IMPACTS OF SURFACE MINING ON THE BIOLOGY AND HYDROLOGY OF A SMALL WATERSHED IN WEST-CENTRAL ALABAMA

GEOLOGICAL SURVEY OF ALABAMA BULLETIN 125

GEOLOGICAL SURVEY OF ALABAMA

Ernest A. Mancini
State Geologist

ENVIRONMENTAL GEOLOGY DIVISION

Maurice F. Mettee, Ph.D.
Chief

BULLETIN 125

IMPACTS OF SURFACE MINING ON THE BIOLOGY AND HYDROLOGY OF A SMALL WATERSHED IN WEST-CENTRAL ALABAMA

By

Steven C. Harris, Ph.D., Patrick E. O'Neil,
Maurice F. Mettee, Ph.D., and Robert V. Chandler

Performed for U.S. Department of Interior,
Bureau of Land Management, Washington, DC 20240
Contract No. AA851-CT1-49, Project Officer Robert L. Todd

Tuscaloosa, Alabama
1985

GEOLOGICAL SURVEY OF ALABAMA

420 Hackberry Lane
P. O. Box O, University Station
Tuscaloosa, Alabama 35486
(205) 349-2852

ERNEST A. MANCINI
State Geologist
and
Oil and Gas Supervisor

DIRECTORS

Executive Assistant, R. C. Bagenstose
Administrative Services, G. W. Swindel, Jr.
Technical Operations, W. E. Smith
Geologic Program, C. W. Copeland, Jr.
Energy Resources, T. W. Daniel, Jr.
Mineral Resources, W. E. Smith
Water Resources, J. D. Moore
Environmental Geology, M. F. Mettee
Geochemistry Laboratory, N. A. Lloyd
Geocartographic Laboratory, T. V. Stone

September 18, 1985

Honorable George C. Wallace
Governor of Alabama
Montgomery, Alabama

Dear Governor Wallace:

I have the honor to transmit a report entitled "Impacts of surface mining on the biology and hydrology of a small watershed in west-central Alabama," by Steven C. Harris, Patrick E. O'Neil, Maurice F. Mettee and Robert V. Chandler. This report has been printed by the Geological Survey of Alabama as Bulletin 125.

This report summarizes information gathered on the biological and hydrological resources of a small watershed in west-central Alabama and the impacts of limited mining within this watershed. This study will provide assistance to the Geological Survey of Alabama and other state and federal agencies in the development of the coal resources of Alabama with minimal environmental impact.

Respectfully,

Ernest A. Mancini

Ernest A. Mancini
State Geologist

PREFACE

The Warrior coal field in Alabama yields nearly 90 percent of the total annual coal production in the State. Future development of this field will require increased information on the quality of the natural waters of the region, and likely necessitate numerous aquatic studies dealing with the environmental impact of coal mining for compliance with state and federal guidelines. At present, such studies are difficult and costly due to a lack of baseline information on the aquatic fauna, water quality, and other geologic and hydrological features of the region. Such baseline information is invaluable not only to meet permit requirements and to assess any effects of mining, but also to provide basic data to measure stream recovery during and following mine reclamation.

The Tyro Creek watershed study, which provides baseline biological and hydrological data for a portion of the Warrior coal field, is a response to basic management needs in this area. The information collected during this study will assist in the assessment of mining and evaluation of subsequent reclamation practices in the watershed. The relationships illustrated in the Tyro Creek study linking water quality, streamflow, and mining activity will also strengthen existing data bases for the Black Warrior basin.

CONTENTS

ILLUSTRATIONS

TABLES

TABLES - CONTINUED

IMPACTS OF SURFACE MINING ON THE BIOLOGY AND HYDROLOGY OF A SMALL WATERSHED IN WEST-CENTRAL ALABAMA

By

Steven C. Harris, Ph.D., Patrick E. O'Neil,
Maurice F. Mettee, Ph.D., and Robert V. Chandler

INTRODUCTION

Alabama contains significant quantities of high grade bituminous coal located in the Warrior, Plateau, Coosa, and Cahaba coal fields. Coal reserves in the state are estimated at 23.4 billion tons, of which 5 billion tons are recoverable by surface mining (Tolson, 1984). Nearly ninety percent of the approximate 23 million tons of coal produced annually in the state come from the Warrior coal field, the largest in the state covering approximately 5,110 square miles.

Large quantities of data have been published that document the effects of strip mining for coal on aquatic ecosystems of the eastern United States. Most notable stream effects include increased siltation, alteration of trace metal concentrations, and acid mine drainage which decreases population densities or eliminates associated biological organisms. Most of these studies were conducted in more northern states and documented effects due to worse case mining practices. Very few aquatic studies, however, have described the sequence of biological and hydrological changes from premining to post-reclamation. This lack of baseline information makes any assessment of the effects of coal surface mining rather speculative.

In September, 1981 the Geological Survey of Alabama (GSA) and the U.S. Bureau of Land Management (BLM) initiated a cooperative study, the purpose of which was to document environmental changes to an aquatic ecosystem resulting from surface mining for federally owned coal in the Warrior coal field of Alabama. The Tyro Creek watershed in Tuscaloosa and Fayette Counties, Alabama was chosen as a system relatively unaffected by mining. Initially, the project was conceived in three phases: (1) development of a premining database on the biota, hydrology, and water quality of the Tyro Creek watershed; (2) monitoring of impacts from mining of federal coal reserves in the watershed; and (3) recovery of the system following mining and subsequent reclamation. Although federal land in the Tyro Creek basin was leased for mining, active mining was never initiated in the watershed. As a result, phases two and three were never initiated, and phase one was continued over the three year span of the study. Since some mining had already occurred in the watershed prior to the initiation of this study, some information was obtained on the long term effects of limited mining on a watershed. This report documents the fauna, hydrology, and water quality of the Tyro Creek watershed over a three year period in relation to seasonality and limited mining impacts.

ACKNOWLEDGMENTS

We are grateful to many people who donated their time and expertise during the project. We appreciate the assistance of the following biologists in the identification of specimens: P.K. Lago, University of Mississippi; J.C. Morse, R. Holzenthal, R. Kelley, S. Hamilton, Clemson University; K.L. Manuel, Duke Power Company; Jan Doughman, U.S. Geological Survey; B. Stark, Mississippi College; and B. Kondratieff, Environmental Science and Chemical, Inc. We also thank Jack Hill, Bureau of Land Management, for his assistance and support throughout the course of the study.

DESCRIPTION OF STUDY AREA

PHYSIOGRAPHY AND GEOLOGY

The Tyro Creek basin is 23.9 square miles (mi^2) in area and is divided almost equally into Fayette and Tuscaloosa Counties, Alabama. The basin features high relief topography superimposed on a sandstone and shale plateau, which is part of the Cumberland Plateau physiographic section (Sapp and Emplaincourt, 1975). Elevations range from 280 to 760 feet above mean sea level (ft msl). Woodlands, well-defined stream valleys, and occasional fields dominate the landscape. Land use is mainly silvicultural and agricultural although surface mining has been, and remains, a significant activity.

Exposed in the basin are the Pottsville Formation of Pennsylvanian age, the Coker Formation of Cretaceous age and alluvium of Quaternary age (fig. 1). The Pottsville Formation is the most extensively exposed geologic unit of the basin, with a thickness of about 2,500 feet. Where exposed, the unit consists of medium to dark gray shale and sandstone, with coal and associated underclays. The rocks contain occasional siderite ($FeCO_3$) bands and are carbonaceous, micaceous, and fossiliferous in part. The stratigraphic dip is to the south-southwest at 20 to 30 feet per mile, except where affected locally by faulting or folding.

The lower 10 to 80 feet of the Coker Formation crops out as outliers of unconsolidated sediment on ridges. The Coker overlies the Pottsville Formation and consists primarily of varicolored sand, gravel, clay, and ferruginous sandstone. Its contact with the Pottsville at 500 to 650 ft msl is an ancient erosional surface which slopes southwest at about 25 feet per mile.

Alluvium is present in floodplains of the major streams draining the basin. The alluvium consists of light brown, poorly stratified layers of sand, silt, clay, gravel, and rock fragments and overlies the Pottsville. It ranges in thickness to as much as 10 feet.

COAL RESOURCES

The Tyro Creek basin is part of the 5,110 mi^2 Warrior coal field (fig. 1). The Warrior coal field has defined coal resources of approximately 49 million short tons (Tolson, 1984). Seven major intervals (or groups) of coal are present in the Warrior field (Culbertson, 1964). Two of these intervals, the Gwin and Utley coal groups, are exposed in the study area (fig. 1) and have a high potential for selective surface mining. The Gwin coal group is described as an interval of two coal beds, as much as 3 feet thick, persistently separated by 30 to 40 feet of rock (Beg and others, 1978). The Gwin is exposed on uplands in the topographic interval 440 to 600 ft msl. The Utley coal group contains two to six unnamed coal beds, up to 3 feet thick and occupies a stratigraphic interval about 60 feet higher than the Gwin group.

SOILS

Soil units are mapped by the Soil Conservation Service on the basis of land physiography, soil properties, vegetation, and surface-drainage patterns. For this reason, soil units are associated with geologic units. Principal soil associations in the study area are the Montevallo-Nauvoo association, steep, and Nauvoo fine sandy loam, 4 to 10 percent slopes, with the Pottsville Formation the Smithdale fine sandy loam, 6 to 15 percent slopes, with the Coker Formation, and the Iuka-Mantachie complex, frequently flooded, with alluvium. Because Montevallo-Nauvoo soils are associated with the Pottsville Formation, these soils are the principal soil types in the area. In general, the soils are acidic, clayey in nature, relatively thin, and low in organic matter. They have moderate-rated permeabilities and erosion factors (table 1). In Soil Conservation Service publications (Johnson, 1981; McNutt and others, 1965), the soils are listed as acceptable for woodland management and wildlife habitat but have moderate to severe limitations for water management.

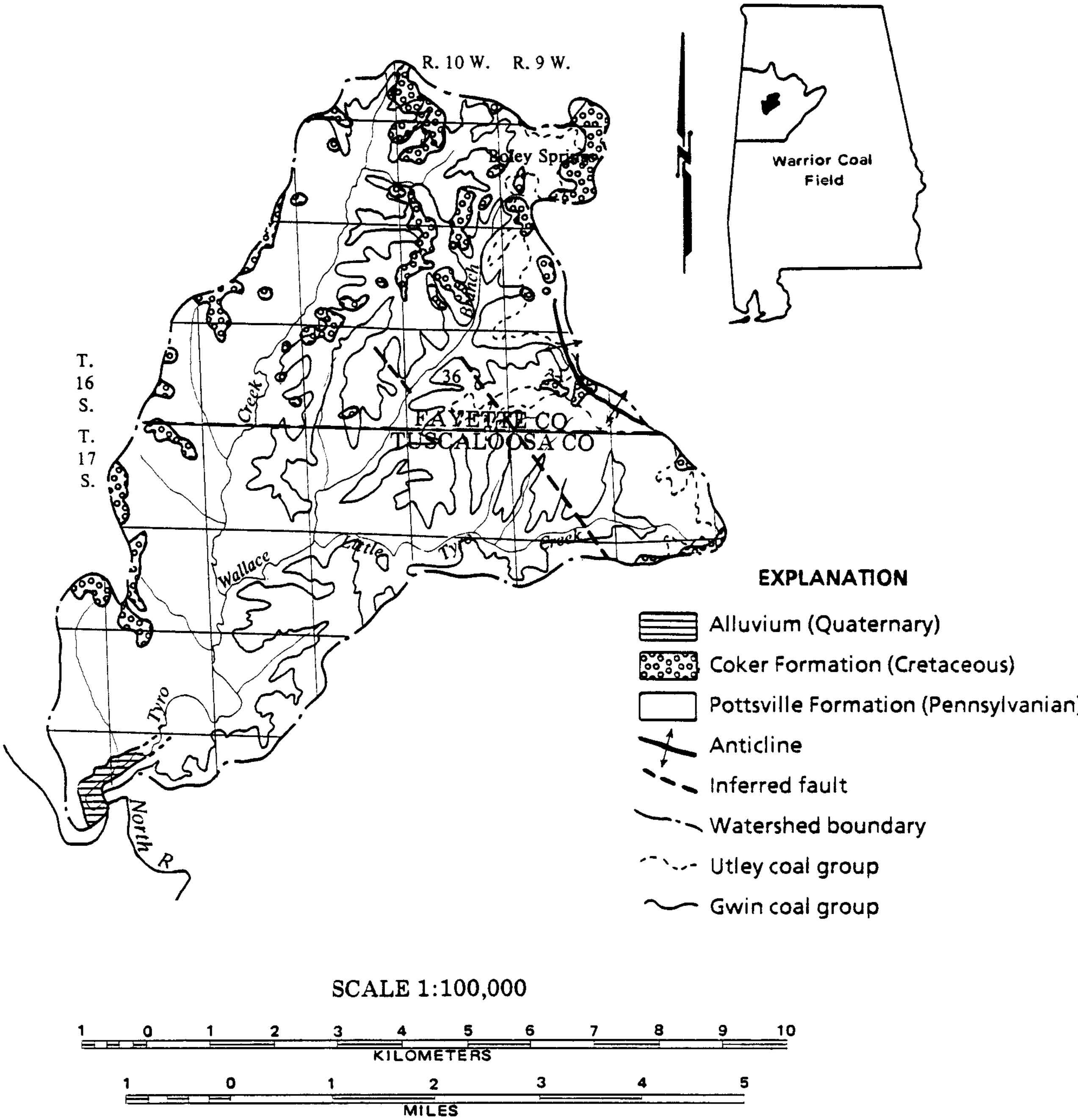


Figure 1.--Generalized geologic map and surface coal resources of the Tyro Creek watershed (modified from Drennen, 1961 and unpublished maps).

Table 1.--Selected properties of soil types in the Tyro Creek basin (modified from Johnson, 1981)

Soil name	Depth (inch)	USDA texture	Classification Unified	Classification AASHTO[1]	Clay <2mm (%)	Permea-bility (inch/hr)	Soil reaction (pH)	Erosion factor (K)[2]	Organic matter (%)	Seasonal high water table (ft)	Depth to bedrock (ft)
Iuka	0-10	Silt loam	SM, SM-SC, ML, CL-ML	A-4	6-15	0.6-2.0	5.1-6.0	0.24	.5-2	1.0-3.0	>5
	10-18	Fine sandy loam, loam, silt loam	SM, SM-SC, ML, CL-ML	A-4	8-18	0.6-2.0	4.5-5.5	0.28			
	18-72	Sandy loam, fine sandy loam, loamy sand	SM, ML, SM-SC	A-2, A-4, A-2	5-15	0.6-2.0	4.5-5.5	0.20			
Mantachie	0- 6	Loam	CL-ML, SM-SC, SM, ML	A-4	8-20	0.6-2.0	4.5-5.5	0.28	1-3	1.0-1.5	>5
	6-60	Loam, clay loam, sandy clay loam	CL, SC, SM-SC, CL-ML	A-4, A-6	18-34	0.6-2.0	4.5-5.5	0.28			
Montevallo	0- 7	Shaly loam	SM-SC, SC, CL-ML, CL	A-4	7-27	0.6-2.0	4.5-6.0	0.37	.5-2	>6.0	0.8-1.6
	7-12	Shaly silt loam, shaly loam, shaly silty clay loam	GM-GC, GC, SM-SC, SC	A-2, A-4, A-6	15-35	0.6-2.0	4.5-6.0	0.32	.5-2		
	12-20	Weathered bedrock	---	---	---	---	---	---			
Nauvoo	0-17	Fine sandy loam	SM-SC, CL-ML, SC, CL	A-4	10-20	2.0-6.0	4.5-5.5	0.28	.5-2	>6.0	3.3-5.0
	17-35	Loam, sandy clay loam, clay loam	SC, CL, ML	A-4, A-6, A-7	18-35	0.6-2.0	4.5-5.5	0.32			
	35-41	Fine sandy loam, loam, sandy clay loam	SM-SC, CL-ML, SC, CL	A-4, A-6	15-30	0.6-2.0	4.5-5.5	0.32			
	41-60	Weathered bedrock	---	---	---	---	---				
Smithdale	0- 5	Fine sandy loam	SM, SM-SC	A-4, A-2	2-15	2.0-6.0	4.5-5.5	0.28	.5-2	>6.0	>5
	5-42	Clay loam, sandy clay loam, loam	SM-SC, SC, CL, CL-ML	A-6, A-4	18-33	0.6-2.0	4.5-5.5	0.24			
	42-72	Loam, sandy loam	SM, ML, CL, SC	A-4	12-27	2.0-6.0	4.5-5.5	0.28			

[1]American Association of State Highway and Transportation Officials.
[2]Values of K range from 0.05 to 0.69. The higher the value, the more susceptible the soil is to erosion.

SURFACE-WATER HYDROLOGY

Streamflow in the study area is primarily a reflection of the physical nature, geology, and climate of the area. The surface-drainage pattern is mainly dendritic superimposed on a "Pottsville" terrain characterized by high-relief features, with thin soils and rocks having poor water-bearing properties. Streams in the area have sharply defined flood peaks and normal flows below an estimated long-term average of 1.5 cubic feet per second per square mile of drainage basin (cfs/mi^2). Base flows are at or near zero cfs due to a low contribution of ground water (i.e., springs and seeps) to streams during dry periods.

An indicator of the high streamflow recession in the basin is the low-flow index (Bingham, 1979). This index, 32 days per flow log cycle, is very low and indicates a short duration of streamflow, particularly during dry periods. Using the low-flow index, the size of the study area (23.9 mi^2), and an equation developed by Bingham, a 7-day median annual low flow (7-day Q_2) of 0.005 cfs/mi^2 was computed. Available information (Pierce, 1959, 1967; Hayes, 1978) indicates that flows of this magnitude characterize parts of Alabama underlain by rocks of low permeability where streamflow fluctuates with and is a reflection of rainfall.

The Tyro Creek basin is located in hydrologic area 23, Eastern Coal Province, described in a report by Harkins and others (1980). They indicated that principal hydrologic problems resulting from the surface mining of coal in this province include erosion and sedimentation, decline in ground-water levels, and degradation of water quality, including an increase in sulfate and manganese levels. Similar problems were noted in a report by Knight and Newton (1977). Presently, effects of mining in the area appear limited mainly to changes in water quality with some siltation in evidence.

CLIMATE

The climate of the area is warm-temperate to subtropical, characterized by long, hot summers, and cool, fairly short winters. The average annual temperature is approximately 62°F (16.7°C) (Lineback and others, 1974). A low range in monthly average temperatures, from about 46°F (7.8°C) for January to 81°F (27.2°C) for July is the result of tempering influences of the Gulf of Mexico.

Precipitation in the area averages about 54 inches a year. Climatic data collected at the National Oceanic Atmospheric Administration (NOAA) weather station at the Oliver Lock and Dam, Tuscaloosa, for the period covered by the study (September, 1981 through July, 1984), show seasonal changes in rainfall (fig. 2). Fall months are generally dry. In winter the interaction of cold fronts and maritime air masses in the Gulf of Mexico produces extended periods of precipitation. Temperatures moderate in spring, but relatively heavy rainfall still occurs. Summers are hot, often humid, and are characterized by afternoon thunderstorms contributing to a near-mean monthly rainfall of about 4 inches.

MATERIALS AND METHODS

SAMPLING STATIONS

Four regular and two supplemental sites were chosen within the Tyro Creek watershed for collection of biological and hydrological samples (fig. 3, table 2, Appendix A). Sites 1 and 2 were located on the main channel of Tyro Creek. Sites 3 and 4 were located on two tributaries to Tyro Creek; Wallace Branch, and Little Tyro Creek, respectively. These four sites were sampled at monthly intervals from September, 1981 through December, 1983 and at bimonthly intervals in 1984. Portions of the basin draining Wallace Branch and Little Tyro Creek had been previously mined. Additional mining was scheduled in the Little Tyro Creek tract, but never initiated. Sites 3 and 4, and site 1, which is downstream of their confluence, served as the primary experimental sites. Site 2, which is upstream of the confluence of Wallace Branch with Tyro Creek served as the control.

In addition to these four regular sites, two supplemental sites were added. One at the headwaters of Tyro Creek (site 5) and one at the headwaters of Wallace Branch (site 6). Site 5 was

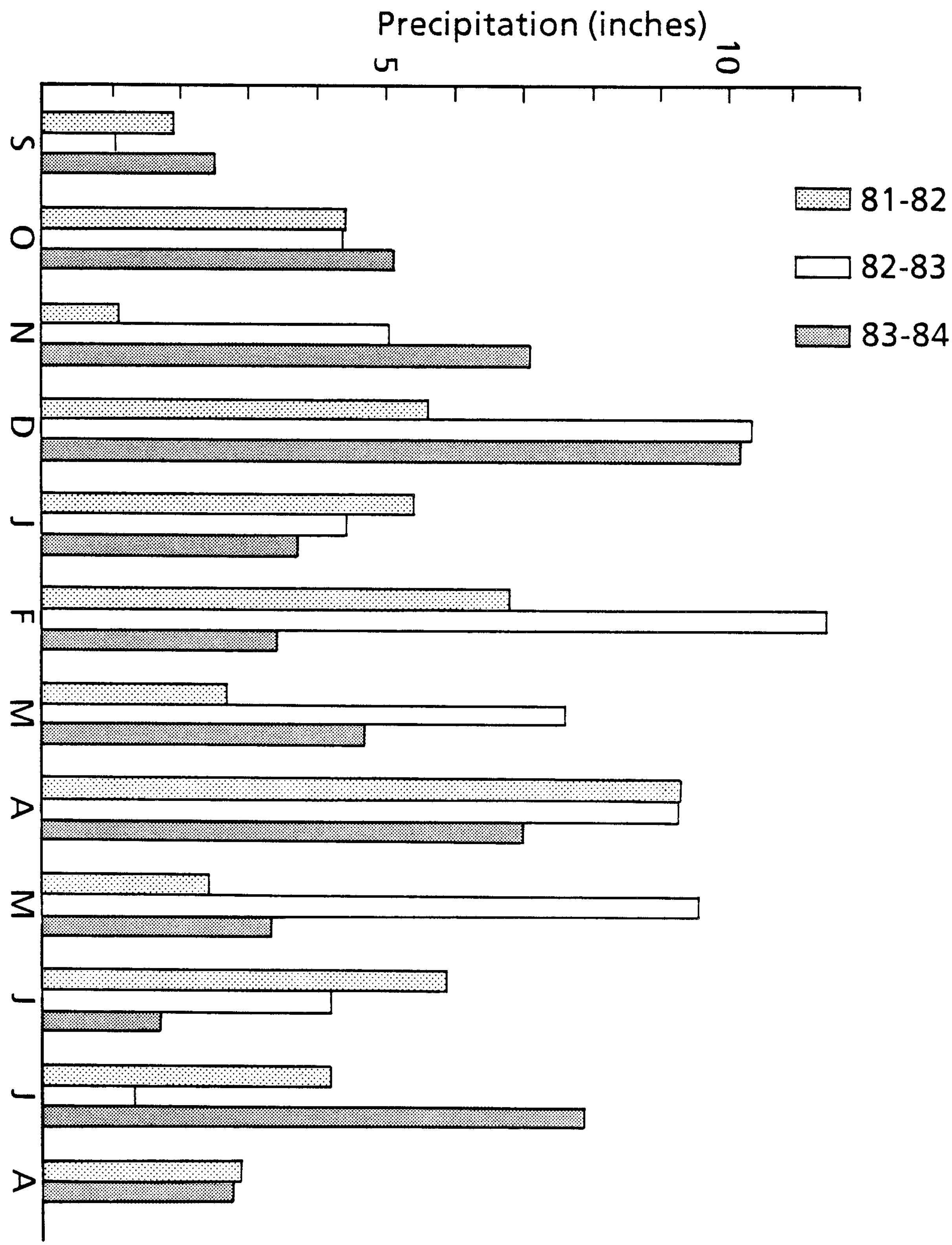


Figure 2.--Total monthly rainfall recorded at Oliver Lock and Dam, Tuscaloosa (NOAA, 1981-1984).

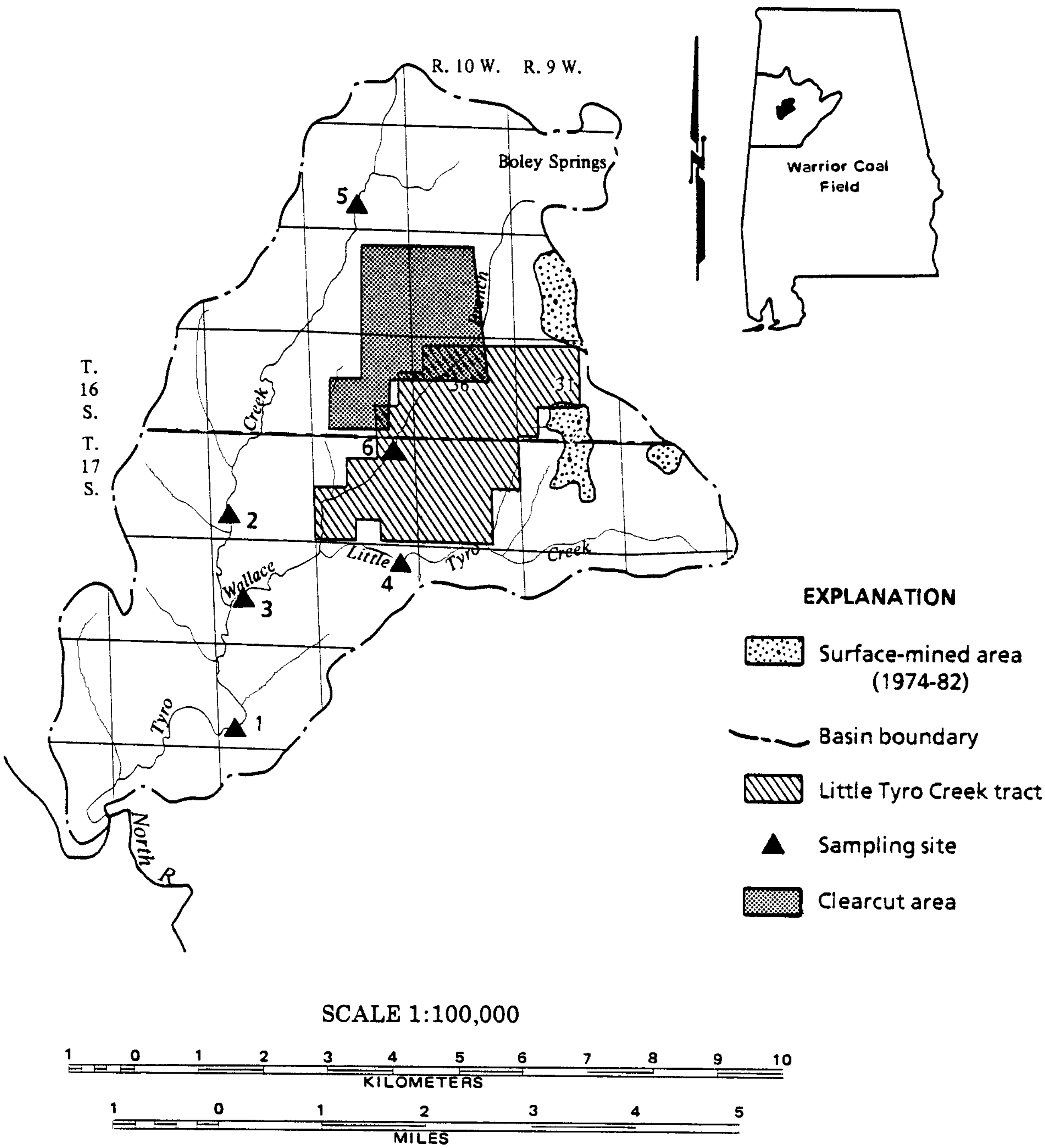


Figure 3.--Sampling sites, areas of surface mining and silviculture in the Tyro Creek watershed.

Table 2.--Sampling site locations in the Tyro Creek watershed and drainage areas

Station	Site numbers (Project)	(USGS)	Latitude	Longitude	Elevation (ft msl)	Drainage area (mi^2)	Percent of drainage area mined
Tyro Creek at bridge	1	02463850	33°33'58"	87°34'34"	290	21.40	4
Tyro Creek at ford	2	02463840	33°35'43"	87°34'35"	310	7.14	0
Wallace Branch near mouth	3	02463847	33°35'02"	87°34'35"	305	11.00	7
Little Tyro Creek	4	02463846	33°35'17"	87°32'55"	325	4.25	11
Tyro Creek at headwaters[1]	5	02463839	33°38'17"	87°33'15"	410	3.01	0
Wallace Branch at headwaters	6	02463843	33°35'20"	87°32'53"	350	3.18	9

[1]Used primarily for biological sampling; other sites are used for biological and hydrological sampling.

used as an additional control site in the watershed, as it was similar in size and drainage to site 4. Only biological data (fishes and adult insects) were collected at this site. Site 5 was collected at regular sampling intervals beginning in March, 1982 and occasionally prior to this point. Site 6 was added to the study in February, 1983 following extensive clearcutting in a portion of the basin (fig. 3). This site was collected at regular sampling intervals the remainder of the study. The full complement of parameters determined at sites 1, 2, 3, and 4 were also measured at site 6. These two sites, although not included in the original scope of work, were incorporated to better understand faunal distributions and relationships within the watershed.

WATER QUALITY

Eight water-quality parameters were measured in the field. Stream discharge was determined according to the procedures described in a following section under streamflow. Twenty-four other parameters (table 3) were measured at the Geochemical Water-Quality Laboratory of the GSA.

FIELD ANALYSES

Dissolved oxygen (DO) was measured in-stream using a Yellow Springs Instrument (YSI) Model 54 dissolved-oxygen meter. Hydrogen-ion concentration was measured with an Orion Model 407-A pH meter with reference electrodes. Specific conductance was measured in micromhos per centimeter (µmhos/cm) with a Model MCl, Mark IV portable conductivity meter. Color, measured in platinum-cobalt (Pt-Co) units, and turbidity, measured in Jackson turbidity units (JTU), were measured with a Hach DR-EL colorimeter. Alkalinity as bicarbonate was determined by titrating a 50 milliliter (ml) water sample with a standard sulfuric acid solution to an end-point pH of 4.5, as determined by an Orion pH meter.

LABORATORY ANALYSES

Water samples were collected at mid-stream for laboratory analyses. One sample was filtered and acidified with a 25 percent nitric acid solution for trace-metal contents analysis. Another sample was filtered, but not acidified, and kept chilled for determination of nitrate (NO_3) content. Raw-water samples were collected for standard chemical analysis using the methods of Skougstad and

Table 3.--Water-quality and bottom-sediment parameters measured in Tyro Creek watershed, September 1981 through July 1984

Field[1] determinations	Laboratory[1] analyses	Bottom sediments
Discharge (cfs)	Suspended sediment	Sieve analyses
Temperature (°C)	Calcium (Ca)	Trace metals and nutrients (mg/kg)
pH (as units)	Chloride (Cl)	Arsenic (As)
Alkalinity (as HCO_3)	Fluoride (F)	Cadmium (Cd)
Specific conductance (µmhos/cm)	Potassium (K)	Chromium (Cr)
Color (Pt-Co)	Magnesium (Mg)	Cobalt (Co)
Turbidity (JTU)	Sodium (Na)	Copper (Cu)
Dissolved oxygen	Nitrate (N) (dissolved)	Iron (Fe)
	Nitrate (NO_3) (dissolved)	Lead (Pb)
	Silica (SiO_2)	Manganese (Mn)
	Sulfate (SO_4)	Mercury (Hg)
	Trace metals (µg/l)	Selenium (Se)
	Arsenic (As)	Strontium (Sr)
	Cadmium (Cd)	Vanadium (V)
	Chromium (Cr)	Zinc (Zn)
	Cobalt (Co)	Chloride (Cl)
	Copper (Cu)	Phosphate (PO_4)
	Iron (Fe)	Nitrate (NO_3)
	Lead (Pb)	pH (as units)
	Vanadium (V)	
	Manganese (Mg)	
	Mercury (Hg)	
	Selenium (Se)	
	Strontium (Sr)	
	Zinc (Zn)	

[1]All measurements in mg/l unless otherwise indicated.

others (1979). Trace-metal contents of water samples were determined using an atomic absorption spectrophotometer (Perkin-Elmer 2380), using methodology outlined by the U.S. Environmental Protection Agency (1979).

SEDIMENT

SUSPENDED SEDIMENT

Representative water samples were obtained using a U.S. Geological Survey DH-40 depth-integrated sampler for determination of sediment content. Normally, the samples were collected at locations in the stream where the cumulative total of measured flow was estimated to be 25 and 75 percent. This procedure for sample collection is a modification of the U.S. Geological Survey's Equal Discharge Interval sampling method (Guy and Norman, 1970). Samples were collected at mid-stream when the measured or estimated flow was very low and the channel narrow.

BOTTOM SEDIMENT

Bottom sediment samples were collected each month for particle size analysis. With the exception of the October and November, 1981 collections, sediment samples were collected in transects across the stream channel using wide-mouth plastic jugs. In October and November, 1981, water levels were low and sediment was collected only at the stream bank. The collected samples were dried and passed through a series of U.S. Standard sieves to determine grain size distribution (table 4). The portion retained by each sieve was weighed and used to calculate percentage of total sample.

A single sediment sample was collected at each site in August, 1982 and July, 1984 for analysis of trace metals and selected nutrients. Sediment was collected from a transect across the stream channel using wide-mouth plastic jars. The jars were then sealed and stored at temperatures ranging from 2° to 4°C until time of analysis.

STREAMFLOW

Streamflow was measured in cubic feet per second (cfs) as instantaneous discharge, using modified U.S. Geological Survey techniques (Carter and Davidian, 1968). Velocity-rated Price pygmy and AA current meters, metal top-settling wading rods, and battery-operated earphones were utilized. Measured sections were perpendicular to flow, ranged from 1 to 27 feet in width, and commonly had water depths of 2.5 feet or less. The transverse profile of each stream site is included in the site descriptions of Appendix A. As gauged stream sections were shallow, they were waded and the 0.5- and 0.6-depth methods of determining flow velocity were used. Zero flows were determined visually. Stream stage as determined by tapedown from fixed reference points was recorded for correlation with measured flows and preparation of flow rating tables. Site descriptions are summarized in Appendix A. These same site descriptions are also contained in Appendix A of Harris and others (1983) in more detail.

BIOLOGICAL

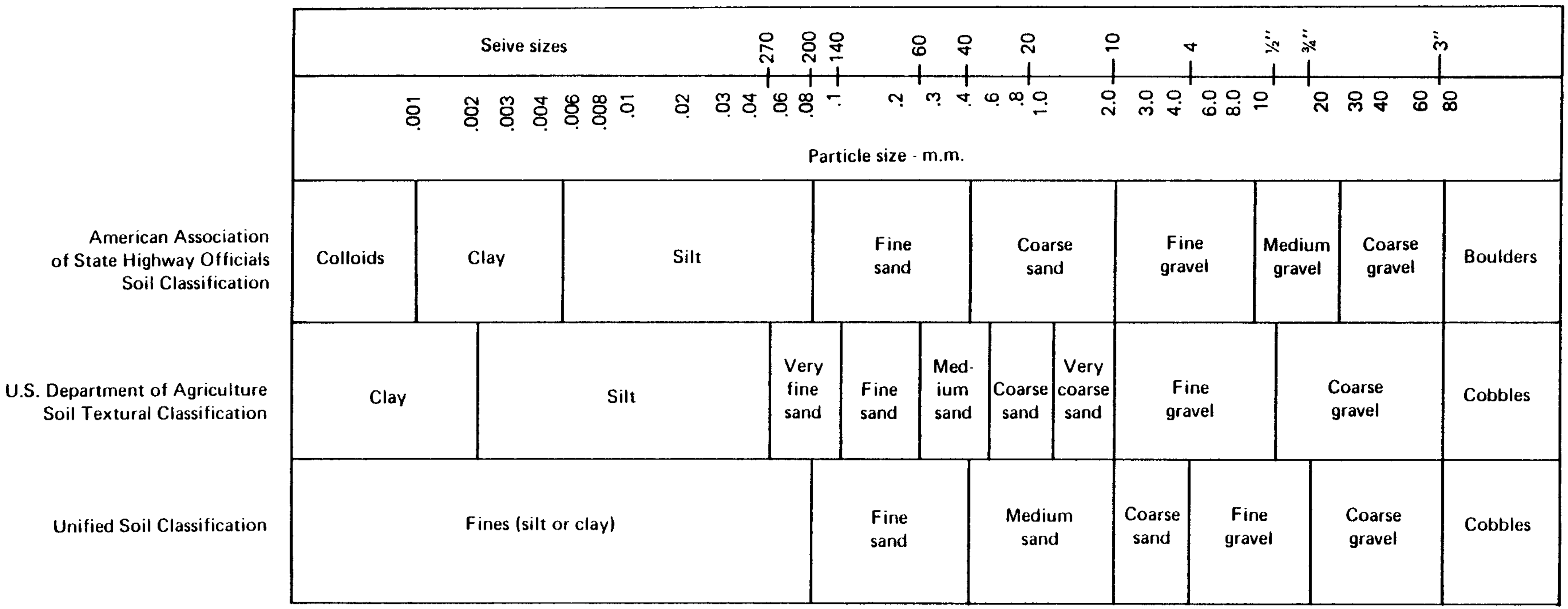
MACROINVERTEBRATES

Macroinvertebrates were collected monthly from September, 1981 through December, 1983, and bimonthly from January, 1984 through July, 1984 at sites 1, 2, 3, 4, and 6 using two different techniques. Samples were not collected at sites 2, 3, and 4 during September and October, 1981 as the streams were dry. Bottom fauna were collected using an Ellis-Rutter portable box sampler, enclosing 0.1 square meter (m^2). Four samples were taken at each site, one near the stream margin and one at the stream center in both a pool and riffle area. Field processing of the samples consisted of screening with a No. 30 sieve and preservation with 95 percent ethanol. In the laboratory, samples were screened again with a No. 30 sieve and placed in white enamel pans. Organisms were separated from the substrate using a saturated sugar solution and a 10X magnifying light, sorted to taxa, and stored in vials. Chironomidae larvae were cleared using a 10 percent solution of potassium hydroxide (KOH) and mounted in Hoyer's medium on microscope slides.

Adult insects were collected at all sites, including site 5, from March through October each year. Adults were collected using battery- powered ultraviolet lights placed over white enamel pans filled with diluted ethanol. The lights were operated on stream banks for approximately 1 hour after dusk. Collections were placed in jars and transported to the laboratory where the Trichoptera, Ephemeroptera, and Plecoptera were sorted from the total collection. These groups were chosen for identification because their immatures are totally aquatic and are good indicators of water-quality conditions. The adults of these three groups are also readily attracted to ultraviolet lights insuring an adequate sample and are easily identified using existing taxonomic keys.

Bottom fauna were identified to genus when possible using the following identification guides: Brigham and others, 1982; Edmonds and others, 1976; Merritt and Cummins, 1984; Parrish, 1975; and Wiggins, 1977. Adult Trichoptera, Ephemeroptera, and Plecoptera were identified to species using mainly the following keys: Blickle, 1979; Edmonds and others, 1976; Morse, 1975; Ross, 1944; and Schmid, 1970. For the purpose of analyzing the benthic data, all taxa regardless of their place in the hierarchy of classification were considered equivalent.

