Prepared in cooperation with the Virginia Department of Conservation and Recreation, Fairfax County, and the City of Fairfax, Virginia

A Multiple-Tracer Approach for Identifying Sewage Sources to an Urban Stream System

Scientific Investigations Report 2006–5317

U.S. Department of the Interior
U.S. Geological Survey

Cover. **Tributaries to Accotink Creek in Virginia** *(top left photograph taken by Brian A. Hasty, U.S. Geological Survey; bottom left photograph taken by Kenneth E. Hyer, U.S. Geological Survey)*.

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Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
million gallons (Mgal)	3,785	cubic meter (m^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

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By Kenneth E. Hyer

Abstract

The presence of human-derived fecal coliform bacteria (sewage) in streams and rivers is recognized as a human health hazard. The source of these human-derived bacteria, however, is often difficult to identify and eliminate, because sewage can be delivered to streams through a variety of mechanisms, such as leaking sanitary sewers or private lateral lines, cross-connected pipes, straight pipes, sewer-line overflows, illicit dumping of septic waste, and vagrancy. A multiple-tracer study was conducted to identify site-specific sources of sewage in Accotink Creek, an urban stream in Fairfax County, Virginia, that is listed on the Commonwealth's priority list of impaired streams for violations of the fecal coliform bacteria standard. Beyond developing this multiple-tracer approach for locating sources of sewage inputs to Accotink Creek, the second objective of the study was to demonstrate how the multiple-tracer approach can be applied to other streams affected by sewage sources. The tracers used in this study were separated into indicator tracers, which are relatively simple and inexpensive to apply, and confirmatory tracers, which are relatively difficult and expensive to analyze. Indicator tracers include fecal coliform bacteria, surfactants, boron, chloride, chloride/bromide ratio, specific conductance, dissolved oxygen, turbidity, and water temperature. Confirmatory tracers include 13 organic compounds that are associated with human waste, including caffeine, cotinine, triclosan, a number of detergent metabolites, several fragrances, and several plasticizers.

To identify sources of sewage to Accotink Creek, a detailed investigation of the Accotink Creek main channel, tributaries, and flowing storm drains was undertaken from 2001 to 2004. Sampling was conducted in a series of eight synoptic sampling events, each of which began at the most downstream site and extended upstream through the watershed and into the headwaters of each tributary. Using the synoptic sampling approach, 149 sites were sampled at least one time for indicator tracers; 52 of these sites also were sampled for confirmatory tracers at least one time. Through the analysis of multiple-tracer levels in the synoptic samples, three major sewage sources to the Accotink Creek stream network were identified, and several other minor sewage sources to the Accotink Creek system likely deserve additional investigation.

Near the end of the synoptic sampling activities, three additional sampling methods were used to gain better understanding of the potential for sewage sources to the watershed. These additional sampling methods included optical brightener monitoring, intensive stream sampling using automated samplers, and additional sampling of several storm-drain networks. The samples obtained by these methods provided further understanding of possible sewage sources to the streams and a better understanding of the variability in the tracer concentrations at a given sampling site. Collectively, these additional sampling methods were a valuable complement to the synoptic sampling approach that was used for the bulk of this study.

The study results provide an approach for local authorities to use in applying a relatively simple and inexpensive collection of tracers to locate sewage sources to streams. Although this multiple-tracer approach is effective in detecting sewage sources to streams, additional research is needed to better detect extremely low-volume sewage sources and better enable local authorities to identify the specific sources of the sewage once it is detected in a stream reach.

Introduction

The presence of elevated levels of fecal coliform bacteria in surface waters indicates the likely presence of pathogens, and poses a health risk to humans who come into contact with these waters. Of the approximately 9,900 miles of rivers that were included in the Commonwealth of Virginia's 2004 305(b) water-quality assessment, roughly 5,000 river miles (or about half the river miles assessed) were classified as impaired because of elevated levels of bacteria (Virginia Department of Environmental Quality, 2004). Cleanup of these contaminated waterways and achievement of bacterial water-quality standards require considerable information on the sources contributing to the problem. Fecal coliform bacteria are found in the fecal material of humans, domesticated animals, and warm-blooded wildlife. While animals may contribute fecal coliform bacteria to a stream, it is likely that the fecal coliform contributions from humans pose the greater public health risk because of the human-specific pathogens that typically are found in human sewage. In addition to the public health concerns associated with sewage in streams, sewage also may contribute substantial amounts of nutrients and organic compounds that can result in eutrophication problems and low concentrations of dissolved oxygen.

In a recent study (Hyer and Moyer, 2003), the patterns and sources of bacteria in Accotink Creek (fig. 1) and two other watersheds in Virginia were evaluated. The study results indicate that a substantial portion of the total fecal coliform load passing the U.S. Geological survey (USGS) streamgaging station 01654000 on Accotink Creek is contributed by human sources, although the exact geographic location and nature of the sewage sources are unknown. In the two other watersheds that were evaluated as part of the study, similar contributions from human sources were observed. In a neighboring urban watershed that is similar to Accotink Creek, bacteria-source tracking was used to identify humans as a major contributor of the fecal coliform bacteria in the stream (Simmons and others, 2000). Samadpour and Chechowitz (1995) also documented substantial human-source contributions of fecal coliform bacteria to surface water. Human-source contributions of fecal coliform bacteria to surface waters appear to be a relatively common problem where humans are present.

Identifying specific geographic sources of sewage to complex watersheds is a challenging task that generally requires a large number of site-specific water samples and the application of sensitive environmental tracers. Furthermore, environmental tracers must be sufficiently cost effective that they can be applied throughout a watershed. Several biological and chemical tracers (some of which are relatively inexpensive to analyze) are available to identify the sources of sewage. These tracers have physical or chemical characteristics that, by their presence or magnitude of occurrence, indicate water that contains sewage. Ideally, these tracers also have environmental fate and transport characteristics that are similar to the fate and transport characteristics of sewage. The greatest success in identifying sewage sources is likely to occur through the use of multiple tracers that provide multiple lines of evidence of sewage. Taken together, these multiple environmental tracers are capable of providing conclusive evidence and defendable results. Other multiple-tracer studies have been applied successfully to identify sources of sewage in both ground water (Chen, 1988) and surface water (Juanico and others, 1990); however, a systematic approach for identifying sewage sources in urban basins is lacking and is needed to help address this apparently widespread problem.

The USGS, in cooperation with Fairfax County, Virginia; the City of Fairfax, Virginia; and the Virginia Department of Conservation and Recreation (DCR), began an investigation in 2001 to identify specific geographic sources of sewage in Accotink Creek (fig. 1). The objectives of the investigation were to develop and demonstrate a multiple-tracer approach for identifying the geographic sources of sewage that have been observed in Accotink Creek, a heavily urbanized watershed in northern Virginia, and to evaluate the utility of each of the tracers for application in other watersheds throughout the Commonwealth. In addition to identifying geographic areas of sewage sources, the data collected during this study will enable watershed managers to identify areas in the basin that have elevated bacterial levels, even if these bacterial levels are not caused by sewage sources.

Purpose and Scope

This report documents the development and application of a multiple-tracer approach to identify specific geographic sources of sewage in Accotink Creek; a similar approach could be used in other watersheds to identify sources of sewage in streams. Surface-water data were collected from 149 sites under low-flow conditions during the period December 2001 through September 2004. The samples were collected under low-flow conditions to characterize relatively stable water-quality conditions throughout the watershed and concentrated sources of sewage. All samples were analyzed for a suite of relatively inexpensive indicator tracers; samples from 52 sites also were analyzed for a suite of more expensive organic compounds that were used to confirm sewage sources. Samples from approximately 60 sites were analyzed for optical brighteners; 6 sites were sampled at hourly intervals with automated samplers; 4 storm-drain networks were sampled in greater detail. Through this multiple-tracer study, several sewage sources to the Accotink Creek watershed were identified, and several other sites were prioritized for further investigation.

The Accotink Creek Study Area

The Accotink Creek watershed is a heavily urbanized watershed (fig. 1). The headwaters of Accotink Creek are in the city of Fairfax, Virginia, and the creek flows for approximately 10.9 miles (mi) before it drains into Lake Accotink in Fairfax County. At least 15 different tributaries drain into Accotink Creek between the headwaters and Lake Accotink. Additionally, many municipal separate storm-sewer systems (MS4s or storm drains) also contribute to the streamflow along the main channel and tributaries. The portion of the Accotink Creek watershed that was included in this study drains an area of 25 square miles (mi^2) and includes a population of more than 110,000 people (2000 U.S. Census Bureau data). Approximately 600 feet (ft) upstream from the bridge at Braddock Road in the Accotink Creek watershed is a streamgaging station that has been active since 1949. This station is managed by the Virginia Department of Environmental Quality (USGS station number 01654000, fig. 1) and was used to define the downstream watershed outlet for this study. There are no permitted fecal coliform bacteria point-source dischargers within the Accotink Creek watershed

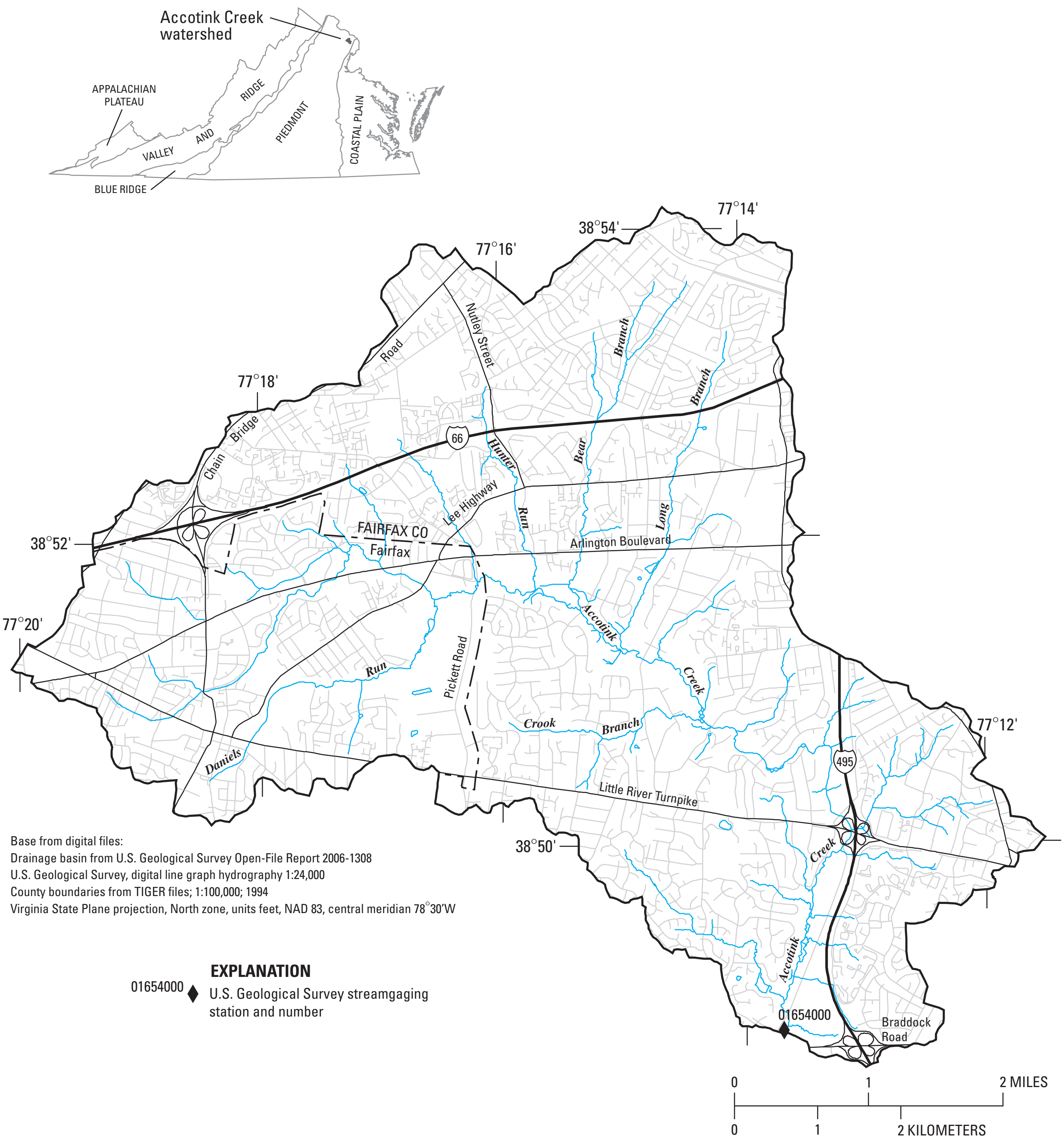

Figure 1. Location of the Accotink Creek watershed study area, Virginia.

(J. Crowther, Virginia Department of Environmental Quality, written commun., 1999).

Although portions of the watershed are forested (especially adjacent to the stream), urban and residential land uses dominate the majority of the watershed and provide opportunities for many different potential sources of feces to the stream. Potential sources of fecal coliform bacteria in the watershed include domestic pets, such as dogs and cats; wildlife, such as raccoons, opossum, rats, squirrels, and deer; waterfowl, such as geese, ducks, and sea gulls; and humans, potentially from cross-connected pipes, leaking or overflowing sewer lines, and failing septic systems. In this study an attempt was made to develop an approach for identifying human sources of sewage from other sources in the watershed.

The Accotink Creek watershed lies in the Piedmont Physiographic Province of Virginia and is underlain by crystalline igneous and metamorphic rocks (Froelich and Zenone, 1985). The geology of the watershed is composed of five formations. The Wissahickon Formation dominates the watershed and is composed of quartz-mica schist, phyllite, and quartzite (Johnston, 1964). The Greenstone Contact Complex is present in some headwater areas of the catchment and is composed of chlorite schist, sericite-chlorite schist, chlorite-quartz schist, talc schist, and small amounts of quartzite (Johnston, 1962). Granitic rocks are distributed throughout the watershed; these rocks are of variable composition, including biotite granite, muscovite granite, biotite-muscovite granite, granodiorite, quartz monzonite, and quartz diorite (Johnston, 1964). A small portion of the watershed is underlain by the Sykesville Formation, which includes muscovite or sericite-biotite-quartz schist and gneiss, quartzite, epidote quartzite, and muscovite-biotite quartzite (Johnston, 1964). Alluvial material (composed of clay and sand, as well as quartz cobbles and pebbles) also is present along the channel and in the flood plain of Accotink Creek (Johnston, 1962).

The soils of the Accotink Creek watershed are present as three distinct soil associations, described by Porter and others (1963). The Glenelg-Elioak-Manor association has developed from the weathering of the crystalline bedrock of the Piedmont. These well-drained and, in some places, excessively well-drained silt-loam soils dominate the watershed. The Fairfax-Beltsville-Glenelg association composes a relatively small portion of the watershed (limited to the headwater areas) and is formed from the residuum of piedmont bedrock and fluvial coastal plain sediments. These soils are present as silt or sand loams and range from somewhat poorly drained to well drained. The Chewacla-Wehadkee association occurs only on a limited basis within the watershed, generally in the bottomland and flood plains along the streams. These silt-loam soils range from moderately well drained to poorly drained and have developed from alluvial material that was washed from the piedmont uplands.

To investigate the potential sources of sewage in Accotink Creek, it is important to understand the different possible sewage sources and the different elements of sewage management in the watershed. Most (more than 95 percent) of the sewage that is generated in the watershed is transported by an extensive sewer-line network that underlies nearly the entire basin. Both Fairfax County and the City of Fairfax have sewer-line maintenance and inspection plans that include routine investigation of lines and replacement of older lines to prevent sewage leaks and other problems (U.S. Environmental Protection Agency, undated; City of Fairfax, undated). There are no combined storm-sewer and sanitary sewer lines in the basin. Approximately 900 homes in the watershed are served by septic systems rather than the sewer system. Inspections of these septic systems are made by the Fairfax County Health Department when new septic systems are installed and when permitted repairs are made to septic systems already in use. Fairfax County resources, however, prevent routine inspection of septic systems throughout the watershed (Fairfax County Department of Health, 2004). In addition, an important consideration in the sewage management within the watershed is that of lateral lines, which connect individual homes or businesses to sewer lines maintained by the city and county. All lateral lines are privately owned by the respective property owners whom they serve, and their maintenance is the responsibility of these property owners. Maintenance of lateral lines, however, typically is performed only when a problem occurs, such as a blockage or overflow. Minor leaks from lateral lines may never be noticed or identified by a homeowner; however, such leaks and failing lateral lines may be a potentially important source of sewage to Accotink Creek. Failure of any of the sewage-management elements in the watershed increase the likelihood of sewage in Accotink Creek. Other possible sources of sewage in Accotink Creek include sewer-line overflows and illicit dumping by septic-waste haulers. Both of these events are considered relatively rare in the basin; however, illicit septic-waste dumping has been reported, and between June 2001 and November 2002, two documented sewer-line overflows occurred in the Accotink Creek watershed area that was included as part of this study (Tom Russell, Fairfax County Public Works and Environmental Services, written commun., November 2002).

Multiple-Tracer Approach

A broad selection of chemical and biological tracers were used during this investigation along with detailed sampling of the Accotink Creek stream network (the main channel, tributaries, and storm drains) to evaluate sources of sewage in the stream. All of the tracers used during this study have been applied individually elsewhere with some success in indicating sewage sources, but in no single previous study have all of the tracers been applied nor have direct comparisons of all these tracers been made. This multiple-tracer approach provides multiple lines of evidence with which to identify geographic sources of sewage. Each of the tracers likely has its own advantages and drawbacks, depending on project objectives, budget, and environmental setting. The detailed sampling conducted during this investigation throughout the watershed allowed for the collection of extremely detailed information on the basin. Through this study, the effectiveness of the multiple tracers was evaluated, and an approach for investigating sources of sewage in any watershed was identified.

Description of the Sewage Tracers

During field activities, close attention was paid to the occurrence of visual clues that indicated potential contamination. These visual clues included overflowing sewers, strongly discolored waters, and the presence of typical human-waste products (toilet paper, feces, and hygiene products) in the stream. The presence and frequency of distinctive odors were noted as encountered.

Water-quality characteristics and physical properties, such as specific conductance, temperature, turbidity, dissolved-oxygen concentrations, surfactants, optical brighteners, and fecal coliform bacteria, have all been used as tracers to determine the presence of sewage in streams. Concentrations of fecal coliform bacteria were used as the primary bacterial tracer for this study because they were being used by the Commonwealth of Virginia as the bacterial standard when the study was initiated. Water temperature measurements can be useful in identifying point sources of relatively cooler or warmer water into a stream, although the use of temperature as a tracer is likely limited to only the most major of temperature differences. The degradation of organic sewage material by in-stream biota consumes oxygen and can result in decreased dissolved-oxygen concentrations. The direct discharge of sewage into a stream can cause elevated turbidity levels, although the particulate material causing the elevated turbidity can settle out rapidly. Sewage has an ionic strength that usually is far greater than that of the natural environment; therefore, the presence of sewage in a stream increases the overall specific conductance of the water (Chen, 1988). Surfactants, which provide the cleaning action of detergents, are common in sewage; the presence of surfactants in stream water at elevated concentrations may indicate contamination by sewage (Brunner and others, 1988). Optical brighteners (present in virtually all laundry detergents) provide information on water samples that contain domestic wastewater from laundry activities and, therefore, also likely contain sewage (Aley, 1985).

Specific ions and trace elements can be used as indicators of sewage. Chloride and bromide appear to be reliable tracers of sewage. Sewage contains elevated levels of chloride relative to both finished drinking water and the natural environment; thus, the presence of elevated chloride concentrations can indicate the presence of sewage (Chen, 1988). Bromide data frequently are coupled with chloride data, because the ratio of the chloride concentration to the bromide concentration (Cl/Br ratio) is a good indicator of sewage (Thomas, 2000). Bromide concentrations in sewage are not elevated relative to those in the natural environment, so sewage that enters a stream should cause an increase in the Cl/Br ratio. Boron can be an effective tracer of sewage sources because natural stream-water concentrations are relatively low. Boron is used primarily in cleaning powders, which eventually are flushed into sewage lines. Stream samples with elevated concentrations of boron generally indicate contributions of sewage (Neal and others, 1998).

Two additional approaches to the tracing of sewage were considered at the onset of this study—bacterial-source tracking and analyses of organic compounds (Zaugg and others, 2002) that frequently are associated with sewage (such as caffeine, coprostanol, cholesterol, nicotine metabolites, several detergent metabolites, and human pharmaceuticals). Both approaches already have been used in Accotink Creek as well as other watersheds in Virginia, and both appear to be reliable in their ability to accurately identify the presence of human-derived fecal coliform bacteria (Hyer and Moyer, 2003). Although both approaches appear reliable, both are expensive to apply. Consequently, these approaches were used in this study only to confirm the results of the less expensive, more accessible tracers, which are termed indicator tracers.

On the basis of all the tracers being considered, the presence of relatively high specific conductance, chloride, boron, chloride/bromide ratio, surfactants, and fecal coliform bacteria, along with relatively low dissolved-oxygen concentrations provide strong evidence of sewage contamination. Water samples showing this collection of positive tracers then were evaluated for the presence of organic wastewater tracers or submitted for bacterial-source tracking analysis, both of which served to directly confirm the presence of sewage.

Sampling Site Selection

This study was designed to provide a detailed understanding of the water-quality conditions and sewage sources throughout the Accotink Creek watershed which lies upstream from Braddock Road (fig. 1). Accordingly, the sampling plan was developed to sample along the entire main channel of Accotink Creek, the tributaries to the creek, and all flowing storm drains. To develop the list of sampling sites, a detailed watershed reconnaissance was conducted to understand the flow conditions. As part of this reconnaissance, the headwaters of the major tributaries were located, and all storm-drain outfalls in the basin were visited at least once to determine whether the drain had flow under base-flow conditions. Through this reconnaissance, 410 storm drains were visited, and approximately 50 were observed to have flow under base-flow conditions. Therefore, all 50 of the storm drains with flow under these conditions were selected as sampling sites. Observance of approximately 10 percent of the storm drains to be flowing under base-flow conditions was consistent with the data that were collected previously by Fairfax County (Russell Smith, Fairfax County Department of Public Works, oral commun., 2000). Because several tributaries have been re-engineered and buried underground, several of the storm-drain outfalls were actually the resurfacing of buried tributaries, and these sites could have been classified as either tributaries or storm drains. For consistency, samples that were collected from the end of a storm-drain outfall generally were classified as storm-drain samples.

After identifying storm drains with flow and the upper limits of the major tributaries, the sampling plan for the main channel of Accotink Creek and the tributaries was developed. Initially, sites were selected to include the main channel of Accotink Creek just upstream from each inflowing tributary. Each inflowing tributary was sampled just before it drained into Accotink Creek. Additional sampling sites were selected on the main channel, if the distance between inflowing tributaries was greater than 0.5 mi. Using this sampling scheme, 16 sites were identified on the main channel of Accotink Creek. In addition to sampling each tributary just before it flowed into the main channel of Accotink Creek, at least two additional samples were collected from each major tributary, with the sampling locations dependent on the presence of storm drains with flow, branches in tributaries, and the overall tributary length. Based on this selection process, 55 tributary sampling sites were identified. Combining the 50 storm-drain sampling sites with the 16 main channel sites and the 55 tributary sampling sites yielded a total of 121 sampling sites initially selected for detailed water-quality sampling. These 121 sites are termed synoptic sampling sites in this report.

Sample Collection and Analysis

At each synoptic sampling site, the physical properties of water temperature, specific conductance, pH, and dissolved oxygen were measured using hand-held water-quality monitors. These monitors were calibrated according to the manufacturer's specifications each morning that they were used. Clean, sterile glass bottles were used to collect samples for surfactant, turbidity, and fecal coliform bacteria analyses. Acid-rinsed polyethylene bottles were used to collect samples for chloride, boron, and bromide analyses. Surfactants were determined within 6 hours of collection and were measured by using a colorimetric detergents kit (for determining anionic detergents), using a methylene blue active substances analysis (EPA Method 425.1). Turbidity was determined in the field using a Hach 2100 turbidimeter. Fecal coliform bacteria were determined by membrane filtration, following standard USGS protocols for bacteria (U.S. Geological survey, variously dated). The aliquots for analysis of chloride, boron, and bromide were kept chilled and delivered, usually within 24 hours of collection, to the Fairfax Environmental Services Laboratory where they were analyzed using standard methods approved by the U.S. Environmental Protection Agency (USEPA). For all analyses, a minimum of 10 percent of the samples were analyzed as blind duplicates or split samples; the split samples were analyzed at the USGS National Water Quality Laboratory in Denver, Colorado. Results of the blind duplicates and split samples were used to ensure that data-quality objectives were being met.

Because many of the storm drains and tributary sites were extremely shallow (flow less than 0.2-ft deep), sampling protocols had to be modified to collect a representative water sample from these locations. Whenever possible, a grab sample was collected from the approximate center of flow in what appeared to be a well mixed region. When flow was too low to permit a grab sample, clean, sterile, disposable syringes were used to collect a sample of the flowing water. Using the syringe for sampling allowed the collection of samples from sites with extremely low flow, while preventing the collection of bottom sediments.

Following sample collection, flow measurements were made at all sites. When possible (usually only in the main channel and some of the major tributaries), streamflow measurements were made following standard USGS protocols (Rantz and others, 1982). When water depths and velocities were insufficient to permit the use of standard USGS streamgaging equipment and protocols, various other flow-measurement techniques were used. In most cases, the stream channel was modified to create uniform flow conditions, allowed to stabilize, and then flow was determined by measuring both the stream area and velocity. Discharge is calculated as the product of stream velocity and area through which flow occurs. Stream velocity was determined by timing how long it took for a floating (or neutrally buoyant) marker (typically a leaf or small piece of tissue paper) to move a specified distance (usually 1–3 ft). Multiple time measurements typically were made and used to calculate mean velocity. The stream area was determined by making multiple width and depth measurements in the modified channel to determine the mean width and depth of the channel. Occasionally, site conditions enabled the direct collection of a known volume of water over a timed period, and discharge could be calculated directly. This condition was encountered primarily at storm drains where there was a drop between the storm-drain outfall and the receiving stream.

When wastewater organic compound confirmatory analysis was needed, samples were collected using 1-liter (L) baked amber glass bottles. The samples were kept chilled and sent by overnight courier to the USGS National Water Quality Laboratory, where the samples were processed according to the standard analytical methodology (Zaugg and others, 2002). Because the wastewater organic compound analysis was developed to analyze for endocrine-disrupting compounds, not all of the 46 compounds that are part of the analysis are indicative of sewage. A subset of 13 compounds that are specific to sewage was developed on the basis of sewage samples that were analyzed as a part of this and other studies; the methodology and data used for the selection of the 13 subset compounds are presented in the results section. One unique element of this organic compound analysis is that the detection method used in the analysis is an "information rich" method; that is, the presence of a specific compound can be verified at concentrations that are below the defined minimum reporting level (Steve Zaugg, U.S. Geological Survey, oral commun., 2000). When the presence of a compound is verified and the concentration is below the minimum reporting level (which actually represents a level of quantification), the reported concentration of the compound is noted with an "E" for estimated.

Initially, the plan was to use the fecal coliform plates from the membrane filtration analysis for subsequent bacterial-source tracking (BST) analyses; however, the BST component of the study was eliminated for several reasons. First, the laboratory selected to perform the BST analyses had extreme difficulty providing data within a reasonable timeframe (prior to the next synoptic sampling). Secondly, further evaluation of the confirmatory tracers seemed to indicate that the wastewater organic compound analyses were more powerful than the BST analyses. The wastewater organic compound analysis is a whole-sample extraction, while the BST analysis is performed on a subset of the bacteria and typically accounts for less than 1 percent of the total bacteria that are present in the sample. Thirdly, BST studies recently have come under sharp criticism by several methods-comparison studies (Stewart and others, 2003; Stoeckel and others, 2004) that demonstrated the need for more extensive quality assurance and quality control (QA/QC) before BST results can be interpreted accurately. For all these reasons, BST was not performed as a part of this study; instead, additional wastewater organic compound analyses were performed.

Synoptic Sampling Plan

To identify the sources that contribute sewage to Accotink Creek, a synoptic sampling approach was developed to intensively sample the entire watershed, including the storm drains, tributaries, and the main channel of Accotink Creek. Because sewage sources to the stream were assumed to be relatively constant in time, synoptic sampling was scheduled to be performed only during low-flow periods (when the effects of sewage dilution by the resident stream water were minimized). Eight sampling events were conducted, and each event required 4 to 5 days of field work to sample all the sites and collect all of the necessary data. To ensure that the sampling represented low-flow conditions, no sampling was performed within 48 hours of a precipitation event, and data from the Braddock Road streamgaging station were used to ensure that the sampling was performed during relatively steady-flow conditions. Because of these conditions, the synoptic sampling could be performed only during periods of at least 7 days of clear, dry weather. Obtaining these conditions proved to be much more difficult than initially anticipated and resulted in numerous project delays, especially during the relatively wet 2002 and 2003 water years[1].

Eight synoptic sampling events were planned to provide sufficient data to document the water-quality conditions and to identify the potential sewage sources within the watershed. The eight sampling events were tiered such that the first four events were used to characterize the water quality throughout the basin and identify specific areas of potential sewage sources; the last four sampling events were used to more intensively sample and describe the specific locations where sewage sources were detected. Initially, the synoptic sampling was to occur on a quarterly basis; however, delays caused by weather and laboratory delays resulted in periods longer than 3 months between some synoptic sampling events.

As designed, 121 samples were collected during each of the first four sampling events, and each synoptic site was visited during each of these sampling events. In an effort to develop a consistent characterization of the Accotink Creek watershed before investing in expensive confirmatory analyses, no wastewater organic compound samples were collected during the first or second sampling events. Collection of wastewater organic compounds was initiated during the third sampling event and was conducted only at sites where tracer concentrations indicated the possible presence of sewage. Changes in the locations of the monitoring sites (but not the total number of sampling sites) were made after the first four sampling events were completed and the data were analyzed. Sampling sites that were similar to neighboring sites and sites that showed no indication of sewage contamination were eliminated. Additional sites were added for the last four sampling events to more intensively sample and describe the areas where sewage sources were indicated. New sites were selected based on the results of the earlier samplings and the associated watershed characteristics, such as different methods of sewage disposal, sewer systems compared to septic systems, sewer line crossings, and such.

Additional Sampling

In addition to the methodology previously described for the collection of synoptic samples, several other types of samples were collected to understand further the potential sewage sources in the Accotink Creek watershed and the variability that was observed in the synoptic samples. All of the additional samples were collected as part of the eighth synoptic sampling event, and the methods associated with the sampling are described below.

Optical Brighteners

As reported in numerous other publications, optical brightener monitoring may offer an informative tool for identifying wastewater inputs to streams (Aley, 1985; Cinotto, 2005). Optical brighteners are added to nearly all laundry detergents to make white fabrics appear whiter and brightly colored fabrics appear brighter. They are useful environmental tracers because they generally are well associated with sewage and are relatively recalcitrant in the natural environment. Near the end of this study, optical brighteners were monitored at many of the synoptic sampling sites that had either highly

[1] Water year is the period October 1 to September 30 and is defined by the year in which the period ends.

variable tracer concentrations or concentration levels that seemed to be indicative of sewage. The added benefit of optical brightener monitors is that they provide time-integrated sampling—something that grab sampling cannot achieve.

The optical brightener monitors were constructed using the methodology developed for use at the Ozark Underground Laboratory (Aley, 1985). The sampler consisted of a 5-inch square piece of unbleached cotton attached with a rubber band over the mouth of a 2-inch diameter, 6-inch long section of polyvinyl chloride (PVC) pipe. The sampler was placed in the stream and affixed in place horizontally using either aluminum wire or nylon mason's line in a manner that allowed the streamflow to pass through the length of PVC pipe. When possible, the samplers were deployed in shaded locations at each site to minimize the effects of photodegradation of the optical brighteners. The samplers were deployed at numerous Accotink Creek sampling sites during a period of anticipated base-flow conditions and left in place for approximately 3 days.

Upon retrieval, the monitors were placed in labeled whirl-pak bags, placed on ice, and returned to the Virginia Water Science Center water-quality laboratory for analysis. In the laboratory, the cotton swatches were individually rinsed with tap water for several minutes to remove any sediment material that was present. This rinsing removed much of the sediment material without causing desorption of any optical brighteners (Tom Aley, Ozark Underground Laboratory, oral commun., February 3, 2004). After rinsing, the still-damp cotton swatches were evaluated in a dark room, using a long-wave ultraviolet (UV) light. Results of the readings were enhanced by using several optical brightener standards that were prepared using deionized water and a liquid detergent that contained optical brighteners. The following standards were used along with the fluorescence response that was observed:

- Deionized water (negative control) Negative
- 1:10,000 Negative
- 1:5,000 Ambiguous
- 1:1,000 Positive
- 1:100 Positive
- 1:10 Positive
- Pure detergent Positive

The sample readings were recorded categorically as being positive, negative, or ambiguous for optical brighteners. After the readings were completed, they were independently verified by two other analysts.

Intensive Sampling

Intensive sampling of several synoptic sampling sites was performed to document the possible water-quality variability at some of the sites. These intensive samples were collected at hourly intervals over roughly a 24-hour period and provided much more detailed information than the grab samples. Therefore, these samples were useful in understanding the variability in some of the synoptic-sample data.

During the eighth synoptic sampling event, automated samplers (autosamplers) were deployed at several potentially impaired sites in an attempt to document the variability in the stream-water composition. At each sampling site, the autosampler was programmed to draw a sample every hour, on the hour. The autosampler then was left in place and allowed to operate for nearly 24 hours before being moved to the next site.

