WATER-QUALITY ASSESSMENT OF THE RIO GRANDE VALLEY STUDY UNIT, COLORADO, NEW MEXICO, AND TEXAS--ANALYSIS OF SELECTED NUTRIENT, SUSPENDED-SEDIMENT, AND PESTICIDE DATA

By S.K. Anderholm, M.J. Radell, and S.F. Richey

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 94-4061

A contribution to the

NATIONAL WATER-QUALITY ASSESSMENT

Albuquerque, New Mexico

1995

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch	0.02540	meter
foot	0.3048	meter
mile	1.609	kilometer
acre	4,047	square meter
square mile	2.590	square kilometer
cubic foot	0.02832	cubic meter
	7.48	gallon
cubic foot per second	0.02832	cubic meter per second
gallon per day	0.003785	cubic meter per day
acre-foot	0.001233	cubic hectometer
acre-foot per year	0.0013803	cubic foot per second
pound	453.6	gram
ton	907.2	kilogram

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

$$^{\circ}C = (^{\circ}F - 32) / 1.8$$

Use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

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

WATER-QUALITY ASSESSMENT OF THE RIO GRANDE VALLEY STUDY UNIT, COLORADO, NEW MEXICO, AND TEXAS--ANALYSIS OF SELECTED NUTRIENT, SUSPENDED-SEDIMENT, AND PESTICIDE DATA

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ABSTRACT

This report contains a summary of data compiled from sources throughout the Rio Grande Valley study unit of the National Water-Quality Assessment program. Information presented includes the sources and types of water-quality data available, the utility of water-quality data for statistical analysis, and a description of recent water-quality conditions and trends and their relation to natural and human factors. Water-quality data are limited to concentrations of selected nutrient species in surface water and ground water, concentrations of suspended sediment and suspended solids in surface water, and pesticides in surface water, ground water, and biota.

The Rio Grande Valley study unit includes about 45,900 square miles in Colorado, New Mexico, and Texas upstream from the streamflow-monitoring station Rio Grande at El Paso, Texas. The area also includes the San Luis Closed Basin and the surface-water closed basins east of the Continental Divide and north of the United States-Mexico international border. The Rio Grande drains about 29,300 square miles in these States; the remainder of the study unit area is in closed basins.

Concentrations of all nutrients found in surface-water samples collected from the Rio Grande, with the exception of phosphorus, generally remained nearly constant from the northernmost station in the study unit to Rio Grande near Isleta, where concentrations were larger by an order of magnitude. Total nitrogen and total phosphorus loads increased downstream between Lobatos, Colorado, and Albuquerque, New Mexico. Nutrient concentrations remained elevated with slight variations until downstream from Elephant Butte Reservoir, where nutrient concentrations were lower. Nutrient concentrations then increased downstream from the reservoir, as evidenced by elevated concentrations at Rio Grande at El Paso, Texas.

Suspended-sediment concentrations were similar at stations upstream from Otowi Bridge near San Ildefonso, New Mexico. The concentration and estimated load were nearly two orders of magnitude larger at this station relative to upstream stations. Cochiti Lake allows suspended sediment to settle, thus the resulting concentration is substantially lower downstream from the reservoir. Downstream from Cochiti Lake, concentrations again increased due to inflow from tributaries, other ephemeral streams and arroyos, and agricultural and urban areas. Two ephemeral tributaries (Rio Puerco and Rio Salado, which are south of Albuquerque) contribute substantial amounts of suspended sediment to the Rio Grande. Suspended-sediment concentrations in the Rio Grande just downstream from Elephant Butte Dam decreased by nearly three orders of magnitude due to settling in the reservoir. Concentrations then increased due to agricultural and urban impacts downstream from the reservoir.

Nutrients in ground water in the study unit do not appear to be a widespread problem. However, localized areas that have elevated nitrate concentrations have been documented. The largest median nitrate concentration was found in water from wells located in the Basin and Range-mountains-urban data stratum (3.0 milligrams per liter) and the smallest median nitrate concentration was found in water from wells located in the Southern Rocky Mountains-mountains-forest data stratum (0.08 milligram per liter). Few (3 percent) nitrate concentrations in water from wells in all data strata were greater than 10 milligrams per liter, and most (82 percent) were less than 2 milligrams per liter. Comparison of nitrate concentrations in water from wells located in specific land-use settings across all hydrogeologic settings, with the exception of the Colorado Plateau, indicated that the largest median nitrate concentration was associated with rangeland land use and that larger nitrate concentrations were found in water from shallow wells. Water from wells located in areas of rangeland land use consistently had larger median nutrient concentrations than water from wells in areas of other land uses.

The largest median ammonia concentration was in water from wells located in the Colorado Plateau-San Juan Basin-rangeland data stratum (0.27 milligram per liter). Most median ammonia concentrations were less than 0.03 milligram per liter, indicating that elevated ammonia concentrations are not a major issue in the study unit.

The largest median orthophosphate concentration was found in water from wells located in the Southern Rocky Mountains-mountains-forest data stratum (0.15 milligram per liter) and the smallest was found in water from wells located in the Basin and Range-mountains-urban data stratum (0.02 milligram per liter). Most orthophosphate concentrations (85 percent) sampled were less than 0.2 milligram per liter, indicating that elevated orthophosphate concentrations are not a major issue in the study unit.

Pesticide analyses were available for only 38 ground-water sampling sites in the Rio Grande Valley study unit. Diazinon, at a concentration of 0.01 microgram per liter, was the only pesticide detected and it was detected at only one site. More study is needed to determine if pesticides are affecting ground-water quality in the Rio Grande Valley study unit.

Surface-water biological pesticide data were inadequate for in-depth analysis. The primary sources of data were the U.S. Fish and Wildlife Service and the U.S. Geological Survey. In the U.S. Fish and Wildlife Service study p,p'-DDE, a degradation product of DDT, was detected most frequently; highest concentrations were found at Stahman Farms in carp (6.3 micrograms per gram wet-weight) and at Hatch in Western kingbird (5.1 micrograms per gram wet-weight). In the U.S. Geological Survey study of Bosque del Apache National Wildlife Refuge no detectable organochlorine concentrations were found in plants, but detectable levels of p,p'-DDE were found in coot and carp, with a maximum concentration of 0.12 microgram per gram wet-weight found in coot.

INTRODUCTION

The National Water-Quality Assessment (NAWQA) program began in 1986 when Congress appropriated funds for the U.S. Geological Survey to address a variety of water-quality issues that include chemical contamination, salinity, sedimentation, and sanitary quality. In 1986, seven pilot studies were initiated. In 1991, when these pilot studies were near completion, the U.S. Geological Survey began implementing a full-scale NAWQA program. The Rio Grande Valley study unit was one of 20 studies throughout the Nation selected to begin assessment activities.

Purpose and Scope

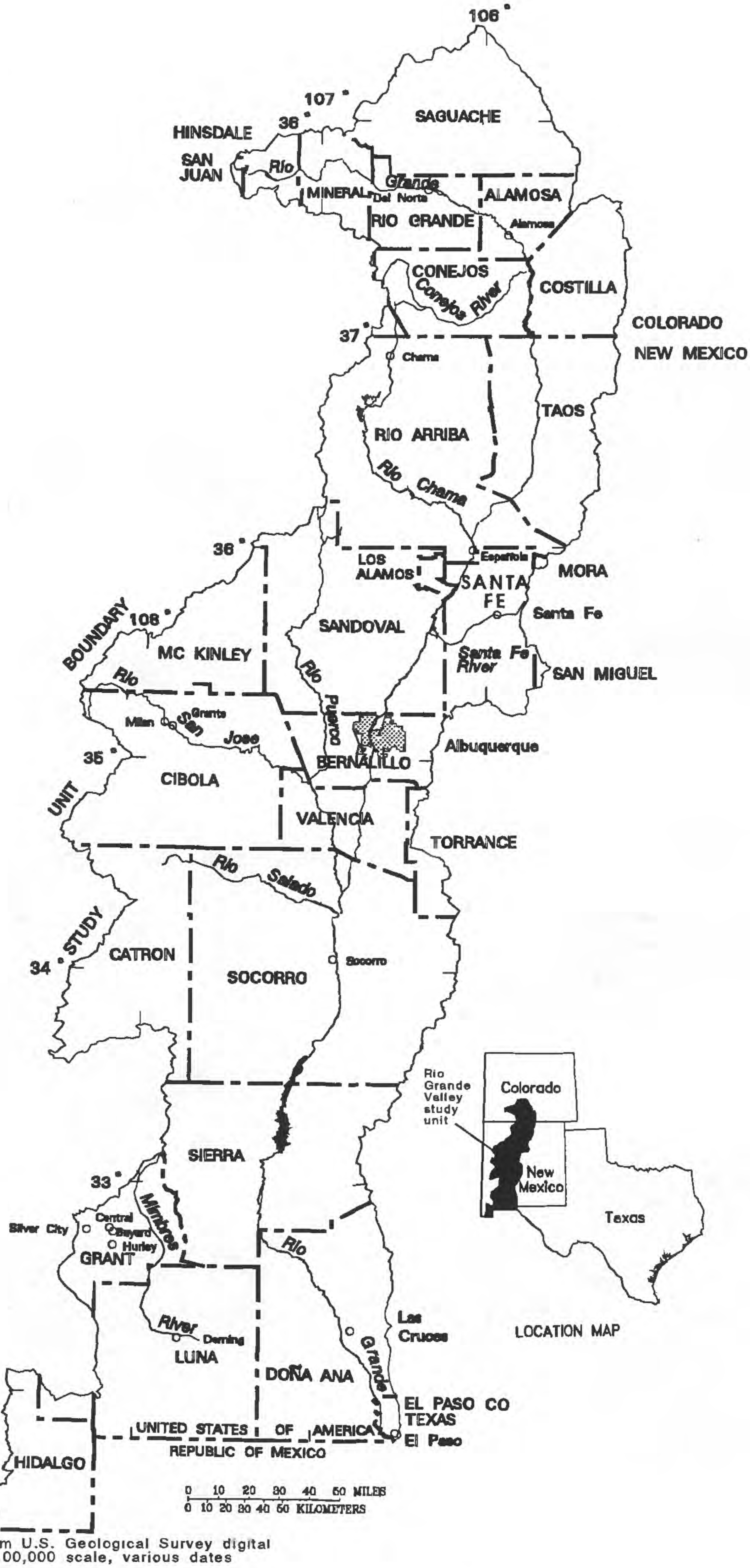
The purposes of this report are to (1) describe the spatial and temporal availability of nutrients, suspended-sediment (or suspended-solids), and pesticides data in the Rio Grande Valley study unit, and (2) present and evaluate the spatial and temporal patterns of concentrations and loads within the study unit. This report contains a summary of data compiled from a variety of sources. Information presented includes the sources and types of water-quality data available, the utility of water-quality data for statistical analysis, and a description of recent water-quality conditions and trends and their relation to natural and human factors. Water-quality data are limited to selected nutrients in surface water and ground water, suspended sediment and suspended solids in surface water, and pesticides in surface water, ground water, and biota.

Acknowledgments

The authors thank the various companies; Federal, State and local agencies; and members of the Rio Grande Valley Liaison Committee for their cooperation in providing information and data used in this report. Specifically, we thank the City of Albuquerque, Colorado Department of Health, Colorado Department of Water Resources, International Boundary and Water Commission, New Mexico Environment Department, New Mexico Water Resources Research Institute, Los Alamos National Laboratory, Colorado State University, Elephant Butte Irrigation District, San Luis Valley Analytical, Bureau of Land Management, Bureau of Reclamation, U.S. Environmental Protection Agency Regions VI and VIII, U.S. Fish and Wildlife Service, U.S. Forest Service, U.S. Geological Survey Geologic Division, and the U.S. Soil Conservation Service.

DESCRIPTION OF THE RIO GRANDE VALLEY STUDY UNIT

The Rio Grande Valley study unit includes about 45,900 square miles (mi^2) in Colorado, New Mexico, and Texas upstream from the streamflow-monitoring station Rio Grande at El Paso, Texas. The area includes the San Luis Closed Basin and the surface-water closed basins east of the Continental Divide and north of the United States-Mexico international border. The Rio Grande drains about 29,300 mi^2 in these States; the remainder of the study unit is in closed basins. Eighty-three percent of the study unit is in New Mexico, 16 percent is in Colorado, and less than 1 percent is in Texas (fig. 1; pl. 1).



Base from U.S. Geological Survey digital data, 1:100,000 scale, various dates

Albers projection, Spheroid Clarke 1866,
Standard parallels 29°30' and 45°30'
Central meridian -96°00'

Figure 1.--General location of the Rio Grande Valley study unit.

Physiography

The Rio Grande Valley study unit includes three physiographic provinces: (1) Southern Rocky Mountains Province, (2) Colorado Plateau Province, and (3) Basin and Range Province (pl. 1). A physiographic province is a region with a unified geomorphic history, thus all parts are similar in geologic structure and climate (Bates and Jackson, 1980). Although physiographic provinces encompass large regions, most provinces also contain smaller areas of localized geologic and climatic differences.

Areas of the study unit in the Southern Rocky Mountains Province include the San Luis Basin and surrounding mountains and the area south to approximately the confluence of the Jemez River and the Rio Grande (pl. 1). This province consists primarily of mountains composed of igneous, volcanic, and sedimentary rocks adjacent to alluvial valleys. In this province, the mountains define the eastern boundary of the study unit. The mountains are rugged and have significant relief above the alluvial valleys. Glacial processes have shaped many of the mountains and valleys in this province (there are many sharp mountain ridges and U-shaped valleys). In the mountains soils are shallow or nonexistent and spruce, pine, and aspen trees are common. Sagebrush and low grasses are common in the valleys. Many streams exist in the mountains because of the large quantity of precipitation.

Areas of the study unit in the Colorado Plateau Province are generally south and west of the Southern Rocky Mountains Province and north and west of the Basin and Range Province (pl. 1). The two main distinguishing features of the Colorado Plateau Province are the regional horizontality of the rocks and the high altitude (generally greater than 5,000 feet (ft)) (Fenneman, 1931). Rocks range in age from Mississippian to Tertiary. Although the rock strata are relatively flat-lying, erosion has greatly dissected the topography and there are areas of local uplift. The area is a succession of low mesas and erosional valleys resulting from the erosion of rocks with different resistances to weathering in an arid climate. In the higher altitudes, ponderosa pine trees are common, but throughout most of the area scattered piñon, juniper trees, and low bushes are the most common vegetation. Most of the area has little grass. Many ephemeral stream channels but few perennial streams are in this area.

The remainder of the study unit is in the Basin and Range Province (pl. 1). This province is characterized by alternating, roughly parallel mountain ranges and alluvial basins. The mountain ranges originate from uplifted fault blocks or volcanic activity. In this province, the entire east side of the study unit is defined by a line of mountains that are uplifted fault blocks as much as 10 miles (mi) wide and more than 10,000 ft in altitude. West of this line of mountains, the Rio Grande Valley is a structural graben (referred to as the Rio Grande Rift) that has a maximum stratigraphic displacement of more than 20,000 ft, measured from the bottom of the graben to the top of the mountains immediately east of Albuquerque (Hawley, 1978). Little vegetation grows in the area with the exception of the mountains where pine trees and low shrubs are common. A few perennial streams are in the mountains, but in general the entire area is drained by ephemeral channels that flow only in response to snowmelt and intense rainfall.

Climate

The climatic differences from the headwaters of the Rio Grande to El Paso are extreme. The Rio Grande and its tributaries span an altitude range of more than 9,000 ft and traverse several climatological zones, from alpine tundra to Sonoran desert. In the northern part of the study unit temperatures typically range from minus 30 ^{o}F in December and January to more than 90 ^{o}F during the summer. In the southern part of the study unit, temperatures typically range from 40 ^{o}F to more than 100 ^{o}F. Mean daily temperature ranges from less than 25 ^{o}F in January in the northern mountains to greater than 75 ^{o}F in July in the central part of the study unit.

Precipitation varies with many factors, including long-term weather patterns (producing drought or above-average precipitation over multiyear periods), seasonal effects, and spatial effects. Seasonal effects include increased precipitation during the summer months due to heat that causes thermal gradients and updrafts, which produce thunderstorms. The source of moisture also has a seasonal pattern. In the winter, storm tracks usually bring in cold air and moisture from the north, producing snow. In the summer, warm air and moisture usually come from the Pacific Ocean to the southwest or from the Gulf of Mexico to the southeast. In average years, approximately 70-80 percent of precipitation occurs from May through October, and 20-30 percent occurs from November through April (fig. 2). Mean monthly precipitation varies greatly from month to month and from site to site (fig. 2). Primary spatial effects include orographically induced precipitation and rain shadows and a decrease in precipitation to the south because of general weather patterns and lower altitudes. All of these factors cause mean annual precipitation to vary widely throughout the study unit and over relatively short distances. For example, near Alamosa, Colo., mean annual precipitation is less than 7 inches (in.), whereas less than 75 mi to the west in the headwaters of the Rio Grande, mean annual precipitation exceeds 50 in. Extremes in mean annual precipitation range from more than 50 in. in the headwaters of the Rio Grande to less than 6 in. south of Albuquerque (fig. 3).

Runoff varies with many factors, including amount of precipitation, soil type, temperature, amount and type of vegetation, and slope of the land. Mean annual runoff, reflecting the variability of these factors in the study unit, ranges from more than 30 in. southwest of Alamosa to less than 0.1 in. near Las Cruces (fig. 4). In general, runoff is greater in the mountainous areas than in the nonmountainous areas, and decreases to the south. Potential evapotranspiration ranges from less than 35 in. per year in the northern mountains to more than 80 in. per year in the southern part of the study unit (fig. 5). In most of the study unit, potential evapotranspiration greatly exceeds precipitation.

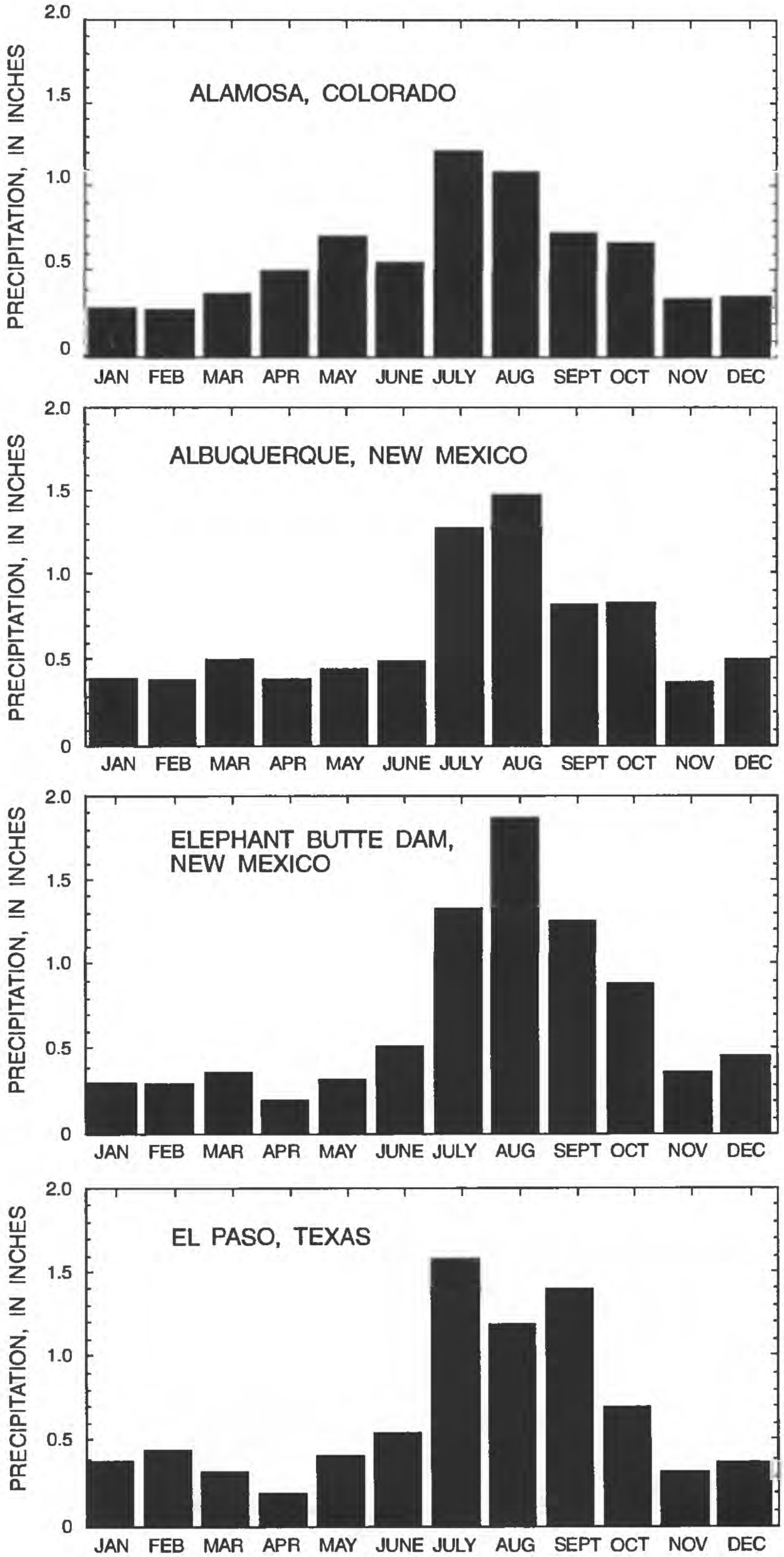


Figure 2.--Mean monthly precipitation for selected sites in the Rio Grande Valley study unit, 1951-80.

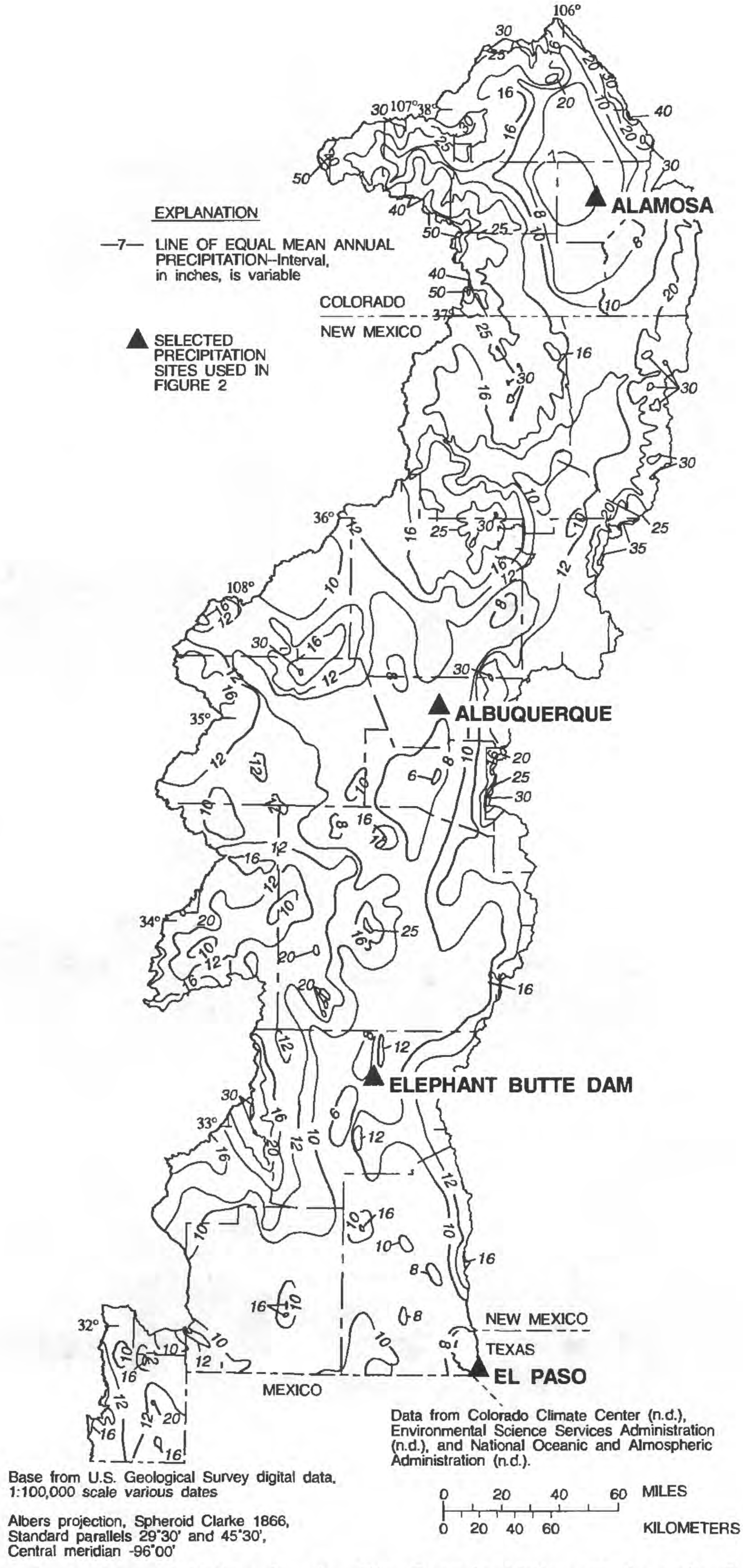


Figure 3.--Mean annual precipitation for the Rio Grande Valley study unit: Colorado, 1951-80; New Mexico, 1931-60.

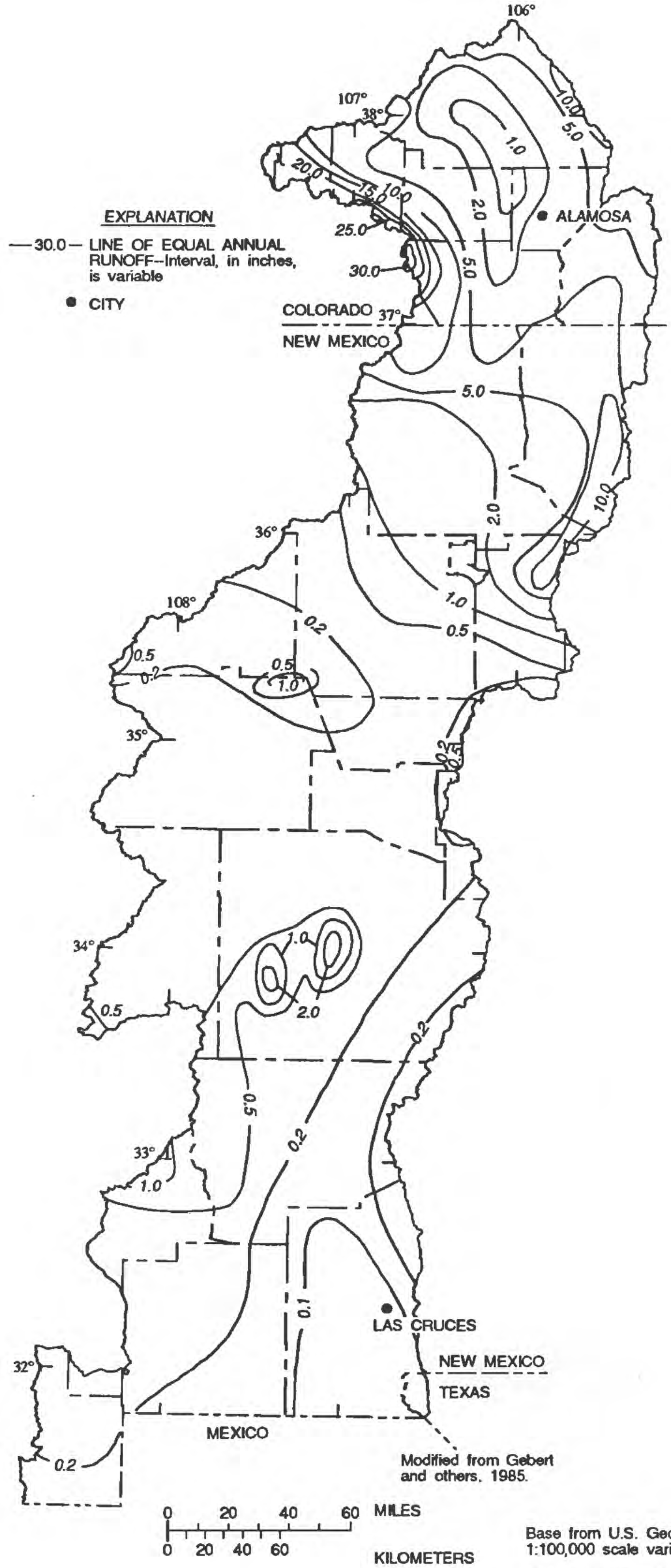
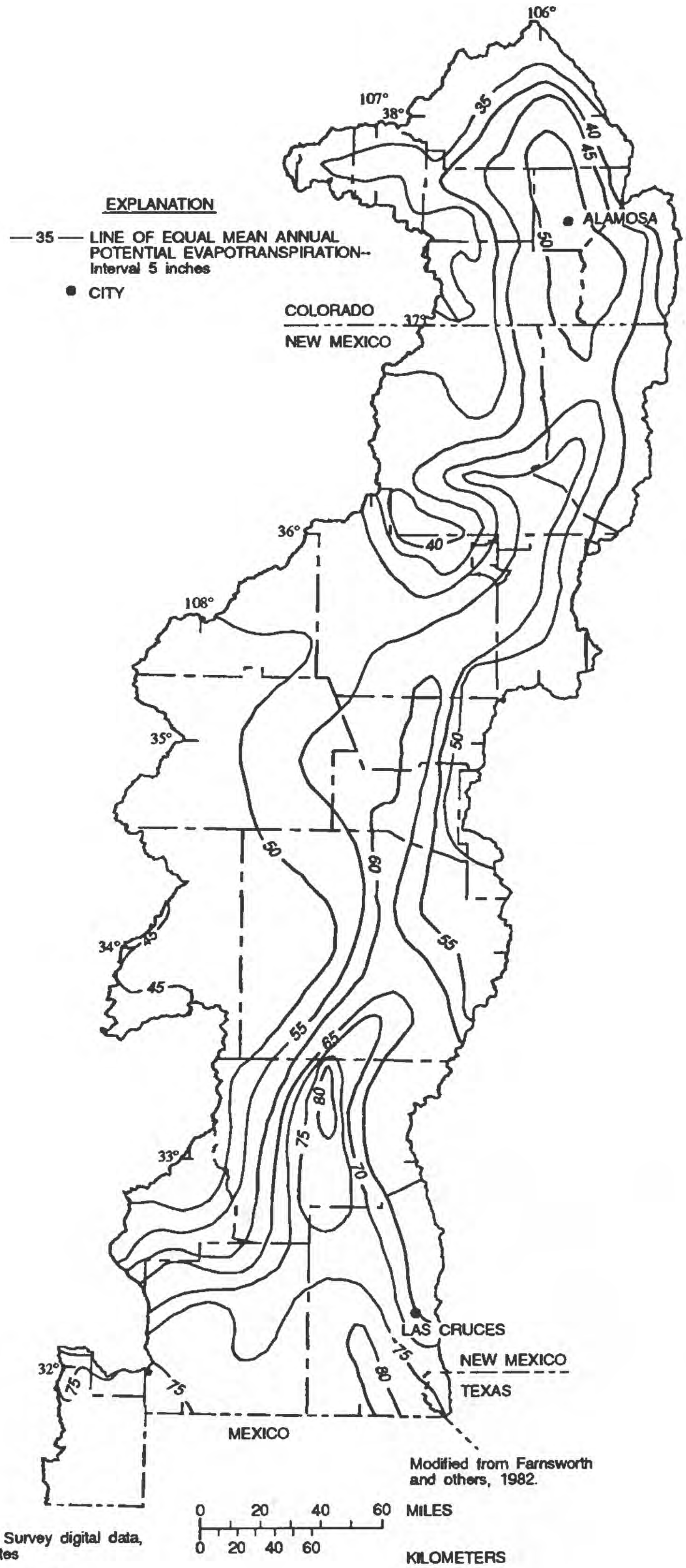


Figure 4.--Mean annual runoff (1951-80) for the Rio Grande Valley study unit.



Base from U.S. Geological Survey digital data, 1:100,000 scale various dates

Albers projection, Spheroid Clarke 1866, Standard parallels 29°30' and 45°30', Central meridian -96°00'

Figure 5.--Mean annual potential evapotranspiration (1951-80) for the Rio Grande Valley study unit.

Hydrologic Setting

The hydrology of the study unit is complex, owing to large changes over short distances of a variety of hydrologic, geologic, topographic, climatic, and vegetative factors. For example, many streams flowing from the bounding mountains cease to flow before reaching the Rio Grande because they lose water by infiltration to the alluvium and evapotranspiration. Before reaching the Rio Grande, the stream channel then may intersect the water table, causing streamflow to resume. Some streams will start and cease to flow repeatedly every few hundred yards with no tributary inflow. Even though surface water and ground water are interrelated, they will be discussed separately for practical purposes.

Surface Water

The Rio Grande is the main surface-water drainage in the study unit. The northern mountains are drained primarily by perennial streams. A large part of the study unit is drained by intermittent and ephemeral streams. Perennial streams are found in areas where the ground water intersects land surface or where there is sufficient flow from precipitation. Many stream reaches in the study unit are intermittent because they are affected by irrigation diversions or they lose water by infiltration to the alluvium, or are ephemeral because they flow only in response to short-term precipitation. Because they have no outlet, streams in surface-water closed basins flow until they are depleted by evaporation, transpiration, or infiltration to the alluvium, or terminate in a playa in the lowest point of the basin.

Several closed surface-water drainage basins are in the study unit. The San Luis Closed Basin receives flow from several perennial streams that originate in the surrounding mountains, but streamflow is depleted by irrigation, evapotranspiration, and infiltration into the alluvium. Surface-water flow in the southern closed basins generally occurs only in the spring and late summer when ephemeral channels flow. The Mimbres River, a major perennial stream that discharges into a southern closed basin, has its headwaters in the mountainous area north and east of Silver City (fig. 1; pl. 1) and flows into the Mimbres Basin where the surface water infiltrates and recharges the ground-water system or is evapotranspired. Streamflow records indicate relatively large flows in the late summer as the result of runoff from intense rainfall.

Annual streamflow within the Rio Grande Valley study unit is highly variable. For example, at the long-term streamflow-monitoring station Rio Grande at Otowi Bridge near San Ildefonso, New Mexico, the smallest mean annual streamflow was 498 cubic feet per second (ft^3/s) in 1904 and the highest mean annual streamflow was 3,320 ft^3/s in 1942. In addition to the natural variation in streamflow, irrigation diversions and importation of water have greatly affected the mean annual streamflow of the Rio Grande.

The interstate flow of the Rio Grande between Colorado and New Mexico and between New Mexico and Texas is regulated by the Rio Grande Compact of 1938. The flow of the Rio Grande between the United States and the Republic of Mexico is regulated by the 1944 Water Treaty between the two nations. Surface-water rights on the Rio Grande in Colorado and New Mexico exceed the mean annual flow of the river. Costilla Creek in Colorado and New Mexico is regulated by the Costilla Compact of 1946 as amended in 1963.

Eighteen reservoirs in the Rio Grande Valley NAWQA study unit each have storage capacities greater than 5,000 acre-feet (acre-ft). The largest is Elephant Butte Reservoir, with 2,065,000 acre-ft of storage capacity. Other major reservoirs (storage capacities greater than 75,000 acre-ft) in the Rio Grande Valley drainage include Abiquiu Reservoir (1,201,000 acre-ft), Cochiti Lake (Reservoir) (502,330 acre-ft), Heron Reservoir (401,300 acre-ft), Caballo Reservoir (331,500 acre-ft), El Vado Reservoir (186,250 acre-ft), Jemez Canyon Reservoir (172,800 acre-ft), Sanchez Reservoir (137,850 acre-ft), and Galisteo Reservoir (88,990 acre-ft) (pl. 2).

The principal purposes of these reservoirs are storage of irrigation water, flood control, and sediment retention. The purpose of a reservoir determines its operation, and thus the volume and retention time of water held in reservoirs vary considerably. For example, Elephant Butte, Heron, and El Vado Reservoirs are used primarily to store water for irrigation, and Abiquiu, Cochiti, Caballo, and Jemez Reservoirs are used primarily for flood and sediment control. The variation in the volume of water stored in the reservoirs used primarily for storage of irrigation water is not as large as the variation in the volume of water stored in the flood control reservoirs; the latter have large fluctuations in water levels in short times. In water year 1985 (October 1, 1984, to September 30, 1985), the minimum volume of water stored in Heron Reservoir was 317,100 acre-ft and the maximum was 401,600 acre-ft with a water-level change of approximately 16 ft. The minimum volume of water stored in Cochiti Reservoir in 1985 was 46,740 acre-ft and the maximum was 282,716 acre-ft with a water-level change of approximately 86 ft. The different methods of operation of these reservoirs result in different impacts on surface-water quality.

The surface-water system of the Rio Grande will be discussed using four river reaches (fig. 6; pl. 2). Reach 1 is the drainage upstream from the streamflow-monitoring station Rio Grande near Lobatos, Colorado (reference number 6 in table 2 later in the report). The reference number assigned to each station, provided in parentheses, is an arbitrarily assigned number used to simplify identification of surface-water stations in this report. Reach 2 is from the Lobatos station to the streamflow-monitoring station Rio Grande at Otowi Bridge near San Ildefonso, New Mexico (25). Reach 3 is from the Otowi Bridge station to the streamflow-monitoring station Rio Grande Floodway at San Marcial, New Mexico (63). Reach 4 is from the San Marcial station to the streamflow-monitoring station Rio Grande at El Paso, Texas (97). Mean annual streamflow for water years 1981-90 at selected main-stem and tributary monitoring stations and selected diversions is presented in figure 6.

Reach 1, which extends from the headwaters of the Rio Grande to the streamflow-monitoring station Rio Grande near Lobatos, Colorado (pl. 2), drains approximately 7,700 mi^2 including 2,940 mi^2 in the San Luis Closed Basin. This reach is about 160 river miles long and includes pristine mountains and the intensively irrigated and farmed San Luis Valley. The headwaters of the Rio Grande are in the San Juan Mountains in southwestern Colorado, which have maximum altitudes exceeding 13,500 ft. The mean annual streamflow at Lobatos for 1981-90 is 613 ft^3/s (fig. 6). The major tributaries to the Rio Grande in this reach are Goose Creek, South Fork of the Rio Grande, and Conejos River (fig. 6), which are generally perennial. The streamflow of the Rio Grande in this reach is affected by reservoirs and diversions for irrigation; diversions are approximately 610 ft^3/s.

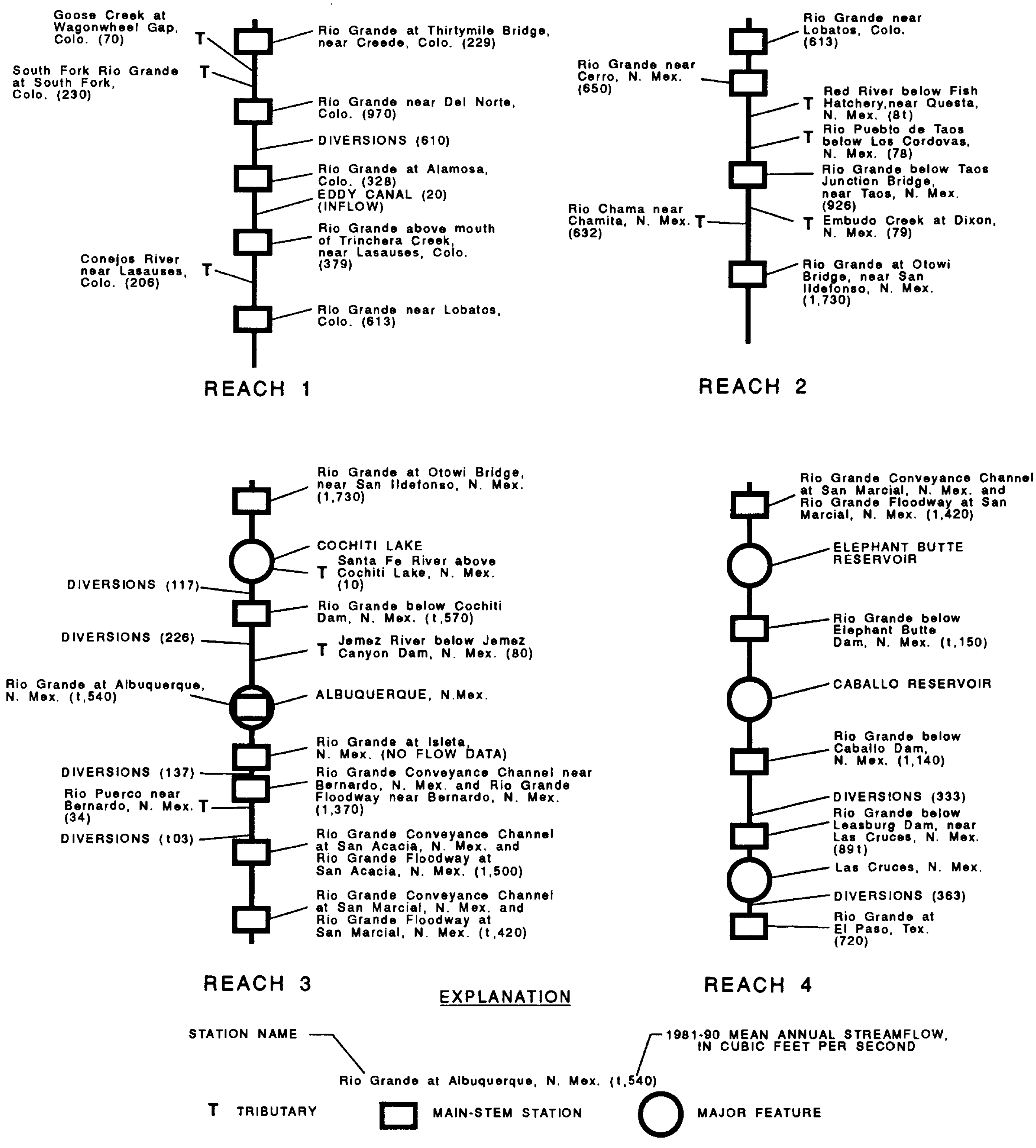


Figure 6.--River reaches, station names, and mean annual streamflow of the Rio Grande, water years 1981-90.

The San Luis Closed Basin is located north of the Rio Grande (pl. 2). This basin is a closed surface-water basin and a closed ground-water basin (Emery and others, 1973; Crouch, 1985). Several surface-water drainages terminate in the closed basin where the water evaporates, is used for irrigation, is transpired by native vegetation, or recharges the aquifer systems. Five major canals transport surface water from the Rio Grande into the San Luis Closed Basin. These canals diverted an average of about 289,500 acre-ft per year (about 400 ft^3/s annual mean) during water years 1981-90. Since 1986, the Franklin Eddy Canal has transported water out of the closed basin. The Franklin Eddy Canal is part of the Bureau of Reclamation San Luis Valley Project Closed Basin Division. The Bureau of Reclamation withdraws water from the unconfined aquifer and discharges the water into the Franklin Eddy Canal, where it flows into the Rio Grande downstream from Alamosa, Colorado. At present (1992) the system uses about 70 wells, and in 1990 delivered about 17,400 acre-ft of water to the Rio Grande (about 24 ft^3/s annual mean). The system, when completed, is projected to include 170 wells and deliver about 105,000 acre-ft of water per year (145 ft^3/s annual mean) to the Rio Grande.

Reach 2 of the main stem of the Rio Grande, which extends from the streamflow-monitoring station Rio Grande near Lobatos, Colorado, to the streamflow-monitoring station Rio Grande at Otowi Bridge near San Ildefonso, New Mexico (fig. 6), has a drainage area of about 6,600 mi^2. The reach is approximately 110 mi. long and the river is confined to a deep canyon throughout most of this reach. Mean annual streamflow for 1981-90 at the streamflow-monitoring station Rio Grande at Otowi Bridge near San Ildefonso, New Mexico, was 1,730 ft^3/s, nearly a threefold increase of reach 1 (fig. 6). Major tributaries are the Red River, Rio Pueblo de Taos, Embudo Creek, and Rio Chama. The Rio Chama, which drains approximately 3,144 mi^2, is the largest tributary, with a mean annual inflow of approximately 632 ft^3/s. Three major reservoirs are on the Rio Chama or tributaries to the Rio Chama (Abiquiu, El Vado, and Heron) and no reservoirs are on the Rio Grande in this reach. The Rio Chama receives transmountain diversions from the San Juan River Basin of approximately 128 ft^3/s. The Rio Grande is a gaining stream throughout most of this reach (Winograd, 1959; McAda and Wasiolek, 1988). Several diversions for irrigation are in the southern part of reach 2 of the Rio Grande and along the Rio Chama. In this reach about 83 mi. of the Rio Grande and the Rio Chama are federally designated Wild and Scenic Rivers.

Reach 3 of the main stem of the Rio Grande, which extends from the streamflow-monitoring station Rio Grande at Otowi Bridge near San Ildefonso, New Mexico, to the streamflow-monitoring stations at San Marcial (conveyance channel and floodway), has a drainage area of about 13,400 mi^2. The reach is about 190 mi. long, and the Rio Grande and adjacent flood plain are in a narrow valley (1 to 3 mi. wide) that is downcut into the basin fill. The area drained by this reach is typified by semiarid rangeland and is surrounded by several mountain ranges. Mean annual streamflow decreases approximately 300 ft^3/s in this reach (fig. 6). Major tributaries are the Santa Fe River, Jemez River, Rio Puerco, and Rio Salado. Many ephemeral channels enter the Rio Grande along reach 3. These ephemeral channels can contribute large inflows that contain significant amounts of dissolved constituents and suspended sediment. These channels generally flow in response to runoff from large quantities of precipitation. The Rio Puerco drains an area of approximately 7,350 mi^2 and instantaneous flows have been estimated to be as large as 35,000 ft^3/s. Sediment concentrations in the Rio Puerco as large as 267,000 milligrams per liter (mg/L) have been measured. Cochiti Reservoir is the only main-stem reservoir in this reach. Streamflow in this reach is affected by several large diversions for irrigation. In addition, several drains intercept shallow ground water and discharge water into the Rio Grande. Diversions of water from the river can dry up the river completely in lengths of reach 3 during parts of the year.

In the southern part of reach 3, from San Acacia to San Marcial, flow in the Rio Grande Floodway (natural river channel) can be diverted into a conveyance channel that was constructed in 1958 to transport water when flow in the Rio Grande is less than 2,000 ft^3/s and to reduce channel losses and the surface area of open water, thus reducing the quantity of evapotranspiration from the river in the area. The original plan was to divert all flow from the floodway into the conveyance channel when flows in the floodway were less than 2,000 ft^3/s. However, since the mid-1970's, streamflow less than 2,000 ft^3/s is not always diverted. Agricultural drains also discharge into the conveyance channel, thus the channel at San Marcial generally has flow.

Reach 4 of the main stem of the Rio Grande, which extends from the streamflow-monitoring stations at San Marcial to the southern end of the study unit at the streamflow-monitoring station Rio Grande at El Paso, Texas, drains approximately 4,510 mi^2. The reach is approximately 180 mi. long, and the Rio Grande and adjacent flood plain are narrow and confined to a valley inset in the adjacent sediments. Mean annual streamflow decreases by about one-half in this reach as the result of diversions for irrigation and evapotranspiration along the river channel: mean annual flow at Rio Grande at El Paso is 720 ft^3/s (fig. 6). No perennial tributaries to the Rio Grande are in this reach; however, many ephemeral channels discharge to the Rio Grande in response to intense rainfall. Two major reservoirs are in this reach of the Rio Grande-- Elephant Butte and Caballo. Elephant Butte is a large reservoir that is used for the storage of irrigation water and power generation. In 1985, the maximum volume of water stored in Elephant Butte Reservoir was 2,013,800 acre-ft and the minimum volume was 1,468,300 acre-ft. The volume of water stored in Caballo Reservoir ranged from 244,300 to 9,700 acre-ft in 1985. Irrigated agricultural areas are along the Rio Grande flood plain throughout reach 4. The mean annual volume of water diverted from the Rio Grande into irrigation canals in this reach is about 700 ft^3/s. Agricultural drains also discharge water to the Rio Grande throughout this reach. Reach 4 of the Rio Grande below Caballo Reservoir has been the subject of several base flow gain/loss studies, most indicating that this is a gaining reach.

Ground Water

Boundaries of the ground-water flow systems in the study unit do not conform to the surface-water drainage boundaries. The ground-water flow-system boundaries are controlled by geology and location of recharge to and discharge from the ground-water flow systems. Many different ground-water flow systems at many different scales are found in the study unit. A large number of these ground-water flow systems are connected and ultimately discharge into the Rio Grande. For uniformity throughout this section, the term "basin" is used in the context of a structural basin, rather than in the context of a topographic basin or a valley.

Two main structural settings can be identified in the Rio Grande Valley study unit: alluvial basins and bedrock basins. The alluvial-basins setting is typified by basins partly or entirely surrounded by highlands composed of rocks older than middle Tertiary. Erosion of the highlands adjacent to these basins has resulted in the deposition of thick middle Tertiary or younger basin-fill deposits. Many alluvial basins in the study unit are in a tectonically active area referred to as the Rio Grande Rift. The Rio Grande Rift is an area delineated by high heat flow, late Quaternary faults, late Pliocene and younger volcanoes, and deep basins (Seager and Morgan, 1979, p. 88). Basins in the Rio Grande Rift contain a greater thickness of basin-fill deposits than the alluvial basins outside the rift; however, basins outside the rift are hydrologically similar to the basins in the rift. The boundaries and nomenclature of the alluvial basins in the Rio Grande Rift are subjective and based on geologic interpretation. Alluvial basins in the Rio Grande Rift are the San Luis, Española, Santo Domingo, Albuquerque-Belen, La Jencia, Socorro, San Marcial, Engle, Palomas, Mesilla, eastern part of Mimbres, San Agustin, and Jornada del Muerto Basins (pl. 1).

The Playas, Hachita, and western part of the Mimbres Basins are located west of the Rio Grande Rift. These basins are similar to the basins in the Rio Grande Rift; however, the deposits filling these basins are generally older. These basins have been filling with basin-fill deposits from early to middle Tertiary, thus the mountains surrounding these basins have eroded more and have less topographic relief than some of the mountains surrounding the basins in the rift.

The bedrock basins in the study unit--the San Juan and Chama Basins--differ from the alluvial basins in that they contain many layers of sedimentary rocks, which range from Mississippian to Quaternary in age. The total thickness of rocks can be large in these basins. Rocks generally dip toward the center of the basins from the margins, and surface rocks are younger toward the centers of the basins. The material composing the bedrock in these basins was deposited in a wide range of depositional environments ranging from deep water marine to arid continental, thus there is a large range in permeability of the rocks. This layering of rock types results in many different, distinct aquifers that are separated by confining beds. Because of this, the hydrology of bedrock basins is much different than that of alluvial basins. These distinctions are significant to understanding the complexity of ground-water flow systems in the study unit.

Many scales of flow systems are in the study unit. The larger and most important flow systems can be grouped into two major types: alluvial basins and bedrock basins. The principal aquifers in alluvial basins are basin-fill deposits, whereas aquifers in bedrock basins are permeable sedimentary rocks. In a strict sense alluvial basins include only the area underlain by basin-fill deposits; however, mountainous areas adjacent to the basin-fill deposits have been included in the discussion of ground-water flow systems in these basins. Two types of alluvial basins are found in the study unit: those through which streams flow and exit, and those having a closed surface-water drainage system. Most of the basins are drained by a through-flowing stream; however, the northern part of the San Luis Basin and San Agustin, Jornada del Muerto, Mimbres, Hachita, and Playas Basins are closed to surface-water drainage.

Alluvial basins

Basin-fill deposits are the principal aquifer in the alluvial basins. These deposits include sedimentary and volcanic deposits that are Tertiary or younger in age. Thickness of these deposits ranges from a feather edge at the basin margins to about 19,000 ft in the San Luis Basin (Leonard and Watts, 1989). Thickness is generally several thousand feet throughout the Rio Grande Rift; however, hydrologic data are available only for the upper several hundred feet of the saturated basin-fill deposits. Coalescent-fan, alluvial-fan, and piedmont deposits are found along the margins of the alluvial basins that are bounded by mountains. These deposits grade into or intertongue with fine-grained sediments. In many of the basins, ancient playa deposits of fine-grained material are interbedded with alluvial-fan deposits. Axial river deposits consisting primarily of clay, silt, sand, and gravel are found along the present channel of the Rio Grande as well as along its ancestral course. Throughout much of the study unit and particularly along the western side of the San Luis Basin and in the Jemez Mountains, extensive and thick deposits of volcanic flows, volcaniclastic rocks, and tuffaceous material are found at the surface or interbedded in the basin-fill deposits. The older basin-fill deposits are semiconsolidated.

Recharge to the basin-fill deposits can occur by several different processes; however, the majority of recharge results from infiltration of surface water derived from the mountainous areas, infiltration of water from the Rio Grande, infiltration from the major tributaries to the Rio Grande, and infiltration of excess irrigation water and water leaking from irrigation ditches. In most alluvial basins in the study unit, direct infiltration of precipitation intercepting the land surface does not result in recharge to the ground-water system. This is due to the intermittent and intense (although small annual amount) precipitation and large rate of evapotranspiration. There is also some inflow from bedrock units to the basin-fill deposits.

Discharge from the basin-fill deposits occurs as discharge to the surface-water systems, evapotranspiration, subsurface ground-water flow to other alluvial-basin flow systems, and pumpage of ground water. The Rio Grande and several other rivers are known to gain flow in certain reaches as the result of ground-water discharge. In many of the basins, streams lose water in the northern part of the basin and gain water in the southern end of the basin. Evapotranspiration along irrigated areas of the Rio Grande probably results in the largest quantity of discharge from the ground-water system because ground water is near land surface in these areas. In most areas of the alluvial basins the depth to water is greater than 50 ft and little or no evapotranspiration would occur in these areas; thus, discharge from alluvial-basin flow systems generally is limited to the area along the Rio Grande.

Ground water in alluvial basins generally flows from the northern, eastern, and western basin margins toward the centers of the basins and, in many basins, also moves southward. Most recharge occurs along the basin margins and most discharge occurs near the center of the basin or in the subsurface to an adjacent alluvial basin. In alluvial basins drained by the Rio Grande, the Rio Grande and irrigated areas along the Rio Grande are major discharge areas for the ground-water system. Movement of ground water from recharge areas to discharge areas can take thousands of years because of the distance traveled and the aquifer characteristics.

On a regional scale, ground-water flow in the alluvial basins drained by the Rio Grande is from basin margins toward the Rio Grande and southward from one basin to the next (pl. 1) until the southern end of the Mesilla Basin is reached. A bedrock high covered by a thin veneer of basin-fill deposits restricts ground-water flow out of the Mesilla Basin (Slichter, 1905). Most ground water discharges at the southern end of the Mesilla Basin to drains or is evapotranspirated (Wilson and others, 1981). Therefore, ground-water flow out of the study unit in the basin-fill deposits along the Rio Grande is minimal. Ground-water flow in the alluvial basins not along the Rio Grande is into basins along the Rio Grande, into alluvial basins west of the Continental Divide, or out of the study unit into Mexico (pl. 1).

In irrigated areas along the Rio Grande in alluvial basins south of the San Luis Basin, small-scale flow systems are superimposed on large-scale flow systems because of recharge and discharge that are related to human activities. The number and extent of these localized flow systems are a function of the geometry of the sources of recharge and areas of discharge resulting from the irrigation network. The main sources of recharge in these areas are the irrigated fields and the canals and laterals that transport water to the fields. The main types of discharge are drains that have been constructed to intercept ground water to maintain water levels below land surface, evapotranspiration from the ground-water system, and wells that are used to supply irrigation water. The Rio Grande might be a source of recharge or an area of discharge depending on river stage and altitude of the water table. The interaction of all of these sources of recharge and areas of discharge is in a constant state of flux during the year, especially during the irrigation season when significant volumes of water recharge the ground-water system, resulting in rising water levels in irrigated areas. These rising water levels increase gradients near the drains, thus increasing ground-water discharge to the drains. During the nonirrigation season, the localized ground-water system is drained and water levels are lowered.

Bedrock basins

The two main bedrock basins in the study unit are the San Juan Basin and the Chama Basin (pl. 1). Other bedrock basins are in the study unit but they are localized and little data are available to define them. Consequently they are not discussed in this report. The San Juan Basin and Chama Basin are similar with respect to stratigraphy and structural geology. Many water-yielding units or aquifers are in these basins and generally each aquifer is a distinct flow system. Localized ground-water flow systems exist in the Quaternary alluvium that has been deposited along many of the streams and valleys eroded in the bedrock.

Recharge results from the same general processes discussed in the section on alluvial-basin flow systems. Mountain-front recharge and infiltration of water from major streams in the basins are the most important sources of recharge to these basins. Direct recharge could also be appreciable in these basins in areas that receive more than 12 in. per year of precipitation. The main types of discharge from the bedrock units are ground-water pumpage, discharge to surface-water systems, leakage through confining beds to adjacent aquifers, and subsurface flow from the bedrock aquifers into the basin-fill deposits. Flow is generally from the recharge or highland areas along the basin margins toward the center of the basins. In the San Juan Basin ground-water movement in rocks of Jurassic age and younger is generally out of the study unit to the north. In the southern San Juan Basin, ground-water movement in rocks older than Jurassic age is from the Zuni Mountains eastward toward the Albuquerque-Belen Basin.

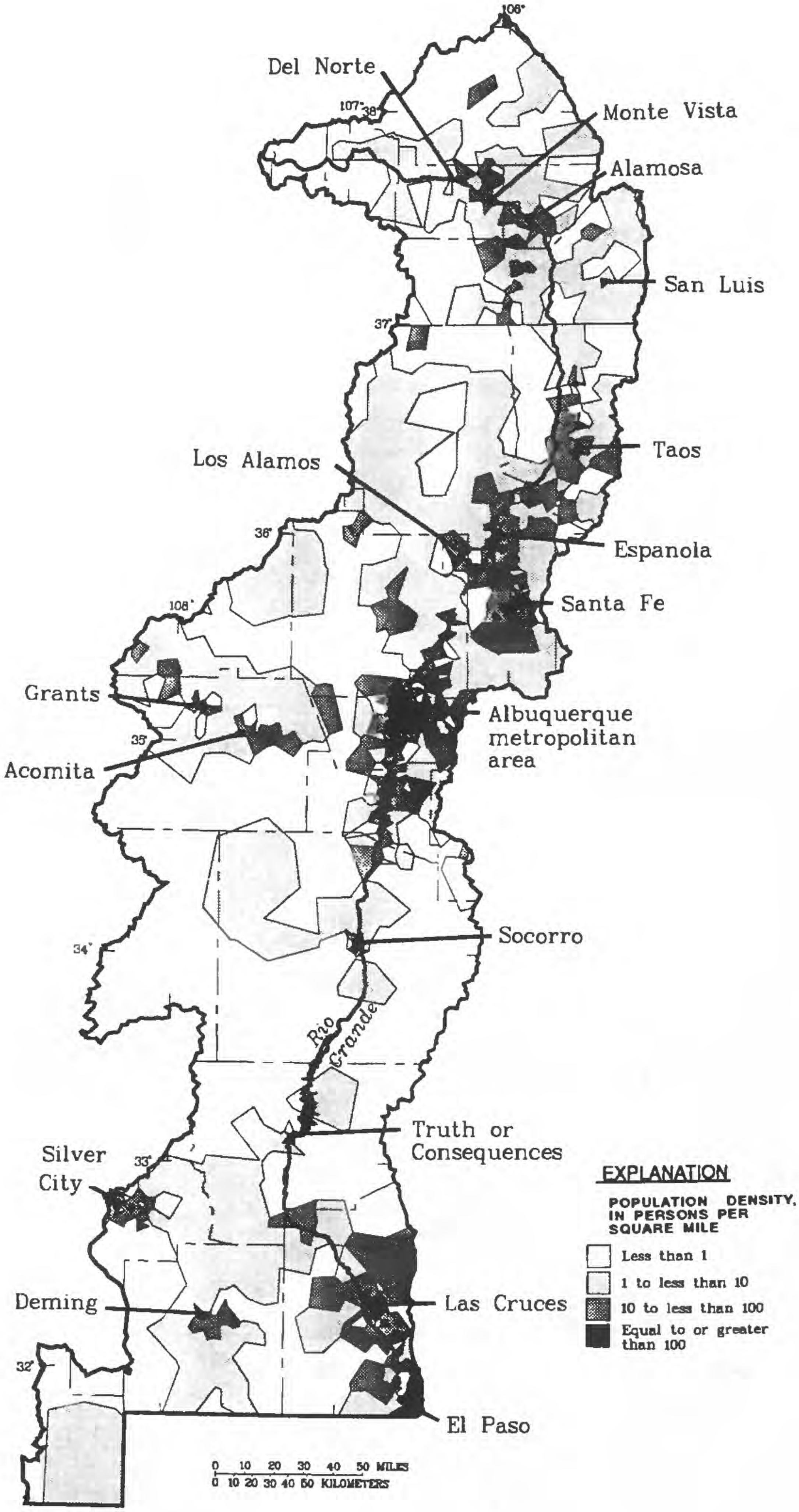
Population and Land Use

The population of the Rio Grande Valley study unit was about 1,072,000 according to the 1990 census. The 1990 population of the study unit in Colorado was about 40,140, in New Mexico about 972,600, and in Texas about 59,200. Cities and towns within the study unit having populations more than 1,000 are listed in table 1 and are shown on plate 1. The 1990 census data listed three cities with populations greater than 50,000: Albuquerque, New Mexico (384,736, although the greater Albuquerque metropolitan area had a population of about 520,000); Las Cruces, New Mexico (62,126); and Santa Fe, New Mexico (55,859). Los Alamos, New Mexico, because it is not a legally incorporated place, is listed as a Census Designated Place with a population of 11,455, which includes the town and surrounding area (thus it is not included in table 1). Alamosa, Colorado (7,579), had the largest population in the Colorado part of the study unit. The metropolitan area of El Paso, Texas, is downstream from the study unit; thus its population also is not included in table 1. Figure 7 is a chloropleth map of population density produced by taking centroids of census tracts and performing thiessen analysis (in the absence of the actual census tract boundary data). Most of the study unit has a population density of less than one person per square mile.

Table 1.--Population of cities and towns having more than 1,000 people

[From 1990 Bureau of the Census statistics. Towns are in New Mexico unless otherwise specified]

City or town	1990 population	City or town	1990 population
Alamosa, Colo.	7,579	Hatch	1,136
Center, Colo.	1,959	Hurley	1,534
Del Norte, Colo.	1,674	Las Cruces	62,126
Monte Vista, Colo.	4,324	Los Lunas	6,013
Albuquerque	384,736	Los Ranchos de Albuquerque	3,955
Bayard	2,598	Mesilla	1,975
Belen	6,547	Milan	1,911
Bernalillo	5,960	Questa	1,707
Bosque Farms	3,791	Rio Rancho	32,505
Central	1,835	Santa Fe	55,859
Chama	1,048	Silver City	10,683
Corrales	5,453	Socorro	8,159
Deming	10,970	Sunland Park	8,179
Española	8,389	Taos	4,065
Grants	8,626	Truth or Consequences	6,221



Base from U.S. Geological Survey digital data, 1:100,000 scale various dates

Albers projection, Spheroid Clarke 1866, Standard parallels 29°30' and 45°30', Central meridian -96°00'

Figure 7.--Approximate population density in 1990 in the Rio Grande Valley study unit.

Land-use information was obtained from Geographic Information Retrieval and Analysis System (GIRAS) land-use and land-cover data digitized from 1:250,000- and 1:100,000-scale maps by the U.S. Geological Survey. The original maps were produced from National Aeronautical and Space Administration high-altitude aerial photographs and National High-Altitude Photography program photographs (U.S. Geological Survey, 1986). Land use within the Rio Grande Valley study unit is primarily in four categories: rangeland (58 percent), forest (36 percent), agriculture (4 percent), and urban (1 percent). All other categories combined are less than 1 percent of the study unit. Areas of urban, agriculture, rangeland, and forest land uses are shown in figure 8. Agricultural land use is generally found in the north in the San Luis Basin and sporadically along the Rio Grande where it is often intermixed with urban land use. Forest generally is found in the mountains and areas of higher altitudes, whereas rangeland is in the lower, flatter areas. Although single land-use classifications are applied to areas, certain areas have multiple land uses, and some areas are marginal for the stated land use. For example, many cattle graze in areas designated as forest, and some of the rangeland can support only one cow per square mile.

The Rio Grande Valley study unit contains a wide variety of special land uses and designated areas. Included in these are numerous Indian reservations, some of which have acquired or are in the process of acquiring authority to establish stream water-quality standards on the reservations. The Rio Grande Valley study unit also includes numerous National Forests, Federal and State Wildlife Refuges, State Parks, several National Monuments, wetlands, three Wild and Scenic River reaches, and two Long-Term Ecological Research (LTER) sites. The study unit is also the habitat of several endangered species.

Water Use

Total water use in the study unit in 1990 was about 3,410,000 acre-ft per year; of this amount about 1,790,000 acre-ft per year was estimated to be consumptive use. Consumptive use is water that is no longer available because it has been evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the water environment. Water use within the Rio Grande Valley study unit was mainly from surface water (59 percent). Irrigation was the major water-use category (89 percent) and public supply was the second major water-use category (8 percent). Public supply includes well water for both municipal and private domestic use.

Major uses of water within the study unit are irrigation, public supply, and industrial. Total irrigated acreage in 1990 was about 914,000 acres, with about 72 percent of the acreage irrigated by the flood method. About 645,000 acres were irrigated in Colorado, of which the majority was in pasture, alfalfa, and other types of hay. Other major irrigated crops were barley, potatoes, spring wheat, oats, and vegetables. About 262,000 acres were irrigated in New Mexico in 1990, supporting a wide variety of crops. Pasture and alfalfa were the major crops in the area north of Cochiti Lake. The major crops were pasture, alfalfa, wheat, and small grains in the area between Cochiti Dam and Elephant Butte Reservoir. Pasture, alfalfa, cotton, chile, orchards (primarily pecans), and grains were the major crops from south of Elephant Butte Reservoir to the southern border of the study unit. Most high-value crops in the New Mexico part of the study unit were in Doña Ana and Luna Counties, in the southern part of the study unit. In Texas about 7,000 acres were irrigated in the study unit; pasture and alfalfa were the major crops.

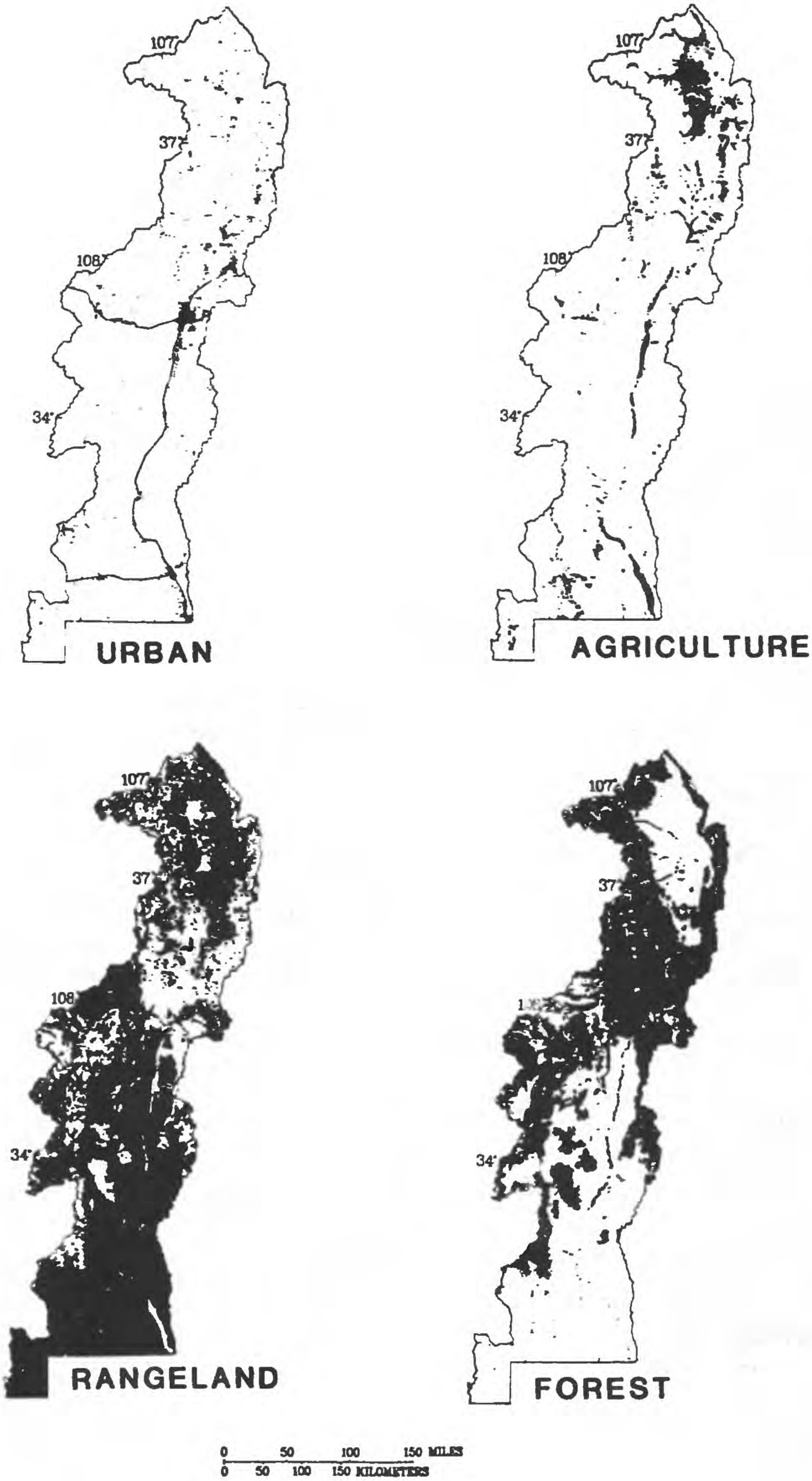


Figure 8.--Areas of urban, agricultural, rangeland, and forest land-use land-cover classifications for the Rio Grande Valley study unit.

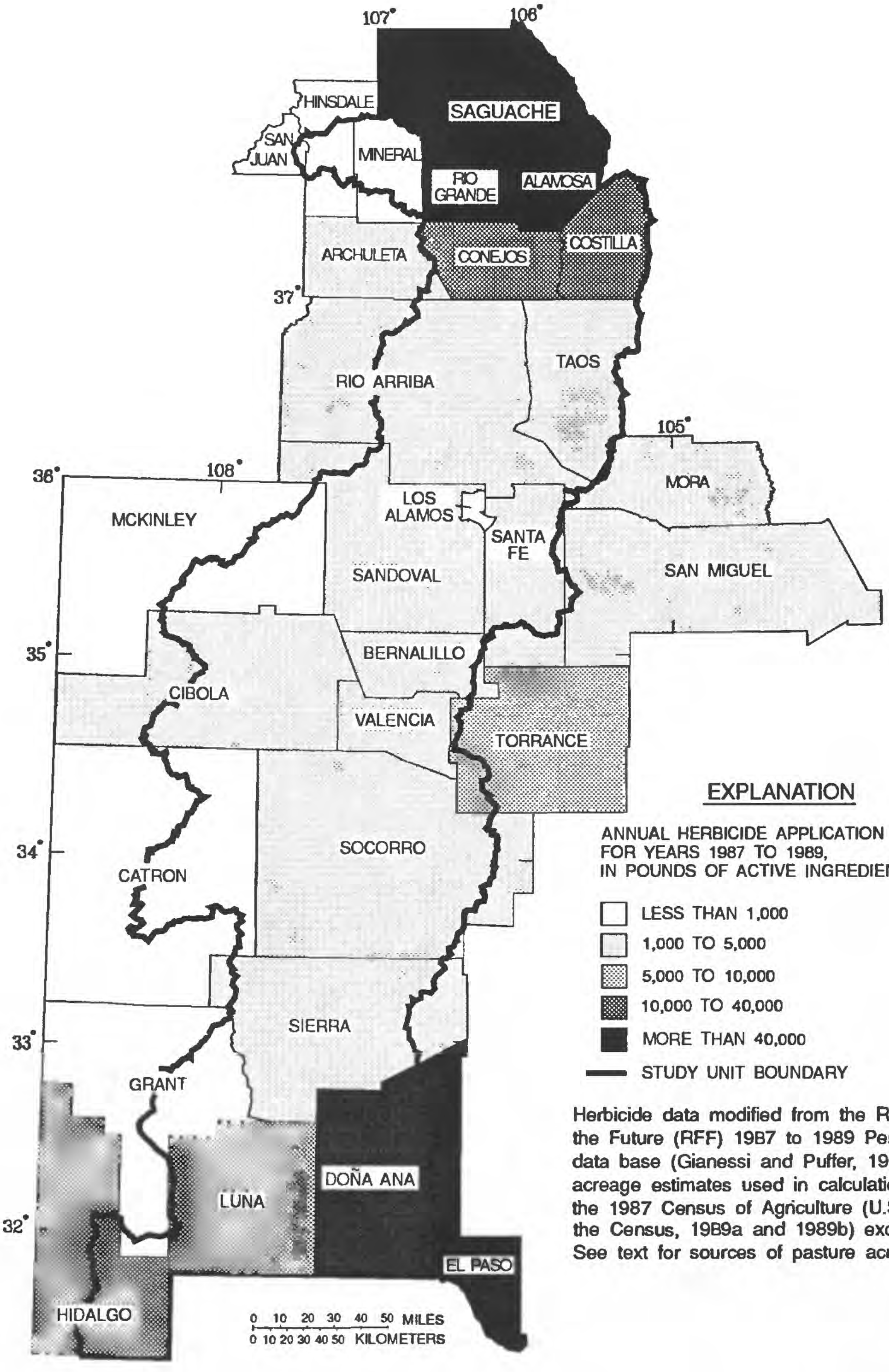
In 1990, water use in Colorado totaled about 1,760,000 acre-ft--about 988,000 acre-ft from surface water and about 774,000 acre-ft from ground water; about 1,060,000 acre-ft was consumptive use. Total irrigated acreage in 1990 was about 645,000 acres, of which about 62 percent was irrigated by the flood method. The irrigated acreage in the San Luis Closed Basin was about 348,000 acres, of which about 50 percent was irrigated by the flood method.

In 1990, water use in New Mexico totaled about 1,530,000 acre-ft--about 981,000 acre-ft from surface water and about 544,000 acre-ft from ground water. Irrigation was the major water use, about 1,243,000 acre-ft, with about 975,000 acre-ft from surface water and 268,000 acre-ft from ground water. About 97 percent of total irrigated acreage was irrigated by the flood method. The counties using the majority of water in 1990 were Doña Ana (514,000 acre-ft), Bernalillo (212,000 acre-ft), Valencia (148,000 acre-ft), Socorro (138,000 acre-ft), Taos (112,000 acre-ft), and Luna (109,000 acre-ft).

In 1990, water use in Texas totaled about 122,000 acre-ft--about 23,300 acre-ft from surface water and about 98,300 acre-ft from ground water. The majority of water used, about 80 percent of the total, was for public supply. Other significant water-use categories were irrigation and industrial use.

Agricultural Chemical Usage

Herbicides are applied in all counties that intersect the study unit (fig. 9). Figure 9 was produced using an updated and expanded Resources for the Future (RFF) data base (Gianessi and Puffer, 1990), and is restricted to herbicide usage. Herbicide-use coefficients (Gianessi and Puffer, 1990) were multiplied by estimated total crop acreage treated, mostly derived from the 1987 Census of Agriculture, to obtain total pounds (lbs) of herbicide active ingredient. In the RFF data base, herbicide application to pasture was found to be in error by an order of magnitude or more for several counties because open rangeland was included in the pasture application calculations. Contacts with local sources indicated that actually little herbicide is applied to rangeland. For example, RFF data indicate that Socorro County had 150,000 lbs active ingredient applied to all crops; because the Socorro County Agent and the Bureau of Land Management indicated very little herbicide application to rangeland, irrigated pasture acreage was used (Lansford and others, 1991). When recalculated, herbicide application to all crops in Socorro County was determined to be only 4,300 lbs active ingredient. Irrigated pasture acreages from local sources were substituted into the RFF data for all counties and the total application rates were recalculated. Irrigated pasture acreages in New Mexico were obtained from Lansford and others (1991); irrigated pasture acreages for Colorado were obtained from M.J. Radell (U.S. Geological Survey, oral commun., 1993); and irrigated pasture acreages for Texas were obtained from Dee Lurry (U.S. Geological Survey, oral commun., 1993). Other limitations of the RFF data are that noncropland is not represented, acres treated are based on a statewide percentage of total crops, and herbicide-use coefficients are used. In general, the counties with the largest herbicide application rates also have large areas of agriculture (fig. 8). Counties having the largest herbicide application rates are Doña Ana, New Mexico (78,500 lbs active ingredient), Rio Grande, Colorado (68,000 lbs active ingredient), and Alamosa, Colorado (53,000 lbs active ingredient). Counties having the smallest application rates are San Juan, Colorado (30 lbs active ingredient), Hinsdale, Colorado (4 lbs active ingredient), and Los Alamos, New Mexico (which has very little or no commercial agriculture).