Table 4.--A comparison of grain-size limits of three soil classification systems to standard sieve sizes (after U.S. Department of Agriculture, 1971)



FISHES

Fishes were collected concurrently with the benthic macroinvertebrate and water samples. Nylon minnow seines, 6 and 8 feet in length (1/8-inch delta weave), were used to collect the samples. Total time devoted to collecting a given sample from a site varied according to flow conditions and stream size. During normal to high flows and in larger streams, more time was required to collect a sample. During drier periods of the year, the isolated pools could be quickly sampled. Although sampling fishes using seines is by no means random, bias, if not minimized, was controlled at consistent levels by using the same equipment, the same personnel, and by collecting similar habitats each month.

Upon capture, specimens were immediately preserved in 10 to 20 percent formalin. In the laboratory, samples were sorted to species and the specimens therein enumerated and weighed to the nearest 0.1 gram (g) using a Mettler Balance. All specimens were retained in permanent storage at the GSA for future reference. Notes of unique stream or biological conditions were made in the field and are also on file at the GSA.

DATA ANALYSIS

Linear regression and correlation analyses were performed on the water-quality data using the Statistical Package for the Social Sciences (SPSSX) software package (Nie and others, 1983). The techniques were used to derive equations relating parameter concentrations as a function of streamflow and subsequently comparing these equations for different mined areas within the watershed. A total of 2,640 correlation coefficients were examined to determine statistically significant, hydrologically meaningful relationships between parameters. Correlation coefficients were considered significant ($p < .05$) when calculated "r" values were between .38 to 1.0 ($n = 28$) for stations 1 through 4, and between .58 to 1.0 ($n = 12$) for station 6.

Biological data were managed using a software program developed by the GSA which has data storage, sorting, editing, and recall capabilities. Because biological data are multivariable, no single analysis approach is likely to adequately describe the observed community phenomena. Therefore, several techniques were used to analyze the data. The simplest technique involved plotting basic community parameters such as number of species or taxa and total catch or density through time and describing the observed variation. The next level of analyses included calculating Shannon-Weaver diversity (H') and evenness (J') indexes. These were calculated using the formulas specified in Lloyd and others (1968) and Pielou (1975).

$$H' = (N\log_2 N - \Sigma\, n_i \log n_i) \cdot (N)^{-1}$$

$$J' = H' \cdot (\log_2 s)^{-1}$$

Where n_i equals total individuals (or biomass) of the ith species; N equals total individuals (or biomass) per sample or sampling unit; and s equals the number of species (or taxa) per sample or sampling unit. All indexes were calculated to logarithms of base 2. Diversity measures relate species richness (number of species or taxa) and the distribution of individuals to the species in any given sample (evenness). A small diversity index usually means fewer taxa with most individuals concentrated in a few taxa. Conversely, a greater diversity index means many taxa with individuals more evenly allocated to the collected taxa.

Most measures of community diversity are sample size dependent (Wilhm, 1970) meaning that a sample containing a large number of individuals will have a greater diversity than a smaller sample simply because of its size, thereby masking any community pattern. To compensate for this undesirable property, diversity was also calculated in a cumulative or asymptotic fashion. This approach appears to relieve sample size dependency and more accurately reflects the underlying structure of the faunal community. Diversity and evenness measures should be interpreted with some degree of caution and reservation because of their highly simplistic nature. Hurlbert (1971) has strongly pointed out the failings of the diversity concept and its nonrelation to biological communities. However, because the use of diversity is standard procedure in regulatory and environmental analysis, we include it here for completeness.

The final approach to data analysis included exploring and defining data patterns with multivariate discriminant ordination techniques using the SPSSX computer program. Discriminating variables were species or taxa whose overall abundance exceeded 1.0 percent and also occurred in ten or more collections. Direct and stepwise methods were both examined and found to yield almost identical results.

RESULTS AND DISCUSSION

WATER QUALITY

Water-quality data collected during the study are compiled in Appendix B. These data represent the results of laboratory and field analyses of 132 samples, for a determination of 4,224 parameter values. These values provided the comparative basis for the computer evaluation to identify correlating parameters.

Stream sanitation is dependent, in part, upon natural self-purification; that is, the ability of a stream to assimilate the effects of natural and manmade pollution. One evident source of stream pollution in the area is acid-mine drainage. This problem is indicated at sites 3 and 6 on Wallace Branch, and site 4 on Little Tyro Creek by low pH and high specific conductance values, particularly during periods of low flow (fig. 4). Manganese, a parameter commonly associated with acid-mine drainage, is also high at the same sites (Appendix B). In contrast to the natural calcium-magnesium bicarbonate type of water at site 2, the water at sites 3, 4, and 6 is of the calcium-magnesium sulfate type, another indication of the effects of acid-mine drainage.

Streamflow in the basin is derived principally from surface runoff of precipitation. Because of this and due to the influence of acid-mine drainage on surface-water quality, certain water-quality parameters may be correlated with streamflow. To determine such relationships, correlation analyses comparing water-quality parameters were performed. The results in computed "p" and "r" values were then scanned and a matrix table of correlating parameters prepared (table 5). From information summarized in the table, nine water-quality parameters, specific conductance, calcium, magnesium, sodium, potassium, sulfate, strontium, sediment content and load were selected for regression with streamflow. Iron and manganese were also added to the list due to their known association with coal mining activities. The resulting linear regressions are shown in figures 5, 6, and 7. When viewed in relation to percent of drainage area mined within each sampling site subbasin, a general trend emerges in the figures. As mined area increases within a basin, the analyzed parameters also increased in value. The longitudinal changes observed in parameter concentration, from low (site 2, 0 percent mined), to high (site 4, 11 percent mined), illustrate this trend. The most significant parameter appears to be manganese content. This parameter increased in direct relationship to the percent of area mined. The mining effect is to increase manganese content well beyond the natural stream-buffering capacity of Tyro Creek. Similar problems have been noted (Harkins and others, 1980) in other parts of the Warrior coal field.

Water quality is usually judged by standards applicable to the intended use of the water. Streams in the study area are classified by the Alabama Department of Environmental Management (ADEM) for "Fish and Wildlife." Water-quality parameters in the Tyro Creek watershed, when compared to ADEM's mine-water discharge standards and to drinking water standards of the U.S. Environmental Protection Agency (USEPA, 1979) indicate several possible problems (table 6). These include low pH, high manganese content, and high color and turbidity values. The significance of these problems is two-fold: the study area is part of the watershed of Lake Tuscaloosa, located about 10 miles (6.2 km) to the south, a source of public-water supply for the City of Tuscaloosa; and the area is similar in character to other parts of the Lake Tuscaloosa watershed. Water-quality problems within the Tyro Creek watershed appear to have a limited potential for creating similar problems in Lake Tuscaloosa, but similar problems in other Warrior coal field tributaries to the North River could, in combination pose a potential threat to the lake particularly during periods of low flow.

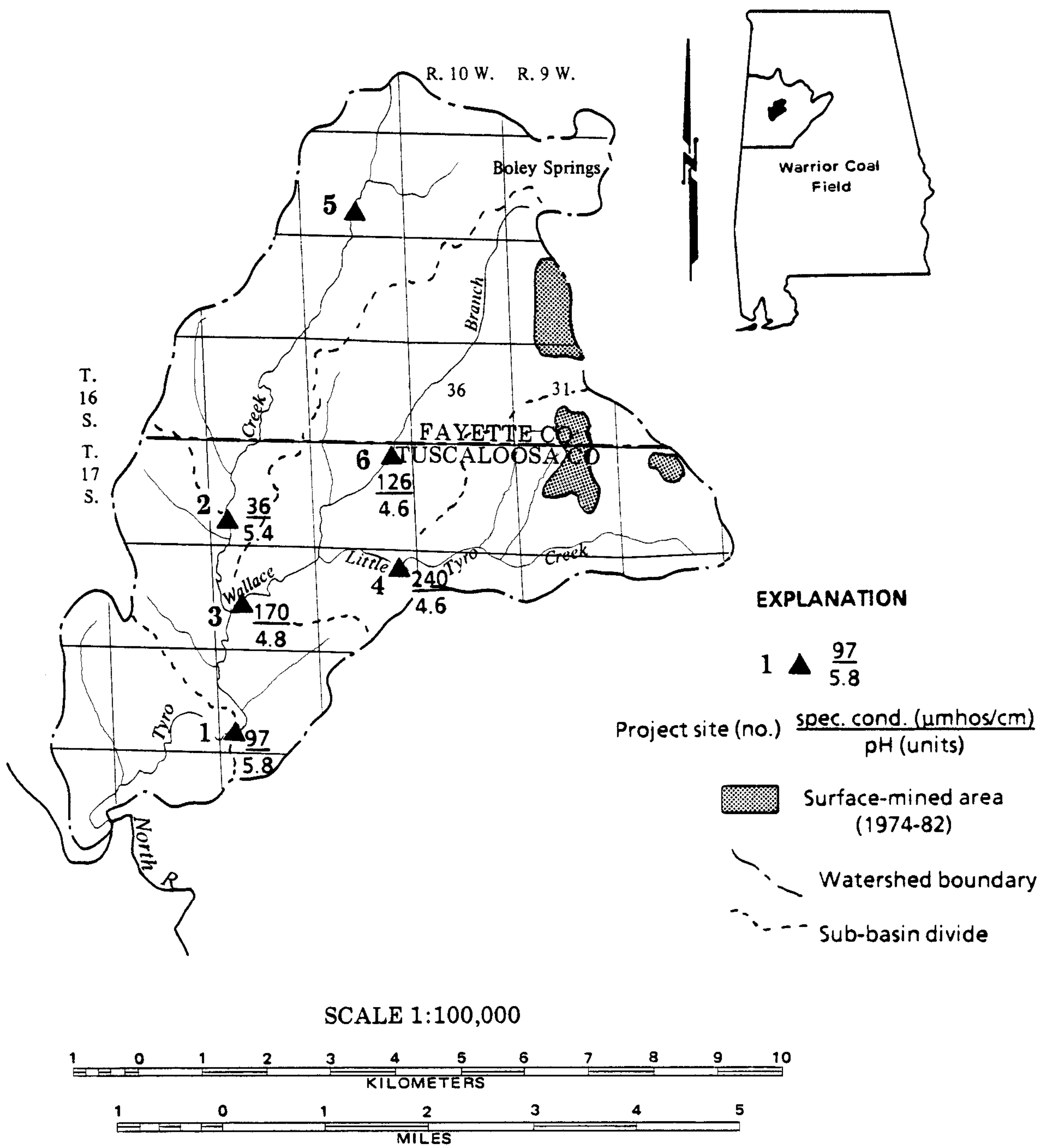
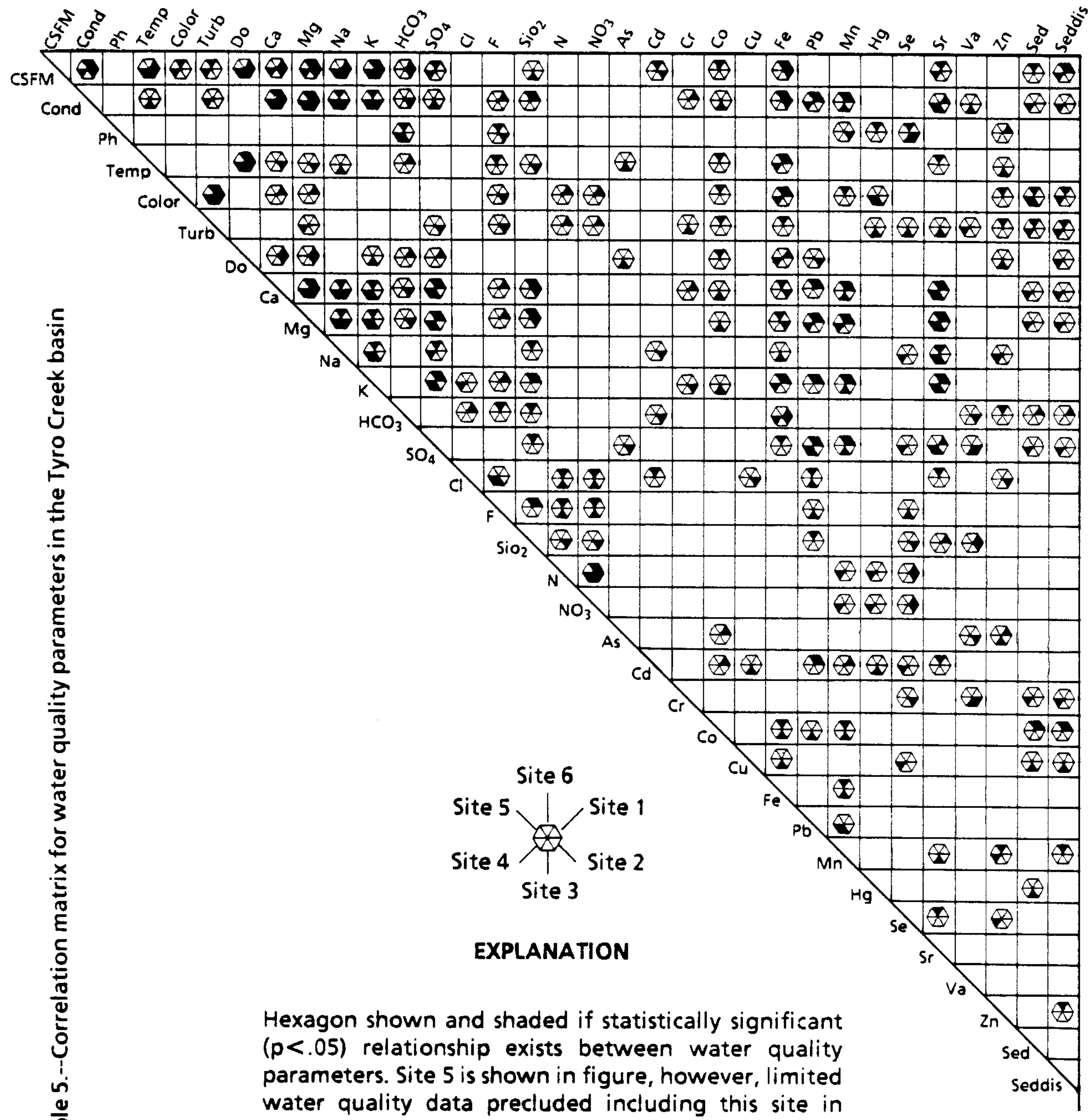


Figure 4.--Specific conductance and pH measured at sampling sites in the Tyro Creek watershed during low flow on September 26-27, 1983.

Table 5.--Correlation matrix for water quality parameters in the Tyro Creek basin



EXPLANATION

Hexagon shown and shaded if statistically significant ($p<.05$) relationship exists between water quality parameters. Site 5 is shown in figure, however, limited water quality data precluded including this site in analysis. Table is based on inspection of > 2,640 correlations.

CFSM - measured flow in cfs/mi² of drainage area

Cond - specific conductance (µmhos/cm)

Sed - suspended sediment (mg/l)

Seddis - sediment load in tons per day

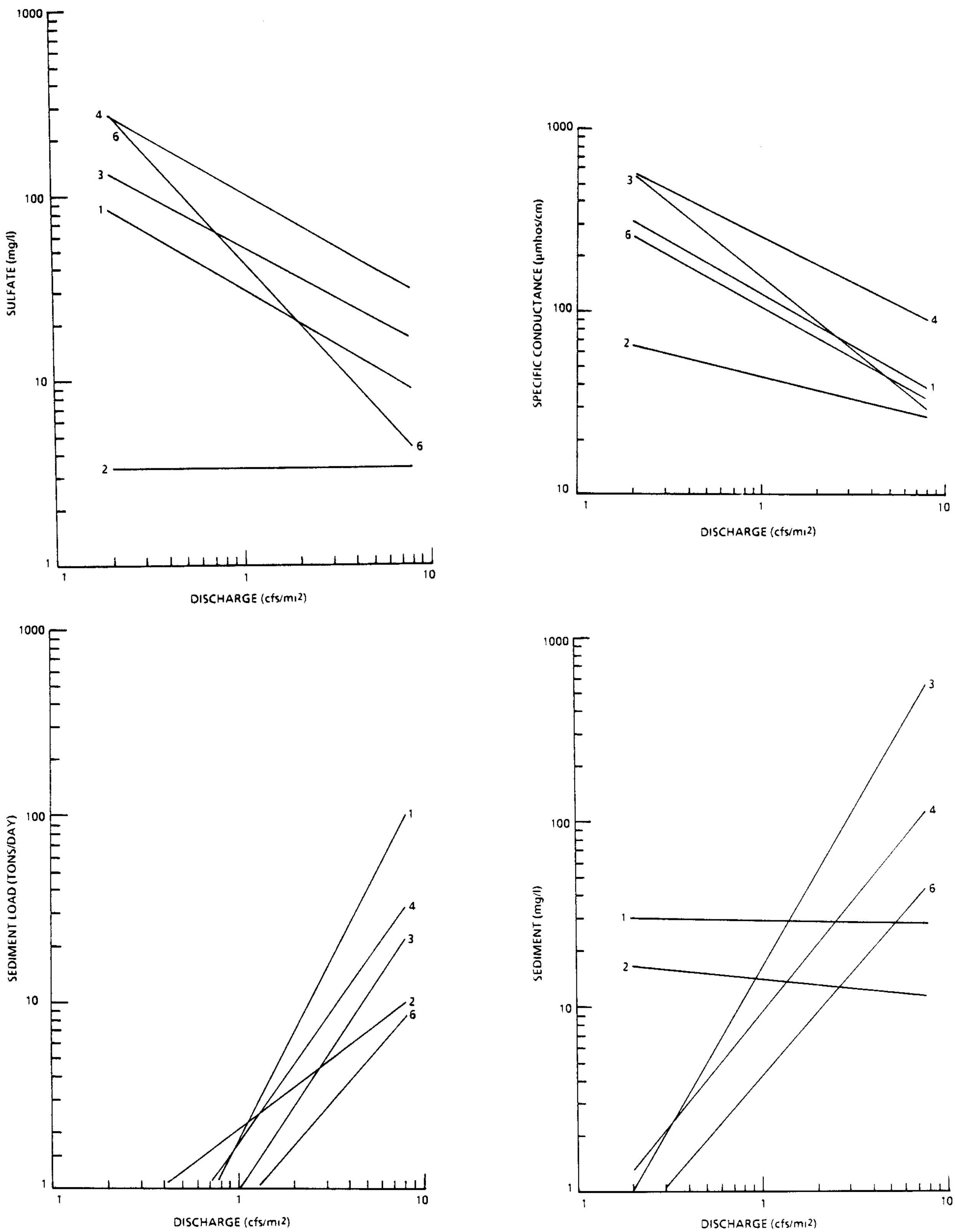


Figure 5.--Regression relationships between discharge and sulfate, specific conductance, sediment load and sediment in the Tyro Creek watershed.

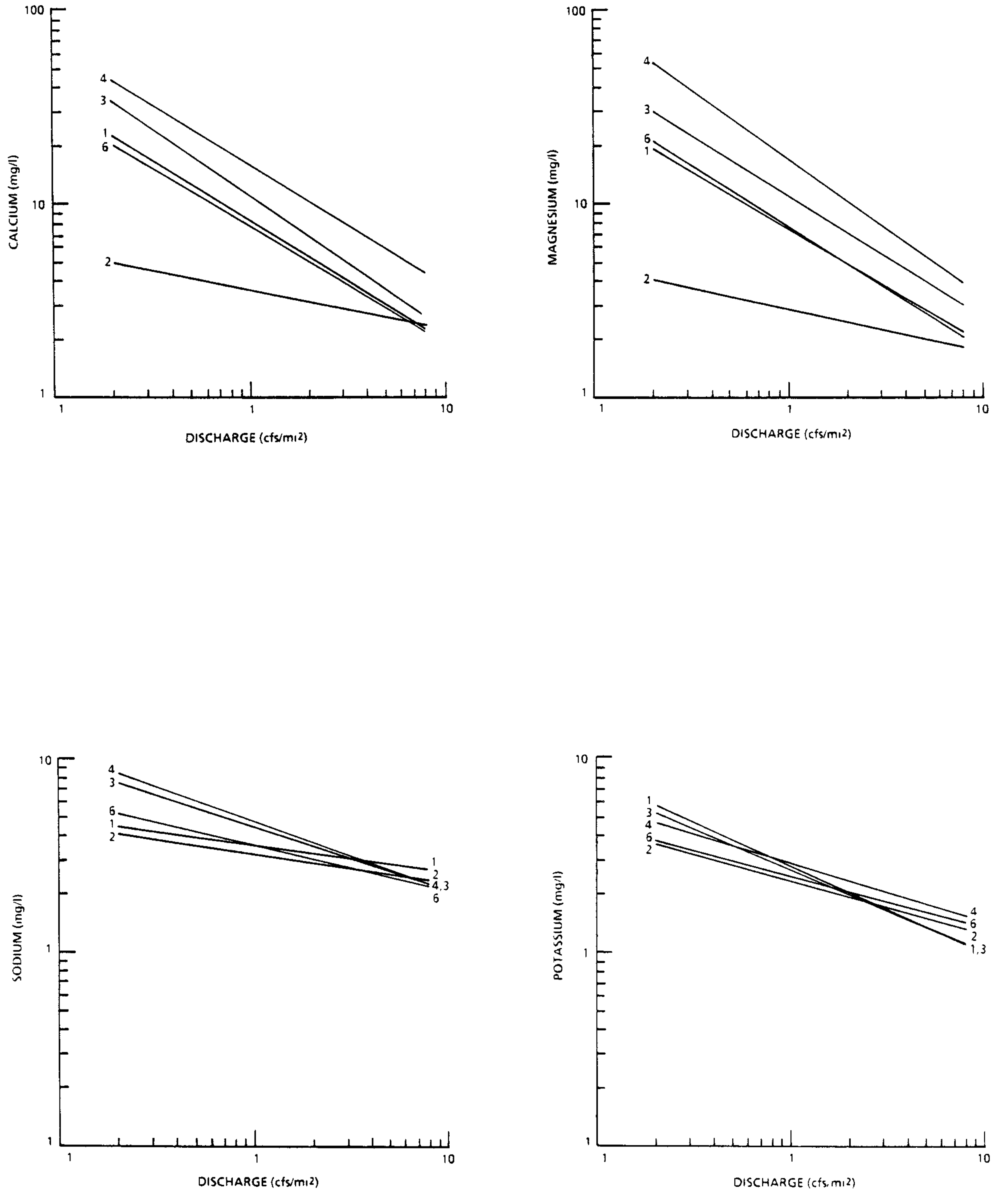


Figure 6.--Regression relationships between discharge and calcium, magnesium, sodium and potassium in the Tyro Creek watershed.

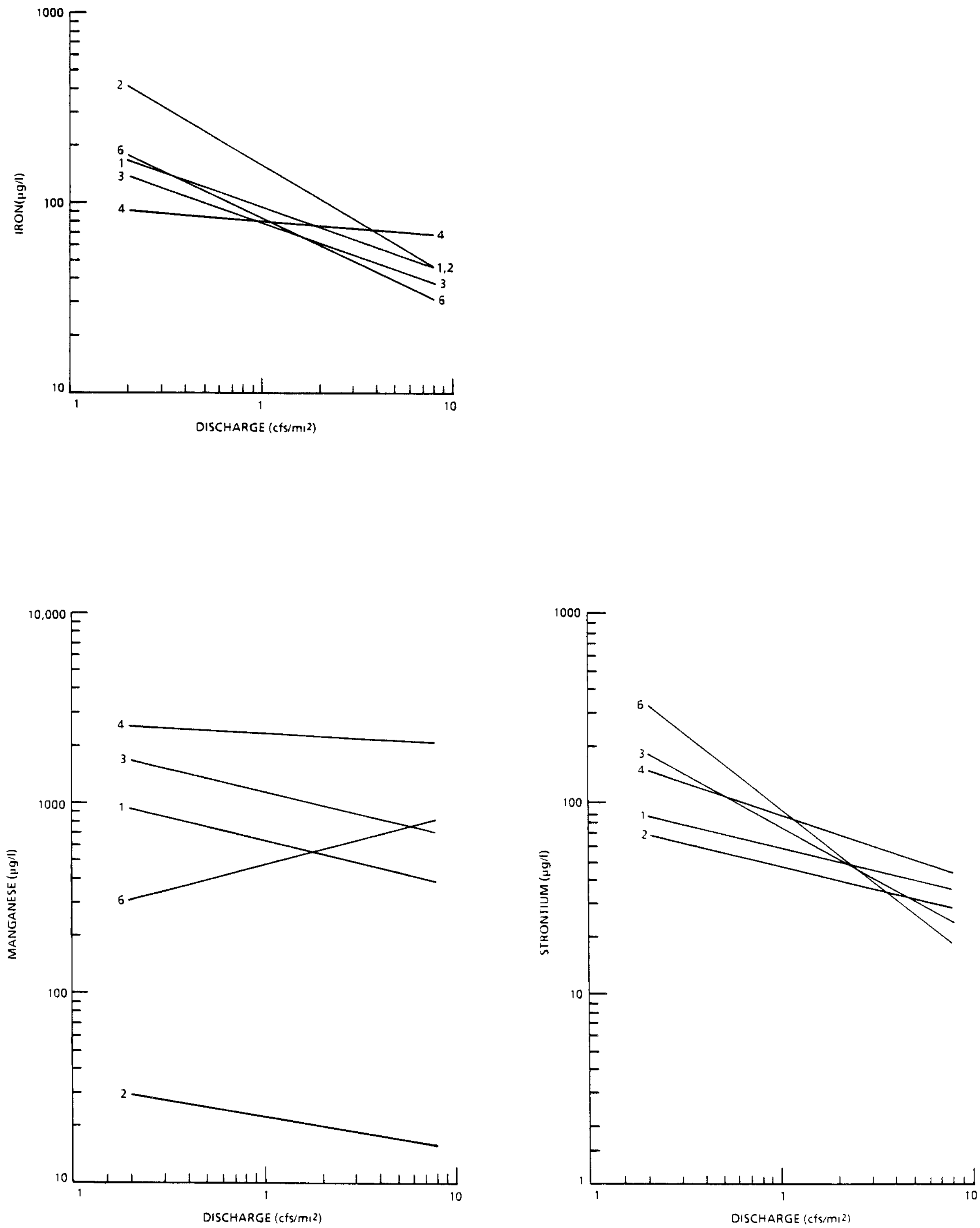


Figure 7.--Regression relationships between discharge and iron, strontium and manganese in the Tyro Creek watershed.

Table 6.--Comparison of water-quality data by collection site to water-quality standards

Water parameter[1]	Limits for surface-mine discharge ADEM (1982)		Sampling sites					Limits for public-water supplies USEPA (1983)
	DA[2]	DM[3]	1 (range)	2 (range)	3 (range)	4 (range)	6 (range)	
Arsenic (As)	-	-	<.001- .004	<.001- .017	<.001- .007	<.001- .005	<.001- .005	.05
Cadmium (Cd)	-	-	<.001- .003	<.001- .003	<.001- .002	<.001- .002	<.001- .001	.01
Chromium (Cr)	-	-	<.001- .002	<.001- .005	<.001- .002	<.001- .005	<.001- .003	.05
Chloride (Cl)	-	-	.0 - 7.6	.2 - 2.5	.0 - 3.8	.0 - 2.8	.0 - 2.0	250
Color (Pt-Co units)*	-	-	0 -200	10 -80	5 - 80	3 -1040	5 - 65	15
Copper (Cu)	-	-	<.001- .100	<.001- .080	<.001- .070	<.001- .060	<.001- .007	1
Fluoride (F)	-	-	.0 - .2	.0 - .2	.0 - .2	.0 - .2	.0 - .1	1.1-1.8[4]
Iron (Fe)*	3	7	.03 - .25	.02 - .39	.01 - .32	.02 - .190	.03 - .1	0.3
Lead (Pb)	-	-	<.001- .012	<.001- .021	<.001- .013	<.001- .016	<.001- .014	.05
Manganese (Mn)*	2	4	.15 - 4.60	<.001- .480	.45 - 7.40	.98 - 5.40	.19 - 1.20	.05
Mercury (Hg)		-	.000- 002	.000	.000- .002	.000- .001	.000- .001	.002
Nitrate (as N)	-	-	.00 - 1.7	.00 - .15	.00 - 1.5	.00 - 1.7	.00 - .23	10
pH (units)*	6.0	9.0	4.7 - 6.8	5.1 - 7.3	4.8 - 6.8	4.4 - 6.7	4.6 - 6.7	5.0-9.0
Selenium (Se)	-	-	<.001- .003	<.001- .003	<.001- .003	<.001- .002	<.001- .003	.01
Sodium (Na)	-	-	1.6 - 3.2	1.6 - 3.2	1.7 - 5.3	1.6 - 5.0	1.8 - 3.3	270
Sulfate (SO_4)		-	.0 - 94	.0 -27	2 -190	33 -220	6.3 - 49	250
Turbidity (JTU units)*	-	-	0 - 72	4 -52	0 - 32	0 -380	0 -120	1
Zinc (Zn)	-	-	<.010- .11	<.010- .13	<.010- .04	<.010- .170	<.010- .060	5

[1]All parameters in mg/l, except as indicated; potential problem parameters indicated by an asterisk (*).
[2]Daily average
[3]Daily maximum
[4]Temperature dependent; limits shown are for 10°C (50°F) to 32.5°C (89°F) maximum daily air temperature.

SEDIMENT

Where mining accelerates weathering and erosion, the pattern of sediment transport and deposition is disrupted and the result can be the "siltation" of a stream. Particle size analyses of sediment (Appendix C) indicated a distinct difference in substrates between Tyro Creek and its tributaries, Wallace Branch and Little Tyro Creek. The substrate at sites 1, 2, and 6 is primarily rock, overlain with coarse gravel and cobble (table 7). At sites 3 and 4, the substrate is predominately sand (table 7). Mining activities often lead to an increased clay, silt, and sand content of sediments, but natural weathering and erosional processes may also be responsible for differences in stream substrate.

The effect of surface mining on sediment character at sites 3 and 4, and possibly site 1, is not evident in the chemical analyses because trace metal and nutrient content for bottom-sediment samples collected at all sites are similar (table 8). A possible reason for the similarity of data is the similarity in geology of subbasin drainage areas. The data suggest that manganese, iron, copper, chromium, lead, vanadium, zinc, chloride, nitrate, and phosphate are present in noticeable amounts in the stream sediment at the five sites. The low pH of the collected samples, ranging from 5.3 to 6.8, reflects the acidic nature of soils and rocks in the area. Arsenic, cadmium, cobalt, mercury, selenium, and strontium were minor constituents of the stream sediment.

STREAMFLOW

A total of 137 determinations of streamflow, 15 or more at each site, were made during the study period. Streamflow measurements and associated data are listed in Appendix B. While the measurements provide insufficient data for determination of the individual components of streamflow, two general hydrologic features are evident.

First, seasonal variation in streamflow tends to reflect regional precipitation (fig. 8). Streamflow was commonly at or slightly above zero cfs at all measuring sites during the dry fall months of the study period, and highest during the wet winter and early spring months. The highest flow, 111 cfs, was measured in April, 1983 at site 1. This flow exceeded the estimated average flow (21.4 cfs) for this site, by a factor of 5.2. Flows measured during the period of study were commonly below estimated long-term averages for all sites, except for the wet months.

A second watershed feature is a general uniformity in streamflow. Computed on the basis of cfs/mi^2 of drainage area to facilitate comparisons, streamflow uniformity within the Tyro Creek watershed is illustrated in figure 9. Flows measured during the study period on the same dates, but at different sites are plotted on an X-Y coordinate basis. With the exception of two data points, which reflect the effects of summer thunderstorms in portions of the watershed, flows center around a line of equal yield, indicating a general equal contribution of unit drainage and to streamflow in the watershed. Since streamflow rates throughout the watershed are similar, mining impacts to water quality or the stream regime can be more accurately defined.

BIOLOGICAL

MACROINVERTEBRATES

Adult insects, limited to the Trichoptera, Ephemeroptera, and Plecoptera, and immature benthic macroinvertebrates were collected during the study. Since adult collections were restricted to three orders that could be identified to species levels, this phase of the study will be considered separately.

ADULT INSECTS

The adult insects collected along the margin of each stream site complemented the benthic sampling program by providing another means of determining the faunal composition. Since the

Table 7.--Substrate particle size (percent) in the Tyro Creek watershed, September 1981 to July 1984

U.S.D.A. Soil Textural Classification	U.S. Standard Sieve Number	Sampling sites (No. samples analyzed) 1(31)		2(31)		3(31)		4(31)		6(15)	
		range	avg.	range	avg.	range	avg.	range	avg.	range	avg.
Coarse gravel and cobble	5	0-98.2	85.7	30.9-97.5	82.2	0-6.8	1.2	0-68.2	15.0	26.3-96.0	53.2
Fine gravel	10	0-5.8	2.0	0.7-6.3	2.5	0-1.2	0.4	0-6.3	1.4	0.3-3.7	1.8
Very coarse sand	18	.4-14.4	2.5	0.8-8.1	3.0	0.1-3.6	1.5	0.1-9.2	2.6	0.3-4.5	2.5
Coarse sand	35	.3-15.1	2.8	0.5-22.8	5.2	1.4-44.6	17.2	0.6-22.6	10.3	0.6-25.2	11.5
Medium sand	60	.3-46.8	3.8	0.2-31.1	5.1	34.5-77.7	57.4	8.2-70.9	45.5	1.5-42.3	23.3
Fine sand	120	.1-12.7	1.8	0.1-11.3	6.3	1.8-52.5	19.0	3.1-50.9	20.3	1.0-16.4	6.4
Very fine sand	230	0-3.0	0.4	0-1.2	0.1	0-1.2	0.1	0-.1-8.4	1.2	0.1-2.1	0.6
Silt	325	0-2.8	0.4	0-1.8	0.2	0-4.7	1.2	0.1-10.1	1.5	0.1-1.1	0.4
Clay	Pan	0-65.1	0.6	0-2.2	0.4	0.1-5.4	0.9	0.1-7.4	1.2	0.1-1.2	0.3

Table 8.--Chemical analyses of bottom-sediment samples collected in the Tyro Creek watershed, August 1982 and September 1984

Parameter[1]	Sampling sites 1 (08/18/82)	1 (09/27/84)	2 (08/17/82)	2 (09/27/84)	3 (08/17/82)	3 (09/27/84)	4 (08/18/82)	4 (09/27/84)	6 (09/27/84)
Arsenic (As)	40	10	10	10	10	10	20	<10	<10
Cadmium (Cd)	10	20	<10	<10	<10	10	<10	20	20
Chromium (Cr)	90	30	80	30	50	20	70	30	20
Cobalt (Co)	20	ND	10	ND	<10	10	60	ND	ND
Copper (Cu)	90	10	220	<10	50	<10	130	<10	<10
Iron (Fe)	25,000	18,000	40,000	7,200	14,000	11,000	40,000	13,900	16,000
Lead (Pb)	70	30	60	20	100	20	50	30	20
Manganese (Mn)	280	1,100	470	110	240	230	580	210	470
Mercury (Hg)	2.4	4.4	0.7	3.3	0.6	10.3	3.0	5.7	8.1
Selenium (Se)	6	ND	3	ND	6	<10	6	<10	ND
Strontium (Sr)	10	30	20	50	10	10	20	<10	40
Vanadium (V)	110	<10	60	20	50	10	60	<10	10
Zinc (Zn)	70	20	60	10	30	10	60	<10	10
Chloride (Cl)	1,000	250	500	250	0	250	1,000	250	200
Phosphate (PO_4)	110	170	198	100	90	240	194	110	60
Nitrate (NO_3)	931	500	530	700	67	700	815	500	800
pH (units)	5.3	7.0	6.8	6.2	6.0	7.0	5.5	5.1	6.6

[1]Results in milligrams per kilogram on dry-weight basis, except as indicated.

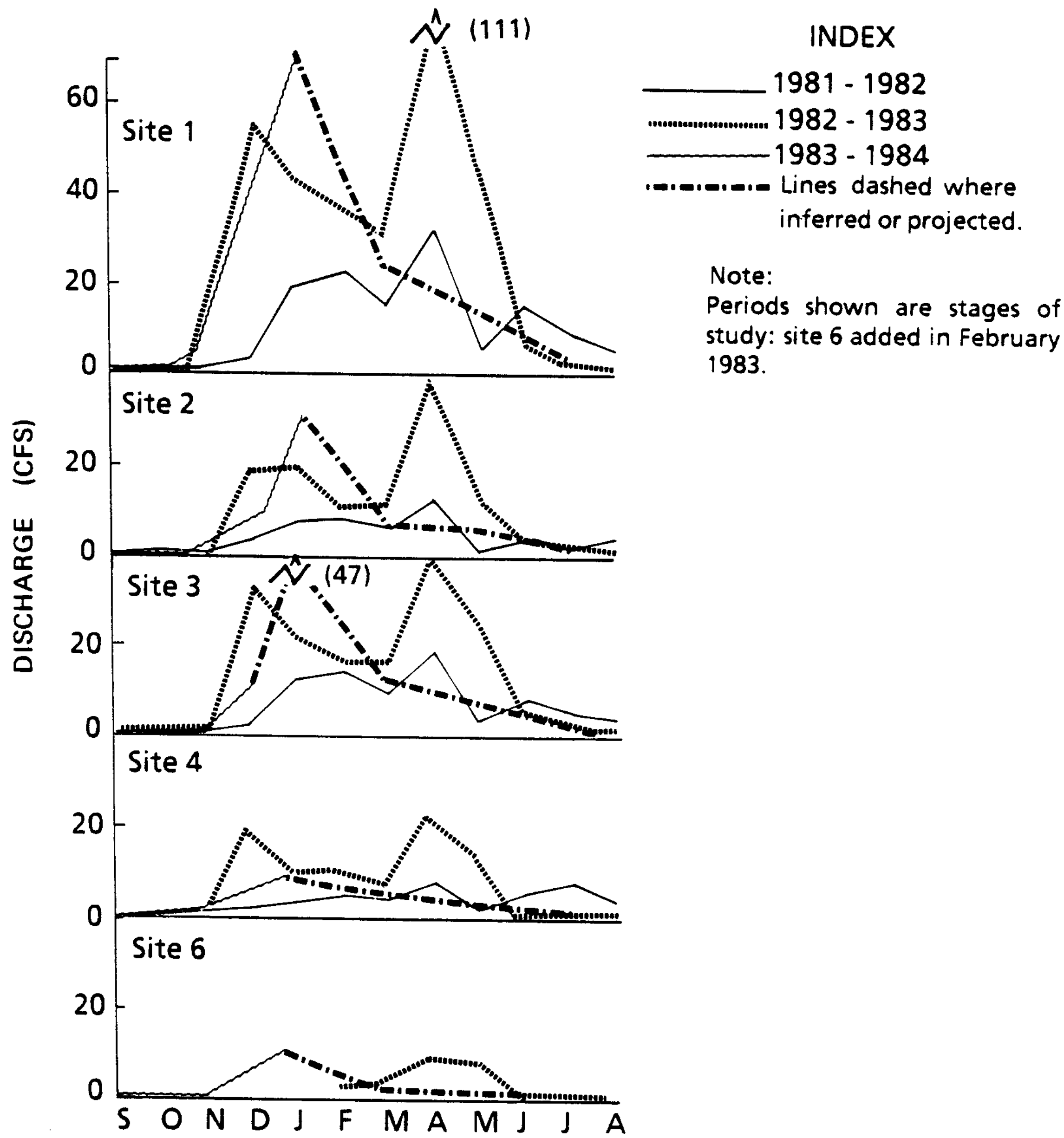


Figure 8.--Comparison of measured stream discharge in the Tyro Creek watershed, September 1981 through July 1984.

