DISTRIBUTION AND VARIABILITY OF FECAL-INDICATOR BACTERIA IN SCIOTO AND OLENTANGY RIVERS IN THE COLUMBUS, OHIO, AREA

By Donna N. Myers

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CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
liter (L)	0.03531	cubic foot
milliliter	0.0607	cubic inch
milligram per liter (mg/L)	0.00006243	pound per square foot
cubic meter per second (m^3/s)	35.31	cubic foot per second
colonies per 100 milliliters (col/100 mL)	283.2	colonies per cubic foot
centimeter	0.3937	inch

Abbreviated water-quality units used in this report: Chemical concentrations and water temperature are given in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per iter (µg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is the same as for concentrations in parts per million.

Specific conductance of water is expressed in microsiemens per centimeter at 25 degrees Celsius (µS/cm). This unit is equivalent to micromhos per centimeter at 25 degrees Celsius (µmho/cm), formerly used by the U.S. Geological Survey.

DISTRIBUTION AND VARIABILITY OF FECAL-INDICATOR BACTERIA IN SCIOTO AND OLENTANGY RIVERS IN THE COLUMBUS, OHIO, AREA

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ABSTRACT

This report presents the results of a study by the U.S. Geological Survey, in cooperation with the City of Columbus, Ohio, to determine the distribution and variability of fecal-indicator bacteria in Scioto and Olentangy Rivers. Fecal-indicator bacteria are among the contaminants of concern to recreational users of these rivers in the Columbus area. Samples were collected to be analyzed for fecal-coliform and *Escherichia coli (E. coli)* bacteria and selected water-quality constituents and physical properties at 10 sites--4 on the Olentangy River and 6 on the Scioto River during the recreational seasons in 1987, 1988, and 1989. Measurements of streamflow also were made at these sites at various frequencies during base flow and runoff.

The concentrations of fecal-coliform and *E. coli* bacteria in the Scioto and Olentangy Rivers spanned a range of five orders of magnitude, from less than 20 to greater than 2,000,000 col/100 mL (colonies per 100 milliliters). In addition, the concentrations of fecal coliform and *E. coli* bacteria are well correlated (r=0.97) in the study area. At times, relatively high concentrations for fecal-indicator bacteria (concentrations greater than 51,000 col/100 mL for fecal-coliform and *E. coli*) were found in Olentangy River at Woody Hayes Drive and at Goodale Street, and in Scioto River at Greenlawn Avenue and at Columbus. Intermediate concentrations of fecal-indicator bacteria (from 5,100 to 50,000 col/100 mL for fecal coliform and from 510 to 50,000 col/100 mL for *E. coli*) were found in Scioto River at Town Street and below O'Shaughnessy Dam near Dublin, Ohio, and in Olentangy River at Henderson Road. The lowest (median) concentrations of fecal-indicator bacteria (from 20 to 5,000 col/100 mL for fecal coliform and from 20 to 500 col/100 mL for *E. coli*) were found at Olentangy River near Worthington, Ohio, Scioto River at Dublin Road Water Treatment Plant, and below Griggs Reservoir.

Fecal-coliform concentrations exceeded the geometric mean and single-sample Ohio Water Quality Standards for recreation less frequently than *E. coli* concentrations. The *E. coli* numerical water-quality standards are more difficult to meet than the fecal coliform standards because they are as much as an order of magnitude lower in some instances.

The geometric mean bathing-water and primary-contact standards for fecal-coliform and *E. coli* bacteria were exceeded in more samples for Olentangy River at Goodale Street than for any other site. The single-sample bathing-water standard for fecal-coliform

bacteria was exceeded in 83 percent of all samples and for *E. coli* in 91 percent of samples for Olentangy River at Goodale Street. Compared to Olentangy River at Goodale Street, geometric means and single-samples exceeded the bathing-water standards somewhat less frequently for Scioto River at Town Street and far less frequently for Scioto River at Dublin Road Water Treatment Plant.

In contrast to results for fecal-indicator bacteria, the differences between sites for pH and for concentrations of total alkalinity, total chloride, total nonfilterable residue, total nitrate plus nitrite as nitrogen, total phosphorus, and total organic carbon were small.

The large contribution of streamflow and discharge of fecal-indicator bacteria from Olentangy River to Scioto River has a major effect on the Scioto River downstream from the confluence of Olentangy River during periods of rainfall and runoff. Fecal-indicator discharges were calculated for times before, during, and at 24-hour intervals for 48 to 72 hours after two runoff-producing storms. Fecal-coliform and *E. coli* concentrations were lower in samples collected before runoff and during receding streamflows at 24- to 48-hours after the storms than in samples collected during runoff. The fecal-indicator discharges entering Scioto River from Olentangy River ranged from 22.6 to nearly 100 percent of the total for two storms studied.

Controlling nonpoint, unregulated, and intermittent sources of fecal-indicator bacteria and associated contaminants in the Columbus area could lead to improved recreational water quality in the Scioto and Olentangy Rivers. In this study, most of the fecal-indicator-bacteria discharge in Scioto River at Town Street was contributed by Olentangy River. Special emphasis on controlling sources of fecal-indicator bacteria to Olentangy River during the recreational season could result in improved water quality for Scioto River in the downtown Columbus area.

INTRODUCTION

Improved treatment of the municipal wastewater discharged to many of the Nation's rivers and streams over the last 20 years has led to improvements in water quality and has stimulated the desire for expanded use of waterways for recreational purposes. Many of these water-quality improvements have come about because of new or upgraded sewage-treatment systems that treat point sources of contamination. Because of improved water quality, waterways are often viewed as economically important natural resources with multiple uses, including recreation.

Although advanced sewage treatment, chlorination, and (or) ozonation greatly reduces bacterial contamination of streams and rivers, urbanized streams have been shown to contain elevated

concentrations of contaminants and fecal bacteria during periods of rainfall and runoff (Novotony and others, 1985). In many coastal areas, beach closings are common occurrences after rainfall and runoff because of fecal contamination of nearshore areas. Common sources of fecal contaminants in urban runoff are street refuse, animal waste, and combined-sewer overflows that occur when the capacity of the sewage-collection system is exceeded.

Fecal-indicator bacteria in Scioto and Olentangy Rivers have been known to be periodically excessive (Ohio Environmental Protection Agency, written commun., 1989), and fecal bacteria are among the contaminants of concern to recreational users. However, the presence of sewage organisms and their indicators in the rivers had not been systematically studied. In July 1987, the U.S. Geological Survey (USGS) began a study, in cooperation with the City of Columbus, Division of Sewerage and Drainage, to determine the distribution and variability of fecal-indicator bacteria in selected reaches of the rivers.

Purpose and Scope

The purpose of this report is to (1) provide data on fecal-indicator bacteria concentrations in Scioto and Olentangy Rivers at various locations in the Columbus, Ohio, area, (2) discuss the suitability of Scioto and Olentangy Rivers for body-contact recreation by comparing observed concentrations of fecal-indicator bacteria to Ohio Water Quality Standards, (3) show the variability of fecal-indicator bacteria concentrations in a selected segment of Scioto River after rainfall and runoff, and (4) describe the general water quality of the Scioto and Olentangy Rivers in terms of selected chemical constituents and physical properties.

The fecal-indicator bacteria studied were fecal coliform and *Escherichia coli* (*E. coli*). Chemical constituents and physical and chemical properties examined include streamflow, specific conductance, pH, and concentrations of dissolved oxygen, total alkalinity, total chloride, total nonfilterable residue, nitrate plus nitrite as nitrogen, total kjeldahl nitrogen, total phosphorus, and total organic carbon. Water-quality samples were collected in three recreational seasons in 1987, 1988, and 1989 to provide a detailed analysis of the areal and temporal patterns of recreational water quality in the Scioto and Olentangy Rivers.

Acknowledgments

The author thanks Ronald Scott, Russell Grice, and George Noethlich of the Columbus Division of Sewerage and Drainage and the Division's Surveillance Laboratory for their assistance during the data-collection and report review phases of the project.

METHODS OF STUDY

Water-sampling sites in the study area (fig. 1) include six sites on Scioto River: below O'Shaughnessy Dam, below Griggs Reservoir, at Dublin Road Water Treatment Plant (WTP), at Town Street, at Greenlawn Avenue, and at Columbus (at Frank Road). Four sites on Olentangy River include Olentangy River near Worthington, at Henderson Road, at Woody Hayes Drive, and at Goodale Street. Two sites, Scioto River below O'Shaughnessy Dam and Olentangy River near Worthington, were selected to represent water quality in the two rivers as they enter the Columbus metropolitan area. Olentangy River at Henderson Road and Scioto River below Griggs Reservoir also represent upstream sites draining suburban land-use settings. The remaining six downstream sites were selected to reflect urban settings, are used for boating, fishing, wading, and occasionally waterskiing.

For purposes of interpreting water-quality data with regard to site location, sites on Scioto River were considered "upstream" if they were above the confluence of the Olentangy and Scioto Rivers. Upstream sites for Scioto River were Scioto River below O'Shaughnessy Reservoir, below Griggs dam, and at Dublin Road WTP. "Downstream" sites on Scioto River were Scioto River at Town Street, at Greenlawn Avenue, and at Columbus (Frank Road). For Olentangy River, "upstream" sites were Olentangy River near Worthington and at Henderson Road. "Downstream" sites on Olentangy River were Olentangy River at Woody Hayes Drive and at Goodale Street.

Water Sampling

Water samples were collected during parts of three recreational seasons: July 28 through October 8, 1987; May 4 through September 28, 1988; and May 18 through July 11, 1989. Samples were collected at least once per month at the 10 sampling sites during these periods.

Three sites--Olentangy River at Goodale Street and Scioto River at Dublin Road WTP and at Town Street--were chosen for intensive study because the stream segment they define is being considered for additional recreational development. At these sites, samples were collected five times in August 1987 and five additional times per month from May through September 1988. These same three locations were sampled before, during, and after three runoff-producing storms. Samples were collected 24, 48, and 72 hours after the storms. (Sampling periods were May 23 through May 27, 1988; July 3 through July 15, 1988; and June 27 through June 30, 1989.)

Samples were collected by means of the D-77 water sampler if stream depth and velocity permitted or by means of the DH-81 sampler if the stream depth was shallower than 2 feet (Ward and Harr, 1990). Depending on stream width and depth, from three to six vertically integrated subsamples were collected into a single bottle.

Samples for analysis of fecal-indicator bacteria were collected in a manner that minimized contamination of the sterile collection containers. Water samples for chemical analysis were collected into clean polypropylene sample bottles. Bacteriological samples were kept in the original collection containers until they were analyzed. All samples were kept in ice chests or were refrigerated to maintain the samples at approximately 4°C until they were analyzed. Samples were not otherwise preserved.

Temperature, specific conductance, pH, and dissolved-oxygen concentration were measured in the field by use of a Hydrolab 4000[1] meter at the time of sampling. All measurements were made a few inches below the stream surface, either from a bridge or by wading. The meter was calibrated according to manufacturer's guidelines each time it was used (Hydrolab Corporation, 1979).

Streamflow Measurement

Instantaneous streamflow measurements were made monthly at two to three sites and also during two runoff-producing storms. These measurements were made to determine streamflow and instantaneous fecal-indicator-bacteria discharges in the Olentangy and Scioto Rivers.

All streamflow measurements were made by use of standard USGS techniques (Rantz, 1982). During runoff-producing storms, streamflow measurements were made almost simultaneously. Some measurements were made by wading at Olentangy River at Goodale Street and Scioto River at Dublin Road WTP. Otherwise, bridge measurements were made for Olentangy River at Goodale Street and downstream from the confluence of the two rivers at Town Street. The discharge of Olentangy River at Goodale Street was subtracted from the discharge at Town Street, and the difference was taken to be the instantaneous streamflow for Scioto River at Dublin Road WTP.

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

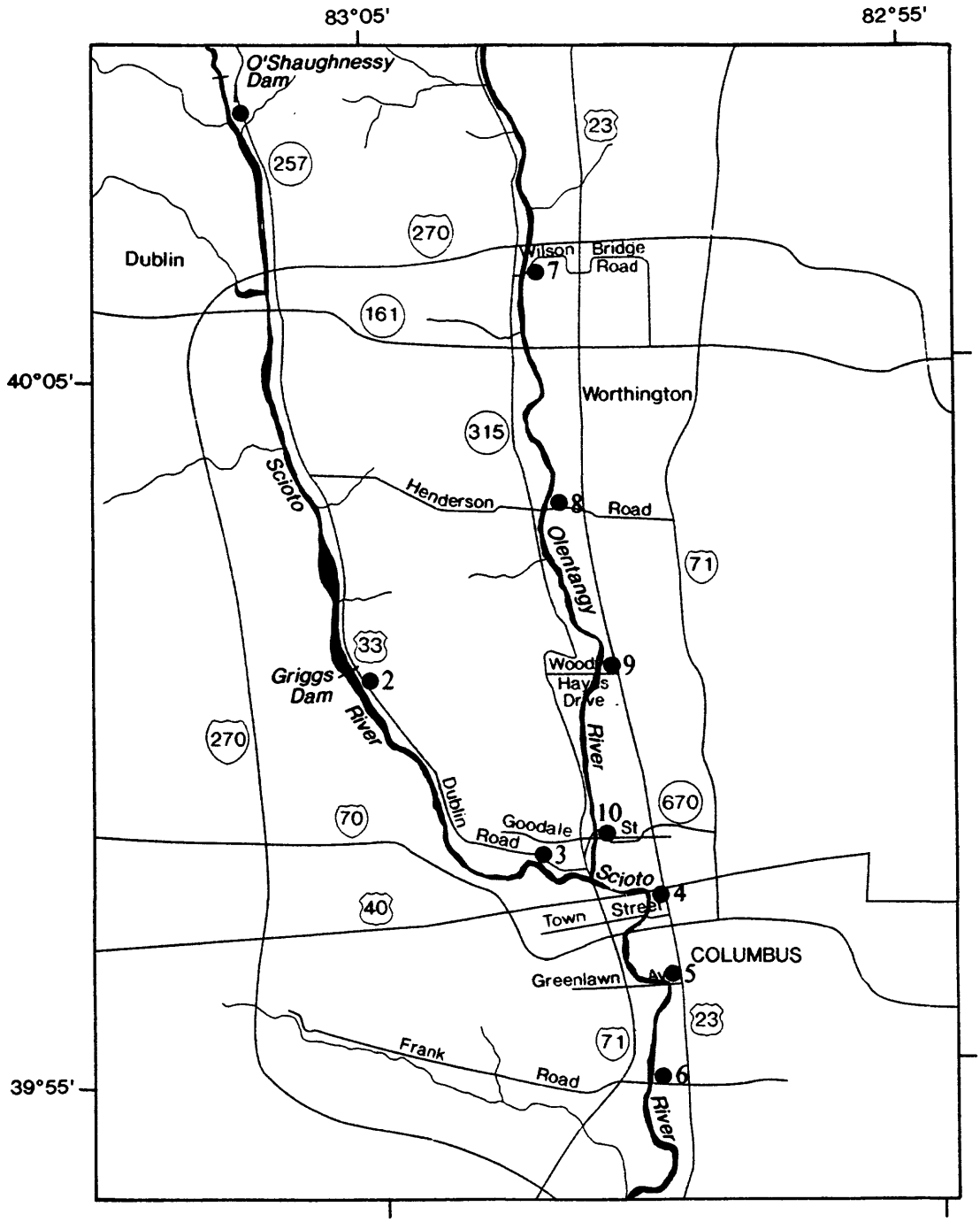

Figure 1.--Locations of study sites.

EXPLANATION

SITE LOCATIONS

- ●1 Scioto River below O'Shaughnessy Dam
- ●2 Scioto River below Griggs Reservoir
- ●3 Scioto River at Dublin Road Water Treatment Plant
- ●4 Scioto River at Town Street
- ●5 Scioto River at Greenlawn Avenue
- ●6 Scioto River at Columbus (Frank Road)
- ●7 Olentangy River near Worthington
- ●8 Olentangy River at Henderson Road
- ●9 Olentangy River at Woody Hayes Drive
- ●10 Olentangy River at Goodale Street

Analysis of Water Samples

All samples for determination of fecal-indicator bacteria were processed within 6 hours of collection at the USGS laboratory in Columbus. Analysis of chemical constituents and physical and chemical properties was done at the Columbus Division of Sewerage and Drainage's Surveillance Laboratory, where samples were fractionated for several types of chemical analyses. All water-chemistry samples were analyzed within 48 hours of the time they were collected.

Enumeration of Fecal-Indicator Bacteria

Fecal-coliform and *E. coli* bacteria are present in the intestines and feces of warm-blooded animals. They are capable of producing gas from lactose in a suitable culture medium at 44.5°C. Bacterial organisms from other sources generally cannot produce gas when subjected to the same conditions (American Public Health Association and others, 1985; Bordner and others, 1978). *E. coli* are defined as those bacteria of the coliform group that produce yellow or yellow-brown colonies on a filter pad saturated with urea substrate broth after primary culturing on mTEC medium at 44.5°C for 24 hours (Dufour and others, 1981). The fecal coliforms are defined as those bacteria of the coliform group that produce blue colonies after primary culturing on mFC medium at 44.5°C for 24 hours (Britton and Greeson, 1989). Although the fecal-coliform test has been used since the 1950's on a nationwide basis to determine recreational water quality, the *E. coli* test has been approved for use by the U.S. Environmental Protection Agency (USEPA) only since 1984.

The USGS membrane-filtration procedure (Britton and Greeson, 1988) was used for fecal-coliform determinations. The USEPA membrane-filtration procedure (U.S. Environmental Protection Agency, 1985) was used for *E. coli* determinations. The USEPA procedure was modified by use of a 0.65-µm pore-size membrane filter rather than the 0.45-µm pore-size membrane filter. The 0.65-µm pore-size membrane filter was used to improve comparability of fecal-coliform determinations (by USGS methods) and *E. coli* determinations. Improved recoveries of fecal-coliform bacteria have been demonstrated by use of the 0.65-µm pore-size filters when compared to the 0.45-µm pore-size membranes (Sladek and others, 1975; Lorenz and others, 1982).

