WATER QUALITY AND BENTHIC MACROINVERTEBRATE BIOASSESSMENT OF GALLINAS CREEK, SAN MIGUEL COUNTY, NEW MEXICO, 1987-90

By Herbert S. Garn
U.S. Geological Survey
and
Gerald Z. Jacobi
New Mexico Highlands University

U. S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 96-4011

Prepared in cooperation with the
U.S. FOREST SERVICE,
NEW MEXICO ENVIRONMENT DEPARTMENT,
NEW MEXICO HIGHLANDS UNIVERSITY,
and the
CITY OF LAS VEGAS

Albuquerque, New Mexico
1996

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, *Secretary*

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, *Director*

For additional information
write to:

District Chief
U.S. Geological Survey
Water Resources Division
4501 Indian School Rd. NE, Suite 200
Albuquerque, New Mexico 87110-3929

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Multiply	By	To obtain
inch	25.4	millimeter
foot	0.3048	meter
cubic foot per second	0.02832	cubic meter per second
cubic foot per second	28.32	liter per second
mile	1.609	kilometer
acre	4,047	square meter
square mile	2.590	square kilometer
acre-foot	1,233	cubic meter

Temperature in degrees Fahrenheit (°F) or degrees Celsius (°C) can be converted as follows:

$$°C = (°F - 32)/1.8$$

$$°F = (1.8 \times °C) + 32$$

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.

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ABSTRACT

Upper Gallinas Creek in north-central New Mexico serves as the public water supply for the City of Las Vegas. The majority of this 84-square-mile watershed is within national forest lands managed by the U. S. Forest Service. In 1985, the Forest Service planned to conduct timber harvesting in the headwaters of Gallinas Creek. The City of Las Vegas was concerned about possible effects from logging on water quality and on water-supply treatment costs. The U.S. Geological Survey began a cooperative study in 1987 to (1) assess the baseline water-quality characteristics of Gallinas Creek upstream from the Las Vegas water-supply diversion, (2) relate water quality to State water-quality standards, and (3) determine possible causes for spatial differences in quality. During 1987-90, water-quality constituents and aquatic benthic macroinvertebrates were collected and analyzed at five sampling sites in the watershed.

Specific conductance, pH, total hardness, total alkalinity, and calcium concentrations increased in a downstream direction, probably in response to differences in geology in the watershed. The water-quality standard for temperature was exceeded at the two most downstream sites probably due to a lack of riparian vegetation and low streamflow conditions. The standards for pH and turbidity were exceeded at all sites except the most upstream one. Concentrations of nitrogen species and phosphorus generally were small at all sites. The maximum total nitrogen concentration of 2.1 milligrams per liter was at the mouth of Porvenir Canyon; only one sample at this site exceeded the water-quality standard for total inorganic nitrogen. At each of the sites, 10 to 15 percent of the samples exceeded the total phosphorus standard of less than 0.1 milligram per liter. Except for aluminum and iron, almost all samples tested for trace elements contained concentrations less than the laboratory detection limit. No trace-element concentrations exceeded the State standard for domestic water supplies. Suspended-sediment concentrations appeared to increase with distance downstream; suspended sediment increased significantly from the uppermost site to the second site near the national forest boundary, most probably caused by runoff from the unpaved forest road adjacent to Gallinas Creek. The aquatic macroinvertebrate assessment indicated that the three upstream sites had good biological conditions and were nonimpaired, whereas the two downstream sites had lowered biological conditions and were slightly impaired. The water-quality and biological assessments provided similar results.

INTRODUCTION

Streamflow from forested, high mountain watersheds is the primary source of surface water in New Mexico. High-quality streams in these watersheds are sources for municipal, domestic, and irrigation water supplies, and habitat for salmonid fish. The watersheds are prime sites for forest recreation. Timber-harvesting activities, which often cause decreases in water quality, may conflict with these other uses of the forests and streams. Continuing and growing demands for water have necessitated that these watersheds be managed for water production and protection of water quality; at the same time pressures are growing to use these areas for other purposes. The Cities of Las Vegas and Santa Fe, New Mexico, as well as others, have municipal water supplies located in these high mountain watersheds. Maintaining the high quality of these waters is needed to minimize water-supply treatment costs and to protect cold-water fisheries.

Gallinas Creek is the primary water supply for the City of Las Vegas, New Mexico. The City acquired the water system in 1983 by donation from the Sangre de Cristo Water Company, a subsidiary of Public Service Company of New Mexico (Smart, 1986). The majority of the watershed is on national forest lands. In 1985, the U.S. Forest Service, Santa Fe National Forest, planned to conduct timber-harvesting activities with the Wesner Timber Sale in the headwaters of the Gallinas Creek watershed (A.W. Smart, U.S. Forest Service, written commun., 1985). The water-supply diversion and intake for the City are about 7 miles downstream from the national forest property boundary and 0.5 mile downstream from the U.S. Geological Survey (USGS) gaging station on Gallinas Creek near Montezuma (fig. 1).

The Wesner timber sale was proposed by the Forest Service as part of the forest management activities planned for the upper Gallinas watershed and Tecolote Creek, the watershed adjacent to and south of Gallinas Creek. The sale was the first major effort to manage the timber in the watershed. Only small timber sales prior to 1970 had occurred along the Gallinas Creek divide and in the upper Tecolote Creek watershed. A large portion of the area consists of old-age trees, and in the spruce-fir zone, a spruce beetle infestation was causing mortality of many of the larger trees. The Forest Service was concerned that if unmanaged, the timber value of these stands could be largely lost and also that dying trees would increase fuel volumes and increase the potential for a catastrophic wildfire in the watershed (A.W. Smart, U.S. Forest Service, written commun., 1985).

The City of Las Vegas was concerned about increased sedimentation and turbidity levels in the stream (and water quality in general) and the effect of logging on treatment costs for the city water supply (George Tyler, City of Las Vegas, oral commun., 1987). Because of concerns by the City of Las Vegas about water-quality effects and water yield, the timber sale and associated road construction were removed from this management area of the Santa Fe National Forest management plan (M.T. Rost, Forest Supervisor, written commun., June 11, 1986). Furthermore, the Forest Service and the City of Las Vegas agreed to other modifications to the land management plan to protect water quality and to evaluate the effects of timber management.

Very limited information is available on the water-quality effects of timber-harvesting activities in New Mexico and the Southwest. No comprehensive hydrologic studies have been conducted in New Mexico to determine the water-quality effects of typical timber-harvesting operations used under the prevailing site conditions in this region. Such information is needed to evaluate the effectiveness of water-quality management plans and best management practices developed to control nonpoint-source pollution from timber-harvesting activities (New Mexico Water Quality Control Commission, 1989).

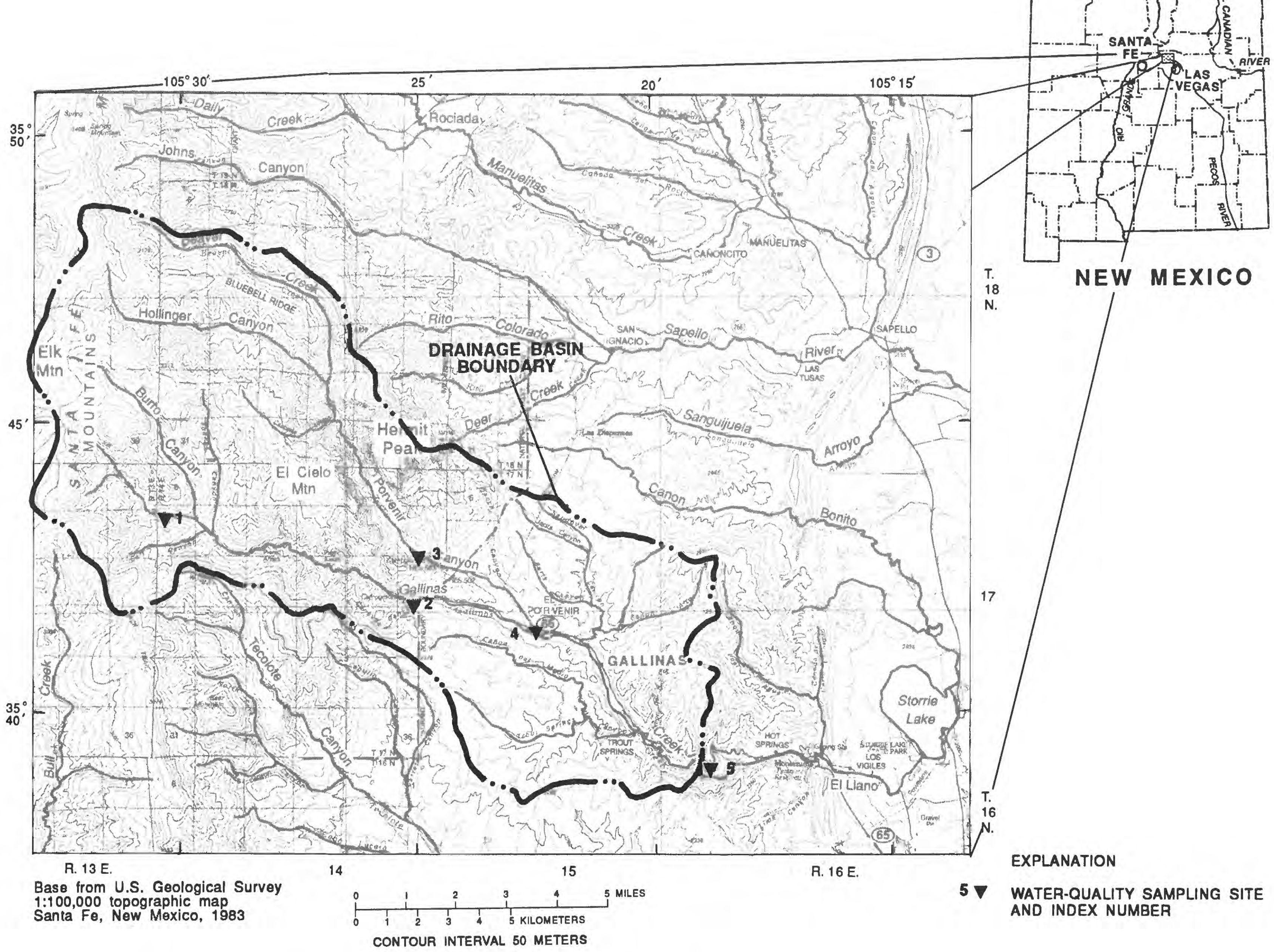


Figure 1.--Gallinas Creek study watershed and location of water-quality sites.

The USGS, in cooperation with the U.S. Forest Service, New Mexico Environment Department, New Mexico Highlands University, and City of Las Vegas entered into an agreement in 1987 to begin a study to evaluate the effects of timber harvesting and road construction on the water quality of Tecolote Creek. Timber-harvesting practices (tractor skidding and sky-line cable logging) to be used for this demonstration timber sale in the upper Tecolote Creek watershed were to be similar to those proposed for the Gallinas Creek watershed. Possible changes found in the water quality of Tecolote Creek were to be related to State water-quality standards with emphasis on the potential effect on Gallinas Creek and the Las Vegas municipal water supply. An investigation to assess the baseline water quality of Gallinas Creek was therefore undertaken as an implicit part of this overall study.

Purpose and Scope

This report (1) presents the baseline water-quality characteristics and aquatic benthic macroinvertebrates of Gallinas Creek at the present level of watershed development upstream from the City of Las Vegas water-supply intake; (2) relates these water-quality characteristics to established State water-quality standards for this stream; and (3) describes possible causes of spatial differences in water quality. Information presented in this report will be useful for the development of a watershed management plan for the Gallinas Creek watershed.

Data on stream-water properties, major ions, nutrients, trace elements, benthic macroinvertebrates, and suspended sediment were collected at five sites in the watershed upstream from the Las Vegas water-supply intake. Water samples were collected at approximately monthly intervals during the snow-free season from 1987 through 1990; macroinvertebrate samples were collected semiannually.

Previous Investigations

Only limited water-quality data had been collected in the Gallinas Creek watershed prior to 1987; this limited data collection was done intermittently and at varying locations. Most of the sampling was done by the U.S. Forest Service and New Mexico Environment Department (previously called the Environmental Improvement Division of the New Mexico Health and Environment Department). A fairly detailed report on the water resources of the watershed, summarizing the data available at the time, is that by Smart (1986). Geology and ground-water resources of the entire county are discussed by Griggs and Hendrickson (1951).

An intensive water-quality survey of Gallinas Creek was conducted by the New Mexico Environment Department June 2-5, 1986 (Smolka, 1986). The objectives of this 4-day survey were to assess the water quality, determine whether water-quality standards were being met, and evaluate the biological integrity of the aquatic macroinvertebrate community.

Discharge and water-quality data for Gallinas Creek are available in USGS Water-Data Reports published annually, and the USGS surface-water and water-quality computer data bases. Discharge data for the streamflow-gaging station on Gallinas Creek near Montezuma, located 0.5 mile upstream from the Las Vegas water-supply diversion, are available continuously from 1916. Discharge data also were previously collected on Gallinas Creek at Montezuma from 1904 to 1966, and South Fork Gallinas Creek near El Porvenir from 1911 to 1920 (U.S. Geological Survey, 1971, p. 36-37). Water-quality records of field measurements and major ions were collected monthly on Gallinas Creek near Montezuma from January 1964 to June 1967. In the present study, all hydrologic records through the end of 1990 were evaluated.

Acknowledgments

The advice and participation of Jim Piatt (New Mexico Environment Department), Bruce Sims (U.S. Forest Service), and George Tyler (City of Las Vegas) are greatly appreciated. M. Donna Jacobi prepared the computer program used in assessing the benthic macroinvertebrate data following U.S. Environmental Protection Agency (USEPA) protocols.

DESCRIPTION OF THE WATERSHED

Gallinas Creek is a tributary of the Pecos River, located between the Canadian River watershed to the east and the Rio Grande watershed to the west. Las Vegas is in the transition zone between the southern extension of the Rocky Mountains and the eastern plains of New Mexico. The eastern plains open to the Great Plains of Texas and Oklahoma. The study area is within the Southern Rocky Mountain physiographic province (Fenneman, 1931; Omernik, 1987).

Gallinas Creek arises on the eastern flanks of the Sangre de Cristo Mountains about 22 miles northwest of Las Vegas, in San Miguel County, New Mexico. The stream flows to the southeast from an altitude of 11,661 feet at Elk Mountain, through Las Vegas, to the Pecos River. The altitude at the lowest point of the study watershed is 6,880 feet at the streamflow-gaging station near Montezuma; the drainage area to the gage is approximately 84 square miles. Porvenir Creek (Porvenir Canyon) is the major tributary of Gallinas Creek with a drainage area much larger than that of the main creek upstream from their confluence.

Climate

New Mexico has a mild arid to semiarid climate characterized by low precipitation, abundant sunshine, low relative humidity, and relatively large diurnal and annual temperature ranges (Houghton, 1972). New Mexico's climate is unique compared with climates of other areas to the north in the Rocky Mountains of Colorado, where winter precipitation forms the bulk of the total. Because of the unique pattern of precipitation in New Mexico, hydrologic effects from management activities are different from those in other areas to the north. Las Vegas is between the Rocky Mountains and the Great Plains, and has a climate that is characteristic of the two regions.

Average annual precipitation for the study area ranges from 15 inches (1951-80) at Las Vegas to more than 30 inches at the higher altitudes above 9,000 feet. Precipitation is characterized by a wide variation in annual and seasonal totals. Summer rains fall almost entirely during brief, but often intense thunderstorms. The general southeasterly air circulation from the Gulf of Mexico brings moisture for these storms, and strong surface heating combined with orographic lifting causes convective air currents and condensation (Houghton, 1972, p. 2). The Gulf of Mexico is the single largest source of moisture during the warm half of the year. The greatest precipitation intensities occur between early July and mid-September. Storms in the Pecos River watershed occur more frequently and last longer than in other parts of the State because of its relation to the source of moist, unstable air from the Gulf of Mexico (Tuan and others, 1973, p. 42). July and August are typically the wettest months of the year; about 40 percent of average annual precipitation falls during that time. For the warm half of the year (May through October), precipitation averages from 68 percent of the annual total in the northern mountains to 80 percent of the annual total in the northeastern plains (Houghton, 1972).

Winter precipitation occurs mainly from frontal storms from the Pacific Ocean, generally moving across the country from west to east. Much of this moisture is dropped over the coastal and inland mountain ranges. For that reason, winter is the driest season in New Mexico. The dryness is more pronounced in the valleys and on eastern slopes of the mountains. Most winter precipitation falls as snow in the mountains, but may occur as rain or snow at the lower altitudes. Average annual snowfall in the study area ranges from about 30 to well over 100 inches at the higher altitudes. Winter precipitation has much more variability from year to year than summer precipitation (Tuan and others, 1973, p. 55).

The following table shows inches of precipitation during the period of study (1987-90) measured at Las Vegas. Annual precipitation was greater than normal 3 of the 4 years. Only 1989 had near-normal precipitation (National Oceanic and Atmospheric Administration, 1987-90).

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1987	0.77	1.12	0.46	0.56	3.94	3.03	1.40	7.55	2.02	0.05	1.06	0.66	22.62
1988	0.21	0.08	0.32	1.53	2.48	3.05	6.27	5.32	2.65	0.27	0.16	0.19	22.53
1989	0.53	0.16	0.11	0.20	1.38	2.06	4.22	2.57	2.06	0.92	0.00	0.2	14.41
1990	1.28	1.02	0.17	1.79	0.65	0.40	3.93	4.58	2.83	0.15	1.36	1.35	19.51
Normal (1951-80)	0.27	0.26	0.46	0.70	1.57	1.35	3.22	3.50	1.53	1.11	0.60	0.42	14.99

Average annual temperatures range from 50 °F at Las Vegas to less than 40 °F in the high mountains and valleys (Houghton, 1972). The average maximum temperature during July ranges from 82 °F at Las Vegas to the 70's at the higher altitudes. The warmest and driest days often are in June before the thunderstorm season begins. Average minimum temperatures in January range from 16 °F at Las Vegas to near 0 °F in the mountains. The freeze-free season ranges from less than 80 days in the mountains to 150 days.

