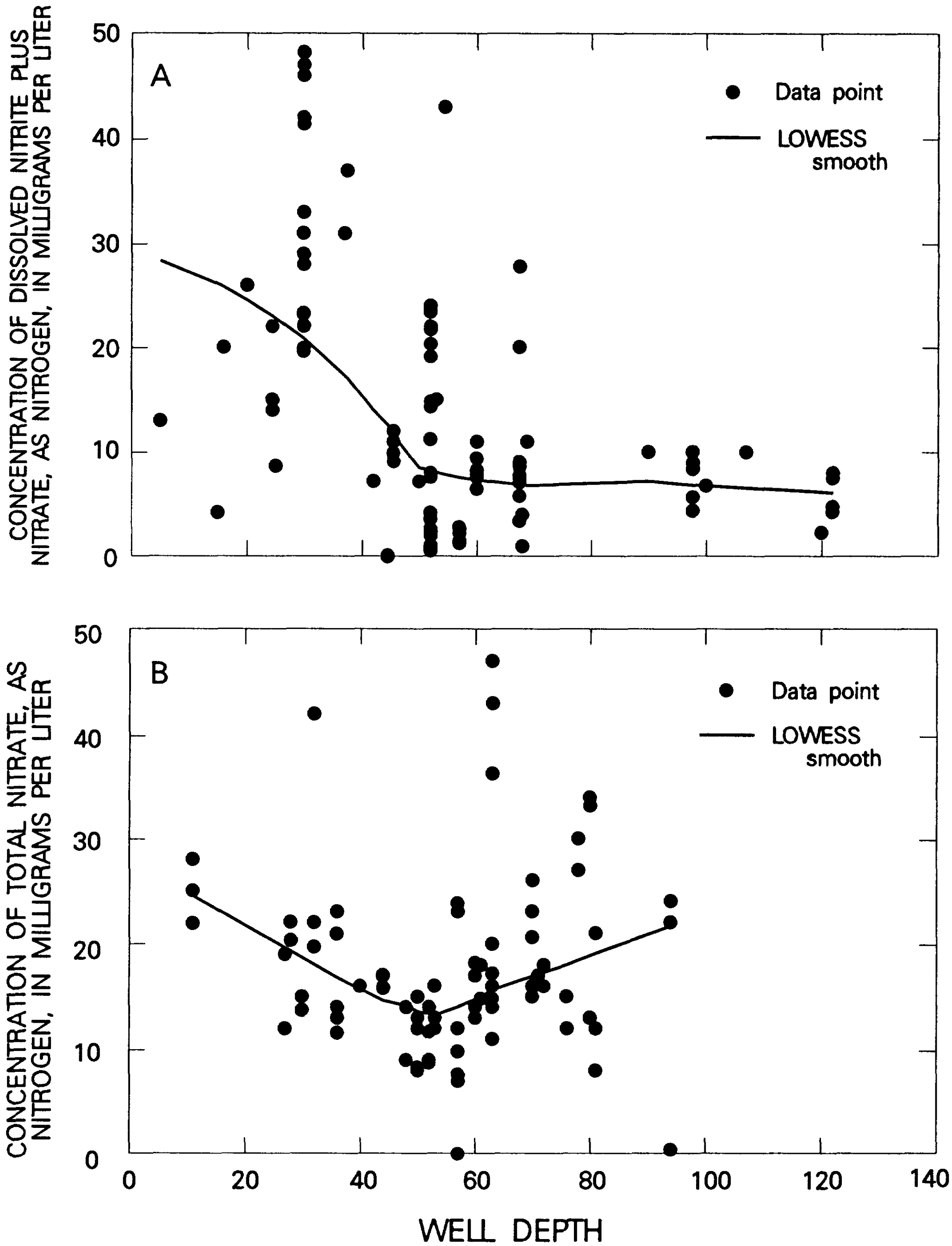

Figure 27. Relations of concentrations of dissolved nitrite plus nitrate, as nitrogen, and total nitrate, as nitrogen, to well depth for selected wells completed in the alluvial aquifer, South Platte River Basin, water years 1980–92.

concentration of dissolved organic nitrogen plus ammonia. However in ground-water samples from domestic wells, the median concentration of dissolved ammonia is much closer to the median concentration of dissolved organic nitrogen plus ammonia. The elevated concentrations of dissolved ammonia in ground-water samples from domestic wells could indicate ammonia inputs from septic tanks or mineralization of organic nitrogen in the Laramie/Fox Hills aquifer (Gaggiani and others, 1987, p.24). Currently, there are not enough data to fully assess these possibilities.

The median concentration of dissolved organic nitrogen plus ammonia in ground-water samples from the South Platte River Basin varied significantly between aquifers and sampling years. For example, the highest median concentrations of dissolved organic nitrogen plus ammonia in ground water generally were measured in samples from the alluvial aquifer and from samples collected prior to 1986 (fig. 28). The lowest median concentrations of dissolved organic nitrogen plus ammonia generally were measured in samples from the Laramie/Fox Hills aquifer and from samples collected in 1986 or later. There was no significant difference in the median concentration of dissolved organic nitrogen plus ammonia between samples from different well types or sampling season (fig. 28).

It is difficult to establish whether the larger concentrations of dissolved organic nitrogen plus ammonia in ground water from the alluvial aquifer underlying agricultural land use, relative to ground water from the alluvial aquifer underlying other land uses (fig. 29), indicated natural processes or effects from agricultural practices. If the elevated concentrations were the result of agricultural processes, one might expect higher con-

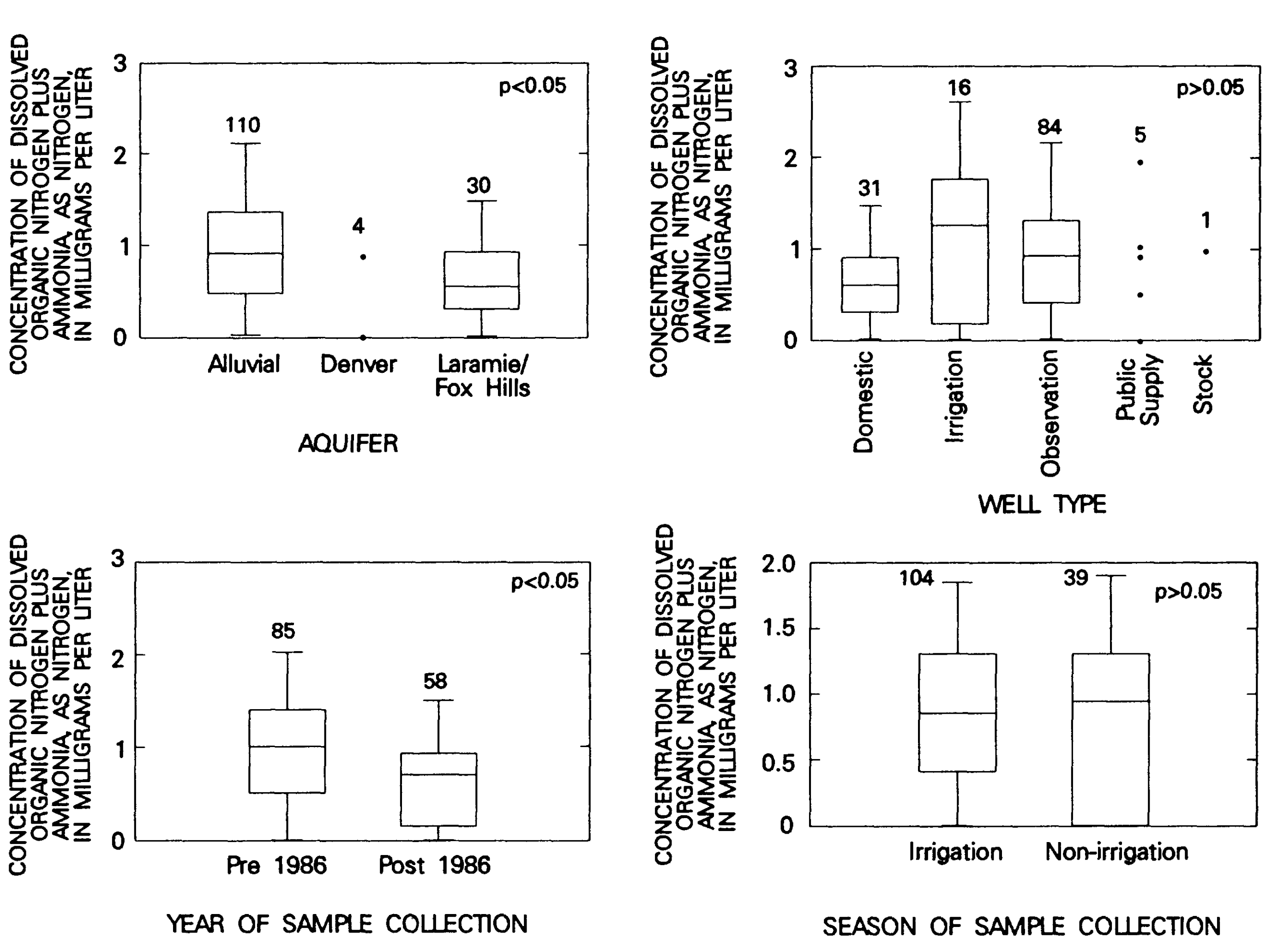

Figure 28. Concentrations of dissolved organic nitrogen plus ammonia, as nitrogen, in ground water from the South Platte River Basin, grouped by aquifer, well type, year of sample collection, and season of sample collection, water years 1980–92.

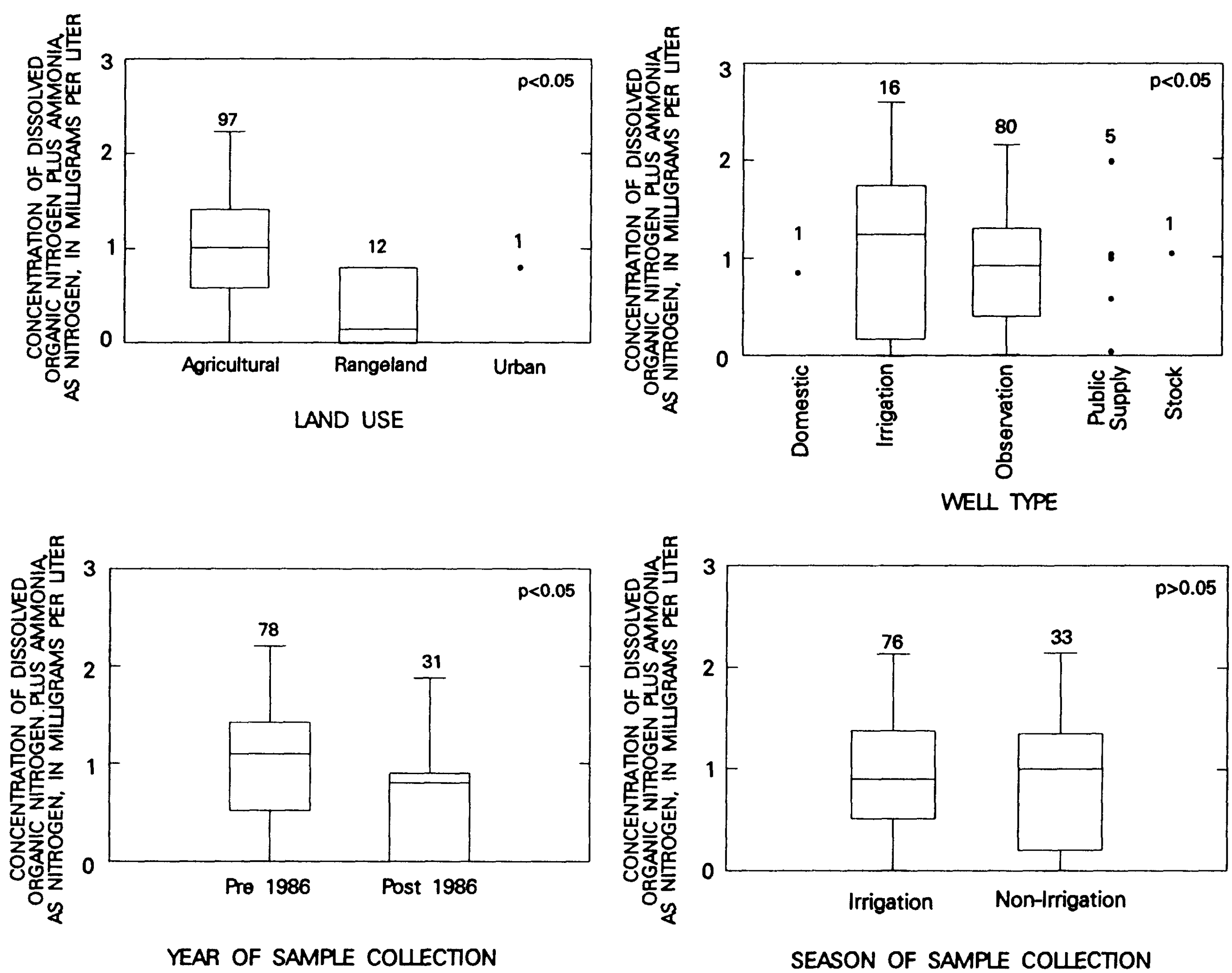

Figure 29. Concentrations of dissolved organic nitrogen plus ammonia, as nitrogen, in ground water from wells completed in the alluvial aquifer, South Platte River Basin, grouped by land use, well type, year of sample collection, and season of sample collection, water years 1980–92.

centrations in shallow wells compared to deep wells, but that was not the case. The median concentration of organic nitrogen plus ammonia in samples from deep wells in the alluvial aquifer was slightly greater than the median concentration in samples from shallow wells (fig. 30). There was no significant difference in the median concentration of dissolved organic nitrogen plus ammonia for samples collected during the irrigation season and the rest of the year. Previous studies have indicated that long-term application of manure to agricultural fields overlying the alluvial aquifer has contributed to elevated dissolved nitrogen concentrations in ground water (Schuff, 1992). Those studies specifically discussed manure as a source of the nitrate in the alluvial aquifer, however, other possible sources for the nitrate could be the mineralization of organic nitrogen and nitrification of ammonia in the manure. It is possible, therefore, that some of the organic nitrogen plus ammonia in ground-water samples from the alluvial aquifer was derived from sources associated with agricultural activities at the land surface. Additional work is needed before these possibilities can be fully evaluated.

The alluvial aquifer was the only aquifer for which there were a sufficient number of ground-water samples analyzed for dissolved phosphorus and orthophosphate to determine whether or not orthophosphate was the predominant form of dissolved phosphorus in ground water. Orthophosphate was not the predominant form of dissolved phosphorus in most ground-water samples from the alluvial aquifer (table 8).

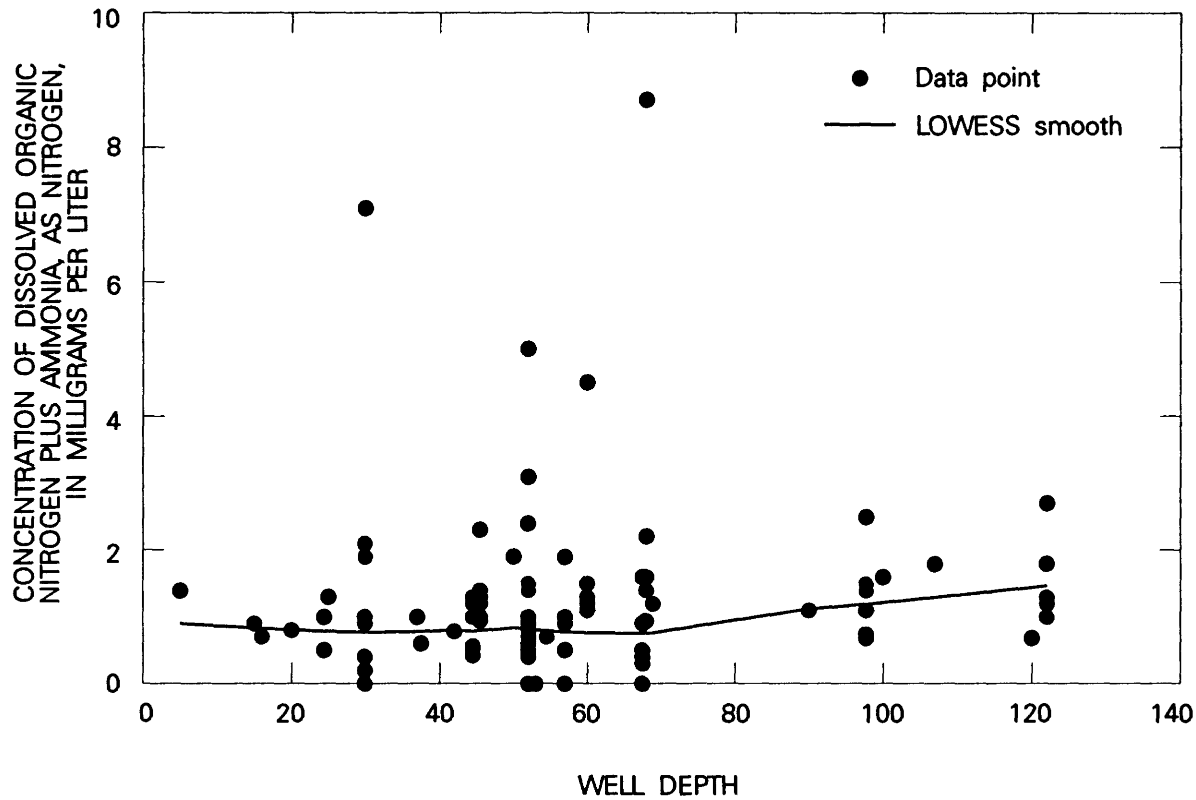

Figure 30. Relation of concentrations of dissolved organic nitrogen plus ammonia, as nitrogen, to well depth for selected wells completed in the alluvial aquifer, South Platte River Basin, water years 1980–92.

The median concentration of dissolved phosphorus in ground-water samples varied significantly between aquifers (fig. 31). The highest median concentrations generally were associated with ground-water samples collected from the alluvial aquifer and observation wells. There were no significant differences in median concentrations of dissolved phosphorus between sampling years or sampling season (fig. 31).

Median concentrations of dissolved phosphorus in ground-water samples collected from the alluvial aquifer were significantly different with respect to land use. Rangeland had a higher median concentration than agricultural land and there was insufficient data for the urban setting from which to draw any conclusions (fig. 32). There was no significant variation in median concentrations of dissolved phosphorus between seasons. Data were insufficient to comment on the relative significance in median concentrations of dissolved phosphorus between well type and year of sample collection. Generally, the observation of several higher concentrations of dissolved phosphorus in ground-water samples from shallow wells, relative to samples from deeper wells, indicate that land-use practices at land surface may have affected dissolved phosphorus concentrations in ground water from the alluvial aquifer (fig. 33). However, this data set does not provide insight into why one land-use setting would be more suspectable to higher concentrations than another. Additional work needs to be done to identify what factors control dissolved phosphorus concentrations in ground water from the alluvial aquifer.

SUSPENDED SEDIMENT

Sediment transport (suspended and bed) and its relation to water quality is an important issue in the South Platte River Basin. The interaction between the water and sediment of the fluvial system controls alluvial-channel hydraulics, bed and bank stability, and stream pattern. The physical properties and volume of sediment transported and deposited by a stream affect the ecology of aquatic and riparian habitats; the ability of a channel to transport flood waters; the operation of impoundment and diversion structures; and the quality of water for municipal, agricultural, industrial, and recreational uses.

Nationally, nutrients and suspended sediment in agricultural areas are the most damaging nonpoint-

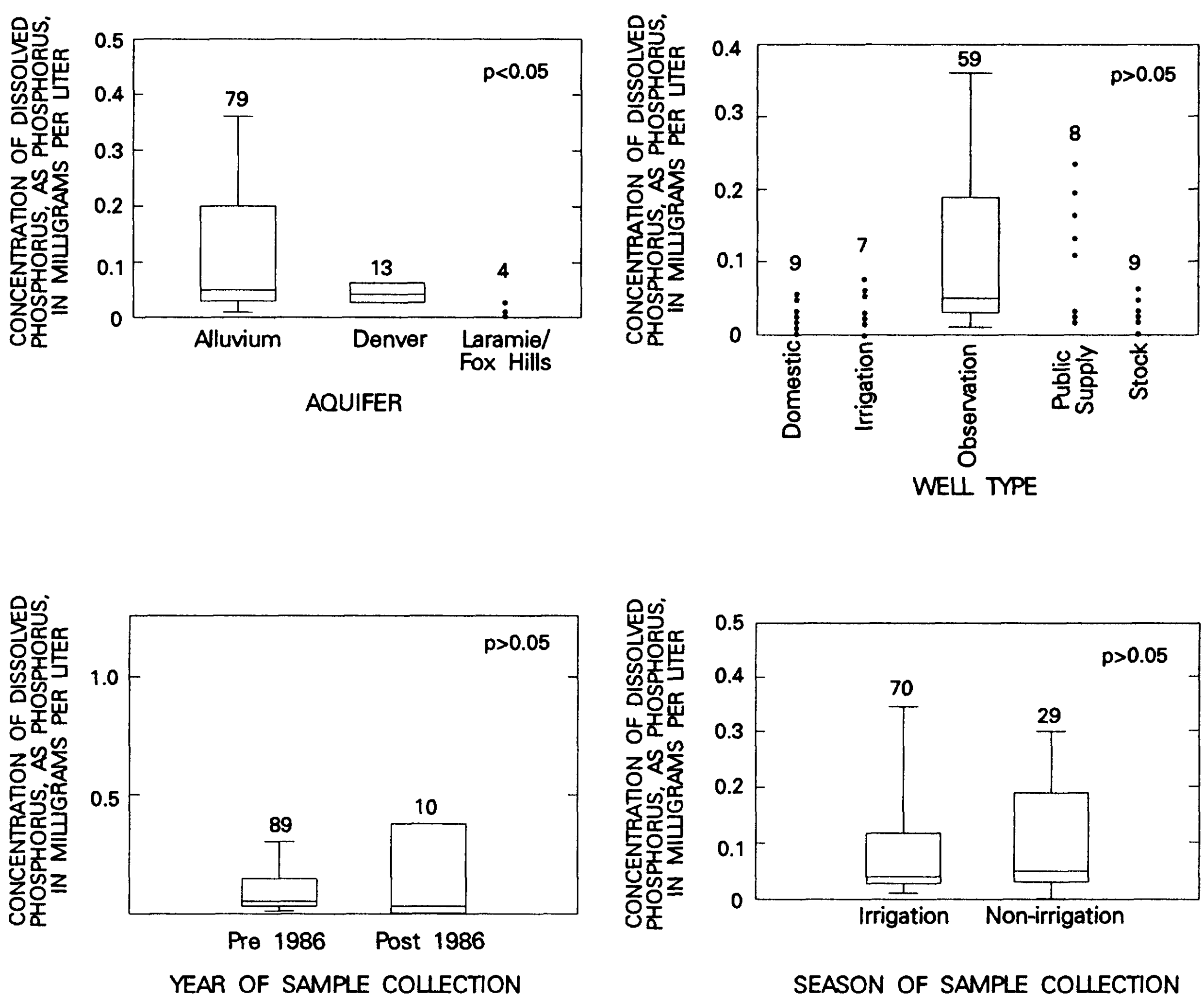

Figure 31. Concentrations of dissolved phosphorus, as phosphorus, in ground water from the South Platte River Basin, grouped by aquifer, well type, year of sample collection, and season of sample collection, water years 1980–92.