The fecal-coliform method (Britton and Greeson, 1989) and the *E. coli* method (Dufour and others, 1981) differ in several ways. The *E. coli* method contains a resuscitation step in which the bacteria are incubated for 2 hours at 35°C prior to incubation at 44.5°C for 24 hours. This resuscitation step allows for improved culturing of stressed organisms. In addition, the *E. coli* method contains a final step after incubation in which colonies are placed in a urea broth for 15 to 20 minutes. Only colonies remaining yellow, indicating a negative test for urease, are counted as *E. coli*.

Chemical Constituents

All determinations of chemical constituents in water samples were made by use of methods recommended by the USEPA for analysis of water and wastes (U.S. Environmental Protection Agency, 1979). The selected chemical constituents and methods of analyses, along with minimum detectable limits as reported by the Surveillance Laboratory, are as follows:

Property or Constituent	Analytical method	Detection limit, in mg/L
Total alkalinity	Fixed-endpoint titration (APHA[1] and others, 1985)	10
Total chloride	Automated ferricyanide method (APHA and others, 1985)	1.0
Total nonfilterable residue	Gravimetric analysis drying at 103-105°C (USEPA[3], 1979)	10
Nitrate plus nitrite-nitrogen	Automated cadmium reduction method (APHA and others, 1985)	0.2
Total kjeldahl nitrogen	Semiautomated salicylate method (USEPA, 1979)	0.2
Total phosphorus	Semiautomated ascorbic acid-acid-ammonium molybdate method (APHA and others, 1985)	0.2
Total organic carbon	Wet-oxidation method (APHA and others, 1985)	1.0

[1]APHA, American Public Health Association

[2]mg/L, milligrams per liter.

[3]USEPA, U.S. Environmental Protection Agency.

Quality Assurance and Quality Control

Quality-assurance and quality-control practices were carried out through all phases of data collection and analysis for USGS laboratory and Surveillance Laboratory activities. Quality-assurance and control practices consisted of interlaboratory and intralaboratory testing. The quality-assurance program effort comprised approximately 15 percent of the total number of samples.

Specifically, the Surveillance Laboratory participated twice each year in the USGS Standard Reference Water Sample Program and annually in the USEPA Performance Evaluation Program. For both testing programs, the Surveillance Laboratory performed satisfactorily. In addition, the Surveillance Laboratory uses commercially prepared check samples and control charts to monitor quality on a daily basis.

For the USGS laboratory in Columbus, quality-control testing of fecal-indicator methods and buffered water was accomplished by use of lyophilized pure cultures of *E. coli* obtained from the USEPA Quality Assurance Laboratory in Cincinnati, Ohio. Blanks prepared from 100 mL of dilution buffer were used as negative controls and filtered before and after each set of samples or at a frequency of no less than 10 percent. Results of samples were not accepted for use if quality-control testing showed contaminated blanks or values outside the acceptable range for recovery of the pure culture. Duplicate samples were analyzed at a frequency of 10 percent to determine precision (replicability of results). Good laboratory practices--including specifications for dilution-water quality, cleaning practices, and safety precautions--were adopted as appropriate from guidelines set forth by Britton and Greeson (1989) and Bordner and others (1978).

For comparative purposes, duplicate samples for fecal-indicator analysis were analyzed by the USGS laboratory and the Surveillance Laboratory on five dates in 1987. In most cases, results of fecal-coliform and *E. coli* samples processed by the USGS laboratory were higher than samples processed by the Surveillance Laboratory. The ratios of USGS laboratory results divided by Surveillance Laboratory results for 31 fecal-coliform samples were made. The median ratio was 1.41 and the ratios ranged from 0.56 to 4.53. These differences decreased over time as both laboratories compared procedures and practices to gain a higher degree of comparability. Specifically, the median ratio for fecal-coliform samples for the first half of the sequence of samples was 2.12, compared to 1.09 for the second half of the sequence of samples.

The consistently larger fecal-coliform and *E. coli* concentrations reported by the USGS laboratory compared to the Surveillance Laboratory from duplicate samples may be due in part to differences in the pore size of filters used to process samples. A 0.45-µm pore-size filter is used in the Surveillance Laboratory, whereas a 0.65-µm pore-size filter is used in the USGS. The 0.65-

and 0.7-µm pore-size filters have been shown to provide better recovery of fecal-coliform bacteria than 0.45-µm pore-size filters (Sladek and others, 1975; Lorenz and others, 1982). Data generated by use of 0.65-µm pore-size filters can be used for determinations of water-quality standards and criteria (U.S. Environmental Protection Agency, 1984). But fecal-indicator concentrations in this report may be higher than concentrations for the same samples had they been processed with 0.45-µm pore-size filters. Results of this study should be interpreted within this context.

DISTRIBUTION OF FECAL-INDICATOR BACTERIA

Sources of fecal-indicator bacteria within the Columbus area are similar to those in other areas of the Nation and include combined sewer overflows, stormwater, and direct urban runoff. In this study area, only one sewage-treatment plant was identified, and it was upstream from Scioto River below O'Shaughnessy Dam. This source, however, was eliminated during 1989. Consequently, most of the fecal-indicator bacteria found at nine other sites in the study area had sources other than sewage-treatment plants, and these sites were affected by either nonpoint sources, combined-sewer overflows, small unregulated sanitary-sewage discharges, or intermittent malfunctions in the sewage-collection system (Ronald Scott, City of Columbus, Division of Sewers and Drains, oral commun., 1988).

Concentrations of Fecal-Indicator Bacteria in Scioto and Olentangy Rivers

In this report, fecal-coliform concentrations of 5,000 col/100 mL or less are referred as "low" because they fall below the least restrictive Ohio water-quality standard for recreation, concentrations between 5,100 to 50,000 are referred to as "intermediate" because they represent concentrations commonly found in surface waters, and concentrations greater than 51,000 are classified as "high" because they represent water possibly contaminated with sewage (Bordner and others, 1978, p. 127). *E. coli* concentrations of 500 col/100 mL or less are referred to as "low", concentrations of 510 to 50,000 col/100 mL are referred to as "intermediate," and concentrations of 51,000 col/100 mL and greater are referred to as "high."

E. coli and fecal-coliform concentrations are highly correlated in the study area over the entire range of observations (r=0.970) (fig. 2). In general, median fecal-coliform concentrations were greater than median *E. coli* concentrations; however, this relation did not always hold true for individual observations, even though *E. coli* is a species of fecal-coliform bacteria.

Box plots are used throughout this report to describe the distribution of data for fecal-indicator bacteria and other water-quality constituents and physical properties.

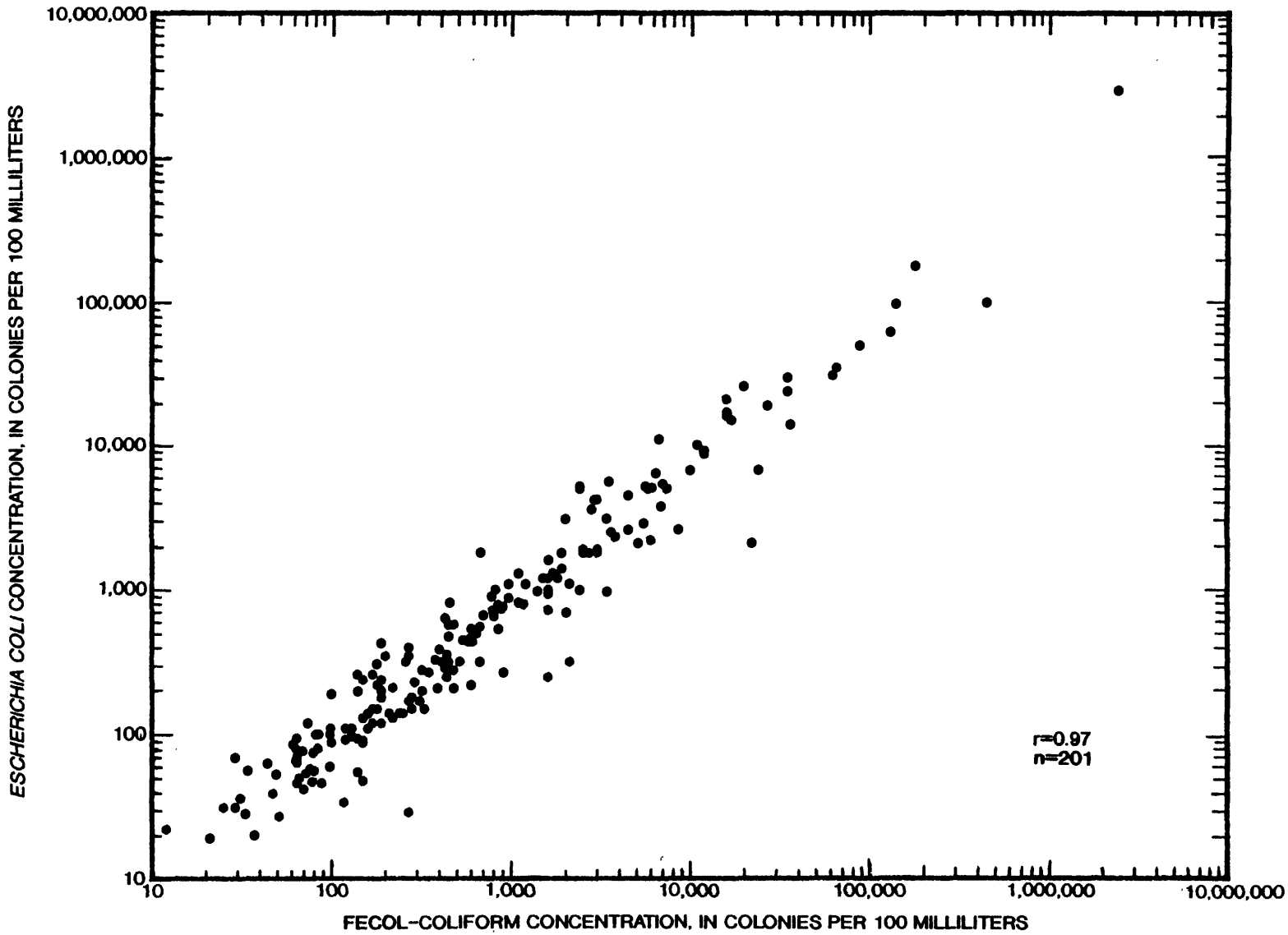

Figure 2.--Correlation of fecal-coliform and *Escherichia coli* concentrations in Scioto and Olentangy Rivers.

The boxplots include graphic representations of the data distribution including the median, interquartile range, and the outside and detached values. Boxplots of fecal-indicator bacteria data are illustrated in figures 3 and 4. For fecal coliform concentrations, extremes ranged from 20 col/100 mL for Scioto River below Griggs Reservoir to 2,000,000 col/100 mL for Scioto River at Greenlawn Avenue. For *E. coli* concentrations, extremes ranged from 16 col/100 mL for Scioto River below Griggs Reservoir to 2,400,000 col/100 mL for Scioto River at Greenlawn Avenue. These data represent samples collected from the two rivers at daily to monthly intervals during base flow as well as during runoff.

Concentrations of fecal-indicator bacteria tended to be higher at "downstream" sites such as Scioto River at Greenlawn Avenue and at Columbus (at Frank Road) and Olentangy River at Woody Hayes Drive and at Goodale Street than at "upstream" sites such as Scioto River below Griggs Reservoir and Olentangy River near Worthington. Summary statistics for fecal-indicator bacteria are listed in tables 1 and 2. The median concentrations of fecal coliform bacteria at 10 stream locations ranged from 62 to 5,400 col/100 mL, whereas the median concentrations of *E. coli* ranged from 62 to 4,000 col/100 mL. The smallest median concentrations were at Scioto River below Griggs Reservoir, and the largest median concentrations were at Olentangy River at Woody Hayes Drive.

At times, concentrations of fecal-indicator bacteria were high in Olentangy River at Woody Hayes Drive and at Goodale Street and in Scioto River at Greenlawn Avenue and at Columbus (at Frank Road). Concentrations of bacteria were intermediate in Scioto River at Town Street, at Dublin Road WTP, and below O'Shaughnessy Dam, and in Olentangy River at Henderson Road. The lowest concentrations of bacteria were in Olentangy River near Worthington and in Scioto River below Griggs Reservoir.

Comparison of Bacteria Concentrations with Ohio Water-Quality Standards for Recreation

Ohio has established recreational Water Quality Standards to protect the designated uses of the surface waters of the State during the recreational season of May 1 through October 15 (Ohio Administrative Code, Chapter 3745-1, 1990, p. 07-07). The standards are expressed in narrative and numerical terms. When fecal-coliform and *E. coli* concentrations are less than or equal to the numerical value set for the corresponding narrative water-use designation, the standard is being met, and a minimal risk to public health is assumed.

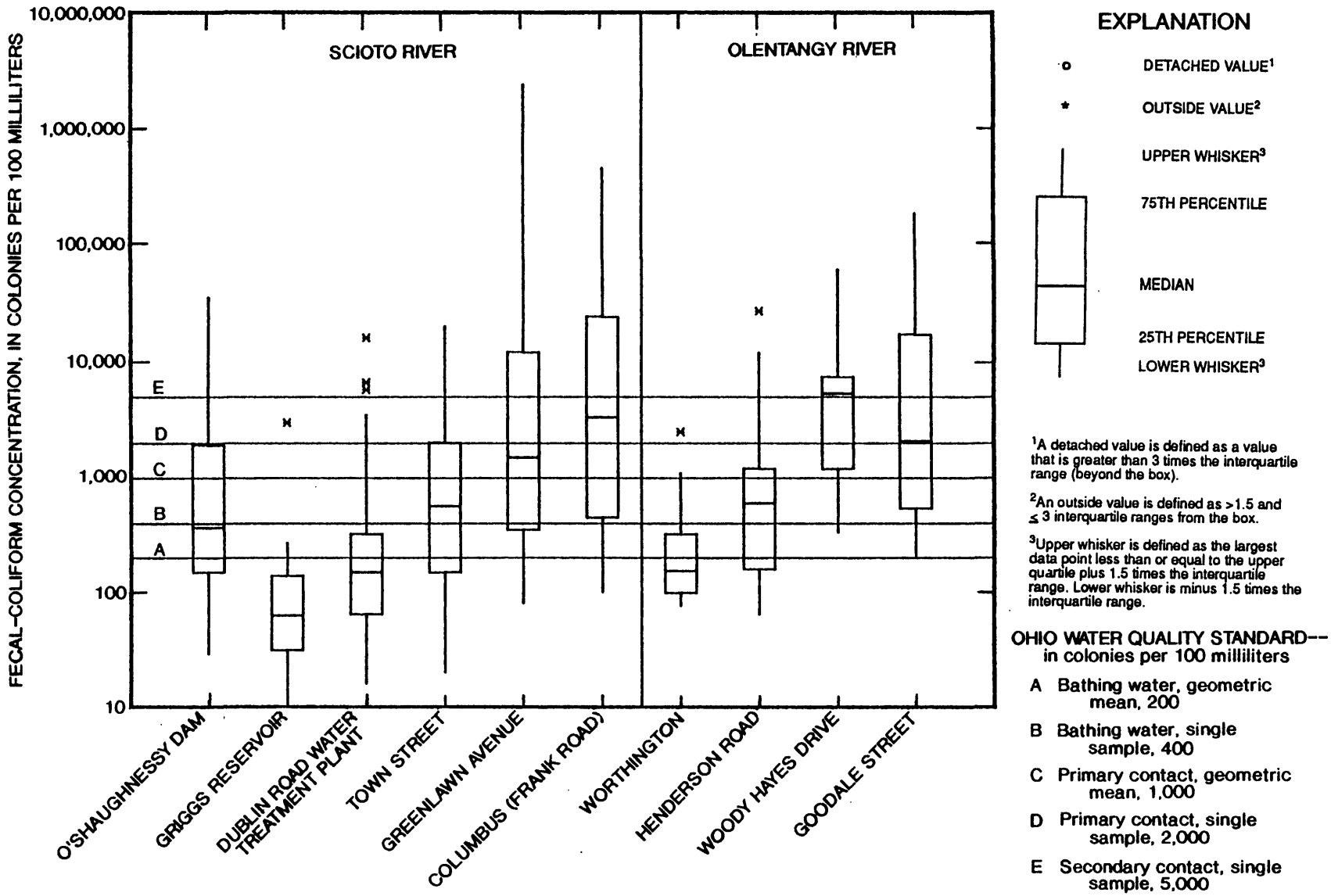

Figure 3.--Fecal-coliform concentration in Scioto and Olentangy Rivers for the 1987, 1988, and 1989 recreational seasons.