Streamflow

The runoff pattern of Gallinas Creek is typical of the mountainous areas where snowmelt is usually the major source of runoff. The average annual discharge (for the period of record, 1916-90) measured near Montezuma was 19.4 cubic feet per second, or 14,060 acre-feet. The following table from Waltemeyer (1989, p. 137) lists mean monthly and mean annual discharge statistics (1927-85) at the gaging station near Montezuma:

Month	Mean (cubic feet per second)	Coefficient of variation	Percentage of annual runoff
October	12	1.48	5.6
November	9.0	1.16	4.1
December	6.2	.67	2.8
January	5.0	.47	2.3
February	5.4	.54	2.4
March	11	.86	5.0
April	35	1.13	15.9
May	54	1.23	24.3
June	21	1.19	9.6
July	15	.94	6.6
August	28	1.07	12.8
September	19	1.32	8.6
Annual	18	.80	100

Although most runoff normally occurs during the snowmelt months of April and May, these may have considerable annual variation. The coefficient of variation is the standard deviation divided by the mean. Persistent summer rainfall can also produce large monthly discharges in some years. Annual peak discharges generally occur in the summer months from intense thunderstorms. Other useful low-flow, high-flow, and flow-duration statistics are presented by Waltemeyer (1989).

The variation of discharge at Gallinas Creek near Montezuma for the duration of the study (1987-90) is shown in the hydrograph in figure 2. Only 1987 had significant snowmelt runoff; the following years had runoff from summer rains greater than that from snowmelt.

Geology and Soils

The Gallinas Creek watershed is in rugged, mountainous topography within the Sangre de Cristo Mountains. The watershed typically has broad ridges and deep canyons with steep side slopes, reflecting the influence of different rock types within the area. Geologic descriptions and mapping units are those as given primarily by Griggs and Hendrickson (1951) and Baltz (1972).

The major geologic units in the watershed include Precambrian metamorphic rocks, the Pennsylvanian Sandia Formation, and the Pennsylvanian and Permian Madera Formation. Small areas of outcroppings of the Pennsylvanian Terrero and Espiritu Santo Formations also are present. Quaternary alluvium is found in the major valley bottoms (Baltz, 1972).

Precambrian metamorphic rocks include quartz-feldspar-amphibole schist, gneiss, and granitic gneiss. These rocks predominate in the upper part of the watershed upstream from the national forest boundary on Gallinas Creek and Porvenir Canyon. A smaller, isolated area of metamorphic rocks occurs along the steep Gallinas Creek "gorge" at the lower end of the study watershed from Trout Springs to Montezuma (fig. 1). The areas of Precambrian rocks typically contain steep and some oversteepened slopes, sharp ridges, and narrow valley bottoms. Hermit Peak, a well-known landmark visible for many miles, is mainly granite gneiss (Baltz, 1972). Typical topography of areas with metamorphic rocks is shown in figure 3A.

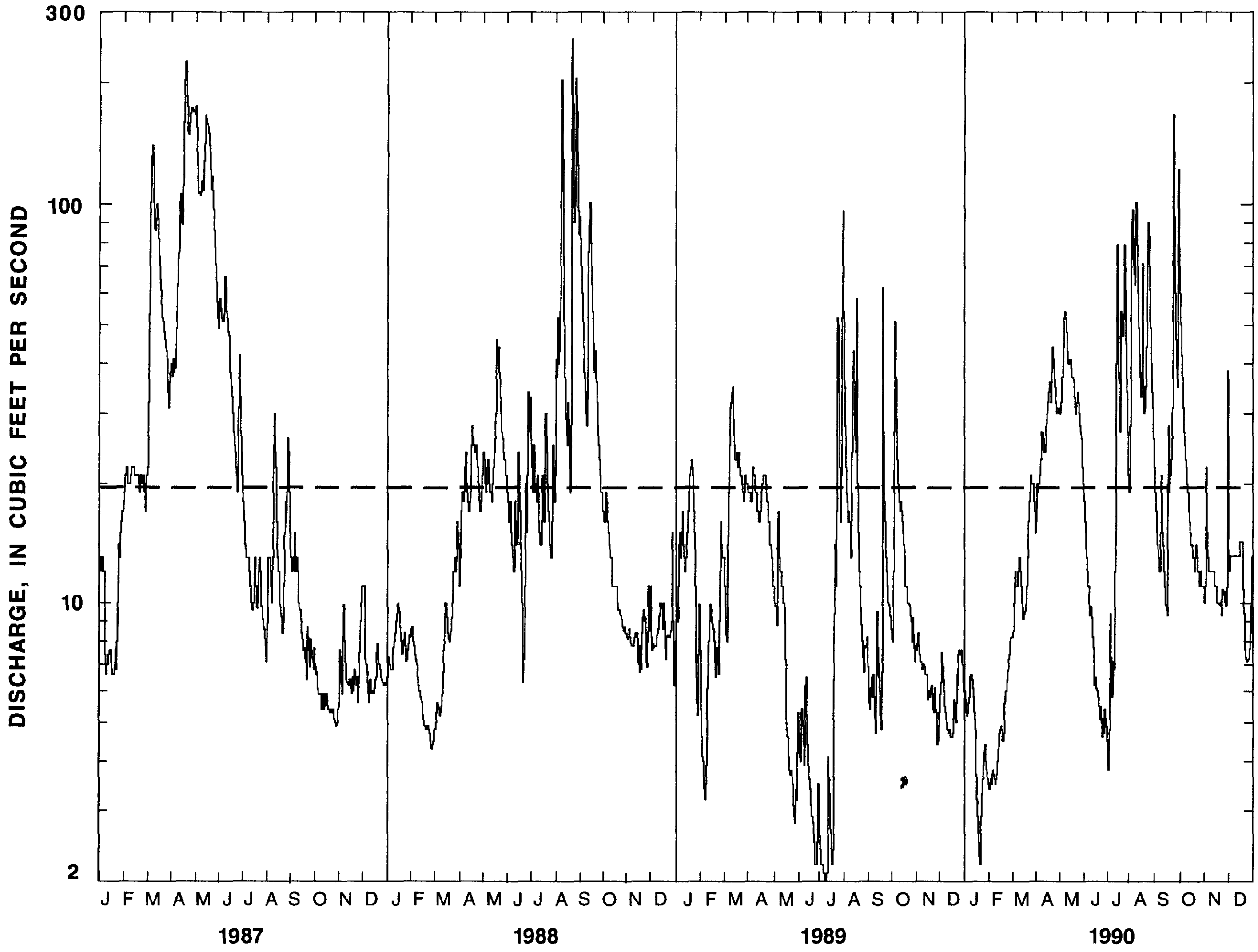
The Terrero and Espiritu Santo Formations crop out in a very narrow belt around the Precambrian rocks, at the base of other sedimentary rocks. The formations consist of sandy limestone, gray crystalline limestone, and dolomitic limestone. They are generally only 20 to 100 feet thick.

The Sandia Formation crops out in a broader belt around the Precambrian rocks. It consists of brown sandstone and shaly limestone in the lower part and mostly dark-gray shale in the upper part. In the watershed, its thickness varies from about 80 to 700 feet.

The Madera Formation is the greatest part (more than 80 percent) of the surface exposure in the lower part of the study watershed downstream from the national forest boundary. The formation consists of a lower and an upper member. The lower member consists of a gray, thin to massive, fossiliferous marine limestone, interbedded thin to thick dark-gray shale, and a few thin to thick gray sandstones. Its thickness is as much as 800 feet. The upper member contains red, gray, and greenish-gray shale and calcareous shale, fossiliferous marine thin to thick limestones, and thin to thick sandstones. This upper member is as much as 400 feet thick in the watershed.

Topography in the lower part of the watershed, where the Madera Formation is exposed, is much more subdued with flatter slopes and very broad ridgetops. In the area of this exposure, the valley bottom also broadens suddenly to as much as 1,000 feet wide (fig. 3B). Porvenir and Gallinas Creeks also have an associated decrease in their gradients in this area. Quaternary alluvial deposits of gravel, sand, silt, and clay are abundant here, whereas they are generally absent in the areas of Precambrian rocks.

Isolated exposures of the Sandia and Madera Formations crop out in the upper part of the watershed, forming a cap on Hermit Peak, El Cielo Mountain, Johnson Mesa, upper Hollinger Creek (Canyon), upper Beaver Creek, and the Elk Mountain area (fig. 1). Quaternary landslide deposits are found in various parts of the watershed, primarily in association with sedimentary rocks (Baltz, 1972). Localized areas of recent instability and mass earth movement also are present.



EXPLANATION

— — — — — AVERAGE DISCHARGE, 74 YEARS, 19.4 CUBIC FEET PER SECOND

———— 08380500 GALLINAS CREEK NEAR MONTEZUMA, NEW MEXICO MEAN DAILY DISCHARGE, IN CUBIC FEET PER SECOND

Figure 2.--Daily discharges at Gallinas Creek near Montezuma, 1987-90.

(A)

(B)

Figure 3.--Topography in the Gallinas Creek watershed as related to geology: (A) steep canyon sides in lower part of watershed near Montezuma; (B) wide valley bottom and flatter slopes near Gallinas, with Hermit Peak in background.

Generalized soil groups in the area were formed from the two major geologic units (Precambrian metamorphic rocks and sedimentary rocks). Soils formed from metamorphic rocks are very shallow to shallow and occasionally deep, on hilly to very steep topography; the surface is usually sandy, gravelly, or stony loam, and subsoils of deeper soils are often clay loam or clay (Hilley and others, 1981; Smart, 1986). These soils are generally well drained, and coarse, subsurface fragments may exceed 70 percent by volume. Soil fertility is generally low to moderate. Soils formed from sandstones and limestones are generally well developed and deeper, on moderate to very steep slopes. Rock outcrops make up as much as 50 percent of the soil unit. Soil properties are highly variable but often may consist of stony loam underlain by extremely stony clay loam. Soil fertility is generally moderate to high. The soil association along the major river bottom is generally a deep loam formed in the alluvium, with a subsoil of clay to clay loam or loam (Hilley and others, 1981).

Vegetation

Vegetation in the study area comprises several life zones over an altitude that ranges from 6,800 to more than 11,000 feet (Hilley and others, 1981; Smart, 1986). Piñon/juniper and ponderosa pine vegetative zones grow at the lower altitudes and on drier sites. Oak brush and mountain mahogany also cover large areas on steep, rocky slopes. The mixed conifer zone is at intermediate and higher altitudes on south- and west-facing slopes. Douglas fir, blue spruce, limber pine, white fir, ponderosa pine, and aspen are the principal trees found in this zone. The spruce-fir zone is found at higher altitudes generally above 9,000 feet on more moist sites, particularly north- and east-facing slopes. Principal trees in this zone include Engelmann spruce, corkbark fir, limber pine, and aspen. Timberline and alpine vegetation grow at an altitude of about 11,500 feet.

Land Uses and Developments

About 59 percent of the study watershed upstream from the streamflow-gaging station on Gallinas Creek near Montezuma is within the Santa Fe National Forest (Smart, 1986). Almost all developments within the watershed are limited to the valley bottom along Gallinas and lower Porvenir Creeks. Private lands along the valley bottom in the lower part of the watershed downstream from the national forest boundary contain the small communities of Gallinas and El Porvenir and numerous seasonal and year-round homes and ranches. Livestock production and outdoor recreation are major economic activities in the area. Most of the valley bottom from Gallinas to the national forest boundary is irrigated pasture for livestock grazing. Most of the Porvenir watershed (25 percent of the entire watershed) is within a designated wilderness area.

Eighteen leased summer homes along Gallinas Creek (Smart, 1986) are on national forest lands. The 5.5-mile-long road shares the narrow canyon bottom with Gallinas Creek and has 12 bridges crossing the stream over a distance of 3.2 miles. Along Gallinas Creek in this canyon are also one campground, seven day-use picnic areas, and additional private seasonal homes in the Calf and Youngs Canyon area. One campground and a Christian camp are located on Porvenir Creek near the national forest boundary. Cattle grazing is permitted along parts of the headwaters and most of upper Porvenir Creek. Grazing use is heaviest along the valley bottoms of Hollinger and Beaver Creeks (Smart, 1986). Gallinas Creek watershed is an important recreation area for hiking, sightseeing, fishing, hunting, and camping. Streams support a coldwater fishery of brook, brown, rainbow, and cutthroat trout.

The City of Las Vegas municipal water-supply diversion on Gallinas Creek is about 7 miles downstream from the national forest boundary. The water system begins with a diversion dam about 0.5 mile downstream from the USGS gaging station and a 24-inch diversion intake pipe. After diversion, water flows to a settling pond, then to the filter plant or to two off-stream reservoirs that have a total storage capacity of 527.8 acre-feet. Water is chlorinated and fluoridated at the filter plant. The plant is an automatic backwash, rapid sand filter. Total treated water storage capacity from the filter plant is 25.0 acre-feet (Dale Clarke, Water Director, City of Las Vegas, written commun., 1991).

The diversion dam capacity is about 12 to 15 cubic feet per second. The total quantity of surface water diverted in 1990 was 2,834 acre-feet for an average demand of 3.91 cubic feet per second. The 1980 and 1990 populations of Las Vegas were 14,322 and 14,753, respectively. Peak monthly demands during the summer may require as much diversion as 5.7 cubic feet per second. Natural streamflow during drier years is often less than this requirement for many days; consequently the City completed a pipeline in 1990 from Storrie Lake to serve as a supplemental water supply (Dale Clarke, written commun., November 1991). The City has considerable concern that surface-water supplies will not be able to meet existing demands during drought periods.

METHODS OF DATA COLLECTION AND ANALYSIS

Water-quality sampling sites were located upstream and downstream from major developments and land uses or natural features that may affect water quality, near the national forest property boundary, near the mouth of major tributaries, and at the gaging station at the lower end of the study watershed. The locations of the sampling sites are shown in figure 1 and described in table 1. The uppermost sampling sites on Porvenir and Gallinas Creeks are upstream from roads and other significant developments.

Table 1.--Description of water-quality sampling sites in the Gallinas Creek watershed

Site number	Station number	Station name	Area (square miles)	Altitude (feet)
1	08379940	Gallinas Creek above Burro Canyon near El Porvenir	4.6	8,600
2	08380000	Gallinas Creek near El Porvenir	20.0	7,440
3	08380075	Porvenir Canyon (Creek) near El Porvenir	20.1	7,520
4	08380090	Porvenir Canyon (Creek) at mouth, near El Porvenir	24.8	7,220
5	08380500	Gallinas Creek near Montezuma	84	6,880

Water-Quality Data Collection

Water samples were collected with emphasis on characterizing discharge-related water-quality variations. Samples were collected about seven or eight times each year from 1987 through 1990 during the snow-free season, usually from April to November. Sampling was done on an approximately monthly basis except during spring snowmelt and rainfall events, during which samples were collected more frequently, and near peak flow. The lowermost site near Montezuma has a continuous-recording streamflow-gaging station; staff gages were installed at the remaining four sites and concurrent discharge measurements were made at the time of sampling.

Water samples were collected for laboratory chemical analysis in open-mouth plastic liter bottles. Because of the small size of the streams (often less than 0.5 foot deep) and good mixing conditions, samples were collected directly with the open-mouth sampling bottle near the center of the stream. Samples were collected at carefully selected sections where the flow was concentrated or where there was a small waterfall. Bottles were rinsed three times with stream water prior to sampling. Acid-rinsed bottles were used for trace-element analyses. Suspended-sediment samples were collected in a similar manner at lower flows by using the open-mouth sediment bottle. At higher streamflows, when depths exceeded about 1.0 foot, a hand-held depth-integrating sampler (USDH-48) was used to collect samples using the equal-width increment (EWI) method. Detailed discussions of equipment and sampling techniques used by the USGS are given by Edwards and Glysson (1988) and Ward and Harr (1990).

Water samples were preserved and chilled with ice while in transit to the New Mexico Environment Department and Scientific Laboratory Division for analysis. The Scientific Laboratory is approved by the USEPA and uses USEPA standard methods for analyses. Samples were analyzed for major ions, nutrients, and trace elements. Whole (unfiltered) water samples were collected and submitted to the lab. Nutrient samples were preserved with sulfuric acid and trace-element samples were preserved with nitric acid in the field. Field measurements of water temperature, dissolved oxygen, specific conductance, and pH were conducted at the time of sampling. Sediment samples were analyzed by the USGS laboratory in Albuquerque, New Mexico.

Discharge and water-quality data were stored in the USGS National Water-Data Storage and Retrieval System (WATSTORE) computer data base. Data were also published in annual Water-Data Reports (U.S. Geological Survey, 1988-91).

Biological Data Collection

Benthic macroinvertebrates were collected from riffle areas at each of the five sites in cooperation with the Environmental Science and Management Program, New Mexico Highlands University (NMHU) in Las Vegas, New Mexico. Sampling locations were selected on rubble/gravel substrates in riffle sections that subjectively were determined to be the best habitat for macroinvertebrate colonization. Site 2 at the downstream boundary of the Santa Fe National Forest was selected as the reference location for the benthic macroinvertebrate study. This site, rather than site 1, more closely represented riparian habitat, stream gradient, altitude, and stream size at sites 3, 4, and 5. All sites are within the Southern Rockies Ecoregion as described by Omernik (1987).