Herbicide data modified from the Resources for the Future (RFF) 1987 to 1989 Pesticide Use data base (Gianessi and Puffer, 1990). Crop acreage estimates used in calculations from the 1987 Census of Agriculture (U.S. Bureau of the Census, 1989a and 1989b) except pasture. See text for sources of pasture acreages.

Base from U.S. Geological Survey digital data, 1:100,000 scale various dates

Albers projection, Spheroid Clarke 1866, Standard parallels 29°30' and 45°30', Central meridian -96°00'

Figure 9.--Annual herbicide application, by county (1987-89), for the Rio Grande Valley study unit.

METHODS USED TO COMPILE, SCREEN, AND ANALYZE AVAILABLE DATA

Federal, State, and local government agencies and other private and public entities were contacted as to the type and availability of water-quality data they had collected. A large variation in the type and format of data was available.

Compilation of Data

A large amount of water-quality data was compiled for this report; however, not all of the data were used in data analysis because of unknown sampling procedures, unknown methods of analysis, and lack of long-term sampling at surface-water stations. Data from the various sources were not combined into one computer data base, but were kept in four main computerized data bases that are in the NWIS (National Water Information System) data-base format. These data bases are the U.S. Geological Survey NWIS data base, the EPA STORET (U.S. Environmental Protection Agency STOrage and RETrieval) data base, the Albuquerque data base (maintained by the New Mexico District of the U.S. Geological Survey in cooperation with the City of Albuquerque), and a data base containing data from the Bureau of Reclamation, Los Alamos National Laboratory, San Luis Valley Analytical (a private laboratory in Alamosa, Colorado), and Colorado State University.

The NWIS data base was the largest data set available. This data base, maintained by the U.S. Geological Survey, contains water-quality data for ground water, surface water, and atmospheric deposition. Most samples were collected and analyzed by the U.S. Geological Survey. Well-construction and streamflow data also are included in this data base.

The STORET data base contains a large amount of data collected by Federal, State, and local government agencies and contractors to the EPA. Most data in the STORET data base are for surface water although limited ground-water data are available for specific areas. Most ground-water data in STORET were collected from a uranium mining area near Grants, New Mexico. These data probably were collected during studies of the effects of uranium mining and ore processing in the area and would not be representative of the land use assigned to it because ground-water quality in this area may have been affected by mining activities not reflected in the land-use data. Data were not collected on a regular basis at most of the surface-water sites. However, at several surface-water sites, especially in Colorado, data were collected bimonthly for several years. A large variety of chemical constituents was analyzed in different samples. Many different agencies collected and analyzed samples that are included in this data base, and the sample collection techniques and analytical methods used for different chemical constituents are not well documented. In some cases the collecting agency was contacted to determine which techniques were used. Ground-water data from STORET were not used in this report; however, some surface-water data were used.

The Albuquerque data base contains ground-water-quality data collected by various State and local agencies. Sampling procedures and methods of analysis vary considerably in these data. Chemical constituents analyzed for in different samples also vary considerably. Much of these data were used in this report. Descriptions of data sets not used are as follows:

The National Uranium Resource Evaluation computerized data base contains a large amount of soil, bed-sediment, ground-water, and surface-water-quality data collected and analyzed by contractors to the U.S Department of Energy. The purpose of this data-collection effort was to evaluate uranium and trace-metal resources of the United States; therefore, these were the constituents generally analyzed in the samples. Nutrient and pesticide data were absent from this data base.

The NADP (National Atmospheric Deposition Network) data base contains wet atmospheric deposition water-quality data collected by various agencies. These data were collected in accordance with strict guidelines and all data were analyzed by the Illinois State Water Survey. Samples were analyzed for major chemical constituents and some nutrient species. These data were used for nutrient loading calculations.

The Bureau of Reclamation Closed Basin Division Project collected data in the San Luis Basin area of the study unit from 1981 to 1992. These data include chemical analyses of surface-water and ground-water samples that in many cases were collected several times per year for many years. Samples generally were analyzed for major chemical constituents and nutrients, and the sampling procedures and methods of analysis are well known. These data are not in digital format and encompass the same area as data in the NWIS data base. The area where data were collected by the Bureau of Reclamation also is localized and does not cover a large part of the study unit.

Los Alamos National Laboratory personnel have collected and analyzed soil, bed-sediment, ground-water, and surface-water-quality data for many years at selected sites near Los Alamos. These data are published each year in a data report. The number of chemical constituents analyzed in different samples varies greatly. Concentrations of major dissolved ions, nutrients, and some trace metals generally were determined in each sample. Data are site specific and not in digital format.

Personnel from San Luis Valley Analytical have collected and analyzed a large number of surface-water samples from rivers and streams in the Alamosa area. These analyses are in digital format and the sampling procedures and methods of analysis are well known. Water samples were analyzed most commonly for major ions and phosphorus. Nutrient data are insufficient.

Personnel from Colorado State University collected a limited amount of data from irrigation wells in the San Luis Valley as part of a study of the effects of agricultural practices on water quality. Data are from a relatively small area in the study area.

Screening of Data

Data in each data base were screened to select data suitable for unbiased statistical analysis. The screening criteria applied to the data were different for surface water and ground water.

Surface-Water Data

The criteria used to screen surface-water data for nutrients and suspended sediment included: (1) 15 or more analyses over at least 3 consecutive years during water years 1972-90 (these water years were used to be consistent with national standards for the NAWQA program); (2) analyses for one or more nutrients (total nitrogen, dissolved ammonia, dissolved nitrate, total phosphorus, and dissolved orthophosphate) or suspended sediment (suspended-solids analyses used for the STORET data); (3) at least daily mean streamflow data (instantaneous streamflow data were used when both were available); (4) relatively uniform distribution of samples over time and range of streamflow; (5) chemical analysis by a laboratory certified by EPA; and (6) knowledge of sampling method. All available pesticide data for water years 1972-90 are presented in this report. Only data from the NWIS and STORET data bases met the screening criteria.

Ground-Water Data

Several screening criteria were applied to ground-water data prior to data analysis. Ground-water data were limited to samples collected from January 1, 1945, to April 30, 1990. Samples from wells surrounded by agricultural or urban land use were limited to those collected from September 30, 1970, to April 30, 1990. If samples were collected from a particular well more than once, the most recent sample was used. The number of multiple analyses at a particular well was generally insufficient to study temporal trends. Data collected by the U.S. Geological Survey in the Los Alamos area were not used in data analysis because the land-use data associated with these wells were not accurate and because a large number of samples collected in this area in the 1950's and 1960's were the result of site-specific monitoring studies. If samples were collected from several wells at a particular location, the sample from the shallowest well was used. If determining which well was the shallowest was not possible, the most recent analysis was used.

Analysis of Data

Various statistical and mathematical methods were used to compare water-quality and streamflow data. Nutrient and suspended-sediment (suspended-solids) data are presented in graphical and tabular formats. Pesticide and biological data are presented in tabular format only.

Censored data, or data referred to as "less than a given value," are below a detection limit that can be determined accurately by laboratory analytical techniques and equipment. Because analytical techniques vary among laboratories and through time, multiple detection limits might exist for a given constituent. Depending on the type of analysis, various methods were used to handle censored data. The handling of these data is discussed separately in the description of each statistical method.

Boxplots were used to graphically display the median, interquartile range, and quartile skew for selected data. The median is the 50th-percentile value, which indicates that 50 percent of the data are less than or equal to that reported value. The center line of the boxplot represents the median. The interquartile range represents the middle 50 percent of the data, or the 75th-percentile value minus the 25th-percentile value. The enclosed portion of the box represents the interquartile range. The quartile skew is easily seen by comparing the portion of the box above and below the median line. For a linear scale, if the upper portion is larger than the lower portion, the data are skewed to the high concentrations. The lines extending from the top and bottom of the boxplot are drawn to the 10th and 90th percentiles of the data. For the surface-water analysis, boxplots and summary statistics (percentiles) were not done if less than 15 data values were available for a given constituent at a given station. A line was drawn across the boxplots at the value of the largest censored-data value. The portion of the boxplot below this line was not drawn. Tables showing the statistical summaries of the data used to construct the boxplots also are provided.

When plotted on the same scale, boxplots can be compared visually and differences and similarities among stations can be identified. The data for a given station also were compared statistically to those for another station.This was done using the Mann-Whitney test (Iman and Conover, 1983). This nonparametric technique uses the ranks of the data and calculates the probability that two independent statistical samples come from the same population. The null hypothesis tested is that the data from two stations have the same distribution. The alternate hypothesis is that data from one of the stations has larger (or smaller) values than the other. The chance of making an error by rejecting the null hypothesis when the null hypothesis is true is measured by probability. If the probability level is 0.05, there is a 5-percent chance of error when rejecting the null hypothesis. In tests to determine statistically significant differences in nutrient and suspended-sediment concentrations a probability level of 0.05 was used.

To determine if water quality has changed through time, the data were analyzed for trends. Trends through time are more apparent when a smoothing routine is used on plots of concentration versus time. The LOWESS, or LOcally WEighted Scatterplot Smoothing (Cleveland, 1979), method was used to highlight trends or patterns in the nutrient and suspended-sediment data through time.

A more rigorous statistical test for trends is the seasonal Kendall test (Hirsch and others, 1982). This test is a nonparametric technique for trend detection, applicable to data sets with seasonal variability. The effect of seasonality is reduced by comparing observations from the same season each year. Seasonality was determined by sampling frequency. If there were enough data, a monthly test was done. Secondly, a bimonthly test was tried (October-November, December-January, etc.). Finally, a quarterly test was tried (September-November, December-February, etc.). The null hypothesis is that the variable of interest and its time of observation are independent, which indicates no trend (Smith and others, 1982). In this report, a probability of 0.05 or less was considered statistically significant for indicating an increasing or decreasing trend. Trend analyses for nutrients and suspended sediment were computed for water years 1980-90 to be consistent with national standards for the NAWQA program. The exceptions were for total phosphorus and dissolved ammonia. For these nutrients, water years 1980-81 were excluded due to possible positive bias in the U.S. Geological Survey data. Water-quality data were tested for trends only if the following criteria were met: (1) no more than 2 years of data were missing at the beginning and ending parts of the period of analysis, and (2) at least one-half of the possible number of seasonal, pairwise data comparisons must have been present in the first and last thirds of the record. To estimate the average rate of change, the censored data were adjusted before testing for trends in the following manner: (1) if fewer than 10 percent of the observations were censored, the censored values were assigned one-half the reporting limit and treated as uncensored; and (2) if more than 10 percent of the data were censored, all data below the largest reporting limit were considered to be at this largest reporting limit.

Trend-test results are reported for concentration data and for flow-adjusted concentration data. By flow adjusting the data, the variability due to differences in streamflow is removed. Flow is adjusted by means of a LOWESS procedure used to relate constituent concentrations and streamflow (Lanfear and Alexander, 1990). No flow adjustment was made if more than 10 percent of the values were censored, if there were fewer than 25 observations, or if more than half of the values had the same flow value.

Correlation analysis was used to test the hypothesis that there is a relation between nutrient concentrations and suspended-sediment or suspended-solids concentration. Spearman's rank correlation (Iman and Conover, 1983), a nonparametric test that uses the rank of the data, was used to determine if there was a relation between the concentrations of total nitrogen and total phosphorus with suspended-sediment concentration. The correlation coefficient measures the strength of association between two variables and can vary between -1 and 1. The closer the coefficient is to -1 or 1, the stronger the correlation. In some cases when there are sufficient data, the associated probability value can indicate a significant correlation, even if the correlation coefficient is not large. This indicates a weak, but true, correlation between the variables, although other effects may be influencing the results. For this study, a correlation with an associated probability of 0.05 or less was considered significant.

Annual loads were estimated for total nitrogen, total phosphorus, and suspended sediment for selected surface-water stations using constituent transport models. The models were based on multiple regression analyses between constituent load and several independent variables. The independent variables included logarithm of streamflow, time (to compensate for long-term trends), and sine and cosine of time (to compensate for seasonal variations). The final model for each station was selected on the basis of residual plots, serial correlation of residuals, standard error, coefficient of determination, and probability values for each coefficient in the regression model. Accuracies of load estimates were dependent on the availability of the samples representing critical hydrologic conditions that control constituent transport. At some stations annual suspended-sediment loads were calculated using daily suspended-sediment concentrations instead of estimating loads using constituent transport models. These calculated values were preferable to estimated values.

For ground-water analysis, summary statistics were calculated using an adjusted log normal maximum likelihood estimator (Helsel and Hirsch, 1992). This method assumes that the entire data set has a log normal distribution, uses the data above the detection limit to fit the best log normal distribution, and uses this distribution to estimate summary statistics for all the data (above and below the detection limit). Boxplots then were constructed using these summary statistics. Multiple comparison tests were done to determine if median nutrient concentrations significantly differed between groups of data. Tukey's test was done on the ranks of the data to determine if there were differences in median nutrient concentrations at the 0.05 probability level between groups of data (Helsel and Hirsch, 1992).

SURFACE-WATER QUALITY

This section presents data from organizations that have collected or currently are collecting data for nutrients, suspended sediment or suspended solids, or pesticides. Many more locations were sampled for these constituents than are presented in this report, but were not included because they did not meet the screening criteria. Ninety-seven surface-water stations within the Rio Grande Valley study unit met the screening criteria for nutrients, suspended sediment, suspended solids, pesticides, or a combination of these constituents (pl. 2).

The two sources of data were the: (1) U.S. Geological Survey NWIS data base (56 stations) and (2) EPA STORET data base (41 stations). The station reference number, station name, source of data, and types of data are listed in table 2.

Nitrogen and phosphorus, as well as other elements, are necessary for plant growth. Forms of nitrogen in water include organic nitrogen, ammonia, nitrite, and nitrate. Forms of phosphorus include the simple ionic orthophosphate and bound phosphate in solution or particulate form. Because dissolved nitrate and phosphate are readily available for plant uptake, their concentrations in natural water are usually small. Elevated nutrient concentrations can cause algal blooms.

Sources of nitrogen in surface water include fertilizer, atmospheric deposition, wastewater-treatment plant discharge, animal waste, septic tank leachate, and natural sources such as nitrogen-fixing algae and mineralization of soil organic matter (U.S. Environmental Protection Agency, 1976; Hem, 1985). High levels of nitrate in drinking water can impair oxygen transport in the blood, especially in infants. This prompted the EPA to set an MCL (maximum contaminant level) of 10 mg/L for nitrate as nitrogen in public drinking-water supplies. Concentrations of ammonia also can have adverse effects on aquatic life.

Sources of phosphorus in the aquatic environment can include phosphate fertilizers, wastewater-treatment plant discharge, animal waste, and erosion of sediments (Hem, 1985). EPA has not established MCL's for phosphorus species in drinking-water supplies.

Suspended sediment can affect water quality in several ways. High suspended-sediment concentration can adversely affect recreational and aesthetic uses. Many trace elements, some organic compounds including pesticides, and some nutrients are effectively sorbed onto and transported with suspended sediment. Biological communities can be adversely affected in environments having high suspended-sediment concentration due to limited light penetration. Finally, high suspended-sediment loads can decrease the storage capacity of reservoirs and other surface-water storage impoundments.

Table 2.–Station reference number, station number, station name, source of data, and type of data for surface-water stations in the Rio Grande Valley study unit

[STORET, U.S. Environmental Protection Agency Storage and Retrieval System data base; NWIS, U.S. Geological Survey National Water Information System data base; BDANWR, Bosque del Apache National Wildlife Refuge. Types of data: n, nutrients; s, suspended solids; d, suspended sediment; p, pesticides]

Station reference number (pl. 2)	Station number	Station name	Source of data	Types of data
1	374916106544701	Rio Grande near Creede, Colo.	STORET	n, s
2	374000106370001	South Fork Rio Grande at South Fork, Colo.	STORET	n, s
3	374122106273801	Rio Grande near Del Norte, Colo.	STORET	n, s
4	372853105524601	Rio Grande at Alamosa, Colo.	STORET	n, s
5	370400106070001	Conejos River near Magote, Colo.	STORET	n, s
6	08251500	Rio Grande near Lobatos, Colo.	NWIS	n, d, p
7	08263500	Rio Grande near Cerro, N. Mex.	NWIS	n, d
8	08264500	Red River below Zwergle Damsite, near Red River, N. Mex.	NWIS	n, d
9	08264970	Red River at Molycorp Mine near Red River, N. Mex.	NWIS	n, d
10	08265000	Red River near Questa, N. Mex.	NWIS	n, d
11	08266000	Cabresto Creek near Questa, N. Mex.	NWIS	n
12	08266500	Red River below Questa, N. Mex.	NWIS	n, d
13	08266820	Red River below fish hatchery near Questa, N. Mex.	NWIS	n, d
14	08267000	Red River at mouth, near Questa, N. Mex.	NWIS	n, d
15	08267400	Rio Grande above Rio Hondo at Dunn Bridge, N. Mex.	NWIS	n, d
16	08268500	Arroyo Hondo at Arroyo Hondo, N. Mex.	NWIS	n, d
17	08276300	Rio Pueblo de Taos below Los Cordovas, N. Mex.	NWIS	n, d, p
18	08276500	Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	NWIS	n, d, p
19	08281100	Rio Grande above San Juan Pueblo, N. Mex.	NWIS	p
20	08284100	Rio Chama near La Puente, N. Mex.	NWIS	n, d
21	08286500	Rio Chama above Abiquiu Reservoir, N. Mex.	NWIS	d
22	08287000	Rio Chama below Abiquiu Dam, N. Mex.	NWIS	d
23	08290000	Rio Chama near Chamita, N. Mex.	NWIS	d, p
24	08291600	Rio Grande at Santa Clara, N. Mex.	NWIS	p
25	08313000	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	NWIS	n, d, p
26	08317200	Santa Fe River above Cochiti Lake, N. Mex.	NWIS	d
27	08317300	Cochiti Lake near Cochiti Pueblo, N. Mex.	NWIS	p
28	08317400	Rio Grande below Cochiti Dam, N. Mex.	NWIS	d
29	08319000	Rio Grande at San Felipe, N. Mex.	NWIS	n, d, p
30	08324000	Jemez River near Jemez, N. Mex.	NWIS	d

Table 2.--Station reference number, station number, station name, source of data, and type of data for surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station number	Station name	Source of data	Types of data
31	08329000	Jemez River below Jemez Canyon Dam, N. Mex.	NWIS	n
32	08329700	Campus Wash at Albuquerque, N. Mex.	NWIS	p
33	08329800	Arroyo del Embudo inlet to floodway channel at Albuquerque, N. Mex.	NWIS	p
34	08329840	Hahn Arroyo at Albuquerque, N. Mex.	NWIS	p
35	08329860	Grant Line Arroyo at Villa Del Oso Drain, Albuquerque, N. Mex.	NWIS	p
36	08329900	North Floodway Channel near Alameda, N. Mex.	NWIS	p
37	08329936	Taylor Ranch Drain at Albuquerque, N. Mex.	NWIS	p
38	08330000	Rio Grande at Albuquerque, N. Mex.	NWIS	n, d, p
39	350411106393701	Rio Grande at Bridge Ave., Albuquerque, N. Mex.	STORET	n
40	350415106392610	10N.03E.30.224 Barelas Bridge pumping station in Albuquerque, N. Mex.	NWIS	p
41	08331000	Rio Grande at Isleta, N. Mex.	NWIS	n, d, p
42	345423106410501	Rio Grande at Isleta Diversion Dam, N. Mex.	STORET	p
43	08332010	Rio Grande Floodway near Bernardo, N. Mex.	NWIS	n, d, p
44	342057106511702	Rio Grande at Bernardo Bridge, US 60, N. Mex.	STORET	p
45	08334000	Rio Puerco above Arroyo Chico, near Guadalupe, N. Mex.	NWIS	d
46	08343500	Rio San Jose near Grants, N. Mex.	NWIS	n, d, p
47	08354000	Rio Salado near San Acacia, N. Mex.	NWIS	n, d
48	08354800	Rio Grande Conveyance Channel at San Acacia, N. Mex.	NWIS	n, d, p
49	08354900	Rio Grande Floodway at San Acacia, N. Mex.	NWIS	n, d, p
50	341525106531201	Rio Grande at San Acacia above diversion dam, N. Mex.	STORET	p
51	335510106510202	Rio Grande at San Antonio, N. Mex.	STORET	p
52	335213106521510	Socorro Main Canal at inflow to BDANWR, N. Mex.	NWIS	p
53	335213106520210	Rio Grande Conveyance Channel at inflow to BDANWR, N. Mex.	NWIS	p
54	335212106514010	Elmendorf Drain at inflow to BDANWR, N. Mex.	NWIS	p
55	335211106512710	San Antonio Drain at inflow to BDANWR, N. Mex.	NWIS	p

Table 2.--Station reference number, station number, station name, source of data, and type of data for surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station number	Station name	Source of data	Types of data
56	334928106525010	BDANWR Interior Drain, 1.2 miles north of BDANWR Headquarters, N. Mex.	NWIS	p
57	334832106525720	Trench pond in field unit 18C at BDANWR, N. Mex.	NWIS	p
58	334828106514710	San Antonio Drain, 1.6 miles east of BDANWR, N. Mex.	NWIS	p
59	334810106522520	Field unit 18B-east triangle at BDANWR, N. Mex.	NWIS	p
60	334616106540720	South Marsh in field unit 25A at BDANWR, N. Mex.	NWIS	p
61	334612106540510	BDANWR Interior Drain near outflow, BDANWR, N. Mex.	NWIS	p
62	08358300	Rio Grande Conveyance Channel at San Marcial, N. Mex.	NWIS	n, d, p
63	08358400	Rio Grande Floodway at San Marcial, N. Mex.	NWIS	n, d, p
64	334145106562701	Rio Grande Conveyance Channel at San Marcial, N. Mex.	STORET	p
65	334200106564501	Rio Grande Floodway at San Marcial, N. Mex.	STORET	p
66	330910107120001	Rio Grande just below Elephant Butte Reservoir, N. Mex.	STORET	p
67	08361000	Rio Grande below Elephant Butte Dam, N. Mex.	NWIS	n, d
68	330630107175801	Rio Grande below Truth or Consequences, N. Mex.	STORET	p
69	08477110	Mimbres River at Mimbres, N. Mex.	NWIS	n, d
70	325358107164501	Caballo Reservoir near dam, N. Mex.	STORET	p
71	325150107165001	Rio Grande just below Caballo, N. Mex.	STORET	p
72	323830107080001	Hatch Drain below Hatch, N. Mex.	STORET	p
73	323905107043001	Rio Grande at Hayner Bridge, N. Mex.	STORET	p
74	323930107043001	Angostura Drain below Rincon, N. Mex.	STORET	p
75	323715107003001	Rincon Drain near Tonoco, N. Mex.	STORET	p
76	322727106533201	Rio Grande below Leasburg Dam, N. Mex.	STORET	p
77	322518106514501	Selden Drain near Hill on US 85, N. Mex.	STORET	p
78	322300106494501	Leasburg Drain above Las Cruces, N. Mex.	STORET	p
79	322236106512101	Rio Grande at N. Mex. Highway 430 near Doña Ana, N. Mex.	STORET	p
80	321836106493401	Rio Grande at Picacho Ave. in Las Cruces, N. Mex.	STORET	p
81	321549106492601	Rio Grande at bridge near La Mesilla, N. Mex.	STORET	p
82	321525106490001	Rio Grande just below Mesilla Dam, N. Mex.	STORET	p
83	321344106475401	Rio Grande at Mesilla Diversion Dam, N. Mex.	STORET	p
84	320715106394501	Del Rio Drain near Vado, N. Mex.	STORET	p
85	320300106404001	La Mesa Drain near Chamberino, N. Mex.	STORET	p

Table 2.--Station reference number, station number, station name, source of data, and type of data for surface-water stations in the Rio Grande Valley study unit--Concluded

Station reference number (pl. 2)	Station number	Station name	Source of data	Types of data
86	315958106380601	Rio Grande near Anthony on N. Mex. Highway 225 Bridge, N. Mex.	STORET	p
87	315850106364501	East Drain near La Tuna, N. Mex.	STORET	p
88	315800106361501	Rio Grande below Anthony, on Highway 278, N. Mex.	STORET	p
89	315455106345501	Vinton R-Drain near Cañutillo, N. Mex.	STORET	p
90	315110106371501	Border Intercept Drain, N. Mex.	STORET	p
91	315048106364701	Nemexas Drain near State Highway 260, N. Mex.	STORET	p
93	314815106323501	Rio Grande at El Paso near El Paso Electric Company Power Plant, Tex.	STORET	p
94	314814106324501	Montoya Drain near the El Paso Electric Company Power Plant, Tex.	STORET	p
95	314810106322501	Rio Grande 1.7 miles up from the American Dam, Tex.	STORET	n, s, p
96	314758106330801	Rio Grande at bridge below Sunland Park, Tex.	STORET	p
97	08364000	Rio Grande at El Paso, Tex.	NWIS	n, d

Nutrients

Nutrient data analyzed in this report include those stations that had 15 or more analyses over at least 3 consecutive years for at least one of the following: total nitrogen, dissolved ammonia, dissolved nitrate, total phosphorus, or dissolved orthophosphate. Many methods of chemical analyses are available for different species of nitrogen. Some analyses are for a particular species, some are for combinations of species, and some are reported for total or dissolved species only. A total nitrogen value was assigned first by checking to see if total nitrogen was reported as nitrogen or as nitrate; if so, this value was used (converted to nitrogen if reported as nitrate). If the analysis for total nitrogen was not reported but analyses for total Kejldahl nitrogen plus organic nitrogen and total nitrite plus nitrate were present, they were summed and reported as total nitrogen. Dissolved-nitrate values were assigned as follows: first, if dissolved nitrate as nitrogen or as nitrate was reported, this value was used (converted to nitrogen if reported as nitrate); second, if dissolved nitrite plus nitrate and dissolved-nitrite analyses were available, dissolved nitrite was subtracted from dissolved nitrite plus nitrate and reported as dissolved nitrate. When data were combined to attain a value for both total nitrogen and dissolved nitrate, only data above the detection limit were used. Using this procedure did not substantially reduce the size of the data sets.

Thirty-six stations met the requirement for number of analyses. All of the stations except one are either on the main stem or on tributaries to the Rio Grande. Mimbres River at Mimbres, New Mexico (69), is in a closed basin in the southern part of the study unit, west of the Rio Grande (pl. 2).

A scatterplot of the concentration of each nutrient for water years 1972-90 shows the temporal distribution of the data for each station. Concentrations of nutrients for the main-stem stations are shown in figures 10-14. Concentrations of nutrients for the remaining stations are shown in figures 15-18. Caution needs to be exercised when comparing stations due to possible differences in the period of sampling and sampling frequency.

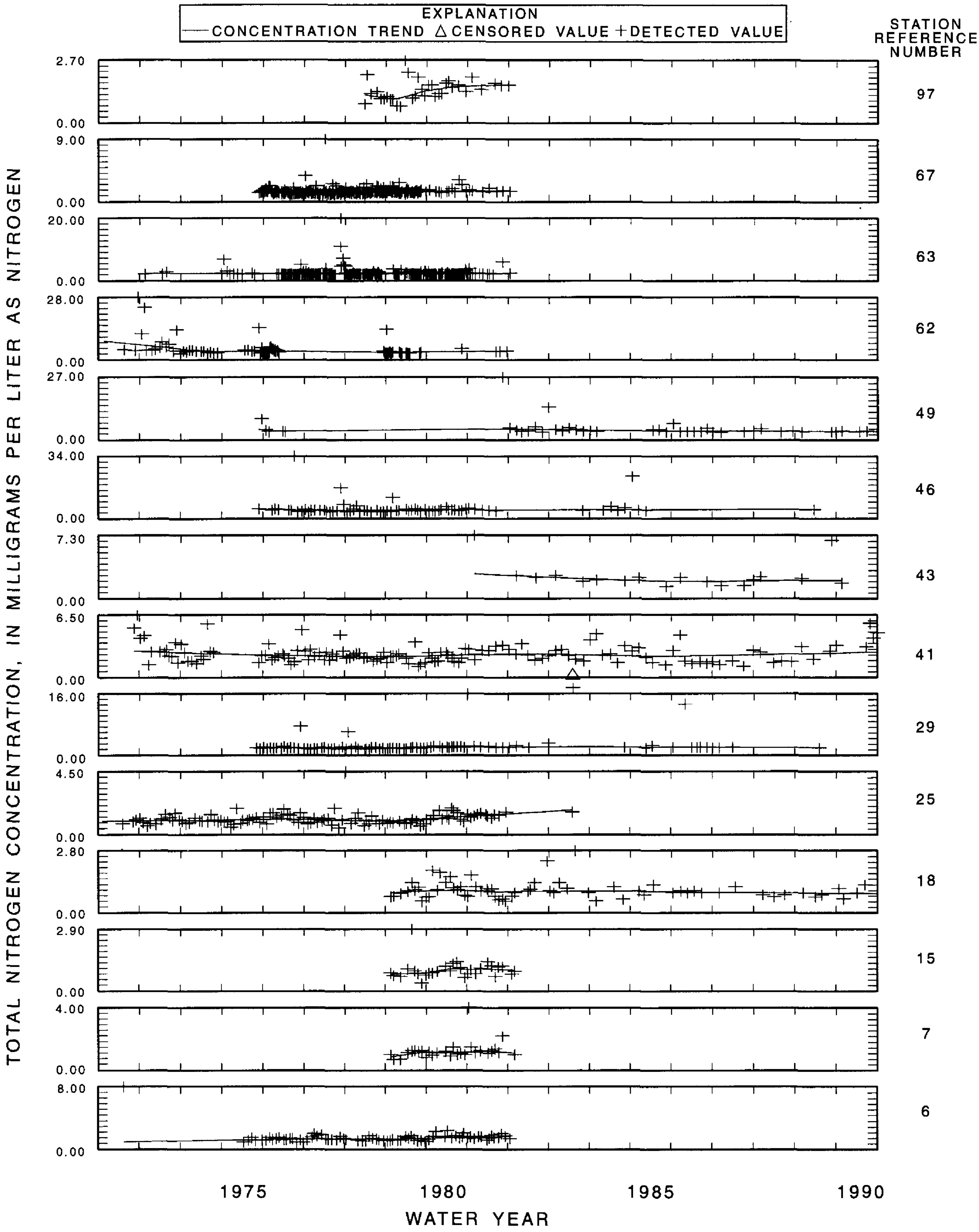


Figure 10.--Total nitrogen concentrations at main-stem stations in the Rio Grande Valley study unit, water years 1972-90.

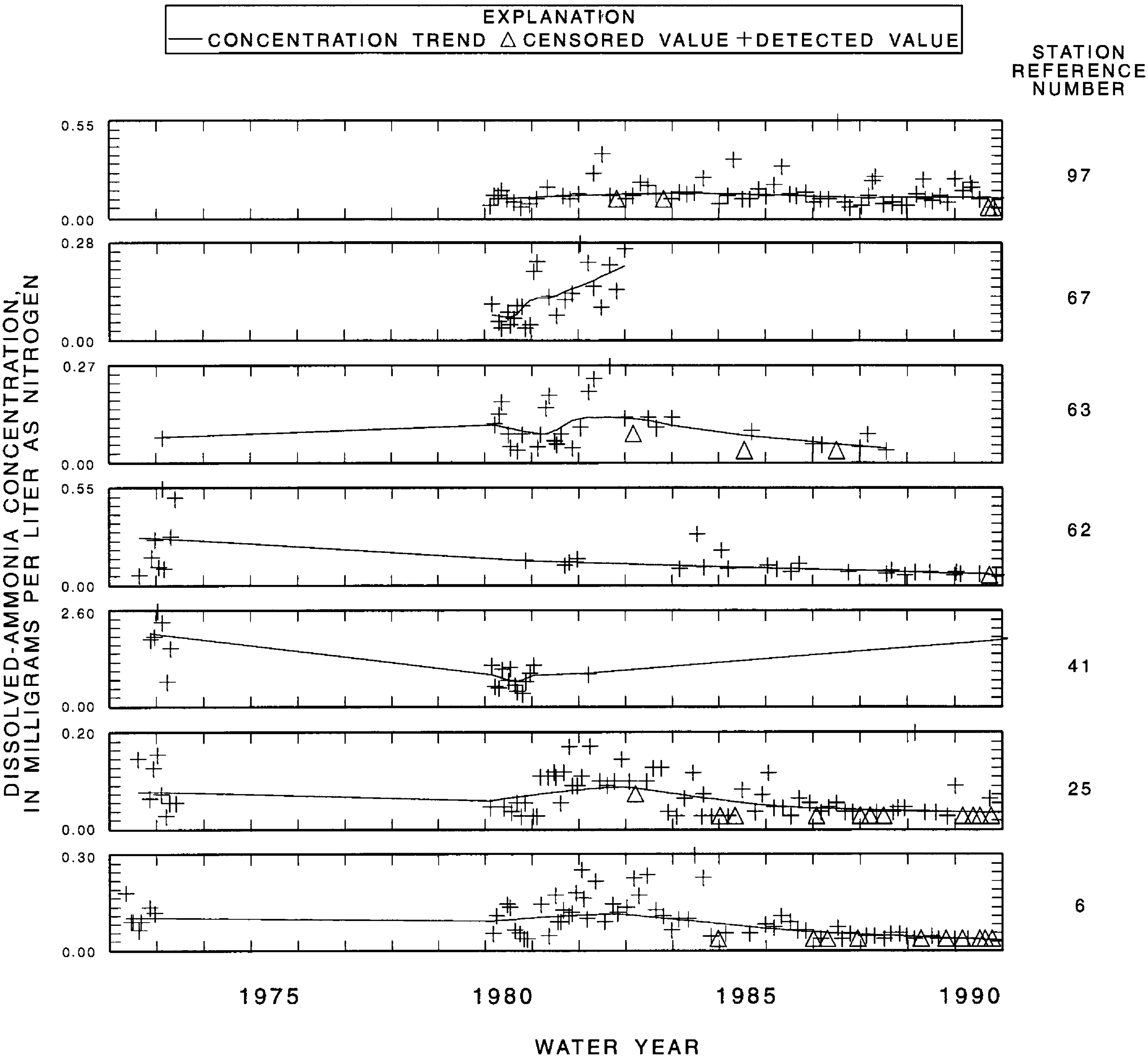


Figure 11.--Dissolved-ammonia concentrations at main-stem stations in the Rio Grande Valley study unit, water years 1972-90.

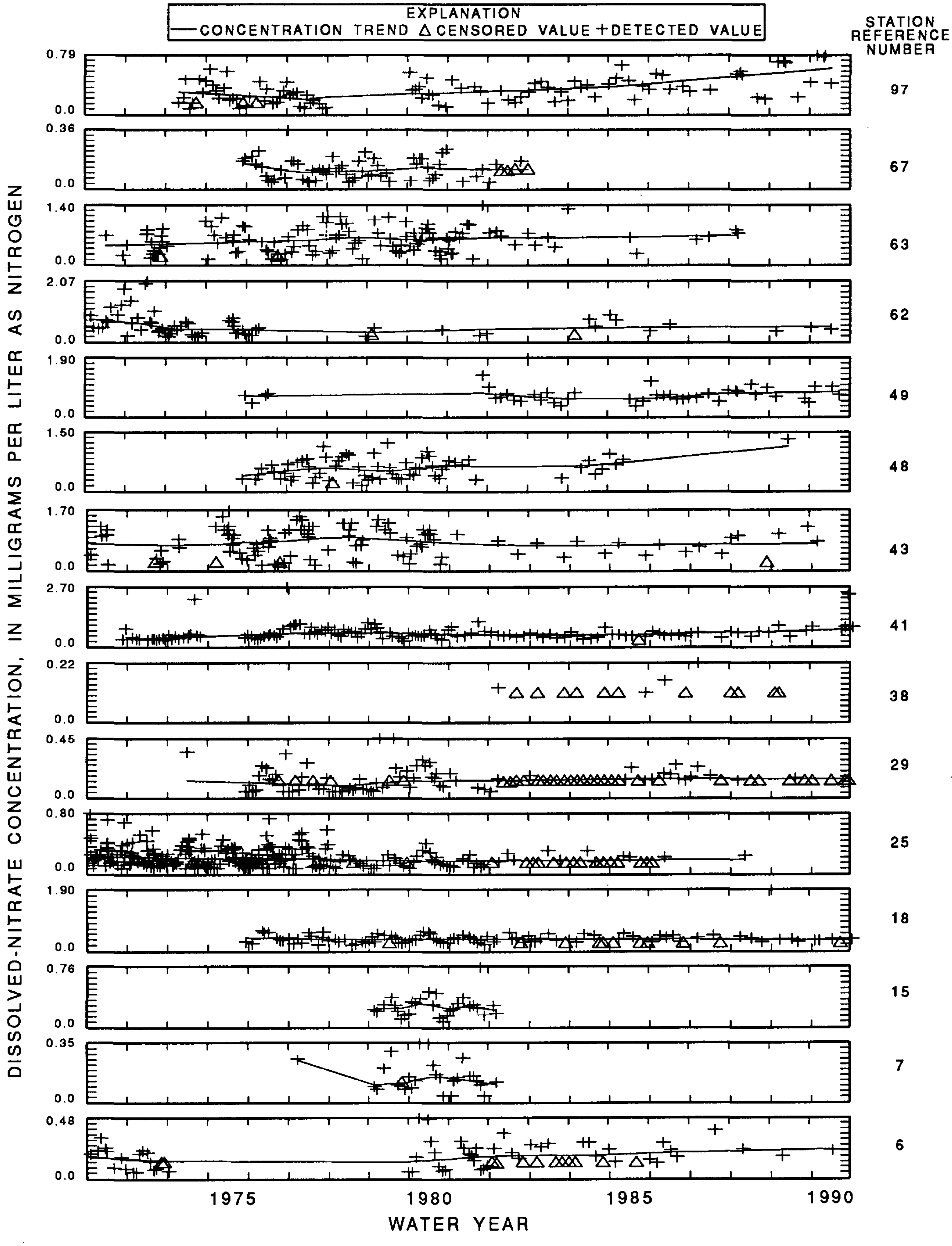


Figure 12.--Dissolved-nitrate concentrations at main-stem stations in the Rio Grande Valley study unit, water years 1972-90.

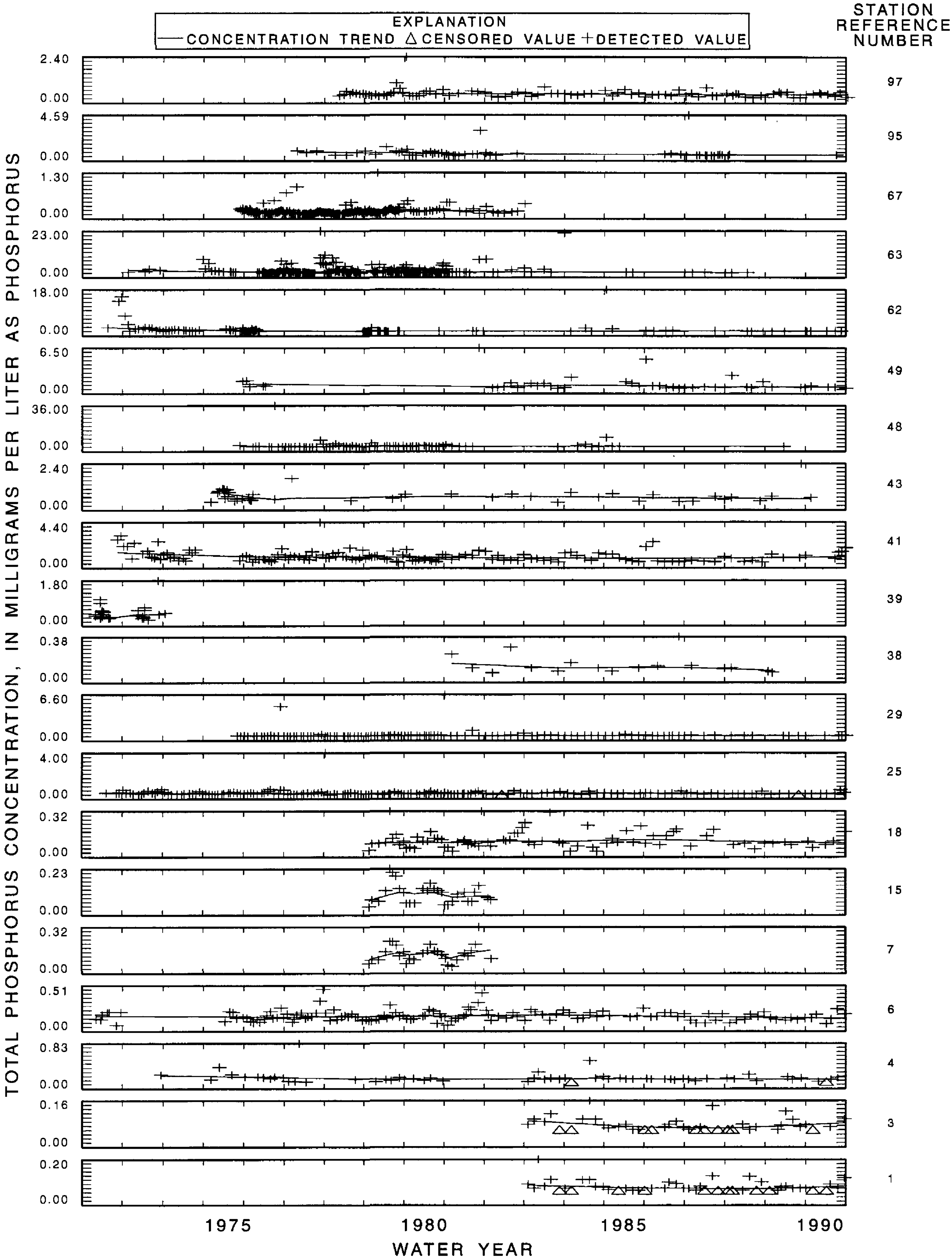


Figure 13.--Total phosphorus concentrations at main-stem stations in the Rio Grande Valley study unit, water years 1972-90.

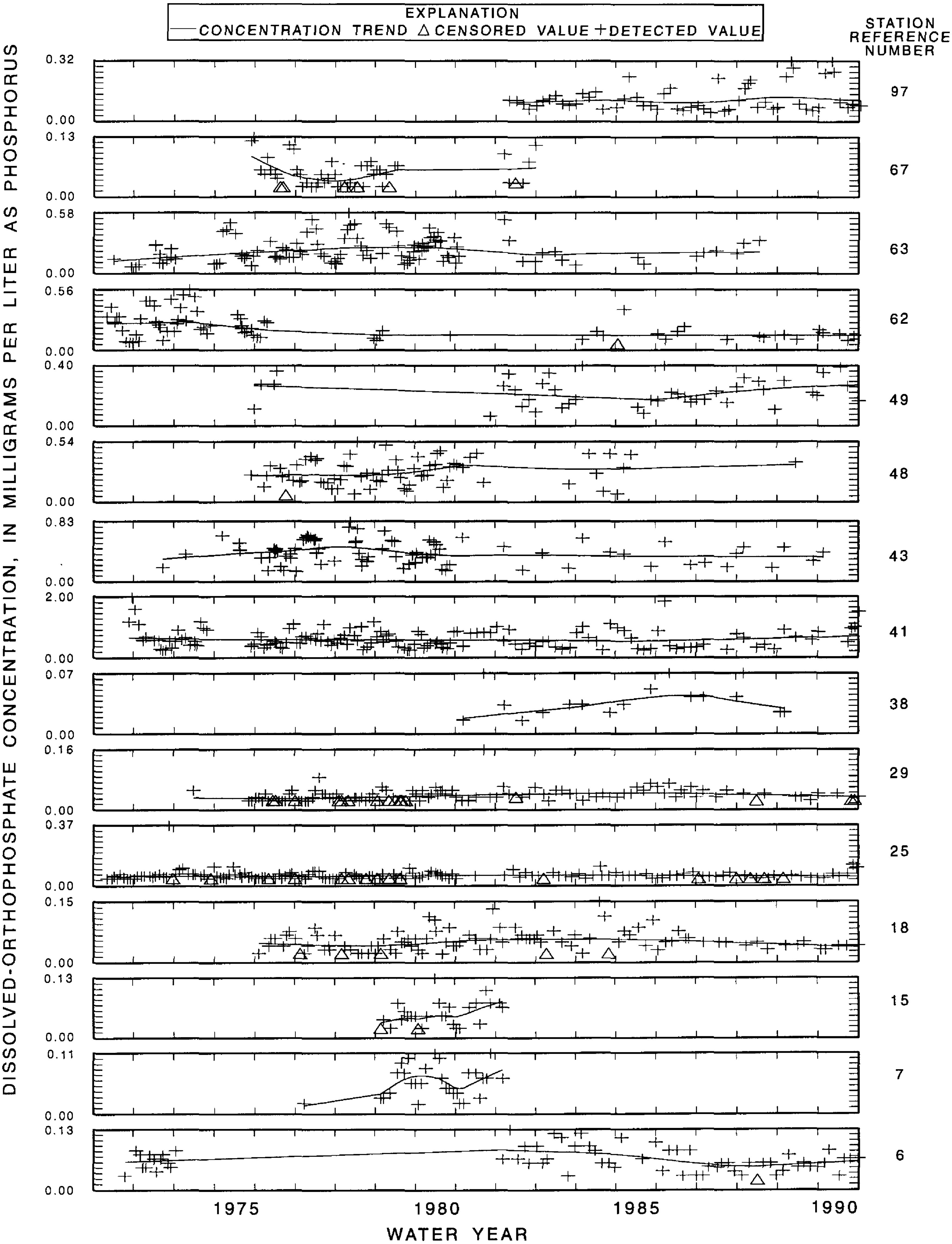


Figure 14.--Dissolved-orthophosphate concentrations at main-stem stations in the Rio Grande Valley study unit, water years 1972-90.

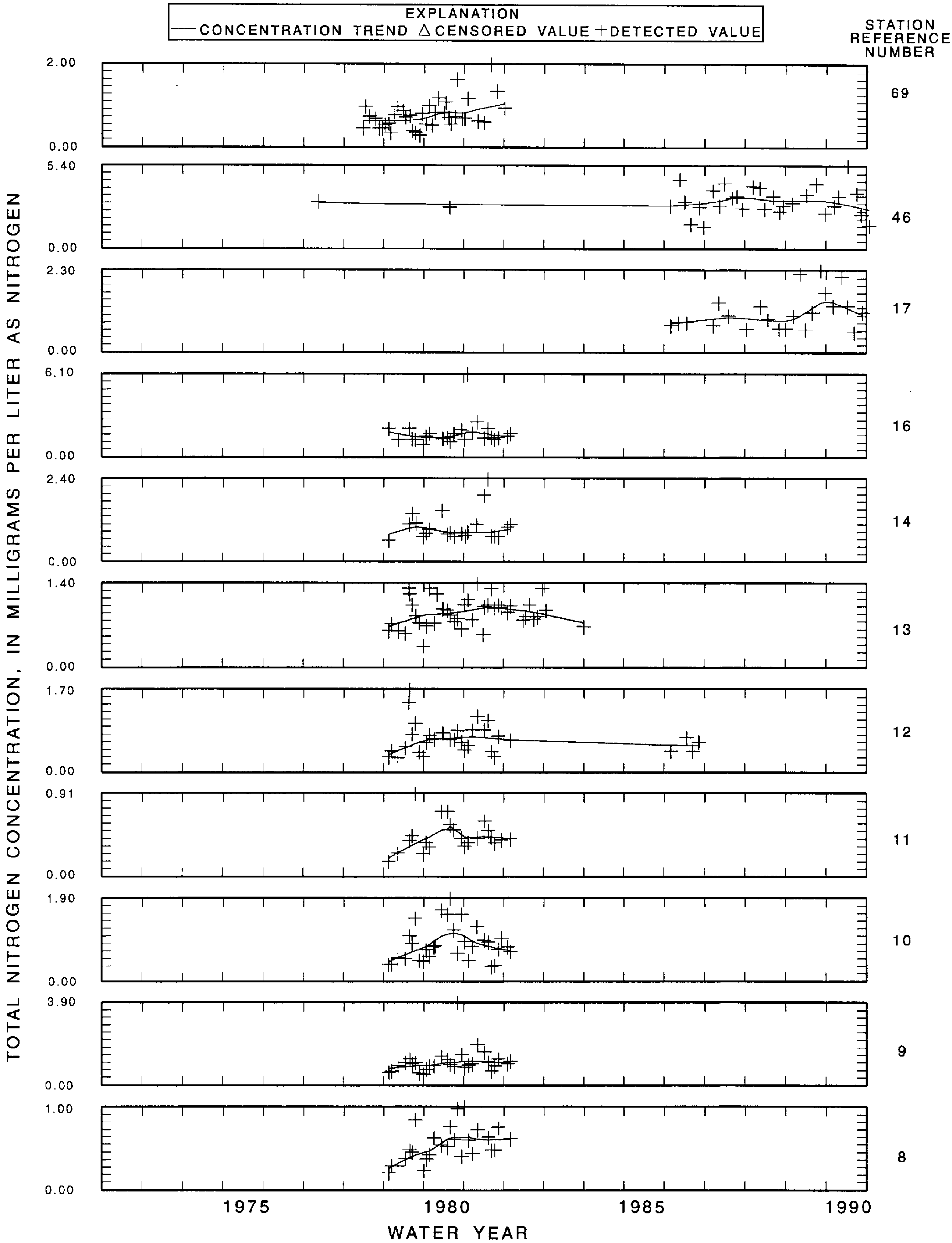


Figure 15.--Total nitrogen concentrations at selected stations in the Rio Grande Valley study unit, water years 1972-90.

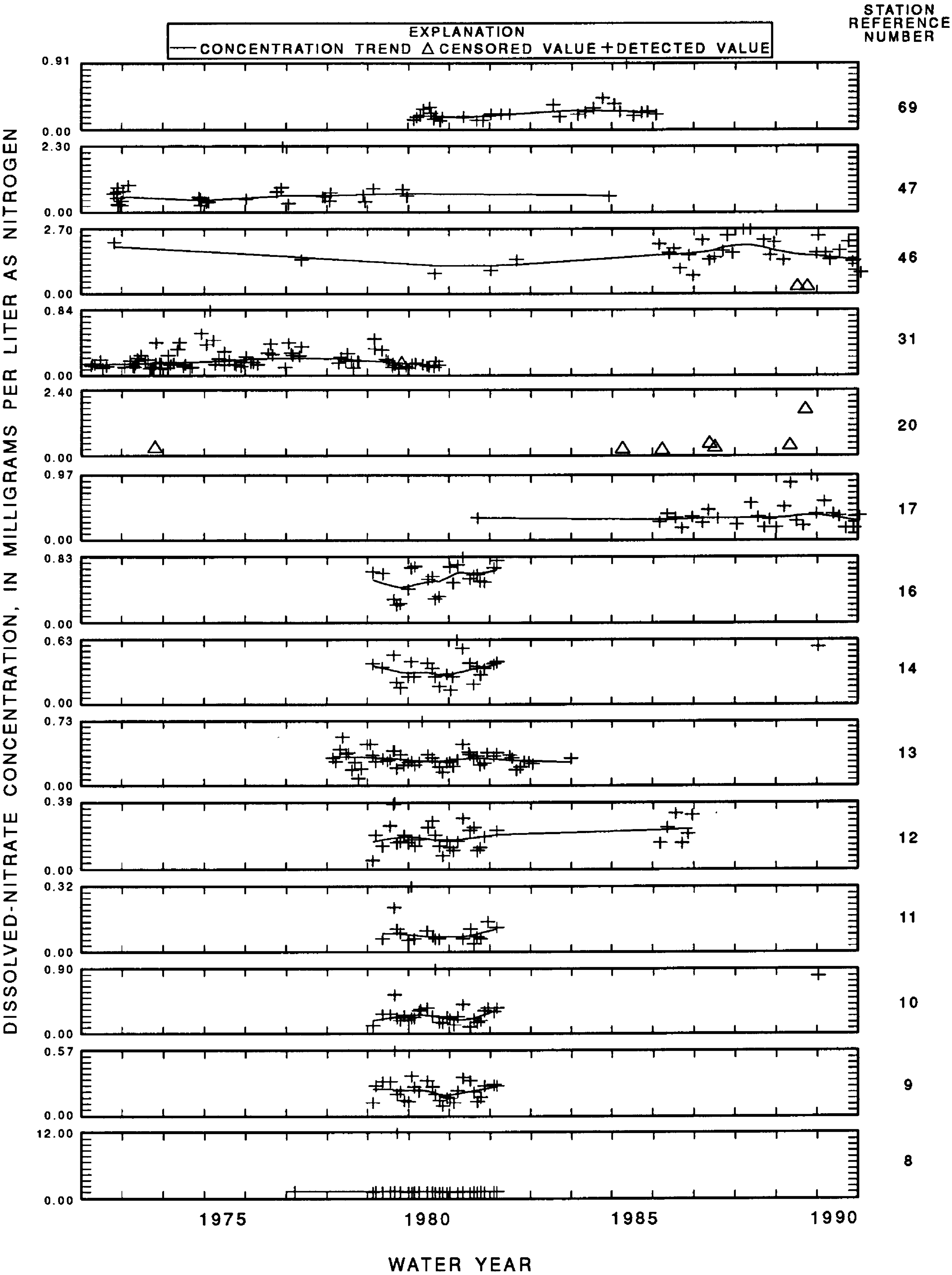


Figure 16.--Dissolved-nitrate concentrations at selected stations in the Rio Grande Valley study unit, water years 1972-90.

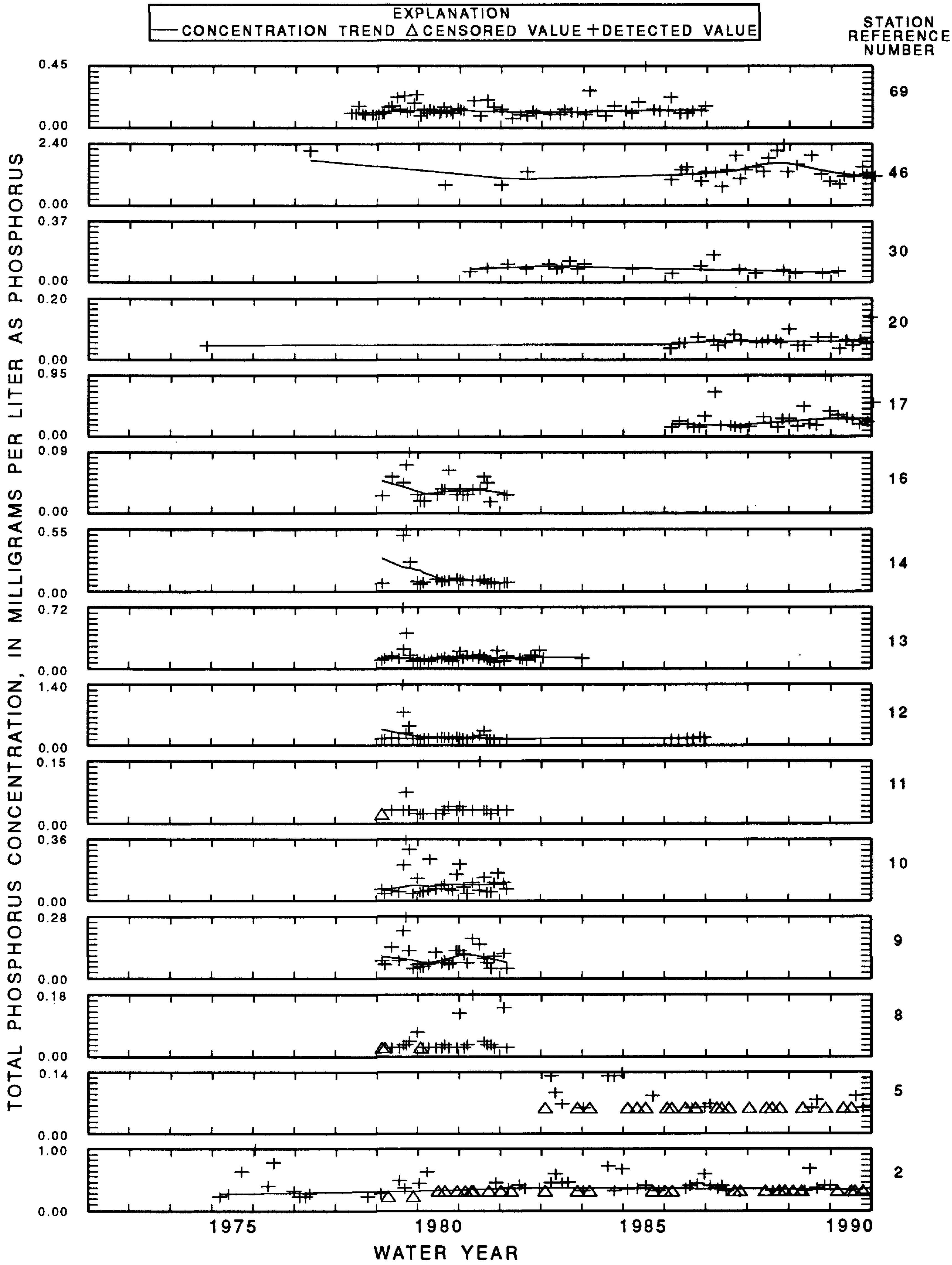


Figure 17.--Total phosphorus concentrations at selected stations in the Rio Grande Valley study unit, water years 1972-90.

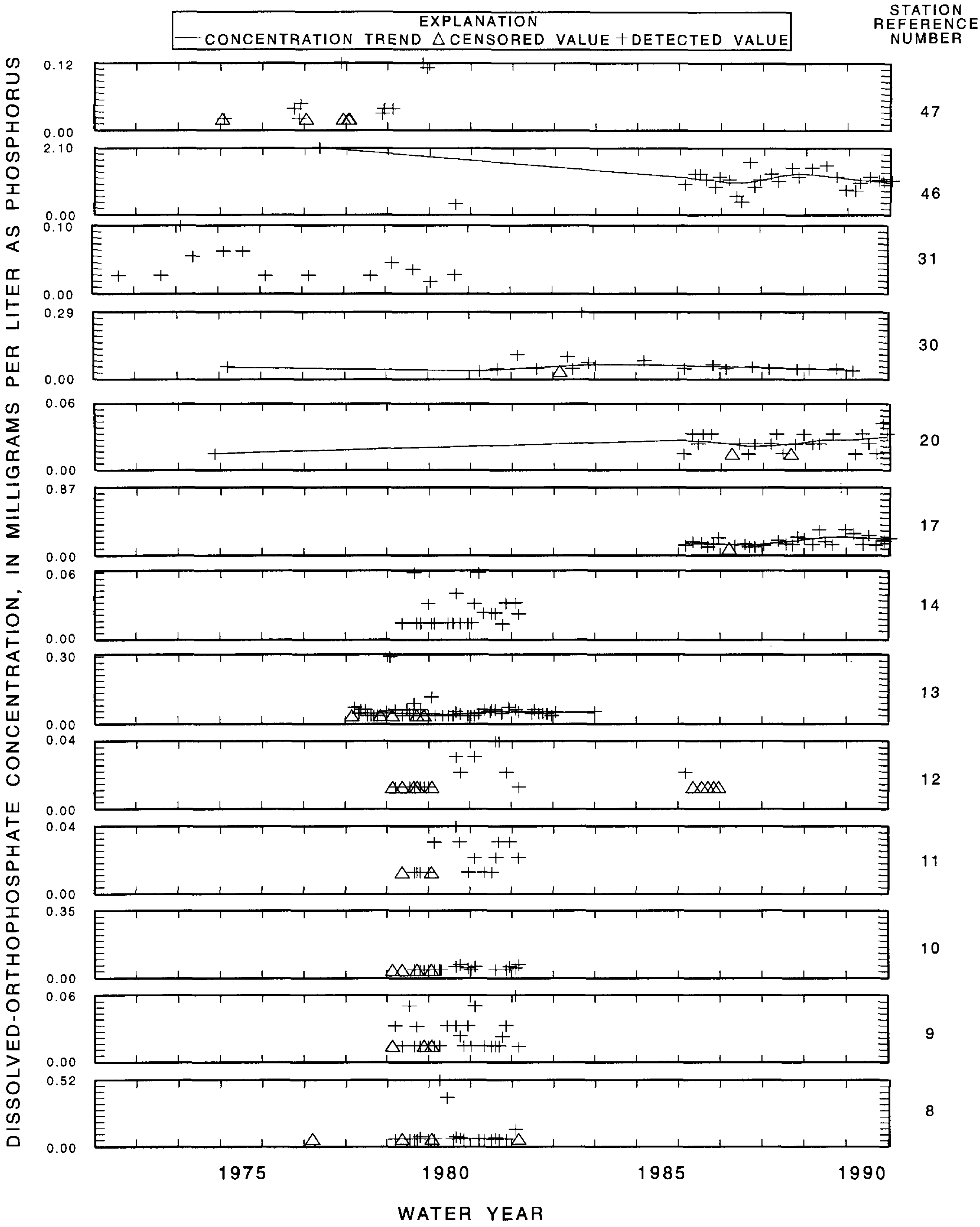


Figure 18.--Dissolved-orthophosphate concentrations at selected stations in the Rio Grande Valley study unit, water years 1972-90.

Boxplots were prepared for each station for each nutrient. These were grouped into two sets of figures: (1) main-stem stations (figs. 19-23) and (2) tributary and other stations (figs. 24-27). A statistical summary of nutrient concentrations for selected stations in the study unit is presented in table 3. There was little or no difference in concentrations of nutrients between specific main-stem stations upstream from Rio Grande at Isleta, New Mexico (41). At this station concentrations for all nutrients were larger than those for the upstream stations. At the station Rio Grande below Elephant Butte Dam, New Mexico (67), concentrations of all constituents, with the exception of dissolved ammonia, were less than concentrations at the next upstream station, Rio Grande Floodway at San Marcial, New Mexico (63). With the exception of dissolved ammonia, concentrations then increased between Rio Grande at Elephant Butte, New Mexico (67), and Rio Grande at El Paso, Texas (97). Stations 48 and 49 are the conveyance channel and floodway stations at San Acacia and stations 62 and 63 are the conveyance channel and floodway stations at San Marcial. Differences in nutrient concentrations between the San Acacia stations could be attributed to differences in streamflow because water is diverted into the conveyance channel from the floodway channel at low-flow rates. The differences in nutrient concentrations at the San Marcial stations can be attributed not only to streamflow but to agricultural returns into the conveyance channel. At both stations, the sampling periods differed (figs. 10-14) and this could have contributed to differences in nutrient concentrations displayed on the boxplots. The tributary station boxplots show some increase in total nitrogen, dissolved nitrate, and total phosphorus for the Red River stations downstream from Red River below Zwergle Damsite near Red River, New Mexico (8), to Red River at mouth near Questa, New Mexico (14). Of all tributaries, Rio San Jose near Grants, New Mexico (46), had the largest concentrations of all nutrients. This station is downstream from the sewage-treatment plant in Grants, and flow in the river is about 15 percent effluent (Risser, 1982, p. 31).

The Mann-Whitney test was used to test for significant differences between adjacent stations on the main stem of the Rio Grande for total nitrogen and total phosphorus (tables 4 and 5). The sampling period varied for stations used in this test, and this needs to be considered when evaluating the results. Differences were considered statistically significant at probability values less than or equal to 0.05. Significant differences in total nitrogen concentration occurred between streamflow-monitoring stations Rio Grande at Otowi Bridge near San Ildefonso, New Mexico (25), and Rio Grande at San Felipe, New Mexico (29); Rio Grande at San Felipe, New Mexico (29), and Rio Grande at Isleta, New Mexico (41); Rio Grande Floodway at San Marcial, New Mexico (63), and Rio Grande below Elephant Butte Dam, New Mexico (67); Rio Grande below Elephant Butte Dam, New Mexico (67), and Rio Grande at El Paso, Texas (97); and San Marcial Conveyance Channel (62) and Floodway (63) stations (table 4). Test results show that more adjacent stations had significant differences in total phosphorus concentrations than in total nitrogen concentrations. Total phosphorus concentrations at Rio Grande at Alamosa, Colorado (4), were significantly larger than those at Rio Grande near Del Norte, Colorado (3). The only pair of adjacent stations whose total phosphorus concentrations did not differ significantly downstream from Rio Grande below Taos Junction Bridge, near Taos, New Mexico (18), was Rio Grande Floodway near Bernardo, New Mexico (43), and Rio Grande Floodway at San Acacia, New Mexico (49) (table 5). Differences between adjacent stations in total nitrogen and total phosphorus may be caused by natural, anthropogenic, or temporal factors (figs. 19 and 22).

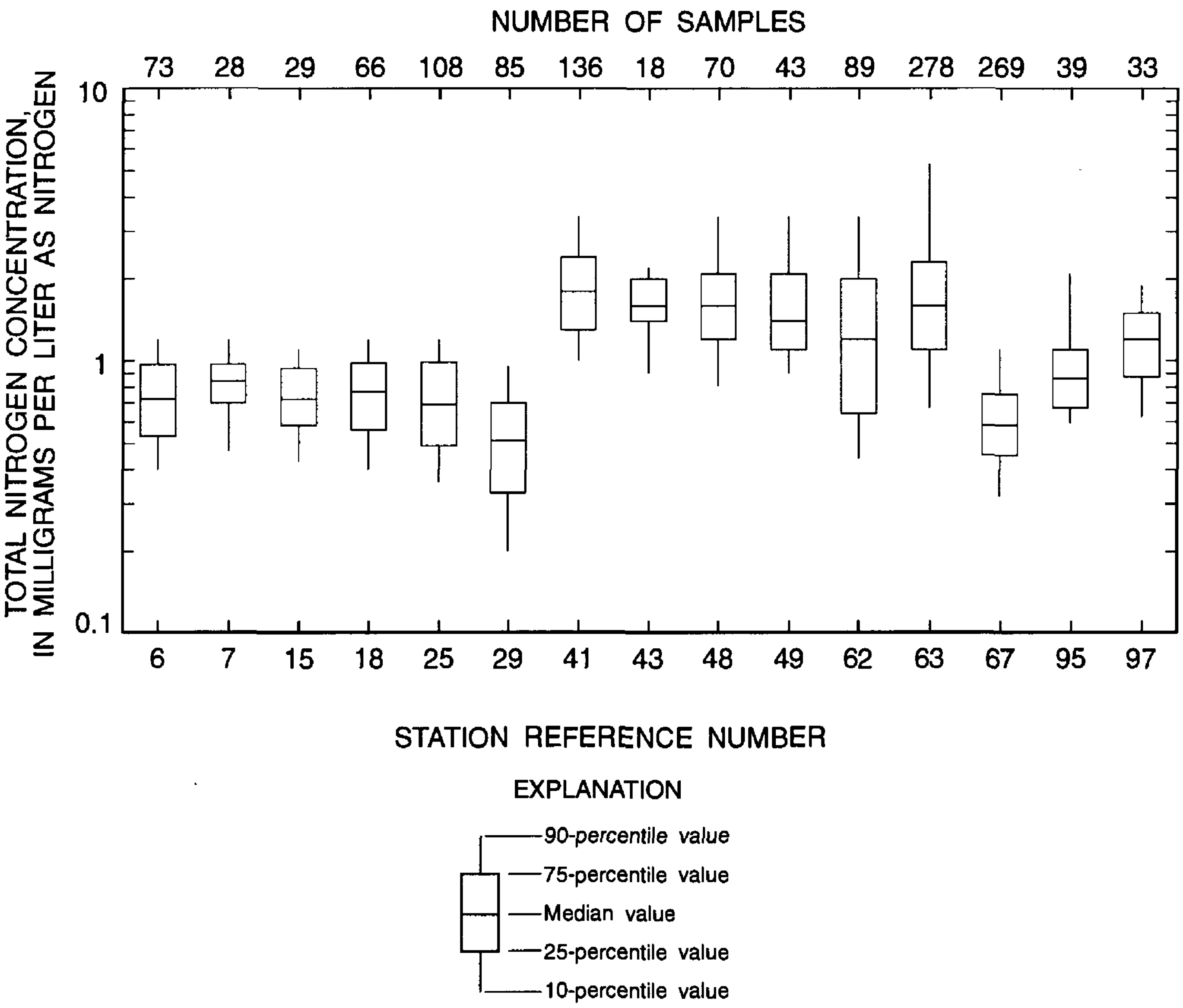


Figure 19.--Total nitrogen concentrations at main-stem stations in the Rio Grande Valley study unit, water years 1972-90.

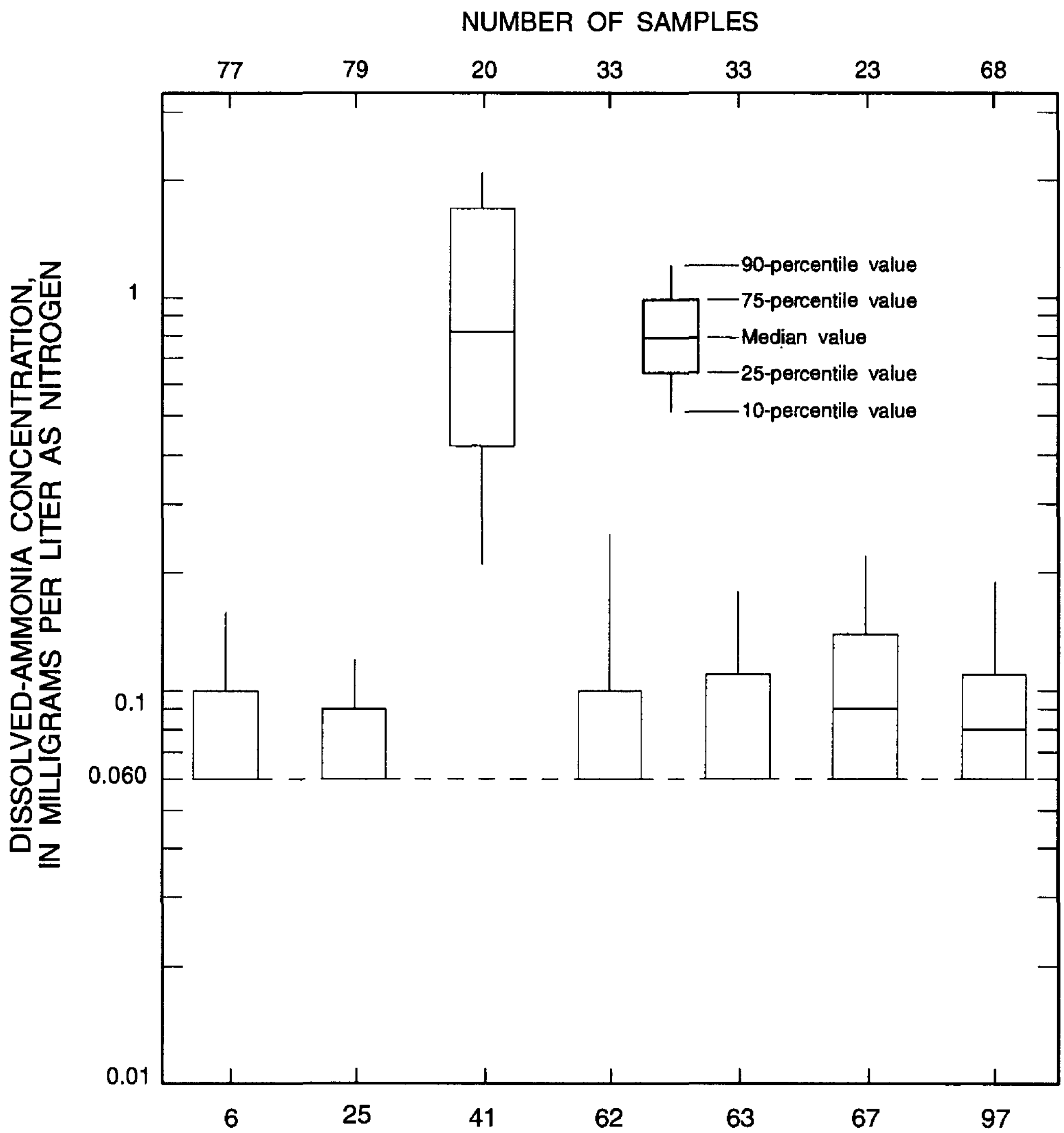


Figure 20.--Dissolved-ammonia concentrations at main-stem stations in the Rio Grande Valley study unit, water years 1972-90.

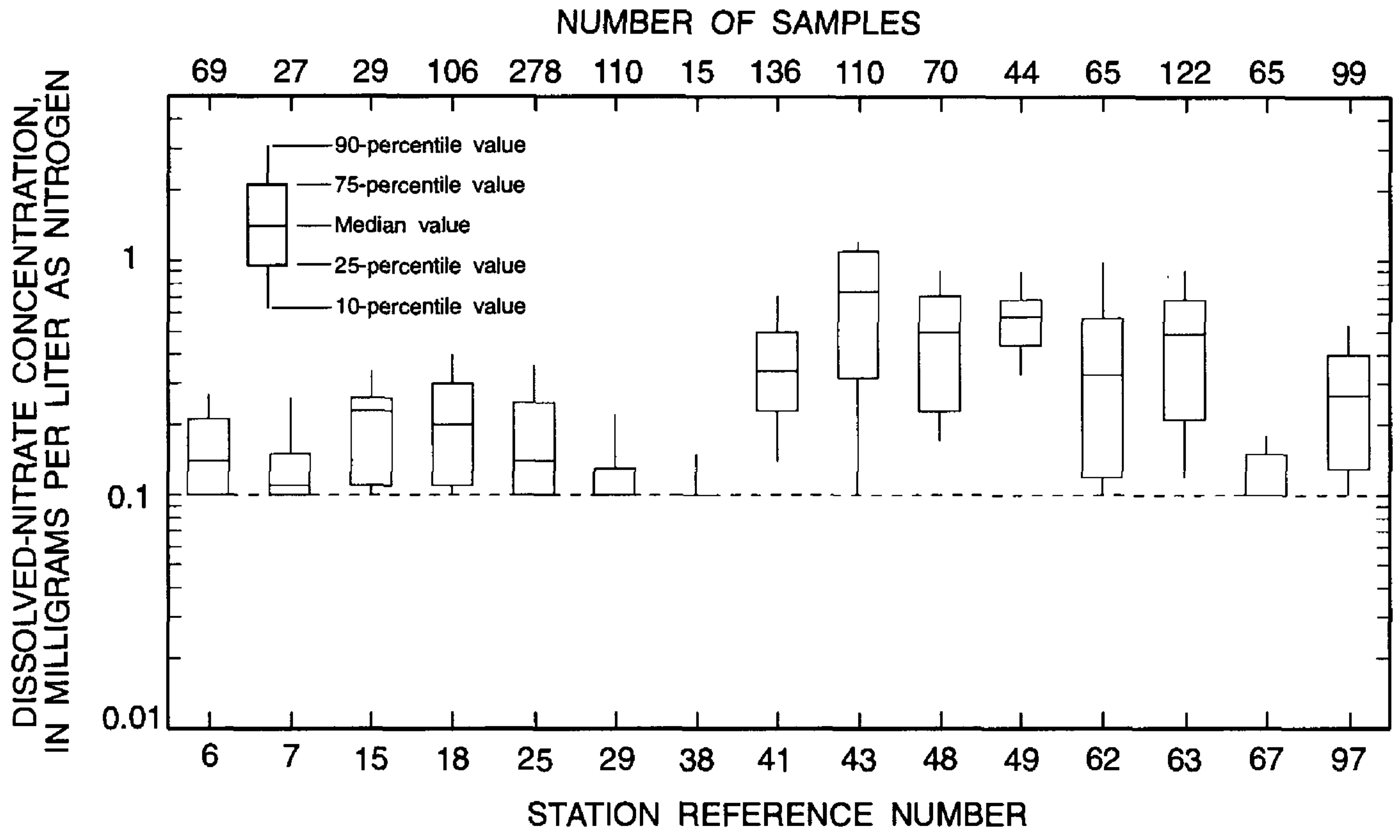


Figure 21.--Dissolved-nitrate concentrations at main-stem stations in the Rio Grande Valley study unit, water years 1972-90.