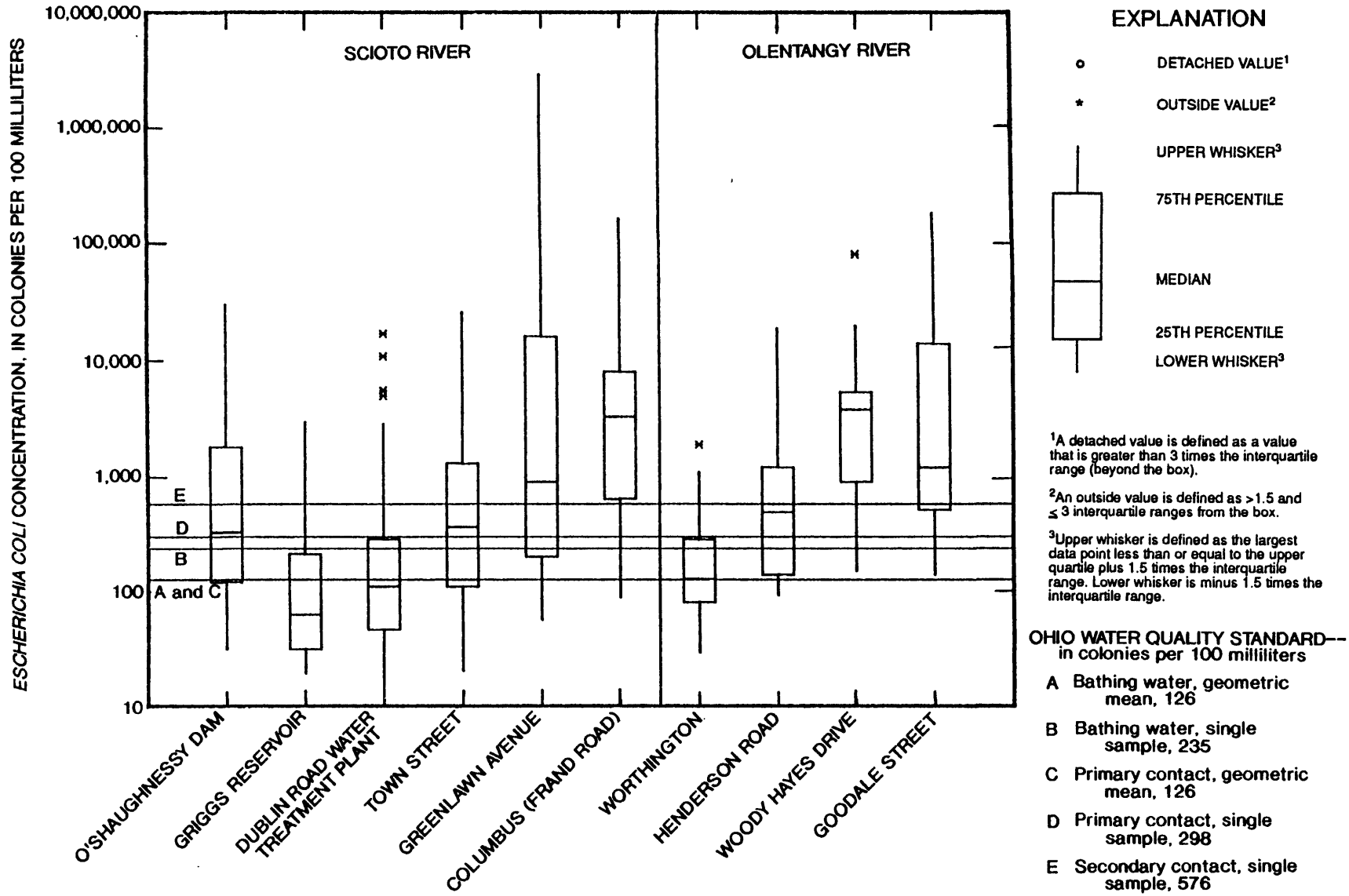

Figure 4.--*Escherichia coli* concentration in Scioto and Olentangy Rivers for 1987, 1988, and 1989 recreational seasons.

Three narrative recreational-use designations are specified in Ohio Water Quality Standards: (1) bathing water--water that is suitable for swimming where a lifeguard and (or) a bathhouse is present, including any additional areas where the water quality is approved by the Director of the Ohio Environmental Protection Agency; (2) primary contact--water that is suitable for full body-contact recreation such as, but not limited to, swimming, canoeing, and scuba diving where neither a bathhouse nor a lifeguard is available; and (3) secondary contact--water that is suitable for partial body-contact recreation such as, but not limited to, wading (Ohio Administrative Code, Chapter 3745-07, 1990, p. 07-34). The numerical Ohio Water Quality Standards for fecal coliform and *E. coli* bacteria for these three recreational-use designations are listed in table 3.

Attainment of Ohio's Water Quality Standards for water-contact recreation is determined by two numerical measures: (1) the geometric mean of either or both fecal coliform and *E. coli* concentrations in no less than five water samples obtained during a 30-day period, or (2) single water samples of either or both fecal-indicator bacteria obtained at frequencies of less than five samples per 30-day period. In this report, both numerical criteria were used to compare study results with recreational water-quality standards (tables 4 and 5). Geometric means or single-sample concentrations for all 10 sites are listed for fecal-coliform bacteria in table 6 and for *E. coli* in table 7.

Geometric means and single-sample concentrations that exceeded primary- and secondary-contact standards were found less frequently for fecal coliform bacteria than for *E. coli* (tables 4 and 5). The *E. coli* standards are more difficult to meet for primary- and secondary-contact uses because they are approximately an order of magnitude lower than the corresponding fecal-coliform standards. For example, the single-sample bathing water standard was exceeded in 56 percent of all samples for fecal-coliform bacteria compared to 61 percent of all samples for *E. coli*. Single-sample primary-contact standards were exceeded in 32.7 percent of samples for fecal coliform bacteria and in 56.4 percent of samples for *E. coli*. Single-sample secondary-contact standards were exceeded in 23.0 percent of all samples for fecal coliform and in 46.3 percent of all samples for *E. coli*. Thus, water-quality standards were exceeded in more samples when *E. coli* was used to indicate recreational quality than when fecal coliform was used as an indicator.

Table 1.--Summary statistics for fecal coliform concentration in Scioto and Olentangy Rivers, July-October 1987, May-October 1988, and May-July 1989

[All data except sample size are colonies per 100 milliliters]

Station name	Number of samples	Geometric mean	Percentage of samples in which fecal coliform concentration was less than or equal to that shown				
			10	25	Median 50	75	90
Scioto River below O'Shaughnessy Dam	18	621	74	150	380	2,200	9,000
Scioto River below Griggs Reservoir	18	71	20	30	62	150	540
Scioto River at Dublin Road Water Treatment Plant	46	179	27	64	150	330	2,900
Scioto River at Town Street	46	575	46	150	560	2,000	10,000
Scioto River at Greenlawn Avenue	18	2,420	120	310	1,400	22,000	33,000
Scioto River at Columbus	19	4,250	180	450	2,900	24,000	120,000
Olentangy River near Worthington	18	226	78	95	160	460	1,200
Olentangy River at Henderson Road	17	626	93	140	600	1,400	15,000
Olentangy River at Woody Hayes Drive	18	3,890	500	1,100	5,400	8,000	28,000
Olentangy River at Goodale Street	46	3,450	310	510	2,100	18,000	12,000

Table 2.--Summary statistics for *Escherichia coli* concentration in Scioto and Olentangy Rivers, July-October 1987, May-October 1988, and May-July 1989

[All data except sample size are colonies per 100 milliliters]

Station name	Number of samples	Geometric mean	Percentage of samples in which *E. coli* concentration was less than or equal to that shown				
			10	25	Median 50	75	90
Scioto River below O'Shaughnessy Dam	18	493	71	110	320	1,800	17,000
Scioto River below Griggs Reservoir	18	85	15	30	62	240	660
Scioto River at Dublin Road Water Treatment Plant	45	140	11	46	110	280	3,700
Scioto River at Town Street	45	427	57	100	360	1,300	5,700
Scioto River at Greenlawn Avenue	17	1,800	89	180	900	24,000	630,000
Scioto River at Columbus	18	3,320	210	560	3,400	13,000	110,000
Olentangy River near Worthington	18	179	45	74	130	400	1,200
Olentangy River at Henderson Road	18	545	94	140	480	1,400	9,700
Olentangy River at Woody Hayes Drive	18	2,830	300	880	4,000	5,500	26,000
Olentangy River at Goodale Street	46	2,570	240	500	1,200	14,000	67,000

Table 3.--Numerical and narrative Ohio water Quality Standards for Recreation

[Effective from May 1 through October 15. All numbers represent colonies per 100 milliliters; n/a, not applicable]

Fecal-indicator bacteria type	Bathing[1] waters	Primary[2] contact	Secondary[3] contact
Fecal coliform			
Geometric mean[4]	200	1,000	n/a
Single sample [5]	400	2,000	5,000
Escherichia coli			
Geometric mean[4]	126	126	n/a
Single sample [5]	235	298	576

[1]Bathing water is suitable for swimming and other full body-contact exposure where a lifeguard and (or) bathhouse are present.

[2]Primary contact water is suitable for full-body contact such as swimming, canoeing, and scuba diving.

[3]Secondary-contact water is suitable for partial-body contact such as wading.

[4]The geometric mean is based on a minimum of five samples in a 30-day period.

[5]The standard for a single sample cannot be exceeded in more than 10 percent of the samples collected in a 30-day period.

Table 4.--Number and percentage of total number of fecal-coliform samples not meeting Ohio Water Quality Standards for recreation at sites on Scioto and Olentangy Rivers, July-October 1987, May-September 1988, and May-July 1989

[Numbers in parentheses are in percent]

Site name	Geometric-mean standard[1]		Single-sample standard[2]		
	Bathing waters[3]	Primary contact[4]	Bathing waters[5]	Primary contact[6]	Secondary contact[7]
Scioto River below O'Shaughnessy Dam	1(100)	1(100)	9(53)	4(25)	3(18)
Scioto River below Griggs Reservoir	0(0)	0(0)	1(6)	1(6)	0(0)
Scioto River at Dublin Road Water Treatment Plant	3(43)	1(14)	9(20)	4(9)	3(7)
Scioto River at Town Street	5(71)	3(43)	28(61)	17(37)	7(15)
Scioto River at Greenlawn Avenue	1(100)	1(100)	12(67)	7(39)	6(33)
Scioto River at Columbus	1(100)	1(100)	16(89)	13(72)	8(44)
Olentangy River near Worthington	0(0)	0(0)	4(22)	1(6)	0(0)
Olentangy River at Henderson Road	1(100)	0(0)	10(56)	3(17)	3(17)
Olentangy River at Woody Hayes Drive	1(100)	1(100)	17(100)	13(76)	10(59)
Olentangy River at Goodale Street	7(100)	5(71)	38(83)	23(50)	17(37)

[1] Number (percent) of mean values exceeding Ohio Water Quality Standards for recreation.

[2] Number (percent) of total observations exceeding Ohio Water Quality Standards for recreation.

[3] 200 colonies per 100 milliliters.

[4] 1,000 colonies per 100 milliliters.

[5] 400 colonies per 100 milliliters.

[6] 2,000 colonies per 100 milliliters.

[7] 5,000 colonies per 100 milliliters.

Table 5.--Number and percentage of total number of *Escherichia coli* samples not meeting Ohio Water Quality Standards for recreation at sites on Scioto and Olentangy Rivers, July-October 1987, May-September 1988, and May-July 1989

[Numbers in parentheses are in percent]

Site name	Geometric-mean standard[1]	Single-sample standard[2]		
	Bathing water and primary contact[3]	Bathing waters[4]	Primary contact[5]	Secondary contact[6]
Scioto River below O'Shaughnessy Dam	1(100)	10(56)	10(56)	8(44)
Scioto River below Griggs Reservoir	0(0)	4(22)	4(22)	1(6)
Scioto River at Dublin Road Water Treatment Plant	4(57)	15(33)	9(20)	6(13)
Scioto River at Town Street	6(86)	27(60)	23(51)	19(42)
Scioto River at Greenlawn Avenue	1(100)	12(71)	11(65)	9(53)
Scioto River at Columbus	1(100)	16(89)	16(89)	14(78)
Olentangy River near Worthington	0(0)	7(39)	4(22)	4(22)
Olentangy River at Henderson Road	1(100)	10(56)	10(56)	8(44)
Olentangy River at Woody Hayes Drive	1(100)	17(94)	17(94)	16(89)
Olentangy River at Goodale Street	7(100)	42(91)	41(89)	33(72)

[1] Number (percent) of mean values exceeding Ohio Water Quality Standards for recreation.

[2] Number (percent) of total observations exceeding Ohio Water Quality Standards for recreation.

[3] 126 colonies per 100 milliliters.

[4] 235 colonies per 100 milliliters.

[5] 298 colonies per 100 milliliters.

[6] 576 colonies per 100 milliliters.

Table 6.--Geometric means or single-sample concentrations of fecal-coliform bacteria at sites on Scioto and Olentangy Rivers, July-October 1987, May-September 1988, and May-July 1989.

[All data are number of colonies per 100 milliliters; numbers in parentheses are from single samples; >, greater than; --, no data]

Site name	Geometric mean or single-sample concentration by month and year											
	7/87	8/87	9/87*	10/87	5/88	6/88	7/88	8/88	9/88	5/89	6/89	7/89
Scioto River below O'Shaughnessy Dam	(3,000)	2,450	310	(190)	(150)	(29)	(5,100)	(150)	(270)	(79)	(1,900)	(150)
Scioto River below Griggs Reservoir	(51)	54	96	(31)	(140)	(21)	(180)	(33)	(61)	(64)	(>3,000)	(27)
Scioto River at Dublin Road Water Treatment Plant	(120)	100	69	(24)	192	242	304	128	174	(85)	1,200	(63)
Scioto River at Town Street	(3,400)	1,460	252	(>1,200)	99	50	1,730	811	309	(820)	5,210	(430)
Scioto River at Greenlawn Avenue	(>100,000)	1,740	558	(>12,000)	(130)	(2,400,000)	(62,000)	(170)	(520)	(1,600)	(53,000)	(350)
Scioto River at Columbus	(24,000)	3,180	5,590	(>120,000)	(180)	(2,900)	(65,000)	(450)	(2,700)	(3,800)	(450,000)	(410)
Olentangy River near Worthington	(270)	152	90	(130)	(900)	(76)	(2,500)	(280)	(1,100)	(120)	(970)	(190)
Olentangy River at Henderson Road	(640)	238	437	(1,200)	(12,000)	(320)	(27,000)	(600)	(1,500)	(64)	(6,000)	--
Olentangy River at Woody Hayes Drive	(7,200)	7,060	641	1,200	(18,000)	(330)	(>60.000)	(5,500)	(3,600)	(910)	(6,100)	(2,500)
Olentangy River at Goodale Street	(>120,000)	76,200	916	(1,200)	571	514	2,040	14,400	1,740	(19,000)	7,910	(540)

*Geometric mean based on two samples. All others based on five samples.

Table 7.--Geometric means or single-sample concentrations of *Escherichia coli* at sites on Scioto and Olentangy Rivers, July-October 1987, May-September 1988, and May-July 1989

[All data are number of colonies per 100 milliliters; Numbers in parentheses re from single samples; >, greater than; --, no data]

Site name	Geometric mean value or single-sample number by month and year											
	7/87	8/87	9/87*	10/87	5/88	6/88	7/88	8/88	9/88	5/89	6/89	7/89
Scioto River below O'Shaughnessy Dam	(1,800)	1,900	281	(180)	(91)	(31)	(2,100)	(88)	(350)	(75)	(1,400)	(130)
Scioto River below Griggs Reservoir	(27)	60	150	(36)	(210)	(19)	(310)	(28)	(85)	(70)	(>3,000)	(33)
Scioto River at Dublin Road Water Treatment Plant	(34)	37	75	(18)	153	211	265	82	116	(100)	1,330	(66)
Scioto River at Town Street	(970)	350	220	(1,600)	107	44	1,260	401	281	(1,000)	5,210	(290)
Scioto River at Greenlawn Avenue	(60,000)	890	595	(>16,000)	(97)	(2,900,000)	(31,000)	(120)	(530)	(1,000)	(>53,000)	(270)
Scioto River at Columbus	(6,700)	2,410	4,970	(>160,000)	(220)	(4,200)	(35,000)	(320)	(1,800)	(2,300)	(100,000)	(320)
Olentangy River near Worthington	(29)	102	104	(110)	(770)	(58)	(1,900)	(150)	(820)	(110)	(1,100)	(200)
Olentangy River at Henderson Road	(500)	280	398	(1,000)	(8,700)	(200)	(19,000)	(470)	(1,200)	(94)	(2,200)	(140)
Olentangy River at Woody Hayes Drive	(900)	5,000	480	(800)	(5,800)	(150)	(>80,000)	(2,900)	(2,500)	(1,800)	(5,100)	(1,800)
Olentangy River at Goodale Street	(12,000)	33,700	848	(1,100)	409	383	1,710	11,700	1,230	(16,000)	7,430	(450)

*Geometric mean based on two samples. All others based on five samples.

Bathing-Water Standards

The geometric mean bathing-water standard is the most difficult standard to attain. Geometric means of fecal coliform and *E. coli* concentrations exceeded the bathing-water standard during all seven 30-day periods in which water samples were collected from Olentangy River at Goodale Street (tables 4 and 5 and fig. 5). The geometric means ranged from 514 to 76,200 col/100 mL for fecal coliform bacteria and from 383 to 33,700 col/100 mL for *E. coli*. Geometric means of fecal-coliform concentrations in samples from Scioto River at Dublin Road WTP exceeded the bathing-water standard in three of seven 30-day periods (43 percent of the samples) and ranged from 69 to 1,200 col/100 mL. For *E. coli* concentrations at Dublin Road WTP, geometric means exceeded the bathing water standard in four of seven 30-day periods (57 percent of the samples) and ranged from 37 to 1,330 col/100 mL. At Scioto River at Town Street, geometric means of fecal-coliform concentrations exceeded the bathing-water standard for six of seven 30-day periods (71 percent of samples) and ranged from 50 to 5,210 col/100 mL. For *E. coli* concentrations at Town Street, the geometric means exceeded the bathing-water standard for six of seven 30-day periods (86 percent of samples) and ranged from 44 to 5,210 col/100 mL.

Geometric means were determined once for all 10 sites in August 1987. In this month, the geometric means of fecal coliform and *E. coli* concentrations exceeded the bathing-water standard at 7 of 10 sites (tables 6 and 7). The geometric mean bathing-water standard for fecal-coliform bacteria was met in all samples collected at two sites, Scioto River below Griggs Reservoir and Olentangy River near Worthington. For *E. coli*, the geometric mean bathing-water standard was met in all samples collected at the same two upstream sites as fecal-coliform concentrations and also at Scioto River at Dublin Road WTP.