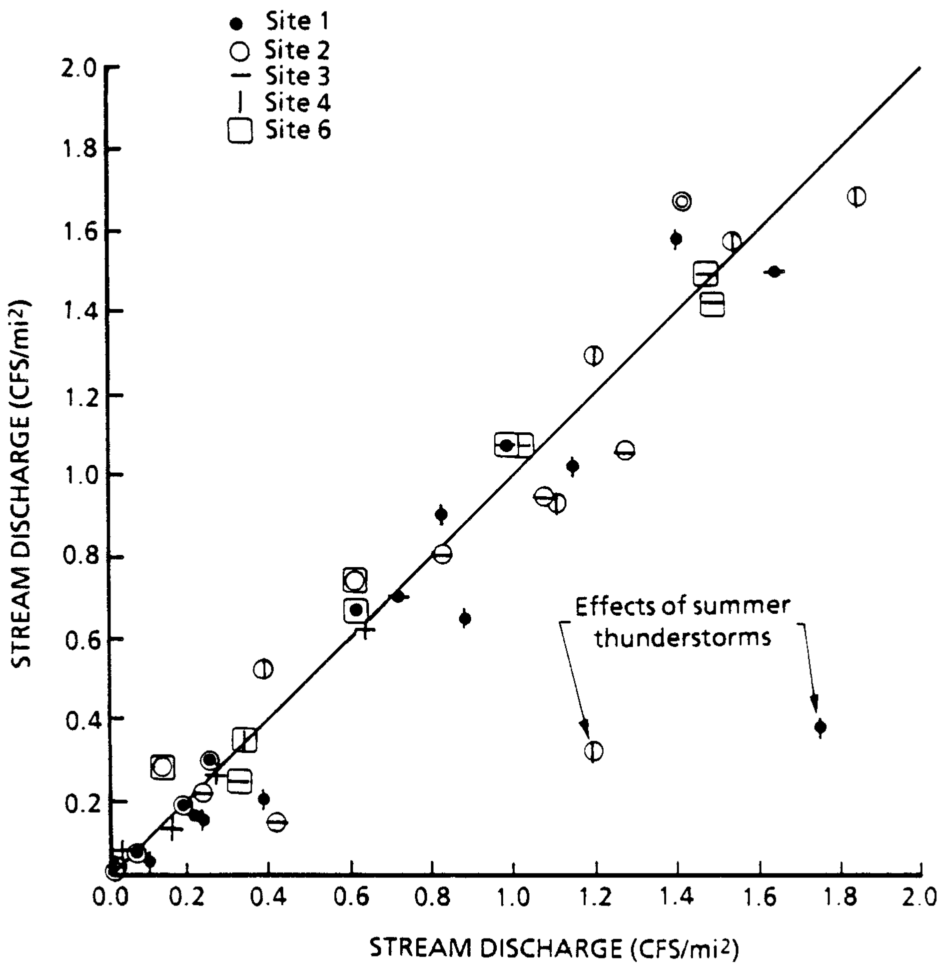


Figure 9.--Test for streamflow uniformity at sites 1 through 6 in the Tyro Creek watershed. Measured discharge is expressed in cfs/mi^2 of drainage basin to facilitate comparison. Values for the smallest site number are plotted on the vertical axis.

ultraviolet light traps collected both terrestrial as well as aquatic insects, only the Trichoptera, Ephemeroptera and Plecoptera, which are entirely aquatic as immatures, are considered here. Within the Tyro Creek watershed 106 species of caddisflies (Trichoptera), 22 species of mayflies (Ephemeroptera) and 13 species of stoneflies (Plecoptera) were collected. In addition to being the most diverse group, caddisflies were also the most numerous, with 5,590 specimens (primarily males) collected. Mayflies and stoneflies were less abundant with 363 and 301 specimens collected, respectively.

Of the caddisflies collected in the Tyro Creek watershed (table 9), the Hydroptilidae were the most diverse and numerous family collected followed by the Leptoceridae and Hydropsychidae. The greatest number of species were collected at sites 1 and 2, with 70 and 75, respectively; the smallest number at site 6, with 27 species (table 10). As would be expected, small numbers of caddisflies were collected in the small tributaries (sites 3, 4, and 6) and headwaters of Tyro Creek (site 5), with numbers increasing in the main channel of Tyro Creek (sites 1 and 2) (table 10). The caddisfly fauna appears to be primarily related to stream size, and although there is likely some impact of previous mining in the watershed on the fauna, it was not clearly evident. Results of a discriminate analysis bear out this generalization. The caddisfly fauna of sites 1 and 2 are grouped together and separate from the grouping of sites 3, 4, 5, and 6 on the basis of stream size (Function I) (fig. 10). While sites 3, 4, and 6 are impacted to some extent by mining, site 5 is not. While there were no species highly correlated with Function II, it did account for 26.5 percent of the observed variation (table 11). No explanation for the role of this function in the caddisfly community is currently possible. However, adult insects, in general, do not segregate along easily definable environmental gradients like many aquatic organisms. This is most likely due to their flying abilities, allowing them to disperse throughout the entire watershed. While an analysis of the adult caddisfly community in the drainage is useful, highly specific correlations between species and habitats are limited because of their mobility.

While several species were common in the watershed, including *Chimarra obscura, Nyctiophylax denningi, Cheumatopsyche geora, Hydroptila hamata, H. quinola, Oxyethira novasota,* and *Oecetis inconspicua,* others were limited in distribution. Two hydroptilids, *Hydroptila recurvata* and *Ochrotrichia tuscaloosa* are restricted to the Black Warrior basin of which Tyro Creek is a part. Several other species were restricted either by season or to specific localities. *Polycentropus chelatus, P. confusus,* and *P. elarus* were only collected in the small tributaries and headwaters of Tyro Creek and primarily in early spring. Phryganeids and odontocerids were only collected at site 5, usually in April. Limnephilids, while widely distributed in the watershed were only present as adults in October (table 9).

The majority of species emerged from May through September, with the largest number of species being collected in July (table 10). The greatest number of specimens were also collected during July, although total catch was fairly high throughout the summer months.

There were several other species of note collected in the watershed. Three species, *Triaenodes cumberlandensis, Orthotrichia curta*, and *Oxyethira roberti* are only known from a few localities in the southeast. *Orthotrichia curta* was previously only known from Florida (Blickle, 1979), *Oxyethira roberti* from reservoirs in Florida and South Carolina (Kelley, 1982), and *Triaenodes cumberlandensis* from Tennessee (Etnier and Way, 1973). In addition, *Hydroptila perdita*, which was widespread in the watershed, was previously unknown from the southeast (Blickle, 1979).

The mayfly fauna collected in the Tyro Creek watershed (table 12) was not nearly as diverse or abundant as that of the caddisflies. Many of the mayflies collected in the light traps were subimagoes and as such could not be accurately identified to species. Most of those which could be assigned to a species were found to be widespread southeastern species. However, three species, *Heptagenia minerva, Paraleptophlebia debilis*, and *Ephemera varia* have not been previously reported from Alabama (Berner, 1977). As only a small number of specimens could be identified to species, interpretations of distribution patterns within the watershed are not possible.

The stonefly fauna collected in the Tyro Creek watershed (table 13) was not particularly diverse or abundant. Only *Acroneuria filicis, Neoperla carlsoni*, and *Perlesta placida* were common and widely distributed. Many of the other species, including *Amphinemura nigritta*, *Strophopteryx fasciata, Leuctra* spp., and *Alloperla* spp., were restricted to the small tributaries of Tyro Creek (table

Table 9.--Trichoptera collected in light traps in the Tyro Creek watershed, 1981-1983

Species	Total number	Sampling site[1]	Seasonal occurrence
Philopotomidae	417		
Chimarra aterrima	78	1,2,3,4,5,6	June-Sept.
C. moselyi	3	1	Aug.
C. obscura	329	1,2,3,4,5	May-Sept.
C. n.sp. (nr. socia)	2	2	July
Dolophilodes distinctus	1	2	Aug.
Wormaldia moesta	4	2,3,4,5	April, May
Polycentropodidae	351		
Cernotina calcea	17	1,2,3	June-Sept.
Cyrnellus fraternus	21	1, 3	July
Neureclipsis crepuscularis	3	3, 5	June, July
Nyctiophylax affinis	6	1,2, 4,5	May, July, Sept.
N. banksi	8	1,2,3,4	May-July, Oct.
N. denningi	249	1,2,3,4,5,6	April-Sept.
Phylocentropus placidus	5	1,2	April, Aug., Sept.
Polycentropus chelatus	5	3,4	March-May
P. cinereus	4	1, 4,5	May, Sept.
P. confusus	22	5,6	May-Sept.
P. crassicornis	7	2, 5	April, May
P. elarus	2	4,5	May, July
P. nr. elarus	1	4	May
Hydropsychidae	745		
Ceratopsyche sparna	1	5	Aug.
Cheumatopsyche geora	565	1,2,3,4,5,6	April-Sept.
C. pasella	25	1,2,3, 5	May-Aug.
C. pettiti	68	1,2,3,4,5,6	May-Sept.
C. pinaca	47	1,2,3,4,5,6	June-Aug.
Diplectrona modesta	4	1,2, 4	July
Hydropsyche alvata	1	3	July
H. betteni	11	1,2,3, 5	May, July-Sept.
H. mississippiensis	1	2	June
H. orris	9	1, 3, 5	Aug., Sept.
H. rossi	7	1,2,3, 5	July, Sept.
Macrostemum carolina	6	1,2,3, 5	June, July
Rhyacophilidae	15		
Rhyacophila carolina	4	2, 5, 6	May, June
R. glaberrima	1	3	Sept.
R. lobifera	10	1,2, 4, 6	April, May

Table 9.--Trichoptera collected in light traps in the Tyro Creek watershed, 1981-1983 - Continued

Hydroptilidae	2889		
Dibusa angata	1	5	April
Hydroptila alabama	186	1,2,3,4,5	May-Sept.
H. amoena	2	2, 6	June
H. angusta	3	1,2, 6	July
H. armata	41	1,2,3,4,5	April-Sept.
H. disgalera	2	2, 5	July, Aug.
H. gunda	25	1,2,3,4	May-Sept.
H. hamata	656	1,2,3,4,5,6	May-Sept.
H. novicola	155	1,2,3,4,5,6	May-June, Sept.
H. oakmulgeensis	1	3	June
H. oneili	182	1,2,3,4,5	May-Oct.
H. paramoena	1	1	Sept.
H. perdita	6	1,2,3,4	July, Sept.
H. quinola	382	1,2,3,4,5,6	April-Oct.
H. recurvata	4	2,3, 5	June, July
H. remita	6	1,2,3	June-Aug.
H. spatulata	23	1,2,3,4	June, July, Sept.
H. vala	18	1,2,3,4,5,6	May
H. virgata	4	2, 4	April, May
H. waskesia	1	4	Sept.
H. waubesiana	68	1,2,3,4,5,6	May-Oct.
Neotrichia alabamensis	1	2	June
N. collata	30	2, 4,5,6	May, June
N. riegeli	478	4	May
Ochrotrichia tarsalis	1	3	Aug.
O. tuscaloosa	20	1,2,3,4	May, June
Orthotrichia aegerfasciella	98	1,2,3,4,5,6	May-Oct.
O. cristata	62	1,2,3,4,5	June-Sept.
O. curta	2	1,2	July, Aug.
O. dentata	1	1	July
Oxyethira janella	16	1,2,3	June-Sept.
O. novasota	344	1,2,3,4,5,6	May-Oct.
O. rivicola	5	1,2,3	June-Aug.
O. roberti	3	2, 5	June, July
O. pallida	40	1,2,3,4,5,6	May-Oct.
Stactobiella palmata	21	1,2,3,4	April-June
Phryganeidae	3		
Agrynia vestita	1	5	
Ptilostomis ocellifera	2	5	April, June
Limnephilidae	26		
Ironquia punctatissimus	1	1	Oct.
Pycnopsyche antica	6	3, 5	Oct.
P. indiana	7	1,2,3, 5	Oct.
P. lepida	10	1,2, 5	Oct.
P. luculenta	2	1, 5	Oct.

Table 9.--Trichoptera collected in light traps in the Tyro Creek watershed, 1981-1983 - Continued

Odontoceridae	2		
Psilotreta frontalis	2	5	April
Leptoceridae	1142		
Ceraclea cancellata	17	1,2,3	June, July
C. maculata	18	1,2,3, 5	June-Sept.
C. nepha	25	1,2,3,4	May, June
C. protonepha	38	1,2,3	May, June
C. tarsipunctata	5	1,2,3	May
C. transversa	6	1,2, 4	May-July
Mystacides sepulchralis	10	1,2, 4,5	July-Sept.
Nectopsyche candida	28	1,2,3, 6	June-Aug.
N. exquisita	44	1,2,3,4,5	June-Aug.
N. pavida	53	1,2,3, 5	May-Sept.
Oecetis avara	2	2,3	June, July
O. cinerascens	1	1	Sept.
O. ditissa	91	1,2,3,4,5,6	May-Sept.
O. georgia	1	6	July
O. inconspicua	95	1,2,3,4,5,6	May-Sept.
O. nocturna	313	1,2,3,4,5,6	May-Sept.
O. osteni	2	1	July, Sept.
O. persimilis	112	1,2,3,4,5,6	May-Sept.
O. sphyra	34	1,2,3	June, Aug.
Triaenodes cumberlandensis	3	2, 4,5	June, Aug.
T. dipsia	1	6	July
T. ignitus	20	1,2,3,4,5,6	June-Sept.
T. injustus	3	1,2,3	July-Aug.
T. marginatus	9	1,2,3,4	May, July, Aug.
T. ochracea	1	3	May
T. pernus	8	1,2, 5	July-Sept.
T. smithi	1	2	Aug.
T. tarda	1	1	June

[1]1-Tyro Creek at bridge
2-Tyro Creek at ford
3-Wallace Branch at mouth
4-Little Tyro Creek
5-Tyro Creek at headwaters
6-Wallace Branch at headwaters

Table 10.--Monthly totals of male Trichoptera species (sp.) and number of specimens (no.) collected in light traps in the Tyro Creek watershed, 1981-1984

Site	March		April		May		June		July		Aug		Sept		Oct		Cumulative Totals	
	sp.	no.	sp.	no.	sp.	no.	sp.	no.	sp.	no.	sp.	no.	sp.	no.	sp.	no.	sp.	no.
1	0	0	5	23	35	149	51	227	97	519	44	424	50	268	10	13	70	1723
2	0	0	4	8	35	106	51	514	62	282	53	398	30	190	6	9	75	1656
3	0	0	1	2	29	71	32	111	41	117	36	174	29	214	5	5	62	694
4	1	1	0	0	35	622	21	45	18	50	21	89	14	31	0	0	48	838
5	0	0	6	12	23	68	20	54	49	302	20	57	22	51	5	9	54	553
6[1]	0	0	2	3	8	22	12	29	16	54	0	0	2	2	0	0	27	120
Cumulative Totals	1	1	14	48	46	1038	56	980	64	1324	49	1142	46	756	12	36		

[1]Not collected in 1981 and 1982.

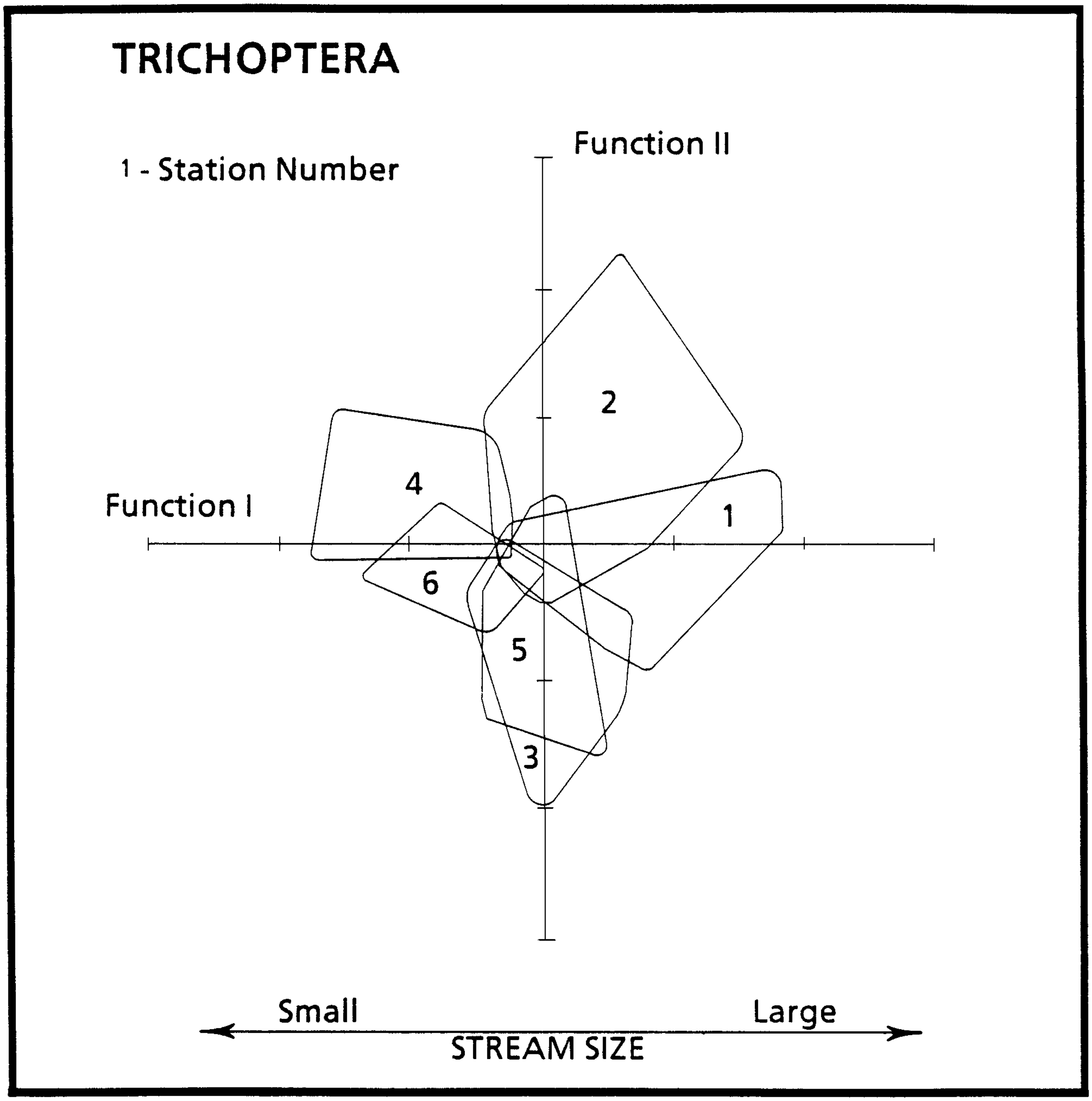


Figure 10.--Scatterplot of Trichoptera collections in the Tyro Creek watershed in relation to the first two functions produced by discriminate analysis.

Table 11.--Correlations between Trichoptera species collected in the Tyro Creek watershed and the first three functions produced by discriminate analysis

Species	Function I	Function II[1]	Function III
Hydroptila alabama	.424		
Hydroptila hamata	.398		
Hydroptila quinola	.389		
Chimarra obscura	.332		
Oecetis nocturna	.282		
Ceraclea protonepha	.271		
Orthotrichia aegerfasciata	.219		
Oxyethira novasota	.213		
Hydroptila novicola	.207		
Hydroptila waubesiana	.199		
Hydroptila oneili			-.417
Chimarra aterrima			-.236
Ceraclea nepha			.195
Eigenvalue	1.517	1.024	.761
Percent of variance	39.31	26.54	19.73
Cumulative percent	39.31	65.85	85.58

[1] Although Function II accounted for 26.54 percent of the observed variation there was no strong correlation with species occurrence. Therefore Function II could not be related to a specific ecological factor.

13). Although the common species were collected throughout the summer, the majority of the stoneflies were collected in the spring. *Alloperla atlantica*, *A. chloris*, *Acroneuria filicis*, and *Neoperla carlsoni* have not been previously reported from the State, and *Leuctra alta* and *L. rickeri* are considered rare in the State (James, 1972).

BENTHIC INVERTEBRATES

A diverse and abundant benthic fauna (16,767 specimens in 218 taxa) was present in the Tyro Creek watershed, particularly at sites 1 and 2 (table 14, Appendix D-1). The largest fauna, 6,216 specimens in 166 taxa, was collected at site 2 between September, 1981 and July, 1984. The lowest number of specimens (463) and taxa (71) were collected at site 6. However, this station was added after the second year of the study and only sampled for 15 months. Of the four stations sampled the entire study, site 3 had the lowest faunal totals, with 1,421 specimens and 101 taxa (table 14). Substrate type, stream size, and mining impacts seem to be the primary factors resulting in low numbers of taxa and individuals at sites 3, 4, and 6 in comparison to sites 1 and 2 (table 14). Sites 1 and 2 on Tyro Creek have diverse stable substrates of cobble and gravel overlying bedrock, while sites 3 and 4 have substrates primarily of shifting sand (table 7). Station 6 had a substrate of cobble intermixed with substantial amounts of sand (table 7). Sand is generally a poor biological habitat and typically supports a low faunal diversity (Hynes, 1972). The importance of substrate is further evidenced by a higher number of taxa and specimens at site 4 than at site 3. Although Little Tyro Creek is a smaller tributary than is Wallace Branch, this stream contains several sections of rocky riffles not present in Wallace Branch. This diversity of habitat likely results in the higher faunal counts for Little Tyro Creek (table 14; Appendix D-1).

Table 12.--Adult Ephemeroptera collected in the Tyro Creek watershed, 1981-1984

Species	Total number	Sampling site[1]	Seasonal occurrence
Baetidae			
Baetis sp.	1	3	July
Centroptilum spp.	15	1,3	May, June
Cloeon spp.	5	1	May
Pseudocloeon spp.	1	1	May
Heptageniidae			
Heptagenia aphrodite	135	1,2,3,5	June-August
Heptagenia minerva	2	3	June
Heptagenia spp.	13	1,2,3,4,5,A	April, May, Sept.
Rhithrogena sp.	1	3	June
Stenacron interpunctatum	19	1,2,5	May-Sept.
Stenacron spp.	3	1,5	July, Sept.
Stenonema femoratum	29	1,3,5	May-August
Stenonema spp.	28	1,2,3,4,5,A	March-July
Oligoneuriidae			
Isonychia bicolor	30	2,5	May-August
Isonychia spp.	18	1,2,3,5	May, June
Siphlonuridae			
Ameletus sp.	1	4	May
Leptophlebiidae			
Habrophlebiodes americana	2	2,5	May, June
Paraleptophlebia debilis	1	2	April
Ephemeridae			
Ephemera varia	6	5	July
Hexagenia munda	31	1,2	May, July
Hexagenia spp.	4	1	July
Ephemerellidae			
Ephemerella spp.	4	1	March, May
Caenidae			
Caenis spp.	14	1,2	May-July

[1] 1-Tyro Creek at bridge
2-Tyro Creek at ford
3-Wallace Branch at mouth
4-Little Tyro Creek
5-Tyro Creek at headwaters
6-Wallace Branch at headwaters
A-Small tributary entering Tyro Creek at bridge

Table 13.--Adult Plecoptera collected in the Tyro Creek watershed, 1981-1984

Species	Total number	Sampling site[1]	Seasonal occurrence
Nemouridae			
Amphinemura nigritta	3	4.6	April, May
Taeniopterygidae			
Strophopteryx fasciata	1	A	March
Capniidae			
Allocapnia sp.	2	A	March
Leuctridae			
Leuctra alta	1	C	April
Leuctra rickeri	4	6,C	April
Leuctra sp.	2	A	May
Perlodidae			
Isoperla sp.	2	A	May
Chloroperlidae			
Alloperla atlantica	7	B,C	April
Alloperla chloris	1	5	April
Perlidae			
Acroneuria abnormis	6	1,5,A	May, June
Acroneuria filicis	54	1,2,3,5,6,A	May, June
Neoperla carlsoni	67	1,2,3,4,5,6	June, July
Neoperla clymene	1	A	June
Perlesta placida	150	1,2,3,5,6,A	May-July

[1]1-Tyro Creek at bridge
2-Tyro Creek at ford
3-Wallace Branch at mouth
4-Little Tyro Creek
5-Tyro Creek at headwaters
6-Wallace Branch at headwaters
A-Small tributary entering Tyro Creek at bridge
B-Small tributary entering Wallace Branch at headwaters
C-Small tributary entering Little Tyro Creek

Table 14.--Summary statistics of macroinvertebrates collected in the Tyro Creek watershed, September 1981 through July 1984

	Sampling sites														
	1			2			3			4			6[1]		
Parameter	R[2]	P[3]	T[4]	R	P	T	R	P	T	R	P	T	R	P	T
Total taxa	124	126	169	113	131	166	76	77	101	90	80	120	48	39	71
Total specimens	3,508	2,258	5,766	3,871	2,345	6,216	578	843	1,421	2,354	547	2,901	398	65	463
Diversity[5] (H')															
Minimum	1.750	0.722	2.499	1.781	0	2.446	0	0	0	0	0	2.255	0	0	2.264
Maximum	4.395	4.350	4.717	4.503	4.473	4.785	4.220	4.291	4.478	4.010	3.765	4.498	3.429	2.914	3.803
Mean	2.988	2.988	3.659	3.189	2.996	3.808	1.810	2.124	2.637	2.676	2.296	3.293	2.343	1.574	3.037
Asymptotic	4.847	5.376	5.617	4.756	5.011	5.381	4.817	5.070	5.208	4.500	5.163	4.917	4.498	4.973	4.876
Evenness[5] (J')															
Minimum	0.525	0.565	0.598	0.388	0	0.428	0	0	0	0	0	0.583	0	0	0.612
Maximum	0.955	1.000	0.952	0.958	1.000	0.921	0.970	1.000	1.000	0.985	1.000	0.984	0.726	1.000	1.000
Mean	0.742	0.857	0.783	0.780	0.777	0.785	0.686	0.783	0.793	0.791	0.857	0.839	0.983	0.716	0.864
Asymptotic	0.697	0.770	0.759	0.697	0.712	0.730	0.794	0.809	0.782	0.693	0.817	0.712	0.805	0.941	0.793
Total area sampled (m^2)	6.4	6.0	12.4	6.0	6.0	12.0	6.0	6.0	12.0	6.0	6.0	12.0	3.0	3.0	6.0

[1]Not collected in 1981 and 1982.
[2]Riffle
[3]Pool
[4]Total
[5]Based on speciments per taxa.

The small size of Wallace Branch and Little Tyro Creek, both tributaries to Tyro Creek, also contributes to the small number of taxa and individuals. Both streams were more subject to drying in the late summer as was the case in September and October, 1981; and to the occurrence of spates following heavy rainfall than was Tyro Creek. Collections during and following high water events generally resulted in very few benthic invertebrates in the small tributaries.

In addition to the physical differences between Tyro Creek and its tributaries, water quality was markedly different at sites 3 and 4. Both sites are affected by mine drainage, particularly site 4 (table 6). Conductance and sulfate values were two to four times higher at sites 3 and 4 as compared to sites 1 and 2. Although site 6 was also impacted by mining, the water quality was not noticeably different from sites 1 and 2. The sand substrates of sites 3, 4, and to some extent 6, also appear to be the result of mining activities via runoff. The extent to which mining has affected the fauna, both in water quality alteration and in sediment loading, cannot be adequately assessed since premining information is not available. However, mining impacts often lead to a lowering of faunal diversity and biomass, and in comparing the tributaries of Tyro Creek to the main stream body, such affects have occurred in this watershed.

A discriminate analysis of the benthic invertebrate data reiterated the general observations made above. This analysis (fig. 11; table 15) indicated that stream sites could be separated on the basis of mining impact (Function I) and substrate type (Function II). Function I could also be assigned to stream size difference. However, since small streams are most heavily affected by mining, the two factors are likely interrelated.

Function II primarily illustrates substrate differences between the stations as reflected in the close affinity between certain faunal groups and particular substrate regimes. Station 3 has a substrate primarily of sand while station 1 is characterized by the occurrence of long pools with sand, silt substrates interconnected by short rocky riffles. While the sand, silt deposition at station 1 is probably natural, station 3 was once a gravel, cobble stream based on monthly observations of sediment in flux and exposures of resident base materials. Station 3 has only recently (10-15 years) been converted to a sand, silt habitat probably due to mining based on excessive amounts and instability of instream sediments. Stations 2, 4, and 6 had gravel, slabrock habitats. At stations 4 and 6, however, excessive sand and silt in depositional areas and occasionally in riffles indicate that mining has affected these streams.

Insects were the most common organisms collected in the watershed (table 16; Appendix D-1), with the dipterans being the most abundant and diverse group. The Diptera, comprising 76 and 63 percent of the fauna at sites 3 and 4 respectively, and 46, 35, and 34 percent of the fauna at sites 1, 2, and 6 respectively, were predominantly Chironomidae (table 16). The Chironomidae, in addition to being abundant at the collecting sites were also very diverse containing at least 74 genera (Appendix D-1), with *Parametriocnemus*, *Polypedilum*, *Procladius*, *Stictochironomus*, *Tanytarsus*, and the *Thienemannimyia* group the most commonly represented. While the Tanypodinae were similarly abundant at most stations, excepting the low levels at station 6, the Orthocladiinae and Chironominae had a more restrictive pattern of occurrence (table 17). The Orthocladiinae, were most frequently collected at site 3 (table 17), where the substrate was almost entirely sand. *Cricotopus*, *Parakiefferiella*, and *Rheosmittia* were the dominant orthoclads at this site (Appendix D-1). At the remaining sites, the proportions of orthoclads in the midge fauna were similar. The Chironominae, in particular the Chironomini constituted a higher percentage of the fauna at sites 3 and 4 (table 17), but numbers were high at all sites (Appendix D-1). Tanytarsini constituted 6-7 percent of the midge fauna at stations 1, 3, and 4, but less than 2 percent at stations 2 and 6 (table 17). Diamesinae were rarely collected in the watershed and only within Tyro Creek. Other dipterans frequently collected were Ceratopogonidae and Tipulidae (table 16). Although Tipulidae, primarily *Tipula* were common at all sites, they constituted a greater percentage of the total fauna in the small tributaries (table 16). Ceratopogonidae, dominated by genera near *Bezzia* and *Palpomyia* constituted similar percentages of the fauna at all sites. Simuliidae, although collected at all sites, only comprised a noticeable portion of the dipteran fauna at site 4 (table 16). *Simulium* was the most common genus collected at this site (Appendix D-1).

The Coleoptera and Ephemeroptera contributed a sizeable percentage of the collected fauna, particularly at site 2 (table 16) where they comprised 31 percent of the fauna. The Coleoptera in the

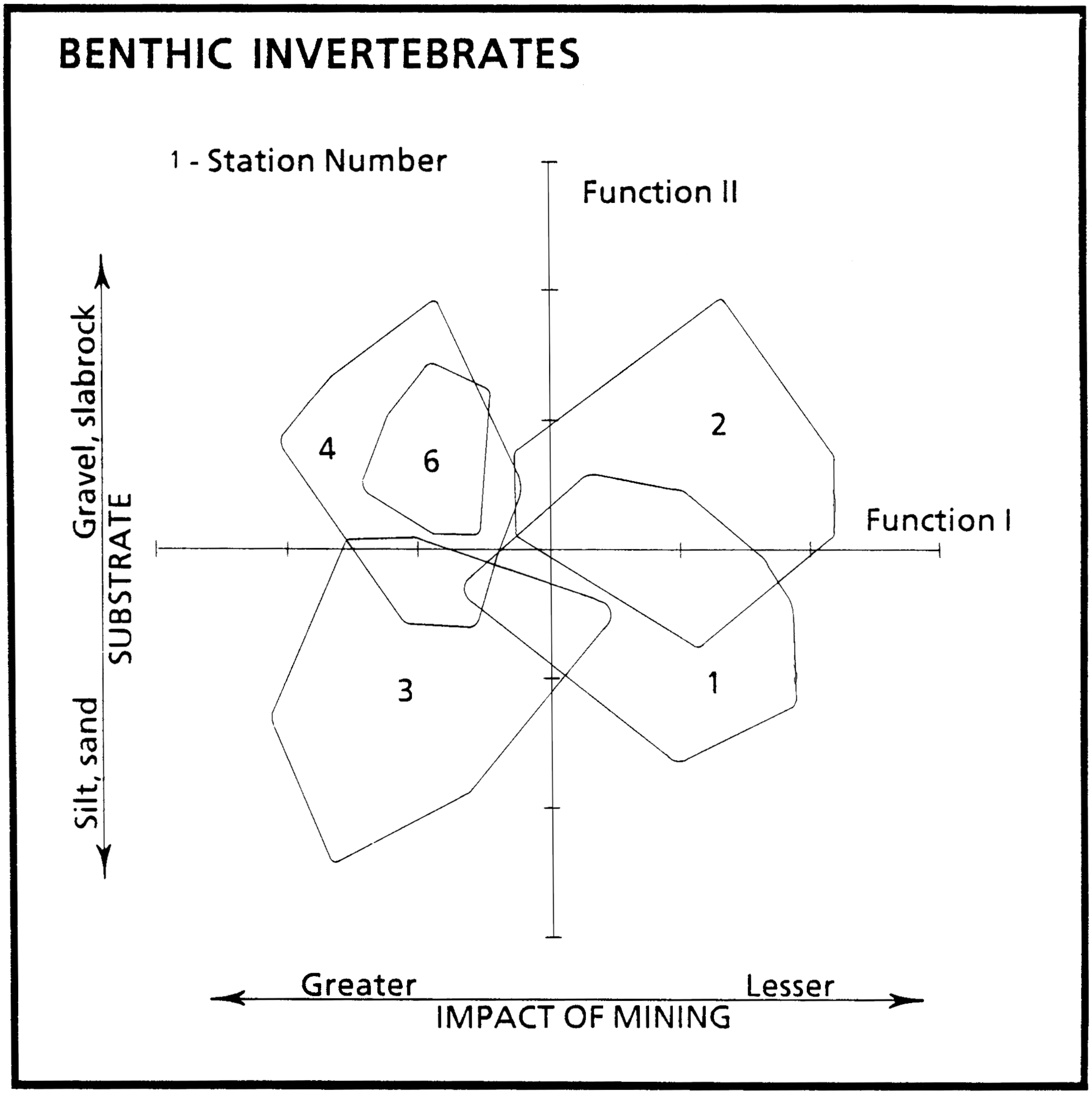


Figure 11.--Scatterplot of benthic macroinvertebrates collected in the Tyro Creek watershed in relation to the first two functions produced by discriminate analysis.

Table 15.--Correlations between benthic taxa collected in the Tyro Creek watershed and the first three functions produced by discriminate analysis

Taxa	Function I[1]	Function II	Function III[1]
Stenelmis	.385		
Procladius	.324		
Stenonema	.311		
Bezzia	.274		
Isonychia	.273		
Palpomyia	.268		
Tabanus	.239		
Cheumatopsyche	.234		
Caenis	.223		
Corydalus	.205		
Rheosmittia		-.373	
Parakiefferiella		-.227	
Saetheria		-.216	
Limnodrilus		-.150	
Erioptera		-.130	
Lirceus		.128	
Natarsia		-.093	
Stictochironomus			-.255
Tipula			.205
Ablabesmyia			.177
Acroneuria			.171
Paramerina			-.166
Sialis			.140
Amphinemura			.136
Simulium			.131
Rheotanytarsus			.127
Cordulegaster			-.118
Eigenvalue	4.095	1.971	1.253
Percent of variance	51.46	24.77	15.75
Cumulative percent	51.46	76.22	91.97

[1] Limited to listing of first 10 taxa.

watershed were dominated by *Helichus* and *Stenelmis* (Appendix D-1). As well as site 2, numbers of these genera were also high at site 1, particularly in the riffles. A diverse mayfly fauna was collected, with 19 genera represented. Although at site 2 mayflies comprised the highest faunal percentage, a large mayfly population also occurred at site 1 (Appendix D-1). At these sites, the fauna was dominated by Baetidae, primarily *Baetis* and *Pseudocloeon*, Heptageniidae, mainly *Stenonema* and Oligoneuriidae, represented by *Isonychia*.