Three quantitative samples were collected at each site in spring prior to snowmelt runoff and in mid-fall after summer rains using a modified Hess circular sampler (Jacobi, 1978). Samples were stored in 70-percent ethyl alcohol for transport to the laboratory at NMHU. At the laboratory, benthic macroinvertebrates were sorted from the debris into similar taxa by students in the Environmental Science and Management Program. References used to compile the taxonomic lists for each location include Edmunds and others (1976), Baumann and others (1977), Wiggins (1977), and Merritt and Cummins (1984).

Data Analysis

The Water-Quality System (QWDATA) of the USGS National Water Information System was used for water-quality data processing and analysis (Maddy and others, 1990). Data analysis included the use of graphical and statistical techniques. Box plots were used for summarizing data and displaying nonparametric statistics of the data for each site. The plots provide a general picture of the distribution of data, the range of most of the data points, and extreme values (Maddy and others, 1990).

Statistical testing used nonparametric (rank or distribution-free) analyses to determine any significant differences in water quality at the different sites. Water-quality data often do not meet the assumptions to use parametric tests. The Wilcoxon test (Conover, 1971, p. 239-250; Crawford and others, 1983) was used to identify differences among paired sites, in downstream order. For pH only, the standard t-test procedure was also used. Software developed by the SAS Institute, Inc.[1] (1990) was used to conduct the analyses.

Significance was based on the following criteria, where p is the significance level of the test: $p \leq 0.01$ was highly significant, $0.01 < p \leq 0.05$ was significant, $0.05 < p \leq 0.10$ was marginally significant, and $p > 0.10$ was considered not significant. The Wilcoxon test analyzes the significance of the difference between two median values and is analogous to the student's t-test for the difference between two means.

The concentration of certain water-quality characteristics measured at a site is often related to streamflow. Some constituents increase with increasing discharge, whereas others may decrease with increasing discharge. Regression analysis, after a log-log (base 10) transformation of the data (except for pH), was used to evaluate whether there was a relation between discharge and selected water-quality measurements.

Dependent and independent variables were transformed to logarithms (base 10) to test the general form of the equation,

$$\text{Log } Y = \log k + a \log Q \qquad (1)$$

$$\text{or, } Y = KQ^a$$

where Y is the concentration or unit of a given water-quality constituent or property;
k is the regression constant;
K is the anti-log of the regression constant;
a is the regression coefficient; and
Q is the instantaneous discharge, in cubic feet per second.

The coefficient of determination (R^2), obtained from the regression, indicates the proportion of the variation in Y that is explained by the regression. For example, an R^2 of 0.6 means that 60 percent of the variation in Y is explained by the regression.

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

Metrics found in Plafkin and others (1989) were used for the data analysis for the aquatic macroinvertebrate assessment. Seven metrics, or parameters, were selected and adapted from Protocol III as indices of comparison. These were selected because individual taxa as well as total communities of macroinvertebrates respond to stresses (flow regime, sediment loading, organic and toxic pollutants, thermal variation, and so on) in different ways. The selected metrics, which encompass a wide range of benthic macroinvertebrate sensitivity to environmental perturbation, included the following:

(1) Standing crop (macroinvertebrate density, number per square meter);
(2) Taxa richness (number of taxa per study site);
(3) CTQ_d (community tolerance dominance quotient from the BCI, which is the biotic condition index methodology of Winget and Mangum (1979);
(4) EPT/(EPT plus Chironomidae) (total number of organisms in Ephemeroptera (E), Plecoptera (P), and Trichoptera (T) divided by the number of EPT plus Chironomidae);
(5) Percent dominant taxon (the number of organisms in the dominant taxa (the taxon that contained the greatest percentage of the total number of organisms) divided by the total number of organisms in the sample);
(6) EPT index (the number of EPT taxa present); and
(7) Community loss (the ratio of the number of taxa at a reference site minus the number of common taxa to the number of taxa at the comparison site).

Standing crop comparisons were used because low standing crops generally indicate the presence of toxins or habitat degradation, whereas high standing crops usually indicate organic enrichment from nutrient inputs. The standing crop of benthic macroinvertebrate organisms should not increase or decrease by more than 100 percent; if so, then perturbation is taking place (Keup and Zarba, 1987).

Taxa richness represents the health of the community through a measure of the variety of taxa present. An improvement in water quality and habitat diversity is usually accompanied by an increase in the number of taxa (Plafkin and others, 1989).

The CTQ_d value from the BCI methodology of Winget and Mangum (1979) was used as the basic tolerance metric for nonorganic perturbations in the bioassessment protocol. Individual taxa tolerances ranged from 2 to 108 (determined by Winget and Mangum); values less than 60 indicate sensitive organisms, whereas values near 100 indicate more tolerant organisms. A CTQ_d value for the community of benthic macroinvertebrates was calculated by multiplying taxon tolerances by the number of organisms in that taxon (log base 10) divided by the total number of organisms in the sample. The resultant value was the CTQ_d for the community at that site.

The EPT/(EPT plus Chironomidae) abundance metric serves as a measure of community balance. An even distribution of organisms among Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies), and Chironomidae (midges) indicates a good biotic condition. A shift toward a lower ratio indicates a disproportionate number of midges.

The percent dominant taxon metric expresses the presence of the most abundant taxon in the total community of macroinvertebrates. A community dominated by one or a few taxa would indicate a stressed environment.

The EPT index represents the number of taxa in the three groups. Because representatives are perturbation-sensitive taxa, the higher the number, the less perturbation indicated.

Community loss measures the loss of macroinvertebrate taxa between a reference site and a comparison site. The lower the value, the more similarity between the two sites (Courtemanch and Davies, 1987).

The following scoring criteria were used to assign scores to the selected metrics for characterizing the macroinvertebrate communities at a particular site. Scoring criteria are generally based on percent comparability to the reference site, except for the percent contribution of dominant taxon and community loss metrics. Scores are totaled for each site and the total is compared with the total for the reference site to describe the biotic condition. Site 2 was selected as the reference site to represent habitat conditions downstream from the national forest boundary.

[%, percent; <, less than; >, greater than; ≥, equal to or greater than]

Metric	Scoring criteria for score of 6	4	2	0
Standing crop[1]	50-149%	35-49% or 150-199%	20-34% or 200-249%	<20% or ≥250%
Number of taxa[1]	≥80%	60-79%	40-59%	<40%
CTQ_d[2]	≥85%	70-84%	50-69%	<50%
EPT/(EPT+Chironomidae)[1]	≥75%	50-74%	25-49%	<25%
Percent dominant taxon[3]	<20%	20-29%	30-39%	≥40%
EPT index[1]	≥90%	80-89%	70-79%	<70%
Community loss[4]	<0.5	0.5-1.4	1.5-3.9	≥4.0

[1]Score is a ratio of study site to reference site x 100.
[2]Score is a ratio of reference site to study site x 100.
[3]Actual percent composition for study and reference sites, not percent comparability to the reference site.
[4]Range of values obtained-comparison to reference site. Incorporates a comparison with the reference; therefore actual index values are used.

The bioassessment rating guide after Plafkin and others (1989), describing the biological-condition categories used in this assessment, are as follows:

[%, percent; > greater than; <, less than]

Percent comparability to reference score	Biological-condition category	Attributes
>83%	Nonimpaired	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for stream size and habitat quality.
[1]54-79	Slightly impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
[1]21-49	Moderately impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
[1]<17	Severely impaired	Few species present. If high densities of organisms, then dominated by one or two taxa.

[1]Percentage values obtained that are intermediate to the indicated ranges will require subjective judgment as to the correct placement. Use of the habitat assessment and physicochemical data may be necessary to aid in the decision process.

SPATIAL VARIABILITY OF WATER-QUALITY CHARACTERISTICS AND BENTHIC MACROINVERTEBRATES

Changes in water quality among the five sites were evaluated by using graphical analyses (box plots) and by conducting statistical tests. Results of the statistical testing to determine any significant correlations with discharge are also presented. Lastly, concentrations of water-quality characteristics and properties are compared with established State water-quality standards. A statistical summary of the water-quality data collected at each of the sites during 1987-90 is given in table 2.

Physical Properties

Box plots (Tukey, 1977) showing the variability of specific conductance, pH, total hardness, and total alkalinity at the five sites are presented in figure 4. In the plots, the upper and lower ends of the box represent the 75th- and 25th-percentile values, and the line in the box is the 50th-percentile or median value. The range of data between the 25th- and 75th-percentile values is the middle 50 percent of the data, or interquartile range. The lines beyond each end of the box are called whiskers and represent the upper and lower range of data that extend 1.5 times the interquartile range beyond the ends of the box. Data points beyond the whiskers are outliers and are indicated by asterisks and by circles (Maddy and others, 1990, p. 5-24). Specific conductance, pH, total hardness, and total alkalinity (fig. 4) generally increase in a downstream direction from one site to another.

Table 3 summarizes the results of statistical testing of differences in water quality shown in figure 4. For water-quality properties, highly significant increases in specific conductance were found from site 1 to 2, from site 2 to 5, and from site 4 to 5. Highly significant to marginally significant differences were also found between sites for pH, total hardness, and total alkalinity, as indicated in table 3. For pH, the nonparametric test and the standard t-test produced identical results. Specific conductance increased by 58 percent from site 2 to 5, and by 64 percent from site 4 to 5 (by comparing median values from table 2). Similarly, total alkalinity increased by 52 percent from site 2 to 5, and by 66 percent from site 4 to 5. Sites 1 and 3 were located upstream from most human-induced effects and may be considered representative of relatively undisturbed conditions.

Sites 3, 4, and 5 had significant to highly significant correlations of specific conductance with discharge, and the regression equations had coefficients of determination (R^2) greater than 0.50. If a regression was found to be significant, but had an R^2 much less than 0.50, then the relation was not considered to be very useful. The significant logarithmic regression models of specific conductance with discharge were as follows:

Site number	Coefficient	Intercept	R^2
3	-0.190	2.23	0.711
4	-0.151	2.23	0.639
5	-0.247	2.59	0.814

As indicated by the negative coefficients, specific conductance was inversely related to discharge at all of the sites. Highly significant relations of turbidity with discharge were found at sites 2 and 5, where discharge explained 41 and 71 percent of the variation in turbidity, respectively, in the logarithmic regression. Turbidity at sites 1 and 3 had a less significant relation with discharge. A weak inverse relation was indicated with pH and discharge, although it was not significant at any of the sampled sites. Other variables tested had no significant relation with discharge or had a very small R^2, much less than 0.50.

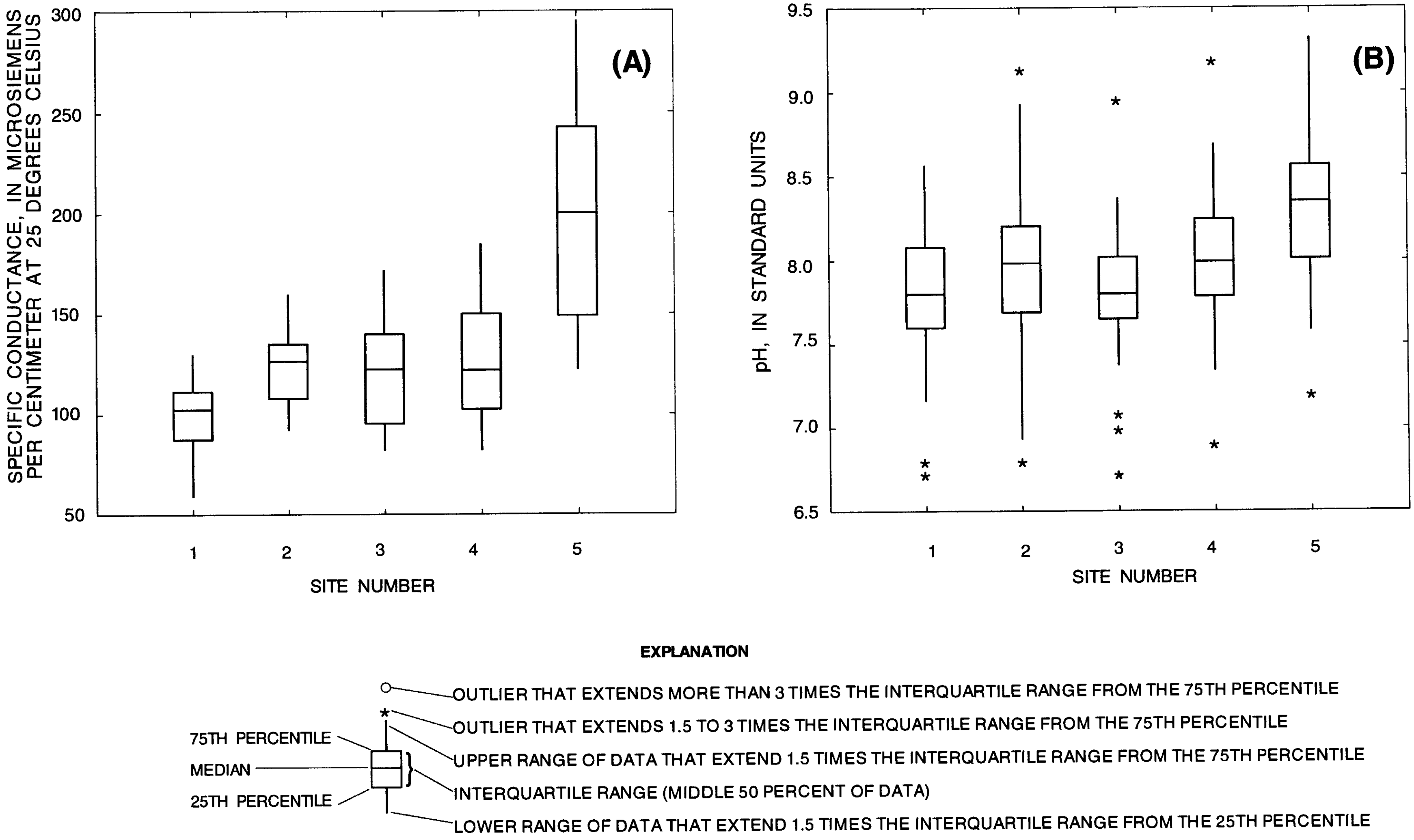


Figure 4.--Selected water-quality properties and constituents in Gallinas Creek at five sites for 1987-90: (A) specific conductance; (B) pH; (C) total hardness; (D) total alkalinity.

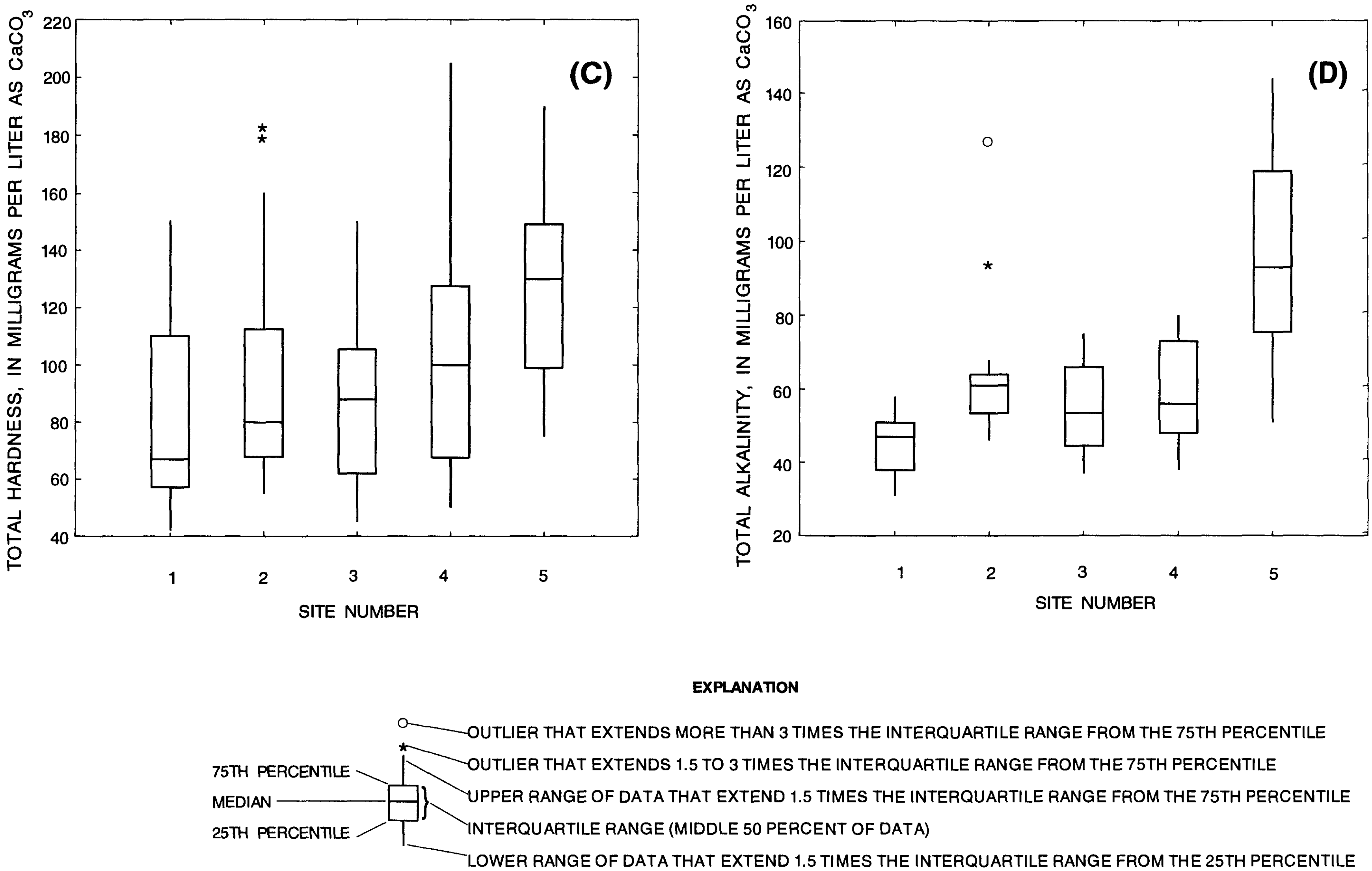


Figure 4.--Selected water-quality properties and constituents in Gallinas Creek at five sites for 1987-90: (A) specific conductance; (B) pH; (C) total hardness; (D) total alkalinity--Concluded.