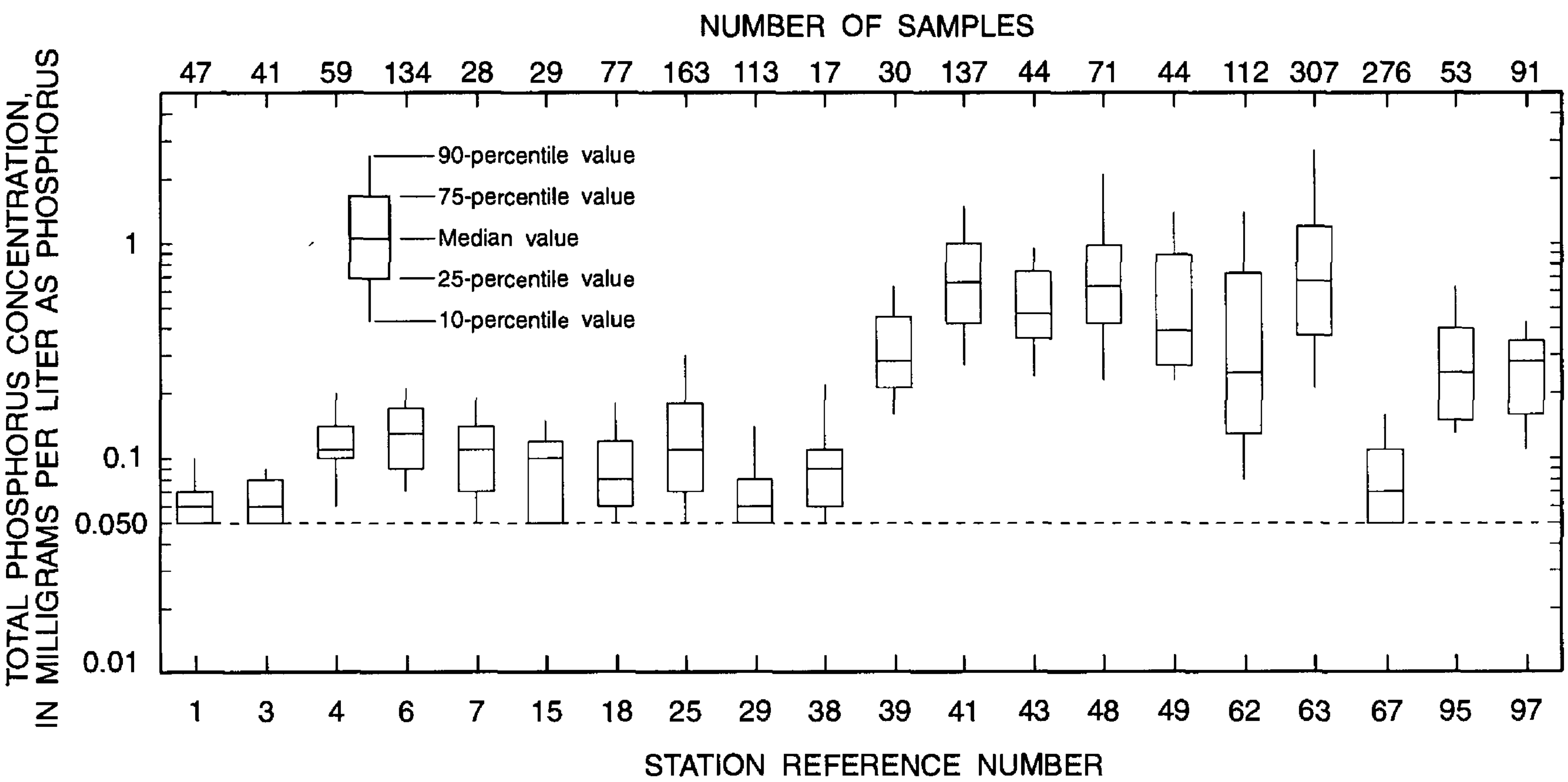


Figure 22.--Total phosphorus concentrations at main-stem stations in the Rio Grande Valley study unit, water years 1972-90.

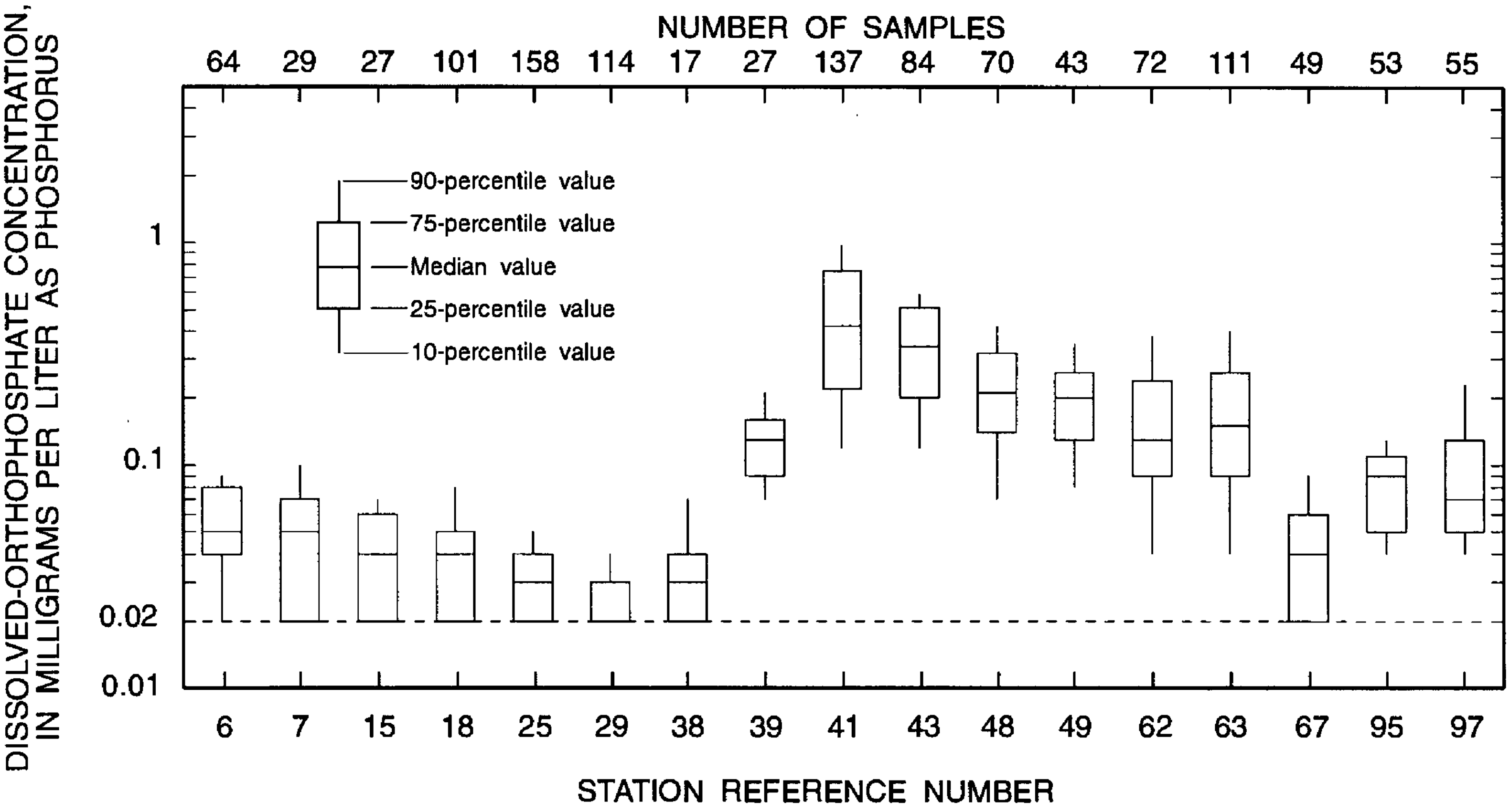


Figure 23.--Dissolved-orthophosphate concentrations at main-stem stations in the Rio Grande Valley study unit, water years 1972-90.

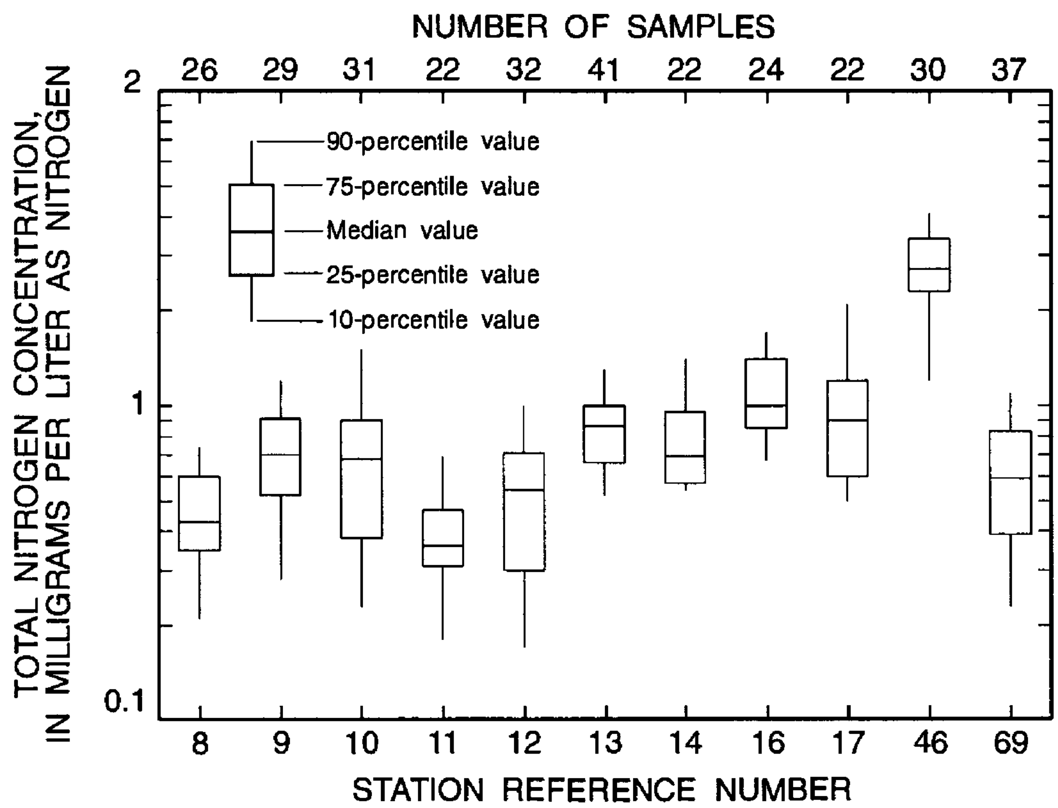


Figure 24.--Total nitrogen concentrations at selected stations in the Rio Grande Valley study unit, water years 1972-90.

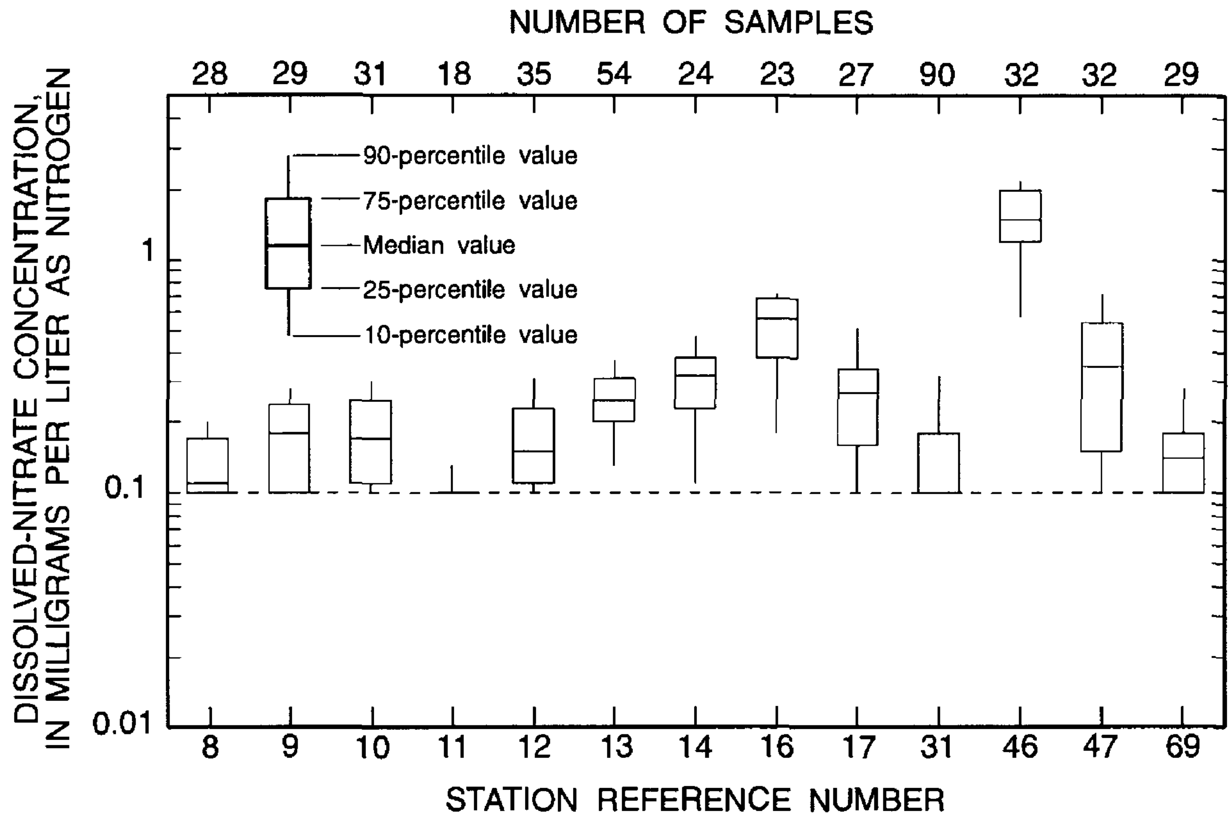


Figure 25.--Dissolved-nitrate concentrations at selected stations in the Rio Grande Valley study unit, water years 1972-90.

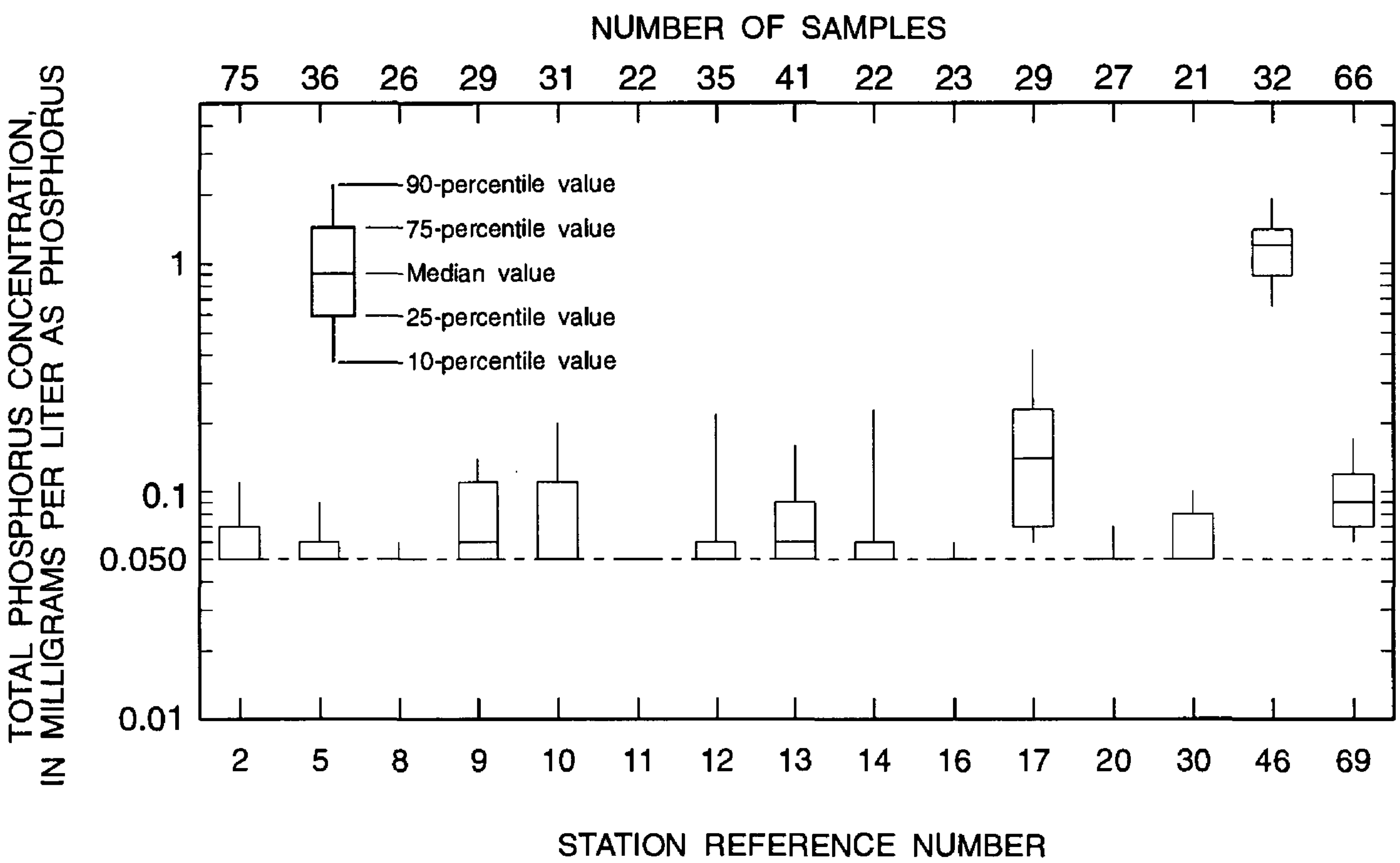


Figure 26.--Total phosphorus concentrations at selected stations in the Rio Grande Valley study unit, water years 1972-90.

Table 3.--Statistical summary of concentrations of nutrients in surface water from selected sampling stations in the Rio Grande Valley study unit, water years 1972-90

[Station reference number: see plate 2 for location. Includes only those stations with 15 or more analyses; <, less than]

Station reference number	Station name	Number of analyses	Concentration at indicated percentile, in milligrams per liter				
			10	25	50	75	90
	Nitrogen, total as N						
6	Rio Grande near Lobatos, Colo.	73	0.40	0.53	0.72	0.97	1.2
7	Rio Grande near Cerro, N. Mex.	28	.47	.70	.84	.97	1.2
8	Red River below Zwergle Damsite, near Red River, N. Mex.	26	.21	.35	.43	.60	.74
9	Red River at Molycorp Mine near Red River, N. Mex.	19	.28	.52	.70	.91	1.2
10	Red River near Questa, N. Mex.	31	.23	.38	.68	.90	1.5
11	Cabresto Creek near Questa, N. Mex.	22	.18	.31	.36	.47	.69
12	Red River below Questa, N. Mex.	32	.17	.30	.54	.71	1.0
13	Red River below fish hatchery, near Questa, N. Mex.	41	.52	.66	.86	1.0	1.3
14	Red River at mouth, near Questa, N. Mex.	22	.54	.57	.69	.96	1.4
15	Rio Grande above Rio Hondo at Dunn Bridge, N. Mex.	29	.43	.58	.72	.94	1.1
16	Arroyo Hondo at Arroyo Hondo, N. Mex.	24	.67	.85	1.0	1.4	1.7
17	Rio Pueblo de Taos below Los Cordovas, N. Mex.	22	.50	.60	.90	1.2	2.1
18	Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	66	.40	.56	.77	.98	1.2
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	108	.36	.49	.69	.99	1.2
29	Rio Grande at San Felipe, N. Mex.	85	.20	.33	.51	.70	.96
41	Rio Grande at Isleta, N. Mex.	136	1.0	1.3	1.8	2.4	3.4
43	Rio Grande Floodway near Bernardo, N. Mex.	18	.90	1.4	1.6	2.0	2.2
46	Rio San Jose near Grants, N. Mex.	30	1.2	2.3	2.7	3.4	4.1
48	Rio Grande Conveyance Channel at San Acacia, N. Mex.	70	.81	1.2	1.6	2.1	3.4

Table 3.--Statistical summary of concentrations of nutrients in surface water from selected sampling stations in the Rio Grande Valley study unit, water years 1972-90--Continued

Station reference number	Station name	Number of analyses	Concentration at indicated percentile, in milligrams per liter				
			10	25	50	75	90
	Nitrogen, total as N--Continued						
49	Rio Grande Floodway at San Acacia, N. Mex.	43	0.90	1.1	1.4	2.1	3.4
62	Rio Grande Conveyance Channel at San Marcial, N. Mex.	89	.44	.64	1.2	2.0	3.4
63	Rio Grande Floodway at San Marcial, N. Mex.	278	.67	1.1	1.6	2.3	5.3
67	Rio Grande below Elephant Butte Dam, N. Mex.	269	.32	.45	.58	.75	1.1
69	Mimbres River at Mimbres, N. Mex.	37	.23	.39	.59	.83	1.1
95	Rio Grande 1.7 miles up from the American Dam, Tex.	39	.59	.67	.86	1.1	2.1
97	Rio Grande at El Paso, Tex.	33	.62	.87	1.2	1.5	1.9
	Nitrogen, nitrate, dissolved as N						
6	Rio Grande near Lobatos, Colo.	69	0.03	0.09	0.14	0.21	0.27
7	Rio Grande near Cerro, N. Mex.	27	.01	.07	.11	.15	.26
8	Red River below Zwergle Damsite, near Red River, N. Mex.	28	.01	.05	.11	.17	.20
9	Red River at Molycorp Mine near Red River, N. Mex.	29	.07	.09	.18	.24	.28
10	Red River near Questa, N. Mex.	31	.03	.11	.17	.25	.30
11	Cabresto Creek near Questa, N. Mex.	18	.03	.04	.05	.09	.13
12	Red River below Questa, N. Mex.	35	.08	.11	.15	.23	.31
13	Red River below fish hatchery near Questa, N. Mex.	54	.13	.20	.25	.31	.37
14	Red River at mouth, near Questa, N. Mex.	24	.11	.23	.32	.38	.47
15	Rio Grande above Rio Hondo at Dunn Bridge, N. Mex.	29	.06	.11	.23	.26	.34
16	Arroyo Hondo at Arroyo Hondo, N. Mex.	23	.18	.38	.56	.68	.72
17	Rio Pueblo de Taos below Los Cordovas, N. Mex.	27	.10	.16	.27	.34	.51

Table 3.--Statistical summary of concentrations of nutrients in surface water from selected sampling stations in the Rio Grande Valley study unit, water years 1972-90--Continued

Station reference number	Station name	Number of analyses	Concentration at indicated percentile, in milligrams per liter: 10	25	50	75	90
	Nitrogen, nitrate, dissolved as N--Continued						
18	Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	106	0.08	0.11	0.20	0.30	0.40
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	278	.03	.08	.14	.25	.36
29	Rio Grande at San Felipe, N. Mex.	110	<.01	.06	.09	.18	.32
31	Jemez River below Jemez Canyon Dam, N. Mex.	90	.02	.04	.10	.19	.35
38	Rio Grande at Albuquerque, N. Mex.	15	<.10	<.10	<.10	<.10	.15
41	Rio Grande at Isleta, N. Mex.	136	.14	.23	.34	.50	.71
43	Rio Grande Floodway near Bernardo, N. Mex.	110	.10	.32	.74	1.1	1.2
46	Rio San Jose near Grants, N. Mex.	32	.57	1.2	1.5	2.0	2.2
47	Rio Salado near San Acacia, N. Mex.	32	.04	.15	.35	.54	.71
48	Rio Grande Conveyance Channel at San Acacia, N. Mex.	70	.17	.23	.50	.71	.90
49	Rio Grande Floodway at San Acacia, N. Mex.	44	.33	.44	.58	.69	.90
62	Rio Grande Conveyance Channel at San Marcial, N. Mex.	65	.03	.12	.33	.57	.98
63	Rio Grande Floodway at San Marcial, N. Mex.	122	.12	.21	.49	.69	.91
67	Rio Grande below Elephant Butte Dam, N. Mex.	65	.02	.04	.09	.15	.18
69	Mimbres River at Mimbres, N. Mex.	29	.04	.09	.14	.18	.28
97	Rio Grande at El Paso, Tex.	99	.08	.13	.27	.40	.54
	Nitrogen, ammonia, dissolved as N						
6	Rio Grande near Lobatos, Colo.	77	<0.01	<0.01	0.05	0.10	0.16
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	79	<.01	<.01	.04	.09	.12
41	Rio Grande at Isleta, N. Mex.	20	.21	.42	.82	1.7	.21

Table 3.--Statistical summary of concentrations of nutrients in surface water from selected sampling stations in the Rio Grande Valley study unit, water years 1972-90--Continued

Station reference number	Station name	Number of analyses	Concentration at indicated percentile, in milligrams per liter				
			10	25	50	75	90
	Nitrogen, ammonia, dissolved as N--Continued						
62	Rio Grande Conveyance Channel at San Marcial, N. Mex.	33	<0.01	0.02	0.05	0.10	0.25
63	Rio Grande Floodway at San Marcial, N. Mex.	33	<.01	.02	.06	.11	.18
67	Rio Grande below Elephant Butte Dam, N. Mex.	23	<.01	.04	.09	.14	.22
69	Mimbres River at Mimbres, N. Mex.	40	<.01	.03	.04	.07	.10
97	Rio Grande at El Paso, Tex.	68	.02	.04	.08	.11	.19
	Phosphorus, total as P						
1	Rio Grande near Creede, Colo.	47	<0.05	<0.05	0.06	0.07	0.10
2	South Fork Rio Grande at South Fork, Colo.	75	.04	.05	.05	.07	.11
3	Rio Grande near Del Norte, Colo.	41	<.05	<.05	.06	.08	.09
4	Rio Grande at Alamosa, Colo.	59	.06	.10	.11	.14	.20
5	Conejos River near Magote, Colo.	36	<.05	<.05	<.05	.06	.09
6	Rio Grande near Lobatos, Colo.	134	.07	.09	.13	.17	.21
7	Rio Grande near Cerro, N. Mex.	28	.04	.07	.11	.14	.19
8	Red River below Zwergle Damsite, near Red River, N. Mex.	26	<.01	<.01	<.01	.02	.06
9	Red River at Molycorp Mine near Red River, N. Mex.	29	.02	.04	.06	.11	.14
10	Red River near Questa, N. Mex.	31	<.01	.02	.04	.11	.20
11	Cabresto Creek near Questa, N. Mex.	22	<.01	<.01	.02	.02	.03
12	Red River below Questa, N. Mex.	35	<.01	.02	.03	.06	.22
13	Red River below fish hatchery near Questa, N. Mex.	41	.02	.05	.06	.09	.16
14	Red River at mouth, near Questa, N. Mex.	22	.02	.03	.05	.06	.23
15	Rio Grande above Rio Hondo at Dunn Bridge, N. Mex.	29	.03	.05	.10	.12	.15

Table 3.--Statistical summary of concentrations of nutrients in surface water from selected sampling stations in the Rio Grande Valley study unit, water years 1972-90--Continued

Station reference number	Station name	Number of analyses	Concentration at indicated percentile, in milligrams per liter: 10	25	50	75	90
			Phosphorus, total as P--Continued				
16	Arroyo Hondo at Arroyo Hondo, N. Mex.	23	0.01	0.02	0.03	0.04	0.06
17	Rio Pueblo de Taos below Los Cordovas, N. Mex.	29	.06	.07	.14	.23	.42
18	Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	77	.04	.06	.08	.12	.18
20	Rio Chama near La Puente, N. Mex.	27	.03	.03	.04	.05	.07
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	163	.04	.07	.11	.18	.30
29	Rio Grande at San Felipe, N. Mex.	113	.03	.04	.06	.08	.14
30	Jemez River near Jemez, N. Mex.	21	.02	.03	.05	.08	.10
38	Rio Grande at Albuquerque, N. Mex.	17	.05	.06	.09	.11	.22
39	Rio Grande at Bridge Ave., Albuquerque, N. Mex.	30	.16	.21	.28	.45	.63
41	Rio Grande at Isleta, N. Mex.	137	.27	.42	.66	1.0	1.5
43	Rio Grande Floodway near Bernardo, N. Mex.	44	.24	.36	.47	.74	.95
46	Rio San Jose near Grants, N. Mex.	32	.65	.89	1.2	1.4	1.9
48	Rio Grande Conveyance Channel at San Acacia, N. Mex.	71	.23	.42	.63	.98	2.1
49	Rio Grande Floodway at San Acacia, N. Mex.	44	.23	.27	.39	.89	1.4
62	Rio Grande Conveyance Channel at San Marcial, N. Mex.	112	.08	.13	.25	.73	1.4
63	Rio Grande Floodway at San Marcial, N. Mex.	307	.21	.37	.67	1.2	2.7
67	Rio Grande below Elephant Butte Dam, N. Mex.	276	.02	.04	.07	.11	.16
69	Mimbres River at Mimbres, N. Mex.	66	.06	.07	.09	.12	.17
95	Rio Grande 1.7 miles up from the American Dam, Tex.	53	.13	.15	.25	.40	.63
97	Rio Grande at El Paso, Tex.	91	.11	.16	.28	.35	.43

Table 3.--Statistical summary of concentrations of nutrients in surface water from selected sampling stations in the Rio Grande Valley study unit, water years 1972-90--Continued

Station reference number	Station name	Number of analyses	Concentration at indicated percentile, in milligrams per liter				
			10	25	50	75	90
	Phosphorus, dissolved orthophosphate, as P						
6	Rio Grande near Lobatos, Colo.	64	0.02	0.04	0.05	0.08	0.09
7	Rio Grande near Cerro, N. Mex.	29	<.01	.02	.05	.07	.10
8	Red River below Zwergle Damsite, near Red River, N. Mex.	24	<.01	<.01	<.01	.02	.10
9	Red River at Molycorp Mine near Red River, N. Mex.	27	<.01	<.01	<.01	.03	.03
10	Red River near Questa, N. Mex.	22	<.01	<.01	<.01	.03	.04
11	Cabresto Creek near Questa, N. Mex.	17	<.01	<.01	<.01	.03	.03
12	Red River below Questa, N. Mex.	24	<.01	<.01	<.01	.02	.03
13	Red River below fish hatchery near Questa, N. Mex.	50	<.01	<.01	.02	.04	.04
14	Red River at mouth, near Questa, N. Mex.	22	<.01	<.01	<.01	.03	.04
15	Rio Grande above Rio Hondo at Dunn Bridge, N. Mex.	27	<.01	.02	.04	.06	.07
17	Rio Pueblo de Taos below Los Cordovas, N. Mex.	29	.03	.05	.07	.15	.21
18	Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	101	<.01	.02	.04	.05	.08
20	Rio Chama near La Puente, N. Mex.	26	<.01	<.01	.02	.03	.03
25	Rio Grande at Otowi Bridge near San Ilde-fonso, N. Mex.	158	<.01	<.01	.03	.04	.05
29	Rio Grande at San Felipe, N. Mex.	114	<.01	<.01	.02	.03	.04
30	Jemez River near Jemez, N. Mex.	21	<.01	.02	.02	.04	.08
38	Rio Grande at Albuquer-que, N. Mex.	17	.01	.02	.03	.04	.07
39	Rio Grande at Bridge Ave., Albuquerque, N. Mex.	27	.07	.09	.13	.16	.21
41	Rio Grande at Isleta, N. Mex.	137	.12	.22	.42	.75	.98
43	Rio Grande Floodway near Bernardo, N. Mex.	84	.12	.20	.34	.51	.59
46	Rio San Jose near Grants, N. Mex.	28	.43	.75	1.0	1.2	1.4

Table 3.--Statistical summary of concentrations of nutrients in surface water from selected sampling stations in the Rio Grande Valley study unit, water years 1972-90--Concluded

Station reference number	Station name	Number of analyses	Concentration at indicated percentile, in milligrams per liter: 10	25	50	75	90
	Phosphorus, dissolved orthophosphate, as P--Continued						
47	Rio Salado near San Acacia, N. Mex.	15	<0.01	<0.01	0.02	0.03	0.12
48	Rio Grande Conveyance Channel at San Acacia, N. Mex.	70	.07	.14	.21	.32	.42
49	Rio Grande Floodway at San Acacia, N. Mex.	43	.08	.13	.20	.26	.35
62	Rio Grande Conveyance Channel at San Marcial, N. Mex.	72	.04	.09	.13	.24	.38
63	Rio Grande Floodway at San Marcial, N. Mex.	111	.04	.09	.15	.26	.40
67	Rio Grande below Elephant Butte Dam, N. Mex.	49	<.01	<.01	.04	.06	.09
95	Rio Grande 1.7 miles up from the American Dam, Tex.	53	.04	.05	.09	.11	.13
97	Rio Grande at El Paso, Tex.	55	.04	.05	.07	.13	.23

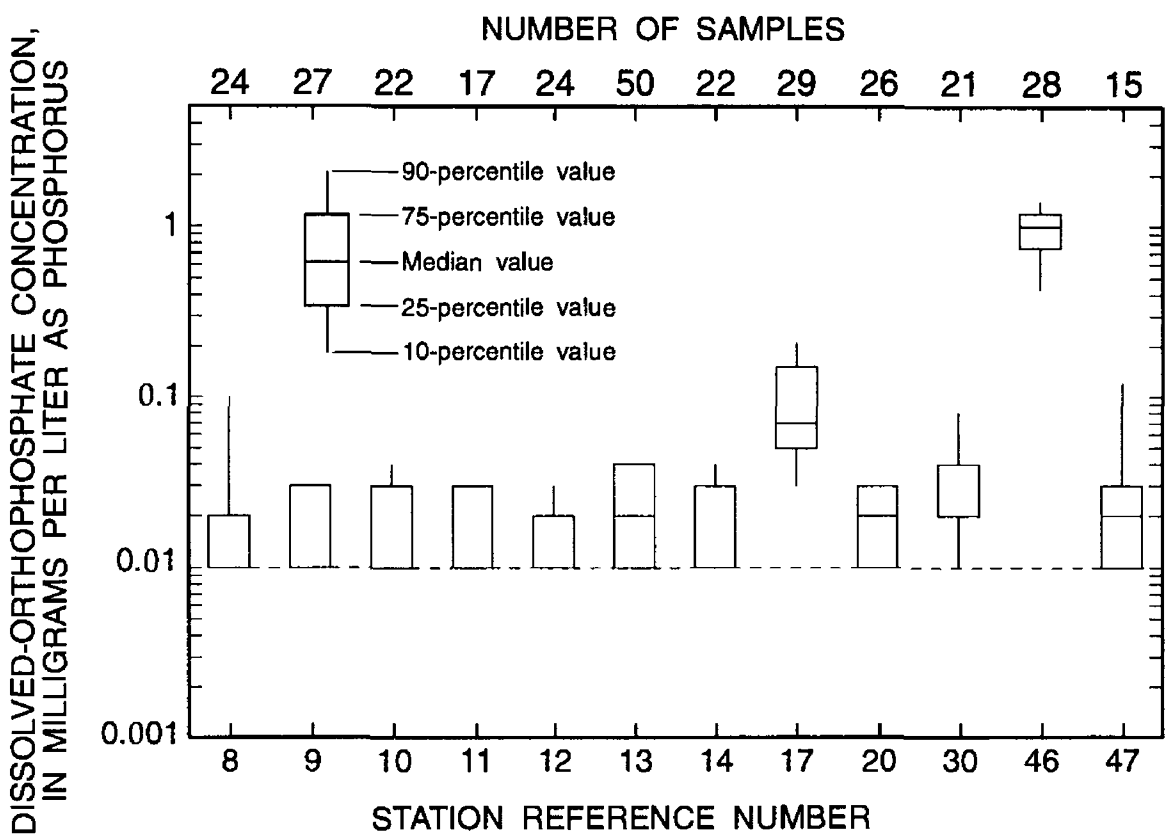


Figure 27.--Dissolved-orthophosphate concentrations at selected stations in the Rio Grande Valley study unit, water years 1972-90.

Table 4.--Results of Mann-Whitney test for differences in total nitrogen concentrations in surface water from selected main-stem stations in the Rio Grande Valley study unit

[Underlined, significance of probability value equal to or less than 0.05; <, less than; *, station with high total nitrogen concentration]

Station reference number (pl. 2)		Station name	Number of analyses	Probability value
6		Rio Grande near Lobatos, Colo.	73	0.10
7		Rio Grande near Cerro, N. Mex.	28	
7		Rio Grande near Cerro, N. Mex.	28	.11
15		Rio Grande above Rio Hondo at Dunn Bridge, N. Mex.	29	
15		Rio Grande above Rio Hondo at Dunn Bridge, N. Mex.	29	.66
18		Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	66	
18		Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	66	.26
25		Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	108	
25	*	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	108	≤.005
29		Rio Grande at San Felipe, N. Mex.	85	
29		Rio Grande at San Felipe, N. Mex.	85	≤.005
41	*	Rio Grande at Isleta, N. Mex.	137	
41		Rio Grande at Isleta, N. Mex.	137	.43
43		Rio Grande Floodway near Bernardo, N. Mex.	18	
43		Rio Grande Floodway near Bernardo, N. Mex.	18	.55
48		Rio Grande Conveyance Channel at San Acacia, N. Mex.	70	.77
49		Rio Grande Floodway at San Acacia, N. Mex.	43	
49		Rio Grande Floodway at San Acacia, N. Mex.	43	
49		Rio Grande Floodway at San Acacia, N. Mex.	43	.69
62		Rio Grande Conveyance Channel at San Marcial, N. Mex.	91	≤.005
63	*	Rio Grande Floodway at San Marcial, N. Mex.	286	
63		Rio Grande Floodway at San Marcial, N. Mex.	286	
63	*	Rio Grande Floodway at San Marcial, N. Mex.	286	≤.005
67		Rio Grande below Elephant Butte Dam, N. Mex.	274	
67		Rio Grande below Elephant Butte Dam, N. Mex.	274	≤.005
97	*	Rio Grande at El Paso, Tex.	33	

Table 5.--Results of Mann-Whitney test for differences in total phosphorus concentrations in surface water from selected main-stem stations in the Rio Grande Valley study unit

[Underlined, significance of probability value equal to or less than 0.05; <, less than; *, station with high total phosphorus concentration]

Station reference number (pl. 2)		Station name	Number of analyses	Probability value
1		Rio Grande near Creede, Colo.	68	0.35
3		Rio Grande near Del Norte, Colo.	68	
3		Rio Grande near Del Norte, Colo.	68	<.005
4	*	Rio Grande at Alamosa, Colo.	72	
4		Rio Grande at Alamosa, Colo.	72	.09
6		Rio Grande near Lobatos, Colo.	135	
6		Rio Grande near Lobatos, Colo.	135	.13
7		Rio Grande near Cerro, N. Mex.	28	
7		Rio Grande near Cerro, N. Mex.	28	.11
15		Rio Grande above Rio Hondo at Dunn Bridge, N. Mex.	29	
15		Rio Grande above Rio Hondo at Dunn Bridge, N. Mex.	29	.87
18		Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	77	
18		Rio Grande below Taos Junction Bridge near Taos, N. Mex.	77	<.005
25	*	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	163	
25	*	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	163	<.005
29		Rio Grande at San Felipe, N. Mex.	113	
29		Rio Grande at San Felipe, N. Mex.	113	<.005
38	*	Rio Grande at Albuquerque, N. Mex.	17	
38		Rio Grande at Albuquerque, N. Mex.	17	<.005
41	*	Rio Grande at Isleta, N. Mex.	137	

Table 5.--Results of Mann-Whitney test for differences in total phosphorus concentrations in surface water from selected main-stem stations in the Rio Grande Valley study unit--Concluded

Station reference number (pl. 2)		Station name	Number of analyses	Probability value
41	*	Rio Grande at Isleta, N. Mex.	137	0.01
43		Rio Grande Floodway near Bernardo, N. Mex.	44	
43		Rio Grande Floodway near Bernardo, N. Mex.	44	.47
48	*	Rio Grande Conveyance Channel at San Acacia, N. Mex.	71	.03
49		Rio Grande Floodway at San Acacia, N. Mex.	44	
49		Rio Grande Floodway at San Acacia, N. Mex.	44	
49		Rio Grande Floodway at San Acacia, N. Mex.	44	.01
62		Rio Grande Conveyance Channel at San Marcial, N. Mex.	114	<.005
63	*	Rio Grande Floodway at San Marcial, N. Mex.	321	
63	*	Rio Grande Floodway at San Marcial, N. Mex.	321	
63	*	Rio Grande Floodway at San Marcial, N. Mex.	321	<.005
67		Rio Grande below Elephant Butte Dam, N. Mex.	281	
67		Rio Grande below Elephant Butte Dam, N. Mex.	281	<.005
97	*	Rio Grande at El Paso, Tex.	91	

The LOWESS smooth lines in figures 10 through 18 provide a visual impression of trends through time for water years 1972-90 for all stations that had nutrient data. The seasonal Kendall trend test also was performed for water years 1980-90 for all stations meeting the criteria used for this test (table 6). Significant trends evident in the flow-adjusted data were: Rio Grande near Lobatos, Colorado (6), had decreasing dissolved ammonia and total phosphorus; Rio Grande at Otowi Bridge near San Ildefonso, New Mexico (25), had decreasing dissolved ammonia; and Rio Grande below Taos Junction Bridge, near Taos, New Mexico (18), had decreasing dissolved orthophosphate.

Thirteen stations were selected for a more rigorous examination. These stations (10 on the main stem of the Rio Grande, 2 on tributaries, and 1 on a river in a closed basin) were selected on the basis of completeness of record and location within the study unit. For the 13 selected stations, the following are included in addition to the above-mentioned analyses and presentation of data: plots of number of analyses versus month for each nutrient; plots of number of analyses versus decile of long-term flow for each nutrient; scatterplots of total nitrogen and total phosphorus concentrations versus suspended-sediment concentration; and scatterplots of nutrients concentrations versus streamflow.

The plots of number of analyses versus month and versus decile of long-term flow for surface-water stations provide additional information about temporal and flow-related aspects of water-quality data. This information is important when making decisions about future data collection and can provide insight to the overall water quality of the Rio Grande Valley study unit. When reporting statistical summaries of data over a given time period, it is useful to know if those data were collected throughout the year and over the entire flow regime at that station. For example, if all data were collected during the summer or during a specific part of the flow regime, the data would not adequately represent the overall water quality at that station. Ideally, data should represent all seasons and all flow regimes. The decile of long-term flow was determined by finding every 10th percentile of the historic long-term flow at a given station based on flow duration curves (Waltemeyer, 1989). The largest flows are in the 1st decile and the smallest flows are in the 10th decile. Plots of suspended-sediment concentration and nutrient concentration or of nutrient concentration and flow can highlight the significance of, or the lack of, a relation between various constituents and properties.

Table 6.--Trend-test results for nutrient concentrations in surface water from selected sampling stations in the Rio Grande Valley study unit

[--, value not calculated; <, less than; underlined, significance of probability value equal to or less than 0.05]

			Results of seasonal Kendall tests for time trend, 1980-90			
			Concentration		Flow-adjusted concentration	
Station reference number (pl. 2)	Station name	Water years	Probability level	Average rate of change (milligrams per liter per year)	Probability level	Average rate of change (milligrams per liter per year)
			Nitrogen, total as N			
18	Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	1980-90	0.24	-0.02	0.22	-0.002
41	Rio Grande at Isleta, N. Mex.	1980-90	.43	-.02	.80	-.004
			Nitrogen, dissolved nitrate as N			
18	Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	1980-90	1.00	0.0	0.88	0.0
29	Rio Grande at San Felipe, N. Mex.	1980-90	.82	.0	--	--
41	Rio Grande at Isleta, N. Mex.	1980-90	1.00	.0	.06	.012
			Nitrogen, dissolved ammonia as N			
6	Rio Grande near Lobatos, Colo.	1982-90	1.00	0.0	<0.005	-0.006
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	1982-90	1.00	.0	<.005	<-.0001
97	Rio Grande at El Paso, Tex.	1982-90	1.00	.0	.30	-.002
			Phosphorus, total as P			
2	South Fork Rio Grande at South Fork, Colo.	1982-90	1.00	0.0	--	--
6	Rio Grande near Lobatos, Colo.	1982-90	.019	-.006	.02	-.006

Table 6.--Trend-test results for nutrient concentrations in surface water from selected sampling stations in the Rio Grande Valley study unit--Concluded

			Results of seasonal Kendall tests for time trend, 1980-90			
			Concentration		Flow-adjusted concentration	
Station reference number (pl. 2)	Station name	Water years	Probability level	Average rate of change (milligrams per liter per year)	Probability level	Average rate of change (milligrams per liter per year)
			Phosphorus, total as P--Continued			
18	Rio Grande below Taos Junction Bridge, near Taos N. Mex.	1982-90	0.59	0.0	0.22	-0.002
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	1982-90	1.00	.0	.57	.002
29	Rio Grande at San Felipe, N. Mex.	1982-90	.026	-.004	.13	-.003
41	Rio Grande at Isleta, N. Mex.	1982-90	.82	.011	.96	.002
97	Rio Grande at El Paso, Tex.	1982-90	.93	.0	.65	.005
			Orthophosphate, dissolved as P			
6	Rio Grande near Lobatos, Colo.	1980-90	1.00	0.0	0.11	-0.003
18	Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	1980-90	1.00	.0	≤.005	-.002
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	1980-90	1.00	.0	.48	-.0006
29	Rio Grande at San Felipe, N. Mex.	1980-90	1.00	.0	.83	-.0001
41	Rio Grande at Isleta, N. Mex.	1980-90	.93	.003	.10	.011
97	Rio Grande at El Paso, Tex.	1980-90	.56	.001	.19	.004

Plots of the number of analyses against month and decile of flow for available nutrients at the 13 selected stations (figs. 28 through 40) show that for most stations, samples were collected throughout the year. However, for Rio Grande near Lobatos, Colorado (6); Rio Grande at Isleta, New Mexico (41); Rio Grande Floodway at San Acacia, New Mexico (49); and Rio Grande at El Paso, Texas (97); sampling generally occurred bimonthly (figs. 29, 33, 35 and 39). Only 3 of the 13 selected stations have been sampled for all available nutrients over the entire flow regime. Even at those stations (Rio Grande at Alamosa, Colorado (4); Rio Grande near Lobatos, Colorado (6); and Rio Grande at Otowi Bridge near San Ildefonso, New Mexico (25)); all deciles of flow are not equally represented (figs. 28, 29, and 32). Two stations, Rio Grande at Isleta, New Mexico (41), and Mimbres River at Mimbres, New Mexico (69), were sampled over the entire flow regime for all nutrients except one--dissolved ammonia and dissolved orthophosphate, respectively (figs. 33 and 40). Several stations had few or no samples collected in the higher deciles of flows (low flows): Rio Chama near La Puente, New Mexico (20) (fig. 31); the conveyance channel and floodway stations at San Acacia (48 and 49) (figs. 34 and 35); and the conveyance channel and floodway stations at San Marcial (62 and 63) (figs. 36 and 37). However, at the San Acacia and San Marcial stations, long-term flow duration curves indicate no flow for a certain percentage of the time. Therefore, samples were collected over the range of actual flow. The highest flows (1st decile) were not sampled often or not sampled at all for some or all nutrients at Rio Grande below Elephant Butte Dam, New Mexico (67), or Rio Grande at El Paso, Texas (97) (figs. 38 and 39). Flow at both of these stations is regulated and, therefore, high flows seldom occur. Red River below fish hatchery near Questa, New Mexico (13), had the largest number of samples in the 7th and 10th deciles of flow for all nutrients (fig. 30). This needs to be considered when interpreting water-quality data for this station.

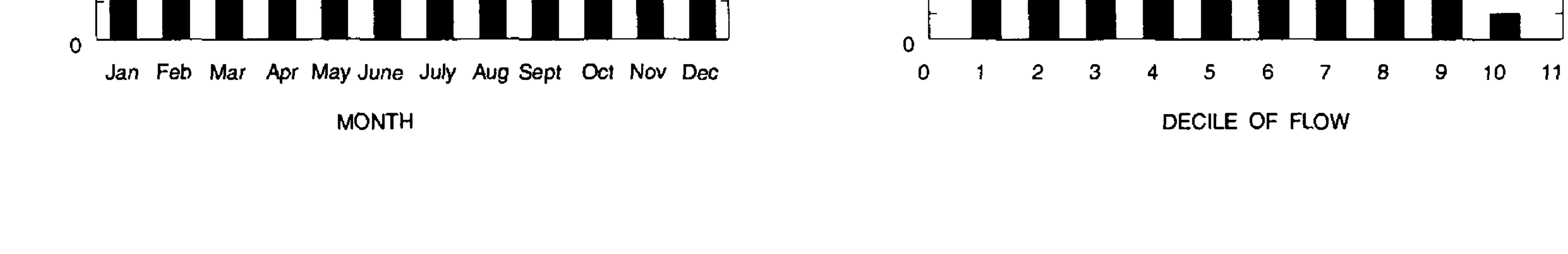


Figure 28.--Number of total phosphorus analyses by month and decile of flow for Rio Grande at Alamosa, Colo., water years 1972-90.

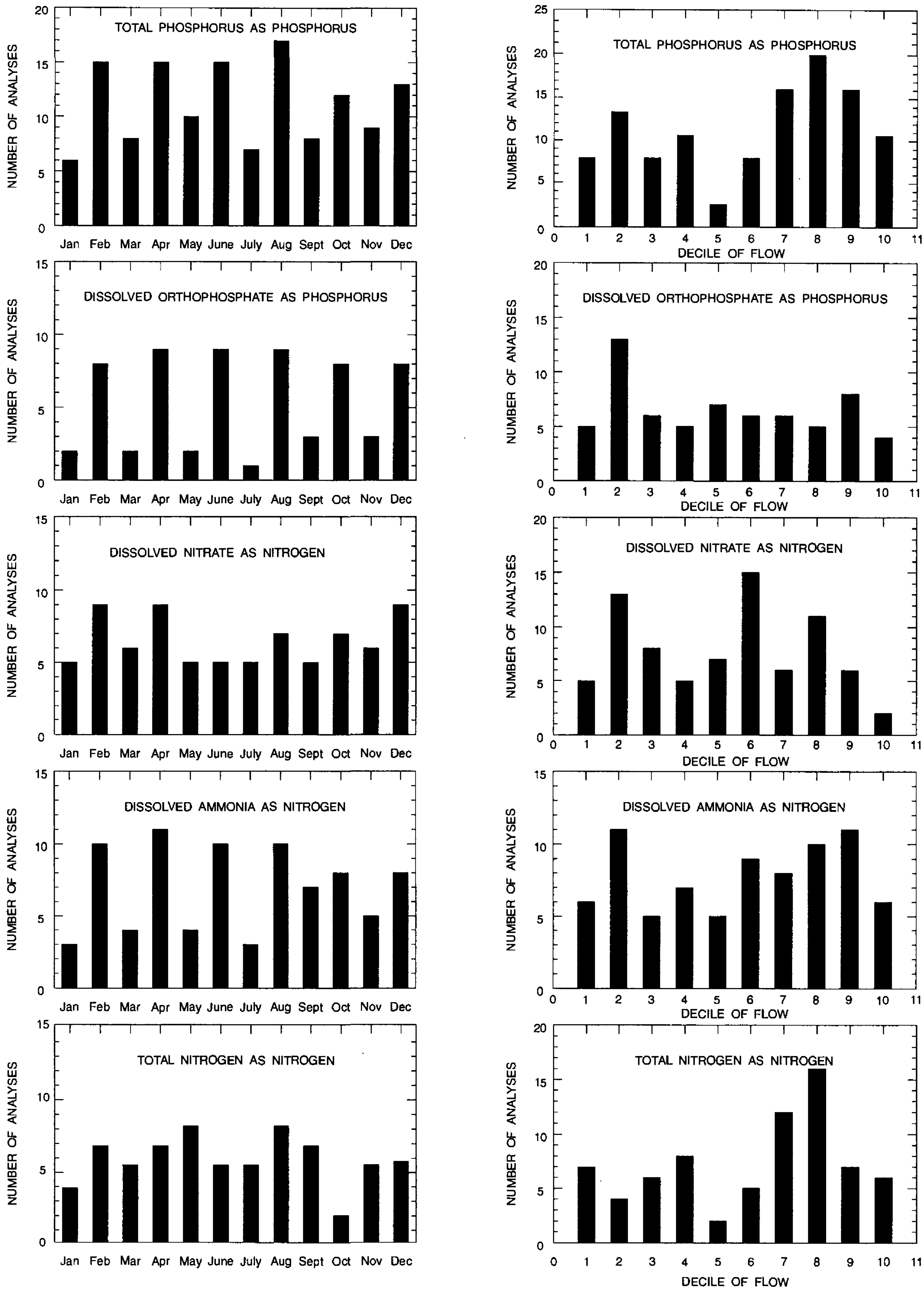


Figure 29.--Number of nutrient analyses by month and decile of flow for Rio Grande near Lobatos, Colo., water years 1972-90.

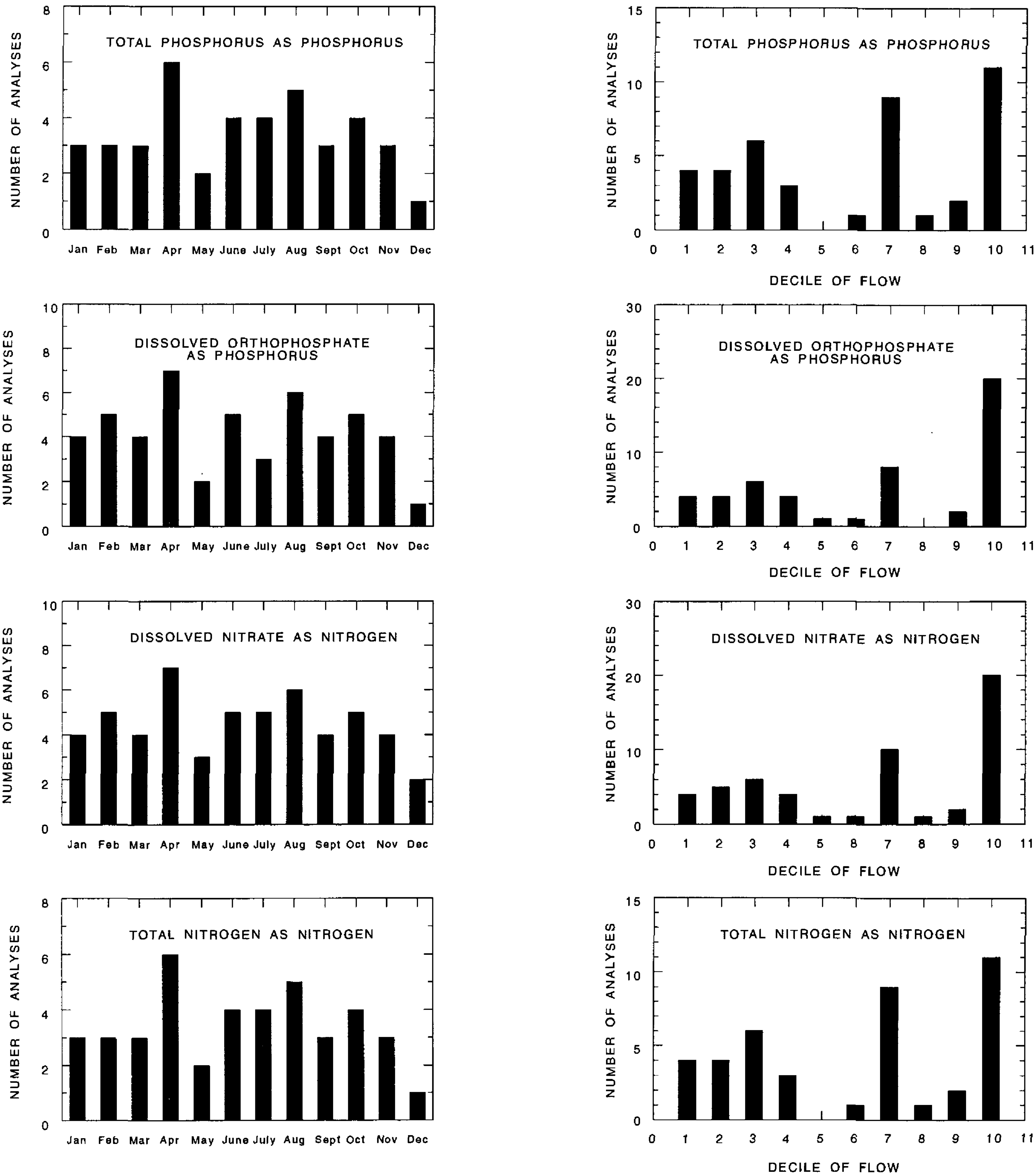


Figure 30.--Number of nutrient analyses by month and decile of flow for Red River below fish hatchery near Questa, N. Mex., water years 1972-90.

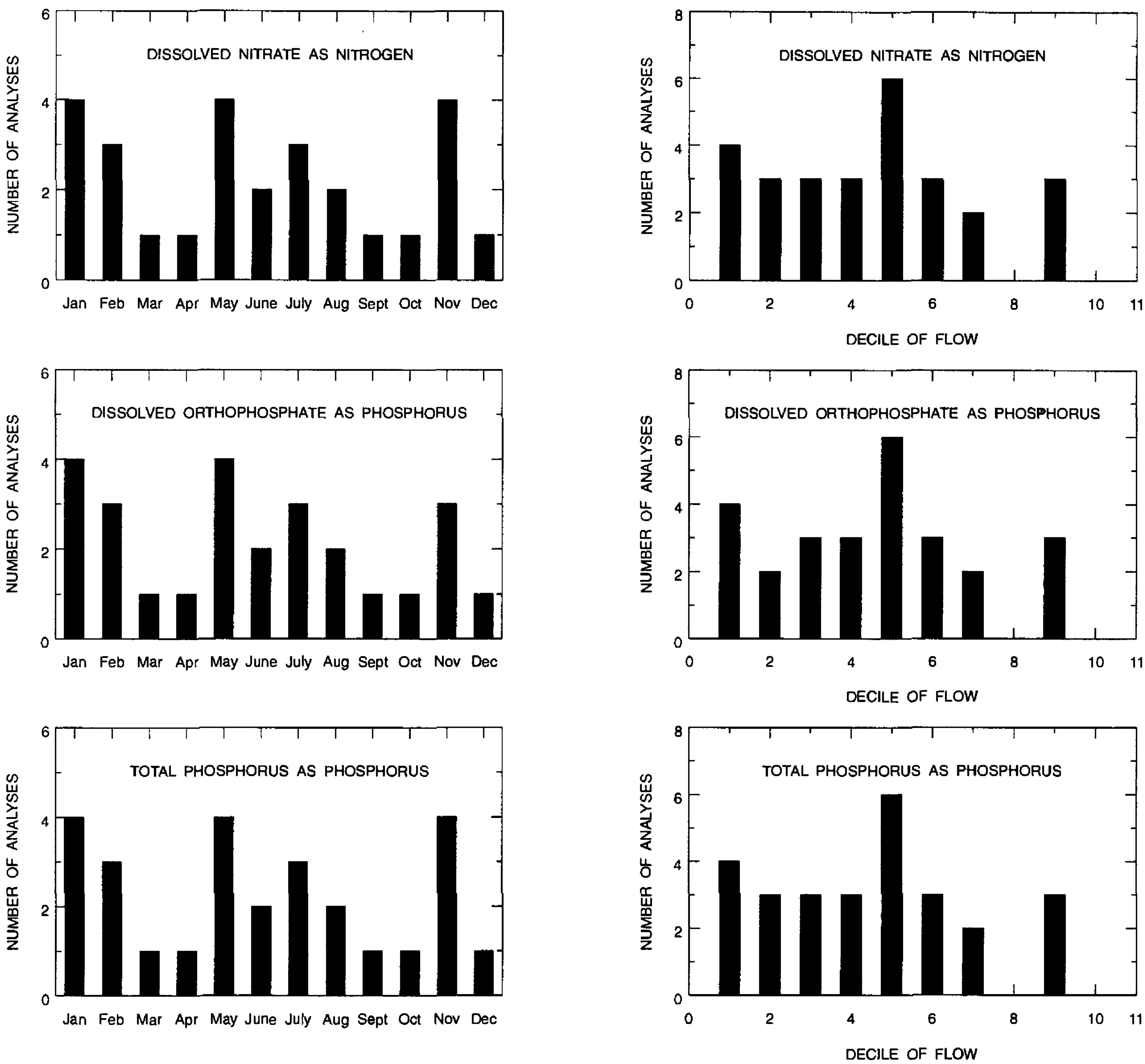


Figure 31.--Number of nutrient analyses by month and decile of flow for Rio Chama near La Puente, N. Mex., water years 1972-90.

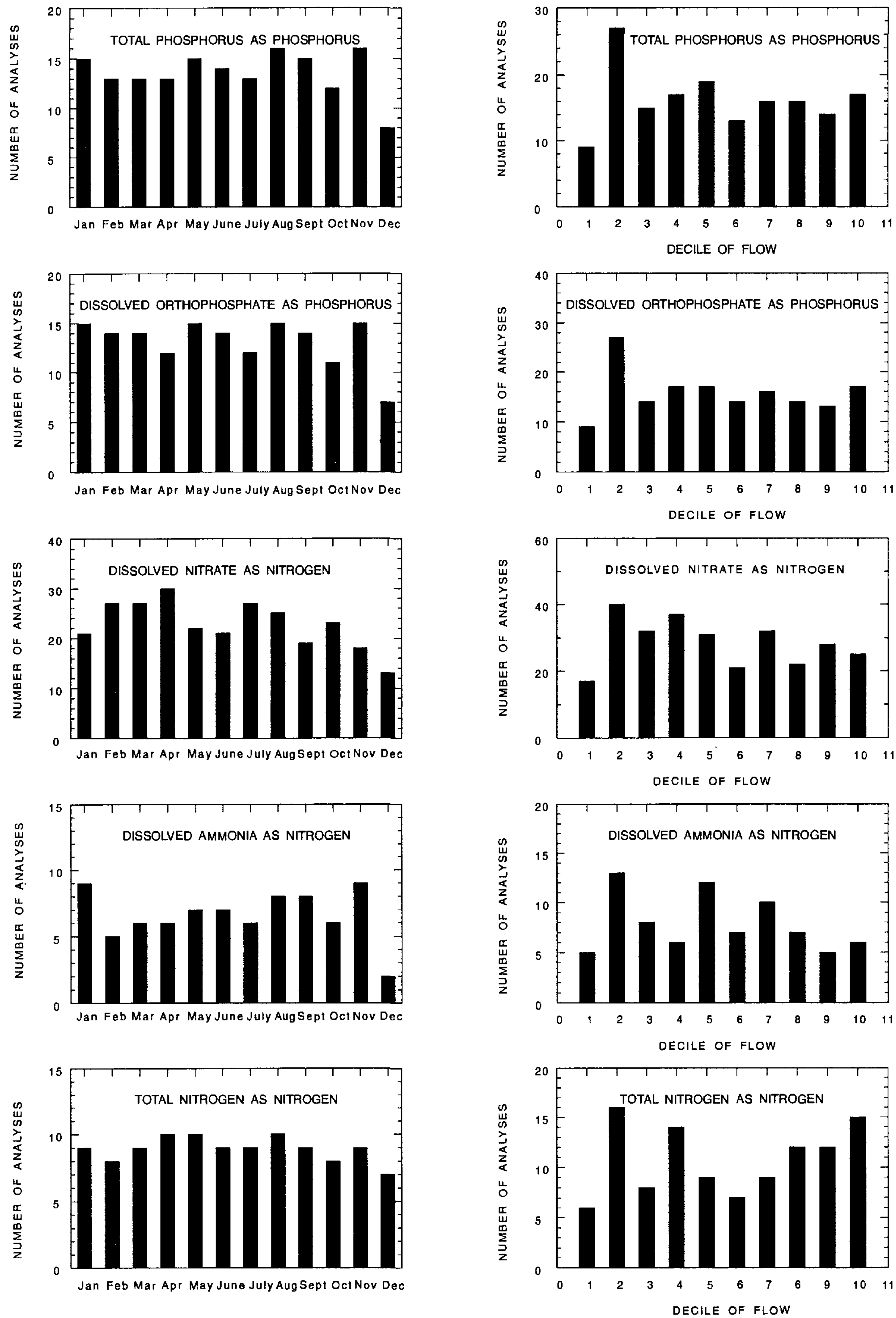


Figure 32.--Number of nutrient analyses by month and decile of flow for Rio Grande at Otowi Bridge near San Ildefonso, N. Mex., water years 1972-90.

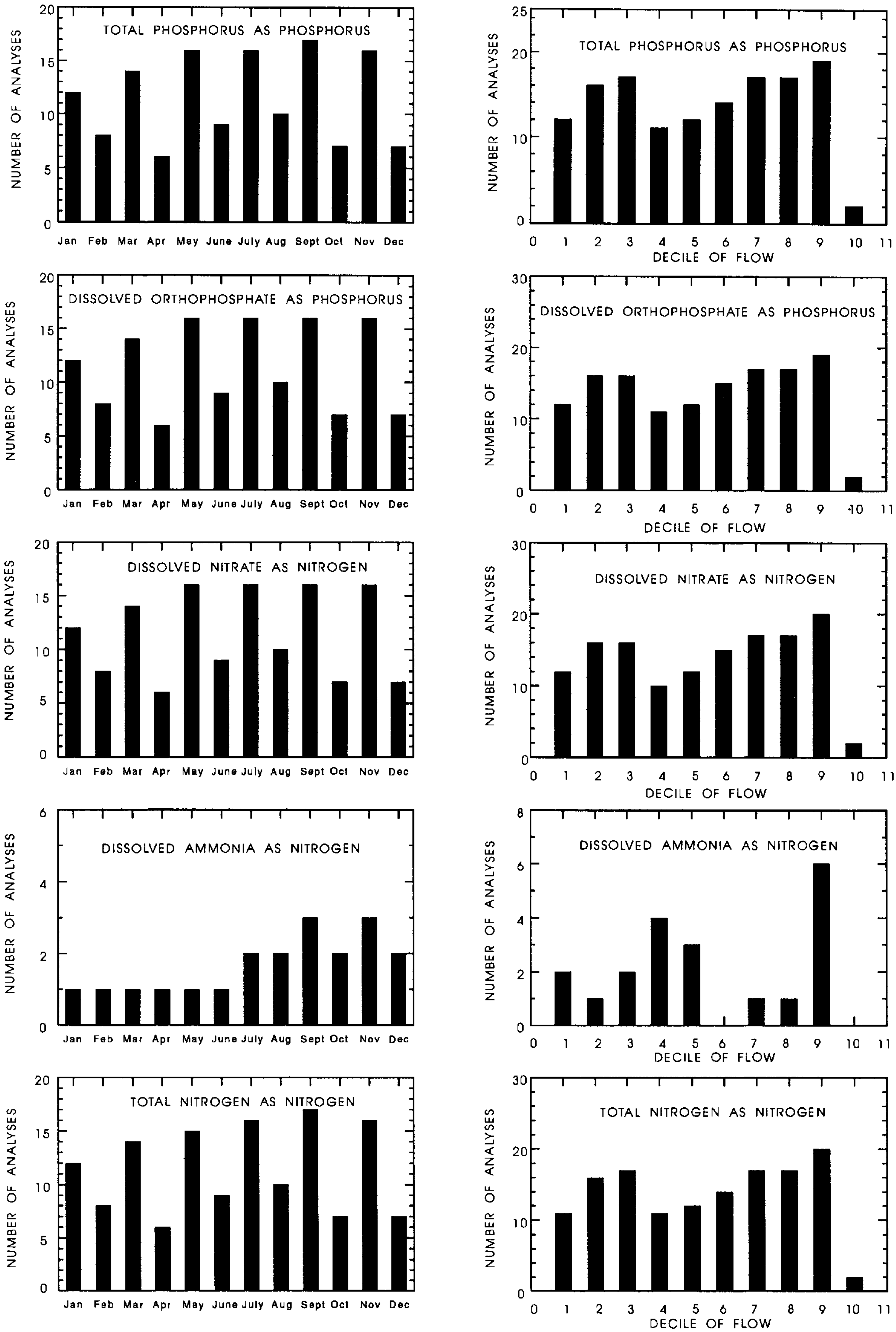


Figure 33.--Number of nutrient analyses by month and decile of flow for Rio Grande at Isleta, N. Mex., water years 1972-90.

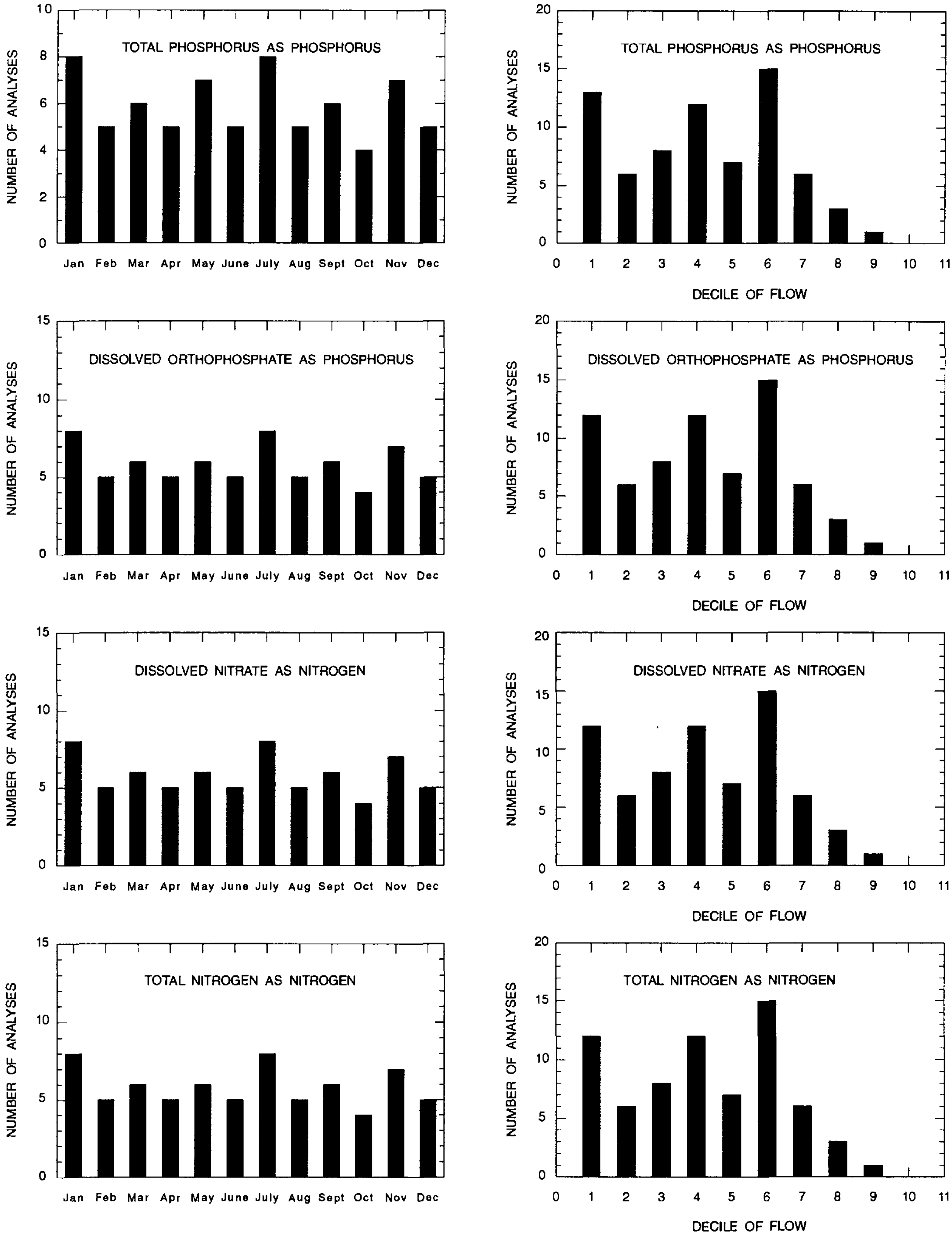


Figure 34.--Number of nutrient analyses by month and decile of flow for Rio Grande Conveyance Channel at San Acacia, N. Mex., water years 1972-90.

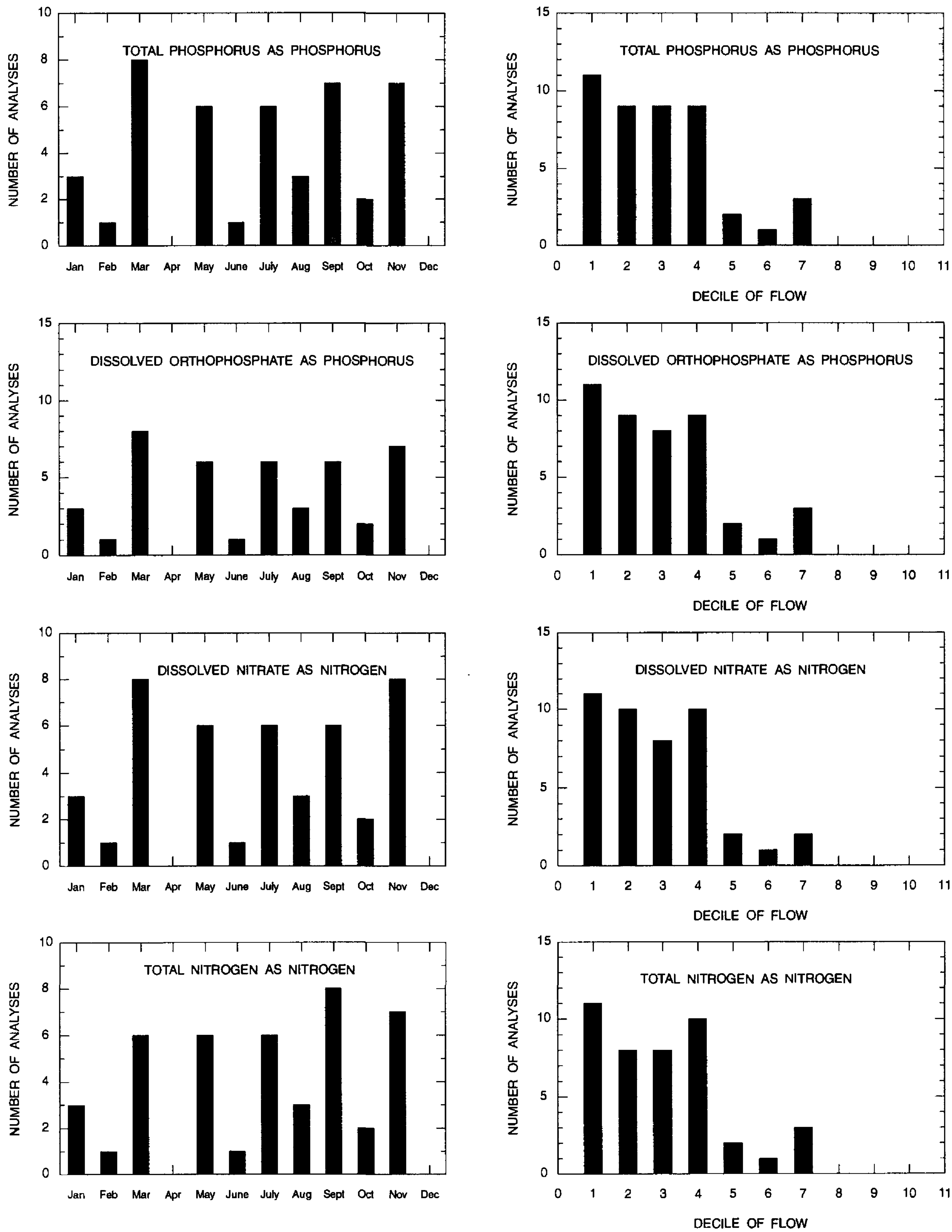


Figure 35.--Number of nutrient analyses by month and decile of flow for Rio Grande Floodway at San Acacia, N. Mex., water years 1972-90.