Table 16.--Percent of total benthic fauna constituted by dominant taxa in the Tyro Creek watershed, September 1981 through July 1984

	Sampling sites														
	1			2			3			4			6[1]		
Taxa	R[2]	P[3]	T[4]	R	P	T	R	P	T	R	P	T	R	P	T
Oligochaeta	0.4	5.0	2.6	1.1	1.4	1.2	3.1	2.3	2.6	1.0	0.7	0.9	0	1.5	0.2
Acarina	0.1	1.6	0.7	0	0.7	0.3	0	0	0	0	0	0	0	0	0
Crustacea	0.9	1.0	1.0	1.1	1.3	1.2	2.2	0.4	1.1	2.3	3.5	2.6	11.6	13.8	11.9
Insecta	98.7	92.2	96.2	97.6	99.2	98.2	94.6	97.4	96.3	96.4	95.8	96.3	86.4	87.7	86.6
Coleoptera	8.6	4.0	6.8	13.8	5.5	10.7	2.6	0.6	1.4	2.3	0.7	2.0	2.3	1.5	2.2
Dryopidae	1.5	1.3	1.4	0.6	1.7	1.0	0.9	0.1	0.4	0.3	0	0.3	1.3	0	1.1
Elmidae	7.0	1.8	4.9	11.3	3.1	8.2	1.6	0.2	0.8	2.0	0	1.6	1.0	0	0.9
Diptera	31.0	69.9	46.3	20.0	60.2	35.2	69.0	81.0	76.1	57.9	82.8	62.6	29.9	61.5	34.3
Ceratopogonidae	2.7	12.4	6.5	0.9	13.1	5.4	2.8	5.2	4.2	2.5	10.4	4.0	1.8	3.1	1.9
Chironomidae	20.6	52.7	33.2	13.2	45.2	25.3	59.7	72.6	67.3	39.5	62.2	43.8	18.3	41.5	21.6
Simuliidae	3.8	0	2.3	1.7	0.1	1.1	0.3	0	0.1	9.3	0.2	7.6	2.8	0	2.4
Tabanidae	0.6	0.5	0.6	0.2	0.9	0.5	0	0.2	0.1	0.1	3.3	0.7	0	1.5	0.2
Tipulidae	2.5	2.8	2.7	3.7	0.6	2.5	4.5	2.5	3.3	4.9	4.2	4.8	6.8	12.3	7.6
Ephemeroptera	10.5	6.4	8.9	27.0	9.1	20.2	2.8	1.8	2.2	1.1	1.6	1.2	5.0	4.6	5.0
Baetidae	2.9	0.8	2.1	4.3	0.6	2.9	1.7	0.9	1.3	0.5	1.5	0.7	2.0	1.5	1.9
Caenidae	0.1	1.3	0.6	0.1	1.2	0.5	0.2	0.5	0.4	0	0	0	0	0	0
Ephemeridae	0	1.9	0.8	0.2	1.5	0.7	0.2	0.1	0.1	0	0.2	0	0	0	0
Heptageniidae	4.0	1.1	2.9	11.0	1.7	7.5	0.5	0	0.2	0.5	0	0.4	3.0	0	2.6
Leptophlebiidae	0.2	0.2	0.2	0	1.8	0.7	0.2	0.2	0.2	0	0	0	0	0	0
Oligoneuriidae	3.1	1.1	2.3	11.0	0	6.9	0	0	0	0.1	0	0.1	0	0	0

Table 16.--Percent of total benthic fauna constituted by dominant taxa in the Tyro Creek watershed, September 1981 through July 1984 - Continued

Hemiptera	0.1	0.3	0.2	0.1	0.1	0.1	0.2	0.9	0.6	0.2	1.3	0.4	0.5	3.1	0.9
Megaloptera	3.3	2.0	2.8	1.9	0.6	1.4	0.9	0.4	0.6	1.1	0.5	1.0	0.8	1.5	0.9
Corydalidae	3.2	0.2	2.0	1.9	0.1	1.2	0.2	0.1	0.1	1.1	0.2	0.9	0.8	1.5	0.9
Odonata	0.3	3.7	1.6	0.3	2.2	1.0	1.0	4.3	3.0	0.1	2.2	0.5	0	4.6	0.6
Gomphidae	0	2.8	1.1	0.2	0.7	0.4	0.2	2.6	1.6	0.1	1.3	0.3	0	3.1	0.4
Plecoptera	16.1	4.1	11.4	13.8	17.4	15.1	14.2	7.2	10.1	13.2	3.8	11.5	35.4	1.5	30.7
Capniidae	3.5	3.5	3.5	7.8	15.9	10.9	11.6	7.0	8.9	6.3	3.3	5.8	13.8	0	11.9
Leuctridae	1.5	0	0.9	0.5	0.2	0.4	0	0.1	0.1	0.9	0	0.7	2.5	1.5	2.4
Nemouridae	4.3	0	2.6	1.0	0.2	0.7	0.3	0	0.1	2.7	0.2	2.2	12.8	0	11.0
Perlidae	5.3	0.1	3.2	2.1	0.1	1.3	2.2	0	0.9	1.9	0.4	1.6	2.3	0	1.9
Taeniopterygidae	1.1	0.4	0.8	0.7	0.9	0.7	0	0.1	0.1	0.1	0	0.1	1.0	0	0.9
Trichoptera	28.9	1.8	18.3	20.7	4.2	14.5	3.5	0.6	1.8	19.4	2.7	16.3	12.3	9.2	11.9
Hydropsychidae	24.9	1.1	15.6	17.7	3.2	12.2	3.3	0.2	1.5	16.1	2.2	13.5	11.3	0	9.7
Philopotamidae	3.2	0.5	2.2	2.9	0.2	1.9	0	0	0	2.9	0.2	2.4	0.8	0	0.6

[1]Not collected in 1981 and 1982.
[2]Riffle
[3]Pool
[4]Total

Table 17.--Percent Chironomidae distribution in the Tyro Creek watershed, September 1981 through July 1984

	Sampling sites														
	1			2			3			4			6[1]		
Taxa	R[2]	P[3]	T[4]	R	P	T	R	P	T	R	P	T	R	P	T
Tanypodinae	1.7	20.5	9.1	1.4	13.5	6.0	6.2	9.4	8.1	2.6	7.5	3.6	0.8	3.1	1.1
Orthocladiinae	7.2	5.5	6.6	6.0	2.3	4.6	28.4	23.6	25.5	9.6	10.8	9.8	8.8	15.4	9.7
Chironominae	11.6	26.2	17.3	5.7	28.5	14.3	25.1	39.6	33.7	27.3	43.9	30.4	8.8	23.1	10.8
Chironomini	10.1	12.9	11.2	4.7	25.9	12.7	23.0	30.1	27.2	20.2	36.0	23.2	7.3	21.5	9.3
Tanytarsini	1.5	13.3	6.1	1.0	2.6	1.6	2.1	9.5	6.5	7.1	7.9	7.2	1.5	1.5	1.5
Diamesinae	0	0.6	0.2	0.1	0.2	0.1	0	0	0	0	0	0	0	0	0

[1]Not collected in 1981 and 1982.
[2]Riffle
[3]Pool
[4]Total

Plecoptera were frequently collected at all sites and comprised over 30 percent of the total invertebrate fauna at site 6 (table 16). *Allocapnia*, a capniid, was the most abundant stonefly occurring in high numbers at all sites. The nemourid, *Amphinemura* was also commonly collected except at site 3. Apparently at this site the genus is limited by a shortage of available habitat. In the Perlidae, *Acroneuria* and *Perlesta* were frequently collected, but primarily at sites 1, 2, and 4, in the faster stream sections (Appendix D-1).

Trichoptera comprised a notable portion of the fauna at every site but 3 (table 16). Hydropsychidae, primarily *Cheumatopsyche*, were the most abundant taxa in the stream system reaching greatest population levels at sites 1 and 2 (Appendix D-1). This group is a frequent inhabitant of rocky stream sections, a feature common to sites 1, 2, 4, and 6, but lacking at site 3. This genus is also tolerant of a wide range of water- quality parameters, which may account for its abundance at site 4. The caddisfly fauna collected in the substrate did not reflect the diversity of fauna in the watershed as evidenced by the adult collections. The Hydroptilidae and Leptoceridae, which were the most common and diverse families collected as adults, were very poorly represented in the bottom fauna collections. Polycentropodidae and Philopotamidae, while collected as larvae, were not as common or diverse as that collected in the light traps. Evidently, the benthic sampling procedure was biased towards certain groups of taxa. Those taxa which occurred in unusual or difficult to collect habitats, such as undercut streambanks, were likely missed in collections.

Odonata, Megaloptera, and Hemiptera, while collected throughout the Tyro Creek system, were usually not present in great numbers at any one site. Most of the hemipterans in the streams were frequently observed on the water surface or on the exposed edges of rocks, but few were collected in the benthic samples. The Megaloptera were represented by three genera, *Corydalus*, *Nigronia*, and *Sialis*. While present at all sites, megalopterans were most abundant in the main channel of Tyro Creek at sites 1 and 2 (Appendix D-1). The most common odonates in the watershed were the Gomphidae, primarily *Gomphus* and *Progomphus*. As with the megalopterans, odonates were more frequently collected at sites 1 and 2 (Appendix D-1).

Other than the insects, the only other group comprising a notable portion of the benthic fauna was the Oligochaeta. Oligochates were fairly common at all sites with Tubificidae, primarily *Limnodrilus*, the most frequently encountered taxa.

A distinct riffle and pool fauna was evident at sites 1, 2, 4, and 6. These sites have in common sections of rocky gravelly runs linking long narrow pools. At site 3, there were no rocky riffles and few pools where streamflow decreased and water depth increased. In general, site 3 had a very uniform sand substrate, with streamflow and stream depth varying little throughout the site section (Appendix C-3). Although attempts were made to collect in both pool and riffle habitats, this distinction was usually absent at site 3. This uniformity of stream habitat is reflected in table 16 and Appendix D-1, where total fauna counts were similar in all collections.

At those sites which possessed distinct riffle and pool habitats, it is interesting to note that while in general both pools and riffles supported a similar number of taxa, at some sites (1 and 2) a greater number of taxa were collected in the pools or in the riffles (sites 4 and 6) (table 14). Habitat availability probably accounts for much of this difference. The pools at sites 4 and 6 had very uniform sand/silt substrates with little detrital accumulation, while at sites 1 and 2, the pools had some vegetation, both aquatic and riparian, detrital accumulations and substrates of sand and silt intermixed with large cobble overlying slabrock. The riffles at sites 4 and 6 provided stable habitat allowing more extensive development of benthic populations, while at stations 1 and 2, both pools and riffles were reasonably stable. The lower number of taxa in both pools and riffles at sites 4 and 6 in comparison to sites 1 and 2 is likely a function of the smaller stream size.

Coleoptera, Ephemeroptera, Megaloptera, Plecoptera, and Trichoptera all tended to be more abundant in the riffles than in the pools (table 16). Of the beetles, the elmids, primarily *Stenelmis*, were most abundant in the riffles. However, *Dubiraphia*, another frequently encountered elmid was predominantly collected in the pools along with the dryopid beetle *Helichus* (Appendix D-1). As with the Coleoptera, a distinct riffle fauna was evident for the Ephemeroptera, consisting of *Baetis*, *Pseudocloeon*, *Heptagenia*, *Rhithrogena*, *Stenonema*, and *Isonychia*. All of these genera are strong swimmers and tend to cling to rocks in fast- flowing environments (Merritt and Cummins, 1984). A pool fauna was also evident for the mayflies dominated by the burrowing genera, *Hexagenia* and

Ephemera. Other taxa which tend to live on the surface of sediments were more abundant in the pools including *Caenis* and *Paraleptophlebia* (Appendix D-1). Within the Megaloptera, *Corydalus* and *Nigronia* were almost entirely restricted to the riffles, while *Sialis* tended to be more abundant in the pools (Appendix D-1). *Corydalus* and *Nigronia* cling to rocks in swift, well oxygenated waters, while *Sialis* tends to burrow in the soft sediments characteristic of pools (Merritt and Cummins, 1984).

Most of the plecopteran genera tended to occur within the riffles of the streams. This is particularly evident with the Perlidae, primarily *Acroneuria* and *Perlesta* and Nemouridae, represented by *Amphinemura* (Appendix D-1). Other common genera in the watershed, including *Allocapnia* and the Taeniopterygidae, showed no clear preference for either pools or riffles. The dominant Trichoptera, Hydropsychidae and Philopotamidae, showed a marked preference for the rocky riffles (table 16; Appendix D-1). *Cheumatopsyche* and *Hydropsyche*, the most common Hydropsychidae collected, are filter feeders relying on a stable substrate and swift current for food. The Philopotamidae, represented primarily by *Chimarra*, are predators relying on the riffle current to move oxygen over their bodies for respiration.

In the Diptera, the large diversity of fauna made determination of a distinct riffle and pool fauna difficult. In general, the Simuliidae, represented in the watershed by *Prosimulium* and *Simulium*, were almost exclusively riffle inhabitants (table 16). As blackflies are dependent on a current for filter feeding, such a distribution is expected. Within the Tipulidae, *Tipula* and *Hexatoma* were most abundant in riffles, while *Gonomyia* and *Pseudolimnophila* were more frequent in pools. Most of the *Tipula*, which were *Tipula abdominalis*, occurred in leaf and detritus packs in the riffles. *Gonomyia* and *Pseudolimnophila* are burrowers occurring in the soft sediments at the margins of the pools. Ceratopogonidae, although poorly known, are thought to be burrowers (Merritt and Cummins, 1984) frequently occurring in pools. Such was the case in the Tyro Creek system as the Ceratopogonidae were far more numerous in the pools than in the riffles (table 16; Appendix D-1).

While many of the Chironomidae genera were present in both riffles and pools with similar frequency, several showed a distinct habitat preference (table 17; Appendix D-1). The Tanypodinae, primarily *Procladius* and *Ablabesmyia* were more common in the pools, especially at sites 1 and 2. However, members of the *Thienemannimyia* group, which were most likely *Conchapelopia* were generally more abundant in the riffles at each site. All of these genera tend to inhabit the surface of fine sediments and are predaceous (Merritt and Cummins, 1984). Within the Chironominae, the Tanytarsini, while overall more common in pools (table 17), did have one taxa, *Rheotanytarsus*, common in riffles. Members of this genus build a nest for filtering of food from the current. *Tanytarsus*, *Cladotanytarsus*, and *Stempellinella*, the other common Tanytarsini, were abundant in the pools. All of these taxa are adapted for climbing on vegetation and roots, or debris along the stream channel. In the Tyro Creek system, most habitat available for climbing Tanytarsini occurred in the pools. The Chironomini, as well as the Orthocladiinae, had many representatives that could be classified as riffle or pool inhabitants. In the Orthocladiinae, *Parakiefferiella* tended to be most common within pools, while *Eukiefferiella*, *Rheocricotopus*, and *Parametriocnemus* occurred with greatest frequency in riffles. Others such as *Rheosmittia* and *Cricotopus* had no clear preference. However, *Rheosmittia* was most abundant at site 3 (Appendix D-1) which had a sandy substrate. In the Chironominae, *Polypedilum* tended to be more abundant in riffles, while *Stictochironomus*, *Microtendipes*, and *Chironomus* were more frequently collected in pools (Appendix D-1). While *Polypedilum* tends to cling and climb on exposed surfaces, the common pool genera are burrowers in sediment (Merritt and Cummins, 1984). Other genera such as *Saetheria* and *Cryptochironomus* occurred with similar frequency in both pools and riffles. As was the case with *Rheosmittia*, largest populations of *Saetheria* occurred at site 3 in the sand substrate. Diamesinae were represented by two genera, *Monodiamesa* and *Potthastia*. Both predominantly occurred in the pools and were only collected at sites 1 and 2 (Appendix D-1).

Since the immature insects dominated the bottom fauna, seasonal patterns of occurrence primarily reflect their emergence as adults. A general decrease in taxa (fig. 12), number of individuals (fig. 13), and diversity (fig. 14) was detected at all stations in the spring. Following this decline, both numbers and taxa generally increase in the stream system, with greatest numbers in the late summer and fall. Some decreases in faunal counts are also a response to high water

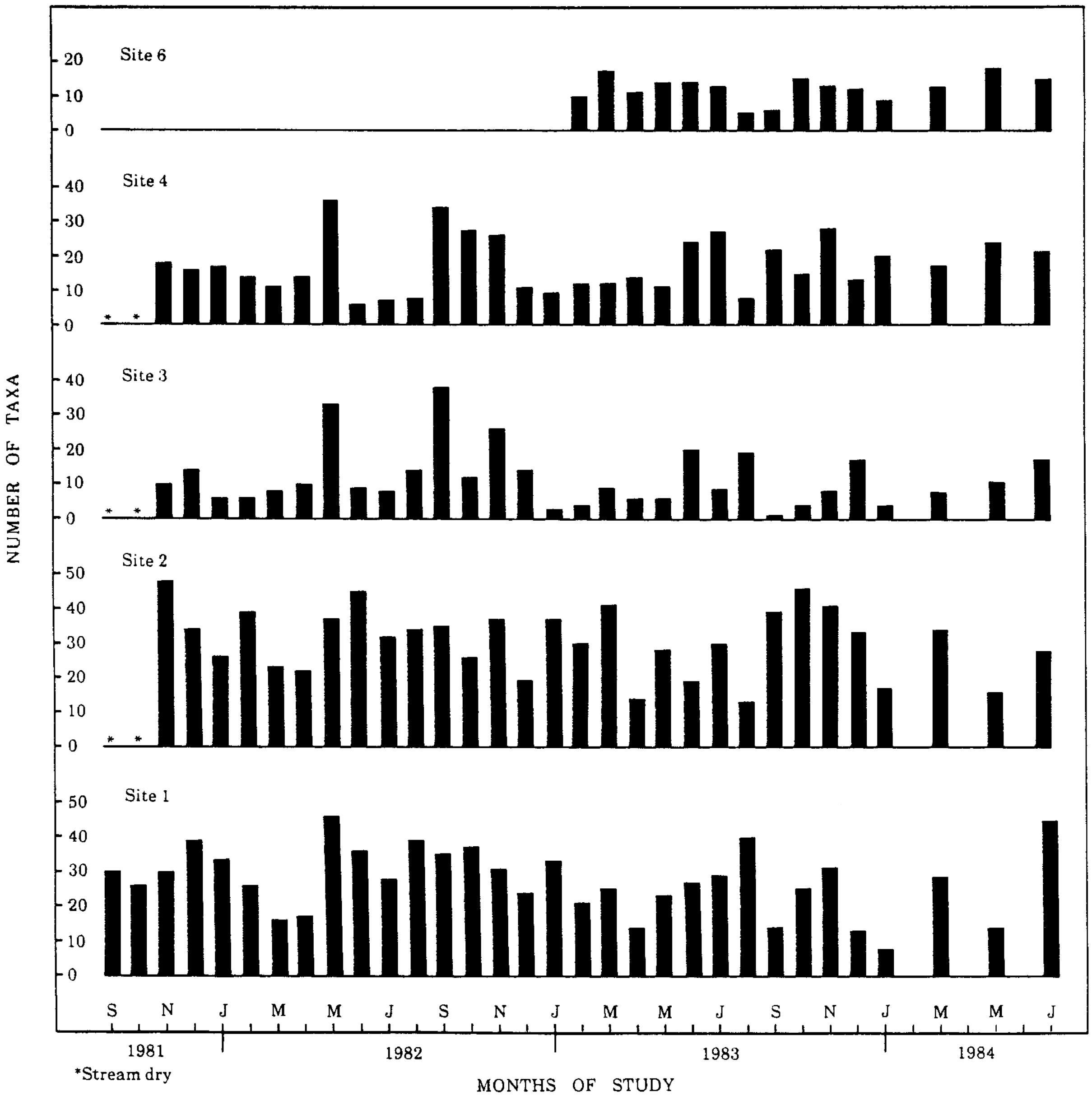


Figure 12.--Number of benthic macroinvertebrate taxa collected monthly from the Tyro Creek watershed, September 1981 through July 1984.

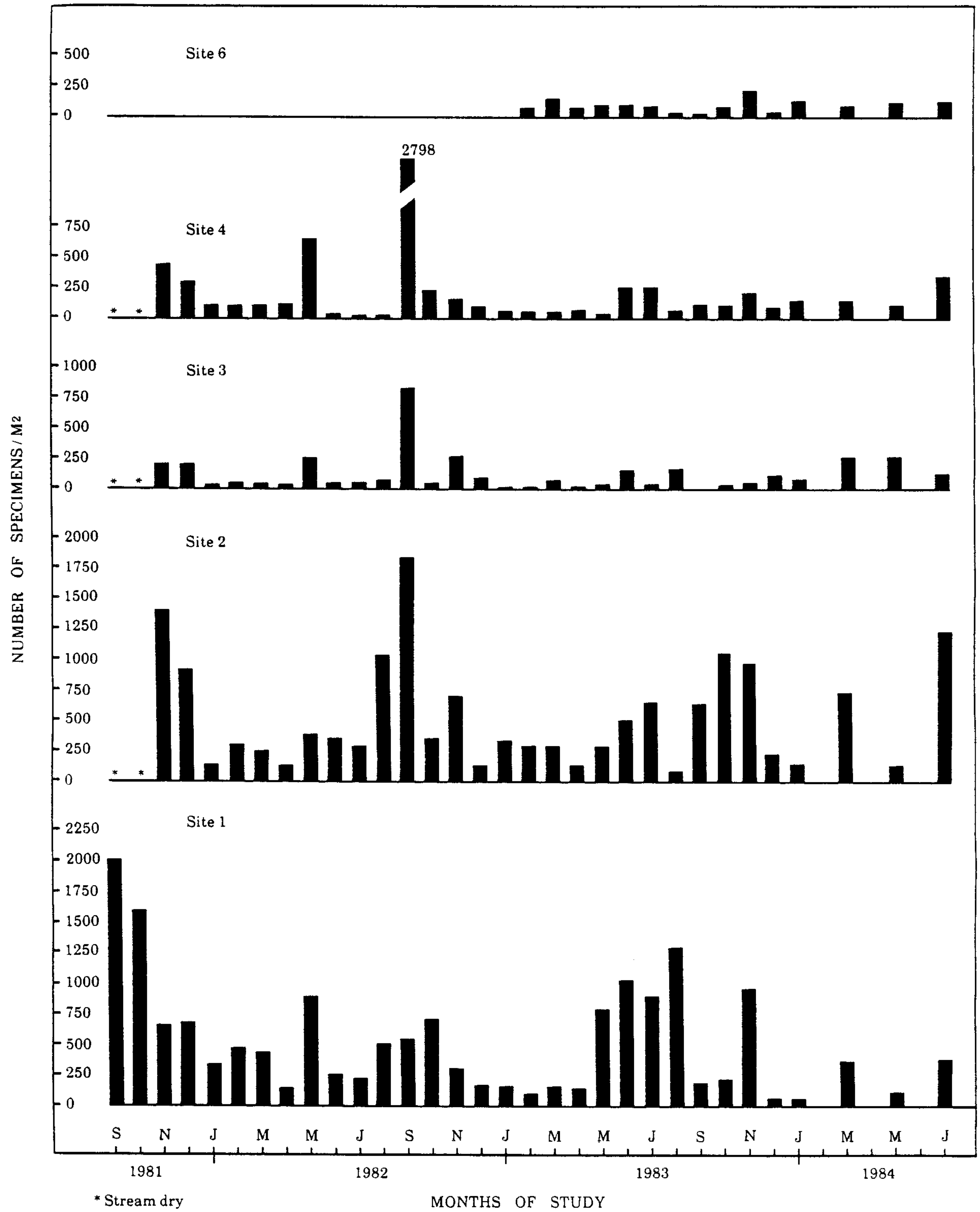


Figure 13.--Density of benthic macroinvertebrate (No./m2) collected monthly from the Tyro Creek watershed, September 1981 through July 1984.

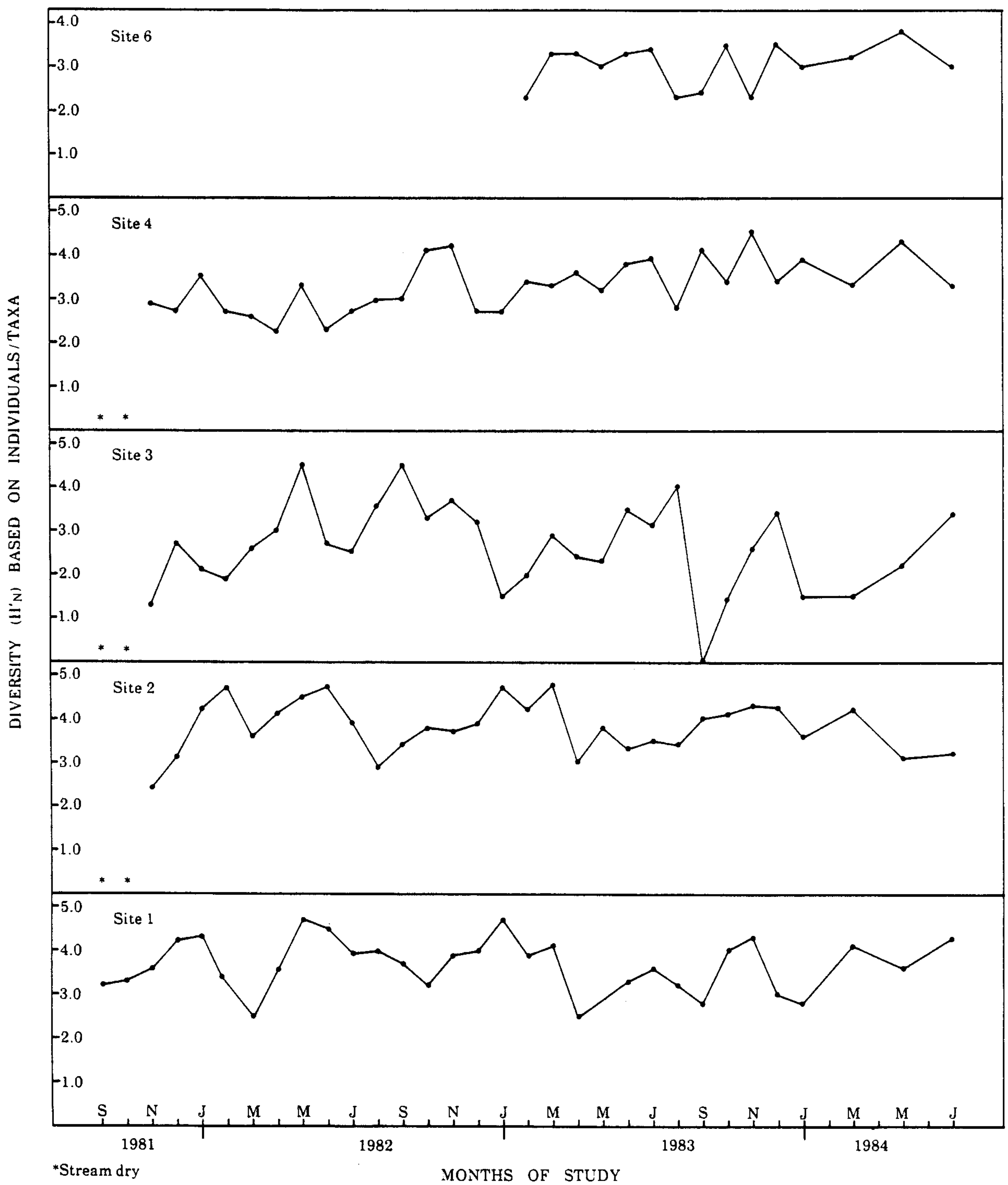


Figure 14.--Monthly diversity (H'_N) of benthic macroinvertebrates collected from the Tyro Creek watershed, September 1981 through July 1984.

conditions in the streams scouring the bottom. Diversity fluctuated widely at sampling sites, but particularly so at site 3 and to a lesser degree at sites 4 and 6 (fig. 14). These sites are located on small tributaries more subjectable to rapid changes in streamflow. This instability of the smaller tributaries is also reflected in the low number of taxa and specimens collected (figs. 12 and 13).

FISHES

A total of 28,426 fishes representing 44 species in nine families were collected from six stations in the Tyro Creek drainage between September, 1981 and July, 1984 (table 18). Abundance, biomass, and occurrence data for species collected at each station are found in Appendix tables E1 through E6.

Notropis bellus was the most abundant species collected (7,408 specimens) throughout the study (table 18). *Notropis chrysocephalus* was the most frequently collected species (156 times) and accounted for the largest biomass (13,069.3 g). *Notropis bellus* was the numerical dominant at stations 1 and 2, *Semotilus atromaculatus* was dominant at sites 3, 4, and 6, and *Notropis chrysocephalus* was dominant at site 5 (tables E1 through E6). *Notropis chrysocephalus* was the dominant species in terms of biomass at sites 2, 3, 5, and 6. *Lepomis megalotis* was the biomass dominant at site 1 and *Semotilus atromaculatus* was the dominant at site 4.

In general, total numbers of species and specimens, and biomass progressively decreased from the larger downstream sites to the smaller upstream sites (table 19). Diversity, both specimens per species (H'_N), and biomass per species (H'_B), also shows this same trend (table 19). Several species normally collected in larger streams, *Notropis asperifrons, N. callistius, N. stilbius, N. volucellus, Minytrema melanops, Ambloplites ariommus, Lepomis macrochirus, L. punctatus, Micropterus salmoides,* and *Percina caprodes,* were found in greater abundance at sites 1 and 2. Conversely, species more commonly found in small streams, *Campostoma oligolepis, Notropis chrysocephalus, Semotilus atromaculatus, Erimyzon oblongus,* and *Etheostoma whipplei* were collected in greater abundance at sites 4, 5, and 6. While most of this difference in fauna is undoubtedly due to stream size, the ability of fishes to recolonize the upstream sites following drought was also a factor.

At the beginning of the study, during September and October, 1981, the stream at sites 2, 3, and 4 was dry. Only site 1 remained flowing during this period. Reinhabitation of the study sites following drought proceeded from the larger downstream stream sections to the smaller upstream and tributary sections of the watershed. This recolonization process required from one to two years. With the resumption of flow during November, 1981, the ichthyofauna at site 2 became re-established very quickly as evidenced by the collection of 17 species and 717 specimens (figs. 15 and 16). Sites 3 and 4, located on small upstream tributaries to Tyro Creek, were recolonized at a much slower rate. Only four species and six specimens were collected in Wallace Branch from November to January and no specimens were taken in Little Tyro Creek until February (figs. 15 and 16). Site 5, at the headwaters of Tyro Creek was unaffected by the drought, and the September, 1981 and 1982 catches were similar (figs. 15 and 16). Collections at this control site were sporadic prior to March, 1982 when it was added to the regular monthly sampling regime.

The largest number of species and specimens and the greatest biomass were collected annually at most sites from August through October (figs. 15, 16, and 17). Diversity (H') also reflected this pattern being greater in the summer and early fall months (fig. 18). These months corresponded to the period when streamflow was lowest and most fishes had completed their spawning activities; hence the numbers of individuals per species was greatest. Owing to these conditions, seining efficiency was greater and total catch was much higher. A secondary peak in the numbers of species and specimens and particularly biomass was seen during March and April for some sites. It was during these months that the adults of some resident and several infrequently occurring species predominantly suckers and sunfishes congregated for spawning purposes. As an example, the biomass peak observed for March, 1982 at site 1 resulted from the collection of several gravid individuals of *Minytrema melanops, Moxostoma erythrurum,* and *M. poecilurum*. The least number of species, specimens, and biomass were generally collected in December and January. A combination of greater stream flow and decreased seining efficiency together with winter mortality

Table 18.--Total number of fishes collected in the Tyro Creek watershed, September 1981 through July 1984

	Sampling sites					
Species	1	2	3	4	5	6
Petromyzontidae - Lampreys	1	--	--	--	--	--
Ammocoete	1	--	--	--	--	--
Esocidae - Pickerels	3	--	1	--	--	--
Esox niger	3	--	1	--	--	--
Cyprinidae - Minnows	7,005	5,112	1,022	1,027	3,964	692
Campostoma oligolepis	250	178	28	12	324	3
Nocomis leptocephalus	1	--	--	--	--	--
Notropis asperifrons	11	294	3	1	5	--
Notropis baileyi	3	1	5	--	--	--
Notropis bellus	4,227	2,080	186	104	809	2
Notropis callistius	24	--	--	--	--	--
Notropis chrysocephalus	932	842	346	218	2,226	276
Notropis stilbius	351	17	2	--	--	--
Notropis texanus	226	1	--	--	--	--
Notropis venustus	168	3	17	6	--	--
Notropis volucellus	1	--	--	--	--	--
Pimephales notatus	580	1,592	44	1	324	1
Semotilus atromaculatus	231	104	391	685	276	408
Catostomidae - Suckers	159	41	11	21	46	4
Erimyzon oblongus	5	3	3	18	10	3
Hypentelium etowanum	1	1	--	--	1	--
Minytrema melanops	33	2	--	--	--	--
Moxostoma erythrurum	67	25	6	3	33	--
Moxostoma poecilurum	53	10	2	--	2	1
Ictaluridae - Freshwater Catfishes	34	26	11	1	21	--
Ictalurus natalis	4	1	7	1	2	--
Ictalurus punctatus	1	--	--	--	--	--
Noturus funebris	1	--	--	--	--	--
Noturus gyrinus	14	17	2	--	19	--
Noturus leptacanthus	14	8	2	--	--	--

Table 18.--Total number of fishes collected in the Tyro Creek watershed, September 1981 through July 1984 - Continued

Cyprinodontidae - Killifishes	245	138	66	1	294	--
Fundulus olivaceus	245	138	66	1	294	--
Aphredoderidae - Pirate Perch	2	1	--	--	--	--
Aphredoderus sayanus	2	1	--	--	--	--
Centrarchidae - Sunfishes	981	643	127	142	381	120
Ambloplites ariommus	5	--	--	--	--	--
Lepomis cyanellus	31	7	3	15	6	--
Lepomis gulosus	2	--	--	--	--	--
Lepomis macrochirus	95	4	--	27	--	--
Lepomis megalotis	744	549	101	100	327	117
Lepomis microlophus	1	--	--	--	--	--
Lepomis punctatus	5	--	--	--	--	--
Micropterus coosae	1	11	1	--	18	--
Micropterus punctulatus	85	70	21	--	30	3
Micropterus salmoides	12	2	1	--	--	--
Percidae - Darters	2,546	1,741	148	93	1,493	62
Etheostoma parvipinne	6	1	5	31	1	3
Etheostoma stigmaeum	1,908	1,396	57	1	885	--
Etheostoma swaini	5	10	--	--	9	--
Etheostoma whipplei	322	146	31	58	455	46
Percina caprodes	77	23	--	--	6	--
Percina maculata	55	34	1	1	7	4
Percina nigrofasciata	173	131	54	2	130	9
TOTALS	10,976	7,702	1,386	1,285	6,199	878

Table 19.--Summary of statistics for fishes collected in the Tyro Creek watershed, September 1981 through July 1984

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Total collections	32	30	30	30[1]	28	15
Total species	44	33	27	19	24	14
Range	8-28	8-21	1-16	0-10	10-16	2-7
Total specimens	10,976	7,702	1,386	1,285	6,199	878
Range	95-1,105	83-711	1-145	0-252	43-421	3-367
Total biomass	16,837	10,515	2,756	2,827	13,326	1,775
Range	88-2,182	84-746	1-303	0-248	131-971	2-259
Asym H'_N	3.182	3.025	3.097	2.296	2.9923	1.926
Range	1.770-3.763	1.994-3.388	0-3.148	0-2.689	2.296-3.088	.881-2.039
Asym J'_N	.58	.60	.65	.54	.65	.51
Range	.48-.82	.59-.86	0-1.0	0-.96	.64-.83	.47-.83
Asym H'_B	4.119	3.705	2.886	2.182	3.050	1.724
Range	2.264-3.839	2.272-3.521	0-2.811	0-2.440	1.698-3.127	.643-1.932
Asym J'_B	.75	.73	.61	.51	.67	.45
Range	.58-.95	.60-.86	0-.99	0-.95	.57-.81	.37-.93

[1]Three collections contained no specimens.

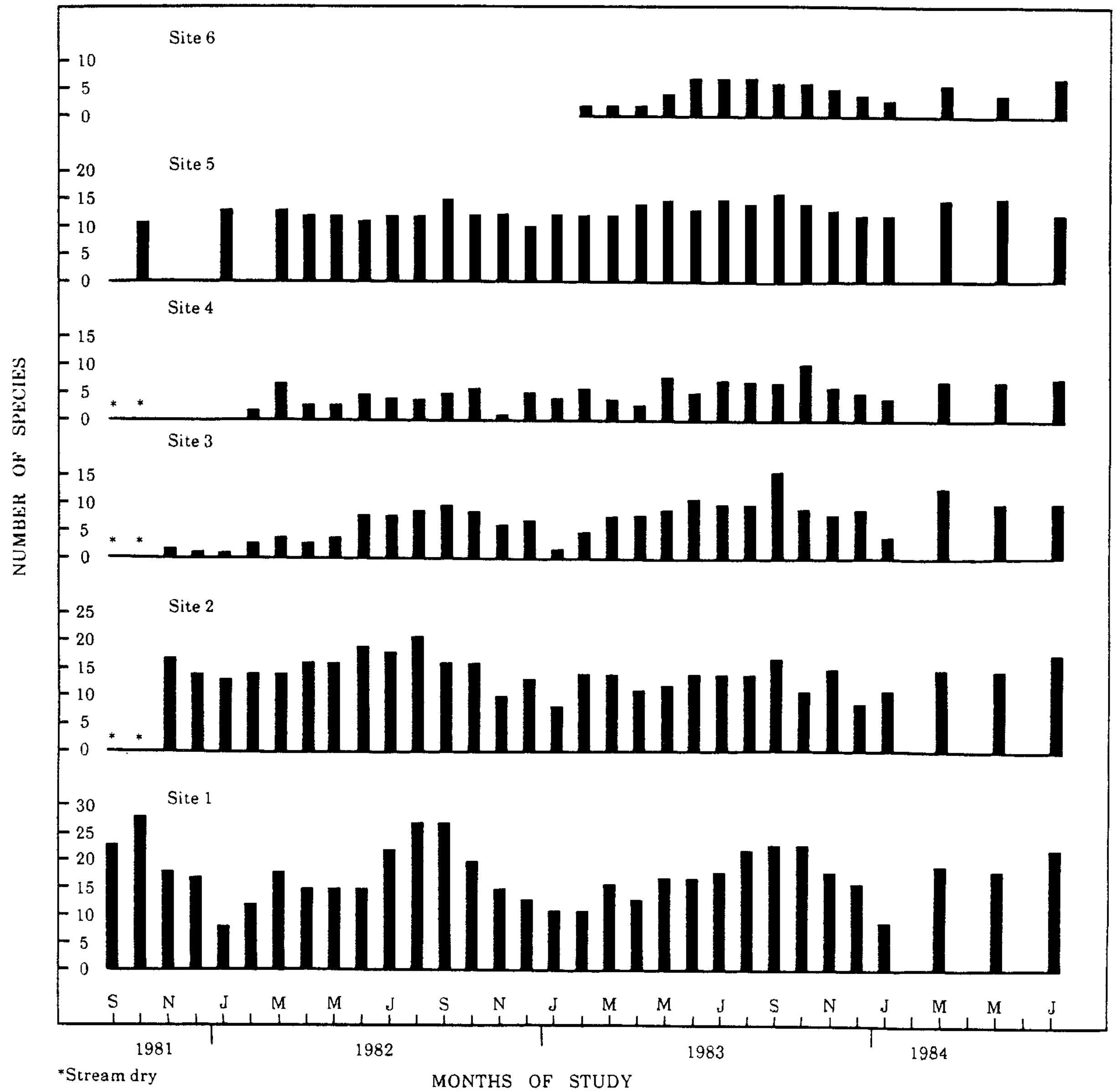


Figure 15.--Number of fish species collected monthly from the Tyro Creek watershed, September 1981 through July 1984.

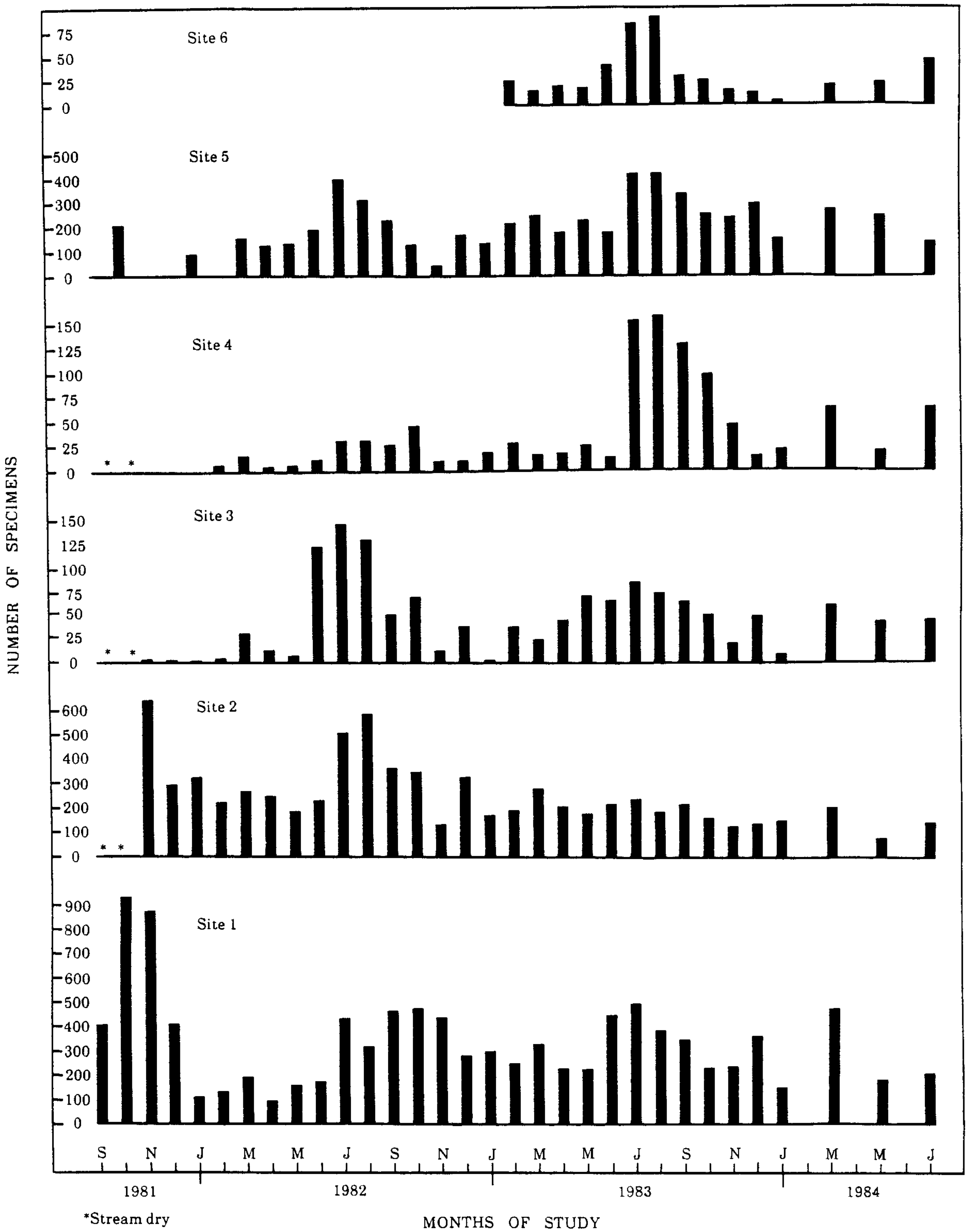


Figure 16.--Number of fish specimens collected monthly from the Tyro Creek watershed, September 1981 through July 1984.