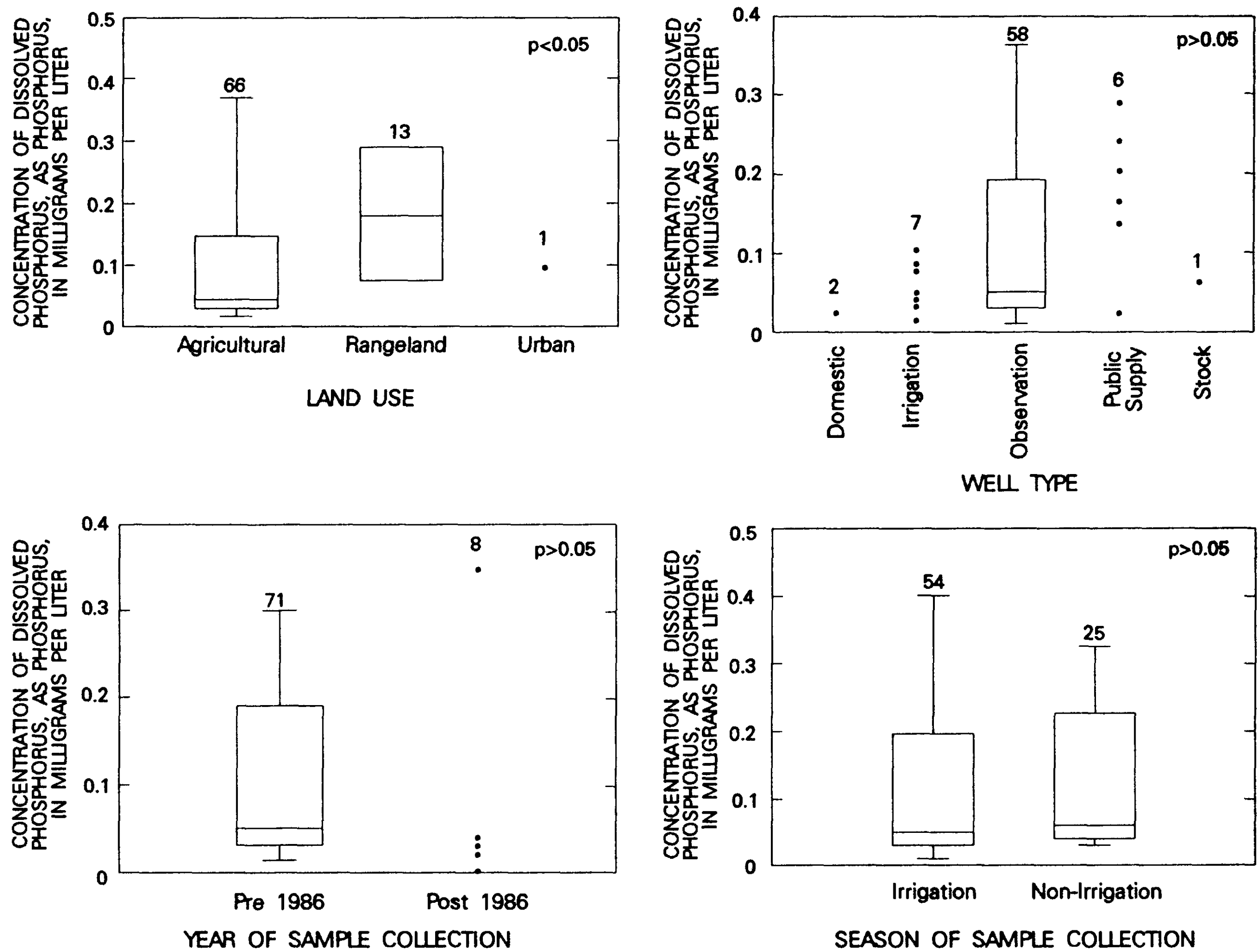

Figure 32. Concentrations of dissolved phosphorus, as phosphorus, in ground water from selected wells completed in the alluvial aquifer, South Platte River Basin, grouped by land use, well type, year of sample collection, and season of sample collection, water years 1980–92.

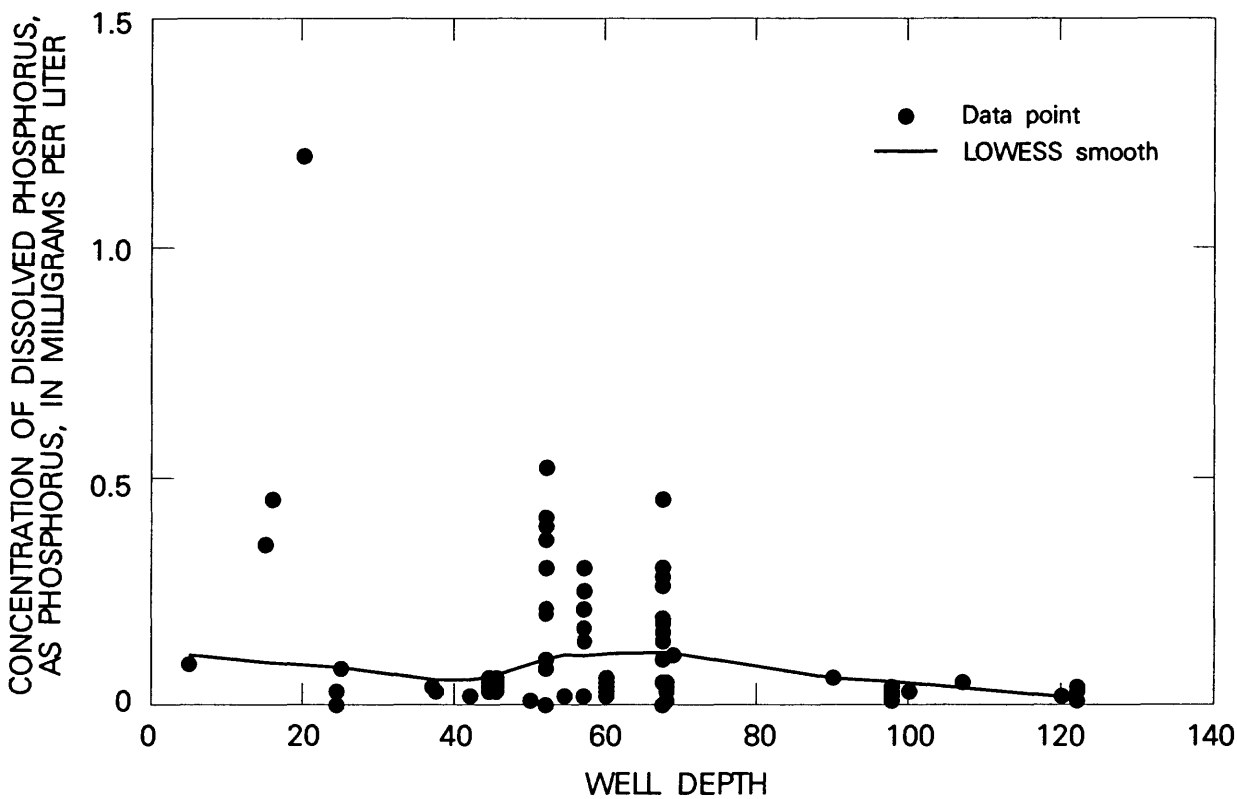

Figure 33. Relation of concentrations of dissolved phosphorus, as phosphorus, to well depth for selected wells completed in the alluvial aquifer, South Platte River Basin, water years 1980–92.

source pollutants (Association of State and Interstate Water Pollution Control Administrators, 1985). Increased sediment concentration increases turbidity in streams, irrigation ditches, and reservoirs. Increased sediment load decreases the storage capacity of reservoirs and adversely affects biota and esthetic values in the stream channel. Sediment particles transport contaminants on their surfaces, facilitating movement of trace elements and organic compounds downstream from their source.

Other human activities such as construction, logging, and mining can increase sediment loading beyond the transport capacity of the stream. This can cause the channel morphology and bed type to change rapidly by decreasing the channel and bed diversity (altering the physical habitat) and can eliminate many species of fish and invertebrates (Shields and others, 1992). Benthic invertebrates live in the bed material of a stream. Their abundance is inversely related to the size of the bed material and directly proportional to the stability of the bed. Fish can migrate from unsuitable conditions and are not as limited by suspended-sediment load or bed-material conditions (Muncy and others, 1979; Fisher and Pearson, 1987).

Most sediment input to the South Platte River could be expected along the agricultural corridor extending from Henderson, Colorado, across the eastern plains to Roscoe, Nebraska, and beyond. This sediment input originates from runoff from fields and from erosion of stream banks. In construction areas along the foothills, and in the urban corridor, sediment input can be expected to vary by amounts and in time.

Description of Data

Surface-water sites in the South Platte River Basin where sediment samples were collected during water years 1980–92 are listed in table 5 (sites with an 'S' in the column 'Type of data'). Additional site and basin characteristics are listed in table 13. In Colorado, four sites are located on the South Platte River, and include Littleton (site 6), the most upstream site, and continuing in a downstream order: Henderson (site 26), to Weldona (site 51) and Julesburg (site 53) on the eastern plains near the Colorado-Nebraska state line. Another site is on the North Fork of the Cache la Poudre River (site 38) in Colorado, a major tributary to the South Platte River.

Table 13. Site and basin characteristics of surface-water sites that have sediment data in the South Platte River Basin, water years 1980–92

[ft, feet; ft/mi, feet per mile; USGS, U.S. Geological Survey]

Site no. (fig. 9)	Site name	Elevation (ft above sea level)	Gradient (ft/mi)	Agency source of data	Number of samples	Sampling frequency
6	South Platte River at Littleton, Colorado	5,304	12.7	USGS	46	every 2 months
26	South Platte River at Henderson, Colorado	5,003	6.71	USGS	25	every 2 months
38	North Fork Cache la Poudre River at Livermore, Colorado	5,715	27.9	USGS	53	monthly
51	South Platte River near Weldona, Colorado	4,307	8.40	USGS	13	irregularly
53	South Platte River at Julesburg, Colorado	3,447	5.17	USGS	64	every 3 months - irregularly

Spatial distribution of sites that have sediment data along the South Platte River is adequate for generalizations about sediment distribution and loads. Additional monitoring is needed for the tributaries to determine their sediment input to the river. The effects of land uses (urban, built-up, agricultural, mixed agricultural and urban, forest, and rangeland) on sediment loads need to be examined to determine their effects on water quality, particularly the role irrigation ditches and storage reservoirs have in defining sediment sources and sinks in the basin.

Temporal distribution of the samples is highly variable. The number of samples per month for each site during the analysis period is shown in figure 34. The sites at Littleton, Colorado (site 6), and Henderson, Colorado (site 26), were sampled every other month since 1980 (table 13), but sampling of the Littleton site was discontinued in 1986. The North Fork Cache la Poudre River site (38) was sampled every month from April 1987 to 1992. The Weldona, Colorado, site (51) was only sampled between April and September for water years 1983–84 and was sampled once again in November 1991 as part of the Narrows Reservoir project (Ruddy, 1984). The site at Julesburg, Colorado (53), was sampled irregularly. The sites on the South Platte River at Henderson, Weldona, and Julesburg, and the site on the North Fork Cache la Poudre River at Livermore presently (1993) are sampled at least monthly.

The number of samples per decile of flow for surface-water sites with sediment data are shown in figure 35. Of the five surface-water sites that are operating continuously and that had sediment data, four had a fairly good distribution of samples across the range of discharge values, but there was some lack of samples in the low- and median-flow ranges. The Julesburg, Colorado, site (53) may be too heavily weighted in high flows. The Weldona, Colorado, site (51) has not been sampled regularly; therefore, the distribution of sediment samples is skewed toward extreme flows (low and high).

The number of samples for each land use in the basin is shown in figure 36; only the agricultural site was fairly well sampled. Gaggiani and others (1987) concluded that not enough suspended-sediment data have been collected to compare to land-use practices. This is still true and needs to be addressed in future sampling programs.

At four of the five surface-water sites where sediment was sampled, particle-size analyses of the suspended sediment was done. Most analyses simply consisted of a sand/silt break, which is a determination of the percentage of the sample that is finer-grained than sand and includes the clay fraction. The sites, land use, number of samples, percent silt and clay, percent sand, and the particle-size fractions are listed in table 14. One site (38, table 14) had no particle-size analyses done on any of the 49 samples collected. Only one site (51, table 14) had detailed particle-size analyses done on all of the samples. The other three sites had particle-size analyses done for only a fraction of the total number of suspended-sediment samples collected:

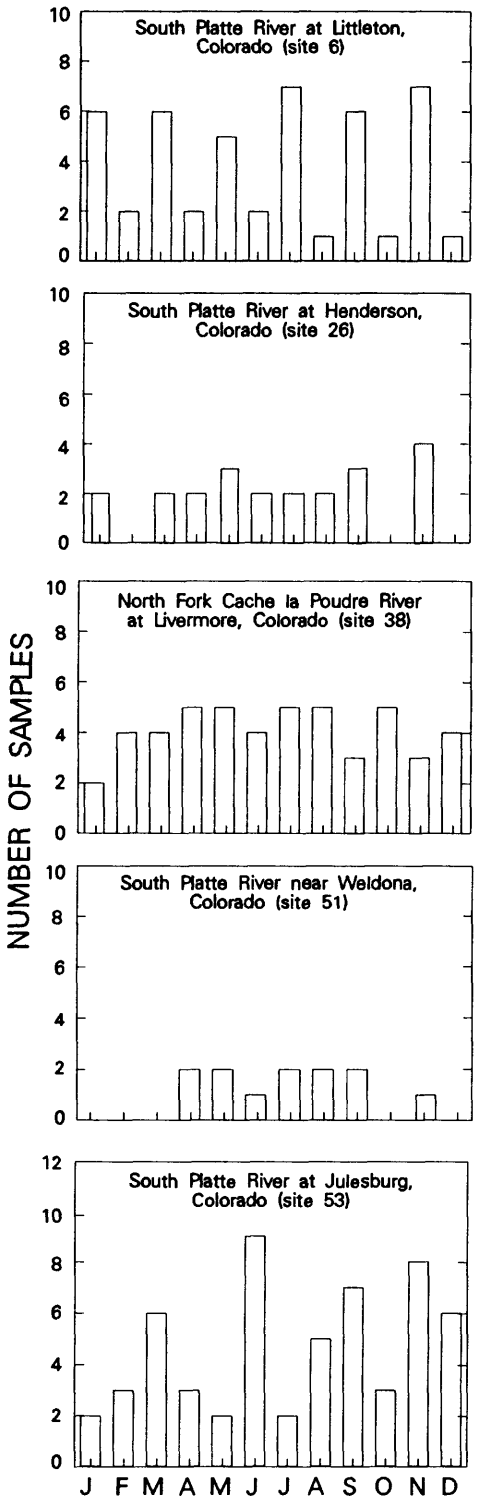

Figure 34. Number of suspended-sediment samples per month for surface-water sites that have sediment data in the South Platte River Basin, water years 1980–92.

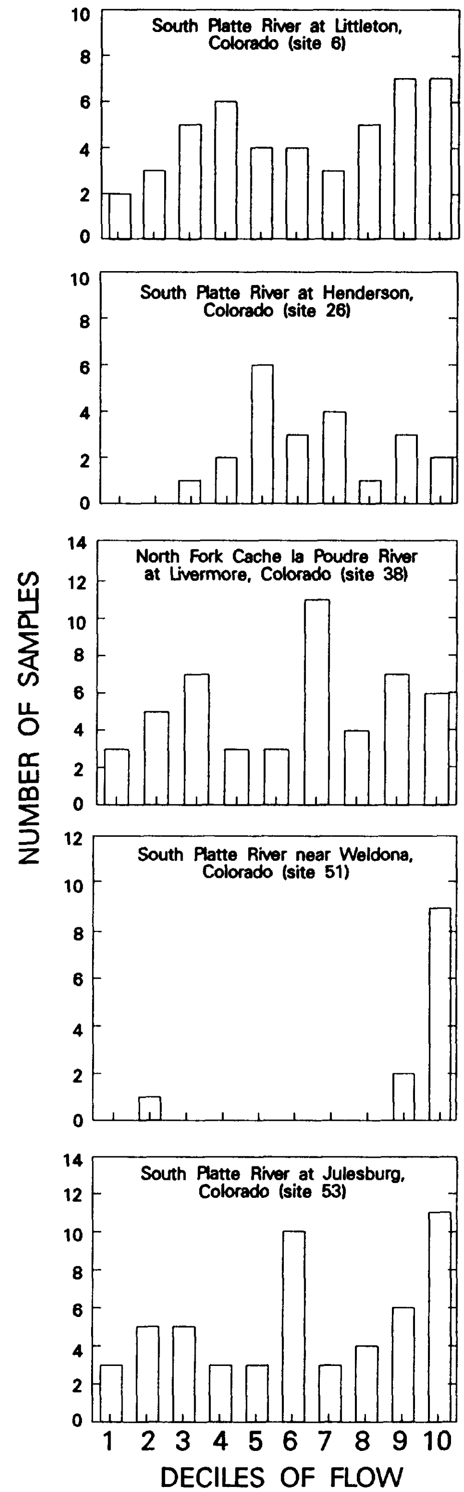

Figure 35. Number of suspended-sediment samples per decile of flow for surface-water sites that have sediment data in the South Platte River Basin, water years 1980–92.

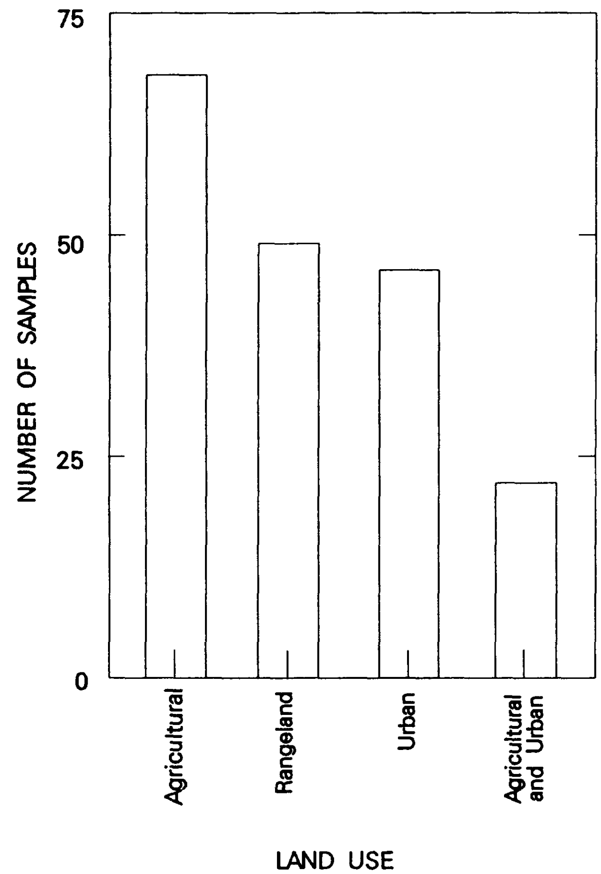

Figure 36. Number of suspended-sediment samples by land use for surface-water sites that have sediment data in the South Platte River Basin, water years 1980–92.

for example, site 6 had 46 suspended-sediment samples, but only 6 particle-size analyses. Therefore to develop a better understanding of the timing and transport of sediment in surface water, particle-size analyses need to be done on samples collected monthly and on an event basis. Specifically, suspended-sediment sample analysis would include the sand-break analysis in addition to sieving and pipetting for selected samples to determine the full range of particle sizes that are being transported in the South Platte River Basin. These types of analyses are necessary to quantify all the sediment being transported and will aid in the analysis of trends and loads for suspended-sediment in the Basin.

Concentrations

Suspended-sediment concentrations in the South Platte River Basin during water years 1980–92 are shown in figure 37 and listed in table 15. There is no standard for suspended-sediment concentration in streams, but fish and invertebrates might be adversely affected by the addition of sediment to the channel (Muncy and others, 1979; Erman and Ligon, 1988). Generally, suspended-sediment concentrations in the South Platte River increase downstream from Littleton, Colorado (site 6), to Julesburg, Colorado (site 53). However, there is a decrease in suspended-sediment concentration from Weldona, Colorado (site 51), to Julesburg, Colorado (site 53), that is probably due to major diversions of water from the South Platte River at several irrigation ditches near Fort Morgan, Colorado. The removal of water and sediment from the river causes a decrease in suspended-sediment concentration and discharge downstream (Ruddy, 1984). An analysis of trends in suspended-sediment concentration would be useful in understanding suspended-sediment distribution in the South Platte River Basin, but there is not yet enough data to allow statistically significant analyses to be done.

In the South Platte River Basin, the different land uses have distinct differences in suspended-sediment concentrations (table 15). The urban land-use site has lower median concentrations than the mixed agricultural and urban and agricultural land-use sites but has a higher median concentration than the rangeland site. The Henderson, Colorado site (26) was classified as mixed agricultural and urban because of land use directly at the gage, as well as the effect of the Denver urban area 12 mi upstream.

Suspended-sediment concentrations measured in irrigation ditches indicated a direct correlation to the suspended-sediment concentrations in the South Platte River near Weldona, Colorado (Ruddy, 1984). Ruddy (1984) also reported that suspended-sediment concentrations decreased downstream in the ditches near Ft. Morgan. This is caused by decreasing flow velocity in the ditch downstream from the headgate, which decreases the power of the water to transport sediment.

Of the few sites in the basin for which particle-size analyses were done, only the urban, mixed agricultural and urban and agricultural land uses were represented (fig. 38). From the existing data, it is apparent that the urban and mixed agricultural and urban sites are similar in particle size, and there is an overall trend of increasing particle size downstream from urban to agricultural land uses. In the agricultural areas, average particle size increases across the plains near Weldona, Colorado (site 51), to Julesburg, Colorado (site 53). Ruddy (1984) reported that the average particle size of sediment in irrigation ditches near Ft. Morgan, Colorado (between the Weldona, Colorado, and Julesburg, Colorado, sites) was 75 percent silt and clay in suspension (finer than sand) as compared to 55 percent finer than sand at the Weldona, Colorado, site (table 30). The sand-sized particles are deposited near the ditch headgates, leaving fine-grained silt and clay in the

Table 14. Number of samples taken in each particle-size fraction and percent sand at surface-water sites that have sediment data in the South Platte River Basin, water years 1980–92

[mm, millimeters; --, no data]

Site no. (fig. 9)	Site name	Land use	Number of samples	Mean percent less than 0.063 mm (silt and clay)	Mean percent greater than 0.063 mm (sand)
6	South Platte River at Littleton, Colorado	urban	46	72	28
26	South Platte River at Henderson, Colorado	agricultural/ urban	22	73	27
38	North Fork Cache la Poudre River at Livermore, Colorado	rangeland	49	--	--
51	South Platte River near Weldona, Colorado	agricultural	12	55	45
53	South Platte River at Julesburg, Colorado	agricultural	56	47	53

Site no. (fig. 9)	Site name	Number of samples by particle-size fraction						
		clay, <0.008 mm	medium silt, 0.008 - 0.031 mm	coarse silt, 0.031- 0.063 mm	very fine sand, 0.063 - 0.125 mm	fine sand 0.125 - 0.250 mm	medium sand, 0.250 - 0.500 mm	coarse sand, 0.500 - 1.00 mm
6	South Platte River at Littleton, Colorado	--	--	6	--	--	--	--
26	South Platte River at Henderson, Colorado	--	--	4	--	--	--	--
38	North Fork Cache la Poudre River at Livermore, Colorado	--	--	--	--	--	--	--
51	South Platte River near Weldona, Colorado	--	--	12	5	5	5	5
53	South Platte River at Julesburg, Colorado	1	1	19	1	1	1	1

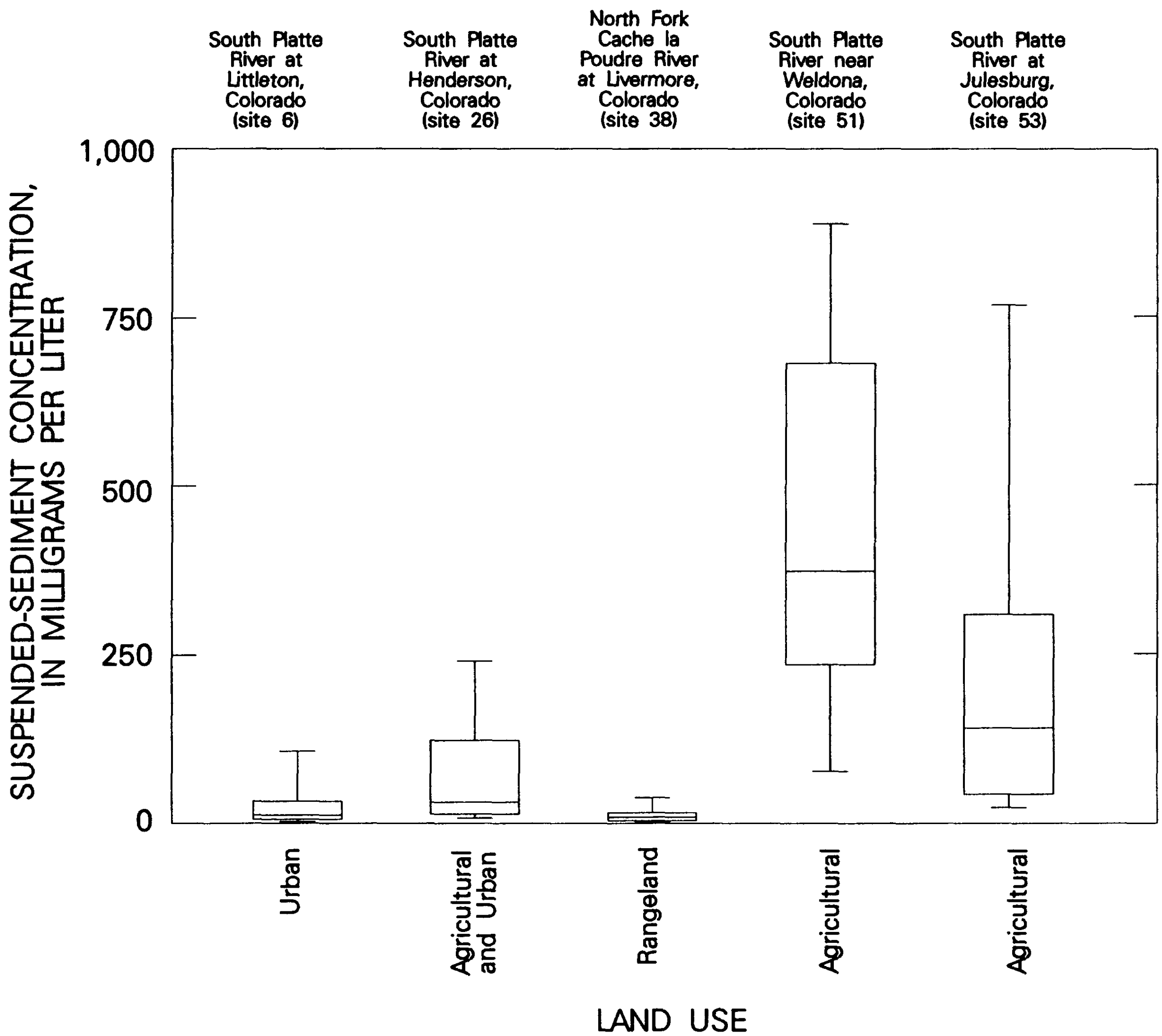

Figure 37. Suspended-sediment concentrations for surface-water sites that have sediment data in the South Platte River Basin, water years 1980–92.