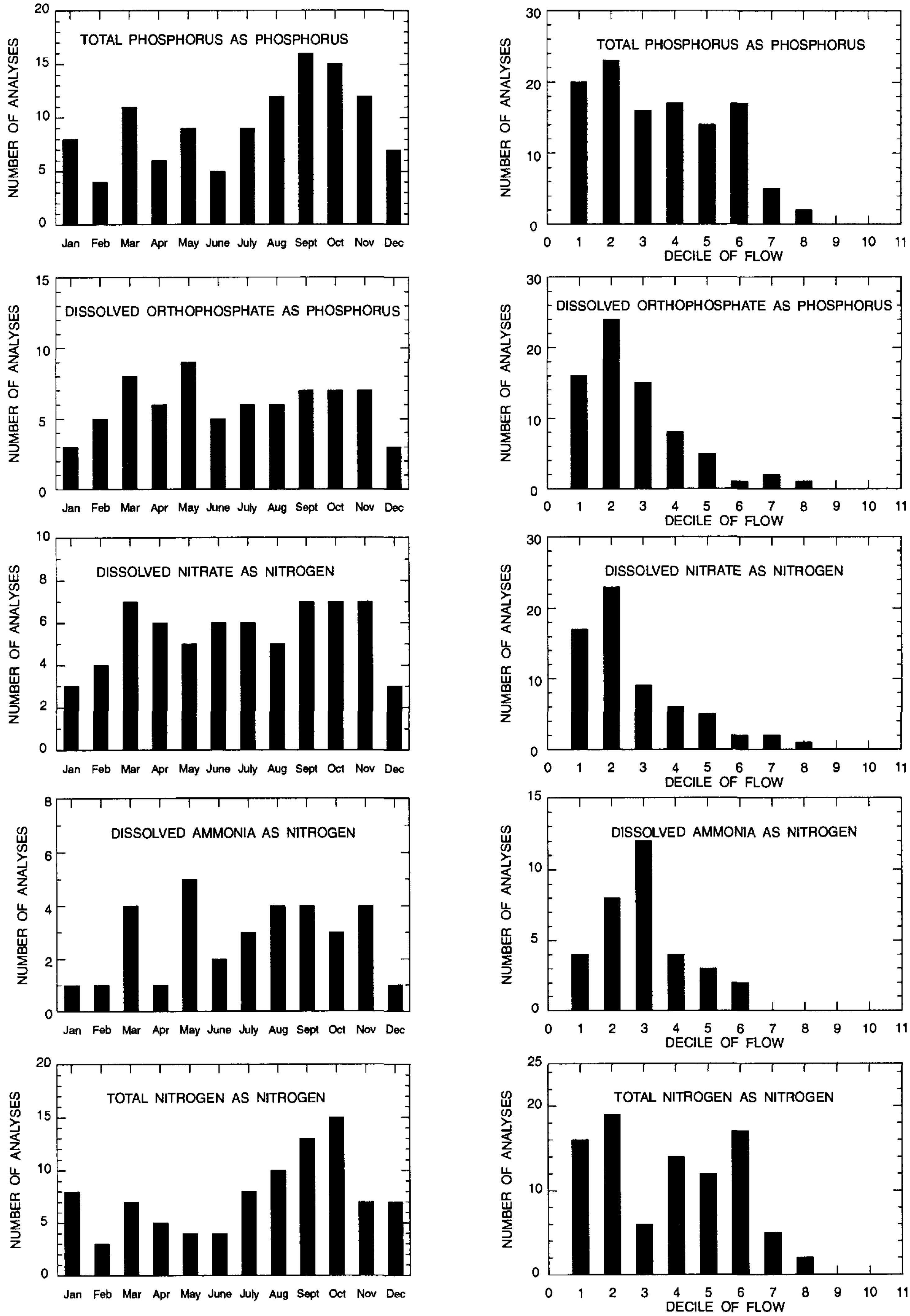


Figure 36.--Number of nutrient analyses by month and decile of flow for Rio Grande Conveyance Channel at San Marcial, N. Mex., water years 1972-90.

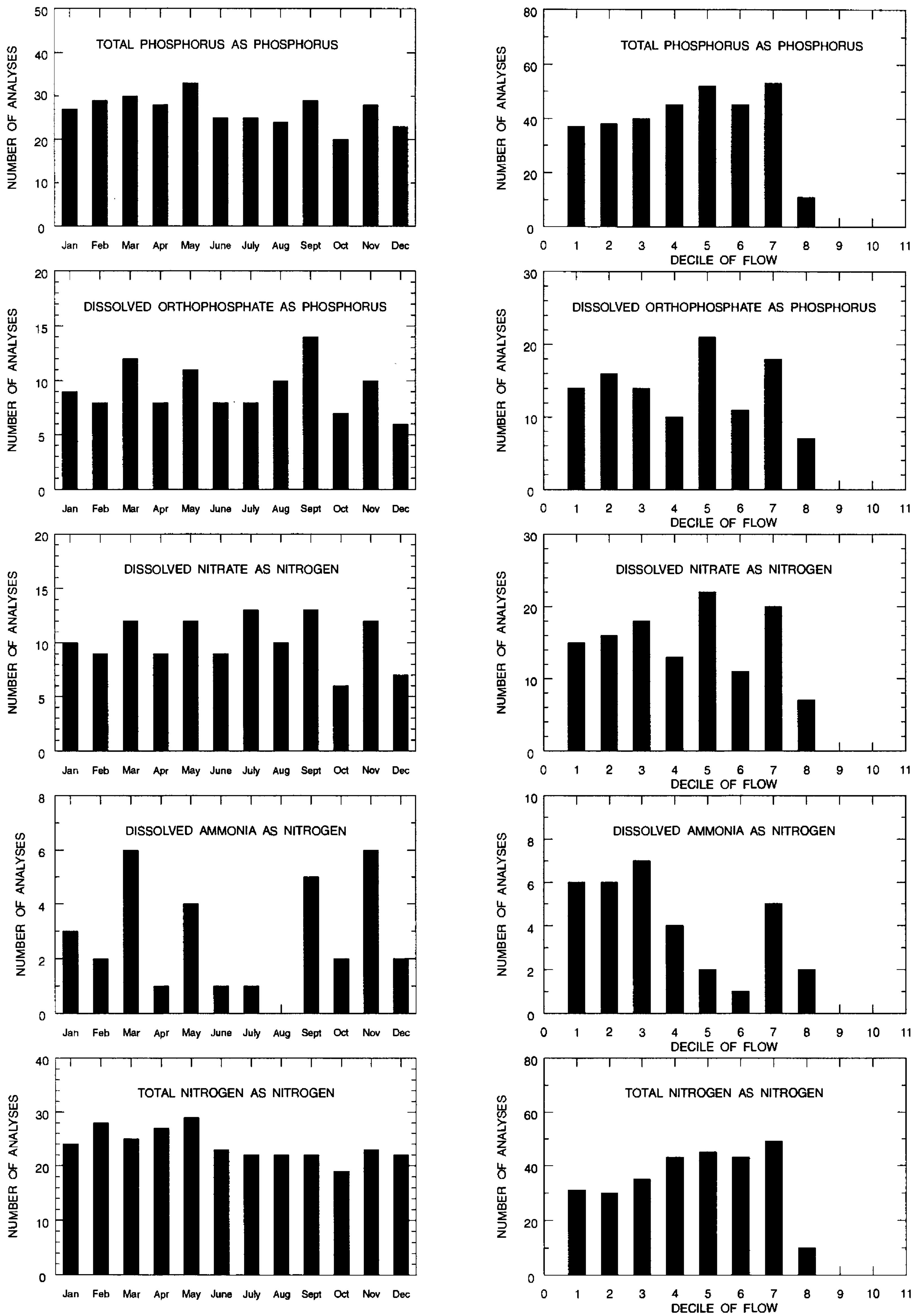


Figure 37.--Number of nutrient analyses by month and decile of flow for Rio Grande Floodway at San Marcial, N. Mex., water years 1972-90.

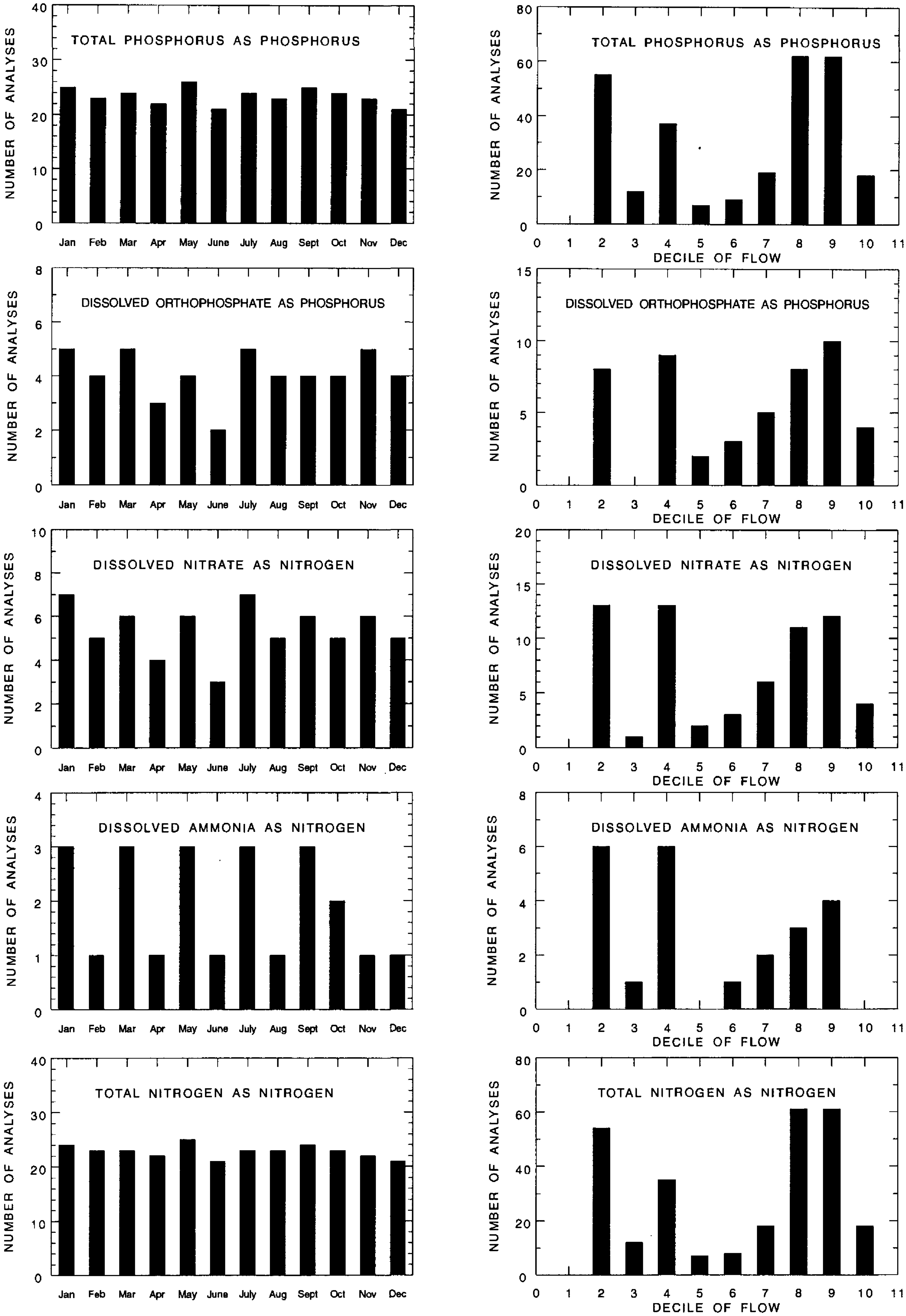


Figure 38.--Number of nutrient analyses by month and decile of flow for Rio Grande below Elephant Butte Dam, N. Mex., water years 1972-90.

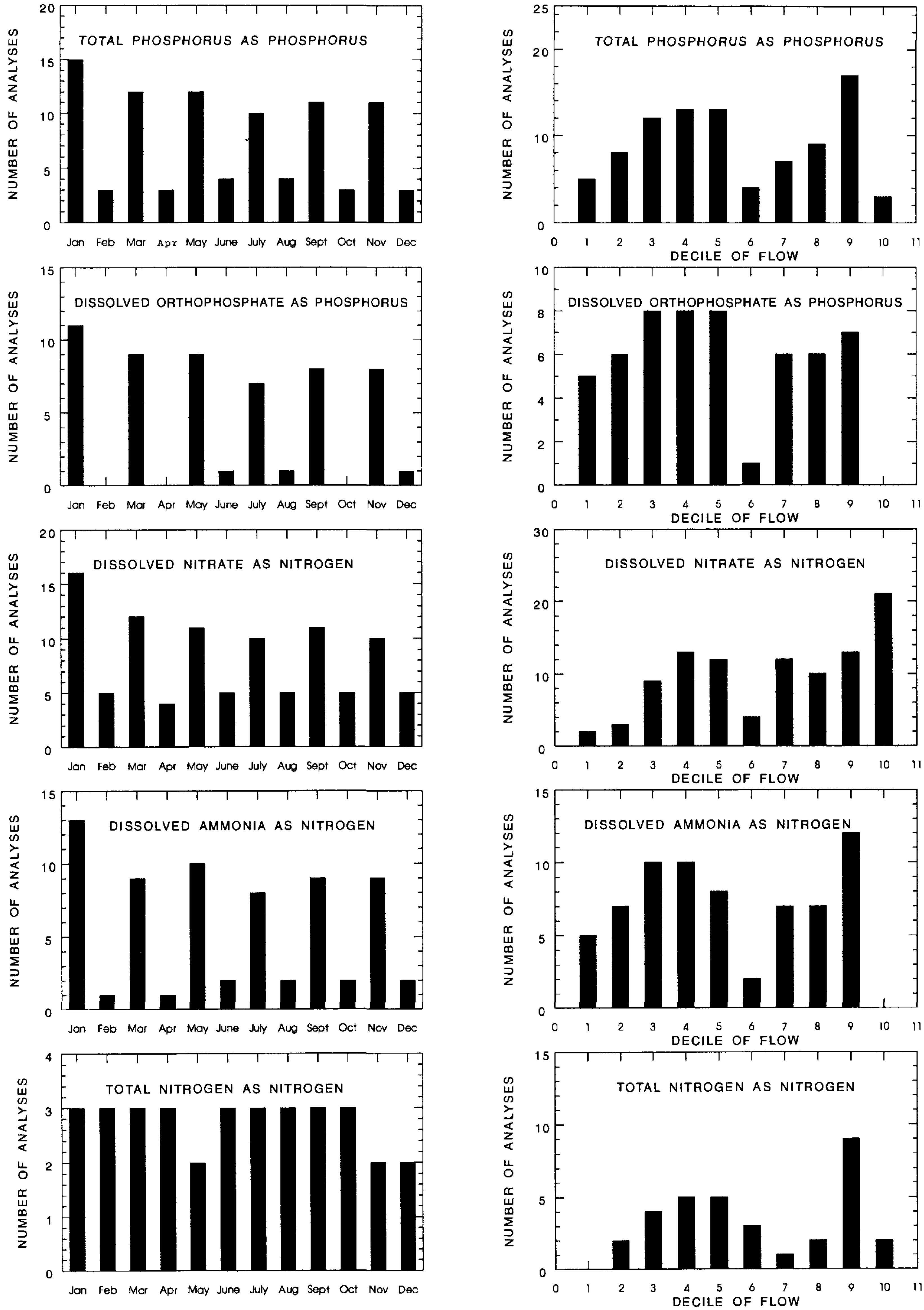


Figure 39.--Number of nutrient analyses by month and decile of flow for Rio Grande at El Paso, Tex., water years 1972-90.

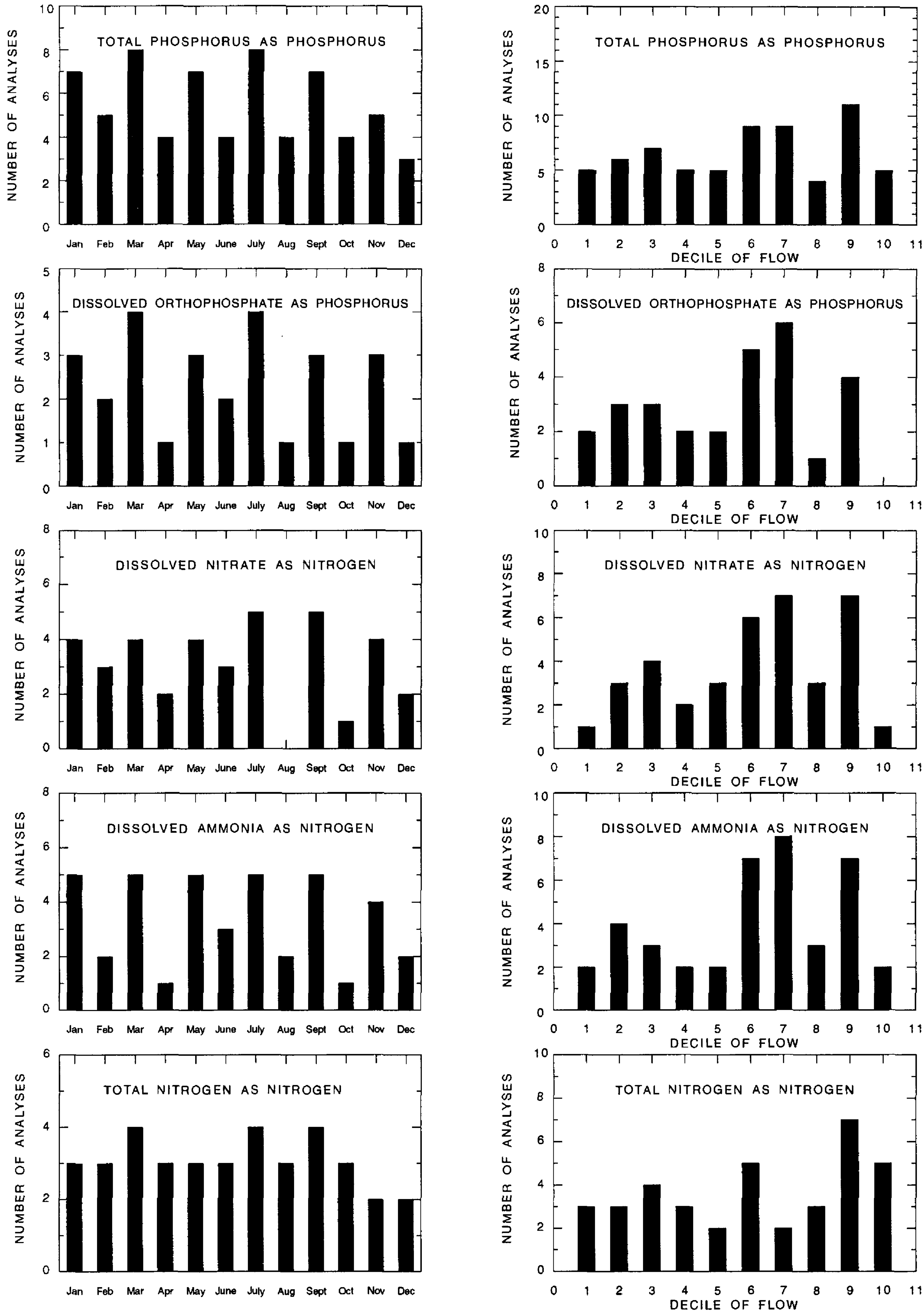


Figure 40.--Number of nutrient analyses by month and decile of flow for Mimbres River at Mimbres, N. Mex., water years 1972-90.

Spearman's rank correlation analysis for the relation between total phosphorus and suspended sediment or suspended solids showed that all stations for which the analysis was done had a significant positive correlation (increasing total phosphorus concentration with increasing suspended-sediment concentration) between the two constituents except for Rio Grande at Isleta, New Mexico (41), which showed a significant negative correlation (table 7; figs. 41-53). However, only seven stations had correlation coefficients greater than or equal to 0.50, indicating a strong correlation between total phosphorus concentration and suspended-sediment concentration (or suspended-solids concentration). The correlation analysis for the relation between total nitrogen and suspended sediment showed six stations that had a significant positive correlation (table 8; figs. 41 through 53). As with total phosphorus, Rio Grande at Isleta, New Mexico (41), showed a significant, but weak, negative correlation between total nitrogen concentration and suspended-sediment concentration. Only four stations had correlation coefficients greater than or equal to 0.50.

Many significant correlations exist for relations between nutrient concentrations and streamflow for the selected stations (table 9; figs. 54 through 66). Generally, significant correlations for the dissolved-nutrient species were negative (decreasing nutrient concentration with increasing streamflow); however, there were exceptions. All nutrient species, dissolved and total, at Rio Grande Conveyance Channel at San Marcial, New Mexico (62), had positive correlations with streamflow. This is due most likely to the operation of the conveyance channel and agricultural-return flow. At Rio Grande at Isleta, New Mexico (41), all nutrient species had strong negative correlations with streamflow. As natural flow in the river increases, the nutrient concentrations in water from the varied sources associated with Albuquerque are diluted. Many of the correlation coefficients for the relation between nutrient species concentration and streamflow were significant at the 0.05 probability level, but were only weakly correlated, with correlation coefficients ranging from -0.5 to 0.5.

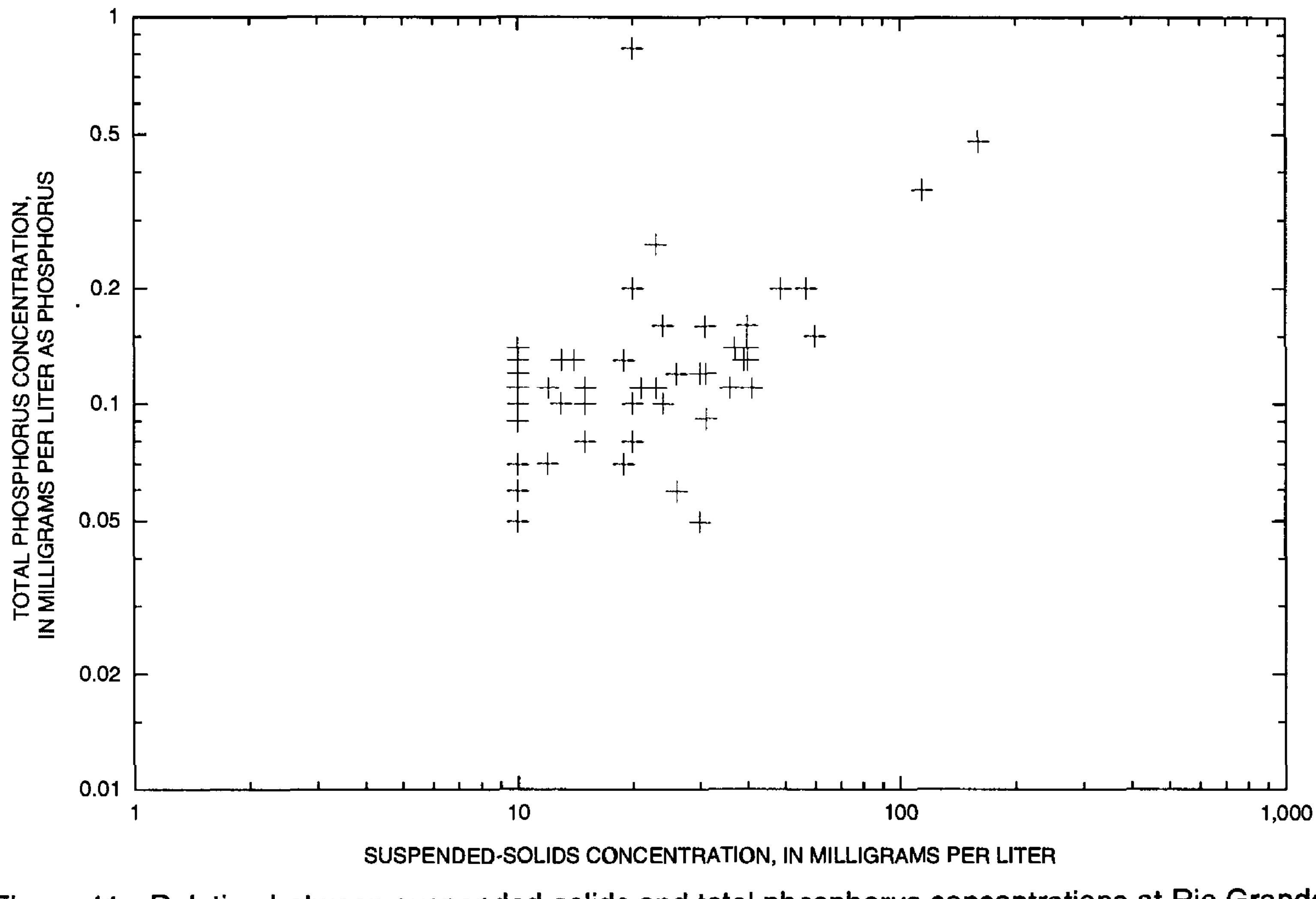


Figure 41.--Relation between suspended-solids and total phosphorus concentrations at Rio Grande at Alamosa, Colo. , water years 1972-90.

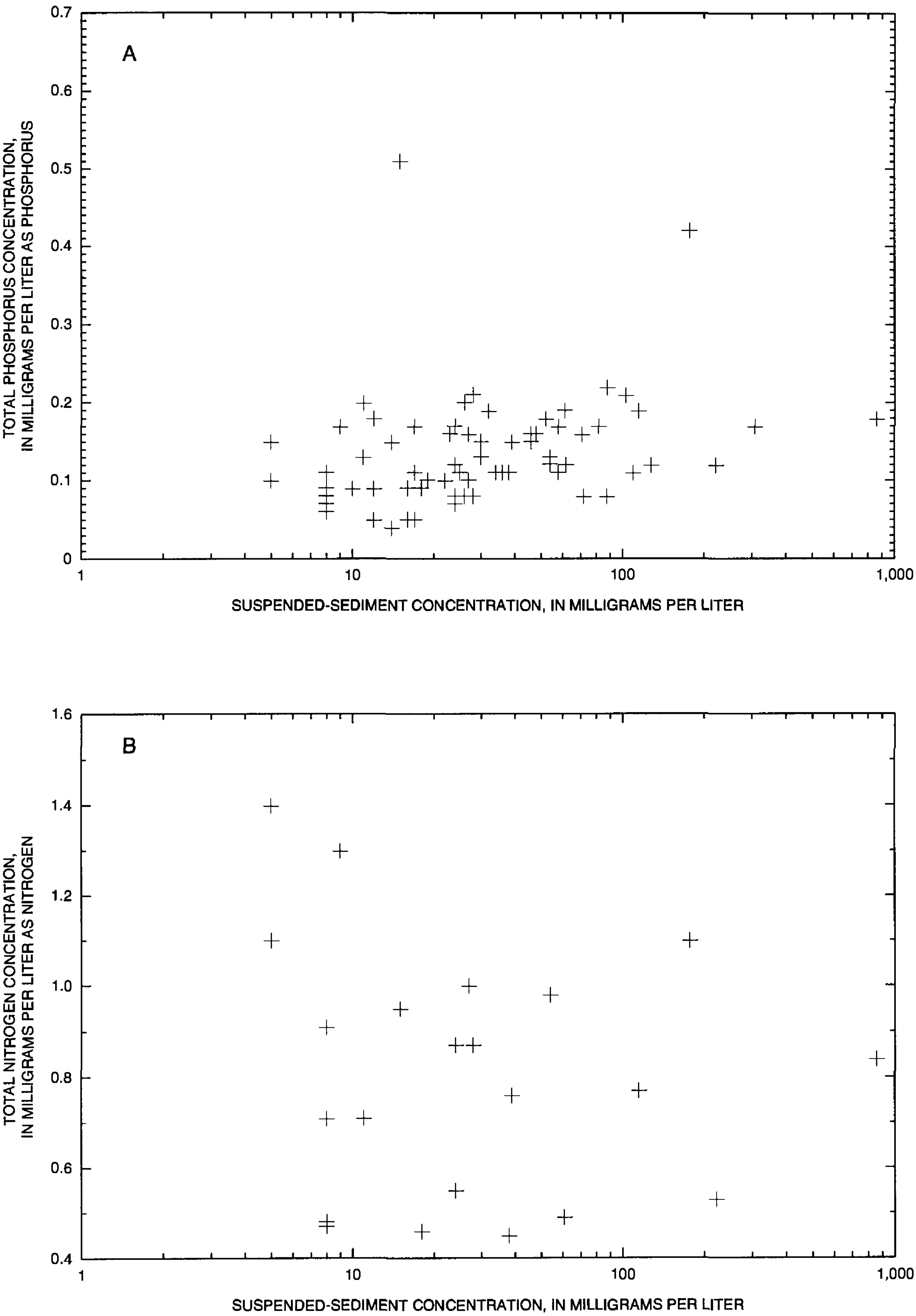


Figure 42.--Relation between suspended-sediment concentration and total phosphorus (A) and total nitrogen (B) concentrations at Rio Grande near Lobatos, Colo., water years 1972-90.

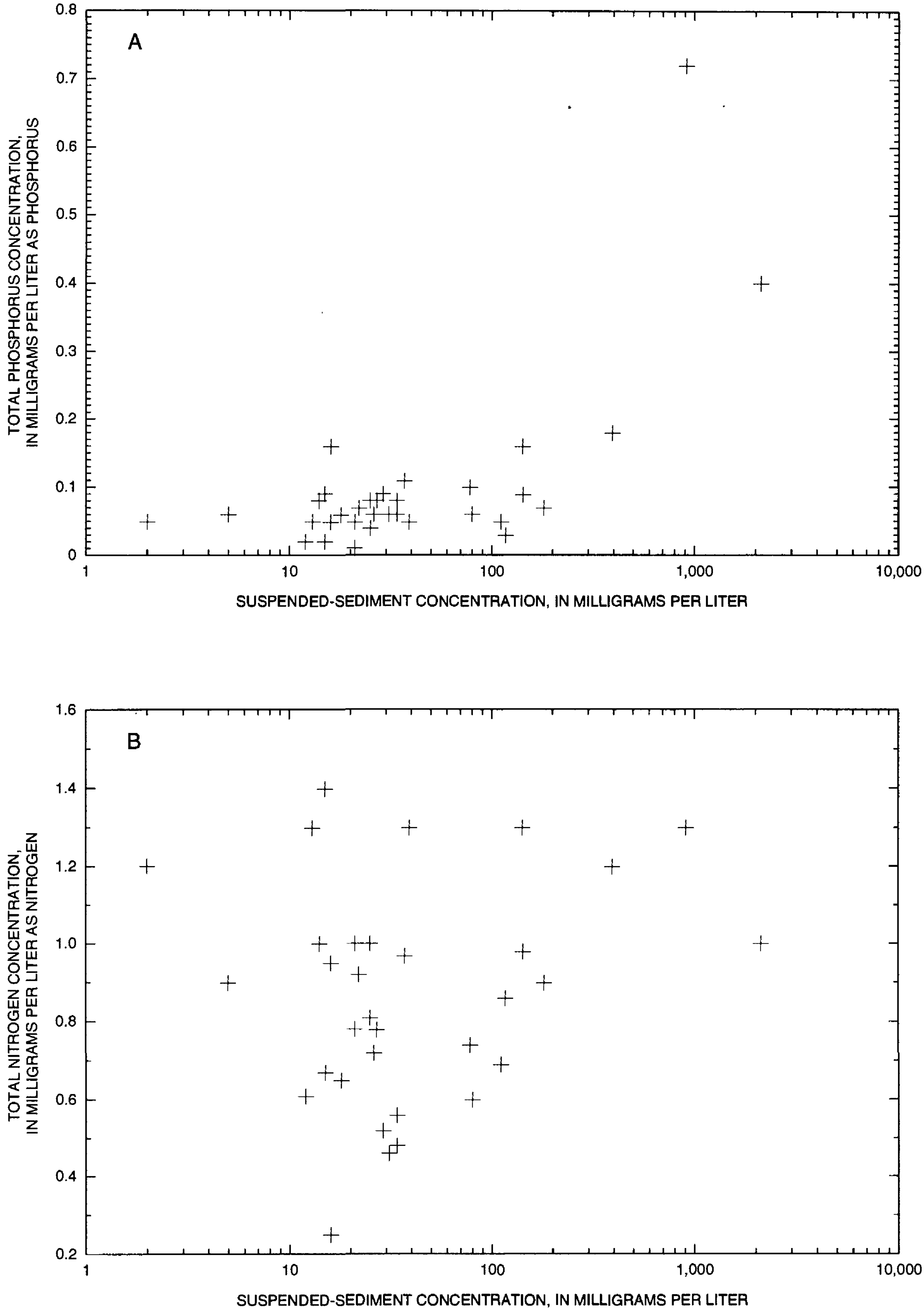


Figure 43.--Relation between suspended-sediment concentration and total phosphorus (A) and total nitrogen (B) concentrations at Red River below fish hatchery near Questa, N. Mex., water years 1972-90.

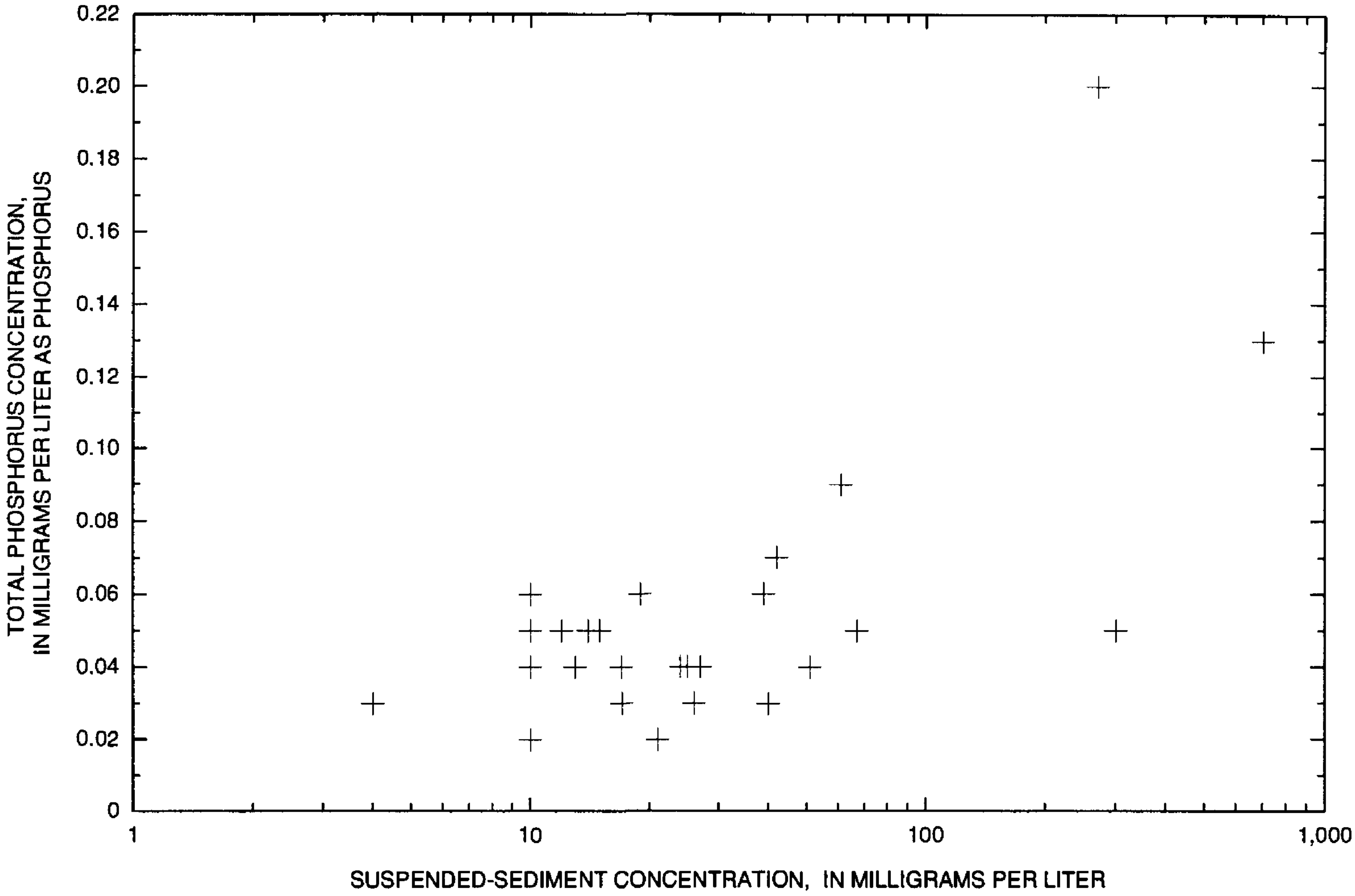
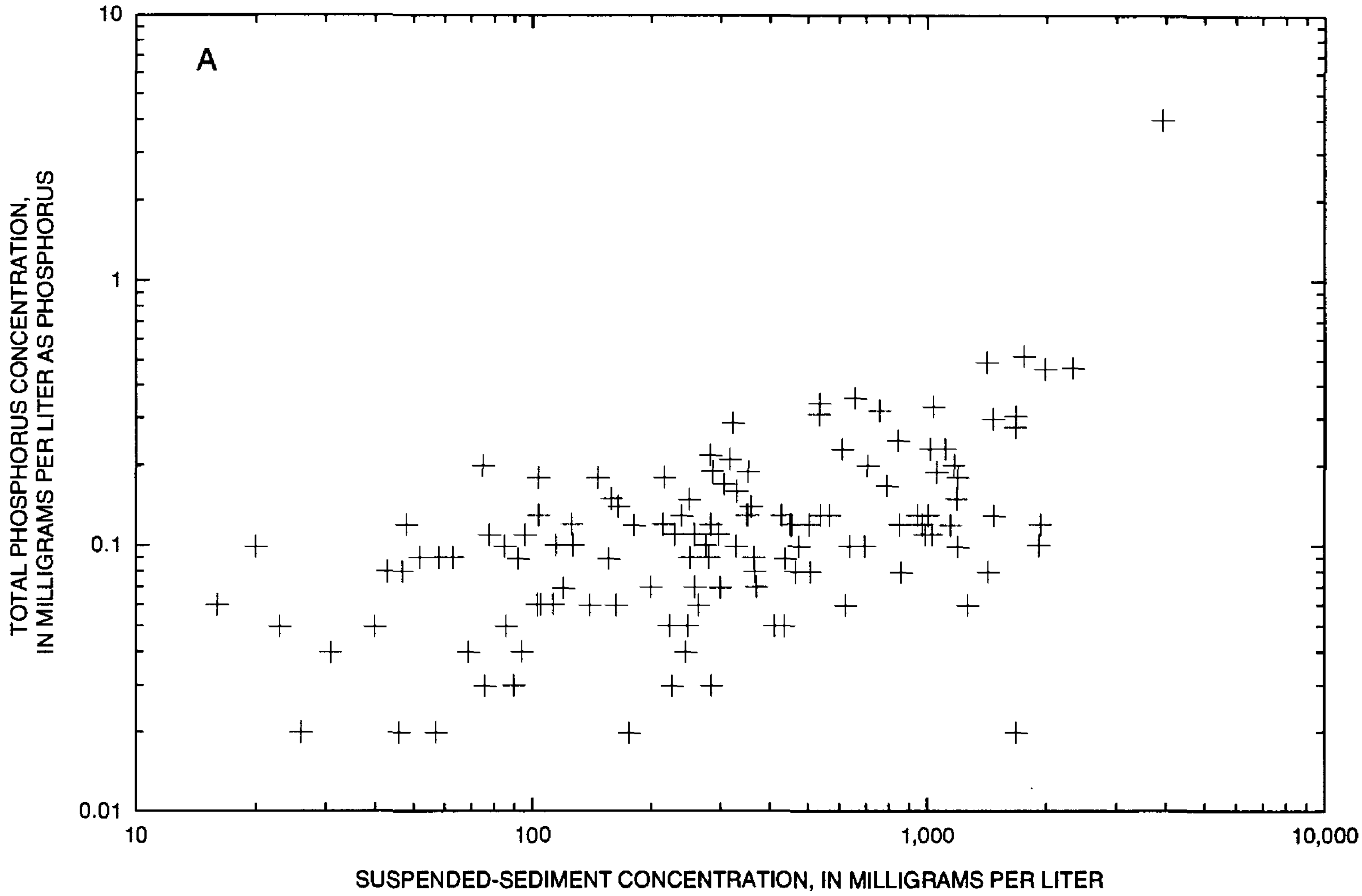


Figure 44.--Relation between suspended-sediment and total phosphorus concentrations at Rio Chama near La Puente, N. Mex., water years 1972-90.



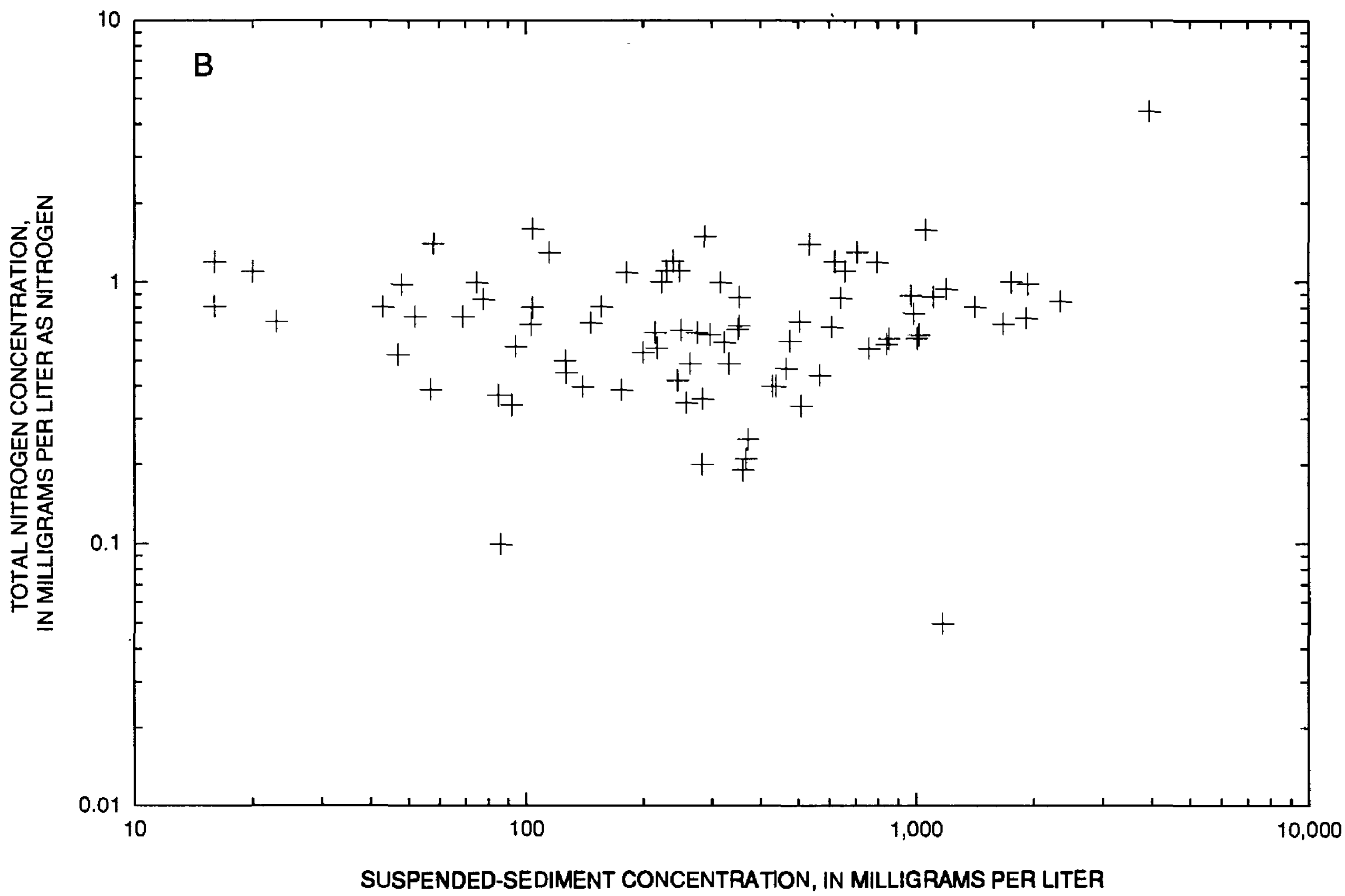


Figure 45.--Relation beween suspended-sediment concentration and total phosphorus (A) and total nitrogen (B) concentrations at Rio Grande at Otowi Bridge near San Ildefonso, N. Mex., water years 1972-90.

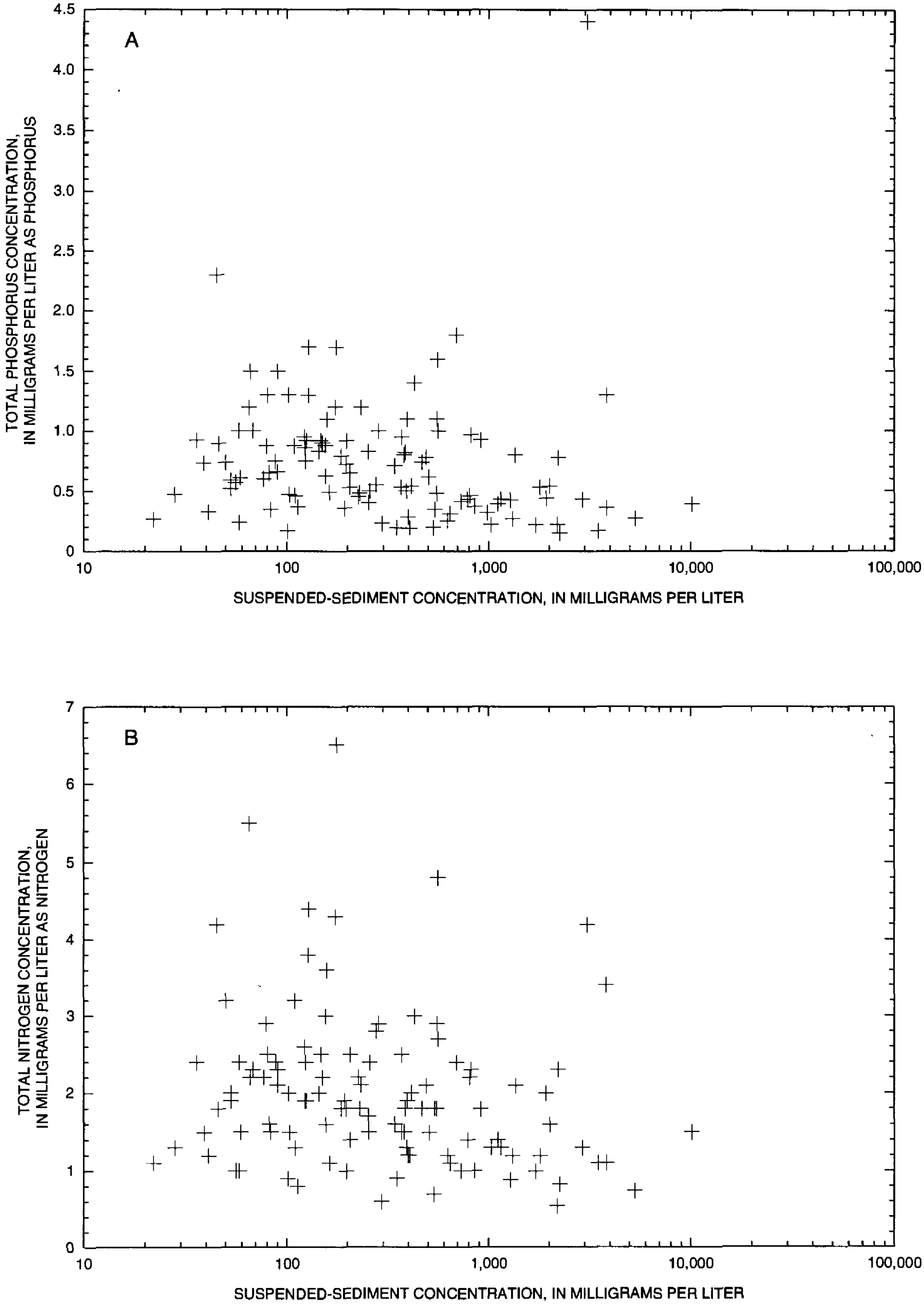


Figure 46.--Relation between suspended-sediment concentration and total phosphorus (A) and total nitrogen (B) concentrations at Rio Grande at Isleta, N. Mex., water years 1972-90.

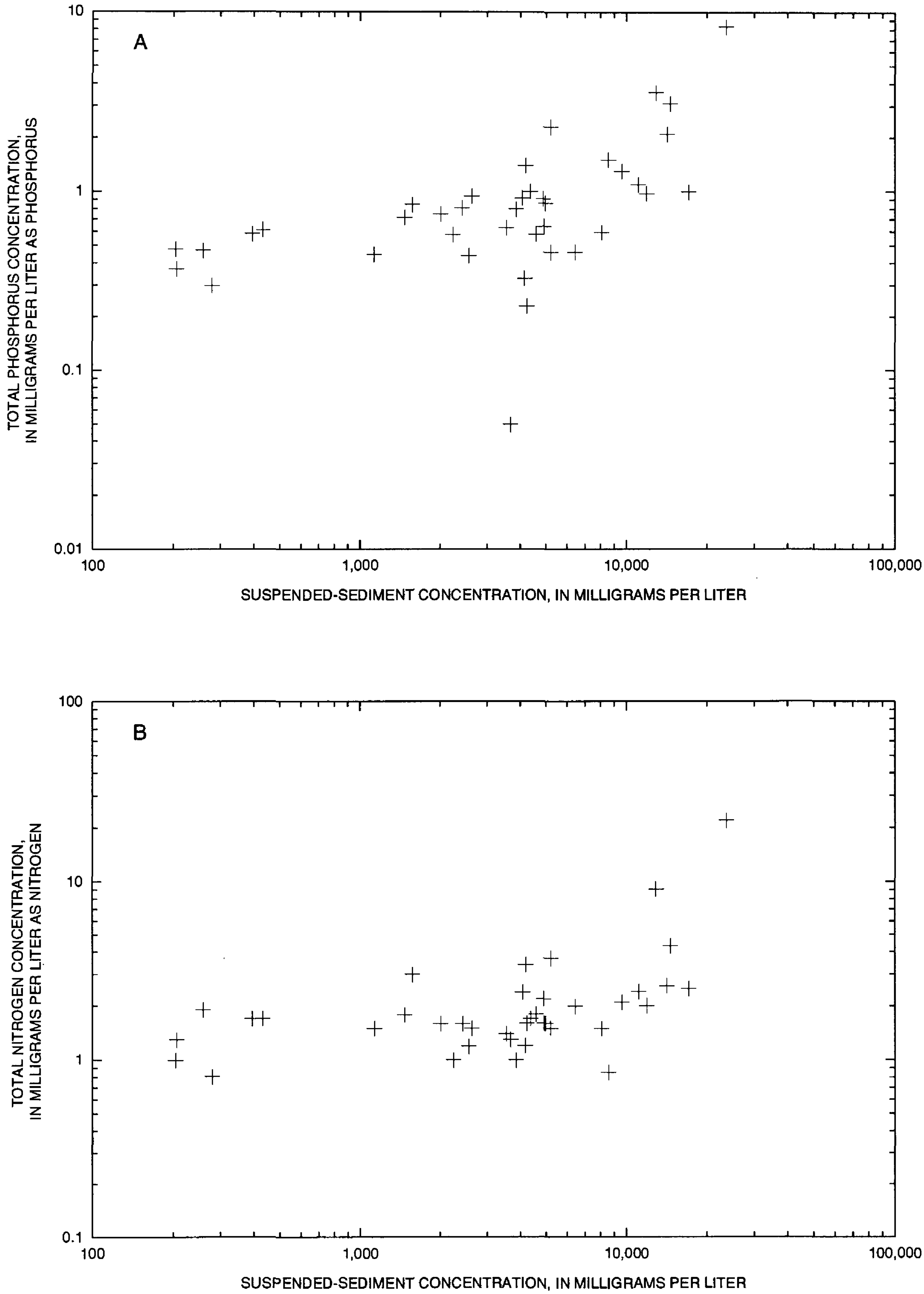
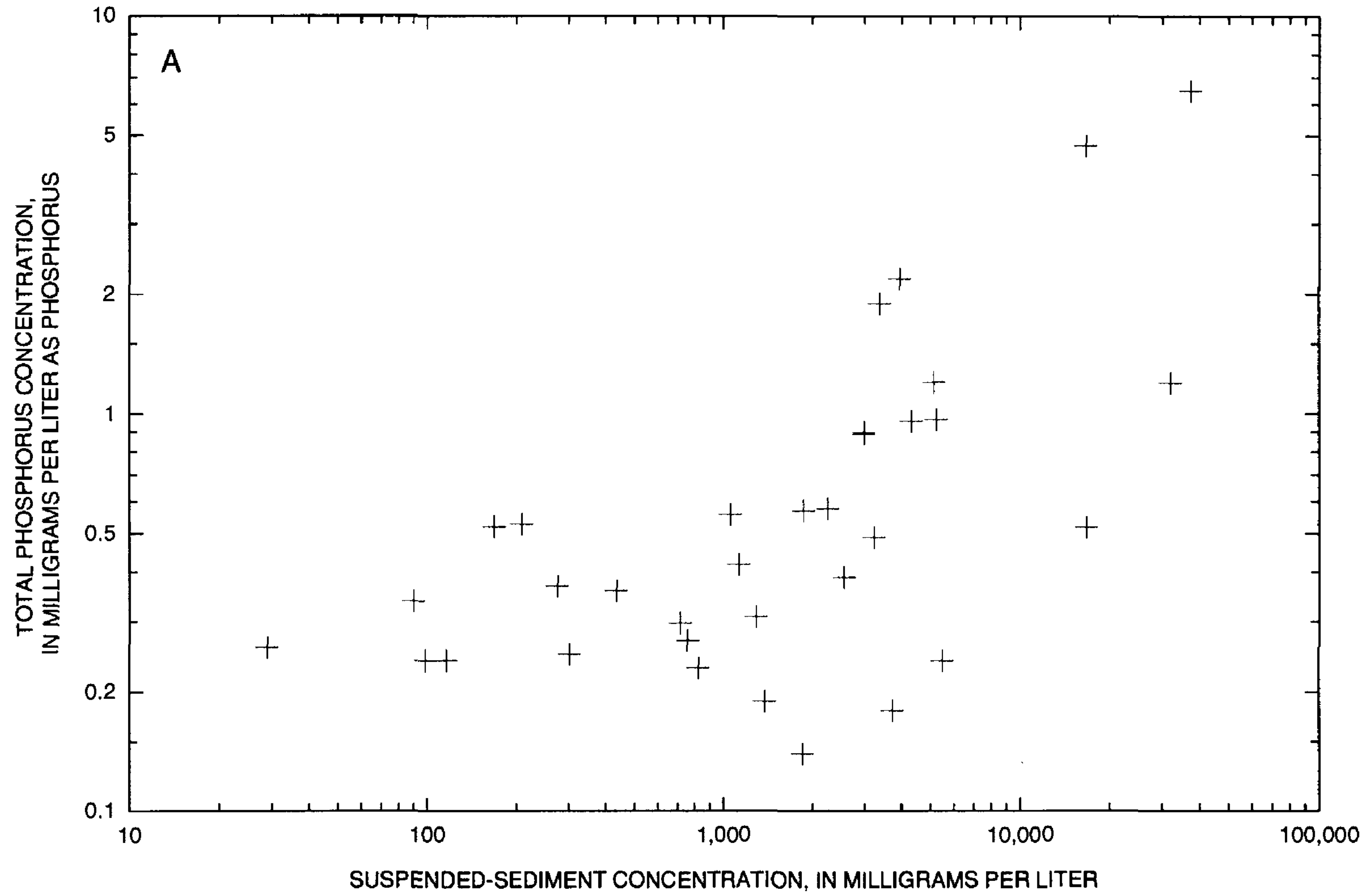


Figure 47.--Relation between suspended-sediment concentration and total phosphorus (A) and total nitrogen (B) concentrations at Rio Grande Conveyance Channel at San Acacia, N. Mex., water years 1972-90.



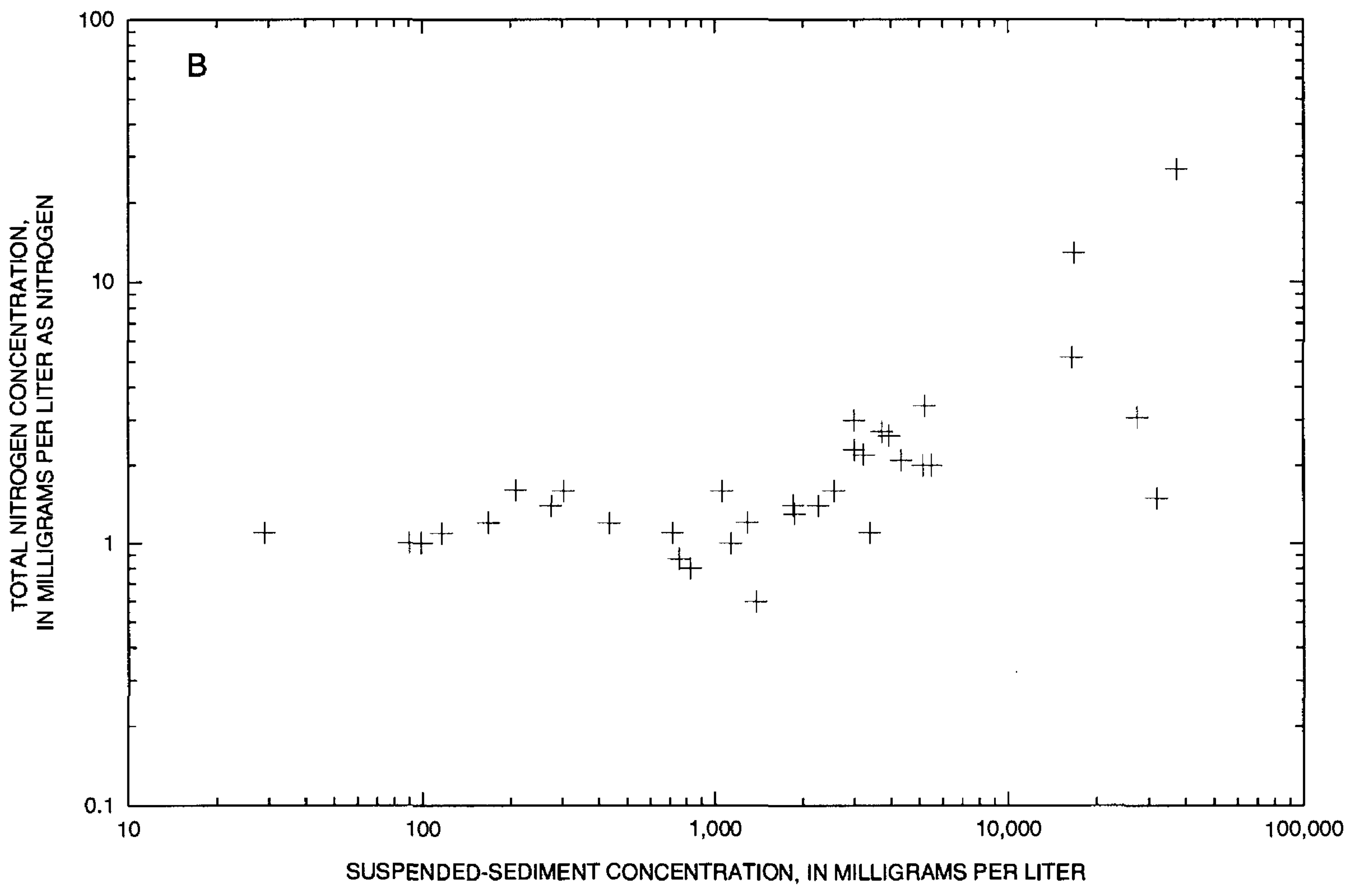
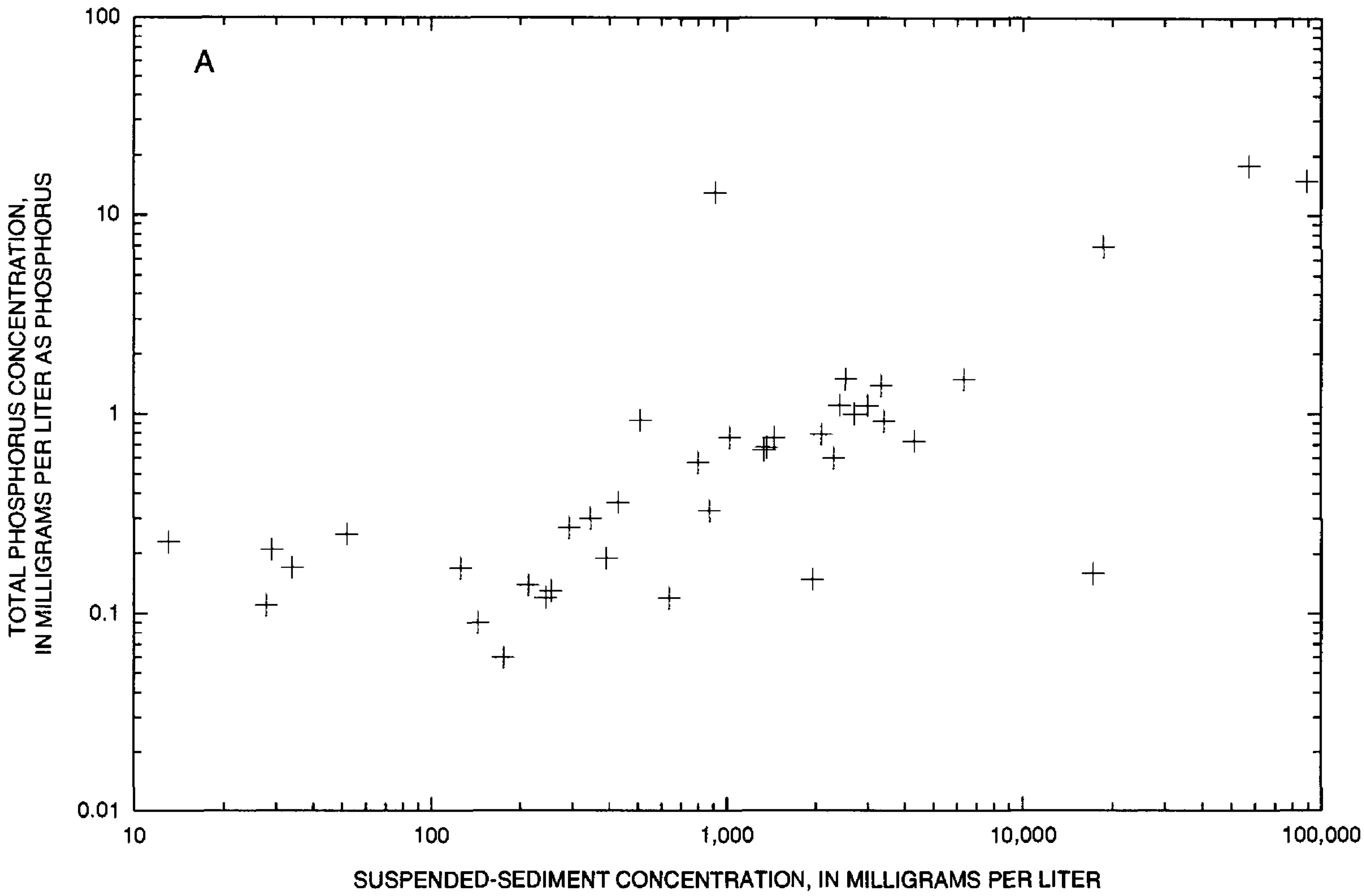


Figure 48.--Relation between suspended-sediment concentration and total phosphorus (A) and total nitrogen (B) concentrations at Rio Grande Floodway at San Acacia, N. Mex., water years 1972-90.



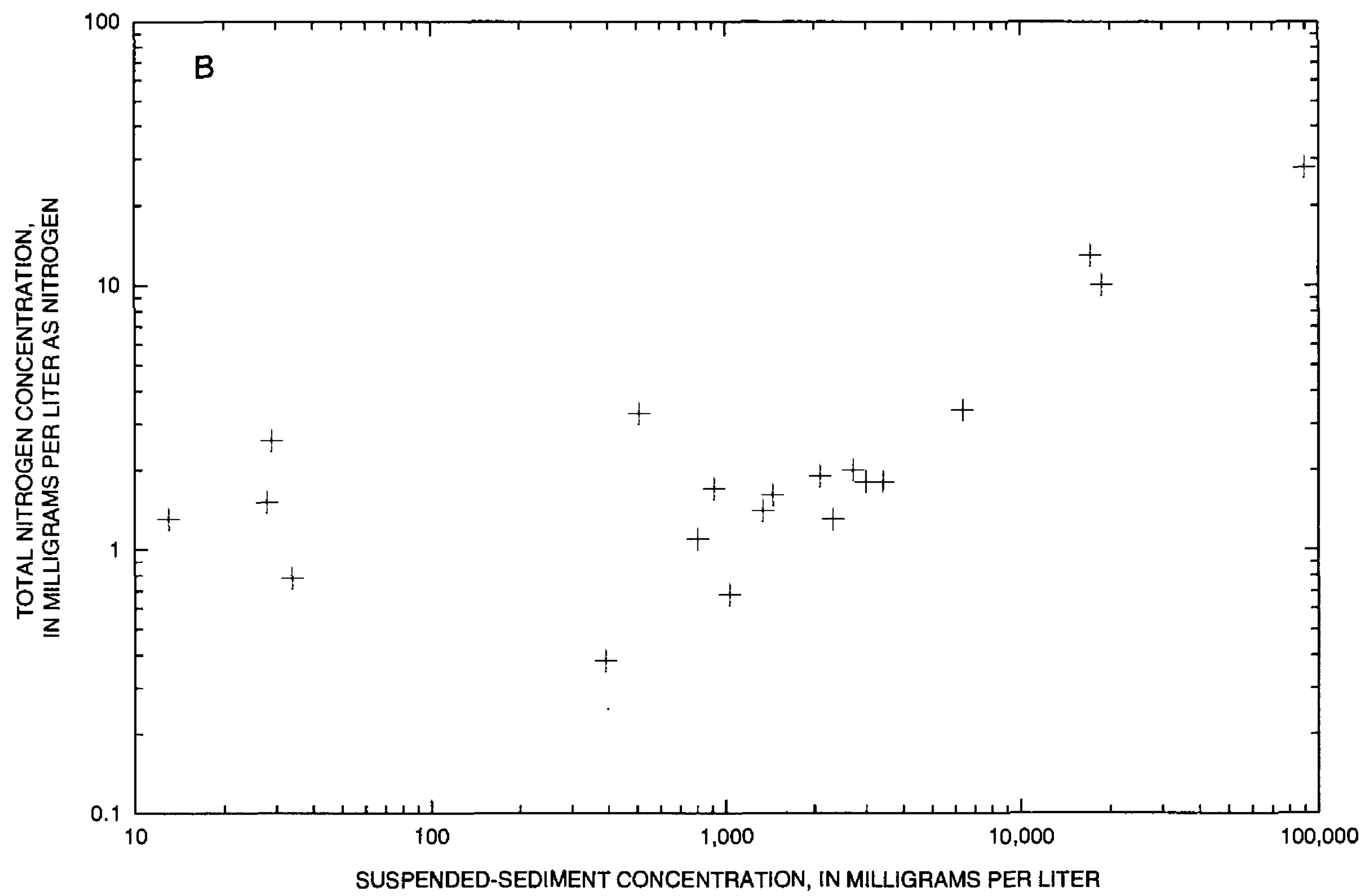
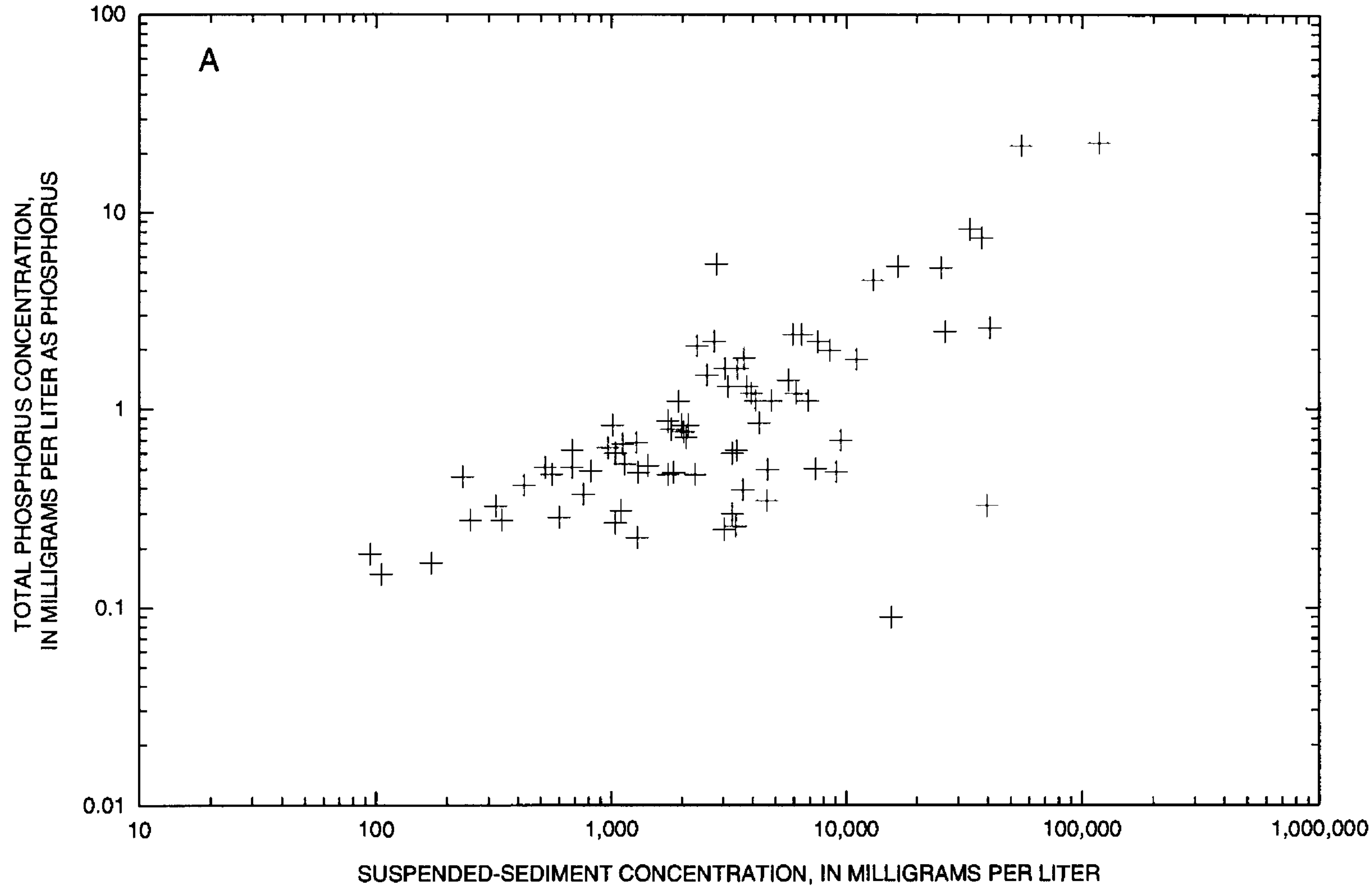


Figure 49.--Relation between suspended-sediment concentration and total phosphorus (A) and total nitrogen (B) concentrations at Rio Grande Conveyance Channel at San Marcial, N. Mex., water years 1972-90.



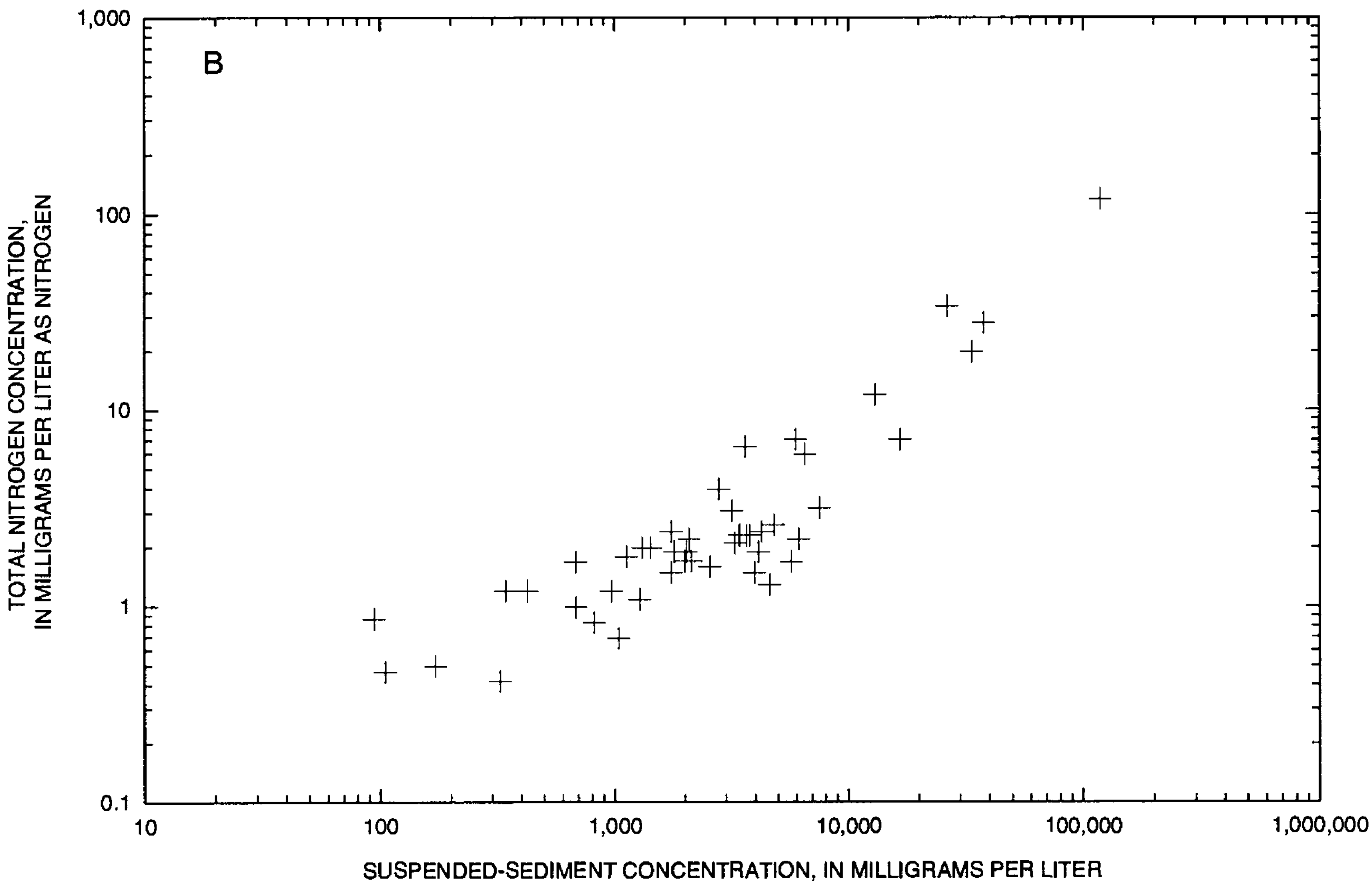


Figure 50.--Relation between suspended-sediment concentration and total phosphorus (A) and total nitrogen (B) concentrations at Rio Grande Floodway at San Marcial, N. Mex., water years 1972-90.