Concentrations of fecal-coliform and *E. coli* bacteria in single samples exceeded the bathing-water standard more often and by larger magnitudes at downstream sites (such as Olentangy River at Goodale Street and Scioto River at Greenlawn Avenue) than at upstream sites (such as Olentangy River near Worthington and Scioto River below Griggs Reservoir). Fecal-indicator concentrations in single samples from Olentangy River at Goodale Street exceeded the bathing-water standard in 83 percent of all samples for fecal-coliform bacteria and in 91 percent of all samples for *E. coli*. In contrast, fecal-indicator concentrations in single samples from Scioto River at Dublin Road WTP exceeded the bathing-water standard in 15 percent of all samples for fecal-coliform bacteria and in 20 percent of all samples for *E. coli*. Fecal-indicator concentrations in single samples from Scioto River at Town Street exceeded the bathing-water standard in 28 percent of all samples for fecal coliform and in 27 percent of all samples for E. coli. Fecal-indicator concentrations in single samples from the remaining seven sites exceeded the bathing-water standard for fecal-coliform and *E. coli* bacteria at least once during the study. The fewest samples in which bacteria concentrations exceeded the single sample standard were from Scioto River below Griggs Reservoir.

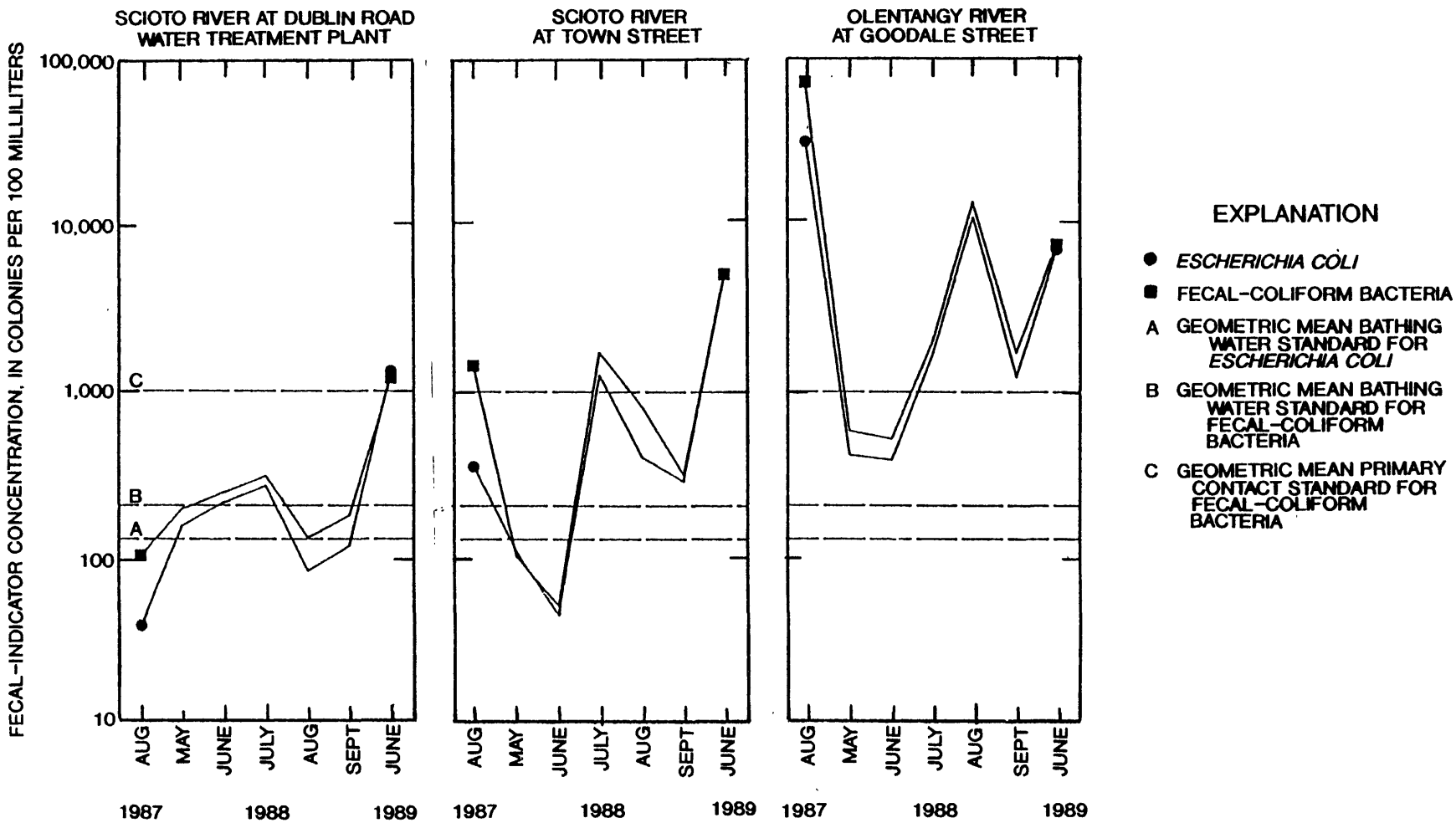

Figure 5.--Geometric means of fecal-coliform and *Escherichia coli* concentrations in Scioto River and one site in Olentangy River during the 1987, 1988, and 1989 recreational seasons.

Primary-Contact Standards

The geometric mean standard for *E. coli* for primary-contact recreation (126 col/100 mL) is the same as for bathing waters; therefore, the numbers of samples in which bacteria concentrations exceeded the standard are the same as those described in the previous section. The geometric mean primary-contact standard for fecal-coliform bacteria (1,000 col/100 mL) was exceeded for five of seven 30-day periods (71 percent of all samples) in Olentangy River at Goodale Street, one of seven 30-day periods (14 percent of all samples) in Scioto River at Dublin Road WTP, and three of seven 30-day periods (43 percent of all samples) in Scioto River at Town Street (fig. 5). The geometric mean primary-contact standard was exceeded at five of the other seven sites sampled in August 1987 (table 6). Fecal indicator concentrations exceeded the geometric mean primary-contact standard more often and by larger magnitudes in samples from Olentangy River at Goodale Street than at the other two intensively sampled sites.

Both fecal-indicator concentrations from single samples exceeded primary-contact standards at least once at all sites but less often for fecal-coliform bacteria than for *E. coli*. Fecal-coliform concentrations in single samples exceeded the primary-contact standard most frequently for Olentangy River at Woody Hayes Drive (76 percent of all samples) and at Goodale Street (50 percent of all samples) and for Scioto River at Columbus (72 percent of all samples). Fecal-coliform concentrations in single samples exceeded the standard least often at Scioto River below Griggs Reservoir and Dublin Road WTP and Olentangy River near Worthington. *E. coli* concentrations in single samples exceeded the primary-contact standard most often for Olentangy River at Woody Hayes Drive (94 percent of all samples) and at Goodale Street (89 percent of all samples).

Secondary-Contact Standards

Secondary-contact standards for fecal-coliform bacteria and *E. coli* are determined only from single samples. The percentage of total samples exceeding this standard for fecal coliforms (5,000 col/100mL) ranged from zero percent at Scioto River below Griggs Reservoir to 59 percent for Olentangy River at Woody Hayes Drive. The percentage of total samples for which the secondary-contact standard of 576 col/100 mL for *E. coli* was exceeded ranged from 6 percent for Scioto River below Griggs Reservoir to 89 percent for Olentangy River at Woody Hayes Drive.

VARIABILITY OF FECAL-INDICATOR BACTERIA

Instantaneous streamflow was measured at three locations--Olentangy River at Goodale Street, Scioto River at Dublin Road WTP, and at Town Street--on 20 dates during the recreational seasons in 1987-89 to gain an understanding of the variability of fecal-indicator concentrations caused by changes in streamflow (table 8). Streamflow was measured monthly, concurrent with collection of fecal-indicator bacteria and other water-quality samples, and before, during, and after two runoff-producing storms. Streamflow measured during rainfall-runoff studies documented amounts of runoff and the relative contribution of water and discharges of fecal-indicator bacteria to the Scioto River from Olentangy River. Instantaneous streamflow was measured monthly to estimate the relative contribution of streamflow during stable base flow to Scioto River from the Olentangy River (as measured at Goodale Street).

Variability of Streamflow in Scioto and Olentangy Rivers

The instantaneous streamflow of Olentangy River (near the confluence with Scioto River, at Goodale Street) was greater than the instantaneous streamflow of Scioto River (as measured at Dublin Road WTP upstream from the confluence with Olentangy River) for the 14 measurements in 1987 and 1988 (table 8). For measurements made during the 1987-88 period, the Olentangy River contributed from 54.8 to nearly 100 percent of the total streamflow in Scioto River at Town Street. The median annual rainfall (total from 16 measurement sites) in the Columbus area for 1987 was 26.7 inches and in 1988 was 37.8 inches (Dave Cashell, Ohio Department of Natural Resources, written commun., 1991) Because 1987 and 1988 were drier during the recreational season than normal years, most of the streamflow of Scioto River during these two recreational seasons was diverted just upstream from the Dublin Road WTP measurement site by the City of Columbus, Division of Water, for drinking water. Therefore, Olentangy River was the primary source of water for Scioto River at the time of most sampling and measurement during 1987 and 1988.

In contrast, 1989 was a wet year in comparison with 1987 and 1988. The median annual rainfall for 1989 in the Columbus area was 44.9 inches (Dave Cashell, Ohio Department of Natural Resources, written commun., 1991). Because of greater runoff during the recreational season in 1989 compared to 1987 and 1988, the instantaneous streamflow of Olentangy River was less than the instantaneous streamflow of Scioto River in four of six measurements during May-July 1989. The contribution of streamflow from Olentangy River to Scioto River at Town Street for the 1989 measurements ranged from 35.2 to 50.1 percent of the total streamflow. Therefore, Olentangy River and Scioto River each made substantial contributions to the total streamflow of Scioto River at Town Street at the time of sampling in 1989.

Table 8.--Instantaneous streamflow at selected sites on Scioto and Olentangy Rivers and corresponding percentage of total contribution to streamflow of Scioto River upstream from Town Street

[Streamflow in cubic feet per second; <, less than; --, no data]

Date	Olentangy River at Goodale Street		Scioto River at Dublin Road WTP		Scioto River at Town Street	
	Streamflow	Percentage of contribution to Scioto River	Streamflow	Percentage of contribution to Scioto River	Streamflow	Percentage of contribution to Scioto River
1987						
July 30	58.0	100.0	<1.0	<1.0	--	--
Aug 27	76.4	100.0	<1.0	<1.0	--	--
Sept 14	35.9	100.0	<1.0	<1.0	--	--
Oct 8	51.2	100.0	<1.0	<1.0	--	--
1988						
May 23	215	69.4	94.8	30.6	--	--
June 21	19.5	100.0	<1.0	<1.0	--	--
July 7	13.0	100.0	<1.0	<1.0	--	--
July 13	30.8	100.0	<1.0	<1.0	--	--
July 14	12.5	100.0	<1.0	<1.0	--	--
July 19	490	78.1	137	21.9	--	
Aug 17	31.9	61.9	19.6	38.1	61.2	100.0
Sept 12	48.8	54.8	40.3	45.2	--	--
Sept 19	68.2	57.7	50.0	42.3	--	--
Sept 20	70.9	58.3	50.7	41.7	--	--
1989						
May 18	561	50.1	--	--	1120	100.0
June 22	1,510	49.8	--	--	3030	100.0
June 27	174	44.1	--	--	395	100.0
June 28	762	55.6	--	--	1370	100.0
June 29	445	35.9	--	--	1240	100.0
June 30	532	35.2	--	--	1510	100.0

Variability of Fecal-Indicator Bacteria Concentrations

Samples for enumeration of fecal-coliform bacteria and *E. coli* during runoff-producing storms were collected at three sites--Olentangy River at Goodale Street, and Scioto River at Dublin Road WTP and Town Street. Samples were collected before, during, and at 24-hour intervals for as much as 72 hours after three runoff-producing storms. The storms occurred on May 23 and July 13, 1988, and on June 27, 1989. Instantaneous streamflow was measured and discharges of fecal-indicator bacteria were calculated for selected time intervals and locations for only the July 1988 and June 1989 storms (tables 9 & 10).

Fecal-coliform and *E. coli* concentrations in samples collected during the first 24 hours after the storms were 5 to 10 times greater than the fecal-indicator concentrations in samples collected before the storms. The concentrations of fecal-indicator bacteria in samples collected 48 to 72 hours after the storms decreased to concentrations close to those preceding runoff (figs. 6 and 7).

This pattern of high fecal-indicator concentrations during and immediately after rainfall and runoff was noted for Olentangy River at Goodale Street and Scioto River at Town Street for all three storms, but fecal-indicator discharges were documented for the two later storms when concurrent streamflow measurements were made (tables 9 and 10 and figs. 6 and 7). This pattern was observed also in samples collected at Scioto River at Dublin Road WTP before, during, and after two storms. The storm of July 13, 1988, did not fit this pattern for Scioto River at the Dublin Road WTP site because this section of the study area received insufficient rainfall during the storm to cause measurable runoff during the time periods measured.

During and immediately after two of the three storms, fecal-coliform and *E. coli* concentrations for Scioto River at Dublin Road WTP increased to and exceeded the single-sample water-quality standard for primary-contact recreation of 2,000 col/100 mL for fecal-coliform bacteria and the standard of 298 col/100 mL for *E. coli*. Samples collected at this site during base flow typically met water-quality standards for bathing water.

In contrast, fecal-coliform and *E. coli* concentrations at Olentangy River at Goodale Street exceeded the single-sample water-quality standards for primary-contact recreation before two of the three storms (figs. 6 and 7). Fecal-indicator concentrations at Olentangy River at Goodale Street exceeded the secondary-contact standard of 5,000 col/100 mL for fecal-coliform bacteria and the standard of 576 col/100 mL for *E. coli* before one of the storms. At Olentangy River at Goodale Street and Scioto River at Town Street, rainfall and runoff further increased the concentrations of fecal-indicator organisms to well above the recreational standards during and immediately after the storms.

Table 9.--Fecal-coliform-bacteria discharges and percentage of discharge contributed to Scioto River upstream from Town Street before, during, and after storms of July 13, 1988, and June 27, 1989.

[Discharge in million colonies per second; --, no data]

Date of storm and sample collection interval	Olentangy River at Goodale Street		Scioto River at Dublin Road WTP	
	Fecal-coliform-bacteria discharge	Percentage of contribution to Scioto River	Fecal-coliform-bacteria discharge	Percentage of contribution to Scioto River
July 13, 1988				
before	2.5	99.6	<0.01	0.4
during	96	99.9	.08	.1
24 hours after	1.6	96.9	.05	3.0
48 hours after	--	--	.03	--
Total	100.1		0.17	
June 27, 1989				
before	940	99.6	4.4	0.4
during	7,600	86.4	1,200	13.6
24 hours after	380	32.5	790	67.5
48 hours after	320	81.6	72	18.4
Total	9,240		2,066.4	

Table 10.--*Escherichia coli* discharges and percentage of total discharge contributed to the Scioto River upstream from Town Street before, during, and after storms of July 13, 1988, and June 27, 1989

[Discharge in million colonies per second; --, no data]

Date of storm and sample collection interval	Olentangy River at Goodale Street		Scioto River at Dublin Road WTP	
	Escherichia coli bacteria discharge	Percentage of contribution to Scioto River	*Escherichia coli* bacteria discharge	Percentage of contribution to Scioto River
July 13, 1988				
before	2.3	>99.6	<0.004	<0.01
during	96	>99.9	.07	<0.01
24 hours after	1.7	97.7	.04	2.3
48 hours after	--	--	.03	--
Total	100.0		0.144	
June 27, 1989				
before	590	99.6	2.6	0.4
during	5,200	73.2	1,900	26.8
24 hours after	380	22.6	1,300	77.4
48 hours after	600	87.1	89	12.9
Total	6,770		3,291.6	

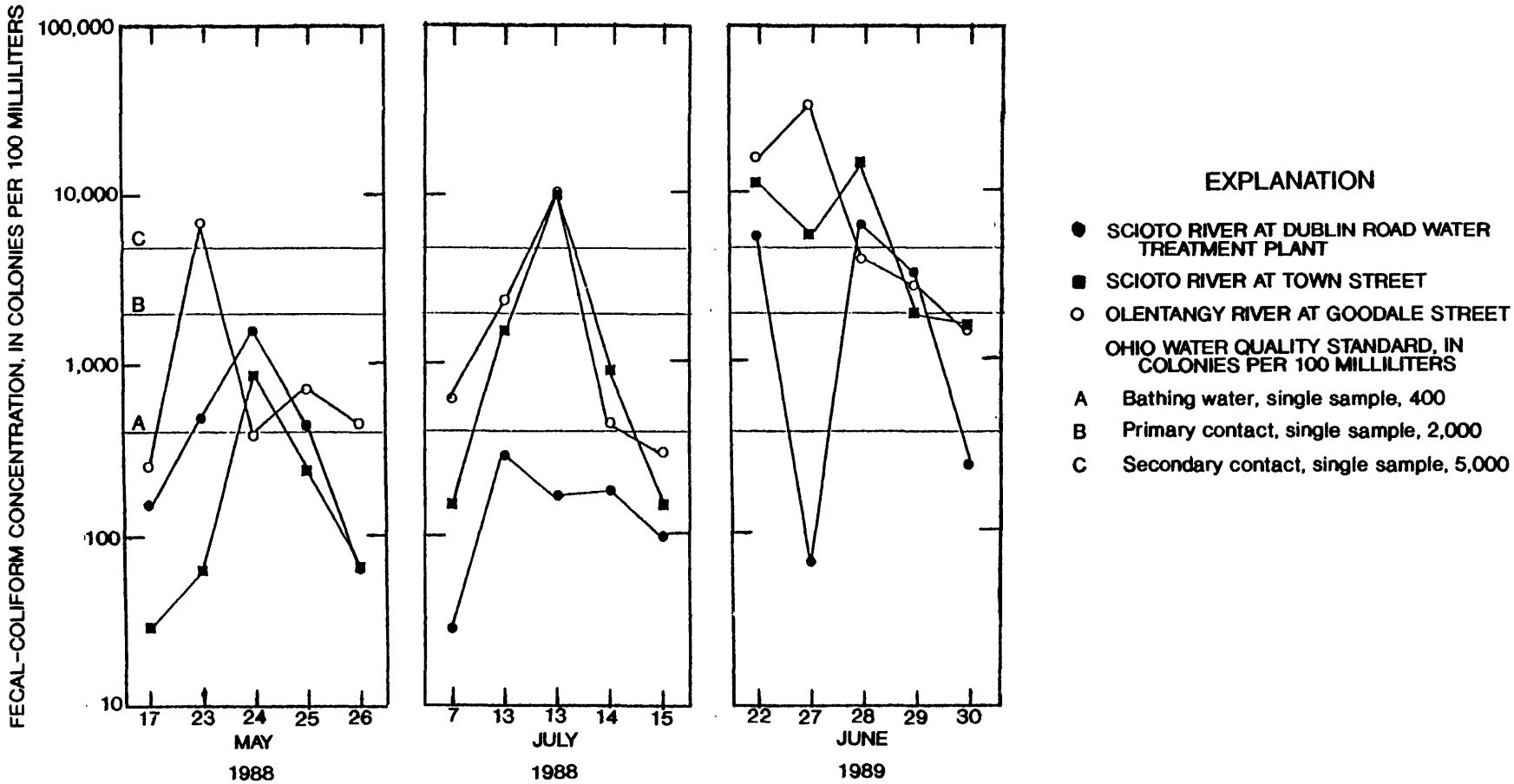

Figure 6.--Fecal-coliform concentration at two sites in Scioto River and one site in Olentangy River before, during, and at 24-hour intervals after three runoff producing storms.