Table 15. Summary statistics of suspended-sediment concentrations, by land use, in the South Platte River Basin, water years 1980–92

[--, no data]

Site no. (fig. 9)	Site name	Land use	Suspended-sediment concentration, in milligrams per liter at indicated percentile				
			10	25	50 (median)	75	90
6	South Platte River at Littleton, Colorado	urban	4	8	14	34	108
26	South Platte River at Henderson, Colorado	agricultural/ urban	9	16	33	124	241
38	North Fork Cache la Poudre River at Livermore, Colorado	rangeland	4	6	11	18	40
51	South Platte River near Weldona, Colorado	agricultural	110	236	373	683	900
53	South Platte River at Julesburg, Colorado	agricultural	24	45	143	310	769

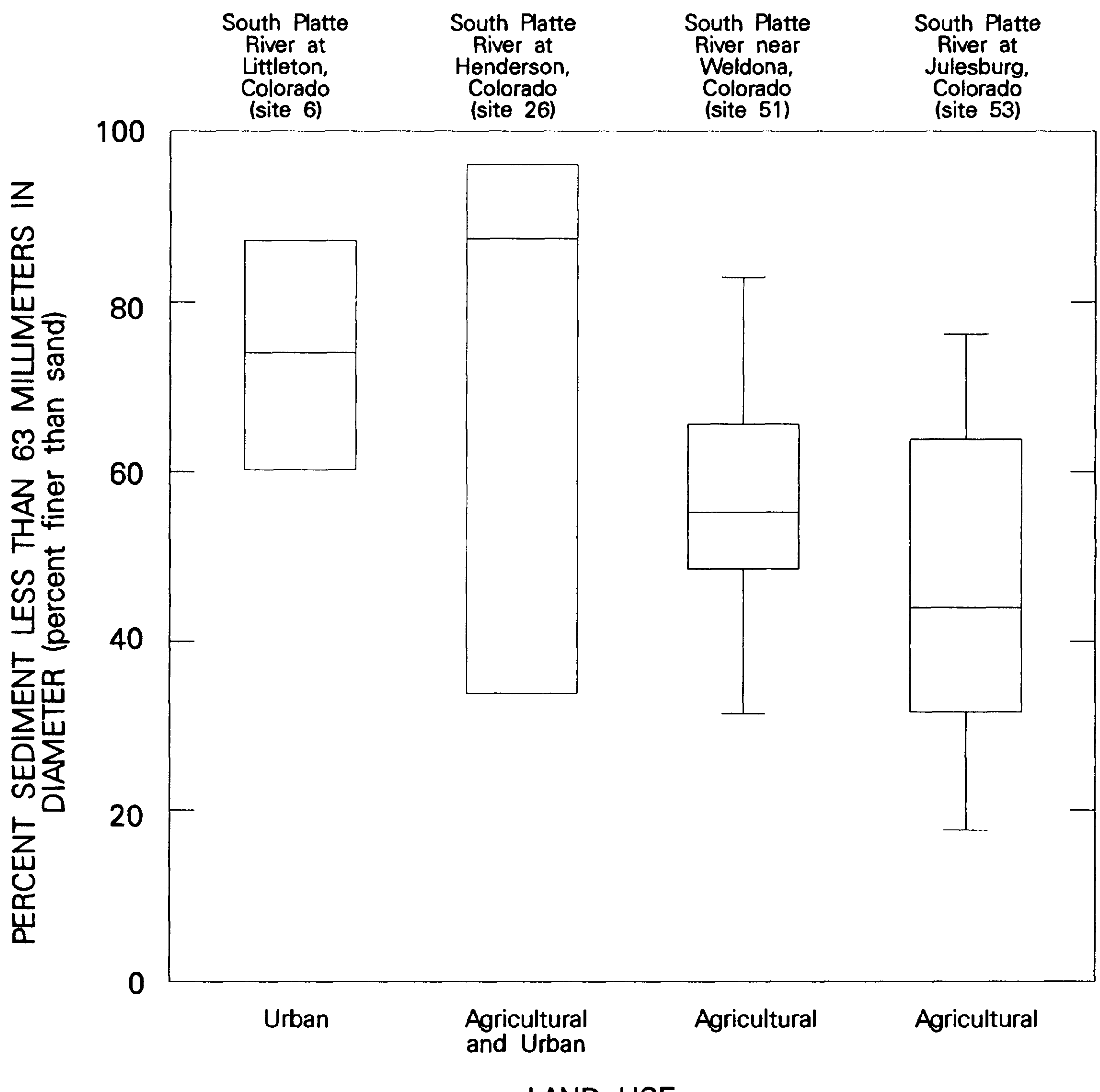

Figure 38. Particle size (percent finer than sand) for suspended-sediment samples for surface-water sites that have sediment data in the South Platte River Basin, water years 1980–92.

ditch. In the South Platte River, the fine-grained sediment is constantly removed through irrigation, leaving larger, sand-sized particles in the channel.

Suspended-sediment concentrations also vary by month in the basin (fig. 39). In the spring, during snowmelt runoff (March to June), more sediment particles are transported in the water column than in the fall. This effect is less pronounced at downstream sites, particularly from Henderson, Colorado (site 26), to Julesburg, Colorado (site 53), where agricultural-return flows and diversions affect or control much of the streamflow and sediment transport.

Changes in suspended-sediment concentration with changes in streamflow are shown in figure 40 for those surface-water sites with sediment data. At the urban (South Platte River at Littleton, Colorado, site 6) and rangeland (North Fork Cache la Poudre River at Livermore, Colorado, site 38) sites, suspended-sediment concentration changes very little with increasing streamflow. At the agricultural site (South Platte River at Julesburg, Colorado, site 53), suspended-sediment concentration changes rapidly with increasing streamflow. This implies there is more sediment available for mobilization in the agricultural environment.

Loads

Ideally, suspended-sediment-load computations can describe sediment movement through a basin. Because of limited data in the South Platte River Basin, only broad generalizations can be made for loads. Trends in suspended-sediment could not be estimated from this data. More detailed sediment data needs to be collected in the basin for better load calculations that include monthly sampling of suspended sediment during all types of flow (including storm events) at many sites in the basin.

The distribution of suspended-sediment load for all sites in the basin that have sediment data are shown in figure 41. Small amounts of sediment move in the South Platte River through the urban area to Henderson, Colorado (site 26). From Henderson, Colorado, to Weldona, Colorado (site 51), there is a dramatic increase in sediment load. Three major tributaries enter the South Platte River along this reach (St. Vrain River, Big Thompson River, and Cache la Poudre River, fig. 1), and the land use along the South Platte River changes from urban to mixed and finally to agricultural land use. There is a decrease in sediment load before Julesburg, Colorado (site 53), which is attributed to the removal of water for irrigation (Ruddy, 1984). Also, ground-water return flows dilute the suspended-sediment concentration and increase the streamflow velocity. The relations between suspended-sediment load and instantaneous streamflow at two sites on the South Platte River and one tributary site are shown in figure 42. There was an expected increase in suspended-sediment load as streamflow and suspended-sediment concentration increased, however, the rate of increase was much greater at the agricultural site than at the urban or rangeland sites.

PESTICIDES

The occurrence of pesticides in surface water and ground water depends largely on the quantities of pesticides applied, the persistence and solubility of the compound, and the geology and hydrology of the specific site of interest. Predicting the occurrence of a given pesticide in water on a basin-wide scale, therefore, requires a variety of sources of information that frequently are not available. One approach to predicting the occurrence of pesticides in water on a basin-wide scale is to compare pesticide occurrences between groups of sampling sites having different land use, hydrologic settings, or other features that are measurable on a basin-wide scale. This approach has been applied in the following section to determine which site characteristics are most frequently associated with the occurrence of pesticides in surface water and ground water.

Description of Surface-Water Data

Pesticide data were available for 564 samples collected at 29 surface-water sites in the study area for water years 1980–92 (table 16). The maximum number of samples at a given surface-water site was 48, at Crow Creek near Cheyenne, Wyoming (site 48). Fourteen surface-water sites had 10 or more samples; however, these surface-water sites were not evenly distributed areally or according to land use. For example, all of the surface-water sites with 10 or more samples were located either along Crow Creek in Wyoming; along the Cache la Poudre River in the vicinity of Ft. Collins; or in the vicinity of Denver. These same surface-water sites are distributed with respect to land use in the basin as follows: seven in built-up areas; three in urban areas; two in forest areas; one each in rangeland and mixed agricultural and urban areas; and, none in agricultural areas (table 16).

The availability of pesticide data by compound class is listed in table 17. Data are most common for pesticides in the organochlorine group (35 percent of available samples). Data for chlorophenoxy acids and organophosphorus compounds were next most abundant. Triazine data were available for only 12 percent of the samples, and less than 1 percent had carbamate

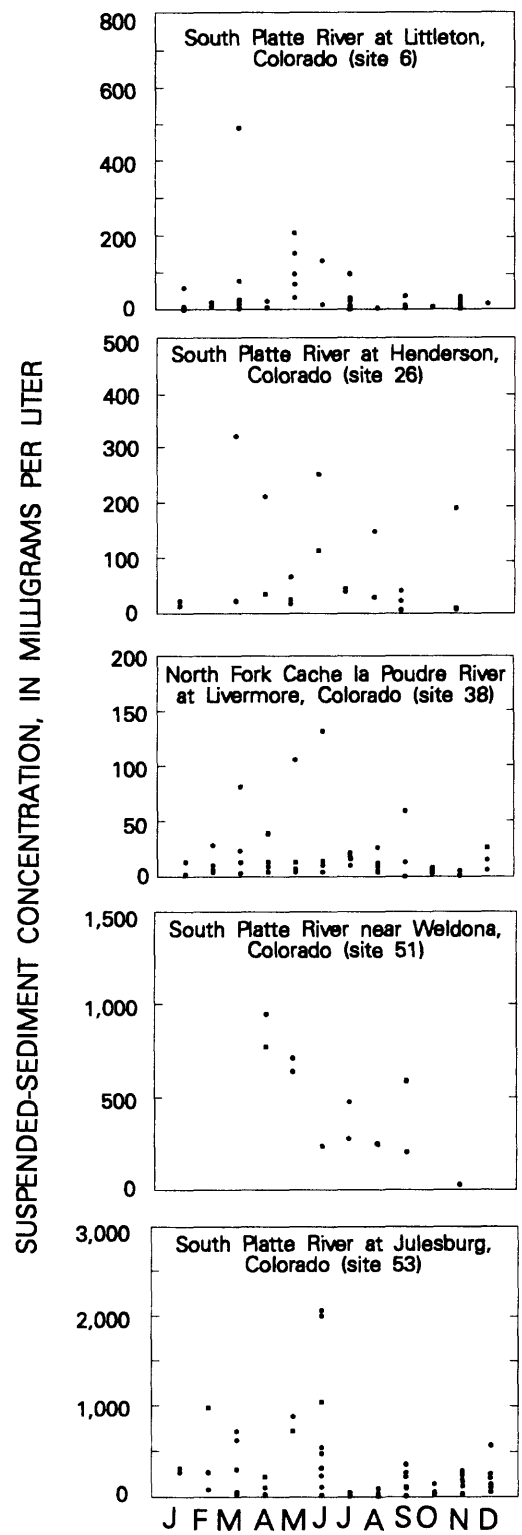

Figure 39. Monthly suspended-sediment concentrations for surface-water sites that have sediment data in the South Platte River Basin, water years 1980–92.

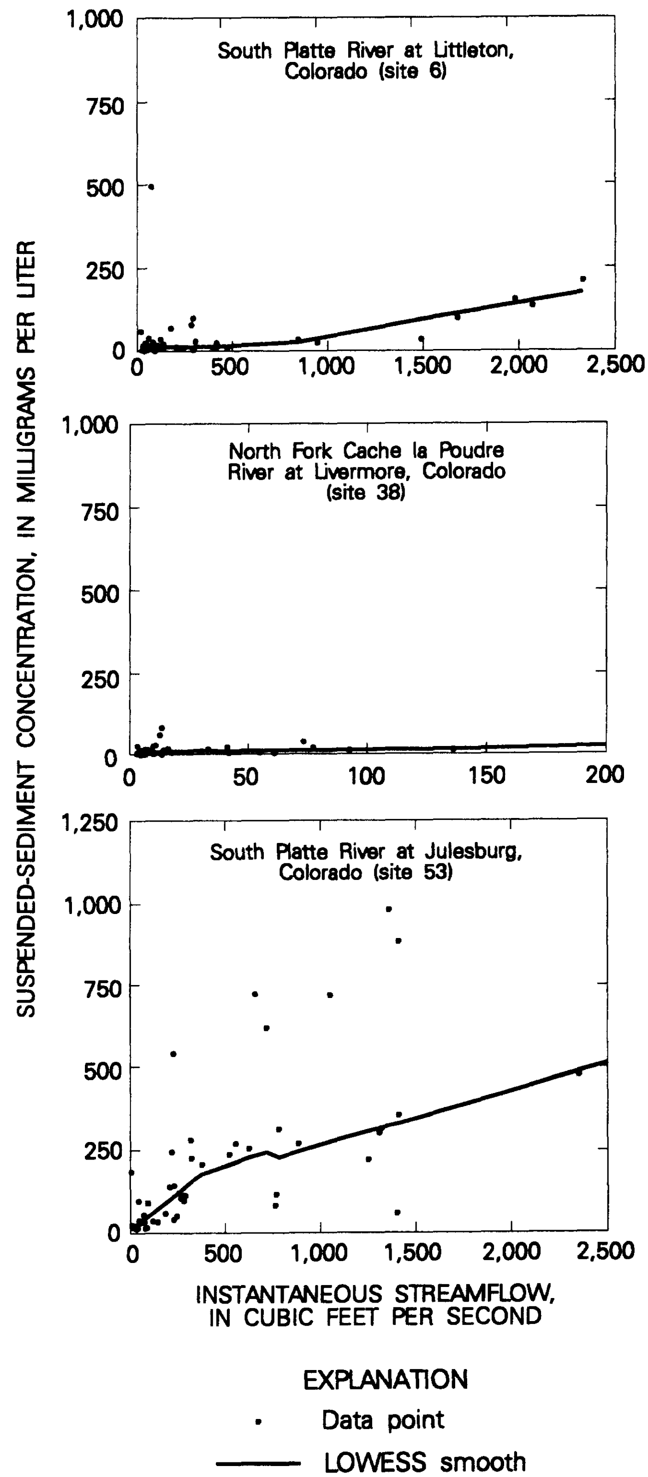

Figure 40. Relations of suspended-sediment concentrations to instantaneous streamflow for surface-water sites that have sediment data in the South Platte River Basin, water years 1980–92. [Lines on graphs are LOWESS smooth lines].

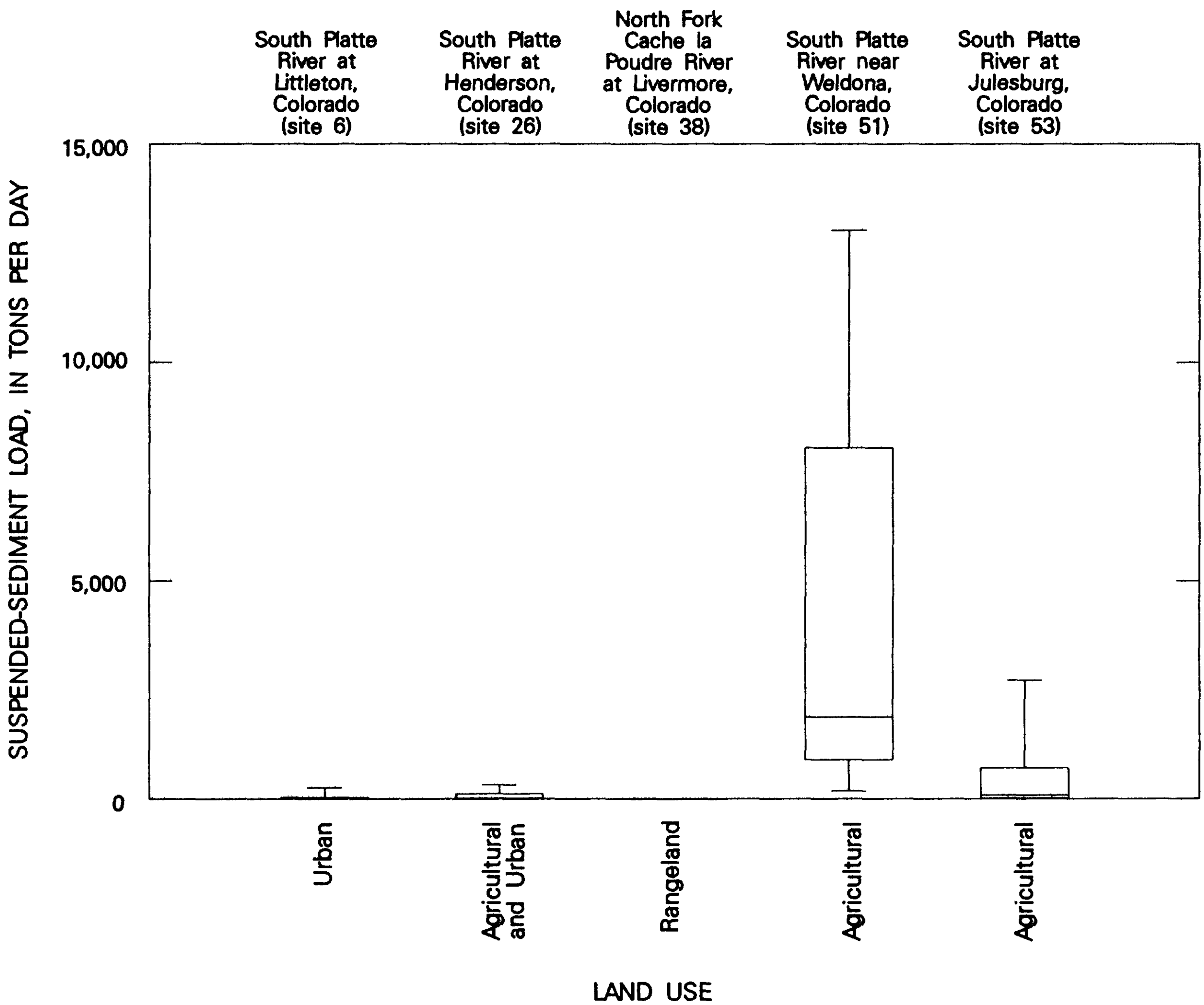

Figure 41. Suspended-sediment load for surface-water sites that have sediment data in the South Platte River Basin, water years 1980–92.

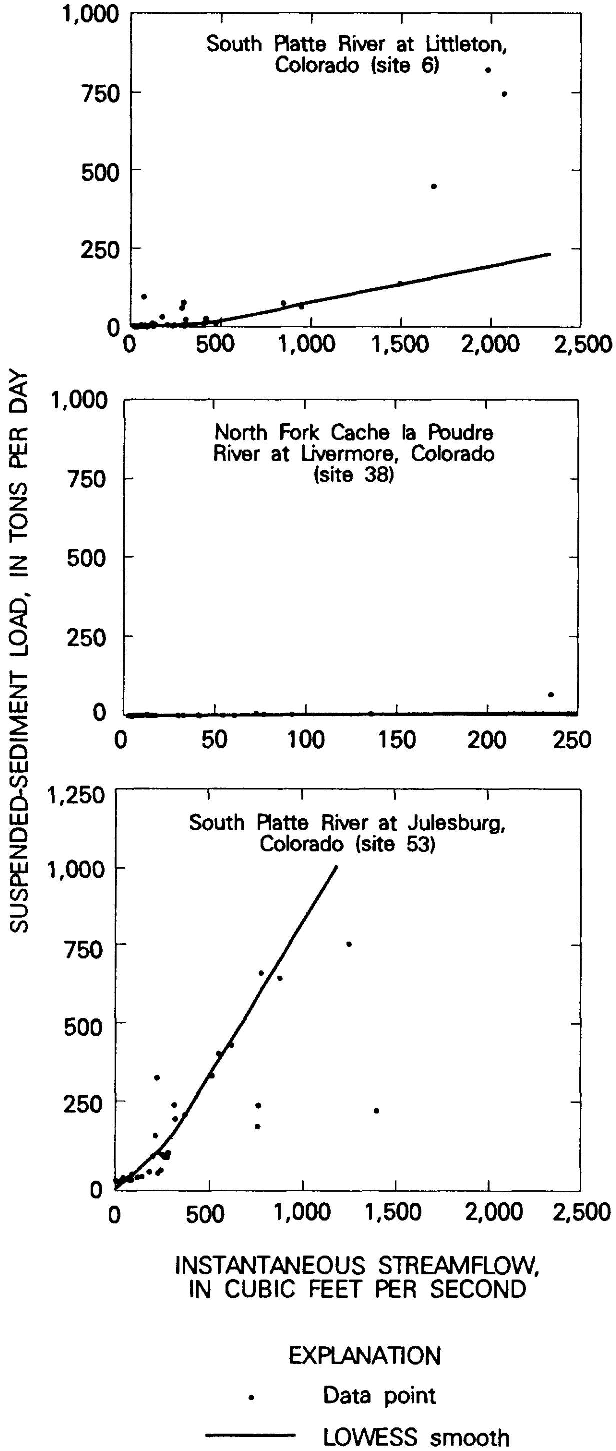

Figure 42. Relations of suspended-sediment load to instantaneous streamflow for surface-water sites that have sediment data in the South Platte River Basin, water years 1980–92. [Lines on graphs are LOWESS smooth lines].

data. The chlorophenoxy acid group had the best distribution between the six land uses (table 17). Sixty-six percent of the organochlorine samples were from surface-water sites located in built-up land use, whereas there were no samples from surface-water sites in rangeland use. Sixty-one percent of the chlorophenoxy acid samples were from surface-water sites located in urban land use, 79 percent of the triazine samples were from surface-water sites located in built-up land use, and 100 percent of the carbamate samples were from surface-water sites located in agricultural and mixed agricultural and urban land use.

The number of analyses in the NWIS and STORET databases for the most commonly applied pesticides in the basin are listed in table 18 (herbicides and insecticides are ranked by order of decreasing application). Seven of the ten most commonly applied herbicides were analyzed five or more times in surface-water samples. Only two of the ten most commonly applied insecticides used in the South Platte River Basin were analyzed more than five times in surface-water samples.

The distribution of pesticide samples by month for all surface-water sites with five or more samples is listed in table 19. None of the surface-water sites had samples from all 12 months, and, generally, most of the surface-water sites had data only for April through October. Only three surface-water sites had sufficient long-term flow records to determine the number of samples by decile of streamflow (table 20). None of the surface-water sites in this group had samples in all deciles of flow.

