Evaluation of Water Quality for Two St. Johns River Tributaries Receiving Septic Tank Effluent, Duval County, Florida

By Shaun M. Wicklein

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acres (ac)	0.4047	hectare
square mile (mi^2)	2.590	square kilometer
	Flow Rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second
inch per year (in/yr)	25.4	millimeter per year

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows: °C=(°F-32)/1.8.

Horizontal coordinate information (latitude-longitude) is referenced to the North American Datum of 1983 (NAD83).

Acronyms and abbreviations:

JEA	Jacksonville Electric Authority
μg/L	micrograms per liter
mg/L	milligrams per liter
mpn/100mL	most probable number per 100 milliliters
NPDES	National Pollutant Discharge Elimination System
NURP	Nationwide Urban Runoff Project
USGS	U.S. Geological Survey

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ABSTRACT

Tributary streamflow to the St. Johns River in Duval County is thought to be affected by septic tank leachate from residential areas adjacent to these tributaries. Water managers and the city of Jacksonville have committed to infrastructure improvements as part of a management plan to address the impairment of tributary water quality. In order to provide data to evaluate the effects of future remedial activities in selected tributaries, major ion and nutrient concentrations, fecal coliform concentrations, detection of wastewater compounds, and tracking of bacterial sources were used to document septic tank influences on the water quality of selected tributaries.

The tributaries Fishing Creek and South Big Fishweir Creek were selected because they drain subdivisions identified as high priority locations for septic tank phase-out projects: the Pernecia and Murray Hill B subdivisions, respectively. Population, housing (number of residences), and septic tank densities for the Murray Hill B subdivision are greater than those for the Pernecia subdivision.

Water-quality samples collected in the study basins indicate influences from ground water and septic tanks. Estimated concentrations of total nitrogen ranged from 0.33 to 2.86 milligrams per liter (mg/L), and ranged from less than laboratory reporting limit (0.02 mg/L) to 0.64 mg/L for total phosphorus. Major ion concentrations met the State of Florida Class III surface-water standards; total nitrogen and total phosphorus concentrations exceeded the U.S. Environmental Protection Agency Ecoregion XII nutrient criteria for rivers and streams 49 and 96 percent of the time, respectively. Organic wastewater compounds detected at study sites were categorized as detergents, antioxidants and flame retardants, manufactured polycarbonate resins, industrial solvents, and mosquito repellent. The most commonly detected compound was para-nonylphenol, a breakdown product of detergent. Results of wastewater sampling give evidence that stream water in the study basins is affected by septic tank effluent.

Fecal coliform bacteria concentrations were measured on a monthly basis; of 115 samples, 63 percent exceeded the State of Florida fecal coliform bacteria standard for Class III surface waters of 800 colonies per 100 milliliters of water on any 1 day. Fecal coliform bacteria concentrations ranged from less than 20 colonies per 100 milliliters of sample to greater than or equal to 160,000 colonies per 100 milliliters of sample. Antibiotic resistance patterns of fecal coliform bacteria were used to identify the sources of fecal coliform bacteria. Significant sources of fecal coliform bacteria included wild animals, dogs, and humans. A majority of the fecal coliform bacteria were classified to be from human sources. Because the primary source of fecal coliform bacteria is from human sources, and most likely septic tank effluent, management of human sources may substantially improve microbiological water quality in both the Fishing Creek and South Branch Big Fishweir Creek basins.

INTRODUCTION

Water managers in the lower St. Johns River basin and the city of Jacksonville are committed to improve the quality of waterways that contribute flow to the St. Johns River, an American Heritage River. The quality of tributary streamflow to the St. Johns River in Jacksonville is thought to be affected by septic tank leachate from residential areas adjacent to the tributaries (Dana Morton, city of Jacksonville, Division of Air and Water Quality, oral commun., 1999). Shallow ground water in these areas likely is the vehicle that transports fecal coliforms and nutrients from septic tank leachate to the surface water. The installation of sanitary sewer systems in the city of Jacksonville for areas presently on septic tank systems is one step being taken to cleanup waterways (City of Jacksonville, 2000).

Although research has been done on the efficiency of septic tank systems to treat wastes, and the deterioration of these systems over time has been studied, the effect of the removal of septic tank systems on the receiving ground and surface waters has not been widely studied. Documentation of water-quality conditions prior to and after replacement of septic tank systems by a centralized system is needed to evaluate the effects of remedial activities. The associated hydrologic conditions under which the water quality is evaluated should be documented to isolate the impact of the septic tank removal from other factors that can affect water quality. The study of environmental effects of septic tank removal will help to further the understanding of human impacts on water quality in river systems.

The U.S. Geological Survey (USGS), in cooperation with the city of Jacksonville Air and Water-Quality Division, began a 4-1/2-year study to evaluate the effects of septic tank removal on two tributaries to the St. Johns River in April 1999. The tributaries Fishing Creek and Big Fishweir Creek were selected because they drain neighborhoods identified by Jacksonville Electric Authority (JEA) as priority locations for septic tank phase-out projects (fig. 1). The neighborhoods are the Pernecia and Murray Hill B subdivisions, which coincide with Fishing Creek and Big Fishweir, respectively.

Major ion and nutrient concentrations, detections of organic wastewater compounds, and fecal coliform concentrations were documented in order to evaluate the effects of septic tank removal projects on stream water quality. Bacterial source tracking, as described by Harwood and others (2000), was included in sampling efforts to further define septic tank influence on the water quality of the tributaries.

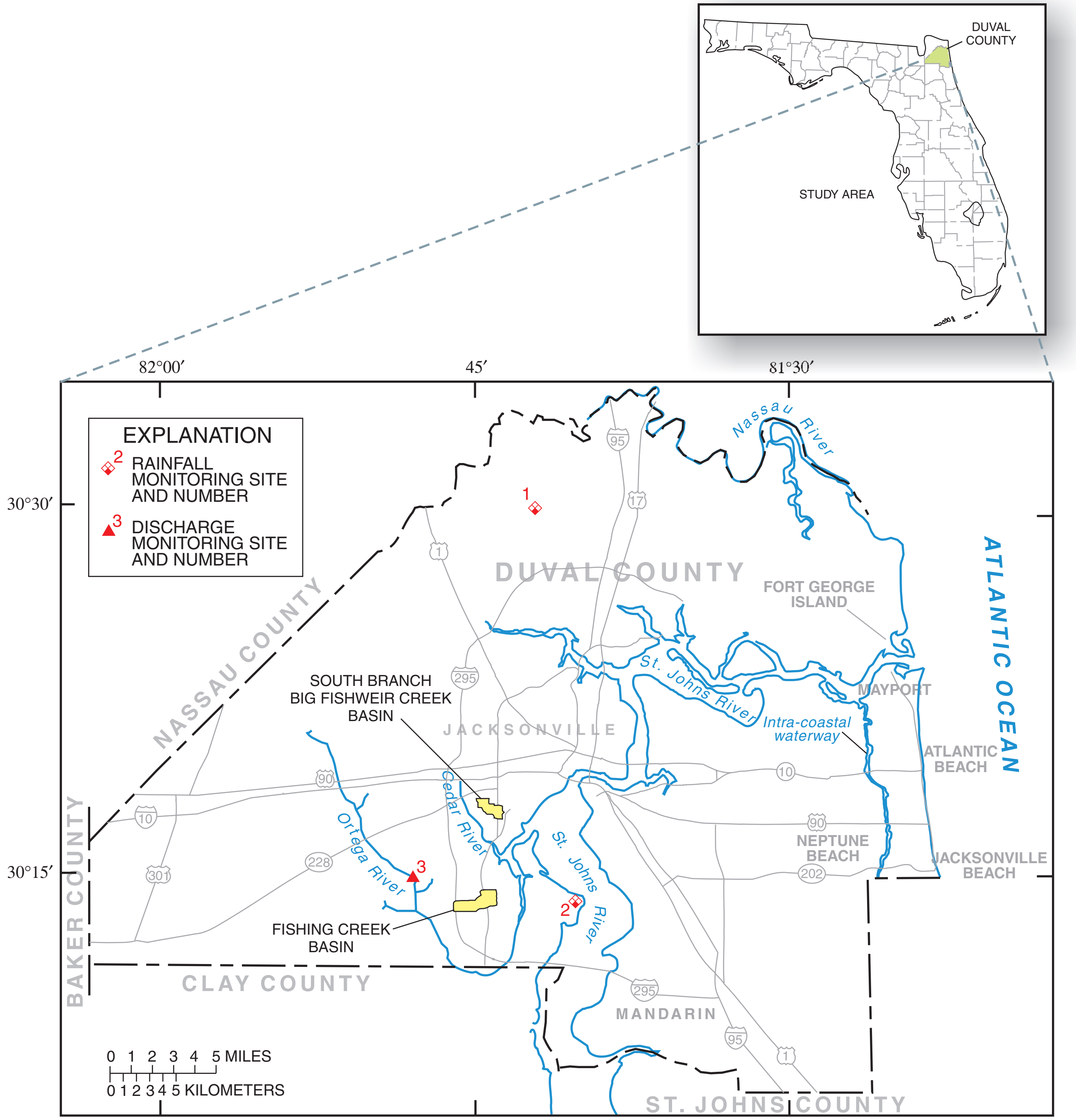
Purpose and Scope

The objective of this study was to evaluate the effects on water quality in two tributaries to the St. Johns River resulting from the replacement of residential septic tank systems by a centralized sewer system. The study, as planned, was divided into two phases. The first phase was to document baseline water-quality conditions prior to connection of targeted areas (fig. 1) to a centralized sewer system. The second phase was to document changes in water-quality constituent concentrations that may result from installation of sanitary sewer systems and removal of septic tank systems in targeted areas. Unforeseen delays, however, in the installation of sanitary sewer systems affected evaluation of hydrologic and water-quality conditions following planned sanitary sewer system installation.

This report, therefore, documents baseline hydrologic and water-quality conditions occurring in 2000-2002 prior to removal of septic tanks and installation of a sanitary sewer system. Basin characteristics are documented to facilitate transferability of results to other locations. The results of sampling for major ions (semi-annually), nutrients (quarterly), organic wastewater compounds (annually) and fecal coliform bacteria (monthly) at two sites in each basin are summarized along with streamflow measurements (quarterly). Bacterial source tracking, used to determine the source of fecal coliform bacteria, is described.

Description of Study Area

The geologic deposits important to this study include the sediments from land surface to a depth of about 100 feet (ft). The sediments consist mostly of unconsolidated fine to medium grained quartz sand with some clay, shell, and limestone. These unconsolidated sediments form the surficial aquifer system. Throughout most of Duval County, the water table in the surficial aquifer system is within 5 ft of land surface (Causey, 1975). Locally, the depth to water is about 10-12 ft. The surficial aquifer system is recharged primarily by rainfall.



Base modified from U.S. Geological Survey digital data, 1:100,000, 1985
Albers Equal-Area Conic projection

Figure 1. Location of study areas and selected monitoring sites in Jacksonville, Duval County, Florida (site numbers refer to table 1).

Discharge from the surficial aquifer system occurs by evaporation, transpiration by plants, seepage into surface-water bodies, leakage into the underlying rocks, and from discharging wells. Underlying the surficial aquifer system are about 400 ft of mostly fine-grained, clay sediments that also include some shell, sand, or limestone. These sediments make up the intermediate confining unit. Underlying the intermediate confining unit is a thick sequence (greater than 1,600 ft) of carbonate rocks that form the artesian aquifer system (Phelps, 1994).

The topography of Duval County is controlled by a series of ancient marine terraces (Cooke, 1945) that were formed due to glacial activity during the Pleistocene Epoch when the sea was relatively stationary at various levels higher than present-day sea level. Six marine terraces are recognized in Duval County: the Coharie, Sunderland, and Wicomico terraces that range in altitude from 215 to 70 ft in the western part of the county; the Penholoway and Talbot terraces that form a coastal ridge at altitudes from 70 to 25 ft; and the Pamlico terrace at altitudes below 25 ft, which forms the low coastal plain throughout most of the eastern and central parts of the County (Anderson, 1972). The study areas occur at elevations associated with the Talbot and Pamlico terraces. Much of the study areas likely were barrier islands during deposition of the Talbot Formation (Cooke, 1945).

Soils in the study areas generally are somewhat to very poorly drained. Sandy and loamy sediments are present on rises, knolls, and flats. Creek bottoms are made up of very poorly and poorly drained Surrency soil types that are present in nearly level depressions and on flood plains (U.S. Department of Agriculture, 1998). The upland soil types generally are fine sands of Pelham, Mascotte, and Sapelo, which are poorly drained and present on nearly level flats and flatwoods.