Table 2.--Statistical summary of selected water-quality data for Gallinas Creek, 1987-90

[ft^3/s, cubic feet per second; deg. C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 deg. C; NTU, nephelometric turbidity units; mg/L, milligrams per liter; <, less than; --, value not calculated]

Site 1
Station number: 08379940 Station name: Gallinas Creek above Burro Canyon near El Porvenir, N. Mex.

	Descriptive statistics				Percentage of samples for which values were less than or equal to those shown				
Property or constituent	Sample size	Maximum	Minimum	Mean	95	75	(Median) 50	25	5
Discharge, instantaneous (ft^3/s)	24	15	0.96	4.065	14	4.9	3.1	1.7	0.97
Water temperature (deg. C)	23	13.0	2.5	8.087	12.9	11.0	8.0	5.5	2.6
Specific conductance (µS/cm)	24	130.	59	99.2	128	112	102	86.2	59.2
Turbidity (NTU)	18	7.0	<1.0	[1]2.0	[1]7.0	[1]3.0	[1]1.0	[1]0.5	[1]0.2
pH (standard units)	24	8.6	6.7	7.77	8.5	8.1	7.8	7.6	6.7
Hardness, total (mg/L as $CaCO_3$)	24	150	42	79.9	145	110	66.5	57.0	42.2
Alkalinity, whole, fe (mg/L as $CaCO_3$)	24	58	31	45.6	57.2	51.5	47.0	38.0	31.2
Calcium, dissolved (mg/L as Ca)	24	32.0	14.0	22.2	32.0	24.0	21.5	18.2	14.2
Magnesium, dissolved (mg/L as Mg)	24	19	<1.0	5.9	[1]18.5	[1]11.2	[1]2.4	[1]1.1	[1]0.6
Sulfate, dissolved (mg/L as SO_4)	24	11	<5.0	6.8	[1]10.6	[1]8.1	[1]6.6	[1]5.6	[1]4.2
Nitrogen, ammonia+organic (mg/L as N)	23	1.8	<0.1	0.30	[1]1.6	[1]0.5	[1]0.2	[1]0.1	[1]0.02
Nitrogen, total (mg/L as N)	22	1.8	<0.14	0.32	[1]1.66	[1]0.47	[1]0.14	[1]0.07	[1]0.02
Phosphorus, total (mg/L as P)	23	0.43	<0.01	0.05	[1]0.38	[1]0.03	[1]0.01	[1]0.001	[1]0.000
Residue, dissolved at 180 deg. C (mg/L)	24	104	64	77.9	102	84.0	75.0	70.0	65.0
Sediment concentration (mg/L)	19	21	2	6.5	21	8	6	3	2

Table 2.--Statistical summary of selected water-quality data for Gallinas Creek, 1987-90--Continued

Site 2
Station number: 08380000 Station name: Gallinas Creek near El Porvenir, N. Mex.

Property or constituent	Sample size	Descriptive statistics: Maximum	Minimum	Mean	Percentage of samples for which values were less than or equal to those shown: 95	75	50 (Median)	25	5
Discharge, instantaneous (ft^3/s)	23	32	1.4	9.78	30.4	13.0	7.6	3.7	1.46
Water temperature (deg. C)	23	19.0	5.5	11.5	18.5	15.0	11.0	9.0	5.6
Specific conductance (µS/cm)	24	160	92.0	124	158	135	126	107	92.8
Turbidity (NTU)	18	40.0	<1.0	[1]5.6	[1]40.0	[1]4.0	[1]2.0	[1]0.4	[1]0.1
pH (standard units)	24	9.1	6.8	7.95	9.0	8.2	8.0	7.6	6.8
Hardness, total (mg/L as $CaCO_3$)	24	180	53	95	180	117	80	67.2	54.0
Alkalinity, whole, fe (mg/L as $CaCO_3$)	24	127	46	62.4	118.7	64.0	61.0	52.7	46.0
Calcium, dissolved (mg/L as Ca)	24	44.0	18.0	25.8	42.0	28.0	24.0	22.0	18.0
Magnesium, dissolved (mg/L as Mg)	24	30	<1.0	7.5	29.7	10.7	3.7	2.1	0.0
Sulfate, dissolved (mg/L as SO_4)	24	12	<5.0	[1]7.3	[1]11.4	[1]8.4	[1]7.2	[1]5.9	[1]4.5
Nitrogen, ammonia+organic (mg/L as N)	23	0.83	<0.10	[1]0.30	[1]0.80	[1]0.58	[1]0.19	[1]0.12	[1]0.04
Nitrogen, total (mg/L as N)	22	0.83	<0.14	0.35	[1]0.81	[1]0.58	[1]0.22	[1]0.17	[1]0.11
Phosphorus, total (mg/L as P)	23	0.31	<0.01	[1]0.04	[1]0.27	[1]0.04	[1]0.01	[1]0.004	[1]0.001
Residue, dissolved at 180 deg. C (mg/L)	24	122	76	93.6	120	100	92.0	83.5	76.5
Sediment concentration (mg/L)	19	54	3	12.7	54	13	9	7	3

Table 2.--Statistical summary of selected water-quality data for Gallinas Creek, 1987-90--Continued

Site 3
Station number: 08380075   Station name: Porvenir Canyon near El Porvenir, N. Mex.

		Descriptive statistics			Percentage of samples for which values were less than or equal to those shown				
Property or constituent	Sample size	Maximum	Minimum	Mean	95	75	(Median) 50	25	5
Discharge, instantaneous (ft^3/s)	22	29	1.2	9.17	28.2	12.5	7.4	2.6	1.2
Water temperature (deg. C)	23	18.5	5.0	11.1	18.3	13.5	11.0	8.0	5.1
Specific conductance (µS/cm)	24	172	82.0	121	168	140	122	95.2	84.0
Turbidity (NTU)	18	25.0	<1.0	[1]4.1	[1]25.0	[1]3.2	[1]1.0	[1]0.2	[1]0.03
pH (standard units)	24	9.0	6.7	7.8	8.8	8.0	7.8	7.6	6.8
Hardness, total (mg/L as $CaCO_3$)	24	150	45	91	150	110	93	60.5	47.0
Alkalinity, whole, fe (mg/L as $CaCO_3$)	24	75	37	55.7	74.7	66.5	53.5	44.2	37.7
Calcium, dissolved (mg/L as Ca)	24	44.0	16.0	26.0	43.0	29.5	25.0	20.0	16.0
Magnesium, dissolved (mg/L as Mg)	24	27	<1.0	[1]6.4	[1]24.5	[1]10.7	[1]2.9	[1]1.8	[1]0.57
Sulfate, dissolved (mg/L as SO_4)	24	28	5.8	9.1	24	9.9	8.8	6.5	5.8
Nitrogen, ammonia+organic (mg/L as N)	23	1.2	<0.1	[1]0.28	[1]1.18	[1]0.24	[1]0.19	[1]0.10	[1]0.03
Nitrogen, total (mg/L as N)	22	1.2	<0.14	[1]0.29	[1]1.18	[1]0.36	[1]0.12	[1]0.08	[1]0.04
Phosphorus, total (mg/L as P)	23	4.54	<0.01	--	--	--	--	--	--
Residue, dissolved at 180 deg. C (mg/L)	24	120	68	93.2	119	105	96.0	80.5	68.5
Sediment concentration (mg/L)	19	17	2	7.05	17	9	6	3	2

Table 2.--Statistical summary of selected water-quality data for Gallinas Creek, 1987-90--Continued

Site 4
Station number: 08380090 Station name: Porvenir Canyon at mouth near El Porvenir, N. Mex.

Property or constituent	Sample size	Descriptive statistics: Maximum	Minimum	Mean	Percentage of samples for which values were less than or equal to those shown: 95	75	(Median) 50	25	5
Discharge, instantaneous (ft^3/s)	21	32	0.67	9.32	31.1	12.5	8.0	2.45	0.70
Water temperature (deg. C)	22	25.0	9.0	14.2	24.8	15.6	13.2	11.5	9.1
Specific conductance (µS/cm)	23	185	82.0	127	181	152	122	102	85
Turbidity (NTU)	17	41.0	<1.0	[1]5.3	[1]41	[1]4.0	[1]1.0	[1]0.1	[1]0.02
pH (standard units)	23	9.2	6.9	8.03	9.1	8.3	8.0	7.8	7.0
Hardness, total (mg/L as $CaCO_3$)	23	210	50	107	206	130	100	65.0	50.4
Alkalinity, whole, fe (mg/L as $CaCO_3$)	23	80	38	59.2	79.8	74.0	56.0	48.0	38.8
Calcium, dissolved (mg/L as Ca)	23	36.0	12.0	25.8	36.0	32.0	25.0	20.0	12.8
Magnesium, dissolved (mg/L as Mg)	23	31	1.5	[1]10.3	[1]30.4	[1]17.0	[1]6.7	[1]2.0	[1]1.5
Sulfate, dissolved (mg/L as SO_4)	23	12	<5.0	[1]8.0	[1]12.0	[1]10.0	[1]7.4	[1]6.5	[1]4.8
Nitrogen, ammonia+organic (mg/L as N)	22	0.87	<0.1	[1]0.26	[1]0.84	[1]0.46	[1]0.12	[1]0.10	[1]0.03
Nitrogen, total (mg/L as N)	21	2.1	<0.14	[1]0.38	[1]2.0	[1]0.54	[1]0.17	[1]0.10	[1]0.04
Phosphorus, total (mg/L as P)	22	0.31	<0.01	[1]0.04	[1]0.29	[1]0.04	[1]0.007	[1]0.001	[1]0.000
Residue, dissolved at 180 deg. C (mg/L)	23	134	68	99.0	131	114	100	82	70.4
Sediment concentration (mg/L)	19	64	1	9.6	64	10	7	3	1

Table 2.--Statistical summary of selected water-quality data for Gallinas Creek, 1987-90--Concluded

Site 5
Station number: 08380500 Station name: Gallinas Creek near Montezuma, N. Mex.

	Descriptive statistics				Percentage of samples for which values were less than or equal to those shown				
Property or constituent	Sample size	Maximum	Minimum	Mean	95	75	(Median) 50	25	5
Discharge, instantaneous (ft^3/s)	23	163	2.1	29.1	143	33	21	8.1	2.6
Water temperature (deg. C)	23	25.0	9.0	15.4	24.9	16.5	14.5	13.0	9.0
Specific conductance (µS/cm)	23	295	122	198	295	245	200	148	124
Turbidity (NTU)	17	100	<1.0	[1]11.0	[1]100	[1]4.5	[1]1.0	[1]0.2	[1]0.02
pH (standard units)	23	9.3	7.6	8.3	9.2	8.6	8.3	8.0	7.6
Hardness, total (mg/L as $CaCO_3$)	23	190	75	128	186	150	130	97	77.2
Alkalinity, whole, fe (mg/L as $CaCO_3$)	23	144	51	95.9	142	121	93	72	51.4
Calcium, dissolved (mg/L as Ca)	23	56.0	24.0	39.3	55.2	48.0	40.0	32.0	24.4
Magnesium, dissolved (mg/L as Mg)	23	22	<1.0	7.2	21.6	9.8	5.4	3.2	0.2
Sulfate, dissolved (mg/L as SO_4)	23	14.0	<5.0	[1]9.1	[1]13.8	[1]12.0	[1]8.1	[1]7.2	[1]4.6
Nitrogen, ammonia+organic (mg/L as N)	22	1.0	<0.1	[1]0.29	[1]0.98	[1]0.44	[1]0.17	[1]0.10	[1]0.03
Nitrogen, total (mg/L as N)	20	1.2	<0.14	[1]0.31	[1]1.18	[1]0.48	[1]0.16	[1]0.10	[1]0.04
Phosphorus, total (mg/L as P)	22	0.33	<0.01	[1]0.04	[1]0.31	[1]0.03	[1]0.01	[1]0.002	[1]0.000
Residue, dissolved at 180 deg. C (mg/L)	23	186	94.0	132	186	162	130	104	94.8
Sediment concentration (mg/L)	19	752	1	56.2	752	26	9	4	1

[1]Value is estimated by using a log-probability regression to predict the values of data below the detection limit.

Table 3.--Summary of statistical test results for spatial differences of water-quality characteristics between site pairs

[H, highly significant difference; S, significant; M, marginally significant; NS, no significant difference (see explanation in Data Analysis Section)]

Site pair	Water-quality characteristic							
	Specific conductance	pH	Hardness	Alkalinity	Calcium	Magnesium	Sulfate	Sediment
1-2	H	NS	M	H	S	NS	NS	S
3-4	NS	M	NS	NS	NS	NS	NS	NS
2-5	H	S	H	H	H	NS	M	NS
4-5	H	S	S	H	H	NS	NS	NS

New Mexico water-quality standards for this segment of Gallinas Creek are listed in table 4. The water-quality standard for water temperature was exceeded at sites 4 and 5 approximately one sampling time each year. These sites are in reaches of the stream having little or no riparian vegetation to shade the stream. High temperatures were recorded during low-flow periods. The standard for turbidity was exceeded occasionally during rainstorm events at all sites except site 1. The greatest measured turbidity and frequency of exceedance occurred at site 5. Although specific conductance generally increased downstream, none of the sites exceeded the standard of 300 microsiemens per centimeter. Measurements of dissolved oxygen were near saturation and well within standards. The standard for pH was exceeded at sites 2 through 5, where pH values greater than 8.8 were recorded on occasion. The greatest pH and greatest frequency of exceedance occurred at Gallinas Creek near Montezuma (site 5).

Water samples were previously collected from Gallinas Creek near Montezuma (site 5) from January 1964 to June 1967. These data primarily included general properties and constituents. Table 5 presents a statistical summary of these data for comparison. Specific-conductance values were generally greater during 1964-67 than during 1987-90, and pH values were generally lower. Total hardness values were similar.

Chemical Characteristics

Major Ions

The variability of selected major cations and anions is depicted in the box plots in figure 5. Calcium and magnesium are the major cations and bicarbonate is the major anion. Calcium concentrations increase dramatically from the most upstream to the most downstream site, whereas magnesium-concentration changes are not significant (table 3). Sulfate concentrations (the second most common anion) also were relatively consistent from site to site, with only a marginally significant increase from site 2 to 5. Sulfate concentrations generally were inversely related to discharge; the relation at site 5 was significant, explaining only 18 percent of the variation in sulfate. State water-quality standards have not been adopted for the major ions in waters of Gallinas Creek upstream from the Las Vegas diversion.

Table 4.--New Mexico water-quality standards for Gallinas Creek upstream from the Las Vegas water-supply diversion

[<, less than; >, greater than; NTU, nephelometric turbidity units; µS/cm, microsiemens per centimeter at 25 degrees Celsius]

A. Designated uses: domestic water supply, high-quality cold-water fishery, irrigation, livestock and wildlife watering, municipal and industrial water supply, and secondary contact recreation.

B. Standards: in any single sample:

Variable	Standard
Temperature	< 20 degrees Celsius
Turbidity	< 10 NTU
Conductance	<300 µS/cm
Dissolved oxygen (DO) or DO	> 6.0 milligrams per liter
saturation (whichever is greater)	> 85.0 percent
pH	6.6-8.8 standard units
Un-ionized ammonia (as N)	< 0.02 milligram per liter
Nitrate nitrogen (as N)	< 10.0 milligrams per liter
Total inorganic nitrogen (as N)	< 1.0 milligram per liter
Total phosphorus (as P)	< 0.1 milligram per liter
Total chlorine residual	< 0.002 milligram per liter
Total organic carbon	< 7.0 milligrams per liter

The monthly logarithmic mean of fecal coliform bacteria shall not exceed 100/100 milliliters; no single sample shall exceed 200/100 milliliters.

Note: additional numeric standards for trace elements are applicable to domestic water supply and high-quality cold-water fishery uses.

Source: New Mexico Water Quality Control Commission (1991).