Description of Ground-Water Data

Pesticide data were available from 20 wells in the South Platte River Basin for water years 1980–92 (table 6). None of the wells had more than one available sample. The areal distribution of wells in the basin was poor—all of the wells were located in Arapahoe and Weld Counties in Colorado or in Laramie County, Wyoming. The distribution of wells by aquifer and well type are listed in table 21. Ninety-five percent of the wells were observation and irrigation wells. Sixty percent of the wells were screened in the alluvial aquifer adjacent to the South Platte River or its tributaries, and 40 percent were screened in the High Plains aquifer. Ninety-two percent of wells completed in the alluvium were in agricultural land use areas, leaving only one well in a rangeland setting. In general, most of the wells can be classified as observation wells that were screened in the alluvial aquifer underlying agricultural land use.

Table 16. Stream locations where pesticide samples were collected in the South Platte River Basin, water years 1980–92

[no., number; --, no data; X, sample analyzed for compound class; n/a, not applicable]

Site no. (fig. 9)	Site name	Maximum number of samples for given compound class	Period of record	Frequency (no. per year)	Land use	Pesticide compound class				
						Carba-mates	Chloro-phenoxy acids	Organo-chlo-rines	Organo-phos phorus	Triazines and other nitrogen-containing compounds
3	South Platte River above Chatfield Reservoir, Colorado	19	1982–90	2	forest	--	--	X	X	X
4	Plum Creek above Chatfield Reservoir, Colorado	19	1982–90	2	built-up	--	--	X	X	X
5	Chatfield Reservoir release, Colorado	18	1982–90	2	built-up	--	--	X	X	X
9	Bear Creek above Harriman Ditch confluence, Colorado	18	1982–90	2	built-up	--	--	X	X	X
13	Turkey Creek above Bear Creek confluence, Colorado	19	1982–90	2	built-up	--	--	X	X	X
14	Bear Creek at Bear Creek Reservoir release, Colorado	17	1982–90	2	built-up	--	--	X	X	X
16	Cherry Creek Reservoir inflow, Colorado	20	1982–90	3	built-up	--	--	X	X	X
17	Cherry Creek Reservoir release, Colorado	7	1984–90	1	built-up	--	--	X	X	X
21	South Platte River at Metro Wastewater Plant, Denver, Colorado	1	1980	n/a	urban	--	--	X	--	--
23	Clear Creek near York Street, Denver, Colorado	1	1980	n/a	urban	--	--	X	--	--
24	South Platte River near 78th Avenue, Denver, Colorado	1	1980	n/a	urban	--	--	X	--	--
26	South Platte River at Henderson, Colorado	1	1991	n/a	agricultural and urban	X	X	--	X	X
27	St. Vrain Creek at Lyons, Colorado	1	1980	n/a	built-up	--	X	X	X	--
28	Left Hand Creek near Boulder, Colorado	1	1980	n/a	forest	--	X	X	X	--
29	St. Vrain Creek below Longmont, Colorado	1	1980	n/a	agricultural and urban	--	X	X	X	--
37	Cache la Poudre River near Fort Collins, Colorado	10	1980–84	2	forest	--	X	X	X	--
40	Cache la Poudre River at Shields Street, Fort Collins, Colorado	10	1980–84	2	built-up	--	X	X	X	--

Table 16. Stream locations where pesticide samples were collected in the South Platte River Basin, water years 1980–92--Continued

Site no. (fig. 9)	Site name	Maximum number of samples for given compound class	Period of record	Frequency (no. per year)	Land use	Pesticide compound class				
						Carba-mates	Chloro-phenoxy acids	Organo-chlo-rines	Organo-phos phorus	Triazines and other nitrogen-containing compounds
41	Cache la Poudre River at Fort Collins, Colorado	7	1980–82	2	urban	--	X	X	X	--
42	Cache la Poudre River below Fort Collins, Colorado	10	1980–84	2	urban	--	X	X	X	--
43	Cache la Poudre River above Box Elder Creek, near Timnath, Colorado	11	1980–84	2	agricultural and urban	--	X	X	X	--
45	South Platte River at Kersey, Colorado	1	1991	n/a	agricultural and urban	X	X	--	X	X
46	Crow Creek at Roundtop Road, near Cheyenne, Wyoming	24	1986–91	4	rangeland	--	X	--	--	--
47	Crow Creek at Warren Air Force Base, Wyoming	47	1983–91	5	urban	--	X	--	--	--
48	Crow Creek near Cheyenne, Wyoming	48	1983–91	5	urban	--	X	--	--	--
49	Crow Creek near Archer, Wyoming	1	1991	n/a	agricultural and urban	--	X	--	--	--
50	Crow Creek near Carpenter, Wyoming	4	1990–91	2	agricultural	--	X	--	--	--
51	South Platte River near Weldona, Colorado	2	1989–91	1	agricultural	X	X	--	X	X
53	South Platte River at Julesburg, Colorado	6	1980–91	less than 1	agricultural	X	X	X	X	X
54	South Platte River at Roscoe, Nebraska	1	1982	n/a	agricultural	--	--	--	--	X

Table 17. Number of pesticide samples collected from surface-water sites, by land use and compound class, in the South Platte River Basin, water years 1980–92

Land use	Carbamates		Chlorophenoxy acids		Organochlorines		Organophosphorus		Triazines and other nitrogen-containing compounds	
	Number of samples	Percent	Number of samples	Percent	Number of samples	Percent	Number of samples	Percent	Number of samples	Percent
agricultural	2	50	9	5	5	3	6	5	4	6
agricultural and urban	2	50	16	9	12	6	14	12	2	3
forest	0	0	11	6	30	15	19	16	8	12
rangeland	0	0	24	13	0	0	0	0	0	0
urban	0	0	110	61	20	10	17	14	0	0
built-up	0	0	11	6	128	66	62	53	52	79
TOTAL	4	100	181	100	195	100	118	100	66	100

Table 18. Number of analyses available in the National Water Information System (NWIS) and Storage and Retrieval (STORET) data bases for the most commonly applied pesticides in the South Platte River Basin, water years 1980–92

Compound	NWIS analyses		STORET analyses	
	Surface water	Ground water	Surface water	Ground water
		Herbicide		
2,4-D	173	15	0	0
EPTC	0	0	0	0
Atrazine	6	9	59	0
Alachlor	5	9	59	0
Butylate	0	0	0	0
Dicamba	125	13	0	0
Cyanazine	6	9	0	0
Metolachlor	5	9	59	0
Picloram	123	13	0	0
Cycloate	4	9	0	0
		Insecticide		
Terbufos	0	0	0	0
Chlorpyrifos	4	9	0	0
Propargite	0	0	0	0
Disulfoton	4	9	0	0
Carbofuran	4	9	0	0
Carbaryl	4	9	0	0
Parathion-ethyl	56	11	0	0
Phorate	4	9	0	0
Dimethoate	0	0	0	0
Diazinon	59	11	59	0

Table 19. Distribution of pesticide samples, by month, at selected surface-water sites in the South Platte River Basin, water years 1980–92

Site number (fig. 9)	Number of samples	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
3	19	0	0	0	1	5	1	5	2	2	3	0	0
4	19	0	0	0	1	5	1	4	2	3	3	0	0
5	18	0	0	0	1	5	1	5	1	2	3	0	0
9	18	0	0	0	1	5	1	5	2	2	2	0	0
13	19	0	0	0	1	5	1	5	2	2	3	0	0
14	17	0	0	0	0	5	1	5	2	1	3	0	0
16	20	0	0	0	1	5	1	5	2	3	3	0	0
17	7	0	1	1	0	2	1	0	0	0	2	0	0
37	10	0	0	0	1	4	0	3	0	2	0	0	0
40	10	1	0	0	0	4	0	3	0	2	0	0	0
41	7	1	0	0	1	2	0	1	0	2	0	0	0
42	10	1	0	0	0	3	1	3	0	2	0	0	0
43	11	1	0	0	1	3	1	3	0	2	0	0	0
46	24	0	0	0	0	4	6	6	6	2	0	0	0
47	47	0	0	0	0	8	10	9	9	9	2	0	0
48	48	0	0	0	0	7	10	9	9	9	2	0	0
53	6	0	1	1	1	0	0	0	1	0	0	2	0

Table 20. Number of pesticide samples, by decile of flow, at selected surface-water sites in the South Platte River Basin, water years 1980–92

Site number (fig. 9)	Site name	Number of samples at indicated decile of flow									
		1	2	3	4	5	6	7	8	9	10
41	Cache la Poudre River at Fort Collins, Colorado	0	0	0	1	1	2	1	0	1	1
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	0	0	0	2	3	0	0	1	1	4
48	Crow Creek near Cheyenne, Wyoming	30	3	0	3	0	0	0	1	3	8

Table 21. Number of wells that have pesticide data, by aquifer and well type, in the South Platte River Basin, water years 1980–92

Characteristic	Number of wells	Percent of total
	Aquifer	
Alluvial	12	60
High Plains	8	40
TOTAL	20	100
	Well type	
Observation	14	70
Irrigation	5	25
Public supply	1	5
TOTAL	20	100

The number of available pesticide samples from wells by compound class and land-use area in the alluvial aquifer is listed in table 22. The nine pesticide samples listed in four of the five compound classes were collected in September 1991 as part of a USGS cooperative study in Weld County, Colorado. Samples were not collected for organochlorine pesticides as part of this study; however, three organochlorine samples were analyzed in the basin and were used in our analysis. One-hundred percent of the pesticide samples in four of the five compound classes were from wells underlying agricultural land use, whereas for the organochlorine analyses sixty-seven percent (two wells) were from wells underlying agricultural areas and thirty-three percent (one well) were from wells underlying rangeland areas.

The availability of pesticide analyses from wells for the most commonly applied pesticides in the South Platte River Basin is listed in table 18. Fifteen of the 20 compounds were analyzed at least 9 times. There were no available samples for the remaining five compounds, which include the second-ranked herbicide (EPTC) and the first-ranked insecticide (terbufos).

All of the available pesticide data for ground water in the basin were from the NWIS database. No data were available from the STORET data base or other data bases obtained for this report. There are a number of ongoing studies of pesticide concentrations in ground water in the basin but by the end of 1993, these data were not available for publication. These studies include a sampling program conducted by the Colorado Departments of Health and Agriculture and Colorado State University. As part of that study, about 100 shallow domestic wells in the South Platte River alluvial aquifer were sampled in the summer of 1992. Water samples were analyzed for many pesticides, including carbamates, triazines, and chlorophenoxy acid herbicides (Bradford Austin, Colorado Department of Health, oral commun., 1993). Another study was conducted by the North Front Range Water Quality Planning Association (NFRWQPA), in cooperation with the Colorado Department of Health, the Weld County Department of Health and the Central Colorado Water Conservancy District. In that study, 19 shallow observation wells screened in the South Platte River alluvial aquifer in Weld County, Colorado, were sampled in 1992. Water samples were analyzed for a wide variety of pesticides (David DuBois, NFRWQPA, oral commun., 1993). A study of pesticides in ground water also is being conducted by the Central Colorado Water Conservancy District (CCWCD). This study is a continuation of the USGS cooperative study mentioned earlier, and those samples are included in this report. However since 1991, the CCWCD has continued the collection of pesticide samples from the South Platte River alluvial aquifer in Weld County, Colorado, which are not represented in this report (Forrest Leaf, CCWCD, oral commun., 1993). A large-scale study of pesticides in ground water has been completed for

Table 22. Pesticide samples from wells, by land use and compound class, in the South Platte alluvial aquifer, water years 1980–92

Land use	Carbamates		Chlorophenoxy acid herbicides		Organochlorine		Organophosphorus		Triazines and other nitrogen-containing compounds	
	Number of samples	Percent	Number of samples	Percent	Number of samples	Percent	Number of samples	Percent	Number of samples	Percent
Agriculture	9	100	9	100	2	67	9	100	9	100
Rangeland	0	0	0	0	1	33	0	0	0	0
TOTAL	9	100	9	100	3	100	9	100	9	100

Nebraska (Exner and Spalding, 1990), a part of which includes the South Platte River Basin in Nebraska. Although the Exner and Spalding data were not tabulated in their report, locations of wells that had detectable levels of pesticides were shown on maps (Exner and Spalding, 1990). Only two of the wells in the South Platte River drainage had detectable pesticide concentrations–atrazine was detected in both wells located in the alluvium of Lodgepole Creek. Most of the wells sampled in the studies listed in this paragraph were screened in the South Platte River alluvial aquifer and were in agricultural land use.

Currently, pesticide analyses for ground water in the South Platte River Basin are very limited by areal distribution of wells, number of analyses per well, number of analyses per land use, and number of analyses per aquifer. When the ongoing studies referenced in the preceding paragraph are completed there will be many more available pesticide analyses for ground water from agricultural land uses in the South Platte River alluvial aquifer. However, there will still be a lack of analyses for other aquifers and land uses.

Concentrations in Surface Water

A limited number of pesticide analyses were available for comparison of surface-water pesticide concentrations by site characteristics. For most pesticides, concentrations were less than laboratory detection levels; therefore, most of the results are presented in terms of percentage of detections (the number of analyses with detectable concentrations, divided by the total number of analyses, and multiplied by 100). The percentage of detections and median concentrations for selected pesticides in surface water, by land use, are listed in table 23. The pesticides chosen for comparison between land uses were either one of the most commonly applied in the basin (table 18), or those having a relatively large number of analyses available for that pesticide. For a given land use in table 23, the percentage of detections for any compound could include data from surface-water sites in the NWIS and the STORET databases.

For the land-use types listed in table 23, the mixed agricultural and urban land use had the greatest number of compounds with detectable concentrations (six), followed by urban, built-up and agricultural (five

Table 23. Percentage of detections and median concentrations for selected pesticides in surface water, by land use, in the South Platte River Basin, water years 1980–92

[Median concentrations, in micrograms per liter; %/no., percentage of detections, first number is percentage of detections and second number is number of analyses; m, median; --, no data; <, less than]

Compound	Land use: Agricultural		Land use: Agricultural and Urban		Land use: Urban		Land use: Built-up		Land use: Rangeland		Land use: Forest	
	%/no.	m	%/no.	m	%/no.	m	%/no.	m	%/no.	m	%/no.	m
Alachlor	0/3	<.1	0/2	<.1	--	--	0/51	<.1	--	--	0/8	<.1
Atrazine	100/4	<.1	50/2	<.1	--	--	6/51	<.1	--	--	0/8	<.1
Chlordane	0/5	<.1	0/12	<.1	0/20	<.1	1/129	<.04	--	--	0/30	<.04
Diazinon	17/6	<.01	50/14	<.01	53/17	<.01	2/62	<.1	--	--	0/19	<.01
Dicamba	17/6	<.01	33/3	<.01	33/92	<.01	--	--	0/24	<.01	--	--
Methoxychlor	0/5	<.01	0/12	<.01	6/17	<.01	0/129	<.04	--	--	0/30	<.04
Metolachlor	0/3	<.1	0/2	<.1	--	--	0/51	<.1	--	--	0/8	<.1
Parathion (ethyl)	0/6	<.01	8/13	<.01	0/17	<.01	0/10	<.01	--	--	0/10	<.01
Parathion-methyl	0/6	<.01	0/13	<.01	0/17	<.01	0/10	<.01	--	--	0/10	<.01
Picloram	83/6	.035	100/3	.1	86/91	.05	--	--	30/23	<.01	--	--
Propachlor	0/2	<.1	0/2	<.1	--	--	0/52	<.1	--	--	0/8	<.1
Simazine	0/4	<.1	0/2	<.1	--	--	12/51	<.1	--	--	0/8	<.1
2,4-D	56/9	<.01	80/15	.02	59/105	.02	55/11	<.01	32/22	<.01	0/11	<.01

each) and rangeland (two). The forest land use had no detections for the pesticides listed in table 23. The pesticides with the highest percentage of detections in the six land uses were atrazine in agricultural land use and picloram in mixed agricultural and urban land use. The pesticide detected in the greatest number of different land uses was 2,4-D. Although these data (fig. 43) indicate that mixed agricultural and urban land use have more detections of pesticides in surface water than other land uses, the variability in percentage of detections for a given pesticide was land-use area dependent. For a compound like atrazine, which is used almost exclusively in agricultural land use, the percentage of detections for analyses from surface-water sites in agricultural land use were much greater than for analyses from surface-water sites in urban land use. In the case of 2,4-D, which is used for broadleaf control in crops, pastures, and lawns, the percentage of detections for analyses from surface-water sites occurred in the greatest number of land uses because of its widespread use. It should be noted that the number of available analyses for a given pesticide was limited, in many cases, both within and between land use. Pesticide analyses are limited by the areal distribution of data for each pesticide compound. Atrazine data have a high density near Denver and 2,4-D data are clustered in several areas, but data for both compounds are lacking in other areas of the basin (fig. 44).

Summary statistics such as percentiles were not computed for the pesticides in table 23, because the majority of the data were nondetections. For certain pesticides (chlordane, diazinon, and methoxychlor), the reported laboratory detection level was variable. For example, the lower level of detection for methoxychlor varied from less than 0.01 to less than 0.04 μg/L. These changes in reported detection levels become troublesome when looking at long-range trends in data.

Of the 13 compounds listed in table 23, only 2 of them (picloram and 2,4-D) had median concentrations from surface-water sites that were greater than the reported detection level (<.01 μg/L). The highest median concentrations of picloram in agricultural, mixed agricultural and urban, and urban land use were 0.035, 0.1, and 0.05 μg/L, respectively; whereas the highest median concentrations of 2,4-D in the mixed agricultural and urban and urban land use was 0.02 μg/L. Only the forest land-use area had no pesticide detections; therefore, the median concentration was its reported detection limit for each pesticide examined in table 23.

Only one pesticide analysis had a concentration that was greater than a State or Federal water-quality criteria (table 24). This water-quality-criteria exceedance was for parathion at St. Vrain Creek below

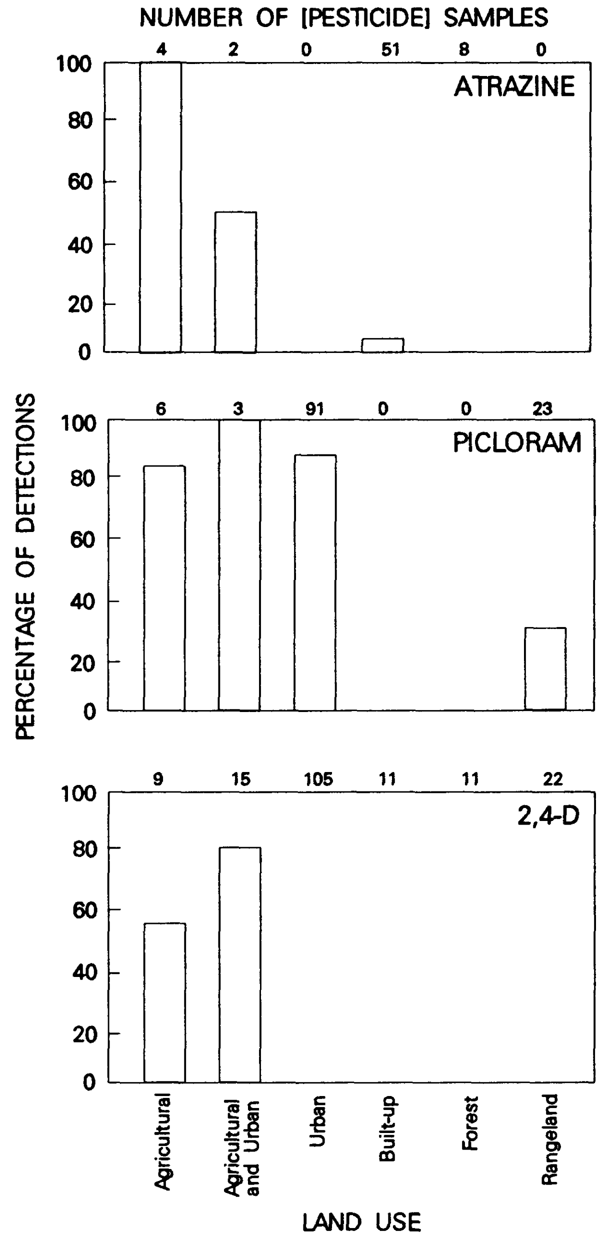

Figure 43. Percentage of detections of selected pesticides, by land use, in surface water in the South Platte River Basin, water years 1980–92. [Numbers at the top of histograms represent number of pesticide samples.]

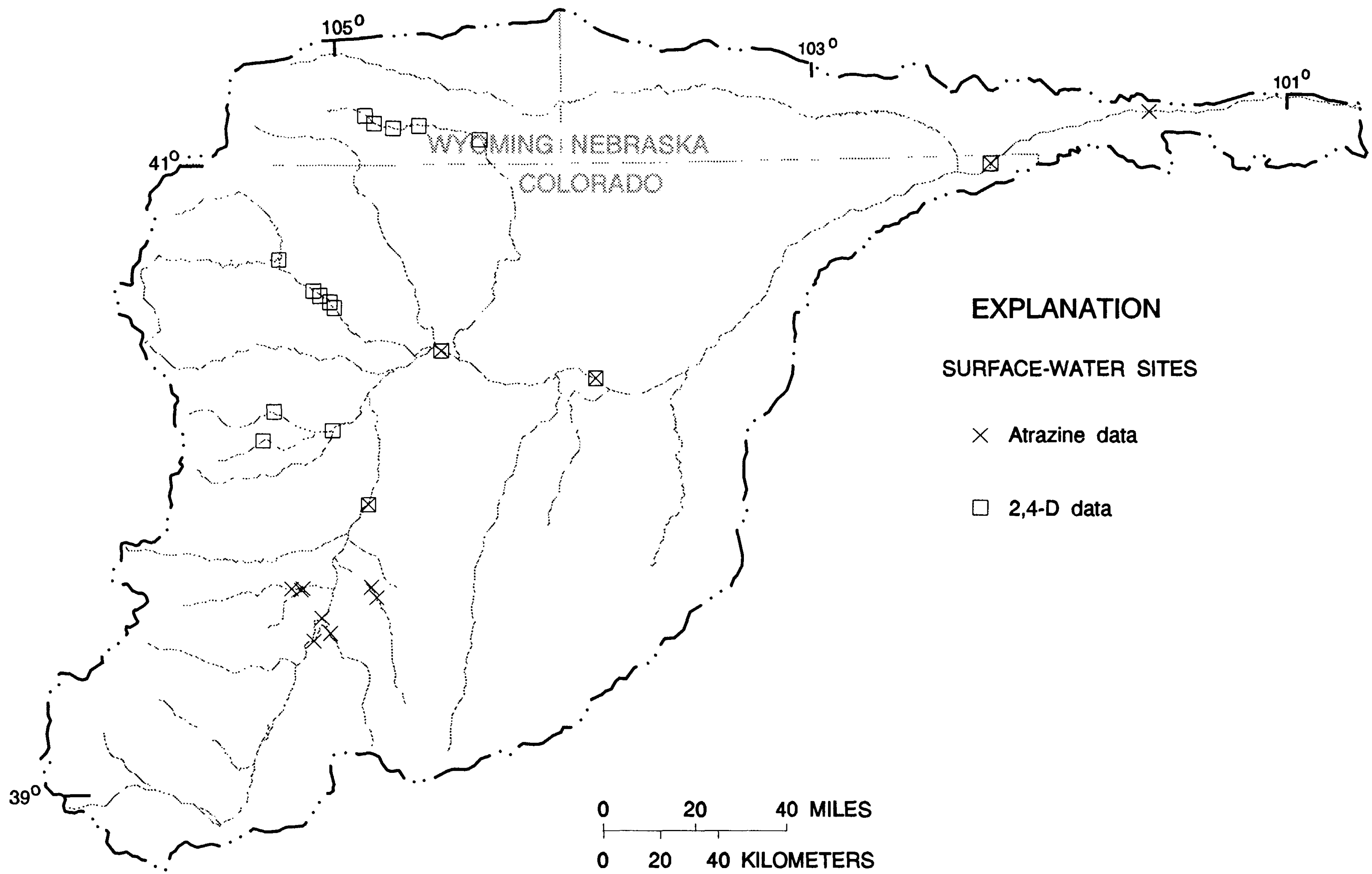

Figure 44. Areral distribution of atrazine and 2,4-D analyses at surface-water sites in the South Platte River Basin, water years 1980–92.