About 75 square miles (mi^2) of surface water covers parts of Duval County (the County has a total area of about 840 mi^2). Two major rivers and their tributaries drain the County: the St. Johns River and the Nassau River. Numerous smaller streams drain to the Intra-coastal waterway or the Atlantic Ocean. Because parts of the County are relatively flat, some drainage divides in low areas are indistinct. During high-flow conditions, water can discharge into another drainage basin. The average runoff for streams in the County is about 50 percent greater than that of the State for Florida, as a whole (Anderson, 1972). This likely is a result of impermeability of sediments underlying the surficial aquifer system in Duval County.

The climate of Duval County is humid subtropical and is characterized by long, warm, humid summers and mild winters. Freezing temperatures may occur during the winter months, but are rare because Duval County borders the Atlantic Ocean and is close to the Gulf Stream, which produces moderate winter temperatures. In an average year, about 65 percent of the total annual precipitation occurs from June to October, with the remaining precipitation more or less evenly distributed throughout the remainder of the year. Typical weather patterns for Duval County include frontal activity during the winter months, causing widespread rainfall and short periods of cooler temperature, and scattered thunderstorm activity during the summer months. The 100-year, 1868-1967, average rainfall recorded at Jacksonville was 51.52 inches (Anderson, 1972).

Rainfall represents the largest input of water to the study areas, and is the main climatic factor affecting the variation in surface-water flows for Duval County. Water supplied by rainfall is depleted by runoff, evapotranspiration, and seepage to the aquifers. In most parts of Duval County, 10-16 inches of rainfall enters the surficial aquifer system in a year (Anderson, 1972). The amount of water that passes through the surficial aquifer to the Floridan aquifer probably is insignificant because artesian flow conditions exist in the eastern two-thirds of the County, and because numerous swampy areas indicate poor subsurface drainage. Thus, in most parts of the County, the majority of the water that enters the surficial aquifer system leaves the aquifer as seepage to streams, and by evapotranspiration. Therefore, the amount of runoff generally is the difference between rainfall and evapotranspiration.

Data Collection and Analysis

Two basins were selected for this study: Fishing Creek (fig. 2) and South Branch Big Fishweir Creek (fig. 3). Surface-water-quality sampling sites were selected at two locations in each of the study basins: one upstream and one downstream from the area in which a sanitary sewer system will be installed and septic tanks will be removed (table 1). Water-quality data were collected monthly to document conditions prior to the installation of a sanitary sewer system (and subsequent discontinuation of septic tank use). Streamflow measurements were made at the time of sampling events (quarterly).

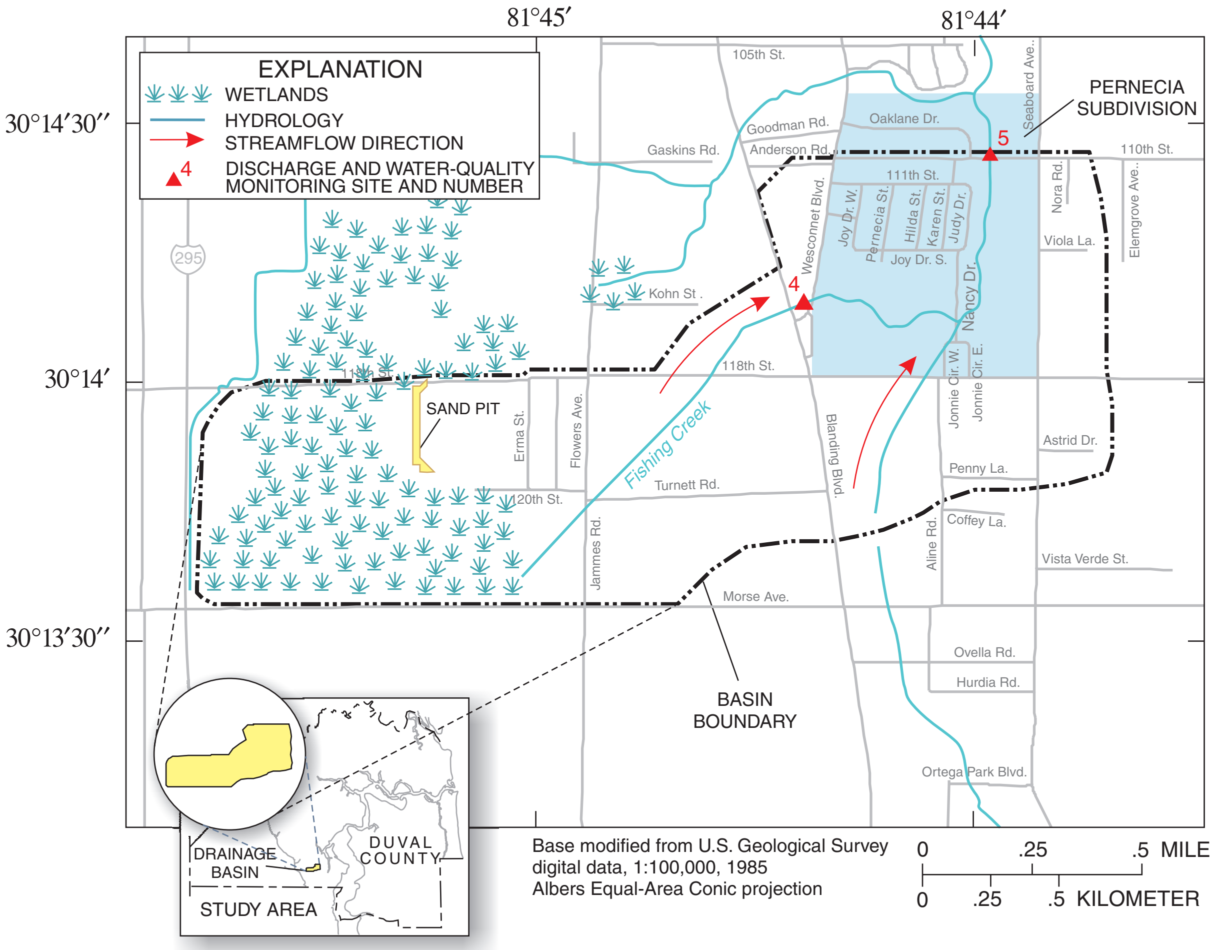


Figure 2. Streamflow and water-quality data collection sites for Fishing Creek basin, Jacksonville, Florida (site numbers refer to table 1).

Table 1. Data collection and compilation sites, Jacksonville, Florida

[NOAA, National Oceanic and Atmospheric Administration; NLMOF, Naval Atlantic Meteorology and Oceanography Facility Jacksonville, Florida; USGS, U.S. Geological Survey. Data type: R, rainfall; D, discharge; P, periodic water-quality; --, not available; NA, not applicable. Map number shown in figures 1, 2, and 3]

Map number	Site name and identification number	Latitude	Longitude	Drainage area[a] (square miles)	Data type	Source of data
1	Jacksonville International Airport (084358)	30° 30' --"	81° 42' --"	NA	R	NOAA
2	Naval Air Station Jacksonville (722065)	30° 14' --"	81° 40' --"	NA	R	NLMOF
3	Ortega River at Jacksonville (02246300)	30° 14' 50"	81° 47' 49"	30.9	D	USGS
4	Fishing Creek at Wesconnet Boulevard (02246435)	30° 14' 10"	81° 44' 22"	.76	D, P	USGS
5	Fishing Creek at 110th Street (0226437)	30° 14' 27"	81° 43' 57"	1.27	D, P	USGS
6	South Branch Big Fishweir Creek at Casssat Avenue (02246465)	30° 17' 35"	81° 43' 51"	.43	D, P	USGS
7	South Branch Big Fishweir Creek at Blanding Boulevard (02246467)	30° 17' 35"	81° 43' 27"	.67	D, P	USGS

[a]Drainage area from U.S.Geological Survey, 2003, Water resources data, Florida, water year 2002, volume 1A.

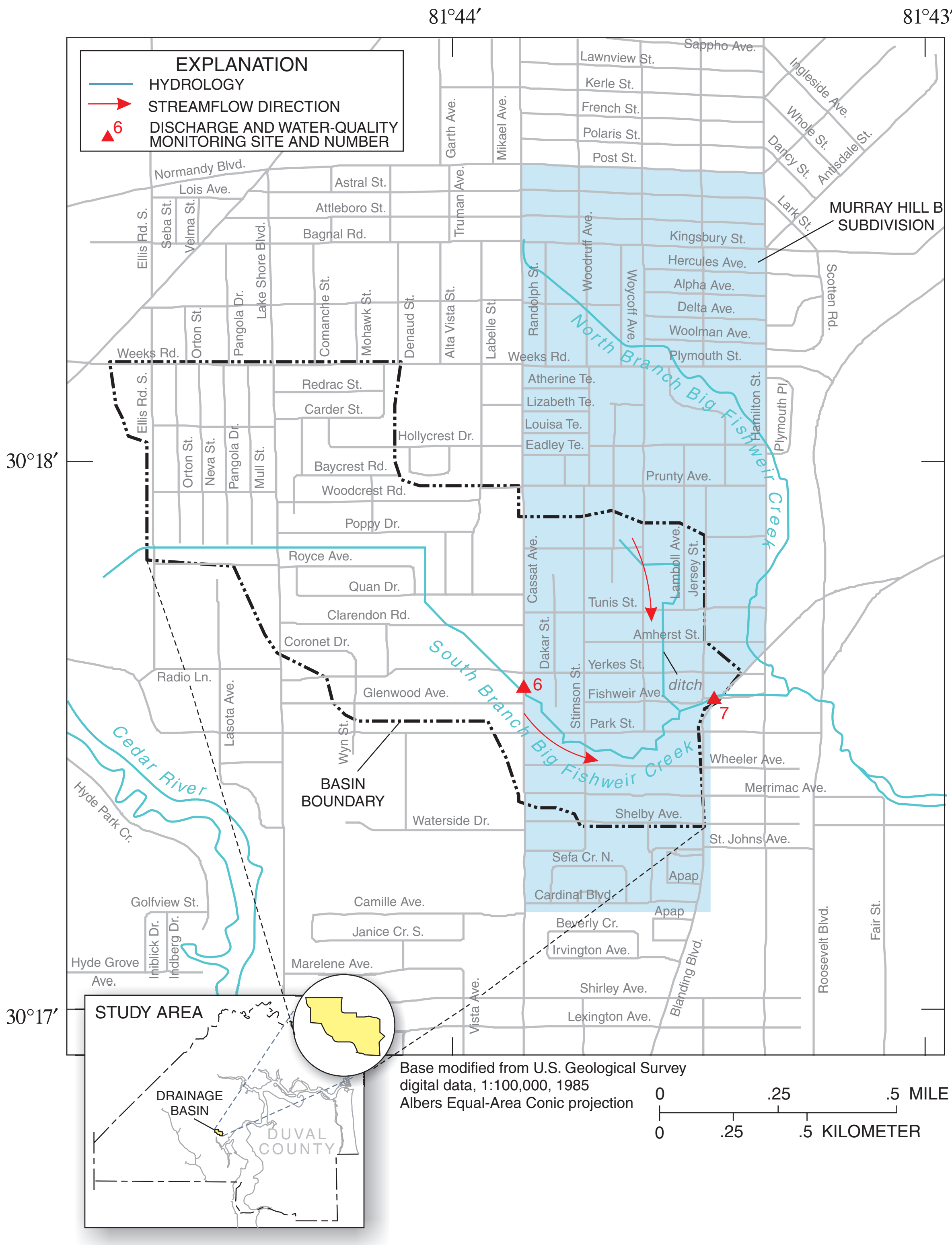


Figure 3. Streamflow and water-quality data collection sites for South Branch Big Fishweir Creek basin, Jacksonville, Florida (site numbers refer to table 1).

In order to describe basin characteristics, information on the size of drainage areas, soil characteristics (soil type and drainage characteristics), land use, septic tank and housing density, and water use in the area (from utility records) were compiled. These basin characteristics aided in the interpretation of water-quality data, and also will help with the transferability of the results to other areas where sanitary sewer systems are to replace septic tanks.

Water samples were collected at four sites (figs. 2 and 3) during 2000-2002. Samples for major ions were collected semi-annually during wet (June-October) and dry (November-May) seasons. Nutrient samples were collected quarterly at times when two of the quarterly sampling events corresponded to the semi-annual sampling events. Large nutrient loads can be transported during storm events, and it is possible that nutrients from septic tank drain fields might be flushed out of the ground-water system at these times. For this reason, major ion and nutrient samples also were collected for three storm events during the study period.

Four water samples were collected at each site and analyzed for organic compounds commonly found in wastewater. Three of the four samples were collected during low-flow and one during a storm event. Fecal coliform bacteria samples were collected monthly. Water samples also were collected four times during the study and analyzed for antibiotic resistance patterns used to classify fecal coliform bacteria sources. All samples were collected according to methods presented in the USGS National Field Manual for the Collection of Water-Quality Data (Wilde and others, 1998).