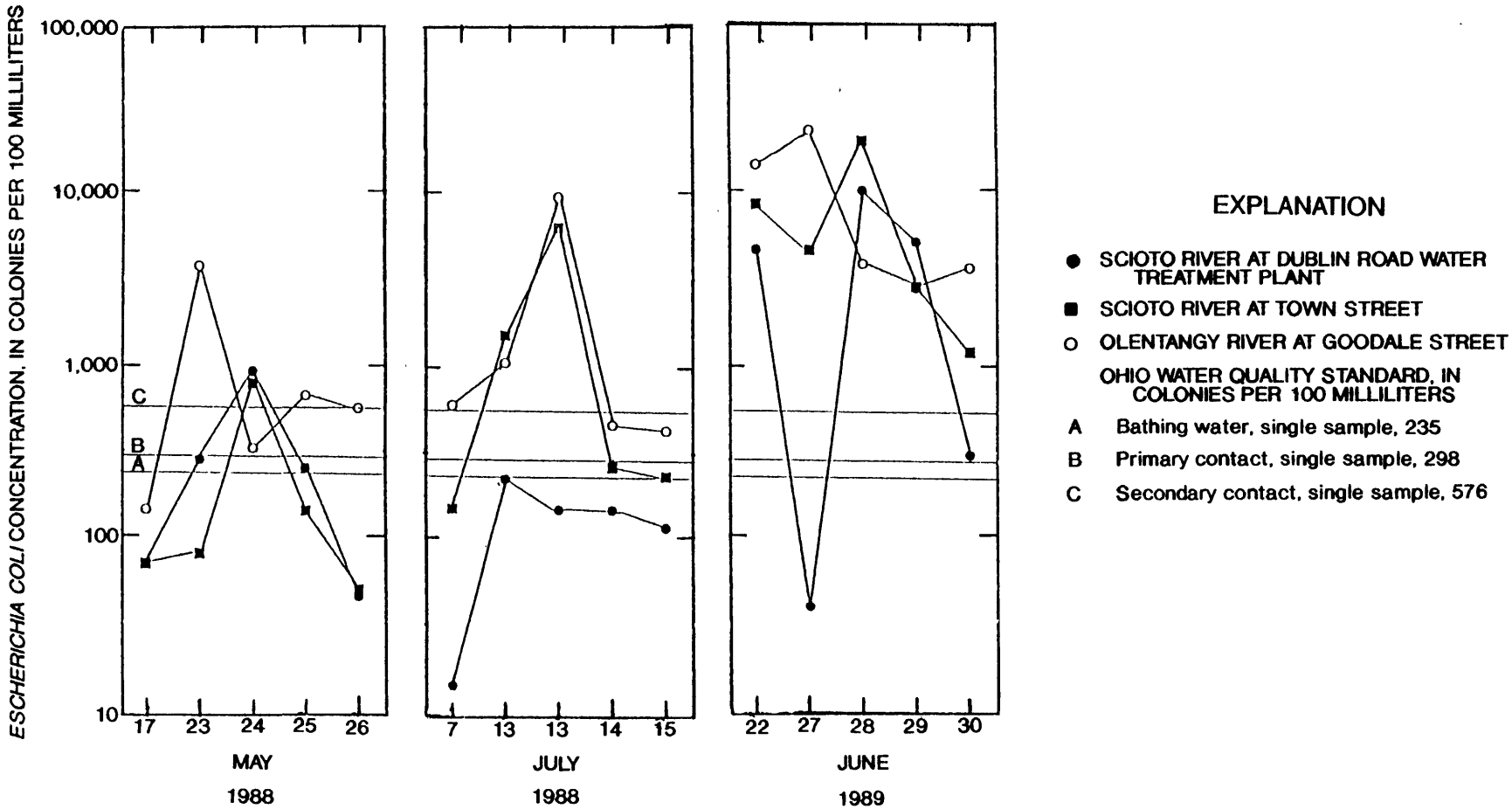

Figure 7.--*Escherichia coli* concentration at two sites in Scioto River and one site in Olentangy River before, during, and at 24-hour intervals after three runoff producing storms.

Variability of Fecal-Indicator-Bacteria Discharges

Discharges of fecal-indicator bacteria were calculated as the product of bacteria concentrations in the sample, a conversion factor, and instantaneous streamflow by the following formula:

$$D = (\text{Concentration} \times 283.1625 \times Q) / 10^6,$$

where

D is discharge, in 10^6 colonies per second;
Concentration is fecal-indicator concentration, in colonies per 100 mL;
Q is streamflow, in cubic feet per second, and
283.1625 is a conversion factor.

Fecal-indicator-bacteria discharges were calculated from samples collected and streamflow measured before, during, and 24 and 48 hours after two separate storms for Olentangy River at Goodale Street and Scioto River at Dublin Road WTP. The July 13, 1988 storm produced a small amount of rainfall, 0.01 to 0.48 inches (Dave Cashell, Ohio Department of Natural Resources, written commun., 1991) and small increases in streamflow in Olentangy River at Goodale Street compared to increases during the June 1989 storm. In contrast, the storm of June 27-28, 1989, produced larger amounts of rainfall, 0.35 to 2.00 inches, spread over 2 days, and streamflows measured or calculated by difference at the two sites (table 8) exceeded that on July 13, 1989.

During and after both storms, Olentangy River was the primary source of fecal-indicator bacteria to the downstream segment of Scioto River; the discharges of fecal-indicator bacteria at Olentangy River at Goodale Street were, for the most part, greater than discharges at Scioto River at Dublin Road WTP (tables 9 and 10). The discharges of fecal-indicator bacteria entering the downstream segment of Scioto River from Olentangy River at Goodale Street ranged from 96.9 to nearly 100 percent of the total discharge computed from samples collected at both upstream sites for the July 1988 storm and from 22.6 to 99.6 percent for the June 1989 storm.

GENERAL WATER QUALITY

Measurements of chemical constituents and physical properties at upstream sites were compared to those at downstream sites to determine if water quality changes with distance downstream. Upstream sites for Scioto River were Scioto River below O'Shaughnessy Reservoir, below Griggs Dam, and at Dublin Road WTP. Upstream sites for Olentangy River were Olentangy River at Worthington and Henderson Road. Comparisons were made of specific conductance, pH, and concentrations of dissolved oxygen, total alkalinity, total chloride, total nonfilterable residue (103-105°C), total nitrate plus nitrite as nitrogen, total kjeldahl nitrogen, total phosphorus, and total organic carbon. Distribution-data for these constituents and properties are shown in box plots (figs. 8-17) and are listed in summary tables by constituent or physical property in the Supplemental Data section at the back of the report (tables 11-20).

For Scioto River, median pH and median concentrations of dissolved oxygen, total chloride, total nonfilterable residue, nitrate plus nitrite as nitrogen, total kjeldahl nitrogen, and total phosphorus were lower at upstream sites than at downstream sites. Median pH ranged from 7.6 to 7.8 at upstream sites and from 7.8 to 7.9 at downstream sites. Median concentrations of dissolved oxygen ranged from 6.1 to 7.7 mg/L at upstream sites and from 7.1 to 8.6 mg/L at downstream sites. Dissolved-oxygen concentration was less than the Ohio Water Quality Standard of 3.0 mg/L for several single measurements of Scioto River below O'Shaughnessy Dam and at Greenlawn Avenue (fig. 10). Median total chloride concentrations ranged from 30 to 35 mg/L at upstream sites and from 45 to 50 mg/L at downstream sites. Median total nonfilterable residue concentrations ranged from 11.0 to 18.0 mg/L at upstream sites and from 18.0 to 20.0 mg/L at downstream sites. Median nitrate plus nitrite as nitrogen concentrations ranged from 0.32 mg/L to 0.70 mg/L at upstream sites and from 0.50 to 0.83 mg/L at downstream sites. Median total kjeldahl nitrogen concentrations ranged from 0.80 to 1.0 mg/L at upstream sites and from 0.90 to 1.3 mg/L at downstream sites. Median total phosphorus concentrations ranged from 0.13 to 0.17 mg/L at upstream sites and from to 0.07 to 0.20 mg/L at downstream sites.

For Scioto River, the medians of specific conductance, total alkalinity, and total organic carbon concentration, were somewhat higher at upstream sites than at downstream sites. Specifically, median specific conductance ranged from 624 to 688 µS/cm at upstream sites and from 605 to 660 µS/cm at downstream sites. Median total alkalinity concentrations ranged from 150 to 170 mg/L at upstream sites and were 150 mg/L at all three downstream locations. Median total organic carbon concentrations ranged from 6.0 to 6.3 mg/L at upstream sites and from 5.9 to 6.0 mg/L at downstream sites.

For Olentangy River, medians for specific conductance, and concentrations of dissolved oxygen, total kjeldahl nitrogen, and total organic carbon were lower at upstream sites than at downstream sites. Median specific conductances were 652 and 686 µS/cm at upstream sites and ranged from 652 to 693 µS/cm at downstream sites. Median dissolved oxygen concentrations ranged from 7.2 to 7.4 mg/L at upstream sites and were 6.4 to 8.2 at downstream sites. Median total kjeldahl nitrogen concentrations each were 0.60 mg/L at two upstream sites and were 0.70 and 0.90 mg/L at two downstream sites. Median total organic carbon concentrations were 5.7 mg/L at upstream sites and 5.7 and 5.8 mg/L at downstream sites.

For Olentangy River, median pH was somewhat higher at upstream sites than at downstream sites. Median pH values ranged from 7.8 and 8.0 at upstream sites and were 7.6 and 7.9 at downstream sites. Median total nonfilterable residue concentrations were 20 and 23 mg/L at upstream sites and 19 and 20 mg/L at downstream sites. Median nitrate plus nitrite as nitrogen concentrations ranged from 1.50 to 1.82 mg/L at upstream sites and from 1.36 to 1.40 mg/L at downstream sites. Median total phosphorus concentration ranged from 0.17 to 0.20 mg/L at upstream sites and was 0.17 mg/L at downstream sites. No pattern of change from upstream to downstream sites in Olentangy River was observed for dissolved oxygen, total alkalinity, and total chloride. Median concentrations ranged from 6.4 to 8.2 mg/L for dissolved oxygen, from 145 to 160 mg/L for total alkalinity, and from 44 to 46 mg/L for total chloride at all four sites on Olentangy River.

SUMMARY AND CONCLUSIONS

Assessments of recreational suitability and general water quality in the Scioto and Olentangy Rivers in the Columbus area were based on results of analyses of samples from 10 fecal-indicator bacteria and sample-collection sites. Three sites were investigated in detail by use of a high frequency of sample collection. This information was used for a detailed evaluation of Ohio Water Quality Standards for recreation and the effect of rainfall and runoff on fecal-indicator concentrations and discharges. Concentrations of fecal-indicator bacteria during parts of three recreational seasons were investigated by collecting samples during July-October 1987, May-September 1988, and May-July 1989.

The concentrations of fecal-coliform and *E. coli* bacteria in Scioto and Olentangy Rivers during this study spanned a range of five orders of magnitude, from less than 20 to more than 2,400,000 col/100 mL. These data represent base flow as well as storm runoff. Concentrations of fecal-indicator bacteria were higher at downstream sample-collection sites than at upstream sites for the two rivers. The median concentrations of fecal-coliform bacteria at 10 stream sites ranged from 62 to 5,350 col/100 mL, whereas the median concentrations of *E. coli* ranged from 62 to 3,950 col/100 mL. The smallest median concentrations were for Scioto River below Griggs Reservoir, and the largest median concentrations were for Olentangy River at Woody Hayes Drive.

The bathing-water standard based on the geometric mean is the most difficult to meet; this standard was met 100 percent of the time only for Scioto River below Griggs Reservoir and for Olentangy River near Worthington. Geometric mean fecal-coliform and *E. coli* concentrations were higher than the bathing-water standard in August 1987 for five of the remaining seven sites for which geometric means were determined in that one month only.

The geometric-mean primary-contact standard for fecal coliforms was exceeded for five of seven 30-day periods (71 percent of the samples) for Olentangy River at Goodale Street and for three of seven 30-day periods (43 percent of the samples) for Scioto River at Town Street. The geometric-mean primary-contact standard for fecal-coliform bacteria was exceeded once in seven 30-day periods (14 percent of the samples) for Scioto River at Dublin Road WTP.

Single-sample primary-contact standards for fecal coliforms and *E. coli* were exceeded at least once at all sites and most frequently at Olentangy River at Woody Hayes Drive and Goodale Street and at Scioto River at Frank Road. Single-sample standards were exceeded least often at upstream sites, including Scioto River below Griggs Reservoir, Scioto River at Dublin Road WTP, and Olentangy River near Worthington.

Because streamflow can be a factor contributing to the variability of fecal-indicator bacteria, instantaneous streamflow was measured at three sites--Olentangy River at Goodale Street, Scioto River at Dublin Road WTP, and Scioto River at Town Street--on 20 separate dates during parts of the recreational seasons of 1987-89. Streamflow was measured monthly and before, during, and after two runoff-producing storms. The streamflow measurements obtained monthly were used for computing the percentage of streamflow contributed by Olentangy River to Scioto River during base flow in the recreational seasons investigated. Streamflow measured during runoff studies documented amounts of runoff and the discharge of fecal-indicator concentrations to the Scioto River from Olentangy River.

The instantaneous streamflow of Olentangy River (near the mouth at Goodale Street) was greater than that of Scioto River (above the confluence with Olentangy River at Dublin Road WTP) for the 14 measurements in 1987 and 1988. Olentangy River was the primary source of water to the Scioto River at Town Street for measurements in 1987 and 1988. In contrast, the instantaneous streamflow of Olentangy River was less than that of Scioto River for four of six measurements in 1989, a wet year compared to that for similar periods of measurement in 1987-88. Therefore, both rivers contributed substantially to the total streamflow of Scioto River in the Columbus, Ohio, area during the 1989 measurement period.

Fecal coliform and *E. coli* concentrations were 5 to 10 times higher in samples collected during the first 24 hours after rainfall and runoff than in samples collected before rainfall and runoff. The concentrations of fecal-indicator bacteria in water samples collected 48 to 72 hours after rainfall and runoff decreased to concentrations close to those preceding runoff.

Olentangy River was the primary source of fecal-indicator-bacteria discharges to the Scioto River at Town Street. During the two storms studied, the discharges of fecal-indicator bacteria from Olentangy River at Goodale Street were as much as an order of magnitude greater than discharges of fecal bacteria from Scioto River at Dublin Road WTP. The discharges to Scioto River at Town Street from Olentangy River ranged from 22.6 to nearly 100 percent of the total at given times.

In contrast to fecal-indicator bacteria, the magnitude of differences in values of water-quality characteristics between upstream and downstream sites was small. For Scioto River, the median values of 7 of 10 constituents and properties were lower at the three upstream sites than at the three downstream sites. For Olentangy River, the median values of only 3 of 10 constituents and properties were lower at the two most upstream sites than at the two most downstream sites.

Sources of fecal-indicator bacteria within the Columbus area include combined-sewer overflows, stormwater, and direct urban runoff. The only sewage-treatment plant in the study area was eliminated in 1989. Thus, most of the fecal-indicator bacteria in the study area were from nonpoint sources; combined-sewer overflows; small, unregulated sanitary-sewage discharges; or intermittent breakdowns in the sewage-collection system.

Control of nonpoint, unregulated, and intermittent sources of fecal-indicator bacteria and associated contaminants in the Columbus area could lead to improved recreational water quality in Scioto and Olentangy Rivers. In this study, most of the discharge of fecal-indicator bacteria to Scioto River at Town Street was from Olentangy River. Special emphasis on controlling sources of fecal-indicator bacteria to Olentangy River during periods of base flow could improve the quality of water in Scioto River above Town Street.