Table 24. Pesticides detected in surface water in the South Platte River Basin, water years 1980–92

[Lower levels of detection, water-quality criteria, and maximum concentrations are in micrograms per liter; --, not applicable; numbers in parentheses for lower levels of detection indicate multiple levels of detection for indicated compounds, reflecting changes in analytical methodology or analyzing agency]

Pesticide	Number of samples	Lower level of detection	Water-quality criteria	Maximum concentration	Number of water-quality-criteria exceedances	Surface-water site having maximum concentration (site number from fig. 9)
Alachlor	64	0.1	[1]2	< 0.1	0	--
Atrazine	65	.1	[1]3	.6	0	Cherry Creek Reservoir inflow, Colorado (site 16)
Chlordane	196	.1 (.04)	[1]2	<.1	0	--
Diazinon	119	.1 (.03, .01)	[1]0.6	.2	0	Bear Creek above Harriman Ditch Confluence, Colorado (site 9)
Dicamba	125	.01	--	.37	--	Crow Creek near Cheyenne, Wyoming (site 48)
Methoxychlor	193	.04 (.01)	[3]100	.12	0	Cache la Poudre River at Fort Collins, Colorado (site 41)
Metolachlor	64	.1	[2]100	<.1	0	--
Parathion (ethyl)	56	.01	[4].065	.1	1	St. Vrain Creek below Longmont, Colorado (site 29)
Parathion-methyl	56	.01	--	<.01	--	--
Picloram	123	.01	--	1.8	--	Crow Creek at Warren Air Force Base, Wyoming (site 47)
Propachlor	64	.1	[2]90	<.1	0	--
Simazine	65	.1	[2]4	.3	0	Cherry Creek Lake release, Colorado (site 17)
2,4-D	173	.01	[1]100	2.1	0	Crow Creek near Cheyenne, Wyoming (site 48)

[1]Established or proposed Maximum Contaminant Level (U.S. Environmental Protection Agency, 1990a).

[2]Lifetime Health Advisory Level (U.S. Environmental Protection Agency, 1989).

[3]Water supply, State of Colorado.

[4]Freshwater-aquatic life, acute (U.S. Environmental Protection Agency, 1987).

Longmont, Colorado (site 29). The concentration of parathion at this surface-water site (0.1 μg/L) exceeded the Federal limit for freshwater-aquatic life acute toxicity.

Only two surface-water sites, both of which are located along Crow Creek in Wyoming (sites 47 and 48), had sufficient data to plot concentration as a function of streamflow and time (figs. 45 and 46). Although data for the pesticide 2,4-D are illustrated in figures 45 and 46, similar patterns exist for the dicamba and picloram data from these surface-water sites. Concentrations of 2,4-D generally decreased as streamflow increased at both surface-water sites. The higher concentrations at low flows may indicate that ground-water discharge was an important source of 2,4-D to Crow Creek upgradient from these surface-water sites. The trend of 2,4-D concentrations in surface water over time at sites 47 and 48 are shown in figure 46. There were no extreme variations in 2,4-D concentrations over time, although there were several large values reported during water years 1986–87 at both surface-water sites, and again in water year 1989 at site 47.

Concentrations in Ground Water

Percentage of detections and median concentrations for selected pesticides in ground water from the South Platte River Basin are listed in table 25. The compounds were chosen because they were either one of the most commonly used in the basin (table 18) or because they had detectable concentrations. Detectable concentrations were measured for atrazine, cyanazine, DCPA, desethylatrazine, deisopropylatrazine, diazinon, metolachlor, and prometon. Except for DCPA and diazinon all of the detections were for triazine and other nitrogen-containing compounds. The maximum percentage of detections for any of the pesticides with respect to aquifer, well type, and land use in the alluvial aquifer are: 50 percent for diazinon in the High Plains aquifer; 44 percent for atrazine, DCPA, desethylatrazine, and deisopropylatrazine in observation wells; and, 44 percent for atrazine, DCPA, desethylatrazine and deisopropylatrazine in the agricultural land-use area underlying the alluvial aquifer (table 25). Detectable concentrations of atrazine and its metabolites (desethyl- and deisopropylatrazine) in ground water are not uncommon, particularly for ground water underlying agricultural areas (Exner and Spalding, 1990).

For all pesticides listed in table 25, median concentrations were at their reported detection level. Detectable concentrations of pesticides were measured in one well completed in the High Plains aquifer and seven other wells completed in the South Platte alluvial aquifer, both of which were collected from land underlying agricultural land use. The highest measured concentration for any pesticide was 6.0 μg/L of desethylatrazine in ground water from well 26 (fig. 10). Well 26 also had the highest atrazine concentration. None of the pesticide analyses exceeded any of the State or Federal water-quality criteria listed in table 26.

In general, the availability of pesticide data for ground water in the basin was very limited, especially with respect to aquifer and land use. Although the previously mentioned ongoing studies of pesticides in ground water for the basin will provide much useful data, those studies are concentrating almost exclusively on the alluvial aquifer underlying agricultural land uses. As indicated in table 25, the biggest gaps in the current data base are for other aquifers in the basin and for other land uses.

SUMMARY

The South Platte River Basin was one of 20 study units selected in 1991 for investigation as part of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) program. One of the first major components of the South Platte River study was a compilation, screening, and interpretation of available nutrient, suspended-sediment, and pesticide data from surface- and ground-water sites in the basin. The retrospective analysis of existing water-quality data will provide: a perspective of recent water-quality conditions in the South Platte River Basin, information on strengths and weaknesses of available data, and implications for water-quality issues and future study priorities and design.

South Platte River Basin

The South Platte River Basin drains about 24,300 square miles in parts of three States–Colorado (79 percent of the basin), Nebraska (15 percent of the basin), and Wyoming (6 percent of the basin). The South Platte River originates along the Continental Divide in the Rocky Mountains of central Colorado and flows about 450 miles northeast across the Great Plains through urban and agricultural areas to its confluence with the North Platte River at North Platte, Nebraska. The majority of the population (approximately 2.4 million) in the basin is concentrated along the Front Range urban corridor in Colorado. Average annual precipitation in the mountains is greater than 30 inches and in the plains averages from 7 to 15 inches. The river is highly regulated along its entire length with large quan-

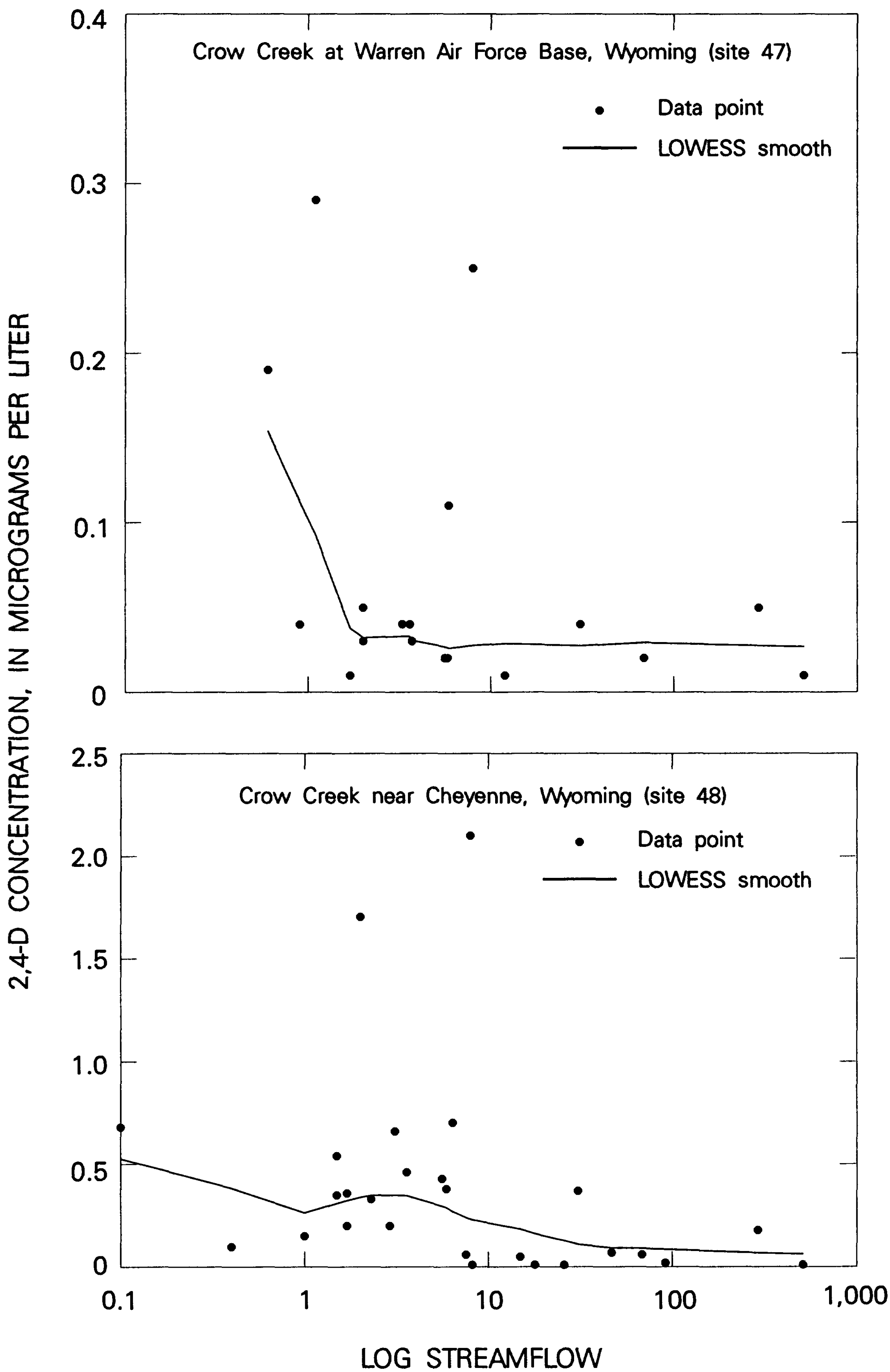

Figure 45. Relations of 2,4-D concentrations to streamflow at selected surface-water sites in the South Platte River Basin, water years 1980–92.

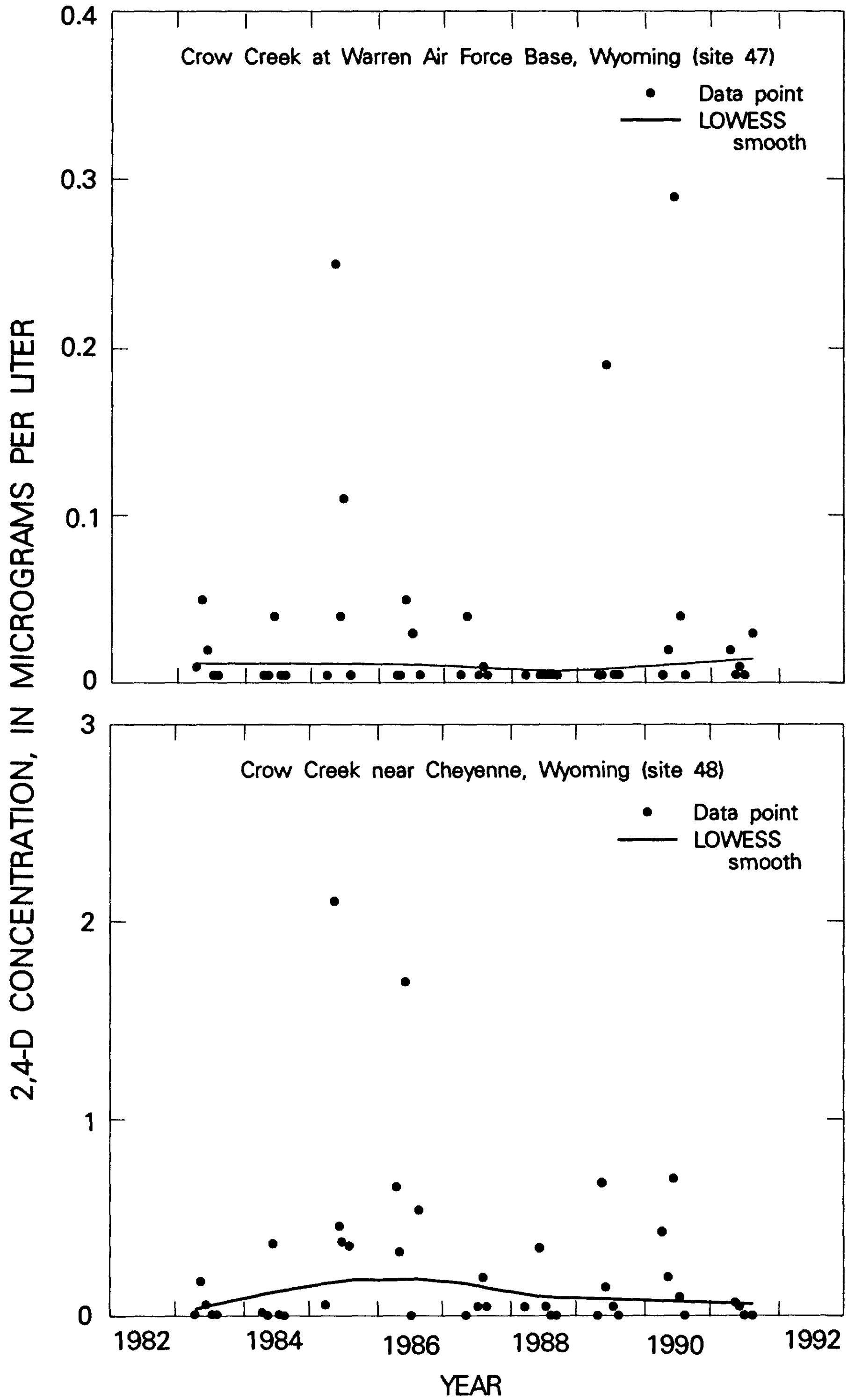

Figure 46. Relations of 2,4-D concentrations to time at selected surface-water sites in the South Platte River Basin, water years 1980–92.

Table 25. Percentage of detections and median concentrations for selected pesticides in ground water, by aquifer, well type, and land use in the alluvial aquifer, in the South Platte River Basin, water years 1980–92

[Median concentrations are in micrograms per liter; %/no., percent detections over total number of analyses; m, median; --, no data]

Compound	Aquifer				Well Type				Land use in the alluvial aquifer			
	Alluvial		High Plains		Observation		Irrigation		Agriculture		Rangeland	
	%/no.	m	%/no.	m	%/no.	m	%/no.	m	%/no.	m	%/no.	m
Alachlor	0/9	<.1	--	--	0/9	<.1	--	--	0/9	<.1	--	--
Atrazine	44/9	<.1	--	--	44/9	<.1	--	--	44/9	<.1	--	--
Carbofuran	0/9	<.5	--	--	0/9	<.5	--	--	0/9	<.5	--	--
Chlordane	0/3	<.5	0/2	<.5	0/5	<.5	--	--	0/2	<.5	0/2	<.5
Chlorpyrifos	0/9	<.01	--	--	0/9	<.01	--	--	0/9	<.01	--	--
Cyanazine	11/9	<.2	--	--	11/9	<.2	--	--	11/9	<.2	--	--
Cycloate	0/9	<.1	--	--	0/9	<.1	--	--	0/9	<.1	--	--
DCPA	44/9	<.01	--	--	44/9	<.01	--	--	44/9	<.01	--	--
Desethylatrazine	44/9	<.2	--	--	44/9	<.2	--	--	44/9	<.2	--	--
Deisopropylatrazine	44/9	<.2	--	--	44/9	<.2	--	--	44/9	<.2	--	--
Diazinon	0/9	<.01	50/2	<.01	9/11	<.01	--	--	0/9	<.01	--	--
Dicamba	0/9	<.01	0/4	<.01	0/9	<.01	0/4	<.01	0/9	<.01	--	--
Disyston	0/9	<.01	--	--	0/9	<.01	--	--	0/9	<.01	--	--
Metolachlor	11/9	<.2	--	--	11/9	<.2	--	--	11/9	<.2	--	--
Parathion (ethyl)	0/9	<.01	0/2	<.01	0/11	<.01	--	--	0/9	<.01	--	--
Parathion-methyl	0/9	<.01	0/2	<.01	0/11	<.01	--	--	0/9	<.01	--	--
Phorate	0/9	<.01	--	--	0/9	<.01	--	--	0/9	<.01	--	--
Picloram	0/9	<.01	0/4	<.01	0/9	<.01	0/4	<.01	0/9	<.01	--	--
Prometon	11/9	<.2	--	--	11/9	<.2	--	--	11/9	<.2	--	--
Propachlor	0/9	<.1	--	--	0/9	<.1	--	--	0/9	<.1	--	--
Carbaryl	0/9	<.5	--	--	0/9	<.5	--	--	0/9	<.5	--	--
Simazine	0/9	<.1	--	--	0/9	<.1	--	--	0/9	<.1	--	--
2,4-D	0/9	<.01	0/6	<.01	0/9	<.01	0/4	<.01	0/9	<.01	--	--

Table 26. Pesticides detected in ground water in the South Platte River Basin, water years 1980–92

[Lower levels of detection, water-quality criteria, and maximum quantifiable concentrations are in micrograms per liter; dashes indicate not applicable. Numbers in parentheses for lower levels of detection are additional lower levels of detection for indicated compounds, reflecting changes in analytical methodology or analyzing agency; <, less than]

Pesticide	Number of samples	Lower level of detection	Water-quality criteria	Maximum quantifiable concentration	Number of water-quality-criteria exceedances	Site number of well having maximum quantifiable concentration (fig. 10)
Alachlor	9	0.1	[1]2	.2	0	37
Atrazine	9	.1	[1]3	2.1	0	26
Carbofuran	9	.5	--	<.5	--	--
Chlordane	5	.5 (.1)	2[a]	<.5	0	--
Chlorpyrifos	9	.01	--	<.01	--	--
Cyanazine	9	.2	[1]10	.3	0	27
Cycloate	9	.1	--	<.1	--	--
DCPA	9	.01	--	1.0	--	34, 35
Desethylatrazine	9	.2	--	6.0	--	26
Deisopropylatrazine	9	.2	--	2.1	--	27
Diazinon	11	.01	[2]0.6	<.01	0	--
Dicamba	13	.01	--	<.01	--	--
Disyston	9	.01	--	<.01	--	--
Metolachlor	9	.2 (.1)	[2]100	.3	0	37
Parathion (ethyl)	11	.01	--	<.01	--	--
Parathion-methyl	11	.01	--	<.01	--	--
Phorate	9	.01	--	<.01	--	--
Picloram	13	.01	--	<.01	--	--
Prometone	9	.2	[1]100	.8	0	37
Propachlor	9	.1	[1]90	<.1	0	--
Carbaryl	9	.5	--	<.5	--	--
Simazine	9	.1	[1]4	<.1	0	--
2,4-D	15	.01	[2]100	<.01	0	--

[1]Lifetime Health Advisory Level (U.S. Environmental Protection Agency, 1989).
[2]Established or proposed Maximum Contaminant Level (U.S. Environmental Protection Agency, 1990a).

tities of water being diverted to ditches and reservoirs primarily for agricultural use. Flows in the river during fall and winter (low flow) are maintained primarily by ground-water return flows from agricultural lands, whereas flows during spring and summer (high flow) are dominated by snowmelt runoff. Six land uses (agricultural, urban, mixed agricultural and urban, built-up, rangeland, and forest) were examined to determine their relation to water quality. The land use occurring in the vicinity of a sampling site was assigned to that site with consideration given to the source of water at each site.

Three aquifers were assessed in the analysis of available data–the South Platte alluvial aquifer system, the High Plains aquifer, and the Denver Basin aquifer system (Dawson, Denver, Arapahoe, and Laramie-Fox Hills aquifers). The unconfined and unconsolidated alluvial aquifer is hydraulically connected with the South Platte River along its main stem and major perennial tributaries; it is recharged by precipitation, by leakage from streams, reservoirs, and ditches, and by percolation of applied irrigation water. The High Plains aquifer generally is unconfined, but is confined locally by lenses of silt and clay. The Denver Basin aquifer system consists of consolidated rocks, which underlie the South Platte River Basin; it is recharged in outcrop areas by rainfall, snowmelt, and streamflow. Discharge from all three aquifers primarily occurs through wells, seeps, springs, inflow to streams, and evapotranspiration.

Sources and Characteristics of Available Water-Quality Data

Most of the data analyzed resided in the U.S. Geological Survey's National Water Information System and the U.S. Environmental Protection Agency's Storage and Retrieval databases. Additional surface-water data were collected by the Denver Regional Council of Governments and Metro Wastewater Reclamation District. Ground-water data collected by Northern Front Range Water Quality Planning Association also were used in the analysis. After initial compilation and screening, data collected from 54 surface-water sites and 107 wells were determined suitable for the analysis. The quantity of data available from these sites and wells varied considerably with respect to constituents sampled. For example, in surface water, 2,427 samples were analyzed for nutrients, 201 for suspended sediment, and 564 for pesticides. For ground water, 272 samples were analyzed for nutrients and 20 samples for pesticides. Nutrient constituents examined included: total nitrogen, total organic nitrogen plus ammonia (for surface-water sites), dissolved organic nitrogen plus ammonia (for ground-water sites), dissolved ammonia, dissolved nitrite, dissolved nitrite plus nitrate, dissolved phosphorus, dissolved orthophosphate, and total phosphorus. All nitrogen species are reported as nitrogen, and all phosphorus species are reported as phosphorus. Suspended-sediment constituents examined included total suspended-sediment concentration and suspended-sediment particle-size distribution. Pesticide constituents examined included these compound classes: carbamates, chlorophenoxy acid herbicides, organochlorine and organophosphorus insecticides, and triazine and other nitrogen-containing herbicides.

Nutrients

Median concentrations of dissolved nitrite plus nitrate, as nitrogen, in samples collected at individual surface-water sites ranged from less than 0.01 to 4.3 milligrams per liter, and median concentrations of total phosphorus ranged from 0.02 to 0.28 milligram per liter. Only two tributary sites, with one sample from each, equaled or exceeded the drinking water maximum contaminant level (MCL) for dissolved nitrite plus nitrate. Point sources in urban areas, particularly wastewater-treatment plants, affected downstream nutrient concentrations as evidenced by elevated nitrogen and phosphorus concentrations downstream from their discharges. Nutrient concentrations also increased downstream from mixed agricultural and urban land uses. Concentrations of dissolved nitrite plus nitrate were substantially higher during low-flow season than at other times of the year; this may be due to snowmelt dilution effects in summer as well as decreased biologic uptake of nitrate during winter. Most nutrient concentrations exhibited no long term temporal trends; however, flow-adjusted concentrations of total organic nitrogen plus ammonia increased slightly over time downstream from Littleton, Colorado, and flow-adjusted concentrations of dissolved phosphorus increased slightly over time downstream from Loveland, Colorado.

Annual nutrient loads were estimated for selected sites in the basin. Generally, total organic nitrogen plus ammonia was most of the total nitrogen load at urban sites, whereas nitrite plus nitrate was most of the load at agricultural sites. The total nitrogen load transported in the South Platte River near the end of the basin at Julesburg, Colorado, was estimated to be 4,300 tons during a median flow year; this is only 1 percent of the estimated total nitrogen input to the basin from precipitation, fertilizer, and manure. Data were insufficient to calculate loads in many parts of the basin and were difficult to interpret because of complex water-management practices.

Nutrient concentrations in ground-water samples varied between aquifers, well types, and land uses in the alluvial aquifer. Median concentrations of nitrite plus nitrate varied between aquifers and well types. The highest median concentrations of dissolved nitrite plus nitrate generally were measured in ground-water samples collected from observation or irrigation wells completed in the alluvial aquifer. Although none of the median concentrations of dissolved nitrite plus nitrate exceeded the 10 milligrams per liter MCL, 46 of the 49 ground-water samples having dissolved nitrite plus nitrate concentrations greater than or equal to the 10 milligrams per liter MCL were from wells completed in the alluvium underlying agricultural areas. Median concentrations of dissolved nitrite plus nitrate in ground-water samples from the alluvial aquifer were higher in agricultural land use than in the other land uses. Median concentrations of dissolved organic nitrogen plus ammonia varied between aquifers and sampling years with the highest concentrations generally measured in samples from the alluvial aquifer collected prior to 1986. Dissolved organic nitrogen plus ammonia concentrations from the alluvial aquifer were highest from wells completed beneath agricultural lands. Concentrations of dissolved phosphorus varied significantly between aquifers with the highest median concentrations generally being associated with observation wells completed in the alluvial aquifer. Rangeland had a higher median concentration of dissolved phosphorus in ground water than samples from wells beneath agricultural lands, however dissolved phosphorus concentrations from wells completed in the alluvial aquifer were highest in agricultural areas. Dissolved nitrite plus nitrate in the Greeley, Colorado area showed no consistent trend with depth, however, east of Greeley a better distribution of data both areally and with depth are needed before a basin-wide relation can be made for dissolved nitrite plus nitrate with depth in the alluvial aquifer. Dissolved phosphorus concentrations indicate an apparent trend with depth in the South Platte alluvial aquifer; concentrations decreased with increasing depth. However, this analysis is tentative because it is based on data that has insufficient areal coverage and delineation with depth.