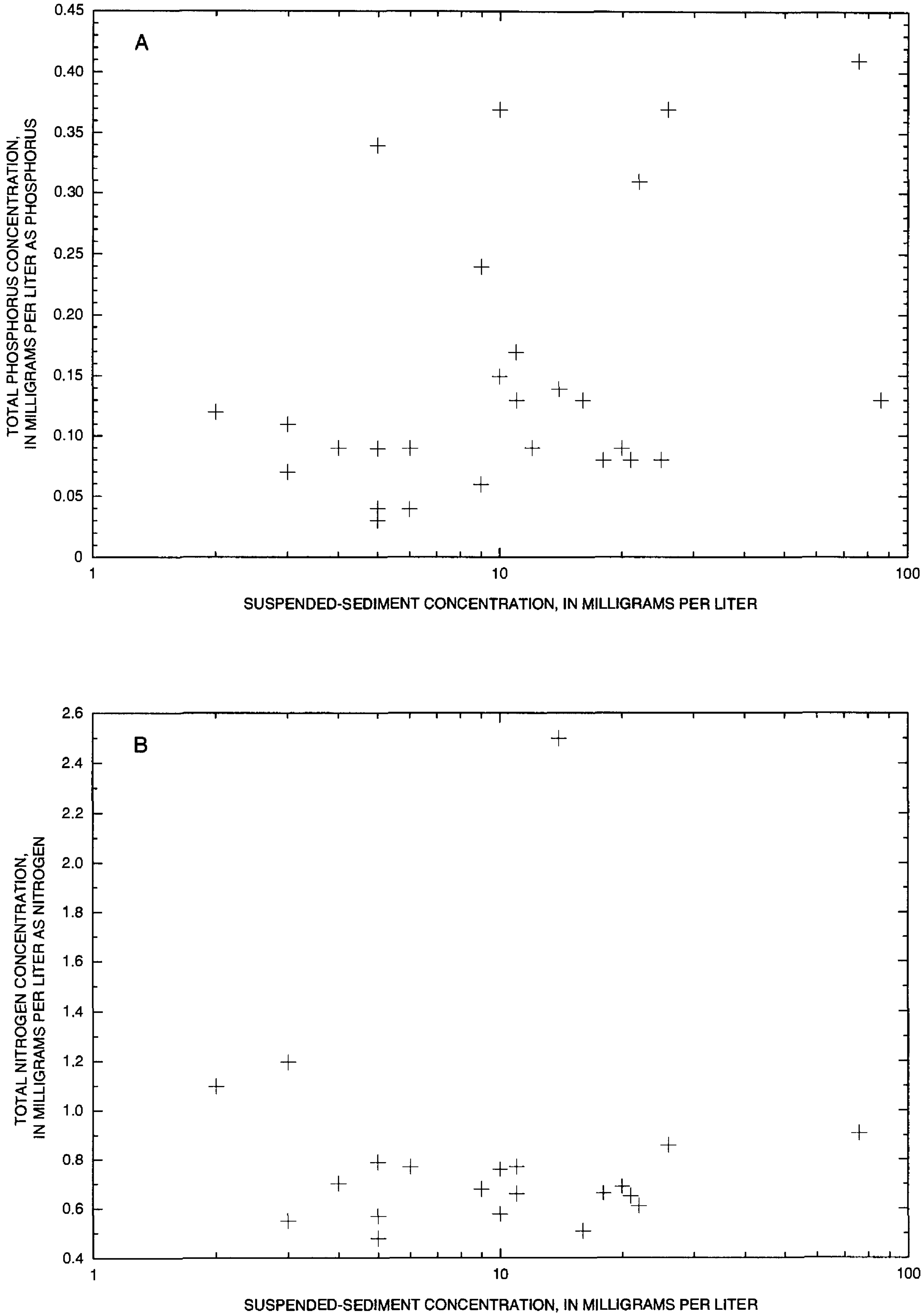


Figure 51.--Relation between suspended-sediment concentration and total phosphorus (A) and total nitrogen (B) concentrations at Rio Grande below Elephant Butte Dam, N. Mex., water years 1972-90.

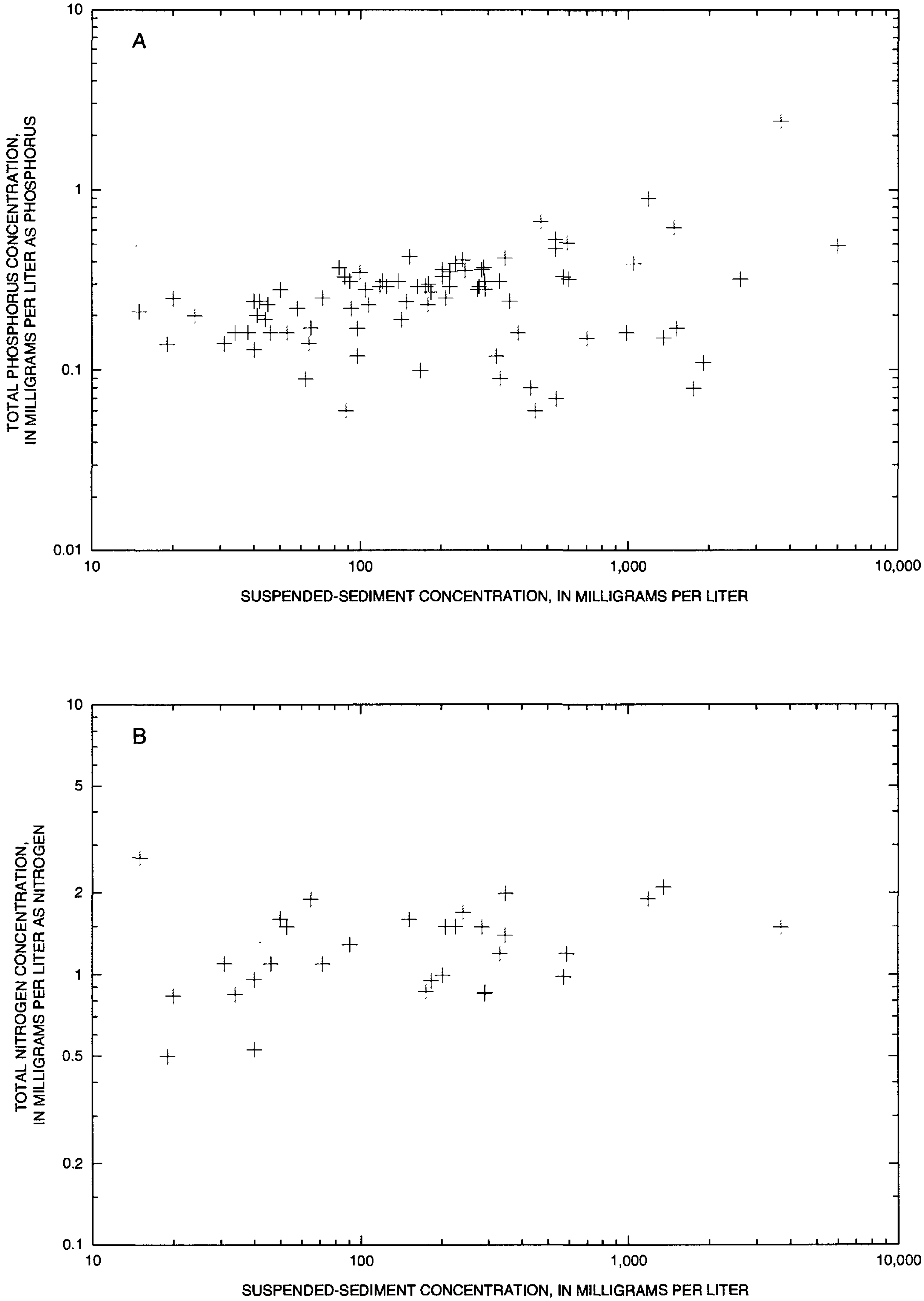


Figure 52.--Relation between suspended-sediment concentration and total phosphorus (A) and total nitrogen (B) concentrations at Rio Grande at El Paso, Tex., water years 1972-90.

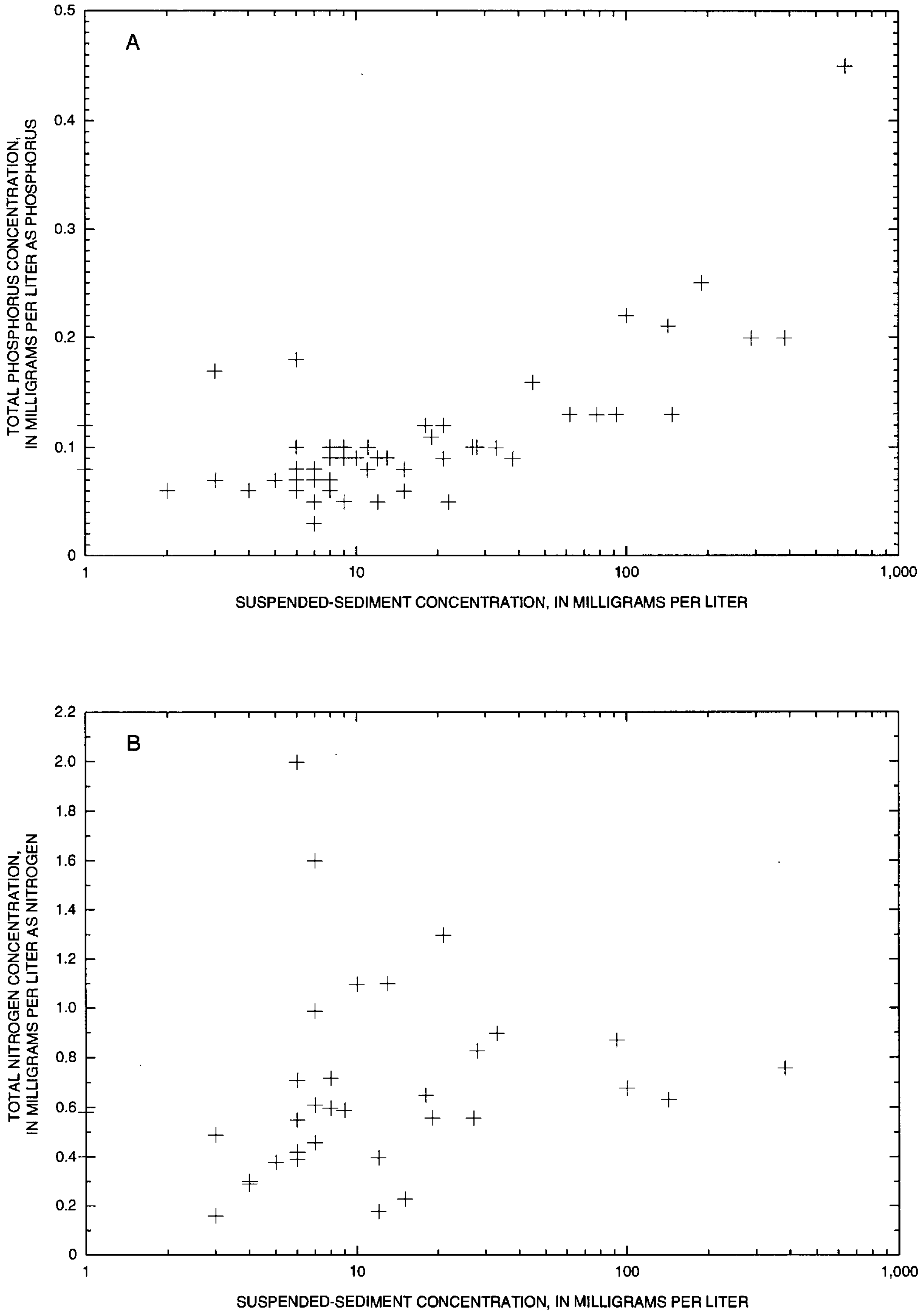


Figure 53.--Relation between suspended-sediment concentration and total phosphorus (A) and total nitrogen (B) concentrations at Mimbres River at Mimbres, N. Mex., water years 1972-90.

Table 7.--Results of Spearman correlation analysis for relation between total phosphorus concentration and suspended-sediment concentration in water from selected surface-water stations in the Rio Grande Valley study unit

[Underlined, significance of probability value equal to or less than 0.05; <, less than]

Station reference number (pl. 2)	Station name	Correlation coefficient	Probability value
4	Rio Grande at Alamosa, Colo.[1]	0.50	<0.005
6	Rio Grande near Lobatos, Colo.	.38	<.005
13	Red River below fish hatchery near Questa, N. Mex.	.50	<.005
20	Rio Chama near La Puente, N. Mex.	.39	.022
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	.56	<.005
41	Rio Grande at Isleta, N. Mex.	-.29	<.005
48	Rio Grande Conveyance Channel at San Acacia, N. Mex.	.60	<.005
49	Rio Grande Floodway at San Acacia, N. Mex.	.58	<.005
62	Rio Grande Conveyance Channel at San Marcial, N. Mex.	.74	<.005
63	Rio Grande Floodway at San Marcial, N. Mex.	.62	<.005
67	Rio Grande below Elephant Butte Dam, N. Mex.	.33	.04
69	Mimbres River at Mimbres, N. Mex.	.46	<.005
97	Rio Grande at El Paso, Tex.	.33	<.005

[1] Suspended-solids concentration used.

Table 8.--Results of Spearman correlation analysis for relation between total nitrogen concentration and suspended-sediment concentration in water from selected surface-water stations in the Rio Grande Valley study unit

[Underlined, significance of probability value equal to or less than 0.05; <, less than]

Station reference number (pl. 2)	Station name	Correlation coefficient	Probability value
6	Rio Grande near Lobatos, Colo.	-0.147	0.26
13	Red River below fish hatchery near Questa, N. Mex.	.117	.25
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	.048	.33
41	Rio Grande at Isleta, N. Mex.	-.245	<.005
48	Rio Grande Conveyance Channel at San Acacia, N. Mex.	.50	<.005
49	Rio Grande Floodway at San Acacia, N. Mex.	.74	<.005
62	Rio Grande Conveyance Channel at San Marcial, N. Mex.	.63	<.005
63	Rio Grande Floodway at San Marcial, N. Mex.	.82	<.005
67	Rio Grande below Elephant Butte Dam, N. Mex.	.03	.46
69	Mimbres River at Mimbres, N. Mex.	.46	<.005
97	Rio Grande at El Paso, Tex.	.375	.017

Table 9.--Results of Spearman correlation analysis for relation between nutrient concentration in water and streamflow for selected surface-water stations in the Rio Grande Valley study unit

[--, value not calculated; underlined, significance of probability value equal to or less than 0.05; <, less than]

Station reference number (pl. 2)	Station name	Total nitrogen		Dissolved nitrate		Dissolved ammonia		Total phosphorus		Dissolved orthophosphate	
		Correlation coefficient	Probability value	Correlation coefficient	Probability value	Correlation coefficient	Probability value	Correlation coefficient	Probability value	Correlation coefficient	Probability value
4	Rio Grande at Alamosa, Colo.	--	--	--	--	--	--	0.03	0.44	--	--
6	Rio Grande near Lobatos, Colo.	-0.23	0.04	-0.15	0.13	0.09	0.23	-.04	.32	-0.03	0.42
13	Red River below fish hatchery near Questa, N. Mex.	.13	.22	-.51	<.005	--	--	.17	.14	-.21	.07
20	Rio Chama near La Puente, N. Mex.	--	--	-.33	.05	--	--	.37	.03	-.15	.23
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	.23	.01	-.02	.41	-.13	.14	.35	<.005	.04	.31

Table 9.--Results of Spearman correlation analysis for relation between nutrient concentration in water and streamflow for selected surface-water stations in the Rio Grande Valley study unit--Continued

		Total nitrogen		Dissolved nitrate		Dissolved ammonia		Total phosphorus		Dissolved orthophosphate	
Station reference number (pl. 2)	Station name	Correlation coefficient	Probability value	Correlation coefficient	Probability value	Correlation coefficient	Probability value	Correlation coefficient	Probability value	Correlation coefficient	Probability value
41	Rio Grande at Isleta, N. Mex.	-0.58	≤0.005	-0.61	≤0.005	-0.92	≤0.005	-0.62	≤0.005	-0.87	≤0.005
48	Rio Grande Conveyance Channel at San Acacia, N. Mex.	.36	≤.005	.24	.02	--	--	.33	≤.005	.10	.20
49	Rio Grande Floodway at San Acacia, N. Mex.	.12	.22	-.41	≤.005	--	--	-.03	.44	-.46	≤.005
62	Rio Grande Conveyance Channel at San Marcial, N. Mex.	.52	≤.005	.61	≤.005	.05	.41	.72	≤.005	.54	≤.005
63	Rio Grande Floodway at San Marcial, N. Mex.	.35	≤.005	-.13	.07	.006	.49	.19	≤.005	-.08	.22

Table 9.--Results of Spearman correlation analysis for relation between nutrient concentration in water and streamflow for selected surface-water stations in the Rio Grande Valley study unit--Concluded

Station reference number (pl. 2)	Station name	Total nitrogen		Dissolved nitrate		Dissolved ammonia		Total phosphorus		Dissolved orthophosphate	
		Correlation coefficient	Probability value	Correlation coefficient	Probability value	Correlation coefficient	Probability value	Correlation coefficient	Probability value	Correlation coefficient	Probability value
67	Rio Grande below Elephant Butte Dam, N. Mex.	-0.16	≤0.005	-0.19	0.07	-0.15	0.25	0.28	≤0.005	0.21	0.08
69	Mimbres River at Mimbres, N. Mex.	.22	.10	.35	.02	.09	.28	.46	≤.005	.82	≤.005
97	Rio Grande at El Paso, Tex.	.37	.02	-.46	≤.005	-.46	≤.005	.16	.06	-.73	≤.005

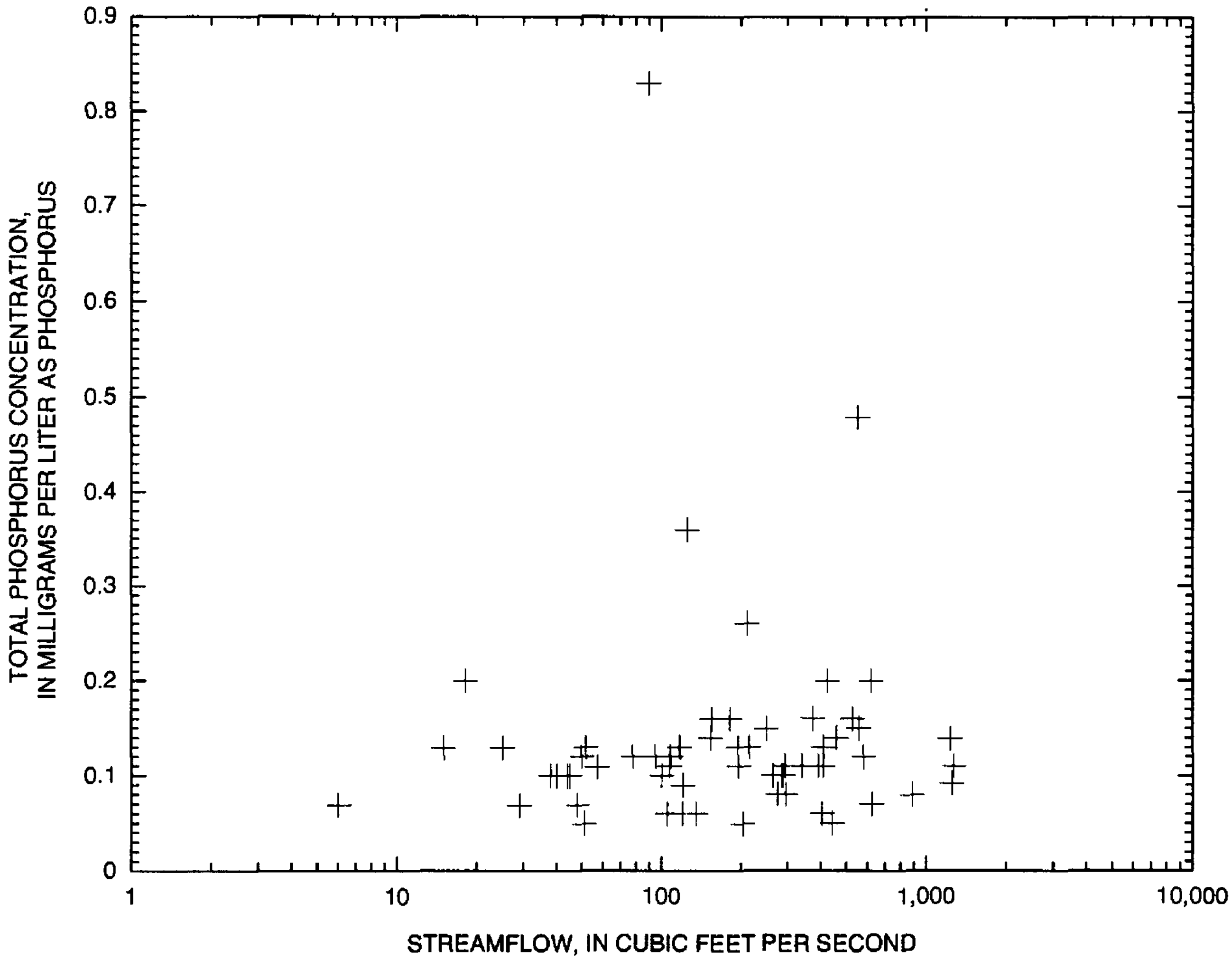


Figure 54.--Relation between total phosphorus concentration and streamflow at Rio Grande at Alamosa, Colo., water years 1972-90.

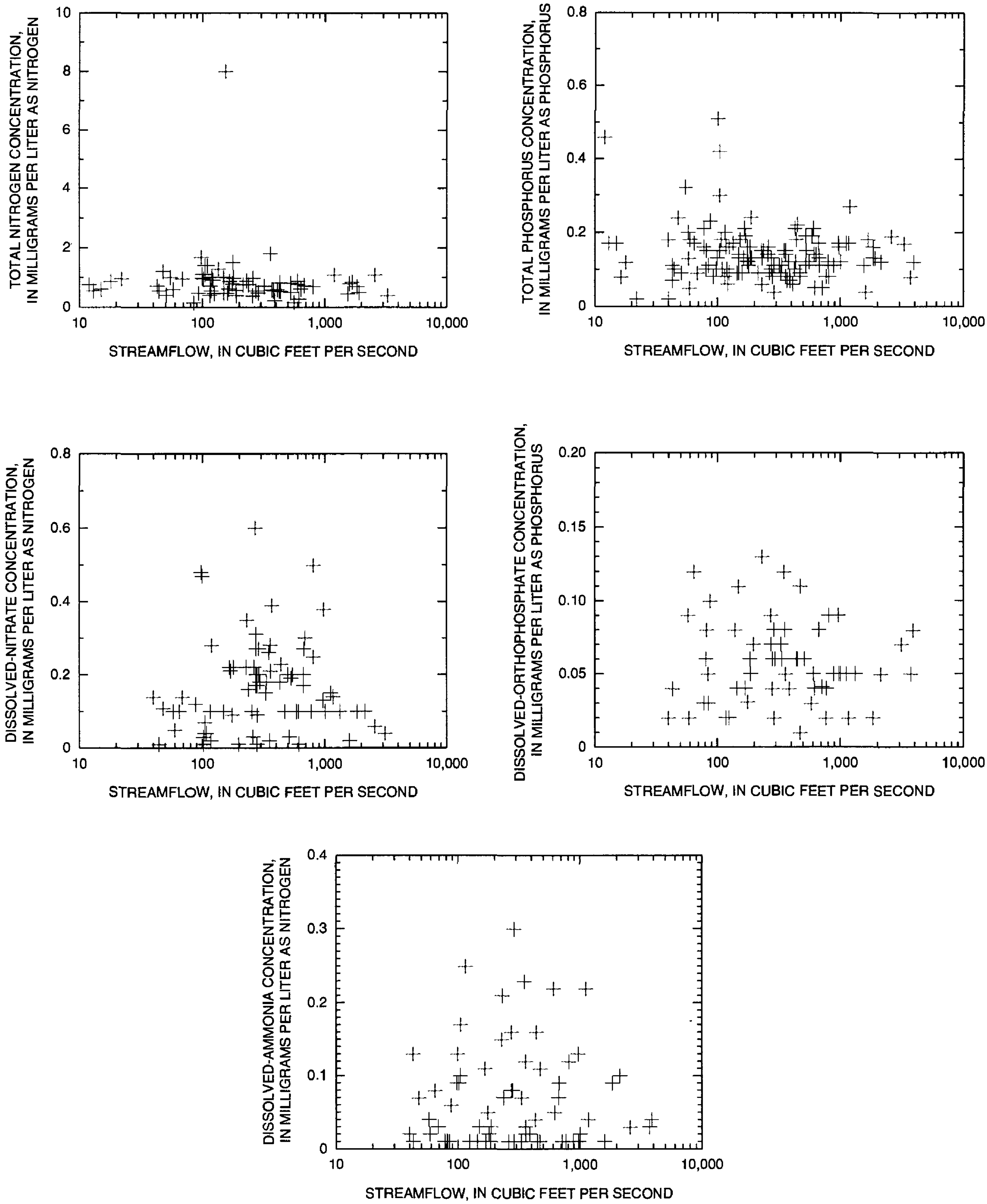


Figure 55.--Relation between nutrient concentration and streamflow at Rio Grande near Lobatos, Colo., water years 1972-90.

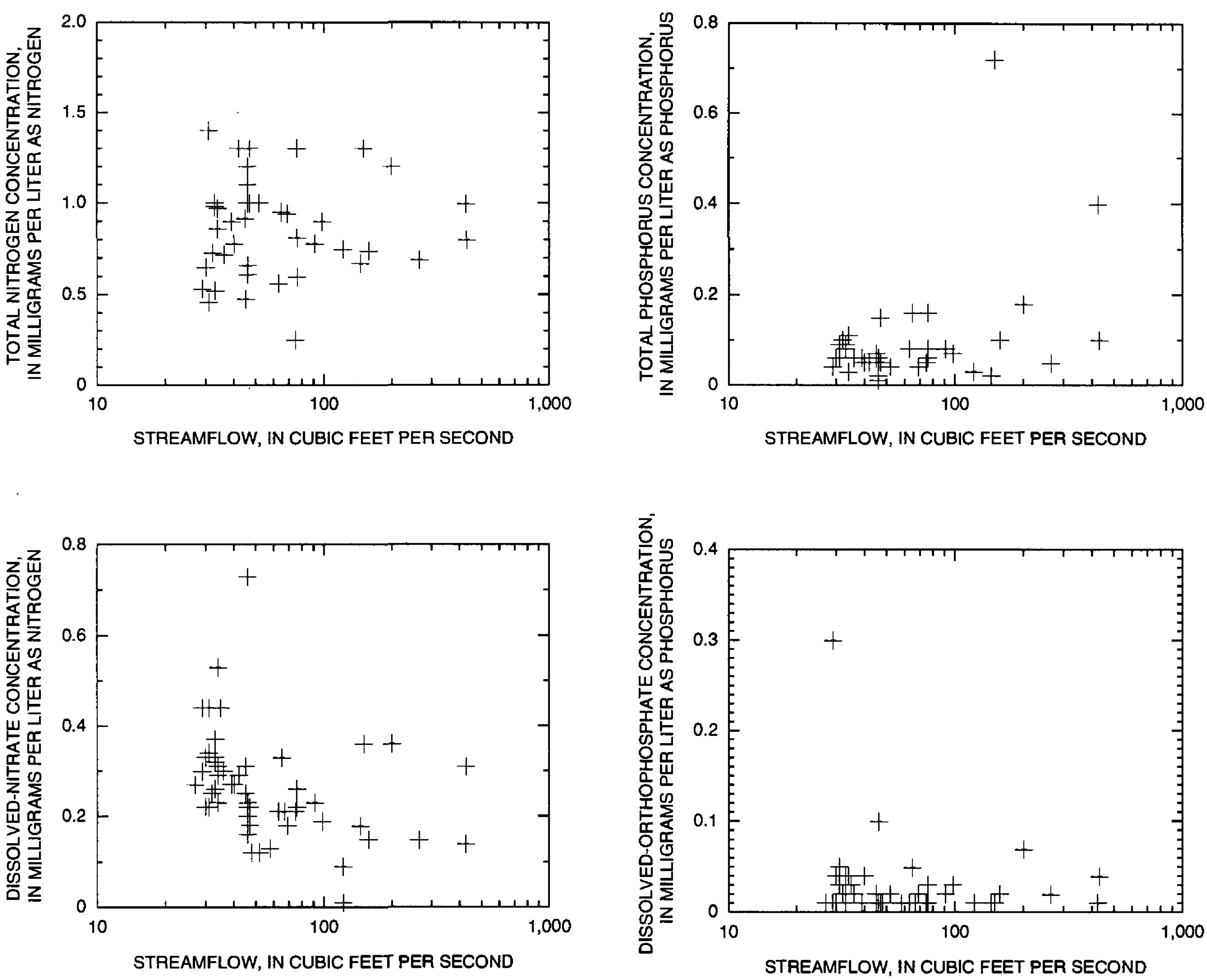


Figure 56.--Relation between nutrient concentration and streamflow at Red River below fish hatchery near Questa, N. Mex., water years 1972-90.

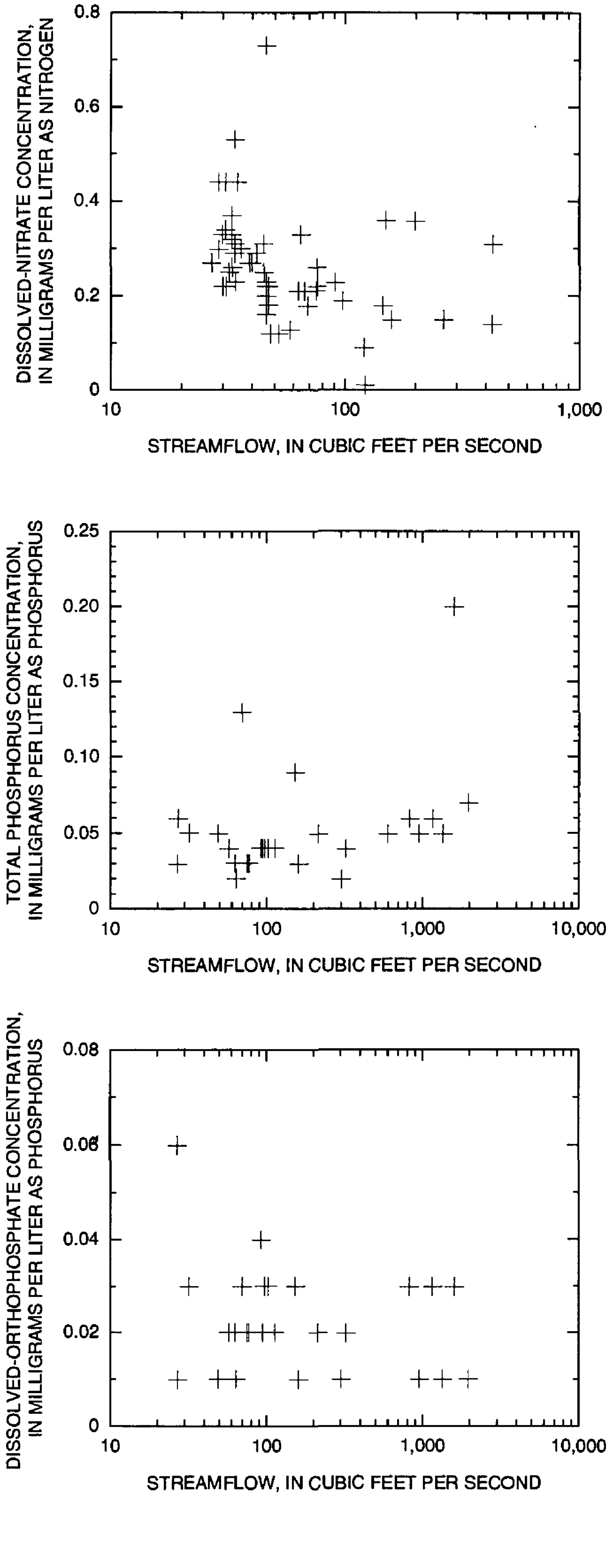


Figure 57.--Relation between nutrient concentration and streamflow at Rio Chama near La Puente, N. Mex., water years 1972-90.

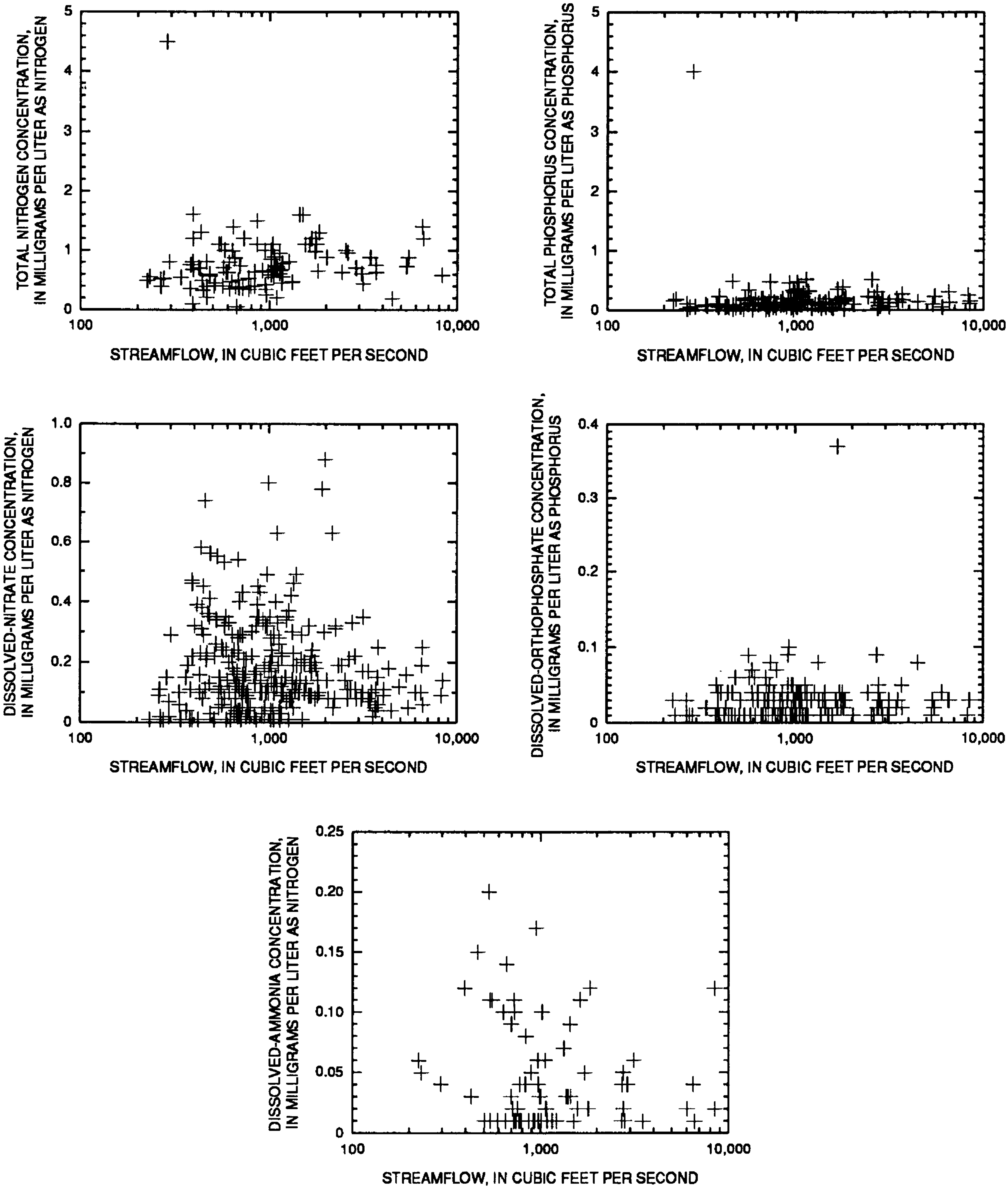


Figure 58.--Relation between nutrient concentration and streamflow at Rio Grande at Otowi Bridge near San Ildefonso, N. Mex., water years 1972-90.

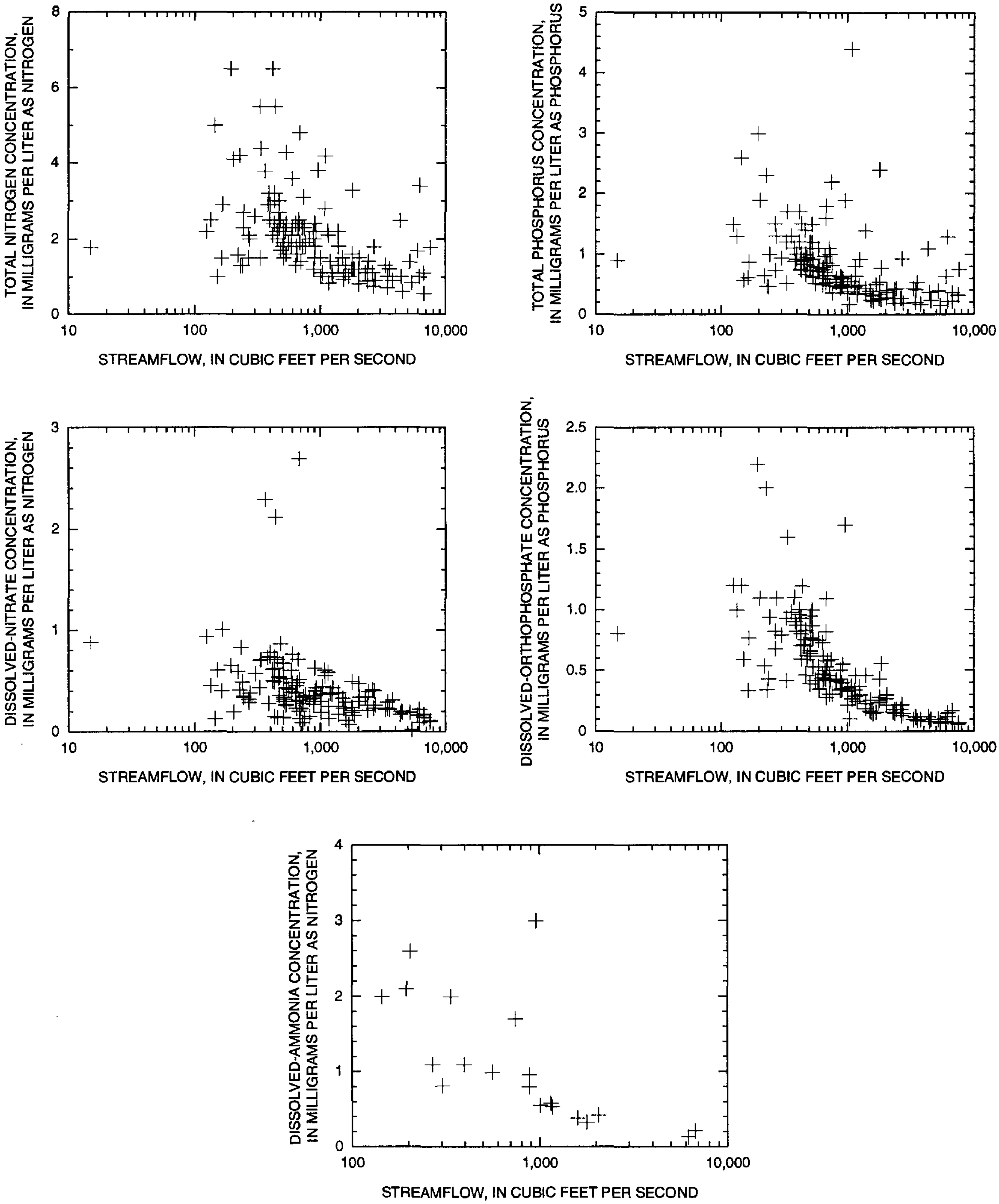


Figure 59.--Relation between nutrient concentration and streamflow at Rio Grande at Isleta, N. Mex., water years 1972-90.

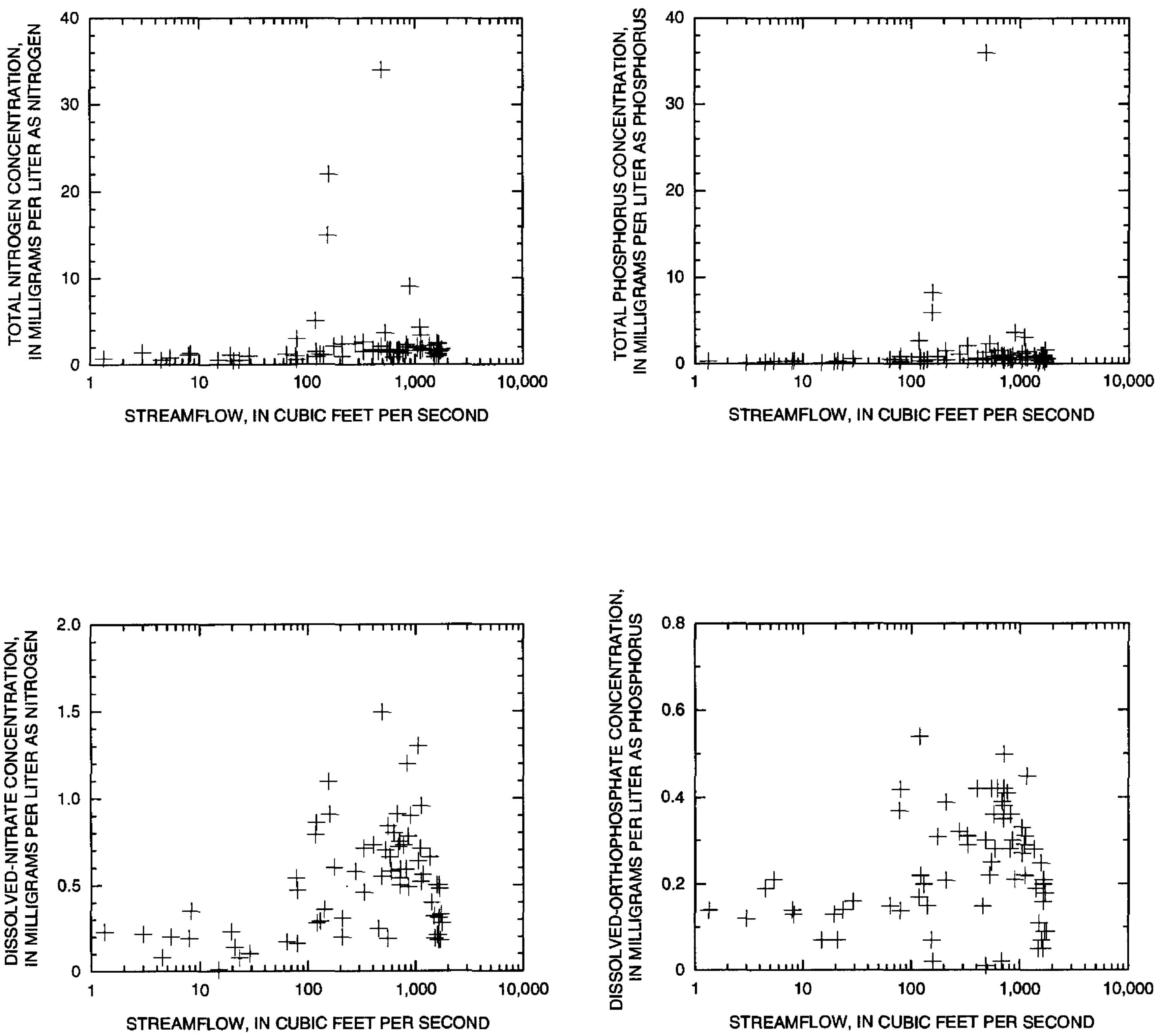


Figure 60.--Relation between nutrient concentration and streamflow at Rio Grande Conveyance Channel at San Acacia, N. Mex., water years 1972-90.

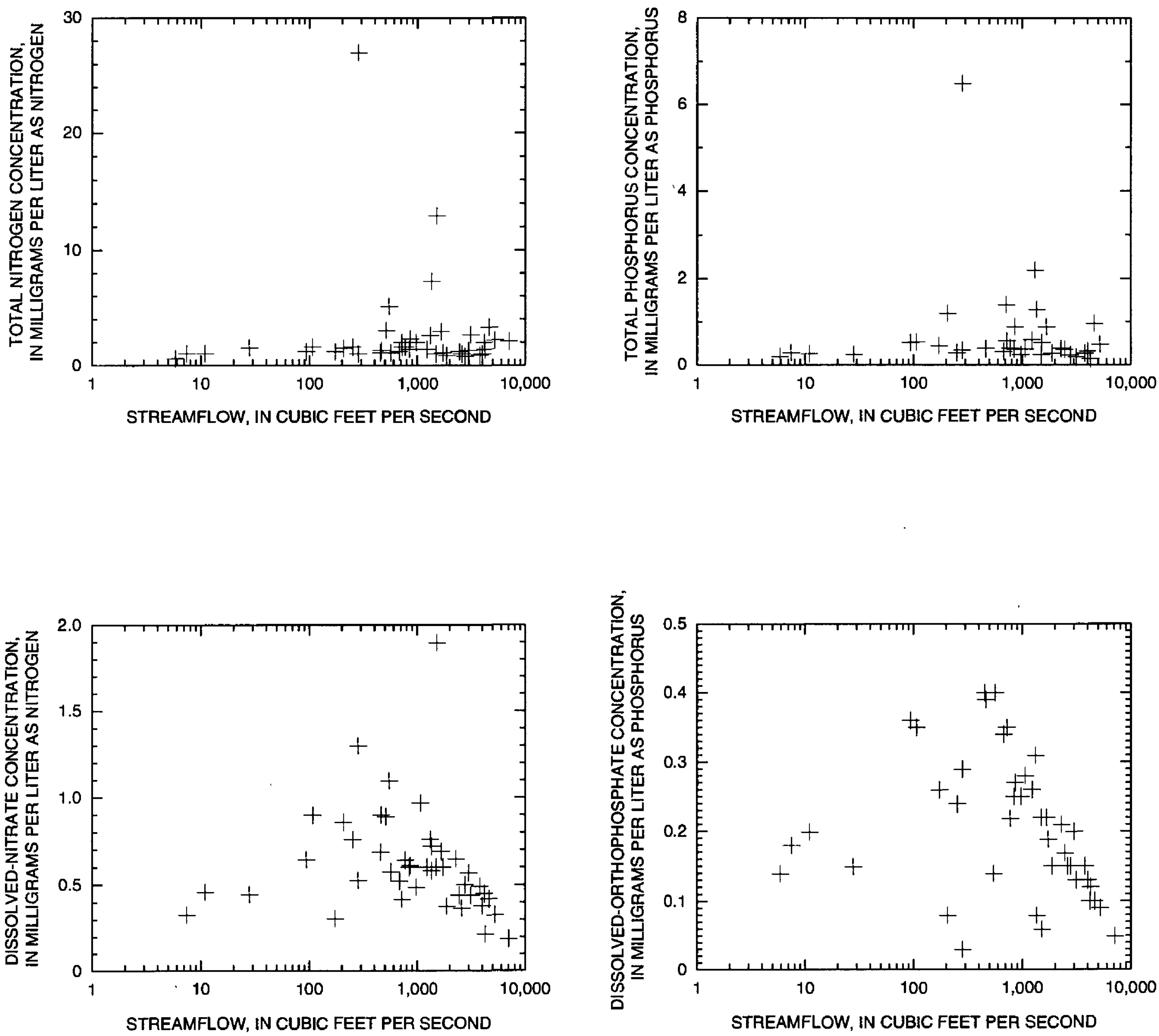


Figure 61.--Relation between nutrient concentration and streamflow at Rio Grande Floodway at San Acacia, N. Mex., water years 1972-90.

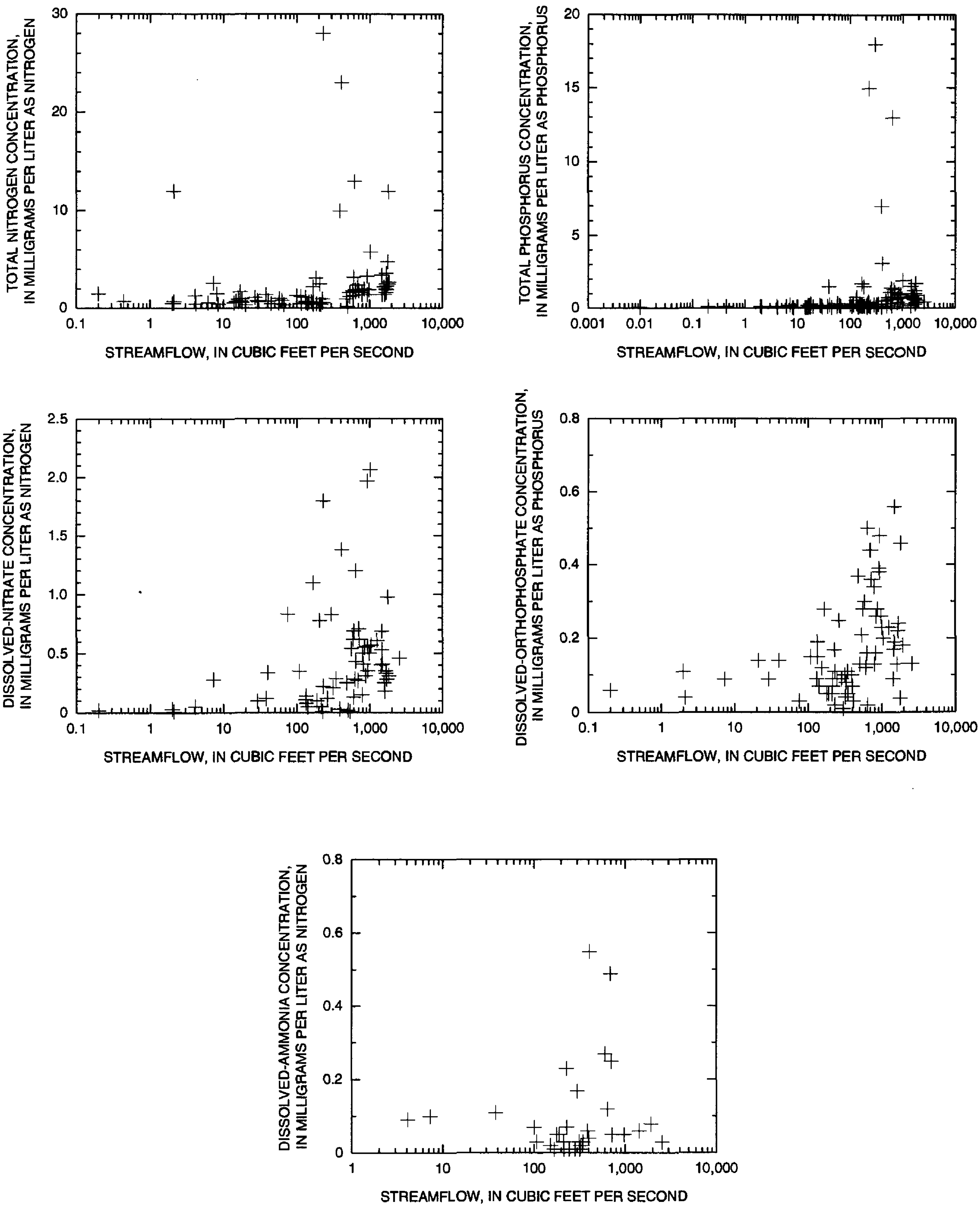


Figure 62.--Relation between nutrient concentration and streamflow at Rio Grande Conveyance Channel at San Marcial, N. Mex., water years 1972-90.

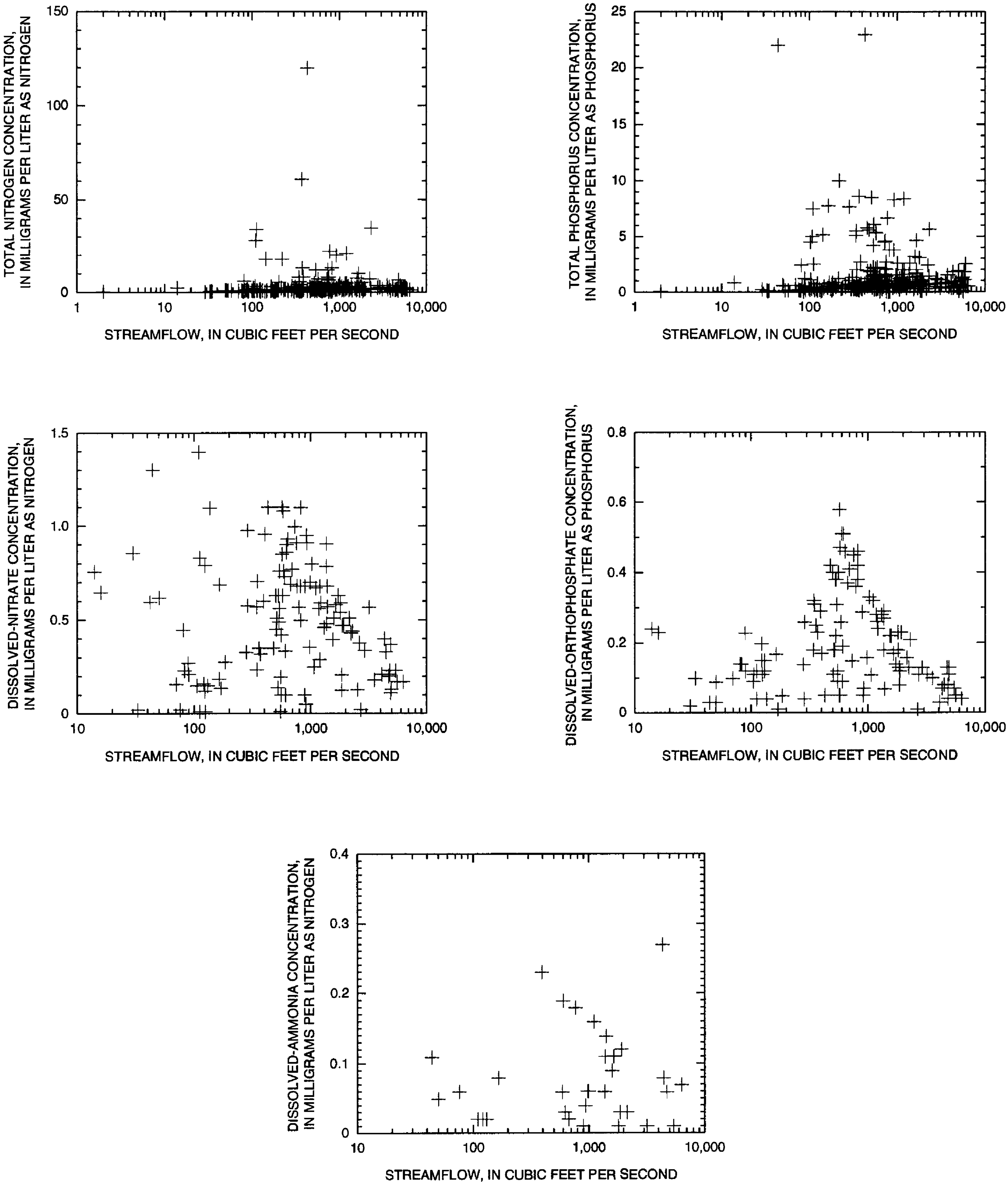


Figure 63.--Relation between nutrient concentration and streamflow at Rio Grande Floodway at San Marcial, N. Mex., water years 1972-90.

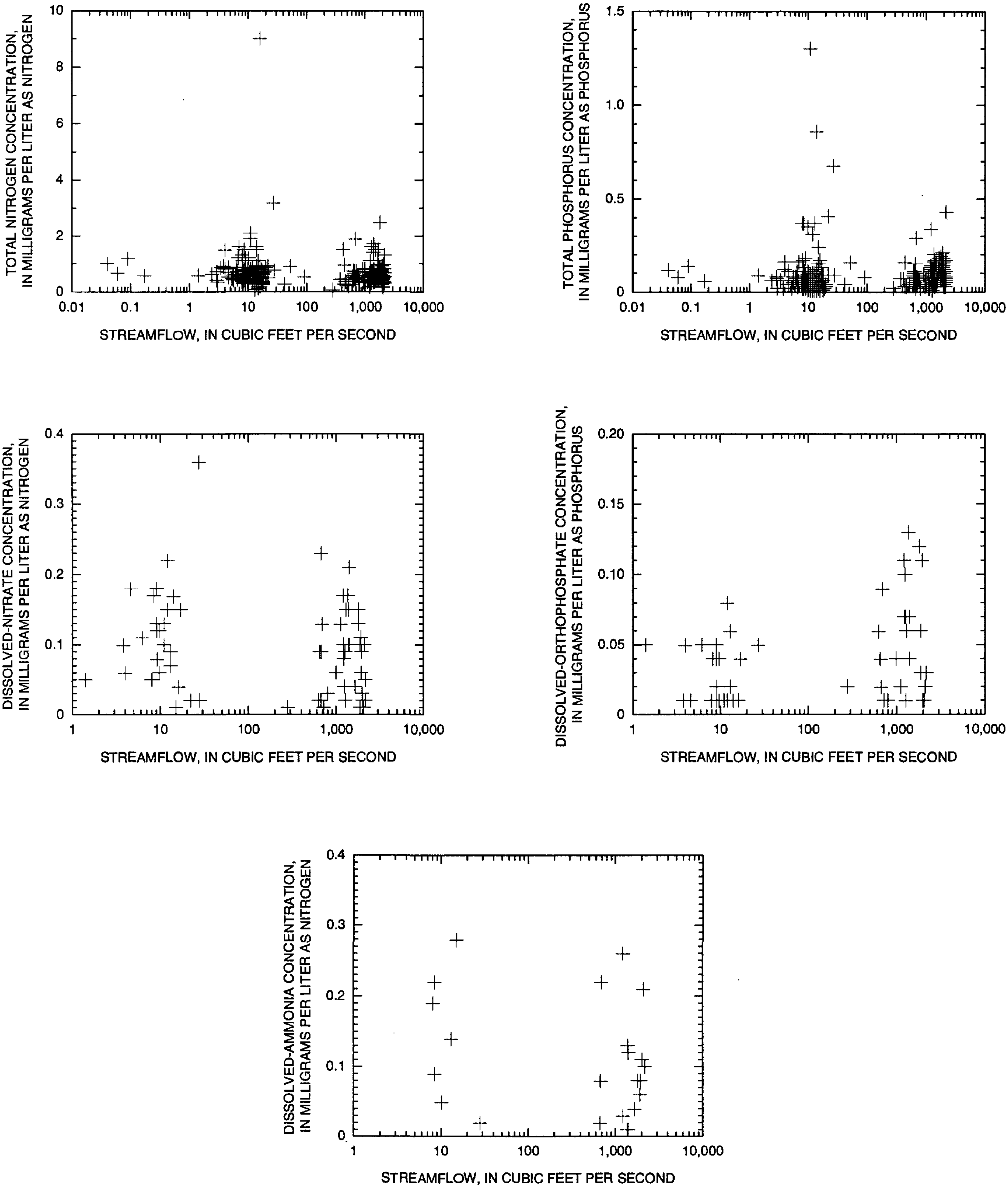


Figure 64.--Relation of nutrient concentration and streamflow at Rio Grande below Elephant Butte Dam, N. Mex., water years 1972-90.

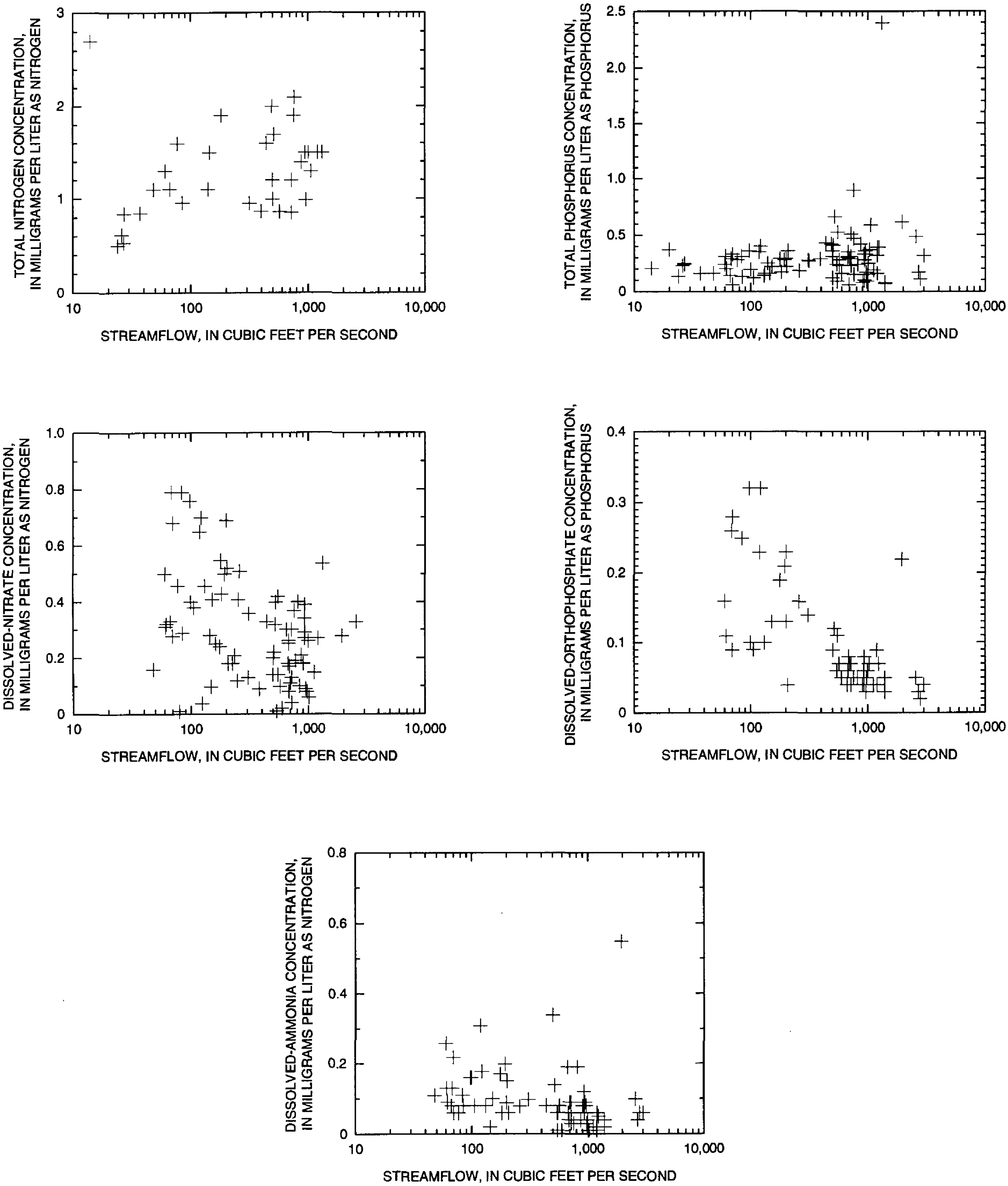


Figure 65.--Relation between nutrient concentration and streamflow at Rio Grande at El Paso, Tex., water years 1972-90.

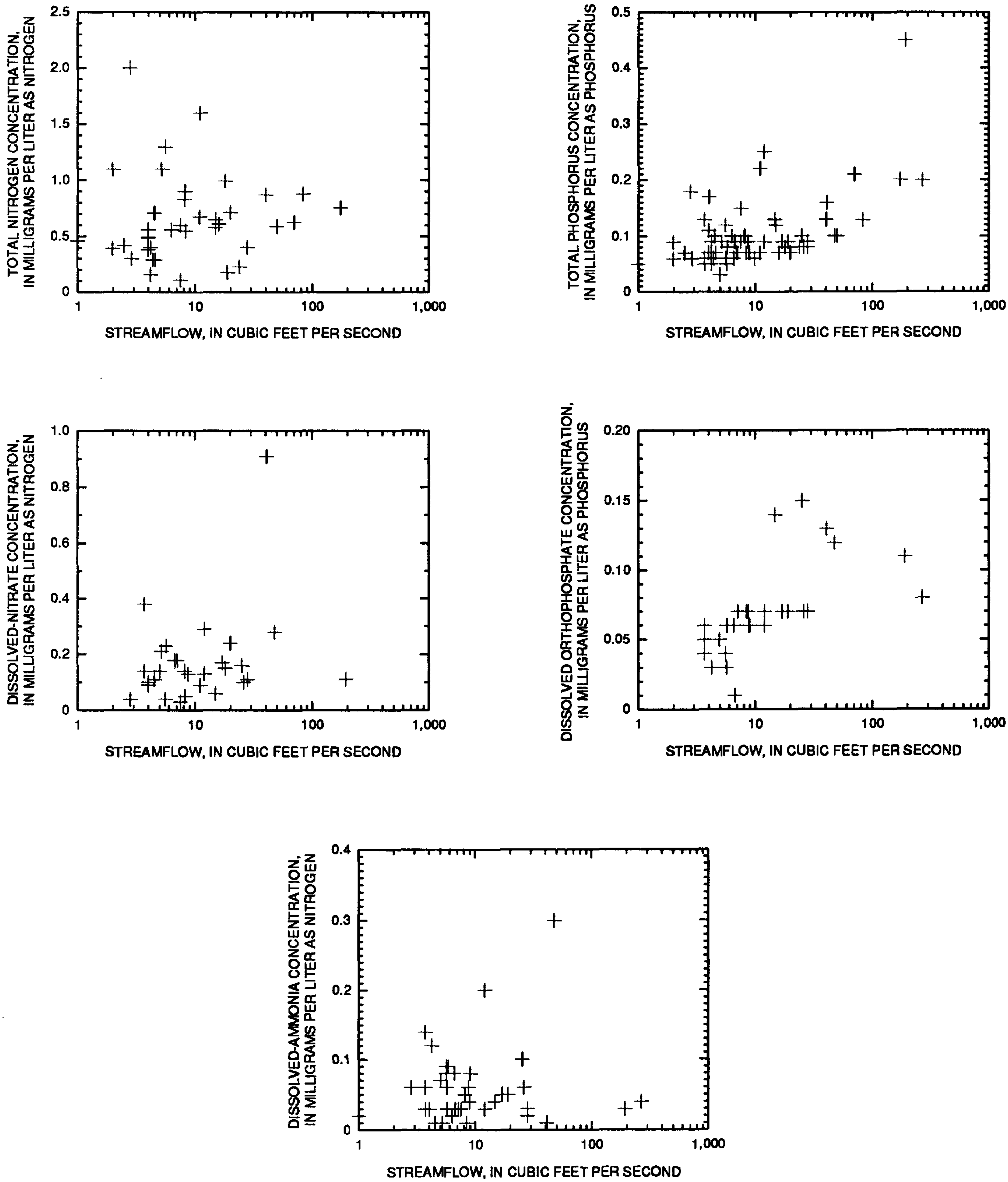


Figure 66.--Relation between nutrient concentration and streamflow at Mimbres River at Mimbres, N. Mex., water years 1972-90.

Suspended Sediment

Suspended-sediment data analyzed in this report are from 16 main-stem stations on the Rio Grande, 17 tributary stations, and 1 closed-basin station. All of these stations had at least 15 analyses that spanned at least 3 consecutive years during water years 1972-90. In addition, suspended-solids data in the STORET data base for six stations are included (five in the San Luis Valley of Colorado and one near El Paso, Texas). Suspended sediment and suspended solids are considered separately in the analysis of data. The term suspended solids refers to particulate that is retained on a filter, and although fairly representative of the sample, does not accurately represent nonfiltered suspended sediment (Skougstad and others, 1979, p. 573). Scatterplots of the concentration over time, boxplots, and trend-test results are presented for each station.

A more rigorous examination of 17 stations (10 main-stem stations and 7 tributary stations) was done to assess contributions from the tributaries. Main-stem stations were selected on the basis of completeness of record and location within the study unit. Included in this examination are plots of the number of occurrences and month and decile of long-term flow, as well as scatterplots of suspended-sediment concentration and streamflow.

Scatterplots of suspended-sediment or suspended-solids concentrations in water for water years 1972-90 show the temporal distribution of data for each station (figs. 67-69). Statistical summaries of suspended-sediment and suspended-solids data for selected sampling stations in the study unit are presented in tables 10 and 11, respectively.

Examination of boxplots of suspended-sediment or suspended-solids concentrations indicates variations in concentration between adjacent stations on main-stem, tributary, and other stations (figs. 70-72). The first major downstream increase in suspended sediment on the main stem was evident at Rio Grande at Otowi Bridge near San Ildefonso, New Mexico (25). At the next downstream station, Rio Grande below Cochiti Dam, New Mexico (28), the suspended-sediment concentration was smaller due to settling in the reservoir. The suspended-sediment concentration was then larger at the next two downstream stations, Rio Grande at San Felipe, New Mexico (29), and Rio Grande at Albuquerque, New Mexico (38). The concentration remained nearly the same with some variation downstream to Rio Grande Floodway near Bernardo, New Mexico (43). Suspended-sediment concentrations at the San Acacia stations (48 and 49) were nearly an order of magnitude greater than that at the Rio Grande Floodway near Bernardo, New Mexico (43), due to the inflow of the Rio Puerco and Rio Salado between these stations. The conveyance channel (48) had a larger suspended-sediment concentration than the floodway (49). Conversely, the conveyance channel at San Marcial (62) had a smaller suspended-sediment concentration than the floodway (63) at San Marcial. The concentration at Rio Grande below Elephant Butte Dam, New Mexico (67), was significantly less than that at the next upstream station. Suspended-sediment concentration was larger at Rio Grande at El Paso, Texas (97), than at Rio Grande below Elephant Butte Dam, New Mexico (67). Median suspended-sediment concentrations at the Rio Puerco (45) and Rio Salado (47) (fig. 71) stations were two to three orders of magnitude greater than those for the main-stem stations.

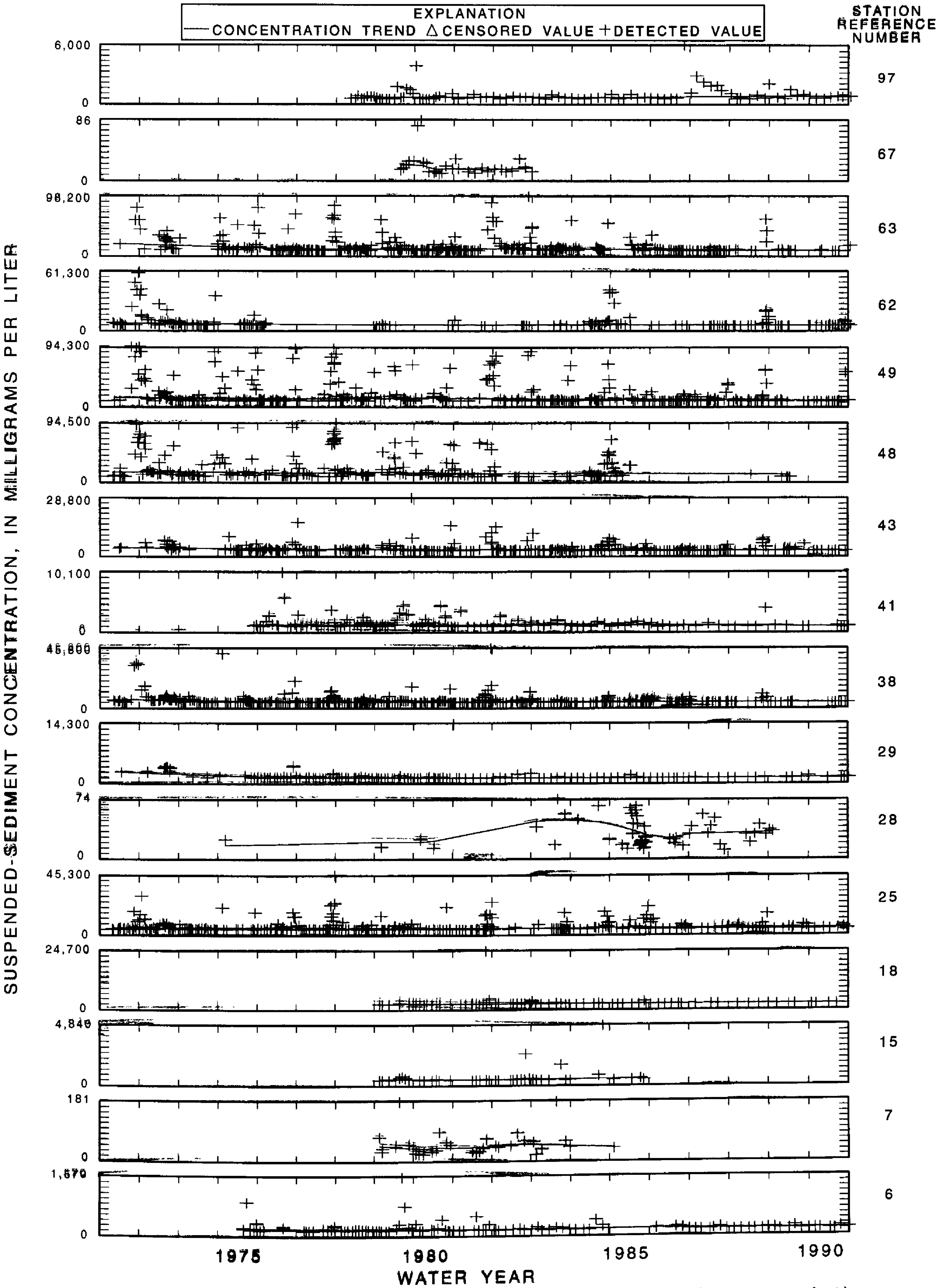


Figure 67.--Suspended-sediment concentration at main-stem stations in the Rio Grande Valley study unit, water years 1972-90.

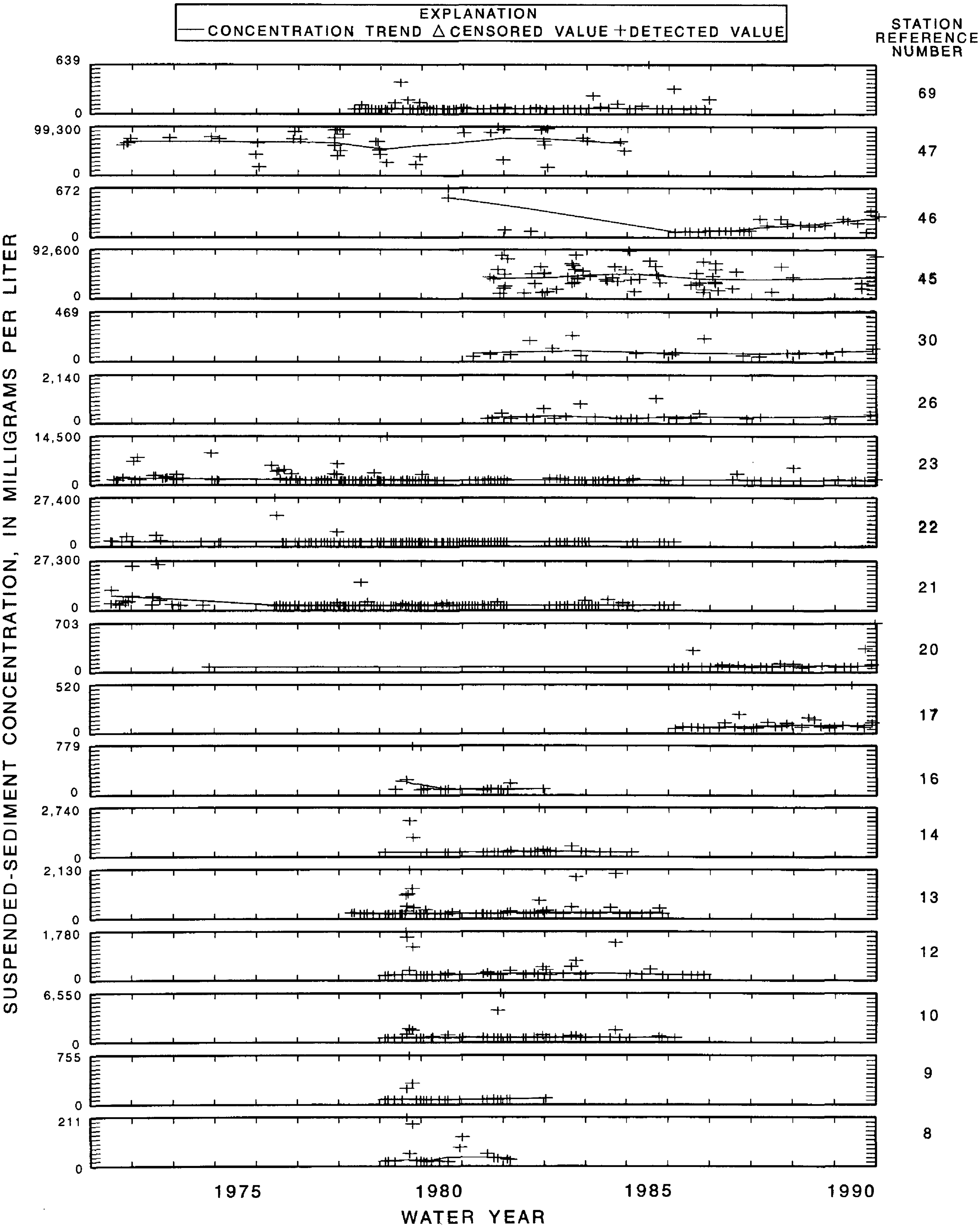


Figure 68.--Suspended-sediment concentration at selected stations in the Rio Grande Valley study unit, water years 1972-90.