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SUPPLEMENTAL DATA

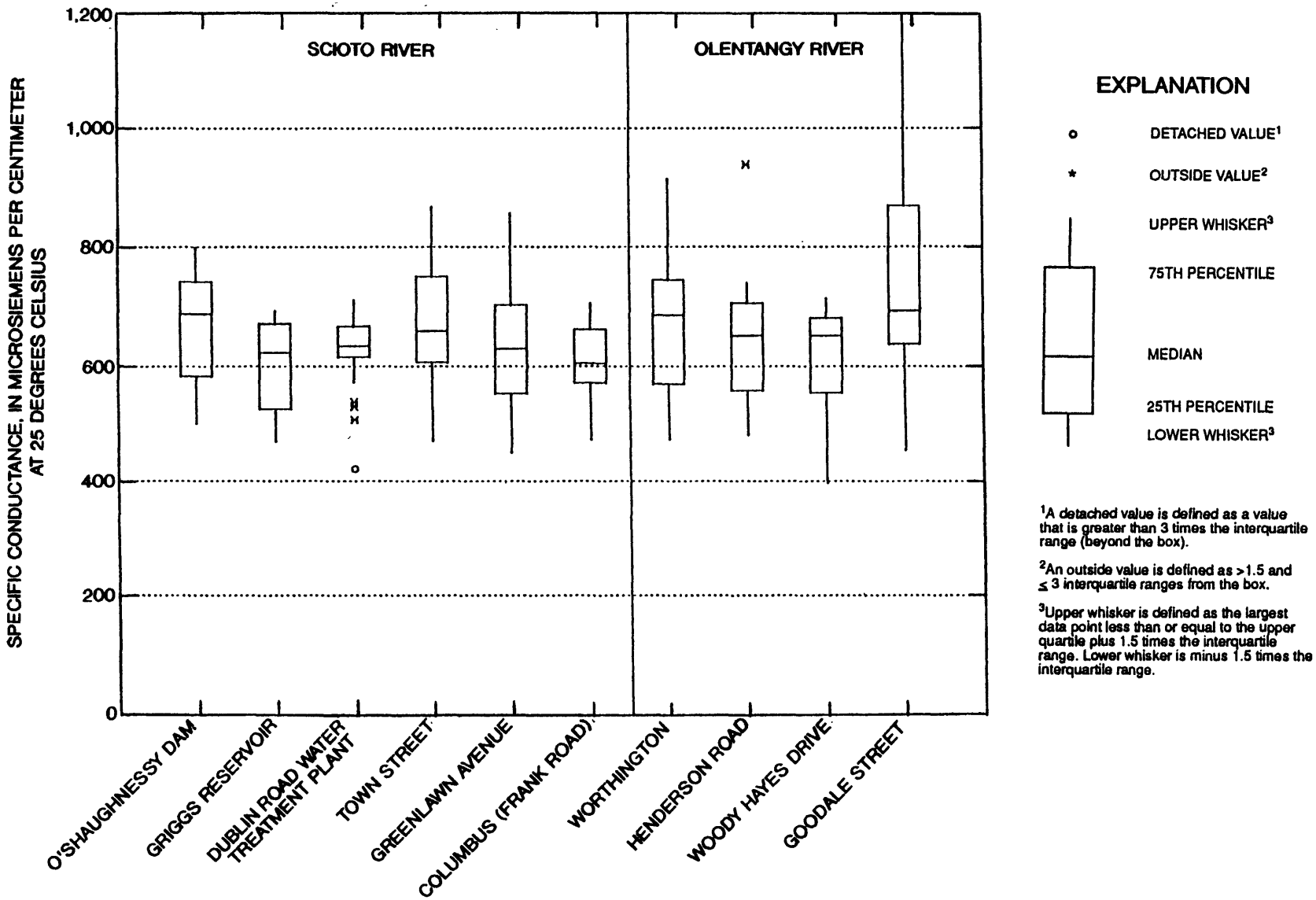
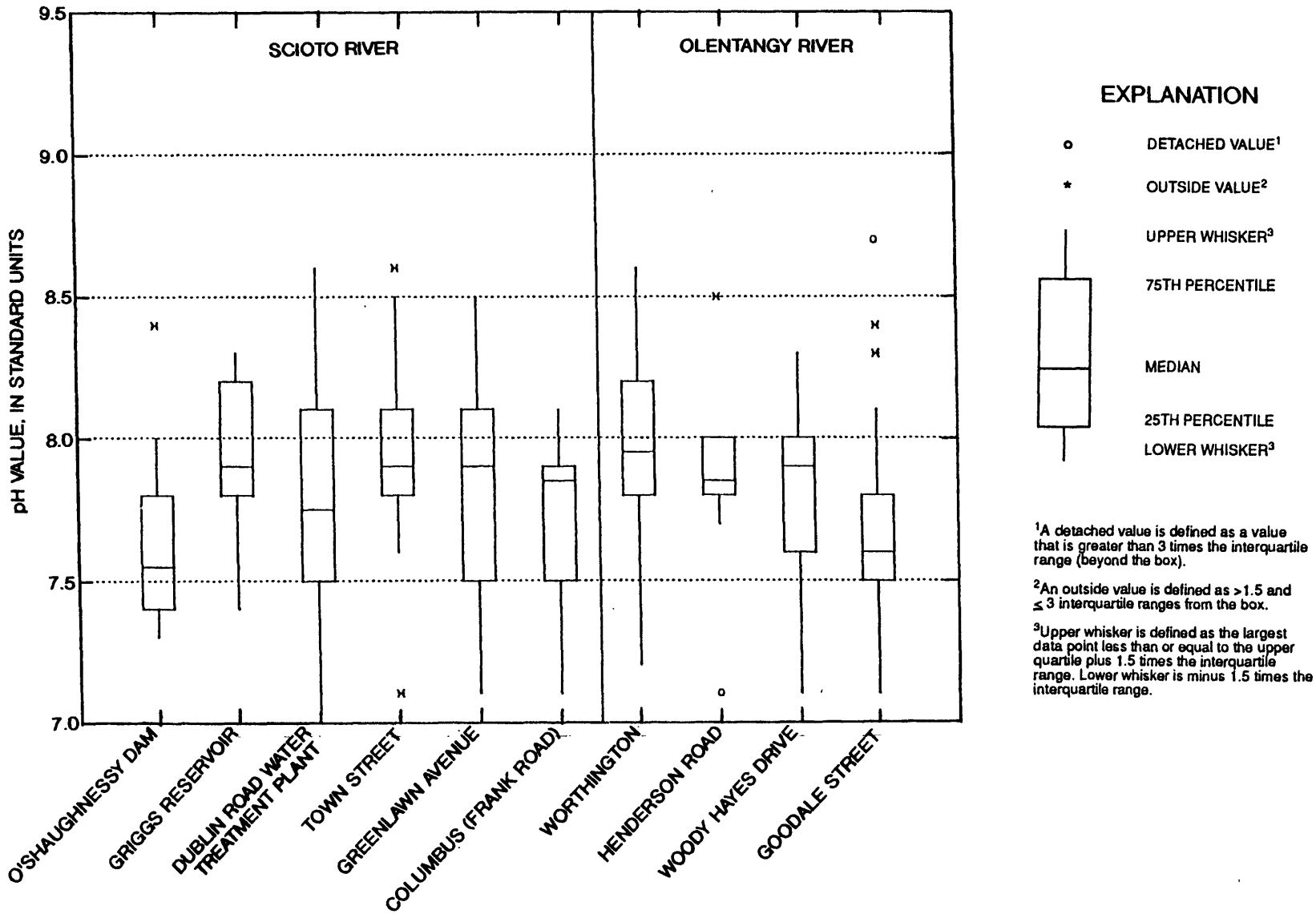


Figure 8.---Box plots showing distribution of specific-conductance values in Scioto and Olentangy Rivers for the recreational seasons of 1987, 1988, and 1989.

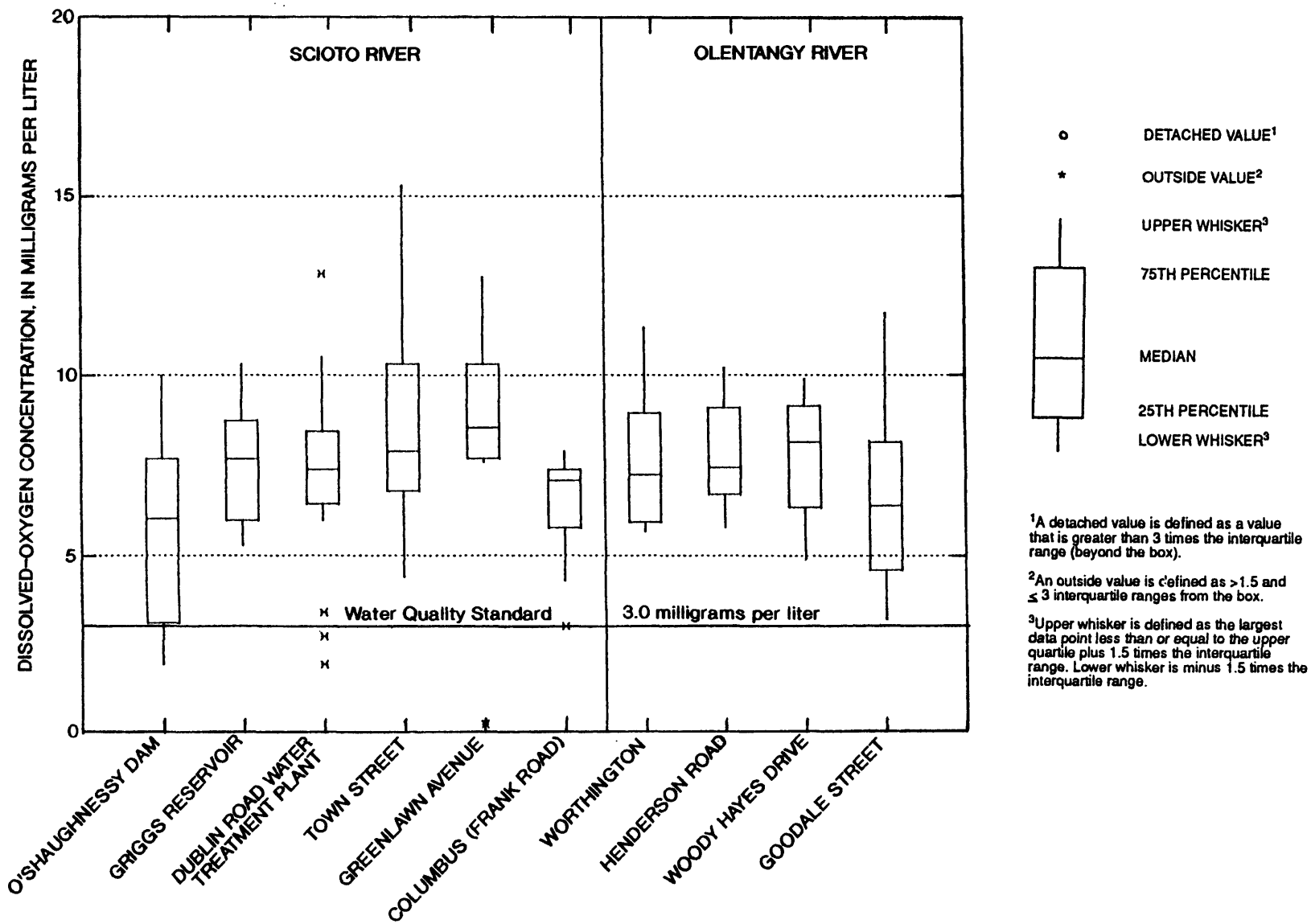


[1]A detached value is defined as a value that is greater than 3 times the interquartile range (beyond the box).

[2]An outside value is defined as >1.5 and ≤ 3 interquartile ranges from the box.

[3]Upper whisker is defined as the largest data point less than or equal to the upper quartile plus 1.5 times the interquartile range. Lower whisker is minus 1.5 times the interquartile range.

Figure 9.--Box plots showing distribution of pH values in Scioto and Olentangy Rivers for the recreational seasons of 1987, 1988, and 1989.

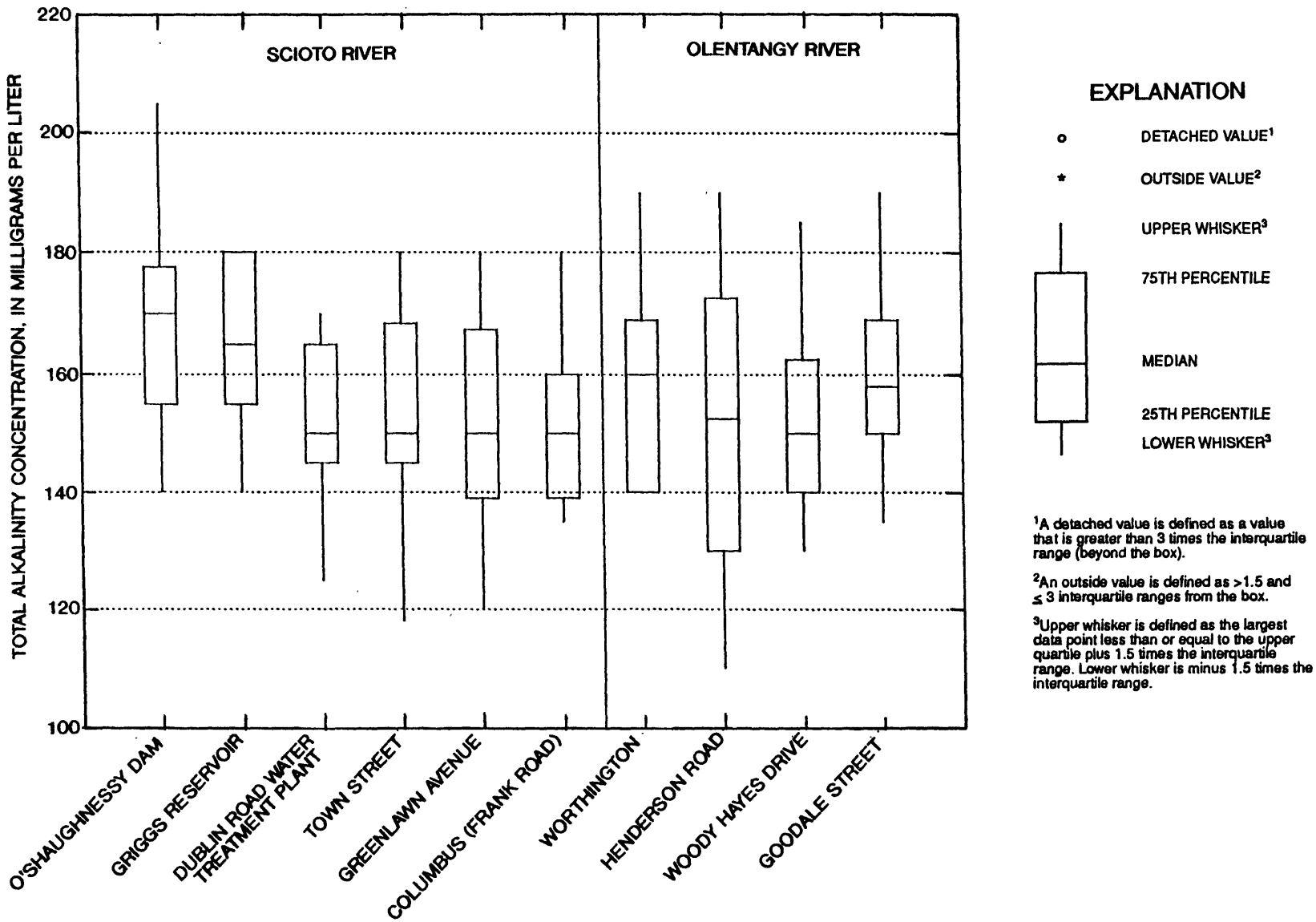


[1]A detached value is defined as a value that is greater than 3 times the interquartile range (beyond the box).

[2]An outside value is defined as >1.5 and ≤ 3 interquartile ranges from the box.

[3]Upper whisker is defined as the largest data point less than or equal to the upper quartile plus 1.5 times the interquartile range. Lower whisker is minus 1.5 times the interquartile range.

Figure 10.--Box plots showing distribution of dissolved-oxygen concentration in Scioto and Olentangy Rivers for the recreational seasons of 1987, 1988, and 1989.

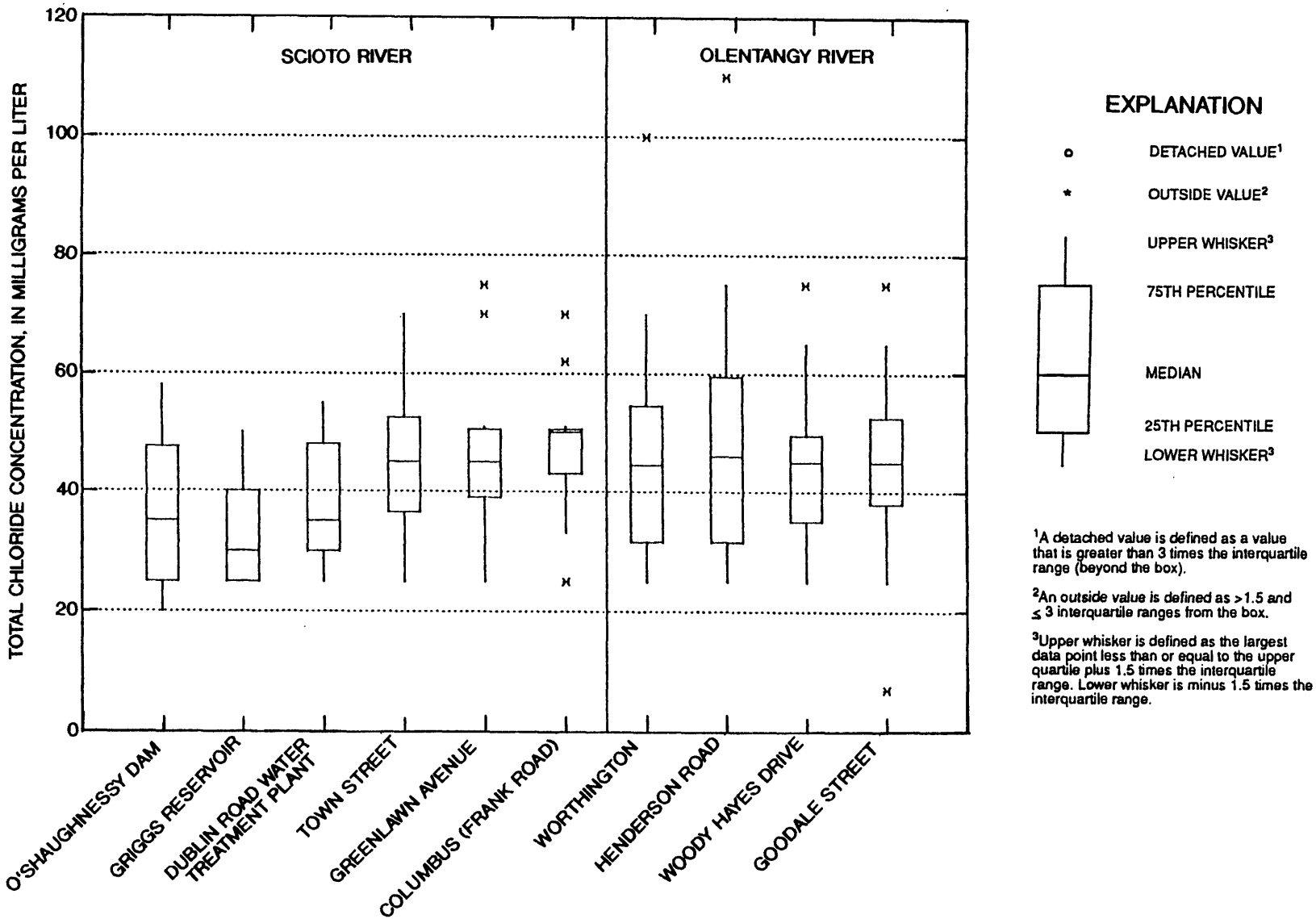


[1]A detached value is defined as a value that is greater than 3 times the interquartile range (beyond the box).