Suspended Sediment

Suspended-sediment data are sparse across the basin. Data were available from only four suspended-sediment-sampling sites along the South Platte River and one tributary site. The temporal distribution of suspended-sediment data was variable; some sites were sampled intensively for short periods, other sites were sampled intermittently, but few regularly. Only three sites had an adequate distribution of samples collected over a broad range of streamflows. Suspended sediment was not sampled frequently enough to enable analysis of loads, concentration trends, or particle-size trends. Two of the four South Platte River suspended-sediment sampling sites are located in agricultural areas. Generally, suspended-sediment concentrations were larger at downstream sites. However, at a number of sites along the South Platte River, flow is diverted to reservoirs and ditches, decreasing flow in the river, resulting in deposition of large quantities of sediment near downstream headgates. Diversions, especially in the lower Basin, affect and control the sediment transport along the river. Suspended-sediment concentrations varied by month, with the highest suspended-sediment loads being transported during snowmelt runoff.

Pesticides

Pesticide data were collected at 29 surface-water sites in the basin during water years 1980–92. However, about one-half of those sites were concentrated in four areas of the basin. Pesticide data for surface-water sites were limited by the number of analyses per site, the distribution of analyses by compound class and land use, the distribution of analyses throughout the year, the distribution of analyses by decile of flow, and the number of analyses for the most commonly applied pesticides. Pesticide data for ground water were available from 20 wells in the basin, none of which had more than one sample. Most of the samples used in this analysis were collected from observation wells completed in the alluvium underlying agricultural areas, therefore more data are needed from other well types, aquifers, and from different land use areas to describe the occurrence and distribution of pesticides on a basin scale.

Most of the pesticide concentrations were less than laboratory reporting levels. In surface water, the percent detections were highest for mixed agricultural and urban land use, slightly lower for urban, built-up and agricultural areas, less in rangeland areas, and zero for forest areas. The pesticides with the highest percent detections among the six land uses were atrazine in agricultural areas and picloram in mixed agricultural and urban land use. The pesticide 2,4-D was detected in the greatest number of different land uses. Of the 13 selected pesticides examined in surface water, only 2 (picloram and 2,4-D) had median concentrations that were greater than detection levels. This is because both picloram and 2,4-D have lower detection levels than atrazine. Only one surface-water site, located in a mixed agricultural and urban land-use area, had a pesticide (parathion) concentration that exceeded a water-quality criteria. Concentrations of 2,4-D decreased with increasing streamflow at two surface-water sites where sufficient data existed to examine this relation. DCPA, diazinon, and triazines and other nitrogen-containing compounds were the only pesticides detected in ground water; all but one of the detectable concentrations occurred in alluvial wells and all detections were from agricultural land-use areas. None of the pesticide concentrations in ground water exceeded State and Federal water-quality criteria.

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SUPPLEMENTAL DATA

Table 27. Streamflow statistics and period of record for surface-water sites with more than 10 years of record in the South Platte River Basin

Site no. (fig. 9)	Site name	Number of years of record	Period of record	Mean annual streamflow, in cubic feet per second at indicated percentile		
				25	50 (median)	75
2	Tarryall Creek near Jefferson, Colorado	12	1912-18, 1977-81	30.3	43.2	55.9
6	South Platte River at Littleton, Colorado	45	1942-86	109.2	164.6	341.9
15	Bear Creek at mouth at Sheridan, Colorado	65	1927-91	16.1	33.6	55.5
19	South Platte River at Denver, Colorado	97	1895-1991	194.1	299.0	438.4
22	Clear Creek at Golden, Colorado	17	1975-92	141.7	172.9	211.6
26	South Platte River at Henderson, Colorado	66	1926-91	225.7	326.5	521.4
27	St. Vrain Creek at Lyons, Colorado	96	1896-1991	91.7	119.8	162.4
28	Left Hand Creek near Boulder, Colorado	18	1929-89	28.7	36.0	44.3
29	St. Vrain Creek below Longmont, Colorado	16	1976-92	76.4	109.3	127.2
30	Boulder Creek at mouth near Longmont, Colorado	42	1927-92	34.8	48.7	84.9
31	St. Vrain Creek at mouth near Platteville, Colorado	65	1927-91	135.5	188.4	287.4
33	Big Thompson River at Loveland, Colorado	14	1979-92	30.1	35.5	88.4
36	Big Thompson River at mouth near La Salle, Colorado	61	1914-84	38.2	62.9	92.8
39	Cache la Poudre River at mouth of Canyon, Colorado	108	1881-1991	285.1	360.0	443.9
41	Cache la Poudre River at Fort Collins, Colorado	16	1975-90	48.5	119.2	265.3
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	12	1980-91	39.9	90.9	330.5
44	Cache la Poudre River near Greeley, Colorado	79	1903-92	57.5	96.0	150.2
45	South Platte River at Kersey, Colorado	91	1901-91	451.4	654.2	1152
51	South Platte River near Weldona, Colorado	40	1953-92	337.7	518.4	939.6
53	South Platte River at Julesburg, Colorado	88	1902-91	228.3	368.5	673.0

Table 28. Harvested acreage for selected crops in the South Platte River Basin, 1991

[dashes indicate zero or negligible acreage; * indicates combined irrigated and non-irrigated acres; data from Colorado Agricultural Statistics Service, 1991; Nebraska Agricultural Statistics Service, 1991; Wyoming Agricultural Statistics Service, 1992]

County	Grain corn (acres)		Silage corn (acres)		Winter wheat (acres)		Spring wheat (acres)	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Colorado								
Adams	7,000	---	2,600	---	2,400	154,600	100	500
Arapahoe	---	---	300	---	200	82,800	---	---
Boulder	8,500	---	2,500	---	700	2,600	300	400
Clear Creek	---	---	---	---	---	---	---	---
Denver	---	---	---	---	---	---	---	---
Douglas	---	---	---	---	---	3,700	---	---
Elbert	---	---	300	---	---	42,500	---	---
El Paso	---	---	200	---	400	3,400	---	---
Gilpin	---	---	---	---	---	---	---	---
Jefferson	---	---	---	---	---	500	---	---
Larimer	22,000	---	10,500	---	1,500	6,700	400	---
Lincoln	500	---	---	---	1,500	150,500	---	---
Logan	40,500	5,500	5,000	---	8,000	136,000	---	300
Morgan	75,000	---	9,000	---	7,800	70,200	200	300
Park	---	---	---	---	---	---	---	---
Sedgwick	34,500	5,500	1,500	---	3,000	78,000	---	---
Teller	---	---	---	---	---	---	---	---
Washington	18,200	2,300	1,000	---	4,700	285,300	---	---
Weld	162,500	---	45,500	---	9,000	166,000	800	200
Nebraska								
Banner	3,600	300	1,000	---	2,800	700	*53,500	
Cheyenne	9,200	800	3,500	---	9,200	1,400	*208,900	
Deuel	8,300	600	800	---	2,200	700	*85,400	
Garden	12,300	400	1,800	1,400	2,000	200	*47,300	
Keith	43,700	4,100	2,000	---	3,600	2,800	*60,600	
Kimball	6,400	300	800	---	4,100	800	*126,100	
Lincoln	134,100	15,900	9,200	8,700	2,200	1,700	*36,800	
Perkins	86,000	4,500	3,100	2,800	8,400	5,800	*135,300	
Wyoming								
Albany	---	---	---	---	---	---	---	---
Laramie	*4,000		*3,300		5,500	65,000	300	200
SUBTOTAL	672,300	40,200	100,600	12,900	79,200	1,261,900	2,100	1,900
TOTALS	*716,500		*116,800		*1,341,100		*757,900	

Table 28. Harvested acreage for selected crops in the South Platte River Basin, 1991--Continued

County	Soybeans (acres)		Barley (acres)		Oats (acres)		Sorghum grain (acres)	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Colorado								
Adams	---	---	2,000	2,000	600	2,200	1,000	1,500
Arapahoe	---	---	---	600	---	700	---	---
Boulder	---	---	2,500	1,000	400	---	---	---
Clear Creek	---	---	---	---	---	---	---	---
Denver	---	---	---	---	---	---	---	---
Douglas	---	---	---	---	---	300	---	---
Elbert	---	---	---	300	800	2,900	---	200
El Paso	---	---	---	---	---	800	---	1,000
Gilpin	---	---	---	---	---	---	---	---
Jefferson	---	---	---	---	---	---	---	---
Larimer	---	---	7,200	100	1,100	---	---	---
Lincoln	---	---	---	---	---	700	600	9,200
Logan	---	---	---	1,700	1,000	1,500	100	800
Morgan	---	---	900	2,600	600	200	100	500
Park	---	---	---	---	---	---	---	---
Sedgwick	---	---	---	3,000	500	1,000	---	---
Teller	---	---	---	---	---	---	---	---
Washington	---	---	---	1,000	500	900	600	3,400
Weld	---	---	19,400	1,600	1,400	300	300	400
Nebraska								
Banner	---	---	*800		*400		100	200
Cheyenne	---	---	*800		*900		---	100
Deuel	100	---	*1,200		*1,400		---	500
Garden	200	---	*400		*1,000		---	200
Keith	600	---	*700		*700		100	300
Kimball	---	---	*1,500		*900		---	100
Lincoln	2,500	100	*100		*500		100	900
Perkins	900	---	*2,200		*900		---	600
Wyoming								
Albany	---	---	100	---	200	---	---	---
Laramie	---	---	4,200	300	1,300	2,000	---	---
SUBTOTAL	4,300	100	36,300	14,200	8,400	13,500	3,000	19,900
TOTAL	*4,400		*58,200		*28,600		*22,900	

Table 28. Harvested acreage for selected crops in the South Platte River Basin, 1991--Continued

County	Dry beans (acres)		Hay (acres)		Potatoes (acres)	Sugar beets	TOTAL		
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated/ non-irrigated combine	Irrigated/ non-irrigated combine	Irrigated	Non-irrigated	Irrigated/ non-irrigated combined
Colorado									
Adams	1,700	---	10,200	10,900	---	610	27,600	171,700	610
Arapahoe	---	400	2,600	4,700	---	---	3,100	89,200	---
Boulder	2,800	---	21,500	2,500	---	840	39,200	6,500	840
Clear Creek	---	---	200	---	---	---	200	---	---
Denver	---	---	---	---	---	---	---	---	---
Douglas	---	---	3,600	4,200	---	---	3,600	8,200	---
Elbert	---	---	7,200	33,800	---	---	8,300	79,700	---
El Paso	---	200	7,100	15,400	---	---	7,700	20,800	---
Gilpin	---	---	200	---	---	---	200	---	---
Jefferson	---	---	4,900	4,400	---	---	4,900	4,900	---
Larimer	10,600	---	29,000	4,000	---	2,310	82,300	10,800	2,310
Lincoln	---	---	3,800	29,200	---	---	6,400	189,600	---
Logan	8,900	---	28,200	14,300	---	4,420	91,700	160,100	4,420
Morgan	15,000	---	20,700	8,800	2,000	9,990	129,300	82,600	11,990
Park	---	---	11,700	3,300	---	---	11,700	3,300	---
Sedgwick	7,000	700	4,700	2,500	---	---	51,200	90,700	---
Teller	---	---	1,300	1,700	---	---	1,300	1,700	---
Washington	6,400	300	7,900	20,600	---	460	39,300	313,800	460
Weld	44,700	300	96,000	28,500	3,600	21,370	379,600	197,300	24,970
Nebraska									
Banner	*3,600		*13,000		---	1,300	7,500	1,200	72,600
Cheyenne	*11,900		*20,000		---	1,800	21,900	2,300	244,300
Deuel	*4,600		*5,900		---	---	11,400	1,800	98,500
Garden	*5,400		*52,000		---	---	16,300	2,200	106,100
Keith	*19,600		*34,000		---	---	50,000	7,200	115,600
Kimball	*7,800		*16,500		---	500	11,300	1,200	153,300
Lincoln	*1,900		*143,000		---	---	148,100	27,300	182,300
Perkins	*18,100		*19,500		---	---	98,400	13,700	176,000
Wyoming									
Albany	---	---	50,500	3,500	---	---	50,800	3,500	---
Laramie	*5,800		49,500	16,500	---	510	60,800	84,000	13,610
SUBTOTAL	97,100	1,900	360,800	208,800	5,600	44,110	1,364,10	1,575,30	1,207,91
TOTAL	*177,700		*873,500		*5,600	*44,110	*4,147,310		

Table 29. Approximate planting dates, days to harvest, and application rates and timing of fertilizers and pesticides for selected crops in the South Platte River Basin

[a.i.,active ingredient; data from Cranshaw and others, 1991; Follett and others, 1991; Peairs and others, 1992]

Crop	Planting dates	Days to harvest	Fertilizer	Herbicide	Insecticide
Field corn	4/15 to 6/1	90 to 140	Nitrogen: dependent on yield goal, method of irrigation, soil N content. For yield goal of 150 bushels per acre, apply about 100 pounds N per acre; 50 percent at preplant, 25 percent at planting, 25 percent lay by.	Atrazine: 1.5 to 3 pounds active ingredient (a.i.) per acre. Applied preplanting and incorporated, preemergent, or early post emergent.	Terbufos: 6 ounces per 1,000 row feet. Apply at planting.
					Chlorpyrifos: 6 to 8 ounces per 1,000 row feet. Apply at planting
			Phosphorus: 50 to 100 pounds P_2O_5 per acre, depending on soil P content. Generally, preplant application.	EPTC: 3 to 6 pounds a.i.per acre. Applied preplanting and incorporated.	Propargite: 1.5 to 2 pounds a.i. per acre. Apply no later than 30 days prior to harvest.
			Potassium: 40 to 60 pounds K_2O per acre, depending on soil P content. Generally, preplant application.	Alachlor: 2 to 3 pounds a.i. per acre. Applied preplanting and incorporated or preemergent.	
Alfalfa	4/15 to 5/15, 8/1 to 8/15	first cutting: 6/1 second cutting: 7/1 third cutting: 8/1 fourth cutting: 9/1	Nitrogen: not needed for established stand. For new seeding, 10 to 30 pounds N per acre, depending on soil N content. Apply at establishment.	Sethoxydim: 0.2 to 0.5 pound a.i. per acre. Apply no later than 7 days before cutting.	Carbofuran: 0.25 to 1.0 pound a.i. per acre. Apply 7 to 28 days before harvest.
				Metribuzin: 0.375 to 1.0 pound a.i. per acre. Dormant treatment.	Chlorpyrifos: 0.75 to 1.0 pound a.i. per acre. Apply no later than 21 days before harvest
			Phosphorus: 150 pounds K_2O_5 per acre, depending on soil P content. Apply at establishment.	Bromoxynil: 0.25 to 0.375 pound a.i. per acre. Apply in spring or fall to seedling alfalfa.	Dimethoate: 0.25 to 0.5 pound a.i. per acre. Apply no later than 10 days before cutting.
			Potassium: 100 pounds K_2O per acre depending on soil potassium content. Apply at establishment.		

Table 29. Approximate planting dates, days to harvest, and application rates and timing of fertilizers and pesticides for selected crops in the South Platte River Basin--Continued

Crop	Planting dates	Days to harvest	Fertilizer	Herbicide	Insecticide
Winter wheat	9/10 to 9/25	110 to 120	Nitrogen: dependent on yield goal, soil N content and other variables. For 50 bushels per acre yield goal, 50 pounds N per acre. Apply at planting, with another application in spring.	2,4-D: 0.5 to 1.0 pound a.i. per acre. Apply in spring after tilling.	Disulfoton: 1.7 ounces per 1,000 row feet. Apply at planting time.
				Bromoxynil: 0.25 to 0.5 pound a.i. per acre. Apply in fall or early spring.	Phorate: 1.2 ounces per 1,000 row feet. Apply at planting.
			Phosphorus: 40 pounds P_2O_5 per acre.	Dicamba: 0.09 to 0.25 pound a.i. per acre. Apply in spring after winter dormancy breaks.	Dimethoate: 0.25 to 0.40 pound a.i. per acre. Apply no later than 35 days before harvest.
			Potassium: 30 pounds K_2O per acre.		
Dry beans	5/25 to 6/10	90 to 110	Nitrogen: as much as 20 pounds N per acre. Applied preplant and incorporated	EPTC: 3 pounds a.i. per acre. Applied preplant and incorporated.	Assana XL:0.0125 to 0.025 pound a.i. per acre. Apply no later than 21 days before harvest.
			Phosphorus: 20 to 40 pounds P_2O_5 per acre. Applied preplant and incorporated.	Trifluralin: 0.5 to 0.75 pound a.i. per acre. Applied preplant and incorporated.	Carbaryl :0.5 to 1.0 pound a.i. per acre.
			Potassium: 20 to 40 pounds K_2O per acre. Applied preplant and incorporated.	Ethalfuralin: 0.75 to 1.5 pound a.i. per acre. Applied preplant or incorporated.	Dimethoate: 0.25 to 0.5 pound a.i. per acre.
Sugar beets	4/1 to 5/25	180 to 210	Nitrogen: dependent on yield goal, soil N content, soil organic matter content, and other variables. For yield goal of 20 tons, about 40 to 60 pounds N per acre.	Cycloate: 3 to 4 pounds a.i. per acre. Applied preplant and incorporated.	Terbules: 18 ounces per 1,000 row feet. Apply at planting.
				EPTC: 3 pounds a.i. per acre. Applied for preemergent weed control.	Carbaryl: 1 to 1.5 pounds a.i. per acre. Apply no later than 14 days before harvest.
			Phosphorus: 50 to 75 pounds P_2O_5 per acre, depending on soil P content.	Sethoxydim: follow label directions.	Chlorpyrifos: 6.5 to 9 ounces per 1,000 row feet. Apply at planting time or postemergence.
			Potassium: 60 pounds K_2O per acre, depending on soil K content.		

Table 30. Herbicides applied annually from 1987 to 1989, by county, South Platte River Basin

[Values in pounds active ingredient; dashes indicate no data; data from Gianessi and Puffer, 1990]

County	Herbicides						
	2,4-D	EPTC	Atrazine	Alachlor	Butylate	Dicamba	Cyanazine
Colorado							
Adams	14,454	9,675	5,757	5,982	4,849	9,176	---
Arapahoe	7,974	721	300	524	---	3,530	---
Boulder	3,193	9,944	4,914	4,974	4,139	1,445	1,232
Clear Creek	128	---	---	---	---	31	---
Denver	138	---	---	---	---	33	---
Douglas	7,105	730	---	---	---	1,783	---
Elbert	25,451	3,608	---	625	---	7,210	---
El Paso	23,980	1,995	---	778	---	5,857	---
Gilpin	55	---	---	---	---	13	---
Jefferson	2,063	382	---	---	---	517	---
Larimer	13,996	31,902	17,063	17,439	14,371	5,527	4,276
Lincoln	37,081	769	---	3,285	---	13,564	571
Logan	25,099	57,542	36,012	36,874	30,330	14,392	9,273
Morgan	19,098	77,735	49,042	50,716	41,305	12,133	12,660
Park	14,065	---	---	---	---	3,376	--
Sedgwick	8,097	34,836	21,427	21,939	18,046	6,281	5,434
Teller	2,356	---	---	---	---	566	---
Washington	30,844	27,825	17,594	20,190	14,818	18,337	4,878
Weld	59,873	206,319	116,745	119,257	98,325	32,142	29,543
Nebraska							
Banner	11,015	4,012	4,153	2,908	1,221	1,078	1,127
Cheyenne	32,720	11,491	13,857	11,725	4,192	2,194	3,859
Deuel	12,804	4,854	10,440	6,553	2,718	887	2,520
Garden	18,189	5,921	13,974	9,415	4,456	2,931	4,091
Keith	15,320	17,876	41,910	29,802	13,685	2,743	12,551
Kimball	20,492	5,421	5,623	5,266	1,840	1,390	1,685
Lincoln	25,421	17,929	114,276	67,180	37,764	7,097	34,610
Perkins	27,261	20,805	74,538	48,805	24,603	3,668	22,551
Wyoming							
Albany	56,019	517	---	---	---	31,986	---
Laramie	54,674	7,969	---	2,244	1,012	20,022	2,023
TOTAL	568,965	560,778	547,625	466,481	317,674	209,909	152,884

Table 30. Herbicides applied annually from 1987 to 1989, by county, South Platte River Basin--Continued

County	Herbicides						
	Metolachlor	Picloram	Cycloate	DCPA	Propazine	Trifluralin	Glyphosphate
				Colorado			
Adams	---	---	---	1,639	---	---	1,965
Arapahoe	---	824	---	---	630	---	608
Boulder	1,139	---	691	---	---	---	---
Clear Creek	---	19	---	---	---	---	---
Denver	---	21	---	---	---	---	--
Douglas	---	1,056	---	---	---	---	27
Elbert	---	3,575	---	---	873	432	464
El Paso	--	3,498	---	376	1,521	---	---
Gilpin	---	8	---	---	---	---	---
Jefferson	---	309	---	---	---	---	7
Larimer	3,959	---	3,010	---	---	---	---
Lincoln	---	4,405	---	---	7,678	---	2,448
Logan	8,346	---	5,353	---	---	---	---
Morgan	11,365	---	10,039	---	5,581	---	---
Park	---	2,138	---	---	---	---	---
Sedgwick	4,966	---	---	---	--	1,709	---
Teller	--	358	---	---	--	---	---
Washington	4,077	---	---	---	7,057	---	3,823
Weld	28,357	---	25,007	28,783	---	---	---
				Nebraska			
Banner	1,895	---	---	---	---	3,901	---
Cheyenne	3,714	---	---	---	---	2,157	1,965
Deuel	2,753	---	---	---	---	---	823
Garden	3,724	3,276	---	---	---	864	---
Keith	11,276	---	---	---	---	2,981	---
Kimball	1,518	---	---	---	---	2,965	---
Lincoln	30,457	4,382	---	---	---	2,914	---
Perkins	20,041	---	---	---	---	3,933	---
				Wyoming			
Albany	---	12,794	---	---	---	--	---
Laramie	---	7,830	---	---	---	---	1,753
TOTAL	137,587	44,493	44,100	30,798	23,340	21,856	13,883

Table 30. Herbicides applied annually from 1987 to 1989, by county, South Platte River Basin--Continued

County	Herbicides					
	Pendimethalin	Terbutryn	Ethalfuralin	Bromoxynil	MCPA	Propachlor
			Colorado			
Adams	---	---	---	2,747	2,963	---
Arapahoe	---	---	---	368	319	---
Boulder	---	---	---	580	---	---
Clear Creek	---	---	---	---	---	---
Denver	---	---	---	---	---	---
Douglas	---	---	---	34	46	---
Elbert	---	---	---	---	---	---
El Paso	---	---	---	---	---	338
Gilpin	---	---	---	---	---	---
Jefferson	---	---	---	18	---	---
Larimer	1,796	---	---	---	---	---
Lincoln	---	956	---	---	---	1,706
Logan	3,791	---	---	---	---	---
Morgan	---	---	---	---	---	---
Park	---	---	---	---	---	---
Sedgwick	2,256	---	----	---	---	---
Teller	---	---	---	---	---	---
Washington	---	---	---	---	---	---
Weld	---	---	---	---	---	---
			Nebraska			
Banner	---	---	---	---	---	---
Cheyenne	---	---	---	---	---	---
Deuel	---	---	---	---	---	1,181
Garden	---	---	---	---	---	---
Keith	---	---	2,473	---	---	---
Kimball	---	---	1,325	---	---	---
Lincoln	---	---	---	---	---	---
Perkins	---	---	2,507	---	---	---
			Wyoming			
Albany	---	---	---	24	---	---
Laramie	---	5,415	---	---	----	---
TOTAL	7,843	6,371	6,305	3,771	3,328	3,225

Table 30. Herbicides applied annually from 1987 to 1989, by county, South Platte River Basin--Continued

County	Herbicides					TOTAL
	Metribuzin	Pronamide	2,4-D,B	Sethoxydim	Simazine	
			Colorado			
Adams	---	---	---	---	---	59,207
Arapahoe	---	---	---	---	---	15,798
Boulder	---	---	---	---	---	32,251
Clear Creek	---	---	---	---	---	178
Denver	---	---	---	---	---	192
Douglas	---	171	137	46	---	11,135
Elbert	---	766	612	---	---	43,616
El Paso	---	418	335	---	---	39,096
Gilpin	---	---	---	---	---	76
Jefferson	---	89	72	24	3	3,484
Larimer	---	---	---	---	---	113,339
Lincoln	---	---	---		---	72,463
Logan	---	---	---	---	---	227,012
Morgan	---	---	---	---	---	289,674
Park	---	---	---	---	---	19,579
Sedgwick	---	---	---	---	---	124,991
Teller	---	---	---	---	---	3,280
Washington	---	---	---	---	---	149,443
Weld	---	---	---	---	---	744,351
			Nebraska			
Banner	1,487	---	---	---	---	32,797
Cheyenne	---	---	---	---	---	87,874
Deuel	---	---	---	---	---	45,533
Garden	---	---	---	---	---	66,841
Keith	---	---	---	---	---	150,617
Kimball	---	---	---	---	---	47,525
Lincoln	---	---	---	---	---	342,030
Perkins	---	---	---	---	---	248,712
			Wyoming			
Albany	---	121	97	32	65	101,655
Laramie	1,557	---	---	---	---	104,499
TOTAL	3,044	1,565	1,253	102	68	---