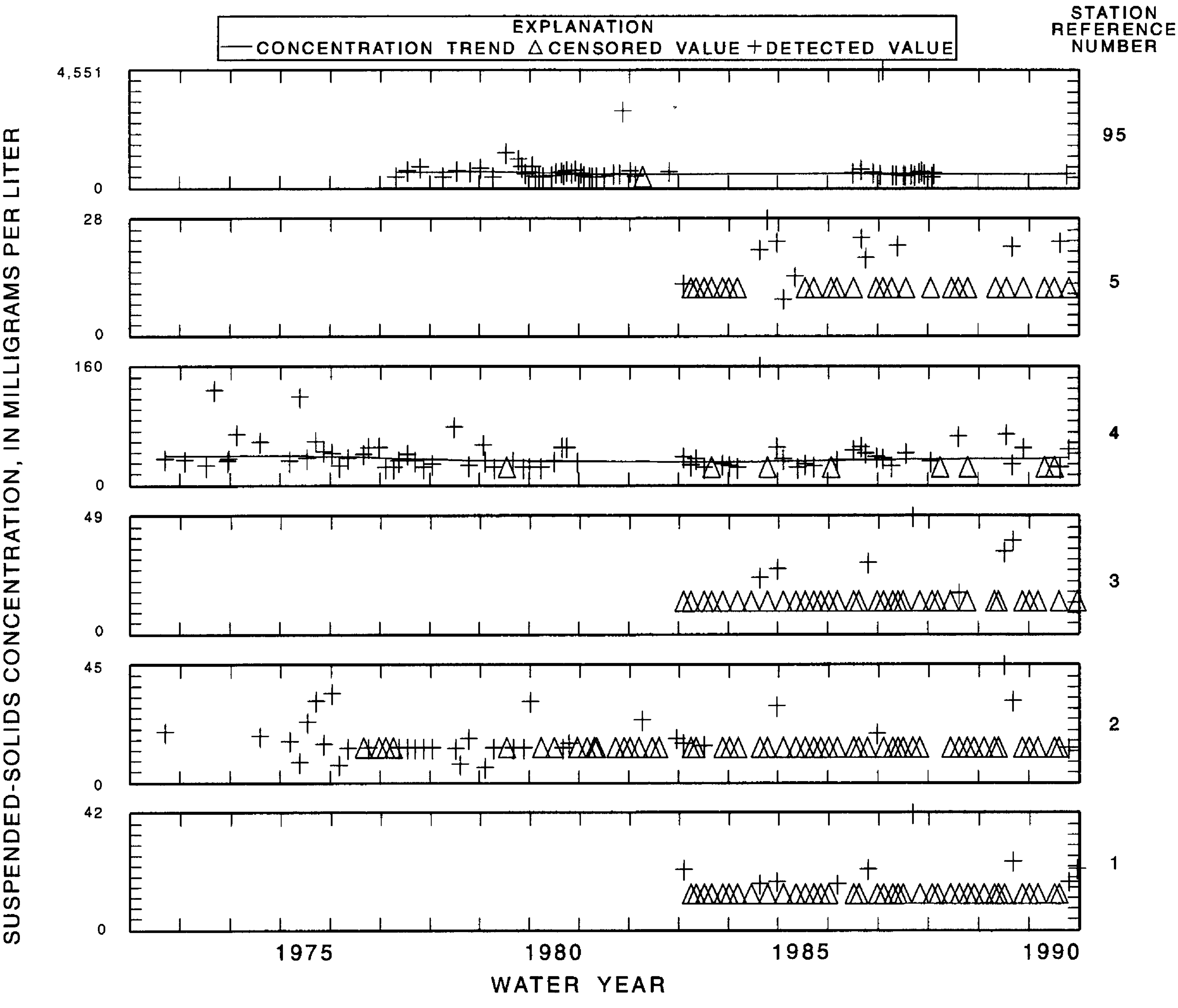


Figure 69.--Suspended-solids concentration at selected stations in the Rio Grande Valley study unit, water years 1972-90.

Table 10.--Statistical summary of concentrations of suspended sediment in surface water from selected sampling stations in the Rio Grande Valley study unit, water years 1972-90

[Includes only those stations having 15 or more analyses]

Station reference number (pl. 2)	Station name	Number of analyses	Concentration at indicated percentile, in milligrams per liter				
			10	25	50	75	90
6	Rio Grande near Lobatos, Colo.	104	9.0	16	28	58	142
7	Rio Grande near Cerro, N. Mex.	31	6.0	14	29	46	75
8	Red River below Zwergle Damsite, near Red River, N. Mex.	20	1	3	80	38	117
9	Red River at Molycorp Mine near Red River, N. Mex.	24	4	8	13	17	196
10	Red River near Questa, N. Mex.	47	12	22	41	150	554
12	Red River below Questa, N. Mex.	44	11	16	28	116	594
13	Red River below fish hatchery near Questa, N. Mex.	69	15	21	31	117	394
14	Red River at mouth, near Questa, N. Mex.	28	9	16	25	59	361
15	Rio Grande above Rio Hondo at Dunn Bridge, N. Mex.	41	10	18	33	93	363
16	Arroyo Hondo at Arroyo Hondo, N. Mex.	18	8	19	24	31	127
17	Rio Pueblo de Taos below Los Cordovas, N. Mex.	28	15	20	29	68	114
18	Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	72	11	16	38	86	286
20	Rio Chama near La Puente, N. Mex.	29	10	12	19	40	67
21	Rio Chama above Abiquiu Reservoir, N. Mex.	113	26	92	153	470	2,690
22	Rio Chama below Abiquiu Dam, N. Mex.	92	14	23	40	96	250
23	Rio Chama near Chamita, N. Mex.	127	43	83	189	542	2,220
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	291	103	281	863	2,370	8,260

Table 10.--Statistical summary of concentrations of suspended sediment in surface water from selected sampling stations in the Rio Grande Valley study unit, water years 1972-90--Concluded

Station reference number (pl. 2)	Station name	Number of analyses	Concentration at indicated percentile, in milligrams per liter				
			10	25	50	75	90
26	Santa Fe River above Cochiti Lake, N. Mex.	26	22	28	68	232	510
28	Rio Grande below Cochiti Dam, N. Mex.	50	9	14	25	39	53
29	Rio Grande at San Felipe, N. Mex.	131	17	35	72	192	939
30	Jemez River near Jemez, N. Mex.	20	6	23	35	85	196
38	Rio Grande at Albuquerque, N. Mex.	371	118	250	637	2,000	4,420
41	Rio Grande at Isleta, N. Mex.	115	56	103	254	641	2,010
43	Rio Grande Floodway near Bernardo, N. Mex.	283	112	255	577	1,160	3,700
45	Rio Puerco above Arroyo Chico, near Guadalupe, N. Mex.	66	5,230	21,200	34,100	50,800	68,700
46	Rio San Jose near Grants, N. Mex.	30	13	24	40	177	244
47	Rio Salado near San Acacia, N. Mex.	41	19,300	44,800	65,900	75,900	91,200
48	Rio Grande Convey-ance Channel at San Acacia, N. Mex.	226	541	2,410	5,200	18,000	56,900
49	Rio Grande Floodway at San Acacia, N. Mex.	325	258	714	2,500	11,000	53,400
62	Rio Grande Convey-ance Channel at San Marcial, N. Mex.	182	141	304	1,350	4,330	15,600
63	Rio Grande Floodway at San Marcial, N. Mex.	347	368	945	2,380	5,950	25,500
67	Rio Grande below Elephant Butte Dam, N. Mex.	29	3	5.0	10	18	25
69	Mimbres River at Mimbres, N. Mex.	68	3.0	6.0	8.0	21	92
97	Rio Grande at El Paso, Tex.	90	40	83	179	431	1,050

Table 11.--Statistical summary of concentrations of suspended solids in surface water from selected sampling stations in the Rio Grande Valley study unit, water years 1972-90

[Includes only those stations having 15 or more analyses; <, less than]

Station reference number (pl. 2)	Station name	Number of analyses	Concentration at indicated percentile, in milligrams per liter				
			10	25	50	75	90
1	Rio Grande near Creede, Colo.	47	<10	<10	<10	<10	15
2	South Fork Rio Grande at South Fork, Colo.	87	<10	<10	<10	<10	16
3	Rio Grande near Del Norte, Colo.	41	<10	<10	<10	<10	25
4	Rio Grande at Alamosa, Colo.	75	<10	<10	20	34	49
5	Conejos River near Magote, Colo.	37	<10	<10	<10	11	21
95	Rio Grande 1.7 miles up from the American Dam, Tex.	53	17	39	152	254	456

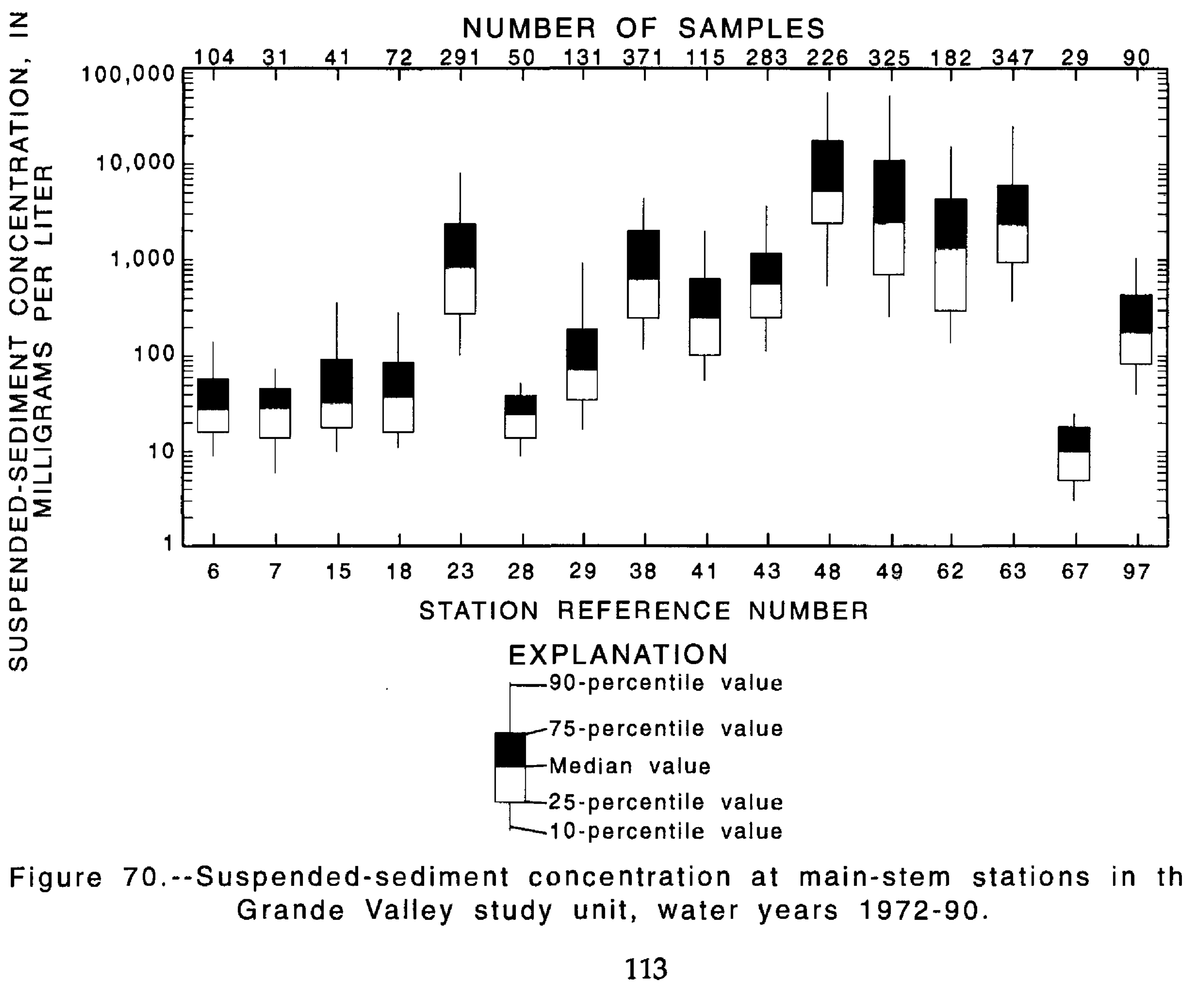


Figure 70.--Suspended-sediment concentration at main-stem stations in the Rio Grande Valley study unit, water years 1972-90.

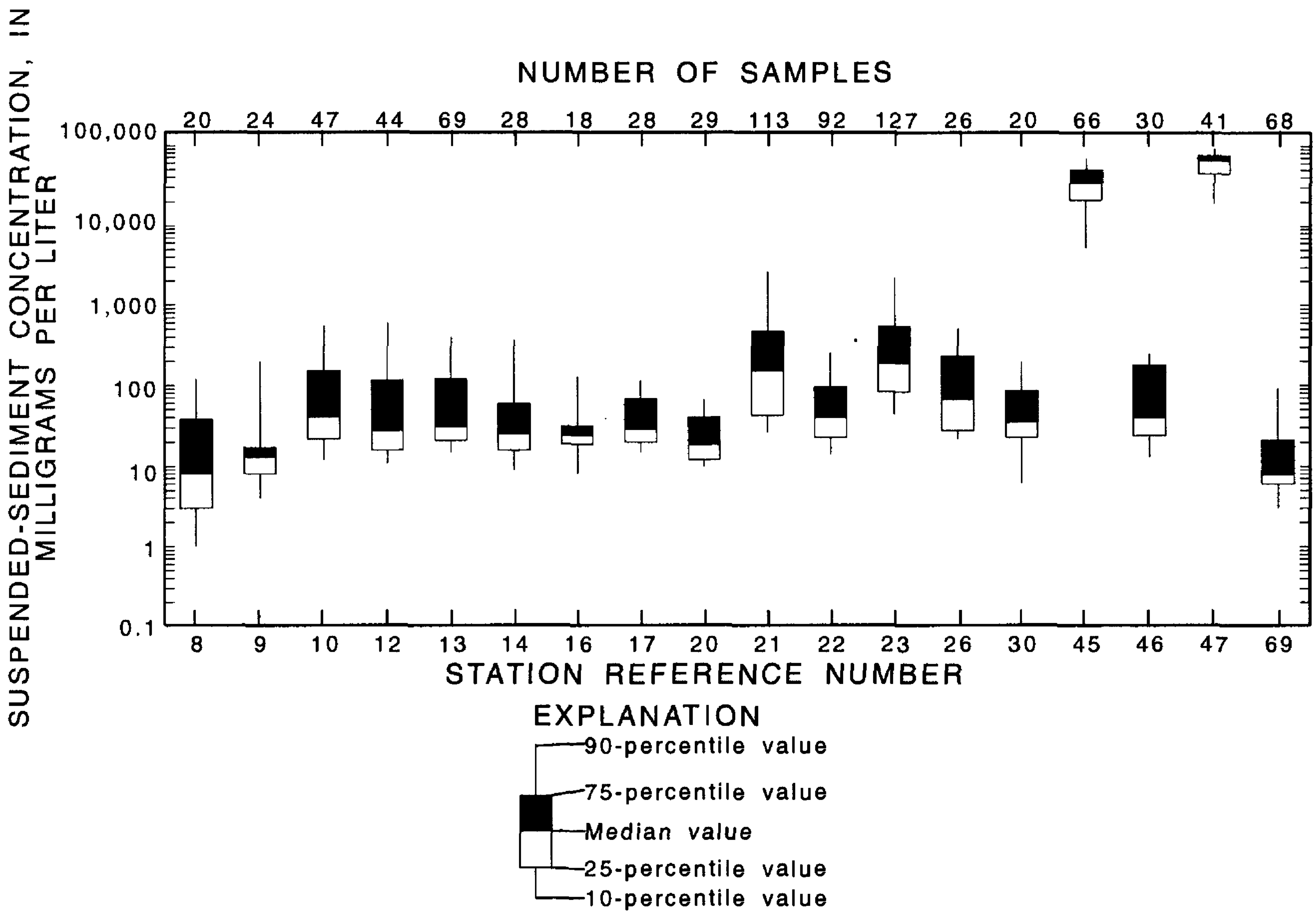


Figure 71.--Suspended-sediment concentration at selected stations in the Rio Grande Valley study unit, water years 1972-90.

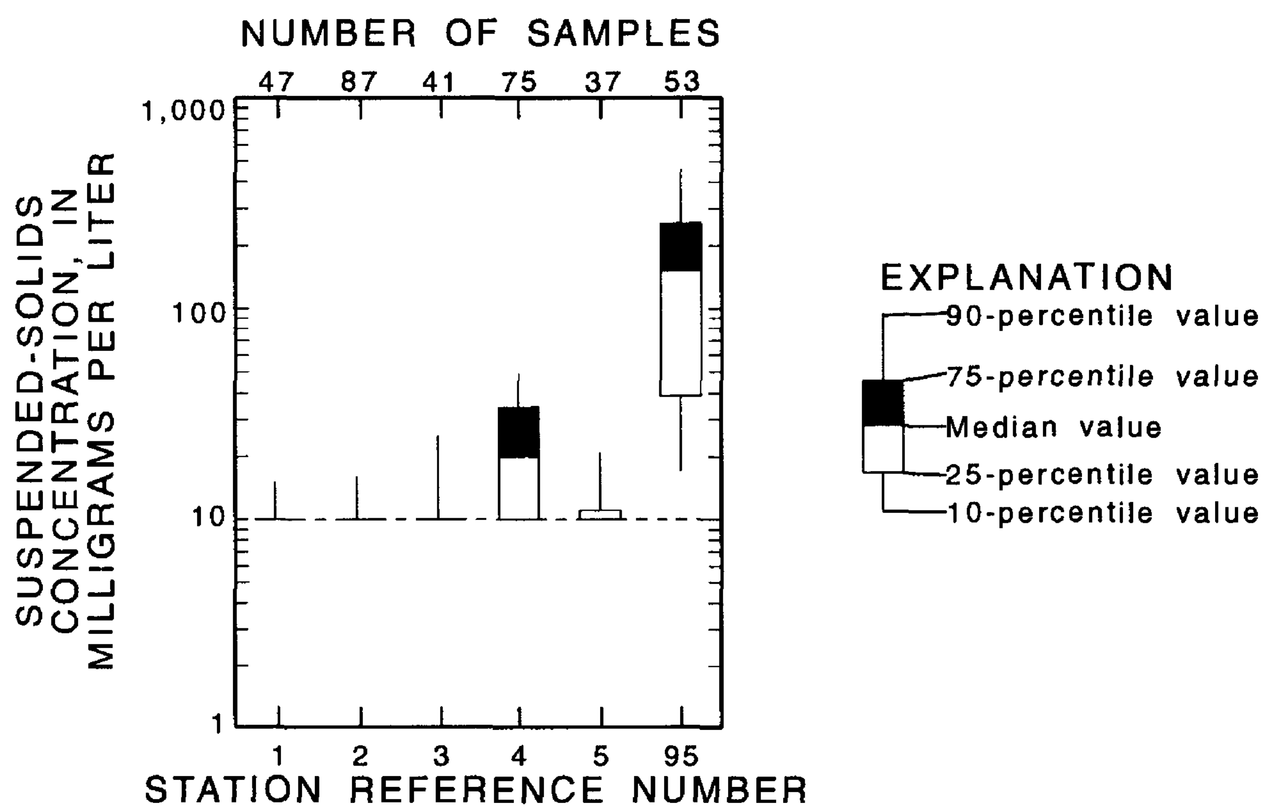


Figure 72.--Suspended-solids concentration at selected stations in the Rio Grande Valley study unit, water years 1972-90.

Boxplots for suspended-solids concentration for the five stations in the San Luis Valley, Colorado (1 through 5) and the Rio Grande 1.7 mi. up from the American Dam, Texas (95), indicate that median concentrations for the San Luis Valley stations were at or below detection limits with the exception of Rio Grande at Alamosa, Colorado (4) (fig. 72). The reason for this exception is not known. The median suspended-solids concentration at Rio Grande 1.7 mi. up from the American Dam, Texas (95), was 152 mg/L.

The Mann-Whitney test was used to test for significant differences in suspended-sediment concentration between adjacent stations on the main stem of the Rio Grande (table 12). Significant differences in suspended-sediment concentrations were apparent between adjacent stations for all pairs of stations except the four most upstream stations and between Rio Grande Floodway at San Acacia, New Mexico (49), and Rio Grande Floodway at San Marcial, New Mexico (63). Significant differences were evident between the conveyance channel and floodway stations at San Acacia (48 and 49), where the conveyance channel had higher concentrations, and at San Marcial (62 and 63), where the floodway had higher concentrations.

The LOWESS smooth lines in figures 67, 68, and 69 provide an indication of trends over time for water years 1972-90 for all stations having suspended-sediment or suspended-solids data. The seasonal Kendall trend test was also performed for all stations meeting the criteria for water years 1980-90 (table 13). Four stations exhibited significant trends in flow-adjusted data for 1980-90; all were downward trends. The stations having suspended-sediment data exhibiting these downward trends were: Rio Grande at Albuquerque, New Mexico (38); Rio Grande Floodway near Bernardo, New Mexico (43); Rio Grande Floodway at San Acacia, New Mexico (49); and Rio Grande Floodway at San Marcial, New Mexico (63).

As previously mentioned in the nutrient section, it is important to assess whether data for a given constituent were collected during all flow regimes and throughout the year. This is especially important with suspended-sediment data because high flows carry a larger portion of the suspended-sediment load than do low flows. Plots of the number of analyses and month and decile of flow are provided for 17 stations (fig. 73). Only Rio Grande below Elephant Butte Dam, New Mexico (67), did not have the largest 10 percent of streamflow represented. The lack of samples in this decile was not crucial at this station because the suspended-sediment concentration was low (table 10), variability in suspended-sediment concentrations was low, and flow is regulated. For some stations, samples may be biased toward the higher flows, with few samples collected at lower flows (such as Rio Grande below Cochiti Dam, New Mexico (28)). Other stations had no streamflow for a percentage of the long-term record (Rio Grande Floodway at San Marcial, New Mexico (63). For rivers that carry a high suspended-sediment load, such as the Rio Puerco and Rio Salado, it is important that the largest flows (first and second deciles) are well represented because large amounts of sediment can be transported in only a few rainfall events. At these sites, fortunately, the largest flows were well represented. Most stations had been sampled throughout the year with the exception of Rio Salado near San Acacia, New Mexico (47), which usually had no flow most of the year.

Table 12.--Results of Mann-Whitney test for differences in suspended-sediment concentrations in surface water from selected main-stem stations in the Rio Grande Valley study unit

[Underlined, significance of probability value equal to or less than 0.05; <, less than; *, station with higher suspended-sediment concentration]

Station reference number (pl. 2)		Station name	Number of analyses	Probability value
6		Rio Grande near Lobatos, Colo.	104	0.52
7		Rio Grande near Cerro, N. Mex.	31	
7		Rio Grande near Cerro, N. Mex.	31	.21
15		Rio Grande above Rio Hondo at Dunn Bridge, N. Mex.	41	
15		Rio Grande above Rio Hondo at Dunn Bridge, N. Mex.	41	.85
18		Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	72	
18		Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	72	≤.005
25	*	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	293	
25	*	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	293	≤.005
28		Rio Grande below Cochiti Dam, N. Mex.	50	
28		Rio Grande below Cochiti Dam, N. Mex.	50	≤.005
29	*	Rio Grande at San Felipe, N. Mex.	131	

Table 12.--Results of Mann-Whitney test for differences in suspended-sediment concentrations in surface water from selected main-stem stations in the Rio Grande Valley study unit--Concluded

Station reference number (pl. 2)		Station name	Number of analyses	Probability value
29		Rio Grande at San Felipe, N. Mex.	131	<u><0.005</u>
38	*	Rio Grande at Albuquerque, N. Mex.	372	
38	*	Rio Grande at Albuquerque, N. Mex.	372	<u><.005</u>
41		Rio Grande at Isleta, N. Mex.	115	
41		Rio Grande at Isleta, N. Mex.	115	<u><.005</u>
43	*	Rio Grande Floodway near Bernardo, N. Mex.	283	
43		Rio Grande Floodway near Bernardo, N. Mex.	283	<u><.005</u>
49	*	Rio Grande Floodway at San Acacia, N. Mex.	339	
49		Rio Grande Floodway at San Acacia, N. Mex.	339	.61
63		Rio Grande Floodway at San Marcial, N. Mex.	362	
63	*	Rio Grande Floodway at San Marcial, N. Mex.	362	<u><.005</u>
67		Rio Grande below Elephant Butte Dam, N. Mex.	29	
67		Rio Grande below Elephant Butte Dam, N. Mex.	29	<u><.005</u>
97	*	Rio Grande at El Paso, Tex.	90	
48	*	Rio Grande Conveyance Channel at San Acacia, N. Mex.	235	<u><.005</u>
49		Rio Grande Floodway at San Acacia, N. Mex.	339	
62		Rio Grande Conveyance Channel at San Marcial, N. Mex.	186	<u><.005</u>
63	*	Rio Grande Floodway at San Marcial, N. Mex.	362	

Table 13.--Trend-test results for suspended-sediment concentrations in surface water from selected sampling stations in the Rio Grande Valley study unit, water years 1980-90

[Underlined, significance of probability level equal to or less than 0.05; <, less than]

Station reference number (pl. 2)	Station name	Results of seasonal Kendall tests for time trend			
		Concentration		Flow-adjusted concentration	
		Probability level	Average rate of change (milligrams per liter per year)	Probability level	Average rate of change (milligrams per liter per year)
6	Rio Grande near Lobatos, Colo.	0.19	0.65	0.59	0.38
18	Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	.27	2.37	.75	.26
23	Rio Chama near Chamita, N. Mex.	.81	3.00	.39	5.9
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	.91	-3.63	.59	-8.27
29	Rio Grande at San Felipe, N. Mex.	.80	.33	.68	1.37
38	Rio Grande at Albuquerque, N. Mex.	.006	-23.29	<.005	-25.26
41	Rio Grande at Isleta, N. Mex.	.41	-6.67	.19	-7.96
43	Rio Grande Floodway near Bernardo, N. Mex.	<.005	-26.53	.005	-28.25
49	Rio Grande Floodway at San Acacia, N. Mex.	<.005	-284.33	<.005	-346.0
63	Rio Grande Floodway at San Marcial, N. Mex.	<.005	-149.25	<.005	-181.75
97	Rio Grande at El Paso, Tex.	.03	11.75	.70	3.62

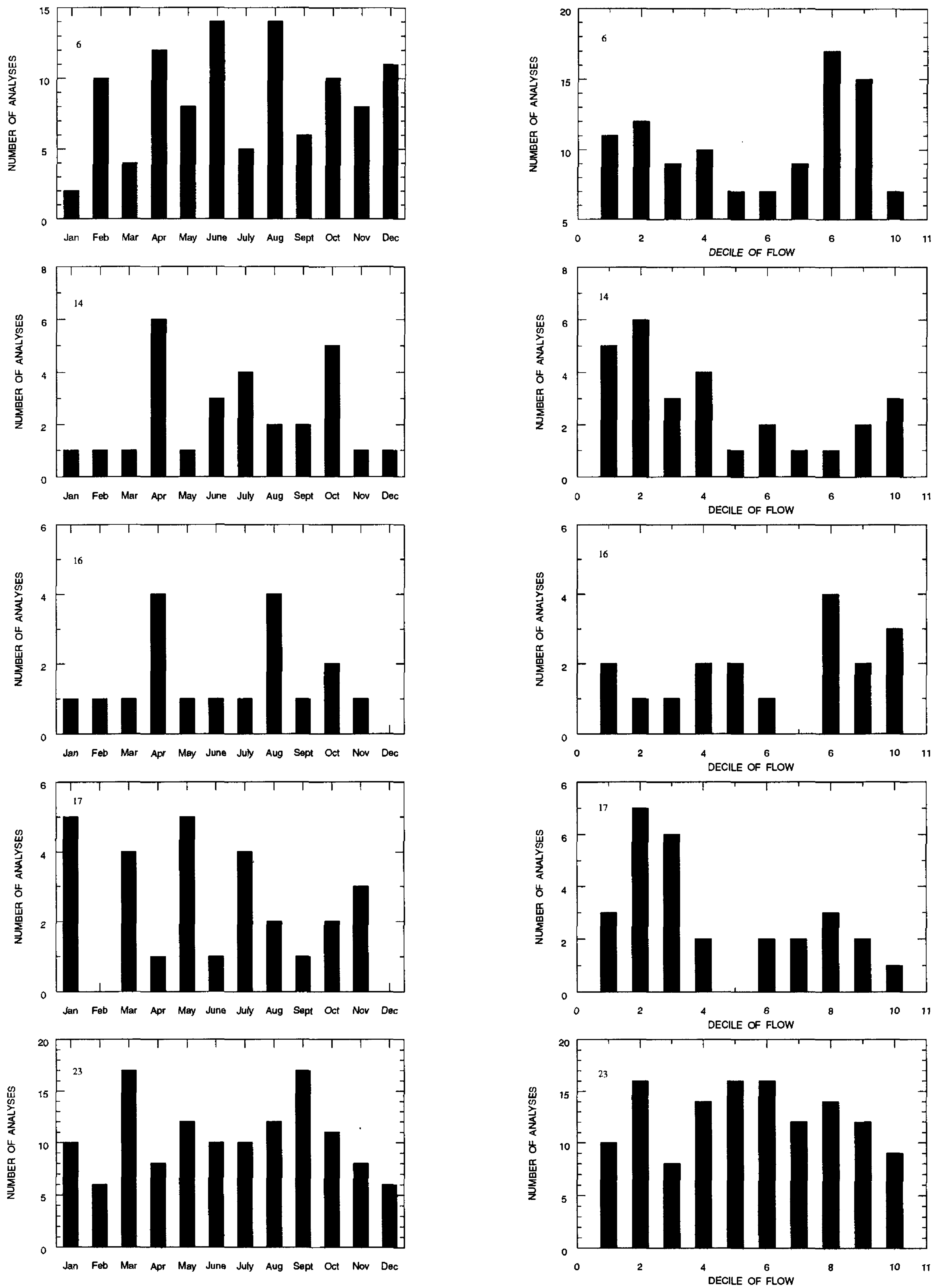


Figure 73.--Number of suspended-sediment analyses by month and decile of flow for selected stations in the Rio Grande Valley study unit, water years 1972-90. [Number in each box is station reference number; see plate 2 for locations.]

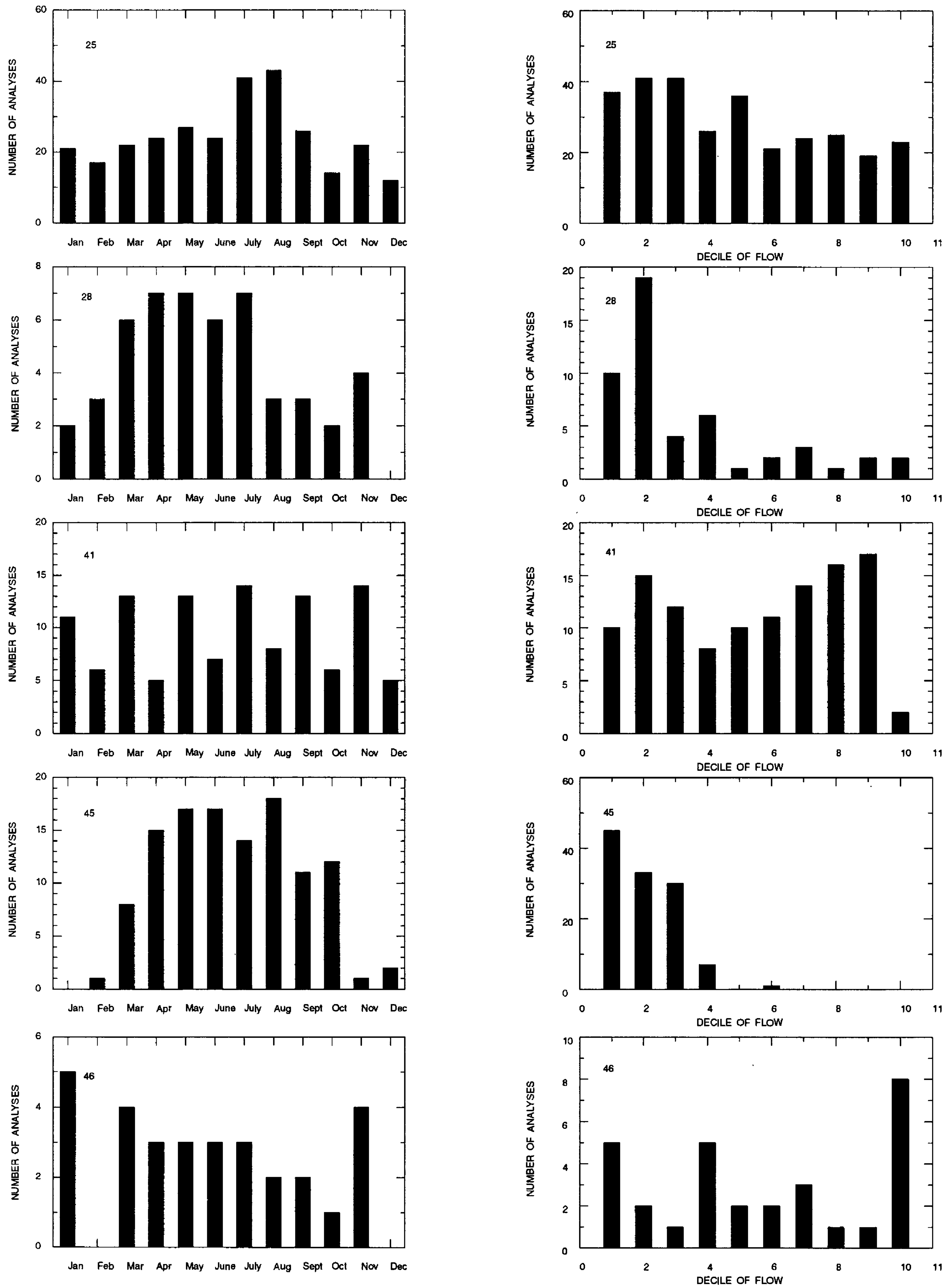


Figure 73.--Continued.

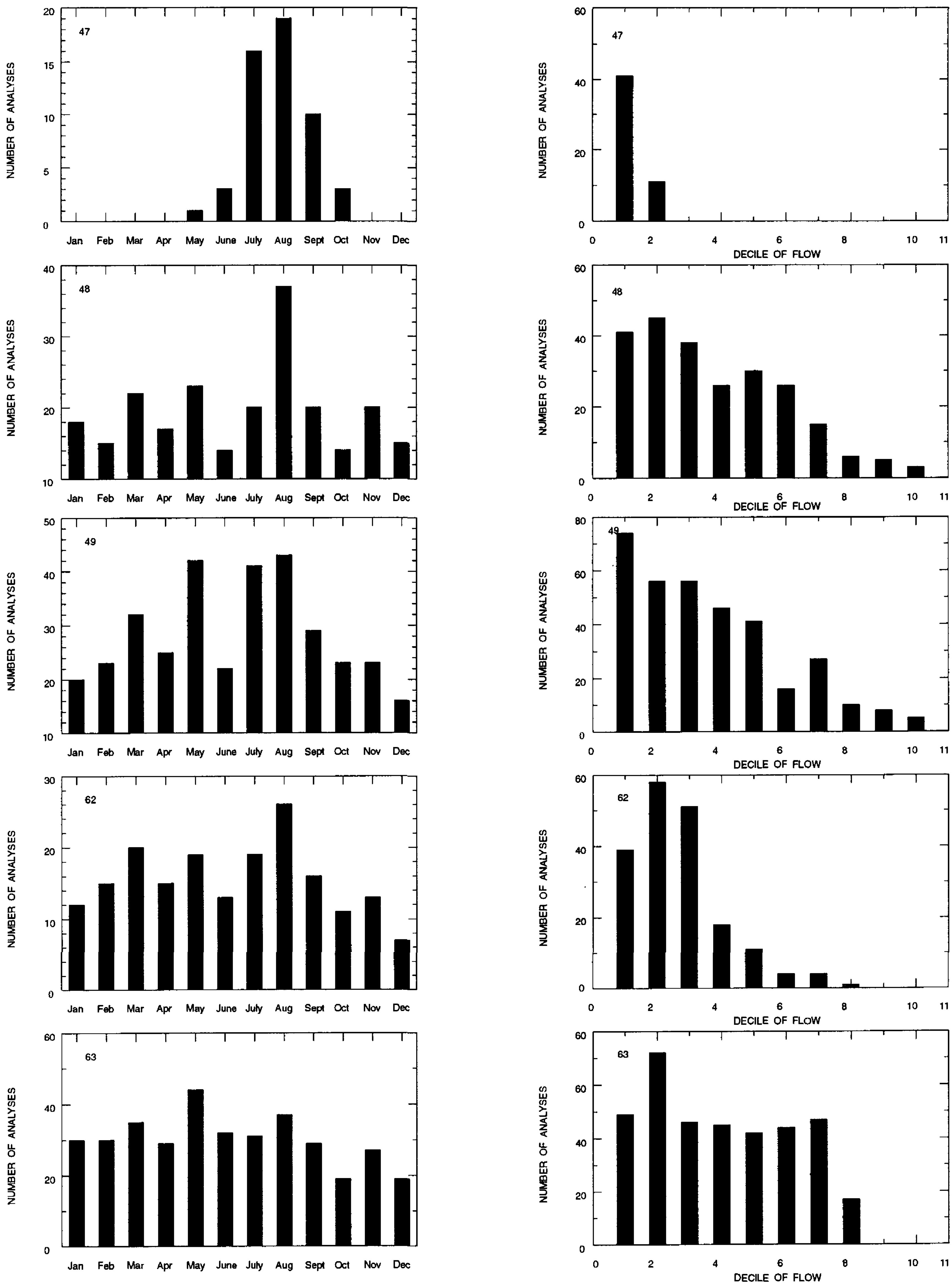


Figure 73.--Continued.

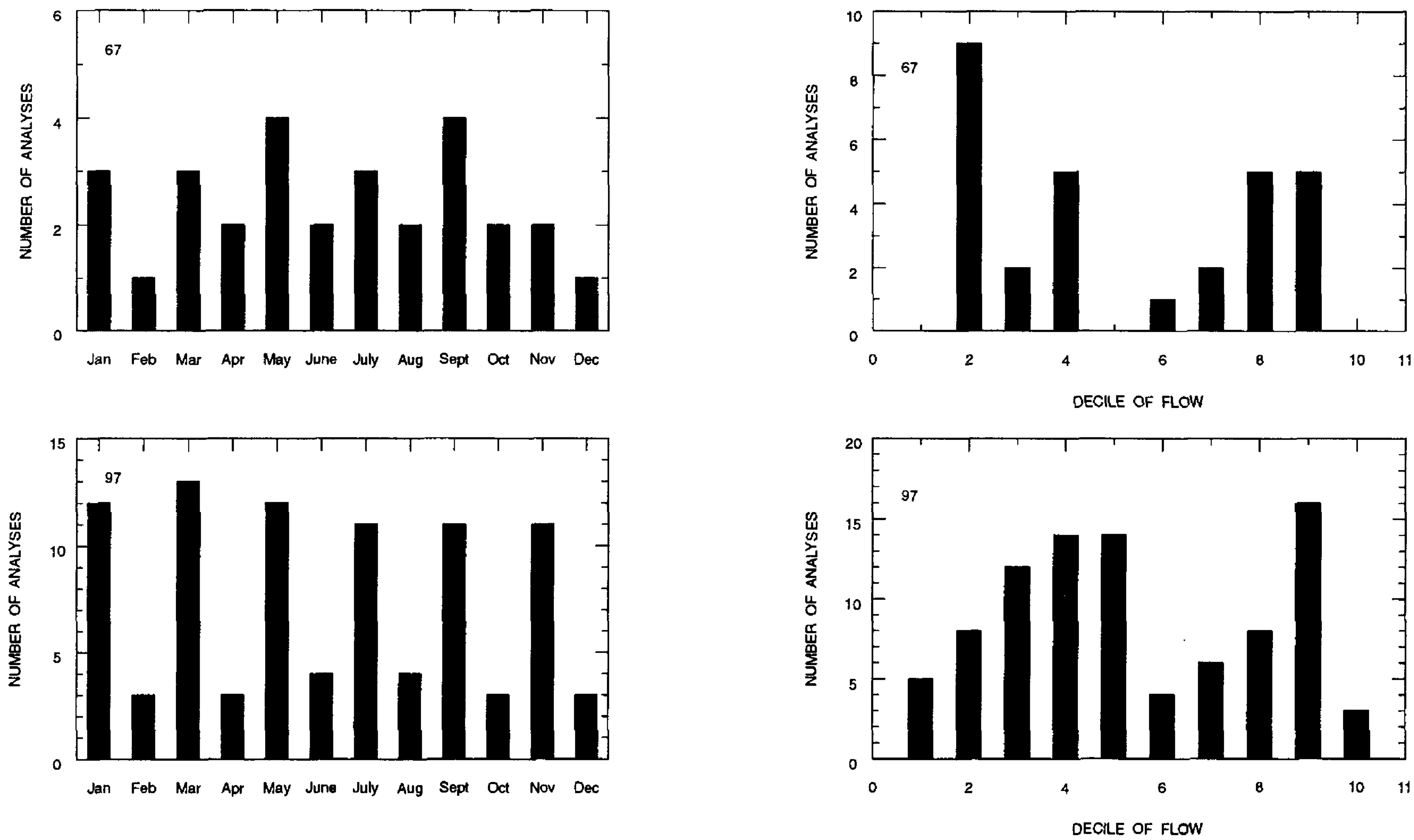


Figure 73.--Concluded.

Plots of suspended-sediment concentration and streamflow generally indicate increasing concentration with increasing streamflow (figs. 74 and 75). Spearman's rank correlation was used to determine the relation between suspended-sediment concentration and streamflow at 17 stations (table 14). All but four main-stem stations on the Rio Grande had significant positive correlations to streamflow (increasing suspended sediment with increasing streamflow). Many correlations were significant, but the low correlation coefficients (between 0 and 0.5) indicate a weak relation. Two are downstream from reservoirs: Rio Grande below Cochiti Dam, New Mexico (28), and Rio Grande below Elephant Butte Dam, New Mexico (67). The other two stations are the floodway stations at San Acacia (49) and San Marcial (63). The lack of a significant correlation at the floodway stations might be the result of the operation of the diversion dam that controls the transfer of water between the floodway and conveyance channel. Three of seven tributary stations showed no significant correlation between suspended-sediment concentration and streamflow: Arroyo Hondo at Arroyo Hondo, New Mexico (16); Rio Pueblo de Taos below Los Cordovas, New Mexico (17); and Rio San Jose near Grants, New Mexico (46). Although no significant correlations between suspended-sediment concentration and streamflow were seen at Arroyo Hondo and Rio San Jose, the largest concentrations of suspended sediment generally occurred during high streamflow.

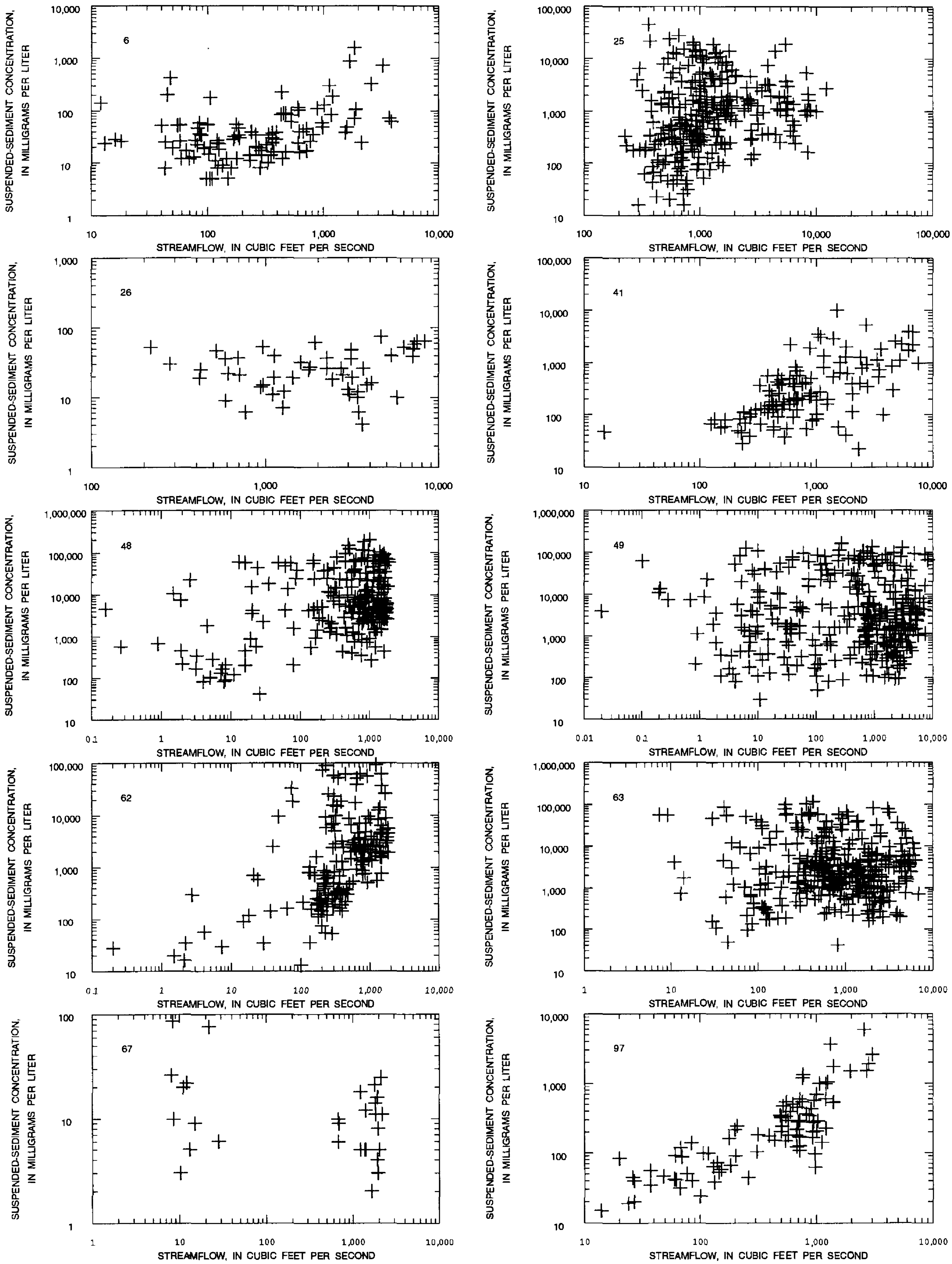


Figure 74.--Relation between suspended-sediment concentration and streamflow at main-stem stations in the Rio Grande Valley study unit, water years 1972-90. [Number in each box is station reference number; see plate 2 for locations.]

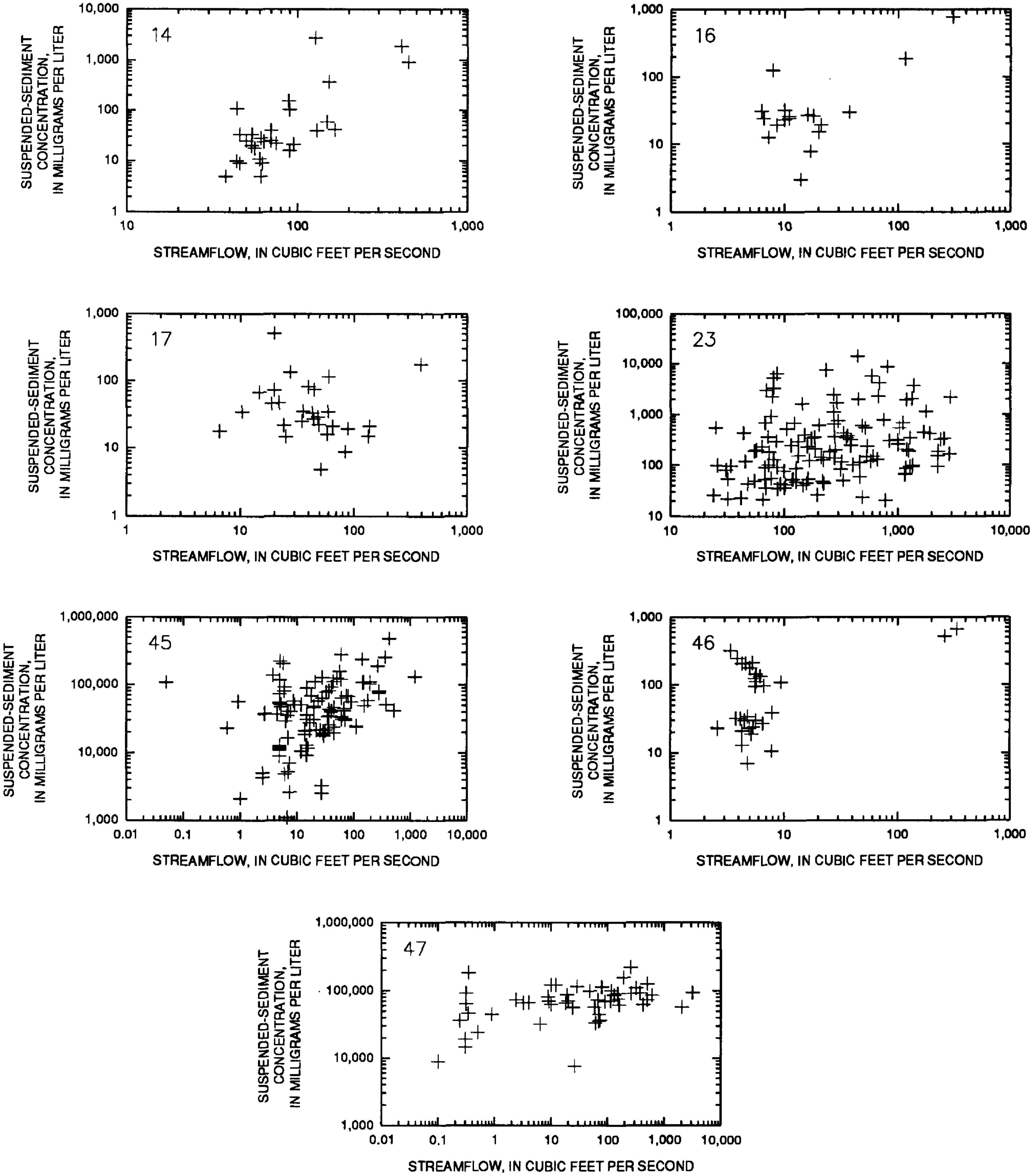


Figure 75.--Relation between suspended-sediment concentration and streamflow at tributary stations in the Rio Grande Valley study unit, water years 1972-90. [Number in each box is station reference number; see plate 2 for locations.]

Table 14.--Results of Spearman correlation analysis for relation between suspended-sediment concentration in water and streamflow for selected surface-water stations in the Rio Grande Valley study unit

[Underlined, significance of probability value equal to or less than 0.05; <, less than]

Station reference number (pl. 2)	Station name	Correlation coefficient	Probability value
6	Rio Grande near Lobatos, Colo.	0.39	≤0.005
14	Red River at mouth, near Questa, N. Mex.	.62	≤.005
16	Arroyo Hondo at Arroyo Hondo, N. Mex.	.15	.27
17	Rio Pueblo de Taos below Los Cordovas, N. Mex.	-.30	.06
23	Rio Chama near Chamita, N. Mex.	.28	≤.005
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	.28	≤.005
28	Rio Grande below Cochiti Dam, N. Mex.	.16	.13
41	Rio Grande at Isleta, N. Mex.	.64	≤.005
45	Rio Puerco above Arroyo Chico, near Guadalupe, N. Mex.	.36	≤.005
46	Rio San Jose near Grants, N. Mex.	.18	.17
47	Rio Salado near San Acacia, N. Mex.	.41	≤.005
48	Rio Grande Conveyance Channel at San Acacia, N. Mex.	.22	≤.005
49	Rio Grande Floodway at San Acacia, N. Mex.	-.007	.45
62	Rio Grande Conveyance Channel at San Marcial, N. Mex.	.56	≤.005
63	Rio Grande Floodway at San Marcial, N. Mex.	-.02	.36
67	Rio Grande below Elephant Butte Dam, N. Mex.	-.23	.11
97	Rio Grande at El Paso, Tex.	.82	≤.005

Calculation of Loads

The sources of nutrient inputs and amounts of nutrient loading to the Rio Grande Valley study unit are estimated in table 15. Values for point-source effluent are based on standard average concentrations for standard industrial codes (Larry Pucket, U.S. Geological Survey, written commun., 1992). For sewage treatment-plant effluent, total nitrogen concentration was assumed to be 15.1 mg/L and phosphorus concentration to be 11.2 mg/L. Exceptions were values for Albuquerque and Las Cruces sewage treatment plants, for which actual data were available. The amount of flow data available for industrial effluent was insufficient to represent accurately the nutrient loading caused by industrial sites in the study unit; however, the study unit lacks much industry so the loads caused by industrial sites are estimated to be minimal.

A GIS (geographic information system) was used to calculate atmospheric loads by obtaining the volume of precipitation for a given area and multiplying by nitrogen concentration in precipitation. Atmospheric deposition data were from five NADP sites within or in close proximity to the study unit for 1985-90. Precipitation was estimated from maps of mean annual precipitation for 1931-60 (New Mexico) and 1951-80 (Colorado). Areas between lines of equal precipitation from these maps were converted to polygons attributed with the average of the precipitation indicated at the bounding equal lines (hereafter called area precipitation). The five points representing NADP sites with ammonia and nitrate data were converted to Thiessen polygons, which means any location within a polygon is closer to the NADP site for that polygon than to the NADP site in any other polygon. For each NADP site, the medians of mean annual ammonia concentrations and mean annual nitrate concentrations were converted to concentration as nitrogen and summed, and this total nitrogen concentration was assigned to that NADP Thiessen polygon. The area precipitation polygons were overlain with the Thiessen polygons. Volume of precipitation within these combined Thiessen-area precipitation polygons was calculated by multiplying area precipitation by the area of the polygon. This precipitation volume then was multiplied by the concentration of total nitrogen for each combined Thiessen-area precipitation polygon, multiplied by 1.43 to incorporate dry deposition loads (Sisterson, 1990), and summed to obtain the total load for each Thiessen, which then was summed to obtain load for the entire study unit.

Data for fertilizer loading are for 1987 and were obtained by calculating the ratio of annual expenditures on commercial fertilizer for the county to expenditures on commercial fertilizer for the State, and multiplying by an estimate of tons of fertilizer sold in the State as reported to the National Fertilizer and Environmental Research Center (Kerie Hitt, U.S. Geological Survey, written commun., 1992). A limitation of these data is that data are based on expenditures, not actual location of application. Larger cities where fertilizer may be purchased are generally within the study unit; therefore, for analysis of the study unit as a whole, this limitation is probably negligible.

Data for manure are also for 1987 and are based on estimates of the nutrient content of daily wastes produced per 1,000 lbs. of animal weight for a variety of species. The number of animals is based on the 1987 Census of Agriculture (Richard Alexander, U.S. Geological Survey, written commun., 1992).

Urban runoff data are available only for the North Floodway Channel in Albuquerque. Many other cities may be contributing significant quantities of nutrients by urban runoff, including Santa Fe, Rio Rancho, and Las Cruces.

On the basis of table 15, less than 5 percent of the total nitrogen load and less than 10 percent of the total phosphorus load are derived from point sources, for which data were limited. Fertilizer and manure contribute the greatest amount of nutrient load for nitrogen and phosphorus. Atmospheric load contributes about 22 percent of the total nitrogen to the study unit. The nonpoint-source data in table 15 are quantitative, indicating amount of input to the study unit. However, it is unknown exactly how to quantify the effect of various types of nonpoint-source nutrient loading on surface- and ground-water quality, especially in the arid Southwest. The relation of nonpoint-source loading to nutrient concentration in surface and ground water is influenced by many factors about which little is known and that would be difficult to quantify at the present time. Some of these factors are (1) precipitation often is infrequent, intense, and very localized, and most stream channels are intermittent; (2) depth to water over most of the study unit is greater than 100 ft; (3) amount of nutrient uptake by xeric plants is poorly understood; (4) ground- and surface-water interactions are complex, and stream segments may gain or lose flow; and (5) amount of dry atmospheric deposition is poorly understood but probably very important to the total atmospheric load. All of these topics are interrelated and would need to be researched to quantify the relation of nonpoint-source nutrient loading to water quality.

Table 15.--Estimated nitrogen and phosphorus loads input to the Rio Grande Valley study unit

[<, less than]

Source	Total nitrogen, in tons per year	Total phosphorus, in tons per year
Point sources		
Sewage treatment effluent	2,724	1,131
Industrial effluent[1]	<1	<1
Nonpoint sources		
Atmospheric deposition	17,092	Not applicable
Fertilizers	27,665	3,189
Manure	28,642	7,530
Urban runoff[2]	300	68
Total	76,423	11,918

[1]Data insufficient; industrial loading estimated to be minimal.
[2]Data insufficient; loading estimated to be much larger.

The effects of nutrient loads input to the study unit are reflected in the nutrient loads measured in surface water. Nutrient and suspended-sediment (or suspended-solids) loads in surface water are a function of streamflow and concentrations of water-quality constituents. Natural variability in climate and land- and water-use activities can cause large variations in constituent loads. Point (sewage treatment effluent) and nonpoint (agricultural fertilizers or atmospheric deposition) sources also affect the loading of nutrients and suspended sediment into surface water. Suspended-sediment loads have been calculated for some stations using daily suspended-sediment concentrations. For stations where these data were not available, annual constituent loads were estimated for total nitrogen, total phosphorus, and suspended sediment for three periods using daily mean flows for 3 years: 1986, a high-flow year; 1972, a low-flow year; and 1975, a near-median flow year. This provides a representative range of expected constituent loads in the Rio Grande Valley study unit. To estimate loads, separate regression models were developed for each station (table 16) using water-quality constituent data collected during water years 1972-90 to calibrate the transport models. The loads then were calculated for the three periods using daily mean flows for those years.

Estimated annual loads for total nitrogen and total phosphorus at selected stations generally followed mean daily streamflow (table 17); however, the magnitude of the differences between years sometimes differed for total nitrogen and total phosphorus. For example, the total phosphorus load at Rio Grande at Otowi Bridge near San Ildefonso, New Mexico (25), was almost five times larger than that at Rio Grande near Lobatos, Colorado (6), for 1975, whereas the total nitrogen load was only three times higher. Suspended-sediment concentrations at Rio Grande at Otowi Bridge near San Ildefonso, New Mexico (25), were many times those at Rio Grande near Lobatos, Colorado (6), which may explain why total phosphorus loads are larger at Rio Grande at Otowi Bridge near San Ildefonso, New Mexico (25). Total nitrogen loads remained nearly the same between Rio Grande at Otowi Bridge near San Ildefonso, New Mexico (25), and Rio Grande at San Felipe, New Mexico (29), but total phosphorus loads generally were smaller at the downstream station, most likely due to the settling of suspended sediment and associated total phosphorus in Cochiti Lake, located between these two stations. Nutrient loads were generally greater at Rio Grande Floodway at San Acacia, New Mexico (49), than at adjacent upstream stations although streamflow generally was lower. Likely nutrient sources are inflow from the Rio Puerco and Rio Salado, sewage effluent from Albuquerque, urban runoff, agricultural-return flows, numerous septic systems along the Rio Grande, fertilizer application, and manure generation (table 15). The total phosphorus load was estimated for Rio Grande at El Paso, Texas (97), but not enough total nitrogen data were available to adequately calibrate the regression model. Streamflow was lower at this station than at the next upstream station due to diversions, and the suspended-sediment concentration was lower due to settling in Elephant Butte Reservoir. These factors were reflected in the lower total phosphorus load.

Table 16.--Regression models used to estimate constituent transport in water from selected surface-water stations in the Rio Grande Valley study unit

[ln (CQ) = I + at + b(sin(2*p*t)) + c(cos(2*p*t)) + d(ln Q): where 1n is natural logarithm; C is concentration, in milligrams per liter; Q is streamflow, in cubic feet per second; I is the regression intercept; t is time, in decimal years; and a, b, c, and d are regression coefficients; --, regression coefficient not included in model]

Station reference number (pl. 2)	Station name	I	Regression coefficients				Probability values			
			a	b	c	d	a	b	c	d
			Total nitrogen as N							
6	Rio Grande near Lobatos, Colo.	5.8223	--	0.2130	0.0526	0.8884	--	0.0268	0.5706	0.0000
13	Red River below fish hatchery near Questa, N. Mex.	5.3304	--	--	--	1.0404	--	--	--	.0000
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	7.6172	--	--	--	1.1214	--	--	--	.0000
29	Rio Grande at San Felipe, N. Mex.	7.2120	--	-.2696	.0759	1.3893	--	.0546	.6061	.0000
49	Rio Grande Floodway at San Acacia, N. Mex.	7.6192	-0.0663	-.2065	-.2942	1.0561	0.0171	.1996	.0716	.0000
62	Rio Grande Conveyance Channel at San Marcial, N. Mex.	4.8551	--	--	--	1.1789	--	--	--	.0000
63	Rio Grande Floodway at San Marcial, N. Mex.	7.4092	--	-.3568	-.0379	1.2303	--	.0000	.5871	.0000
			Total phosphorus as P							
6	Rio Grande near Lobatos, Colo.	4.2946	--	0.1351	-0.2212	0.9372	--	0.0271	0.0002	0.0000
13	Red River below fish hatchery near Questa, N. Mex.	2.9920	--	--	--	1.3910	--	--	--	.0000
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	5.8451	-0.0679	-.1295	-.4098	1.2027	0.0000	.1264	.0000	.0000
29	Rio Grande at San Felipe, N. Mex.	5.2154	--	--	--	1.3129	--	--	--	.0000
41	Rio Grande at Isleta, N. Mex.	6.4123	-.0414	--	--	.7901	.0001	--	--	.0000

Table 16.--Regression models used to estimate constituent transport in water from selected surface-water stations in the Rio Grande Valley study unit--Concluded

Station reference number (pl. 2)	Station name	I	Regression coefficients a	b	c	d	Probability values a	b	c	d
					Total phosphorus as P--Continued					
43	Rio Grande Floodway near Bernardo, N. Mex.	6.3328	--	0.2418	0.3023	0.9561	--	0.0307	0.0063	0.0000
49	Rio Grande Floodway at San Acacia, N. Mex.	6.3873	--	--	--	.9921	--	--	--	.0000
62	Rio Grande Conveyance Channel at San Marcial, N. Mex.	3.1418	-0.0688	--	--	1.3315	0.0005	--	--	.0000
63	Rio Grande Floodway at San Marcial, N. Mex.	6.5259	--	-.3644	.1235	1.1682	--	.0000	.1480	.0000
97	Rio Grande at El Paso, Tex.	5.5440	--	--	--	.8924	--	--	--	.0000
				Suspended sediment						
6	Rio Grande near Lobatos, Colo.	10.0710	--	0.2061	-0.5428	1.2007	--	0.0755	0.0000	0.0000
13	Red River below fish hatchery near Questa, N. Mex.	10.1941	--	--	--	2.3147	--	--	--	.0000
23	Rio Chama near Chamita, N. Mex.	12.0221	-0.1149	--	--	1.3939	0.0000	--	--	.0000
28	Rio Grande below Cochiti Dam, N. Mex.	11.4707	--	--	--	1.1046	--	--	--	.0000
29	Rio Grande at San Felipe, N. Mex.	12.5533	-.1398	-.4467	-.2860	1.8220	.0000	.0050	.0804	.0000
41	Rio Grande at Isleta, N. Mex.	11.8799	-.1127	--	--	1.6394	.0000	--	--	.0000
43	Rio Grande Floodway near Bernardo, N. Mex.	12.5571	-.1122	-.4294	-.3660	1.1531	.0000	.0001	.0002	.0000
47	Rio Salado near San Acacia, N. Mex.	14.7795	--	--	--	1.0682	--	--	--	.0000
97	Rio Grande at El Paso, Tex.	12.4270	.0929	--	--	1.9655	.1968	--	--	.0000

Table 17.--Calculated or estimated nutrient and suspended-sediment loads in water from selected surface-water sampling stations in the Rio Grande Valley study unit, water years 1972, 1975, and 1986

[Load values, in tons, are based on available calibration data for water years 1972-90; calculated values are bold; --, insufficient streamflow or nutrient data available]

Station reference number (pl. 2)	Station name	Mean daily flow (cubic feet per second)			Total nitrogen (as N) load			Total phosphorus (as P) load			Total suspended-sediment load		
		1972	1975	1986	1972	1975	1986	1972	1975	1986	1972	1975	1986
6	Rio Grande near Lobatos, Colo.	238	552	1,264	189	385	694	30	79	143	11,400	57,600	122,000
13	Red River below fish hatchery near Questa, N. Mex.	--	--	94	--	--	82	--	--	10	--	--	21,300
23	Rio Chama near Chamita, N. Mex.	234	565	792	--	--	--	--	--	--	**319,400**	972,000	394,000
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	707	1,473	2,423	538	1,260	2,160	141	386	289	**1,464,500**	**1,525,500**	**1,517,000**
28	Rio Grande below Cochiti Dam, N. Mex.	645	1,287	2,355	--	--	--	--	--	--	17,100	**56,485**	**48,622**
29	Rio Grande at San Felipe, N. Mex.	713	1,395	2,466	517	1,250	2,600	60	157	307	32,800	1,020,000	456,000
38	Rio Grande at Albuquerque, N. Mex.	527	1,353	2,241	--	--	--	--	--	--	**2,428,000**	**2,808,000**	**338,500**
43	Rio Grande Floodway near Bernardo, N. Mex.	41	1,150	2,119	--	--	--	32	748	1,210	81,600	**2,462,000**	**673,700**
([1])	Rio Puerco near Bernardo, N. Mex.	13.2	14.2	13.6	--	--	--	--	--	--	**9,490,000**	**6,829,000**	**1,848,000**
47	Rio Salado near San Acacia, N. Mex.	89	16.2	--	--	--	--	--	--	--	7,590,000	1,360,000	--
48	Rio Grande Conveyance Channel at San Acacia, N. Mex.	527	497	0.16	--	--	--	--	--	--	**10,091,000**	**3,487,000**	--

Table 17.--Calculated or estimated nutrient and suspended-sediment loads in water from selected surface-water sampling stations within the Rio Grande Valley study unit, water years 1972, 1975, and 1986--Concluded

Station reference number (pl. 2)	Station name	Mean daily flow (cubic feet per second)			Total nitrogen (as N) load			Total phosphorus (as P) load			Total suspended-sediment load		
		1972	1975	1986	1972	1975	1986	1972	1975	1986	1972	1975	1986
49	Rio Grande Floodway at San Acacia, N. Mex.	50	800	2,523	--	3,640	5,080	--	592	1,860	**3,254,000**	**7,030,000**	**4,227,000**
62	Rio Grande Conveyance Channel at San Marcial, N. Mex.	563	329	287	1,480	837	621	768	339	101	**11,094,000**	**934,000**	**53,100**
63	Rio Grande Floodway at San Marcial, N. Mex.	26	881	1,889	95	2,660	6,220	43	1,150	2,680	**1,401,000**	**7,791,000**	**2,610,000**
97	Rio Grande at El Paso, Tex.	189	512	975	--	--	--	51	128	226	6,860	55,200	774,000

([1]) This station used only for suspended-sediment loads and is not shown on plate 2.

Annual suspended-sediment loads were either calculated from daily suspended-sediment concentrations or estimated. Loads were estimated for nine main-stem stations, four tributary stations, and the conveyance channels at San Acacia and San Marcial (table 17). Annual loads ranged from 6,860 tons at Rio Grande at El Paso, Texas (97), in 1972 to 11,094,000 tons at Rio Grande Conveyance Channel at San Marcial, New Mexico (62), in 1972. The suspended-sediment load at Rio Grande at Otowi Bridge near San Ildefonso, New Mexico (25), was one to two orders of magnitude greater than that at Rio Grande near Lobatos, Colorado (6). This increase could be due to inflow from several tributaries between these two stations (Red River, Rio Pueblo de Taos, Embudo Creek, Arroyo Hondo, and Rio Chama) and the flushing of ephemeral channels, which contribute to the larger suspended-sediment load. The effects of sediment settling in reservoirs can be seen in the smaller loads at Rio Grande below Cochiti Dam, New Mexico (28), and Rio Grande at El Paso, Texas (97), the latter station located downstream from Elephant Butte and Caballo Reservoirs. Sediment sources between Rio Grande at Albuquerque, New Mexico (38), and the floodway station at San Acacia (49), are the Rio Puerco, Rio Salado (table 17), and numerous arroyos and ephemeral channels that can carry large sediment loads during intense summer thunderstorms.

Discussion of Nutrients and Suspended Sediment

Concentrations of total nitrogen and total phosphorus generally remained fairly constant from Rio Grande near Lobatos, Colorado (6), to Rio Grande at Otowi Bridge near San Ildefonso, New Mexico (25); however, estimated nutrient loads varied. Differences in estimated total nitrogen load between stations were larger downstream but this is due primarily to differences in streamflow, whereas differences in total phosphorus load can be attributed not only to differences in streamflow, but also to differences in suspended-sediment concentration. The larger suspended-sediment concentration and estimated load at Rio Grande at Otowi Bridge near San Ildefonso, New Mexico (25), are due to the inflow of the Rio Chama, flushing of other ungaged ephemeral streams, and the erosional energy of the Rio Grande due to steep gradients upstream.

Concentrations of all constituents were smaller downstream from Cochiti Lake due to smaller velocities and settling of suspended sediment within the reservoir. Nutrient and suspended-sediment concentrations in the Rio Grande were greater downstream from Albuquerque than at stations upstream from Albuquerque. The total phosphorus load downstream from Albuquerque was greater than that at the upstream stations although streamflow remained fairly constant. Possible sources of phosphorus include urban and agricultural application of fertilizers, sewage treatment effluent, and other urban runoff. Many ephemeral streams and arroyos can contribute significant amounts of suspended sediment during intense rainfall.

Flow of the Rio Grande at San Acacia can be diverted into the conveyance channel (48) or remain in the main channel or floodway (49). At times, the entire flow can be in either channel. Concentrations of total phosphorus and suspended sediment were significantly different for the two stations. This most likely can be attributed to the differences in streamflow when water was diverted into the conveyance channel.

Some of the largest median suspended-sediment concentrations on the main stem of the Rio Grande were at the San Acacia stations. The Rio Puerco and Rio Salado flow into the Rio Grande upstream from San Acacia. The median suspended-sediment concentrations for these rivers were 34,100 and 65,500 mg/L, respectively. In addition to these inflows, many arroyos and ephemeral streams also can contribute sediment and nutrients. Calculated or estimated loads for the Rio Puerco and Rio Salado accounted for almost the entire suspended-sediment load at the San Acacia stations. Lack of suspended-sediment samples during high flow could have lead to some inaccuracies in the estimates of suspended-sediment loads because a large amount of sediment can be transported over a relatively short time. In addition, unknown external factors that can affect suspended-sediment and nutrient loads were not considered in the regression models.

Nutrient and suspended-sediment concentrations for the conveyance channel and floodway stations at San Marcial (62 and 63) were significantly different from each other. The reason for this may be that the conveyance channel often has flow when the floodway has little or no flow. Agricultural-return flows also discharge to the conveyance channel. Suspended-sediment loads in the floodway generally were lower downstream from San Acacia due to deposition of sediment between the two stations.

Elephant Butte and Caballo Reservoirs are located on the Rio Grande between San Marcial and the station at the southernmost boundary of the study unit, Rio Grande at El Paso, Tex. (97). Downstream from Elephant Butte Reservoir, total nitrogen and total phosphorus concentrations were lower by an order of magnitude and suspended-sediment concentration was lower by two orders of magnitude relative to the next upstream station. All constituent concentrations then increased by an order of magnitude at Rio Grande at El Paso, Tex. (97). Possible sources of nutrients and sediment downstream from the reservoir are the areas of intensive agriculture along the river and the urban effects from the city of Las Cruces, the second most populated urban area in the study unit.

The factors controlling surface-water quality in the Rio Grande Valley study unit are not well understood and much information is still needed. The complex interaction of tributaries, canals, drains, ephemeral channels, and the main stem complicate the interpretation of overall water quality. Many land uses that could affect water quality are intermixed and occur within a narrow strip along the Rio Grande. With present information, which activities or sources of nutrients and suspended sediment are affecting the water quality of the river is difficult to determine. This report provides an insight into many areas that need further study to understand the overall water quality within the Rio Grande Valley study unit.

Pesticides

Pesticides are used in agricultural areas and urban areas and are becoming increasingly of concern in assessing water quality. Even in small concentrations, some pesticides are either probable or possible carcinogens and can cause adverse health effects on humans and wildlife (U.S. Environmental Protection Agency, 1987). The occurrence of pesticides in surface water depends on the extent of usage and the characteristics of the compound. The distribution and concentration of synthetic organic compounds, such as pesticides, in surface-water systems are affected by sorption, bioaccumulation, photolysis, hydrolysis, biodegradation, and volatilization (Smith and others, 1988). Characteristics of a compound in the environment such as solubility and resistance to degradation affect its mobility and occurrence in a given area. Less soluble, hydrophobic compounds are more likely to be associated with sediments.

Synthetic organic compound data were available from the NWIS and STORET data bases. Compounds that were analyzed for number of detections and maximum concentration are presented in table 18. Data collected during water years 1972-90 were divided into three categories: chlorinated insecticides and PCB's (polychlorinated biphenyls); organophosphorous insecticides; and herbicides (tables 19-21). Locations of synthetic organic compound detections in whole water (including sediment in the sample) for these categories are shown in figures 76, 77, and 78, respectively. Detection limits varied over time and only the minimum detection limits are included in table 18. Rio Grande at Isleta, New Mexico (41), was the station with the most detections of all pesticides in the study unit. About 98 percent of the 5,192 separate analyses for pesticides were below the analytical detection limit.

Chlorinated insecticides and PCB's strongly partition into the organic component of sediment and dissolved-organic matter and are persistent in the environment. These insecticides and PCB's also partition strongly into the lipid reservoirs of aquatic organisms and can be bioconcentrated (Smith and others, 1988). DDE, a metabolite of DDT, was the most frequently detected chlorinated compound (35 percent of detections) in streambed sediments and water, with 10 detections in each. Other detections include dieldrin (two in streambed sediments, seven in water), lindane (zero, six), chlordane (two, four), DDT (four, two), DDD (four, one), heptachlor epoxide (zero, one), heptachlor (zero, one), PCB's (three, zero), and endrin (one, zero). Throughout the study unit, the most detections in streambed sediments (six detections) were at Rio Grande at San Felipe, New Mexico (29). The most detections for all chlorinated insecticides and PCB's in whole water (18 detections) were at Rio Grande Conveyance Channel at San Marcial, New Mexico (62) (table 19; fig. 76).

Organophosphorous insecticides in general are among the least environmentally persistent pesticides because of their relatively rapid chemical and biological degradation in soil and surface-water systems. Diazinon was the most frequently detected organophosphorous insecticide (14 percent of analyses) because it is one of the more persistent organophosphorous insecticides and has one of the lowest detection limits (Smith and others, 1988). Organophosphorous insecticides that were detected include diazinon (one detection in streambed sediments, 38 in whole water), malathion (zero, three), ethyl trithion (zero, three), and chlorpyrifos (zero, one). The only detection in streambed sediments was for diazinon at San Antonio Drain at inflow to BDANWR (Bosque del Apache National Wildlife Refuge), New Mexico (55). The most detections in whole water for all organophosphorous insecticides (17 detections) were at Rio Grande at Isleta, New Mexico (41) (table 20; fig. 77).