Streamflow was measured at each site when collecting quarterly water-quality samples and during storm events. Measurements were made using conventional current meter methods described by Rantz and others (1982). Field properties, consisting of water temperature, specific conductance, dissolved oxygen concentration, and pH, were measured using a multi-parameter water-quality meter calibrated according to the meter's operational manual and methods described by Wilde and others (1998). Field measurements were made whenever water samples were collected.

Water samples collected during the study were sent to several laboratories for analysis. Major ions and nutrients were analyzed at the USGS Ocala Water Quality and Research Laboratory in Ocala, Florida, according to methods presented in Fishman and Friedman (1989) and the U.S. Environmental Protection Agency (2003). Constituents analyzed as part of the major ion and nutrient sampling are listed in appendix 1. Samples for analyses of organic wastewater compounds were processed at the USGS National Water-Quality Laboratory in Denver, Colorado, according to methods presented in Zaugg and others (2002). Compounds analyzed included alkylphenol ethoxylate nonionic surfactants and their degradates, food additives, fragrances, antioxidants, flame retardants, plasticizers, industrial solvents, disinfectants, fecal sterols, polycyclicaromatic hydrocarbons, and high-use pesticides (app. 2). Samples collected for fecal coliform bacteria analyses, using the most-probable-number method, were analyzed at the Florida Department of Health laboratory in Jacksonville, Florida, according to methods presented in Clesceri and others (1998, p. 9-48).

Antibiotic resistance patterns of fecal coliform bacteria from water samples were analyzed by the Department of Biology, University of South Florida, Tampa, Florida, using materials, methods, and statistical analysis described by Harwood and others (2000). Water samples were collected at sites, chilled to 4 degrees Celsius, and shipped to the University of South Florida. Fecal coliform bacteria were isolated from water samples within 8 hours of sample collection by membrane filtration using mFC agar. A known-source library of fecal coliform bacteria isolates was used for classification of fecal coliform bacteria isolated from water samples (Harwood and others, 2000). The library was developed in the Jacksonville area from approximately 1998-2000 and contains 1,777 human-origin fecal coliform bacteria isolates and 4,367 animal-origin fecal coliform bacteria isolates. Wiggins and others (2003) concluded that a multi-watershed library of at least 2,300 samples is needed for reliable classification of fecal coliform bacteria within the region of collection. The library used for this study contains 6,144 fecal coliform bacteria isolates, which were collected in the Jacksonville area. The library is not representative of all wildlife, but contains 337 fecal coliform bacteria isolates from a limited number of species: rabbits, racoons, ducks, wood storks, night heron, and egrets. This library was considered acceptable to use for this study.

The antibiotic resistance patterns of fecal coliforms isolated from stream-water samples were determined using eight antibiotics: amoxicillin, gentamicin, cephalothin, ofloxacin, erythromycin, tetracycline, moxalactam, and chlortetracycline (Dr. Valerie Harwood, Department of Biology, University of South Florida, written commun., 2002). Discriminant analysis was used to classify individual sample isolates into groups on the basis of the values of several classification variables (Harwood and others, 2000). Fecal coliform bacteria isolates were categorized into one of five potential sources: chicken, cow, dog, human, and wild animal. Results from the analysis of antibiotic resistance patterns of fecal coliform bacteria are assessed for accuracy of fecal coliform bacteria isolates classification by comparing to known sources. The rate of correct classification of fecal coliform bacteria isolates from known sources gives an indication of how accurately sample results represent the actual source of fecal coliform bacteria. Isolates of fecal coliform bacteria were correctly classified from known sources for a two-way split at a rate of 69 percent for human sources and an average correct classification rate of 78 percent for combined animal sources and for a six-way split at a rate of 54 percent for human, 57 percent for chicken, 54 percent for cow, 95 percent for dog, 72 percent for swine, and 51 percent for wild animal sources (Harwood and others, 2000). Water samples for this study were split into five classification catagories (chicken, cow, dog, human, and wild animal) that likely would produce a correct classification rate less than that of a two-way split and similar to a six-way split. Given the type of bacteria isolated (fecal coliform) and the database used for discriminant analysis of fecal coliform bacteria isolates, the probability of fecal coliform bacteria isolates being assigned to any one of the classification categories by chance alone is 20 percent. The probability of chance classification (20 percent) of fecal coliform bacteria isolates was considered the lower limit for considering any one source category to be a significant contributor of fecal coliform bacteria to the water.

Quality-assurance procedures were followed for collection and processing of water-quality samples. These procedures included checking and calibrating equipment daily as well as collecting additional samples for quality control. Analysis of quality-assurance samples provided information on the potential for sample contamination during collection, processing, and laboratory analysis.

Quality-assurance samples consisted of one field blank and three duplicate samples for major ions, one field blank and six duplicate samples for nutrients (nitrogen and phosphorus species), one field blank and two duplicate samples for analyses of organic wastewater compounds, and six field blanks for bacteria. Water samples for quality control were collected on randomly selected days at randomly selected sites during the study period.

Field blanks provide information on possible contamination introduced to the sample during collection and processing (handling) of the sample in the field. Field blank samples were prepared by pouring water certified to be free of the analytes of interest through all sampling equipment as if an environmental sample was being processed. Constituent concentrations for field blank samples were less than the method-reporting limits for all samples. Duplicate quality-assurance samples were collected simultaneously with scheduled water samples, and were processed using the same equipment for both samples. Collection of duplicate samples provided information on the uniformity of sample handling in the field and sample processing by the laboratory. The small nature of the duplicate data set, six or less sample sets per constituent family, did not allow for an acceptable statistical comparison of quality-assurance and environmental water samples. Constituent concentrations for duplicate quality-assurance samples and environmental water samples were compared. The comparison indicated no contamination due to collection, handling, or processing.

Data were graphically compared and statistically tested to evaluate whether any differences in constituent concentrations were observed between sites and basins. Data were analyzed for similarities and differences between upstream and downstream sites. Basin characteristics were evaluated along with the water-quality data to determine possible relations between observed water-quality constituent concentrations.

Summary statistics are presented and a nonparametric rank sum test (Helsel and Hirsch, 1992) was used to determine whether differences between sites in the study areas were statistically significant. The rank sum test makes no assumption about the data distribution and was used because the data were not normally distributed. The rank sum test uses a statistic called a p-value. When the p-value is less than the chosen confidence level (in this study, 0.05), sample populations are considered statistically different. The lower the p-value, the more significant the difference.

BASIN CHARACTERISTICS

Duval County originally was comprised of many small towns and unincorporated areas, each with its own public services and infrastructure. In the 1970's the small towns and unincorporated areas in Duval County were combined into the unified city of Jacksonville. As a result, the city of Jacksonville contained many areas that had little or no centralized public water or sanitary sewer systems. The two neighborhoods of interest to this study, the Pernecia and Murray Hill B subdivisions, consist of residences serviced by individual septic tank systems. As part of infrastructure improvements addressed by the Better Jacksonville Plan (City of Jacksonville, 2000), these subdivisions were scheduled for installation of sanitary sewer systems and removal of septic tank systems.

The Pernecia and Murray Hill B subdivisions are suburban residential neighborhoods that are intersected by the study basins, Fishing Creek and South Branch Big Fishweir Creek, respectively (figs. 2 and 3). Both subdivisions contain single-family homes, duplexes, and some small-business development along the major four-lane roadways. Greater than 90 percent of the land use in each basin is single- or multi-family residences located along two-lane streets with swale drainage ditches (Amy McGrath, Jacksonville Electric Authority, written commun., 2002). The Pernecia subdivision covers an area of about 193 acres, of which 156 acres drain to Fishing Creek. The Murray Hill B subdivision is about 465 acres, of which 154 acres drain to South Branch Big Fishweir Creek. The population and number of residences and septic tanks in the Pernecia and Murray Hill B subdivisions are provided in table 2.

Exact totals for residential water and sewer usage for the Pernecia and Murray Hill B subdivisions are difficult to obtain because residences are serviced by individual water supply wells and septic tank systems. Study area reconnaissance indicated that no National Pollutant Discharge Elimination System (NPDES) permitted discharges exist within or upstream from the study basins and no point-source discharges were observed in the study basins (Dana Morton, city of Jacksonville, Division of Air and Water Quality, oral commun., 2002). Records of the JEA (2002) indicate that the average annual water and sewer usage per residence was about 10,700 and 8,860 cubic feet, respectively, between October 1, 2001, and September 30, 2002 (table 3). These numbers are based on the Duval County average and likely represent the average usage for any one residence during the year sampled. Given the diversity of residences accounted for in the JEA (2002) report, it is likely that the average water and sewer usages presented in table 3 are representative of the Pernecia and Murray Hill B subdivisions.

Fishing Creek

The Fishing Creek basin (figs. 1 and 2) is located west of the St. Johns River and joins the Ortega River south (upstream) of its confluence with the Cedar River. Land areas in the basin generally are low lying with little topographic relief. The downstream end of the study area is located approximately 2 miles upstream from the confluence with the Ortega River. The Fishing Creek study basin has a drainage area of 812.8 acres and contains 156 acres of the Pernecia subdivision.

Table 2. Subdivision and study basin characteristics, Jacksonville, Florida, 2000

[Source of data: Amy McGrath, Jacksonville Electric Authority, written commun., 2002]

Subdivision	Associated study basin	Study basin drainage area (acres)	Subdivision				Intersecting area[a] (acres)
			Area (acres)	Population (count)	Residences (count)	Septic tanks (count)	
Pernecia	Fishing Creek	812.8	193.2	522	246	251	156
Murray Hill B	South Branch Big Fishweir Creek	428.8	464.8	2,766	1,077	1,245	154

[a]Area within the subdivision that drains to the study basin.

Table 3. Residential water use, Duval County, Florida, 2002

Usage type	Average usage for individual accounts[a]		
	Annual (cubic feet)	Daily (cubic feet)	Daily (gallons)
Water	10,700	29.3	219
Sewer	8,860	24.3	182

[a]Based on Jacksonville Electric Authority 2002 Annual Report.

Upland areas in the Fishing Creek basin that drain to the stream channel tend to be relatively low and flat. The creek generally is narrow, 25 ft or less in width, with definitive banks that are 3-6 ft high, especially in the lower reaches of the basin. During high-flow conditions, the stream has overflowed its banks and spread into the adjacent neighborhood; conversely, during extended droughts, the stream has become intermittent for extended periods. Two distinct areas can be characterized in the Fishing Creek study basin: the western part of the basin upstream from Blanding Boulevard, and the northeastern part of the basin downstream from Blanding Boulevard. In the upstream part of the basin, west of Blanding Boulevard, the stream channel flows through densely wooded areas and becomes poorly defined, expanding into low-lying swampy areas. The upstream part of the basin is less populated, especially in the far western part. East of Blanding Boulevard, the channel is well-defined and meanders through a wooded riparian zone in a moderately populated suburban residential area (the Pernecia subdivision). Based on 2000 data (table 2), population, housing (number of residences), and septic tank densities for the Pernecia subdivision were 2.7 people per acre, 1.3 houses per acre, and 1.3 septic tanks per acre, respectively. Due to the non-uniformity of housing distribution in the basin, densities likely are larger for areas in the northeastern part of the basin where the Pernecia subdivision is located.

Big Fishweir Creek

The Big Fishweir Creek basin (figs. 1 and 3) is located west of the St. Johns River and joins the Ortega River at its confluence with the St. Johns River. The North and South Branches of Big Fishweir Creek come together approximately 0.75 miles (mi) upstream from the mouth. The study basin is located on the South Branch of Big Fishweir Creek less than 0.25 mi upstream from the confluence of the North and South Branches. Land areas within the basin generally are low-lying with moderate topographic relief. The South Branch Big Fishweir Creek study basin has a drainage area of 428.8 acres and contains 154 acres of the Murray Hill B subdivision.

The South Branch Big Fishweir Creek is narrow, 20 ft or less, with banks approximately 3-5 ft high. The stream channel is modified throughout the basin and has sections of man-made channel armoring in the upper and middle reaches between Lakeshore Boulevard and Park Street. The channel in the upper reaches of the basin has been straightened and is deeply incised for drainage purposes. The basin divide in the upper basin is poorly defined because in this area the creek is connected to the Cedar River basin to the west. The riparian zone of the creek generally is lightly wooded and characterized by grassy areas common in suburban backyards. The South Branch Big Fishweir Creek is not known to be intermittent; a small amount of base flow generally is present even during extended dry periods. High flows usually are contained within the banks except during extreme events. Upland areas draining to the stream channel in the South Branch Big Fishweir Creek basin have greater slope than those in the Fishing Creek basin, especially in the lower parts of the basin. Based on 2000 data (table 2), population, housing (number of residences), and septic tank densities for the Murray Hill B subdivision were 6.0 people per acre, 2.3 houses per acre, and 2.7 septic tanks per acre, respectively.