The samples from the auto-samplers were analyzed in the field for surfactants, turbidity, and specific conductance. Bacteria could not be analyzed because the holding time was beyond the 6-hour limit. After analysis for surfactants, turbidity, and specific conductance, the samples were transported to the laboratory to be analyzed for chloride, boron, and bromide. The patterns in these tracers over the 24-hour period were evaluated and interpreted.

Prior to deploying each autosampler, all tubing and sample bottles were cleaned using 5-percent hydrochloric acid and rinsed with deionized water until the tubing was clean (when the final rinse water passing through the tubing and bottles had a specific conductance of approximately 1 microsiemen per centimeter (µS/cm). After being used at one synoptic sampling site, the tubing and bottles of each autosampler were rinsed with copious amounts of deionized water prior to reuse at another site. Bottle and tubing blanks were collected both before the autosamplers were first deployed and after each field cleaning to ensure that the cleaning procedures were adequate.

Sampling of Individual Storm-Drain Networks

After the sixth sampling event, several "priority" storm drains were identified as having elevated bacterial concentrations and(or) possible sewage sources. The Fairfax County Stormwater Management Division initiated a visual inspection of several of these priority storm drains, but the potential source of the elevated tracers could not be determined. Additional detailed sampling was conducted at four of the priority storm-drain sites in an attempt to better understand the sources of water in these storm-drain networks and to see if the source of the elevated-tracer concentrations could be located.

The storm-drain network sampling associated with an individual storm-drain outfall was accomplished by first performing an investigation of the entire storm-drain network to identify the branches that were flowing and the relative discharge in each branch of the network. Using Fairfax County tax maps that also contained the storm-drain networks, this investigation was accomplished by starting at the downstream end of the network and moving in an upstream direction. This investigation allowed the development of an overall understanding of each network.

On the basis of the initial investigation of the relative flow conditions, several within-network sampling sites were selected to segregate the storm-drain network into different components. For each storm-drain outfall that was investigated, between three and eight samples were collected from throughout the storm-drain network. During sampling, as many of the indicator tracers as possible were collected, but some characteristics could not be determined because of the site conditions (commonly, dissolved oxygen, water temperature, and flow). Site access proved to be a challenge, as many of the storm sewer-lines could not be easily accessed from the land surface. The challenges of site access cannot be overlooked in studies that include sampling of storm-drain networks.

Identification of Sewage Sources to Accotink Creek

Below are the results from the sampling activities. Included are validations of this multiple-tracer approach and identification of the confirmatory organic compounds, as well as a presentation of the sampling results and a description of how these multiple tracers can be used for the identification of sewage sources to streams.

Observation of a Sewage Source During Site Reconnaissance

During the detailed reconnaissance, a condition was encountered that appeared to be a short-lived sewage source to an Accotink Creek tributary; this situation offered an early opportunity to evaluate the field application of several of the sewage tracers. This sewage source was discovered because the tributary in question was divided between two different tax maps which caused reconnaissance of the storm-drain outfalls on the south side of the tributary to occur on day 1 and reconnaissance of the storm drains on the north side of the tributary to be completed on day 2. During the day-1 reconnaissance, the flow in the tributary and the drains on the south side of the tributary were all clear and appeared to be typical of an urban stream. On day 2 of the reconnaissance, the flow in the tributary was dark gray and appeared to be sewage (fig. 2). Prior to arriving on the banks of the tributary on day 2, an extremely strong sewage odor was noticed all around the tributary (sufficiently strong that the field team began to search for the sewage source before reaching the tributary). The source of the gray water was traced upstream to a storm-drain outfall that functioned as the headwaters for the tributary.

While investigating the source of this gray water in the tributary, it was determined that the flow in the outfall containing the gray water was decreasing steadily. For this reason, the search for the source of the water was halted, and water samples were collected to characterize the gray water. For comparison purposes, a sample also was collected from a nearby flowing storm-drain outfall on the south side of the tributary that visually was clear (even though nothing more was known about the water quality of this visually clear site). Because the study was only in the reconnaissance phase and sampling had not been anticipated, not all tracers could be determined for these samples. The storm-drain outfall with the gray water was labeled site S7, and the clear-flowing storm-drain site was labeled site S8. These site identifiers were retained for the remainder of the study. The tracer concentrations for these two samples are presented in table 1.

Table 1. Indicator tracer concentrations at sites S7 and S8 associated with the apparent sewage at site S7 that was discovered during watershed reconnaissance and site selection in the Accotink Creek watershed, Virginia.

[mg/L, milligrams per liter; >, greater than; NTU, nephelometric turbidity units; µS/cm, microsiemens per centimeter; col/100 mL, colonies per 100 milliliters]

Indicator tracer	Site S7 (fig. 3)	Site S8 (fig. 3)
Surfactants (mg/L)	>3	0.25
Turbidity (NTU)	224	1
Specific conductance (µS/cm)	413	326
Dissolved oxygen (mg/L)	5.1	7
Fecal coliform bacteria (col/100 mL)	13,300	26,300

Figure 2. A short-lived sewage source to an unnamed tributary (site S7) to Accotink Creek, Virginia, September 28, 2001.

The results from these samples demonstrate sharp differences in some sewage tracer concentrations and only minor differences in others. As anticipated, the gray-water site (S7) had substantially elevated levels of surfactants and turbidity relative to site S8 (table 1). Specific conductance was only slightly greater at site S7 than at site S8. Dissolved-oxygen (DO) levels were relatively low at both sites, but the DO concentration at site S7 was approaching the State ambient water-quality standard of 4.0 milligrams per liter (mg/L). Site S8 had elevated fecal coliform bacteria levels compared with those at site S7, but both sites had levels that were well in excess of the statewide instantaneous fecal coliform bacteria standard (1,000 colonies per 100 milliliters (col/100 mL)). These observed fecal coliform bacteria and DO concentrations indicate that site S8 may also have water-quality problems. Site S7 was revisited approximately 4 days later, and the turbid conditions had abated; site S7 was resampled for fecal coliform bacteria only, and the concentration had decreased to 1,700 col/100 mL (still somewhat elevated, but substantially reduced relative to the gray-water conditions). Although the source of this gray water was never specifically located (because conditions were already abating when the situation was discovered), the elevated surfactants, turbidity, fecal coliform bacteria, and specific conductance (as well as the decreased DO) indicate that the gray water was likely a short-lived sewage source to this unnamed tributary to Accotink Creek. Possible sources of this sewage include illegal septic-tank truck dumping, which has been documented, or some type of a short-lived release from a septic system, sewer line, or lateral line. Although detailed information regarding sites S7 and S8 was unavailable at the time of this initial sampling, the results of further data collection during this study indicate that both sites may contribute sewage to Accotink Creek. These data will be presented later in the report.

Validation of the Multiple-Tracer Approach for Detecting Sewage in Water

Useful sewage tracers have physical or chemical characteristics that, by their presence or magnitude of occurrence, indicate the presence of sewage in water. Ideally, these tracers also have environmental fate and transport characteristics that are similar to the fate and transport of sewage. Because no single sewage tracer available is likely to perfectly satisfy these criteria, the greatest success in identifying sewage sources is likely to occur through the use of multiple-tracer compounds that, taken collectively, can provide a "weight-of-evidence" approach for identifying waters that contain sewage. Although the potential tracer candidates, as presented in the methods section of this report, were identified, the applied value of these tracers for this study was evaluated.

One way of theoretically evaluating the potential use of a particular tracer is to evaluate the background level of the tracer in the natural environment and compare the background level to the level of the tracer found in untreated sewage. Based on this comparison, useful sewage tracers have widely different tracer concentrations in these two environments.

To demonstrate this comparison, six untreated sewage samples were collected from different locations in Fairfax County and Fairfax City. Three sewage samples were collected by removing sewer-line manhole covers in the Accotink Creek watershed and grab sampling the flow in the sewer line. These three grab samples were identified as SS1–SS3. Two additional sewage samples were collected from the two main-sewer trunk lines that drain into the sewage-treatment plant that serves Fairfax County (the Noman M. Cole Pollution Control Plant). One trunk line drains directly from the Accotink Creek area (labeled NPC1), and the other drains sewage from a neighboring basin (NPC2). The sixth sewage sample was collected from a septic-tank truck as it arrived at the sewage-treatment plant (NCP4). This particular septic-tank truck contained sewage pumped from a single septic tank that served a 16-family development in Fairfax County. For comparison, the analytical results of indicator tracer concentrations in these sewage samples and the median tracer concentrations that were observed at USGS streamgaging station 01654000 (fig. 1) at Braddock Road (site A1) are given in table 2.

These data demonstrate substantial differences between the tracer concentrations in sewage and those detected in the environmental samples from Accotink Creek (site A1). These substantial differences support the use of these tracers for detecting sewage inputs to Accotink Creek, and the data also establish relative upper limits that can be expected for each tracer in water that contains sewage. The difference in concentrations of several of the tracers is an order of magnitude or greater in the sewage samples than in the background stream sample, which indicates that stream samples containing sewage should be readily distinguishable from the background water-quality conditions.

Table 2. Indicator tracer concentrations for six raw sewage samples collected in or around the Accotink Creek watershed, and the median tracer composition observed at site A1, U.S. Geological Survey streamgaging station 01654000 at Braddock Road, which defines the downstream limit of the study area.

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/100 mL, colonies per 100 milliliters; nd, no data; >, greater than; USGS, U.S. Geological Survey]

Sample ID	Sampling date	Sampling time	Boron (mg/L)	Chloride (mg/L)	Specific conductance (µS/cm)	Turbidity (NTU)	Surfactants (mg/L)	Fecal coliform bacteria (col/100 mL)	Wastewater organic compounds	Sampling location
NCP1	7/12/02	1015	0.199	70	832	135	5.0	2,300,000	yes	Accotink main trunk line.
NCP2	7/12/02	1030	.232	74	833	178	5.0	3,400,000	nd	Pohick main trunk line.
NCP4	7/12/02	1120	.591	80	965	236	7.5	1,300,000	yes	Septic system.
SS1	7/12/02	1115	.281	66	806	>1,000	7.5	3,800,000	nd	Sanitary sewer line.
SS2	7/12/02	1030	.177	83	721	116	10.0	750,000	nd	Sanitary sewer line.
SS3	7/12/02	1245	.239	61	739	257	7.5	4,100,000	nd	Sanitary sewer line.
Median concentration in raw sewage			0.236	72	819	207	7.5	2,850,000	nd	
Median concentration at site A1			0.025	40	237	5.54	0.13	89	nd	USGS streamgaging station 01654000

Selection of Organic Compound Data Indicative of Sewage

As described in the methods section, not all of the 46 wastewater organic compounds typically analyzed are strongly associated with sewage. Many are included in the analysis because they are suspected endocrine disrupters. To develop a set of compounds that are strongly associated with sewage, the untreated sewage samples from sites NCP1 and NCP4 were submitted to the USGS National Water Quality Laboratory for organic compound analysis. About the same time as these sewage samples were being analyzed at the laboratory, sewage data from the Wilkison and others (2002) study became available. In this study, at least 58 untreated sewage samples were collected from various sewage-treatment plants at different times. To improve the understanding of which compounds likely are associated with sewage, the data from Wilkison and others (2002) were considered in the development of a data subset of sewage-indicative organic compounds. The criteria used to determine the subset of organic compounds that are strongly associated with sewage are as follows:

1. The data from Wilkison and others (2002) were summarized to identify the compounds that were present in a high percentage of the sewage samples collected. To be considered, a compound must have been detected in at least 75 percent of the samples.

2. Working only with the subset of compounds that were detected in at least 75 percent of the Wilkison and others (2002) sewage samples, the compounds that were present at relatively elevated concentrations were identified. Only compounds that were present at elevated levels were retained because dilution likely plays an important role in this system. Compounds that typically occur in sewage near the analytical detection limit probably are not very useful sewage tracers. An arbitrary rule was established to identify compounds that occurred at relatively elevated concentrations—both mean and median concentrations that were greater than or equal to 0.75 micrograms per liter (µg/L) in the Wilkison and others (2002) data set. Compounds that met criteria 1 and 2 above were scored as positive and given a rank of 1. All other compounds were scored as negative and given a rank of zero.

3. The organic compound results from the untreated sewage samples (NCP1 and NCP4) collected as a part of this study were summarized. The same 0.75-µg/L arbitrary concentration value was used to identify whether the compound occurred at a relatively elevated level. For each of these two sewage samples, organic compounds that were present at elevated concentrations were given a score of 1, and compounds that were not detected (or not detected at greater than the 0.75-µg/L threshold) were given a score of zero.

4. Next, each organic compound was screened for whether or not it could be considered indicative of domestic sewage. For example, caffeine, cotinine (a nicotine metabolite), detergent metabolites, and triclosan (a common antimicrobial compound in hand soaps) were considered indicative of sewage because they result from domestic activities. However, DEET (a common insecticide) and *para*-cresol (a wood preservative) were not considered indicative of domestic sewage because

they result from other activities. Organic compounds that were associated with domestic sewage were given a score of 1, and compounds that were not strongly associated with domestic sewage were given a score of zero.

5. This analysis resulted in four categories with which to evaluate each compound and its association with sewage:
   - The Wilkison and others (2002) untreated sewage data
   - The NCP1 sewer-line sample data
   - The NCP4 septic-system sample data
   - Whether the compound was indicative of domestic sewage
6. The results of the four categories were summed for each compound, and the compounds that scored 3 or 4 were considered to be useful sewage tracers for identifying stream waters that contain sewage. This analysis identified a subset of 13 compounds that are indicative of sewage, and the general uses of these compounds are presented in table 3.

Although this approach for selecting organic compounds relies on several arbitrary decisions, the resulting subset represents a group of 13 compounds that commonly are found in domestic sewage at relatively elevated concentrations. All 13 compounds were detected in the NCP1 sewer-line sample, and 11 compounds were detected in the NCP4 septic sample (table 3). The absence of two compounds in the NCP4 sample possibly is because the compounds were not used in the 16-family subdivision using the septic system, or the compounds may have been degraded in the septic system.

The octanol-water partition coefficient (partition coefficient) is a measure of how relatively hydrophobic a compound is—the greater the partition coefficient, the more hydrophobic the compound and the more likely the compound is to partition out of solution by adsorbing onto solid mineral surfaces. For example, of the compounds with partition coefficients in table 3, caffeine is the most soluble and diethylhexyl phthalate is the least soluble and the most likely to adsorb to particulate surfaces.

Because the organic compound analysis is extremely sensitive, both spiked samples and blank samples were submitted as blind samples to the laboratory during the course of this study. The spike samples were prepared in duplicate; all 13 organic compounds of interest were identified in the spikes, and the concentrations that were determined in each spike were highly consistent. Six blank samples were prepared and submitted to the laboratory for analysis; on average, one organic compound was detected in these blanks, which demonstrated that more than one organic compound should be present in a given sample before concluding that the sample contains sewage.

Synoptic Sampling Results

Below is an overview of the synoptic sampling results, including a summary of the sampling events, and an analysis of the synoptic sampling data for the identification of both major and minor sewage sources.

Table 3. The subset of 13 organic compounds identified as useful sewage tracers, their primary uses, and octanol-water partition coefficients. Also included are concentrations of these tracers in two raw sewage samples.

[K_{ow}, octanol-water partition coefficient; nd, not detected; —, not available. Shading indicates estimated concentration value]

Compound	Log K_{ow}	NCP1	NCP4	Uses[a]
Caffeine	0.16	36	160	Beverages, diuretic, very mobile/biodegradable.
Cotinine	.34	1	nd	Primary nicotine metabolite.
Diethyl phthalate (DEP)	2.82	6.8	11	Plasticizer for polymers and resins.
Diethylhexyl phthalate (DEHP)	8.39	3.5	5.5	Plasticizer for polymers and resins, pesticide inert.
Galaxolide (HHCB)	6.26	.77	5.8	Musk fragrance, persistent and widespread use in ground water.
Menthol	3.38	18	18	Cigarettes, cough drops, liniment, mouthwash.
NPEO1-total	—	12	31	Nonionic detergent metabolite.
NPEO2-total	—	9.9	24	Nonionic detergent metabolite.
OPEO1	—	1.8	nd	Nonionic detergent metabolite.
para-Nonylphenol (total NP)	5.92	36	59	Nonionic detergent metabolite.
Skatol	2.60	1	38	Fragrance, stench in feces and coal tar.
Tonalide (AHTN)	6.35	3.8	8.2	Musk fragrance, persistent and widespread use in ground water.
Triclosan	4.66	5.2	6.8	Disinfectant, antimicrobial.

[a] Zaugg and others, 2002, 2006.

Summary of the Sampling Events

Eight synoptic sampling events were conducted during this study from December 2001 to September 2004. Summary details related to each synoptic sampling event are presented in table 4, and a map of all the synoptic sampling sites is given in figure 3. Variations occurred in the number of samples collected during the first four sampling events because of slight variations in the flow conditions for each event; for example, 123 samples were collected during the second sampling event when the streamflow in Accotink Creek (at USGS streamgaging station 01654000) was 8.1 cubic feet per second (ft^3/s), and only 90 samples were collected during the fourth sampling event when the flow in Accotink Creek was only 2.4 ft^3/s and several of the synoptic sampling sites were dry.

All of the sampling events were performed by starting at the most downstream location in the watershed and moving in an upstream direction. In this manner, none of the stream samples were compromised by any upstream sampling activity. Despite the similarity of all synoptic sampling events, there were differences associated with each sampling event that are noted here to provide the environmental context for each event:

First sampling event (December 2001): No samples were collected for analysis of wastewater organic compounds; these analyses did not occur until the third sampling event. Laboratory results for the bromide analyses failed all quality-assurance tests (related to blind duplicates and split samples), causing the bromide data to be rejected. Therefore, no bromide data are available for this event.

Second sampling event (April 2002): No samples were collected for analysis of wastewater organic compounds. Again, laboratory results for the bromide analyses failed several quality-assurance tests (related to blind duplicates and split samples that were run by the USGS National Water Quality Laboratory), causing the bromide data to be rejected. Therefore, no bromide data are available for this event.

Third sampling event (July 2002): This sampling event was the first for which selected samples were submitted for analysis of confirmatory organic compounds. Following day 2 of sampling, there was a light overnight rainfall that did not appear to result in any runoff processes. By the morning of day 3, the streamgage at Braddock Road had not recorded an obvious runoff response, and investigation of a number of storm-drain outfalls indicated that the storm-drain networks were not responding to the rainfall. Because of these observations, sampling continued on the third and fourth days. When the bacteria samples from day 3 were enumerated, however, it became apparent that the fecal coliform counts were extremely elevated (relative to counts for the first 2 days), and that the rainfall had likely initiated a runoff response in the watershed. A subsequent detailed inspection of the Braddock Road hydrograph confirmed a very small increase (0.04 ft) in water level following the rainfall. Once the effects of the rainfall were realized, six sites that were sampled on day 3 were resampled on day 5. These data confirmed a substantial decrease in the bacterial concentrations between day 3 and day 5, and indicate that the samples collected on day 3 and possibly day 4 were affected by the rainfall and runoff. As such, only the data for days 1 and 2 (including the organic compound data for these two days) were retained in the database and analyzed as base-flow samples. In short, the data from the third sampling event represent only the lower half of the watershed. Lastly, the analytical results for bromide continued to fail the quality-assurance tests (related to blind duplicates and split samples that were run by the USGS National Water Quality Laboratory), causing the bromide data to be rejected. Therefore, no bromide data are available for this event.

Fourth sampling event (October 2002): The Fairfax Environmental Services Laboratory changed its analytical

Table 4. Summary of the number and type of samples collected from the Accotink Creek watershed, Virginia, during synoptic sampling in relation to discharge at the Braddock Road streamgaging station.

[ft^3/s, cubic feet per second]

Sampling event number	Sampling date	Main-channel samples	Tributary samples	Storm-drain samples	Total samples collected	Organic samples analyzed	Accotink Creek flow at Braddock Road (ft^3/s)
1	December 3–7, 2001	15	51	44	110	0	2.7
2	April 2–5, 2002	16	55	52	123	0	8.1
3	July 8–12, 2002	10	14	17	41	6	.32
4	October 21–24, 2002	15	46	29	90	18	2.4
5	April 14–17, 2003	19	56	47	122	34	19.8
6	November 10–11, 2003	11	26	20	57	12	19
7	February 17–20, 2004	21	55	33	109	18	18
8	September 12–14, 2004	8	63	44	115	15	4.9

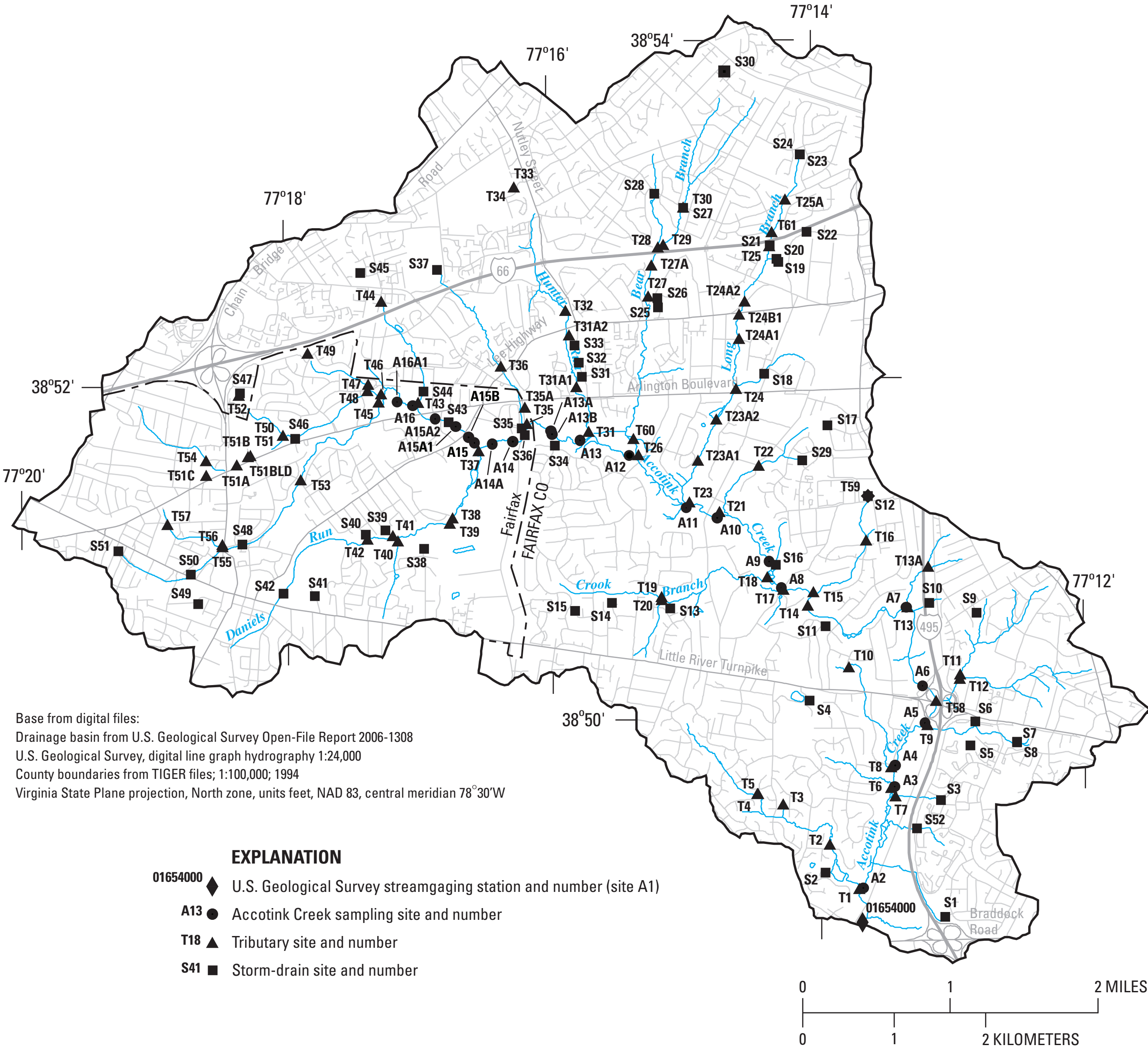

Figure 3. Location of sampling sites in the Accotink Creek watershed, Virginia.

procedure for bromide, and the quality-assurance tests indicated that the bromide data were usable. This marks the first time that the chloride/bromide ratio could be calculated.

Fifth sampling event (April 2003): Having completed four sampling events, several new sampling sites were added in the watershed during this event to better characterize the areas with relatively elevated tracer concentrations. To accommodate these additional sampling sites, several sites with relatively low tracer concentrations were not sampled.

Sixth sampling event (November 2003): After 2 days of sampling in only the lower half of the watershed, a rainstorm occurred that clearly initiated runoff. Because samples already had been submitted to the Fairfax Environmental Services Laboratory and samples for wastewater organic compounds were already being analyzed at the USGS National Water Quality Laboratory, it was decided to use the data from this partial sampling event.

Seventh sampling event (February 2004): During this event, several new sampling sites were added to the basin to better characterize areas with relatively elevated tracer concentrations. To accommodate these additional sampling sites, several sites with relatively low tracer concentrations were not sampled.

Eighth sampling event (September 2004): By this sampling event, many of the sampling sites were well characterized, and sites with consistently low tracer concentrations had been identified. Conversely, numerous sites exhibited extremely variable tracer levels; these inconsistent water-quality levels made it challenging to identify sites with sewage sources. Accordingly, only sites that were either relatively variable or sites with relatively elevated tracer levels were sampled. Additional sampling elements were added to this sampling event to permit improved characterization of the variability that had been observed at these sites. By reducing the overall number of sampling sites, each remaining site was sampled twice during this sampling event (roughly 1–2 days apart). Additionally, optical brightener monitors were deployed at all the sites that were sampled, and intensive sampling over a 24-hour period was conducted at several of the sampling sites. Lastly, the additional sampling of storm-drain networks also was performed at the end of this sampling event.

Cases of Major Sewage Inputs

During two synoptic sampling events, direct sewage sources to Accotink Creek were identified. These sewage sources were of sufficient volume that they caused extremely elevated tracer levels in the stream-water samples, which demonstrated how effective the suite of sewage tracers can be for identifying major sewage sources to streams. One sewage source occurred at site T13, and another occurred at site T51BLD (fig. 3), and both incidents are discussed in detail.

The first major sewage source that was discovered during a synoptic sampling event occurred during the fourth sampling event. While sampling an unnamed tributary to Accotink Creek (site T13), the tributary water was decidedly gray in color and a sewage odor was prevalent. Elevated concentrations of the water-quality tracers also indicated the presence of sewage in this tributary. With knowledge that the tributary likely contained sewage, a field crew followed the gray water approximately 0.25 mile upstream from site T13 and discovered an overflowing sewer-line manhole that was contributing untreated sewage to the tributary. Fairfax County Wastewater Management was contacted and they responded and removed a clog that had developed in the sewer line just below the overflowing manhole.

The data that were collected downstream from this overflowing sewer line provided field validation of the multiple-tracer approach and demonstrated how far down-stream the signal from this sewage source could be detected (table 5).

Table 5. Indicator tracer concentrations in samples collected during and following a sewer-line overflow that contributed sewage directly to an unnamed tributary, approximately 0.25 mile upstream from site T13, in the Accotink Creek watershed of Virginia.

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/100 mL, colonies per 100 milliliters; <, less than. Shading indicates estimated concentration value. Site A7 is located just upstream from where the sewage-impacted tributary drains into Accotink Creek and represents unimpacted conditions; sites A6–A1 are located downstream from the sewage input and are impacted by this overflowing sewer line. Also presented are the indicator tracer concentrations (at site T13 and site T13A, which are located 30 feet below the overflowing sewer line) that were observed following the repair of the sewer line]

Site ID (fig. 3)	Event	Sampling date	Sampling time	Boron (mg/L)	Chloride (mg/L)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Turbidity (NTU)	Surfactants (mg/L)	Fecal coliform bacteria (col/100 mL)
During the period of the overflowing sewer line										
A7	4	10/22/02	1040	0.032	22	159.8	9.97	7	0.13	290
T13	4	10/22/02	1015	.166	64	674	3.13	19	5	870,000
A6	4	10/22/02	855	.060	28	213.1	8.07	7	.75	16,000
A5	4	10/21/02	1625	.042	27	206.2	7.33	8	.5	76,000
A4	4	10/21/02	1330	.046	27	180.1	8.67	5	.25	1,500
A3	4	10/21/02	1225	.048	26	181	8.50	6	.25	3,000
A2	4	10/21/02	1245	.029	23	168	9.65	6	.25	530
A1	4	10/21/02	1120	.029	22	163	8.96	6	.13	630
Following the repair of the overflowing sewer line										
T13A	5	4/14/03	1630	0.010	53	265.5	9.26	4	0.13	123
T13A	6	11/10/03	1545	.013	52	159.3	9.15	2	.13	77
T13A	7	2/17/04	1600	.017	87	277.1	12.20	2	.13	3
T13	5	4/14/03	1725	.007	64	318	9.71	2	.13	87
T13	6	11/10/03	1645	.012	52	266.7	10.47	2	.13	43
T13	7	2/17/04	1700	.012	89	293.7	12.41	2	0	< 3

Although site T13 is located approximately 0.25 mile downstream from the overflowing sewer line, the sewage-tracer concentrations at the site were similar to the raw-sewage samples in table 2. For comparison, a water-quality sample was collected from Accotink Creek just upstream from the confluence of the unnamed tributary and Accotink Creek (site A7, fig. 3). The tracer concentrations observed at site T13 (affected by sewer overflow) and A7 in October 2002 are strikingly different (table 5). The sample collected at site T13 had elevated surfactant, turbidity, boron, fecal coliform bacteria, chloride, and specific conductance concentrations. The sample from site T13 also had dissolved-oxygen concentrations that were much less than those observed at site A7. These distinctly different tracer concentrations further support the effectiveness of this collection of sewage tracers for locating major sewage sources to a stream.

In addition, elevated downstream tracer concentrations from this overflow were evident in the Accotink Creek water-quality data nearly 2 miles downstream from the confluence of the unnamed tributary with Accotink Creek (table 5). Elevated fecal coliform bacteria and surfactant concentrations were detected in the samples collected from sites A6 downstream through site A2. By site A1, the sewage signal became sufficiently dilute that most of the water-quality data appeared to be similar to the background water quality typically observed at Braddock Road, with the exception of fecal coliform bacteria concentrations, which remained elevated relative to the background levels typically observed at this site.

Following repair of the sewer line by the Fairfax County Wastewater Services, site T13 was sampled several more times, as was a new sampling site (T13A) that was located about 60 feet downstream from the overflowing sewer line. These post-repair data represent some of the lowest fecal coliform and surfactant concentrations of all samples in the watershed (table 5), indicating that the repair was effective.

Despite the fact that the overflowing sewer line was the obvious source of sewage in the unnamed tributary, a wastewater organic compound sample was collected at site T13 as a positive control. As expected, detectable concentrations of all 13 compounds were observed in the sample, further supporting the use of this suite of wastewater organic compounds as a confirmatory tracer of sewage (table 6).

Table 6. Wastewater organic-compound concentrations observed at tributary site T13 in response to an overflowing sewer line located 0.25 mile upstream from site T13 in the Accotink Creek watershed of Virginia.

[µg/L, micrograms per liter. Shading indicates estimated concentration value]

Compound (µg/L)	Site T13
Caffeine	27
Cotinine	.78
Diethyl phthalate (DEP)	5.2
Diethylhexyl phthalate (DEHP)	3
Galaxolide (HHCB)	.51
Menthol	15
NPEO1-total	18
NPEO2-total	7.5
OPEO1	1.7
para-Nonylphenol (total NP)	19
Skatol	.66
Tonalide (AHTN)	2.2
Triclosan	2.7

Another sewage incident was observed during the eighth sampling event. Data from earlier sampling events indicated that the tributary upstream from site T51 (fig. 3) likely was impaired by sewage. These data are presented and discussed later in this report. After sampling site T51, a detailed reconnaissance was performed upstream from the site, and a small, previously unsampled storm-drain outfall was observed to be flowing near site T51B. This storm drain was labeled as site T51BLD and was sampled for a subset of indicator tracers and a complete suite of confirmatory tracers. Site conditions prevented sampling for all the indicator tracers. The results of this sampling are presented in table 7. The site had relatively elevated concentrations of all sewage indicators, although the boron concentrations were not especially elevated. The presence of 11 confirmatory tracer compounds further demonstrates that the sample contained sewage.

Because site T51BLD is located in Fairfax City, the City officials were informed of the sewage leak and location. City crews responded and conducted a visual inspection of the storm-drain line using a closed circuit video camera, but no obvious source of the sewage in the drain could be identified. City crews then inspected several nearby office buildings for cross-connected lines, malfunctioning systems, floor drains, and such. Despite these efforts, the source of the sewage was not identified.

Following the City's unsuccessful attempts to locate the source of the sewage in this storm drain, additional samples were collected from the storm drain during November and December 2004 to determine whether the sewage was a persistent problem. The additional samples were analyzed only for fecal coliform bacteria and surfactant concentrations, and the results are included in table 7. These additional samples indicate substantially reduced fecal coliform bacteria concentrations in the storm-drain outfall. Although surfactant concentrations were elevated in the two additional samples, only one sample had substantially elevated concentrations relative to background levels. These data seem to indicate that the sewage contributions in the storm drain are not persistent, which may be the reason that the Fairfax City staff could not locate the source of the sewage. As will be discussed later, there still may be a source of sewage in this tributary above site T51, as it does not appear that the sewage source has disappeared completely.

Table 7. Concentrations of indicator and confirmatory tracer compounds associated with sewage at storm-drain site T51BLD in the Accotink Creek watershed, Virginia. Also presented are the fecal coliform and surfactant concentrations from two additional samples that were collected from site T51BLD several months later.