Table 5.--Statistical summary of selected water-quality data for Gallinas Creek near Montezuma collected from January 1964 to June 1967

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; °C, degrees Celsius]

	Descriptive statistics				Percentage of samples for which values were less than or equal to those shown				
Property or constituent	Sample size	Maximum	Minimum	Mean	95	75	(Median) 50	25	5
Specific conductance (μS/cm)	49	335	154	260	323	303	263	220	177
pH (standard units)	49	8.8	7.0	7.7	8.4	8.0	7.7	7.5	7.1
Hardness, total (mg/L as $CaCO_3$)	49	170	72	128	160	150	130	105	85
Calcium, dissolved (mg/L as Ca)	24	58	30	46	57	55	48	38	30
Magnesium, dissolved (mg/L as Mg)	22	4.7	1.7	3.0	4.7	3.3	2.9	2.4	1.8
Sulfate, dissolved (mg/L as SO_4)	28	16	9.0	13	16	15	13	10	9.0
Residue, dissolved at 180 °C (mg/L)	24	187	104	152	186	178	158	126	104

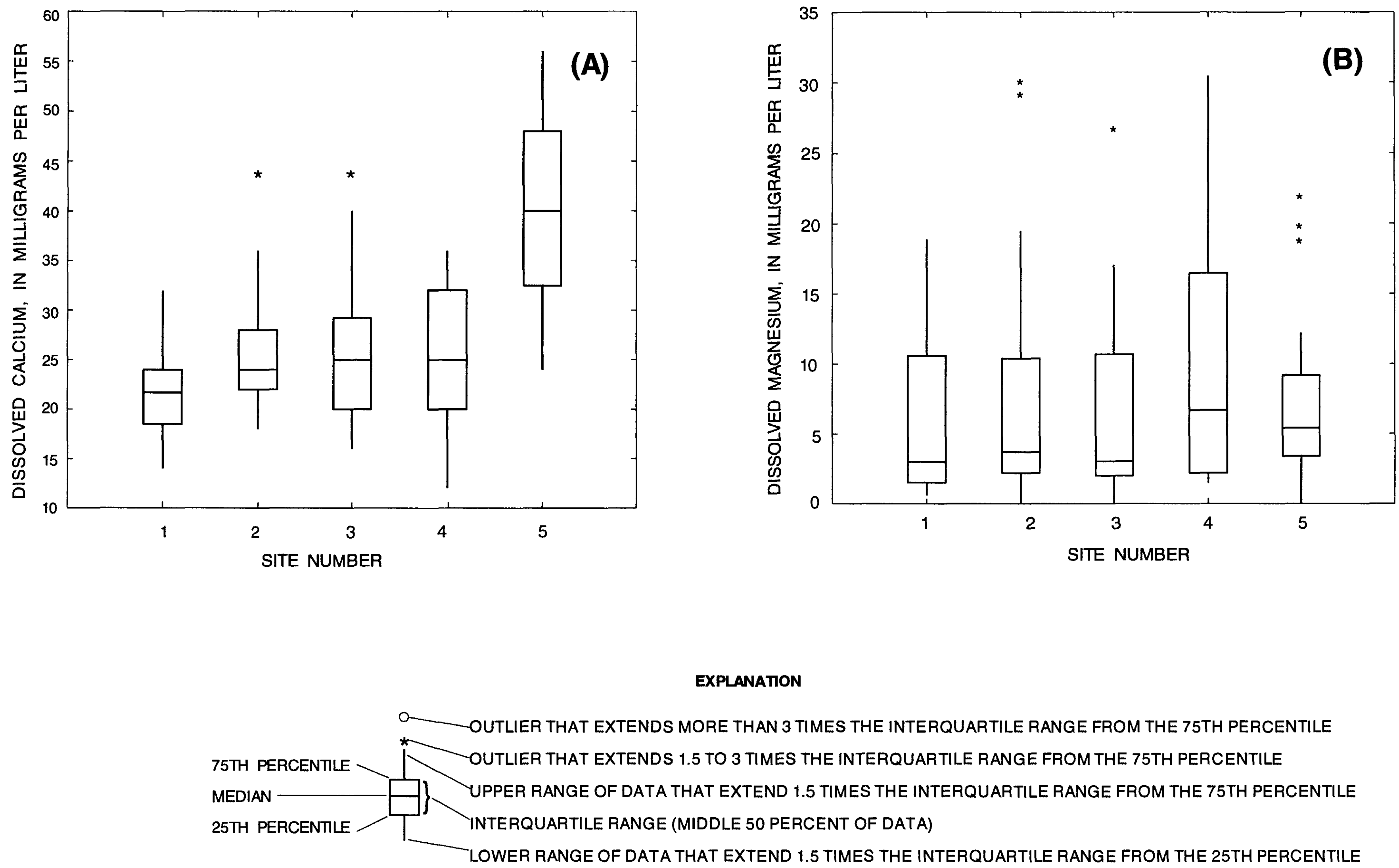


Figure 5.--Selected water-quality constituents in Gallinas Creek at five sites for 1987-90: (A) calcium; (B) magnesium; (C) sulfate.

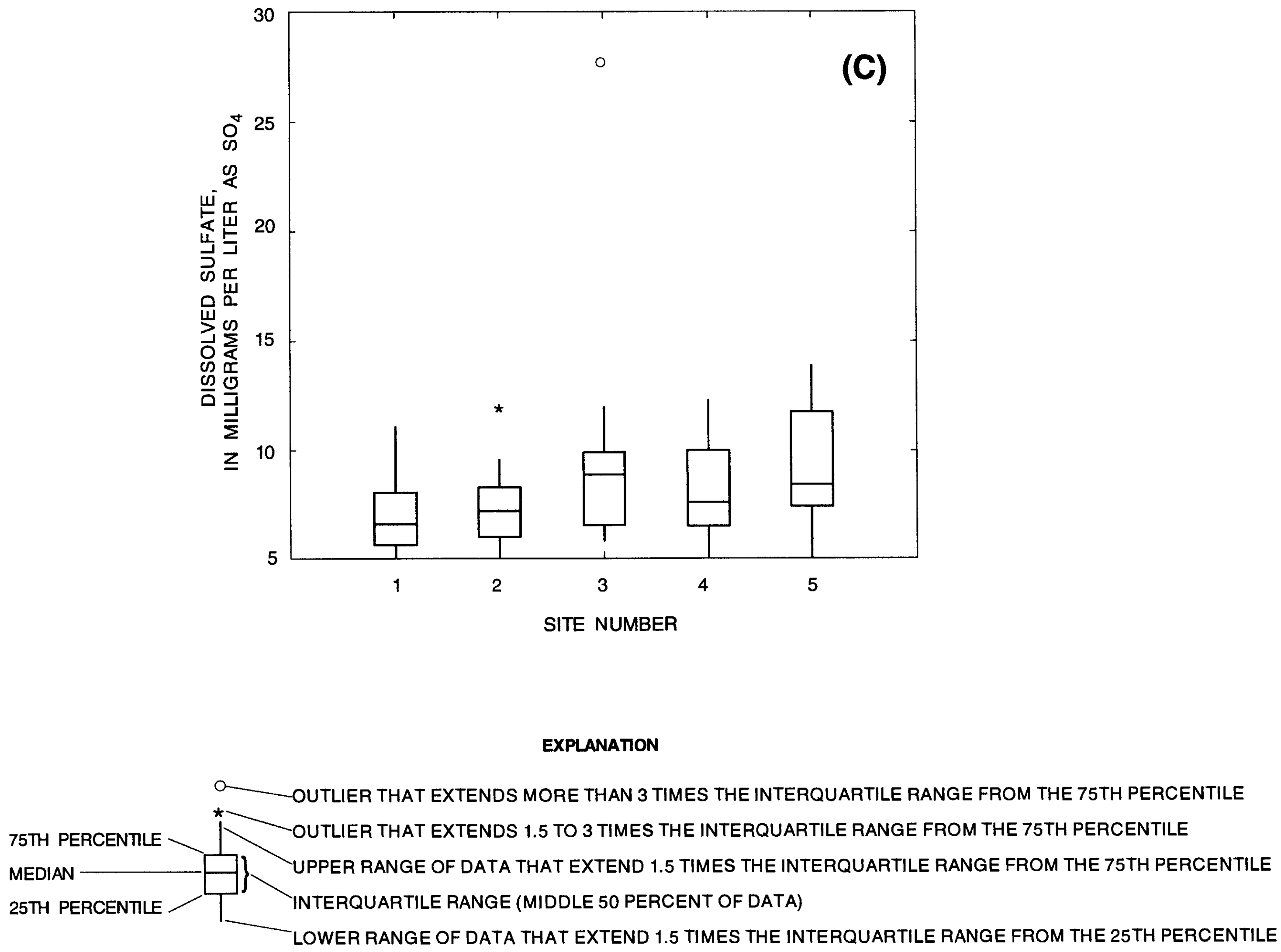


Figure 5.--Selected water-quality constituents in Gallinas Creek at five sites for 1987-90: (A) calcium; (B) magnesium; (C) sulfate--Concluded.

Nutrients

The presentation of statistical summaries and analyses of nutrient data was limited because a large percentage of values were below the detection limit. In general, a statistical summary for a constituent was not calculated if fewer than five observations were above the detection limit, and were selectively omitted from table 2 if less than 25 percent of the values were above the detection limit. More than 50 percent of the samples should be above the detection limit to calculate an accurate and meaningful median; similarly, greater than 75 percent of the samples should be above the detection limit to calculate accurate 25th and 75th percentiles.

Sites sampled in the Gallinas Creek watershed generally had small concentrations of the various nitrogen constituents and phosphorus. Less than 25 percent of the samples for nitrite plus nitrate nitrogen and ammonia nitrogen had concentrations above the detection limits of 0.04 milligram per liter (mg/L) as nitrogen and 0.1 mg/L as nitrogen, respectively. A maximum concentration of 1.99 mg/L as nitrogen for nitrite plus nitrate nitrogen was measured at site 4. The maximum ammonia nitrogen concentration was 0.67 mg/L as nitrogen at site 1. These were rare occurrences of possible nutrient flushing; only one sample at site 4 exceeded the water-quality standard for total inorganic nitrogen.

For total nitrogen, less than 50 percent of the measured concentrations exceeded the multiple detection limits of 0.14 to 0.25 mg/L. The maximum total nitrogen concentration of 2.1 mg/L was measured at site 4.

Approximately 30 to 45 percent of the samples at each of the sites exceeded the detection limit of 0.01 mg/L for total phosphorus. At each of the sites, 10 to 15 percent of the samples exceeded the total phosphorus water-quality standard of less than 0.1 mg/L.

Regression analyses revealed that ammonia plus organic nitrogen and total phosphorus were significantly positively related to discharge at some of the sites. A highly significant discharge relation with ammonia and organic nitrogen was found at sites 1 and 5; a significant relation was found at site 4. The largest R^2, however, explained only 43 percent of the variation. Marginally significant discharge relations with total phosphorus also were found at sites 1 and 3; a highly significant relation was found at site 5 that also explained 43 percent of the variation.

Trace Elements

Data analyses of trace-element concentrations were very limited because almost all data values were below the detection limit used by the laboratory. The following detection limits were used:

Trace element	Detection limit, in micrograms per liter
Aluminum, total	50
Arsenic, total recoverable	5
Barium, total	100
Cadmium, total	1
Chromium, total	5
Copper, total	50
Lead, total	10
Manganese, total	50
Mercury, total	0.5
Selenium, total	5
Silver, total	1
Zinc, total	50

Of 15 to 17 water samples collected at each site, only 1 to 4 had concentrations of any trace elements that were greater than the detection limit. No samples were analyzed that contained concentrations above the detection limit for arsenic, barium, copper, lead, mercury, selenium, and silver.

Except for total aluminum and iron, all other trace elements, namely cadmium, chromium, manganese, and zinc, were found at levels only slightly greater than their detection limits. Two of only three samples collected and analyzed for total aluminum at each of the five sites had elevated concentrations of aluminum. Total aluminum concentrations ranged from 800 to 1,300 micrograms per liter (μg/L) at all sites. Iron is a commonly occurring element that was found at moderate concentrations at all sites. Median total iron concentrations were 125, 290, 150, 180, and 160 μg/L at sites 1-5, respectively. Maximum concentrations of total iron ranged from 1,200 to 2,700 μg/L.

Sites 2 and 3 each had one sample with detectable cadmium concentrations of 2 and 3 μg/L, respectively. One sample each at sites 3 and 5 exceeded the detection limit for chromium. Four samples at site 5 and one at site 2 had concentrations of manganese that were greater than the detection limit. Site 2 had one sample for zinc that was greater than the detection limit and site 4 had two samples for zinc greater than the detection limit. All detectable concentrations were small, generally less than three times the detection limit.

None of the samples contained trace-element concentrations that exceeded the State water-quality standards for domestic water supplies. The acute standards applicable to high-quality coldwater fisheries, however, may have been approached for aluminum if a large portion of the total concentration was in the dissolved phase. The acute standard for dissolved aluminum is 750 μg/L (New Mexico Water Quality Control Commission, 1991, p. 48).

Sediment

Suspended-sediment concentrations were relatively small at the two upstream sites (1 and 3) on Gallinas and Porvenir Creeks. Median concentrations were 6 mg/L and the maximum was 21 mg/L (table 2) at these sites. Suspended-sediment concentrations appeared to increase downstream, as indicated by the 75th-percentile and maximum values. The maximum concentration of 752 mg/L was measured at site 5 near Montezuma. The change in sediment concentration from site 1 to 2 was significant (table 3). Results of the statistical testing were limited by the number of samples and the range in discharge during the study. Almost all higher flow samples were collected during the falling limb of the hydrograph because of the difficulty of timely sampling during rainstorm events.

Suspended-sediment concentrations were significantly related to discharge only at site 5; however, the regression relation with discharge explained only 27 percent of the variation. A highly significant relation of suspended sediment with turbidity was found at sites 2 and 5. Turbidity explained 72 and 65 percent of the variation in suspended sediment at sites 2 and 5, respectively, in the log-log transformed regression equation. No significant relation was found at the remaining sites. Aside from a general water-quality standard regarding stream-bottom deposits, there is no State numerical standard for sediment concentration.

Benthic Macroinvertebrates

A diverse assemblage of aquatic macroinvertebrates was collected from the five study sites during the 3 years of sampling: 103 taxa were identified. From all sites combined for each sampling date, numbers of taxa ranged from 74 in October 1989 to 57 in April 1990. The following are taxa representatives by order: Trichoptera (caddisflies) - 27 taxa; Diptera (true flies) - 25 taxa, with the family Chironomidae (midges) - 12 taxa; Plecoptera (stoneflies) - 14 taxa; Ephemeroptera (mayflies) - 13 taxa; and "other" invertebrates - 24 taxa. "Other" included Odonata (dragon/damselflies), Hemiptera (true bugs), Coleoptera (beetles), Lepidoptera (moths), Hydracarina (mites), Mollusca (clams and snails), Aschelminthes (round worms), Annelida (segmented worms), and Platyhelminthes (flatworms).

Summary comparisons of the bioassessment for each sampling date are presented in tables 6 to 11. Complete taxonomic lists and summary calculations for each sampling date are presented in appendixes 1-6. All five sites were rated high for habitat and water quality using the BCI methodology of Winget and Mangum (1979) during all sampling seasons for the 3 years. This was determined using key environmental variables such as percent gradient, substrate composition, and total alkalinity and sulfate concentrations. Occasionally, riffles at sites 4 and 5 contained more interstitial fines in the streambed material than upstream sites 1, 2, and 3. Interstitial fines clog hiding and attachment locations and may be abrasive to macroinvertebrates, which make colonization difficult. Potential upstream sources of sediment include developments and roads.

The following are summary comparisons for each sampling date:

September 1987

Standing crops ranged from a high of 8,347 organisms per square meter (organisms/m^2) at site 3 to a low of 3,009 organisms/m^2 at site 1 (table 6). Number of taxa per site ranged from 33 at site 2 to 21 at site 4. Diversity indices (Shannon and Weaver, 1963) were generally high, from 3.24 (site 4) to 4.24 (site 1), showing that a diverse fauna was present and that no taxon dominated the biota at a particular site (appendix 1). The tolerant riffle beetle *Heterlimnius corpulentus* represented 21 percent of the biota at site 4.

Sites 1, 2, and 3 had low CTQ_d values (near 50), which indicated a dominance of sensitive or intolerant taxa. The biota farther downstream at sites 4 and 5 were dominated by more tolerant organisms, resulting in CTQ_d values of 68 and 76, respectively. According to the seven-criteria bioassessment (Plafkin and others, 1989), the three upstream locations were nonimpaired, whereas sites 4 and 5 were slightly impaired--that is, the benthic macroinvertebrate community composition was less than expected.

April 1988

Standing crops ranged from a high of 8,061 organisms/m^2 at site 4 to a low of 2,856 organisms/m^2 at site 1 (table 7). Number of taxa ranged from 36 at site 3 to 26 at site 4. Diversity indices were high at all stations (equal to or greater than 3.54) except site 4 (2.44). Site 4 was dominated by the midge *Eukiefferiella* sp., which composed 44 percent of total biota (appendix 2).

Upstream sites 1, 2, and 3 contained high-quality biota (CTQ_d less than 60), whereas the other two locations contained more tolerant biota (CTQ_d of 67 to 69). The three upstream locations were rated nonimpaired. Site 5 was rated at the upper level of slightly impaired. A low biological-condition assessment value (55 percent of potential) was observed at site 4, indicating that the site was also slightly impaired. Here, several sensitive Ephemeroptera, Plecoptera, and Trichoptera taxa were missing and more tolerant taxa dominated (blackflies, 24 percent; and midges, 44 percent).

October 1988

Standing crops were all within the same general order of magnitude, 2,191 to 3,299 organisms/m^2 (table 8). Numbers of taxa ranged from 34 at site 3 to 21 at site 4. The diversity indices (appendix 3) for sites 1, 3, and 5 were high (greater than 4.0); indices for sites 2 and 4 were lower, 3.46 and 2.98, respectively. At site 4 the fewest number of taxa were present and the tolerant beetle *Heterlimnius corpulentus* dominated, composing 42 percent of the total number of organisms.

Sites 1, 2, and 3 were dominated by intolerant or sensitive biota (CTQ_d less than 54). The reduction of sensitive Ephemeroptera, Plecoptera, and Trichoptera taxa at sites 4 and 5 resulted in these two locations being rated as slightly impaired (table 8).

April 1989

Standing crops were low and varied from 2,800/m^2 at downstream site 5 to 1,474/m^2 at site 3 (table 9). Diversity indices were high at sites 1, 2, and 3 (equal to or greater than 3.84) but were lower at site 4 (2.92) and site 5 (2.89) (appendix 4). Sites 4 and 5 contained high numbers of the intermediately tolerant mayfly *Baetis tricaudatus*. Sites 1 and 3 were rated as nonimpaired compared with site 2. Downstream sites 4 and 5 were rated slightly impaired (table 9). Sites 4 and 5 received low scores because of the loss of sensitive EPT taxa (from 21 at site 2 to 11 at sites 4 and 5) and the dominance of one taxon, the mayfly *Baetis tricaudatus*.