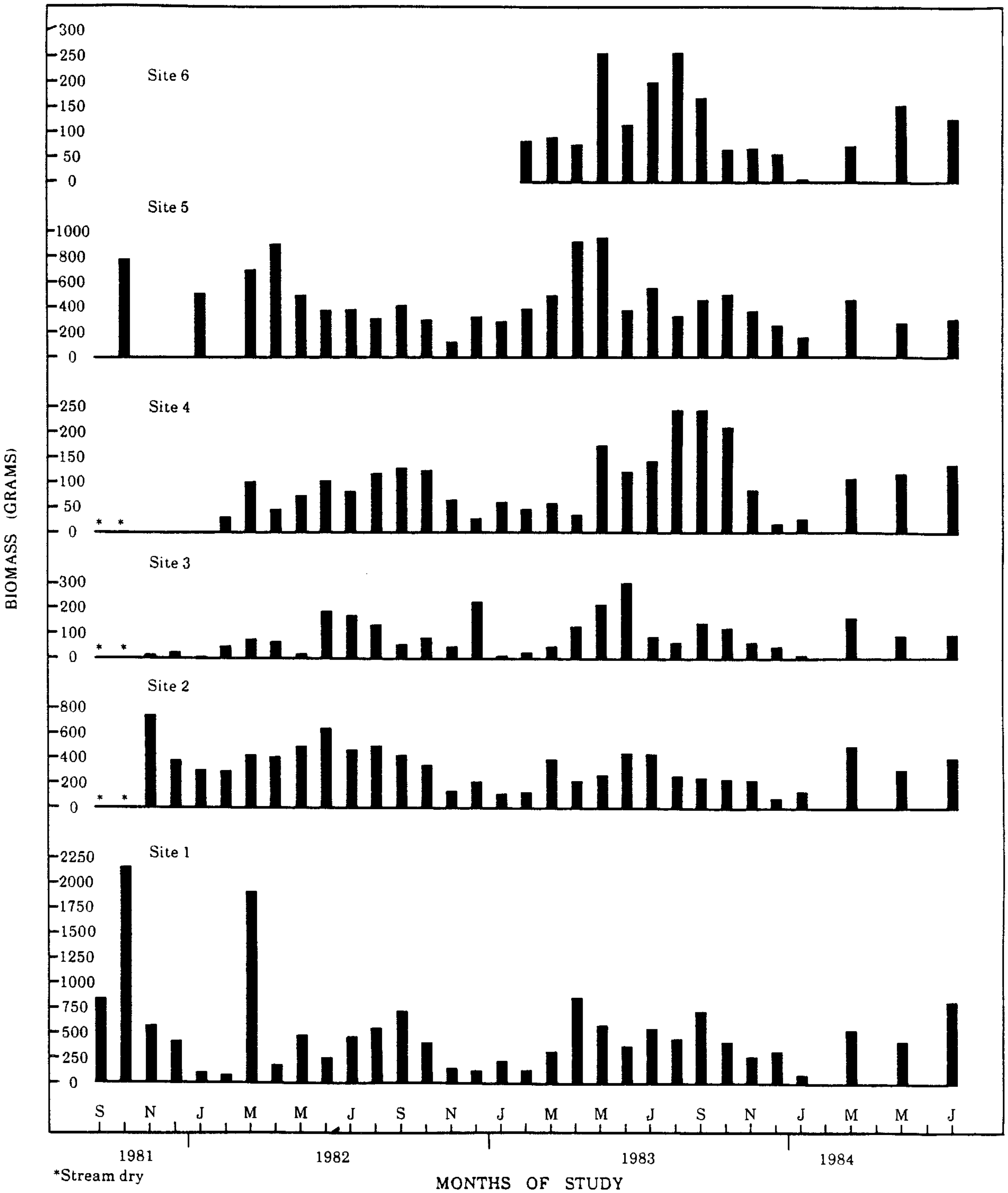


Figure 17.--Biomass (grams) of fishes collected monthly from the Tyro Creek watershed, September 1981 through July 1984.

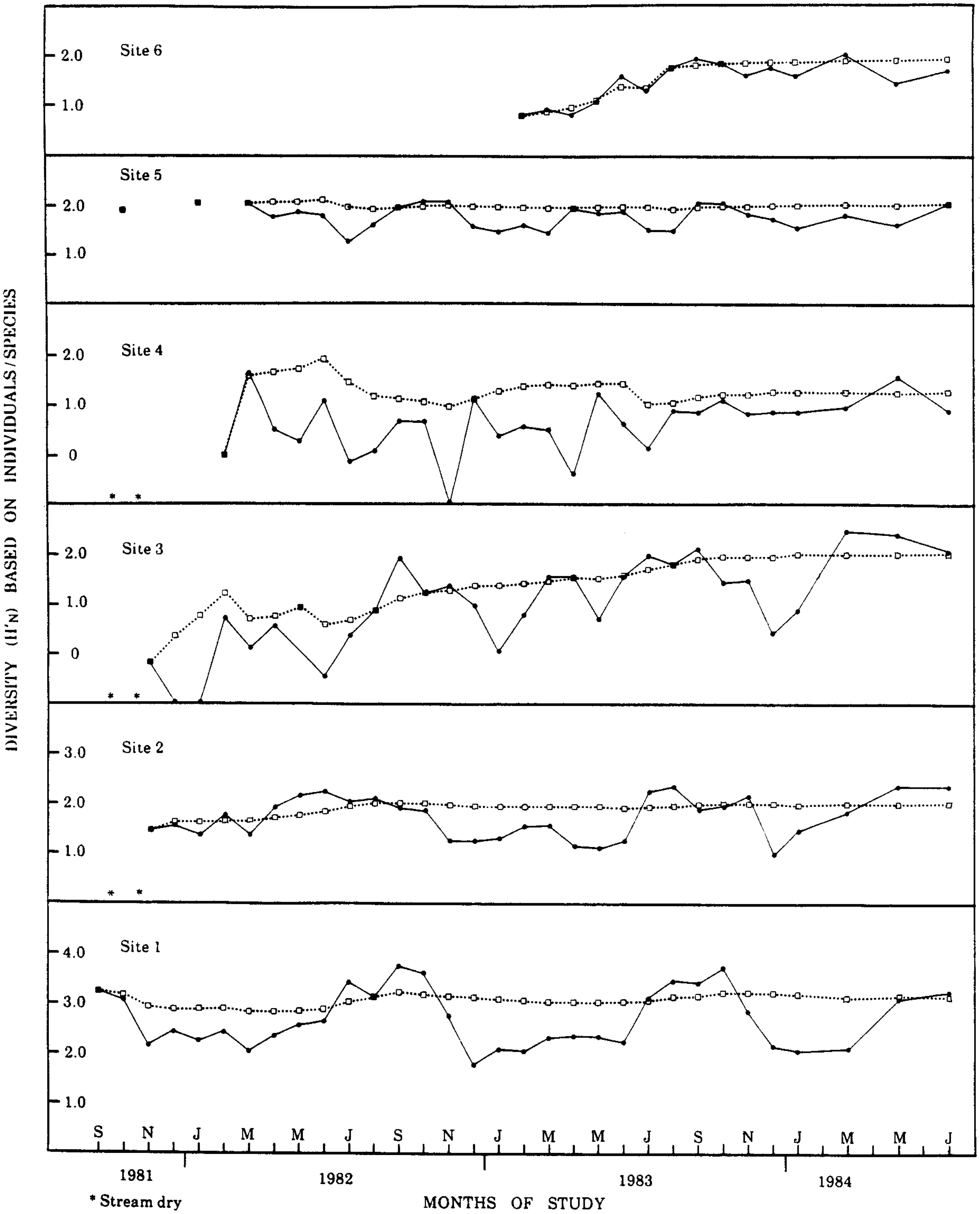


Figure 18.--Monthly and asymptotic diversity (H'_N) of fishes collected in the Tyro Creek watershed, September 1981 through July 1984.

of fishes and their migration downstream probably accounted for the decline in catch success during these months.

The effects of mining in the watershed can be seen in comparing data from sites located on the mainstem of Tyro Creek (sites 1, 2, and 5) to sites located on upstream tributaries (sites 3, 4, and 6). Noticeably fewer specimens were collected at sites 3 (1,386) and 4 (1,285) than at site 5 (6,199) even though the latter site was located further upstream in an unaffected portion of the Tyro Creek watershed. Similarly, the biomass totals from sites 3 (2,756 g) and 4 (2,826 g) were less than the biomass collected from site 5 (13,326 g). Although fewer total species were collected at sites 4 (19) and 5 (24) than at site 3 (27), more species were collected per sample at site 5 (table 19; fig. 15). Consequently, monthly and asymptotic Shannon-Weaver indices for site 5 varied less than sites 3 and 4 (fig. 18).

Twenty-one of the 24 species collected at sites 1, 2, and 5 (table 20) were also found at site 3. Only one individual of *Hypentelium etowanum* was collected at site 5 and therefore, its absence at site 3 was not unexpected. Nine *Etheostoma swaini* and six *Percina caprodes* were collected at site 5. Their absence at site 3 is probably due to mining effects. As these species are benthic in habitat, the substrate changing at site 3 from its natural gravel configuration to sand has likely had a deleterious effect. Five additional species, *Notropis baileyi*, *N. stilbius*, *N. venustus*, *Noturus leptacanthus*, and *Micropterus salmoides*, were collected at site 3 but not site 5. This was not unexpected and was probably due to a lack of sufficient suitable habitat at site 5. The presence of *Notropis venustus* even in small numbers at sites 4 (6 specimens) and 6 (2 specimens) was unexpected since this species normally occurs in larger streams as evidenced by 168 specimens collected at site 1.

Seven species were collected at site 5 but not at site 4 (table 20). Three of these species, *Moxostoma erythrurum*, *Micropterus coosae*, *M. punctulatus*, and possibly *Etheostoma swaini* and *Percina caprodes* should have occurred in at least one collection from site 4 but were probably absent due to the effects of mining. The dominance of *Semotilus atromaculatus* at sites 3 and 4 suggests that mining has caused a shift in fish population structure at these sites. Jandebeur (1975) and O'Neil and others (1981) found *Semotilus* in greatest abundance in first- and second-order undisturbed Warrior coal field streams. Its presence as 28 percent of the fish fauna at site 3 and 53 percent from site 4 was unexpected because both are third-order streams and have been affected by sedimentation from mining in the drainage.

The absence of 12 species from site 6 (table 20) is probably due in part to the mining effects on the water quality of Wallace Branch below its junction with Little Tyro Creek, however, the shorter sampling period (15 months) for site 6 makes data comparison difficult. Additionally, approximately 600 acres of forest in the upper Wallace Branch watershed were clear cut and burned prior to the initiation of sampling at site 6. Although this large scale alteration of ground cover probably altered the hydrology and water quality of upper Wallace Branch, its effect on the fish fauna could not be accurately measured.

A discriminate analysis reiterates the separation of fish faunas between the main channel of Tyro Creek and its tributaries (fig. 19). This distribution and organization of fish communities within the basin was controlled primarily by two factors which are inherently interrelated. Mining impacts (Function I), which not only tends to shift species presence or absence, but also radically change abundance, effectively grouped 55 percent of the samples. Habitat type (Function II), which accounts for the occurrence of several species in certain areas of the watershed and is influenced to some extent by mining activities, accounted for 26 percent of the sample variation (table 21).

The faunal composition of Tyro Creek (table 18) was very similar to that reported in a previous study (O'Neil and others, 1981) that described the fish faunas in four drainage systems of the Warrior coal field. From these studies a dominant ichthyofaunal group for streams in the Warrior coal field region can be compiled consisting of the following species: *Campostoma oligolepis*, *Notropis asperifrons*, *N. bellus*, *N. chrysocephalus*, *N. venustus*, *Pimephales notatus*, *Semotilus atromaculatus*, *Erimyzon oblongus*, *Moxostoma erythrurum*, *M. poecilurum*, *Fundulus olivaceus*, *Lepomis cyanellus*, *L. megalotis*, *Micropterus punctulatus*, *Etheostoma parvipinne*, *E. stigmaeum*, *E. whipplei*, *Percina maculata*, and *P. nigrofasciata*.

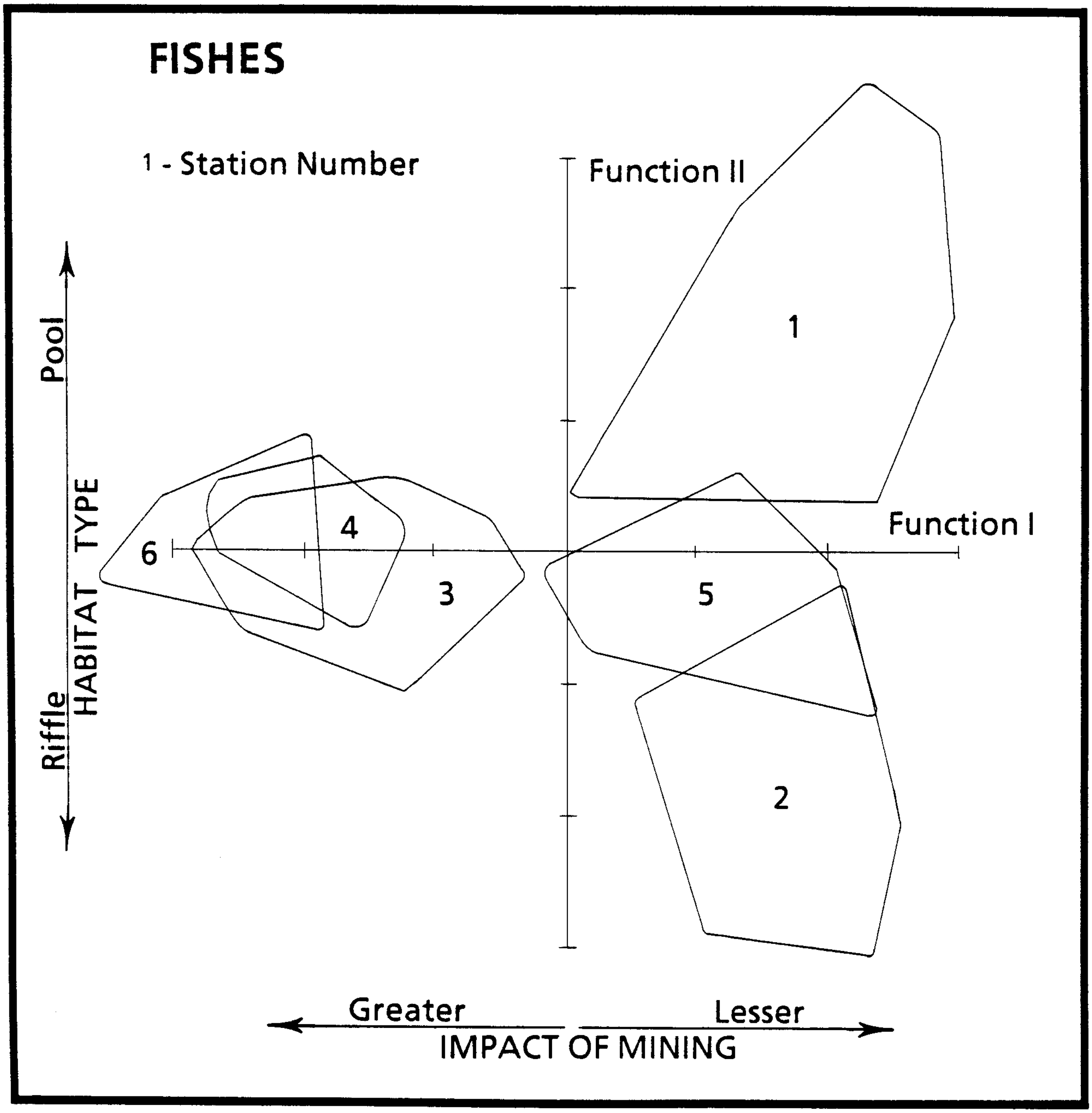


Figure 19.--Scatterplot of fishes collected in the Tyro Creek watershed in relation to the first two functions produced by discriminate analysis.

Table 20.--Comparison of dominant fish species in the Tyro Creek watershed by collection site

Species	Occurrence at Sites 1	2	3	4	5	6
Campostoma oligolepis	X	X	X	X	X	X
Notropis asperifrons	X	X	X	X	X	--
N. bellus	X	X	X	X	X	X
N. chrysocephalus	X	X	X	X	X	X
Pimephales notatus	X	X	X	X	X	X
Semotilus atromaculatus	X	X	X	X	X	X
Erimyzon oblongus	X	X	X	X	X	X
Hypentelium etowanum	X	X	--	--	X	--
Moxostoma erythrurum	X	X	X	X	X	--
M. poecilurum	X	X	X	X	X	X
Ictalurus natalis	X	X	X	X	X	--
Noturus gyrinus	X	X	X	--	X	--
Fundulus olivaceus	X	X	X	X	X	--
Lepomis cyanellus	X	X	X	X	X	--
L. megalotis	X	X	X	X	X	X
Micropterus coosae	X	X	X	--	X	--
M. punctulatus	X	X	X	--	X	X
Etheostoma parvipinne	X	X	X	X	X	X
E. stigmaeum	X	X	X	X	X	--
E. swaini	X	X	--	--	X	--
E. whipplei	X	X	X	X	X	X
Percina caprodes	X	X	--	--	X	--
P. maculata	X	X	X	X	X	X
P. nigrofasciata	X	X	X	X	X	X
Totals	24	24	21	17	24	13

SUMMARY

This report is a compilation of water quality, hydrological, and biological information from six sites, four primary and two supplemental, in the Tyro Creek watershed (Tuscaloosa County, Alabama) prior to the initiation of surface mining for Federal coal reserves in the basin. Although the Little Tyro Creek tract was leased for mining, active mining in the basin had not started at the completion of this study. Previous mining in the watershed did, however, allow some analysis of mining impacts to the Tyro Creek system.

Thirty-four physical and chemical parameters were analyzed in 132 samples during the course of the study. These analyses indicated that Wallace Branch (sites 3 and 6) and Little Tyro Creek (site 4) were affected by previous surface mining for coal in the watershed. These affects included high specific conductance, low pH, high sulfate and manganese concentrations, and increased sediment load. Regression relationships between streamflow (cfs/mi^2) and various water-quality parameters indicated a pattern of decreasing parameter values with increasing streamflow. An exception was sediment content which tended to increase with increased streamflow. In general, water-quality parameter concentrations increased in relation to the percent of basin mined. Site 4, which had the

Table 21.--Correlations between fish species collected in the Tyro Creek watershed and the first three functions produced by discriminate analysis

Species	Function I	Function II	Function III
Etheostoma stigmaeum	.662		
Notropis bellus	.488		
Pimephales notatus	.386		
Lepomis megalotis	.223		
Moxostoma erythrurum	.139		
Noturus gyrinus	.106		
Notropis asperifrons		-5.80	
Notropis texanus		.318	
Notropis stilbius		.264	
Notropis venustus		.237	
Lepomis macrochirus		.128	
Minytrema melanops		.105	
Campostoma oligolepis			-.230
Percina caprodes			.191
Moxostoma poecilurum			.143
Eigenvalue	14.510	6.867	4.175
Percent of variance	55.29	26.17	15.91
Cumulative percent	55.29	81.46	97.37

largest percent of its basin previously mined, had the highest values for selected water-quality parameters including specific conductance, magnesium, and sulfate. The regression equations developed in the study will allow predictions concerning the effect of future mining on water quality in the Tyro Creek watershed. This information will also be useful in predicting the effects of mining on water quality in other small stream watersheds of the Warrior coal field.

Streamflow in the basin was derived principally from surface runoff of precipitation. Streamflow throughout the basin was nearly uniform with seasonal fluctuations reflecting yearly precipitation patterns. Substrate in Tyro Creek (sites 1 and 2) was mainly bedrock overlain with cobble and gravel while the tributaries, Wallace Branch (site 3 and 6) and Little Tyro Creek (site 4) had predominately sandy substrates. Previous mining activity has contributed to an increased sand content in the substrate at sites 3, 4, and 6, but natural weathering and erosional processes may also be responsible.

The Tyro Creek watershed supported a diverse and abundant macroinvertebrate fauna. One hundred and six species of adult Trichoptera were collected with UV light traps in the watershed, two of which were undescribed and three of which were rare in the southeast. Hydroptilidae and Leptoceridae were the most common families collected. Most of the caddisflies emerged from May through September, with the largest number of species being collected in July. Although the previous mining in the watershed likely had some effect, most of the difference in Trichoptera fauna between sites appeared to be a function of stream size. In general, sites on the main channel of Tyro Creek supported a more diverse and abundant caddisfly fauna than did the small tributaries. As only a small number of Ephemeroptera (22 species) and Plecoptera (13 species) were collected in the light traps, it was not possible to distinguish definite distribution patterns within the watershed. Most of the species of mayflies and stoneflies were widespread southeastern species.

Benthic samples yielded 16,767 specimens in 218 taxa. The largest fauna, 6,216 specimens in 166 taxa was collected at site 2 and the lowest totals (463 specimens and 71 taxa) were collected at site 6. Dipterans, primarily Chironomidae, were the most frequently encountered group in the streams, although at sites 1 and 2, Ephemeroptera, Plecoptera, and Trichoptera were also abundant. In general, sites 1 and 2 supported a more diverse and abundant benthic fauna than did sites 3, 4, and 6. These differences were attributed to stream size, substrate type, and mining impacts. Sites 1, 2, 4, and 6 possessed a distinct riffle and pool fauna. Site 3, with a uniform sand substrate and flow regime, lacked the rocky runs linking narrow pools characteristic of the other sites. Since the immature insects dominated the benthic fauna, seasonal patterns of occurrence primarily reflected their emergence as adults. A general decrease in taxa and specimens was detected at all stations in the spring followed by a gradual increase. Diversity tended to fluctuate less at sites 1 and 2 than at sites 3, 4, and 6, reflecting the instability of the smaller tributaries.

A total of 28,426 fishes representing 44 species in nine families were collected in the Tyro Creek watershed. While *Notropis bellus* was the most abundant species in the watershed (7,408 species), *N. chrysocephalus* was the most frequently collected. In terms of biomass, *N. chrysocephalus* was the dominant at sites 2, 3, 5, and 6, *Lepomis megalotis* at site 1, and *Semotilus atromaculatus* at site 2. In general, numbers of species and specimens, and total biomass progressively decreased from the larger downstream sites to the smaller upstream sites. Recolonization of sites 2, 3, and 4 following a drought required 1 to 2 years with the slowest rate occurring in the small tributaries. The largest number of species and specimens, as well as greatest biomass, was collected annually at most sites from August through October. These months corresponded to the period when streamflow was lowest and most fishes had completed their spawning activities. The effects of previous mining in the watershed on water quality and habitat accounted for most of distribution patterns and community structure of the fish fauna of the Tyro Creek system. The ichthyofaunal composition of the Tyro Creek system was similar to that reported from other small drainages in the Black Warrior basin.

LITERATURE CITED

Alabama Department of Environmental Management, 1982, Water-quality criteria: Alabama Department of Environmental Management, Montgomery, unpublished report.

Beg, M.A., Daniel, T.W., Jr., Clarke, O.M., Jr., Kidd, J.T., and Masingill, J.H., 1978, Mineral resources of Tuscaloosa County, Alabama: Alabama Geological Survey Special Map 185, 78 p.

Berner, Lewis, 1977, Distributional patterns of southeastern mayflies (Ephemeroptera): Bulletin of Florida State Museum, Biological Sciences, v. 22, p. 1-56.

Bingham, R.H., 1979, Low-flow characteristics of Alabama streams: Alabama Geological Survey Bulletin 117, 39 p.

Blickle, R.L., 1979, Hydroptilidae (Trichoptera) of America, north of Mexico: New Hampshire Agricultural Experiment Station Bulletin 509, 97 p.

Brigham, D.G., Brigham, W.V., and Gnilka, Arnold, 1982, Aquatic insects of North and South Carolina: Mohomet, Illinois, Midwest Aquatic Enterprises.

Carter, R.W., and Davidian, Jacob, 1968, General procedures for gaging streams: U.S. Geological Survey, TWRI, Book 3, Chapter A6, 13 p.

Culbertson, W.C., 1964, Geology and coal resources of the coal-bearing rocks of Alabama: U.S. Geological Survey Bulletin 1182-B, 79 p.

Drennen, C. W., 1961, Geologic map of Tuscaloosa County, Alabama: Alabama Geological Survey Special Map 16.

Edmunds, G.F., Jensen, S.L., and Berner, Lewis, 1976, Mayflies of North and Central America: St. Paul, Minnesota, North Central Publishing Company, 330 p.

Etnier, D.A., and Way, J.D., 1973, New southeastern Trichoptera: Journal of the Kansas Entomological Society, v. 46, p. 422-430.

Guy, H.P., and Norman, V.W., 1970, Field methods for measurement of fluvial sediments: U.S. Geological Survey, TWRI, Book 3, Chapter 2, 59 p.

Harkins, J.R., and others, 1980, Hydrologic assessment, Eastern Coal Province, Area 23, Alabama: U.S. Geological Survey open-file report 80-683, 76 p.

Harris, S.C., O'Neil, P.E., Chandler, R.V., Mettee, M.F., and McCullough, E.J., 1983, Biological and hydrological impacts of surface mining for federal minerals on the Tyro Creek watershed, Alabama, Phase I: Premining-Aquatic baseline information: Alabama Geological Survey Bulletin 116, 98 p.

Hayes, E.C., 1978, 7-day low-flows and flow duration of Alabama streams through 1973: Alabama Geological Survey Bulletin 113, 163 p.

Hurlbert, S.H., 1971, The nonconcept of species diversity: A critique and alternative parameters: Ecology, v. 52, p. 577-586.

Hynes, H.B.N., 1972, The ecology of running waters: Toronto, University of Toronto Press, 555 p.

James, A.M., 1972, The stoneflies (Plecoptera) of Alabama: Auburn University, Ph.D. dissertation, 161 p.

Jandebeur, T.S., 1975, Fish species diversity, occurrence, and abundance in the North River drainage system of Alabama: University of Alabama, Ph.D. dissertation, 183 p.

Johnson, K.W., 1981, Soil survey of Tuscaloosa County, Alabama: U.S. Department of Agriculture, 118 p.

Kelley, R.W., 1982, The micro-caddisfly genus Oxyethira (Trichoptera: Hydroptilidae) morphology, biogeography, evolution, and classification: Clemson University, Ph.D. dissertation, 190 p.

Knight, A.L., and Newton, J.G., 1977, Water and related problems in coal mine areas of Alabama: U.S. Geological Survey Water Resources Investigation 76-130, 51 p.

Lineback, N.G., Pierce, L.B., and Turnage, N.E., 1974, The map abstract of water resources, Alabama: Alabama Geological Survey Map Abstract 2, 105 p.

Lloyd, M.J., Zar, J.H., and Karr, J.R., 1968, On the calculation of information-theoretical measures of diversity: American Midland Naturalist, v. 79, p. 257-272.

McNutt, R.B., Hickman, G.L., and Russell, K.E., 1965, Soil survey of Fayette County, Alabama: U.S. Department of Agriculture, series 1962, no. 4, 117 p.

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

Mettee, M.F., O'Neil, P.E., and Shamburger, V.M., 1982, An environmental assessment of areas favorable to lignite mining in southwestern Alabama: Alabama Geological Survey Bulletin 110, 150 p.

Morse, J.C., 1975, A phylogeny and revision of the caddisfly genus *Ceraclea* (Trichoptera, Leptoceridae): Contributions of the American Entomological Society, v. 11, p. 1-97.

Nie, N.H., Hull, C.H., Jenkins, J.G., Steinbrenner, K., and Bent, D.H., 1975, Statistical package for the social sciences, second edition: New York, McGraw Hill Company, 675 p.

O'Neil, P.E., Mettee, M.F., and Williams, J.S., 1981, A study of the fishes in selected streams that drain lands of federal minerals ownership, Tuscaloosa, Fayette, and Walker Counties, Alabama: Alabama Geological Survey Bulletin 119, 92 p.

Parrish, F.K., 1975, Keys to water-quality indicative organisms of the southeastern United States: Cincinnati, Ohio, Environmental Monitoring and Support Laboratory, Environmental Research Center, U.S. Environmental Protection Agency, 195 p.

Pielou, E.C., 1975, Ecological diversity: New York, John Wiley & Sons, 165 p.

Pierce, L.B., 1959, Surface water resources and hydrology of west- central Alabama: Alabama Geological Survey Special Report 24, 236 p.

______ 1967, 7-day low-flows and flow duration of Alabama streams: Alabama Geological Survey Bulletin 87, part A, 114 p.

Ross, H.H., 1944, The caddisflies, or Trichoptera, of Illinois: Illinois Natural History Survey Bulletin 23, p. 1-326.

Sapp, D.C., and Emplaincourt, J.L., 1975, Physiographic regions of Alabama: Alabama Geological Survey Special Map 168.

Schmid, F., 1970, Le genre *Rhyacophila* de la famille des Rhyacophilidae: Memoirs of the Entomological Society of Canada, v. 66, p. 1-230.

Skougstad, M.W., Fishman, M.J., Friedman, L.C., Erdmann, D.E., and Duncan, S.S., 1979, Techniques of water-resources investigation of the United States Geological Survey, methods for determination of inorganic substances in water and fluvial sediments: Washington, U.S. Government Printing Office, Book 5, Chapter A1, 626 p.

Tolson, J.S., 1984, Alabama coal data for 1983: Alabama Geological Survey Information Series 58E, 130 p.

U.S. Department of Agriculture, 1971, Guide for interpreting engineering uses of soils: Washington, U.S. Government Printing Office, 73 p.

U.S. Department of Commerce, National Climatic Center, 1981-1984, Monthly climatological data, Alabama: Asheville, North Carolina, National Climatic Center.

U.S. Environmental Protection Agency, 1979, Methods for chemical analysis of water and wastes: Cincinnati, Ohio, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, EPA-600-4-79-020, 430 p.

______1983, National revised primary drinking water regulations: Federal register, v. 48, no. 194, p. 45502-45521.

Wiggins, G.B., 1977, Larvae of North American caddisfly genera (Trichoptera): Toronto, University of Toronto Press, 401 p.

Wilhm, J.L., 1970, Effect of sample size on Shannon's formula: Southwestern Naturalist, v. 14, no. 4, p. 441-445.

APPENDIX A

Sampling site descriptions

SURFACE WATER STATION DESCRIPTION

Station: Tyro Creek at Bridge (Project Site No. 1, USGS No. 02463850)

Location: Lat. 33°33'58", Long. 87°34'34"
NE¼SW¼SW¼ sec. 15, T.17S., R.10W., Tuscaloosa County, bridge on County Road, 4.7 miles (7.2 km) east of New Lexington and 2.4 miles (3.9 km) upstream of confluence with North River.

Description: Stream substrate consists of gray, thin-bedded sandstone and shale partially covered with rock fragments. Exposed in left bank is an 8- to 10-ft. section of sandstone and shale. Sandy clay (alluvium) is exposed in the lower right bank which is subject to flood overflow.

Hydrologic Control: Station is a single channel pool; flow from pool divides downstream at low stage. Low-stage control is rock ledge and flood debris 75 ft. downstream of bridge. Medium- to high-stage control is primarily reach; some control may be exerted by steep left bank. Drainage area is 21.4 mi^2.

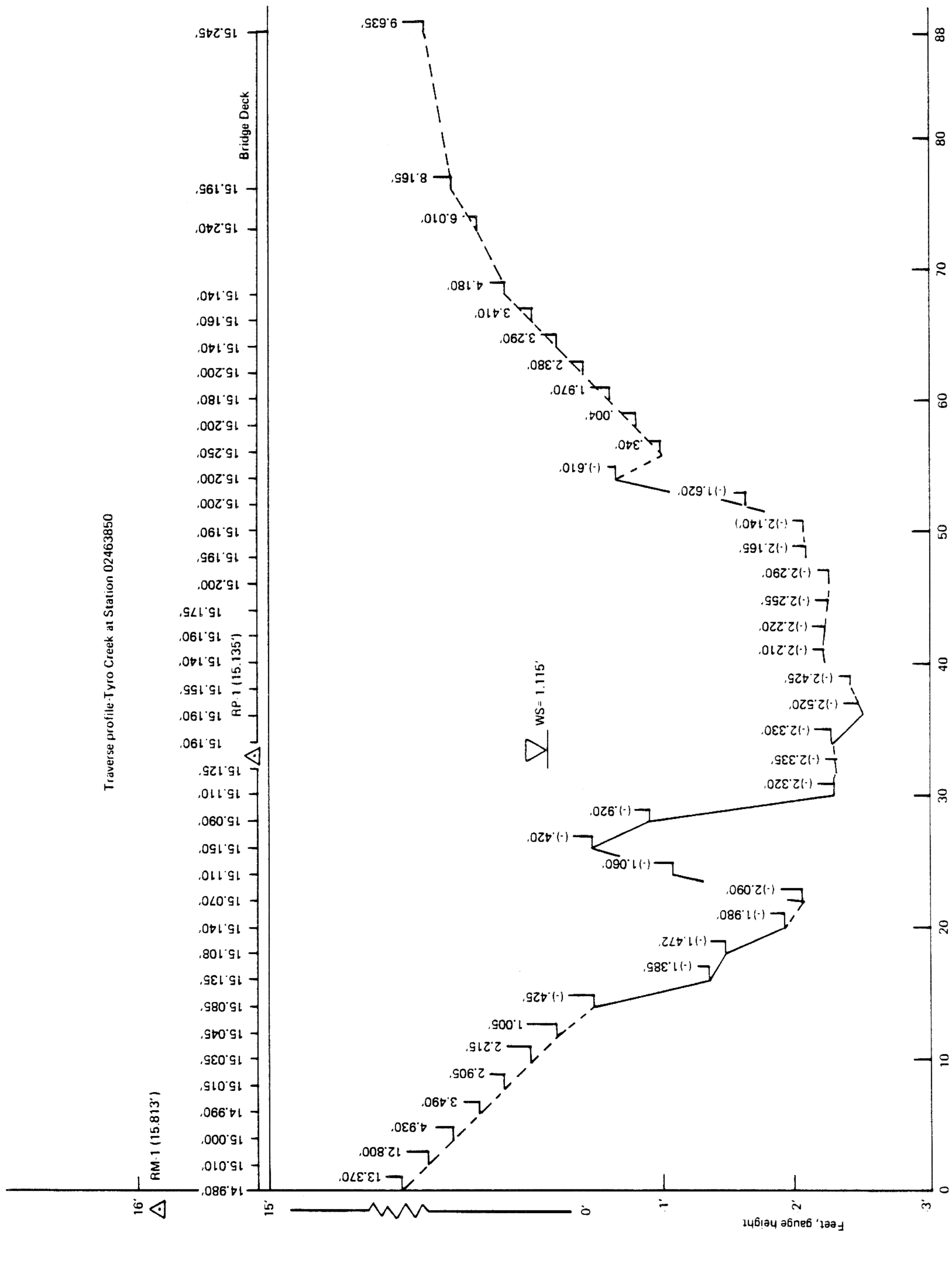


Figure A-1.--Transverse profile at site 1, June 15, 1982.

SURFACE WATER STATION DESCRIPTION

Station :	Tyro Creek at Ford (Project Site No. 2, USGS No. 02463840)
Location:	Lat. 33°35'43", Long. 87°34'35" NE$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 3, T. 17 S., R.10 W., Tuscaloosa County, on left bank, 5.2 miles (8.4 km) northeast of New Lexington and 0.8 miles (1.3 km) south of the Fayette-Tuscaloosa County line.
Description:	Stream substrate consists of gray, thin-bedded sandstone and shale partially covered by rock fragments and sand with quartz gravel. Exposed in right and left banks is silty sandy clay with rock fragments and gravel, overlain by silty clayey sand. The banks are 2 to 4 ft. high, wooded, and subject to overflow.
Hydrologic Control:	One channel at all stages. Channel width is 29 ft. Low- to medium-stage control is rock riffle 20 ft. in down-stream direction (south). Medium- to high-stage control is reach. Drainage area is 7.14 mi^2.

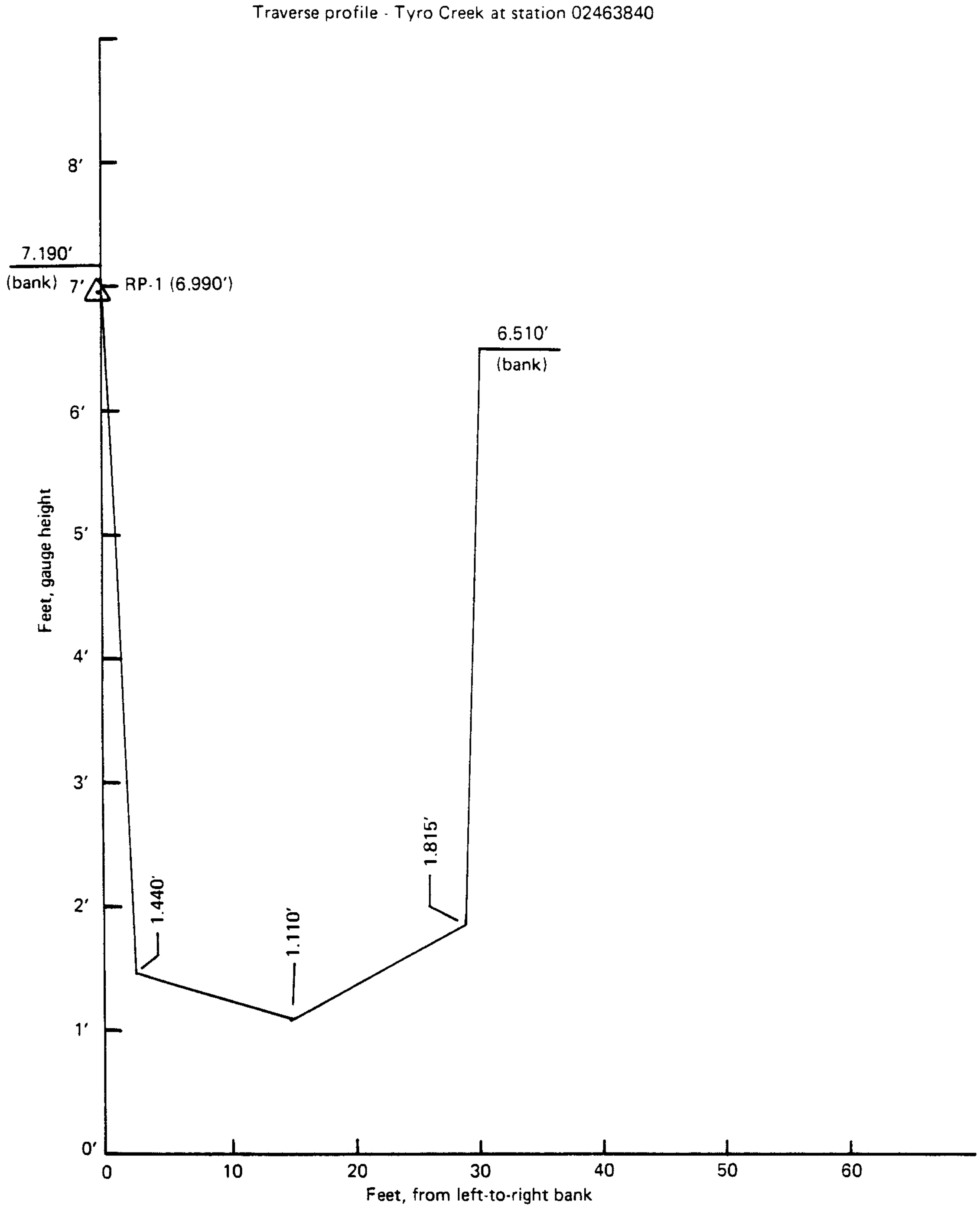


Figure A-2.--Transverse profile of site 2, June 14, 1982.