[mg/L, milligrams per liter; —, value not determined; NTU, nephelometric turbidity units; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; nd, compound not detected. Shading indicates estimated concentration value]

Indicator tracers			
Compound	Sampling date		
	9/14/04	11/30/04	12/12/04
Boron (mg/L)	0.031	—	—
Chloride (mg/L)	67	—	—
Turbidity (NTU)	229	—	—
Surfactants (mg/L)	25	0.25	10
Fecal coliform bacteria (col/100 mL)	4,000,000	60	200

Confirmatory tracers	
Compound (µg/L)	9/14/04
Caffeine	2.8
Cotinine	3.2
Diethyl phthalate (DEP)	1.2
Diethylhexyl phthalate (DEHP)	24
Galaxolide (HHCB)	nd
Menthol	2.1
NPEO1-total	4
NPEO2-total	14
OPEO1	2.3
para-Nonylphenol (total NP)	5
Skatol	.11
Tonalide (AHTN)	nd
Triclosan	.24

During this study, the occurrences of three major direct sewage sources to the Accotink stream network were documented:

- The episodic occurrence of sewage at site S7 that was detected during the watershed reconnaissance.
- The overflowing sewer line at site T13A.
- The occurrence of sewage at site T51BLD that disappeared before the source could be identified.

Although the discovery and correction of the sewage source at site T13A is an important finding and resulted in a water-quality improvement in Accotink Creek, the other two sources were not identified. Such episodic occurrences of sewage could recur at any time, and it will be very difficult to identify the sources without detailed monitoring.

Initial expectations were that more than three major sources of sewage would have been observed in the Accotink Creek watershed during this study. Observing so few major sources is positive in that it indicates that the overall integrity of the sewage-handling infrastructure in the basin is not suffering from widespread, major occurrences of sewage contributions during relatively low streamflow conditions. Because so few major sewage sources to the streams were identified during the study, the possibility of low-volume (minor) sewage sources was evaluated.

Use of the Tracers for Identifying Minor Sewage Sources

Although the suite of sewage tracers used in this study was selected specifically to identify sewage sources, the tracers were not selected for their ability to identify minor sewage sources. Minor sewage sources are here defined as those that contribute relatively low volumes of sewage to a stream and result in a water sample with some sewage characteristics that are greatly diluted by relatively clean stream water.

Selection of the Most Sensitive Tracers for Identifying Minor Sewage Sources

To better understand which of the indicator tracers are most effective for identifying minor sewage sources to streams, dilution calculations were performed to evaluate the relative difference between the typical tracer concentrations that were observed in Accotink Creek and the tracer concentrations that were observed in untreated sewage. Conceptually, the tracers with the greatest relative concentration differences between the typical stream concentration and the untreated sewage concentration will be the best tracers to use in identifying minor sewage sources because they are least likely to be masked by the effects of dilution. For this analysis, the data in table 2, which includes the indicator tracer concentrations in raw sewage samples and the median concentration of a typical Accotink Creek sample, were used to calculate the relative difference. The ratio of the median sewage concentration to the median stream concentration was used to identify the tracers most likely to be useful in identifying minor sewage sources (table 8). Through this analysis, the concentrations of surfactants, fecal coliform bacteria, boron, and turbidity in raw sewage were all observed to be at least nine times greater than those typically observed in streams. Conversely, the ratios of chloride and specific conductance indicate that the stream levels were not very different from the levels typically observed in sewage. Consequently, neither chloride nor specific conductance was considered quantitatively in the evaluation

Table 8. Ratio of median indicator tracer concentrations in six raw sewage samples to the median indicator tracer concentrations observed in stream samples at site A1 for use in determining which tracers are most sensitive to minor sewage sources in the Accotink Creek watershed, Virginia.

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/100 mL, colonies per 100 milliliters]

	Boron (mg/L)	Chloride (mg/L)	Specific conductance (µS/cm)	Turbidity (NTU)	Surfactants (mg/L)	Fecal coliform bacteria (col/100 mL)
Median concentration in raw sewage	0.236	72	819	207	7.5	2,850,000
Median concentration at site A1	.025	39.5	237	5.5	.13	89
Ratio of median concentrations in sewage to median concentrations at site A1	**9**	**2**	**3**	**37**	**58**	**32,203**

of minor sewage sources. Although turbidity appears to be a good indicator of minor sewage sources, it was not used in the quantitative analysis because many of the particulates that contribute to elevated turbidity levels in sewage will readily settle out in streams, thereby decreasing the effectiveness of turbidity to be a good indicator (note in table 5, for example, how quickly the turbidity signal decreased). Accordingly, it was decided that surfactants, fecal coliform bacteria, and boron were likely the most sensitive indicator tracers to use in identifying minor sewage sources.

The use of several other tracers that were part of the indicator tracer suite also was considered for identifying minor sewage sources, but ultimately these tracers were not used for various reasons. These tracers included water temperature, DO, and the Cl/Br ratio. Water temperature initially was considered as a sewage tracer, presumably because the water temperature in the area around the sewage source would be relatively different from the temperature of nearby water samples. After several early sampling events, however, it was observed that many of the storm drains had pronounced water temperature fluctuations throughout the day (as much as 5 to 10 degrees Celsius (°C)), depending on the daily change in air temperature. Therefore, differences in water temperature were considered unreliable as tracers of minor sewage sources in this system. Similarly, DO concentrations throughout the watershed were observed to fluctuate on a daily basis (more elevated in the afternoon); the temporal variability in this tracer made it poorly suited for the identification of minor sewage sources. Lastly, the Cl/Br concentrations ratio was expected to provide a powerful tool for the identification of sewage sources to streams. During the first three sampling events, however, problems with laboratory analyses resulted in the bromide data being rejected. For event 4 and all subsequent events, the bromide results met the data-quality needs of the project, and the ratios were calculated. The median Cl/Br ratio for the fourth sampling event was 667, which is considered elevated and indicative of either sewage or halite additions in Accotink Creek (Thomas, 2000). Although halite does not occur naturally in the basin, road salting is performed widely during the winter months. Road salting makes it difficult to identify whether the elevated Cl/Br ratio is the result of the presence of either sewage or halite in the streams. This issue was resolved, however, because of nearly continuous specific conductance data that were available at the Braddock Road streamgaging station for a portion of this study; approximately 13 months of data are presented in figure 4. These data illustrate a specific conductance pattern that is highly indicative of road salt because the specific conductance values peak during the winter months, when the road salts are actively in use, and decline as the salts leach out of the watershed over the rest of the year. These specific conductance data indicate that the use of the Cl/Br ratio in identifying sewage sources to Accotink Creek is compromised by the road-salting pattern in the basin; consequently, this potentially powerful sewage tracer cannot be used quantitatively to identify minor sewage sources. Therefore, the most sensitive of the indicator tracers appear to be surfactants, fecal coliform bacteria, and boron; these most sensitive indicator tracers were subsequently used to evaluate the likelihood of minor sewage sources in the basin.

In addition to the use of boron, surfactants, and fecal coliform bacteria for identifying minor sewage sources to Accotink Creek, the 13 organic compounds that were used as confirmatory tracers also were used for identifying minor sewage sources. These organic compounds were considered useful because the analytical method is able to detect the presence of these compounds at levels far below the reporting levels. Although the analysis of these compounds at levels below their reporting levels is no longer considered quantitative, the presence of the compound can be verified. Therefore, the number of organic compounds detected in a given sample (rather than the specific concentration of each of the compounds) was used as a measure of the likelihood that the given sample contains sewage. For example, a sample that contains detectable levels of 10 of the 13 organic compounds (regardless of the concentration at which the compounds occur) is likely to contain some sewage, while a sample that has detectable concentrations of only 1 or none of the organic compounds is unlikely to contain sewage.

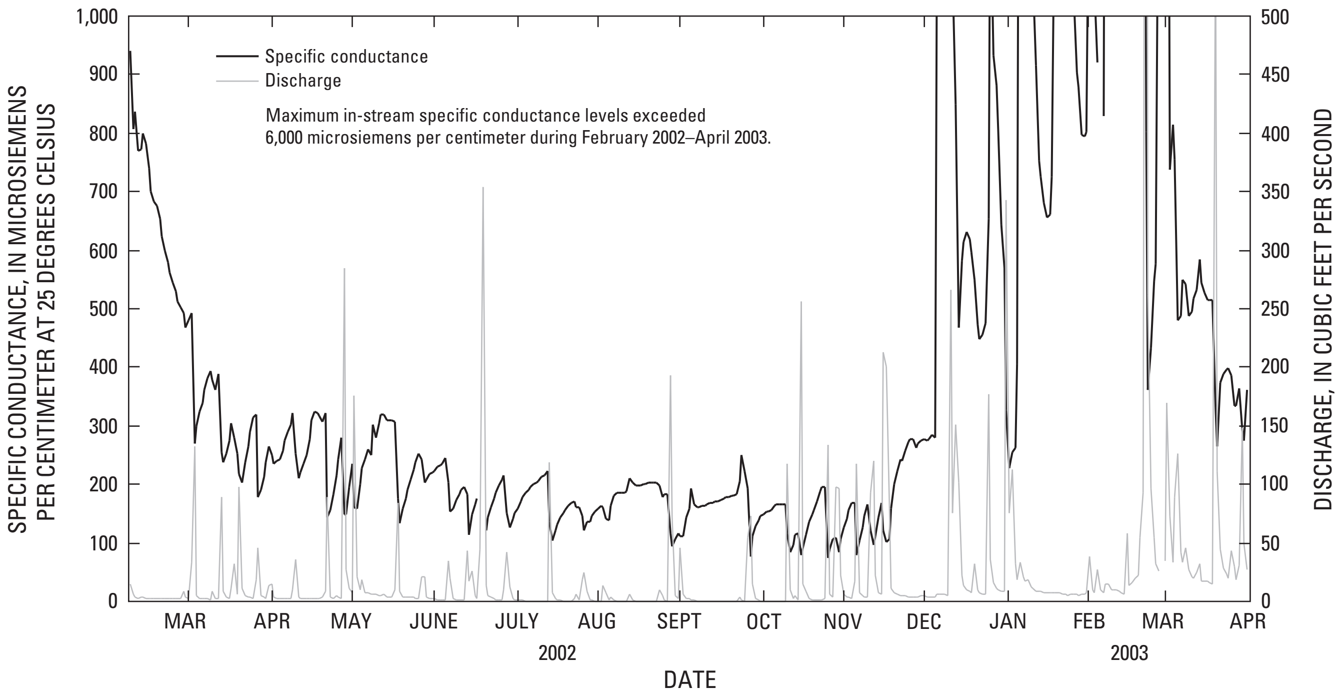

Figure 4. Time series of specific conductance in Accotink Creek at the Braddock Road streamgaging station (01654000) in the Accotink Creek watershed, Virginia. To enhance resolution of the lower specific conductance values and the general flushing response over the year, the y-axis has been truncated at 1,000 microsiemens per centimeter.

Qualitative Summary of the Synoptic Sampling Results

The results of each sampling event were summarized for each site to provide an overall understanding of the water-quality conditions. Detailed indicator tracer data are available in Appendix 1, and detailed wastewater organic compound data are available in Appendix 2. The summary in table 9 can be used to qualitatively identify sites that may have minor sewage sources, based on the median concentrations of fecal coliform bacteria, surfactants, and boron that were calculated for each site and the number of water samples collected from each site. Additionally, the number of samples that were submitted for analysis of confirmatory organic compounds and the median number of compounds detected at each site are provided (table 9).

The summary in table 9 can be used to address two fundamental issues in the Accotink Creek watershed:

- Identifying sites that have elevated fecal coliform bacteria concentrations
- Identifying sites that may be subject to sewage inputs

The summary results are presented in decreasing order by the median fecal coliform concentration at each site, which allows direct determination of the sites in the basin with the most elevated fecal coliform concentrations. In theory, this list of sites could be used as a priority list for further investigation in an attempt to reduce fecal coliform contributions to the stream. Although not all bacteria from each sampling site are transported into Accotink Creek and contribute to the bacterial impairment at the Braddock Road streamgaging station, the data provide a starting point for remediation or implementation of best management practices (BMPs) that may occur as part of future watershed-management practices. Table 9 also offers a relatively simple mechanism for identifying the sites that may be affected by sewage. The median tracer concentrations and the median number of organic compounds that were detected were conditionally formatted based on the relative concentrations that were considered to be background levels. Although the selection of these background conditions were somewhat arbitrary (based on approximate median observed boron and surfactant concentrations throughout the watershed and the geometric mean standard for fecal coliform concentrations), they assisted in data analysis because sites that are subject to sewage inputs are more likely to have relatively elevated concentrations of fecal coliform bacteria, surfactants, and boron in addition to relatively elevated numbers of organic compound detections. For example, site S3 (near the bottom of table 9) had relatively low tracer concentrations and very few detections of organic compounds in the samples, but site S46 (near the top of table 9) had relatively elevated indicator tracer concentrations and a relatively large number of organic compound detections in the samples (indicating that this site may have sewage sources). Caution is advised, however, when drawing inferences from any sites represented by only one or two samples, as these few samples may not fully represent the sites. Despite its qualitative nature, table 9 provides a mechanism for easily evaluating the water quality at each site relative to the water quality observed at other sampling sites and for identifying sites that may have sewage sources.

Table 9. Median concentrations of fecal coliform bacteria, surfactant, and boron; the number of water samples collected and analyzed for confirmatory tracers; and the median number of organic compounds detected in these confirmatory tracer samples from the synoptic sampling sites in the Accotink Creek watershed, Virginia.

[mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; nd, no data. Red indicates fecal coliform greater than or equal to 200, surfactants greater than 0.13, and boron greater than 0.020. Organic compound detections less than 2.5 are green, between 2.5 and 5.4 are blue, and greater than or equal to 5.5 are red. Conditional formatting has been used to identify which sites had elevated tracer concentrations or elevated numbers of organic compound detections. The table is sorted by the median fecal coliform concentrations]

Site ID (fig. 3)	Median boron (mg/L)	Median surfac-tant (mg/L)	Median fecal coliform bacteria (col/100 mL)	Number of samples	Median organic compound detections	Number of organics samples
T51BLD	0.031	25.00	4,000,000	1	11	1
T51B	.016	1.50	10,400	3	8	1
S37	.014	.12	6,400	6	1	2
T51A	.022	2.50	4,800	5	10	1
T35A	.014	.13	3,700	5	9	1
T35	.026	.13	3,500	7	7	3
T51C	.020	.13	2,800	3	nd	nd
S46	.087	.25	2,400	7	8	4
S18	.032	.13	2,000	9	2	2
A15B	.021	.13	1,875	3	3	1
T23A2	.016	.13	1,571	4	nd	nd
T24B1	.019	.13	1,255	4	nd	nd
S41	.016	.13	1,233	7	3	1
S51	.035	.13	1,233	7	3	3
S42	.031	.13	1,200	7	1	1
S7	.009	.13	1,133	9	4	2
T59	.023	.00	1,100	1	nd	nd
S8	.019	.20	1,033	9	4	3
T23A1	.017	.13	1,033	4	6	1
S20	.010	.13	933	9	6	2
T22	.027	.13	933	7	3	2
T31A1	.018	.19	927	4	nd	nd
T3	.030	.13	910	6	nd	nd
T50	.022	.13	800	7	1	2
T56	.023	.13	700	7	2	2
T51	.025	.38	664	8	8	5
T18	.020	.14	655	6	nd	nd
T24	.021	.13	639	10	3	7
T24A1	.022	.25	600	5	nd	nd
S23	.008	.13	570	7	0	1
S48	.020	.13	508	7	3	2
T25A	.011	.13	470	5	nd	nd
S24	.011	.13	445	8	nd	nd
S5	.013	.13	410	9	2	1
T24A2	.022	.13	410	5	nd	nd
T55	.036	.13	410	7	2	1
S29	.028	.13	400	9	2	3
A6	.022	.13	385	8	7	2
A13	.025	.13	370	8	3	2
T44	.024	.13	370	7	nd	nd
T29	.025	.13	350	5	2	1
T33	.023	.13	330	8	1	1
T23	0.023	0.13	320	10	4	3
S44	.058	.13	310	7	4	3
T42	.021	.13	300	5	nd	nd
T38	.012	.13	275	6	nd	nd
T31	.027	.13	270	8	3	3
S16	.015	.15	250	3	nd	nd
T37	.016	.13	240	7	nd	nd
T25	.018	.13	235	8	3	1
T26	.026	.13	230	4	nd	nd
S31	.023	.13	200	7	nd	nd
A5	.022	.12	197	6	nd	nd
A14	.019	.15	195	5	1	1
T27	.016	.13	195	6	nd	nd
T41	.018	.13	193	5	nd	nd
S47	.027	.13	190	6	nd	nd
S28	.008	.13	182	4	nd	nd
A11	.024	.13	180	7	nd	nd
A9	.022	.13	180	7	nd	nd
T1	.016	.13	180	7	nd	nd
A16	.023	.13	177	5	2	1
S39	.009	.13	177	4	nd	nd
A13B	.016	.13	170	1	nd	nd
A7	.022	.13	170	7	nd	nd
S35	.051	.13	170	7	1	1
T52	.017	.13	170	5	nd	nd
T60	.015	.13	170	3	nd	nd
A13A	.035	.13	163	2	nd	nd
A12	.025	.13	162	6	nd	nd
S6	.027	.44	162	8	6	3
A8	.022	.13	160	7	nd	nd
S13	.021	.13	160	9	nd	nd
S52	.037	.13	152	8	nd	nd
S17	.021	.13	143	6	nd	nd
T2	.019	.13	133	7	nd	nd
A10	.022	.15	130	1	nd	nd
S19	.034	.13	130	5	nd	nd
S26	.012	.10	127	3	nd	nd
A14A	.018	.13	122	2	nd	nd
T21	.022	.10	120	1	nd	nd
T12	.020	.13	120	6	nd	nd
A15A2	.023	.13	118	2	nd	nd
T27A	.013	.13	116	2	nd	nd

Table 9. Median concentrations of fecal coliform bacteria, surfactant, and boron; the number of water samples collected and analyzed for confirmatory tracers; and the median number of organic compounds detected in these confirmatory tracer samples from the synoptic sampling sites in the Accotink Creek watershed, Virginia. — Continued

[mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; nd, no data. Red indicates fecal coliform greater than or equal to 200, surfactants greater than 0.13, and boron greater than 0.020. Organic compound detections less than 2.5 are green, between 2.5 and 5.4 are blue, and greater than or equal to 5.5 are red. Conditional formatting has been used to identify which sites had elevated tracer concentrations or elevated numbers of organic compound detections. The table is sorted by the median fecal coliform concentrations]

Site ID (fig. 3)	Median boron (mg/L)	Median surfac-tant (mg/L)	Median fecal coliform bacteria (col/100 mL)	Number of samples	Median organic compound detections	Number of organics samples
T39	0.023	0.13	115	4	nd	nd
T40	.026	.13	110	7	1	1
S22	.039	.13	105	8	nd	nd
A15	.026	.13	103	7	3	3
T16	.016	.00	103	3	1	1
T20	.024	.13	103	5	nd	nd
A15A1	.019	.19	102	2	nd	nd
S50	.030	.13	100	7	2	2
T15	.017	.13	100	3	nd	nd
T8	.020	.10	100	5	nd	nd
T57	.026	.13	99	4	nd	nd
T30	.039	.10	97	1	nd	nd
T58	.005	.00	97	1	nd	nd
T31A2	.020	.19	96	2	nd	nd
T4	.024	.00	93	3	0	1
T43	.019	.13	90	5	nd	nd
T9	.021	.13	90	7	1	3
A1	.025	.13	89	6	nd	nd
A2	.019	.12	85	6	nd	nd
S4	.010	.08	85	4	nd	nd
T7	.010	.05	83	7	nd	nd
A4	.024	.14	80	4	nd	nd
S10	.039	.05	79	2	nd	nd
T36	.020	.13	78	8	0	3
T13A	.013	.13	77	3	0	1
T6	.020	.13	77	5	2	1
S33	.016	.13	75	4	nd	nd
S15	.020	.13	73	7	1	2
T49	.015	.10	73	3	nd	nd
T32	.024	.13	70	6	nd	nd
A3	.019	.13	69	6	nd	nd
T48	.024	.13	67	5	1	1
T53	.025	.10	67	5	nd	nd
T28	0.012	0.12	64	2	nd	nd
T19	.024	.13	63	7	nd	nd
T13	.012	.00	59	5	7	2
S27	.008	.13	58	4	nd	nd
T34	.014	.07	54	2	nd	nd
T11	.022	.15	53	3	nd	nd
T17	.015	.00	49	3	nd	nd
T45	.033	.13	45	5	nd	nd
S1	.009	.07	45	4	nd	nd
S14	.012	.15	42	3	nd	nd
T46	.024	.13	42	5	nd	nd
T47	.017	.13	40	5	0	1
T10	.027	.13	39	3	nd	nd
S2	.011	.13	37	3	nd	nd
S43	.018	.00	35	3	nd	nd
S21	.149	.25	32	2	nd	nd
T54	.017	.12	32	4	nd	nd
S49	.039	.13	28	5	nd	nd
S25	.028	.00	25	3	nd	nd
S30	.021	.07	23	2	nd	nd
S34	.015	.10	23	4	nd	nd
T5	.018	.00	22	1	nd	nd
S32	.027	.13	20	6	nd	nd
T14	.013	.13	20	3	nd	nd
S9	.005	.15	18	3	nd	nd
S3	.008	.00	16	7	2	3
S11	.012	.09	15	2	nd	nd
S40	.007	.09	15	2	nd	nd
A16A1	.018	.13	10	1	nd	nd
S45	.047	.13	7	3	nd	nd
S12	.037	.07	3	4	0	1
S36	.049	.20	3	3	nd	nd
S38	.014	.13	3	3	nd	nd

Quantitative Summary of the Synoptic Sampling Results

A quantitative summary of the data was developed based on the relative concentrations of the three most sensitive indicator tracers (fecal coliform bacteria, surfactants, and boron) and the relative number of organic compounds that were detected, to provide a quantitative mechanism for identifying the sampling sites that are most likely to be affected by sewage. Two analyses were conducted; the first considered only the sites where at least one organic compound sample was collected, and the second considered all sites that were sampled (regardless of whether organic compound analysis was performed). For the analytical approach, it was assumed that the results for the three indicator tracers and the organic compound analysis should be weighted equally—that is, each of the fecal coliform bacteria, surfactants, boron, and number of organic compounds detected contributed 25 percent of the overall computation. Because most of these properties were not normally distributed, the nonparametric approach of ranking the data was used. For each indicator tracer and confirmatory organic tracer, the median concentration at each site and the median number of organic compounds detected were ranked from greatest to smallest. This analytical approach was applied first on the 52 samples that had organic compound analytical results (table 10) and second on the limited data set for all 149 sites (table 11).

The data were ranked for the 52 sites that had at least one organic compound detection by assigning a value of 52 to the greatest median value of each of the three indicator tracers (surfactants, fecal coliform bacteria, and boron) and the median number of organic compounds detected. The lowest tracer values were assigned a value of 1 (table 10). For example, site T51B had the greatest concentration of fecal coliform bacteria and was assigned a rank of 52; site S3, however, had a median concentration of fecal coliform bacteria of 16 col/100 mL and a rank of 2. After ranking all four tracers, the rankings for each site were summed. The sum then was divided by the possible total of 208 (4x52) and multiplied by 100 to get a relative impairment index that ranged from 0 to 100. The greater the value of the relative impairment index, the more likely a given site has sewage sources relative to the other sampled sites. The results of this analytical approach are given in table 10 and are sorted in descending order by the value of the relative impairment index for each site. This table provides a key summary of all the synoptic sampling data by identifying the sampling sites that are most likely to contain minor sewage sources. Theoretically, the relative impairment index could be used to prioritize sites (or stream sections) for additional investigation to identify minor sewage sources.

The relative impairment index also was calculated for all 149 sampling sites based only on the data from the three most sensitive indicator tracers (fecal coliform bacteria, boron, and surfactants). For this approach, the median concentration data for each of these three tracers were ranked by assigning the greatest concentration a score of 149 and the lowest concentration a score of 1 (table 11). The rankings for the three indicator tracers were summed, divided by the total possible score of 447 (149x3), and multiplied by 100 to develop a relative impairment index that ranged from 1 to 100. This approach differs slightly from the approach presented in table 10 in that the organic compound data were excluded and a relative impairment index value was calculated for all 149 sites. The results of this calculation, presented in table 11, are sorted in descending order by the final relative impairment index value for each site. Table 11 provides a summary of the sites that are most likely to contain sewage, and the list potentially could be used for prioritizing sites that may be worthy of further investigation. Again, caution is advised when interpreting data

Table 10. Relative impairment indices, listed in descending order, for 52 synoptic sampling sites based on indicator tracer data and confirmatory organic compound data. (The theoretical addition of sewage samples appears at the bottom of the table.)

[mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters]

Site ID (fig. 3)	Median boron (mg/L)	Median surfactant (mg/L)	Median fecal coliform bacteria (col/100 mL)	Number of samples	Median organic compound detections	Number of organic compound samples	Ranking for boron	Ranking for surfactants	Ranking for fecal coliform bacteria	Ranking for organic compounds	Relative index (max=100)
S46	0.087	0.25	2,400	7	8	4	52	48	47	49	94.2
T51A	.022	2.50	4,800	5	10	1	26	52	50	52	86.5
T51	.025	.38	664	8	8	5	35	49	34	49	80.3
T51B	.016	1.50	10,400	3	8	1	11	51	52	49	78.4
T35	.026	.13	3,500	7	7	3	38	26	48	47	76.4
S6	.027	.44	162	8	6	3	41	50	16	43	72.1
S51	.035	.13	1,233	7	3	3	47	26	43.5	33	71.9
S8	.019	.20	1,033	9	4	3	16.5	47	39.5	40	68.8
S18	.032	.13	2,000	9	2	2	46	26	46	23	67.8
S44	.058	.13	310	7	4	3	51	26	22	40	66.8

Table 10. Relative impairment indices, listed in descending order, for 52 synoptic sampling sites based on indicator tracer data and confirmatory organic compound data. (The theoretical addition of sewage samples appears at the bottom of the table.) — Continued

[mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters]

Site ID (fig. 3)	Median boron (mg/L)	Median surfactant (mg/L)	Median fecal coliform bacteria (col/100 mL)	Number of samples	Median organic compound detections	Number of organic compound samples	Ranking for boron	Ranking for surfactants	Ranking for fecal coliform bacteria	Ranking for organic compounds	Relative index (max=100)
T35A	0.014	0.13	3,700	5	9	1	8.5	26	49	51	64.7
T22	.027	.13	933	7	2.5	2	41	26	37.5	28	63.7
A15B	.021	.13	1,875	3	3	1	23	26	45	33	61.1
T55	.036	.13	410	7	2	1	48	26	29.5	23	60.8
S42	.031	.13	1,200	7	1	1	45	26	42	12.5	60.3
A6	.022	.13	385	8	6.5	2	26	26	27	45.5	59.9
T23A1	.017	.13	1,033	4	6	1	13.5	26	39.5	43	58.7
T31	.027	.13	270	8	3	3	41	26	21	33	58.2
S29	.028	.13	400	9	2	3	43	26	28	23	57.7
A13	.025	.13	370	8	3	2	35	26	26	33	57.7
T23	.023	.13	320	10	4	3	29.5	26	23	40	57.0
T24	.021	.13	639	10	3	7	23	26	33	33	55.3
S41	.016	.13	1,233	7	3	1	11	26	43.5	33	54.6
A15	.026	.13	103	7	3	3	38	26	13.5	33	53.1
S20	.010	.13	933	9	6	2	4	26	37.5	43	53.1
S48	.020	.13	508	7	3	2	19.5	26	31	33	52.6
T29	.025	.13	350	5	2	1	35	26	25	23	52.4
T56	.023	.13	700	7	1.5	2	29.5	26	35	18	52.2
S7	.009	.13	1,133	9	3.5	2	3	26	41	38	51.9
S35	.051	.13	170	7	1	1	50	26	17	12.5	50.7
S50	.030	.13	100	7	2	2	44	26	12	23	50.5
T50	.022	.13	800	7	1	2	26	26	36	12.5	48.3
A16	.023	.13	177	5	2	1	29.5	26	18	23	46.4
A14	.019	.15	195	5	1	1	16.5	46	19	12.5	45.2
T25	.018	.13	235	8	3	1	15	26	20	33	45.2
T33	.023	.13	330	8	1	1	29.5	26	24	12.5	44.2
T40	.026	.13	110	7	1	1	38	26	15	12.5	44.0
S5	.013	.13	410	9	2	1	6.5	26	29.5	23	40.9
S37	.014	.12	6,400	6	1	2	8.5	6	51	12.5	37.5
T48	.024	.13	67	5	1	1	32.5	26	5	12.5	36.5
T6	.020	.13	77	5	2	1	19.5	26	7.5	23	36.5
T9	.021	.13	90	7	1	3	23	26	10	12.5	34.4
S23	.008	.13	570	7	0	1	1.5	26	32	3.5	30.3
S12	.037	.07	3	4	0	1	49	5	1	3.5	28.1
S15	.020	.13	73	7	0.5	2	19.5	26	6	7	28.1
T36	.020	.13	78	8	0	3	19.5	26	9	3.5	27.9
T13	.012	.00	59	5	6.5	2	5	2.5	4	45.5	27.4
T4	.024	.00	93	3	0	1	32.5	2.5	11	3.5	23.8
T47	.017	.13	40	5	0	1	13.5	26	3	3.5	22.1
T13A	.013	.13	77	3	0	1	6.5	26	7.5	3.5	20.9
T16	.016	.00	103	3	1	1	11	2.5	13.5	12.5	19.0
S3	.008	.00	16	7	2	3	1.5	2.5	2	23	13.9
Theoretical addition of results of the sample collected below the sewer-line overflow and the six raw sewage samples that were collected											
T13	0.166	5	870,000	1	13	1	53	53	53	54	98.6
Sewage	.236	7.5	2,850,000	6	12	2	54	54	54	53	99.5

Table 11. Relative impairment indices, listed in descending order, for 149 synoptic sampling sites based on indicator tracer data only. (The theoretical addition of sewage samples appears at the end of the table.

[mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; nd, no data. Shading indicates relative index values for the 11 sites with the greatest relative impairment indices in table 10]

Site ID (fig. 3)	Median boron (mg/L)	Median surfactant (mg/L)	Median fecal coliform bacteria (col/100 mL)	Number of samples	Median organic compound detections	Number of organic compound samples	Ranking for boron	Ranking for surfactants	Ranking for fecal coliform bacteria	Relative index (max=100)
S46	0.087	0.25	2,400	7	8	4	148	144	143	97.3
T51	.025	.38	664	8	8	5	112.5	146	125	85.8
T51A	.022	2.50	4,800	5	10	1	86.5	149	147	85.6
S18	.032	.13	2,000	9	2	2	132	80.5	142	79.3
S51	.035	.13	1,233	7	3	3	135.5	80.5	137.5	79.1
T24A1	.022	.25	600	5	nd	nd	86.5	144	122	78.9
S6	.027	.44	162	8	6	3	123.5	147	80.5	78.5
S42	.031	.13	1,200	7	1	1	131	80.5	136	77.7
T35	.026	.13	3,500	7	7	3	118	80.5	145	76.8
T3	.030	.13	910	6	nd	nd	129.5	80.5	128	75.6
T51B	.016	1.50	10,400	3	8	1	40	148	149	75.4
S44	.058	.13	310	7	4	3	147	80.5	107	74.8
T22	.027	.13	933	7	2.5	2	123.5	80.5	130.5	74.8
S8	.019	.20	1,033	9	4	3	60.5	141.5	132.5	74.8
T55	.036	.13	410	7	2	1	137	80.5	116	74.6
T18	.020	.14	655	6	nd	nd	69	130.5	124	72.4
S29	.028	.13	400	9	2	3	127.5	80.5	114	72.0
T31A1	.018	.19	927	4	nd	nd	53	139	129	71.8
S35	.051	.13	170	7	1	1	146	80.5	85	69.7
S21	.149	.25	32	2	nd	nd	149	144	17.5	69.5
T31	.027	.13	270	8	3	3	123.5	80.5	104	68.9
A13	.025	.13	370	8	3	2	112.5	80.5	111.5	68.1
T29	.025	.13	350	5	2	1	112.5	80.5	110	67.8
T56	.023	.13	700	7	1.5	2	96.5	80.5	126	67.8
T26	.026	.13	230	4	nd	nd	118	80.5	100	66.8
A15B	.021	.13	1,875	3	3	1	77	80.5	141	66.8
A13A	.035	.13	163	2	nd	nd	135.5	80.5	82	66.7
S47	.027	.13	190	6	nd	nd	123.5	80.5	94	66.7
T44	.024	.13	370	7	nd	nd	105	80.5	111.5	66.4
S52	.037	.13	152	8	nd	nd	138.5	80.5	77	66.2
A10	.022	.15	130	1	nd	nd	86.5	134.5	73.5	65.9
T50	.022	.13	800	7	1	2	86.5	80.5	127	65.8
T51C	.020	.13	2,800	3	nd	nd	69	80.5	144	65.7
A14	.019	.15	195	5	1	1	60.5	134.5	96.5	65.2
S36	.049	.20	3	3	nd	nd	145	141.5	2	64.5
S19	.034	.13	130	5	nd	nd	134	80.5	73.5	64.4
S22	.039	.13	105	8	nd	nd	141.5	80.5	64	64.0
T33	.023	.13	330	8	1	1	96.5	80.5	109	64.0
T23	.023	.13	320	10	4	3	96.5	80.5	108	63.8
T24A2	.022	.13	410	5	nd	nd	86.5	80.5	116	63.3
A4	.024	.14	80	4	nd	nd	105	130.5	45	62.8
T24	.021	.13	639	10	3	7	77	80.5	123	62.8
A6	.022	.13	385	8	6.5	2	86.5	80.5	113	62.6
T24B1	.019	.13	1,255	4	nd	nd	60.5	80.5	139	62.6

Table 11. Relative impairment indices, listed in descending order, for 149 synoptic sampling sites based on indicator tracer data only. (The theoretical addition of sewage samples appears at the end of the table. — Continued

[mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; nd, no data. Shading indicates relative index values for the 11 sites with the greatest relative impairment indices in table 10]

Site ID (fig. 3)	Median boron (mg/L)	Median surfactant (mg/L)	Median fecal coliform bacteria (col/100 mL)	Number of samples	Median organic compound detections	Number of organic compound samples	Ranking for boron	Ranking for surfactants	Ranking for fecal coliform bacteria	Relative index (max=100)
A11	0.024	0.13	180	7	nd	nd	105	80.5	91	61.9
S31	.023	.13	200	7	nd	nd	96.5	80.5	99	61.7
A12	.025	.13	162	6	nd	nd	112.5	80.5	80.5	61.2
S16	.015	.15	250	3	nd	nd	33	134.5	103	60.5
S48	.020	.13	508	7	3	2	69	80.5	120	60.3
S50	.030	.13	100	7	2	2	129.5	80.5	58	60.0
A16	.023	.13	177	5	2	1	96.5	80.5	88.5	59.4
T40	.026	.13	110	7	1	1	118	80.5	65	58.9
T42	.021	.13	300	5	nd	nd	77	80.5	106	58.9
T31A2	.020	.19	96	2	nd	nd	69	139	53	58.4
A15	.026	.13	103	7	3	3	118	80.5	62	58.3
T23A2	.016	.13	1,571	4	nd	nd	40	80.5	140	58.3
T23A1	.017	.13	1,033	4	6	1	47	80.5	132.5	58.2
A15A1	.019	.19	102	2	nd	nd	60.5	139	60	58.1
A9	.022	.13	180	7	nd	nd	86.5	80.5	91	57.7
S41	.016	.13	1,233	7	3	1	40	80.5	137.5	57.7
T35A	.014	.13	3,700	5	9	1	28.5	80.5	146	57.0
T57	.026	.13	99	4	nd	nd	118	80.5	56	56.9
A7	.022	.13	170	7	nd	nd	86.5	80.5	85	56.4
T11	.022	.15	53	3	nd	nd	86.5	134.5	28	55.7
T20	.024	.13	103	5	nd	nd	105	80.5	62	55.4
A8	.022	.13	160	7	nd	nd	86.5	80.5	78.5	54.9
A15A2	.023	.13	118	2	nd	nd	96.5	80.5	68	54.8
T39	.023	.13	115	4	nd	nd	96.5	80.5	66	54.4
A1	.025	.13	89	6	nd	nd	112.5	80.5	49	54.1
T45	.033	.13	45	5	nd	nd	133	80.5	25.5	53.5
S49	.039	.13	28	5	nd	nd	141.5	80.5	16	53.2
S13	.021	.13	160	9	nd	nd	77	80.5	78.5	52.8
T59	.023	.00	1,100	1	nd	nd	96.5	5.5	134	52.8
T25	.018	.13	235	8	3	1	53	80.5	101	52.5
S17	.021	.13	143	6	nd	nd	77	80.5	76	52.2
S45	.047	.13	7	3	nd	nd	144	80.5	4	51.1
T41	.018	.13	193	5	nd	nd	53	80.5	95	51.1
T10	.027	.13	39	3	nd	nd	123.5	80.5	21	50.3
S7	.009	.13	1,133	9	3.5	2	9	80.5	135	50.2
S20	.010	.13	933	9	6	2	12	80.5	130.5	49.9
T32	.024	.13	70	6	nd	nd	105	80.5	37	49.8
T37	.016	.13	240	7	nd	nd	40	80.5	102	49.8
S5	.013	.13	410	9	2	1	24.5	80.5	116	49.4
T48	.024	.13	67	5	1	1	105	80.5	34.5	49.2
T30	.039	.10	97	1	nd	nd	141.5	23	54.5	49.0
T12	.020	.13	120	6	nd	nd	69	80.5	69.5	49.0
T19	.024	.13	63	7	nd	nd	105	80.5	32	48.7
T27	.016	.13	195	6	nd	nd	40	80.5	96.5	48.5

Table 11. Relative impairment indices, listed in descending order, for 149 synoptic sampling sites based on indicator tracer data only. (The theoretical addition of sewage samples appears at the end of the table. — Continued

[mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; nd, no data. Shading indicates relative index values for the 11 sites with the greatest relative impairment indices in table 10]

Site ID (fig. 3)	Median boron (mg/L)	Median surfactant (mg/L)	Median fecal coliform bacteria (col/100 mL)	Number of samples	Median organic compound detections	Number of organic compound samples	Ranking for boron	Ranking for surfactants	Ranking for fecal coliform bacteria	Relative index (max=100)
T2	0.019	0.13	133	7	nd	nd	60.5	80.5	75	48.3
S32	.027	.13	20	6	nd	nd	123.5	80.5	10.5	48.0
T25A	.011	.13	470	5	nd	nd	15	80.5	119	48.0
A5	.022	.12	197	6	nd	nd	86.5	29	98	47.8
S24	.011	.13	445	8	nd	nd	15	80.5	118	47.8
T52	.017	.13	170	5	nd	nd	47	80.5	85	47.5
T1	.016	.13	180	7	nd	nd	40	80.5	91	47.3
T46	.024	.13	42	5	nd	nd	105	80.5	23.5	46.8
T9	.021	.13	90	7	1	3	77	80.5	50.5	46.5
S23	.008	.13	570	7	0	1	5.5	80.5	121	46.3
A13B	.016	.13	170	1	nd	nd	40	80.5	85	46.0
S37	.014	.12	6,400	6	1	2	28.5	29	148	46.0
T38	.012	.13	275	6	nd	nd	19.5	80.5	105	45.9
A14A	.018	.13	122	2	nd	nd	53	80.5	71	45.8
T60	.015	.13	170	3	nd	nd	33	80.5	85	44.4
S10	.039	.05	79	2	nd	nd	141.5	11.5	44	44.1
T36	.020	.13	78	8	0	3	69	80.5	43	43.1
T43	.019	.13	90	5	nd	nd	60.5	80.5	50.5	42.8
T6	.020	.13	77	5	2	1	69	80.5	41.5	42.7
S15	.020	.13	73	7	0.5	2	69	80.5	38.5	42.1
T15	.017	.13	100	3	nd	nd	47	80.5	58	41.5
T21	.022	.10	120	1	nd	nd	86.5	23	69.5	40.0
S28	.008	.13	182	4	nd	nd	5.5	80.5	93	40.0
S39	.009	.13	177	4	nd	nd	9	80.5	88.5	39.8
S14	.012	.15	42	3	nd	nd	19.5	134.5	23.5	39.7
A3	.019	.13	69	6	nd	nd	60.5	80.5	36	39.6
T27A	.013	.13	116	2	nd	nd	24.5	80.5	67	38.5
T53	.025	.10	67	5	nd	nd	112.5	23	34.5	38.0
T4	.024	.00	93	3	0	1	105	5.5	52	36.4
S33	.016	.13	75	4	nd	nd	40	80.5	40	35.9
S12	.037	.07	3	4	0	1	138.5	14.5	2	34.7
T8	.020	.10	100	5	nd	nd	69	23	58	33.6
T47	.017	.13	40	5	0	1	47	80.5	22	33.4
S25	.028	.00	25	3	nd	nd	127.5	5.5	15	33.1
T13A	.013	.13	77	3	0	1	24.5	80.5	41.5	32.8
S9	.005	.15	18	3	nd	nd	1.5	134.5	9	32.4
A16A1	.018	.13	10	1	nd	nd	53	80.5	5	31.0
A2	.019	.12	85	6	nd	nd	60.5	29	47.5	30.6
S27	.008	.13	58	4	nd	nd	5.5	80.5	30	26.0
T14	.013	.13	20	3	nd	nd	24.5	80.5	10.5	25.8
S2	.011	.13	37	3	nd	nd	15	80.5	20	25.8
S26	.012	.10	127	3	nd	nd	19.5	23	72	25.6
S38	.014	.13	3	3	nd	nd	28.5	80.5	2	24.8
T16	.016	.00	103	3	1	1	40	5.5	62	24.1

Table 11. Relative impairment indices, listed in descending order, for 149 synoptic sampling sites based on indicator tracer data only. (The theoretical addition of sewage samples appears at the end of the table. — Continued

[mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters; nd, no data. Shading indicates relative index values for the 11 sites with the greatest relative impairment indices in table 10]

Site ID (fig. 3)	Median boron (mg/L)	Median surfactant (mg/L)	Median fecal coliform bacteria (col/100 mL)	Number of samples	Median organic compound detections	Number of organic compound samples	Ranking for boron	Ranking for surfactants	Ranking for fecal coliform bacteria	Relative index (max=100)
S30	0.021	0.07	23	2	nd	nd	77	14.5	13.5	23.5
T49	.015	.10	73	3	nd	nd	33	23	38.5	21.1
T54	.017	.12	32	4	nd	nd	47	29	17.5	20.9
T28	.012	.12	64	2	nd	nd	19.5	29	33	18.2
S43	.018	.00	35	3	nd	nd	53	5.5	19	17.3
S4	.010	.08	85	4	nd	nd	12	17	47.5	17.1
T34	.014	.07	54	2	nd	nd	28.5	14.5	29	16.1
T5	.018	.00	22	1	nd	nd	53	5.5	12	15.8
S34	.015	.10	23	4	nd	nd	33	23	13.5	15.5
T7	.010	.05	83	7	nd	nd	12	11.5	46	15.5
T17	.015	.00	49	3	nd	nd	33	5.5	27	14.7
T58	.005	.00	97	1	nd	nd	1.5	5.5	54.5	13.8
T13	.012	.00	59	5	6.5	2	19.5	5.5	31	12.5
S1	.009	.07	45	4	nd	nd	9	14.5	25.5	11.0
S11	.012	.09	15	2	nd	nd	19.5	18.5	6.5	10.0
S40	.007	.09	15	2	nd	nd	3	18.5	6.5	6.3
S3	.008	.00	16	7	2	3	5.5	5.5	8	4.3
Theoretical addition of results of the sample collected below the sewer-line overflow and the six raw sewage samples that were collected										
T13	0.166	5.00	870,000	1	13	1	150	150	150	99.3
Sewage	.236	7.50	2,850,000	6	12	2	151	151	151	100.0

from sites represented by only 1 or 2 samples, as these results may not be fully representative of the site.

To further evaluate the use of the relative impairment indices, both the data in tables 10 and 11 were evaluated by the theoretical addition of two sewage samples. First, the data from the overflowing sewer line that was located upstream from site T13 was added (table 5). Second, the median concentrations from the six sewage samples that were collected at the start of the study (table 2) were added and the matrices were recalculated. The theoretical addition of these samples to the databases used in tables 10 and 11 resulted in the sewage samples scoring the highest relative impairment indices of any samples (actual results are listed at the bottom of tables 10 and 11).

Calculating the relative impairment index with and without the organic compound data provides an opportunity to evaluate the extent to which the organic compound data are important in identifying minor sewage inputs. For example, 11 of the top 12 sites in table 10, which includes the organic compound data (table 10), are in the upper 11 percent of table 11, which does not include the organic compound data. This seems to indicate that similar results would have been reached without the organic compound analyses. This supports the hypothesis, however, that the three relatively inexpensive indicator tracers appear to be useful for identifying minor sewage sources to streams. Although the organic compound analyses are not especially critical for identifying minor sewage sources, they likely serve a fundamental role as a confirmatory tracer. Therefore, organic compound analysis of confirmatory tracers seems particularly valuable before investing in a major operation to identify or repair a potential sewage source.

In addition to indicating the relative likelihood that a given site is subject to sewage, the relative impairment index scores can be plotted using GIS software to scale up from individual sites to more of a basinwide perspective of possible sewage sources throughout the watershed (figs. 5, 6). Although several of the sites with elevated relative impairment indices are scattered throughout the watershed, three intriguing clusters appear near sites S8, T35, and T51 (fig. 5). The area around S8 has been of interest since the initial study site reconnaissance was performed and the apparent illicit septic

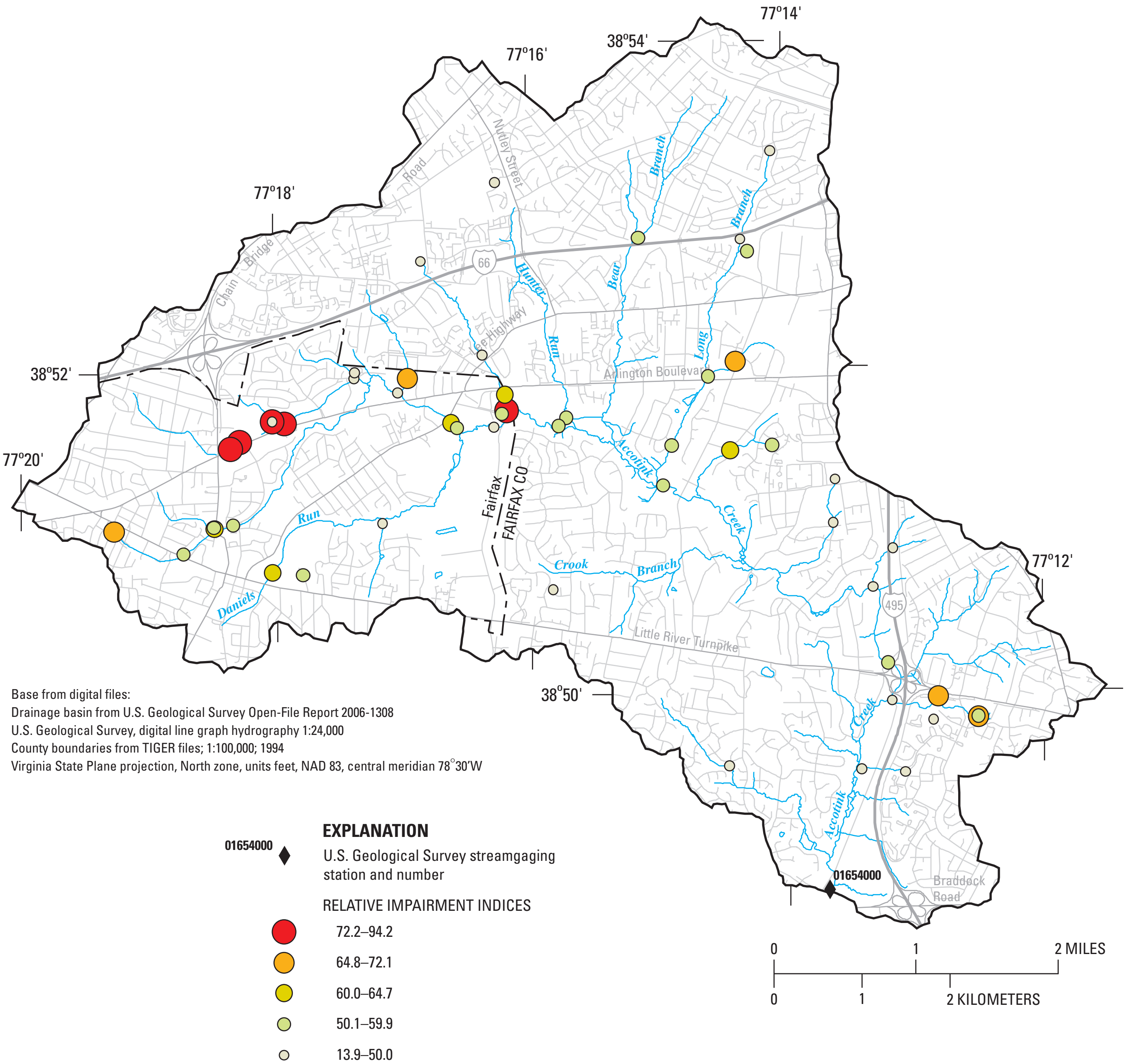

Figure 5. Location of 52 sites in the Accotink Creek watershed of Virginia with relative impairment indices that include confirmatory tracer data.

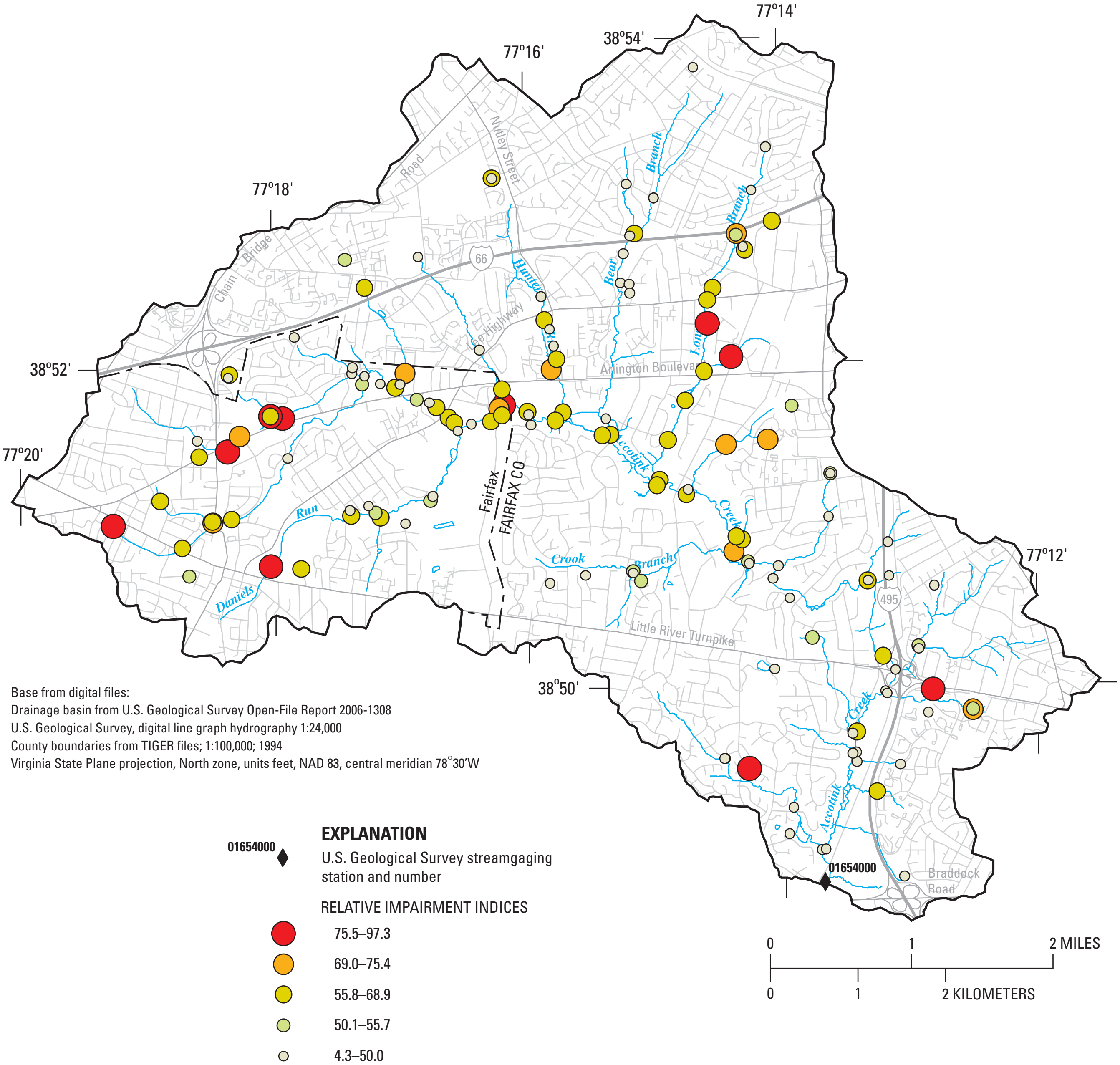

Figure 6. Location of 149 sites in the Accotink Creek watershed of Virginia with relative impairment indices that include only indicator tracer data.

dumping was identified at site S7. The data indicate that both sites S6 and S8 may have minor sewage contributions to the streams. No further investigation has been done at these sites to confirm or deny this possibility. Near the end of the study, when focus was on the stretch of tributary between sites T35 and T35A, it was discovered that at least one lateral sewer line that runs from an adjacent condominium complex to the primary sewer line had failed. Although it is uncertain whether this was the only source of sewage to this section of tributary, it was a definitive source of sewage that was discontinued. The repair of the lateral line was accomplished after all sampling for this study had been completed. Although the area around site T51 has been repeatedly investigated by Fairfax City, no sewage sources to the stream have been identified despite the one major sewage contribution to the tributary that was identified at site T51BLD. Based on the relatively elevated impairment indices associated with the sampling sites along this stretch of tributary, it is hypothesized that there is likely a source of sewage somewhere upgradient from these sites, although the source remains undiscovered.

One of the more challenging aspects in identifying minor sewage sources is that the water quality at individual sampling sites was far more variable than initially expected, especially given that all the samples were collected under base-flow conditions. Consequently, it is meaningful to describe the variability in the tracer concentrations at each site, in addition to the median concentrations that are presented in table 9. To characterize this variability, the median absolute deviation (MAD) was used (Helsel and Hirsch, 2002) rather than a standard deviation calculation. The strength of the MAD calculation is that it is stable in the presence of outliers, whereas the standard deviation term is unstable and generally inflated. Outliers or extreme values result in a measure of variability that is greater than what actually is indicated by the data, because the standard deviation calculation relies on a comparison to the sample mean, which is strongly influenced by outliers (Helsel and Hirsch, 2002).

The MAD is calculated by first determining the absolute difference between each observed tracer concentration and the median tracer concentration for a given site. Next, the MAD is determined as the median of these absolute differences. Conceptually, this is best demonstrated by example. If five samples from a given site were analyzed for fecal coliform bacterial concentrations and the results were 3, 10, 60, 100, and 900 col/100 mL, the standard deviation would be 385, which is largely inflated by the 900 col/100 mL value even though most of the samples had relatively low concentrations of fecal coliform bacteria. In this example, the median concentration of fecal coliform bacteria is 60, and the absolute deviations from this median are 57, 50, 0, 40, and 840. The median of these deviations (MAD) is 50, which more reasonably represents the variability in this data set. The MAD was calculated for 141 sampling sites for which enough data were available to perform this calculation; only one water sample was collected at 9 sampling sites, and the MAD could not be calculated for these sites. Results of the MAD calculations performed on indicator tracer data from the 141 sites are presented in table 12. In addition to the calculation of the MAD for each constituent at each site, a ranking and summation routine similar to the protocol used in table 11 was used to summarize the data and quantify the sites that were most variable. For each indicator tracer, the MAD values were ranked from least to greatest and scored from 1 to 141. After ranking all three of the sensitive indicator tracers, the rankings for a given site were summed, divided by the total maximum score of 423 (141x3), and multiplied by 100. This value provides a relative variability index for each study site represented by at least two water-quality samples. Sites with greater relative variability indices had more variable sample compositions than sites that were very consistent and had lower relative indices. To provide a point of reference, the MAD for each indicator tracer was calculated for the entire data set and used to apply conditional formatting. Although the use of these MAD values for the entire data set is arbitrary, it provides a mechanism for indicating the sites and indicator tracers that demonstrate relatively more variability.

This summary of water-quality variability for each tracer and each site is complementary to the median tracer concentrations that were observed at each sampling site (presented in tables 10 and 11). By summarizing the variability, both the median concentrations and the variability of the data around the median can be investigated. Not surprisingly, many of the sites with relatively large impairment indices also had relatively elevated variability indices. This indicates that although the sites with elevated relative impairment scores may be subject to sewage sources, the sites are also highly variable and the tracer concentrations are not always elevated. This also may indicate that many of the minor sewage sources in the watershed are transitory or otherwise short lived. Consequently, the use of only quarterly grab samples (as occurred in this study) may not be the best approach for identifying locations of varying sewage sources; therefore, several other methods for locating minor sewage sources were investigated near the end of the study.

Table 12. Median absolute deviation (MAD) values for the synoptic sampling sites and conditional formatting of the MAD scores to identify the sites with the greatest variability in tracer concentrations.

[MAD, median absolute deviation; red values indicate boron greater than 0.007, surfactants greater than 0.02, and fecal coliform bacteria greater than 157.5; nd, no data. MAD scores were ranked from greatest to smallest for each tracer, and the ranks were used to calculate a relative variability index for each site. Sites are sorted according to their final relative variability index; sites with higher indices had more variable tracer concentrations between sampling events]

Site ID (fig. 3)	Boron MAD	Surfactant MAD	Fecal coliform bacteria MAD	Number of samples	Ranking for boron MAD	Ranking for surfactant MAD	Ranking for fecal coliform bacteria MAD	Relative index (max=100)
S46	0.052	0.12	2,393	7	141	132.5	137	97.0
T51A	.007	.50	4,790	5	113.5	140	139	92.8
T51	.009	.25	495	8	128.5	139	120	91.6
S8	.009	.07	1,025	9	128.5	124.5	132	91.0
S6	.013	.13	153	8	135	137.5	93	86.4
S19	.023	.13	127	5	138.5	137.5	89	86.3
T3	.007	.04	806	6	113.5	110.5	125	82.5
T56	.005	.12	555	7	93.5	132.5	123	82.5
S37	.004	.12	5,209	6	75.5	132.5	140	82.3
S17	.011	.04	133	6	133.5	110.5	91	79.2
T35	.005	.03	1,400	7	93.5	99.5	134.5	77.4
S22	.007	.08	101	8	113.5	128	84.5	77.1
S42	.007	.02	1,000	7	113.5	82	130	77.0
T22	.004	.12	367	7	75.5	132.5	112	75.7
T51B	.002	1.25	10,335	3	36	141	141	75.2
T23	.007	.03	225	10	113.5	99.5	101	74.2
A15	.006	.12	74	7	103.5	132.5	73	73.1
T18	.007	.01	520	6	113.5	70.5	122	72.3
T23A1	.003	.06	384	4	55.5	119	113	68.0
S4	.005	.05	79	4	93.5	114.5	74.5	66.8
S18	.004	.01	1,500	9	75.5	70.5	136	66.7
S29	.010	.00	393	9	131.5	34	115	66.3
T7	.005	.05	73	7	93.5	114.5	71.5	66.1
T31A1	.002	.06	592	4	36	119	124	66.0
T24	.008	.00	444	10	123.5	34	119	65.4
A7	.007	.03	57	7	113.5	99.5	61.5	64.9
S31	.004	.03	191	7	75.5	99.5	98	64.5
S44	.011	.00	240	7	133.5	34	102	63.7
S35	.023	.00	160	7	138.5	34	94	63.0
A5	.008	.02	54	6	123.5	82	60	62.8
T40	.007	.02	72	7	113.5	82	69.5	62.6
S48	.007	.00	431	7	113.5	34	117	62.5
T29	.003	.03	332	5	55.5	99.5	109	62.4
A4	.009	.03	25	4	128.5	99.5	33	61.7
S52	.024	.00	113	8	140	34	87	61.7
S23	.001	.12	330	7	16.5	132.5	107.5	60.6
S49	.008	.03	25	5	123.5	99.5	33	60.5
T33	.007	.00	325	8	113.5	34	106	59.9
S50	.015	.00	95	7	136	34	81.5	59.5
T53	.008	.03	15	5	123.5	99.5	22.5	58.0
S30	.005	.07	18	2	93.5	124.5	26	57.7
A9	.006	.02	50	7	103.5	82	57.5	57.4

Table 12. Median absolute deviation (MAD) values for the synoptic sampling sites and conditional formatting of the MAD scores to identify the sites with the greatest variability in tracer concentrations. — Continued

[MAD, median absolute deviation; red values indicate boron greater than 0.007, surfactants greater than 0.02, and fecal coliform bacteria greater than 157.5; nd, no data. MAD scores were ranked from greatest to smallest for each tracer, and the ranks were used to calculate a relative variability index for each site. Sites are sorted according to their final relative variability index; sites with higher indices had more variable tracer concentrations between sampling events]

Site ID (fig. 3)	Boron MAD	Surfactant MAD	Fecal coliform bacteria MAD	Number of samples	Ranking for boron MAD	Ranking for surfactant MAD	Ranking for fecal coliform bacteria MAD	Relative index (max=100)
S47	0.007	0.00	169	6	113.5	34	95	57.3
T42	.003	.02	255	5	55.5	82	103	56.9
T9	.004	.03	64	7	75.5	99.5	65.5	56.9
S20	.004	.00	930	9	75.5	34	129	56.4
S10	.005	.05	22	2	93.5	114.5	28	55.8
T8	.005	.03	32	5	93.5	99.5	41	55.3
S5	.002	.03	174	9	36	99.5	97	55.0
T57	.004	.07	24	4	75.5	124.5	30.5	54.5
A6	.003	.01	280	8	55.5	70.5	104	54.4
S45	.008	.03	4	3	123.5	99.5	7	54.4
T35A	.003	.00	2,633	5	55.5	34	138	53.8
T1	.002	.12	50	7	36	132.5	57.5	53.4
T20	.004	.02	64	5	75.5	82	65.5	52.7
S41	.003	.00	1,140	7	55.5	34	133	52.6
T45	.004	.03	38	5	75.5	99.5	46	52.2
T24A2	.004	.00	343	5	75.5	34	111	52.1
T24B1	.003	.00	1,024	4	55.5	34	131	52.1
S32	.007	.02	17	6	113.5	82	24.5	52.0
T2	.002	.03	101	7	36	99.5	84.5	52.0
T55	.004	.00	337	7	75.5	34	110	51.9
T6	.008	.02	7	5	123.5	82	13	51.7
S28	.001	.06	95	4	16.5	119	81.5	51.3
S51	.003	.00	893	7	55.5	34	127	51.2
T39	.006	.01	32	4	103.5	70.5	41	50.8
S24	.004	.00	320	8	75.5	34	105	50.7
A16	.003	.03	53	5	55.5	99.5	59	50.6
T12	.005	.00	97	6	93.5	34	83	49.8
T24A1	.003	.00	503	5	55.5	34	121	49.8
A3	.006	.01	27	6	103.5	70.5	36	49.6
T38	.004	.00	205	6	75.5	34	100	49.5
A13	.004	.00	172	8	75.5	34	96	48.6
T23A2	.003	.00	417	4	55.5	34	116	48.6
T10	.007	.02	4	3	113.5	82	7	47.9
T31A2	.000	.06	93	2	4	119	79	47.8
A1	.003	.03	35	6	55.5	99.5	44.5	47.2
S13	.004	.00	132	9	75.5	34	90	47.2
A15B	.002	.00	925	3	36	34	128	46.8
T31	.004	.00	124	8	75.5	34	88	46.7
T4	.005	.00	72	3	93.5	34	69.5	46.6
S7	.002	.00	867	9	36	34	126	46.3
T16	.004	.00	93	3	75.5	34	79	44.6
S16	.004	.00	90	3	75.5	34	77	44.1

Table 12. Median absolute deviation (MAD) values for the synoptic sampling sites and conditional formatting of the MAD scores to identify the sites with the greatest variability in tracer concentrations. — Continued

[MAD, median absolute deviation; red values indicate boron greater than 0.007, surfactants greater than 0.02, and fecal coliform bacteria greater than 157.5; nd, no data. MAD scores were ranked from greatest to smallest for each tracer, and the ranks were used to calculate a relative variability index for each site. Sites are sorted according to their final relative variability index; sites with higher indices had more variable tracer concentrations between sampling events]

Site ID (fig. 3)	Boron MAD	Surfactant MAD	Fecal coliform bacteria MAD	Number of samples	Ranking for boron MAD	Ranking for surfactant MAD	Ranking for fecal coliform bacteria MAD	Relative index (max=100)
A8	0.007	0.00	30	7	113.5	34	38.5	44.0
S26	.003	.03	24	3	55.5	99.5	30.5	43.9
A14	.002	.02	65	5	36	82	67	43.7
S12	.003	.07	0	4	55.5	124.5	2	43.0
T26	.002	.02	59	4	36	82	63	42.8
T48	.005	.00	44	5	93.5	34	52	42.4
A11	.005	.00	40	7	93.5	34	50	42.0
T15	.001	.02	93	3	16.5	82	79	42.0
T34	.001	.07	26	2	16.5	124.5	35	41.6
A13A	.020	.00	1	2	137	34	4	41.4
S15	.004	.00	63	7	75.5	34	64	41.0
T51C	.000	.00	1,400	3	4	34	134.5	40.8
A2	.002	.02	44	6	36	82	52	40.2
S21	.009	.00	4	2	128.5	34	7	40.1
T37	.002	.00	204	7	36	34	99	40.0
T50	.001	.00	433	7	16.5	34	118	39.8
S36	.010	.00	0	3	131.5	34	2	39.6
T47	.005	.00	30	5	93.5	34	38.5	39.2
T25A	.001	.00	390	5	16.5	34	114	38.9
T46	.006	.00	19	5	103.5	34	27	38.9
T36	.004	.00	45	8	75.5	34	54	38.7
T27	.002	.00	134	6	36	34	92	38.3
T25	.004	.00	44	8	75.5	34	52	38.2
A15A2	.003	.00	73	2	55.5	34	71.5	38.1
S25	.006	.00	15	3	103.5	34	22.5	37.8
T28	.001	.02	57	2	16.5	82	61.5	37.8
S11	.002	.04	7	2	36	110.5	13	37.7
T14	.001	.12	5	3	16.5	132.5	9.5	37.5
T44	.001	.00	330	7	16.5	34	107.5	37.4
A12	.004	.00	39	6	75.5	34	48	37.2
T41	.003	.00	66	5	55.5	34	68	37.2
S1	.001	.07	10	4	16.5	124.5	16	37.1
A15A1	.001	.06	9	2	16.5	119	15	35.6
S2	.002	.03	7	3	36	99.5	13	35.1
S34	.005	.00	14	4	93.5	34	21	35.1
T13A	.003	.00	46	3	55.5	34	55	34.2
T19	.001	.02	33	7	16.5	82	43	33.5
T11	.005	.00	6	3	93.5	34	11	32.7
T27A	.001	.00	104	2	16.5	34	86	32.3
S9	.001	.05	3	3	16.5	114.5	5	32.2
S40	.000	.04	12	2	4	110.5	18	31.3
T54	.002	.02	5	4	36	82	9.5	30.1

Table 12. Median absolute deviation (MAD) values for the synoptic sampling sites and conditional formatting of the MAD scores to identify the sites with the greatest variability in tracer concentrations. — Continued

[MAD, median absolute deviation; red values indicate boron greater than 0.007, surfactants greater than 0.02, and fecal coliform bacteria greater than 157.5; nd, no data. MAD scores were ranked from greatest to smallest for each tracer, and the ranks were used to calculate a relative variability index for each site. Sites are sorted according to their final relative variability index; sites with higher indices had more variable tracer concentrations between sampling events]

Site ID (fig. 3)	Boron MAD	Surfactant MAD	Fecal coliform bacteria MAD	Number of samples	Ranking for boron MAD	Ranking for surfactant MAD	Ranking for fecal coliform bacteria MAD	Relative index (max=100)
T13	0.003	0.00	28	5	55.5	34	37	29.9
T43	.001	.00	83	5	16.5	34	76	29.9
S27	.002	.00	49	4	36	34	56	29.8
S39	.001	.00	79	4	16.5	34	74.5	29.6
S38	.002	.02	0	3	36	82	2	28.4
T52	.000	.01	35	5	4	70.5	44.5	28.1
S33	.002	.00	39	4	36	34	48	27.9
T32	.002	.00	39	6	36	34	48	27.9
A14A	.002	.00	25	2	36	34	33	24.4
S43	.001	.00	32	3	16.5	34	41	21.6
S3	.002	.00	11	7	36	34	17	20.6
T60	.001	.00	13	3	16.5	34	19.5	16.5
T49	.000	.00	23	3	4	34	29	15.8
T17	.000	.00	17	3	4	34	24.5	14.8
S14	.000	.00	13	3	4	34	19.5	13.6
A10	nd	nd	nd	1	nd	nd	nd	nd
A13B	nd	nd	nd	1	nd	nd	nd	nd
A16A1	nd	nd	nd	1	nd	nd	nd	nd
T21	nd	nd	nd	1	nd	nd	nd	nd
T30	nd	nd	nd	1	nd	nd	nd	nd
T5	nd	nd	nd	1	nd	nd	nd	nd
T51BLD	nd	nd	nd	1	nd	nd	nd	nd
T58	nd	nd	nd	1	nd	nd	nd	nd
T59	nd	nd	nd	1	nd	nd	nd	nd

Additional Sampling

Three additional types of sampling were performed as part of the final sampling event to better understand the variability in water quality at a given site and to further evaluate minor sewage sources to Accotink Creek. These additional sampling techniques included optical brightener monitoring, intensive stream sampling over a 24-hour period, and detailed sampling of several storm-drain networks.