October 1989

Standing crops varied considerably from a high of 8,642 organisms/m^2 at downstream site 5 to 1,310/m^2 at site 4 (table 10). Diversity indices ranged from 3.38 at site 2 to 4.42 at site 1; no location was dominated by one taxon (appendix 5). Total taxa were high at all locations, ranging from 29 at sites 3 and 4 to 37 at site 1. Upstream sites 1, 2, and 3 contained sensitive biota (CTQ_d less than 60), whereas downstream sites 4 and 5 contained more tolerant taxa (CTQ_d of 67 to 72). According to the biological-condition rating, sites 1, 2, and 3 were rated nonimpaired, whereas sites 4 and 5 were slightly impaired.

April 1990

Standing crops were low, ranging from 3,500 organisms/m^2 at site 4 to 1,521/m^2 at site 1 (table 11). Numbers of taxa varied from 31 at site 2 to 17 at site 4. The diversity index was high at all locations (equal to or greater than 3.36) except at site 4 where it was 2.34 (appendix 6). This was due to the dominance of the black fly Simuliidae, which accounted for 52 percent of the total number of organisms.

Only site 1 contained a dominance of sensitive organisms (CTQ_d less than 55). All other sites ranged from a CTQ_d of 63 to 75. Upstream sites 1, 2, and 3 were rated nonimpaired. Sites 4 and 5 were rated slightly impaired.

During 1987-90, all upstream locations (sites 1-3) were rated as nonimpaired in reference to the condition of the macroinvertebrate community. They were indicative of good water and habitat quality, which received minimal perturbation.

The two downstream locations, site 4 at the mouth of Porvenir Canyon and site 5 near Montezuma, always indicated lower biological conditions than the upstream sites; they were always rated slightly impaired. Occasionally, riffles at sites 4 and 5 contained more interstitial fines in the streambed material than upstream sites 1, 2, and 3. Site 4, which was downstream from private homes and grazing land, was generally the lowest rated site during the survey.

Table 6.--Bioassessment of Gallinas Creek watershed, September 1987

[CTQ_d, community tolerance dominance quotient from the biotic condition index of Winget and Mangum (1979); EPT/(EPT + Chironomidae), total number of organisms in Ephemeroptera (E), Plecoptera (P), and Trichoptera (T) divided by number of EPT plus Chironomidae; EPT index, number of EPT taxa present; see explanation in Methods of Data Collection and Analysis, p. 14-15; site locations are shown in fig. 1 and described in table 1]

Metric	Site number				
	2 (Reference)	1	3	4	5
Calculated value					
Standing crop (number of organisms per square meter)	4,742	3,009	8,347	3,294	5,118
Number of taxa	33	28	30	21	30
CTQ_d	50.5	46.7	51.8	68.4	76.3
EPT/(EPT+Chironomidae)	0.84	0.95	0.81	0.65	0.67
Percentage of dominant taxa	15	20	16	21	20
EPT index	19	18	19	10	15
Community loss	0	0.39	0.7	0.95	0.68
Percentage of reference					
Standing crop (number of organisms per square meter)	100	63	176	69	108
Number of taxa	100	85	91	64	91
CTQ_d	100	100	97	74	66
EPT/(EPT+Chironomidae)	100	100	96	77	80
Percentage of dominant taxa[1]	15	20	16	21	20
EPT index	100	95	100	53	79
Community loss[1]	0	0.39	0.7	0.95	0.68
Score					
Standing crop (number of organisms per square meter)	6	6	4	6	6
Number of taxa	6	6	6	4	6
CTQ_d	6	6	6	4	4
EPT/(EPT+Chironomidae)	6	6	6	4	4
Percentage of dominant taxa	6	4	6	4	4
EPT index	6	6	6	0	2
Community loss	6	6	4	4	4
Biological condition					
Total	42	40	38	26	30
Percentage of reference	100	95	90	62	71
Condition		Nonimpaired	Nonimpaired	Slightly impaired	Slightly impaired

[1]Actual values, not a percent comparability to reference site.

Table 7.--Bioassessment of Gallinas Creek watershed, April 1988

[CTQ_d, community tolerance dominance quotient from the biotic condition index of Winget and Mangum (1979); EPT/(EPT + Chironomidae), total number of organisms in Ephemeroptera (E), Plecoptera (P), and Trichoptera (T) divided by number of EPT plus Chironomidae; EPT index, number of EPT taxa present; see explanation in Methods of Data Collection and Analysis, p. 14-15; site locations are shown in fig. 1 and described in table 1]

Metric	Site number				
	2 (Reference)	1	3	4	5
Calculated value					
Standing crop (number of organisms per square meter)	7,482	2,856	6,085	8,061	3,684
Number of taxa	33	34	36	26	34
CTQ_d	58.1	52	58.5	67.7	69
EPT/(EPT+Chironomidae)	0.88	0.9	0.78	0.21	0.7
Percentage of dominant taxa	22	14	34	44	21
EPT index	19	20	21	15	16
Community loss	0	0.26	0.17	0.69	0.62
Percentage of reference					
Standing crop (number of organisms per square meter)	100	38	81	108	49
Number of taxa	100	100	100	79	100
CTQ_d	100	100	99	86	84
EPT/(EPT+Chironomidae)	100	100	89	24	80
Percentage of dominant taxa[1]	22	14	34	44	21
EPT index	100	100	100	79	84
Community loss[1]	0	0.26	0.17	0.69	0.62
Score					
Standing crop (number of organisms per square meter)	6	4	6	6	4
Number of taxa	6	6	6	4	6
CTQ_d	6	6	6	6	4
EPT/(EPT+Chironomidae)	6	6	6	0	6
Percentage of dominant taxa	4	6	2	0	4
EPT index	6	6	6	2	4
Community loss	6	6	6	4	4
Biological condition					
Total	40	40	38	22	32
Percentage of reference	100	100	95	55	80
Condition		Nonimpaired	Nonimpaired	Slightly impaired	Slightly impaired

[1]Actual values, not a percent comparability to reference site.

Table 8.--Bioassessment of Gallinas Creek watershed, October 1988

[CTQ_d, community tolerance dominance quotient from the biotic condition index of Winget and Mangum (1979); EPT/(EPT + Chironomidae), total number of organisms in Ephemeroptera (E), Plecoptera (P), and Trichoptera (T) divided by number of EPT plus Chironomidae; EPT index, number of EPT taxa present; see explanation in Methods of Data Collection and Analysis, p. 14-15; site locations are shown in fig. 1 and described in table 1]

Metric	Site number 2 (Reference)	1	3	4	5
Calculated value					
Standing crop (number of organisms per square meter)	2,809	2,738	3,299	2,191	2,766
Number of taxa	33	32	34	21	27
CTQ_d	49.2	51.4	53.9	67.3	71.9
EPT/(EPT+Chironomidae)	0.79	0.96	0.88	0.88	0.91
Percentage of dominant taxa	36	19	22	41	11
EPT index	19	20	20	9	12
Community loss	0	0.5	0.46	1.38	1.04
Percentage of reference					
Standing crop (number of organisms per square meter)	100	97	117	78	98
Number of taxa	100	97	100	64	82
CTQ_d	100	96	91	73	68
EPT/(EPT+Chironomidae)	100	100	100	100	100
Percentage of dominant taxa[1]	36	19	22	41	11
EPT index	100	[2]100	[2]100	47	63
Community loss[1]	0	0.5	0.46	1.38	1.04
Score					
Standing crop (number of organisms per square meter)	6	6	6	6	6
Number of taxa	6	6	6	4	6
CTQ_d	6	6	6	4	2
EPT/(EPT+Chironomidae)	6	6	6	6	6
Percentage of dominant taxa	2	6	4	0	0
EPT index	6	6	6	0	0
Community loss	6	6	6	4	4
Biological condition					
Total	38	42	40	24	24
Percentage of reference	100	[2]100	[2]100	63	63
Condition		Nonimpaired	Nonimpaired	Slightly impaired	Slightly impaired

[1]Actual values, not a percent comparability to reference site.
[2]Values greater than 100 are reported as 100.

Table 9.--Bioassessment of Gallinas Creek watershed, April 1989

[CTQ_d, community tolerance dominance quotient from the biotic condition index of Winget and Mangum (1979); EPT/(EPT + Chironomidae), total number of organisms in Ephemeroptera (E), Plecoptera (P), and Trichoptera (T) divided by number of EPT plus Chironomidae; EPT index, number of EPT taxa present; see explanation in Methods of Data Collection and Analysis, p. 14-15; site locations are shown in fig. 1 and described in table 1]

Metric	Site number				
	2 (Reference)	1	3	4	5
Calculated value					
Standing crop (number of organisms per square meter)	2,625	1,867	1,474	2,305	2,800
Number of taxa	36	31	28	20	27
CTQ_d	55.5	52.7	52.9	58.3	70.7
EPT/(EPT+Chironomidae)	0.82	0.94	0.98	0.95	0.94
Percentage of dominant taxa	19	14	18	28	50
EPT index	21	19	17	11	11
Community loss	0	0.55	0.36	0.95	0.74
Percentage of reference					
Standing crop (number of organisms per square meter)	100	71	56	88	107
Number of taxa	100	86	78	56	75
CTQ_d	100	100	100	95	79
EPT/(EPT+Chironomidae)	100	100	100	100	100
Percentage of dominant taxa[1]	19	14	18	28	50
EPT index	100	90	81	52	52
Community loss[1]	0	0.55	0.36	0.95	0.74
Score					
Standing crop (number of organisms per square meter)	6	6	6	6	6
Number of taxa	6	6	4	2	4
CTQ_d	6	6	6	6	4
EPT/(EPT+Chironomidae)	6	6	6	6	6
Percentage of dominant taxa	6	6	6	4	0
EPT index	6	6	4	0	0
Community loss	6	4	6	4	4
Biological condition					
Total	42	40	38	28	24
Percentage of reference	100	95	90	67	57
Condition		Nonimpaired	Nonimpaired	Slightly impaired	Slightly impaired

[1]Actual values, not a percent comparability to reference site.

Table 10.--Bioassessment of Gallinas Creek watershed, October 1989

[CTQ_d, community tolerance dominance quotient from the biotic condition index of Winget and Mangum (1979); EPT/(EPT + Chironomidae), total number of organisms in Ephemeroptera (E), Plecoptera (P), and Trichoptera (T) divided by number of EPT plus Chironomidae; EPT index, number of EPT taxa present; see explanation in Methods of Data Collection and Analysis, p. 14-15; site locations are shown in fig. 1 and described in table 1]

Metric	Site number				
	2 (Reference)	1	3	4	5
Calculated value					
Standing crop (number of organisms per square meter)	4,814	2,762	3,799	1,310	8,642
Number of taxa	33	37	29	29	35
CTQ_d	52.1	53.6	59.1	66.9	72
EPT/(EPT+Chironomidae)	0.83	0.77	0.81	0.93	0.93
Percentage of dominant taxa	29	14	19	25	28
EPT index	21	22	16	12	15
Community loss	0	0.3	0.45	0.76	0.63
Percentage of reference					
Standing crop (number of organisms per square meter)	100	57	79	27	180
Number of taxa	100	100	88	88	100
CTQ_d	100	97	88	78	72
EPT/(EPT+Chironomidae)	100	93	98	100	100
Percentage of dominant taxa[1]	29	14	19	25	28
EPT index	100	100	76	57	71
Community loss[1]	0	0.3	0.45	0.76	0.63
Score					
Standing crop (number of organisms per square meter)	6	6	6	2	4
Number of taxa	6	6	6	6	6
CTQ_d	6	6	6	4	4
EPT/(EPT+Chironomidae)	6	6	6	6	6
Percentage of dominant taxa	4	6	6	4	4
EPT index	6	6	2	0	2
Community loss	6	6	6	4	4
Biological condition					
Total	40	42	38	26	30
Percentage of reference	100	100	95	65	75
Condition		Nonimpaired	Nonimpaired	Slightly impaired	Slightly impaired

[1]Actual values, not a percent comparability to reference site.

Table 11.--Bioassessment of Gallinas Creek watershed, April 1990

[CTQ_d, community tolerance dominance quotient from the biotic condition index of Winget and Mangum (1979); EPT/(EPT + Chironomidae), total number of organisms in Ephemeroptera (E), Plecoptera (P), and Trichoptera (T) divided by number of EPT plus Chironomidae; EPT index, number of EPT taxa present; see explanation in Methods of Data Collection and Analysis, p. 14-15; site locations are shown in fig. 1 and described in table 1]

	Site number				
Metric	2 (Reference)	1	3	4	5
Calculated value					
Standing crop (number of organisms per square meter)	3,053	1,521	2,334	3,500	2,472
Number of taxa	31	29	27	17	28
CTQ_d	63.3	54.5	63.7	71.5	75
EPT/(EPT+Chironomidae)	0.91	0.8	0.8	0.63	0.93
Percentage of dominant taxa	28	12	11	52	37
EPT index	16	15	15	8	11
Community loss	0	0.62	0.44	1.18	0.61
Percentage of reference					
Standing crop (number of organisms per square meter)	100	50	76	115	81
Number of taxa	100	94	87	55	90
CTQ_d	100	100	99	89	84
EPT/(EPT+Chironomidae)	100	88	88	69	102
Percentage of dominant taxa[1]	28	12	11	52	37
EPT index	100	94	94	50	69
Community loss[1]	0	0.62	0.44	1.18	0.61
Score					
Standing crop (number of organisms per square meter)	6	6	6	6	6
Number of taxa	6	6	6	2	6
CTQ_d	6	6	6	6	4
EPT/(EPT+Chironomidae)	6	6	6	4	6
Percentage of dominant taxa	4	6	6	0	2
EPT index	6	6	6	0	0
Community loss	6	4	6	4	4
Biological condition					
Total	40	40	42	22	28
Percentage of reference	100	100	100	55	70
Condition		Nonimpaired	Nonimpaired	Slightly impaired	Slightly impaired

[1]Actual values, not a percent comparability to reference site.

DISCUSSION OF PROBABLE CAUSES OF SPATIAL DIFFERENCES

A general relation exists between the composition of stream water and the drainage-basin geology with which the water has been in contact. The relation is complicated by the influence of atmospheric input, soil formation processes and soil composition, biological and biochemical activity, and human activities that affect natural processes (Hem, 1985, p. 189-190). The situation is complicated further by the influence of multiple rock types, mixing of unlike waters, chemical reactions, and adsorption of dissolved ions.

Significant increases in specific conductance, pH, total hardness, total alkalinity and bicarbonate, and calcium concentrations between stations in a downstream direction are largely a reflection of the differences in geology in the watershed. The increases illustrate the effect of different rock types on surface-water quality. The drainage area upstream from site 1 is almost entirely composed of exposures of metamorphic/igneous rocks consisting primarily of quartz-feldspar-amphibole schist, gneiss, granitic gneiss, and granite (Griggs and Hendrickson, 1951; Baltz, 1972). Most metamorphic and igneous rocks are relatively resistant and impermeable; surface water from areas of these exposed rocks generally contains low dissolved solids because of slow weathering processes (Hem, 1985, p. 201).

Sites 2 and 3 have similar water quality. Both sites have drainage areas of predominantly metamorphic rocks influenced to a small degree by exposures of the Sandia Formation and the Madera Formation. Sites 2 and 3 are located near the contact between predominantly metamorphic/igneous terrane and predominantly sedimentary terrane. Downstream from these sites, the area is almost entirely composed of the Sandia Formation and lower and upper members of the Madera Formation (sandstones, limestones, and shales). Only a small area of metamorphic rocks crops out in the steep canyon in the lowermost part of the study watershed near site 5 near Montezuma (Baltz, 1972).

Water from areas of sedimentary-rock terrane is generally high in pH, dissolved solids, and calcium compared with water that has been in contact with igneous and metamorphic rocks. Sedimentary rocks are, in general, less resistant to decomposition and solution and more permeable than igneous rocks. Limestone is mainly calcium carbonate, and common cementing materials in sandstone are also calcium carbonate and iron carbonate. Thus, water from sedimentary terrane will have a predominance of calcium and bicarbonate ions. Changes in water-quality characteristics from sites 3 to 4, 2 to 5, and 4 to 5 are therefore influenced by the occurrence and distribution of these sedimentary rocks.

Water temperatures occasionally were observed above 20 °C at sites 4 and 5. High temperatures at these sites result from a combination of lower altitude, low streamflow conditions, and lack of riparian vegetation to shade the stream from solar insolation. Much of the valley bottom from the head of the canyon downstream from the village of Gallinas to the national forest boundary is pastureland for livestock grazing, and has little or no streamside vegetation for shading or streambank protection.

Turbidities were 10 or more units during runoff events at all sites except site 1. Turbidities at site 3 exceeding this water-quality standard are most probably due to natural causes. High turbidities at site 2 probably are affected by the road that shares the narrow canyon bottom with Gallinas Creek upstream from the national forest boundary. Over a distance of 3.2 miles, the road has 12 bridge crossings and is only a few feet from the edge of the stream (fig. 6A). Runoff and sediment from the road wash directly into Gallinas Creek in this reach. The increase in suspended sediment from site 1 to 2, including this stretch of road, was the only one found to be statistically significant (table 3).