Table 31. Common name, trade name, compound class, and typical application of pesticides commonly used in the South Platte River Basin

[Data from Biggars and Seiber, 1987; Gianessi and Puffer, 1990; Bohmont, 1991]

Common name	Trade name	Compound class	Typical application
		Herbicides	
2,4-D	Various names	Phenoxyacetic acid	Broadleaf control in cereal crops, pastures, lawns
2,4-D,B	Butyrac	Phenoxybutyric acid	Postemergent weed control in legumes
Alachlor	Lasso	Substituted amide	Preemergent weed control in corn and other agronomic crops
Atrazine	AAtrex	s-triazine	Preemergent and early postemergent weed control in corn
Bromoxynil	Buctril	Benzonitrile	Early postemergent weed control for certain small grains
Butylate	Sutan	Thiocarbamate	Preplant incorporated for weed control in corn
Cyanazine	Bladex	s-triazine	Preemergent and early postemergent weed control in corn
Cycloate	Ro-Neet	Thiocarbomate	Preplant weed control in sugar beets
DCPA	Dacthal	Phthalic acid	Preemergent weed control in onions
Dicamba	Banvel	Benzoic acid	Preemergent and post emergent weed control in certain grass crops
EPTC	Eptam	Thiocarbamate	Preplant incorporated for weed control in several crops
Ethalfuralin	Sonalan	Organofluorine	Preplant incorporated for weed control in dry beans
Glyphosphate	Roundup	Amino acid	General vegetation control typically for non-crop lands
MCPA	Methoxone	Phenoxyacetic acid	Broadleaf control in cereal crops, pasture land, lawns
Metolachlor	Dual	Substituted amide	Preemergent weed control in corn
Metribuzin	Sencor	as-triazine	Preemergent and postemergent weed control in potatoes
Pendimethalin	Prowl		Preplant incorporated for weed control in dry beans
Picloram	Tordon	Pyridyl	Non-cropland weed control
Pronamide	Kerb	Substituted amide	Preemergent weed control in alfalfa
Propachlor	Ramrod	Substituted amide	Preemergent weed control in various agronomic crops
Propazine	Milogard	s-triazine	Preemergent weed control in sorghum

Table 31. Common name, trade name, compound class, and typical application of pesticides commonly used in the South Platte River Basin--Continued

Common name	Trade name	Compound class	Typical application
		Herbicides--Continued	
Sethoxydim	Poast	Diphenoxy	Postemergent weed control in alfalfa
Simazine	Princep	s-triazine	Longterm soil sterilant
Terbutryn	Igran	s-triazine	Preemergent weed control in sorghum
Trifluralin	Treflan	Dinitroaniline	Preplant incorporated for various agronomic and horticultural crops
		Insecticides	
Carbaryl	Sevin	Carbamate	Corn, alfalfa, sugar beets, turf grass
Carbofuran	Furadan	Carbamate	Corn, alfalfa, sugar beets, potatoes, and others
Chlorpyrifos	Lorsban	Organophosphorus	Corn, onions, alfalfa, sugar beets, and others
Diazinon	Various names	Organophosphorus	Onions, cole crops, turf grass
Dimethoate	Cygon	Organophosphorus	Corn, alfalfa, small grains
Disulfoton	Di-Syston	Organophosphorus	Corn, cole crops, potatoes, small grains
Parathion-ethyl	Various names	Organophosphorus	Onions, alfalfa, small grains
Phorate	Thimet	Organophosphorus	Corn, sugar beets, potatoes
Propargite	Comite	Organosulfur	Corn
Terbufos	Counter	Organophosphorus	Corn, sugar beets

Table 32. Estimated chemical fertilizer application in the South Platte River Basin, water year 1991

[Values in tons per county; data from U.S. Environmental Protection Agency, 1990b]

County	Fertilizer						
	Nitrogen	Anhydrous ammonia	Phosphorus as P_2O_5	Nitrogen in solution	Potassium as K_2O	Ammonium nitrate	TOTAL
Colorado							
Adams	5,465	2,579	1,557	1,195	657	339	11,792
Arapahoe	414	195	118	90	50	26	893
Boulder	1,493	705	425	327	179	93	3,222
Clear Creek	5	2	1	1	1	0	10
Denver	0	0	0	0	0	0	0
Douglas	186	88	53	41	22	12	402
Elbert	703	332	200	154	84	44	1,517
El Paso	648	306	185	142	78	40	1,399
Gilpin	0	0	0	0	0	0	0
Jefferson	365	172	104	80	44	23	788
Larimer	3,894	1,837	1,110	852	468	242	8,403
Lincoln	3,444	1,625	981	753	414	214	7,431
Logan	7,869	3,713	2,242	1,721	945	489	16,979
Morgan	10,984	5,183	3,130	2,402	1,319	682	23,700
Park	188	89	54	41	23	12	407
Sedgwick	4,445	2,098	1,267	972	534	276	9,592
Teller	23	11	7	5	3	1	50
Washington	9,180	4,332	2,616	2,008	1,103	570	19,809
Weld	22,243	10,496	6,338	4,865	2,672	1,381	47,995
Nebraska							
Banner	1,871	1,218	374	437	88	34	4,022
Cheyenne	7,924	5,156	1,585	1,850	371	144	17,030
Deuel	2,834	1,844	567	662	133	51	6,091
Garden	3,211	2,089	642	750	150	58	6,900
Keith	8,196	5,333	1,639	1,913	384	148	17,613
Kimball	1,678	1,092	336	392	79	30	3,607
Lincoln	16,187	10,533	3,237	3,779	759	293	34,788
Perkins	12,215	7,948	2,443	2,852	572	221	26,251
Wyoming							
Albany	1,165	775	256	161	27	85	2,469
Laramie	5,269	3,508	1,159	729	122	382	11,169
TOTAL	132,099	73,259	32,626	29,174	11,281	5,890	

Table 33. Number of surface-water nutrient samples by site and decile of flow in the South Platte River Basin, water years 1980-92

Site no. (fig 9)	Site name	Decile of flow									
		1	2	3	4	5	6	7	8	9	10
	Total organic nitrogen plus ammonia, as nitrogen										
2	Tarryall Creek near Jefferson, Colorado	8	1	5	2	2	2	1	1	0	0
6	South Platte River at Littleton, Colorado	3	3	5	6	4	2	2	5	7	7
8	Bear Creek at Morrison, Colorado	1	1	1	2	2	0	0	0	0	0
15	Bear Creek at mouth at Sheridan, Colorado	1	1	2	0	0	0	0	0	0	0
22	Clear Creek at Golden, Colorado	1	3	1	1	4	1	1	2	0	0
26	South Platte River at Henderson, Colorado	1	2	6	3	5	1	5	2	0	0
30	Boulder Creek at mouth near Longmont, Colorado	1	2	1	5	2	0	0	0	0	0
33	Big Thompson River at Loveland, Colorado	6	3	7	9	10	7	10	6	11	13
38	North Fork Cache la Poudre River at Livermore, Colorado	3	7	7	3	5	15	5	8	5	0
41	Cache la Poudre River at Fort Collins, Colorado	2	4	5	9	10	11	12	10	13	12
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	1	5	6	9	9	13	14	9	13	11
45	South Platte River at Kersey, Colorado	1	0	0	0	0	0	0	0	0	0
51	South Platte River near Weldona, Colorado	1	2	3	3	1	2	1	0	0	0
53	South Platte River at Julesburg, Colorado	5	4	4	4	3	10	4	6	9	18
54	South Platte River at Roscoe, Nebraska	4	7	6	4	10	2	2	3	3	7
	Dissolved ammonia, as nitrogen										
6	South Platte River at Littleton, Colorado	2	3	5	6	4	3	2	5	7	8
26	South Platte River at Henderson, Colorado	1	2	6	3	5	1	5	2	0	0
27	St. Vrain Creek at Lyons, Colorado	3	4	3	3	1	1	2	0	0	0
29	St. Vrain Creek below Longmont, Colorado	1	2	1	1	1	5	2	2	2	0
30	Boulder Creek at mouth near Longmont, Colorado	1	2	1	5	2	0	0	0	0	0
33	Big Thompson River at Loveland, Colorado	13	8	20	16	14	13	13	10	16	13

Table 33. Number of surface-water nutrient samples by site and decile of flow in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig 9)	Site name	Decile of flow									
		1	2	3	4	5	6	7	8	9	10
	Dissolved ammonia, as nitrogen--Continued										
38	North Fork Cache la Poudre River at Livermore, Colorado	3	6	7	3	5	15	5	8	5	0
39	Cache la Poudre River at mouth of Canyon, Colorado	1	1	0	0	0	0	0	0	0	0
41	Cache la Poudre River at Fort Collins, Colorado	5	10	12	21	19	13	12	13	16	17
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	10	18	12	16	19	14	15	10	14	15
45	South Platte River at Kersey, Colorado	1	0	0	0	0	0	0	0	0	0
51	South Platte River near Weldona, Colorado	1	2	3	3	1	2	1	0	0	0
53	South Platte River at Julesburg, Colorado	5	4	4	4	3	10	4	6	9	18
	Dissolved nitrite, as nitrogen										
6	South Platte River at Littleton, Colorado	1	2	1	1	2	0	0	0	0	0
26	South Platte River at Henderson, Colorado	1	2	6	3	5	1	5	2	0	0
30	Boulder Creek at mouth near Longmont, Colorado	1	2	1	5	2	0	0	0	0	0
33	Big Thompson River at Loveland, Colorado	13	8	20	16	14	13	13	10	16	13
38	North Fork Cache la Poudre River at Livermore, Colorado	3	6	7	3	5	15	5	8	5	0
41	Cache la Poudre River at Fort Collins, Colorado	5	10	12	21	19	13	12	13	16	17
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	10	18	12	16	19	14	15	10	14	15
45	South Platte River at Kersey, Colorado	1	0	0	0	0	0	0	0	0	0
51	South Platte River near Weldona, Colorado	1	2	3	3	1	2	1	0	0	0
53	South Platte River at Julesburg, Colorado	2	1	3	2	1	5	1	3	5	5
	Dissolved nitrite plus nitrate, as nitrogen										
6	South Platte River at Littleton, Colorado	2	3	5	6	4	3	2	5	7	8
43	Clear Creek at Golden, Colorado	1	3	1	1	4	1	1	2	0	0

Table 33. Number of surface-water nutrient samples by site and decile of flow in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig 9)	Site name	Decile of flow									
		1	2	3	4	5	6	7	8	9	10
	Dissolved nitrite plus nitrate, as nitrogen--Continued										
26	South Platte River at Henderson, Colorado	1	2	6	3	5	1	5	2	0	0
27	St. Vrain Creek at Lyons, Colorado	3	4	3	3	1	1	2	0	0	0
29	St. Vrain Creek below Longmont, Colorado	1	2	1	1	1	5	2	2	2	0
30	Boulder Creek at mouth near Longmont, Colorado	3	6	4	8	5	14	13	22	18	12
31	St. Vrain Creek at mouth near Platteville, Colorado	1	2	2	4	2	4	5	8	6	3
33	Big Thompson River at Loveland, Colorado	13	8	17	10	6	7	6	9	14	7
36	Big Thompson River at mouth near La Salle, Colorado	1	1	1	3	3	6	2	10	10	0
38	North Fork Cache la Poudre River at Livermore, Colorado	3	6	7	3	5	15	5	8	4	0
39	Cache la Poudre River at mouth of Canyon, Colorado	2	8	5	5	4	1	3	3	5	0
41	Cache la Poudre River at Fort Collins, Colorado	4	9	12	17	14	6	7	8	8	11
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	11	16	12	12	17	6	7	3	9	10
44	Cache la Poudre River near Greeley, Colorado	1	2	5	3	1	5	6	2	4	8
45	South Platte River at Kersey, Colorado	1	1	2	4	3	3	0	0	0	0
51	South Platte River near Weldona, Colorado	5	8	7	6	4	11	9	15	24	22
53	South Platte River at Julesburg, Colorado	5	4	4	4	3	10	4	6	9	18
54	South Platte River at Roscoe, Nebraska	1	3	1	4	2	2	1	3	0	0
	Dissolved orthophosphate, as phosphorus										
6	South Platte River at Littleton, Colorado	1	2	3	4	2	1	4	6	5	0
26	South Platte River at Henderson, Colorado	1	2	6	3	5	1	5	2	0	0
30	Boulder Creek at mouth near Longmont, Colorado	2	2	1	5	2	0	0	0	0	0
33	Big Thompson River at Loveland, Colorado	5	3	1	3	3	3	1	2	0	0

Table 33. Number of surface-water nutrient samples by site and decile of flow in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig 9)	Site name	Decile of flow									
		1	2	3	4	5	6	7	8	9	10
	Dissolved orthophosphate, as phosphorus--Continued										
38	North Fork Cache la Poudre River at Livermore, Colorado	1	2	6	2	4	10	2	5	4	0
41	Cache la Poudre River at Fort Collins, Colorado	2	4	5	2	1	1	1	0	0	0
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	6	6	1	2	1	1	0	0	0	0
45	South Platte River at Kersey, Colorado	1	0	0	0	0	0	0	0	0	0
51	South Platte River near Weldona, Colorado	1	2	3	3	1	2	1	0	0	0
53	South Platte River at Julesburg, Colorado	2	3	3	2	2	7	2	3	6	11
54	South Platte River at Roscoe, Nebraska	1	0	0	0	0	0	0	0	0	0
	Dissolved Phosphorus, as Phosphorus										
2	Tarryall Creek near Jefferson, Colorado	9	1	5	2	2	2	1	1	0	0
6	South Platte River at Littleton, Colorado	2	3	5	6	4	3	2	5	7	8
22	Clear Creek at Golden, Colorado	1	3	1	1	4	1	1	2	0	0
26	South Platte River at Henderson, Colorado	1	2	5	3	5	1	5	2	0	0
27	St. Vrain Creek at Lyons, Colorado	1	0	0	0	0	0	0	0	0	0
30	Boulder Creek at mouth near Longmont, Colorado	3	6	4	8	5	15	11	21	19	12
31	St. Vrain Creek at mouth near Platteville, Colorado	1	2	2	4	2	4	5	8	6	3
33	Big Thompson River at Loveland, Colorado	7	4	8	9	10	9	12	8	11	13
36	Big Thompson River at mouth near La Salle, Colorado	1	1	1	3	3	6	2	10	10	0
38	North Fork Cache la Poudre River at Livermore, Colorado	1	2	6	2	4	10	2	5	4	0
39	Cache la Poudre River at mouth of Canyon, Colorado	2	7	4	5	4	1	3	4	5	0
41	Cache la Poudre River at Fort Collins, Colorado	2	6	5	10	14	12	12	11	13	14

Table 33. Number of surface-water nutrient samples by site and decile of flow in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig 9)	Site name	Decile of flow									
		1	2	3	4	5	6	7	8	9	10
	Dissolved phosphorus, as phosphorus–Continued										
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	3	8	7	11	11	14	14	9	13	12
44	Cache la Poudre River near Greeley, Colorado	1	2	5	3	1	5	6	2	4	8
45	South Platte River at Kersey, Colorado	1	1	2	3	3	3	0	0	0	0
51	South Platte River near Weldona, Colorado	5	7	7	6	4	11	9	15	23	22
53	South Platte River at Julesburg, Colorado	5	4	3	4	3	10	4	6	9	18
54	South Platte River at Roscoe, Nebraska	1	3	1	4	1	2	1	3	0	0
	Total phosphorus, as phosphorus										
2	Tarryall Creek near Jefferson, Colorado	8	1	5	2	2	2	1	1	0	0
6	South Platte River at Littleton, Colorado	2	3	5	6	4	2	2	5	7	8
8	Bear Creek at Morrison, Colorado	1	1	1	2	2	1	0	0	0	0
15	Bear Creek at mouth at Sheridan, Colorado	1	1	2	0	0	0	0	0	0	0
22	Clear Creek at Golden, Colorado	1	3	1	1	4	1	1	2	0	0
26	South Platte River at Henderson, Colorado	1	2	6	3	4	1	5	2	0	0
27	St. Vrain Creek at Lyons, Colorado	3	4	3	3	1	1	2	0	0	0
29	St. Vrain Creek below Longmont, Colorado	1	2	1	1	1	5	2	2	2	0
30	Boulder Creek at mouth near Longmont, Colorado	1	3	1	5	2	0	0	0	0	0
33	Big Thompson River at Loveland, Colorado	1	0	0	0	0	0	0	0	0	0
38	North Fork Cache la Poudre River at Livermore, Colorado	3	7	7	3	5	15	5	8	5	0
39	Cache la Poudre River at mouth of Canyon, Colorado	1	1	0	0	0	0	0	0	0	0
45	South Platte River at Kersey, Colorado	1	0	0	0	0	0	0	0	0	0
51	South Platte River near Weldona, Colorado	1	3	3	3	1	2	1	0	0	0
53	South Platte River at Julesburg, Colorado	5	4	4	4	3	10	4	6	9	18
54	South Platte River at Roscoe, Nebraska	4	7	6	4	10	2	2	3	3	7

Table 34. Number of surface-water nutrient samples by site and month in the South Platte River Basin, water years 1980-92

Site no. (fig. 9)	Site name	Month (1=January)											
		1	2	3	4	5	6	7	8	9	10	11	12
	Total organic nitrogen plus ammonia, as nitrogen												
2	Tarryall Creek near Jefferson, Colorado	2	2	2	2	2	2	2	2	2	2	2	0
3	South Platte River above Chatfield Reservoir, Colorado	1	5	2	1	6	10	9	8	6	6	1	0
4	Plum Creek above Chatfield Reservoir, Colorado	4	2	1	6	8	6	5	6	5	1	0	0
5	Chatfield Reservoir release, Colorado	1	5	2	2	6	10	9	7	6	6	1	0
6	South Platte River at Littleton, Colorado	6	2	6	2	6	1	7	1	7	2	6	1
8	Bear Creek at Morrison, Colorado	1	1	1	2	2	0	0	0	0	0	0	0
9	Bear Creek above Harriman Ditch confluence, Colorado	1	5	2	1	6	9	9	9	5	6	1	0
13	Turkey Creek above Bear Creek confluence, Colorado	1	5	2	1	6	10	9	9	5	6	1	0
15	Bear Creek at mouth at Sheridan, Colorado	1	2	1	1	1	1	1	0	0	0	0	0
16	Cherry Creek Reservoir inflow, Colorado	1	4	2	1	6	9	8	9	4	6	1	0
18	Cherry Creek at Denver, Colorado	1	1	0	0	0	0	0	0	0	0	0	0
19	South Platte River at Denver, Colorado	1	2	1	1	1	0	0	0	0	0	0	0
20	South Platte River near 64th Avenue, Denver, Colorado	6	6	6	6	5	5	5	5	3	5	5	5
22	Clear Creek at Golden, Colorado	1	2	1	2	2	1	4	1	1	0	0	0
24	South Platte River near 78th Avenue, Denver, Colorado	4	6	6	6	5	5	5	5	3	5	5	4

Table 34. Number of surface-water nutrient samples by site and month in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig. 9)	Site name	Month (1=January)											
		1	2	3	4	5	6	7	8	9	10	11	12
	Total organic nitrogen plus ammonia, as nitrogen--Continued												
25	South Platte River near 88th Avenue, Denver, Colorado	1	2	2	2	1	1	1	1	1	1	1	0
26	South Platte River at Henderson, Colorado	2	1	3	3	3	2	2	2	3	4	0	0
30	Boulder Creek at mouth near Longmont, Colorado	1	1	2	2	1	1	2	1	0	0	0	0
32	Big Thompson River above Loveland, Colorado	8	7	7	7	7	6	7	6	7	8	6	7
33	Big Thompson River at Loveland, Colorado	8	7	7	6	7	5	7	7	7	8	6	7
34	Big Thompson River below Loveland, Colorado	8	7	7	7	7	6	7	7	7	8	6	7
37	Cache la Poudre River near Fort Collins, Colorado	5	5	5	5	5	5	5	5	4	5	4	5
38	North Fork Cache la Poudre River at Livermore, Colorado	4	5	6	5	4	5	5	5	3	5	5	6
40	Cache la Poudre River at Shields Street, Fort Collins, Colorado	8	8	8	7	7	7	7	7	6	8	7	8
41	Cache la Poudre River at Fort Collins, Colorado	8	8	8	7	7	7	7	7	6	8	7	8
42	Cache la Poudre River below Fort Collins, Colorado	8	8	8	7	6	7	7	7	7	8	8	8
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	8	8	8	7	7	7	7	7	7	8	8	8
45	South Platte River at Kersey, Colorado	1	0	0	0	0	0	0	0	0	0	0	0
47	Crow Creek at Warren Air Force Base, Wyoming	4	1	5	4	4	1	0	0	0	0	0	0
48	Crow Creek near Cheyenne, Wyoming	2	1	1	3	1	3	1	1	3	1	0	0

Table 34. Number of surface-water nutrient samples by site and month in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig. 9)	Site name	Month (1=January)											
		1	2	3	4	5	6	7	8	9	10	11	12
	Total organic nitrogen plus ammonia, as nitrogen--Continued												
49	Crow Creek near Archer, Wyoming	2	2	1	1	1	0	0	0	0	0	0	0
51	South Platte River near Weldona, Colorado	1	2	1	3	3	3	0	0	0	0	0	0
52	Lodgepole Creek near Kimball, Nebraska	1	1	1	1	1	1	1	1	1	1	1	0
53	South Platte River at Julesburg, Colorado	2	5	9	4	3	11	2	5	9	3	8	7
54	South Platte River at Roscoe, Nebraska	4	4	4	4	4	4	4	4	4	4	4	4
	Dissolved ammonia, as nitrogen												
6	South Platte River at Littleton, Colorado	6	2	6	1	6	2	7	1	6	1	6	1
26	South Platte River at Henderson, Colorado	2	1	3	3	3	2	2	2	3	4	0	0
27	St. Vrain Creek at Lyons, Colorado	2	2	1	1	1	1	1	1	1	2	2	2
28	Left Hand Creek near Boulder, Colorado	2	2	1	1	1	1	1	1	1	2	2	2
29	St. Vrain Creek below Longmont, Colorado	2	2	1	1	1	1	1	1	1	2	2	2
30	Boulder Creek at mouth near Longmont, Colorado	1	1	2	2	1	1	2	1	0	0	0	0
32	Big Thompson River above Loveland, Colorado	12	11	12	13	11	10	12	11	11	11	10	12
33	Big Thompson River at Loveland, Colorado	12	11	12	12	11	10	12	11	11	12	11	12
34	Big Thompson River below Loveland, Colorado	12	11	12	13	11	11	12	10	11	11	10	12
35	Big Thompson River at Interstate Highway-25, Colorado	3	4	5	6	4	4	5	4	4	3	3	5

Table 34. Number of surface-water nutrient samples by site and month in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig. 9)	Site name	Month (1=January)											
		1	2	3	4	5	6	7	8	9	10	11	12
	Dissolved ammonia, as nitrogen--Continued												
37	Cache la Poudre River near Fort Collins, Colorado	5	5	5	5	5	5	5	5	4	5	5	5
38	North Fork Cache la Poudre River at Livermore, Colorado	4	5	6	5	4	5	5	5	3	4	5	6
39	Cache la Poudre River at mouth of Canyon, Colorado	1	1	0	0	0	0	0	0	0	0	0	0
40	Cache la Poudre River at Shields Street, Fort Collins, Colorado	11	13	13	12	12	11	12	12	8	12	13	13
41	Cache la Poudre River at Fort Collins, Colorado	11	13	12	11	12	12	11	11	9	11	12	13
42	Cache la Poudre River below Fort Collins, Colorado	11	13	13	12	11	11	12	12	10	12	13	13
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	11	13	13	12	12	11	12	12	10	11	13	13
45	South Platte River at Kersey, Colorado	1	0	0	0	0	0	0	0	0	0	0	0
51	South Platte River near Weldona, Colorado	1	2	1	3	3	3	0	0	0	0	0	0
53	South Platte River at Julesburg, Colorado	2	5	9	4	3	11	2	5	9	3	8	7
	Dissolved nitrite, as nitrogen												
6	South Platte River at Littleton, Colorado	1	1	1	1	1	1	1	0	0	0	0	0
20	South Platte River near 64th Avenue, Denver, Colorado	6	6	5	6	5	5	5	5	4	5	5	5
24	South Platte River near 78th Avenue, Denver, Colorado	4	6	6	6	5	5	5	5	4	5	5	4
25	South Platte River near 88th Avenue, Denver, Colorado	1	2	2	2	1	1	1	1	1	1	1	1
26	South Platte River at Henderson, Colorado	2	1	3	3	3	2	2	2	3	4	0	0