SURFACE WATER STATION DESCRIPTION

Station: Wallace Branch (lower) (Project Site No. 3, USGS No. 02463847)

Location: Lat. 33°35'02", Long. 87°34'35"
NE¼NW¼SW¼ sec. 10, T. 17 S., R. 10 W., Tuscaloosa County, on right bank, 2.0 miles (3.2 km) north of Sterling and 75 ft. upstream of confluence with Tyro Creek.

Description : Stream substrate consists of sand and scattered coal fragments. Exposed in right and left banks are silty and clayey sands. The banks are 6 to 7 ft. high, wooded, relatively level, and subject to overflow. Channel shifts and fills on right side.

Hydrologic Control: Station is in bend of stream. Low- to high-stage control is mainly reach; some control is exerted by backwater from downstream Tyro Creek. Channel width is 24 ft. Drainage area is 11.0 mi^2.

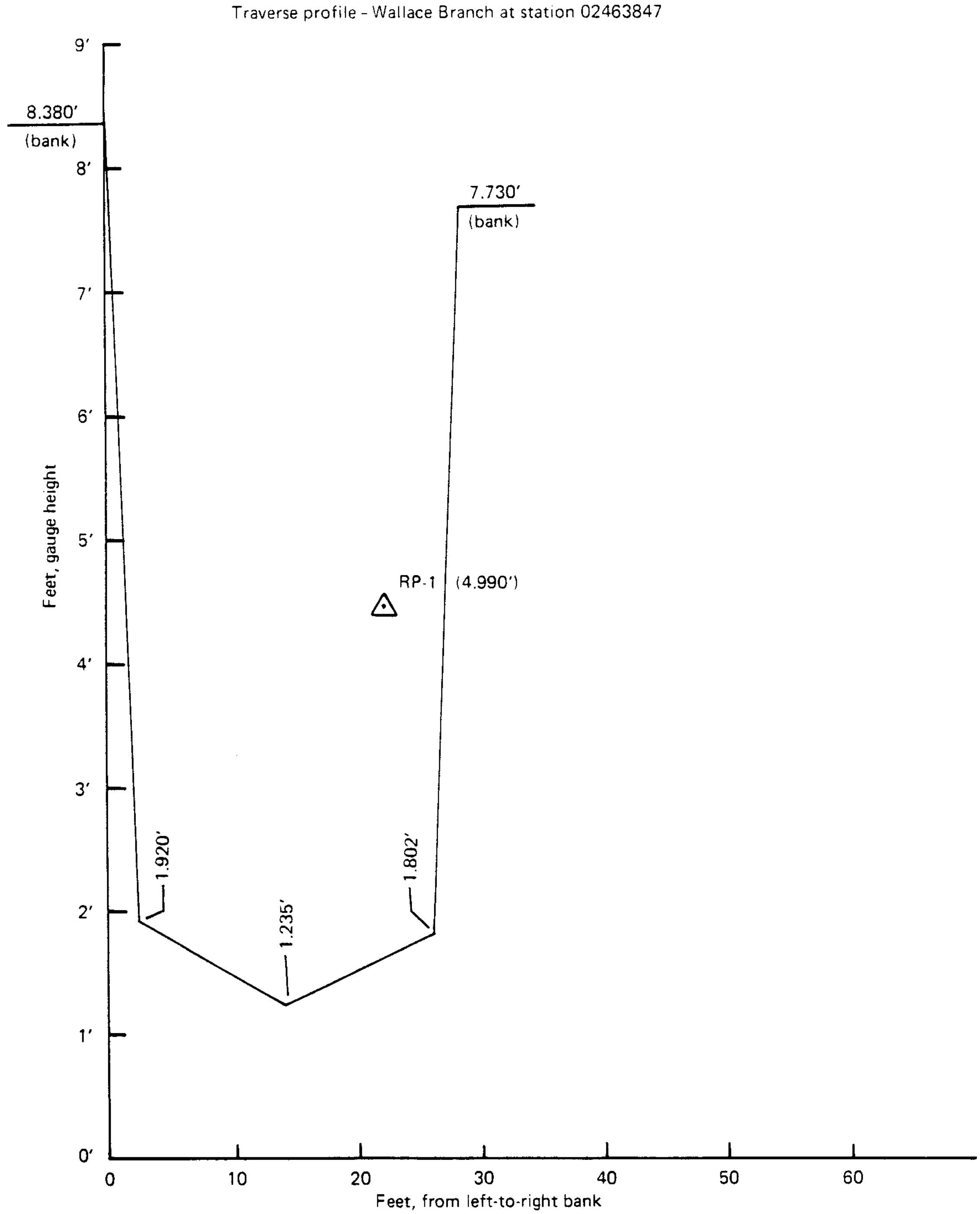


Figure A-3.--Transverse profile of site 3, June 14, 1982.

SURFACE WATER STATION DESCRIPTION

Station:	Little Tyro Creek (Project Site No. 4, USGS No. 02463846)
Location:	Lat. 33°35'17" N., Long. 87°32'55" SW¼NE¼NE¼ sec. 11, T. 17 S., R. 10 W., Tuscaloosa County, on right bank, 3.3 miles (5.3 km) west of Sandtown and 1.3 miles (2.1 km) south of the Fayette-Tuscaloosa County line.
Description:	Stream substrate consists of gray, laminated shale covered by rock fragments, sand, and scattered quartz gravel. Exposed in right and left banks is sandy silty clay with rock fragments and gravel, overlain by silty clayey sand. The banks are 4 to 7 ft. high and wooded.
Hydrologic Control:	Low- to medium-stage channel is on right side and consists of a rock riffle. Control is reach of stream. Drainage area is 4.25 mi^2.

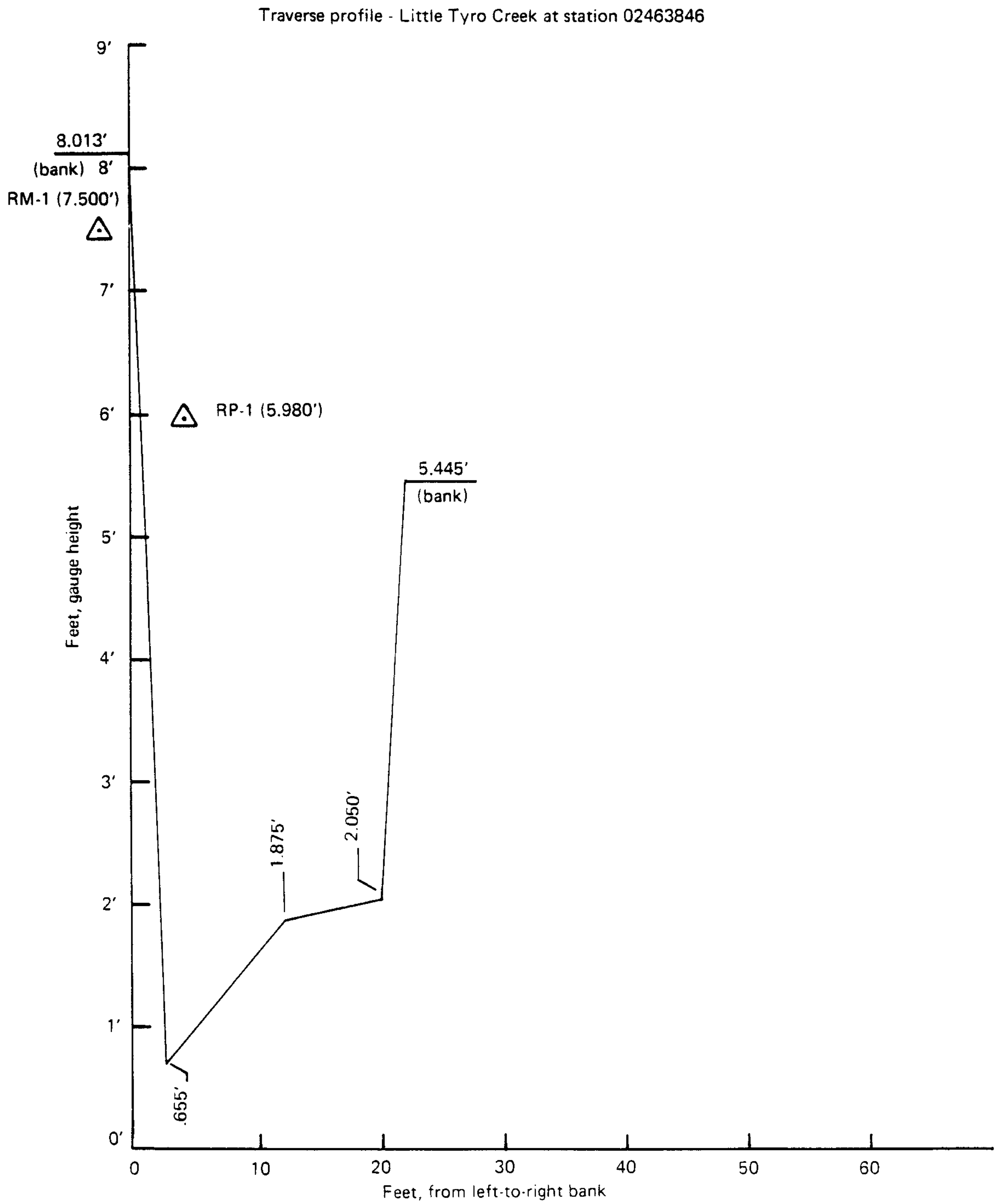


Figure A-4.--Transverse profile of site 4, June 14, 1982.

SURFACE WATER STATION DESCRIPTION

Station: Wallace Branch (upper) (Project Site No. 6, USGS No. 02463843)

Location: Lat. 33°35'20", Long. 87°32'53"
NW¼NE¼NE¼ sec. 2, T. 17 S., R. 10 W., Tuscaloosa County, on right bank, immediately south of the Fayette-Tuscaloosa County line.

Description: Stream substrate consists of gray, thin-bedded shale partially covered by rock fragments and sand containing quartz gravel. Exposed in right and left banks is silt, sand, micaceous and tan-red color in part. The banks are 3-4 ft. high, wooded, and subject to overflow.

Hydrologic Control: One channel at all stages. Low- to high-stage control is mainly reach; some control may be exerted by downstream rock bluff section. Channel width is 17 ft. Drainage area is 3.18 mi^2.

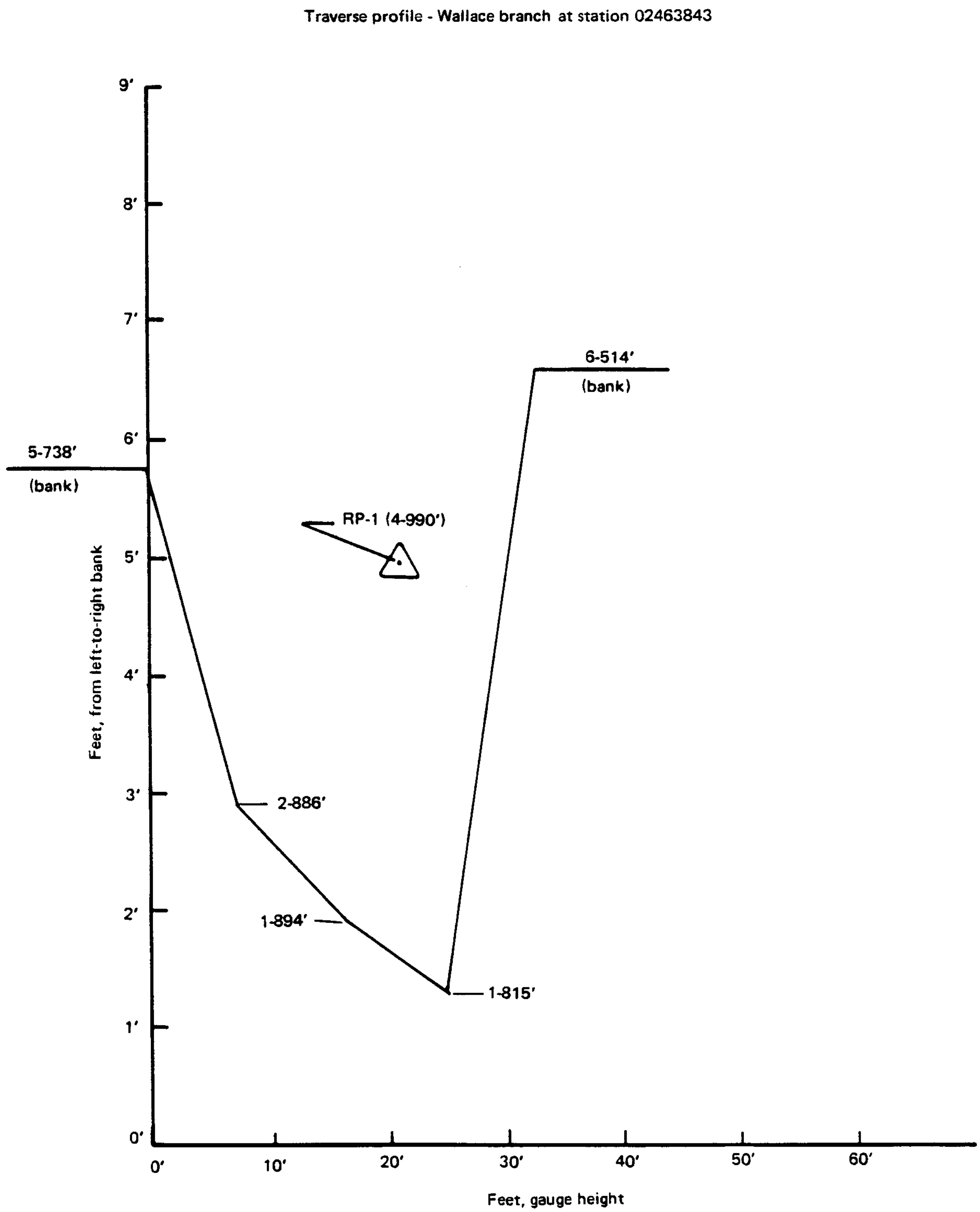


Figure A-5.--Transverse profile of site 6, March 2, 1983.

APPENDIX B

Water-quality data

Table B-1.--Water-quality data for Tyro Creek site 1, September 1981 to July 1984

Parameters	1981				1982								
	09/24	10/22	11/16	12/21	01/20	02/25	03/19	04/29	05/19	06/15	07/22	08/18	09/14
Physical-chemical													
Discharge (cfs)	.0	.0	.0	3.5	19	22	14	32	4.1	15	8.4	4.2	.02
Discharge (cfs/mi^2)	.0	.0	.0	.16	.89	1.03	.65	1.50	.19	.70	.39	.20	.0
Specific conductance (µmhos/cm)	222	200	172	130	85	69	80	57	89	85	268	140	155
pH	6.4	6.0	5.9	5.5	6.6	5.7	5.7	5.5	5.7	5.5	4.7	5.8	6.0
Temperature (°C)	17.5	11.0	12.0	0.5	8.5	10.0	19.5	13.5	19.0	20.5	24.5	24.5	23.5
Color (Pt-Co)	110	90	30	40	65	40	38	11	200	60	110	70	70
Turbidity (JTU)	25	30	15	20	15	15	10	6	72	23	45	23	25
Oxygen (dissolved, ppm)	7.5	6.6	6.4	13.0	11.6	10.4	8.0	9.4	7.9	8.5	7.8	6.8	6.3
Sediment (suspended, mg/l)	33	15	18	19	191	857	237	141	293	207	606	193	8
Sediment (discharge, T/day)	.0	.0	.0	.18	9.6	50	9.0	12	3.2	8.2	13.7	2.2	.0
Chemical (mg/l)													
Calcium (Ca)	14	13	10	7.7	4.2	3.4	3.8	3.1	5.6	3.9	13	7.3	8.6
Magnesium (Mg)	12	12	9.8	7.1	4.3	3.5	3.9	3.0	5.9	4.3	15	6.9	7.9
Sodium (Na)	2.1	2.6	2.2	3.1	2.5	2.1	2.3	2.2	2.8	2.0	2.0	2.7	3.2
Potassium (K)	3	3	3	1	.9	.8	.8	.8	1	.9	2	2	2
Bicarbonate (HCO_3)	8	19	12	6	15	4	7	6	11	10	1	11	17
Sulfate (SO_4)	74	69	63	42	28	23	24	14	28	22	94	40	38
Chloride (Cl)	.8	.8	.0	1.2	.8	2.5	1.0	.4	1.6	1.0	.8	1.0	1.4
Fluoride (F)	.1	.0	.1	.0	.0	.0	.1	.1	.2	.1	.1	.1	.1
Silica (SiO_2)	3.2	2.4	7.6	9.6	9.2	9.1	8.6	8.7	7.9	8.9	5.8	8.2	7.3
Nitrate (N)	.11	.0	.0	.02	.03	.02	.01	.01	1.7	.01	.10	.0	.0
Nitrate (NO_3)	.50	.0	.0	.09	.14	.09	.04	.04	7.7	.04	.44	.0	.0
Trace elements (µg/l)													
Arsenic (As)	1	1	<1	4	<1	4	3	<1	<1	<1	<1	1	<1
Cadmium (Cd)	<1	<1	3	1	<1	1	<1	1	<1	<1	1	2	<1
Chromium (Cr)	<1	<1	<1	<1	<1	<1	<1	1	<1	<1	<1	<1	<1
Cobalt (Co)	<10	<10	20	10	<10	30	<10	<10	<10	<10	70	<10	<10
Copper (Cu)	5	5	5	2	44	30	100	<1	<1	23	1	19	<1
Iron (Fe)	40	90	140	140	90	40	110	60	40	30	80	180	200
Lead (Pb)	9	7	9	12	1	3	<1	<1	<1	<1	4	4	1
Manganese (Mn)	1600	1100	4400	1600	830	570	620	550	430	550	4600	730	240
Mercury (Hg)	.0	.0	.0	--	.5	.0	.0	.0	.0	2.0	.0	.0	.0
Selenium (Se)	<1	<1	<1	<1	<1	<1	<1	2	3	<1	<1	<1	<1
Strontium (Sr)	90	90	30	40	50	50	50	30	60	60	80	80	60
Vanadium (V)	1.0	1.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Zinc (Zn)	<10	<10	<10	140	<10	10	50	<10	<10	10	110	<10	10

Table B-1.--Water-quality data for Tyro Creek site 1, September 1981 to July 1984 - Continued

Parameters	1982 10/18	1982 11/17	1982 12/15	1983 01/13	1983 02/17	1983 03/23	1983 04/25	1983 05/26	1983 06/20	1983 07/25	1983 08/24	1983 09/26
Physical-chemical												
Discharge (cfs)	0.97	.72	55	43.2	36.8	29.5	111	46.4	6.15	0.26	.10	1.37
Discharge (cfs/mi²)	.05	.03	2.57	2.02	1.72	1.38	5.19	2.17	.29	.01	.00	.06
Specific conductance (μmhos/cm)	99	138	69	118	74	59	47	52	95	66	76	97
pH	5.6	5.6	6.4	6.4	5.0	5.8	5.2	6.5	6.0	5.8	5.7	5.8
Temperature (°C)	13.5	7.5	10.5	7.0	8.0	7.5	12.0	17.0	21.0	27.5	26.0	16.0
Color (Pt-Co)	100	90	50	30	55	35	50	--	30	50	60	90
Turbidity (JTU)	30	15	30	10	25	15	30	--	5	20	15	15
Oxygen (dissolved, ppm)	9.6	11.5	9.4	14.6	10.4	11.1	10.6	9.0	7.8	5.4	4.6	7.8
Sediment (suspended, mg/l)	11	2	14	8	6	--	28	10	3	7	11	18
Sediment (discharge, T/day)	.03	.00	2.08	.93	.60	--	8.39	1.25	.05	.00	.00	.07
Chemical (mg/l)												
Calcium (Ca)	5.6	7.1	4.0	3.0	3.5	3.3	2.3	3.1	5.9	5.3	5.2	5.6
Magnesium (Mg)	5.4	6.8	3.4	2.8	3.9	3.3	2.2	3.0	5.8	4.0	4.6	5.5
Sodium (Na)	2.6	2.9	2.0	2.2	1.9	2.1	1.6	1.9	2.3	2.4	2.2	2.3
Potassium (K)	2	2	.8	.8	.7	1.0	.7	.7	11	2	2	2
Bicarbonate (HCO_3)	10	12	20	8	6	9	6	6	10	20	22	16
Sulfate (SO_4)	28	16	23	6.0	21	18	9.8	16	36	25	20	34
Chloride (Cl)	1.6	.0	7.6	.9	1.3	1.4	1.2	.4	.4	.2	1.4	1.2
Fluoride (F)	.1	.2	.1	.0	.1	.1	.1	.0	.0	.0	.1	.1
Silica (SiO_2)	9.7	8.2	9.2	9.7	9.6	9.6	8.3	9.8	10	8.8	6.4	8.6
Nitrate (N)	.00	.00	.08	.06	.12	.03	.07	.06	.04	.02	.00	.26
Nitrate (NO_3)	.00	.00	.35	.27	.53	.13	.31	.27	.18	.09	.00	1.17
Trace elements (μg/l)												
Arsenic (As)	<1	--	1	<1	4	1	<1	5	<1	1	<1	<1
Cadmium (Cd)	1	<1	1	<1	1	1	<1	<1	1	1	<1	1
Chromium (Cr)	1	<1	<1	<1	2	<1	1	<1	<1	1	1	<1
Cobalt (Co)	<10	<10	<10	<10	10	<10	<10	<10	<10	<10	<10	<10
Copper (Cu)	<1	2	8	17	18	1	2	3	<1	13	4	2
Iron (Fe)	60	70	100	80	40	70	60	60	70	140	250	110
Lead (Pb)	5	<1	4	<1	<1	<1	1	6	2	2	<1	<1
Manganese (Mn)	270	220	700	420	830	640	320	440	380	580	400	640
Mercury (Hg)	.0	.0	.0	.0	.0	.0	.0	.0	.0	.5	.0	.0
Selenium (Se)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1
Strontium (Sr)	40	50	50	60	50	40	30	40	60	50	30	50
Vanadium (V)	.0	.0	.0	.0	.0	.0	2.0	.0	1.0	2.0	.0	1.0
Zinc (Zn)	10	10	30	20	70	<10	10	20	10	20	<10	10

Table B-1.--Water-quality data for Tyro Creek site 1, September 1981 to July 1984 - Continued

Parameters	1983			1984			
	10/21	11/17	12/21	01/26	03/15	05/16	07/25
Physical-chemical							
Discharge (cfs)	0.97	5.03	25.4	70.2	22.9	13.9	2.43
Discharge (cfs/mi²)	.05	.24	1.19	3.28	1.07	.65	.11
Specific conductance (µmhos/cm)	73	87	--	46	68	66	81
pH	5.3	5.9	--	5.1	6.2	5.6	6.8
Temperature (°C)	18.0	8.0	--	7.0	11.0	15.5	25.0
Color (Pt-Co)	40	160	--	10	25	0	130
Turbidity (JTU)	10	45	--	10	10	0	20
Oxygen (dissolved, ppm)	8.2	10.4	--	11.6	9.8	10.2	7.4
Sediment (suspended, mg/l)	10	--	--	9	7	12	22
Sediment (discharge, T/day)	.03	--	--	1.71	.43	.45	.14
Chemical (mg/l)							
Calcium (Ca)	4.5	5.5	--	2.7	3.1	3.1	4.9
Magnesium (Mg)	4.1	5.2	--	2.4	3.1	3.3	4.8
Sodium (Na)	2.7	2.5	--	2.7	2.1	2.0	3.0
Potassium (K)	2	2	--	.6	.7	.7	1
Bicarbonate (HCO_3)	18	6	--	3	6	12	24
Sulfate (SO_4)	.0	.0	--	11	12	17	28
Chloride (Cl)	1.3	1.5	--	.4	.8	.4	3.8
Fluoride (F)	.2	.1	--	.1	.0	.1	.1
Silica (SiO_2)	4.5	7.4	--	6.4	5.8	4.8	9.8
Nitrate (N)	.00	.00	--	.06	.03	.06	.02
Nitrate (NO_3)	.00	.00	--	.27	.13	.30	.09
Trace elements (µg/l)							
Arsenic (As)	2	1	--	<1	<1	1	1
Cadmium (Cd)	1	1	--	<1	1	1	1
Chromium (Cr)	<1	1	--	1	1	1	1
Cobalt (Co)	<10	<10	--	<10	<10	<10	<10
Copper (Cu)	7	1	--	1	<1	2	--
Iron (Fe)	80	110	--	70	50	80	90
Lead (Pb)	3	1	--	1	1	3	10
Manganese (Mn)	150	390	--	270	370	350	300
Mercury (Hg)	.0	.0	--	.0	.0	.0	--
Selenium (Se)	2	1	--	<1	1	2	<1
Strontium (Sr)	50	50	--	30	70	60	50
Vanadium (V)	2.6	4.0	--	2.0	2.0	3.0	.0
Zinc (Zn)	20	10	--	50	<10	<10	<10

Table B-2.--Water-quality data for Tyro Creek site 2, September 1981 to July 1984

Parameters	1981 11/16	1981 12/16	1982 01/21	1982 02/24	1982 03/18	1982 04/28	1982 05/19	1982 06/14	1982 07/21	1982 08/17	1982 09/14	1982 10/18	1982 11/16
Physical-chemical													
Discharge (cfs)	.02	3.7	6.8	7.6	5.8	12	1.4	2.3	.99	1.6	.07	0.64	.45
Discharge (cfs/mi²)	.0	.52	.95	1.06	.81	1.68	.20	.32	.14	.22	.01	.09	.06
Specific conductance (µmhos/cm)	52	42	38	37	37	35	33	44	58	63	67	48	57
pH	6.3	6.7	7.3	5.8	5.7	5.1	6.2	5.5	5.8	6.1	5.9	5.5	6.0
Temperature (°C)	19.0	5.0	11.0	10.5	18.5	14.0	20.5	21.0	24.0	23.0	22.0	12.5	7.0
Color (Pt-Co)	25	35	30	50	35	23	60	70	50	75	80	45	70
Turbidity (JTU)	4	15	17	20	14	7	20	52	20	40	50	25	20
Oxygen (dissolved, ppm)	7.0	12.2	11.1	12.4	8.4	10.2	8.2	8.4	7.2	8.2	6.2	9.4	12.0
Sediment (suspended, mg/l)	4	5	92	76	74	56	768	164	105	136	11	2	2
Sediment (discharge, T/day)	.0	.05	1.7	1.6	1.2	1.8	3.0	1.0	.28	.59	.0	.0	.0
Chemical (mg/l)													
Calcium (Ca)	3.0	2.7	1.8	1.4	1.8	2.1	2.3	2.2	2.9	3.0	4.1	2.5	2.9
Magnesium (Mg)	2.4	1.7	1.4	1.1	1.4	1.3	1.7	1.7	2.0	2.2	2.9	1.9	2.1
Sodium (Na)	2.2	3.1	2.7	2.0	2.2	2.1	2.2	1.8	2.3	3.2	3.1	2.2	2.5
Potassium (K)	2	2	.8	.7	.7	.7	.9	1	1.3	1.3	1.7	1	2
Bicarbonate (HCO_3)	18	22	18	6	15	8	11	18	15	16	22	16	20
Sulfate (SO_4)	3.9	2.8	4.2	2.8	2.6	1.9	1.0	1.4	1.4	3.1	2.2	3.7	.0
Chloride (Cl)	1.6	1.2	.8	2.5	1.0	.5	1.8	1.2	1.4	1.1	1.2	1.6	2.0
Fluoride (F)	.0	.0	.0	.1	.1	.1	.2	.2	.1	.1	.1	.1	.1
Silica (SiO_2)	8.6	8.9	8.9	8.6	8.0	8.5	7.2	7.7	6.8	7.0	5.4	8.7	7.6
Nitrate (N)	.0	.01	.03	.01	.0	.03	.08	.01	.0	.0	.0	.0	.0
Nitrate (NO_3)	.0	.04	.14	.04	.0	.14	.35	.04	.0	.0	.0	.0	.0
Trace elements (µg/l)													
Arsenic (As)	4	3	<1	2	<1	<1	<1	<1	<1	<1	1	<1	--
Cadmium (Cd)	<1	1	<1	1	<1	1	<1	1	2	1	<1	1	<1
Chromium (Cr)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cobalt (Co)	<10	<10	<10	10	<10	20	<10	<10	<10	<10	<10	<10	<10
Copper (Cu)	10	2	6	80	50	<1	<1	16	14	7	<1	<1	22
Iron (Fe)	240	140	90	70	360	110	70	30	120	380	280	250	390
Lead (Pb)	12	3	2	<1	<1	2	<1	<1	2	3	6	6	<1
Manganese (Mn)	37	5	480	24	68	27	16	21	28	18	58	9	31
Mercury (Hg)	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Selenium (Se)	<1	<1	<1	<1	<1	1	2	<1	<1	<1	<1	<1	<1
Strontium (Sr)	90	40	40	40	30	60	50	80	40	60	30	30	50
Vanadium (V)	1.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Zinc (Zn)	<10	10	50	130	10	<10	<10	50	10	10	10	<10	10

Table B-2.--Water-quality data for Tyro Creek site 2, September 1981 to July 1984 - Continued

Parameters	1982	1983											
	12/14	01/12	02/17	03/23	04/25	05/26	06/20	07/25	08/24	09/26	10/20	11/18	12/20
Physical-chemical													
Discharge (cfs)	19.1	19.7	9.91	11.0	39.8	13.2	1.79	0.40	0.00	1.04	0.96	1.93	9.22
Discharge (cfs/mi²)	2.68	2.76	1.39	1.54	5.57	1.85	.25	.06	.00	.15	.13	.27	1.29
Specific conductance (µmhos/cm)	40	36	31	28	25	26	32	36	41	36	43	36	--
pH	6.5	6.3	6.5	5.1	5.8	6.5	6.7	5.5	5.4	5.4	5.2	5.6	--
Temperature (°C)	10.0	5.5	6.5	8.5	12.0	18.0	19.0	27.0	30.0	16.0	17.0	10.0	--
Color (Pt-Co)	70	40	25	50	50	--	35	40	10	20	50	30	--
Turbidity (JTU)	15	25	20	5	25	--	5	25	5	10	5	10	--
Oxygen (dissolved, ppm)	10.4	11.2	10.2	10.8	10.4	8.7	8.0	6.3	7.2	8.8	8.2	10.8	--
Sediment (suspended, mg/l)	7	6	5	--	9	500	2	8	3	4	6	6	--
Sediment (discharge, T/day)	.36	.32	.13	--	.97	17.82	0.01	0.01	0.00	0.01	0.02	0.03	--
Chemical (mg/l)													
Calcium (Ca)	2.1	1.8	1.7	1.4	1.6	1.6	1.6	2.9	2.8	2.3	2.5	2.4	--
Magnesium (Mg)	1.4	1.3	1.3	1.3	1.1	1.2	1.4	1.9	2.1	1.7	2.0	1.9	--
Sodium (Na)	1.9	3.2	1.9	1.8	1.6	1.8	1.9	2.3	2.1	2.1	2.4	2.6	--
Potassium (K)	0.7	.6	.6	.7	.6	.6	.9	1	2	1	1	1	--
Bicarbonate (HCO_3)	16	16	12	4	10	6	16	16	18	14	18	12	--
Sulfate (SO_4)	2.8	4.9	3.0	4.8	3.8	14	10	15	2.4	4.2	4.2	2.7	--
Chloride (Cl)	2.2	1.2	1.4	1.3	1.2	0.2	0.4	.02	1.4	1.4	2.0	1.5	--
Fluoride (F)	.1	.1	.1	.0	.1	.0	.0	.0	.1	.1	.1	.1	--
Silica (SiO_2)	9.8	9.9	9.5	9.4	8.3	9.2	8.2	7.7	6.3	7.7	4.4	8.5	--
Nitrate (N)	.01	.07	.04	.10	.04	.06	.03	.02	.00	.15	--	.05	--
Nitrate (NO_3)	.04	.31	.18	.40	.18	.27	.13	.09	.00	.66	--	.22	--
Trace elements (µg/l)													
Arsenic (As)	3	1	2	3	<1	4	<1	1	<1	<1	1	17	--
Cadmium (Cd)	<1	<1	1	3	3	<1	1	<1	<1	<1	<1	1	--
Chromium (Cr)	1	<1	2	<1	<1	<1	1	1	1	<1	1	2	--
Cobalt (Co)	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	--
Copper (Cu)	13	2	<1	12	2	8	2	6	3	3	<1	1	--
Iron (Fe)	150	70	110	70	70	60	50	210	180	80	100	160	--
Lead (Pb)	<1	3	<1	<1	1	4	4	2	<1	3	1	3	--
Manganese (Mn)	35	28	18	33	24	20	<1	30	20	20	10	10	--
Mercury (Hg)	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	--
Selenium (Se)	<1	<1	<1	<1	<1	<1	<1	<1	2	<1	3	1	--
Strontium (Sr)	30	30	90	30	30	30	30	30	30	30	40	60	--
Vanadium (V)	.0	.0	.0	.0	.0	.0	1.0	1.0	.0	1.0	1.8	5.0	--
Zinc (Zn)	20	10	10	<10	10	10	<10	10	10	10	20	10	--

Table B-2.--Water-quality data for Tyro Creek site 2, September 1981 to July 1984 - Continued

Parameters	1984			
	01/25	03/14	05/16	07/25
Physical-chemical				
Discharge (cfs)	32.6	6.71	5.37	0.58
Discharge (cfs/mi^2)	4.57	.94	.75	.08
Specific conductance (μmhos/cm)	33	35	31	36
pH	5.4	6.6	5.3	6.4
Temperature (°C)	8.0	6.0	17.0	26.0
Color (Pt-Co)	80	25	20	50
Turbidity (JTU)	20	10	5	10
Oxygen (dissolved, ppm)	12.0	11.9	9.4	7.8
Sediment (suspended, mg/l)	8	1	8	7
Sediment (discharge, T/day)	.70	.02	.12	.01
Chemical (mg/l)				
Calcium (Ca)	1.7	1.8	2.6	2.2
Magnesium (Mg)	1.3	1.3	1.4	1.6
Sodium (Na)	1.7	1.9	2.1	2.6
Potassium (K)	.7	.6	1	1
Bicarbonate (HCO_3)	4	10	6	14
Sulfate (SO_4)	5.2	.0	1.3	2.0
Chloride (Cl)	.5	.2	.6	.9
Fluoride (F)	.1	.0	.1	.1
Silica (SiO_2)	6.5	5.2	4.4	7.4
Nitrate (N)	.11	.07	.09	.02
Nitrate (NO_3)	.49	.31	.40	.09
Trace elements (μg/l)				
Arsenic (As)	<1	1	1	1
Cadmium (Cd)	1	1	1	1
Chromium (Cr)	5	1	1	1
Cobalt (Co)	<10	<10	<10	<10
Copper (Cu)	1	1	2	--
Iron (Fe)	40	80	20	170
Lead (Pb)	1	1	1	21
Manganese (Mn)	20	30	20	20
Mercury (Hg)	.0	.0	.0	--
Selenium (Se)	3	<1	1	<1
Strontium (Sr)	20	40	20	60
Vanadium (V)	2.0	2.0	3.0	3.0
Zinc (Zn)	20	10	<10	<10

Table B-3 --Water-quality data for Wallace Branch site 3, September 1981 to July 1984

Parameters	1981		1982										
	11/17	12/21	01/21	02/24	03/18	04/29	05/18	06/15	07/21	08/17	09/15	10/19	11/16
Physical-chemical													
Discharge (cfs)	.08	2.4	12	14	9.0	18	2.9	7.9	4.5	2.5	.06	.81	.58
Discharge (cfs/mi^2)	.01	.22	1.09	1.27	.82	1.64	.26	.72	.41	.23	.01	.07	.05
Specific conductance (μmhos/cm)	330	208	118	95	111	85	138	104	140	225	210	145	200
pH	5.6	5.8	6.8	5.6	5.6	5.1	5.9	5.5	5.7	5.7	6.0	5.4	5.6
Temperature (°C)	11.0	0.5	12.0	14.0	22.0	13.0	21.0	21.5	25.0	24.0	23.5	12.0	8.5
Color (Pt-Co)	5	20	60	50	30	25	48	80	30	50	25	45	20
Turbidity (JTU)	2.0	.0	25	15	12	7	12	32	10	21	10	25	0
Oxygen (dissolved, ppm)	8.0	13.4	10.8	11.8	7.6	9.8	8.9	8.4	8.2	7.2	6.9	9.8	12.0
Sediment (suspended, mg/l)	42	8	182	1600	855	601	540	1290	435	139	2	3	0
Sediment (discharge, T/day)	.01	.05	5.7	61	21	29	4.2	27	5.3	.94	.0	.01	.0
Chemical (mg/l)													
Calcium (Ca)	21	12	6.6	5.0	5.4	4.4	7.8	6.3	7.2	14	11	8.5	11
Magnesium (Mg)	20	11	6.3	5.3	5.9	4.4	8.5	6.1	7.1	14	11	8.4	11
Sodium (Na)	3.8	3.6	2.6	2.1	2.2	1.9	3.0	2.6	5.3	2.9	4.4	3.6	3.7
Potassium (K)	4	1	1	.9	.9	.8	1	1	1	2	2	2	2
Bicarbonate (HCO_3)	4	4	15	12	10	6	8	6	4	6	8	10	10
Sulfate (SO_4)	190	66	40	34	37	28	47	31	43	85	64	49	60
Chloride (Cl)	.0	1.0	.7	2.5	.8	.4	3.8	1.0	1.2	.9	1.6	1.0	1.8
Fluoride (F)	.0	.0	.0	.0	.1	.1	.2	.1	.1	.1	.1	.0	.1
Silica (SiO_2)	11	9.2	9.3	9.1	8.8	.0	9.3	9.3	8.2	8.6	8.8	11	10
Nitrate (N)	.0	.04	.04	.03	.04	.05	1.5	.0	.0	.01	.0	.0	.0
Nitrate (NO_3)	.0	.18	.18	.13	.18	.22	6.7	.0	.0	.04	.0	.0	.0
Trace elements (μg/l)													
Arsenic (As)	<1	4	<1	2	1	1	<1	<1	<1	<1	<1	<1	--
Cadmium (Cd)	1	1	<1	1	2	1	<1	2	<1	1	1	1	<1
Chromium (Cr)	<1	<1	<1	<1	<1	1	<1	<1	1	<1	<1	<1	<1
Cobalt (Co)	60	20	<10	<10	10	20	<10	<10	<10	10	<10	<10	<10
Copper (Cu)	5	8	3	30	70	<1	<1	<1	1	<1	<1	<1	2
Iron (Fe)	260	100	40	50	320	250	10	160	50	50	100	90	90
Lead (Pb)	12	8	<1	3	1	4	<1	<1	1	5	2	13	<1
Manganese (Mn)	7400	2600	1200	1000	1100	1100	1100	790	920	2000	760	740	810
Mercury (Hg)	.0	.0	.0	.0	.0	.0	.0	2.0	.0	.0	.0	.0	.0
Selenium (Se)	<1	<1	<1	<1	<1	2	2	<1	<1	<1	<1	<1	<1
Strontium (Sr)	100	80	60	60	50	50	60	60	50	90	70	40	80
Vanadium (V)	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Zinc (Zn)	<10	40	10	<10	10	<10	<10	10	10	10	<10	<10	10