Optical Brightener Monitoring

The optical brightener monitoring was performed at approximately 60 of the synoptic sampling sites that had either highly variable conditions or conditions that seemed indicative of sewage contamination. After the samplers were deployed, they were left in place for approximately 3 days. By the third day, several of the samplers were missing altogether or, in several cases, the cotton swatches were missing (often with the retaining rubber bands lying nearby). In many cases where the sampler or cotton swatch were missing, fresh wildlife tracks (predominantly raccoon) were observed in the vicinity of the sampler. In total, nine of the optical brightener samples were lost during deployment (S18, T24A2, S50, S48, S51, A15B, T37, S24, and T42).

The remaining optical brightener samples were transported to the laboratory, rinsed, and interpreted in a dark room; strongly positive results were obtained for sites T35, T35A, S7, and S8 (fig. 3). Ambiguous results were obtained for site T33, and all other samples were negative. Results were confirmed by two other independent analysts. The optical brightener results are most readily interpreted in the context of the relative impairment indices that are presented in table 10. Sites T35, T35A, and S8 are among the first 12 sites listed, supporting the notion that these sites are influenced by sewage. Site S7 appears farther down on table 10 (number 29), which indicates that this site is influenced less by sewage; however, it was site S7 that had the apparent illicit septic-tank dumping that was observed during watershed reconnaissance. Interestingly, none of the sites around site T51 had positive results for optical brighteners. This seems to indicate that the sewage source near site T51 (and even the raw sewage at site T51BLD) did not contain laundry detergents, and the sewage in this tributary was from a source that was free of optical brighteners—possibly a nearby business or office complex.

Although these analyses seem fairly useful, they are likely more so when used in conjunction with other methods to support the inferences that are drawn. For example, a negative optical brightener result does not confirm the absence of sewage, because the sewage source may not contain laundry detergent (likely the case with the sites around T51). Similarly, a positive result is strongly indicative of sewage, although some humic and fulvic acids fluoresce under an ultraviolet light and may cause a false-positive reading. Overall, the optical brightener monitoring further indicated the presence of sewage at sites T35, T35A, and S8, as well as possible sewage at site S7.

Intensive Stream Sampling Using Automated Samplers

Intensive sampling of several synoptic sampling sites was performed to document the possible water-quality variability that can occur at some of the sites. These intensive samples were collected using an automated sampler programmed to sample hourly over approximately a 24-hour period. These samples provide a level of time integration and much more detailed information than the grab samples, which essentially represent a “snap shot” in time.

All intensive sampling was conducted in conjunction with the eighth sampling event. The automated sampler was deployed for approximately 24 hours, the samples were retrieved and analyzed, the bottles were cleaned, and the automated sampler was re-deployed at another sampling site. Using this approach, sites T35 and T51 were sampled first, sites A15 and T23 were sampled next, and sites S8 and S7 were sampled thereafter. Unfortunately, the samples from sites A15 and T23 were affected by rainfall soon after the samplers were deployed, and these samples did not represent variability under base-flow conditions. The remaining four sites were successfully sampled under base-flow conditions, and the data from these four sites (T35, T51, S7, and S8) were interpreted (figs. 7–10).

Little interpretable variability in the water-quality data was observed during sampling at sites T35 and S7 (figs. 7, 8), although boron concentrations varied at both sites, indicating that the timing of sample collection at these sites could be important. The water-quality data at sites T51 and S8 were considerably variable (figs. 9, 10), and the variable patterns may be indicative of sewage sources. The data from site S8 (fig. 10) illustrate a rapid increase in surfactants, turbidity, and specific conductance with the sixth sample, while boron has a slightly later increase in concentration that actually may represent a separate input rather than a delayed input. After several hours, tracer concentrations at site S8 eventually returned to initial concentrations. Similarly, site T51 had a pronounced increase in surfactants, turbidity, specific conductance, and boron (fig. 9). The results from this intensive sampling of sites T51 and S8 indicate highly variable tracer concentrations depending on the time of day, and this variability likely has caused some of the variability in the synoptic sampling data. In addition, the intensive data from sites T51 and S8 may be indicative of short-lived sewage sources, rather than a steady sewage source. A variable-rate sewage source is more difficult to identify, and synoptic sampling may or may not identify the input depending on the time that the sample is collected.

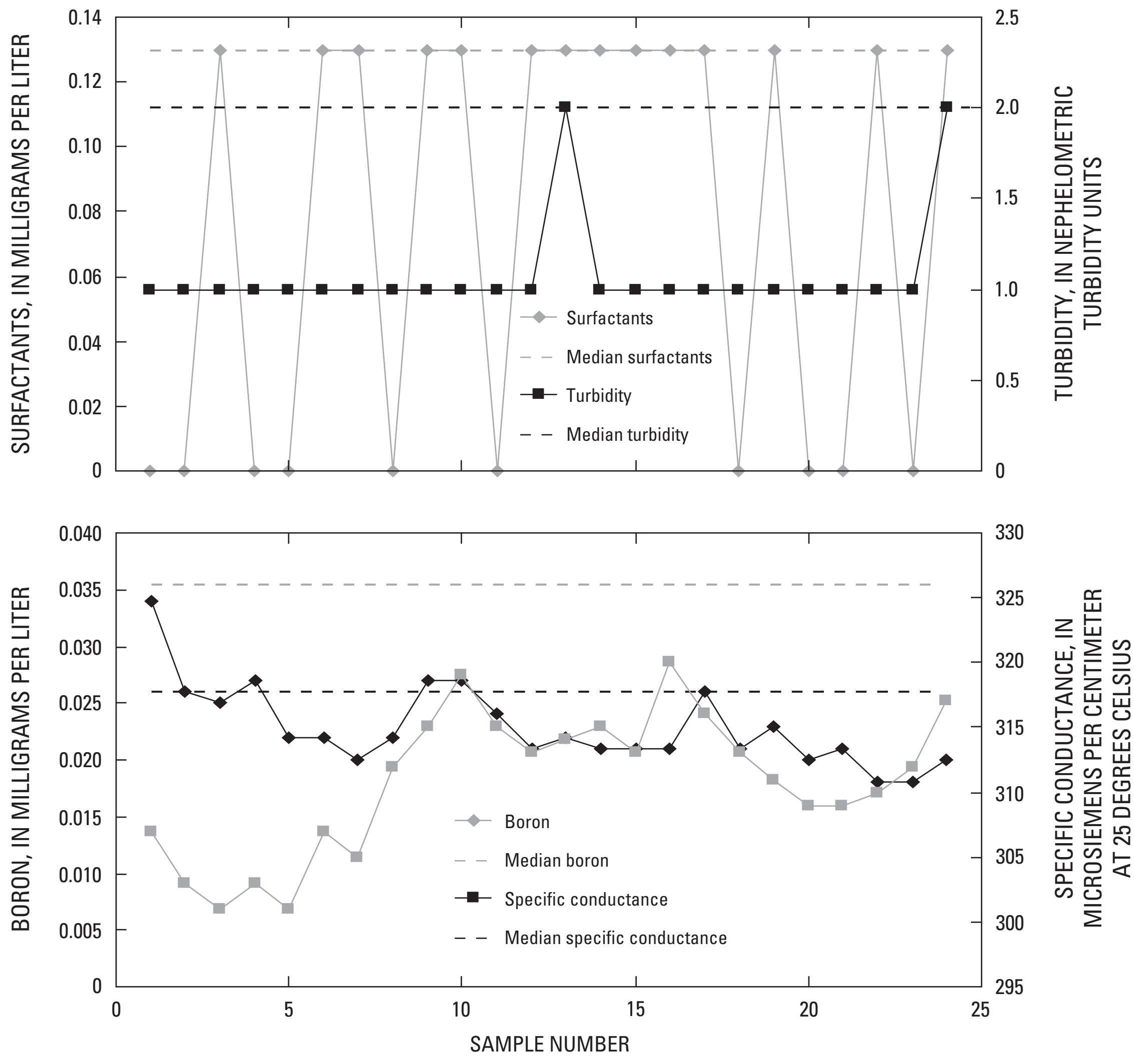

Figure 7. Intensive automated water-quality sampling data collected during September 2004 from siteT35 in the Accotink Creek watershed, Virginia. (For reference, the median concentration of each tracer (from all eight sampling events) is plotted as a horizontal dashed line.)

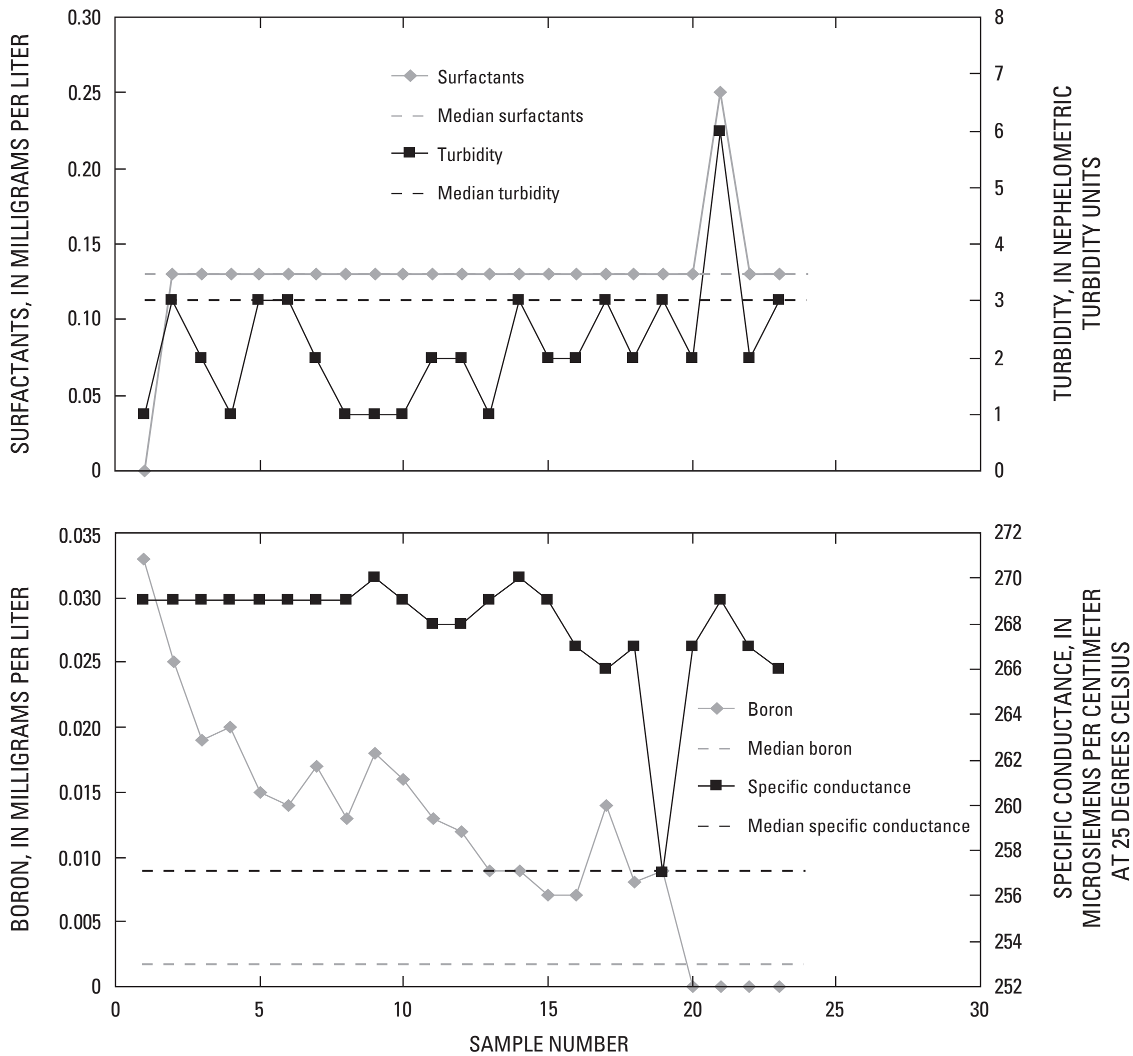

Figure 8. Intensive automated water-quality sampling data collected during September 2004 from site S7 in the Accotink Creek watershed, Virginia. (For reference, the median concentration of each tracer (from all eight sampling events) is plotted as a horizontal dashed line.)

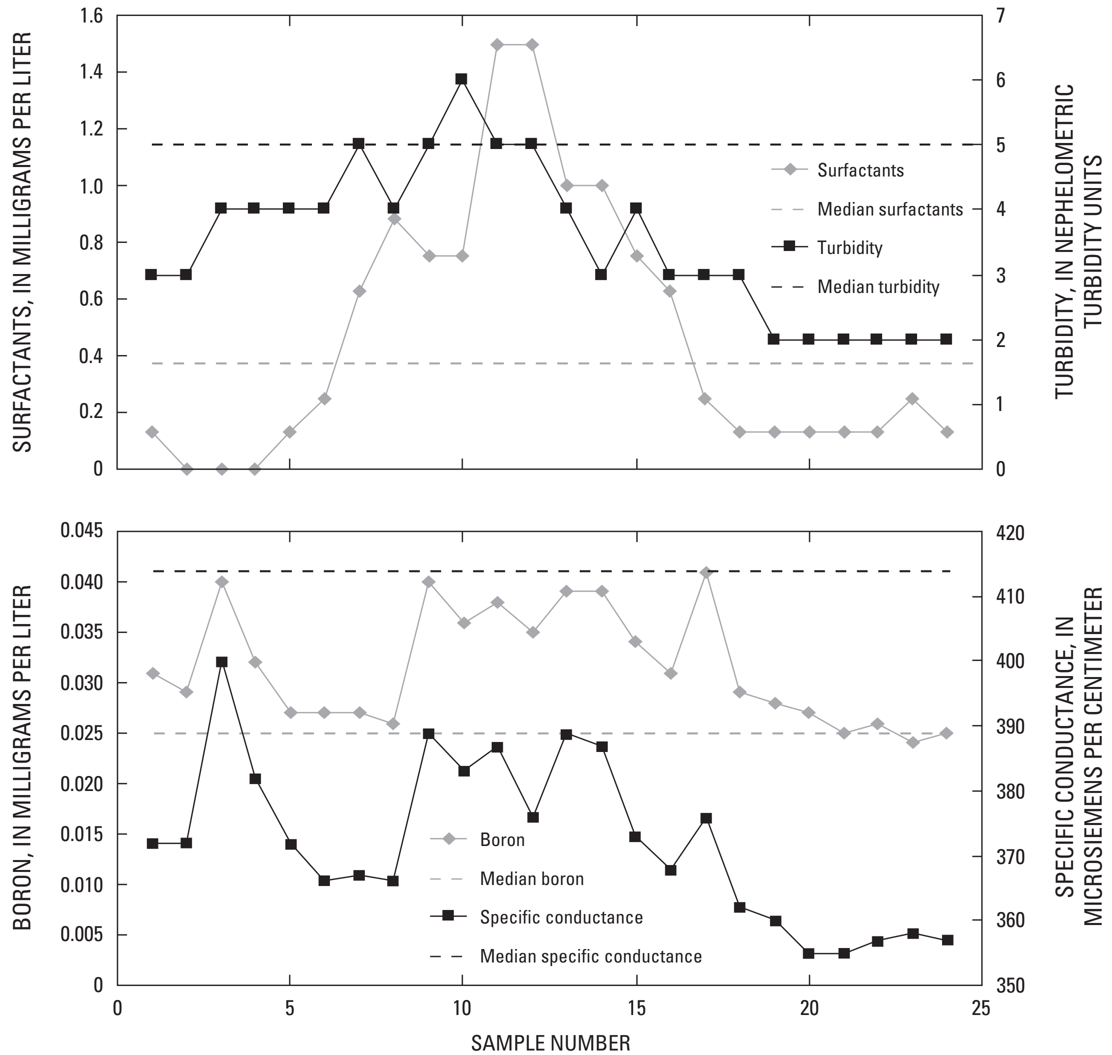

Figure 9. Intensive automated water-quality sampling data collected during September 2004 from site T51 in the Accotink Creek watershed, Virginia. (For reference, the median concentration of each tracer (from all eight sampling events) is plotted as a horizontal dashed line.)

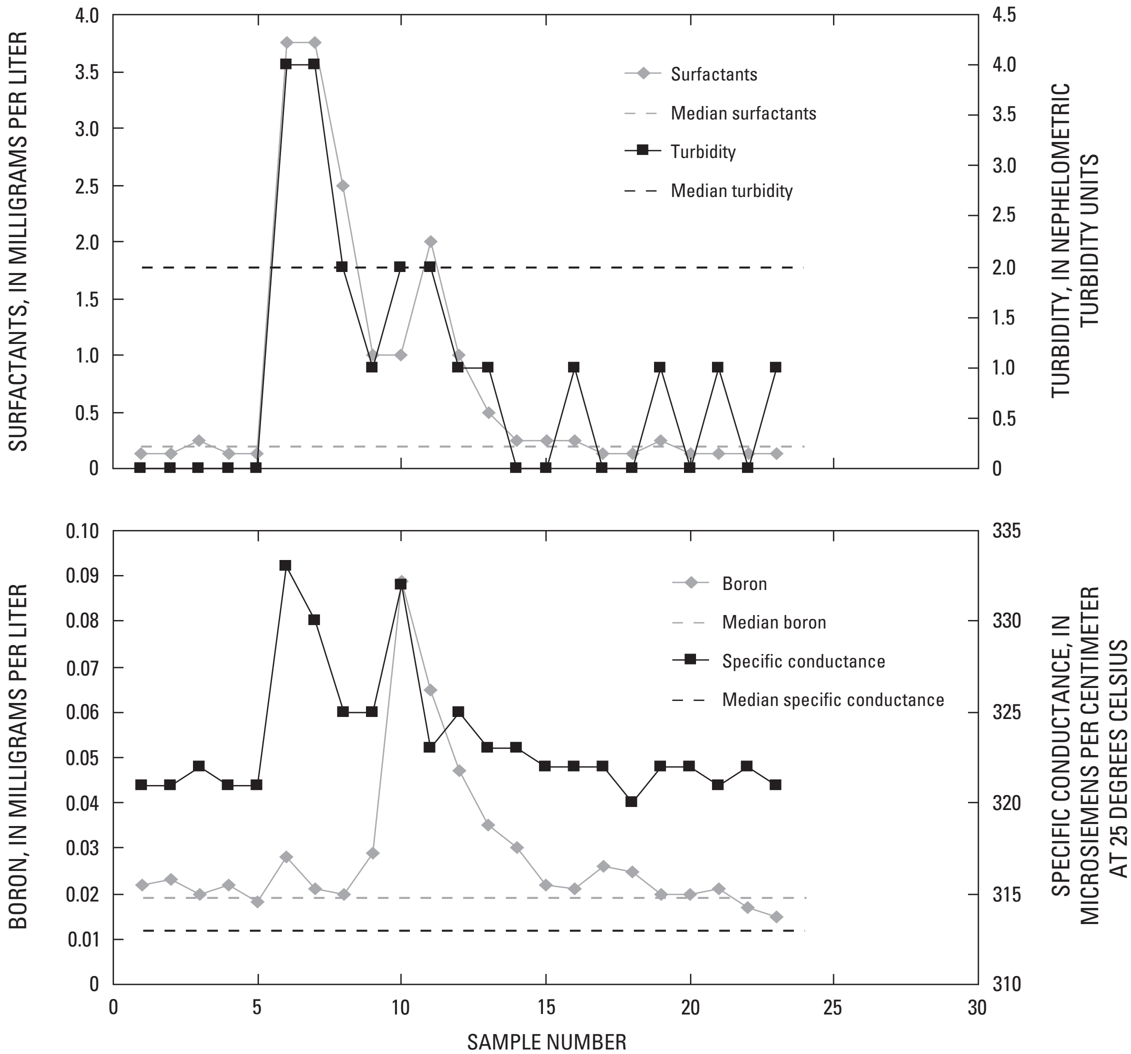

Figure 10. Intensive automated water-quality sampling data collected during September 2004 from site S8 in the Accotink Creek watershed, Virginia. (For reference, the median concentration of each tracer (from all eight sampling events) is plotted as a horizontal dashed line.)

Additional Sampling of Storm-Drain Networks

Shortly after the eighth sampling event, further sampling of the storm-drain networks associated with sites S18, S20, S29, and S37 was conducted to characterize the sources of water that contributed to each of the storm-drain outfalls. These storm drains were selected for additional sampling based on relatively elevated concentrations of fecal coliform bacteria, surfactants, and(or) boron, which indicated the possible presence of sewage. In each storm-drain network, between three and eight water-quality samples were collected depending on the hydrology, size, and complexity of the storm-drain network.

Site S18 had two primary network branches that were flowing during sampling (fig. 11). The outfall (site S18) had slightly elevated concentrations of fecal coliform bacteria and boron but rather low concentrations of surfactants (table 13); this pattern is consistent with the results of the previous sampling at this site. Although the conditions observed during this sampling were not particularly indicative of sewage, the elevated concentrations of bacteria and boron could indicate some sewage contributions. The storm-drain sampling indicated relatively low surfactant concentrations throughout the network and relatively elevated boron concentrations in much of the network. Elevated concentrations of fecal coliform bacteria were observed in only one storm drain—the drain that originates upstream from site S18F, routes flow down to site S18C, and then to the storm-drain outfall (site S18). It is likely that this one line (S18F) is primarily responsible for the elevated concentrations of fecal coliform bacteria observed at site S18.

Site S20 is a relatively complex storm-drain network (fig. 12), but sampling the network was relatively simple because only one branch of the network had flow and the remainder of the network did not. In addition to the storm-drain outfall, two samples were collected near the upgradient end of the flowing line. Overall, the tracer concentrations at the outfall (site S20) were relatively low on the day of the sampling with the exception of the concentrations of fecal coliform bacteria, which were relatively elevated (table 13). The surfactant and boron concentrations indicate that this outfall likely did not contain sewage on the day that sampling was conducted. The upstream sampling sites (S20A and S20B) had relatively different water-quality properties, however. Site S20A had elevated concentrations of fecal coliform bacteria, surfactants, and turbidity but relatively low concentrations of boron. While it is unclear whether the composition of the water observed at site S20A was influenced by sewage, the source of the flow at S20A may justify additional investigation. Alternatively, site S20B had low concentrations of fecal coliform bacteria, surfactants, and turbidity but slightly elevated boron concentrations. Additionally, while sampling this storm-drain network, a white discharge was observed occasionally in the flow from site S20B. The whitish flow occurred as a short-lived pulse that only lasted about 30 seconds at a time before flow conditions returned to the typical clear conditions. The source of this whitish discharge was not determined.

During earlier sampling events, the water-quality composition of the storm-drain outfall at site S29 was highly variable with respect to concentrations of fecal coliform bacteria, surfactants, and boron. On the day of the storm-drain network sampling at site S29 (fig. 13), the composition of the water was slightly elevated with respect to concentrations of boron and fecal coliform bacteria but not surfactants (table 13). Although the conditions observed during this sampling were not particularly indicative of sewage, the elevated concentrations of bacteria and boron could indicate some sewage sources. Most of the flow on the sampling day was identified to be coming from site S29A, and the chemical composition of water samples from sites S29A and S29 were very similar. Samples collected from flow in another arm of the network indicated that the concentrations of fecal coliform bacteria and surfactants were relatively low. One interesting observation while sampling the flow at site S29D was the relatively warm temperature (35 °C); in addition, site S29D had the highest concentrations of fecal coliform bacteria of all the sites in this storm-drain network. The source of the warm water was not located.

The final storm-drain network that was sampled was site S37 (fig. 14), most of which underlies the Oakton High School complex. This site is characterized by strongly elevated concentrations of fecal coliform bacteria (median of 6,400 col/100 mL, table 9) but typically low surfactant and boron concentrations. Several organic compound samples indicated a very low number of detections (typically only one compound was detected), indicating that this storm drain likely was a source of elevated concentrations of fecal coliform bacteria but not sewage. During sampling, a strong chloride odor was detected; network reconnaissance identified the source, which was a bleach and water solution that was being used to clean an ice maker in the athletic field concession stand. Through additional investigation, it was deduced that the sink drains from the concession stand were plumbed directly into the storm-drain system and not into a sewer line. Upon learning of this, the school administrators stopped using these drains. As beneficial as it was to identify this improperly connected drain line, the use of the bleach cleaning solution appears to have reduced the bacteria concentrations in the storm-drain network to the lowest ever observed at this site. Although the use of bleach in this storm-drain network may have reduced fecal coliform concentrations, all the tracer concentrations were rather low in the network samples, even in the sample from site S37F, which is located above the bleach-affected storm drain (table 13). Overall, it seems reasonable to conclude that this site is a source of elevated concentrations of fecal coliform bacteria but not sewage.

Cumulatively, the additional analyses that were performed near the end of the study offered several mechanisms for understanding the potential for minor sewage sources and the variability that was observed among the sampling sites. Although the synoptic grab sampling offered the best way

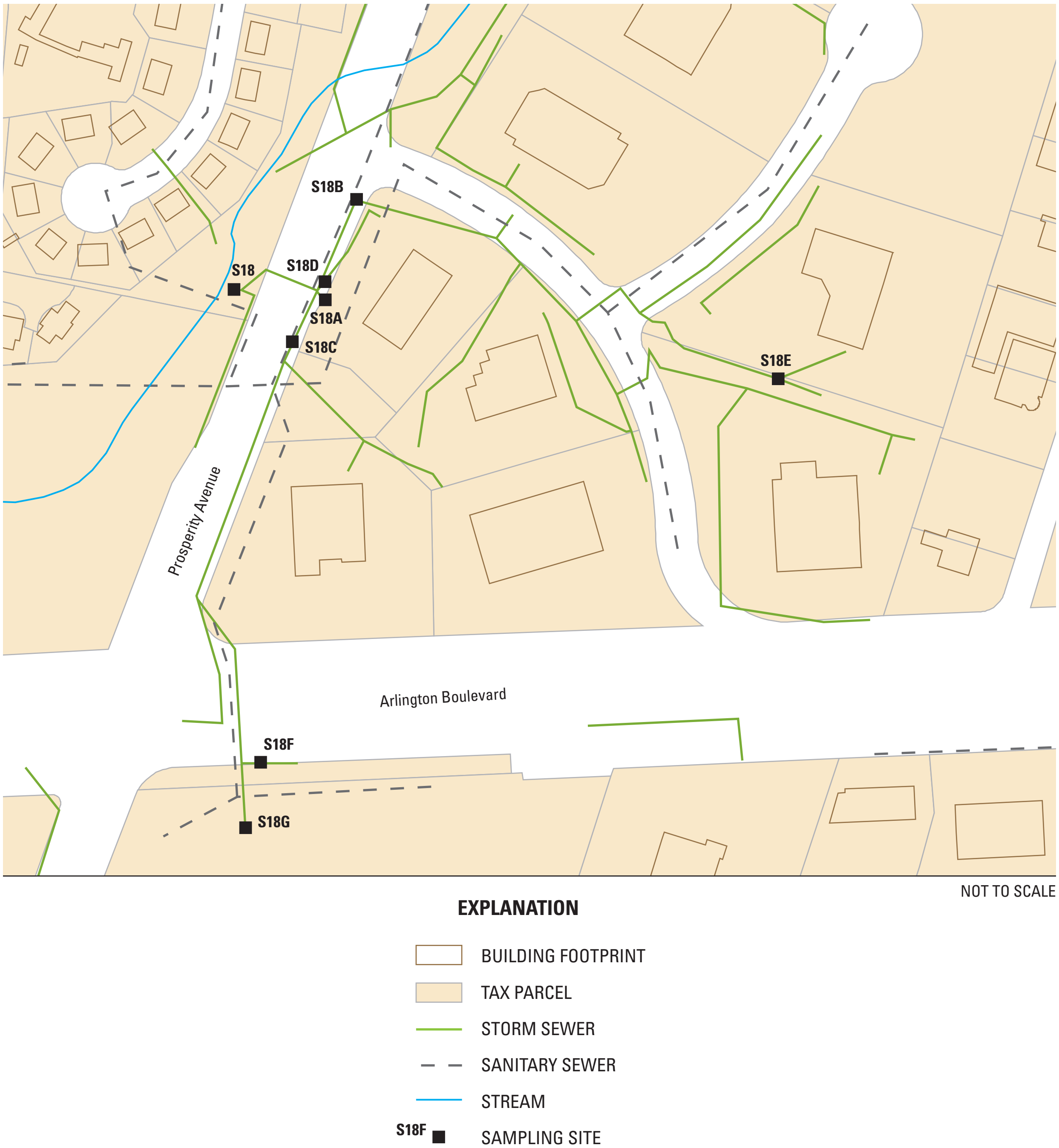

Figure 11. Generalized map of the storm-drain network sampling locations for site S18 (fig. 3). (Roads, tax parcels, and building footprints have been added to better identify the location of the sampling sites.)

Table 13. Indicator tracer data from the storm-drain network sampling at sites S20, S18, S29, and S37 in the Accotink Creek watershed, Virginia.