STREAMFLOW

Measurements of streamflow were made approximately quarterly when water-quality samples were collected and during storm events. The measured flows ranged from 107 cubic feet per second (ft^3/s) at Fishing Creek at 110th Street to 0.02 ft^3/s at the South Branch Big Fishweir Creek at Cassat Avenue (table 4). Three of the four measurement sites had two or more observations of no flow. The only site where no-flow conditions were not observed was the South Branch Big Fishweir at Cassat Avenue site. The downstream site on the South Branch of Big Fishweir Creek (at Blanding Boulevard) had two observations of no flow, but these observations were noted as being caused by backwater from debris. It is likely that a small amount of flow occurred at the observation times at the South Branch of Big Fishweir Creek at Blanding Boulevard site.

Table 4. Measured streamflow summary for data collection sites, Jacksonville, Florida

[USGS, U.S. Geological Survey; discharge values are in cubic feet per second; e, estimated. Map number shown in figures 1, 2, and 3]

Map number	Site name and USGS identification number	Number of measure-ments	Maximum measured discharge	Date	Minimum measured discharge	Date	Observations of no-flow
4	Fishing Creek at Wesconnet Boulevard (02246435)	11	75.4	9/15/2001	.07	9/5/2000	7
5	Fishing Creek at 110th Street (0226437)	13	107	9/15/2001	.07	7/11/2000	4
6	South Branch Big Fishweir Creek at Casssat Avenue (02246465)	14	9.87	9/15/2001	.02	7/11/2000	0
7	South Branch Big Fishweir Creek at Blanding Boulevard (02246467)	13	15.9	9/15/2001	.10e	6/12/2000 7/11/2000	2[a]

[a]No observable or measurable flow due to backwater from downstream debris causing ponded conditions.

Measured streamflows for Fishing Creek generally were greater than those for South Branch Big Fishweir Creek, and in both basins streamflow increases from upstream to downstream (fig. 4). Based on calculations from periodic streamflow measurements, the runoff per unit area is greater in the Fishing Creek basin. However, the South Branch of Big Fishweir basin has a higher housing density, which generally would result in increased runoff per unit area, so it is possible that soil types and inflow from the surficial aquifer are the causes of increased runoff per unit area in the Fishing Creek basin.

Streamflow measurements were somewhat evenly distributed throughout the range of flows measured (fig. 4). The relatively small (14 or less per site) number of streamflow measurements made during the study period can easily be skewed from the normal distribution of measurements by outliers. Skew in the measured streamflows is indicated at the Fishing Creek at Wesconnet Boulevard site where 11 measurements were made, 2 of which were during storm events. This tended to bias percentiles of the sample set above the median streamflow, although a majority of flows were measured at less than 0.50 ft^3/s.

Streamflow was not measured continuously at sites, and it was unknown whether periodically measured streamflows were representative of the range of hydrologic conditions that may occur at study sites. Comparisons were made at a continuous-monitoring streamflow site at the Ortega River at 103rd Street near Jacksonville (map number 3, fig. 1) to determine whether periodically measured streamflows were representative of the range of hydrologic conditions during the study. Both of the study basins lie east of the drainage area included at the Ortega River at 103rd Street site, but the site is close enough to the study basins that the observed hydrologic conditions are considered representative of those at the study sites. A comparison of daily mean streamflows provides an indication of the range of hydrologic conditions observed at study sites (fig. 5).

Daily streamflows observed during the study period (January 1, 2000, to September 30, 2002) tend to be less then those observed over the period of record (January 1, 1965, to September 30, 2002) at the Ortega River at 103rd Street site. This is consistent with the below-average rainfall observed during the study period (table 5). The median for days when samples were taken at Fishing Creek and South Branch Big Fishweir Creek closely represents the study period and long-term medians. The range of conditions for sampled days is slightly less than that for the study period and long-term period of record. Given the small number of streamflow observations at sampling sites, the observed hydrologic conditions represent the long-term hydrologic conditions fairly well.

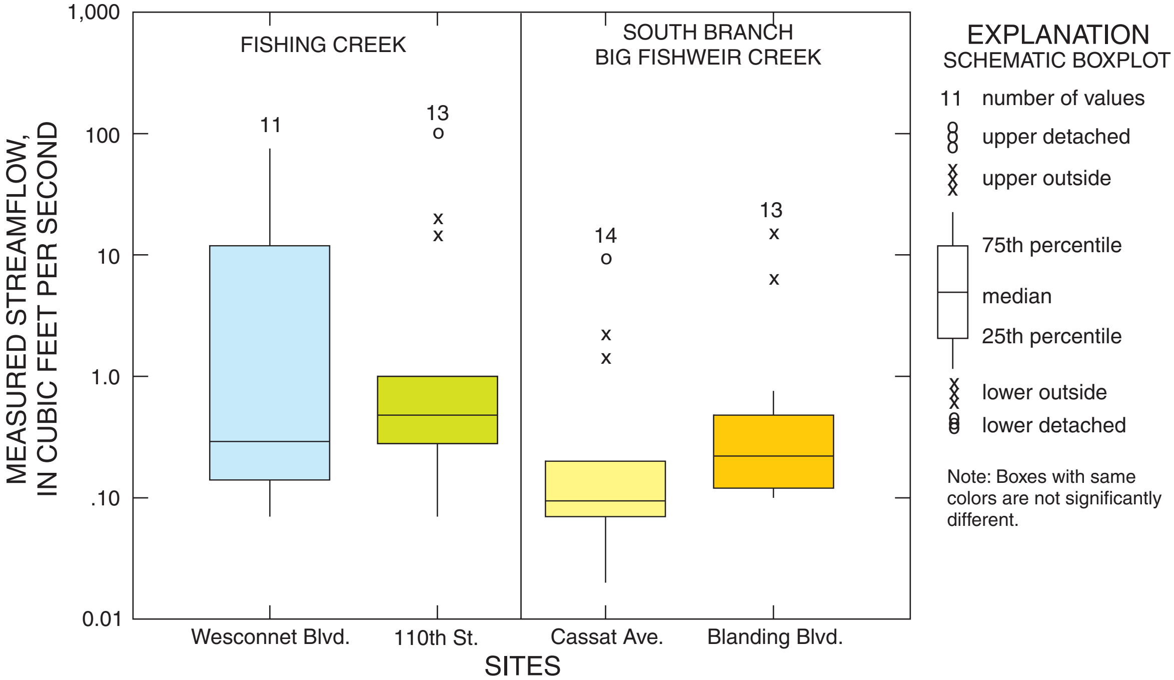


Figure 4. Measured streamflow at data collection sites, Jacksonville, Florida, 2000-2002 (site numbers refer to table 1).

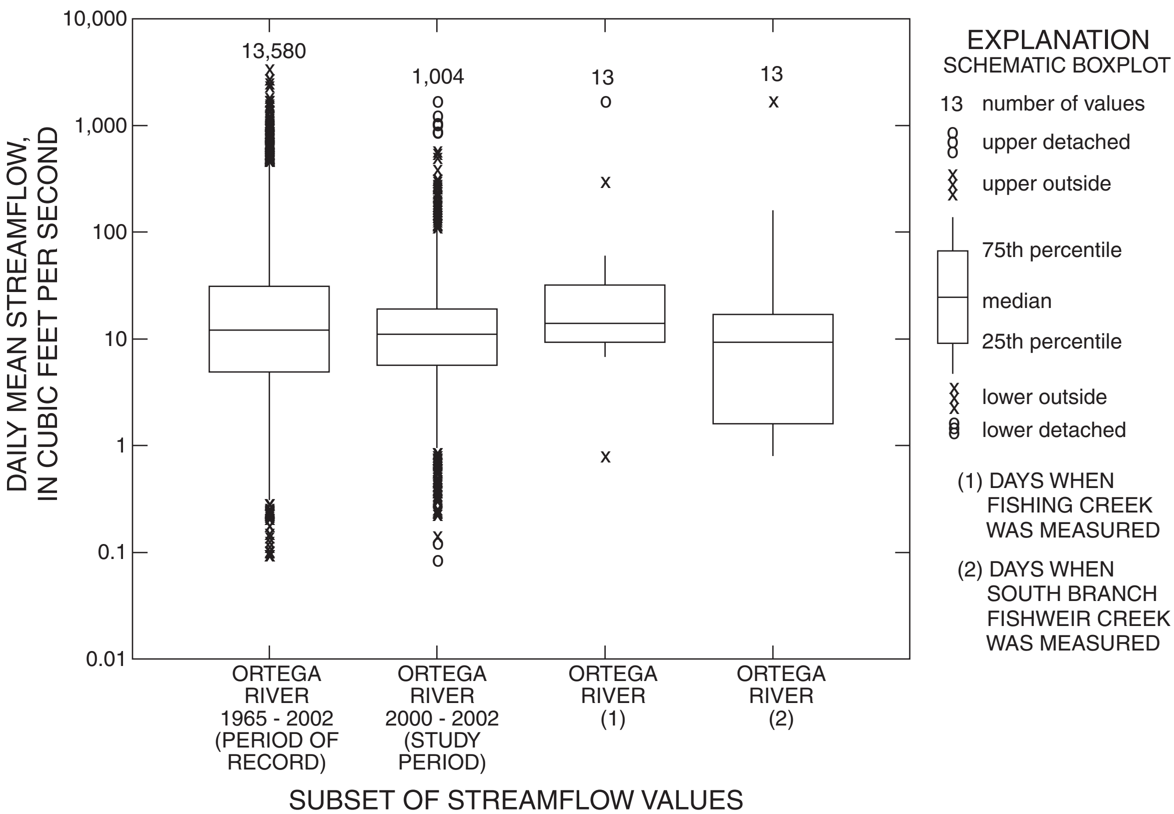


Figure 5. Comparison of daily mean streamflow for Ortega River near Jacksonville for the period of record, January 1, 1965, to September 30, 2002; January 1, 2000, to September 30, 2002; and daily mean streamflows for days on which measurements were made at Fishing Creek at 110th Street and South Branch Big Fishweir Creek at Blanding Boulevard.

Table 5. Rainfall summary for selected sites in Jacksonville, Florida

[Map number shown in figure 1]

Map number	Site name and identification number	Annual rainfall total, inches			Average annual rainfall, inches (period of record)
		2000	2001	2002	
1	Jacksonville International Airport (084358)	39.77	49.14	54.74	52.9 (1931-2000)
2	Naval Air Station Jacksonville (722065)	40.64	51.57	46.96	47.5 (1945-1998)

EVALUATION OF WATER QUALITY AND POTENTIAL EFFECTS OF SEPTIC TANK EFFLUENT

The State of Florida developed a surface-water quality standards system, which includes classification, criteria, anti-degradation policy, and special protection of certain waters (Florida Department of Environmental Protection, 2002). According to the State of Florida, the streams in this study are classified as Class III surface waters: used for recreation and propagation and maintenance of a healthy, well-balanced population of fish and wildlife.

Although the water-quality data generally represent the full range of hydrologic conditions previously described, a majority of the samples were taken at sites during periods of low flow, less than 2.5 ft^3/s. Samples collected during low-flow periods represent surface water-quality conditions resulting from ground-water seepage (primarily septic effluent and upward movement of ground water from the surficial aquifer system). Samples collected during storm events represent water-quality conditions associated with surface runoff and shallow sub-surface flow of water to the stream. The surface runoff component of streamflow introduces variability in water-quality constituent concentrations observed and may dilute constituent concentrations due to the volume of water discharging to the stream. Constituent concentrations contributed to the stream water during storm events may overwhelm contributions from septic tanks, even though shallow sub-surface flow could "wash" constituents associated with septic tank effluent from the soil matrix.

The Nationwide Urban Runoff Project (NURP) investigated variability in constituent concentrations for urbanized basins (Novotny and Olem, 1994, p. 491-493). The investigation involved collecting intensive storm-runoff water-quality samples from 28 cities across the United States. Analysis of the data from that study indicated that land-use effects are eclipsed by the storm-to-storm variability, and therefore, land use is of little use to predict urban runoff quality or to explain site-to-site differences. Because the sample sets collected for this study are relatively small and contain samples collected during storm-runoff events, it is reasonable to assume that differences in water quality between basins will be difficult to detect given the results of the NURP. If more samples had been collected and analyzed for low-flow events only, then the results likely could determine differences in water quality of stream water between study basins based on land-use type (suburban high density versus suburban low density). There were not enough samples collected for this study, however, to perform individual comparisons and analysis for sample sets representing the ground-water and storm-flow components of the streamflow.