Table 34. Number of surface-water nutrient samples by site and month in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig. 9)	Site name	Month (1=January)											
		1	2	3	4	5	6	7	8	9	10	11	12
	Dissolved nitrite, as nitrogen–Continued												
30	Boulder Creek at mouth near Longmont, Colorado	1	1	2	2	1	1	2	1	0	0	0	0
32	Big Thompson River above Loveland, Colorado	12	11	12	13	11	10	12	11	11	11	10	12
33	Big Thompson River at Loveland, Colorado	12	11	12	12	11	10	12	11	11	12	11	12
34	Big Thompson River below Loveland, Colorado	12	11	12	13	11	11	12	10	11	11	10	12
35	Big Thompson River at Interstate Highway-25, Colorado	3	4	5	6	4	4	5	4	4	3	3	5
37	Cache la Poudre River near Fort Collins, Colorado	5	5	5	5	5	5	5	5	4	5	5	5
38	North Fork Cache la Poudre River at Livermore, Colorado	4	5	6	5	4	5	5	5	3	4	5	6
40	Cache la Poudre River at Shields Street, Fort Collins, Colorado	11	13	13	12	12	11	12	12	8	12	13	13
41	Cache la Poudre River at Fort Collins, Colorado	11	13	12	11	12	12	11	11	9	11	12	13
42	Cache la Poudre River below Fort Collins, Colorado	11	13	13	12	11	11	12	12	10	11	13	13
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	11	13	13	12	12	11	12	12	10	11	13	13
45	South Platte River at Kersey, Colorado	1	0	0	0	0	0	0	0	0	0	0	0
51	South Platte River near Weldona, Colorado	1	2	1	3	3	3	0	0	0	0	0	0
53	South Platte River at Julesburg, Colorado	2	4	1	1	6	2	4	5	3	0	0	0
	Dissolved nitrite plus nitrate, as nitrogen												
6	South Platte River at Littleton, Colorado	6	2	6	1	6	2	7	1	6	1	6	1

Table 34. Number of surface-water nutrient samples by site and month in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig. 9)	Site name	Month (1=January)											
		1	2	3	4	5	6	7	8	9	10	11	12
	Dissolved nitrite plus nitrate, as nitrogen--Continued												
22	Clear Creek at Golden, Colorado	1	2	1	2	2	1	4	1	1	0	0	0
26	South Platte River at Henderson, Colorado	2	1	3	3	3	2	2	2	3	4	0	0
27	St. Vrain Creek at Lyons, Colorado	2	2	1	1	1	1	1	1	1	2	2	2
28	Left Hand Creek near Boulder, Colorado	2	2	1	1	1	1	1	1	1	2	2	2
29	St. Vrain Creek below Longmont, Colorado	2	2	1	1	1	1	1	1	1	2	2	2
30	Boulder Creek at mouth near Longmont, Colorado	10	8	9	7	10	9	8	9	10	8	11	6
31	St. Vrain Creek at mouth near Platteville, Colorado	3	3	3	3	3	3	3	3	3	4	3	3
32	Big Thompson River above Loveland, Colorado	7	7	8	10	10	8	8	8	7	10	7	9
33	Big Thompson River at Loveland, Colorado	7	7	8	9	10	8	8	7	7	10	8	9
34	Big Thompson River below Loveland, Colorado	7	7	5	7	9	9	8	7	6	10	7	8
35	Big Thompson River at Interstate Highway-25, Colorado	3	4	5	6	4	4	5	4	3	4	3	4
36	Big Thompson River at mouth near La Salle, Colorado	3	3	3	3	3	3	3	3	3	4	3	3
37	Cache la Poudre River near Fort Collins, Colorado	5	5	5	5	5	5	5	5	4	5	5	5
38	North Fork Cache la Poudre River at Livermore, Colorado	4	5	6	5	4	4	5	5	3	4	5	6
39	Cache la Poudre River at mouth of Canyon, Colorado	3	3	3	3	3	3	2	3	3	4	3	3
40	Cache la Poudre River at Shields Street, Fort Collins, Colorado	6	8	8	8	12	8	9	8	6	11	8	9

Table 34. Number of surface-water nutrient samples by site and month in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig. 9)	Site name	Month (1=January)											
		1	2	3	4	5	6	7	8	9	10	11	12
	Dissolved nitrite plus nitrate, as nitrogen--Continued												
41	Cache la Poudre River at Fort Collins, Colorado	6	7	7	7	12	9	8	7	6	10	8	9
42	Cache la Poudre River below Fort Collins, Colorado	6	8	8	8	11	7	9	8	7	10	9	9
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	6	9	8	8	12	8	9	8	7	10	9	9
44	Cache la Poudre River near Greeley, Colorado	3	3	3	3	4	3	3	3	4	4	3	3
45	South Platte River at Kersey, Colorado	1	1	1	1	1	1	1	1	1	2	2	1
47	Crow Creek at Warren Air Force Base, Wyoming	1	1	0	0	0	0	0	0	0	0	0	0
51	South Platte River near Weldona, Colorado	9	9	10	10	8	11	9	7	11	9	12	8
52	Lodgepole Creek near Kimball, Nebraska	1	1	1	0	0	0	0	0	0	0	0	0
53	South Platte River at Julesburg, Colorado	2	5	9	4	3	11	2	5	9	3	8	7
54	South Platte River at Roscoe, Nebraska	4	1	4	4	4	0	0	0	0	0	0	0
	Dissolved orthophosphate, as phosphorus												
6	South Platte River at Littleton, Colorado	4	1	4	1	4	1	5	4	4	0	0	0
7	Upper Bear Creek near Evergreen Reservoir, Colorado	1	1	1	1	1	1	1	1	1	1	1	1
10	Lower Bear Creek near Bear Creek Reservoir, Colorado	1	1	1	1	1	1	1	1	1	1	1	1
11	Upper Turkey Creek near Twin Forks, Colorado	1	1	1	1	1	1	1	1	1	1	0	0
12	Lower Turkey Creek near Bear Creek Reservoir, Colorado	1	1	1	1	1	1	1	1	1	1	1	1

Table 34. Number of surface-water nutrient samples by site and month in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig. 9)	Site name	Month (1=January)											
		1	2	3	4	5	6	7	8	9	10	11	12
	Dissolved orthophosphate, as phosphorus--Continued												
20	South Platte River near 64th Avenue, Denver, Colorado	6	6	6	6	5	5	4	5	4	5	5	5
24	South Platte River near 78th Avenue, Denver, Colorado	4	6	6	6	5	5	4	5	4	5	5	4
25	South Platte River near 88th Avenue, Denver, Colorado	1	2	2	2	1	1	1	1	1	1	1	0
26	South Platte River at Henderson, Colorado	2	1	3	3	3	2	2	2	3	4	0	0
30	Boulder Creek at mouth near Longmont, Colorado	1	1	2	2	1	1	1	2	1	0	0	0
32	Big Thompson River above Loveland, Colorado	1	1	2	2	1	1	2	1	1	2	2	2
33	Big Thompson River at Loveland, Colorado	1	2	2	1	1	2	2	1	1	2	3	3
34	Big Thompson River below Loveland, Colorado	1	2	2	2	1	1	2	1	1	2	3	3
35	Big Thompson River at Interstate Highway-25, Colorado	1	1	2	2	1	1	1	1	1	1	2	2
37	Cache la Poudre River near Fort Collins, Colorado	1	0	0	0	0	0	0	0	0	0	0	0
38	North Fork Cache la Poudre River at Livermore, Colorado	2	4	4	3	3	3	3	3	2	3	3	3
40	Cache la Poudre River at Shields Street, Fort Collins, Colorado	1	2	2	1	1	1	2	1	2	2	2	0
41	Cache la Poudre River at Fort Collins, Colorado	1	2	2	1	1	1	2	1	1	2	2	0
42	Cache la Poudre River below Fort Collins, Colorado	1	2	2	1	1	1	2	1	1	2	2	0
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	1	2	2	2	1	1	2	1	1	2	2	0

Table 34. Number of surface-water nutrient samples by site and month in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig. 9)	Site name	Month (1=January)											
		1	2	3	4	5	6	7	8	9	10	11	12
	Dissolved orthophosphate, as phosphorus--Continued												
45	South Platte River at Kersey, Colorado	1	0	0	0	0	0	0	0	0	0	0	0
51	South Platte River near Weldona, Colorado	1	2	1	3	3	3	0	0	0	0	0	0
53	South Platte River at Julesburg, Colorado	3	7	2	1	8	3	7	6	5	0	0	0
54	South Platte River at Roscoe, Nebraska	1	0	0	0	0	0	0	0	0	0	0	0
	Dissolved phosphorus, as phosphorus												
2	Tarryall Creek near Jefferson, Colorado	2	2	2	2	2	2	2	2	2	1	2	2
6	South Platte River at Littleton, Colorado	6	2	6	1	6	2	7	1	6	1	6	1
7	Upper Bear Creek near Evergreen Reservoir, Colorado	1	1	1	1	1	1	1	1	1	1	1	1
10	Lower Bear Creek near Bear Creek Reservoir, Colorado	1	1	1	1	1	1	1	1	1	1	1	1
11	Upper Turkey Creek near Twin Forks, Colorado	1	1	1	1	1	1	1	1	1	1	0	0
12	Lower Turkey Creek near Bear Creek Reservoir, Colorado	1	1	1	1	1	1	1	1	1	1	1	1
22	Clear Creek at Golden, Colorado	1	2	1	2	2	1	4	1	1	0	0	0
26	South Platte River at Henderson, Colorado	2	1	3	3	3	2	2	2	3	3	0	0
27	St. Vrain Creek at Lyons, Colorado	1	0	0	0	0	0	0	0	0	0	0	0
28	Left Hand Creek near Boulder, Colorado	1	0	0	0	0	0	0	0	0	0	0	0
30	Boulder Creek at mouth near Longmont, Colorado	9	8	9	8	10	9	8	9	10	8	10	6

Table 34. Number of surface-water nutrient samples by site and month in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig. 9)	Site name	Month (1=January) 1	2	3	4	5	6	7	8	9	10	11	12
	Dissolved phosphorus, as phosphorus--Continued												
31	St. Vrain Creek at mouth near Platteville, Colorado	3	3	3	3	3	3	3	3	3	4	3	3
32	Big Thompson River above Loveland, Colorado	9	7	7	7	7	6	11	8	7	8	7	11
33	Big Thompson River at Loveland, Colorado	9	7	7	6	7	4	11	8	7	8	7	10
34	Big Thompson River below Loveland, Colorado	9	7	7	7	7	6	11	8	7	8	6	11
35	Big Thompson River at Interstate Highway-25, Colorado	2	4	1	4	0	0	0	0	0	0	0	0
36	Big Thompson River at mouth near La Salle, Colorado	3	3	3	3	3	3	3	3	3	4	3	3
37	Cache la Poudre River near Fort Collins, Colorado	5	5	5	5	5	5	5	5	4	5	5	5
38	North Fork Cache la Poudre River at Livermore, Colorado	2	4	4	3	3	3	3	3	2	3	3	3
39	Cache la Poudre River at mouth of Canyon, Colorado	3	3	3	3	3	3	3	3	3	3	2	3
40	Cache la Poudre River at Shields Street, Fort Collins, Colorado	9	10	10	7	7	9	10	7	7	8	8	9
41	Cache la Poudre River at Fort Collins, Colorado	9	10	10	7	7	8	9	8	6	8	8	9
42	Cache la Poudre River below Fort Collins, Colorado	9	10	10	7	6	8	10	7	8	8	8	9
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	9	10	10	7	7	9	10	7	8	8	8	9
44	Cache la Poudre River near Greeley, Colorado	3	3	3	3	3	3	3	3	3	4	3	3
45	South Platte River at Kersey, Colorado	1	1	1	1	1	1	1	1	1	2	1	1

Table 34. Number of surface-water nutrient samples by site and month in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig. 9)	Site name	Month (1=January)											
		1	2	3	4	5	6	7	8	9	10	11	12
	Dissolved phosphorus, as phosphorus--Continued												
51	South Platte River near Weldona, Colorado	8	9	10	10	7	11	9	7	11	9	11	8
52	Lodgepole Creek near Kimball, Nebraska	1	1	1	0	0	0	0	0	0	0	0	0
53	South Platte River at Julesburg, Colorado	2	5	9	4	3	11	2	5	9	3	7	7
54	South Platte River at Roscoe, Nebraska	4	4	4	4	0	0	0	0	0	0	0	0
	Total phosphorus, as phosphorus												
1	Antero Reservoir Outlet at South Platte River, Colorado	3	1	1	2	0	0	0	0	0	0	0	0
2	Tarryall Creek near Jefferson, Colorado	2	2	2	2	2	2	2	2	2	2	2	0
3	South Platte River above Chatfield Reservoir, Colorado	1	5	2	1	6	10	9	8	6	6	1	0
4	Plum Creek above Chatfield Reservoir, Colorado	4	2	1	6	8	6	5	6	5	1	0	0
5	Chatfield Reservoir release, Colorado	1	5	2	2	6	10	9	7	6	6	1	0
6	South Platte River at Littleton, Colorado	5	2	6	2	6	2	7	1	6	1	6	1
7	Upper Bear Creek near Evergreen Reservoir, Colorado	1	1	1	1	1	1	1	1	1	1	1	1
8	Bear Creek at Morrison, Colorado	1	1	2	2	2	0	0	0	0	0	0	0
9	Bear Creek above Harriman Ditch confluence, Colorado	1	5	2	1	6	10	9	9	5	6	1	0
10	Lower Bear Creek near Bear Creek Reservoir, Colorado	1	1	1	1	1	1	1	1	1	1	1	0
12	Lower Turkey Creek near Bear Creek Reservoir, Colorado	1	1	1	1	1	1	1	1	1	1	1	1
13	Turkey Creek above Bear Creek confluence, Colorado	1	5	2	1	6	10	9	9	5	6	1	0

Table 34. Number of surface-water nutrient samples by site and month in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig. 9)	Site name	Month (1=January)											
		1	2	3	4	5	6	7	8	9	10	11	12
	Total phosphorus, as phosphorus--Continued												
15	Bear Creek at mouth at Sheridan, Colorado	1	1	1	1	0	0	0	0	0	0	0	0
16	Cherry Creek Reservoir inflow, Colorado	1	4	2	1	6	9	8	9	4	6	1	0
18	Cherry Creek at Denver, Colorado	2	2	2	2	0	0	0	0	0	0	0	0
19	South Platte River at Denver, Colorado	1	1	0	0	0	0	0	0	0	0	0	0
22	Clear Creek at Golden, Colorado	1	2	1	2	2	1	4	1	1	0	0	0
26	South Platte River at Henderson, Colorado	2	1	3	3	2	2	2	2	3	4	0	0
27	St. Vrain Creek at Lyons, Colorado	2	2	1	1	1	1	1	1	1	2	2	2
28	Left Hand Creek near Boulder, Colorado	2	2	1	1	1	1	1	1	1	2	2	2
29	St. Vrain Creek below Longmont, Colorado	2	2	1	1	1	1	1	1	1	2	2	2
30	Boulder Creek at mouth near Longmont, Colorado	1	1	2	2	1	2	2	1	0	0	0	0
32	Big Thompson River above Loveland, Colorado	1	0	0	0	0	0	0	0	0	0	0	0
33	Big Thompson River at Loveland, Colorado	1	0	0	0	0	0	0	0	0	0	0	0
34	Big Thompson River below Loveland, Colorado	1	1	0	0	0	0	0	0	0	0	0	0
38	North Fork Cache la Poudre River at Livermore, Colorado	4	5	6	5	4	5	5	5	3	5	5	6
39	Cache la Poudre River at mouth of Canyon, Colorado	1	1	0	0	0	0	0	0	0	0	0	0
45	South Platte River at Kersey, Colorado	1	0	0	0	0	0	0	0	0	0	0	0

Table 34. Number of surface-water nutrient samples by site and month in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig. 9)	Site name	Month (1=January)											
		1	2	3	4	5	6	7	8	9	10	11	12
	Total phosphorus, as phosphorus--Continued												
47	Crow Creek at Warren Air Force Base, Wyoming	4	1	5	4	4	1	0	0	0	0	0	0
48	Crow Creek near Cheyenne, Wyoming	2	1	1	3	1	3	1	1	3	1	0	0
49	Crow Creek near Archer, Wyoming	2	2	1	1	1	0	0	0	0	0	0	0
51	South Platte River near Weldona, Colorado	1	2	1	3	1	3	3	0	0	0	0	0
52	Lodgepole Creek near Kimball, Nebraska	1	1	1	1	1	1	1	1	1	1	1	0
53	South Platte River at Julesburg, Colorado	2	5	9	4	3	11	2	5	9	3	8	7
54	South Platte River at Roscoe, Nebraska	4	4	4	4	4	4	4	4	4	4	4	4

Table 35. Regression coefficients and associated probability values of models used to estimate nutrient loads for selected sites in the South Platte River Basin, water years 1980-92

[no., number; Ln (CQ) = I + a(Ln Q) + bt + c(sine t) + d(cosine t): where Ln is natural logarithm; C is concentration, in milligrams per liter; Q is discharge, in cubic feet per second; I is the regression intercept; t is time; and a, b, c, and d are regression coefficients]

Site no. (fig. 9)	Site name	I	Regression coefficients				Probability values for regression coefficients			
			a	b	c	d	a	b	c	d
	Total organic nitrogen plus ammonia, as nitrogen									
6	South Platte River at Littleton, Colorado	5.9769	0.9747	-0.0785	0.1195	-0.2101	0.0000	0.0125	0.1876	0.0682
33	Big Thompson River at Loveland, Colorado	4.1648	0.8399	-0.1122	-0.0212	-0.2854	0.0000	0.0000	0.7542	0.0003
41	Cache la Poudre River at Fort Collins, Colorado	4.5909	0.9526	-0.0196	0.1388	-0.0857	0.0000	0.6299	0.2480	0.5450
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	5.3284	0.9824	-0.0687	-0.0440	0.2072	0.0000	0.0046	0.5413	0.0097
53	South Platte River at Julesburg, Colorado	6.9099	1.1866	-0.0522	-0.1055	-0.0944	0.0000	0.0000	0.1201	0.1533
54	South Platte River at Roscoe, Nebraska	7.0763	1.1055	0.0880	0.0406	-0.0424	0.0000	0.0762	0.6318	0.5924
	Dissolved ammonia, as nitrogen									
6	South Platte River at Littleton, Colorado	3.5767	0.8313	-0.0765	0.1601	-0.1717	0.0000	0.1999	0.3706	0.3879
33	Big Thompson River at Loveland, Colorado	1.3960	0.7079	-0.1521	0.1972	-0.0509	0.0000	0.0000	0.0774	0.7109
41	Cache la Poudre River at Fort Collins, Colorado	1.7049	0.9806	-0.1213	0.1976	0.0074	0.0000	0.0000	0.0182	0.9369
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	3.1267	1.0863	-0.0967	0.0002	0.6555	0.0000	0.0000	0.9982	0.0000
53	South Platte River at Julesburg, Colorado	4.3839	0.8640	-0.1106	0.0350	0.8229	0.0000	0.0012	0.8421	0.0000
	Dissolved nitrite, as nitrogen									
33	Big Thompson River at Loveland, Colorado	-0.5409	0.7499	-0.0566	0.0123	-0.3016	0.0000	0.0014	0.8701	0.0007
41	Cache la Poudre River at Fort Collins, Colorado	0.2324	0.9553	-0.0287	0.0525	0.1515	0.0000	0.0380	0.4165	0.0713
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	1.1918	0.8818	-0.0750	-0.3301	0.0561	0.0000	0.0000	0.0000	0.4793

Table 35. Regression coefficients and associated probability values of models used to estimate nutrient loads for selected sites in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig. 9)	Site name	I	Regression coefficients				Probability values for regression coefficients			
			a	b	c	d	a	b	c	d
	Dissolved nitrite plus nitrate, as nitrogen									
6	South Platte River at Littleton, Colorado	4.9528	0.6414	-0.0297	0.6818	0.4418	0.0000	0.5115	0.0000	0.0133
30	Boulder Creek at mouth near Longmont, Colorado	4.4031	1.1322	0.0732	-0.1532	0.5094	0.0000	0.0014	0.1108	0.0000
31	St.Vrain Creek at mouth near Platteville, Colorado	7.3707	0.5870	-0.0618	-0.1754	-0.0427	0.0000	0.1913	0.0010	0.4511
33	Big Thompson River at Loveland, Colorado	3.1313	0.8041	-0.1506	0.0836	0.5572	0.0000	0.0000	0.2305	0.0000
41	Cache la Poudre River at Fort Collins, Colorado	3.4938	0.6767	-0.0387	0.1836	0.6835	0.0000	0.0063	0.0172	0.0000
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	4.8007	0.6880	-0.1179	-0.1106	0.5704	0.0000	0.0000	0.0875	0.0000
44	Cache la Poudre River near Greeley	7.0334	0.6791	-0.0952	-0.0276	0.2782	0.0000	0.2120	0.7024	0.0005
51	South Platte River near Weldona, Colorado	8.7644	0.9523	0.0207	0.0327	0.4520	0.0000	0.0214	0.4074	0.0000
53	South Platte River at Julesburg, Colorado	7.5017	1.0932	0.0482	0.3126	0.6548	0.0000	0.0026	0.0006	0.0000
	Dissolved phosphorus, as phosphorus									
6	South Platte River at Littleton, Colorado	2.4071	0.9003	0.1329	0.0414	-0.0188	0.0000	0.0016	0.7436	0.8984
30	Boulder Creek at mouth near Longmont, Colorado	3.5469	1.0363	0.0634	0.2394	0.9455	0.0000	0.0267	0.0452	0.0000
31	St.Vrain Creek at mouth near Platteville, Colorado	5.4373	0.7074	0.1162	0.1658	0.5199	0.0000	0.0567	0.0133	0.0000
33	Big Thompson River at Loveland, Colorado	0.8724	0.8425	-0.0343	0.0046	-0.0622	0.0000	0.1867	0.9662	0.6148
41	Cache la Poudre River at Fort Collins, Colorado	1.1855	0.9222	-0.0374	0.0467	-0.0923	0.0000	0.2746	0.7065	0.5055
43	Cache la Poudre River above Box Elder Creek near Timnath, Colorado	2.9312	1.2913	-0.0515	-0.3286	0.8528	0.0000	0.2686	0.0519	0.0000

Table 35. Regression coefficients and associated probability values of models used to estimate nutrient loads for selected sites in the South Platte River Basin, water years 1980-92--Continued

Site no. (fig. 9)	Site name	I	Regression coefficients				Probability values for regression coefficients			
			a	b	c	d	a	b	c	d
	Dissolved phosphorus, as phosphorus--Continued									
44	Cache la Poudre River near Greeley, Colorado	4.9272	0.6580	-0.1414	0.1321	0.3818	0.0000	0.1941	0.2090	0.0009
51	South Platte River near Weldona, Colorado	6.4218	1.2755	0.0358	0.2255	0.6163	0.0000	0.0865	0.0142	0.0000
53	South Platte River at Julesburg, Colorado	4.6464	1.3477	0.0133	0.5752	0.4237	0.0000	0.4917	0.0000	0.0001
	Dissolved orthophosphate, as phosphorus									
53	South Platte River at Julesburg, Colorado	4.3598	1.4278	0.0460	0.4951	0.4601	0.0000	0.1792	0.0007	0.0033
	Total phosphorus, as phosphorus									
6	South Platte River at Littleton, Colorado	3.0966	0.9489	0.0652	0.3365	-0.1219	0.0000	0.2389	0.0500	0.5733
53	South Platte River at Julesburg, Colorado	5.2386	1.4270	0.0015	0.2286	0.0521	0.0000	0.9204	0.0076	0.5215
54	South Platte River at Roscoe, Nebraska	5.3474	1.2043	-0.1144	0.2221	-0.0494	0.0000	0.1170	0.0803	0.6718

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