(A)

(B)

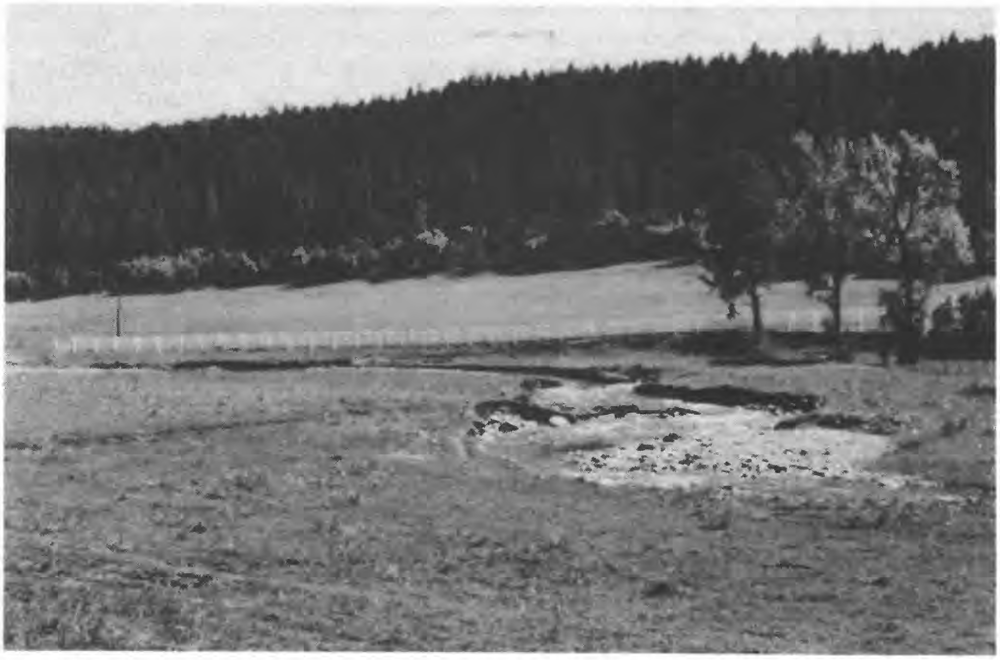


Figure 6.--(A) Proximity of forest road to Gallinas Creek upstream from national forest property boundary; (B) pasture and heavy livestock grazing along Gallinas Creek stream bottom downstream from national forest property boundary.

Increases in maximum turbidities and suspended-sediment concentrations also appear from sites 3 to 4, 2 to 5, and 4 to 5 (table 2), although these were not statistically significant probably because of data limitations. The greatest turbidities and suspended-sediment concentrations were observed at site 5. These increases probably are at least partly caused by homes, developments, and livestock pastures along the stream bottom of lower Porvenir and Gallinas Creeks. Streambank erosion in heavily grazed pastures having no protective streamside vegetation (fig. 6B) could be a significant source of human-induced sediment. The natural sediment yield of storm runoff from the steep slopes in the lower part of Gallinas Creek near Montezuma is also a factor in the high turbidity and suspended sediment at site 5 upstream from the City of Las Vegas water-supply diversion.

One major concern of the City of Las Vegas was the effect of increased sedimentation and turbidity levels in the stream at the municipal water-supply diversion. Water-supply diversion to the treatment plant is halted when turbidity levels approach 25 to 30 turbidity units (George Tyler, Chief Plant Operator, City of Las Vegas, oral commun., 1991). An increase in the magnitude and frequency of turbidity and suspended sediment could therefore adversely affect the treatment costs and supply of the City's water. In this study, about 12 percent of the samples upstream from the water-supply diversion had turbidities greater than 25 units; all of these were storm event samples.

Interpretation of the nutrient and trace-element data was limited because of the large percentage of data below detection limits. Statistical analysis to test for differences between stations could not be performed for this reason. In general, however, concentrations of nutrients and trace elements in the Gallinas Creek watershed are small, as indicated by the large number of samples below the detection limits.

Nutrient data indicate an initial flush of nitrogen species and phosphorus during snowmelt runoff and rainstorm events. This is a natural process that occurred at all sites, as supported by event samples collected by automatic water samplers in the adjacent Tecolote Creek watershed (U.S. Geological Survey, 1988-1991). With rare exceptions, the larger total nitrogen values observed at all sites were due to organic nitrogen, assumed to originate from decomposition of natural plant materials. The effects of human-caused nutrient pollution were not conclusively demonstrated. The water-quality standard for total inorganic nitrogen was exceeded once at site 4, which may be caused by wastewater septic systems, livestock corrals and pastures next to the stream, and application of fertilizer. The maximum ammonia nitrogen concentration was at site 1 and the maximum total phosphorus concentration was at site 3, both relatively unaffected by human activity. The standard for total phosphorus was exceeded at all sites with about equal frequency.

Concentrations of most trace elements were below the detection limit; those for cadmium, chromium, manganese, and zinc were occasionally found at levels only slightly greater than their detection limits. Total aluminum and iron were detected at moderate concentrations at all sites. Both aluminum and iron are abundant elements in the Earth's crust, but concentrations in surface water generally are small. The larger concentrations measured probably were due to particulate material included (Hem, 1985, p. 75, 83). These concentrations are probably due largely to natural causes and not human activities.

The aquatic macroinvertebrate assessment provided results similar to the water-quality assessment, indicating that sites 4 and 5 probably were somewhat impaired by human activities. The biological characterization of the watershed will also be useful as a baseline for future studies. Because benthic macroinvertebrates are residents in the stream, their biological condition reflects environmental changes that may be missed by periodic water sampling. The organisms respond to and integrate the effects of all environmental factors, such as streamflow conditions, temperature regime, and water quality. The macroinvertebrate assessment perhaps showed, more dramatically, the effects of these environmental differences between the sites. On the other hand, the detailed discharge and water-quality data were invaluable for identifying the probable causes of these changes in biological condition.

The macroinvertebrate assessment determined the biological condition of Gallinas and Porvenir Creeks on the basis of resident biota (specifically, the fish-food organisms). The benthic macroinvertebrates are residents, many having year-long life cycles that encompass the seasonality of natural changes or anthropogenic perturbations in water and habitat quality. Therefore, seasonal and long-term changes may be detected through benthic macroinvertebrate collections, whereas changes in water quality may be missed through periodic or seasonal water-quality sampling.

This study is among the first in the Rocky Mountains to apply the USEPA's Rapid Bioassessment Protocol (Plafkin and others, 1989) as used by Jacobi and completed in conjunction with a detailed water-quality assessment. The bioassessment provided valuable information confirmed by the water-quality investigation. By providing similar results, the two methods confirmed and strengthened the findings of the study. When used together, benthic macroinvertebrate and water sampling provide a better understanding of the distribution and effect of contaminants than using only one of the measures.

SUMMARY

Upper Gallinas Creek in north-central New Mexico serves as the public water supply for the City of Las Vegas. The majority of this 84-square-mile watershed is within national forest lands managed by the U.S. Forest Service. In 1985, the Forest Service planned to conduct timber harvesting in the headwaters of Gallinas Creek. The City of Las Vegas was concerned about possible effects on water quality and on water-supply treatment costs. A study was begun in 1987 to assess the baseline water-quality characteristics of Gallinas Creek upstream from the Las Vegas water-supply diversion, relate water quality to State water-quality standards, and determine possible causes for spatial differences in quality. During 1987-90, water-quality samples and aquatic benthic macroinvertebrates were collected and analyzed at five sampling sites in the watershed. Findings from this study are summarized as follows:

(1) Downstream increases in specific conductance, pH, total hardness, total alkalinity and bicarbonate, and calcium were significant to highly significant. These increases are a reflection of the changes in geology in the drainage basin.

(2) Surface-water sites in the Gallinas Creek watershed generally had small concentrations of various nutrients; the majority of samples had concentrations below the detection limit. Large total nitrogen concentrations usually were due to organic nitrogen.

(3) Almost all samples tested for trace elements had concentrations less than the detection limit. Moderate concentrations of total aluminum and iron were found at all sites.

(4) Suspended-sediment concentrations were relatively small at the two upstream sampling locations; concentrations increased downstream. Suspended sediment increased significantly from site 1 to site 2. A highly significant relation of suspended sediment and turbidity was found at sites 2 and 5.

(5) A diverse assemblage of aquatic organisms was found at the five sites, representing 103 different taxa. The bioassessment indicated that sites 4 and 5 had poorer biological conditions, and were rated slightly impaired during the study.

(6) The State water-quality standard for water temperature was occasionally exceeded at sites 4 and 5; the standards for pH and turbidity were exceeded at all sites except site 1. The standard for total inorganic nitrogen was exceeded only once at site 4. At all sites, 10 to 15 percent of samples tested for total phosphorus exceeded the standard of 0.1 mg/L, largely due to natural causes.

(7) The biological assessment used in conjunction with water-quality and streamflow monitoring provided multiple lines of evidence that confirmed observed differences in condition. The combined assessment using the two measures provided more information and stronger results than that from using only one of the measures.

REFERENCES

Baltz, E.H., 1972, Geologic map and cross sections of the Gallinas Creek area, Sangre de Cristo Mountains, San Miguel County, New Mexico: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-673, scale 1:24,000.

Baumann, R.W., Gaufin, A.R., and Surdick, R.F., 1977, The stoneflies (Plecoptera) of the Rocky Mountains: American Entomological Society Memoir no. 31, 208 p.

Conover, W.J., 1971, Practical nonparametric statistics: New York, John Wiley and Sons, p. 239-250.

Courtemanch, D.L., and Davies, S.P., 1987, A coefficient of community loss to assess detrimental change in aquatic communities: Water Resources, v. 21, no. 2, p. 217-222.

Crawford, C.G., Slack, J.R., and Hirsch, R.M., 1983, Nonparametric tests for trends in water-quality data using the Statistical Analysis System: U.S. Geological Survey Open-File Report 83-550, 102 p.

Edmunds, G.F., Jr., Jensen, S.L., and Berner, L., 1976, The mayflies of North and Central America: Minneapolis, University of Minnesota Press, 330 p.

Edwards, T.K., and Glysson, G.D., 1988, Field methods for measurement of fluvial sediment: U.S. Geological Survey Open-File Report 86-531, 118 p. (Techniques of Water-Resources Investigations, book 3, chap. C2, in press).

Fenneman, N.M., 1931, Physiography of western United States: New York, McGraw-Hill, 534 p.

Griggs, R.L., and Hendrickson, G.E., 1951, Geology and ground-water resources of San Miguel County, New Mexico: Socorro, New Mexico Bureau of Mines and Mineral Resources Ground-Water Report 2, 121 p.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Hilley, T.E., McCarty, T.E., Martin, P.G., Sellnow, S.L., and Taylor, Carl, 1981, Soil survey of San Miguel County area, New Mexico: U.S. Department of Agriculture, Soil Conservation Service and Forest Service, 169 p.

Houghton, F.E., 1972, Climate of New Mexico, *in* Climates of the States: Silver Spring, Md., U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Climatography of the United States, no. 60-29, 18 p.

Jacobi, G.Z., 1978, An inexpensive circular sampler for collecting benthic macroinvertebrates in streams: Archiv. fur Hydrobiologia, 83: p. 126-131.

Keup, L.E., and Zarba, C.S., 1987, Benthic quality standards: Proceedings, 35th Annual Meeting, North American Benthological Society, Orono, Maine, June 2-5, 1987.

Maddy, D.V., Lopp, L.E., Jackson, D.L., Coupe, R.H., and Schertz, T.L., 1990, National Water Information System user's manual, v. 2, chap. 2, Water-quality system: U.S. Geological Survey Open-File Report 89-617, p. 1-1 to D-36.

Merritt, R.W., and Cummins, K.W., eds., 1984, An introduction to the aquatic insects of North America: Dubuque, Iowa, Kendall/Hunt Publishing Co., 722 p.

REFERENCES--Concluded

National Oceanic and Atmospheric Administration, 1987-90, Climatological data - annual summary, New Mexico: U.S. Department of Commerce (published annually).

New Mexico Water Quality Control Commission, 1989, New Mexico nonpoint source pollution water quality assessment: Santa Fe, NMWQCC, 85 p.

_____1991, Water quality standards for interstate and intrastate streams in New Mexico: Santa Fe, WQCC 91-1, 49 p.

Omernik, J.M., 1987, Ecoregions of the conterminous United States: Annals of the Association of American Geographers, v. 77, p. 118-125.

Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K., and Hughes, R.M., 1989, Rapid Bioassessment Protocols for use in streams and rivers--Benthic macroinvertebrates and fish: Office of Water, EPA/444/4-89-001, Washington, D.C., U.S. Environmental Protection Agency, 160 p.

SAS Institute, Inc., 1990, SAS/STAT user's guide, version 6: Cary, N.C., SAS Institute, Inc., v. 2, 1686 p.

Shannon, C.E., and Weaver, W., 1963, The mathematical theory of communication: Urbana, University of Illinois Press.

Smart, A.W., 1986, Water resources investigation of the Gallinas watershed: Santa Fe, N. Mex., Santa Fe National Forest, unpublished report, 62 p.

Smolka, L.R., 1986, Intensive survey of the Gallinas River, San Miguel County, New Mexico, June 2-5, 1986: New Mexico Environmental Improvement Division, Surveillance and Standards Section, 35 p.

Tuan, Yi-Fu, Everard, C.E., Widdison, J.G., and Bennett, Iven, 1973, The climate of New Mexico: State Planning Office, 197 p.

Tukey, J.W., 1977, Exploratory data analysis: Reading, Mass., Addison-Wesley, 668 p.

U.S. Geological Survey, 1971, Index of surface-water records to September 30, 1970 - Part 8, Western Gulf of Mexico Basins: U.S. Geological Survey Circular 658, 53 p.

_____1988-91, Water resources data, New Mexico, water years 1987-90: U.S. Geological Survey Water-Data Reports NM-87-1 to NM-90-1 (published annually).

Waltemeyer, S.D., 1989, Statistical summaries of streamflow data in New Mexico through 1985: U.S. Geological Survey Water-Resources Investigations Report 88-4228, 204 p.

Ward, J.C., and Harr, C.A., eds., 1990, Methods for collection and processing of surface-water and bed-material samples for physical and chemical analyses: U.S. Geological Survey Open-File Report 90-140, 71 p.

Wiggins, G.B., 1977, Larvae of the North American Caddisfly genera (Trichoptera): University of Toronto Press, 300 p.

Winget, R.W., and Mangum, F.A., 1979, Biotic condition index--integrated biological, physical, and chemical stream parameters for management: Provo, Utah, U.S. Forest Service, Intermountain Region, 51 p.

APPENDIXES 1-6

Appendix 1.--Quantitative benthic macroinvertebrate collections from Gallinas Creek watershed, September 1987

[CTQd, community tolerance dominance quotient from the biotic condition index of Winget and Mangum (1979); see explanation in Methods of Data Collection and Analysis; site locations are shown on fig. 1 and described in table 1]

Taxa	Site number				
	1	2	3	4	5
PLECOPTERA - stoneflies					
Podmosta delicatula			1,004		
Zapada cinctipes	391	79			
Capniidae	40				
Taenionema sp.	45				
Megarcys signata				17	
Pteronarcella badia		17	6		
Isoperla sp.			34		
Chloroperlidae B	68	17	34	23	
Suwallia sp.			57		
Claassenia sabulosa		23	23		
Hesperoperla pacifica	136	45	74		
EPHEMEROPTERA - mayflies					
Baetis tricaudatus	227	261	352	612	232
Heptagenia sp.	130			96	79
Rhithrogena sp.	6				
Rhithrogena robusta		102	85		
Epeorus sp.	62				
Paraleptophlebia sp.	153	51	561	45	23
Tricorythodes sp.					244
Drunella grandis		414	79		
Drunella doddsi	346	96	57		
Ephemerella infrequens	91	34	284		
TRICHOPTERA - caddisflies					
Rhyacophila brunea cpx.	221	34	198		
Rhyacophila valuma	45	142		159	96
Glossosoma sp.	91	28			142
Chimarra sp.	85	289			79
Dolophilodes sortosa			357		
Hydropsyche cockerelli			482	57	130
Cheumatopsyche sp.					227
Arctopsyche grandis	289	828		17	
Hydroptila sp.			11		11
Oxyethira sp.					34
Oligophlebodes sp.					17
Psychoronia sp.	11	578	1,310		
Lepidostoma sp.	108	28	970	125	
Brachycentrus sp.				17	284
Helicopsyche borealis					833
Polycentropus sp.					51

Appendix 1.--Quantitative benthic macroinvertebrate collections from Gallinas Creek watershed, September 1987--Concluded

Taxa	Site number				
	1	2	3	4	5
DIPTERA - true flies					
Antocha monticola		136	130	6	
Dicranota sp.	40	17	40		11
Holorusia grandis					6
Tipula sp.		11		11	
Pericoma sp.		34	62		
Simuliidae	40	102	85	493	102
Chironomidae A	79				
Eukiefferiella sp.		11	11		
Cricotopus sp.		164		522	1,021
Nostocladius sp.	62	295	1,123		181
Podonominae		96	11		
Micropsectra sp.				113	40
Ceratopogonidae		28			34
Oreogeton sp.		11			
Hemerodromia sp.	11	11	28	11	45
HEMIPTERA - true bugs					
Ambrysus mormon				23	108
COLEOPTERA - beetles					
Helichus sp.				6	34
Narpus sp.	11				
Heterlimnius corpulentus	170	726	607	703	544
LEPIDOPTERA - moths					
Paragyractis (Petrophila) sp.				6	284
ANNELIDA - segmented worms					
Naididae					11
Lumbriculidae	34	6	125	232	51
PLATYHELMINTHES - flatworms					
Turbellaria					164
ARTHROPODA - other arthropods					
Hydracarina A - mites	17	28	147		
Standing crop (organisms per square meter)	3,009	4,742	8,347	3,294	5,118
Total taxa	28	33	30	21	30
CTQ_d	46.7	50.5	51.8	68.4	76.3
Diversity index	4.24	3.97	3.89	3.24	3.96

Appendix 2.--Quantitative benthic macroinvertebrate collections from Gallinas Creek watershed, April 1988

[CTQd, community tolerance dominance quotient from the biotic condition index of Winget and Mangum (1979); see explanation in Methods of Data Collection and Analysis; site locations are shown on fig. 1 and described in table 1]