Herbicides generally are environmentally nonpersistent and do not partition into sediment organic matter or biological lipid reservoirs (Smith and others, 1988). The only herbicides detected in the Rio Grande Valley study unit were in whole water for 2,4-D (30 detections) and silvex (eight detections). The most detections for 2,4-D were at Rio Grande at Isleta, New Mexico (41), and at Rio Grande Floodway at San Acacia, New Mexico (49), each having six detections (table 21). The most detections for silvex were at Rio Grande Conveyance Channel at San Marcial, New Mexico (62), which had two detections. Overall, the station with the most herbicide detections was Rio Grande at Isleta, New Mexico (41), with seven detections (table 21; fig. 78).

Table 18.--Synthetic organic compounds detected in surface water and streambed sediments in the Rio Grande Valley study unit, water years 1972-90

[Lowest levels of detection and maximum concentrations are in micrograms per liter; --, not applicable. Data not shown for less than 10 samples]

Synthetic organic compound	Water: Number of detections (number of samples)	Water: Lowest level of detection	Water: Maximum concentration detected	Streambed sediments: Number of detections (number of samples)	Streambed sediments: Lowest level of detection	Streambed sediments: Maximum concentration detected
Chlorinated insecticides and PCB's						
Aldrin	0 (151)	0.01	--	0 (37)	0.1	--
Alpha BHC	0 (11)	.01	--	--	--	--
Beta BHC	0 (11)	.01	--	--	--	--
Chlordane	4 (149)	.02	0.4	2 (35)	1	3
DDD	1 (151)	.01	.01	4 (35)	.1	1.7
DDE	10 (151)	.01	.06	10 (35)	.1	5.2
DDT	2 (151)	.01	.03	4 (35)	.1	.3
Dieldrin	7 (151)	.01	.01	2 (37)	.1	2.4
Endrin	0 (287)	.01	--	1 (37)	.1	.1
Lindane	6 (283)	.01	.09	0 (32)	.1	--
PCB's	0 (126)	.1	--	3 (33)	1	2
Mirex	0 (103)	.01	--	--	--	--
Endosulfan	0 (110)	.01	--	--	--	--
Methoxychlor	0 (270)	.01	--	0 (27)	.1	--
Toxaphene	0 (132)	1	--	0 (29)	10	--
Heptachlor epoxide	1 (290)	.01	.01	0 (37)	.1	--
Heptachlor	1 (294)	.01	.01	0 (37)	.1	--
Organophosphorous insecticides						
Diazinon	38 (282)	0.01	1.2	1 (10)	5	--
Ethion	0 (264)	.01	--	--	--	--
Malathion	3 (282)	.01	1.7	--	--	--
Parathion	0 (282)	.01	--	0 (10)	3	--
Methyl parathion	0 (282)	.01	--	0 (10)	3	--

Table 18.--Synthetic organic compounds detected in surface water and streambed sediments in the Rio Grande Valley study unit, water years 1972-90--Concluded

Synthetic organic compound	Water: Number of detections (number of samples)	Water: Lowest level of detection	Water: Maximum concentration detected	Streambed sediments: Number of detections (number of samples)	Streambed sediments: Lowest level of detection	Streambed sediments: Maximum concentration detected
			Organophosphorous insecticides			
Methyl trithion	0 (125)	0.01	--	--	--	--
Chlorpyrifos	1 (13)	.01	0.01	--	--	--
Di-Syston	0 (15)	.01	--	--	--	--
Phorate	0 (15)	.01	--	--	--	--
Ethyl trithion	3 (125)	.01	.01	--	--	--
Atrazine	0 (26)	.1	--	--	--	--
Dacthal	--	--	--	--	--	--
Metalochlor	0 (15)	.1	--	--	--	--
Metribuzin	0 (15)	.1	--	--	--	--
			Herbicides			
2,4-D	30 (135)	0.01	1.4	--	--	--
Alachlor	0 (15)	.1	--	--	--	--
2,4,5-T	0 (135)	.01	--	--	--	--
Cyanazine	0 (15)	.1	--	--	--	--
Ametryne	0 (15)	.1	--	--	--	--
2,4-DP	0 (90)	.01	--	--	--	--
Propazine	0 (15)	.1	--	--	--	--
Trifluralin	0 (15)	.1	--	--	--	--
Simetryne	0 (15)	.1	--	--	--	--
Simazine	0 (15)	.1	--	--	--	--
Prometone	0 (15)	.1	--	--	--	--
Prometryne	0 (15)	.1	--	--	--	--
Silvex	8 (135)	.01	.19	--	--	--

Table 19.--Summary of data on chlorinated insecticides and PCB's in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit

[Concentrations in streambed sediments are reported in micrograms per kilogram; total concentrations in whole water are in micrograms per liter; --, not applicable; BDANWR, Bosque del Apache National Wildlife Refuge]

Station reference number (pl. 2)	Station name	Synthetic organic compound	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
			Streambed sediments				
6	Rio Grande near Lobatos, Colo.	Chlorinated insecticides	1975-82	23	DDD	2	0.1 -0.2
					DDE	2	.16-.2
					DDT	1	.3
		PCB's	1977-82	6	None	0	--
18	Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	PCB's	1981-85	5	None	0	--
19	Rio Grande above San Juan Pueblo, N. Mex.	Chlorinated insecticides	1987-88	4	None	0	--
24	Rio Grande at Santa Clara, N. Mex.	Chlorinated insecticides	1987-90	9	None	0	--
25	Rio Grande at Otowi Bridge, near San Ildefonso, N. Mex.	Chlorinated insecticides	1978-79	2	DDE	1	.1
		PCB's	1978-79	2	None	0	--
29	Rio Grande at San Felipe, N. Mex.	Chlorinated insecticides	1978-79	2	DDD	1	.1
					DDE	2	.40-.50
					DDT	1	.1
					Dieldrin	1	.1
					Endrin	1	.1
		PCB's	1978-79	2	None	0	--
41	Rio Grande at Isleta, N. Mex.	Chlorinated insecticides	1987	1	DDE	1	.20
		PCB's	1979	1	PCB	1	1.0

Table 19.--Summary of data on chlorinated insecticides and PCB's in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station name	Synthetic organic compound	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
		Streambed sediments--Continued					
42	Rio Grande at Isleta Diversion	Chlorinated insecticides	1981	2	None	0	--
	Dam, N. Mex.	PCB's	1981	1	None	0	--
48	Rio Grande Conveyance Channel at San	Chlorinated insecticides	1979	1	None	0	--
	Acacia, N. Mex.	PCB's	1979	1	None	0	--
49	Rio Grande Floodway at San Acacia,	Chlorinated insecticides	1987	1	None	0	--
	N. Mex.	PCB's	1987	1	None	0	--
53	Rio Grande Conveyance Channel at	Chlorinated insecticides	1987	1	None	0	--
	inflow to BDANWR, N. Mex.	PCB's	1987	1	None	0	--
54	Elmendorf Drain at inflow to	Chlorinated insecticides	1987	1	Chlordane	1	3.0
					DDD	1	1.7
					DDE	1	1.3
	BDANWR, N. Mex.	PCB's	1987	1	PCB's	1	2.0
55	San Antonio Drain at inflow to	Chlorinated insecticides	1987	1	Chlordane	1	3.0
					DDE	1	.4
	BDANWR, N. Mex.	PCB's	1987	1	PCB's	1	2.0
56	BDANWR Interior Drain, 1.2 miles	Chlorinated insecticides	1987	1	DDT	1	.1
	north of BDANWR Headquarters, N. Mex.	PCB's	1987	1	None	0	

Table 19.--Summary of data on chlorinated insecticides and PCB's in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station name	Synthetic organic compound	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
		Streambed sediments--Continued					
61	BDANWR Interior Drain near outflow, BDANWR, N. Mex.	Chlorinated insecticides	1987	1	DDT	1	0.1
		PCB's	1987	1	None	0	--
62	Rio Grande Conveyance Channel at San Marcial, N. Mex.	Chlorinated insecticides	1972-73	8	DDE	1	.06
					Dieldrin	1	2.4
		PCB's	1972-73	8	None	0	--
63	Rio Grande Floodway at San Marcial, N. Mex.	Chlorinated insecticides	1987	1	None	0	--
		PCB's	1987	1	None	0	--
95	Rio Grande 1.7 miles up from the American Dam, Tex.	Chlorinated insecticides	1978-87	5	DDE	1	5.2
		PCB's	1978-87	5	None	0	--
		Total in whole-water sample					
6	Rio Grande near Lobatos, Colo.	Chlorinated insecticides	1975-82	23	None	0	--
		PCB's	1977-82	13	None	0	--
17	Rio Pueblo de Taos below Los Cordovas, N. Mex.	Chlorinated insecticides		1	None	0	--
18	Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	Chlorinated insecticides	1981-85	5	None	0	--
19	Rio Grande above San Juan Pueblo, N. Mex.	Chlorinated insecticides	1987-88	4	None	0	--
		PCB's	1987-88	3	None	0	--

Table 19.--Summary of data on chlorinated insecticides and PCB's in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station name	Synthetic organic compound	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
		Total in whole-water sample--Continued					
23	Rio Chama near Chamita, N. Mex.	Chlorinated insecticides	1987-90	9	None	0	--
		PCB's	1987-90	9	None	0	--
24	Rio Grande at Santa Clara, N. Mex.	Chlorinated insecticides	1987-90	9	None	0	--
		PCB's	1987-90	9	None	0	--
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	Chlorinated insecticides	1972, 1978-85	9	None	0	--
		PCB's	1972, 1978-85	8	None	0	--
27	Cochiti Lake near Cochiti Pueblo, N. Mex.	Chlorinated insecticides	1981-85	5	None	0	--
		PCB's	1981-85	5	None	0	--
29	Rio Grande at San Felipe, N. Mex.	Chlorinated insecticides	1978-85	8	None	0	--
		PCB's	1978-85	8	None	0	--
32	Campus Wash at Albuquerque, N. Mex.	Chlorinated insecticides	1990	1	None	0	--
		PCB's	1990	1	None	0	--
33	Arroyo del Embudo inlet to floodway channel at Albuquerque, N. Mex.	Chlorinated insecticides	1990	1	None	0	--
		PCB's	1990	1	None	0	--
35	Grant Line Arroyo at Villa del Oso Drain, Albuquerque, N. Mex.	Chlorinated insecticides	1981	1	Chlordane	1	0.2
					Lindane	1	.09
		PCB's	1981	1	None	0	--

Table 19.--Summary of data on chlorinated insecticides and PCB's in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station name	Synthetic organic compound	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
		Total in whole-water sample--Continued					
36	North Floodway Channel near Alameda, N. Mex.	Chlorinated insecticides	1990	2	Chlordane	1	0.2
		PCB's	1990	2	None	0	--
37	Taylor Ranch Drain at Albuquerque, N. Mex.	Chlorinated insecticides	1982	1	Chlordane	1	.4
					Heptachlor	1	.01
					Heptachlor epoxide	1	.01
					Lindane	1	.2
		PCB's	1982	1	None	0	--
38	Rio Grande at Albuquerque, N. Mex.	Chlorinated insecticides	1981-88	8	None	0	--
		PCB's	1981-88	8	None	0	--
41	Rio Grande at Isleta, N. Mex.	Chlorinated insecticides	1972-90	15	DDE	2	.01
					Dieldrin	2	.01
					Lindane	1	.01
		PCB's	1972-90	14	None	0	--
42	Rio Grande at Isleta Diversion Dam, N. Mex.	PCB's	1981	1	None	0	--
43	Rio Grande Floodway near Bernardo, N. Mex.	Chlorinated insecticides	1982, 1984-85	3	None	0	--
		PCB's	1982, 1984-85	3	None	0	--
44	Rio Grande at Bernardo Bridge, US 60, N. Mex.	Chlorinated insecticides	1987	1	None	0	--
46	Rio San Jose near Grants, N. Mex.	Chlorinated insecticides	1986-90	5	None	0	--
		PCB's	1986-90	5	None	0	--

Table 19.--Summary of data on chlorinated insecticides and PCB's in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit—Continued

Station reference number (pl. 2)	Station name	Synthetic organic compound	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
		Total in whole-water sample--Continued					
48	Rio Grande Conveyance Channel at San Acacia, N. Mex.	Chlorinated insecticides	1978-80, 1984	4	None	0	--
		PCB's	1978-80, 1984	4	None	0	--
49	Rio Grande Floodway at San Acacia, N. Mex.	Chlorinated insecticides	1981-83, 1985-89	8	None	0	--
		PCB's	1981-83, 1985-90	9	None	0	--
50	Rio Grande at San Acacia above diversion dam, N. Mex.	Chlorinated insecticides	1987	1	None	0	--
51	Rio Grande at San Antonio, N. Mex.	Chlorinated insecticides	1987	1	Chlordane	1	0.025
62	Rio Grande Conveyance Channel at San Marcial, N. Mex.	Chlorinated insecticides	1972-85	17	DDD	1	.01
					DDE	8	.01-.06
					DDT	2	.02-.03
					Dieldrin	5	.01
					Lindane	2	.01
		PCB's	1972-85	12	None	0	--
63	Rio Grande Floodway at San Marcial, N. Mex.	Chlorinated insecticides	1972, 1980, 1982-83	6	Lindane	1	.01
		PCB's	1980, 1982-83	3	None	0	--
64	Rio Grande Conveyance Channel at San Marcial, N. Mex.	Chlorinated insecticides	1975	5	None	0	--

Table 19.--Summary of data on chlorinated insecticides and PCB's in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station name	Synthetic organic compound	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
		Total in whole-water sample--Continued					
65	Rio Grande Floodway at San Marcial, N. Mex.	Chlorinated insecticides	1975	5	None	0	--
66	Rio Grande just below Elephant Butte Reservoir, N. Mex.	Chlorinated insecticides	1975	5	None	0	--
68	Rio Grande below Truth or Consequences, N. Mex.	Chlorinated insecticides	1975	5	None	0	--
70	Caballo Reservoir near dam, N. Mex.	Chlorinated insecticides	1975	5	None	0	--
71	Rio Grande just below Caballo, N. Mex.	Chlorinated insecticides	1975	5	None	0	--
72	Hatch Drain below Hatch, N. Mex.	Chlorinated insecticides	1975	5	None	0	--
73	Rio Grande at Hayner Bridge, N. Mex.	Chlorinated insecticides	1975	5	None	0	--
74	Angostura Drain below Rincon, N. Mex.	Chlorinated insecticides	1975	5	None	0	--
75	Rincon Drain near Tonoco, N. Mex.	Chlorinated insecticides	1975	5	None	0	--

Table 19.--Summary of data on chlorinated insecticides and PCB's in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station name	Synthetic organic compound	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
			Total in whole-water sample--Continued				
76	Rio Grande below Leasburg Dam, N. Mex.	Chlorinated insecticides	1975	5	None	0	--
77	Selden Drain near Hill on US 85, N. Mex.	Chlorinated insecticides	1975	5	None	0	--
78	Leasburg Drain above Las Cruces, N. Mex.	Chlorinated insecticides	1975	5	None	0	--
79	Rio Grande at N. Mex. Highway 430 near Doña Ana, N. Mex.	Chlorinated insecticides	1981	1	None	0	--
81	Rio Grande at bridge near La Mesilla, N. Mex.	Chlorinated insecticides	1981	1	None	0	--
82	Rio Grande just below Mesilla Dam, N. Mex.	Chlorinated insecticides	1975	5	None	0	--
83	Rio Grande at Mesilla Diversion Dam, N. Mex.	Chlorinated insecticides	1981	1	None	0	--
84	Del Rio Drain near Vado, N. Mex.	Chlorinated insecticides	1975	5	None	0	--
85	La Mesa Drain near Chamberino, N. Mex.	Chlorinated insecticides	1975	5	None	0	--

Table 19.--Summary of data on chlorinated insecticides and PCB's in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Concluded

Station reference number (pl. 2)	Station name	Synthetic organic compound	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
		Total in whole-water sample--Continued					
86	Rio Grande near Anthony on N. Mex. Highway 225 Bridge, N. Mex.	Chlorinated insecticides	1988	1	None	0	–
87	East Drain near La Tuna, N. Mex.	Chlorinated insecticides	1975	5	None	0	–
88	Rio Grande below Anthony, on Highway 278, N. Mex.	Chlorinated insecticides	1975	5	None	0	–
89	Vinton R-Drain near Cañutillo, N. Mex.	Chlorinated insecticides	1975	5	None	0	–
90	Border Intercept Drain, N. Mex.	Chlorinated insecticides	1975	5	None	0	–
91	Nemexas Drain near State Highway 260, N. Mex.	Chlorinated insecticides	1975	4	None	0	–
92	West Drain near State Highway 260, N. Mex.	Chlorinated insecticides	1975	5	None	0	–
93	Rio Grande at El Paso near El Paso Electric Company Power Plant, Tex.	Chlorinated insecticides	1975	5	None	0	–
94	Montoya Drain near the El Paso Electric Company Power Plant, Tex.	Chlorinated insecticides	1975	5	None	0	–

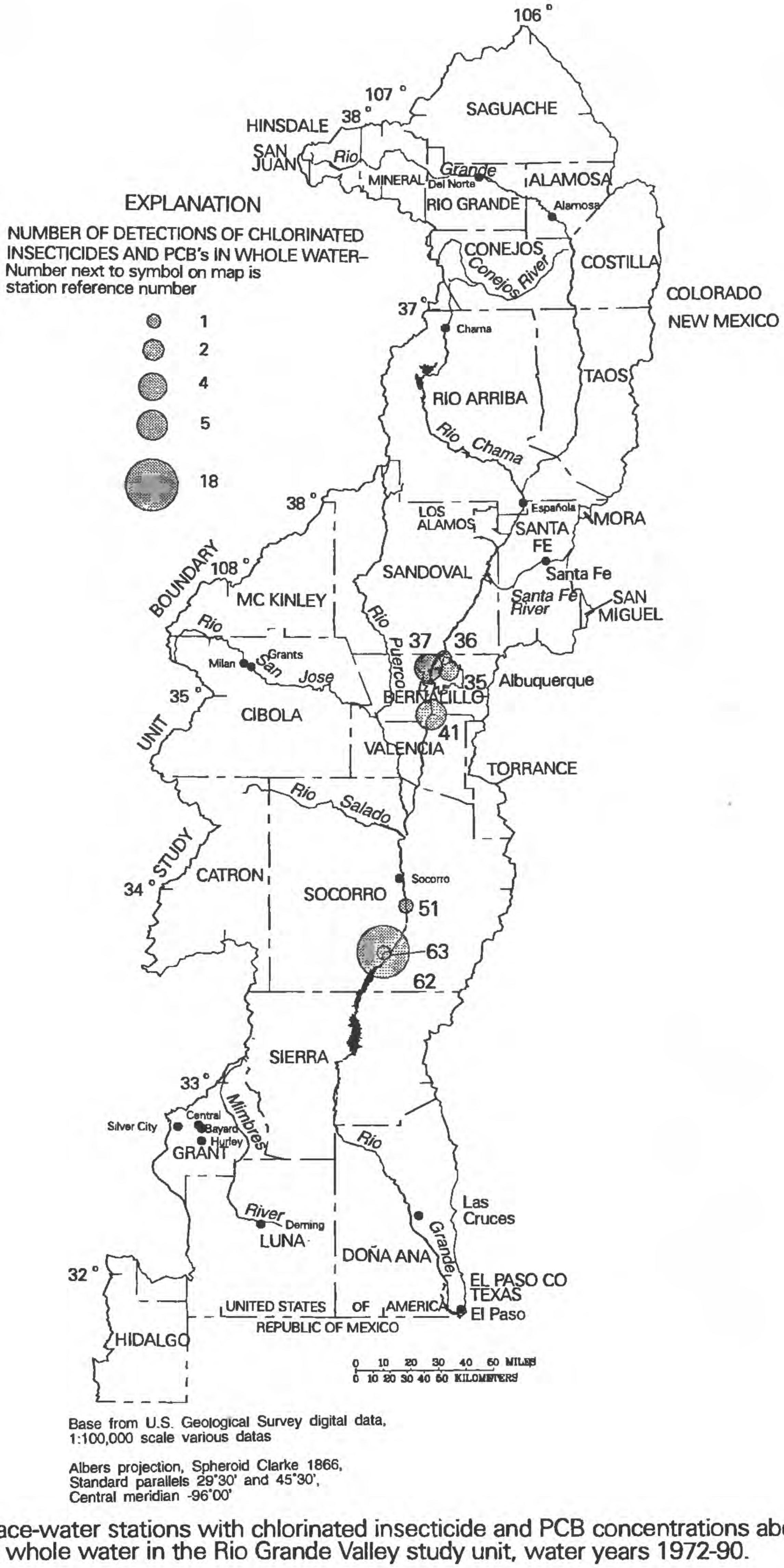


Figure 76.–Surface-water stations with chlorinated insecticide and PCB concentrations above detection limits in whole water in the Rio Grande Valley study unit, water years 1972-90.

Table 20.--Summary of data on organophosphorous insecticides in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit

[Water year and number of samples for some individual compounds in a group may be less than those shown for the group; concentration in streambed sediments is in micrograms per kilogram; total concentration in whole water is in micrograms per liter; --, not applicable; BDANWR, Bosque del Apache National Wildlife Refuge]

Station reference number (pl. 2)	Station name	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
			Streambed sediments			
6	Rio Grande near Lobatos, Colo.	1975-79	6	None	0	--
55	San Antonio Drain at inflow to BDANWR, N. Mex.	1988	1	Diazinon	1	0.01
95	Rio Grande 1.7 miles up from the American Dam, Tex.	1978, 1980-82	4	None	0	--
			Total in whole-water sample			
6	Rio Grande near Lobatos, Colo.	1975-82	23	None	0	--
17	Rio Pueblo de Taos below Los Cordovas, N. Mex.	1981	1	Diazinon	1	0.02
18	Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	1984-85	2	None	0	--
19	Rio Grande above San Juan Pueblo, N. Mex.	1987-88	4	Diazinon	1	.01

Table 20.--Summary of data on organophosphorous insecticides in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station name	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
			Total in whole-water sample--Continued			
23	Rio Chama near Chamita, N. Mex.	1987-90	8	None	0	--
24	Rio Grande at Santa Clara, N. Mex.	1987-90	9	None	0	--
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	1980-85	6	None	0	--
27	Cochiti Lake near Cochiti Pueblo, N. Mex.	1981-85	5	None	0	--
29	Rio Grande at San Felipe, N. Mex.	1980-85	6	None	0	--
35	Grant Line Arroyo at Villa del Oso Drain, Albuquerque, N. Mex.	1981	1	Diazinon	1	0.24
37	Taylor Ranch Drain at Albuquerque, N. Mex.	1982	1	Diazinon	1	1.2
				Malathion	1	1.7
38	Rio Grande at Albuquerque, N. Mex.	1981-88	8	Diazinon	1	.01
41	Rio Grande at Isleta, N. Mex.	1979-90	11	Diazinon	11	.01-.17
				Malathion	2	.01-.03
				Ethyl trithion	3	.01
				Chlorpyriphos	1	.01

Table 20.--Summary of data on organophosphorous insecticides in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station name	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
			Total in whole-water sample--Continued			
43	Rio Grande Floodway near Bernardo, N. Mex.	1981-85	4	Diazinon	3	0.01-0.03
44	Rio Grande at Bernardo Bridge, US 60, N. Mex.	1987	1	None	0	--
46	Rio San Jose near Grants, N. Mex.	1986-90	5	Diazinon	3	.01-.02
48	Rio Grande Conveyance Channel at San Acacia, N. Mex.	1980, 1984	2	Diazinon	2	.01-.02
49	Rio Grande Floodway at San Acacia, N. Mex.	1981-89	9	Diazinon	6	.01-.02
50	Rio Grande at San Acacia above diversion dam, N. Mex.	1981	1	None	0	--
51	Rio Grande at San Antonio, N. Mex.	1987	1	None	0	--
52	Socorro Main Canal at inflow to BDANWR, N. Mex.	1988	1	Diazinon	1	.01
53	Rio Grande Conveyance Channel at inflow to BDANWR, N. Mex.	1987	1	None	0	--

Table 20.--Summary of data on organophosphorous insecticides in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station name	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
			Total in whole-water sample--Continued			
54	Elmendorf Drain at inflow to BDANWR, N. Mex.	1982-88	2	Diazinon	1	0.01
55	San Antonio Drain at inflow to BDANWR, N. Mex.	1987-88	2	None	0	--
56	BDANWR Interior Drain, 1.2 miles north of BDANWR Headquarters, N. Mex.	1987-88	2	None	0	--
57	Trench pond in field unit 18C at BDANWR, N. Mex.	1988	1	None	0	--
58	San Antonio Drain, 1.6 miles east of BDANWR, N. Mex.	1988	1	None	0	--
59	Field unit 18B-east triangle at BDANWR, N. Mex.	1988	1	None	0	--
60	South Marsh in field unit 25A at BDANWR, N. Mex.	1988	1	None	0	--

Table 20.--Summary of data on organophosphorous insecticides in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station name	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
			Total in whole-water sample--Continued			
61	BDANWR Interior Drain near outflow, BDANWR, N. Mex.	1988	1	None	0	--
62	Rio Grande Conveyance Channel at San Marcial, N. Mex.	1972-73, 1981, 1984-85	13	Diazinon	4	0.01-0.07
63	Rio Grande Floodway at San Marcial, N. Mex.	1972, 1980, 1982-83, 1987	5	Diazinon	2	.01
64	Rio Grande Conveyance Channel at San Marcial, N. Mex.	1975	5	None	0	--
65	Rio Grande Floodway at San Marcial, N. Mex.	1975	5	None	0	--
66	Rio Grande just below Elephant Butte Reservoir, N. Mex.	1975	5	None	0	--
68	Rio Grande below Truth or Consequences, N. Mex.	1975	5	None	0	--
70	Caballo Reservoir near dam, N. Mex.	1975	5	None	0	--
71	Rio Grande just below Caballo, N. Mex.	1975	5	None	0	--

Table 20.--Summary of data on organophosphorous insecticides in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station name	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
Total in whole-water sample--Continued						
72	Hatch Drain below Hatch, N. Mex.	1975	5	None	0	--
73	Rio Grande at Hayner Bridge, N. Mex.	1975	5	None	0	--
74	Angostura Drain below Rincon, N. Mex.	1975	5	None	0	--
75	Rincon Drain near Tonoco, N. Mex.	1975	5	None	0	--
76	Rio Grande below Leasburg Dam, N. Mex.	1975	5	None	0	--
77	Selden Drain near Hill on US 85, N. Mex.	1975	5	None	0	--
78	Leasburg Drain above Las Cruces, N. Mex.	1975	5	None	0	--
80	Rio Grande at Picacho Ave., in Las Cruces, N. Mex.	1988	1	None	0	--
81	Rio Grande at bridge near La Mesilla, N. Mex.	1988	1	None	0	--
82	Rio Grande just below Mesilla Dam, N. Mex.	1975	5	None	0	--

Table 20.--Summary of data on organophosphorous insecticides in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station name	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
			Total in whole-water sample--Continued			
84	Del Rio Drain near Vado, N. Mex.	1975	5	None	0	--
85	La Mesa Drain near Chamberino, N. Mex.	1975	5	None	0	--
86	Rio Grande near Anthony on N. Mex. Highway 225 Bridge, N. Mex.	1988	1	None	0	--
87	East Drain near La Tuna, N. Mex.	1975	5	None	0	--
89	Vinton R-Drain near Cañutillo, N. Mex.	1975	5	None	0	--
90	Border Intercept Drain, N. Mex.	1975	5	None	0	--
91	Nemexas Drain near State Highway 260, N. Mex.	1975	5	None	0	--
92	West Drain near State Highway 260, N. Mex.	1975	5	None	0	--
93	Rio Grande at El Paso near El Paso Electric Company Power Plant, Tex.	1975	5	None	0	--

Table 20.--Summary of data on organophosphorous insecticides in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Concluded

Station reference number (pl. 2)	Station name	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
			Total in whole-water sample--Continued			
94	Montoya Drain near the El Paso Electric Company Power Plant, Tex.	1975	5	None	0	--
96	Rio Grande at bridge below Sunland Park, Tex.	1988	1	None	0	--

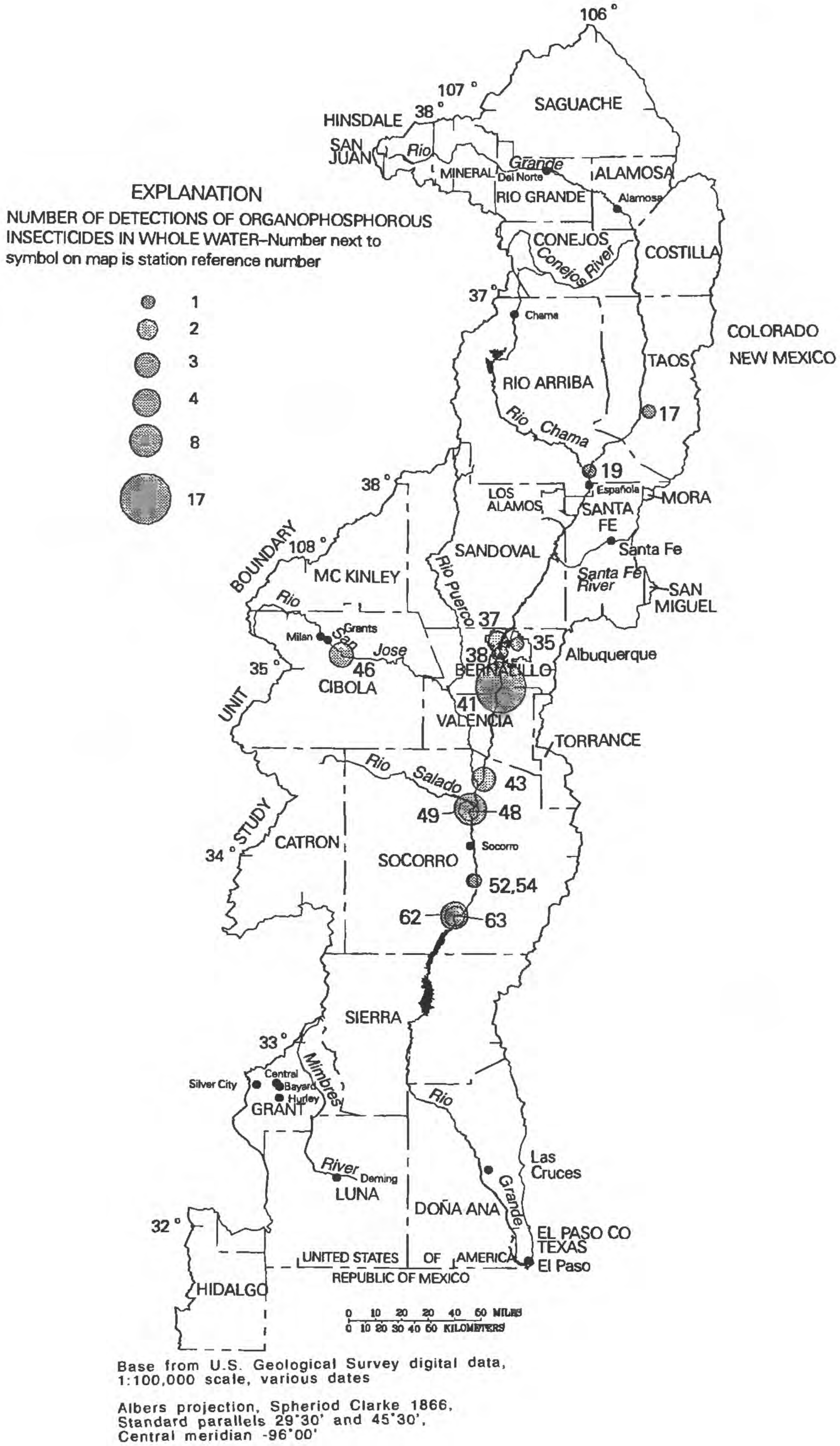


Figure 77.--Surface-water stations with organophosphorous insecticide concentrations above detection limits in whole water in the Rio Grande Valley study unit, water years 1972-90.

Table 21.--Summary of data on herbicides in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit

[Water year and number of samples for some individual compounds in a group may be less than those shown for the group; concentration in streambed sediment is reported in micrograms per kilogram; total concentration in whole water is in micrograms per liter; --, not applicable; BDANWR, Bosque del Apache National Wildlife Refuge]

Station reference number (pl. 2)	Station name	Herbicide	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
		Streambed sediments					
6	Rio Grande near Lobatos, Colo.	Chlorophenoxy Acid herbicides	1976-78	4	None	0	--
		Triazine and other nitrogen-containing herbicides	1976-77	3	None	0	--
95	Rio Grande 1.7 miles up from the American Dam, Tex.	Chlorophenoxy Acid herbicides	1980	1	None	0	--
		Total in whole-water sample					
6	Rio Grande near Lobatos, Colo.	Chlorophenoxy Acid herbicides	1975-78, 1980, 1982	13	None	0	--
		Triazine and other nitrogen-containing herbicides	1975-78	11	None	0	--
18	Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	Chlorophenoxy Acid herbicides	1981, 1983-84	3	None	0	--
19	Rio Grande above San Juan Pueblo, N. Mex.	Chlorophenoxy Acid herbicides	1987-88	4	None	0	--
23	Rio Chama near Chamita, N. Mex.	Chlorophenoxy Acid herbicides	1987-90	8	None	0	--
24	Rio Grande at Santa Clara, N. Mex.	Chlorophenoxy Acid herbicides	1987-90	8	None	0	--

Table 21.--Summary of data on herbicides in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station name	Herbicide	Water year	Number of samples	Compound detected	Number of detec-tions	Range of detected concen-trations
			Total in whole-water sample--Continued				
25	Rio Grande at Otowi Bridge near San Ildefonso, N. Mex.	Chlorophenoxy Acid herbicides	1972, 1980-85	7	2,4-D Silvex	2 1	0.02-0.20 .05
27	Cochiti Lake near Cochiti Pueblo, N. Mex.	Chlorophenoxy Acid herbicides	1985	1	None	0	--
29	Rio Grande at San Felipe, N. Mex.	Chlorophenoxy Acid herbicides	1980-85	6	2,4-D	2	.01
34	Hahn Arroyo at Albuquerque, N. Mex.	Chlorophenoxy Acid herbicides	1980	1	2,4-D Silvex	1 1	1.4 .19
35	Grant Line Arroyo at Villa del Oso Drain, Albuquerque, N. Mex.	Chlorophenoxy Acid herbicides	1981	1	2,4-D Silvex	1 1	.10 .01
37	Taylor Ranch Drain at Albuquerque, N. Mex.	Chlorophenoxy Acid herbicides	1982	1	2,4-D Silvex	1 1	.23 .02
38	Rio Grande at Albuquerque, N. Mex.	Chlorophenoxy Acid herbicides	1981-88	8	2,4-D	3	.01
40	10N.03E.30.224B Barelas Bridge pumping station in Albuquerque, N. Mex.	Chlorophenoxy Acid herbicides	1980	1	None	0	--
41	Rio Grande at Isleta, N. Mex.	Chlorophenoxy Acid herbicides	1972, 1980-86, 1988-89	12	2,4-D Silvex	6 1	.01-.06 .01

Table 21.--Summary of data on herbicides in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station name	Herbicide	Water year	Number of samples	Compound detected	Number of detec-tions	Range of detected concen-trations
		Total in whole-water sample--Continued					
43	Rio Grande Floodway near Bernardo, N. Mex.	Chlorophenoxy Acid herbicides	1982-85	4	2,4-D	1	0.01
44	Rio Grande at Bernardo Bridge, US 60, N. Mex.	Chlorophenoxy Acid herbicides	1987	1	None	0	--
46	Rio San Jose near Grants, N. Mex.	Chlorophenoxy Acid herbicides	1986-90	5	2,4-D	2	.01-.02
48	Rio Grande Conveyance Channel at San Acacia, N. Mex.	Chlorophenoxy Acid herbicides	1980-81, 1984	3	2,4-D	2	.03
49	Rio Grande Floodway at San Acacia, N. Mex.	Chlorophenoxy Acid herbicides	1982-83, 1985-90	8	2,4-D	6	.01-.05
		Triazine and other nitrogen-containing herbicides	1987	1	None	0	--
50	Rio Grande at San Acacia above diversion dam, N. Mex.	Chlorophenoxy Acid herbicides	1987	1	None	0	--
51	Rio Grande at San Antonio, N. Mex.	Chlorophenoxy Acid herbicides	1987	1	2,4-D	1	.024
52	Socorro Main Canal at inflow to BDANWR, N. Mex.	Chlorophenoxy Acid herbicides	1988	1	None	0	--
		Triazine and other nitrogen-containing herbicides	1988	1	None	0	--

Table 21.--Summary of data on herbicides in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Continued

Station reference number (pl. 2)	Station name	Herbicide	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
		Total in whole-water sample--Continued					
53	Rio Grande Conveyance Channel at inflow to BDANWR, N. Mex.	Triazine and other nitrogen-containing herbicides	1987	1	None	0	--
54	Elmendorf Drain at inflow to BDANWR, N. Mex.	Chlorophenoxy Acid herbicides	1987-88	2	None	0	--
		Triazine and other nitrogen-containing herbicides	1987-88	2	None	0	--
55	San Antonio Drain at inflow to BDANWR, N. Mex.	Chlorophenoxy Acid herbicides	1987-88	2	None	0	--
		Triazine and other nitrogen-containing herbicides	1987-88	2	None	0	--
56	BDANWR Interior Drain, 1.2 miles north of BDANWR Headquarters, N. Mex.	Chlorophenoxy Acid herbicides	1987-88	2	None	0	--
		Triazine and other nitrogen-containing herbicides	1987-88	2	None	0	--
57	Trench pond in field unit 18C at BDANWR, N. Mex.	Triazine and other nitrogen-containing herbicides	1988	1	None	0	--
58	San Antonio Drain, 1.6 miles east of BDANWR, N. Mex.	Chlorophenoxy Acid herbicides	1988	1	None	0	--
		Triazine and other nitrogen-containing herbicides	1988	1	None	0	--
59	Field unit 18B-east triangle at BDANWR, N. Mex.	Triazine and other nitrogen-containing herbicides	1988	1	None	0	--

Table 21.--Summary of data on herbicides in streambed sediments and water from selected surface-water stations in the Rio Grande Valley study unit--Concluded

Station reference number (pl. 2)	Station name	Herbicide	Water year	Number of samples	Compound detected	Number of detections	Range of detected concentrations
		Total in whole-water sample--Continued					
60	South Marsh in field unit 25A at BDANWR, N. Mex.	Triazine and other nitrogen-containing herbicides	1988	1	None	0	--
61	BDANWR Interior Drain near outflow, BDANWR, N. Mex.	Chlorophenoxy Acid herbicides	1987	1	None	0	--
		Triazine and other nitrogen-containing herbicides	1987	1	None	0	--
62	Rio Grande Conveyance Channel at San Marcial, N. Mex.	Chlorophenoxy Acid herbicides	1972-85	16	2,4-D Silvex	1 2	0.01 .01-.08
63	Rio Grande Floodway at San Marcial, N. Mex.	Chlorophenoxy Acid herbicides	1972, 1980, 1982-83, 1985, 1987	8	2,4-D Silvex	1 1	.01 .02
		Triazine and other nitrogen-containing herbicides	1987	1	None	0	--
80	Rio Grande at Picacho Ave. in Las Cruces, N. Mex.	Chlorophenoxy Acid herbicides	1988	1	None	0	--
81	Rio Grande at bridge near La Mesilla, N. Mex.	Chlorophenoxy Acid herbicides	1988	1	None	0	--
86	Rio Grande near Anthony on N. Mex. Highway 225 Bridge, N. Mex.	Chlorophenoxy Acid herbicides	1988	1	None	0	--
96	Rio Grande at bridge below Sunland Park, Tex.	Chlorophenoxy Acid herbicides	1988	1	None	0	--

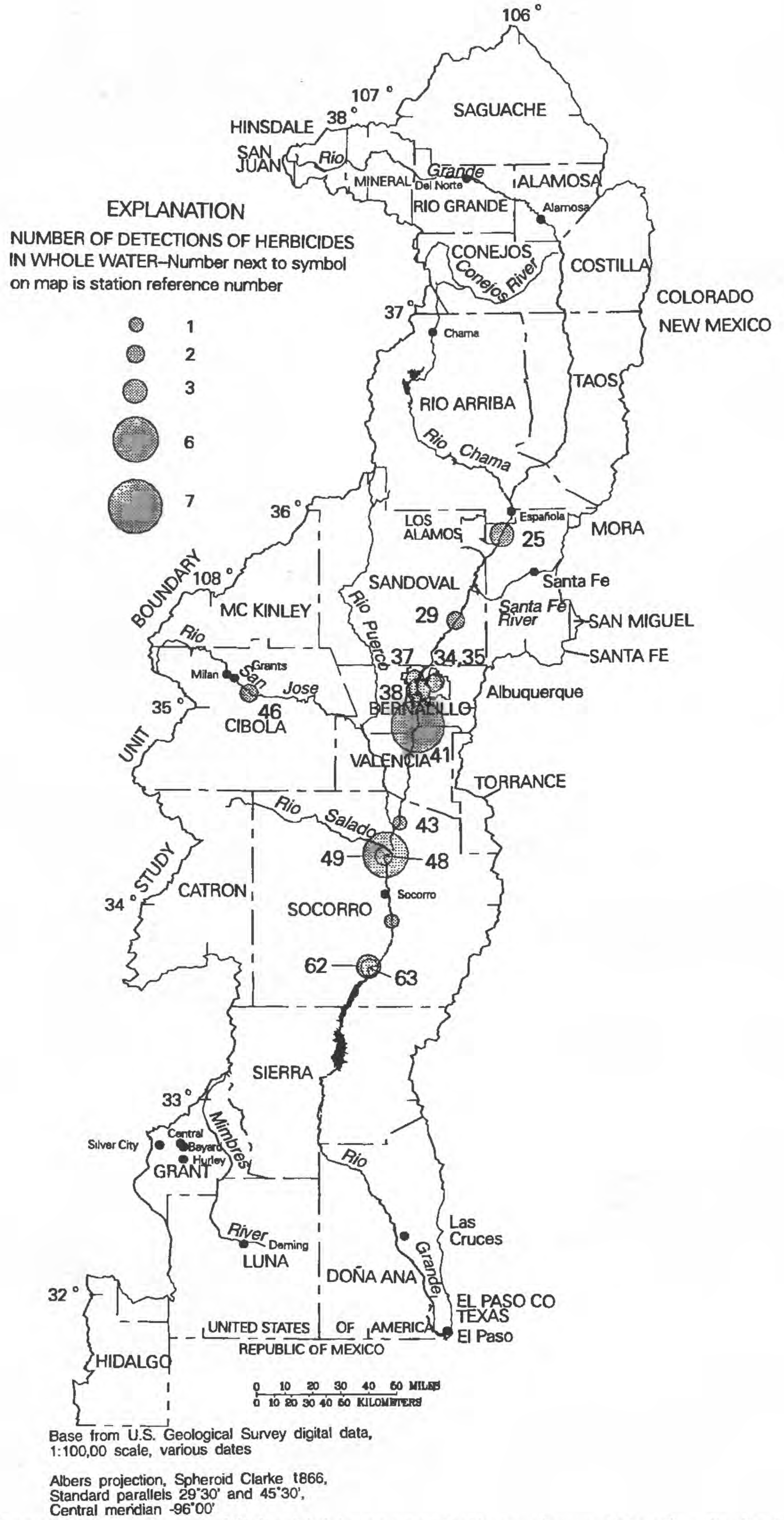


Figure 78.–Surface-water stations with herbicide concentrations above detection limits in whole water in the Rio Grande Valley study unit, water years 1972-90.

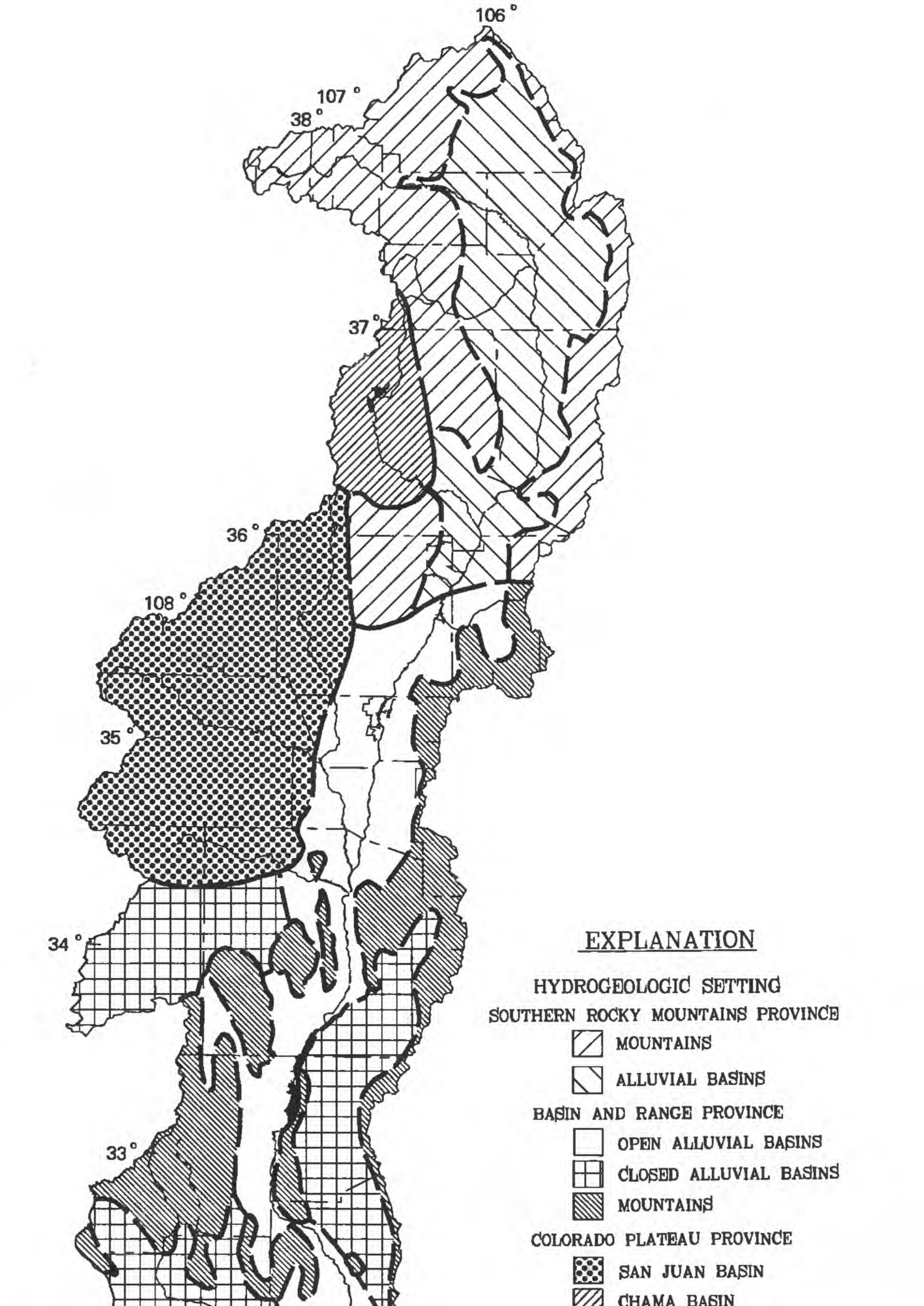
GROUND-WATER QUALITY

This section of the report describes areal variation of nutrient and pesticide ground-water-quality data and discusses statistical differences in the concentrations of nutrients in ground water in different settings defined on the basis of hydrogeology and land-use information. Water-quality data were assigned to a data stratum. Analysis to determine differences, if any, in nutrient concentrations in water from wells located in different data strata was done separately for the NWIS data base and the Albuquerque data base because these were the only two data bases that contained a large number of analyses of water from wells.

Stratification of the Study Unit

Water-quality data were grouped or "stratified" to illustrate the water-quality characteristics of differing hydrogeologic and land-use settings. Water quality in a particular data stratum then was compared with water quality in other data strata. The Rio Grande Valley NAWQA study unit was divided into seven major hydrogeologic areas on the basis of physiography, geology, and hydrology (fig. 79). The study unit first was divided into three areas on the basis of the physiographic provinces: (1) Southern Rocky Mountains Province, (2) Basin and Range Province, and (3) Colorado Plateau Province (pl. 1). The physiographic provinces are delineated by structural differences. These structural differences result in differences in the landforms that are found in these areas. The climates also are somewhat different in each of these provinces, resulting in differences in the characteristics of the streams, vegetation, and soils. The three major physiographic provinces were further subdivided on the basis of a combination of geology and hydrology. The Southern Rocky Mountain Province and the Basin and Range Province were divided into alluvial basins and mountainous areas. The alluvial basins area in the Basin and Range Province was further divided into alluvial basins drained by the Rio Grande (open alluvial basins) and alluvial basins not drained by the Rio Grande (closed alluvial basins). The Colorado Plateau Province was divided into the San Juan Basin and the Chama Basin. These two separate structural basins are generally not connected hydraulically although the climate and vegetation in the two basins are similar.

The Southern Rocky Mountain-mountains hydrogeologic setting surrounds the Southern Rocky Mountains-alluvial basins hydrogeologic setting in the northern third of the study unit (pl. 3). The area is generally at high altitude, ranging from about 6,560 ft at the confluence of Rio Vallecitos and Rio Ojo Caliente (pl. 1) in Rio Arriba County, New Mexico, to more than 13,000 ft in Hinsdale County, Colorado. The major aquifers in this hydrogeologic setting are the thin alluvium in the valleys and the fractured igneous, sedimentary, and volcanic rocks that comprise the mountains. Depth to water is relatively shallow in this hydrogeologic setting. Many streams are perennial, but may cease to flow due to evapotranspiration or infiltration to the alluvium when they reach the Southern Rocky Mountains-alluvial basins setting. Land use is almost exclusively forest and the forest vegetation is composed of ponderosa pine and douglas fir. Soils are thin to absent in many areas of the higher mountains. The largest town in this setting is Del Norte, Colorado (population 1,674). Population is sparse throughout the rest of the area.



Base from U.S. Geological Survey digital data, 1:100,000 scale, various dates

Albers projection, Spheriod Clarke 1866, Standard parallels 29°30' and 45°30', Central meridian -96°00'

Figure 79.--Hydrogeologic settings of the Rio Grande Valley study unit.

The Southern Rocky Mountains-alluvial basins hydrogeologic setting is located in the central part of the northern third of the study unit. It includes most of the San Luis Valley and the alluvial basins of the Rio Grande and its tributaries south to almost Santa Fe, New Mexico. The main aquifers in this hydrogeologic setting are the basin-fill deposits, and the depth to water is generally less than 50 ft near the major rivers; however, the depth to water is large in some areas, especially in the areas in New Mexico not in the Rio Grande flood plain. This setting has a large number of perennial tributaries flowing into the Rio Grande, including Red River, Rio Pueblo de Taos, and Rio Chama, among others. Many irrigation canals and drains are in the San Luis Valley and are a dominant surface-water feature in this area. Irrigation canals also have been constructed along most perennial streams in areas suitable for farming. The northern part of the San Luis Valley is a closed basin. Ground water is generally shallow close to the Rio Grande and deepens away from the river. Agriculture is the principal land use in the San Luis Valley and is also common along narrow strips following perennial streams. Rangeland occurs south of the San Luis Valley in areas away from the Rio Grande. Vegetation at higher altitudes, from 5,500 to 7,000 ft, consists mainly of piñon pine and junipers. Below 5,500 ft the vegetation grades to deciduous shrubs and grassland; the principal shrub is big sagebrush. Grasses are mainly ricegrass and galleta. The largest city is Española, with a population of 8,389. Outside of small towns, the population is sparse.

The Basin and Range-open alluvial basins hydrogeologic setting includes the largest length of the Rio Grande, from El Paso, Texas, to just north of Santa Fe, New Mexico. The main aquifers in this hydrogeologic setting are the basin-fill deposits, and these deposits have a large range in depth to water. In the Rio Grande flood plain, depth to water is generally less than 30 ft, but in most of the rest of this hydrogeologic setting the depth to water is much larger and can be greater than 500 ft. Few perennial tributaries to the Rio Grande are in this area. Many irrigation canals and drains have been constructed along the flood plain where farming is suitable. Agriculture is practiced along the Rio Grande for much of this length; rangeland is the dominant land use away from the bottomland in the valley. Vegetation along the Rio Grande is riparian, consisting of cottonwoods, ash-leaved maple, alder, birch, sycamore, New Mexico olive, and walnut. Salt cedar, an introduced shrub or tree, is also common in the southern area along the Rio Grande and is considered a pest species. In areas above the Rio Grande flood plain vegetation is mainly shrubs and grasses. Principal shrubs include creosote bush, acacia, and four-wing saltbush. Principal grasses include burrograss, grama grass, black grama, dropseed, and ricegrass. The largest cities in the study unit are in this setting: Albuquerque, Las Cruces, and Santa Fe (table 1).

The Basin and Range-closed alluvial basins hydrogeologic setting is located in several areas in the southern part of the study unit (pl. 3). The main aquifers in this hydrogeologic setting are the basin-fill deposits, and depth to water is generally greater than 50 ft. The only perennial stream in this area is the Mimbres River. Many ephemeral streams are in the area that flow only in response to intense rainfall. Rangeland is the primary land use. Vegetation is mainly shrubs and grasses. The primary shrubs are creosote bush and four-wing saltbush, and the primary grasses are grama grass and black grama. The largest cities are Deming (population 10,970), Silver City (population 10,683), and Hurley (population 1,534). Outside of cities, the population is very sparse.

The Basin and Range-mountains hydrogeologic setting comprises most areas in the higher altitudes in the southern part of the study unit and the mountains defining the eastern boundary of the study unit to just north of Santa Fe. The main aquifers in this hydrogeologic setting are the thin alluvium in the valleys and the fractured igneous, sedimentary, and volcanic rocks that comprise the mountains. Although many ephemeral stream channels are in this setting, the only major perennial stream is the Mimbres River. Forest is the main land use, with some rangeland in the lower altitudes. Vegetation in areas of Grant, Sierra, Bernalillo, and Valencia Counties (pl. 1) is primarily ponderosa pine, piñon pine, and juniper, with small areas of grama grass. Other areas have less rainfall, thus vegetation is mainly creosote bush and grama grass. Principal towns are Bayard (population 2,598) and Central (population 1,835).

The Colorado Plateau-San Juan Basin hydrogeologic setting is located in McKinley, Cibola, eastern Sandoval, and northern Catron and Socorro Counties (pl. 1). Many consolidated sedimentary aquifers in this hydrogeologic setting are separated by confining units. Many of the aquifers dip toward the center of the San Juan Basin, thus many of them become confined a short distance from the outcrop area. The Rio San Jose and Rio Puerco are the primary streams and are perennial in most of this setting. The main land uses are rangeland and forest. Uranium mining is common in the area north of Grants. Vegetation is mainly grasses, consisting of grama grass, wheatgrass, saltbush, and sacaton. Shrubs such as saltbush also are found in eastern Bernalillo and Sandoval Counties. Ponderosa pine and douglas fir grow in the mountains northeast and east of Grants. The largest cities are Grants (population 8,626) and Milan (population 1,911).

The Colorado Plateau-Chama Basin hydrogeologic setting is located in the western half of Rio Arriba County. This hydrogeologic setting is underlain by many consolidated bedrock aquifers that are separated by confining units. The Rio Chama is the primary perennial stream. Land use is mainly forest and small amounts of rangeland. Limited areas along the Rio Chama support agriculture. Vegetation is mostly ponderosa pine and douglas fir, with large areas of grasslands with mountain muhly and pine dropseed. Chama (population 1,048) is the principal town in this area. Little water-quality data are available for this hydrogeologic setting, so no statistical analyses were performed.

After a well was assigned to a hydrogeologic setting, the well was assigned to a particular land use so that the quality of water from this well could be assigned to a particular data stratum. Land use was assigned to each well sampled by determining the land use at the location of the well using GIRAS land-use data. The chemistry of water pumped from a well in a particular land-use area may be affected by different land uses upgradient from that well. For purposes of data analysis in this report, however, the land use at the location of the well was assumed to be the only land use affecting the chemistry of water pumped from that well.

When water-quality data from a particular land-use setting in the alluvial basins (as discussed in the Ground Water section) were sufficient, the data were aggregated to facilitate comparison of these data across different land-use categories. Data from different land-use settings across the entire study unit were not aggregated because of the large differences in aquifers and ground-water flow systems in the alluvial basins and bedrock basins.

Nutrients

A large amount of nutrient data are in the NWIS data base; however, different procedures were used in sample preparation (filtered versus unfiltered) and analysis. For example, some samples had been analyzed for dissolved nitrate, whereas other samples had been analyzed for total nitrite plus nitrate. Plots and regressions were done on the NWIS data to determine if total and dissolved analyses were essentially the same and to determine if different species could be combined for data analysis. On the basis of these plots and regressions, it was determined that three major groups of nutrients could be identified using the data and that combining species was reasonable. These groups are nitrate, ammonia, and orthophosphate. To combine species for a group, a fixed order of selection was done until a value was obtained; the procedure was then stopped and that value was used. Nitrate was determined with the following priority: dissolved nitrate, dissolved (nitrate + nitrite) minus dissolved nitrite, dissolved nitrate plus nitrite, total nitrate, total (nitrate + nitrite) minus total nitrite, total nitrate plus nitrite. For example, if a sample was analyzed for dissolved nitrate, no combining was done. If a sample was analyzed for only total nitrate plus nitrite, this value was then assigned as nitrate for the sample. Ammonia was determined with the following priority: dissolved ammonia, dissolved Kejldahl nitrogen minus dissolved organic nitrogen, total ammonia, total Kejldahl nitrogen minus total organic nitrogen. Orthophosphate was determined with the following priority: dissolved orthophosphate, dissolved phosphorus, total phosphorus.

Of the three groups of data (nitrate, ammonia, and orthophosphate) the group having the most sampling sites was nitrate. In the areal plots and various figures showing available data, sampling sites with nitrate analyses were used.

The NWIS data base had the largest number of sampling sites and the data were areally distributed throughout the study area (pl. 3). Data were limited to samples collected from 1945 to 1990 for rangeland and forest land use and from 1970 to 1990 for urban and agricultural land use to minimize bias caused by urban development and changes in agricultural practices.

The Albuquerque data base contains a large amount of data collected from wells in and around Albuquerque (fig. 80). In general these data were collected to determine water quality in the Albuquerque area; however, some of these data probably were collected to monitor specific areas of concern. Public-supply wells and domestic wells are included. All data in this data base were used with the exception of data collected during State-run water fairs. Data from water fairs were not included because analyses for nutrients were done using field test kits on water samples collected and brought to a central location by individual well owners. The same nutrient data groups that were identified using the NWIS data base were used for the Albuquerque data base; however, values were reported as nitrate, ammonia, and orthophosphate in this data base so no combining and selection processes were necessary.

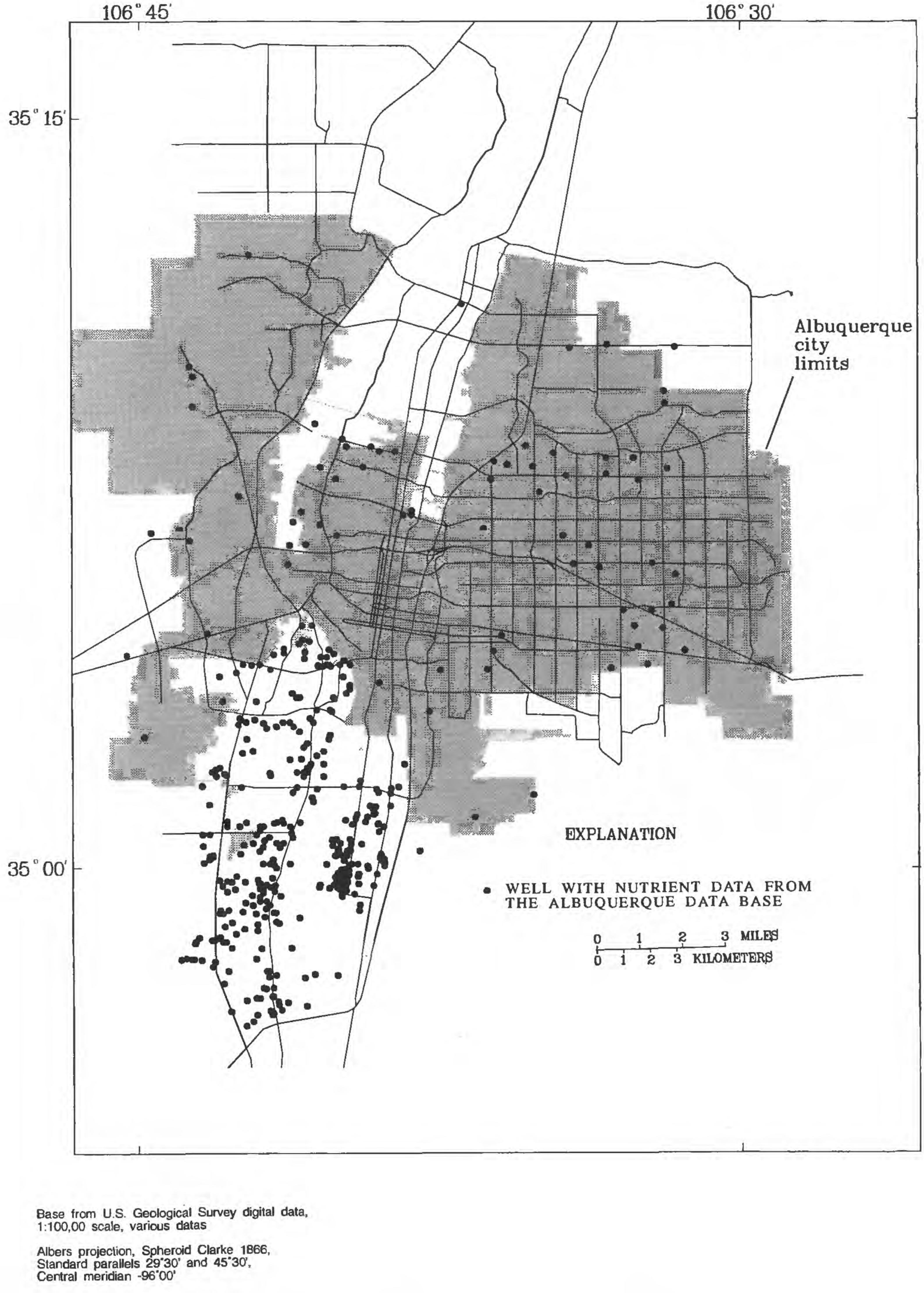


Figure 80.--Location of wells having nutrient analyses from the Albuquerque data base in the Rio Grande Valley study unit.

Nitrate

A total of 2,173 analyses contain a nitrate value in the NWIS data base. Boxplots of nitrate concentrations in water from wells in all data strata having 10 or more samples illustrate the variation across all data strata and the relative differences in the quality of water from wells in the various data strata (fig. 81). The largest median nitrate concentration was in water from wells located in the Basin and Range-mountains-urban data stratum (3.0 mg/L as N) and the smallest was found in water from wells located in the Southern Rocky Mountains-mountains-forest data stratum (0.08 mg/L) (fig. 81). Few (3 percent) nitrate concentrations in water from wells in all data strata were greater than or equal to 10 mg/L, which is the EPA MCL for drinking water. Most (82 percent) nitrate concentrations in water from wells sampled were less than or equal to 2 mg/L (fig. 81). This indicates that, for most of the study unit, nitrate concentrations are not a problem in ground water.

In the Southern Rocky Mountains-mountains hydrogeologic setting, 85 wells were sampled for nitrate concentration. Seventy-five of these wells were in the forest land-use setting and 10 were in the rangeland land-use setting (fig. 81). Median nitrate concentrations in water from wells in these two different land-use settings had no significant difference (Tukey's test on the ranks of data (Helsel and Hirsch, 1992, p. 196-202)) (table 22).

In the Southern Rocky Mountains-alluvial basins hydrogeologic setting, 318 wells were sampled for nitrate concentration, the largest number from the rangeland and agricultural land-use settings. The median nitrate concentration was largest in water from wells located in the urban land-use setting (0.66 mg/L) and smallest in the rangeland land-use setting (0.16 mg/L) (fig. 81). There was a significant difference in median nitrate concentrations in water from wells located in the agricultural and rangeland land-use settings (table 22). No significant difference was found in the median nitrate concentrations in water from wells sampled in the other land-use settings in this hydrogeologic setting.

In the Basin and Range-open alluvial basins hydrogeologic setting, 703 wells were sampled for nitrate concentration, the largest number from the rangeland land-use setting. The largest median nitrate concentration was in water from wells in the rangeland land use (0.51 mg/L) and the smallest was in water from the urban (0.11 mg/L) land-use setting (fig. 81). The median nitrate concentration in water from wells in the agricultural land-use setting was also small, with a median value of 0.13 mg/L. There was a significant difference in median nitrate concentrations in water from wells in the rangeland and urban land-use and the rangeland and the agricultural land-use settings (table 22). No significant difference was found in median nitrate concentrations in water from wells located in the other land-use settings.

In the Basin and Range-closed alluvial basins hydrogeologic setting, 264 wells were sampled for nitrate concentration, the largest number from the rangeland land-use setting. The largest median nitrate concentration was in water from wells in the rangeland land-use setting (0.95 mg/L) and the smallest was in water from wells in the forest land-use setting (0.34 mg/L) (fig. 81). No significant difference was found in median nitrate concentrations in water from wells located in these two land-use settings (table 22).

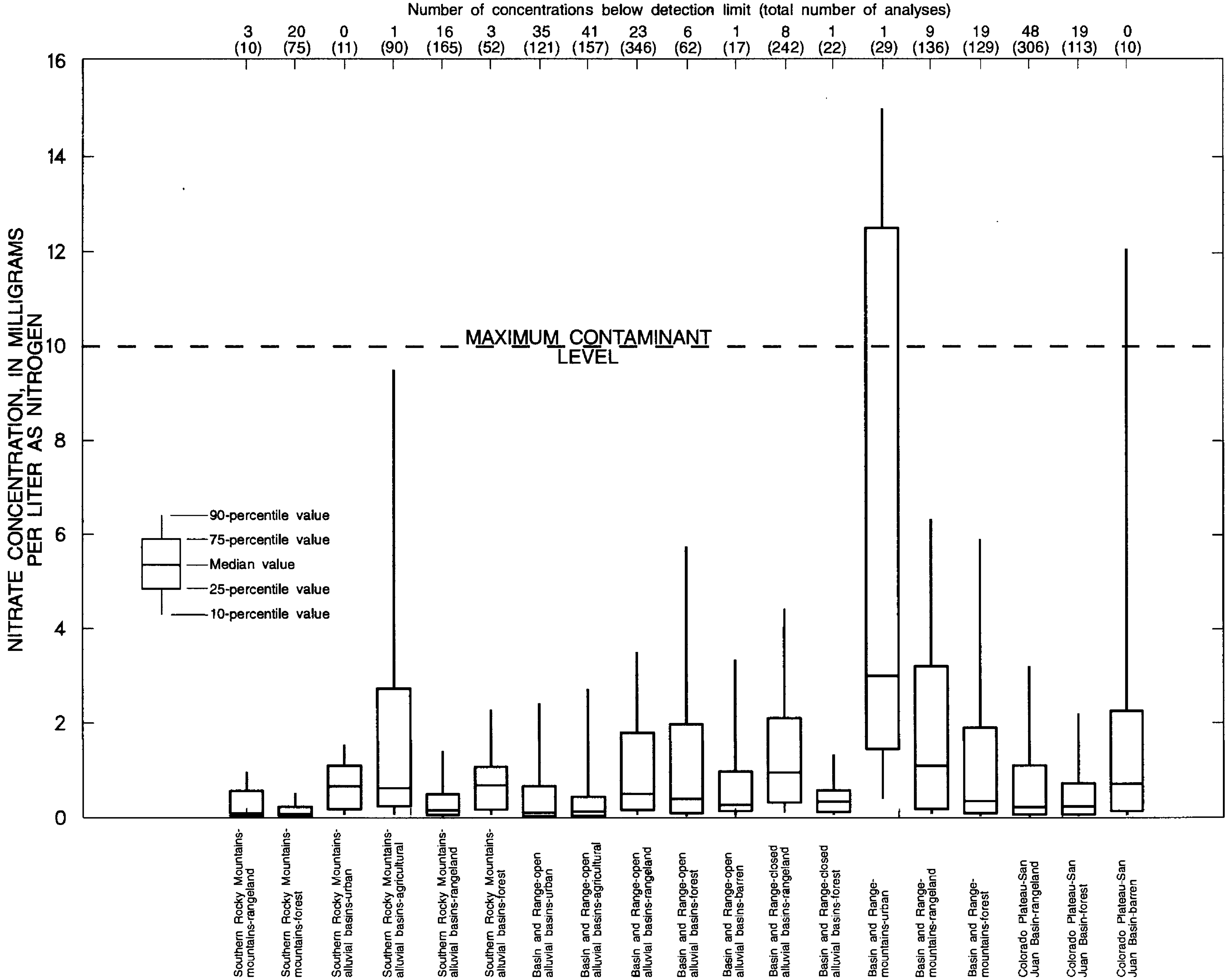


Figure 81.--Concentrations of nitrate in water from wells located in different data strata in the Rio Grande Valley study unit (U.S. Geological Survey National Water Information System data base).

Table 22.--Results of pairwise significance tests between median nitrate concentrations in water from wells located in different data strata in the Rio Grande Valley study unit (U.S. Geological Survey National Water Information System data base)

[*Strata with same letter indicate that median nitrate concentrations are not significantly different from median nitrate concentrations of strata with X in column, at the probability level of 0.05; Tukey's test on the ranks of data (Helsel and Hirsch, 1992, p. 196-202)*]

Stratum																			
Basin and Range-mountains-urban	X	B	C		E		G												
Basin and Range-mountains-rangeland	A	X	C	D	E	F	G	H	I		K	L							
Basin and Range-closed alluvial basins-rangeland	A	B	X	D	E	F	G	H	I		K	L							
Southern Rocky Mountains-alluvial basins-agricultural		B	C	X	E	F	G	H	I	J	K	L						R	
Colorado Plateau-San Juan Basin-barren	A	B	C	D	X	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Basin and Range-open alluvial basins-rangeland		B	C	D	E	X	G	H	I	J	K	L							
Southern Rocky Mountains-alluvial basins-urban	A	B	C	D	E	F	X	H	I	J	K	L	M	N	O	P	Q	R	S
Southern Rocky Mountains-alluvial basins-forest		B	C	D	E	F	G	X	I	J	K	L	M	N	O			R	
Basin and Range-open alluvial basins-forest		B	C	D	E	F	G	H	X	J	K	L	M	N	O			R	
Basin and Range-mountains-forest				D	E	F	G	H	I	X	K	L	M	N				R	
Basin and Range-open alluvial basins-barren		B	C	D	E	F	G	H	I	J	X	L	M	N	O	P	Q	R	S
Basin and Range-closed alluvial basins-forest		B	C	D	E	F	G	H	I	J	K	X	M	N	O	P	Q	R	S
Colorado Plateau-San Juan Basin-rangeland					E		G	H	I	J	K	L	X	N	O	P	Q	R	
Colorado Plateau-San Juan Basin-forest					E		G	H	I	J	K	L	M	X	O	P	Q	R	
Southern Rocky Mountains-alluvial basins-rangeland					E		G	H	I		K	L	M	N	X	P	Q	R	S
Basin and Range-open alluvial basins-agricultural					E		G				K	L	M	N	O	X	Q	R	S
Basin and Range-open alluvial basins-urban					E		G				K	L	M	N	O	P	X	R	S
Southern Rocky Mountains-mountains-rangeland				D	E	F	G	H	I	J	K	L	M	N	O	P	Q	X	S
Southern Rocky Mountains-mountains-forest					E		G				K	L			O	P	Q	R	X

In the Basin and Range-mountains hydrogeologic setting, 294 wells were sampled for nitrate concentration, the largest number of samples collected from wells in the rangeland and forest land-use settings. The largest median nitrate concentration was in water from wells located in the urban land-use setting (3.0 mg/L) and the smallest was in water from wells in the forest land-use setting (0.35 mg/L) (fig. 81). There was no significant difference in median nitrate concentrations in water from wells in the urban and rangeland land-use settings, but there was a significant difference in median nitrate concentrations in water from wells located in these two separate land-use settings and the forest land-use setting (table 22).

In the Colorado Plateau-San Juan Basin hydrogeologic setting, 429 wells were sampled for nitrate concentration, the largest number of samples collected from wells in the rangeland land-use setting. The largest median nitrate concentration was in water from wells located in the barren land-use setting (0.71 mg/L) and the smallest was in water from wells located in the rangeland and forest land-use settings (0.23 mg/L) (fig. 81). No significant difference was found in median nitrate concentrations in water from wells in these three different land-use settings (table 22).

Data for individual land uses in the hydrogeologic settings that include the alluvial basins (all hydrogeologic settings with the exception of the Colorado Plateau settings) were aggregated and summary statistics were calculated to examine the effect of land use on water quality in the alluvial basins. The largest median nitrate concentration was in water from wells located in rangeland (0.59 mg/L) and the smallest was in water from wells located in barren land-use settings (0.19 mg/L) (fig. 82). The median nitrate concentrations in water from wells in rangeland land use are significantly larger than those from wells in urban, agricultural, and forest land uses at the 0.05 significance level (table 23). Seventy-five percent of the nitrate concentrations were less than 2 mg/L in all land-use settings, with the exception of the Colorado Plateau settings. Ground water containing nitrate concentrations less than 2 mg/L probably is not significantly affected by humans, and these concentrations reflect natural nitrate concentrations.

Nitrate concentrations tend to be larger in the samples from the shallower wells for all land-use settings (fig. 83). Although there is a significant variation in the depths of wells sampled in the various land-use settings, the majority of the wells sampled have depths less than 1,000 ft. Two general groups of well depth are indicated in the urban land-use category -- less than 400 ft and greater than 400 ft (fig. 83). Shallower wells had many more samples with nitrate concentrations larger than 2 mg/L. These wells probably are located near the Rio Grande where the water table is near land surface and the effects of human activities may be affecting ground-water quality.

All wells sampled in the Albuquerque data base are located in the Basin and Range-open alluvial basins hydrogeologic setting. The data base contains 443 nitrate values for wells located in urban, agricultural, and rangeland land-use settings and 359 of these are for wells in the urban land-use setting. The largest median nitrate concentration in ground water was from wells in the rangeland land-use setting (0.491 mg/L), and the smallest was from wells in the agricultural land-use setting (0.065 mg/L) (fig. 84). There were 29 nitrate values greater than 10 mg/L for wells located in urban land use, 2 from agricultural land use, and 5 from rangeland land use. There were significant differences among median nitrate concentrations in water from wells in rangeland land use as compared to agricultural land use (table 24). This indicates that the median nitrate concentrations in water from wells located in rangeland land use are significantly (at the 0.05 level) larger than those in water from wells located in agricultural land use.