[mg/L, milligrams per liter; ºC, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; col/100 mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; —, not determined; <, less than. Shading indicates estimated concentration value]

Site ID (figs. 11–14)	Sampling date	Sampling time	Boron (mg/L)	Chloride (mg/L)	Water temperature (ºC)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Turbidity (NTU)	Surfactants (mg/L)	Fecal coliform bacteria (col/100 mL)	Discharge (ft^3/s)
S20	9/23/04	1045	0.010	20	—	169	—	11	0.13	2,700	0.0280
S20A	9/23/04	1130	.012	20	20.0	181	—	32	.25	1,933	.0001
S20B	9/23/04	1135	.032	18	—	215	—	2	.13	43	.0000
S18	9/23/04	1205	.039	96	19.0	263	7.1	1	.13	480	.0290
S18A	9/23/04	1215	< .007	141	—	585	—	0	.13	< 10	—
S18B	9/23/04	1230	.010	< 1	—	63	—	2	.13	290	.0060
S18D	9/23/04	1255	.059	85	—	390	—	1	.13	69	.0010
S18C	9/23/04	1245	.075	43	—	404	—	1	.13	1,133	.0020
S18E	9/23/04	1330	.065	< 1	—	69	—	2	.13	< 3	.0001
S18F	9/23/04	1355	.075	50	—	291	—	2	0	1,333	.0002
S18G	9/23/04	1354	.487	< 1	—	108	9.0	1	0	< 3	.0002
S29	9/23/04	1425	.045	49	21.7	285	7.8	2	.13	440	.2070
S29A	9/23/04	1445	.048	62	21.3	208	8.9	3	.13	380	.0118
S29B	9/23/04	1530	—	—	—	—	—	3	.25	< 3	—
S29C	9/23/04	1635	.039	28	29.6	68.5	6.3	1	.13	44	.0118
S29D	9/23/04	1650	.030	17	35.0	199	—	2	.13	500	.0118
S37	9/24/04	950	.013	7	19.5	149	—	6	0	460	.0320
S37A	9/24/04	1010	.020	6	21.0	110	—	1	0	114	.0032
S37D	9/24/04	1100	.024	6	—	107	—	0	0	100	—
S37E	9/24/04	1105	< .007	4	—	147	—	2	0	230	—
S37F	9/24/04	1130	.044	23	—	276	—	2	.13	29	—

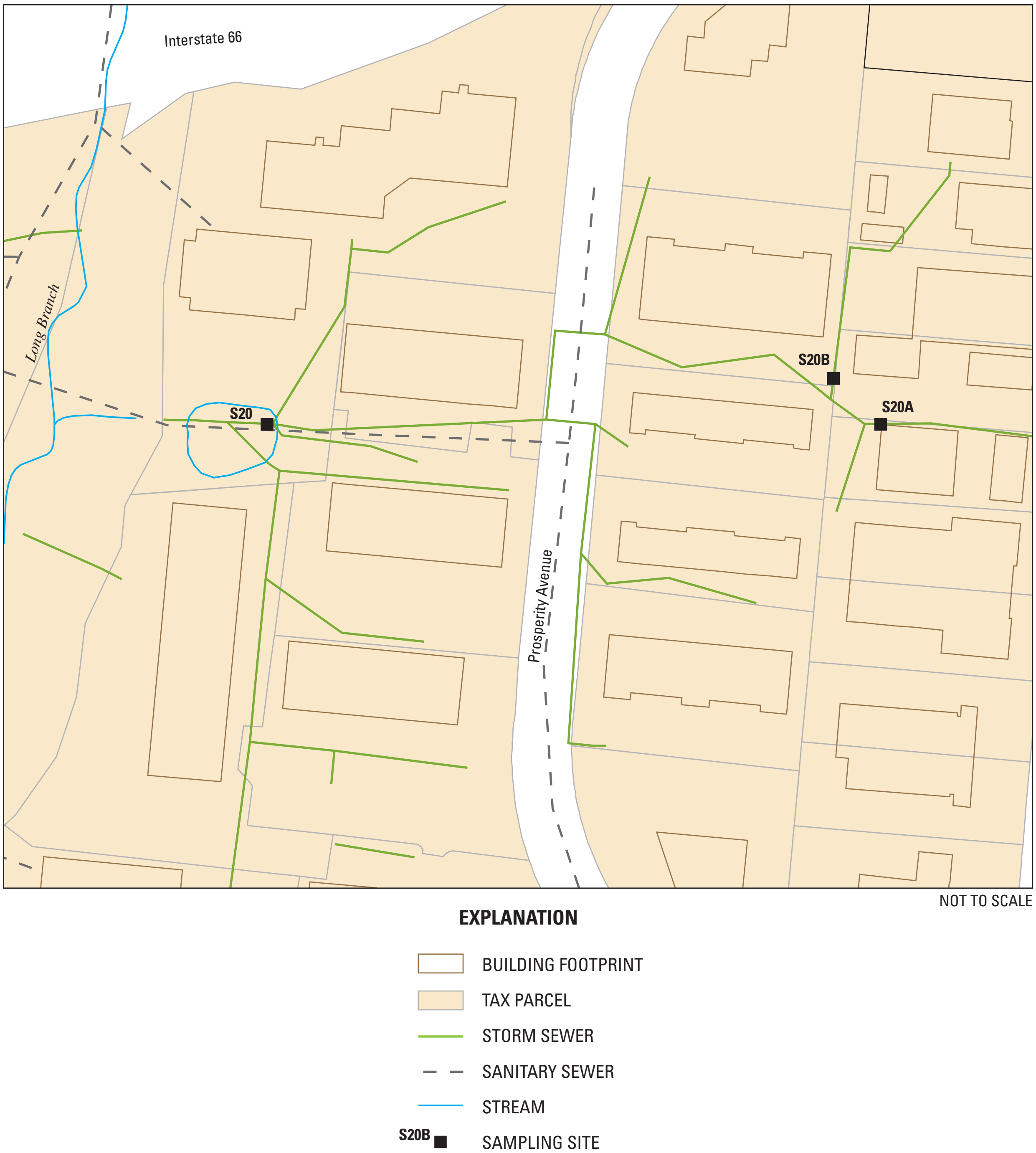

Figure 12. Generalized map of the storm-drain network sampling locations for site S20 (fig. 3). (Roads, tax parcels, and building footprints have been added to better identify the location of the sampling sites.)

Figure 13. Generalized map of the storm-drain network sampling locations for site S29 (fig. 3). (Roads, tax parcels, and building footprints have been added to better identify the location of the sampling sites.)

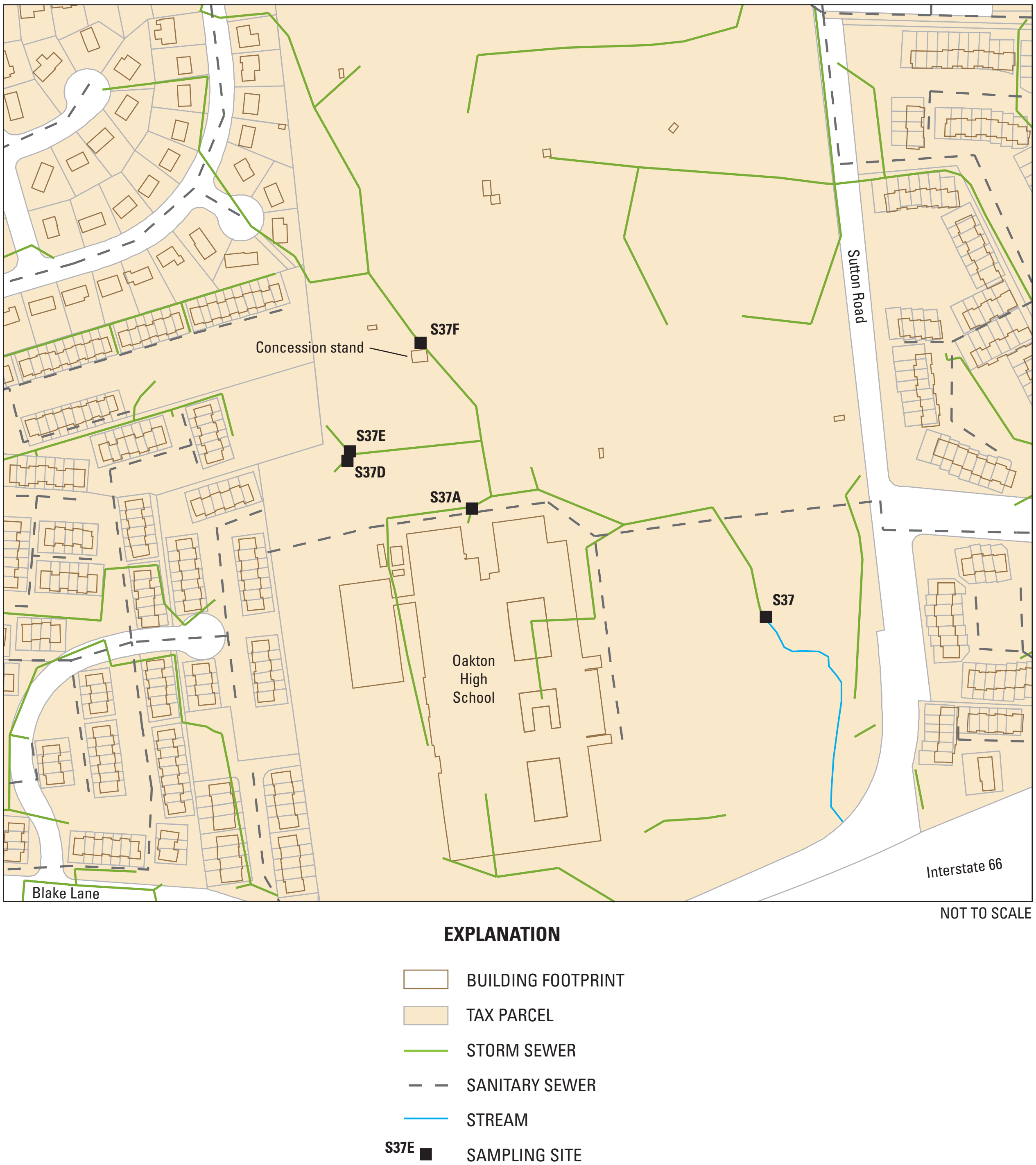

Figure 14. Generalized map of the storm-drain network sampling locations for site S37 (fig. 3). (Roads, tax parcels, and building footprints have been added to better identify the location of the sampling sites.)

to develop a watershed-level understanding of the system, each of the other tools provided information in addition to synoptic sampling, and their usefulness likely is dependent on the system being investigated. These tools add another line of evidence (in addition to synoptic sampling) that can be used to identify sewage sources.

Transferability of This Approach

One objective of this study was to develop an approach that could be transferred and applied to other watersheds throughout Virginia and the mid-Atlantic region. It was because of this objective that a relatively simple and inexpensive collection of indicator tracers was used. Although the analyses for the 13 organic compounds as confirmatory tracers are not as easy or inexpensive to apply as the indicator tracers, these analyses for organic compounds are becoming more cost efficient and common in analytical chemistry laboratories.

Using theoretical results from direct sewage sampling as well as an overflowing sewer line, this study has demonstrated the effectiveness of this suite of sewage tracers in identifying major sewage sources to a stream. Consequently, a similar synoptic sampling study could be developed in other watersheds where sustained major sewage sources are a concern. In application, it likely would take only a few sampling events to identify whether a watershed was affected by major sewage sources.

Additionally, a subset of indicator tracers appears to be effective in identifying minor sewage sources to streams, but the approach likely is not as powerful as it is for locating major sewage sources. Although this subset of the indicator tracers can be used to identify minor sewage sources to streams, it is important to use confirmatory organic compound analyses and other tracer tools, such as optical brightener monitoring. Identifying minor sewage sources requires more sampling than does identifying major sewage sources. Minor sewage sources become increasingly more difficult to identify as the percentage of sewage contribution to total streamflow becomes smaller and smaller.

In addition to the challenges of locating minor sewage sources to a stream reach, it can be difficult to identify the specific manner in which sewage is being contributed to the stream. Both Fairfax County and the City of Fairfax investigated their respective sites that had elevated relative impairment indices; however, the identification of minor sewage sources was very challenging. For example, the City of Fairfax was unable to identify the source of sewage along the T51 tributary, despite data that indicated a sewage source. Additionally, Fairfax County was unable to identify a source of sewage at sites T35 and T35A until residents of a nearby condominium complex complained to property management about sewage problems, and at least one broken lateral line was discovered and replaced. Because minor sewage sources are difficult to locate using standard sampling techniques and difficult to identify and repair, minor sewage sources to streams are a continuing challenge in urbanized watersheds.

Next Steps and Future Directions

This study was designed to develop a suite of tracers that can be used effectively for identifying sewage sources to streams. Because of the complex pathways in which sewage can be routed into streams, the sampling design for this study included synoptic sampling under base-flow conditions. Sampling under base-flow conditions ensured the greatest opportunity for relatively stable water-quality conditions throughout the watershed and the highest concentrations of sewage. Although the study was successful in the development of an approach for identifying major sewage sources and appears to have been successful in the development of an approach for identifying minor sewage sources, a number of future directions remain to be considered.

Although a list of priority sites that are most likely to be affected by sewage sources have been identified (tables 10 and 11), it has been extremely difficult for local authorities to confirm minor sewage sources even at some of the most likely sites, such as T35 and T51. Locating minor sources is a challenge because of the inherently low volumes of sewage that are contributed to a stream and because the sewage generally is transported through subsurface pathways rather than over the land surface. Furthermore, some potential sewage sources are outside the management of local governments. For example, a thorough evaluation of sites T35 and T35A revealed no problems with the sewer lines and no problems with cross-connected pipes; it was not until several months had passed that the damaged lateral line at a nearby condominium complex was discovered and repaired. Situations such as these will always be difficult for local authorities to identify.

In addition to the difficulties associated with locating minor sewage sources, there also are difficulties associated with episodic and wet-weather sources of sewage. Episodic sources are short-lived sewage releases similar to the occurrence at site S7, which was identified during the initial watershed reconnaissance. By the time the input was discovered the flows had begun to decrease. Wet-weather sources are sewage sources that occur only in conjunction with rainfall, such as overland runoff of pooled sewage from a failed septic system or episodic sewage overflow caused by the temporary pressurization of a sewer line. The synoptic sampling design used in this study was not designed to locate these types of sewage sources, and it would be very difficult to develop a study to specifically investigate these types of sources. As such, it remains unknown how significant either of these sources may be in the Accotink Creek watershed.

An additional consideration that likely compounded the difficulty in locating sewage sources to Accotink Creek is related to the actions taken by both the City of Fairfax and Fairfax County authorities in rehabilitating the sewer-line infrastructure; both local governments are proactive in reviewing the condition of the sewer lines, maintaining them as needed, and replacing or re-lining them as necessary (U.S. Environmental Protection Agency, undated; City of Fairfax, undated). It would be interesting to apply this same study approach in another watershed where such a proactive maintenance approach for sewer lines is not being used.

Summary and Conclusions

The U.S. Geological Survey, in cooperation with the Virginia Department of Conservation and Recreation, Fairfax County, and the City of Fairfax, conducted a multiple-tracer study to investigate the sources of the sewage observed in Accotink Creek, an urban watershed in northern Virginia. The suite of tracers used in this study was selected on the basis of earlier sewage-tracer studies, even though none of these earlier studies attempted to apply all the tracers at one time. The tracers used in this study were indicator tracers that are relatively simple and inexpensive to apply, and confirmatory tracers that are relatively difficult and expensive to analyze. Indicator tracers included fecal coliform bacteria, surfactants, boron, chloride, chloride/bromide ratio, specific conductance, dissolved oxygen, turbidity, and water temperature. The confirmatory tracers included 13 organic compounds that are associated with human waste and include caffeine, cotinine, triclosan, a number of detergent metabolites, several fragrances, and several plasticizers. Following a literature review to identify the suite of sewage tracers, raw sewage was sampled and compared to background stream-water tracer concentrations to validate that the selected tracers were indeed indicative of sewage sources. Based on the validation of the tracers for identifying sewage sources to a stream, the study was designed as a series of eight base-flow synoptic sampling events to characterize the tracer concentrations in the main channel of Accotink Creek, its tributaries, and all storm drains with flow.

Through the synoptic sampling and subsequent data analysis, several major sewage sources were identified using the suite of tracers selected. To the extent possible, all major sewage sources were addressed immediately by the appropriate local authorities to ensure that the sources of sewage were eliminated. In addition, several other sampling sites were identified that likely have minor sewage sources, and these sites may need additional study and investigation. Surfactants, boron, and fecal coliform bacteria were the most efficient indicator tracers for identifying minor sewage sources because they had the greatest relative concentration differences between the background Accotink Creek stream-water tracer composition and the composition of raw sewage. In the identification of both major and minor sewage sources, the wastewater organic compound tracers were valuable for confirming the results of the indicator tracers. Although the project was successful at identifying several sewage inputs to Accotink Creek, the variabilities in the tracer concentrations between synoptic sampling events at some sampling sites proved to be challenging in regard to data interpretation.

Near the end of the synoptic sampling, several additional sampling techniques were used to better characterize the sites with potential sewage sources and to better understand the variabilities in tracer concentrations that were observed at certain sampling sites. These additional sampling techniques included optical brightener monitoring, intensive stream sampling using automated samplers, and additional sampling of several storm-drain networks. Collectively, the additional sampling techniques provided a complement to the synoptic sampling approach that was used for the bulk of this study.

Through this multiple-tracer study, several sewage sources to the Accotink Creek watershed were identified and several other sites were prioritized for further investigation. In addition to directly resulting in improved water quality in Accotink Creek, this study serves as a template for investigating sewage sources to other watersheds.

Although this multiple-tracer approach was demonstrated to be effective for detecting sewage sources to streams, additional research is needed to better detect extremely low-volume sewage sources and enable local authorities to identify the specific sources of sewage once it is detected in a stream reach.

Acknowledgments

The extensive water-quality sampling for this study was only possible because of the assistance provided by many hard-working, highly motivated USGS and Fairfax County staff members. USGS employees who participated in collecting samples include: Douglas Moyer, Trisha Baldwin, John Jastram, Russell Lotspeich, Brent Banks, Alan Simpson, Jefferson Keaton, Jennifer Krstolic, Steven Schriver, and Dawn Land. Fairfax County staff who participated in collecting samples include: Laura Grape, Shannon Curtis, Chad Grupe, Danielle Derwin, Amanda Pennock, Gayle England, Matthew Handy, and Russell Smith. Fairfax County Environmental Laboratory personnel, including David Bushman, Brian Polick, Judy Fincham, Amro Veun, Gerry Shero, Nedson Dumbo, Roger Rionda, Pat O’Connor, and LaWanda Posey, are thanked for performing the boron, chloride, and bromide analyses. Steven Zaugg, of the USGS, analyzed the wastewater organic compounds for this study and was extremely helpful in the interpretation of these data. Peter Cinotto and Denise Dumouchelle, both of the USGS, are thanked for providing technical reviews of this report.

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Appendix 1. Indicator tracer data from synoptic sampling events for sites sampled in the Accotink Creek watershed, Virginia.

[rem, remark; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/10 0mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; na, not applicable; nd, not determined]

Site ID	Event	Sampling date	Sampling time	Bo rem	Boron (mg/L)	Br rem	Bromide (mg/L)	Chloride (mg/L)	Air temp	Water temp	pH	Specific conductance (µS/cm)
A1	1	12/3/2001	1715	na	0.028	na	nd	33	9.5	9.6	7.2	178
A11	1	12/5/2001	1240	na	0.024	na	nd	38	22.0	10.0	7.0	257
A12	1	12/6/2001	1005	na	0.025	na	nd	50	17.0	9.3	7.0	292
A13	1	12/6/2001	1140	na	0.029	na	nd	54	20.5	10.0	6.9	323
A14	1	12/6/2001	935	na	0.029	na	nd	79	15.5	9.5	7.1	421
A15	1	12/6/2001	1505	na	0.080	na	nd	111	22.5	12.6	7.3	542
A16	1	12/6/2001	1138	na	0.028	na	nd	118	21.0	9.8	7.2	544
A2	1	12/4/2001	950	na	0.027	na	nd	31	17.0	7.4	7.4	234
A3	1	12/3/2001	1202	na	0.028	na	nd	35	15.5	8.8	7.3	232
A4	1	12/3/2001	1315	na	0.030	na	nd	34	16.0	9.8	7.2	145
A5	1	12/4/2001	835	na	0.030	na	nd	34	5.0	7.8	6.8	245
A6	1	12/4/2001	851	na	0.029	na	nd	32	5.7	7.0	7.8	235
A7	1	12/4/2001	1601	na	0.026	na	nd	31	13.0	8.9	7.5	236
A8	1	12/5/2001	1030	na	0.022	na	nd	36	18.0	8.8	6.8	254
A9	1	12/5/2001	1031	na	0.025	na	nd	36	21.5	8.9	7.0	261
S1	1	12/4/2001	1650	na	0.010	na	nd	21	17.5	12.5	6.5	224
S10	1	12/4/2001	1350	na	0.034	na	nd	12	20.0	10.0	6.0	182
S12	1	12/5/2001	1620	na	0.037	na	nd	44	21.0	22.5	6.8	449
S13	1	12/5/2001	1240	na	0.021	na	nd	52	25.5	12.2	7.4	375
S14	1	12/5/2001	1603	na	0.007	na	nd	38	23.0	16.0	7.3	248
S15	1	12/5/2001	1650	na	0.013	na	nd	77	17.0	nd	7.1	353
S16	1	12/5/2001	935	na	0.011	na	nd	34	15.0	8.6	6.9	182
S17	1	12/5/2001	1120	na	0.014	na	nd	41	25.0	nd	5.7	259
S18	1	12/5/2001	1530	na	0.032	na	nd	63	20.0	11.8	6.9	253
S2	1	12/4/2001	1118	na	0.013	na	nd	100	18.5	10.2	7.2	288
S20	1	12/5/2001	1555	na	0.016	na	nd	18	23.0	nd	5.6	168
S22	1	12/5/2001	1715	na	0.057	na	nd	35	16.0	14.6	8.0	445
S23	1	12/6/2001	820	na	0.013	na	nd	12	12.0	nd	5.5	164
S24	1	12/6/2001	825	na	0.011	na	nd	12	12.0	nd	5.7	166
S25	1	12/6/2001	1135	na	0.028	na	nd	15	19.0	nd	5.8	125
S26	1	12/6/2001	1120	na	0.015	na	nd	16	19.0	11.4	7.2	122
S29	1	12/5/2001	1035	na	0.016	na	nd	17	17.0	12.0	7.3	233
S3	1	12/4/2001	1550	na	0.006	na	nd	26	19.5	15.0	6.3	205
S31	1	12/6/2001	1410	na	0.023	na	nd	15	24.5	13.0	6.5	133
S32	1	12/6/2001	1520	na	0.041	na	nd	32	20.0	15.0	6.3	418
S33	1	12/6/2001	1610	na	0.015	na	nd	28	18.0	15.0	6.5	231
S34	1	12/6/2001	840	na	0.011	na	nd	17	13.0	11.0	6.6	170
S35	1	12/6/2001	905	na	0.028	na	nd	94	14.0	nd	6.1	440
S36	1	12/6/2001	855	na	0.059	na	nd	269	14.0	nd	5.8	1,111
S37	1	12/7/2001	925	na	0.026	na	nd	6	14.5	8.0	7.3	144
S38	1	12/7/2001	1449	na	0.022	na	nd	29	19.0	14.1	7.1	193
S39	1	12/7/2001	1040	na	0.016	na	nd	19	17.0	11.5	7.6	144
S4	1	12/3/2001	1700	na	nd	na	nd	nd	nd	nd	nd	nd
S41	1	12/7/2001	1359	na	0.018	na	nd	35	21.5	13.5	6.6	238
S42	1	12/7/2001	1236	na	0.038	na	nd	88	19.0	13.1	7.4	458
S43	1	12/6/2001	1600	na	0.019	na	nd	38	20.0	nd	6.4	296
S44	1	12/6/2001	1308	na	0.098	na	nd	27	26.0	nd	6.2	367
S45	1	12/7/2001	900	na	0.047	na	nd	18	14.5	16.5	7.2	253
S46	1	12/7/2001	1120	na	0.162	na	nd	98	18.0	nd	8.0	1,039
S47	1	12/7/2001	1315	na	0.061	na	nd	124	19.0	nd	6.1	619

Dissolved oxygen (mg/L)	Turbidity rem	Turbidity (NTU)	Surfactants (mg/L)	FC rem	Fecal coliform bacteria (col/100 mL)	Dup FC rem	Fecal coliform bacteria duplicate (col/100 mL)	Organics	Discharge rem	Discharge (ft^3/s)
9.0	na	4.7	0.15	na	87	na	nd	nd	e	2.7
6.8	na	6.1	0.20	na	203	na	nd	nd	e	0.852
6.8	na	4.8	0.00	na	117	na	nd	nd	e	0.395
5.7	na	7.0	0.15	na	147	na	nd	nd	e	1.02
7.4	na	3.0	0.15	na	208	na	nd	nd	e	0.466
8.9	na	4.0	0.10	na	103	na	93	nd	e	0.238
8.9	na	2.0	0.25	na	177	na	nd	nd	e	0.385
10.0	na	5.8	0.00	na	140	na	nd	nd	e	1.64
9.0	na	4.2	0.00	na	147	na	nd	nd	e	1.626
9.5	na	3.6	0.15	na	117	na	nd	nd	e	1.394
9.4	na	5.0	0.00	na	133	na	nd	nd	e	1.53
10.4	na	3.4	0.13	na	867	na	nd	nd	e	1.26
9.2	na	5.3	0.25	na	113	na	nd	nd	e	1.48
6.6	na	5.0	0.00	na	83	na	nd	nd	e	1.08
5.6	na	9.0	0.25	na	130	na	nd	nd	e	1.371
nd	na	3.0	0.00	na	200	na	nd	nd	na	nd
nd	na	27.5	0.00	e	57	na	nd	nd	e	0.000
nd	na	3.0	0.00	e,<	3	na	nd	nd	e	0.009
8.2	na	10.0	0.15	e	20,200	na	nd	nd	e	0.002
nd	na	1.0	0.15	e	42	na	nd	nd	e	0.000
nd	na	1.0	0.15	na	4,000	na	nd	nd	e	0.045
9.2	na	15.0	0.15	na	340	na	nd	nd	e	0.009
nd	na	1.4	0.00	e	10	na	nd	nd	e	0.007
5.7	na	20.1	0.13	na	2,000	na	nd	nd	e	0.025
7.4	na	16.5	0.22	na	260	na	nd	nd	e	0.002
nd	na	12.1	0.30	na	933	na	nd	nd	e	0.051
7.8	na	31.0	0.25	e	20	na	nd	nd	e	0.007
nd	na	0.9	0.10	na	1,533	na	nd	nd	e	0.003
nd	na	0.5	0.00	e	11,000	na	nd	nd	e	0.007
nd	na	8.4	0.00	e	25	na	nd	nd	e	0.005
10.1	na	2.4	0.00	na	103	na	nd	nd	e	0.014
9.0	na	3.0	0.10	na	400	na	nd	nd	e	0.002
nd	na	8.2	0.45	e	30	na	nd	nd	e	0.009
nd	na	11.1	0.75	na	200	na	150	nd	e	0.001
nd	na	23.6	10.00	na	97	na	nd	nd	na	nd
nd	na	15.0	0.15	e	36,500	na	nd	nd	e	0.000
nd	na	1.0	0.10	e	15	na	nd	nd	e	0.001
nd	na	2.0	0.15	e	26	na	nd	nd	e	0.002
nd	na	65.0	0.20	e	54	na	nd	nd	e	0.001
nd	na	0.9	0.25	e	18,000	na	nd	nd	e	0.001
10.4	na	2.0	0.15	e,<	3	e,<	3	nd	e	0.003
nd	na	nd	nd	na	163	na	nd	nd	e	0.000
nd	na	nd	0.25	e	200	na	nd	nd	e	0.000
5.1	na	4.0	0.15	na	469	na	nd	nd	e	0.055
10.4	na	3.0	0.15	na	193	na	200	nd	e	0.023
nd	na	6.0	0.00	na	127	na	140	nd	e	0.000
nd	na	6.0	0.25	na	2,700	na	nd	nd	e	0.004
nd	na	0.9	0.20	e	7	na	nd	nd	e	0.001
nd	na	3.5	0.13	e	16	e	16	nd	e	0.001
nd	na	2.2	0.25	na	90	na	nd	nd	e	0.001

Appendix 1. Indicator tracer data from synoptic sampling events for sites sampled in the Accotink Creek watershed, Virginia. — Continued

[rem, remark; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/10 0mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; na, not applicable; nd, not determined]

Site ID	Event	Sampling date	Sampling time	Bo rem	Boron (mg/L)	Br rem	Bromide (mg/L)	Chloride (mg/L)	Air temp	Water temp	pH	Specific conductance (µS/cm)
S48	1	12/7/2001	1010	na	0.019	na	nd	132	16.5	13.0	7.1	600
S49	1	12/7/2001	1530	na	0.059	na	nd	68	18.0	14.5	8.8	547
S5	1	12/4/2001	1205	na	0.014	na	nd	25	19.0	13.2	6.4	192
S50	1	12/7/2001	1210	na	0.045	na	nd	108	17.0	14.0	7.0	538
S51	1	12/7/2001	1710	na	0.035	na	nd	65	16.0	13.9	7.9	97
S6	1	12/4/2001	1100	na	0.044	na	nd	14	17.0	10.5	6.3	265
S7	1	12/4/2001	1340	na	0.008	na	nd	24	20.5	12.0	6.8	201
S8	1	12/4/2001	1325	na	0.112	na	nd	34	20.5	13.0	6.5	349
S9	1	12/4/2001	1340	na	0.005	na	nd	14	25.0	9.0	5.6	188
T1	1	12/4/2001	915	na	0.008	na	nd	33	17.0	9.1	6.7	141
T10	1	12/3/2001	1700	na	0.027	na	nd	39	14.0	10.2	6.7	236
T11	1	12/4/2001	1110	na	0.027	na	nd	18	17.5	9.0	7.2	64
T12	1	12/4/2001	1140	na	0.025	na	nd	42	13.0	7.6	7.3	99
T13	1	12/4/2001	1619	na	0.016	na	nd	62	14.5	10.2	7.4	305
T14	1	12/5/2001	900	na	0.014	na	nd	13	9.5	8.5	7.2	139
T15	1	12/5/2001	1400	na	0.017	na	nd	22	18.5	11.6	6.9	239
T16	1	12/5/2001	1535	na	0.016	na	nd	17	21.0	13.2	6.9	145
T17	1	12/5/2001	955	na	0.015	na	nd	16	15.0	8.5	5.9	161
T18	1	12/5/2001	1105	na	0.028	na	nd	34	21.5	9.6	7.1	251
T19	1	12/5/2001	1357	na	0.023	na	nd	64	19.0	12.6	7.2	339
T2	1	12/4/2001	1205	na	0.029	na	nd	35	21.5	9.4	7.1	95
T20	1	12/5/2001	1424	na	0.024	na	nd	32	24.0	10.9	7.2	228
T22	1	12/5/2001	830	na	0.027	na	nd	25	12.0	8.2	7.2	224
T23	1	12/5/2001	1220	na	0.028	na	nd	46	22.0	9.7	7.2	291
T24	1	12/5/2001	1345	na	0.024	na	nd	52	27.0	11.0	7.1	326
T25	1	12/5/2001	1635	na	0.020	na	nd	138	16.0	11.8	6.9	650
T26	1	12/6/2001	945	na	0.028	na	nd	44	17.0	9.1	7.1	244
T27	1	12/6/2001	1210	na	0.019	na	nd	50	22.0	11.7	6.8	207
T3	1	12/4/2001	1300	na	0.025	na	nd	47	22.5	13.3	6.8	110
T30	1	12/6/2001	1340	na	0.039	na	nd	17	22.0	nd	5.8	241
T31	1	12/6/2001	1040	na	0.027	na	nd	67	21.0	9.6	6.7	325
T32	1	12/6/2001	1635	na	0.025	na	nd	97	16.0	12.7	6.8	434
T33	1	12/6/2001	1740	na	0.028	na	nd	59	17.5	10.5	6.3	340
T35	1	12/6/2001	831	na	0.030	na	nd	52	14.0	9.4	7.3	326
T36	1	12/7/2001	1425	na	0.024	na	nd	46	17.5	12.7	7.0	254
T37	1	12/6/2001	1430	na	0.026	na	nd	20	26.5	13.2	7.0	104
T39	1	12/7/2001	850	na	0.027	na	nd	23	16.0	10.6	7.0	181
T4	1	12/4/2001	1405	na	0.024	na	nd	26	19.5	13.3	6.6	159
T40	1	12/7/2001	1000	na	0.043	na	nd	26	15.5	11.1	6.9	145
T41	1	12/7/2001	1020	na	0.024	na	nd	23	15.0	10.9	6.9	182
T42	1	12/7/2001	1125	na	0.023	na	nd	24	17.5	11.6	7.1	55
T43	1	12/6/2001	1201	na	0.019	na	nd	35	18.0	12.8	7.2	242
T44	1	12/7/2001	1350	na	0.031	na	nd	26	17.5	12.7	7.4	236
T45	1	12/7/2001	1000	na	0.033	na	nd	47	14.5	11.5	7.2	288
T46	1	12/7/2001	940	na	0.024	na	nd	107	14.5	10.9	7.4	481
T47	1	12/7/2001	845	na	0.018	na	nd	76	14.5	11.0	7.4	371
T48	1	12/7/2001	905	na	0.024	na	nd	121	14.5	10.8	7.4	527
T49	1	12/7/2001	1035	na	0.015	na	nd	58	14.5	12.1	7.2	309
T50	1	12/7/2001	1145	na	0.022	na	nd	148	20.0	11.9	7.2	605
T51	1	12/7/2001	1205	na	0.034	na	nd	86	20.0	12.8	7.1	428