Taxa	Site number				
	1	2	3	4	5
PLECOPTERA - stoneflies					
Amphinemura banksi	17		125	6	
Podmosta delicatula		720	45	6	
Capniidae			6	6	
Taenionema sp.	221				
Pteronarcella badia		6			
Periodidae			23	11	
Isoperla sp.	6	11	6		
Chloroperlidae B			40		
Triznaka sp.					68
Suwallia sp.	40	6	34	6	
Claassenia sabulosa		23	28		
Hesperoperla pacifica	57	11	91		
EPHEMEROPTERA - mayflies					
Baetis tricaudatus	79	68	74	788	255
Heptagenia sp.	278		289	40	6
Rhithrogena sp.	23	45	85		
Epeorus sp.	408	79	11	23	
Paraleptophlebia sp.	28	51	335	68	45
Tricorythodes sp.					442
Drunella grandis		96			
Drunella doddsi	153	28	6		
Ephemerella infrequens	62	658	403	51	125
TRICHOPTERA - caddisflies					
Rhyacophila brunea cpx.	91	181	68		
Rhyacophila valuma	62	28	6		
Rhyacophila hyalinata					11
Atopsyche grandis				51	244
Glossosoma sp.	6				40
Chimarra sp.					17
Neureclipsis sp.		6			
Hydropsyche sp.			249		
Hydropsyche sp. a				6	
Hydropsyche cockerelli		680			40
Neureclipsis sp.		6			
Hydropsyche sp.			249		
Hydropsyche sp. a				6	
Hydropsyche cockerelli		680			40
Arctopsyche grandis	119	57		23	
Hydroptila sp.					6
Limnephilus sp.			6		
Oligophlebodes sp.	181				
Apatania sp.					6

Appendix 2.--Quantitative benthic macroinvertebrate collections from Gallinas Creek watershed, April 1988--Concluded

Taxa	Site number				
	1	2	3	4	5
Psychoronia sp.	74			6	6
Lepidostoma sp.	62	731	1,973	23	
Brachycentrus sp.					164
Helicopsyche borealis					408
DIPTERA - true flies					
Antocha monticola	17	119	11		
Dicranota sp.	45	68	68	40	51
Holorusia grandis					11
Tipula sp.	11				17
Pericoma sp.	28	45	68		
Simuliidae	79	68	40	1,950	68
Eukiefferiella sp.		1,650	981	3,572	
Cricotopus sp.	74	102			28
Nostocladius sp.		11	45	624	782
Macropelopia sp.		204	102		
Podonominae			6		
Orthocladius sp.	119				
Paraphaenocladius sp.	17				
Ceratopogonidae	11	6	28	40	17
Chelifera sp.			6		17
Hemerodromia sp.					40
ODONATA - damsel/dragonflies					
Gomphidae					6
HEMIPTERA - true bugs					
Ambrysus mormon				6	51
Macrovelia sp.	6	6			
COLEOPTERA - beetles					
Haliplidae				6	
Helichus sp.				170	136
Narpus sp.	17		6		
Heterlimnius corpulentus	289	1,474	533		6
LEPIDOPTERA - moths					
Parargyractis (Petrophila) sp.					96
MOLLUSCA - snails/clams					
Sphaeriidae	28	6	11		11
ASCHELMINTHES - round worms					
Nematoda				28	
ANNELIDA - segmented worms					
Naididae					204
Lumbriculidae	142	85	232	505	130
PLATYHELMINTHES - flatworms					
Turbellaria					130
ARTHROPODA - other arthropods					
Hydracarina A - mites	6	153	45	6	
Standing crop (number per square meter)	2,856	7,482	6,085	8,061	3,684
Total taxa	34	33	36	26	34
CTQ_d	52	58.1	58.5	67.7	69
Diversity index	4.36	3.56	3.54	2.44	4.01

Appendix 3.--Quantitative benthic macroinvertebrate collections from Gallinas Creek watershed, October 1988

[CTQd, community tolerance dominance quotient from the biotic condition index of Winget and Mangum (1979); see explanation in Methods of Data Collection and Analysis; site locations are shown on fig. 1 and described in table 1]

Taxa	Site number				
	1	2	3	4	5
PLECOPTERA - stoneflies					
Amphinemura banksi	510	57	181		
Podmosta delicatula			6		
Capniidae	11		11	6	147
Taenionema sp.	181				
Pteronarcella badia		17			
Megarcys signata		6			
Isoperla sp.		11	11		
Chloroperlidae B	6		57	17	23
Suwallia sp.	40	57			
Claassenia sabulosa		11	28		
Hesperoperia pacifica	85	40	51		
EPHEMEROPTERA - mayflies					
Baetis tricaudatus	23			17	312
Baetis insignificans	198	45	272	102	
Heptagenia sp.	40	11	284	23	
Rhithrogena sp.	181		284		
Rhithrogena robusta		85	23		
Epeorus sp.	6		17		
Paraleptophlebia sp.	45	57	62		
Tricorythodes sp.					28
Drunella grandis		102	17		
Drunella doddsi	176	45	51		
Ephemerella infrequens	147	369	147		
TRICHOPTERA - caddisflies					
Rhyacophila brunea cpx.	108	23			
Rhyacophila valuma			85		
Rhyacophila hyalinata	11	11	23		
Atopsyche sp.				204	193
Glossosoma sp.	57				108
Chimarra sp.					34
Dolophilodes sortosa	23				
Hydropsyche cockerelli			17		130
Arctopsyche grandis	232	147		57	
Hydroptila sp.					23
Psychoronia sp.		17			
Nectopsyche sp.					6
Lepidostoma sp.	210	176	726	153	
Brachycentrus sp.					62
Helicopsyche borealis				11	272

Appendix 3.--Quantitative benthic macroinvertebrate collections from Gallinas Creek watershed, October 1988--Concluded

Taxa	Site number				
	1	2	3	4	5
DIPTERA - true flies					
Antocha monticola		45	17		
Dicranota sp.	6		23	57	
Hexatoma sp. A		11		6	
Hexatoma sp. B					28
Holorusia grandis				11	
Tipula sp.		6			17
Pericoma sp.		6	11		
Simuliidae	51	11	28	62	34
Chironomidae A		6			
Tvetenia sp.				23	68
Cricotopus sp.					17
Nostocladius sp.	17	40			
Stempellina sp.	40				
Micropsectra sp.		295	125	57	45
Orthocladius sp.	11				
Paraphaenocladius sp.	17		79		
Chelifera sp.		6			
Oreogeton sp.	11				
Hemerodromia sp.				6	6
ODONATA - *damsel/dragonflies*					
Erpetogomphus sp.					11
HEMIPTERA - true bugs					
Ambrysus mormon				6	6
COLEOPTERA - beetles					
Helichus sp.		6	6		
Elmidae		6			
Zaitzevia parvula			153		
Narpus sp.	6	6			
Heterlimnius corpulentus	136	1,021	386	913	255
LEPIDOPTERA - moths					
Parargyractis (Petrophila) sp.				6	147
MOLLUSCA - snails/clams					
Sphaeriidae			11		17
ANNELIDA - segmented worms					
Naididae			45	284	312
Lumbriculidae	136	57	40	170	181
PLATYHELMINTHES - flatworms					
Turbellaria	6				284
ARTHROPODA - other arthropods					
Hydracarina A - mites			11		
NEMATOMORPHA - Gordian worms					
Gordius sp.	11		11		
Standing crop (number per square meter)	2,738	2,809	3,299	2,191	2,766
Total taxa	32	33	34	21	27
CTQ_d	51.4	49.2	53.9	67.3	71.9
Diversity index	4.13	3.46	4.01	2.98	4.04

Appendix 4.--Quantitative benthic macroinvertebrate collections from Gallinas Creek watershed, April 1989

[CTQd, community tolerance dominance quotient from the biotic condition index of Winget and Mangum (1979); see explanation in Methods of Data Collection and Analysis; site locations are shown on fig. 1 and described in table 1]

Taxa	Site number				
	1	2	3	4	5
PLECOPTERA - stoneflies					
Amphinemura banksi	6	17	6	40	17
Capniidae		136	34		
Taenionema sp.	187				
Pteronarcella badia		28			
Isoperla sp.	23	17	40		
Chloroperlidae B		6		40	
Suwallia sp.	23	6	6		62
Claassenia sabulosa		11			
Hesperoperla pacifica	34	17	62		
EPHEMEROPTERA - mayflies					
Ameletus sp.			6		
Baetis tricaudatus	40	130	74	641	1,406
Baetis insignificans	23				
Cinygmula sp.	108		11	91	11
Rhithrogena sp.	193	68	272	6	
Epeorus sp.	11	96	227	34	6
Paraleptophlebia sp.		17	28	6	6
Tricorythodes sp.					6
Drunella grandis	6	102	11	6	
Drunella doddsi	51	17	11		
Ephemerella infrequens	34	471	85		68
TRICHOPTERA - caddisflies					
Rhyacophila brunea cpx.	91	91	28		
Rhyacophila valuma	62				
Rhyacophila coloradensis		6			
Atopsyche sp.				28	119
Glossosoma sp.	11				
Dolophilodes sorotsa		6			
Hydropsyche cockerelli		113	6		266
Arctopsyche sp.	266	45		6	
Oligophlebodes sp.	6				
Psychoronia sp.	6				
Lepidostoma sp.	125	57	130	618	
Brachycentrus americanus					51

Appendix 4.--Quantitative benthic macroinvertebrate collections from Gallinas Creek watershed, April 1989--Concluded

Taxa	Site number				
	1	2	3	4	5
DIPTERA - true flies					
Tipulidae					11
Antocha monticola		57	6		
Dicranota sp.	11	23	23	23	28
Hexatoma sp. A					6
Tipula sp.		6		6	40
Pericoma sp.		11	11		
Simuliidae	198	96	34	414	261
Chironomidae A	6	6			
Eukiefferiella sp.		17	6		68
Cricotopus sp.	23				28
Nostocladius sp.	45	221	6	34	6
Macropelopia sp.		57			
Micropsectra sp.		11	6	51	28
Paraphaenocladius sp.	11				
Chelifera sp.					6
Oreogeton sp.	6	6			11
HEMIPTERA - true bugs					
Ambrysus mormon					
COLEOPTERA - beetles					
Helichus sp.				6	6
Zaitzevia parvula		62	79	11	
Narpus sp.	6	11	11		
Heterlimnius corpulentus	187	561	198	102	74
LEPIDOPTERA - moths					
Parargyractis (Petrophila) sp.					62
ANNELIDA - segmented worms					
Naididae					
Lumbriculidae	62	23	57	142	130
PLATYHELMINTHES - flatworms					
Turbellaria	6				17
ARTHROPODA - other arthropods					
Hydracarina A - mites					
Standing crop (number per square meter)	1,867	2,625	1,474	2,305	2,800
Total taxa	31	36	28	20	27
CTQ_d	52.7	55.5	52.9	58.3	70.7
Diversity index	4.09	4.02	3.84	2.92	2.89

Appendix 5.--Quantitative benthic macroinvertebrate collections from Gallinas Creek watershed, October 1989

[CTQd, community tolerance dominance quotient from the biotic condition index of Winget and Mangum (1979); see explanation in Methods of Data Collection and Analysis; site locations are shown on fig. 1 and described in table 1]

Taxa	Site number				
	1	2	3	4	5
PLECOPTERA - stoneflies					
Amphinemura banksi	40	57	74		
Podmosta delicatula	17				
Capniidae	17	6		6	
Taenionema sp.	11				
Pteronarcella badia		6			
Periodidae			11		
Isoperla sp.		68	11		
Chloroperlidae B				6	34
Suwallia sp.	28		45	6	
Claassenia sabulosa		11	34		
Hesperoperla pacifica	125	91	176		
EPHEMEROPTERA - mayflies					
Baetis tricaudatus	74		51	45	
Baetis insignificans	17			11	266
Heptagenia sp.	130		227	74	
Rhithrogena sp.	45	23	28		
Epeorus sp.	28		23		
Paralepotophlebia sp.	17	6	125	6	34
Tricorythodes sp.					198
Drunella grandis				6	
Drunella doddsi	301	28			
Ephemerella infrequens	108	907	505		17
TRICHOPTERA - caddisflies					
Rhyacophila brunea cpx.	68	68	45		
Rhyacophila valuma	74	11			
Atopsyche sp.				96	204
Glossosoma sp.	130				51
Chimarra sp.		11			2,461
Dolophilodes sortosa	11	11			
Hydropsyche cockerelli		686	108		550
Cheumatopsyche sp.					1,168
Arctopsyche grandis	204	11		34	
Hydroptila sp.					45
Oligophlebodes sp.	170	102			
Psychronia sp.			709		
Leptoceridae	11	11	6		68
Lepidostoma sp.	6	57		125	
Brachycentrus sp.		17			74
Micrasema sp.		550			
Helicopsyche borealis					386
Polycentropus sp.				6	28

Appendix 5.--Quantitative benthic macroinvertebrate collections from Gallinas Creek watershed, October 1989--Concluded

Taxa	Site number				
	1	2	3	4	5
DIPTERA - true flies					
Antocha monticola	40	91	113	17	
Dicranota sp.	34	28	11	45	68
Hexatoma sp. A		23		11	
Hexatoma sp. B					130
Tipula sp.				11	6
Pericoma sp.	23	51	45		
Simuliidae	11	23	23	227	346
Chironomidae A	40				
Eukiefferiella sp.		23			
Cricotopus sp.	170	45	476	23	312
Nostocladius sp.	221	505	23		85
Podonominae			17		6
Micropsectra sp.				11	34
Orthocladius sp.	34				
Paraphaenocladius sp.	23				
Ceratopogonidae	11				
Chelifera sp.	6				
Hemerodromia sp.				17	11
ODONATA - damsel/dragonflies					
Erpetogomphus sp.					6
Aeshnidae					23
Aeshna sp.				6	
Argia sp.				6	
HEMIPTERA - true bugs					
Ambrysus mormon				11	85
COLEOPTERA - beetles					
Helichus sp.			6		
Narpus sp.		11	45	11	23
Heterlimnius corpulentus	380	1,208	669	323	646
LEPIDOPTERA - moths					
Parargyractis (Petrophila) sp.					238
MOLLUSCA - snails/clams					
Physa sp.				11	
Sphaeriidae	23		6	6	6
ASCHELMINTHES - round worms					
Nematoda	6				
ANNELIDA - segmented worms					
Erpobdella sp.					6
Naididae				17	11
Lumbriculidae	108	51	153	136	51
PLATYHELMINTHES - flatworms					
Turbellaria					970
ARTHROPODA - other arthropods					
Hydracarina A - mites		17	34		
Standing crop (number per square meter)	2,762	4,814	3,799	1,310	8,647
Total taxa	37	33	29	29	35
CTQ_d	53.6	52.1	59.1	66.9	72.1
Diversity index	4.42	3.38	3.71	3.61	3.66

Appendix 6.--Quantitative benthic macroinvertebrate collections from Gallinas Creek watershed, April 1990

[CTQd, community tolerance dominance quotient from the biotic condition index of Winget and Mangum (1979); see explanation in Methods of Data Collection and Analysis; site locations are shown on fig. 1 and described in table 1]

Taxa	Site number				
	1	2	3	4	5
PLECOPTERA - stoneflies					
Amphinemura banksi	11		28	26	
Podmosta delicatula	6	125	68	9	
Pteronarcella badia		6			
Cultus aestivalis	6				
Isoperla sp.		17	17		
Chloroperlidae B		6			
Suwallia sp.		17		77	130
Hesperoperla pacifica	91	34	57		
EPHEMEROPTERA - mayflies					
Baetis tricaudatus	113	130	187	723	924
Heptagenia sp.	68		153	85	
Rhithrogena sp.	45	23	119		
Epeorus sp.	91		28	9	
Paraleptophlebia sp.		17	62	9	
Tricorythodes sp.					284
Drunella grandis		17		9	
Drunella doddsi	74		11		
Ephemerella infrequens	57	573	193		11
TRICHOPTERA - caddisflies					
Rhyacophila brunea cpx.	79	28	17		
Rhyacophila valuma	11		23		6
Rhyacophila coloradensis	17				
Atopsyche sp.					17
Anagapetus sp.					11
Chimarra sp.					40
Hydropsyche cockerelli		102	74		204
Arctopsyche grandis	40				
Oligophlebodes sp.	85				
Lepidostoma sp.	74	482	153		
Micrasema sp.					79
Helicopsyche borealis		6			11

Appendix 6.--Quantitative benthic macroinvertebrate collections from Gallinas Creek watershed, April 1990--Concluded

Taxa	Site number				
	1	2	3	4	5
DIPTERA - true flies					
Antocha monticola	6	6			
Dicranota sp.	34	11	28	77	
Tipula sp.		6		9	11
Prionocera sp.		6			136
Pericoma sp.	17	6	23		
Simulium sp.	17	23	45	1,836	6
Eukiefferiella sp.		91	153	230	23
Tvetenia sp.				34	
Cricotopus sp.	23		17		23
Nostocladius sp.	28	6		128	68
Macropelopia sp.		45			
Micropsectra sp.			28	153	23
Orthocladius sp.	108				
Paraphaenocladius sp.	62		68		
Ceratopogonidae	34				11
Chelifera sp.		6			6
Oreogeton sp.		11			
Hemerodromia sp.	6				
ODONATA - damsel/dragonflies					
Erpetogomphus sp.					6
HEMIPTERA - true bugs					
Ambrysus mormon					57
COLEOPTERA - beetles					
Zaitzevia parvula		147	238		
Narpus sp.	6	6	74		
Heterlimnius corpulentus	176	862	187	60	210
LEPIDOPTERA - moths					
Parargyractis (Petrophila) sp.					28
MOLLUSCA - snails/clams					
Planorbidae					17
Sphaeriidae					6
ANNELIDA - segmented worms					
Naididae		34	34		28
Lumbriculidae	136	204	249	26	96
Standing crop (number per square meter)	1,521	3,053	2,334	3,500	2,472
Total taxa	29	31	27	17	28
CTQ_d	54.5	63.3	63.7	71.5	75
Diversity index	4.36	3.36	4.26	2.34	3.36

*U.S. GOVERNMENT PRINTING OFFICE: 1996-775-763/45044