[2]An outside value is defined as >1.5 and ≤ 3 interquartile ranges from the box.

[3]Upper whisker is defined as the largest data point less than or equal to the upper quartile plus 1.5 times the interquartile range. Lower whisker is minus 1.5 times the interquartile range.

Figure 11.--Box plots showing distribution of total alkalinity concentration in Scioto and Olentangy Rivers for the recreational seasons of 1987, 1988, and 1989.



[1]A detached value is defined as a value that is greater than 3 times the interquartile range (beyond the box).

[2]An outside value is defined as >1.5 and ≤ 3 interquartile ranges from the box.

[3]Upper whisker is defined as the largest data point less than or equal to the upper quartile plus 1.5 times the interquartile range. Lower whisker is minus 1.5 times the interquartile range.

Figure 12.--Box plots showing distribution of total chloride concentration in Scioto and Olentangy Rivers for the recreational seasons of 1987, 1988, and 1989.

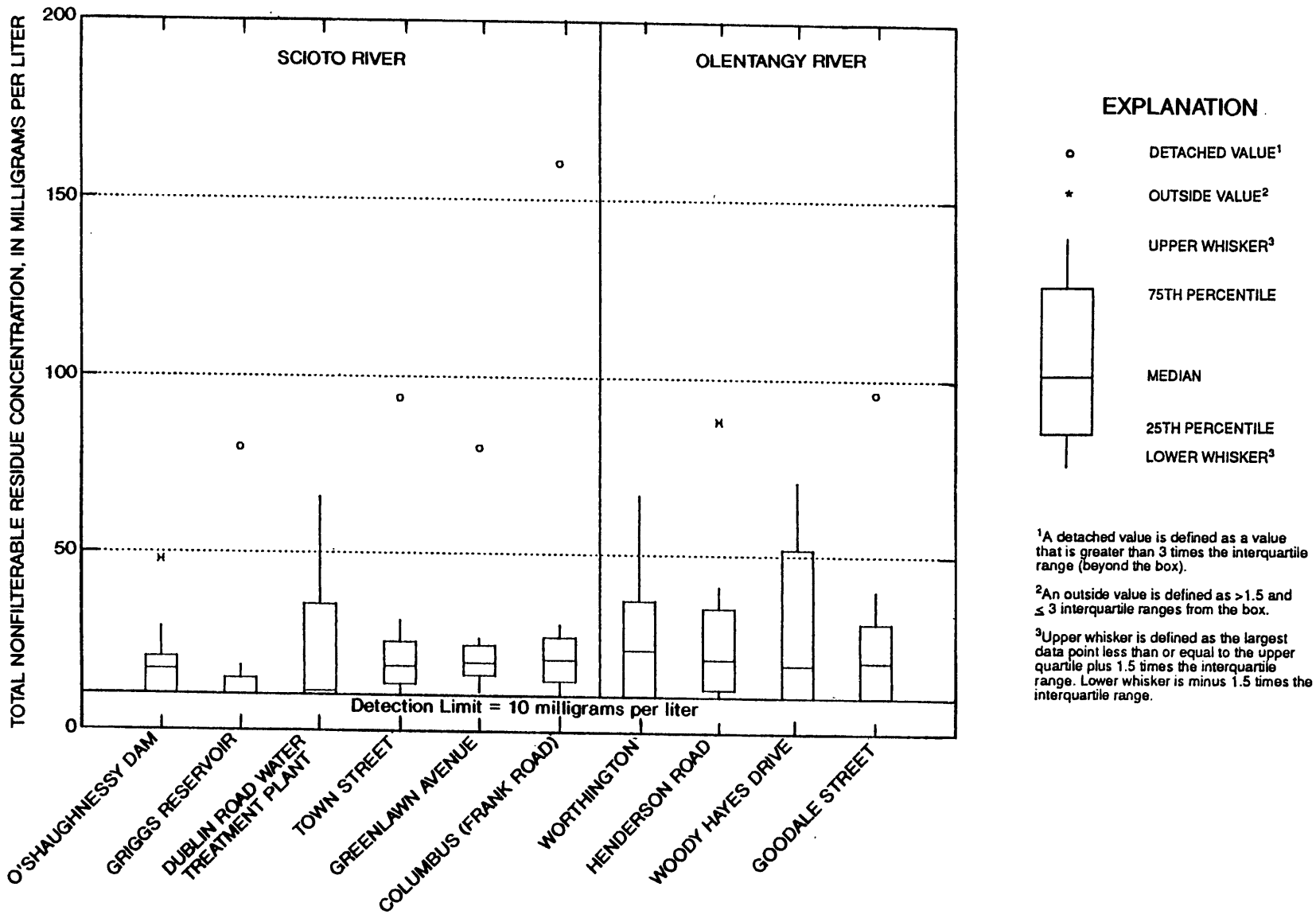


Figure 13.--Box plots showing distribution of total nonfilterable residue concentration in Scioto and Olentangy Rivers for the recreational seasons of 1987, 1988, and 1989.

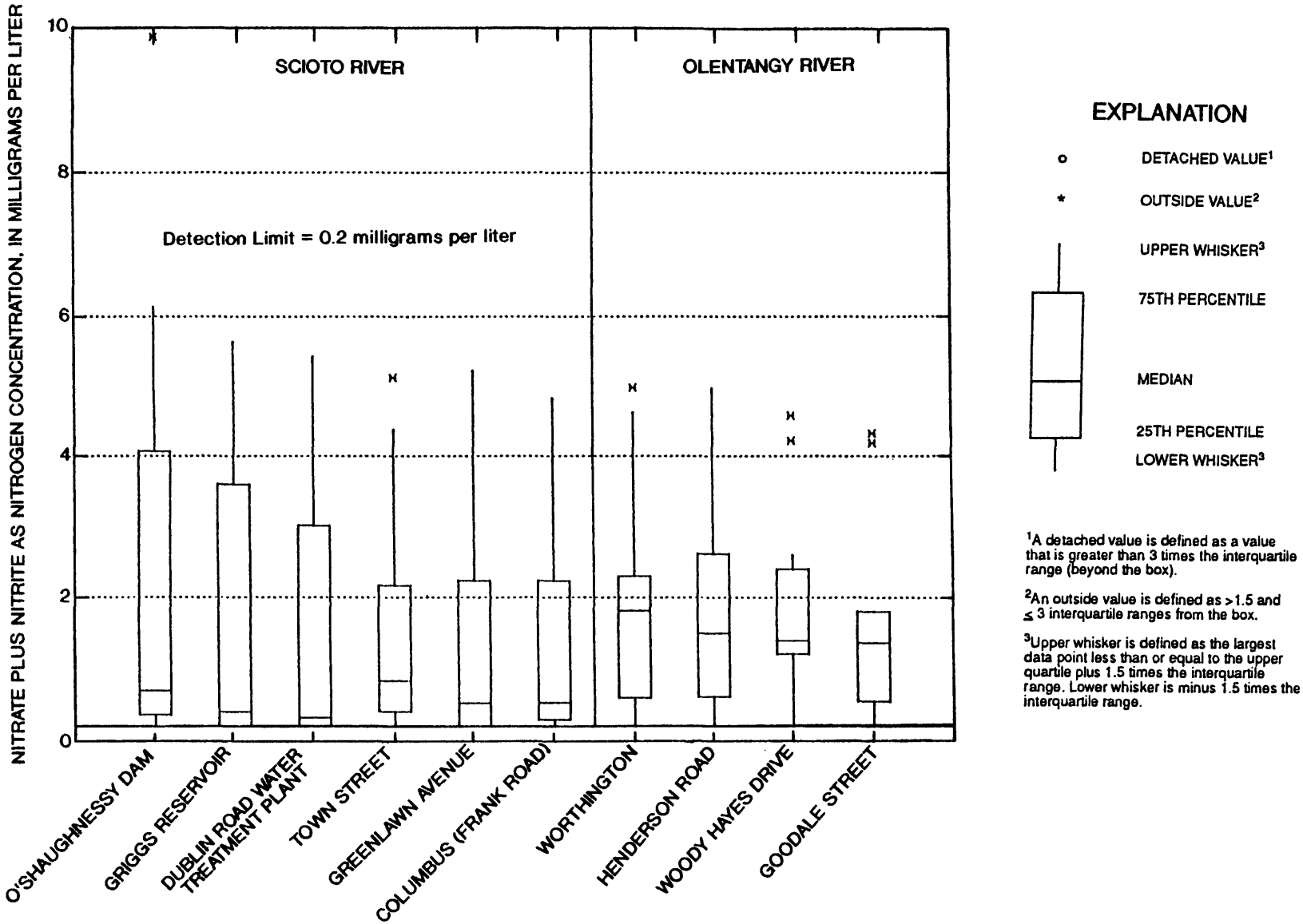


Figure 14.--Box plots showing distribution of nitrate plus nitrite as nitrogen concentration in Scioto and Olentangy Rivers for the recreational seasons of 1987, 1988, and 1989.

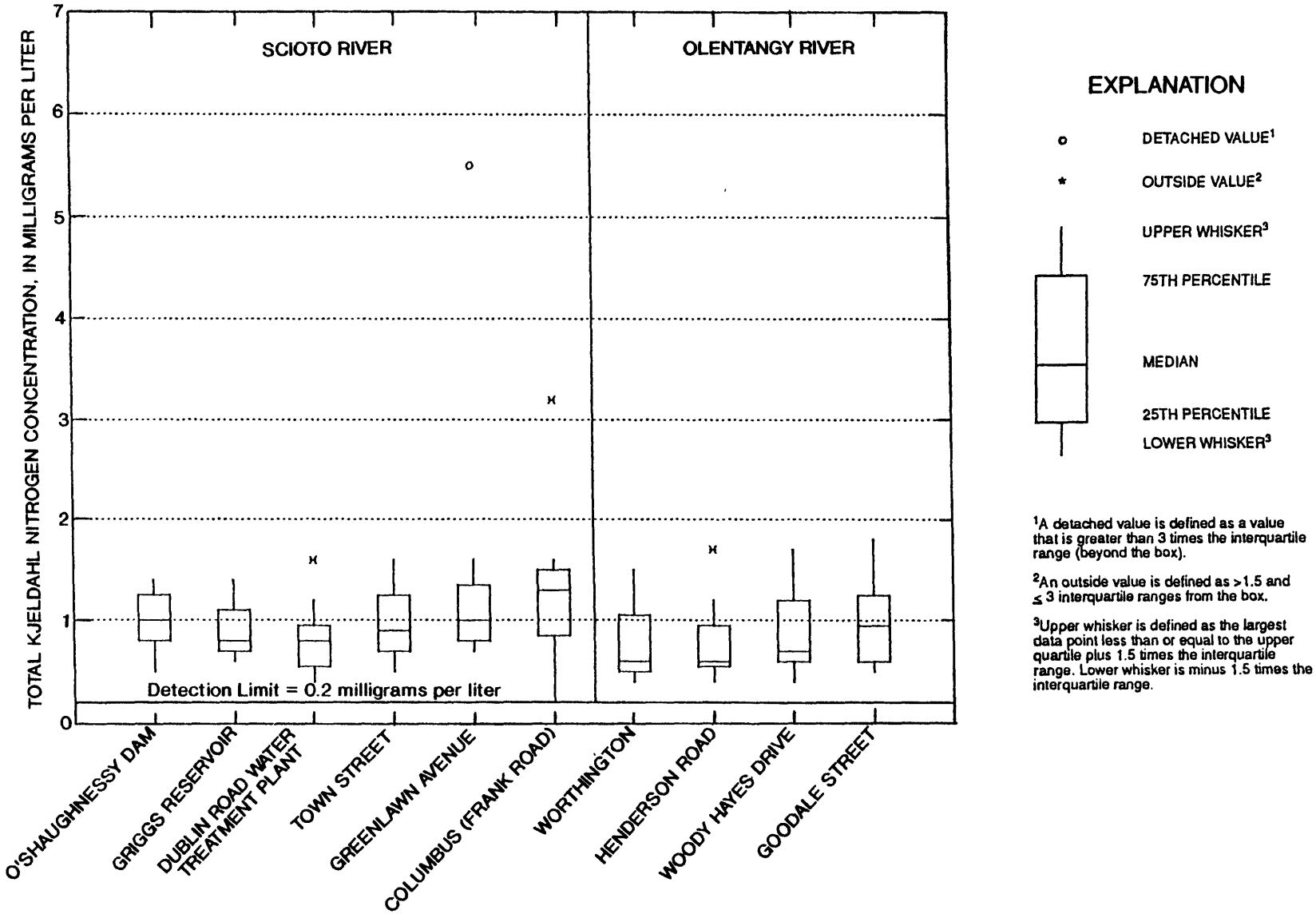


Figure 15.--Box plots showing distribution of total kjeldahl nitrogen concentration in Scioto and Olentangy Rivers for the recreational seasons of 1987, 1988, and 1989.

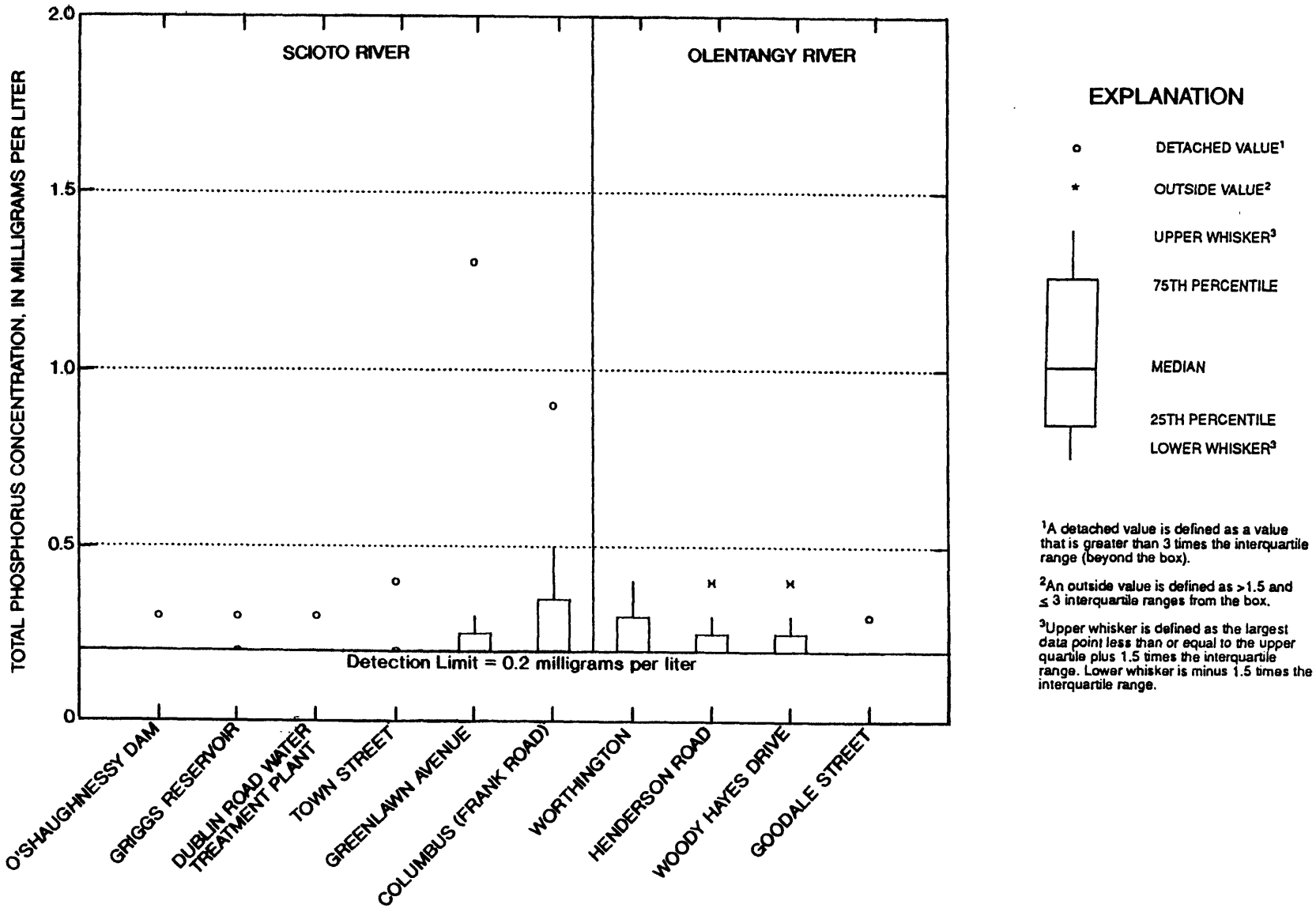
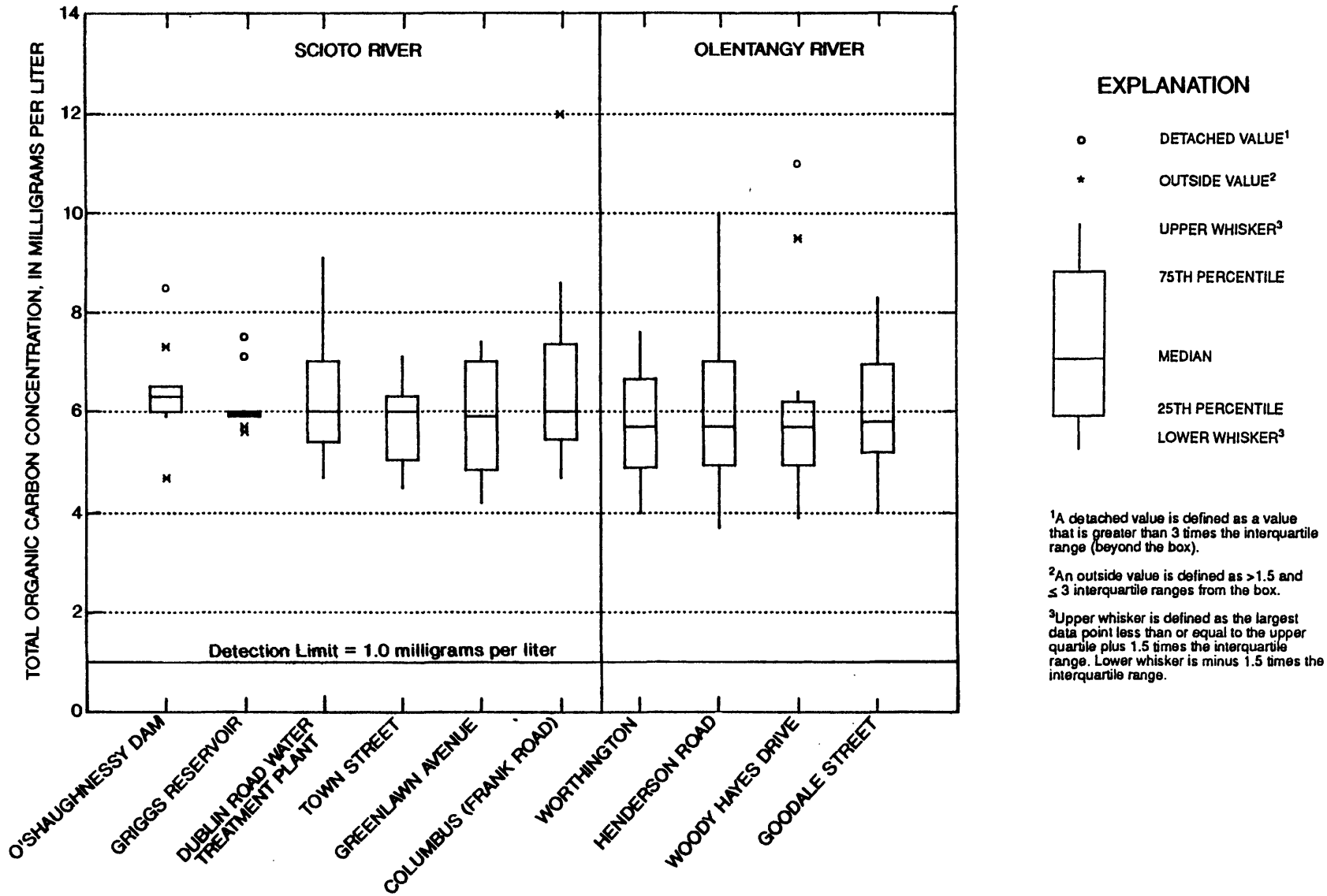