The water-quality standards system for Class III surface waters state that nutrients (total nitrogen and total phosphorus) shall be limited as needed to prevent violations of other standards, that man-induced nutrient enrichment shall be considered degradation, and that nutrient concentrations of a water body shall not be altered so as to cause an imbalance in the natural populations of aquatic flora and fauna (Florida Department of Environmental Protection, 2002). The U.S. Environmental Protection Agency (2000) lists nutrient criteria for rivers and streams in Ecoregion XII, which encompasses the study areas, as 0.90 milligrams per liter (mg/L) for total nitrogen and 0.04 mg/L for total phosphorus.

Waste from warm blooded animals contributes a variety of intestinal bacteria that can be pathogenic to humans; body contact with water that contains pathogens can result in several types of diseases in humans. The State of Florida fecal coliform bacteria standard for Class III surface waters is 800 colonies per 100 milliliters of water on any 1 day (Florida Department of Environmental Protection, 2002). Sources of bacteria can be from municipal wastewater discharges, leachate from domestic septic tank systems, runoff or ground-water seepage from live-stock producing areas (pasture and feedlots), areas where manure is applied as fertilizer, or from wildlife populations. Septic tanks are designed to reduce or eliminate most human health or environmental threats posed by pollutants in wastewater. Properly functioning septic tank systems result in retention and die-off of most pathogenic bacteria (U.S. Environmental Protection Agency, 2002b). Therefore, the presence of these organisms in surface water indicates fecal contamination and may also indicate the presence of pathogenic organisms.

The most widely used indicator bacteria are total coliform, fecal coliform, enterococci and fecal streptococci groups, and *Escherichia coli* (U.S. Environmental Protection Agency, 2002a). The city of Jacksonville maintains a monitoring network throughout Duval County, and collects samples that are analyzed for fecal coliform bacteria (Deuerling and Cooner, 1995). To maintain uniformity in data collection practices throughout the County and to evaluate the water-quality conditions of the stream water, fecal coliform bacteria were sampled and analyzed as part of this study.

Antibiotic use by animals and humans results in patterns of antibiotic resistance in fecal coliform bacteria that reflect to some extent the exposure of fecal coliform bacteria to antibiotics (Harwood and others, 2000). The analysis used for this study is based on the assumption that fecal coliform bacteria from human sources will have a different resistance to selected antibiotics than those from different animal sources (Simpson and others, 2002). The antibiotic resistance patterns of fecal coliform bacteria were used to identify the sources of fecal coliform bacteria. Determination of the source of fecal material would indicate whether human waste (septic tank effluent) is impacting the quality of the stream water.

Major Ions

Major ion concentrations can be used to compare surface-water and shallow ground-water characteristics and some can also be used as indicators of the effects of septic tank effluent. Pitt and others (1975) classified certain constituents as naturally occurring in ground water or associated with septic tank effluent, and summarized the chemical characteristics of shallow ground water in areas influenced by septic tanks in Dade County, Florida. Phelps (1994) summarized chemical characteristics of water from the surficial aquifer system in Duval County. A comparison of data from this study and those summarized by Pitt and others (1975) and Phelps (1994) is given in table 6.

Table 6. Summary of major ion constituents from surface-water samples for Fishing Creek and South Branch Big Fishweir Creek, Duval County, Florida, 2000-02; the surficial aquifer system in Duval County,1970-89; and selected surficial aquifer wells in areas serviced by septic tanks, Dade County, Florida, 1970-73

[All concentrations are dissolved and given in milligrams per liter, except where noted. µS/cm, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter]

Constituent	Study basins[a], 2000-02		Duval County[b], 1970-89		Septic tank influenced[c], 1970-73	
	Mean	Range of values	Mean	Range of values	Mean	Range of values
calcium	54	16 - 84	120	51 - 180	89	30 - 120
chloride	28	5.4 - 72	16	3 - 100	28	2.0 - 50
iron, µg/L	231	24 - 811	1,510	10 - 12,000	1,910	.7 - 36,000
magnesium	7.3	2.1 - 12	4.2	1.6 - 13	3.2	.9 - 8.0
pH, standard units	7.1	6.2 - 7.7	5.8	3.8 - 8.1	7.7[d]	6.8 - 8.5
potassium	3.3	1.7 - 5.1	.8	.4 - 1.0	3.1	.2 - 5.7
sodium	19	4.2 - 50	9.5	6.4 - 14	19	2.6 - 35
specific conductance, µS/cm	409	63 - 902	218	31 - 960	541	182 - 694
sulfate	40	3.9 - 83	12	.2 - 87	26	0.0 - 42

[a]Samples collected for this study.
[b]Phelps, 1994, table 3.
[c]Pitt, 1975, tables 5 and 6.
[d]Median pH value.

The specific conductance of water is a simple, useful measure of the presence of dissolved ions. Specific conductance values observed at study sites generally are comparable to specific conductance values observed in shallow ground water throughout Duval County (table 6). Dissolved calcium and magnesium, dissolution products of native rock, also indicate the influence of shallow ground water on the water chemistry of stream water. Sodium, potassium, chloride, and sulfate are naturally present in water, but also can be useful indicators of septic tank effluent (Pitt and others, 1975). The maximum dissolved potassium and sodium concentrations exceed background data for Duval County and are similar to those observed in Dade County at sites influenced by septic tank effluent.

Sodium is a conservative constituent that tends to remain in solution, and is introduced to septic tanks from grey and black water sources. Given the conservative nature of sodium, effluent from septic tanks likely will discharge elevated levels of sodium. Water samples for the Fishing Creek basin indicated sodium concentrations increased from upstream to downstream, and concentrations of sodium were greater in South Branch Big Fishweir Creek than in Fishing Creek (fig. 6). Increases in sodium concentrations from upstream to downstream in the Fishing Creek basin likely are due to the accumulation of septic tank effluent containing sodium as stream water moves downstream. The greater concentration of sodium in the South Branch Big Fishweir Creek basin likely is the result of higher septic tank densities and leaky infrastructure or improperly functioning septic tank systems upstream from the study area. The fact that sodium concentrations did not increase from upstream to downstream in the South Branch Big Fishweir Creek basin indicate that the stream may be at carrying capacity for constituents upstream from the South Branch Big Fishweir Creek at Cassat Avenue. Therefore, further addition of constituents within the study area will not affect constituent concentrations. Based on analysis of major ion samples, water-quality characteristics of the stream water in the study basins indicate influence from ground-water sources and septic tank activity.

Trace constituent data generally were not useful in evaluating effects of septic tank effluent. Water samples analyzed for boron and manganese had concentrations ranging from 20 to 99 micrograms per liter (μg/L) and 2.1 to 12 μg/L, respectively. Fifteen water samples from the Upper Floridan aquifer (Phelps, 2001) had boron concentrations ranging from 19 to 49 μg/L and manganese concentrations ranging from 0.3 to 10 μg/L. The higher range of boron concentrations observed in the present study might be indicative of the influence of septic tanks in the study basins, because boron is a constituent in household products.

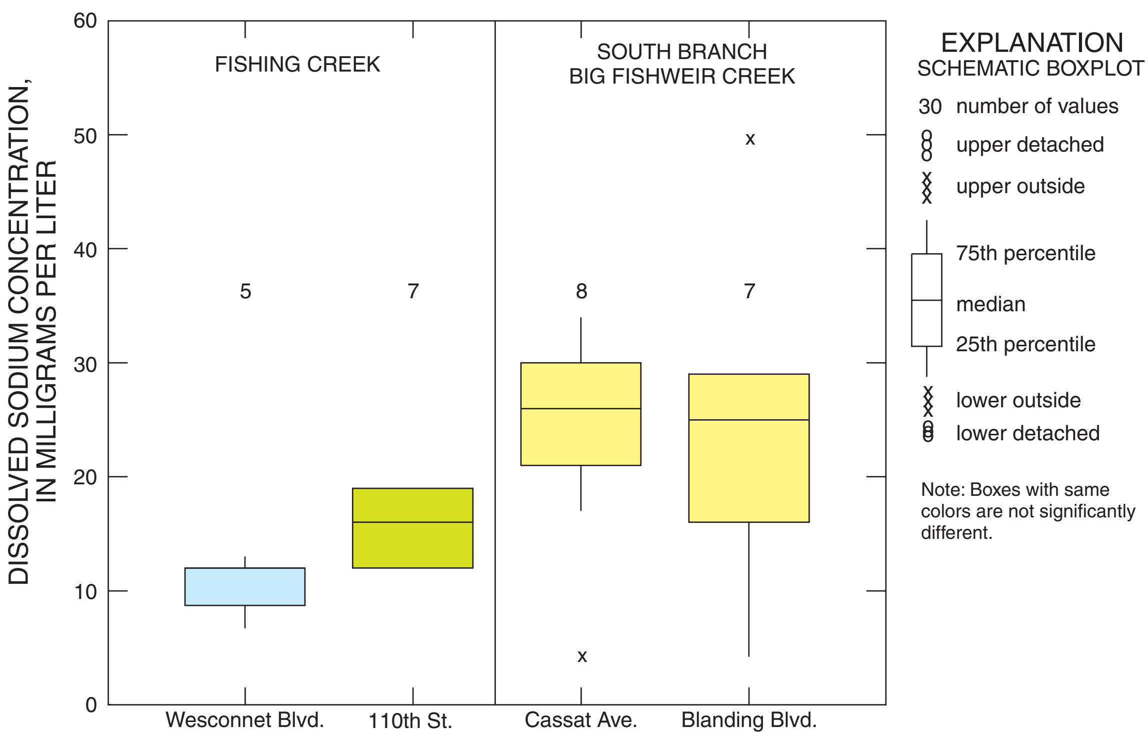


Figure 6. Concentrations of dissolved sodium at data collection sites, Jacksonville, Florida (site numbers refer to table 1).

Nutrients

The basic forms of nitrogen in water are nitrite, nitrate, ammonia, and organic nitrogen. Greater than 50 percent of samples analyzed for nitrite nitrogen had concentrations less than the laboratory reporting limit (0.01 mg/L); values ranged from less than the laboratory reporting limit to 0.07 mg/L. Concentrations for nitrate nitrogen and ammonia nitrogen ranged from less than laboratory reporting limit (0.02 and 0.01 mg/L, respectively) to 1.1 and 1.7 mg/L, respectively. Organic nitrogen concentrations were calculated by subtracting ammonia nitrogen concentrations from the ammonia-plus-organic nitrogen concentrations. Stream-water samples generally contained greater amounts of organic nitrogen than other nitrogen species (fig. 7). Organic nitrogen concentrations ranged from 0.07 to 1.56 mg/L at study sites.

Dissolved nitrite-plus-nitrate nitrogen were combined with total ammonia-plus-organic nitrogen to obtain an estimate of the total nitrogen concentration observed at study sites; total phosphorus was reported by the laboratory (table 7). Total nitrogen concentrations given in this report are considered an underestimate of total nitrogen because inorganic nitrogen sorbed to suspended sediment is not accounted for in the analysis of dissolved nitrite-plus-nitrate nitrogen. Water samples collected had estimated total nitrogen concentrations ranging from 0.33 to 2.86 mg/L and total phosphorus concentrations ranging from less than laboratory reporting limit (0.02 mg/L) to 0.64 mg/L. Concentrations of total nitrogen and total phosphorus in water sampled at study sites (Ecoregion XII) exceeded the U.S. Environmental Protection Agency (2000) nutrient criteria for rivers and streams 49 and 96 percent of the time, respectively.

The number of samples collected at sites was relatively small (less than 15), which makes statistical comparisons between sites of relatively limited use. Plots of total nitrogen (fig. 8) and total phosphorus (fig. 9) indicate that samples were not normally distributed at sites and had varied distributions. Visual comparison of the sample populations shows a difference from upstream to downstream and between Fishing Creek and South Branch Big Fishweir Creek basins. A comparison test was performed to determine whether sample sets of total nitrogen and total phosphorus have the same mean value. The statistical comparison indicated an upstream to downstream difference for total nitrogen in the South Branch Big Fishweir Creek basin (fig. 8) and a difference in mean concentration between the Fishing Creek and South Branch Big Fishweir Creek basins for total phosphorus (fig. 9).