Table B-3.--Water-quality data for Wallace Branch site 3, September 1981 to July 1984 - Continued

	1982	1983											
Parameters	12/14	01/13	02/18	03/22	04/26	05/25	06/21	07/26	08/24	09/26	10/20	11/17	12/20
Physical-chemical													
Discharge (cfs)	33.9	22.2	16.2	15.7	42.2	30.7	2.60	0.06	0.00	0.34	0.41	1.70	12.1
Discharge (cfs/mi²)	3.08	2.02	1.47	1.43	3.84	2.79	.24	.01	.00	.03	.04	.15	1.10
Specific conductance (μmhos/cm)	83	119	99	100	64	73	139	102	144	170	158	150	--
pH	6.1	5.6	5.9	5.2	5.2	5.4	6.0	5.8	6.2	4.8	5.0	6.5	--
Temperature (°C)	9.0	6.0	6.0	6.0	12.0	15.5	22.0	26.5	30.0	16.0	16.5	9.0	--
Color (Pt-Co)	20	30	55	45	55	--	10	50	15	25	20	25	--
Turbidity (JTU)	12	5	20	25	20	--	2	25	0	0	5	10	--
Oxygen (dissolved, ppm)	11.5	12.4	11.8	9.3	8.6	8.4	8.2	4.0	4.7	7.0	8.0	11.6	--
Sediment (suspended, mg/l)	92	182	18	--	61	27	4	28	9	3	4	--	--
Sediment (discharge, T/day)	8.42	10.9	.79	--	6.95	2.24	0.03	0.00	0.00	0.00	0.00	--	--
Chemical (mg/l)													
Calcium (Ca)	4.6	4.2	4.9	4.4	3.4	4.2	8.0	6.6	9.6	10	9.3	9.5	--
Magnesium (Mg)	4.4	4.3	5.9	5.4	3.6	4.0	8.9	6.2	9.0	11	9.4	9.7	--
Sodium (Na)	2.6	2.0	2.0	2.0	1.7	1.8	2.7	3.0	3.0	3.1	3.3	2.8	--
Potassium (K)	.8	.7	.7	.9	.7	.7	1	2	2	2	2	2	--
Bicarbonate (HCO_3)	14	8	6	6	4	8	12	20	18	6	10	16	--
Sulfate (SO_4)	29	42	33	30	21	31	56	37	45	74	59	20	--
Chloride (Cl)	.2	.8	1.5	1.4	1.0	.2	.6	1.0	1.4	.9	1.8	1.4	--
Fluoride (F)	.1	.0	.1	.1	.1	.0	.0	.0	.1	.1	.1	.1	--
Silica (SiO_2)	10	11	10	10	9.0	10	12	11	6.9	9.4	5.4	8.6	--
Nitrate (N)	.10	.07	.10	.21	.08	.08	.05	.04	.00	.08	.06	.01	--
Nitrate (NO_3)	.44	.31	.44	.93	.35	.35	.22	.18	.00	.36	.27	.04	--
Trace elements (μg/l)													
Arsenic (As)	2	2	7	1	<1	1	<1	<1	2	<1	1	<1	--
Cadmium (Cd)	<1	1	1	1	1	2	1	1	<1	1	<1	1	--
Chromium (Cr)	<1	<1	1	<1	<1	<1	1	<1	2	<1	1	1	--
Cobalt (Co)	<10	10	20	20	10	20	<10	<10	<10	<10	<10	10	--
Copper (Cu)	<1	4	<1	15	2	1	2	3	2	4	1	1	--
Iron (Fe)	50	50	80	30	30	40	60	140	50	70	140	90	--
Lead (Pb)	<1	<1	<1	<1	<1	12	2	6	<1	<1	<1	1	--
Manganese (Mn)	880	880	1400	1400	780	800	860	880	890	1600	600	1300	--
Mercury (Hg)	.0	.0	.0	.0	.0	.0	.0	.5	.0	.0	.0	.0	--
Selenium (Se)	<1	<1	<1	<1	<1	1	<1	<1	2	3	3	<1	--
Strontium (Sr)	30	70	50	30	30	60	50	50	80	80	80	80	--
Vanadium (V)	.0	.0	.0	.0	.0	2.0	1.0	.0	.0	.0	1.7	3.0	--
Zinc (Zn)	10	10	20	<10	10	10	<10	<10	<10	20	20	10	--

Table B-3.--Water-quality data for Wallace Branch site 3, September 1981 to July 1984 - Continued

Parameters	1984			
	01/25	03/15	05/17	07/25
Physical-chemical				
Discharge (cfs)	46.9	11.9	6.89	1.10
Discharge (cfs/mi^2)	4.26	1.08	.63	.10
Specific conductance (μmhos/cm)	56	93	55	116
pH	5.3	6.3	5.0	6.1
Temperature (°C)	8.5	14.0	16.0	27.0
Color (Pt-Co)	30	20	15	25
Turbidity (JTU)	5	10	5	3
Oxygen (dissolved, ppm)	12.4	10.0	8.8	7.4
Sediment (suspended, mg/l)	42	9	8	6
Sediment (discharge, T/day)	5.32	.29	.15	.02
Chemical (mg/l)				
Calcium (Ca)	3.0	4.3	4.9	7.0
Magnesium (Mg)	3.1	4.5	5.5	7.5
Sodium (Na)	1.8	1.8	3.7	3.4
Potassium (K)	.6	.8	.8	1
Bicarbonate (HCO_3)	4	6	4	8
Sulfate (SO_4)	16	23	32	44
Chloride (Cl)	.4	.4	.9	1.1
Fluoride (F)	.1	.0	.1	.1
Silica (SiO_2)	6.7	6.8	5.1	11
Nitrate (N)	.03	.17	.01	.02
Nitrate (NO_3)	.13	.75	.04	.09
Trace elements (μg/l)				
Arsenic (As)	<1	<1	1	1
Cadmium (Cd)	1	1	2	1
Chromium (Cr)	2	1	1	1
Cobalt (Co)	<10	<10	<10	<10
Copper (Cu)	1	<1	2	--
Iron (Fe)	50	50	10	40
Lead (Pb)	6	1	4	1
Manganese (Mn)	520	650	700	450
Mercury (Hg)	.0	.2	.0	--
Selenium (Se)	1	<1	<1	<1
Strontium (Sr)	20	30	70	60
Vanadium (V)	2.0	2.0	2.0	3.0
Zinc (Zn)	30	10	<10	<10

Table B-4.--Water-quality data for Little Tyro Creek site 4, September 1981 to July 1984

Parameters	1981		1982										
	11/17	12/16	01/20	02/25	03/19	04/28	05/18	06/14	07/22	08/18	09/14	10/18	11/17
Physical-chemical													
Discharge (cfs)	.17	1.6	3.5	4.8	3.7	7.8	1.1	5.0	7.4	1.6	.18	.21	.37
Discharge (cfs/mi^2)	.04	.38	.82	1.13	.87	1.84	.26	1.18	1.74	.38	.04	.05	.09
Specific conductance (μmhos/cm)	370	230	180	165	200	118	235	155	147	230	268	292	330
pH	5.6	6.5	6.7	5.9	5.9	5.5	5.9	5.2	4.4	5.2	5.3	5.4	5.7
Temperature (°C)	8.0	7.0	7.5	10.5	18.0	15.0	18.0	20.5	21.5	21.0	23.0	13.5	8.5
Color (Pt-Co)	3	5	25	50	10	10	40	65	160	95	45	10	35
Turbidity (JTU)	2.0	4.0	4.0	15	8.0	5	30	25	65	42	25	5	5
Oxygen (dissolved, ppm)	9.2	12.0	10.6	10.2	8.2	10.6	10.0	7.4	8.4	8.0	6.0	9.6	10.0
Sediment (suspended, mg/l)	2	20	184	129	291	114	248	192	474	211	2	2	4
Sediment (discharge, T/day)	.0	.08	1.7	1.7	2.9	2.4	.76	2.6	9.5	.91	.0	.0	.0
Chemical (mg/l)													
Calcium (Ca)	24	14	1.1	8.1	9.1	6.5	14	7.2	7.0	12	15	18	19
Magnesium (Mg)	22	14	1.1	9.9	11	7.2	15	8.6	8.0	14	15	19	19
Sodium (Na)	5.0	4.3	2.2	2.4	2.6	2.2	3.6	2.1	2.4	2.8	4.0	4.1	4.5
Potassium (K)	3	2	1	1	1	1	1	1	1	2	2	2	2
Bicarbonate (HCO_3)	2	22	15	5	6	4	5	6	0	2	4	8	6
Sulfate (SO_4)	220	93	72	64	71	44	83	49	51	89	96	130	120
Chloride (Cl)	.0	1.1	.6	2.5	.6	.5	2.8	1.1	.8	.8	1.4	1.1	1.8
Fluoride (F)	.0	.0	.0	.0	.1	.2	.2	.1	.1	.1	.1	.1	.1
Silica (SiO_2)	13	11	9.8	9.4	9.4	.0	9.4	9.1	7.6	8.1	10	12	12
Nitrate (N)	.0	.05	.05	.04	.04	.04	1.7	.0	.03	.07	.0	.0	.0
Nitrate (NO_3)	.0	.22	.22	.18	.18	.18	7.3	.0	.13	.31	.0	.0	.0
Trace elements (μg/l)													
Arsenic (As)	<1	4	<1	4	<1	<1	<1	<1	<1	<1	<1	<1	--
Cadmium (Cd)	2	1	<1	<1	1	1	<1	1	2	1	1	1	<1
Chromium (Cr)	1	<1	<1	<1	<1	<1	<1	<1	1	<1	<1	<1	<1
Cobalt (Co)	40	30	40	<10	30	40	30	10	30	40	<10	10	20
Copper (Cu)	10	<1	3	60	60	<1	<1	<1	1	<1	<1	<1	2
Iron (Fe)	180	110	100	60	50	60	70	80	60	90	90	150	130
Lead (Pb)	13	<1	2	1	<1	<1	<1	<1	2	13	5	8	<1
Manganese (Mn)	4400	3200	1900	2300	2400	2300	2900	1500	2100	2800	980	2800	2600
Mercury (Hg)	.0	.0	1.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Selenium (Se)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	<1
Strontium (Sr)	20	80	70	70	60	60	90	50	50	100	90	90	100
Vanadium (V)	1.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Zinc (Zn)	<10	120	30	10	30	<10	<10	30	30	60	20	20	20

Table B-4.--Water-quality data for Little Tyro Creek site 4, September 1981 to July 1984 - Continued

Parameters	1982 12/14	1983 01/12	02/17	03/23	04/25	05/25	06/21	07/26	08/24	09/27	10/21	11/17	12/20
Physical-chemical													
Discharge (cfs)	19.3	9.49	9.01	6.79	22.3	14.3	1.41	0.01	0.00	0.26	0.18	0.72	5.15
Discharge (cfs/mi^2)	4.54	2.23	2.12	1.60	5.25	3.36	0.33	0.00	0.00	0.06	0.04	0.17	1.21
Specific conductance (μmhos/cm)	205	134	105	150	93	120	215	207	227	240	248	226	--
pH	5.9	5.4	5.0	6.1	5.4	5.3	6.4	6.4	5.2	4.6	4.8	5.2	--
Temperature (°C)	10.5	1.0	11.0	11.0	14.5	14.0	20.0	25.0	22.0	16.0	18.0	7.0	--
Color (Pt-Co)	1040	30	10	30	40	--	10	35	30	10	15	30	--
Turbidity (JTU)	380	5	5	15	10	--	2	15	15	0	5	10	--
Oxygen (dissolved, ppm)	10.4	11.0	10.1	10.4	8.6	9.6	8.0	4.6	5.0	9.0	8.0	11.0	--
Sediment (suspended, mg/l)	424	1	13	--	11	15	1	4	15	1	7	13	--
Sediment (discharge, T/day)	22.1	.03	.32	--	.66	.58	.00	.00	.00	.00	.00	.03	--
Chemical (mg/l)													
Calcium (Ca)	11	6.2	7.9	7.2	3.4	5.5	13	13	14	14	15	16	--
Magnesium (Mg)	13	6.9	10	9.5	5.4	6.9	15	13	15	15	15	17	--
Sodium (Na)	2.3	2.2	2.3	2.1	1.6	1.7	2.9	4.0	3.6	3.4	3.9	3.5	--
Potassium (K)	2	.9	.9	1	.8	.8	2	2	2	2	2	2	--
Bicarbonate (HCO_3)	8	9	3	10	5	4	20	12	12	2	6	2	--
Sulfate (SO_4)	91	44	63	57	34	46	97	90	100	110	98	64	--
Chloride (Cl)	0.4	1.0	1.4	1.6	1.0	0.2	0.5	1.2	1.1	1.0	1.8	1.4	--
Fluoride (F)	.1	.0	.1	.1	.1	.1	.0	.0	.1	.1	.1	.1	--
Silica (SiO_2)	7.8	11	11	11	8.6	10	13	13	11	11	6.7	9.6	--
Nitrate (N)	.29	.09	.11	.07	.02	.06	.02	.02	.00	.08	.00	.02	--
Nitrate (NO_3)	1.3	.40	.49	.31	.09	.27	.09	.09	.00	.36	.00	.09	--
Trace elements (μg/l)													
Arsenic (As)	2	<1	5	1	<1	1	<1	1	2	1	2	<1	--
Cadmium (Cd)	1	1	1	<1	2	2	2	1	<1	<1	1	1	--
Chromium (Cr)	<1	<1	1	<1	<1	<1	1	1	2	1	2	<1	--
Cobalt (Co)	80	30	50	40	20	<10	20	<10	<10	20	<10	20	--
Copper (Cu)	8	<1	<1	8	2	<1	7	11	14	3	6	1	--
Iron (Fe)	190	100	120	130	80	60	90	20	50	100	110	90	--
Lead (Pb)	1	<1	<1	<1	<1	7	16	10	<1	2	3	<1	--
Manganese (Mn)	5400	1600	2800	2800	1500	1800	3100	2400	1700	3000	1800	2600	--
Mercury (Hg)	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	--
Selenium (Se)	<1	<1	<1	<1	<1	<1	<1	<1	1	2	2	1	--
Strontium (Sr)	70	50	60	50	50	50	100	90	90	110	110	100	--
Vanadium (V)	.0	.0	.0	.0	1.0	.0	1.0	.0	2.0	.0	1.7	4.0	--
Zinc (Zn)	110	10	30	20	10	20	50	170	<10	100	30	30	--

Table B-4.--Water-quality data for Little Tyro Creek site 4, September 1981 to July 1984 - Continued

Parameters	1984			
	01/26	03/14	05/17	07/25
Physical-chemical				
Discharge (cfs)	11.8	4.86	2.72	0.41
Discharge (cfs/mi^2)	2.78	1.14	.64	.10
Specific conductance (μmhos/cm)	96	142	150	215
pH	5.8	6.1	5.1	5.2
Temperature (°C)	4.0	10.0	14.5	23.0
Color (Pt-Co)	5	10	35	20
Turbidity (JTU)	2	10	5	10
Oxygen (dissolved, ppm)	12.6	10.1	10.4	7.5
Sediment (suspended, mg/l)	6	4	--	3
Sediment (discharge, T/day)	.19	.05	--	.00
Chemical (mg/l)				
Calcium (Ca)	4.6	6.5	7.8	12
Magnesium (Mg)	5.4	7.6	9.2	14
Sodium (Na)	1.8	2.0	2.2	3.8
Potassium (K)	.9	.9	1	2
Bicarbonate (HCO_3)	5	5	4	6
Sulfate (SO_4)	33	46	60	90
Chloride (Cl)	.9	.6	.8	1.4
Fluoride (F)	.0	.0	.1	.1
Silica (SiO_2)	6.6	6.7	5.2	13
Nitrate (N)	.02	.03	.00	.04
Nitrate (NO_3)	.09	.13	.00	.18
Trace elements (μg/l)				
Arsenic (As)	1	1	1	1
Cadmium (Cd)	1	1	<1	1
Chromium (Cr)	5	<1	1	1
Cobalt (Co)	20	20	10	10
Copper (Cu)	1	1	2	--
Iron (Fe)	70	50	70	70
Lead (Pb)	1	<1	4	1
Manganese (Mn)	1200	1500	1600	1800
Mercury (Hg)	.2	.0	.0	--
Selenium (Se)	<1	<1	<1	<1
Strontium (Sr)	40	70	60	90
Vanadium (V)	1.0	2.0	.0	3.0
Zinc (Zn)	70	20	10	<10

Table B-5.--Water-quality data for Wallace Branch site 6, September 1981 to July 1984

Parameters	1983											1984	
	02/18	03/22	04/26	05/26	06/21	07/25	08/24	09/27	10/20	11/18	12/21	01/25	03/15
Physical-chemical													
Discharge (cfs)	4.78	4.92	10.1	7.75	1.12	0.06	0.00	0.07	0.23	0.42	6.27	11.3	3.33
Discharge (cfs/mi^2)	1.45	1.49	3.06	2.35	.34	.02	.00	.02	.07	.13	1.90	3.42	1.01
Specific conductance (μmhos/cm)	58	59	44	49	112	73	74	126	129	122	--	61	68
pH	6.3	5.2	6.2	6.4	5.2	6.3	6.4	4.6	5.1	6.5	--	5.0	6.7
Temperature (°C)	11.0	8.5*	16.0	15.5	21.0	26.5	24.0	16.0	21.0	9.0	--	9.0	8.0
Color (Pt-Co)	20	50	35	--	25	50	60	10	30	5	--	65	20
Turbidity (JTU)	20	15	20	--	5	15	15	0	20	0	--	20	10
Oxygen (dissolved, ppm)	9.5	9.5	8.6	9.6	7.8	6.8	4.2	8.6	8.6	10.8	--	12.0	11.2
Sediment (suspended, mg/l)	--	--	21	7	3	3	9	4	5	6	--	33	3
Sediment (discharge, T/day)	--	--	.57	.15	.01	.00	.00	.00	.00	.01	--	1.01	.03
Chemical (mg/l)													
Calcium (Ca)	3.7	3.0	2.4	2.8	6.6	4.6	4.4	7.7	8.8	9.0	--	2.7	3.2
Magnesium (Mg)	3.0	3.0	2.2	2.6	7.1	4.1	3.8	7.0	7.6	8.0	--	2.3	3.0
Sodium (Na)	2.2	1.8	1.7	2.0	2.3	2.7	2.5	3.2	3.3	3.2	--	1.8	1.7
Potassium (K)	1	.8	.8	.6	1	1	2	2	2	2	--	.8	.8
Bicarbonate (HCO_3)	8	8	9	13	8	16	9	2	12	12	--	6	9
Sulfate (SO_4)	17	20	6.3	25	44	30	21	54	48	49	--	9.4	12
Chloride (Cl)	1.4	1.7	0.5	0.0	0.4	1.0	1.0	1.2	1.9	1.8	--	1.0	.4
Fluoride (F)	.1	.1	.1	.0	.0	.0	.1	.1	.1	.1	--	.1	.0
Silica (SiO_2)	9.4	9.4	8.8	9.8	10	11	10	10	5.5	9.1	--	6.7	6.4
Nitrate (N)	.09	.23	.04	.09	.10	.04	.01	.04	.00	.02	--	.00	.04
Nitrate (NO_3)	.40	1.0	.18	.40	.44	.18	.04	.18	.00	.09	--	.00	.18
Trace elements (μg/l)													
Arsenic (As)	5	<1	<1	2	<1	1	<1	<1	1	<1	--	<1	1
Cadmium (Cd)	<1	<1	1	<1	1	1	<1	<1	<1	1	--	1	1
Chromium (Cr)	<1	<1	<1	<1	<1	<1	1	<1	1	1	--	3	<1
Cobalt (Co)	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	--	<10	<10
Copper (Cu)	<1	1	6	7	2	3	3	5	3	1	--	1	<1
Iron (Fe)	60	30	70	40	70	130	140	60	80	120	--	40	50
Lead (Pb)	<1	<1	1	2	14	2	<1	3	5	1	--	1	1
Manganese (Mn)	770	890	590	580	1200	190	410	470	330	760	--	440	630
Mercury (Hg)	.0	.5	.0	.0	.0	.5	.0	.0	.0	.0	--	.0	.1
Selenium (Se)	<1	<1	<1	2	<1	<1	<1	3	1	1	--	<1	<1
Strontium (Sr)	60	40	40	30	70	60	50	80	200	80	--	20	60
Vanadium (V)	.0	.0	.0	2.0	1.0	.0	2.0	1.0	1.6	4.0	--	2.0	1.0
Zinc (Zn)	<10	<10	20	<10	<10	40	<10	60	20	10	--	30	10

Table B-5.--Water-quality data for Wallace Branch site 6, September 1981 to July 1984 - Continued

Parameters	1984	
	05/16	07/25
Physical-chemical		
Discharge (cfs)	1.90	.39
Discharge (cfs/mi^2)	.58	.12
Specific conductance (μmhos/cm)	64	90
pH	5.4	6.2
Temperature (°C)	7.5	24.5
Color (Pt-Co)	10	20
Turbidity (JTU)	0	5
Oxygen (dissolved, ppm)	8.4	7.8
Sediment (suspended, mg/l)	5	6
Sediment (discharge, T/day)	.03	.01
Chemical (mg/l)		
Calcium (Ca)	3.3	5.0
Magnesium (Mg)	3.2	4.8
Sodium (Na)	1.9	2.9
Potassium (K)	.9	.1
Bicarbonate (HCO_3)	8	10
Sulfate (SO_4)	20	31
Chloride (Cl)	2.0	1.1
Fluoride (F)	.1	.1
Silica (SiO_2)	4.8	11
Nitrate (N)	.03	.04
Nitrate (NO_3)	.13	.18
Trace elements (μg/l)		
Arsenic (As)	1	1
Cadmium (Cd)	1	1
Chromium (Cr)	1	1
Cobalt (Co)	<10	<10
Copper (Cu)	4	--
Iron (Fe)	50	70
Lead (Pb)	3	2
Manganese (Mn)	720	390
Mercury (Hg)	.0	--
Selenium (Se)	<1	<1
Strontium (Sr)	40	70
Vanadium (V)	5.0	2.0
Zinc (Zn)	<10	<10

APPENDIX C

Bottom sediment data

Table C-1.--Particle size (percent) of substrate at Tyro Creek site 1

USDA Soil Textural Classification	U.S. Standard Sieve Number	Oct	Nov	Dec	Jan 1983	Feb	March	April	May	June	July	August	Sept
Coarse gravel and cobble	5	89.7	91.0	93.2	93.4	86.3	89.3	93.2	78.6	89.3	91.4	78.5	92.4
Fine gravel	10	2.9	2.8	1.4	0.9	2.6	1.4	0.6	2.2	0.8	2.3	2.9	1.3
Very coarse sand	18	2.9	2.8	1.6	1.0	2.9	1.5	0.5	3.1	1.0	2.3	2.5	1.4
Coarse sand	35	1.7	1.8	1.0	1.1	3.3	1.7	1.3	5.7	3.6	1.9	3.6	1.7
Medium sand	60	1.4	1.1	1.8	2.4	3.6	3.7	3.6	7.1	3.8	1.0	5.8	1.8
Fine sand	120	0.6	0.3	0.7	0.8	1.0	1.9	0.7	1.5	0.8	0.5	3.3	0.7
Very fine sand	230	0.3	0.03	0.1	0.04	0.1	0.1	0.02	0.1	0.03	0.1	1.2	0.3
Silt	325	0.3	0.1	0.2	0.2	0.1	0.3	0.1	1.1	0.5	0.2	0.7	0.3
Clay	Pan	0.3	0.03	0.07	0.2	0.1	0.2	0.05	0.6	0.2	0.3	1.5	0.3

Table C-1.--Particle size (percent) of substrate at Tyro Creek site 1 - Continued

USDA Soil Textural Classification	U.S. Standard Sieve Number	Oct[1]	Nov[1]	Dec	Jan 1982	Feb	March	April	May	June	July	August	Sept
Coarse gravel and cobble	5	0.4	0.0	90.4	41.7	95.0	91.8	91.8	46.0	77.4	82.5	87.0	91.2
Fine gravel	10	0.3	0.0	1.8	5.8	1.2	0.7	1.8	1.8	2.0	0.5	3.8	2.2
Very coarse sand	18	9.3	2.5	2.2	14.4	1.4	1.2	1.9	3.1	1.9	0.9	4.6	2.1
Coarse sand	35	13.8	15.1	1.6	12.3	1.1	2.5	1.2	9.5	1.8	3.8	2.1	1.0
Medium sand	60	46.8	7.8	1.6	7.7	0.7	2.9	1.4	25.4	5.3	9.0	1.0	1.6
Fine sand	120	8.9	5.7	0.2	5.4	0.2	0.7	1.1	12.7	7.6	2.4	0.4	0.7
Very fine sand	230	3.0	1.7	0.03	3.0	0.02	0.02	0.1	0.9	1.4	0.1	0.1	0.3
Silt	325	2.8	2.1	0.2	1.6	0.07	0.3	0.5	0.4	1.6	0.3	0.2	0.4
Clay	Pan	14.8	65.1	1.5	8.1	0.3	0.1	0.2	0.2	1.1	0.5	0.8	0.4

[1]Sample collected at the stream bank; all other collections are steam transects.

Table C-1.--Particle size (percent) of substrate at Tyro Creek site 1 - Continued

USDA Soil Textural Classification	U.S. Standard Sieve Number	Oct	Nov	Dec	Jan 1984	March	May	July
Coarse gravel and cobble	5	89.7	91.5	98.2	95.4	88.7	83.8	89.3
Fine gravel	10	1.7	2.4	0.6	1.2	1.9	3.0	3.3
Very coarse sand	18	2.0	2.5	0.3	0.9	2.0	3.5	3.5
Coarse sand	35	2.8	2.2	0.3	0.9	2.5	2.8	1.8
Medium sand	60	2.4	1.03	0.3	1.1	2.6	4.8	0.9
Fine sand	120	0.8	0.2	0.1	0.3	1.1	1.6	0.5
Very fine sand	230	0.2	0.1	0.03	0.2	0.7	0.3	0.2
Silt	325	0.1	0.1	0.02	0.02	0.2	0.1	0.2
Clay	Pan	0.2	0.05	0.03	0.1	0.4	0.1	0.3

Table C-2.--Particle size (percent) of substrate at Tyro Creek site 2

USDA Soil Textural Classification	U.S. Standard Sieve Number	Nov	Dec	Jan 1982	Feb	March	April	May	June	July	August	Sept
Coarse gravel and cobble	5	30.9	79.9	65.8	44.1	95.0	81.9	85.7	93.8	78.1	88.3	87.9
Fine gravel	10	2.7	2.8	4.1	3.1	0.7	2.0	3.7	1.6	3.1	3.2	2.7
Very coarse sand	18	4.0	3.5	3.8	6.1	0.8	2.7	3.8	1.2	3.3	3.1	3.0
Coarse sand	35	14.5	5.7	4.8	22.8	0.9	5.0	3.2	1.4	3.6	2.0	3.4
Medium sand	60	31.3	4.4	12.8	19.2	1.0	5.5	2.9	1.2	5.8	1.5	2.4
Fine sand	120	11.3	1.9	5.8	3.3	0.4	2.0	0.5	0.3	3.4	0.5	0.3
Very fine sand	235	1.2	0.4	0.4	0.2	0.1	0.1	0.04	0.1	0.1	0.1	0.04
Silt	325	1.8	0.4	1.1	0.5	0.2	0.5	0.1	0.2	0.9	0.2	0.05
Clay	Pan	2.2	1.1	1.6	0.7	0.9	0.3	0.03	0.3	1.7	1.1	0.1

Table C-2.--Particle size (percent) of substrate at Tyro Creek site 2 - Continued

USDA Soil Textural Classification	U.S. Standard Sieve Number	Oct	Nov	Dec	Jan 1983	Feb	March	April	May	June	July	August	Sept
Coarse gravel and cobble	5	91.3	68.2	72.1	59.8	86.9	92.8	87.1	83.9	83.2	79.2	74.1	88.4
Fine gravel	10	1.8	6.3	2.0	4.5	1.9	1.1	2.0	3.4	2.4	2.1	2.7	2.8
Very coarse sand	18	1.9	8.1	2.5	5.9	1.9	1.2	2.5	4.4	3.6	2.9	4.0	3.2
Coarse sand	35	2.6	11.0	7.6	13.6	4.2	2.4	4.3	5.3	6.1	6.8	7.9	3.4
Medium sand	60	1.8	5.5	12.7	13.4	3.8	1.9	2.9	2.3	4.0	6.8	8.7	1.6
Fine sand	120	0.4	0.5	2.6	2.0	1.0	0.5	0.8	0.5	0.6	1.7	2.7	0.3
Very fine sand	230	0.1	0.05	0.1	0.1	0.1	0.04	0.1	0.02	0.02	0.1	0.2	0.04
Silt	325	0.1	0.1	0.3	0.4	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1
Clay	Pan	0.1	0.05	0.1	0.2	0.1	0.05	0.1	0.1	0.04	0.2	0.1	0.1

Table C-2.--Particle size (percent) of substrate at Tyro Creek site 2 - Continued

USDA Soil Textural Classification	U.S. Standard Sieve Number	Oct	Nov	Dec	Jan 1984	March	May	July
Coarse gravel and cobble	5	89.3	72.2	96.4	97.5	88.2	94.6	82.8
Fine gravel	10	2.1	3.2	0.8	0.8	1.7	1.6	3.0
Very coarse sand	18	2.05	4.2	0.8	0.8	3.0	1.5	3.0
Coarse sand	35	2.6	8.3	1.1	0.5	4.7	1.2	3.2
Medium sand	60	3.0	9.8	0.6	0.2	2.0	0.8	5.9
Fine sand	120	0.8	2.0	0.2	0.1	0.4	0.2	1.7
Very fine sand	230	0.1	0.2	0.1	0.05	0.1	0.05	0.2
Silt	325	0.02	0.05	0.03	0.02	0.02	0.02	0.1
Clay	Pan	0.03	0.1	0.02	0.05	0.01	0.02	0.1

Table C-3.--Particle size (percent) of substrate at Wallace Branch site 3

USDA Soil Textural Classification	U.S. Standard Sieve Number	Nov	Dec	Jan 1982	Feb	March	April	May	June	July	August	Sept
Coarse gravel and cobble	5	0.2	0.8	6.8	3.9	1.7	0.7	0.0	2.5	2.1	0.1	0.5
Fine gravel	10	0.04	0.5	1.0	0.8	0.6	0.1	0.5	1.2	0.4	0.05	0.3
Very coarse sand	18	0.6	1.6	2.2	1.8	1.8	0.6	0.8	0.9	1.3	0.2	0.9
Coarse sand	35	10.4	13.5	17.8	12.9	8.4	10.4	9.3	12.8	17.6	1.4	16.6
Medium sand	60	77.7	68.3	58.2	65.9	51.7	70.0	60.7	50.8	66.9	37.0	64.5
Fine sand	120	10.7	13.4	12.5	13.5	33.2	17.6	24.7	23.0	9.9	50.5	16.5
Very fine sand	230	0.1	0.4	0.9	0.5	0.7	0.4	1.6	0.9	0.2	2.8	0.6
Silt	325	0.1	1.0	0.2	0.5	1.6	0.1	1.1	4.7	0.7	4.7	0.05
Clay	Pan	0.1	0.6	0.3	0.2	0.4	0.1	1.2	3.2	0.9	3.4	0.1

Table C-3.--Particle size (percent) of substrate at Wallace Branch site 3 - Continued

USDA Soil Textural Classification	U.S. Standard Sieve Number	Oct	Nov	Dec	Jan 1983	Feb	March	April	May	June	July	August	Sept
Coarse gravel and cobble	5	1.1	0.2	1.2	1.0	0.2	0.5	0.1	0.0	0.4	0.1	0.7	3.3
Fine gravel	10	0.4	0.1	0.4	0.2	0.0	0.3	0.0	0.0	0.1	0.1	0.9	1.2
Very coarse sand	18	0.8	0.2	1.4	0.9	0.4	2.9	0.2	0.3	1.5	0.5	3.6	3.6
Coarse sand	35	15.7	2.1	11.5	17.8	2.8	17.6	6.4	4.8	7.1	11.7	40.8	41.7
Medium sand	60	64.4	47.4	43.2	66.4	34.5	58.8	59.7	48.7	40.5	74.0	49.5	46.9
Fine sand	120	16.4	44.3	29.7	13.2	52.5	14.5	30.5	38.1	35.8	13.0	2.5	1.8
Very fine sand	230	0.6	3.0	8.4	0.1	6.9	2.1	0.9	2.6	5.0	0.2	0.2	0.4
Silt	325	0.3	2.4	3.3	0.2	2.0	1.2	1.9	3.8	4.2	0.2	1.3	0.3
Clay	Pan	0.2	0.3	0.8	0.1	0.7	2.1	0.3	1.6	5.4	0.2	0.5	0.8

Table C-3.--Particle size (percent) of substrate at Wallace Branch site 3 - Continued

USDA Soil Textural Classification	U.S. Standard Sieve Number	Oct	Nov	Dec	Jan 1984	March	May	July
Coarse gravel and cobble	5	0.9	1.3	2.2	0.1	0.5	0.2	1.2
Fine gravel	10	0.3	0.5	0.7	0.03	0.3	0.4	0.6
Very coarse sand	18	1.3	2.6	3.1	0.1	1.0	0.5	2.0
Coarse sand	35	33.8	44.6	31.2	11.2	20.3	24.5	44.1
Medium sand	60	59.6	47.9	56.2	75.0	61.4	63.9	48.7
Fine sand	120	3.5	2.0	6.2	12.3	14.5	8.4	3.1
Very fine sand	230	0.3	0.6	0.3	1.04	1.6	1.5	0.2
Silt	325	0.1	0.2	0.02	0.1	0.2	0.2	0.04
Clay	Pan	0.2	0.2	0.03	0.1	0.2	0.3	0.1

Table C-4.--Particle size (percent) of substrate at Little Tyro Creek site 4

USDA Soil Textural Classification	U.S. Standard Sieve Number	Nov	Dec	Jan 1982	Feb[1]	March	April	May	June	July	August	Sept
Coarse gravel and cobble	5	0.8	0.3	0.6		2.1	5.8	3.8	23.8	1.8	9.2	2.2
Fine gravel	10	0.4	0.04	0.3		0.2	1.3	1.0	1.4	0.9	0.3	0.4
Very coarse sand	18	3.2	1.6	1.0		1.1	3.7	2.6	2.8	3.1	0.6	1.4
Coarse sand	35	22.1	16.6	14.8		8.6	11.8	12.8	10.5	16.8	12.8	14.2
Medium sand	60	63.7	70.9	63.0		65.7	53.2	58.9	44.2	49.3	44.7	64.3
Fine sand	120	9.3	10.0	17.1		21.2	20.7	18.8	13.2	18.7	25.4	14.5
Very fine sand	235	0.3	0.2	1.1		0.6	0.3	1.3	0.1	0.9	2.3	2.3
Silt	325	0.2	0.2	1.5		0.4	1.5	0.2	2.1	3.4	3.4	0.4
Clay	Pan	0.1	0.2	0.7		0.2	1.7	0.5	1.9	5.2	1.3	0.4

[1]Sample lost

Table C-4.--Particle size (percent) of substrate at Little Tyro Creek site 4 - Continued

USDA Soil Textural Classification	U.S. Standard Sieve Number	Oct	Nov	Dec	Jan 1983	Feb	March	April	May	June	July	August	Sept
Coarse gravel and cobble	5	7.2	0.0	0.0	27.8	0.1	40.4	24.0	26.1	0.2	55.1	2.6	18.3
Fine gravel	10	0.6	0.0	0.0	5.5	0.0	4.7	0.2	2.2	0.1	0.7	0.6	3.0
Very coarse sand	18	1.5	0.3	0.1	9.2	0.2	6.3	0.2	3.2	1.0	1.3	1.9	5.6
Coarse sand	35	15.1	4.1	0.8	13.8	2.5	7.7	0.6	7.1	15.5	4.3	14.9	12.5
Medium sand	60	61.2	29.7	45.3	26.0	39.9	12.0	30.9	37.5	65.8	25.6	66.4	42.5
Fine sand	120	12.5	33.6	46.8	15.2	50.9	23.2	38.4	21.4	16.1	11.5	11.9	14.9
Very fine sand	230	0.4	14.8	4.2	1.1	3.7	3.6	3.3	0.5	0.3	0.4	0.4	0.8
Silt	325	1.2	10.1	2.8	1.0	2.0	1.4	1.4	1.3	0.6	0.5	0.7	1.3
Clay	Pan	0.2	7.4	0.1	0.5	0.9	1.3	0.9	0.6	0.4	0.4	0.7	1.1

Table C-4.--Particle size (percent) of substrate at Little Tyro Creek site 4 - Continued

USDA Soil Textural Classification	U.S. Standard Sieve Number	Oct	Nov	Dec	Jan 1984	March	May	July
Coarse gravel and cobble	5	9.2	20.2	68.2	17.8	41.7	34.1	13.2
Fine gravel	10	1.8	3.3	6.3	3.5	1.6	1.2	0.2
Very coarse sand	18	3.8	6.3	6.6	5.5	1.3	1.04	0.5
Coarse sand	35	5.8	12.1	6.9	22.6	2.1	1.5	2.5
Medium sand	60	44.5	35.1	8.2	36.7	30.1	19.05	61.1
Fine sand	120	21.0	16.4	3.1	11.7	21.2	34.5	20.6
Very fine sand	230	8.8	4.8	0.4	1.8	1.5	6.2	1.2
Silt	325	4.3	1.2	0.1	0.2	0.3	1.4	0.4
Clay	Pan	0.8	0.6	0.1	0.3	0.2	1.01	0.3

Table C-5.--Particle size (percent) of substrate at Wallace Branch site 6

USDA Soil Textural Classification	U.S. Standard Sieve Number	Feb 1983	March	April	May	June	July	August	Sept
Coarse gravel and cobble	5	26.3	28.2	39.0	36.0	74.0	74.4	49.3	66.1
Fine gravel	10	2.0	0.7	1.9	1.6	1.3	2.5	3.4	3.7
Very coarse sand	18	3.4	1.1	3.1	2.1	1.5	2.1	3.9	4.5
Coarse sand	35	20.0	10.1	16.9	8.6	4.5	3.0	11.7	9.7
Medium sand	60	35.7	42.3	32.0	40.9	13.5	12.2	20.1	9.9
Fine sand	120	11.5	16.4	6.6	9.5	4.7	5.0	8.6	4.0
Very fine sand	230	0.1	0.4	0.1	0.2	0.1	0.5	0.7	0.5
Silt	325	0.8	0.7	0.3	0.6	0.4	0.2	1.1	0.8
Clay	Pan	0.1	0.1	0.1	0.5	0.2	0.3	1.2	0.8