Figure 16.--Box plots showing distribution of total phosphorus concentration in Scioto and Olentangy Rivers for the recreational seasons of 1987, 1988, and 1989.



[1]A detached value is defined as a value that is greater than 3 times the interquartile range (beyond the box).

[2]An outside value is defined as >1.5 and ≤ 3 interquartile ranges from the box.

[3]Upper whisker is defined as the largest data point less than or equal to the upper quartile plus 1.5 times the interquartile range. Lower whisker is minus 1.5 times the interquartile range.

Figure 17.--Box plots showing distribution of total organic carbon concentration in Scioto and Olentangy Rivers for the recreational seasons of 1987, 1988, and 1989.

Table 11.--Summary statistics for specific conductance at sites on Scioto and Olentangy Rivers, data collected monthly or more frequently during July-October 1987, May-October 1988, and May-July 1989

[All data except number of samples are microsiemens per centimeter]

Site name	Number of samples	Mean	Standard deviation	Percentage of samples in which specific conductance was less than or equal to that shown				
				Median				
				10	25	50	75	90
Scioto River below O'Shaughnessy Dam	12	664.4	102.2	506	571	688	751	793
Scioto River below Griggs Reservoir	12	602.0	85.1	470	504	624	674	690
Scioto River at Dublin Road Water Treatment Plant	27	625.8	65.2	525	615	635	670	691
Scioto River at Town Street	27	663.5	106.2	490	604	660	758	840
Scioto River at Greenlawn Avenue	12	631.7	118.8	457	549	630	718	832
Scioto River at Columbus	11	605.5	73.5	478	561	605	674	700
Olentangy River near Worthington	12	674.2	123.2	492	567	686	761	878
Olentangy River at Henderson Road	12	646.2	126.4	484	553	652	711	879
Olentangy River at Woody Hayes Drive	12	611.2	100.8	418	541	652	684	712
Olentangy River at Goodale Street	27	752.2	180.5	589	637	693	876	1,060

Table 12.--Summary statistics for pH for sites on Scioto and Olentangy Rivers, data collected monthly or more frequently during July-October 1987, May-October 1988, and May-July 1989

[All data except number of samples are standard units]

Site name	Number of samples	Mean	Standard deviation	Percentage of samples in which pH was less than or equal to that shown				
						Median		
				10	25	50	75	90
Scioto River below O'Shaughnessy Dam	10	7.65	0.33	7.3	7.4	7.6	7.8	8.4
Scioto River below Griggs Reservoir	10	7.94	.29	7.4	7.8	7.9	8.2	8.3
Scioto River at Dublin Road Water Treatment Plant	26	7.77	.39	7.3	7.5	7.8	8.1	8.3
Scioto River at Town Street	26	7.96	.35	7.6	7.8	7.9	8.1	8.5
Scioto River at Greenlawn Avenue	10	7.86	.46	7.1	7.4	7.9	8.2	8.5
Scioto River at Columbus	8	7.71	.33	6.5	7.4	7.8	7.9	7.3
Olentangy River near Worthington	10	7.96	.36	7.3	7.8	8.0	8.2	8.6
Olentangy River at Henderson Road	10	7.86	.35	7.2	7.8	7.8	8.0	8.4
Olentangy River at Woody Hayes Drive	10	7.81	.35	7.1	7.6	7.9	8.0	8.3
Olentangy River at Goodale Street	26	7.70	.38	7.3	7.5	7.6	7.8	8.3

Table 13.--Summary statistics for dissolved-oxygen concentration at sites on Scioto and Olentangy Rivers, data collected monthly or more frequently during July-October 1987, May-October 1988, and May-July 1989

[All data except number of samples are milligrams per liter]

Site name	Number of samples	Mean	Standard deviation	Percentage of samples in which dissolved-oxygen concentration was less than or equal to that shown				
				Median				
				10	25	50	75	90
Scioto River below O'Shaughnessy Dam near Dublin	12	5.67	2.78	2.0	2.8	6.0	7.8	9.8
Scioto River below Griggs Reservoir	12	7.58	1.57	5.4	5.9	7.7	8.8	10.0
Scioto River at Dublin Road Water Treatment Plant	27	7.24	2.39	3.3	6.4	7.4	8.7	9.9
Scioto River at Town Street	26	8.63	2.92	4.8	6.7	7.9	10.6	13.3
Scioto River at Greenlawn Avenue	10	8.36	3.27	.9	7.7	8.6	10.4	12.5
Scioto River at Columbus, Ohio	9	6.30	1.66	3.0	5.0	7.1	7.5	7.9
Olentangy River near Worthington	12	7.58	1.85	5.7	5.9	7.2	9.0	10.9
Olentangy River at Henderson Road	12	7.81	1.45	5.9	6.6	7.4	9.2	9.9
Olentangy River at Woody Hayes Drive	12	7.73	1.82	4.9	5.9	8.2	9.2	9.9
Olentangy River at Goodale Street	27	6.48	2.47	3.3	4.6	6.4	8.5	10.5

Table 14.--Summary statistics for total alkalinity concentration at sites on Scioto and Olentangy Rivers, data collected monthly during July-October 1987, May-October 1988, and May-July 1989

[All data except number of samples are milligrams per liter, total as $CaCO_3$]

Site name	Number of samples	Mean	Standard deviation	Percentage of samples in which total alkalinity concentration was less than or equal to that shown				
				Median				
				10	25	50	75	90
Scioto River below O'Shaughnessy Dam	11	167.2	19.7	141	150	170	180	202
Scioto River below Griggs Reservoir	10	163.5	15.3	140	151	165	180	202
Scioto River at Dublin Road Water Treatment Plant	11	153.2	14.4	128	145	150	170	170
Scioto River at Town Street	11	154.1	19.5	121	145	150	175	180
Scioto River at Greenlawn Avenue	11	152.1	20.7	121	138	150	170	180
Scioto River at Columbus	11	151.4	13.9	135	138	150	160	176
Olentangy River near Worthington	11	160.5	15.9	140	150	160	170	187
Olentangy River at Henderson Road	11	148.6	25.2	112	120	145	170	187
Olentangy River at Woody Hayes Drive	11	153.9	16.6	132	140	150	165	183
Olentangy River at Goodale Street	11	162.4	19.3	138	150	158	178	198

Table 15.--Summary statistics for total chloride concentration at sites on Scioto and Olentangy Rivers, data collected monthly during July-October 1987, May-October 1988, and May-July 1989

[All data except number of samples are milligrams per liter]

Site name	Number of samples	Mean	Standard deviation	Percentage of samples in which total chloride concentration was less than or equal to that shown				
						Median		
				10	25	50	75	90
Scioto River below O'Shaughnessy Dam near Dublin	12	36.8	13.7	20	25	35	49	57
Scioto River below Griggs Reservoir	11	33.4	9.8	25	25	30	40	50
Scioto River at Dublin Road Water Treatment Plant	11	37.6	10.7	25	30	35	49	54
Scioto River at Town Street	11	44.8	12.6	27	34	45	55	67
Scioto River at Greenlawn Avenue	11	47.0	14.7	27	39	45	51	74
Scioto River at Columbus	11	47.4	12.3	27	42	50	51	68
Olentangy River near Worthington	12	46.9	21.5	25	31	44	57	91
Olentangy River Henderson Road	12	49.8	24.3	26	31	46	62	100
Olentangy River Woody Hayes Drive	11	44.8	15.3	25	33	45	50	73
Olentangy River at Goodale Street	12	44.2	17.6	12	37	45	54	72

Table 16.--Summary statistics for total nonfilterable residue concentration (103 to 105°C) for sites on Scioto and Olentangy Rivers, data collected monthly during July-October 1987, May-October 1988, and May-July 1989

[All data except number of samples are milligrams per liter]

Site name	Number of samples	Mean	Standard deviation	Percentage of samples in which total nonfilterable residue concentration was less than or equal to that shown				
				10	25	Median 50	75	90
Scioto River below O'Shaughnessy Dam near Dublin	11	18.2	12.2	6.8	9.9	18.0	21.0	44.2
Scioto River below Griggs Reservoir	11	17.0	21.2	4.8	7.4	11.9	15.0	67.6
Scioto River at Dublin Road Water Treatment Plant	11	22.5	23.5	3.5	6.6	11.0	53.0	64.0
Scioto River at Town Street	11	24.3	24.3	6.5	12.0	18.0	29.0	81.4
Scioto River at Greenlawn Avenue	11	24.4	19.0	12	15.0	19.0	24.0	69.2
Scioto River at Columbus, Ohio	11	31.8	43.1	8.5	14.0	20.0	27.0	134
Olentangy River near Worthington	12	27.3	19.2	7.4	12.0	23.0	37.5	62.8
Olentangy River at Henderson Road	12	26.0	22.9	5.6	12.0	20.5	35.5	73.9
Olentangy River at Woody Hayes Drive	10	27.6	23.1	5.6	9.9	19.0	52.0	69.1
Olentangy River at Goodale Street	12	28.0	24.3	7.6	12.2	20.0	37.0	79.2

Table 17.--Summary statistics for nitrate plus nitrite as nitrogen concentrati for sites on Scioto and Olentangy Rivers, data collected monthly during July-October 1987, May-October 1988, and May-July 1989

[All data except number of samples are milligrams per liter]

Site name	Number of samples	Mean	Standard deviation	Percentage of samples in which nitrate nitrite as nitrogen concentration was less than or equal to that shown				
				10	25	Median 50	75	90
Scioto River below O'Shaughnessy Dam near Dublin	12	2.37	3.19	0.23	0.34	0.70	5.0	8.8
Scioto River below Griggs Reservoir	11	1.83	2.25	.04	.12	.40	4.8	5.5
Scioto River at Dublin Road Water Treatment Plant	11	1.62	2.29	.03	.11	.32	4.8	5.4
Scioto River at Town Street	11	1.60	1.78	.10	.26	.83	3.2	5.0
Scioto River above Greenlawn Avenue	11	1.45	1.97	.04	.12	.52	3.4	5.1
Scioto River at Columbus	12	1.34	1.76	.06	.16	.50	2.8	4.7
Olentangy River near Worthington	12	1.87	1.58	.20	.40	1.8	2.4	4.9
Olentangy River at Henderson Road	12	1.85	1.57	.22	.47	1.5	2.7	4.8
Olentangy River at Woody Hayes Drive	11	1.95	1.36	.26	1.20	1.4	2.6	4.5
Olentangy River at Goodale Street	12	1.58	1.38	.19	.38	1.4	1.8	4.3

Table 18.--Summary statistics for total kjeldahl nitrogen concentration for sites on Scioto and Olentangy Rivers, data collected monthly during July-October 1987, May-October 1988, and May-July 1989

[All data except number of samples are milligrams per liter]

Station name Site name	Number of samples	Mean	Standard deviation	Percentage of samples in which total kjeldahl nitrogen concentration was less than or equal to that shown				
						Median		
				10	25	50	75	90
Scioto River below O'Shaughnessy Dam	12	1.01	0.27	0.56	0.80	1.0	1.3	1.4
Scioto River below Griggs Reservoir	11	.91	.27	.62	.70	.80	1.2	1.4
Scioto River at Dublin Road Water Treatment Plant	11	.81	.36	.42	.50	.80	1.1	1.5
Scioto River at Town Street	11	1.01	.37	.54	.70	.90	1.3	1.6
Scioto River at Greenlawn Avenue	11	1.46	1.37	.70	.80	1.0	1.4	4.7
Scioto River at Columbus	11	1.29	.77	.30	.80	1.3	1.5	2.9
Olentangy River near Worthington	12	.78	.35	.43	.50	.60	1.1	1.4
Olentangy River at Henderson Road	12	.76	.39	.40	.52	.60	1.0	1.6
Olentangy River at Woody Hayes Drive	11	.89	.42	.42	.60	.70	1.3	1.6
Olentangy River at Goodale Street	12	.99	.43	.50	.60	.95	1.3	1.7

Table 19.--Summary statistics for total phosphorus concentration at sites on Scioto and Olentangy Rivers, data collected monthly during July-October 1987, May-October 1988, and May-July 1989

[All data except number of samples are milligrams per liters]

Site name	Number of samples	Mean	Standard deviation	Percentage of samples in which total organic carbon concentration was less than or equal to that shown				
				10	25	Median 50	75	90
Scioto River below O'Shaughnessy Dam	12	0.164	0.063	0.12	0.14	0.17	0.20	0.27
Scioto River below Griggs Reservoir	11	.128	.071	.08	.10	.13	.17	.28
Scioto River at Dublin Road Water Treatment Plant	12	.151	.065	.08	.10	.14	.20	.27
Scioto River at Town Street	11	.113	.115	.02	.03	.07	.20	.36
Scioto River at Greenlawn Avenue	11	.211	.378	.03	.06	.13	.30	1.10
Scioto River at Columbus	11	.273	.252	.10	.15	.20	.40	.82
Olentangy River near Worthington	12	.236	.083	.16	.19	.20	.30	.30
Olentangy River at Henderson Road	12	.176	.107	.09	.12	.17	.28	.37
Olentangy River at Woody Hayes Drive	11	.180	.109	.09	.12	.17	.30	.38
Olentangy River at Goodale Street	12	.158	.079	.11	.14	.17	.20	.30

Table 20.--Summary statistics for total organic carbon concentration for sites on Scioto and Olentangy Rivers, data collected monthly during July-October 1987, May-October 1988, and May-July 1989

[All data except number of samples are milligrams per liters]

Site name	Number of samples	Mean	Standard deviation	Percentage of samples in which total organic carbon concentration was less than or equal to that shown				
				Median				
				10	25	50	75	90
Scioto River below O'Shaughnessy Dam	11	6.37	0.94	4.9	6.0	6.3	6.5	8.3
Scioto River below Griggs Reservoir	10	6.16	.62	5.6	5.8	6.0	6.3	7.5
Scioto River at Dublin Road Water Treatment Plant	9	6.46	1.52	4.7	5.4	6.0	7.8	9.1
Scioto River at Town Street	9	6.46	1.52	4.7	5.4	6.0	7.8	9.1
Scioto River at Greenlawn Avenue	11	7.12	4.73	4.3	4.7	5.9	7.2	18
Scioto River at Columbus	11	6.79	2.10	4.7	5.2	6.0	7.5	11
Olentangy River near Worthington	11	5.76	1.17	4.1	4.8	5.7	6.9	7.5
Olentangy River at Henderson Road	12	6.01	1.73	3.8	4.9	5.7	7.2	9.3
Olentangy River at Woody Hayes Drive	11	6.16	1.20	3.9	4.9	5.7	6.4	10
Olentangy River at Goodale Street	12	6.08	1.25	4.3	5.2	5.8	7.1	8.1

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