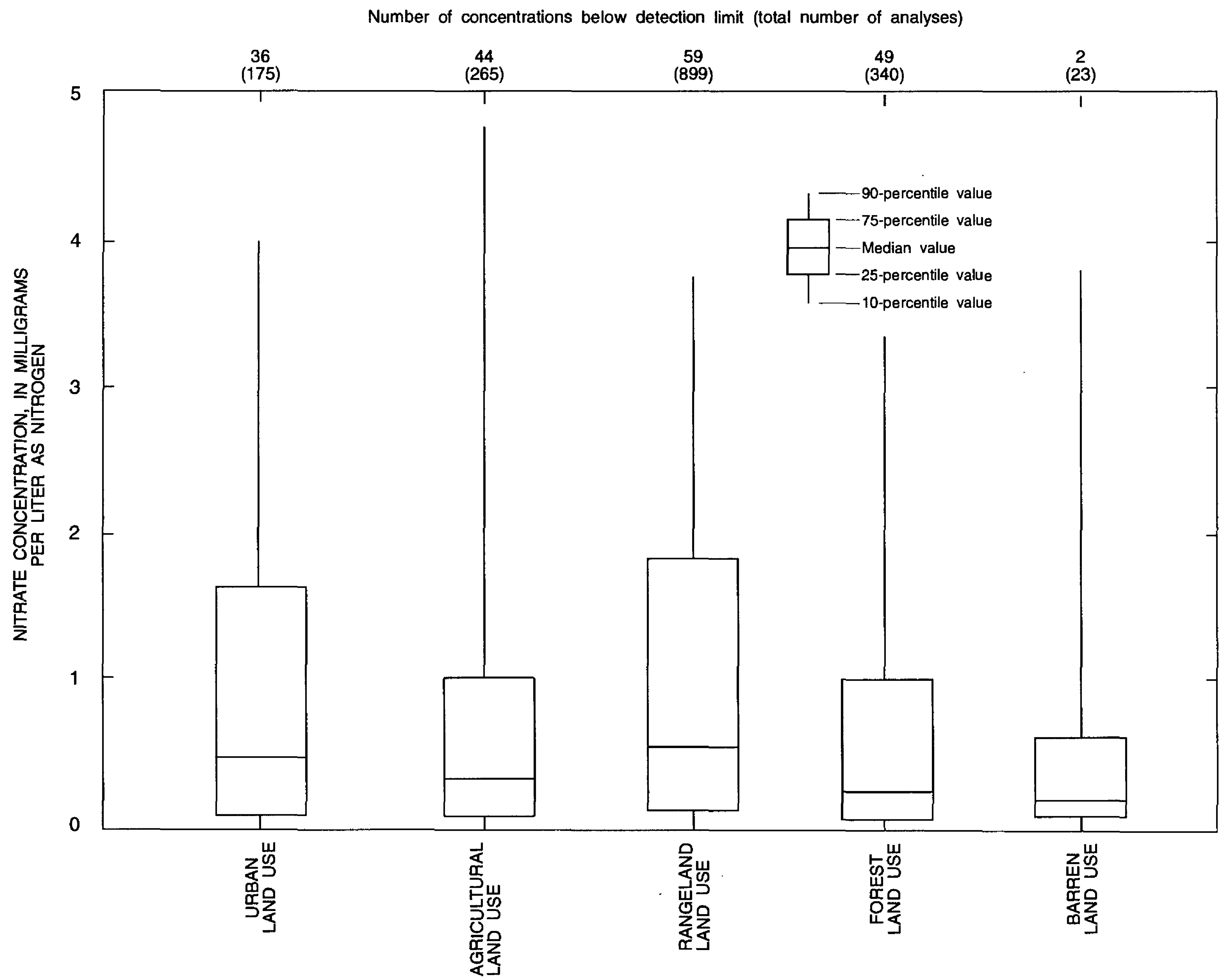


Figure 82.--Concentrations of nitrate in water from wells located in different land-use settings in the Rio Grande Valley study unit (U.S. Geological Survey National Water Information System data base).

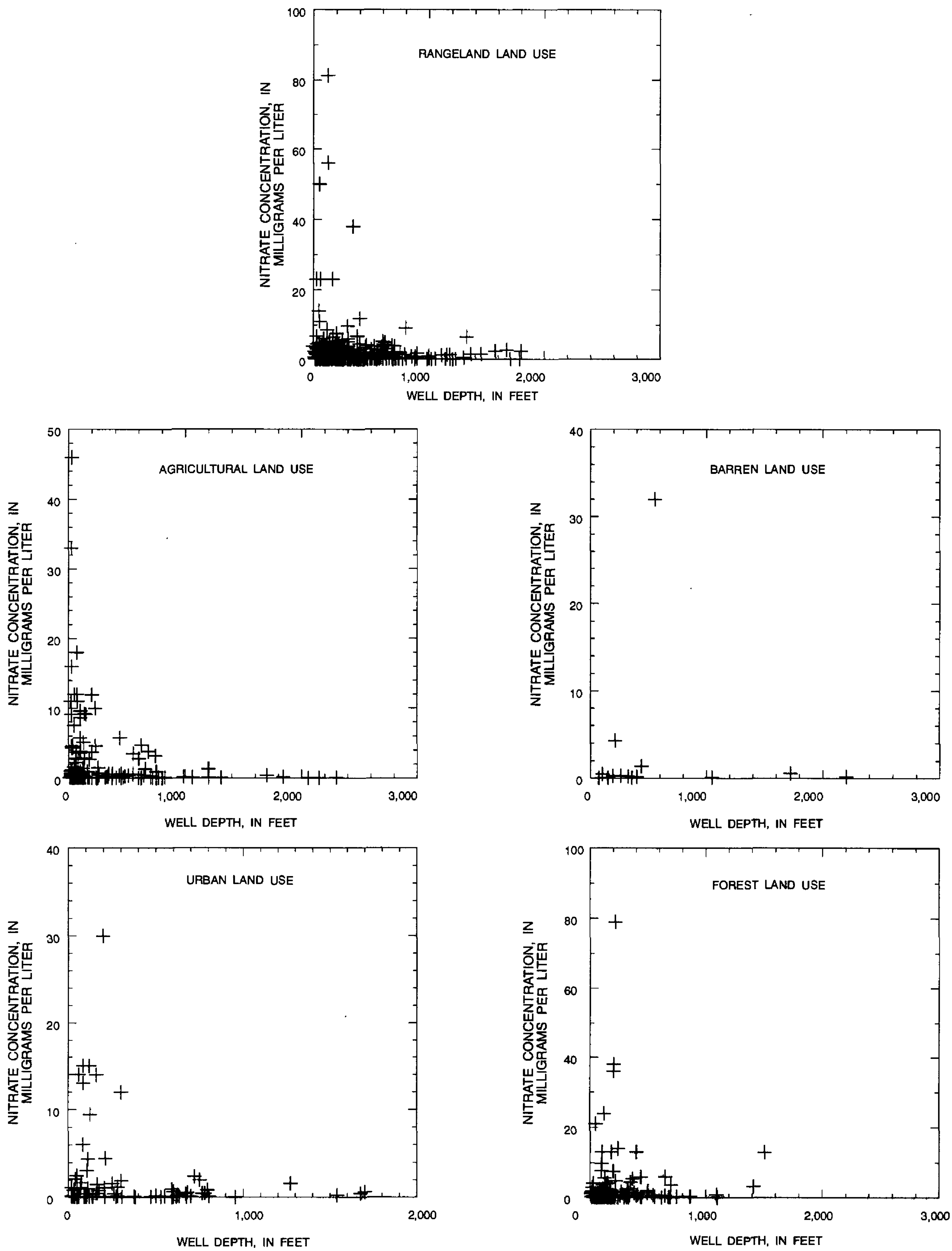


Figure 83.--Relation between nitrate concentration and well depth in wells in different land-use settings in the Rio Grande Valley study unit (U.S. Geological Survey National Water Information System data base).

Table 23.–Results of pairwise significance tests between median nitrate concentrations in water from wells located in different land-use settings in the alluvial basins in the Rio Grande Valley study unit (U.S. Geological Survey National Water Information System data base)

[Land uses with same letter indicate that median nitrate concentrations are not significantly different from median nitrate concentrations of land uses with X in column, at the probability level of 0.05; Tukey's test on the ranks of data (Helsel and Hirsch, 1992, p. 196-202)]

Land use					
Urban	X	B		D	E
Agricultural	A	X		D	E
Rangeland			X		E
Forrest	A	B		X	E
Barren	A	B	C	D	X

Table 24.--Results of pairwise significance tests between median nitrate and ammonia concentrations in water from wells located in different land-use settings in the Rio Grande Valley study unit (Albuquerque data base)

[Land uses with same letter indicate that median concentrations are not significantly different from median concentrations of land uses with X in column, at the probability level of 0.05; Tukey's test on the ranks of data (Helsel and Hirsch, 1992, p. 196-202)]

Land use			
Nitrate concentration			
Urban	X	B	C
Agricultural	A	X	
Rangeland	A		X
Ammonia concentration			
Urban	X	B	C
Agricultural	A	X	C
Rangeland	A	B	X

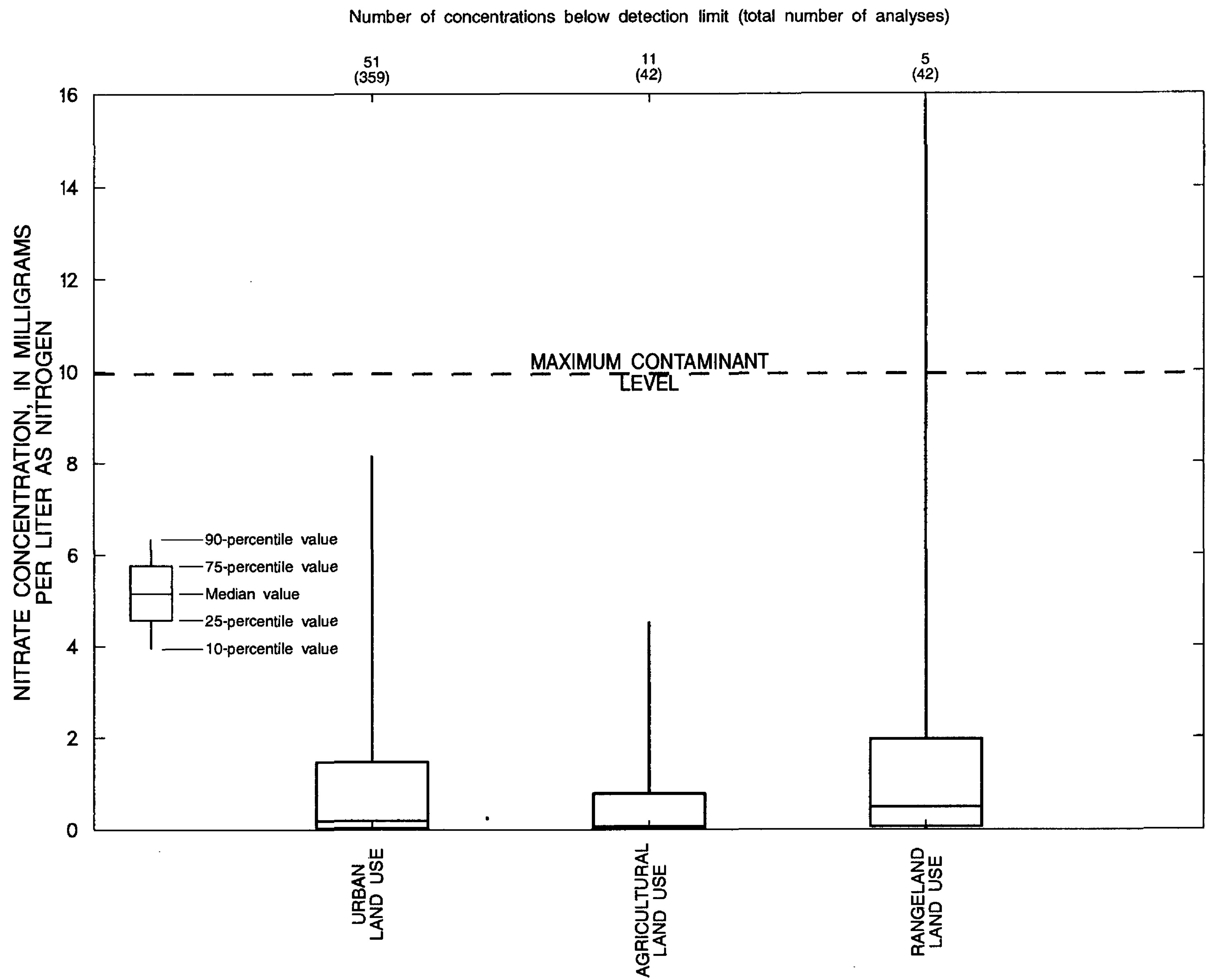


Figure 84.--Concentrations of nitrate in water from wells located in different land-use settings in the Rio Grande Valley study unit (Albuquerque data base).

In summary, the largest median nitrate concentrations were in water from wells located in the Basin and Range-mountains-urban data stratum and, with the exception of nitrate concentrations in water from wells in the urban land-use setting in this data stratum, the median nitrate concentrations were less than 2 mg/L in water from wells in all data strata. These relatively low nitrate concentrations indicate that human activities, such as agricultural practices and use of septic tanks, have not had a significant effect on nitrate concentrations throughout most of the study unit and that elevated nitrate concentrations are not a major concern throughout most of the study unit. Nitrate concentrations greater than 10 mg/L have been documented in several relatively small areas in the study unit (Titus, 1980; Edelmann and Buckles, 1984; and Gallaher and others, 1987), and these larger concentrations have been attributed to human activities such as agricultural practices and use of septic tanks. Examination of the effect of land use on nitrate concentrations in the alluvial basins (all hydrogeologic settings except those for the Colorado Plateau) indicates that the largest median nitrate concentrations in analyses in the NWIS data base were in water from wells located in the rangeland land-use setting. In the Albuquerque data base, water from wells in the rangeland land-use setting also had the greatest median nitrate concentration. Although these concentrations are relatively small (less than 1 mg/L) this does indicate that nitrate concentrations are generally larger in the rangeland land-use setting than in other areas.

Ammonia

In the NWIS data base, water from 222 wells had been sampled and analyzed for ammonia concentration, and 42 of these samples were from wells located in data strata with less than 10 samples collected; therefore, these are not shown in figure 85. The largest median ammonia concentration was in water from wells located in the Colorado Plateau-San Juan Basin-rangeland data stratum (0.27 mg/L as N) (fig. 85). None of the 15 samples collected from wells in the Southern Rocky Mountains-alluvial basins-agricultural data stratum (not shown in fig. 85) contained ammonia concentrations greater than 0.01 mg/L. With the exception of the median ammonia concentration in water from wells located in the Colorado Plateau-San Juan Basin-rangeland data stratum, median ammonia concentrations in water from wells located in all other data strata were less than or equal to 0.03 mg/L. This indicates no major areas in the study unit where elevated ammonia concentrations are a concern. There was a significant difference between the median ammonia concentration in water from wells in the Colorado Plateau-San Juan Basin-rangeland data stratum and all other data strata (table 25). Comparison of median ammonia concentrations in water from wells located in a specific hydrogeologic setting with different land-use settings indicates no significant differences with land use in the specific hydrogeologic settings (table 25).

Summary statistics calculated for different land uses in the alluvial basins (all hydrogeologic settings except Colorado Plateau) indicate that the largest median ammonia concentration was in water from wells located in the rangeland land-use setting (0.04 mg/L) and the smallest was in water from wells located in the urban and agricultural land-use settings (0.017 and 0.018 mg/L, respectively) (fig. 86). Median ammonia concentrations in water from wells located in rangeland land use are significantly larger than those in water from wells located in agricultural land use (table 26).

The Albuquerque data base, which has data from only the Basin and Range-open alluvial basins hydrogeologic setting, contains 274 ammonia values for ground water in the urban, agricultural, and rangeland land-use settings; most values are for urban land use. The largest median ammonia concentration in ground water was from wells located in the urban land-use setting (0.10 mg/L) and the smallest was from wells located in the rangeland land-use setting (0.064 mg/L) (fig. 87). There was no significant difference among the median ammonia concentrations in water from wells located in the three different land-use settings (table 24).

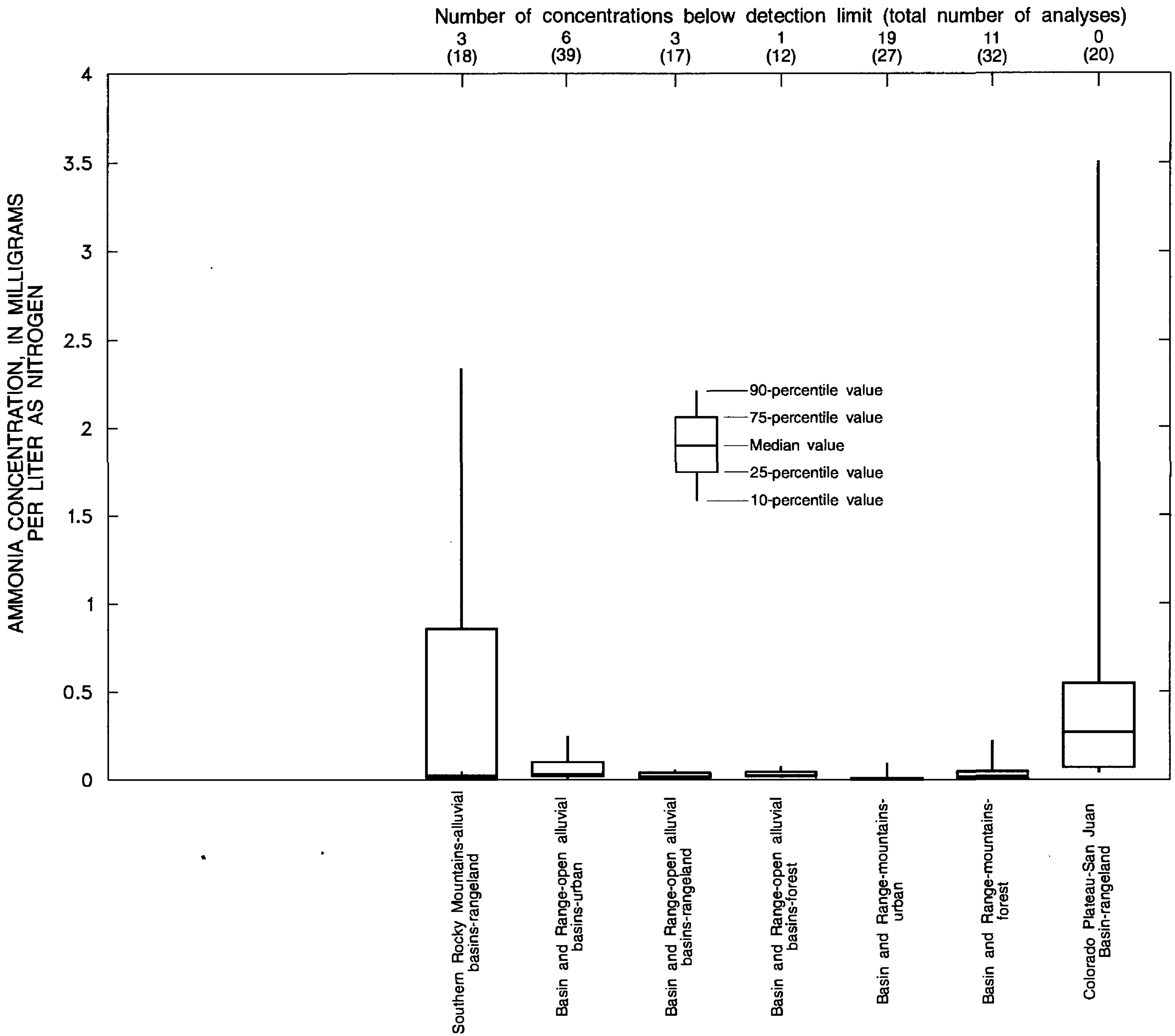


Figure 85.--Concentrations of ammonia in water from wells located in different data strata in the Rio Grande Valley study unit (U.S. Geological Survey National Water Information System data base).

Table 25.--Results of pairwise significance tests between median ammonia concentrations in water from wells located in different data strata in the Rio Grande Valley study unit (U.S. Geological Survey National Water Information System data base)

[Strata with same letter indicate that median ammonia concentrations are not significantly different from median ammonia concentrations of strata with X in column, at the probability level of 0.05; Tukey's test on the ranks of data (Helsel and Hirsch, 1992, p. 196-202)]

Stratum								
Colorado Plateau-San Juan Basin-rangeland	X							
Southern Rocky Mountains-alluvial basins-rangeland		X	C	D	E	F		
Basin and Range-open alluvial basins-urban		B	X	D	E	F		
Basin and Range-open alluvial basins-forest		B	C	X	E	F		
Basin and Range-open alluvial basins-rangeland		B	C	D	X	F	G	
Basin and Range-mountains-forest		B	C	D	E	X	G	
Basin and Range-mountains-urban					E	F	X	H
Southern Rocky Mountains-alluvial basins-agricultural							G	X

Table 26.--Results of pairwise significance tests between median ammonia concentrations in water from wells located in different land-use settings in the alluvial basins in the Rio Grande Valley study unit (U.S. Geological Survey National Water Information System data base)

[Land uses with same letter indicate that median ammonia concentrations are not significantly different from median ammonia concentrations of land uses with X in column, at the probability level of 0.05; Tukey's test on the ranks of data (Helsel and Hirsch, 1992, p. 196-202)]

Land use				
Urban	X	B	C	D
Agricultural	A	X		D
Rangeland	A		X	D
Forest	A	B	C	X

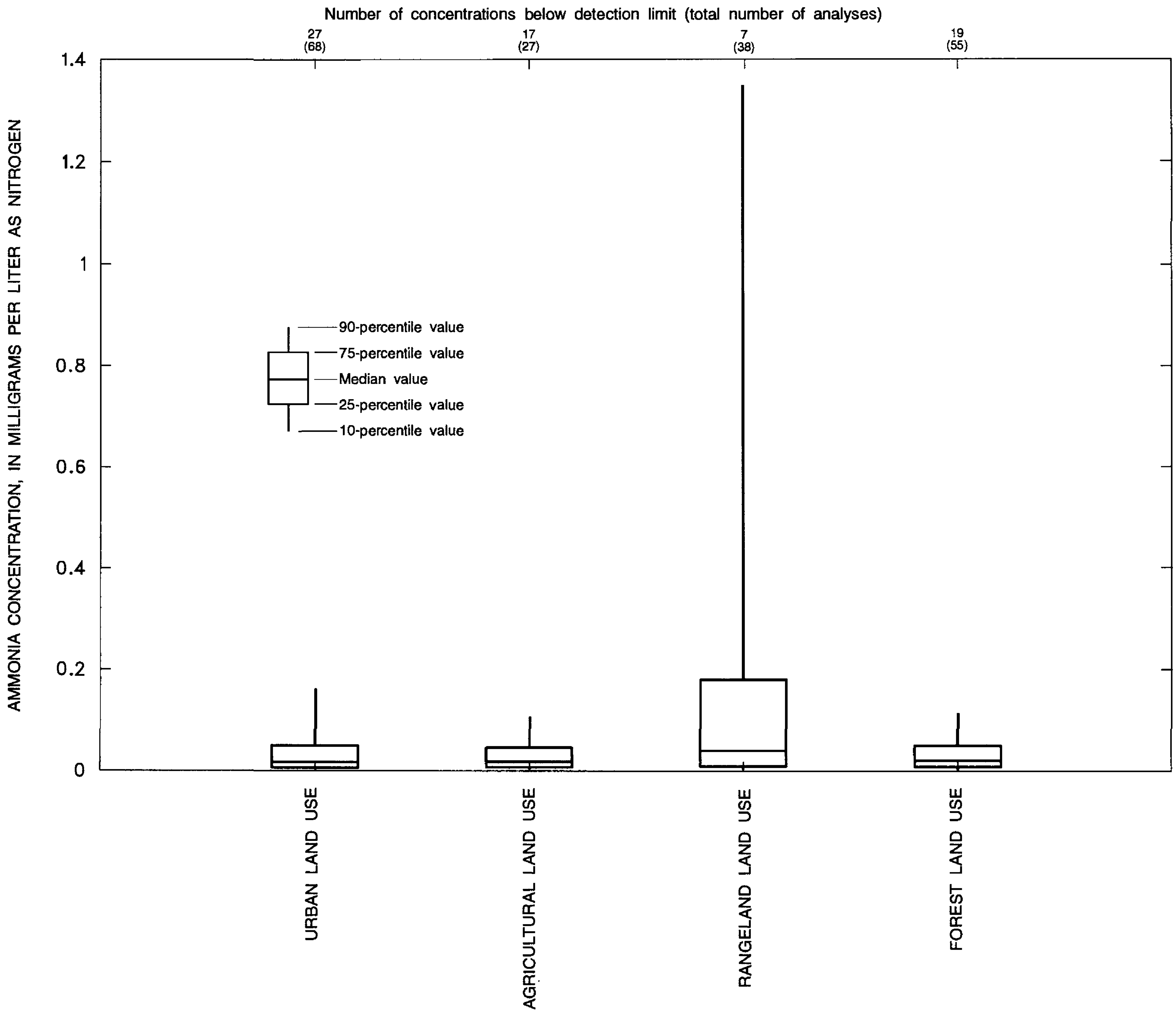


Figure 86.--Concentrations of ammonia in water from wells located in different land-use settings in the Rio Grande Valley study unit (U.S. Geological Survey National Water Information System data base).

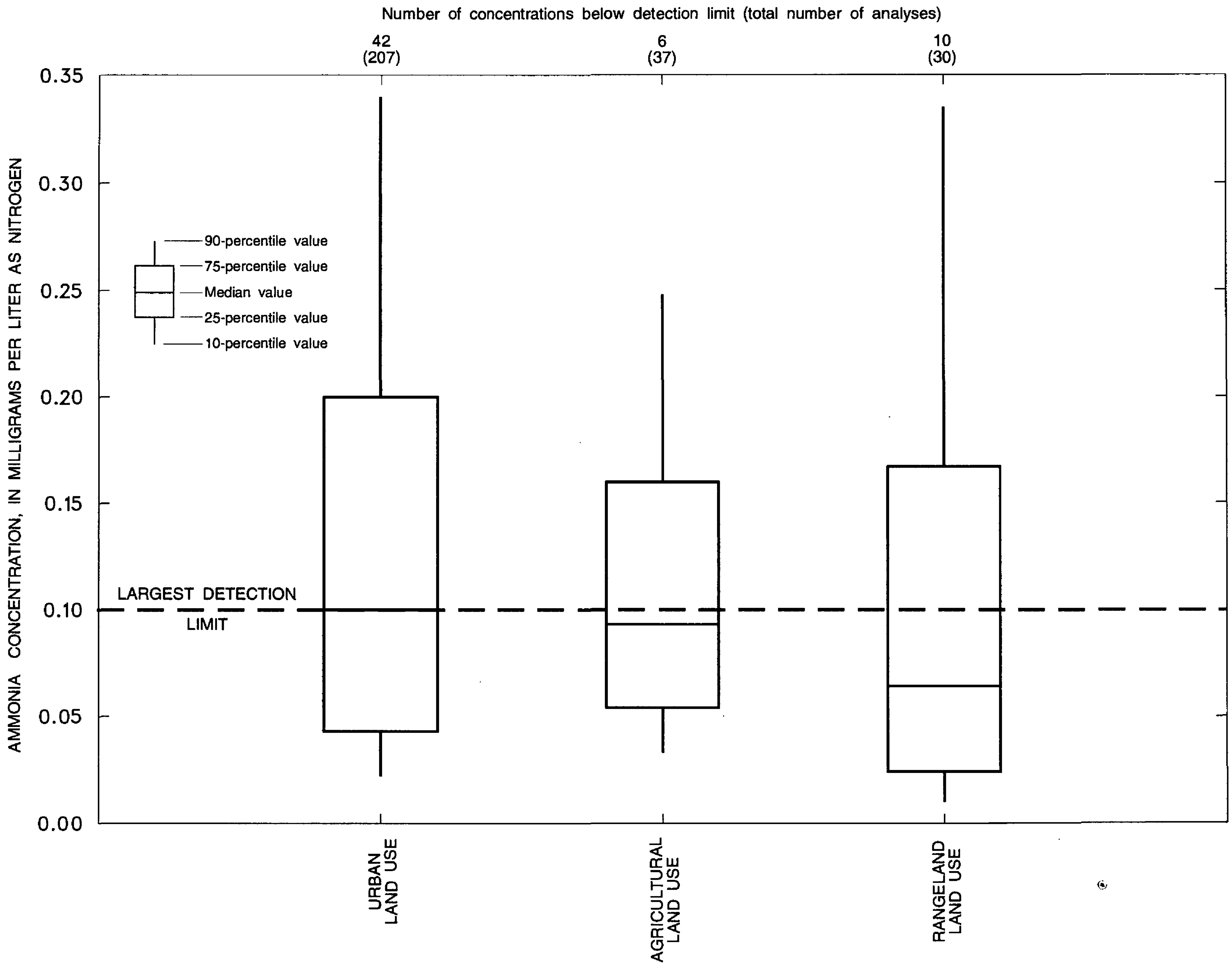


Figure 87.--Concentrations of ammonia in water from wells located in different land-use settings in the Rio Grande Valley study unit (Albuquerque data base).

Orthophosphate

In the NWIS data base, 655 analyses included orthophosphate values, 62 of which were for samples collected from wells located in data strata where less than 10 samples were collected; therefore these are not shown in figure 88. Water from wells located in the Basin and Range-open alluvial basins-urban data stratum had the largest number of analyses (95). The largest median orthophosphate concentration in ground water was in water from wells located in the Southern Rocky Mountains-mountains-forest data stratum (0.15 mg/L as orthophosphate (PO_4)) and the smallest was in water from wells located in the Basin and Range-mountains-urban data stratum (0.02 mg/L) (fig. 88). Orthophosphate concentrations in water from most of the wells sampled (85 percent) are less than 0.2 mg/L, indicating that elevated orthophosphate concentrations in ground water are not a major concern in the study unit.

In the Southern Rocky Mountains-alluvial basins setting 93 wells were sampled for orthophosphate concentration, the largest number from the rangeland land-use setting. The largest median orthophosphate concentration was in water from wells in the rangeland land-use setting (0.12 mg/L) and the smallest was in water from wells in the forest land-use setting (0.076 mg/L) (fig. 88). There was no significant difference among the median orthophosphate concentrations in water from wells located in these three land-use categories in this hydrogeologic setting (table 27).

In the Basin and Range-open alluvial basins hydrogeologic setting 258 wells were sampled for orthophosphate concentration, the largest number for the urban land-use setting. The largest median orthophosphate concentration was in water from wells in the rangeland land-use setting (0.06 mg/L) (fig. 88). However, there was no significant difference among median orthophosphate concentrations in water from wells located in any of the different land-use settings (table 27).

In the Basin and Range-closed alluvial basins hydrogeologic setting, only 24 wells were sampled for orthophosphate concentration, all in the rangeland land-use setting. The median phosphate concentration was 0.09 mg/L as orthophosphate.

In the Basin and Range-mountains hydrogeologic setting, 72 wells were sampled for orthophosphate concentration, the largest number for the forest land-use setting. The largest median orthophosphate concentration was in water from wells located in the forest land-use setting (0.03 mg/L) and the smallest was in water from wells located in the urban land-use setting (0.02 mg/L) (fig. 88). There was no significant difference in median orthophosphate concentrations in water from wells located in these two different land-use settings (table 27).

In the Colorado Plateau-San Juan Basin hydrogeologic setting, 95 wells were sampled for orthophosphate concentration, the largest number for the rangeland land-use setting. The largest median orthophosphate concentrations were in water from wells located in the rangeland land-use setting (0.043 mg/L) and the smallest was from the forest land-use setting (0.023 mg/L) (fig. 88). There was no significant difference between median orthophosphate concentrations in water from wells located in these two different land-use settings (table 27).

Summary statistics calculated for different land uses in the alluvial basins (all hydrogeologic settings except Colorado Plateau) indicate that the largest median orthophosphate concentrations were in water from wells in the rangeland land-use setting (0.09 mg/L) and the smallest were in water from wells in the urban land-use setting (0.03 mg/L) (fig. 89). The median orthophosphate concentration in water from wells in the rangeland land-use setting was significantly larger than that in water from wells in both urban and agricultural land-use settings (table 28).

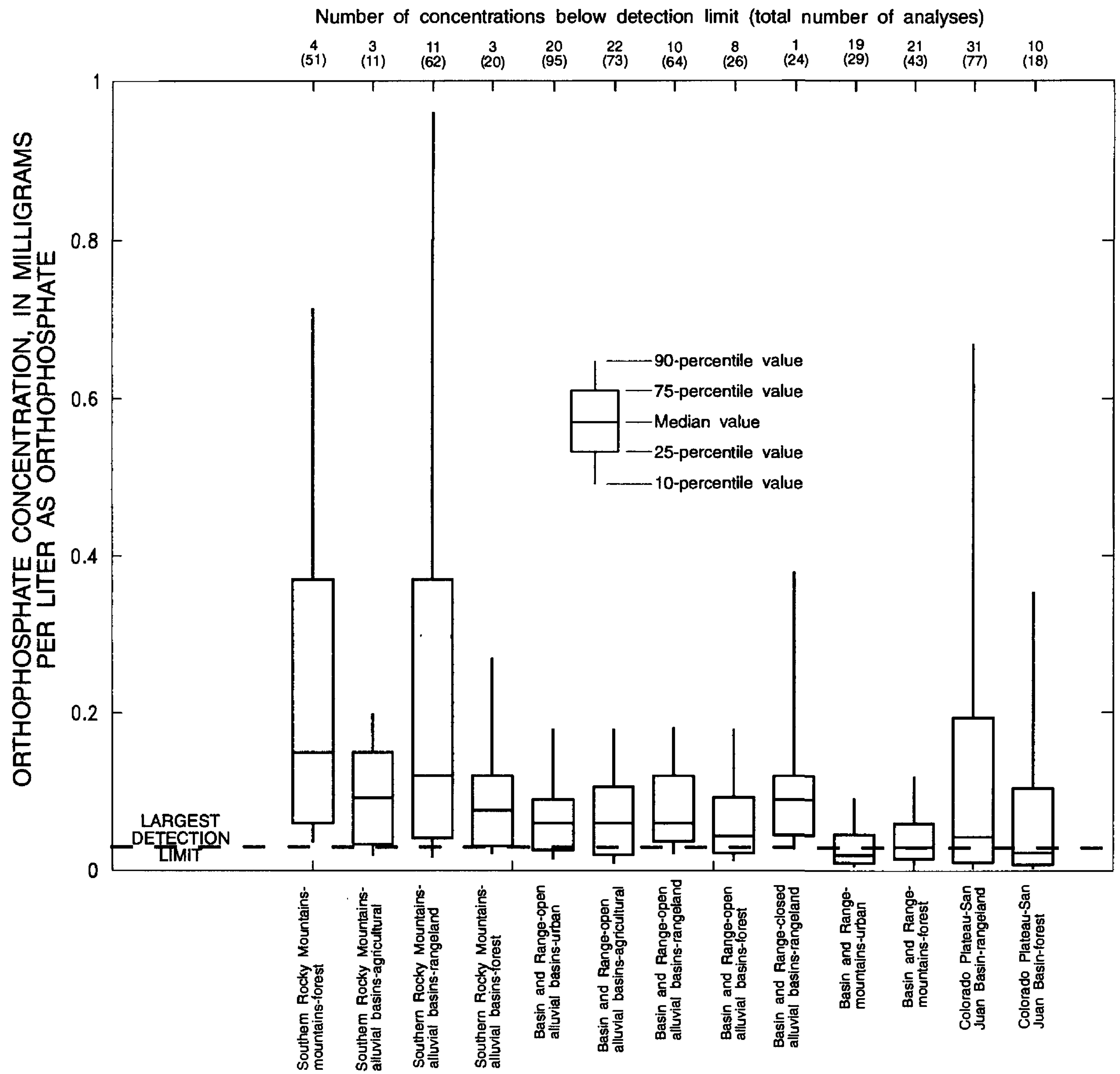


Figure 88.--Concentrations of orthophosphate in water from wells located in different data strata in the Rio Grande Valley study unit (U.S. Geological Survey National Water Information System data base).

Table 27.--Results of pairwise significance tests between median orthophosphate concentrations in water from wells located in different data strata in the Rio Grande Valley study unit (U.S. Geological Survey National Water Information System data base)

[Strata with same letter indicate that median orthophosphate concentrations are not significantly different from median orthophosphate concentrations of strata with X in column, at the probability level of 0.05; Tukey's test on the ranks of data (Helsel and Hirsch, 1992, p. 196-202)]

Stratum													
Southern Rocky Mountains-mountains-forest	X	B	C	D	E	F							
Southern Rocky Mountains-alluvial basins-rangeland	A	X	C	D	E	F							
Basin and Range-closed alluvial basins -rangeland	A	B	X	D	E	F	G	H	I	J	K		
Southern Rocky Mountains-alluvial basins-forest	A	B	C	X	E	F	G	H	I	J	K	L	
Basin and Range-open alluvial basins-rangeland	A	B	C	D	X	F	G	H	I	J	K		
Southern Rocky Mountains-alluvial basins-agricultural	A	B	C	D	E	X	G	H	I	J	K	L	M
Basin and Range-open alluvial basins-urban			C	D	E	F	X	H	I	J	K	L	
Basin and Range-open alluvial basins-agricultural			C	D	E	F	G	X	I	J	K	L	M
Colorado Plateau-San Juan Basin-rangeland			C	D	E	F	G	H	X	J	K	L	M
Basin and Range-open alluvial basins-forest			C	D	E	F	G	H	I	X	K	L	M
Colorado Plateau-San Juan Basin-forest			C	D	E	F	G	H	I	J	X	L	M
Basin and Range-mountains-forest				D		F	G	H	I	J	K	X	M
Basin and Range-mountains-urban						F		H	I	J	K	L	X

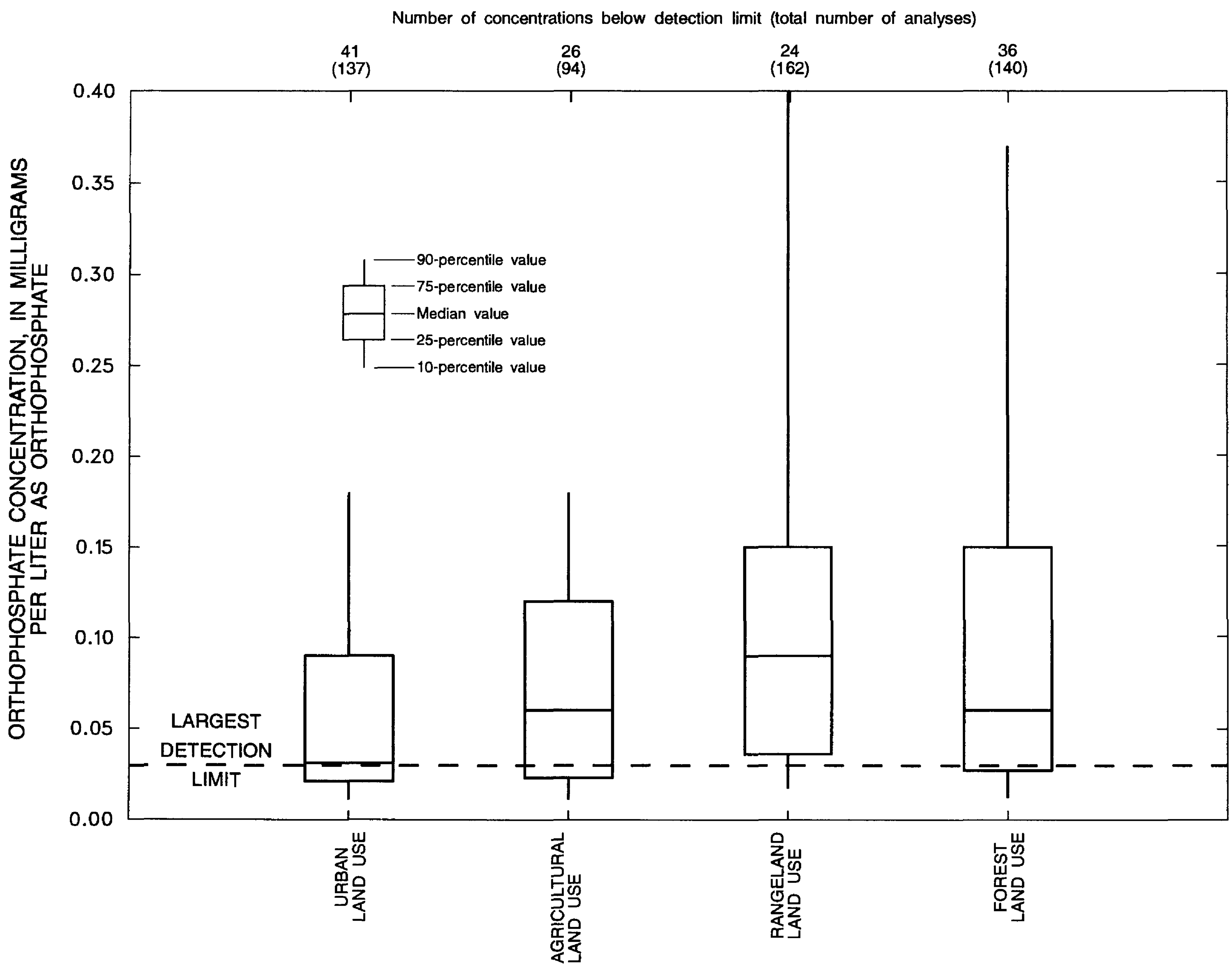


Figure 89.--Concentrations of orthophosphate in water from wells located in different land-use settings in the Rio Grande Valley study unit (U.S. Geological Survey National Water Information System data base).

Table 28.--Results of pairwise significance tests between median orthophosphate concentrations in water from wells located in different land-use settings in the alluvial basins in the Rio Grande Valley study unit (U.S. Geological Survey National Water Information System data base)

[Land uses with same letter indicate that median orthophosphate concentrations are not significantly different from median orthophosphate concentrations of land uses with X in column, at the probability level of 0.05; Tukey's test on the ranks of data (Helsel and Hirsch, 1992, p. 196-202)]

Land use				
Urban	X	B		D
Agricultural	A	X		D
Rangeland			X	D
Forest	A	B	C	X

Discussion of Nutrients

On the basis of data used in this report, nutrients in ground water in the study area do not appear to be a widespread problem. Although elevated nitrate concentrations have been documented in localized areas as discussed earlier, nitrate concentrations in ground water are generally small.

For all nutrients (nitrate, ammonia, and orthophosphate) the largest concentrations were found in water from wells in the rangeland land-use setting. The reason for this is unknown because there commonly is not a large density of cattle in these areas and the depth to water is generally larger than 100 ft. These relatively large nutrient concentrations in the rangeland land-use setting may be due to poor well construction in these areas. Wells are the only areas in the rangeland land-use setting where there are large numbers of cattle because often there are few wells and cattle come from miles away to drink at these wells. If poor or leaky sanitary seals are on these wells, animal waste could be moving down to ground water along the well annulus, which would result in relatively large nutrient concentrations. This is compounded by the fact that when a stock well is replaced, the replacement usually is constructed within a few hundred feet of the old well. Because the first stock wells were constructed many years ago, localized nutrient contamination could have occurred for a long time near wells located in rangeland land-use areas.

The relatively large nutrient concentrations also could be naturally occurring. Robertson (1991, p. C21) indicated that nitrate concentrations of natural origin ranged from 30 to 40 mg/L as NO_3 in the Vekol Valley in Arizona. The hydrogeologic setting in this area of Arizona is similar to the alluvial-basin flow systems in the study unit. Median nitrate concentrations in precipitation (wet fall only) from 1985 to 1990 at each of the five atmospheric deposition stations in or adjacent to the study unit ranged from 0.15 to 0.19 mg/L as N. Semiarid regions have many nitrogen-fixing plants and little organic matter in the unsaturated zone. Nutrients in precipitation may be concentrated by evapotranspiration and carried downward to ground water in recharge water, thus causing the relatively large nutrient concentrations. This might not be occurring in urban and agricultural land-use settings because these areas have more vegetation that would remove nutrients from the unsaturated zone, and they also have more organic matter in the soil that may result in denitrification of nitrate in the unsaturated zone.

Pesticides

Pesticide analyses were available for only 38 wells in the Rio Grande Valley study unit (NWIS data base). The number of compounds for which analyses were done varied widely among samples. The only pesticide detected in ground water was diazinon at 0.01 microgram per liter (μg/L) . A previous study of pesticides in ground water in the San Luis Valley of Colorado detected four compounds: metribuzin, EPTC, chlorothalonil, and 2,4-D (Durnford and others, 1990). Further data-collection efforts would be needed to determine if pesticides are present and widespread in ground water in the Rio Grande Valley study unit.

PESTICIDE DATA FOR BIOTA

Biological pesticide data were inadequate for in-depth analysis. The primary sources of data were the U.S. Fish and Wildlife Service (Roy and others, 1992) and the U.S. Geological Survey (Ong and others, 1991).

U.S. Fish and Wildlife Service data (table 29) are from three areas of the study unit: the upper Rio Grande (Colorado State line downstream to the confluence of the Rio Grande and Red River); the middle Rio Grande (Rio Grande from Santa Fe to Elephant Butte Reservoir, and Rio San Jose); and the lower Rio Grande (Rio Grande from Hatch to Chamberino). All upper Rio Grande analyses and some analyses from the other two areas lacked accurate locations and thus are not presented. Sample locations of the middle and lower areas are shown in figure 90. In the U.S. Fish and Wildlife study, 29 organochlorine compounds were analyzed in biota in the middle and lower areas. Only p,p'-DDE, a degradation product of DDT, was consistently detected in the three areas of the Rio Grande. Overall, in the U.S. Fish and Wildlife Service study, organochlorine compounds were not detected in 87 percent of analyses of 2,707 samples of fish. Highest levels of p,p'-DDE were found in the lower Rio Grande, and the maximum concentration was 6.30 micrograms per gram (μg/g) wet-weight in carp from the Stahman Farms site (site 16 in fig. 90). High levels of p,p'-DDE were also found at the Hatch site (site 13 in fig. 90) in the Western kingbird, which contained 5.10 μg/g wet-weight (table 29).

U.S. Geological Survey data (Ong and others, 1991) for birds, fish, and plants were collected at the Bosque del Apache National Wildlife Refuge (fig. 91). For 25 organochlorine compounds, no detectable concentrations were found in plants, which included bullrush, curlyleaf pondweed, coontale, and sedge. Detectable levels of p,p'-DDE were found in coot and carp, with a maximum concentration of 0.12 μg/g wet-weight found in coot (table 30). Other compounds were detected in black-necked stilt, threadfin shad, brown bullhead, and eggs from three species of birds (table 31).

Table 29.--Organochlorine residues in biota samples from two areas in the Rio Grande Valley study unit

[Data from Roy and others (1992). Concentrations are in micrograms per gram wet-weight. Lower levels of detections are 0.05 for toxaphene and PCB's, and 0.01 for other organochlorine compounds; --, not analyzed; nd, constituent not detected at above limits. Sample locations shown in figs. 90 and 91]

Species	Sample location	Composite amount	Moisture (%)	Lipid (%)	Heptachlor epoxide	PCB, total	p,p'-DDE	o,p'-DDD	p,p'-DDT	HCB	A-BHC	R-BHC	B-BHC	S-BHC
Coot	Unit 15B	3	72.0	2.27	nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd
Coot	Unit 25A	7	69.0	7.81	nd	nd	0.02	nd	nd	nd	nd	nd	nd	nd
Coot	Unit 18BE	2	64.0	10.90	nd	nd	0.12	nd	nd	nd	nd	nd	nd	nd
Coot	Elephant Butte	10	71.0	4.71	nd	nd	0.04	nd	nd	nd	nd	nd	nd	nd
Coot	Rio San Jose/Acoma	10	70.2	5.76	nd	nd	0.02	nd	nd	nd	nd	nd	nd	nd
Coot	La Joya	1	69.4	9.08	nd	0.32	0.06	nd	nd	nd	nd	nd	nd	nd
Coot	Madrone	10	70.0	9.40	nd	nd	0.04	nd	nd	nd	nd	nd	nd	nd
Coot	Isleta Marsh	9	67.8	11.30	nd	nd	0.02	nd	nd	nd	nd	nd	nd	nd
Coot	Santa Fe Marsh	5	66.6	8.14	nd	nd	0.09	nd	nd	nd	nd	nd	nd	nd
Western kingbird	Elephant Butte	10	70.0	4.48	nd	nd	0.14	nd	nd	nd	nd	nd	nd	nd
Western kingbird	Rio San Jose/Acoma	10	66.6	4.96	nd	nd	0.26	nd	nd	nd	nd	nd	nd	nd
Western kingbird	Rio Puerco-San Jose	10	69.6	4.60	nd	nd	0.08	nd	nd	nd	nd	nd	nd	nd
Western kingbird	La Joya	9	69.0	5.09	nd	nd	1.70	nd	nd	nd	nd	nd	nd	nd
Western kingbird	Belen-Madrone	10	65.0	7.92	0.02	nd	0.24	nd	nd	nd	nd	nd	nd	nd
Western kingbird	Alb-Isleta Pueblo	10	66.6	7.12	0.01	nd	0.17	nd	nd	nd	nd	nd	nd	nd
Western kingbird	Cochiti Pueblo	10	69.2	3.19	nd	nd	0.66	nd	nd	nd	nd	nd	nd	nd
Ruddy duck	La Joya	2	58.4	14.50	nd	nd	3.50	0.02	0.05	nd	nd	nd	nd	nd
Flycatcher	Belen-Madrone	1	63.5	4.68	nd	nd	0.06	nd	nd	nd	nd	nd	nd	nd
Carp	Riverside Drain	10	75.8	1.86	nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd
Carp	Unit 18BE	10	72.4	6.23	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Carp	Unit 25A	10	78.4	1.20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Carp	Elephant Butte	6	73.2	4.79	nd	0.07	0.02	nd	nd	nd	nd	nd	nd	nd
Carp	La Joya	10	78.0	1.32	nd	0.10	0.01	0.02	nd	nd	nd	nd	nd	nd
Carp	Madrone Pond	10	78.6	0.66	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Carp	Albuquerque Riverside Drain	10	72.0	0.60	nd	0.20	0.04	0.02	nd	nd	nd	nd	nd	nd
Carp	Cochiti Reservoir	8	76.0	4.38	nd	nd	0.02	nd	nd	nd	nd	nd	nd	nd
Carp	Morgan Lake	10	75.0	1.45	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Rio Grande sucker	Rio San Jose/Acoma	3	61.0	7.92	nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd
Rio Grande sucker	Albuquerque Riverside Drain	12	73.8	6.36	nd	0.41	0.15	0.04	nd	nd	nd	nd	nd	nd
Rio Grande sucker	Cochiti Reservoir	9	74.0	4.84	nd	nd	0.04	0.01	nd	nd	nd	nd	nd	nd
Threadfin shad	Elephant Butte	10	76.4	2.79	nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd
Threadfin shad	Madrone Pond	10	71.0	8.76	nd	nd	0.06	0.01	nd	nd	nd	nd	nd	nd
Channel catfish	La Joya	10	74.4	5.54	nd	0.48	0.06	0.03	nd	nd	nd	nd	nd	nd
Channel catfish	Cochiti Reservoir	10	67.8	14.50	nd	nd	0.10	0.03	0.02	nd	nd	nd	nd	nd
Yellow bullhead	Unit 25A	10	77.4	2.25	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cyprinidae	Unit 18BE	1	76.0	2.73	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Table 29.--Organochlorine residues in biota samples from two areas in the Rio Grande Valley study unit--Continued

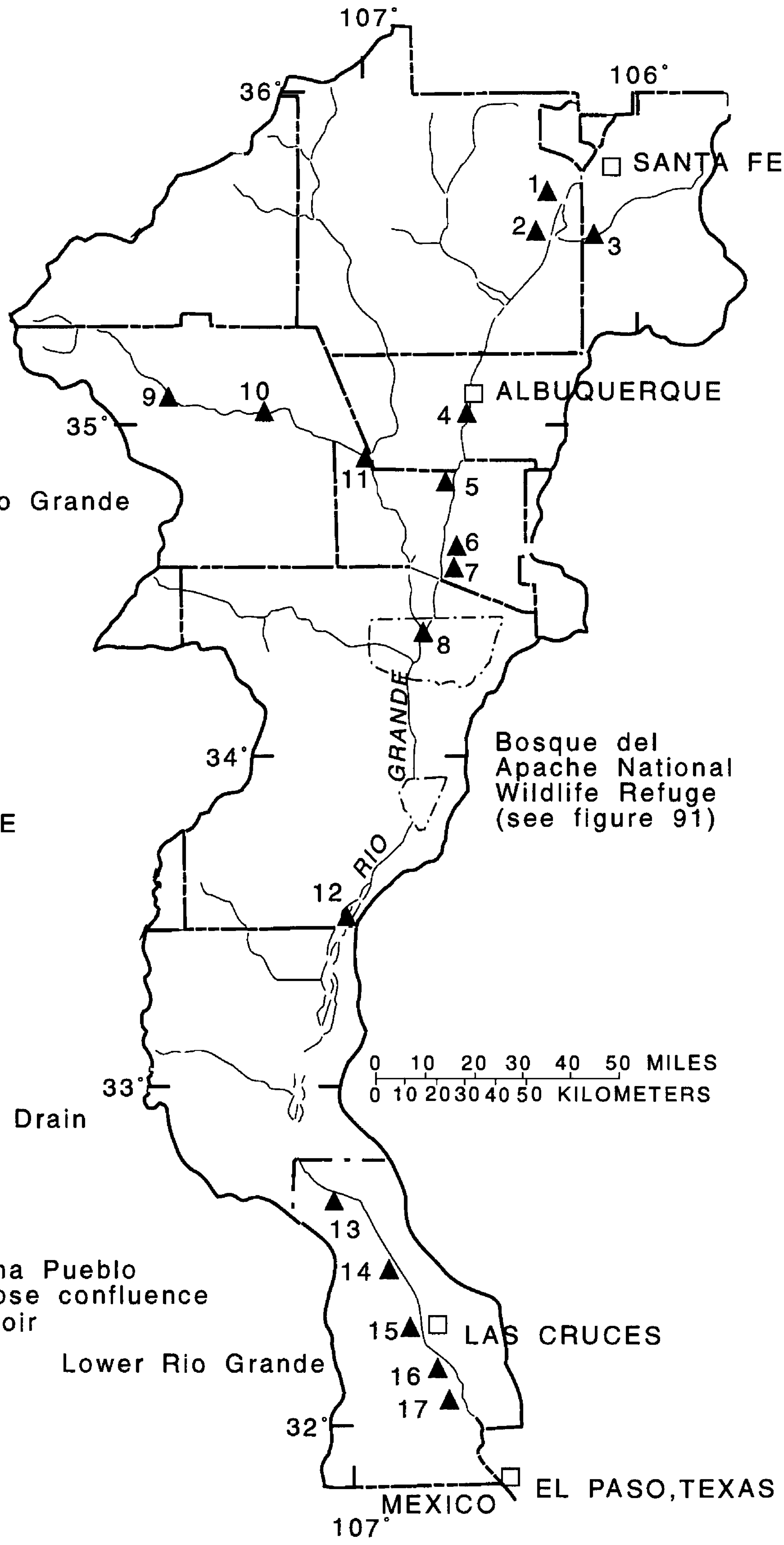
Species	Sample location	Oxy-chlor-dane	R-chlor-dane	T-nona-chlor	Toxa-phene	o,p'-DDE	A-chlor-dane	Diel-drin	En-drin	Cis-nona-chlor	o,p'-DDT	p,p'-DDD	Mirex	Dac-thal
Coot	Unit 15B	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Coot	Unit 25A	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Coot	Unit 18BE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Coot	Elephant Butte	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Coot	Rio San Jose/Acoma	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Coot	La Joya	0.03	nd	nd	nd	nd	nd	0.01	nd	nd	nd	--	nd	nd
Coot	Madrone	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Coot	Isleta Marsh	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Coot	Santa Fe Marsh	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Western kingbird	Elephant Butte	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Western kingbird	Rio San Jose/Acoma	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Western kingbird	Rio Puerco-San Jose	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Western kingbird	La Joya	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Western kingbird	Belen-Madrone	0.07	nd	0.06	nd	nd	nd	0.02	nd	nd	nd	--	nd	nd
Western kingbird	Alb-Isleta Pueblo	0.01	nd	0.01	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Western kingbird	Cochiti Pueblo	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Ruddy duck	La Joya	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Flycatcher	Belen-Madrone	0.02	nd	0.01	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Carp	Riverside Drain	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Carp	Unit 18BE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Carp	Unit 25A	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Carp	Elephant Butte	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Carp	La Joya	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Carp	Madrone Pond	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Carp	Albuquerque Riverside Drain	nd	nd	0.03	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Carp	Cochiti Reservoir	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Carp	Morgan Lake	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Rio Grande sucker	Rio San Jose/Acoma	nd	nd	nd	nd	nd	nd	0.01	nd	nd	nd	--	nd	nd
Rio Grande sucker	Albuquerque Riverside Drain	0.01	nd	0.04	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Rio Grande sucker	Cochiti Reservoir	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Threadfin shad	Elephant Butte	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Threadfin shad	Madrone Pond	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Channel catfish	La Joya	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Channel catfish	Cochiti Reservoir	nd	nd	0.02	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Yellow bullhead	Unit 25A	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Cyprinidae	Unit 18BE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd

Table 29.--Organochlorine residues in biota samples from two areas in the Rio Grande Valley study unit--Continued

Species	Sample location	Composite amount	Moisture (%)	Lipid (%)	Heptachlor epoxide	PCB, total	p,p'-DDE	o,p'-DDD	p,p'-DDT	HCB	A-BHC	R-BHC	B-BHC	S-BHC
Black crappie	Cochiti Reservoir	12	71.4	8.37	nd	nd	0.07	0.02	0.02	nd	nd	nd	nd	nd
Green sunfish	Unit 25A	10	75.2	0.57	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Red shiner	Rio San Jose	2	73.6	7.14	nd	nd	0.02	nd	nd	nd	nd	nd	nd	nd
Crayfish	Rio San Jose	4	71.0	2.12	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pondweed	Unit 18BE	2	91.4	0.08	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Western kingbird	Hatch	7	69.7	5.68	0.01	nd	5.10	nd	0.01	nd	nd	nd	0.03	nd
Western kingbird	Radium Springs	7	71.8	4.12	nd	nd	1.40	nd	nd	nd	nd	nd	nd	nd
Western kingbird	West Las Cruces	7	72.7	4.15	nd	nd	2.40	nd	nd	nd	nd	nd	0.06	nd
Western kingbird	Stahman Farms	7	70.3	4.02	nd	nd	3.80	nd	nd	nd	nd	nd	nd	nd
Western kingbird	Chamberino	7	67.6	6.63	nd	nd	2.10	nd	nd	nd	nd	nd	nd	nd
Mouse	Hatch	20	70.1	3.70	nd	nd	0.13	nd	nd	nd	nd	nd	nd	nd
Mouse	Radium Springs	7	70.9	3.78	nd	nd	0.03	nd	nd	nd	nd	nd	nd	nd
Mouse	West Las Cruces	7	71.2	3.51	nd	nd	0.02	nd	nd	nd	nd	nd	nd	nd
Mouse	Stahman Farms	12	70.6	3.21	nd	nd	0.06	nd	nd	nd	nd	nd	nd	nd
Mouse	Chamberino	7	70.6	2.34	nd	nd	0.08	nd	nd	nd	nd	nd	nd	nd
Lizard	Hatch	8	69.7	5.38	0.01	nd	0.07	nd	nd	nd	nd	nd	nd	nd
Lizard	Radium Springs	8	70.3	4.53	nd	nd	0.02	nd	nd	nd	nd	nd	nd	nd
Lizard	West Las Cruces	8	67.3	5.98	nd	nd	0.14	nd	nd	nd	nd	nd	nd	nd
Lizard	Stahman Farms	7	69.5	4.58	nd	nd	0.03	nd	nd	nd	nd	nd	nd	nd
Lizard	Chamberino	7	68.5	5.88	nd	nd	0.03	nd	nd	nd	nd	nd	nd	nd
Black bullhead/ channel catfish	Hatch	10	74.6	6.15	0.02	nd	0.69	nd	0.01	nd	nd	nd	nd	nd
Channel catfish	Radium Springs	6	75.2	2.74	nd	nd	0.26	nd	nd	nd	nd	nd	nd	nd
Channel catfish	West Las Cruces	5	74.2	5.40	0.03	nd	1.20	nd	0.01	nd	nd	nd	nd	nd
Black bullhead/ channel catfish	Stahman Farms	7	74.0	6.02	nd	nd	1.20	nd	0.05	nd	nd	nd	nd	nd
Channel catfish	Chamberino	6	72.4	5.97	nd	nd	3.00	0.04	0.04	nd	nd	nd	nd	nd
Carp	Hatch	6	73.8	5.52	nd	nd	0.38	nd	0.01	nd	nd	nd	nd	nd
Carp	Radium Springs	7	72.2	4.14	nd	nd	1.50	nd	0.04	nd	nd	nd	nd	nd
Carp	West Las Cruces	8	74.4	5.36	nd	nd	1.30	nd	0.01	nd	nd	nd	nd	nd
Carp	Stahman Farms	4	68.0	11.00	nd	nd	6.30	0.09	0.05	nd	nd	nd	nd	nd
Carp	Chamberino	6	71.2	6.81	nd	nd	0.45	nd	nd	nd	nd	nd	nd	nd

Table 29.--Organochlorine residues in biota samples from two areas in the Rio Grande Valley study unit--Concluded

Species	Sample location	Oxy-chlor-dane	R-chlor-dane	T-nona-chlor	Toxa-phene	o,p'-DDE	A-chlor-dane	Diel-drin	En-drin	Cis-nona-chlor	o,p'-DDT	p,p'-DDD	Mirex	Dac-thal
Black crappie	Cochiti Reservoir	nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Green sunfish	Unit 25A	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Red shiner	Rio San Jose	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Crayfish	Rio San Jose	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Pondweed	Unit 18BE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	nd	nd
Western kingbird	Hatch	0.03	nd	0.03	nd	nd	nd	nd	nd	nd	nd	0.01	nd	nd
Western kingbird	Radium Springs	0.01	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Western kingbird	West Las Cruces	0.01	nd	0.01	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Western kingbird	Stahman Farms	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Western kingbird	Chamberino	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Mouse	Hatch	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Mouse	Radium Springs	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Mouse	West Las Cruces	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Mouse	Stahman Farms	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Mouse	Chamberino	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Lizard	Hatch	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Lizard	Radium Springs	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Lizard	West Las Cruces	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Lizard	Stahman Farms	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Lizard	Chamberino	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Black bullhead/ channel catfish	Hatch	nd	nd	0.02	nd	nd	nd	nd	nd	nd	nd	0.06	nd	nd
Channel catfish	Radium Springs	nd	nd	0.01	nd	nd	nd	nd	nd	nd	nd	0.02	nd	nd
Channel catfish	West Las Cruces	nd	nd	nd	nd	0.02	nd	nd	nd	nd	nd	0.09	nd	0.14
Black bullhead/ channel catfish	Stahman Farms	nd	nd	nd	nd	0.02	nd	nd	nd	nd	nd	0.10	nd	nd
Channel catfish	Chamberino	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.27	nd	0.14
Carp	Hatch	nd	nd	0.02	nd	nd	nd	nd	nd	nd	nd	0.05	nd	0.01
Carp	Radium Springs	nd	nd	nd	nd	0.02	nd	nd	nd	nd	nd	0.10	nd	nd
Carp	West Las Cruces	nd	nd	nd	nd	0.02	nd	nd	nd	nd	nd	0.09	nd	0.07
Carp	Stahman Farms	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.47	nd	0.01
Carp	Chamberino	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.05	nd	nd



EXPLANATION

▲[1] SAMPLING SITE AND NUMBER

MIDDLE RIO GRANDE SAMPLING SITES

1. Cochiti Reservoir
2. Cochiti Pueblo
3. Santa Fe Marsh
4. Albuquerque Riverside Drain
5. Isleta Marsh
6. Belen-Madrone
7. Madrone Ponds
8. La Joya
9. Rio San Jose
10. Rio San Jose at Acoma Pueblo
11. Rio Puerco/Rio San Jose confluence
12. Elephant Butte Reservoir

LOWER RIO GRANDE SAMPLING SITES

13. Hatch
14. Radium Springs
15. West Las Cruces
16. Stahman Farms
17. Chamberino

Figure 90.--U.S. Fish and Wildlife Service biological sampling sites in the Rio Grande Valley study unit.

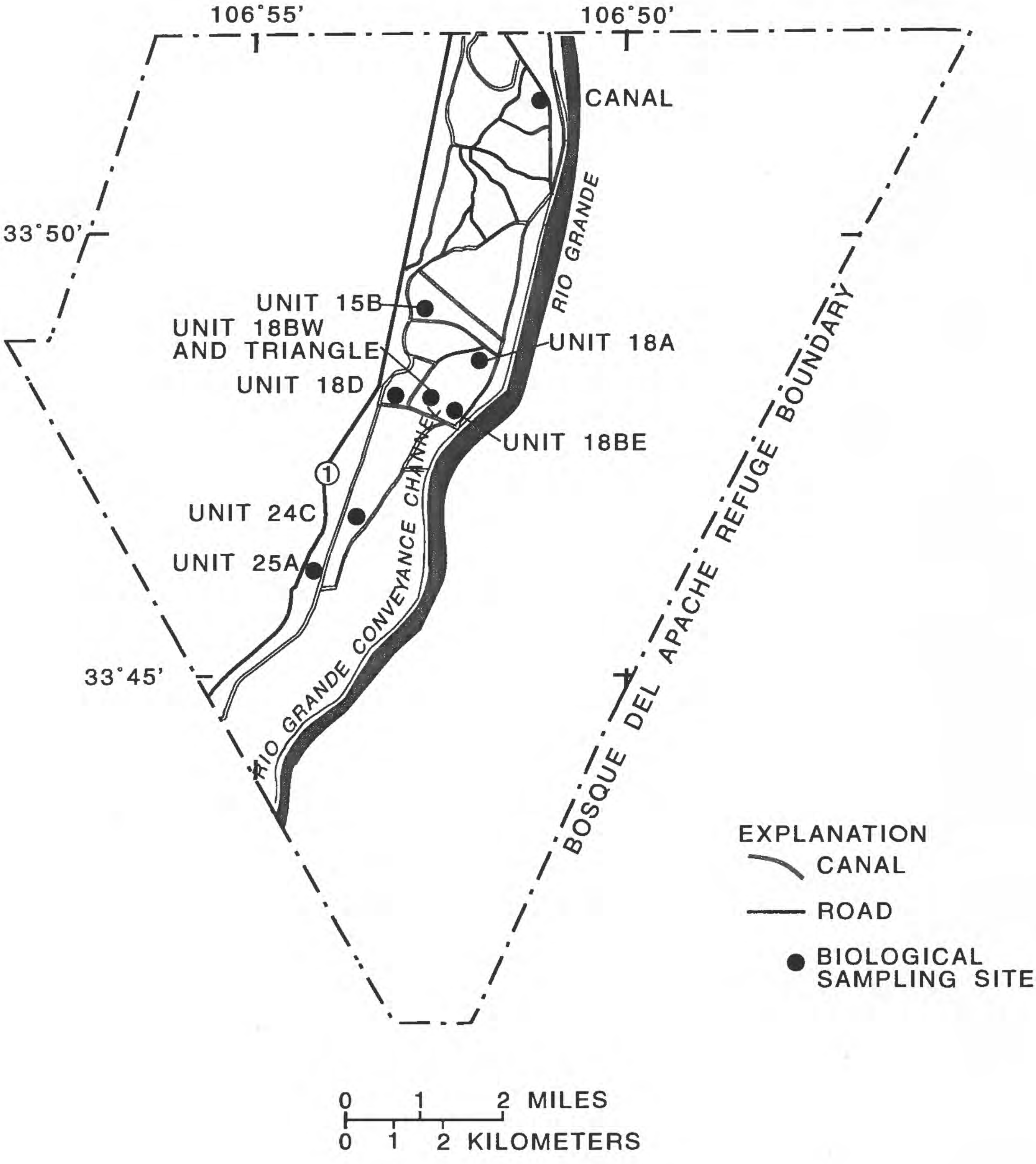


Figure 91.--Biological sampling sites in the Bosque del Apache National Wildlife Refuge (from Ong and others, 1991).

Table 30.--Organochlorine residues in birds and fish collected from the Bosque del Apache National Wildlife Refuge, 1986

[Results in micrograms per gram wet-weight and dry-weight; ND, not detected; data from Ong and others (1991)]

Organochlorine compound	Collection site[1] (biological sample)														
	18BE (coot)		18BW (coot)		18D (coot)		24C (coot)		18BE (carp)		25A (carp)	Canal (minnow carp)	Bosque del Apache National Wildlife Refuge (carp)	25A (brown bullhead)	25A (green sunfish)
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Dry	Dry	Dry	Dry	Dry
HCB	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
BHC (total)	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
Alpha-BHC	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
Gamma-BHC	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
Beta-BHC	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
Delta-BHC	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
Oxychlordane	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
Heptachlor epoxide	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
Gamma-chlordane	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
Trans-nonachlor	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
Toxaphene	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
PCB's (total)	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
o,p'-DDE	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
Gamma-chlordane	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
p,p'-DDE	0.003	0.01	0.003	0.01	0.006	0.02	0.04	0.12	0.002	0.01	ND	ND	ND	ND	ND
Dieldrin	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
o,p'-DDD	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
Endrin	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
cis-nonachlor	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
o,p'-DDT	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
p,p'-DDD	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
p,p'-DDT	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
Mirex	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
Dacthal	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
Dicofol	--	ND	--	ND	--	ND	--	ND	--	ND	ND	ND	ND	ND	ND
Moisture content (percent)		72.0		68.4		69.0		64.0		75.8	72.4	76.0	78.4	77.4	75.2

[1]Locations shown in figure 91.

Table 31.--Organochlorine residues in biological samples collected from the Bosque del Apache National Wildlife Refuge, 1988

[Results in micrograms per gram wet-weight; ND, not detected; data from Ong and others (1991)]

Collection site (fig. 91)	Sample	Oxy-chlor-dane	p,p'-DDE	p,p'-DDD	p,p'-DDT	Total PCB homologs	PCB (CL-5)	PCB (CL-7)	PCB (CL-8)
18A, 18BE, triangle	Black-necked stilt (adult)[1]	ND	2.49	0.10	0.08	2.67	ND	0.20	0.18
18BW	Black-necked stilt (immature)[1]	ND	0.08	ND	ND	0.08	ND	ND	ND
15B, 24C	Mallard egg [1]	ND	0.07	ND	ND	0.70	ND	ND	ND
18D, 24C	Coot egg [1]	ND	0.27	ND	ND	0.27	ND	ND	ND
18BW	Black-necked stilt egg	0.15	2.29	ND	ND	2.29	ND	ND	ND
25A	Threadfin shad	ND	0.07	ND	ND	0.07	ND	ND	ND
18D, 25A	Brown bullhead	ND	ND	ND	ND	ND	0.15	ND	ND

[1]Composite sample.

SUMMARY

The Rio Grande Valley NAWQA study unit includes about 45,900 mi^2 in Colorado, New Mexico, and Texas upstream from the streamflow-monitoring station Rio Grande at El Paso, Texas. The area also includes the San Luis Closed Basin and the surface-water closed basins that are east of the Continental Divide and north of the United States-Mexico international border. The Rio Grande drains about 29,300 mi^2 in these States; the remainder of the study unit area is in closed basins.

The Rio Grande is the main surface-water drainage in the study unit. The northern mountainous areas are drained primarily by perennial streams. A large part of the study unit is drained by intermittent and ephemeral streams. Many stream reaches in the study unit are intermittent because they are affected by irrigation diversions or they lose water by infiltration to the alluvium, or are ephemeral because they flow only in response to short-term precipitation.

Land use within the Rio Grande Valley NAWQA study unit is primarily in four categories: rangeland (58 percent), forest land (36 percent), agricultural land (4 percent), and urban (1 percent). Major uses of water within the study unit are irrigation, public supply, and industrial. Total irrigated acreage in 1990 was about 914,000 acres, and about 72 percent of the acreage was irrigated by the flood method. Total annual water use in the study unit in 1990 was about 3,410,000 acre-ft; of this amount about 1,790,000 acre-ft was estimated to be consumptive use.

A large amount of surface-water-quality data have been collected for many years at streamflow-gaging stations and miscellaneous sites along the Rio Grande and its major tributaries. Surface-water samples collected from Lobatos, Colorado, downstream to El Paso, Texas, have been analyzed for many nutrient species and pesticides. Surface-water samples collected upstream from Lobatos, Colorado, generally have been analyzed for only total phosphorus and a few pesticides.

Nutrient and suspended-sediment concentrations in surface water followed basically the same pattern throughout the Rio Grande Valley study unit. The first major increase along the main stem of the Rio Grande in nutrient concentrations and a corresponding increase in suspended sediment occurred at Rio Grande at Isleta. This station is downstream from Albuquerque. Urban and agricultural application of fertilizers, sewage treatment effluent, and septic systems all affect the Rio Grande. Suspended-sediment concentration increased downstream between Lobatos and Albuquerque and corresponded to a slight increase in total phosphorus concentrations resulting from inflow of the Rio Chama, flushing of ephemeral channels, and erosion of the channel due to steep gradients upstream; however, these concentrations and loads were smaller downstream from Cochiti Lake.

Surface-water samples from the conveyance channel and floodway stations at San Acacia had similar concentrations of most nutrients and extremely elevated suspended-sediment concentrations (more than an order of magnitude larger than those at the adjacent upstream station). However, samples collected at the conveyance channel and floodway stations at San Marcial had dissimilar water quality with respect to most nutrients and suspended sediment. Often the flow in the conveyance channel is due solely to agricultural-return flows and differs from water in the floodway.

Elephant Butte Reservoir, between San Marcial, New Mexico, and El Paso, Texas, provides an opportunity for suspended sediment and nutrients to settle or be utilized. Las Cruces, New Mexico, the second most populated city in the study unit, and a major agricultural area are

downstream from the reservoir. Nutrient and suspended-sediment concentrations were higher downstream due to urban and agricultural effects, and these higher concentrations were evident in the water quality downstream at El Paso.

The U.S. Geological Survey NWIS data base contains 2,173 ground-water sampling sites with nitrate analyses, 222 sites with ammonia analyses, and 655 sites with orthophosphate analyses. These sites are relatively evenly distributed throughout most of the Rio Grande Valley study unit. The Albuquerque data base contains 443 ground-water sampling sites with nitrate analyses and 274 sites with ammonia analyses. These sites are limited to the Albuquerque area. Other ground-water-quality data are available for the Rio Grande Valley study unit; however, these data were collected in limited areas to examine site-specific issues and therefore were not used.

Water-quality data were grouped or "stratified" to illustrate water-quality characteristics of differing hydrogeologic and land-use settings. The largest median nitrate concentration was found in water from wells located in the Basin and Range-mountains-urban data stratum (3.0 mg/L) and the smallest was found in water from wells located in the Southern Rocky Mountains-mountains-forest data stratum (0.08 mg/L). Few (3 percent) nitrate concentrations in water from wells in all land-use settings were greater than 10 mg/L. Most (82 percent) nitrate concentrations were less than 2 mg/L. Comparison of nitrate concentrations in water from wells located in specific land-use settings throughout all hydrogeologic settings, with the exception of the Colorado Plateau, indicated that the largest median nitrate concentration was associated with rangeland land use and that larger nitrate concentrations tended to be found in water from shallow wells.

The largest median ammonia concentration was in water from wells located in the Colorado Plateau-San Juan Basin-rangeland data stratum (0.27 mg/L) and was significantly larger than any other median ammonia concentrations in other data strata. Most median ammonia concentrations were less than 0.03 mg/L, indicating that elevated ammonia concentrations are not a major concern in the study unit.

The largest median orthophosphate concentration was in water from wells located in the Southern Rocky Mountains-mountains-forest data stratum (0.15 mg/L as orthophosphate (PO_4)) and the smallest was in water from wells located in the Basin and Range-mountains-urban data stratum (0.02 mg/L). Orthophosphate concentrations in water from most of the wells sampled (85 percent) were less than 0.2 mg/L, indicating that elevated orthophosphate concentrations also are not a major concern in the study unit.

Data indicate that ground water in the study unit does not appear to have a widespread problem with nutrients. Water in wells associated with rangeland land use consistently had larger median nutrient concentrations than water from wells in areas of other land uses. This was an unexpected result because there generally is not a large density of cattle in these areas and the depth to water is generally greater than 100 ft. Possible causes may be poor well construction, proximity to cattle feeding areas, or naturally occurring nutrients.

Only 38 sampling sites had pesticide analyses in the Rio Grande Valley study unit. Diazinon, at a concentration of 0.01 µg/L, was the only pesticide detected at any of these sites. Compilation and analysis of pesticide data for surface and ground water indicate temporal and areal data deficiencies; therefore, a future study of pesticides throughout the study unit would be needed for improved evaluation of pesticide occurrence.

Biological pesticide data were inadequate for in-depth analysis. Primary sources of data were the U.S. Fish and Wildlife Service and the U.S. Geological Survey. In the U.S. Fish and Wildlife Service study p,p'-DDE, a degradation product of DDT, was detected most frequently; highest concentrations were found at Stahman Farms in carp (6.3 μg/g wet-weight) and at Hatch in Western kingbird (5.1 μg/g wet-weight). In the U.S. Geological Survey study (for the Bosque del Apache National Wildlife Refuge), no detectable organochlorine concentrations were found in plants; detectable levels of p,p'-DDE were found in coot and carp, and a maximum concentration of 0.12 μg/g wet-weight was found in coot.

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