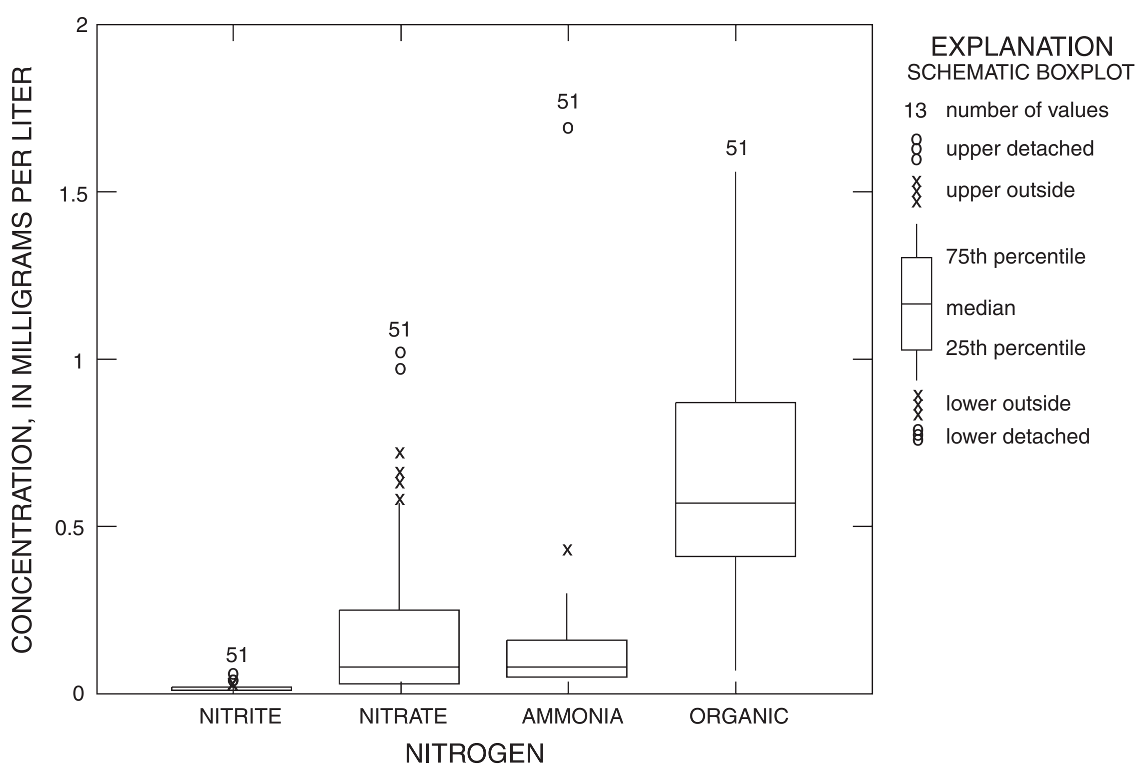


Figure 7. Concentrations of nitrogen species at data collection sites, Jacksonville, Florida.

Table 7. Summary of nitrogen and phosphorus concentrations for surface-water samples, Jacksonville, Florida

[USGS, U.S. Geological Survey; constituent concentration values are in milligrams per liter; <, less than. Map numbers shown in figures 2 and 3]

Map number	Site name and USGS identification number	Number of samples	Total nitrogen			Total phosphorus		
			Mean	Median	Range of values	Mean	Median	Range of values
4	Fishing Creek at Wesconnet Boulevard (02246435)	11	1.00	.82	.55 - 1.64	.08	.07	.04 - .19
5	Fishing Creek at 110th Street (0226437)	13	1.00	1.05	.53 - 1.73	.07	.06	<.02 - .18
6	South Branch Big Fishweir Creek at Casssat Avenue (02246465)	14	.86	.69	.33 - 2.86	.11	.08	.07 - .64
7	South Branch Big Fishweir Creek at Blanding Boulevard (02246467)	13	1.26	1.30	.45 - 2.00	.13	.12	.08 - .53

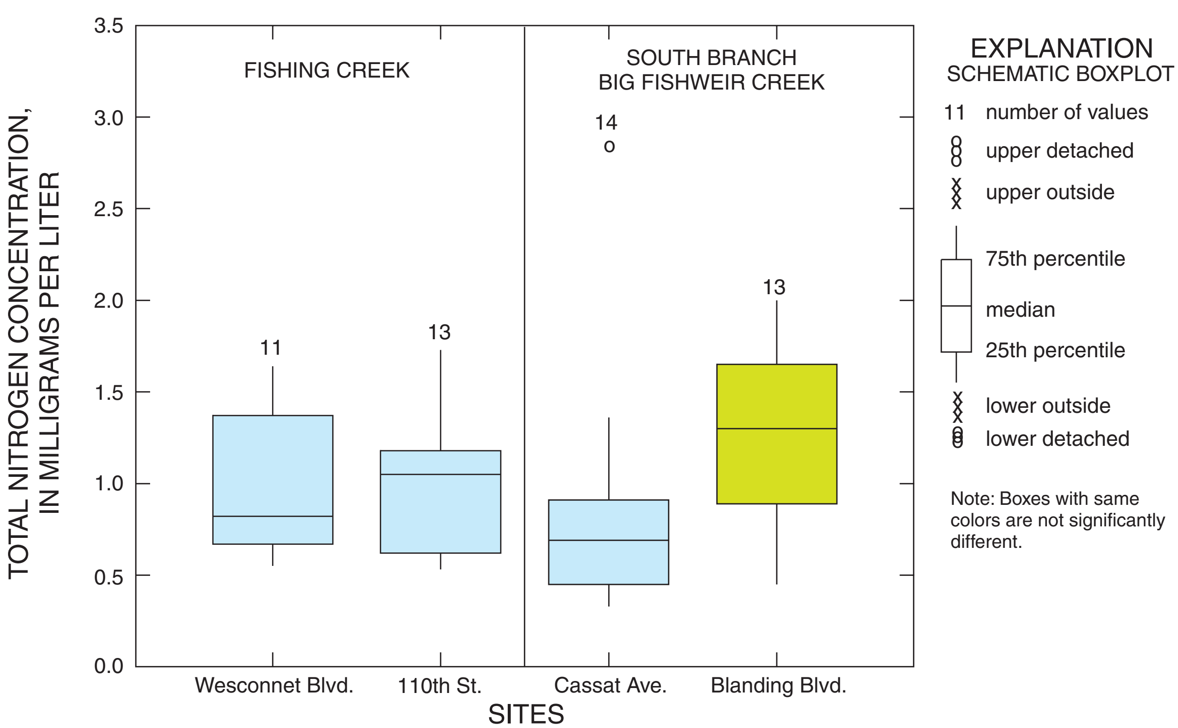


Figure 8. Concentrations of total nitrogen at data collection sites, Jacksonville, Florida (site names refer to table 1).

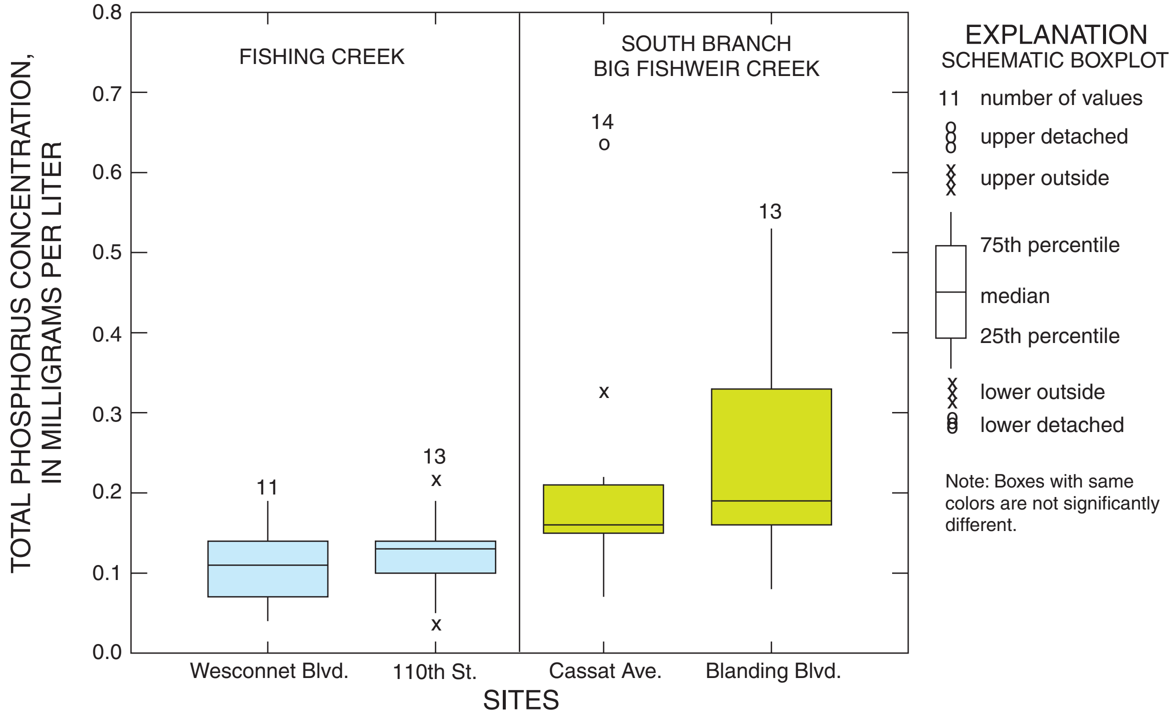


Figure 9. Concentrations of total phosphorus at data collection sites, Jacksonville, Florida (site names refer to table 1).

The potential effects of septic tanks on stream-water quality can be evaluated by comparing constituent contributions to septic tanks, removal efficiencies, and constituent concentrations observed in stream-water samples. Wastewater discharges to septic tanks were studied by the U.S. Environmental Protection Agency (U.S. Environmental Protection Agency, 2002b) and the State of Florida (Florida Executive Office of the Governor, 1999). These studies reported characterizations of septic tank effluent, and gave the average daily constituent concentrations contributed directly to septic tanks for total nitrogen and total phosphorus as ranging from 26 to 75 and 6 to 12 mg/L, respectively (U.S. Environmental Protection Agency, 2002b). Sikora and Corey (1976) list the potential removal efficiency of septic tank systems for total nitrogen and total phosphorus as 10 to 40 percent and 85 to 95 percent, respectively. These removal efficiencies are based on observations of ground water exiting the septic tank drain field.

Based on constituent contributions to septic tanks, removal efficiencies, and constituent concentrations observed in stream-water samples, removal efficiency for both total nitrogen and total phosphorus are greater than 90 percent. Water samples collected for this study were taken at a great distance (hundreds of feet) from individual septic tanks. These samples reflect potential input from other sources, such as fertilizer application, and changes in nitrogen and phosphorus as a result of adsorption and microbially mediated transformation. Based on calculations of removal efficiency, septic tank systems in the study basins were functioning properly at times and for hydrologic conditions when samples were collected. However, the hydrology of the study areas (shallow surficial aquifer system, fine-grained upland soils, and little topographic relief) and construction methods of individual septic systems affect the operation and efficiency of septic tank systems in the study areas, and therefore, affect stream-water quality.

Wastewater Constituents

Chemical analysis of stream-water samples for compounds commonly found in wastewater was used to evaluate the impact of sanitary sewer or septic tank outflow on the water quality of study streams. Organic wastewater compounds detected above the minimum laboratory-reporting level are listed in table 8.

Table 8. Concentrations of organic wastewater compounds above the minimum laboratory-reporting level, Jacksonville, Florida

[d, nonionic detergent metabolite; a, manufactured polycarbonate resins, antioxidant, flame retardant; i, insecticide, urban uses, mosquito repellent; p, plasticizer, flame retardant; c, beverages, diuretic; s, solvent for lacquer, plastic, oil, silicon, resin; m, cigarettes, cough drops, liniment, mouthwash; e, compound was detected but concentrations with low recovery, high variable recovery, unstable instrument response, or from technical mixture are not quantified; µg/L, micrograms per liter. Map numbers shown in figures 2 and 3]

Map number	Site name	Sample date	Constituent name	Possible compound uses or sources[a]	Concen-tration (µg/L)
4	Fishing Creek at Wesconnett Boulevard	8/21/2001	para-Nonylphenol (total)	d	e
4	Fishing Creek at Wesconnett Boulevard	2/26/2002	Bisphenol A	a	1.1
4	Fishing Creek at Wesconnett Boulevard	2/26/2002	para-Nonylphenol (total)	d	e
5	Fishing Creek at 110th Street	7/11/2000	N,N-diethyl-meta-toluamide (Deet)	i	1.32
5	Fishing Creek at 110th Street	2/26/2002	Bisphenol A	a	2.7
6	South Branch Big Fishweir Creek at Cassat Avenue	7/11/2000	tri(2-chloroethyl)phosphate	p	.88
6	South Branch Big Fishweir Creek at Cassat Avenue	8/21/2001	Caffeine	c	2
6	South Branch Big Fishweir Creek at Cassat Avenue	8/21/2001	Isophorone	s	12
6	South Branch Big Fishweir Creek at Cassat Avenue	8/21/2001	Menthol	m	.85
6	South Branch Big Fishweir Creek at Cassat Avenue	8/21/2001	N,N-diethyl-meta-toluamide (Deet)	i	.81
6	South Branch Big Fishweir Creek at Cassat Avenue	8/21/2001	para-Nonylphenol (total)	d	e
7	South Branch Big Fishweir Creek at Blanding Boulevard	8/22/2001	Isophorone	s	3.1
7	South Branch Big Fishweir Creek at Blanding Boulevard	8/22/2001	para-Nonylphenol (total)	d	e
7	South Branch Big Fishweir Creek at Blanding Boulevard	2/26/2002	para-Nonylphenol (total)	d	e

[a]Zaugg, 2002, table 1.