Dissolved oxygen (mg/L)	Turbidity rem	Turbidity (NTU)	Surfactants (mg/L)	FC rem	Fecal coliform bacteria (col/100 mL)	Dup FC rem	Fecal coli-form bacteria duplicate (col/100 mL)	Organics	Discharge rem	Discharge (ft^3/s)
nd	na	0.8	0.10	e	1,133	na	nd	nd	e	0.011
nd	na	3.0	0.10	na	80	na	nd	nd	e	0.017
8.0	na	1.0	0.00	na	3,600	na	nd	nd	e	0.073
nd	na	3.2	0.25	na	515	na	450	nd	e	0.006
9.2	na	0.3	0.00	na	165	na	nd	nd	e	0.028
nd	na	7.0	0.25	na	73	na	nd	nd	e	0.000
8.5	na	4.1	0.13	e	42,000	na	nd	nd	e	0.025
6.0	na	3.3	0.10	e	30,000	na	nd	nd	e	0.004
nd	na	5.6	0.15	e	14,000	na	nd	nd	e	0.000
3.8	na	29.3	0.00	na	867	na	nd	nd	e	0.019
7.2	na	0.8	0.00	e	35	na	nd	nd	e	0.029
6.0	na	1.4	0.15	e	47	na	nd	nd	e	0.01
8.9	na	1.1	0.15	na	77	na	nd	nd	e	0.147
9.3	na	1.0	0.00	na	113	na	nd	nd	e	0.038
nd	na	2.0	0.25	e	15	na	nd	nd	e	0.014
9.5	na	8.0	0.00	na	1,667	na	nd	nd	e	0.055
8.6	na	2.0	0.00	na	103	na	nd	nd	e	0.013
nd	na	15.0	0.00	na	800	na	nd	nd	e	0.002
6.9	na	5.0	0.15	na	103	na	nd	nd	e	0.199
9.5	na	3.0	0.15	na	540	na	nd	nd	e	0.115
7.7	na	2.7	0.13	na	133	na	nd	nd	e	0.051
10.0	na	2.0	0.15	e	39	na	nd	nd	e	0.189
7.4	na	3.5	0.00	na	3,000	na	nd	nd	e	0.03
8.5	na	2.0	0.00	na	100	na	nd	nd	e	0.33
9.4	na	2.3	0.13	e	777	na	nd	nd	e	0.132
2.7	na	30.4	0.25	na	900	na	nd	nd	e	0.004
8.1	na	8.7	0.20	na	1,667	na	nd	nd	e	0.288
5.2	na	3.4	0.00	na	350	na	nd	nd	e	0.08
7.9	na	1.9	0.20	na	220	na	nd	nd	e	0.003
nd	na	1.5	0.10	na	97	na	nd	nd	e	0.000
5.0	na	6.0	0.20	na	310	na	nd	nd	e	0.114
9.2	na	2.0	0.10	na	190	na	nd	nd	e	0.074
nd	na	4.0	0.20	na	390	na	nd	nd	e	0.013
8.3	na	3.0	0.25	na	1,333	na	nd	nd	e	0.1
8.2	na	1.1	0.13	e	70	na	nd	nd	e	0.137
5.7	na	2.0	0.10	na	205	na	nd	nd	e	0.13
9.4	na	2.0	0.15	na	733	na	623	nd	e	0.071
8.6	na	16.7	0.00	na	93	na	nd	nd	e	0.032
4.6	na	2.0	0.15	na	550	na	nd	nd	e	0.009
7.9	na	2.0	0.15	na	193	na	150	nd	e	0.062
6.0	na	2.0	0.15	na	210	na	nd	nd	e	0.017
10.2	na	1.0	0.15	e	64	na	nd	nd	e	0.122
9.4	na	4.6	0.10	na	1,033	na	nd	nd	e	0.031
8.3	na	1.7	0.00	na	117	na	nd	nd	e	0.198
9.3	na	1.8	0.13	e	23	na	nd	nd	e	0.217
9.7	na	3.3	0.13	e	40	na	nd	nd	e	0.141
9.8	na	2.9	0.20	e	23	na	nd	nd	e	0.218
9.2	na	2.5	0.10	e	50	na	nd	nd	e	0.144
10.1	na	3.8	0.00	na	430	na	nd	nd	e	0.116
6.4	na	6.4	1.00	na	198	na	nd	nd	e	0.054

Appendix 1. Indicator tracer data from synoptic sampling events for sites sampled in the Accotink Creek watershed, Virginia. — Continued

[rem, remark; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/10 0mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; na, not applicable; nd, not determined]

Site ID	Event	Sampling date	Sampling time	Bo rem	Boron (mg/L)	Br rem	Bromide (mg/L)	Chloride (mg/L)	Air temp	Water temp	pH	Specific conductance (µS/cm)
T52	1	12/7/2001	1250	na	0.017	na	nd	168	19.0	11.8	7.0	662
T53	1	12/7/2001	900	na	0.033	na	nd	43	12.5	11.4	7.3	294
T54	1	12/7/2001	1345	na	0.020	na	nd	25	17.5	12.5	7.7	260
T55	1	12/7/2001	1115	na	0.036	na	nd	53	16.5	11.5	8.7	336
T56	1	12/7/2001	1055	na	0.028	na	nd	32	16.5	12.5	7.3	244
T57	1	12/7/2001	1250	na	0.024	na	nd	34	18.0	14.8	6.7	196
T6	1	12/3/2001	1105	na	0.028	na	nd	48	15.5	7.6	7.2	316
T7	1	12/3/2001	1218	na	0.018	na	nd	25	16.0	9.0	6.8	13
T8	1	12/3/2001	1245	na	0.025	na	nd	61	15.0	9.8	7.2	282
T9	1	12/4/2001	900	na	0.023	na	nd	71	17.0	7.1	7.0	390
A1	2	4/2/2002	1005	na	0.018	na	nd	41	16.0	10.8	7.2	228
A10	2	4/3/2002	1025	na	0.022	na	nd	48	26.5	14.5	7.3	250
A11	2	4/3/2002	905	na	0.02	na	nd	48	25.0	13.6	7.2	250
A12	2	4/4/2002	855	na	0.024	na	nd	68	10.5	9.9	7.2	327
A13	2	4/4/2002	925	na	0.028	na	nd	71	11.0	10.0	7.2	350
A14	2	4/4/2002	945	na	0.018	na	nd	77	8.0	10.0	7.4	383
A15	2	4/4/2002	1240	na	0.02	na	nd	86	13.5	11.7	8.0	423
A16	2	4/4/2002	1600	na	0.02	na	nd	102	13.0	15.1	8.4	465
A2	2	4/2/2002	1035	na	0.018	na	nd	47	26.5	11.8	7.7	232
A3	2	4/2/2002	1300	na	0.018	na	nd	43	20.5	13.6	7.7	253
A4	2	4/2/2002	1430	na	0.017	na	nd	43	21.5	14.3	8.2	249
A5	2	4/2/2002	1020	na	0.029	na	nd	40	19.0	10.4	7.3	237
A6	2	4/3/2002	915	na	0.021	na	nd	41	25.5	13.8	7.7	229
A7	2	4/3/2002	1225	na	0.022	na	nd	40	25.0	15.4	7.7	230
A8	2	4/3/2002	1545	na	0.018	na	nd	46	13.0	15.2	7.2	249
A9	2	4/3/2002	1024	na	0.022	na	nd	46	22.5	14.2	7.0	256
S1	2	4/2/2002	1600	na	0.008	na	nd	26	25.0	11.0	7.2	236
S10	2	4/3/2002	1010	na	0.044	na	nd	8	nd	nd	7.4	205
S11	2	4/2/2002	1610	na	0.013	na	nd	19	19.5	nd	7.6	239
S12	2	4/3/2002	1500	na	0.031	na	nd	41	13.5	20.0	8.0	350
S13	2	4/3/2002	1240	na	0.018	na	nd	35	21.5	11.5	7.6	251
S14	2	4/3/2002	1415	na	0.012	na	nd	38	15.5	11.0	7.6	236
S15	2	4/3/2002	1455	na	0.02	na	nd	69	14.5	11.5	7.1	315
S16	2	4/3/2002	1120	na	0.015	na	nd	28	24.0	16.2	6.8	107
S17	2	4/3/2002	1140	na	0.026	na	nd	37	27.0	18.0	6.9	223
S18	2	4/3/2002	1255	na	0.03	na	nd	92	22.0	14.5	6.7	465
S19	2	4/3/2002	1350	na	0.072	na	nd	28	22.0	16.8	7.4	318
S2	2	4/2/2002	1150	na	0.011	na	nd	167	26.5	11.1	6.9	179
S20	2	4/3/2002	1325	na	0.032	na	nd	28	22.0	16.8	7.4	189
S21	2	4/3/2002	1440	na	0.14	na	nd	872	nd	16.2	9.2	2,470
S22	2	4/3/2002	1510	na	0.037	na	nd	41	13.5	14.9	7.9	283
S23	2	4/3/2002	1530	na	0.012	na	nd	14	nd	14.0	7.5	146
S24	2	4/3/2002	1535	na	0.014	na	nd	19	nd	14.4	7.3	185
S25	2	4/4/2002	1105	na	0.022	na	nd	18	18.0	nd	6.5	120
S26	2	4/4/2002	1045	na	0.012	na	nd	18	18.0	nd	6.4	170
S27	2	4/4/2002	1305	na	0.008	na	nd	21	19.0	nd	6.4	157
S28	2	4/4/2002	1325	na	0.008	na	nd	23	nd	nd	6.4	191
S29	2	4/3/2002	1110	na	0.028	na	nd	30	22.5	17.9	7.2	276
S3	2	4/2/2002	1340	na	0.007	na	nd	27	21.0	12.5	7.4	218
S30	2	4/4/2002	1345	na	0.016	na	nd	36	17.5	nd	6.3	208

Dissolved oxygen (mg/L)	Turbidity rem	Turbidity (NTU)	Surfactants (mg/L)	FC rem	Fecal coliform bacteria (col/100 mL)	Dup FC rem	Fecal coli-form bacteria duplicate (col/100 mL)	Organics	Discharge rem	Discharge (ft^3/s)
11.5	na	0.8	0.13	e	20	e	21	nd	e	0.137
9.1	na	0.4	0.00	e	52	na	nd	nd	e	0.077
nd	na	4.1	0.10	e	520	na	nd	nd	e	0.012
nd	na	0.9	0.15	na	167	na	163	nd	e	0.075
nd	na	0.9	0.00	e	700	na	nd	nd	e	0.073
7.0	na	1.0	0.30	na	143	na	nd	nd	e	0.229
10.3	na	0.6	0.00	na	77	na	nd	nd	e	0.034
9.0	na	2.3	0.00	e	671	na	nd	nd	e	0.04
9.8	na	0.9	0.00	na	73	na	nd	nd	e	0.097
8.3	na	1.0	0.00	na	250	na	nd	nd	e	0.044
10.3	na	7.0	0.00	na	160	na	nd	nd	e	8.084
10.7	na	6.0	0.15	na	130	na	nd	nd	na	nd
9.9	na	6.0	0.10	e	64	na	nd	nd	e	3.25
9.0	na	4.8	0.10	na	190	na	nd	nd	e	1.57
9.6	na	5.1	0.10	na	340	na	nd	nd	e	1.6
10.3	na	3.9	0.15	na	130	na	nd	nd	e	1.28
13.0	na	4.5	0.00	e	29	na	nd	nd	e	1.49
12.8	na	3.4	0.10	e	13	e	20	nd	e	0.888
11.8	na	6.0	0.10	na	120	na	nd	nd	e	5.75
12.8	na	6.5	0.20	e	51	na	nd	nd	e	6.56
12.2	na	5.6	0.20	e	93	na	nd	nd	e	4.99
10.8	na	6.0	0.10	na	240	na	nd	nd	e	5.54
10.1	na	5.2	0.15	na	250	na	nd	nd	e	4.23
9.7	na	4.0	0.13	na	200	na	nd	nd	e	4.39
10.4	na	5.0	0.13	e	160	na	nd	nd	e	4.71
9.8	na	6.0	0.15	na	180	na	nd	nd	e	4.53
nd	na	1.0	0.00	e	25	na	nd	nd	e	0.013
nd	na	4.4	0.10	na	100	na	nd	nd	e	0.000
nd	na	37.6	0.05	e	8	na	nd	nd	e	0.000
nd	na	0.7	0.15	e,<	3	na	nd	nd	e	0.004
nd	na	16.0	0.10	e	28	na	nd	nd	e	0.007
nd	na	4.4	0.15	e	55	na	nd	nd	e	0.002
11.0	na	3.1	0.15	na	1,000	na	nd	nd	e	0.072
9.9	na	18.0	0.15	na	70	na	nd	nd	e	0.037
nd	na	0.8	0.20	na	93	na	nd	nd	e	0.014
7.8	na	4.5	0.20	na	200	na	nd	nd	e	0.015
nd	na	1.0	0.50	na	130	na	nd	nd	e	0.011
8.6	na	4.0	0.10	e	37	na	nd	nd	e	0.001
nd	na	2.5	0.25	e	29	na	nd	nd	e	0.022
nd	na	1.9	0.25	e	28	na	nd	nd	e	0.001
nd	na	6.0	0.10	e,<	3	na	nd	nd	e	0.000
nd	na	1.6	0.00	na	570	na	nd	nd	e	0.006
nd	na	1.5	0.00	na	340	na	nd	nd	e	0.076
nd	na	0.8	0.00	na	430	na	nd	nd	e	0.01
nd	na	1.9	0.10	na	170	na	nd	nd	e	0.001
nd	na	1.0	0.00	e	15	e	21	nd	e	0.001
nd	na	2.0	0.00	na	2,200	na	2,400	nd	e	0.007
nd	na	7.4	0.25	e	22,000	na	nd	nd	e	0.01
nd	na	2.0	0.00	e	7	na	nd	nd	e	0.016
nd	na	1.0	0.00	e	5	e	14	nd	e	0.001

Appendix 1. Indicator tracer data from synoptic sampling events for sites sampled in the Accotink Creek watershed, Virginia. — Continued

[rem, remark; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/10 0mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; na, not applicable; nd, not determined]

Site ID	Event	Sampling date	Sampling time	Bo rem	Boron (mg/L)	Br rem	Bromide (mg/L)	Chloride (mg/L)	Air temp	Water temp	pH	Specific conductance (µS/cm)
S31	2	4/4/2002	1030	na	0.037	na	nd	20	14.0	10.1	6.8	155
S32	2	4/4/2002	1050	na	0.03	na	nd	36	14.0	12.0	6.8	217
S33	2	4/4/2002	1140	na	0.014	na	nd	25	12.5	11.0	6.8	142
S34	2	4/4/2002	1415	na	0.009	na	nd	43	12.5	9.5	6.3	261
S35	2	4/4/2002	905	na	0.057	na	nd	71	11.5	14.0	7.4	396
S36	2	4/4/2002	1035	<	0.005	na	nd	251	23.0	12.0	6.0	998
S37	2	4/5/2002	900	na	0.019	na	nd	8	nd	nd	6.6	130
S38	2	4/5/2002	1455	na	0.012	na	nd	35	14.8	10.4	6.4	204
S39	2	4/5/2002	1120	na	0.009	na	nd	35	11.5	9.0	7.6	150
S4	2	4/2/2002	1510	<	0.005	na	nd	79	25.5	nd	7.3	368
S40	2	4/5/2002	1215	na	0.007	na	nd	31	14.0	7.0	6.4	218
S41	2	4/5/2002	1405	na	0.016	na	nd	44	14.5	12.4	6.2	249
S42	2	4/5/2002	1330	na	0.025	na	nd	65	14.5	9.9	7.9	361
S43	2	4/4/2002	1425	na	0.012	na	nd	47	15.0	11.0	6.7	322
S44	2	4/4/2002	1458	na	0.076	na	nd	31	9.5	9.5	6.6	376
S45	2	4/5/2002	830	na	0.025	na	nd	23	nd	nd	6.5	240
S46	2	4/5/2002	1040	na	0.172	na	nd	140	18.0	nd	6.1	1,124
S47	2	4/5/2002	1205	na	0.024	na	nd	297	18.5	11.9	8.2	1,013
S48	2	4/5/2002	910	na	0.02	na	nd	136	9.0	10.8	7.6	590
S49	2	4/5/2002	1040	na	0.028	na	nd	164	10.5	12.0	6.4	644
S5	2	4/2/2002	1425	na	0.011	na	nd	24	21.5	12.8	6.3	201
S50	2	4/5/2002	1158	na	0.022	na	nd	87	12.5	9.5	6.5	433
S51	2	4/5/2002	1220	na	0.037	na	nd	70	10.0	10.4	7.8	413
S52	2	4/2/2002	1530	na	0.062	na	nd	36	24.5	14.3	7.0	186
S6	2	4/2/2002	1305	na	0.033	na	nd	108	26.0	13.0	7.6	520
S7	2	4/2/2002	1205	na	0.012	na	nd	29	22.0	14.5	7.0	223
S8	2	4/2/2002	1220	na	0.016	na	nd	27	22.0	13.4	6.4	292
S9	2	4/3/2002	1030	na	0.007	na	nd	15	nd	nd	6.8	149
T1	2	4/2/2002	1030	na	0.016	na	nd	46	26.5	14.3	6.9	226
T10	2	4/2/2002	1550	na	0.02	na	nd	48	19.0	13.7	7.1	267
T11	2	4/3/2002	1040	na	0.022	na	nd	35	27.5	14.4	7.1	204
T12	2	4/3/2002	1050	na	0.02	na	nd	36	27.5	14.9	7.7	224
T13	2	4/3/2002	1200	na	0.015	na	nd	64	24.5	15.8	7.4	314
T14	2	4/3/2002	1340	na	0.013	na	nd	12	18.0	13.7	7.2	128
T15	2	4/3/2002	1430	na	0.018	na	nd	20	16.0	15.8	7.1	161
T16	2	4/4/2002	900	na	0.012	na	nd	21	nd	nd	6.8	151
T17	2	4/3/2002	1630	na	0.015	na	nd	34	13.0	10.5	7.2	192
T18	2	4/3/2002	945	na	0.019	na	nd	33	22.0	13.6	7.0	219
T19	2	4/3/2002	1255	na	0.027	na	nd	67	20.5	14.9	7.1	315
T2	2	4/2/2002	1215	na	0.017	na	nd	27	19.0	12.9	7.3	175
T20	2	4/3/2002	1330	na	0.02	na	nd	34	18.0	15.9	7.2	196
T21	2	4/3/2002	1010	na	0.022	na	nd	23	26.5	14.9	7.5	158
T23	2	4/3/2002	845	na	0.025	na	nd	52	25.0	13.4	7.2	252
T24	2	4/3/2002	1225	na	0.03	na	nd	57	28.0	16.9	7.3	302
T25	2	4/3/2002	1405	na	0.017	na	nd	47	16.0	14.2	7.5	250
T26	2	4/4/2002	820	na	0.017	na	nd	49	10.5	8.9	7.4	250
T27	2	4/4/2002	1015	na	0.015	na	nd	63	18.0	9.7	7.1	304
T28	2	4/4/2002	1205	na	0.013	na	nd	69	12.0	11.6	7.5	321
T29	2	4/4/2002	1145	na	0.022	na	nd	35	12.0	10.1	7.4	222
T3	2	4/2/2002	1250	na	0.034	na	nd	46	26.0	18.8	6.8	207

Dissolved oxygen (mg/L)	Turbidity rem	Turbidity (NTU)	Surfactants (mg/L)	FC rem	Fecal coliform bacteria (col/100 mL)	Dup FC rem	Fecal coliform bacteria duplicate (col/100 mL)	Organics	Discharge rem	Discharge (ft³/s)
nd	na	1.9	0.10	e	3	na	nd	nd	e	0.006
nd	na	0.4	0.10	e,<	3	na	nd	nd	e	0.002
nd	na	1.0	0.13	na	70	na	nd	nd	e	0.004
nd	na	1.0	0.10	e,<	3	na	nd	nd	e	0.035
9.0	na	1.6	0.00	na	500	na	nd	nd	e	0.056
nd	na	13.5	0.20	e,<	3	na	nd	nd	e	0.004
nd	na	0.6	0.10	e	44,000	e	40,400	nd	e	0.004
7.6	na	7.2	0.10	e,<	3	na	nd	nd	e	0.007
11.8	na	1.4	0.05	e	33	na	nd	nd	e	0.008
nd	na	37.6	0.10	e,<	10	na	nd	nd	e	0.000
nd	na	4.2	0.05	e	27	na	nd	nd	e	0.008
8.3	na	1.3	0.10	e	42,800	na	nd	nd	e	0.043
12.6	na	6.3	0.15	e	200	na	nd	nd	e	0.048
nd	na	1.9	0.00	e,<	3	e	10	nd	e	0.001
nd	na	2.1	0.35	na	310	na	330	nd	e	0.006
nd	na	2.6	0.10	e	20	e	3	nd	e	0.004
nd	na	4.6	0.30	na	93	na	nd	nd	e	0.000
11.2	na	2.8	0.20	e	13	na	nd	nd	e	0.101
11.1	na	3.8	0.10	e	6,200	na	nd	nd	e	0.293
nd	na	2.1	0.20	e	3	na	nd	nd	e	0.004
4.7	na	3.0	0.10	e	27	na	nd	nd	e	0.024
nd	na	18.0	4.50	e	20	na	nd	nd	e	0.008
10.1	na	1.0	0.00	na	340	na	nd	nd	e	0.048
7.4	na	3.0	0.13	na	77	na	nd	nd	e	0.007
nd	na	8.0	0.50	e	35	na	nd	nd	e	0.000
7.2	na	3.0	0.00	na	130	na	nd	nd	e	0.045
5.7	na	2.0	0.10	na	73	na	nd	nd	e	0.012
nd	na	5.5	0.10	e	18	na	nd	nd	e	0.000
10.4	na	4.0	0.00	na	180	na	nd	nd	e	0.428
11.8	na	2.3	0.15	e	39	na	nd	nd	e	0.101
10.8	na	1.8	0.15	na	140	na	nd	nd	e	0.106
12.4	na	1.7	0.10	e	1,300	na	nd	nd	e	0.188
9.3	na	3.0	0.00	e	59	na	nd	nd	e	0.082
9.6	na	2.0	0.00	na	230	na	nd	nd	e	0.034
7.6	na	7.1	0.15	na	100	na	nd	nd	e	0.122
nd	na	1.4	0.00	e	10	na	nd	nd	e	0.258
nd	na	19.0	0.00	e	32	na	nd	nd	e	0.016
10.0	na	2.6	0.15	na	1,100	na	nd	nd	e	0.406
10.5	na	2.3	0.10	e	30	na	nd	nd	e	0.128
11.6	na	2.0	0.00	e	32	na	nd	nd	e	0.534
10.9	na	1.1	0.10	e	53	na	nd	nd	e	0.423
10.8	na	8.2	0.10	na	120	na	nd	nd	e	0.342
8.4	na	2.4	0.15	e	58	na	nd	nd	e	0.685
12.0	na	5.5	0.15	na	100	na	nd	nd	e	0.957
9.9	na	2.3	0.10	na	210	na	nd	nd	e	0.253
9.7	na	5.1	0.10	na	240	na	nd	nd	e	0.566
11.6	na	1.6	0.15	na	83	na	nd	nd	e	0.679
12.2	na	2.0	0.10	na	120	na	140	nd	e	0.123
12.9	na	2.0	0.10	e	18	na	nd	nd	e	0.139
9.2	na	1.0	0.00	e	18	na	nd	nd	e	0.013

Appendix 1. Indicator tracer data from synoptic sampling events for sites sampled in the Accotink Creek watershed, Virginia. — Continued

[rem, remark; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/10 0mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; na, not applicable; nd, not determined]

Site ID	Event	Sampling date	Sampling time	Bo rem	Boron (mg/L)	Br rem	Bromide (mg/L)	Chloride (mg/L)	Air temp	Water temp	pH	Specific conductance (µS/cm)
T31	2	4/4/2002	845	na	0.035	na	nd	95	13.0	9.0	7.0	416
T32	2	4/4/2002	1220	na	0.021	na	nd	95	16.0	11.7	6.9	409
T33	2	4/4/2002	1315	na	0.031	na	nd	376	13.0	13.5	7.0	1,300
T34	2	4/4/2002	1330	na	0.013	na	nd	24	13.0	12.2	6.7	158
T35	2	4/4/2002	1055	na	0.02	na	nd	64	10.0	11.3	7.9	337
T36	2	4/5/2002	1320	na	0.016	na	nd	62	12.5	11.1	7.6	277
T37	2	4/4/2002	1155	na	0.016	na	nd	33	12.0	12.5	8.5	205
T38	2	4/5/2002	835	na	0.016	na	nd	28	9.0	7.5	7.3	154
T39	2	4/5/2002	920	na	0.016	na	nd	35	8.0	8.2	7.8	211
T4	2	4/2/2002	1320	na	0.019	na	nd	20	22.5	16.5	6.7	97
T40	2	4/5/2002	950	na	0.028	na	nd	53	8.0	8.0	7.3	256
T41	2	4/5/2002	1030	na	0.015	na	nd	36	9.0	8.4	7.4	211
T42	2	4/5/2002	1228	na	0.016	na	nd	43	12.5	11.8	8.6	237
T43	2	4/4/2002	1530	na	0.018	na	nd	50	16.5	15.6	9.1	296
T44	2	4/5/2002	1255	na	0.024	na	nd	34	15.0	13.6	8.3	226
T45	2	4/5/2002	810	na	0.02	na	nd	57	7.0	7.3	7.3	294
T46	2	4/5/2002	840	na	0.016	na	nd	192	7.0	8.4	7.9	698
T47	2	4/5/2002	920	na	0.01	na	nd	71	13.0	8.8	8.2	325
T48	2	4/5/2002	855	na	0.019	na	nd	214	9.0	8.1	7.8	857
T49	2	4/5/2002	955	na	0.014	na	nd	59	14.0	9.7	7.2	239
T5	2	4/2/2002	1340	na	0.018	na	nd	19	22.5	16.3	7.5	129
T50	2	4/5/2002	1055	na	0.021	na	nd	275	13.0	10.3	8.2	590
T51	2	4/5/2002	1120	na	0.023	na	nd	78	13.0	9.8	7.1	380
T52	2	4/5/2002	1215	na	0.012	na	nd	182	18.5	11.1	7.5	660
T53	2	4/5/2002	820	na	0.025	na	nd	58	6.0	7.3	7.9	321
T54	2	4/5/2002	1330	na	0.017	na	nd	42	10.5	10.7	7.4	267
T55	2	4/5/2002	940	na	0.037	na	nd	62	8.0	8.0	8.1	376
T56	2	4/5/2002	1005	na	0.023	na	nd	40	8.0	9.3	7.5	248
T57	2	4/5/2002	1300	na	0.028	na	nd	45	10.0	12.1	6.9	258
T6	2	4/2/2002	1045	na	0.015	na	nd	85	15.0	12.2	7.5	398
T7	2	4/2/2002	1335	na	0.01	na	nd	25	20.0	14.7	7.2	156
T8	2	4/2/2002	1410	na	0.019	na	nd	57	21.0	15.3	7.5	278
T9	2	4/2/2002	1030	na	0.025	na	nd	176	19.0	12.6	7.0	674
A1	3	7/8/2002	1100	na	0.028	na	nd	29	29.0	21.7	6.9	207
A11	3	7/9/2002	900	na	0.025	na	nd	28	26.0	22.2	6.9	211
A2	3	7/8/2002	1200	na	0.019	na	nd	30	29.5	22.0	7.2	208
A3	3	7/8/2002	1230	na	0.019	na	nd	36	30.0	21.5	7.2	216
A4	3	7/8/2002	1350	na	0.035	na	nd	38	29.5	23.2	7.2	201
A5	3	7/8/2002	1100	na	0.012	na	nd	37	31.7	24.7	7.2	121
A6	3	7/8/2002	1600	na	0.02	na	nd	26	35.5	25.1	8.5	190
A7	3	7/9/2002	915	na	0.03	na	nd	27	23.2	21.6	7.1	206
A8	3	7/9/2002	1115	na	0.03	na	nd	32	29.3	22.7	6.9	238
A9	3	7/9/2002	835	na	0.028	na	nd	32	24.0	21.9	6.8	235
S12	3	7/9/2002	1230	na	0.05	na	nd	39	31.0	28.0	7.5	403
S13	3	7/9/2002	1100	na	0.026	na	nd	52	27.0	20.5	7.4	337
S15	3	7/9/2002	1210	na	0.026	na	nd	92	21.5	17.8	7.7	413
S17	3	7/9/2002	1035	na	0.113	na	nd	60	34.0	19.5	7.3	160
S18	3	7/9/2002	1145	na	0.146	na	nd	36	28.0	21.0	6.8	309
S19	3	7/9/2002	1240	na	0.034	na	nd	7	37.0	22.0	7.4	92
S20	3	7/9/2002	1235	na	0.026	na	nd	14	37.0	22.0	7.1	162

Dissolved oxygen (mg/L)	Turbidity rem	Turbidity (NTU)	Surfactants (mg/L)	FC rem	Fecal coliform bacteria (col/100 mL)	Dup FC rem	Fecal coliform bacteria duplicate (col/100 mL)	Organics	Discharge rem	Discharge (ft^3/s)
7.9	na	4.8	0.10	na	280	na	nd	nd	e	0.197
11.3	na	3.0	0.20	na	70	na	nd	nd	e	0.285
10.2	na	2.0	0.25	e	5	na	nd	nd	e	0.088
8.9	na	13.0	0.00	na	80	na	nd	nd	e	0.075
13.5	na	9.2	0.10	na	4,300	na	nd	nd	e	0.255
13.1	na	2.0	0.05	e	26	na	nd	nd	e	0.195
13.0	na	1.8	0.10	e	36	na	nd	nd	e	0.274
11.5	na	3.1	0.10	na	3,500	na	nd	nd	e	0.082
14.2	na	1.5	0.10	na	130	na	nd	nd	e	0.229
10.4	na	1.0	0.00	e	21	na	nd	nd	e	0.216
9.8	na	1.8	0.00	na	4,100	e	2,200	nd	e	0.042
12.6	na	3.0	0.10	e	50	e	44	nd	e	0.247
13.9	na	4.1	0.15	e	45	na	nd	nd	e	0.265
15.1	na	0.9	0.10	e	7	e,<	3	nd	e	0.181
12.2	na	3.3	0.10	na	67	na	nd	nd	e	0.175
11.3	na	1.7	0.10	e	45	na	nd	nd	e	0.406
12.3	na	2.2	0.15	e	42	na	nd	nd	e	0.568
12.3	na	1.7	0.10	e	10	na	nd	nd	e	0.024
11.2	na	2.9	0.25	e	3	na	nd	nd	e	0.544
10.9	na	4.9	0.10	na	73	na	nd	nd	e	0.235
10.4	na	1.0	0.00	e	22	na	nd	nd	e	0.216
15.0	na	2.6	0.25	e	40	na	nd	nd	e	0.026
11.4	na	5.4	0.15	e,<	3	na	nd	nd	e	0.1
13.1	na	0.5	0.10	e	52	na	nd	nd	e	0.215
12.7	na	1.7	0.10	e	63	na	nd	nd	e	0.24
11.7	na	1.0	0.00	e	35	na	nd	nd	e	0.069
13.1	na	4.8	0.10	e	28	na	nd	nd	e	0.108
13.4	na	1.2	0.00	na	73	na	nd	nd	e	0.078
8.3	na	1.0	0.00	e	63	na	nd	nd	e	0.092
11.0	na	1.4	0.15	na	150	na	nd	nd	e	0.032
9.7	na	4.1	0.15	e	74	na	nd	nd	e	0.131
10.8	na	3.8	0.10	e	68	na	nd	nd	e	0.348
11.3	na	5.0	0.10	e	52	na	nd	nd	e	0.166
5.3	na	5.1	0.10	na	97	na	nd	nd	e	0.32
3.1	na	8.2	0.25	na	59	na	nd	nd	e	0.221
6.5	na	4.3	0.00	na	77	na	nd	nd	e	0.23
5.9	na	5.0	0.15	na	120	na	nd	nd	e	0.238
6.5	na	4.0	0.10	na	67	na	nd	nd	e	0.298
8.7	na	8.0	0.10	na	600	na	nd	nd	e	0.537
10.7	na	2.5	0.00	na	260	na	nd	nd	e	0.35
6.6	na	3.0	0.10	na	170	na	nd	nd	e	0.274
5.2	na	8.0	0.10	na	190	na	nd	nd	e	0.329
2.0	na	6.4	0.05	na	320	na	nd	nd	e	0.809
nd	na	2.0	0.00	e,<	3	na	nd	yes	e	0.046
nd	na	1.8	0.05	na	160	na	nd	nd	e	0.001
9.2	na	4.7	0.10	na	3,000	na	nd	yes	e	0.023
nd	na	2.6	0.50	e	690	na	nd	nd	e	0.009
nd	na	4.2	0.10	na	2,700	na	nd	nd	e	0.014
nd	na	7.8	0.00	na	4,200	na	nd	nd	e	0.003
nd	na	1.0	0.00	e	7,700	na	nd	nd	e	0.009

Appendix 1. Indicator tracer data from synoptic sampling events for sites sampled in the Accotink Creek watershed, Virginia. — Continued

[rem, remark; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/10 0mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; na, not applicable; nd, not determined]