Table C-5.--Particle size (percent) of substrate at Wallace Branch site 6 - Continued

USDA Soil Textural Classification	U.S. Standard Sieve Number	Oct	Nov	Dec	Jan 1984	March	May	July
Coarse gravel and cobble	5	53.0	29.5	50.7	36.3	72.4	96.0	66.2
Fine gravel	10	2.7	2.2	1.7	0.8	1.1	0.3	2.6
Very coarse sand	18	3.6	3.0	2.7	1.8	1.0	0.2	3.5
Coarse sand	35	16.8	25.2	13.6	17.2	5.2	0.6	8.8
Medium sand	60	20.05	35.7	23.2	34.2	14.9	1.5	14.2
Fine sand	120	2.7	4.0	5.2	8.8	4.6	1.0	4.0
Very fine sand	230	0.9	0.3	2.1	0.6	0.6	0.3	0.5
Silt	325	0.1	0.05	0.4	0.1	0.1	0.1	0.1
Clay	Pan	0.1	0.1	0.4	0.1	0.1	0.1	0.1

APPENDIX D

Benthic macroinvertebrate data

Table D-1.--Total numbers and percent relative abundance ( ) of macroinvertebrates collected in the Tyro Creek watershed, September 1981 through July 1984

	Sampling sites									
	1		2		3		4		6[1]	
Taxa	Riffle	Pool	Riffle	Pool	Riffle	Pool	Riffle	Pool	Riffle	Pool
Nemertea										
Prostoma		1(0.0)								
Nematoda	2(0.1)		3(0.1)	2(0.1)					2(0.5)	
Mollusca			2(0.1)	3(0.1)						
Pelecypoda										
Sphaeriidae										
Sphaerium				3(0.1)						
Unionidae										
Villosa			2(0.1)							
Annelida										
Oligochaeta	10(0.4)	114(5.0)	43(1.1)	32(1.4)	18(3.1)	19(2.3)	24(1.0)	4(0.7)		1(1.5)
Aeolosomatidae										
Aeolosoma			6(0.2)							
Enchytraeidae							1(0.0)			
Lumbriculidae	4(0.1)	14(0.6)	31(0.8)	10(0.4)	2(0.3)	1(0.1)	2(0.1)			1(1.5)
Naididae										
Amphichaeta							2(0.1)			
Tubificidae										
Limnodrilus	6(0.2)	100(4.4)	6(0.2)	22(0.9)	16(2.8)	18(2.1)	15(0.6)	4(0.7)		
Potamothrix							4(0.2)			
Arthropoda										
Acarina	4(0.1)	36(1.6)	1(0.0)	16(0.7)						
Aturidae										
Kongsbergia				1(0.0)						

Table D-1.--Total numbers and percent relative abundance ( ) of macroinvertebrates collected in the Tyro Creek watershed, September 1981 through July 1984 - Continued

Hygrobatidae										
Hygrobates	1(0.0)	6(0.3)		1(0.0)						
Lebertiidae										
Lebertia	1(0.0)	5(0.2)								
Limnesiidae										
Limnesia				1(0.0)						
Rhynchohydracaridae										
Clathrosperchon		2(0.1)								
Torrenticolidae										
Torrenticola	1(0.0)		1(0.0)	1(0.0)						
Unionicolidae										
Neumania	1(0.0)	20(0.9)		10(0.4)						
Unionicola		3(0.1)		2(0.1)						
Crustacea	33(0.9)	23(1.0)	43(1.1)	31(1.3)	13(2.3)	3(0.4)	55(2.3)	19(3.5)	46(11.6)	9(13.8)
Amphipoda										
Crangonyx	1(0.0)			3(0.1)			3(0.1)	5(0.9)	5(1.3)	2(3.1)
Hyalella	1(0.0)	1(0.0)								
Cladocera		1(0.0)								
Copepoda										
Cylopoida	7(0.2)	8(0.4)		14(0.6)				2(0.4)		
Isopoda										
Lirceus	17(0.5)	8(0.4)	29(0.7)	8(0.3)	12(2.1)	3(0.4)	48(2.0)	9(1.6)	40(10.1)	7(10.8)
Decapoda										
Orconectes	7(0.2)	5(0.2)	14(0.4)	6(0.3)	1(0.2)		4(0.2)	3(0.5)	1(0.3)	
Insecta										
Coleoptera	299(8.6)	91(4.0)	536(13.8)	128(5.5)	15(2.6)	5(0.6)	55(2.3)	4(0.7)	9(2.3)	1(1.5)
Carabidae										
Omophron						1(0.1)				
Dryopidae										
Helichus	53(1.5)	29(1.3)	25(0.6)	39(1.7)	5(0.9)	1(0.1)	8(0.3)		5(1.3)	
Dytiscidae										
Hydroporus	2(0.1)	19(0.8)	11(0.3)	9(0.4)			5(0.2)	2(0.4)		
Elmidae	244(7.0)	41(1.8)	437(11.3)	73(3.1)	9(1.6)	2(0.2)	46(2.0)		4(1.0)	
Ancyronyx		2(0.1)	5(0.1)	4(0.2)						
Dubiraphia		10(0.4)	4(0.1)	51(2.2)		1(0.1)				1(1.5)
Macronychus			1(0.0)	4(0.2)						
Microcylloepus			1(0.0)							
Optioservus			9(0.2)							
Oulimnius	2(0.1)		14(0.4)				3(0.1)			
Stenelmis	242(6.9)	29(1.3)	403(10.4)	14(0.6)	9(1.6)	1(0.1)	43(1.8)		4(1.0)	

Table D-1.--Total numbers and percent relative abundance ( ) of macroinvertebrates collected in the Tyro Creek watershed, September 1981 through July 1984 - Continued

Eubriidae										
Ectopria			2(0.1)							
Gyrinidae										
Dineutus				1(0.0)		1(0.1)				
Gyrinus		1(0.0)								
Helodidae										
Cyphon		1(0.0)		2(0.1)						
Hydraenidae										
Hydraena			2(0.1)							
Hydrophilidae										
Berosus								1(0.2)		
Enochrus				3(0.1)	1(0.2)		1(0.0)			
Psephenidae										
Psephenus			59(1.5)	1(0.0)				1(0.2)		
Collembola	1(0.0)	2(0.1)	2(0.1)		3(0.5)	5(0.6)	24(11.8)		1(0.3)	
Isotomidae										
Isotoma	1(0.0)	2(0.1)	2(0.1)		1(0.2)	5(0.6)	20(0.8)			
Poduridae										
Podura					2(0.3)				1(0.3)	
Sminthuridae										
Sminthurides							4(0.2)			
Diptera	1089(31.0)	1578(69.9)	776(20.0)	1412(60.2)	399(69.0)	683(81.0)	1362(57.9)	453(82.8)	119(29.9)	40(61.5)
Ceratopogonidae	95(2.7)	280(12.4)	34(0.9)	307(13.1)	16(2.8)	44(5.2)	58(2.5)	57(10.4)	7(1.8)	2(3.1)
Alluaudomyia	2(0.1)	35(1.6)		18(0.8)				1(0.2)		
Culicoides	1(0.0)	12(0.5)		17(0.7)	6(1.0)	11(1.3)	2(0.1)	11(2.0)	2(0.5)	2(3.1)
Dasyhelea		2(0.1)				1(0.1)				
Forcipomyia	4(0.1)									
nr. *Bezzia*	78(2.2)	181(8.0)	30(0.8)	110(4.7)	10(1.7)	20(2.4)	50(2.1)	20(3.7)	5(1.3)	
nr. *Palpomyia*	10(0.3)	50(2.2)	4(0.1)	162(6.9)		12(1.4)	6(0.3)	25(4.6)		
Chaoboridae										
Chaoborus		20(0.9)								
Chironomidae	724(20.6)	1191(52.7)	510(13.2)	1061(45.2)	345(59.7)	612(72.6)	931(39.5)	340(62.2)	73(18.3)	27(41.5)
Ablabesmyia	6(0.2)	95(4.2)	3(0.1)	12(0.5)	7(1.2)	17(2.0)	3(0.1)	10(1.8)		
Brillia	2(0.1)					1(0.1)	12(0.5)			
Bryophaenocladius	1(0.0)									
Chaetocladius	7(0.2)		9(0.2)	2(0.1)		2(0.2)	2(0.1)	4(0.7)	1(0.3)	
Chironomus		52(2.3)	2(0.1)	4(0.2)		14(1.7)		20(3.7)		1(1.5)
Cladotanytarsus	1(0.0)	13(0.6)		12(0.5)		8(0.9)				
Corynoneura	2(0.1)	8(0.4)	10(0.3)	16(0.7)	2(0.3)	5(0.6)	16(0.7)	9(1.6)		
Crieotopus	5(0.1)	2(0.1)	20(0.5)	2(0.1)	18(3.1)	20(2.4)	6(0.3)	1(0.2)		

Table D-1.--Total numbers and percent relative abundance ( ) of macroinvertebrates collected in the Tyro Creek watershed, September 1981 through July 1984 - Continued

Cryptochironomus	5(0.1)	24(1.1)	17(0.4)	17(0.7)	3(0.5)	5(0.6)	2(0.1)	6(1.1)		3(4.6)
Crytocladopelma		10(0.4)								
Cryptotendipes		10(0.4)		15(0.6)	6(1.0)	6(0.7)	1(0.0)	3(0.5)		
Demicryptochironomus	4(0.1)		9(0.2)	2(0.1)						
Dicrotendipes		14(0.6)		1(0.0)		1(0.1)				
Diplocladius	2(0.1)	4(0.2)	6(0.2)		3(0.5)		2(0.1)		1(0.3)	
Endochironomus	3(0.1)	10(0.4)		2(0.1)						
Eukiefferiella	74(2.1)	1(0.0)	28(0.7)	2(0.1)	2(0.3)		14(0.6)		7(1.8)	
Glypotendipes		1(0.0)		9(0.4)						
Harnischia		5(0.2)						1(0.2)		
Heleniella					1(0.2)			1(0.2)		
Heterotrissocladius	1(0.0)									
Krenosmittia			1(0.0)							
Labrundinia	2(0.1)		1(0.0)	2(0.1)	1(0.2)			3(0.5)		
Larsia		1(0.0)					1(0.0)			
Limnophyes					2(0.3)		5(0.2)	7(1.3)	2(0.5)	1(1.5)
Lopescladius			1(0.0)							
Mesosmittia		2(0.1)		1(0.0)	1(0.2)					
Micropsectra	1(0.0)					12(1.4)	1(0.0)			
Microtendipes	1(0.0)	23(1.0)	19(0.5)	132(5.6)			1(0.0)		2(0.5)	
Monodiamesa		12(0.5)		4(0.1)						
Nanocladius	1(0.0)	9(0.4)	8(0.2)							
Natarsia	9(0.3)	12(0.5)	1(0.0)	7(0.3)	3(0.5)	7(0.8)		2(0.4)		
Nilotanypus	3(0.1)		7(0.2)	1(0.0)			2(0.1)			
Nilothauma		1(0.0)		2(0.1)		1(0.1)		1(0.2)		
nr. *Nanocladius*	5(0.1)	2(0.1)	1(0.0	1(0.0)						
nr. *Oliverida*				6(0.2)						
Orthocladius	10(0.3)	3(0.1)	1(0.0)	1(0.0)						
Pagastiella		4(0.2)		2(0.1)						
Parachaetocladius	8(0.2)	9(0.4)	7(0.2)	3(0.1)	3(0.5)	1(0.1)	41(1.7)	8(1.5)	3(0.8)	
Parachironomus		1(0.0)								
Paracladius		4(0.2)								
Paracladopelma		2(0.1)	2(0.1)	11(0.5)	1(0.2)	11(1.3)		16(2.9)		
Parakiefferiella	4(0.1)	49(2.2)	5(0.1)	8(0.3)	12(2.1)	59(7.0)	1(0.0)	6(1.1)		3(4.6)
Paralauterborniella				9(0.4)						
Paramerina	6(0.2)	4(0.2)	6(0.2)	10(0.4)	8(1.4)	21(2.5)	1(0.0)	5(0.9)		
Parametriocnemus	92(2.6)	9(0.4)	115(3.0)	2(0.1)	23(4.0)	9(1.1)	107(4.5)	6(1.1)	19(4.8)	3(4.6)
Paraphaenocladius	8(0.2)			2(0.1)	1(0.2)		1(0.0)			
Paratanytarsus									1(0.3)	
Paratendipes	1(0.0)	6(0.3)	5(0.1)	15(0.6)	2(0.3)	23(2.7)		2(0.4)		2(3.1)

Table D-1.--Total numbers and percent relative abundance ( ) of macroinvertebrates collected in the Tyro Creek watershed, September 1981 through July 1984 - Continued

Phaenopsectra	1(0.0)	9(0.4)				3(0.4)		8(1.5)		
Polypedilum	266(7.6)	68(3.0)	109(2.8)	27(1.2)	62(10.7)	67(7.9)	471(20.0)	120(21.9)	27(6.8)	6(9.2)
Potthastia		1(0.0)	2(0.1)							
Procladius	2(0.1)	333(14.7)	7(0.2)	251(10.7)	6(1.0)	25(3.0)		12(2.2)		1(1.5)
Psectrocladius	2(0.1)	1(0.0)		1(0.0)		1(0.1)				
Pseudochironomus	61(1.7)	2(0.1)		3(0.1)						
Pseudorthocladius		8(0.4)	6(0.2)	1(0.0)	1(0.2)		2(0.1)	2(0.4)		2(3.1)
Pseudosmittia		2(0.1)		1(0.0)	1(0.2)	2(0.2)		1(0.2)		
Psilometriocnemus		1(0.0)								
Rheocricotopus	22(0.6)		6(0.2)		18(3.1)		13(0.6)	2(0.4)	2(0.5)	
Rheosmittia	4(0.1)	3(0.1)	7(0.2)	2(0.1)	72(12.4)	91(10.8)		10(1.8)		
Rheotanytarsus	27(0.8)	20(0.9)	3(0.1)		3(0.5)	12(1.4)	157(6.7)	9(1.6)	5(1.3)	
Robackia					1(0.2)					
Saetheria	2(0.1)	3(0.1)			58(10.0)	77(9.1)		4(0.7)		1(1.5)
Smittia	2(0.1)	6(0.3)		1(0.0)		8(0.9)		2(0.4)		1(1.5)
Stempellina		5(0.2)		3(0.1)						
Stempellinella	4(0.1)	12(0.5)	13(0.3)	30(1.3)		5(0.6)	3(0.1)	7(1.3)		
Stenochironomus	8(0.2)	7(0.3)	15(0.4)	13(0.6)		3(0.4)		4(0.7)		
Stictochironomus	4(0.1)	24(1.1)	5(0.1)	292(12.4)		27(3.2)				1(1.5)
Symposiocladius					4(0.7)					
Tanypus				2(0.1)						
Tanytarsus	19(0.5)	251(11.1)	22(0.6)	15(0.6)	9(1.6)	43(5.1)	6(0.3)	27(4.9)		1(1.5)
Thienemanniella	2(0.1)		1(0.0)	1(0.0)			4(0.2)			
Thienemannimyia group	30(0.9)	18(0.8)	29(0.7)	28(1.2)	11(1.9)	2(0.2)	55(2.3)	4(0.7)	3(0.8)	
Tribelos		15(0.7)		52(2.2)		16(1.9)	1(0.0)	12(2.2)		
Zavrelimyia	1(0.0)		1(0.0)	3(0.1)		7(0.8)		5(0.9)		1(1.5)
Culicidae		8(0.4)		1(0.0)				7(1.3)		
Aedes								3(0.5)		
Anopheles		8(0.4)		1(0.0)				3(0.5)		
Culex								1(0.2)		
Dixidae										
Dixella		2(0.1)		2(0.1)		1(0.1)	3(0.1)	1(0.2)		1(1.5)
Dolichopodidae	4(0.1)	2(0.1)	3(0.1)	2(0.3)		1(0.0)				
Empididae										
Clinocera			1(0.0)				6(0.3)			
Hemerodromia	20(0.6)		9(0.2)	1(0.0)	6(1.0)		25(1.1)	5(0.9)	1(0.3)	1(1.5)
Psychodidae										
Psychoda			1(0.0)	2(0.1)	2(0.3)	2(0.2)		1(0.2)		

Table D-1.--Total numbers and percent relative abundance ( ) of macroinvertebrates collected in the Tyro Creek watershed, September 1981 through July 1984 - Continued

Simuliidae	134(3.8)		67(1.7)	2(0.1)	2(0.3)		220(9.3)	1(0.2)	11(2.8)	
Metacnephia	1(0.0)									
Prosimulium	14(0.4)		19(0.5)	2(0.1)					2(0.5)	
Simulium	119(3.4)		48(1.2)		2(0.3)		220(9.3)	1(0.2)	9(2.3)	
Syrphidae										
Neoascia						1(0.1)				
Tabanidae										
Chrysops		6(0.3)	1(0.0)	5(0.2)		2(0.2)	1(0.0)	15(2.7)		1(1.5)
Tabanus	22(0.6)	5(0.2)	8(0.2)	15(0.6)			1(0.0)	3(0.5)		
Tanyderidae										
Protoplasa	1(0.0)		2(0.1)							
Tipulidae	89(2.5)	64(2.8)	143(3.7)	13(0.6)	26(4.5)	21(2.5)	116(4.9)	23(4.2)	27(6.8)	8(12.3)
Erioptera		8(0.4)	1(0.0)		3(0.5)	5(0.6)	2(0.1)	1(0.2)		
Gonomyia	1(0.0)	28(1.2)	1(0.0)	1(0.0)	1(0.2)			3(0.5)		2(3.1)
Hexatoma	26(0.7)	18(0.8)	79(2.0)	3(0.1)			26(1.1)		1(0.3)	2(3.1)
Ormosia			1(0.0)							1(1.5)
Pilaria		2(0.1)		4(0.1)			1(0.0)	2(0.4)		2(3.1)
Pseudolimnophila			33(0.9)	1(0.0)					1(0.3)	
Tipula	62(1.8)	8(0.4)	28(0.7)	4(0.1)	22(3.8)	16(1.9)	87(3.7)	17(3.1)	25(6.3)	1(1.5)
Ephemeroptera	369(10.5)	144(6.4)	1044(27.0)	213(9.1)	16(2.8)	15(1.8)	26(1.1)	9(1.6)	20(5.0)	3(4.6)
Baetidae	102(2.9)	17(0.8)	167(4.3)	14(0.6)	10(1.7)	8(0.9)	11(0.5)	8(1.5)	8(2.0)	1(1.5)
Baetis	40(1.1)	3(0.1)	90(2.3)	2(0.1)	5(0.9)	3(0.4)	7(0.3)	1(0.2)		
Centroptilum	12(0.3)	9(0.4)	19(0.5)	11(0.5)		5(0.6)		7(1.3)		
Pseudocloeon	50(1.4)	5(0.2)	58(1.5)	1(0.0)	5(0.9)		4(0.2)		8(2.0)	1(1.5)
Baetiscidae										
Baetisca	1(0.0)	1(0.0)	5(0.1)							
Caenidae										
Brachycercus				1(0.0)						
Caenis	4(0.1)	29(1.3)	3(0.1)	26(1.1)	1(0.2)	4(0.5)				
Ephemerellidae										
Ephemerella	1(0.0)	1(0.0)	2(0.1)	4(0.1)						
Eurylophella	3(0.1)		3(0.1)	7(0.3)						
Ephemeridae										
Ephemera		32(1.4)	2(0.1)							
Hexagenia	1(0.0)	11(0.5)	6(0.2)	35(1.5)	1(0.2)	1(0.1)		1(0.2)		
Heptageniidae	142(4.0)	25(1.1)	426(11.0)	41(1.7)	3(0.5)		12(0.5)		12(3.0)	
Heptagenia	52(1.5)	1(0.0)								
Rhithrogena	11(0.3)		37(1.0)							
Stenacron	1(0.0)		2(0.1)	5(0.2)						
Stenonema	78(2.2)	24(1.1)	387(10.0)	36(1.5)	3(0.5)		12(0.5)		12(3.0)	

Table D-1.--Total numbers and percent relative abundance ( ) of macroinvertebrates collected in the Tyro Creek watershed, September 1981 through July 1984 - Continued

Leptophlebiidae										
Leptophlebia				21(0.9)			1(0.0)			
Paraleptophlebia	6(0.2)	4(0.2)		22(0.9)	1(0.2)	2(0.2)				
Oligoneuriidae										
Isonychia	107(3.1)	24(1.1)	427(11.0)	1(0.0)			2(0.1)			
Siphlonuridae										
Ameletus	1(0.0)		3(0.1)							2(3.1)
Tricorythidae										
Tricorythodes	1(0.0)									
Hemiptera	3(0.1)	6(0.3)	4(0.1)	4(0.1)	1(0.2)	8(0.9)	4(0.2)	7(1.3)	2(0.5)	2(3.1)
Corixidae										
Trichocorixa								1(0.2)		
Gerridae										
Gerris								1(0.2)		
Rheumatobates				1(0.0)						
Trepobates	1(0.0)	6(0.3)	2(0.1)			2(0.2)				1(1.5)
Mesoveliidae										
Mesovelia						2(0.2)			2(0.5)	
Salididae										1(1.5)
Veliidae										
Microvelia	1(0.0)		2(0.1)	1(0.0)	1(0.2)	4(0.5)	1(0.0)	5(0.9)		
Rhagovelia	1(0.0)			2(0.1)			3(0.1)			
Megaloptera	115(3.3)	45(2.0)	72(1.9)	13(0.6)	5(0.9)	3(0.4)	27(1.1)	3(0.5)	3(0.8)	1(1.5)
Corydalidae										
Corydalus	80(2.3)	2(0.1)	54(1.4)			1(0.1)	8(0.3)	1(0.2)	2(0.5)	1(1.5)
Nigronia	32(0.9)	2(0.1)	18(0.5)	1(0.1)	1(0.2)		17(0.7)		1(0.3)	
Sialidae										
Sialis	3(0.1)	41(1.8)		12(0.5)	4(0.7)	2(0.2)	2(0.1)	2(0.4)		
Odonata	10(0.3)	83(3.7)	10(0.3)	51(2.2)	6(1.0)	36(4.3)	3(0.1)	12(2.2)		3(4.6)
Aeshnidae										
Boyeria	1(0.0)	1(0.0)		1(0.0)						
Calopterygidae										
Calopteryx	5(0.1)				1(0.2)	2(0.2)	1(0.2)			
Coenagrionidae										
Argia	2(0.1)		2(0.1)							
Enallagma	2(0.1)	10(0.4)								
Ischnura				9(0.4)						

Table D-1.--Total numbers and percent relative abundance ( ) of macroinvertebrates collected in the Tyro Creek watershed, September 1981 through July 1984 - Continued

Cordulegastridae										
Cordulegaster		5(0.2)	1(0.0)	9(0.4)	4(0.7)	9(1.1)	1(0.0)	4(0.7)		1(1.5)
Corduliidae										
Helocordulia		4(0.2)	1(0.0)	2(0.1)		2(0.2)				
Gomphidae		63(2.8)	6(0.2)	16(0.7)	1(0.2)	22(2.6)	2(0.1)	7(1.3)		2(3.1)
Gomphus		33(1.5)		11(0.5)		8(0.9)	1(0.0)	2(0.4)		1(1.5)
Lauthus		2(0.1)	4(0.1)				1(0.0)			
Progomphus		28(1.2)		4(0.2)	1(0.2)	14(1.7)		5(0.9)		1(1.5)
Stylogomphus			2(0.1)	1(0.1)						
Macromiidae										
Macromia		1(0.0)		14(0.6)		1(0.1)				
Plecoptera	564(16.1)	93(4.1)	533(13.8)	407(17.4)	82(14.2)	61(7.2)	312(13.2)	21(3.8)	141(35.4)	1(1.5)
Capniidae										
Allocapnia	124(3.5)	79(3.5)	302(7.8)	372(15.9)	67(11.6)	59(7.0)	149(6.3)	18(3.3)	55(13.8)	
Chloroperlidae										
Alloperla	7(0.2)	1(0.0)	16(0.4)	2(0.1)			10(0.4)		7(1.8)	
Leuctridae										
Leuctra	53(1.5)		20(0.5)	5(0.2)		1(0.1)	21(0.9)		10(2.5)	1(1.5)
Nemouridae										
Amphinemura	152(4.3)		38(1.0)	4(0.2)	2(0.3)		63(2.7)	1(0.2)	51(12.8)	
Perlidae	185(5.3)	2(0.1)	80(2.1)	3(0.1)	13(2.2)		44(1.9)	2(0.4)	9(2.3)	
Acroneuria	103(2.9)	1(0.0)	14(0.4)				8(0.3)			
Beloneuria	1(0.0)									
Eccoptura							4(0.2)			
Neoperla	1(0.0)									
Perlesta	73(2.1)		66(1.7)	3(0.1)	13(2.2)		17(0.7)	2(0.4)	8(2.0)	
Perlinella	7(0.2)	1(0.0)					15(0.6)		1(0.3)	
Perlodidae										
Cultus									1(0.3)	
Isoperla	6(0.2)	2(0.1)	51(1.3)	1(0.0)			23(1.0)		4(1.0)	
Taeniopterygidae										
Strophopteryx	6(0.2)	5(0.2)	7(0.2)	14(0.6)			1(0.0)		4(1.0)	
Taeniopteryx	31(0.9)	4(0.2)	19(0.5)	6(0.3)		1(0.1)	1(0.0)			
Trichoptera	1012(28.9)	41(1.8)	802(20.7)	99(4.2)	20(3.5)	5(0.6)	457(19.4)	15(2.7)	49(12.3)	6(9.2)
Hydropsychidae	873(24.9)	25(1.1)	687(17.7)	74(3.2)	19(3.3)	2(0.2)	380(16.1)	12(2.2)	45(11.3)	
Cheumatopsyche	843(24.0)	25(1.1)	641(16.6)	73(3.1)	12(2.1)	1(0.1)	308(13.1)	10(1.8)	20(5.0)	2(3.1)
Diplectrona	9(0.3)				7(1.2)	1(0.1)	33(1.4)	2(0.4)	24(6.0)	3(4.6)
Hydropsyche	21(0.6)		46(1.2)	1(0.0)			39(1.7)		1(0.3)	

Table D-1.--Total numbers and percent relative abundance ( ) of macroinvertebrates collected in the Tyro Creek watershed, September 1981 through July 1984 - Continued

Hydroptilidae										
Hydroptila	1(0.0)									
Lepidostomatidae										
Lepidostoma							1(0.0)			
Leptoceridae										
Oecetis		1(0.0)								
Triaenodes				5(0.2)						
Limnephilidae		1(0.0)				2(0.2)			1(0.3)	1(1.5)
Pycnopsyche		1(0.0)		7(0.3)		1(0.1)	3(0.1)	1(0.2)		
Philopotamidae										
Chimarra	111(3.2)	12(0.5)	113(2.9)	5(0.2)			68(2.9)	1(0.2)	1(0.3)	
Wormaldia	1(0.0)								2(0.5)	
Polycentropodidae	4(0.1)		1(0.0)	3(0.1)			2(0.1)	1(0.2)		
Neureclipsis	1(0.0)									
Nyctiophylax				3(0.1)			1(0.0)	1(0.2)		
Polycentropus	3(0.1)		1(0.0)				1(0.0)			
Rhyacophilidae										6(1.5)
Rhyacophila	22(0.6)	1(0.0)	1(0.0)		1(0.2)		3(0.1)			
TOTALS	3508	2258	3871	2345	578	843	2354	547	398	65

[1]Not collected in 1981 and 1982.

APPENDIX E

Fish data

Table E-1.--Abundance, biomass, and occurrence of fishes collected from Tyro Creek site 1, September 1981 through July 1984

Species	Total specimens	Percent numerical abundance	Total biomass (g)	Percent biomass abundance	Number[1] of occurrences
Notropis bellus	4227	38.5	1831.7	10.9	32
Etheostoma stigmaeum	1908	17.4	728.9	4.3	32
Notropis chrysocephalus	932	8.5	2265.8	13.5	32
Lepomis megalotis	744	6.8	2988.1	17.7	28
Pimephales notatus	580	5.3	416.0	2.5	32
Notropis stilbius	351	3.2	465.9	2.8	24
Etheostoma whipplei	322	2.9	190.0	1.1	32
Campostoma oligolepis	250	2.3	557.2	3.3	23
Fundulus olivaceus	245	2.2	164.1	1.0	26
Semotilus atromaculatus	231	2.1	454.2	2.7	15
Notropis texanus	226	2.1	184.4	1.1	27
Percina nigrofasciata	173	1.6	143.7	.9	23
Notropis venustus	168	1.5	530.1	3.1	23
Lepomis macrochirus	95	.9	106.9	.5	15
Micropterus punctulatus	85	.8	242.0	1.4	15
Percina caprodes	77	.7	385.9	2.3	22
Moxostoma erythrurum	67	.6	1211.9	7.2	19
Percina maculata	55	.5	92.2	.5	23
Moxostoma poecilurum	53	.5	1236.7	7.3	17
Minytrema melanops	33	.3	708.1	4.2	8
Lepomis cyanellus	31	.3	308.4	1.8	11
Notropis callistius	24	.2	62.8	.4	11
Noturus leptacanthus	14	.1	17.7	.1	8
Noturus gyrinus	14	.1	16.5	.1	7
Micropterus salmoides	12	.1	512.8	3.0	8
Notropis asperifrons	11	.1	9.2	.1	5
Etheostoma parvipinne	6	.1	3.5	<.1	6
Ambloplites ariommus	5	<.1	462.8	2.7	4
Etheostoma swaini	5	<.1	2.5	<.1	4
Lepomis punctatus	5	<.1	5.5	<.1	4
Erimyzon oblongus	5	<.1	16.3	.1	5
Ictalurus natalis	4	<.1	2.7	<.1	4
Esox niger	3	<.1	245.9	1.5	3
Notropis baileyi	3	<.1	1.8	<.1	3
Lepomis gulosus	2	<.1	46.1	.3	2
Aphredoderus sayanus	2	<.1	7.3	<.1	2
Ictalurus punctatus	1	<.1	34.3	.2	1
Lepomis microlophus	1	<.1	38.8	.2	1
Hypentelium etowanum	1	<.1	15.8	.1	1
Micropterus coosae	1	<.1	120.3	.7	1
Ammocoete (unid)	1	<.1	.8	<.1	1
Notropis volucellus	1	<.1	.4	<.1	1
Nocomis leptocephalus	1	<.1	.5	<.1	1
Noturus funebris	1	<.1	.1	<.1	1
Totals	10,976		16,837.1		

[1]Total collections = 32

Table E-2.--Abundance, biomass, and occurrence of fishes collected from Tyro Creek site 2, November 1981 through July 1984

Species	Total specimens	Percent numerical abundance	Total biomass (g)	Percent biomass abundance	Number[1] of occurrences
Notropis bellus	2080	27.0	1040.6	9.9	30
Pimephales notatus	1592	20.7	1138.7	10.8	30
Etheostoma stigmaeum	1396	18.1	609.7	5.8	30
Notropis chrysocephalus	842	10.9	2185.6	20.8	30
Lepomis megalotis	549	7.1	1800.4	17.1	30
Notropis asperifrons	294	3.8	176.0	1.7	30
Campostoma oligolepis	178	2.3	554.5	5.3	26
Etheostoma whipplei	146	1.9	181.8	1.7	26
Fundulus olivaceus	138	1.8	192.3	1.8	25
Percina nigrofasciata	131	1.7	155.1	1.5	27
Semotilus atromaculatus	104	1.4	442.2	4.2	21
Micropterus punctulatus	70	.9	139.7	1.3	11
Percina maculata	34	.4	96.0	.9	16
Moxostoma erythrurum	25	.3	535.0	5.1	15
Percina caprodes	23	.3	215.2	2.0	15
Noturus gyrinus	17	.2	17.8	.2	13
Notropis stilbius	17	.2	27.6	.3	6
Micropterus coosae	11	.1	235.9	2.2	4
Moxostoma poecilurum	10	.1	458.8	4.4	8
Etheostoma swaini	10	.1	9.4	.1	9
Noturus leptacanthus	8	.1	11.0	.1	5
Lepomis cyanellus	7	.1	111.7	1.1	4
Lepomis macrochirus	4	.1	12.3	.1	4
Erimyzon oblongus	3	<.1	34.1	.3	3
Notropis venustus	3	<.1	16.5	.2	3
Minytrema melanops	2	<.1	51.9	.5	1
Micropterus salmoides	2	<.1	11.3	.1	2
Hypentelium etowanum	1	<.1	44.0	.4	1
Aphredoderus sayanus	1	<.1	5.3	.1	1
Notropis baileyi	1	<.1	1.3	<.1	1
Etheostoma parvipinne	1	<.1	.2	<.1	1
Ictalurus natalis	1	<.1	.6	<.1	1
Notropis texanus	1	<.1	2.2	<.1	1
Totals	7,702		10,514.7		

[1]Total collections = 30

Table E-3.--Abundance, biomass, and occurrence of fishes collected from Wallace Branch site 3, November 1981 through July 1984

Species	Total specimens	Percent numerical abundance	Total biomass (g)	Percent biomass abundance	Number[1] of occurrences
Semotilus atromaculatus	391	28.2	510.2	18.5	23
Notropis chrysocephalus	346	25.0	1169.2	42.4	27
Notropis bellus	186	13.4	149.6	5.4	19
Lepomis megalotis	101	7.3	283.6	10.3	19
Fundulus olivaceus	86	4.8	45.5	1.7	14
Etheostoma stigmaeum	57	4.1	40.7	1.5	15
Percina nigrofasciata	54	3.9	63.0	2.3	19
Pimephales notatus	44	3.2	34.0	1.2	16
Etheostoma whipplei	31	2.2	15.7	.6	12
Campostoma oligolepis	28	2.0	22.4	.8	10
Micropterus punctulatus	21	1.5	73.4	2.7	8
Notropis venustus	17	1.2	54.0	2.0	5
Ictalurus natalis	7	.5	4.0	.1	3
Moxostoma erythrurum	6	.4	1.8	.1	3
Etheostoma parvipinne	5	.4	2.9	.1	1
Notropis baileyi	5	.4	3.5	.1	2
Lepomis cyanellus	3	.2	44.4	1.6	3
Erimyzon oblongus	3	.2	22.4	.8	2
Notropis asperifrons	3	.2	2.6	.1	2
Noturus gyrinus	2	.1	2.6	.1	2
Moxostoma poecilurum	2	.1	2.9	.1	2
Notropis stilbius	2	.1	2.6	.1	2
Noturus leptacanthus	2	.1	3.2	.1	1
Esox niger	1	.1	90.0	3.3	1
Micropterus coosae	1	.1	108.0	3.9	1
Micropterus salmoides	1	.1	1.8	.1	1
Percina maculata	1	.1	2.1	.1	1
Totals	1,386		2,756.2		

[1]Total collections = 30

Table E-4.--Abundance, biomass, and occurrence of fishes collected from Little Tyro Creek site 4, February 1982 through July 1984

Species	Total specimens	Percent numerical abundance	Total biomass (g)	Percent biomass abundance	Number[1] of occurrences
Semotilus atromaculatus	685	53.3	1530.3	54.1	26
Notropis chrysocephalus	218	17.0	510.2	18.1	24
Notropis bellus	104	8.1	120.5	4.3	13
Lepomis megalotis	100	7.8	306.7	10.9	17
Etheostoma whipplei	58	4.5	68.4	2.4	17
Etheostoma parvipinne	31	2.4	33.8	1.2	9
Lepomis macrochirus	27	2.1	15.2	.5	1
Erimyzon oblongus	18	1.4	20.7	.7	6
Lepomis cyanellus	15	1.2	143.2	5.1	11
Campostoma oligolepis	12	.9	39.5	1.4	6
Notropis venustus	6	.5	20.1	.7	3
Moxostoma erythrurum	3	.2	5.8	.2	2
Percina nigrofasciata	2	.2	5.5	.2	2
Ictalurus natalis	1	.1	.5	<.1	1
Etheostoma stigmaeum	1	.1	.9	<.1	1
Percina maculata	1	.1	2.7	.1	1
Fundulus olivaceus	1	.1	.5	<.1	1
Pimephales notatus	1	.1	1.1	<.1	1
Notropis asperifrons	1	.1	.9	<.1	1
Totals	1,285		2,826.5		

[1]Total collections = 30

Table E-5.--Abundance, biomass, and occurrence of fishes collected from Tyro Creek site 5, October 1981 through July 1984

Species	Total specimens	Percent numerical abundance	Total biomass (g)	Percent biomass abundance	Number[1] of occurrences
Notropis chrysocephalus	2226	35.9	5898.5	44.3	28
Etheostoma stigmaeum	885	14.3	417.7	3.1	28
Notropis bellus	809	13.1	448.5	3.4	28
Etheostoma whipplei	455	7.3	452.9	3.4	28
Lepomis megalotis	327	5.3	1015.0	7.6	28
Campostoma oligolepis	324	5.2	1287.5	9.7	28
Pimephales notatus	324	5.2	272.7	2.0	26
Fundulus olivaceus	294	4.7	423.6	3.2	27
Semotilus atromaculatus	276	4.5	748.4	5.6	27
Percina nigrofasciata	130	2.1	255.5	1.9	26
Moxostoma erythrurum	33	.5	31.0	2.3	11
Micropterus punctulatus	30	.5	309.0	2.3	9
Noturus gyrinus	19	.3	18.5	.1	13
Micropterus coosae	18	.3	704.9	5.3	11
Erimyzon oblongus	10	.2	95.7	.7	10
Etheostoma swaini	9	.1	9.2	.1	8
Percina maculata	7	.1	22.8	.2	5
Lepomis cyanellus	6	.1	12.6	.1	6
Percina caprodes	6	.1	62.6	.5	5
Notropis asperifrons	5	.1	2.3	<.1	3
Ictalurus natalis	2	<.1	2.2	<.1	2
Moxostoma poecilurum	2	<.1	521.8	3.9	2
Hypentelium etowanum	1	<.1	30.7	.2	1
Etheostoma parvipinne	1	<.1	.6	<.1	1
Totals	6,199		13,326.2		

[1]Total collections = 28

Table E-6.--Abundance, biomass, and occurrence of fishes collected from Wallace Branch site 6, March 1983 through July 1984

Species	Total specimens	Percent numerical abundance	Total biomass (g)	Percent biomass abundance	Number[1] of occurrences
Semotilus atromaculatus	408	46.5	506.9	28.6	15
Notropis chrysocephalus	276	31.4	1040.0	58.6	15
Lepomis megalotis	117	13.3	63.0	3.5	5
Etheostoma whipplei	46	5.2	36.9	2.1	10
Percina nigrofasciata	9	1.0	32.3	1.8	6
Percina maculata	4	.5	12.9	.7	4
Campostoma oligolepis	3	.3	25.4	1.4	3
Erimyzon oblongus	3	.3	27.6	1.6	2
Etheostoma parvipinne	3	.3	1.7	.1	3
Micropterus punctulatus	3	.3	16.1	.9	3
Notropis bellus	2	.2	2.6	.1	2
Notropis venustus	2	.1	6.3	.4	2
Moxostoma poecilurum	1	.1	.2	<.1	1
Pimephales notatus	1	.1	3.0	.2	1
Totals	878		1,774.9		

[1]Total collections = 15