Compounds detected were detergents, antioxidants and flame retardants, manufactured polycarbonate resins, industrial solvents, and mosquito repellent. The most commonly detected compound was para-nonylphenol, which is a detergent metabolite; it was detected in both the Fishing Creek and South Branch Big Fishweir Creek basins. The likely source of para-nonylphenol is wastewater from washing machines and dishwashing detergents discharged to septic tanks. Another compound detected in both basins was N,N-diethyl-meta-toluamide (Deet). The source of this compound likely is wastewater produced by residents bathing or washing clothing after using personal insecticides containing Deet or runoff of overspray. Another compound detected in the Fishing Creek basin was bisphenol-A; this compound is used primarily to make polycarbonate plastic and epoxy resins. Samples for the South Branch Big Fishweir Creek basin had a greater number of compounds (table 8) detected than did samples from the Fishing Creek basin. The South Branch Big Fishweir Creek basin contains some small business development, which likely contributed to detections of compounds such as isophorone, an industrial solvent. Most of the compounds detected are commonly associated with grey water discharges to septic tanks in the study areas; therefore, their presence indicates that the Fishing Creek and South Branch Big Fishweir Creek basins are influenced by wastewater from septic tanks.

Bacteria

Fecal coliform bacteria concentrations were measured on a monthly basis; of 115 samples, 63 percent exceeded the State of Florida fecal coliform bacteria standard for Class III surface waters of 800 colonies per 100 milliliters of water on any 1 day. The results of individual water samples collected for fecal coliform bacteria analysis are given in appendix 3. Fecal coliform bacteria in water samples were reported as most probable number per 100 milliliters (mpn/100mL) of sample and ranged from less than 20 mpn/100mL at Fishing Creek at Wesconnet Boulevard to equal to or greater than 160,000 mpn/100mL at South Branch Big Fishweir Creek at Blanding Boulevard (table 9). The median and geometric mean indicate that colony concentrations increase from upstream to downstream for the Fishing Creek basin, and that the South Branch Big Fishweir Creek basin has higher colony concentrations than those for the Fishing Creek basin.

Table 9. Fecal coliform bacteria summary for surface-water samples, Jacksonville, Florida

[USGS, U.S. Geological Survey; <, less than; fecal coliform bacteria values are reported as most probable number per 100 milliliters. Map numbers shown in figures 2 and 3]

Map number	Site name and USGS identification number	Number of samples	Maximum	Minimum	Median	Geometric mean
4	Fishing Creek at Wesconnet Boulevard (02246435)	25	50,000	<20	70	138
5	Fishing Creek at 110th Street (0226437)	28	50,000	20	900	926
6	South Branch Big Fishweir Creek at Casssat Avenue (02246465)	31	160,000	40	5,000	3,720
7	South Branch Big Fishweir Creek at Blanding Boulevard (02246467)	31	≥160,000	800	6,000	7,040

Fecal coliform bacteria concentrations were significantly higher in the South Branch Big Fishweir Creek basin than in the Fishing Creek basin (fig. 10). This likely is the result of the higher density of septic tanks per acre in the South Branch Big Fishweir Creek basin. Fecal coliform bacteria concentrations also were significantly greater at the downstream site on Fishing Creek compared to the upstream site. Increases in bacteria concentrations from upstream to downstream in the Fishing Creek basin likely are due to the accumulation of septic tank effluent as stream water moves downstream. There was no significant difference in the fecal coliform bacteria concentrations between the two South Branch Big Fishweir Creek sites. This likely is due to the varaiation in housing and septic tank density in the Fishing Creek basin and higher colony concentrations observed in the South Branch Big Fishweir Creek basin, which make it more difficult to observe significant differences in the sample population mean given a similar increase in colony concentrations from upstream to downstream. The lack of significant difference between upstream and downstream bacteria concentrations may also be an indication that the South Branch Big Fishweir Creek basin is at carrying capacity and addition of septic tank effluent to the stream will not affect bacteria populations. Overall, fecal coliform bacteria concentrations exceeded the State of Florida Class III surface-water standards and reflect the impact of septic tank effluent on the quality of stream water.

Water samples analyzed for antibiotic resistance patterns of fecal coliform bacteria were used to evaluate the potential impact of human activity on the quality of stream water. A total of 16 samples was collected, and fecal coliform bacteria isolates were classified into five source catagories for each sample; chicken, cow, dog, human, and wildlife. Fecal coliform bacteria were detected and classified at significant levels (greater than 20 percent) for 23 of the 80 potential classifications (1 chicken, 3 dog, 14 human, and 5 wildlife). Individual sample results (app. 4) were combined for each of the study sites to obtain an average likelihood of potential sources for the entire study period (table 10). Significant sources of fecal coliform bacteria isolates over the study period as determined by the antibiotic resistance analysis were wild animals and humans. A majority of the fecal coliform bacteria were classified to be from human sources; these were detected at a significant level for all study sites in both the Fishing Creek and South Branch Big Fishweir Creek basins. Fecal coliform bacteria classified as from wild animals were detected at significant levels at Fishing Creek at 110th Street. Detections of fecal coliform bacteria isolates from wild animal sources for Fishing Creek at 110th Street occurred during and following installation of the sanitary sewer system infrastructure in the basin. Samples collected at this site indicated a change in known source classification from human to a mix of human and wild animal and later dog and wild animal over the study period (app. 4). The change in classification of known sources likely occurred due to drainage changes made in the stream and other parts of the basin during construction and connection of residences to the sanitary sewer system following its completion in November 2002 (Dana Morton, city of Jacksonville, Division of Air and Water Quality, oral commun., 2003). Results of the fecal coliform bacteria antibiotic resistance analysis indicate that movement of septic tank effluent through the soil matrix and discharged to the stream contributes to fecal coliform bacteria populations observed in the stream water. Because the primary source of fecal coliform bacteria is from human sources, most likely septic tank effluent, management of human sources may substationally improve microbiological water quality in both the Fishing Creek and South Branch Big Fishweir Creek basins.

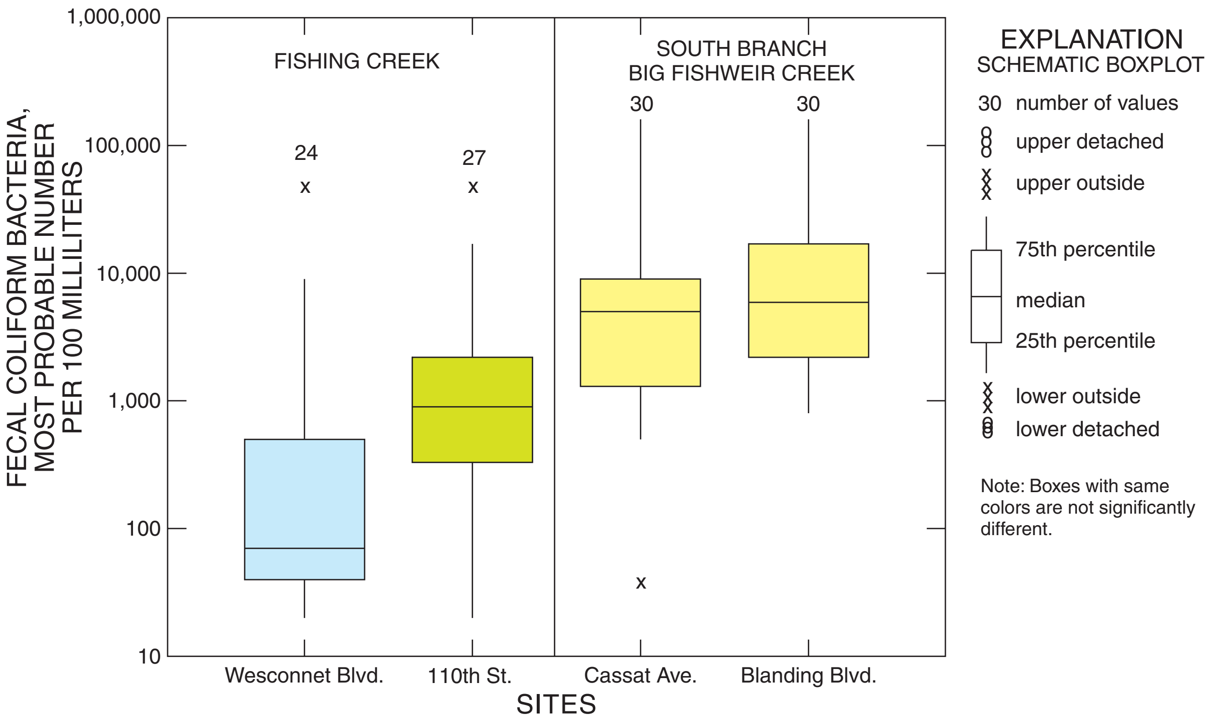


Figure 10. Concentrations of fecal coliform bacteria at data collection sites, Jacksonville, Florida (site names refer to table 1).

Table 10. Summary of discriminant analysis of antibiotic resistance patterns used to classify fecal coliform bacteria from known sources into source categories for surface-water samples, Jacksonville, Florida

[USGS, U.S. Geological Survey; map numbers shown in figures 2 and 3. Percentages may not equal 100 percent due to rounding]

Map number	Site name and USGS identification number	Classifications of fecal coliform bacteria isolates					Total count (percent)
		Chicken count (percent)	Cow count (percent)	Dog count (percent)	Human count (percent)	Wild count (percent)	
4	Fishing Creek at Wesconnet Boulevard (02246435)	6 (3.2)	1 (.5)	17 (9.1)	126 (67.4)	37 (19.8)	187 (100)
5	Fishing Creek at 110th Street (0226437)	3 (2.3)	4 (3.1)	18 (13.7)	62 (47.3)	44 (33.6)	131 (100)
6	South Branch Big Fishweir Creek at Casssat Avenue (02246465)	12 (6.7)	1 (.6)	10 (5.6)	145 (80.6)	12 (6.7)	180 (100)
7	South Branch Big Fishweir Creek at Blanding Boulevard (02246467)	11 (5.7)	0 (.0)	34 (17.6)	131 (67.9)	17 (8.8)	193 (100)

SUMMARY

Tributary streamflow to the St. Johns River in Duval County is thought to be affected by septic tank leachate from residential areas adjacent to these tributaries. Water managers and the city of Jacksonville have committed to infrastructure improvements as part of a management plan to address the impairment of tributary water quality. Major ion, nutrient, and fecal coliform concentrations, detection of wastewater compounds, and tracking of bacterial sources were used to document septic tank influences on the water quality of selected tributaries in order to provide data to evaluate the effects of future remedial activities in selected tributaries.

The tributaries of Fishing Creek and South Big Fishweir Creek were selected because they coincide with subdivisions identified as high-priority locations for septic tank phase-out projects: the Pernecia and Murray Hill B subdivisions, respectively. The data collection networks consisted of two sites in each study basin located at points upstream and downstream from areas where septic tanks are to be replaced by a sanitary sewer system. These sites provided information on the hydrologic and water-quality characteristics of the study basins over the study period, April 1999 to September 2002.

The Fishing Creek basin is west of the St. Johns River and joins the Ortega River south (upstream) of its confluence with the Cedar River. The Big Fishweir Creek basin is west of the St. Johns River and joins the Ortega River at its confluence with the St. Johns River. Both creeks are relatively narrow, 25 feet or less in width, with definitive banks that are 3-6 feet high, especially in the lower reaches of the basin. The Pernecia subdivision covers an area of about 193 acres, of which 156 acres drain to Fishing Creek; the Murray Hill B subdivision is about 465 acres, of which 154 acres drain to South Branch Big Fishweir Creek. Population, housing (number of residences), and septic tank densities for the Fishing Creek and South Branch Big Fishweir Creek basins are 2.7 and 6.0 people per acre, 1.3 and 2.3 houses per acre, and 1.3 and 2.7 septic tanks per acre, respectively.

Measured streamflows ranged from 107 cubic feet per second (ft^3/s) at Fishing Creek at 110th Street to 0.02 ft^3/s at the South Branch Big Fishweir Creek at Cassat Avenue. Streamflows for Fishing Creek tend to be greater than those for South Branch Big Fishweir Creek, and streamflow increases from upstream to downstream in both basins. Based on calculations from periodic measurements of streamflow, the runoff per unit area is greater in the Fishing Creek basin than in the South Branch Big Fishweir Creek basin.

Water samples analyzed for major ions and nutrients were collected in conjunction with discharge measurements. A majority of the samples collected were during periods of low flow, less than 2.5 ft^3/s, and generally represent base-flow conditions. Analysis of major ion samples indicates influence from groundwater sources and septic tank activity. The maximum levels for dissolved potassium and sodium exceed those elsewhere in Duval County and are similar to those in Dade County at sites influenced by septic tank effluent.

Stream-water samples generally contained greater amounts of organic nitrogen than other nitrogen species, and concentrations ranged from 0.07 to 1.56 milligrams per liter (mg/l). Concentrations of total nitrogen ranged from 0.33 to 2.86 mg/L, and concentrations for total phosphorus ranged from less than laboratory reporting limit (0.02 mg/l) to 0.64 mg/l. Concentrations of total nitrogen and total phosphorus sampled at study sites exceeded the U.S. Environmental Protection Agency Ecoregion XII nutrient criteria for rivers and streams 49 and 96 percent of the time, respectively.

Wastewater compounds detected at study sites were categorized as detergents, antioxidants and flame retardants, manufactured polycarbonate resins, industrial solvents, and mosquito repellent. The South Branch Big Fishweir Creek basin had a greater number of compounds detected than the Fishing Creek basin. The most common compound detected was para-nonylphenol, which is a breakdown product of detergent. It was detected in both the Fishing Creek and South Branch Big Fishweir Creek study basins. Results of wastewater sampling indicate the presence of septic tank leachate in stream water.

Fecal coliform bacteria concentrations were measured on a monthly basis; of 115 samples, 63 percent exceeded the State of Florida fecal coliform bacteria standard for Class III surface waters of 800 colonies per 100 milliliters of water on any 1 day. Fecal coliform bacteria concentrations ranged from less than than 20 most probable number per 100 milliliters (mpn/100mL) of sample at Fishing Creek at Wesconnet Boulevard to equal to or greater than

160,000 mpn/100mL at South Branch Big Fishweir Creek at Blanding Boulevard. Fecal coliform bacteria concentrations were significantly higher in the South Branch Big Fishweir Creek basin than in the Fishing Creek basin during the study. Antibiotic resistance patterns of fecal coliform bacteria were used to identify the sources of fecal coliform bacteria. Significant sources of fecal coliform bacteria included wild animals, dogs, and humans. A majority of the fecal coliform bacteria were classified to be from human sources. Because the primary source of fecal coliform bacteria is from human sources, most likely septic tank effluent, management of human sources may substationally improve microbiological water quality in both the Fishing Creek and South Branch Big Fishweir Creek basins.

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Appendix 1. Constituents analyzed as part of major ion and nutrient sampling

[mg/L; milligrams per liter]

Constituent name	Method reporting limit (mg/L)
acid neutralizing capacity	1
boron	.002
calcium	.02
chloride	.1
fluoride	.1
iron	.002
magnesium	.03
manganese	.001
nitrogen, ammonia, dissolved	.01
nitrogen, ammonia plus organic nitrogen, total	.2
nitrogen, nitrite, dissolved	.01
nitrogen, nitrite plus nitrate, dissolved	.02
pH	.1[a]
phosphorus, dissolved	.02
phosphorus, total	.02
phosphorus, phosphate, ortho, dissolved	.018
potassium	.1
silica	.01
sodium	.1
specific conductance	1.[b]
sulfate	.2

[a]standard units
[b]microSiemens per centimeter at 25 degrees Celsius

Appendix 2. Constituents analyzed as part of the U.S. Geological Survey National Water-Quality Laboratory organic wastewater sample series

[mg/L, micrograms per liter]

Constituent name	Method reporting limit (μg/L)
1-Methylnaphthalene	.5
1,4-Dichlorobenzene	.5
2,6-Dimethylnaphthalene	.5
2-Methylnaphthalene	.5
3-beta-Coprostanol	2
3-Methyl-1(H)-indole (Skatole)	1
3-tert-Butyl-4-hydroxy anisole (BHA)	5
4-Cumylphenol	1
4-n-Octylphenol	1
4-tert-Octylphenol	1
5-Methyl-1H-benzotriazole	2
Acetophenone	.5
Acetyl hexamethyl tetrahydronaphthalene (AHTN)	.5
Anthracene	.5
Anthraquinone	.5
Benzo[a]pyrene	.5
Benzophenone	.5
beta-Sitosterol	2
beta-Stigmastanol	2
Bisphenol A	1
Bromacil	.5
Bromoform	.5
Caffeine	.5
Camphor	.5
Carbaryl	1
Carbazole	.5
Cholesterol	2
Chlorpyrifos	.5
Cotinine	1
d-Limonene	.5
Diazinon	.5
Dichlorvos	1
Fluoranthene	.5
Hexadydrohexamethylcyclopentabenzopyran (HHCB)	.5
Indole	.5
Isoborneol	.5
Isophorone	.5
Isopropylbenzene	.5
Isoquinoline	.5
Menthol	.5
Metalaxyl	.5
Methyl salicylate	.5
Metolachlor	.5
N,N-diethyl-meta-toluamide (DEET)	.5
Naphthalene	.5
Nonylphenol, diethoxy- (total)	5
Octylphenol, diethoxy-	1
Octylphenol, monoethoxy-	1
p-Cresol	1
para-Nonylphenol (total)	5
Pentachlorophenol	2
Phenanthrene	.5
Phenol	.5
Prometon	.5
Pyrene	.5
Tetrachloroethylene	.5
Tri(2-chloroethyl)phosphate	.5
Tris(dichlorisopropyl)phosphate	.5
Tributyl phosphate	.5
Triclosan	1
Triethyl citrate (ethyl citrate)	.5
Triphenyl phosphate	.5
Tri(2-butoxyethyl)phosphate	.5

Appendix 3. Fecal coliform bacteria counts for surface-water samples

[Fecal coliform bacteria values are reported as most probable number per 100 milliliters; <, less than; >, greater than or equal]

Fishing Creek at Wesconnet Boulevard (02246435)	
Date	Bacteria estimate
2/7/2000	270
3/8/2000	70
4/18/2000	20
5/23/2000	<20
8/8/2000	20
9/5/2000	70
9/18/2000	700
10/10/2000	20
11/28/2000	500
12/12/2000	40
1/16/2001	500
2/6/2001	300
3/13/2001	500
4/10/2001	40
7/9/2001	500
9/10/2001	110
10/15/2001	220
11/6/2001	40
12/10/2001	50,000
1/15/2002	9,000
2/26/2002	40
3/26/2002	20
4/9/2002	40
7/9/2002	40
9/25/2002	1,400

Fishing Creek at 110th Street (02246437)	
Date	Bacteria estimate
2/7/2000	1,700
3/8/2000	800
4/18/2000	110
5/23/2000	3,000
7/11/2000	800
8/8/2000	20
9/5/2000	1,400
9/18/2000	140
10/10/2000	330
11/28/2000	270
12/12/2000	170
1/16/2001	1,300
2/6/2001	330
3/13/2001	3,000
4/10/2001	300
6/6/2001	1,100
7/9/2001	700
9/10/2001	1,300
10/15/2001	2,200
11/6/2001	5,000
12/10/2001	50,000
1/15/2002	17,000
2/26/2002	1,700
3/26/2002	700
4/9/2002	3,000
7/9/2002	900
8/12/2002	500
9/25/2002	2,800

South Branch Big Fishweir Creek at Cassat Avenue (02246465)	
Date	Bacteria estimate
2/8/2000	3,000
3/8/2000	1,700
4/18/2000	5,000
5/23/2000	5,000
6/12/2000	160,000
7/11/2000	11,000
8/8/2000	11,000
9/6/2000	50,000
10/10/2000	5,000
11/28/2000	5,000
12/13/2000	9,000
1/16/2001	5,000
2/7/2001	3,000
3/13/2001	1,100
4/10/2001	1,300
5/15/2001	40
6/6/2001	1,300
7/9/2001	3,500
9/10/2001	2,200
10/15/2001	700
11/7/2001	1,100
12/10/2001	30,000
1/15/2002	17,000
2/26/2002	800
3/26/2002	7,000
4/9/2002	500
5/7/2002	5,000
6/18/2002	16,000
7/9/2002	1,300
8/12/2002	5,000
9/25/2002	2,200

South Branch Big Fishweir Creek at Blanding Boulevard (02246467)	
Date	Bacteria estimate
2/8/2000	17,000
3/8/2000	7,000
4/18/2000	5,000
5/23/2000	1,700
6/12/2000	160,000
7/11/2000	30,000
8/8/2000	16,000
9/6/2000	90,000
10/10/2000	50,000
11/28/2000	≥16,000
12/13/2000	9,000
1/16/2001	3,000
2/7/2001	1,700
3/13/2001	2,800
4/10/2001	800
5/15/2001	800
6/6/2001	1,700
7/9/2001	≥16,000
8/22/2001	2,400
9/10/2001	9,000
10/15/2001	2,200
11/7/2001	1,700
12/10/2001	90,000
1/15/2002	22,000
2/26/2002	800
3/26/2002	2,200
4/9/2002	2,400
5/7/2002	2,200
6/18/2002	9,000
7/9/2002	≥160,000
9/25/2002	50,000

Appendix 4. Discriminant analysis of antibiotic resistance patterns used to classify fecal coliform bacteria from known sources into source categories for surface-water samples

[USGS, U.S. Geological Survey]

Site name and USGS identification number	Categories					Total count (percent)
	Chicken count (percent)	Cow count (percent)	Dog count (percent)	Human count (percent)	Wild count (percent)	
September 2001 sampling						
Fishing Creek at Wesconnet Boulevard (02246435)	3 (6)	1 (2)	5 (10)	40 (80)	1 (2)	50 (100)
Fishing Creek at 110th Street (0226437)	1 (16.7)	0 (0)	0 (0)	5 (83.3)	0 (0)	6 (100)
South Branch Big Fishweir Creek at Casssat Avenue (02246465)	0 (0)	1 (2.7)	1 (2.7)	35 (94.6)	0 (0)	37 (100)
South Branch Big Fishweir Creek at Blanding Boulevard (02246467)	0 (0)	0 (0)	0 (0)	51 (100)	0 (0)	51 (100)
Total	7 (3.7)	2 (1)	14 (7.3)	167 (87)	2 (1.04)	192 (100)
December 2001 sampling						
Fishing Creek at Wesconnet Boulevard (02246435)	1 (2.1)	0 (0)	1 (2.1)	46 (95.8)	0 (0)	48 (100)
Fishing Creek at 110th Street (0226437)	2 (4.2)	4 (8.3)	2 (4.2)	40 (83.3)	0 (0)	48 (100)
South Branch Big Fishweir Creek at Casssat Avenue (02246465)	4 (8.3)	0 (0)	6 (12.5)	38 (79.2)	0 (0)	48 (100)
South Branch Big Fishweir Creek at Blanding Boulevard (02246467)	1 (2.1)	0 (0)	6 (12.5)	41 (85.4)	0 (0)	48 (100)
Total	8 (4.2)	4 (2.1)	15 (7.8)	165 (85.9)	0 (0)	192 (100)
September 2002 sampling						
Fishing Creek at Wesconnet Boulevard (02246435)	1 (2.1)	0 (0)	0 (0)	37 (78.7)	9 (19.2)	47 (100)
Fishing Creek at 110th Street (0226437)	0 (0)	0 (0)	2 (6.7)	15 (50)	13 (43.3)	30 (100)
South Branch Big Fishweir Creek at Casssat Avenue (02246465)	8 (17)	0 (0)	0 (0)	38 (80.8)	1 (2.1)	47 (100)
South Branch Big Fishweir Creek at Blanding Boulevard (02246467)	10 (21.3)	0 (0)	21 (44.7)	12 (25.5)	4 (8.5)	47 (100)
Total	19 (11.1)	0 (0)	23 (13.4)	102 (59.6)	27 (15.8)	171 (100)
February 2003 sampling						
Fishing Creek at Wesconnet Boulevard (02246435)	1 (2.4)	0 (0)	11 (26.2)	3 (7.1)	27 (64.3)	42 (100)
Fishing Creek at 110th Street (0226437)	0 (0)	0 (0)	14 (29.8)	2 (4.3)	31 (66)	47 (100)
South Branch Big Fishweir Creek at Casssat Avenue (02246465)	0 (0)	0 (0)	3 (6.2)	34 (70.8)	11 (22.9)	48 (100)
South Branch Big Fishweir Creek at Blanding Boulevard (02246467)	0 (0)	0 (0)	7 (14.9)	27 (57.4)	13 (27.7)	47 (100)
Total	1 (0.5)	0 (0)	35 (19)	66 (35.9)	82 (44.6)	184 (100)