Site ID	Event	Sampling date	Sampling time	Bo rem	Boron (mg/L)	Br rem	Bromide (mg/L)	Chloride (mg/L)	Air temp	Water temp	pH	Specific conductance (µS/cm)
S22	3	7/9/2002	1350	na	0.035	na	nd	18	39.5	25.9	7.6	208
S24	3	7/9/2002	1410	na	0.018	na	nd	12	23.5	18.0	7.2	230
S29	3	7/9/2002	955	na	0.078	na	nd	23	26.0	21.5	7.5	286
S3	3	7/8/2002	1450	na	0.047	na	nd	33	30.0	21.7	7.5	253
S34	3	7/9/2002	1250	na	0.024	na	nd	119	25.0	20.7	7.5	479
S4	3	7/8/2002	1510	na	0.01	na	nd	76	nd	nd	6.9	362
S5	3	7/8/2002	1530	na	0.013	na	nd	25	27.0	18.0	6.2	209
S52	3	7/8/2002	1345	na	0.115	na	nd	58	30.0	21.5	6.8	455
S7	3	7/8/2002	1630	na	0.039	na	nd	277	30.0	27.2	7.5	1,190
S8	3	7/8/2002	1650	na	0.063	na	nd	65	30.0	20.7	6.9	567
T1	3	7/8/2002	1135	na	0.008	na	nd	37	29.5	20.9	6.7	280
T19	3	7/9/2002	1010	na	0.024	na	nd	44	27.0	20.9	7.1	276
T2	3	7/8/2002	1320	na	0.018	na	nd	35	29.0	22.5	6.7	209
T20	3	7/9/2002	1035	na	0.047	na	nd	33	29.0	21.8	7.0	211
T22	3	7/9/2002	1430	na	0.054	na	nd	46	31.0	27.0	7.6	393
T23	3	7/9/2002	830	na	0.039	na	nd	46	26.0	21.2	7.1	325
T24	3	7/9/2002	1115	na	0.046	na	nd	46	27.0	21.7	7.4	340
T3	3	7/8/2002	1350	na	0.045	na	nd	56	nd	nd	7.0	266
T58	3	7/8/2002	1530	<	0.005	na	nd	141	35.5	22.6	7.1	582
T59	3	7/9/2002	1345	na	0.023	na	nd	7	33.0	22.1	6.7	52
T6	3	7/8/2002	1110	na	0.028	na	nd	68	28.0	20.1	7.2	371
T7	3	7/8/2002	1253	<	0.005	na	nd	21	31.0	nd	7.1	170
T8	3	7/8/2002	1320	na	0.02	na	nd	42	nd	20.9	7.1	215
T9	3	7/8/2002	1218	na	0.017	na	nd	102	35.0	24.9	7.5	485
A11	4	10/22/2002	850	na	0.029	na	0.035	25	9.0	10.6	7.2	183
A12	4	10/23/2002	830	na	0.029	na	0.036	26	8.0	10.5	7.2	195
A13	4	10/23/2002	834	na	0.025	na	0.042	22	8.0	10.8	6.9	158
A14	4	10/23/2002	915	na	0.039	na	0.047	36	10.0	10.9	7.1	226
A15	4	10/23/2002	1025	na	0.027	na	0.051	37	16.0	10.9	7.3	242
A16	4	10/23/2002	1205	na	0.031	na	0.052	45	17.0	11.0	7.5	261
A7	4	10/22/2002	1040	na	0.032	na	0.028	22	13.0	10.8	7.3	160
A8	4	10/22/2002	845	na	0.039	na	0.034	26	9.5	10.5	7.1	171
A9	4	10/22/2002	835	na	0.035	na	0.035	26	10.0	10.6	7.1	179
S12	4	10/22/2002	1230	na	0.036	<	0.002	36	16.0	16.4	7.8	394
S13	4	10/22/2002	1155	na	0.029	na	0.045	92	nd	nd	7.6	286
S15	4	10/22/2002	1250	na	0.024	na	0.085	90	nd	nd	7.4	399
S17	4	10/22/2002	1110	na	0.016	na	0.132	44	12.5	14.5	7.4	286
S18	4	10/22/2002	1225	na	0.032	na	0.090	44	18.0	13.1	6.8	259
S20	4	10/22/2002	1255	na	0.010	na	0.061	15	17.5	17.0	8.1	137
S22	4	10/22/2002	1340	na	0.087	na	0.036	14	nd	nd	7.3	324
S29	4	10/22/2002	1025	na	0.029	na	0.180	150	10.0	14.5	9.7	441
S3	4	10/21/2002	1303	na	0.016	na	0.081	29	15.0	16.0	7.9	233
S31	4	10/23/2002	1043	na	0.036	na	0.038	20	13.0	13.0	7.2	165
S32	4	10/23/2002	1115	na	0.023	na	0.122	15	13.5		6.9	136
S33	4	10/23/2002	1140	na	0.017	na	0.085	24	14.0	14.5	7.2	142
S35	4	10/23/2002	820	na	0.051	na	0.103	62	9.0	16.0	7.4	338
S4	4	10/21/2002	1425	na	0.016	na	0.028	49	16.0	15.0	7.3	259
S41	4	10/24/2002	1200	na	0.025	na	0.114	47	11.0	14.8	6.0	246
S42	4	10/24/2002	1135	na	0.045	na	0.069	46	11.0	12.0	7.3	318
S43	4	10/23/2002	1145	na	0.018	na	0.163	40	15.0	nd	7.7	302

Dissolved oxygen (mg/L)	Turbidity rem	Turbidity (NTU)	Surfactants (mg/L)	FC rem	Fecal coliform bacteria (col/100 mL)	Dup FC rem	Fecal coliform bacteria duplicate (col/100 mL)	Organics	Discharge rem	Discharge (ft^3/s)
6.1	na	nd	0.00	na	190	na	nd	nd	e	0.001
nd	na	2.7	0.10	e	30,000	na	nd	nd	e	0.000
nd	na	26.7	0.35	e,>	50,000	na	nd	nd	e	0.005
10.8	na	1.0	0.00	e	12,000	na	nd	yes	e	0.036
8.5	na	1.2	0.10	na	830	na	nd	nd	e	0.01
nd	na	5.0	0.05	e,<	3	na	nd	nd	e	0.000
6.5	na	2.0	0.15	na	240	na	nd	nd	e	0.015
nd	na	1.0	0.10	na	490	na	nd	nd	e	0.003
7.6	na	1.0	0.25	na	440	na	nd	nd	e	0.535
7.0	na	1.0	0.20	na	3,100	na	nd	nd	e	0.016
7.2	na	10.2	0.00	na	77	na	nd	nd	e	0.011
6.0	na	0.9	0.05	e	59	na	nd	nd	e	0.006
2.3	na	7.0	0.10	na	770	na	nd	nd	e	0.037
5.9	na	0.8	0.05	na	320	na	nd	nd	e	0.06
nd	na	5.0	0.00	na	900	na	nd	nd	e	0.018
5.0	na	5.7	0.10	na	370	na	nd	nd	e	0.466
9.3	na	4.1	0.10	na	4,300	na	nd	yes	e	0.388
nd	na	1.3	0.00	e	9,700	na	nd	nd	e	0.001
9.6	na	4.4	0.00	na	97	na	nd	nd	e	0.001
7.2	na	8.0	0.00	na	1,100	na	nd	nd	e	0.027
6.2	na	1.0	0.10	na	70	na	nd	yes	e	0.024
nd	na	2.0	0.05	na	87	na	nd	nd	e	0.000
7.0	na	2.0	0.10	na	140	na	nd	nd	e	0.013
11.5	na	7.0	0.10	na	700	na	nd	yes	e	0.096
8.5	na	5.0	0.13	na	140	na	185	nd	e	0.926
8.7	na	6.0	0.13	e	200	na	nd	nd	e	0.002
8.4	na	7.0	0.13	na	260	na	nd	nd	e	0.443
8.8	na	5.0	0.25	e	2,100	na	nd	nd	e	0.17
9.5	na	4.0	0.00	na	90	na	nd	yes	e	0.147
10.8	na	3.0	0.13	na	230	na	nd	nd	e	0.279
10.0	na	7.0	0.13	na	290	na	nd	nd	e	1.759
9.0	na	5.0	0.13	na	160	na	nd	nd	e	1.612
8.6	na	5.0	0.13	na	370	na	nd	nd	e	0.563
9.5	na	2.0	0.13	e,<	3	na	nd	nd	e	0.01
nd	na	5.0	0.13	na	470	na	nd	nd	e	0.002
nd	na	1.0	0.13	e	37	e	33	nd	e	0.031
nd	na	1.0	0.13	e	10	na	nd	nd	e	0.002
6.4	na	2.0	0.13	e	2,400	na	1,700	nd	e	0.001
nd	na	1.0	0.00	e	3	e	3	nd	e	0.002
nd	na	4.0	0.13	e	230	na	nd	nd	e	0.000
nd	>	1,000.0	0.00	e	1,750	na	nd	yes	e	0.197
nd	na	2.0	0.00	e	10	na	nd	yes	e	0.002
nd	na	2.0	0.13	e	230	na	390	nd	e	0.004
nd	na	5.0	0.13	e	37	na	nd	nd	e	0.001
nd	na	3.0	0.13	na	80	na	nd	nd	e	0.009
8.2	na	1.0	0.13	na	170	na	130	nd	e	0.023
nd	na	7.0	0.00	na	160	na	nd	nd	e	0.001
4.1	na	1.0	0.13	e	640	na	nd	nd	e	0.028
9.7	na	6.0	0.13	na	1,300	na	nd	nd	e	0.000
nd	na	1.0	0.00	e	35	e	21	nd	e	0.000

Appendix 1. Indicator tracer data from synoptic sampling events for sites sampled in the Accotink Creek watershed, Virginia. — Continued

[rem, remark; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/10 0mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; na, not applicable; nd, not determined]

Site ID	Event	Sampling date	Sampling time	Bo rem	Boron (mg/L)	Br rem	Bromide (mg/L)	Chloride (mg/L)	Air temp	Water temp	pH	Specific conductance (µS/cm)
S44	4	10/23/2002	1305	na	0.127	na	0.119	26	nd	nd	7.0	410
S45	4	10/23/2002	1230	na	0.055	na	0.065	18	17.0	22.5	7.2	260
S46	4	10/24/2002	1040	na	0.055	na	0.037	18	13.0	13.5	7.3	438
S48	4	10/24/2002	903	na	0.039	na	0.186	118	12.5	13.5	7.2	565
S49	4	10/24/2002	1025	na	0.039	na	0.062	51	nd	nd	7.2	380
S5	4	10/21/2002	1320	na	0.026	na	0.081	23	15.5	15.5	6.3	201
S50	4	10/24/2002	1053	na	0.045	na	0.067	71	10.5	14.0	7.1	442
S51	4	10/24/2002	1308	na	0.058	na	0.120	65	10.0	13.9	8.0	414
S52	4	10/21/2002	1230	na	0.141	na	0.039	63	14.5	13.1	7.0	422
S6	4	10/21/2002	1435	na	0.012	<	0.002	5	16.5	nd	7.6	73
S7	4	10/21/2002	1412	na	0.026	na	0.056	22	14.5	14.1	6.7	228
S8	4	10/21/2002	1345	na	0.109	na	0.050	30	13.5	14.8	6.2	313
T1	4	10/21/2002	1210	na	0.018	na	0.039	21	nd	13.1	6.9	179
T10	4	10/21/2002	1510	na	0.043	na	0.035	27	15.0	13.0	6.8	154
T12	4	10/22/2002	810	na	0.029	na	0.055	49	8.0	8.9	7.1	290
T16	4	10/22/2002	1300	na	0.021	na	0.058	15	16.5	11.0	8.4	118
T18	4	10/22/2002	1020	na	0.030	na	0.043	17	11.0	10.4	7.0	125
T19	4	10/22/2002	1105	na	0.058	na	0.294	79	12.0	10.5	7.2	365
T2	4	10/21/2002	1400	na	0.022	na	0.040	24	nd	12.7	6.8	182
T20	4	10/22/2002	1130	na	0.035	na	0.038	23	12.0	10.8	7.0	159
T23	4	10/22/2002	830	na	0.031	na	0.074	39	6.0	10.4	7.2	247
T24	4	10/22/2002	1200	na	0.031	na	0.105	48	12.0	10.9	7.2	321
T25	4	10/22/2002	1320	na	0.029	na	0.042	73	18.5	11.9	7.0	175
T26	4	10/23/2002	810	na	0.027	na	0.030	21	8.5	10.2	7.0	160
T27	4	10/23/2002	920	na	0.022	na	0.050	33	11.0	10.3	6.8	178
T29	4	10/23/2002	1030	na	0.025	na	0.031	61	14.5	11.0	7.2	331
T31	4	10/23/2002	930	na	0.030	na	0.045	40	9.0	10.3	7.0	219
T32	4	10/23/2002	1210	na	0.030	<	0.002	101	12.5	15.5	7.0	440
T33	4	10/23/2002	1300	na	0.100	na	0.052	73	17.0	12.2	6.8	352
T35	4	10/23/2002	840	na	0.038	na	0.065	44	9.0	10.3	7.0	270
T36	4	10/23/2002	1355	na	0.019	na	0.042	30	17.5	11.9	6.8	165
T37	4	10/23/2002	1105	na	0.014	na	0.028	15	15.0	11.3	7.2	118
T38	4	10/24/2002	815	na	0.016	na	0.049	14	13.0	11.9	7.2	103
T39	4	10/24/2002	840	na	0.031	<	0.002	17	13.0	10.5	7.1	132
T4	4	10/21/2002	1440	na	0.036	na	0.039	43	nd	nd	7.3	263
T40	4	10/24/2002	920	na	0.036	<	0.002	20	11.5	10.9	6.9	155
T41	4	10/24/2002	940	na	0.019	na	0.025	17	11.5	11.0	6.8	128
T42	4	10/24/2002	1035	na	0.024	na	0.028	21	10.5	11.3	6.6	154
T43	4	10/23/2002	1240	na	0.028	na	0.057	36	19.0	14.6	7.3	255
T44	4	10/23/2002	1200	na	0.055	na	0.053	25	16.0	11.8	7.2	148
T45	4	10/24/2002	835	na	0.037	na	0.058	37	10.0	11.1	7.2	214
T46	4	10/24/2002	845	na	0.030	na	0.090	124	10.0	10.6	7.4	296
T47	4	10/24/2002	805	na	0.017	na	0.070	62	11.0	10.8	7.3	318
T48	4	10/24/2002	915	na	0.030	na	0.089	89	10.5	10.8	7.4	417
T49	4	10/24/2002	1005	na	0.015	na	0.089	74	11.0	11.2	7.3	284
T50	4	10/24/2002	1105	na	0.024	na	0.093	156	11.0	11.1	7.3	640
T51	4	10/24/2002	1115	na	0.044	na	0.156	101	11.0	12.0	7.2	499
T52	4	10/24/2002	1225	na	0.019	na	0.071	182	11.5	10.7	7.1	167
T53	4	10/24/2002	815	na	0.048	na	0.038	37	10.5	10.6	7.4	252
T55	4	10/24/2002	933	na	0.048	na	0.073	57	12.0	10.6	7.3	331

Dissolved oxygen (mg/L)	Turbidity rem	Turbidity (NTU)	Surfactants (mg/L)	FC rem	Fecal coliform bacteria (col/100 mL)	Dup FC rem	Fecal coliform bacteria duplicate (col/100 mL)	Organics	Discharge rem	Discharge (ft^3/s)
nd	na	1.0	0.13	na	70	na	nd	yes	e	0.000
nd	na	1.0	0.13	e	3	e	3	nd	e	0.005
nd	na	8.0	0.75	na	5,300	na	nd	yes	e	0.000
nd	na	1.0	0.13	e	56	na	nd	yes	e	0.016
nd	na	2.0	0.13	na	520	na	nd	nd	e	0.012
6.8	na	2.0	0.00	na	460	na	nd	nd	e	0.017
nd	na	8.0	0.13	na	570	na	nd	yes	e	0.034
9.7	na	1.0	0.13	na	2,000	na	nd	yes	e	0.032
7.7	na	3.0	0.13	e	210	na	nd	nd	e	0.034
nd	na	7.0	0.25	na	250	na	nd	nd	e	0.002
8.3	na	1.0	0.13	na	160	na	nd	nd	e	0.028
5.4	na	2.0	0.37	na	2,100	na	nd	nd	e	0.004
8.5	na	3.0	0.13	na	130	na	nd	nd	e	0.045
4.3	na	2.0	0.13	na	260	na	nd	nd	e	0.023
10.2	na	1.0	0.13	na	300	na	nd	nd	e	0.026
nd	na	2.0	0.13	na	360	na	nd	yes	e	0.005
11.0	na	3.0	0.13	e	210	na	nd	nd	e	0.157
12.1	na	2.0	0.13	na	360	na	nd	nd	e	0.025
7.4	na	14.0	0.13	na	1,600	na	nd	nd	e	0.049
10.6	na	1.0	0.13	na	190	na	nd	nd	e	0.088
7.6	na	4.0	0.13	na	400	na	nd	nd	e	0.292
8.9	na	4.0	0.25	na	2,200	na	nd	yes	e	0.226
4.3	na	5.0	0.13	na	220	na	nd	nd	e	0.000
8.6	na	6.0	0.13	e	220	na	nd	nd	e	0.141
7.4	na	4.0	0.13	na	870	na	nd	nd	e	0.042
nd	na	2.0	0.13	na	200	na	nd	nd	e	0.002
8.0	na	7.0	0.13	na	260	na	nd	yes	e	0.142
10.0	na	3.0	0.13	e	59	na	nd	nd	e	0.056
7.1	na	1.0	0.13	na	970	na	nd	nd	e	0.019
7.5	na	2.0	0.13	na	770	na	nd	yes	e	0.051
9.4	na	1.0	0.13	na	260	na	nd	nd	e	0.087
9.7	na	2.0	0.13	na	970	na	770	nd	e	0.038
10.0	na	4.0	0.13	na	340	na	nd	nd	e	0.068
9.8	na	1.0	0.13	na	100	na	nd	nd	e	0.062
nd	na	6.0	0.13	na	200	na	nd	yes	e	0.000
9.0	na	1.0	0.13	e	65	na	nd	nd	e	0.025
8.5	na	1.0	0.13	na	240	na	nd	nd	e	0.011
4.7	na	1.0	0.13	na	300	na	nd	nd	e	0.074
11.3	na	10.0	0.13	na	550	na	nd	nd	e	0.157
8.3	na	1.0	0.13	na	370	na	300	nd	e	0.023
9.2	na	1.0	0.13	e	220	na	nd	nd	e	0.304
9.4	na	2.0	0.13	na	80	na	nd	nd	e	0.161
9.1	na	1.0	0.13	na	170	na	nd	yes	e	0.007
9.7	na	3.0	0.13	na	100	na	nd	nd	e	0.154
9.2	na	3.0	0.13	na	900	na	nd	nd	e	0.092
9.5	na	4.0	0.13	na	800	na	nd	yes	e	0.01
7.3	na	3.0	0.50	na	560	na	nd	yes	e	0.025
9.7	na	3.0	0.25	na	170	na	nd	nd	e	0.062
9.9	na	1.0	0.13	na	830	na	nd	nd	e	0.312
9.6	na	1.0	0.13	na	550	na	nd	nd	e	0.049

Appendix 1. Indicator tracer data from synoptic sampling events for sites sampled in the Accotink Creek watershed, Virginia. — Continued

[rem, remark; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/10 0mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; na, not applicable; nd, not determined]

Site ID	Event	Sampling date	Sampling time	Bo rem	Boron (mg/L)	Br rem	Bromide (mg/L)	Chloride (mg/L)	Air temp	Water temp	pH	Specific conductance (µS/cm)
T56	4	10/24/2002	957	na	0.040	na	0.027	34	9.5	11.9	7.4	298
T57	4	10/24/2002	1212	na	0.032	na	0.085	40	11.0	15.5	6.6	241
T6	4	10/21/2002	1104	na	0.020	na	0.082	44	14.5	12.0	7.2	270
T7	4	10/21/2002	1240	na	0.018	na	0.032	15	16.0	12.1	6.7	115
T8	4	10/21/2002	1300	na	0.028	na	0.037	40	16.5	12.1	7.2	189
T9	4	10/21/2002	1525	na	0.033	na	0.078	60	16.5	12.5	7.2	339
A1	5	4/14/2003	1020	na	0.028	na	0.069	73	13.0	11.4	7.4	372
A11	5	4/15/2003	746	na	0.035	na	0.073	87	10.5	12.9	7.2	427
A12	5	4/16/2003	826	na	0.027	na	0.054	103	19.0	15.5	7.0	467
A13	5	4/16/2003	846	na	0.027	na	0.073	106	21.0	15.0	7.3	450
A13A	5	4/16/2003	1144	na	0.055	na	0.081	118	30.0	16.2	8.1	402
A14	5	4/16/2003	940	na	0.019	na	0.066	105	21.5	15.4	7.5	458
A14A	5	4/16/2003	1400	na	0.019	na	0.047	99	34.0	18.1	8.7	427
A15	5	4/16/2003	1520	na	0.036	na	0.061	106	31.0	18.5	8.7	151
A15A1	5	4/16/2003	1710	na	0.02	na	0.084	115	29.0	19.9	8.7	477
A15A2	5	4/16/2003	1815	na	0.025	na	0.087	120	26.5	19.6	8.4	487
A16	5	4/17/2003	844	na	0.022	na	0.087	140	15.0	14.3	7.2	579
A2	5	4/14/2003	1110	na	0.022	na	0.068	76	20.0	12.0	7.8	372
A3	5	4/14/2003	1120	na	0.01	na	0.076	78	22.5	11.9	7.5	369
A4	5	4/14/2003	1220	na	0.009	na	0.08	79	29.0	13.2	8.1	372
A5	5	4/14/2003	1430	na	0.014	na	0.081	77	30.5	15.2	8.3	359
A6	5	4/14/2003	1540	na	0.010	na	0.083	77	21.0	15.0	8.7	366
A7	5	4/14/2003	1650	na	0.011	na	0.083	78	20.0	15.1	8.1	368
A8	5	4/14/2003	1610	na	0.015	na	0.076	77	22.0	15.3	8.0	386
A9	5	4/15/2003	945	na	0.022	na	0.163	85	21.0	13.1	7.1	399
S1	5	4/14/2003	1028	na	0.003	na	0.045	61	11.5	11.3	7.1	334
S11	5	4/14/2003	1415	na	0.01	na	0.065	38	24.0	16.2	7.0	161
S13	5	4/15/2003	1240	<	0.005	na	0.085	36	32.0	12.4	6.8	251
S14	5	4/15/2003	1320	na	0.012	na	0.049	44	30.5	11.9	7.0	221
S15	5	4/15/2003	1357	na	0.017	na	0.129	75	28.5	12.2	6.7	303
S16	5	4/15/2003	925	na	0.022	na	0.063	45	16.0	10.6	6.5	255
S17	5	4/15/2003	1030	na	0.039	na	0.16	83	22.5	14.0	6.7	501
S18	5	4/15/2003	720	na	0.032	na	0.11	139	12.0	12.7	6.6	528
S19	5	4/15/2003	1130	na	0.022	na	0.016	36	24.5	nd	7.0	263
S2	5	4/14/2003	1225	na	0.009	na	0.031	124	19.0	11.8	6.6	539
S20	5	4/15/2003	1110	na	0.009	na	0.079	39	24.5	nd	6.6	208
S21	5	4/15/2003	1115	na	0.158	na	0.138	1,500	23.0	14.4	8.3	3,080
S22	5	4/15/2003	1159	na	0.032	na	0.045	54	28.0	13.1	7.3	285
S23	5	4/15/2003	1220	na	0.01	na	0.048	20	16.0	10.8	6.6	171
S24	5	4/15/2003	1215	na	0.018	na	0.052	49	16.0	11.0	8.4	273
S25	5	4/16/2003	1115	na	0.038	na	0.037	21	28.0	14.2	6.1	133
S26	5	4/16/2003	1055	<	0.005	na	0.106	25	23.0	13.8	7.0	214
S27	5	4/16/2003	1405	na	0.015	na	0.065	37	24.5	11.0	6.4	206
S28	5	4/16/2003	1336	na	0.011	na	0.049	34	20.5	10.8	7.1	221
S29	5	4/15/2003	955	na	0.013	na	0.059	27	16.5	13.2	6.4	200
S3	5	4/14/2003	1210	na	0.008	na	0.08	83	20.5	13.5	7.0	386
S30	5	4/16/2003	1445	na	0.026	na	0.106	59	25.5	15.5	6.6	282
S31	5	4/16/2003	1415	na	0.029	na	0.038	34	29.0	14.0	6.4	168
S32	5	4/16/2003	1346	na	0.032	na	0.119	51	28.5	11.5	6.2	261
S33	5	4/16/2003	1315	na	0.028	na	0.09	68	31.5	13.0	6.3	265

Dissolved oxygen (mg/L)	Turbidity rem	Turbidity (NTU)	Surfactants (mg/L)	FC rem	Fecal coliform bacteria (col/100 mL)	Dup FC rem	Fecal coliform bacteria duplicate (col/100 mL)	Organics	Discharge rem	Discharge (ft^3/s)
9.4	na	2.0	0.13	na	145	na	nd	nd	e	0.229
6.4	na	1.0	0.13	na	110	na	nd	nd	e	0.012
8.5	na	1.0	0.13	na	100	na	nd	nd	e	0.034
8.7	na	1.0	0.13	na	510	na	nd	nd	e	0.015
9.7	na	2.0	0.13	na	350	na	nd	nd	e	0.046
9.3	na	1.0	0.13	na	90	na	nd	yes	e	0.095
11.0	na	5.0	0.25	e	28	na	nd	nd	e	19.8
8.7	na	4.0	0.13	na	180	na	nd	nd	e	8.775
7.8	na	4.0	0.13	na	133	na	nd	nd	e	2.207
8.9	na	6.0	0.13	na	490	na	nd	yes	e	5.242
12.9	na	5.0	0.13	na	162	na	nd	nd	e	5.431
12.1	na	5.0	0.13	na	70	na	nd	yes	e	4.812
14.1	na	3.0	0.13	na	147	na	nd	nd	e	3.888
14.6	na	5.0	0.13	na	420	na	340	yes	e	4.134
13.8	na	3.0	0.13	na	93	na	nd	nd	e	3.065
12.7	na	3.0	0.13	na	190	na	nd	nd	e	3.939
9.9	na	3.0	0.13	na	193	na	nd	yes	e	2.095
11.3	na	5.0	0.13	e	22	na	nd	nd	e	15.498
11.2	na	4.0	0.13	e	33	na	nd	nd	e	15.548
11.8	na	3.0	0.13	e	37	na	nd	nd	e	16.123
12.8	na	3.0	0.13	e	23	na	nd	nd	e	15.22
12.5	na	3.0	0.25	e	30	na	nd	nd	e	13.67
12.2	na	4.0	0.25	e	51	na	nd	nd	e	12.66
11.8	na	5.0	0.13	e	67	na	nd	nd	e	12.471
10.6	na	6.0	0.13	na	205	na	nd	nd	e	11.08
9.8	na	2.0	0.13	e	44	na	nd	nd	e	0.142
7.6	na	4.0	0.13	e	22	na	nd	nd	e	0.009
10.1	na	62.0	0.13	e	23,500	na	nd	nd	e	0.016
10.5	na	1.0	0.13	e	20	na	nd	nd	e	0.046
9.7	na	3.0	0.13	na	73	na	nd	yes	e	0.394
9.9	na	9.0	0.13	na	250	na	nd	nd	e	0.045
7.0	na	5.0	0.13	e	814	na	nd	nd	e	0.032
7.4	na	3.0	0.13	e,<	3	na	nd	yes	e	0.058
8.0	na	7.0	0.13	e	29	na	nd	nd	e	0.000
9.1	na	6.0	0.13	e	30	na	nd	nd	e	0.001
8.0	na	1.0	0.13	e,<	3	na	nd	yes	e	0.036
7.8	na	1.0	0.25	e	35	na	nd	nd	e	0.000
8.5	na	3.0	0.13	e	10	na	nd	nd	e	0.089
10.0	na	2.0	0.13	na	310	na	nd	yes	e	0.066
9.0	na	6.0	0.13	na	93	na	nd	nd	e	0.143
14.1	na	2.0	0.13	e	10	na	nd	nd	e	0.021
9.8	na	6.0	0.13	na	127	na	nd	nd	e	0.029
8.0	na	1.0	0.13	e	3	na	nd	nd	e	0.018
10.3	na	3.0	0.13	e	10	e	30	nd	e	0.119
7.3	na	2.0	0.13	na	77	na	nd	yes	e	0.060
9.1	na	7.0	0.13	e	5	na	nd	nd	e	0.043
9.7	na	1.0	0.13	e	40	na	nd	nd	e	0.130
5.0	na	2.0	0.25	e	9	na	nd	nd	e	0.010
5.0	na	2.0	0.13	e<	3	na	nd	nd	e	0.000
8.0	na	1.0	0.13	e,<	3	na	nd	nd	e	0.014

Appendix 1. Indicator tracer data from synoptic sampling events for sites sampled in the Accotink Creek watershed, Virginia. — Continued

[rem, remark; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/10 0mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; na, not applicable; nd, not determined]

Site ID	Event	Sampling date	Sampling time	Bo rem	Boron (mg/L)	Br rem	Bromide (mg/L)	Chloride (mg/L)	Air temp	Water temp	pH	Specific conductance (µS/cm)
S34	5	4/16/2003	1115	na	0.018	na	0.044	44	27.0	11.8	7.0	189
S35	5	4/16/2003	820	na	0.596	na	0.03	370	22.0	nd	nd	nd
S35	5	4/16/2003	825	na	0.618	na	0.026	385	22.0	12.3	9.6	1,511
S36	5	4/16/2003	1020	na	0.049	na	0.179	306	26.0	16.0	6.4	1,127
S37	5	4/16/2003	1725	na	0.013	na	0.071	14	31.5	12.2	7.0	131
S38	5	4/17/2003	1140	na	0.014	na	0.041	86	15.5	12.2	6.8	355
S39	5	4/17/2003	940	na	0.008	na	0.055	63	14.5	11.1	6.9	289
S40	5	4/17/2003	1010	na	0.007	na	0.034	29	14.5	12.0	7.0	178
S41	5	4/17/2003	1110	na	0.019	na	0.089	80	14.5	12.3	6.2	357
S42	5	4/17/2003	1040	na	0.031	na	0.101	110	16.5	11.7	7.6	508
S44	5	4/17/2003	907	na	0.058	na	0.101	56	14.5	11.6	7.5	329
S46	5	4/17/2003	1000	na	0.035	na	0.031	136	14.0	11.4	6.9	614
S47	5	4/17/2003	1115	na	0.026	na	0.082	316	12.0	12.4	7.7	1,164
S48	5	4/17/2003	1034	na	nd	na	nd	nd	15.5	12.0	nd	nd
S49	5	4/17/2003	1200	na	0.047	na	0.518	283	19.0	14.5	nd	nd
S5	5	4/14/2003	1307	na	0.012	na	0.073	38	24.0	12.8	6.4	267
S50	5	4/17/2003	1301	na	0.030	na	0.223	164	18.0	12.0	nd	nd
S51	5	4/17/2003	1334	na	0.033	na	0.132	109	16.0	12.0	7.7	563
S52	5	4/14/2003	1129	na	0.014	na	0.049	52	19.5	12.8	7.2	215
S6	5	4/14/2003	1235	na	0.021	na	0.021	144	22.0	nd	7.0	588
S7	5	4/14/2003	1427	na	0.007	na	0.078	69	25.5	12.7	6.8	383
S8	5	4/14/2003	1408	na	0.003	na	0.048	30	25.5	14.3	6.4	253
S9	5	4/14/2003	1730	na	0.004	na	0.049	23	21.0	nd	6.4	178
T1	5	4/14/2003	1055	na	0.017	na	0.037	36	20.0	13.6	7.2	216
T11	5	4/14/2003	1458	na	0.012	na	0.076	41	26.5	16.4	7.3	219
T12	5	4/14/2003	1524	na	0.011	na	0.081	45	24.5	16.3	8.0	257
T13	5	4/14/2003	1725	na	0.007	na	0.085	64	22.0	15.2	7.2	318
T13A	5	4/14/2003	1630	na	0.010	na	0.082	53	24.0	15.3	7.0	266
T14	5	4/14/2003	1510	na	0.008	na	0.073	15	23.0	15.0	7.1	58
T15	5	4/14/2003	1500	na	0.010	na	0.028	35	23.0	24.5	7.2	167
T17	5	4/14/2003	1545	na	0.010	na	0.045	28	28.5	12.2	6.7	165
T18	5	4/15/2003	1045	na	0.021	na	0.083	113	25.5	13.0	7.1	263
T19	5	4/15/2003	1150	na	0.024	na	0.106	62	26.0	13.6	6.8	289
T2	5	4/14/2003	1256	na	0.030	na	0.019	352	21.0	15.1	7.1	1,375
T20	5	4/15/2003	1155	na	0.024	na	0.08	67	26.0	14.0	7.1	355
T22	5	4/15/2003	920	na	0.020	na	0.907	35	18.0	12.0	7.0	237
T23	5	4/15/2003	735	na	0.027	na	0.1	77	10.5	12.0	6.9	394
T24	5	4/15/2003	730	na	0.021	na	0.1	81	11.0	11.1	6.7	399
T24A1	5	4/15/2003	920	na	0.023	na	0.07	164	17.0	11.5	7.1	440
T24A2	5	4/15/2003	1019	na	0.022	na	0.063	95	25.0	12.4	7.1	428
T25	5	4/15/2003	1110	na	0.019	na	0.059	93	23.0	12.7	7.4	382
T25A	5	4/15/2003	1244	na	0.015	na	0.051	33	32.5	15.7	8.6	205
T26	5	4/16/2003	835	na	0.025	na	0.076	92	19.0	15.2	7.3	428
T27	5	4/16/2003	1146	na	0.015	na	0.067	59	28.0	15.5	7.0	294
T28	5	4/16/2003	1310	na	0.011	na	0.054	35	28.0	17.5	7.4	211
T29	5	4/16/2003	1254	na	0.025	na	0.072	49	29.5	16.8	7.4	274
T3	5	4/14/2003	1330	na	0.038	na	0.121	66	22.5	16.5	6.5	150
T31	5	4/16/2003	1015	na	0.018	na	0.046	112	25.5	15.3	7.1	457
T32	5	4/16/2003	1457	na	0.024	na	0.082	147	30.0	18.0	7.4	262
T33	5	4/16/2003	1621	na	0.019	na	0.122	76	29.0	17.8	7.3	372

Dissolved oxygen (mg/L)	Turbidity rem	Turbidity (NTU)	Surfactants (mg/L)	FC rem	Fecal coliform bacteria (col/100 mL)	Dup FC rem	Fecal coliform bacteria duplicate (col/100 mL)	Organics	Discharge rem	Discharge (ft^3/s)
11.5	na	16.0	0.13	e	30	na	nd	nd	e	0.110
nd	na	2.0	0.13	na	110	na	nd	yes	na	nd
11.1	na	32.0	0.25	na	492	na	nd	Not sent	na	nd
4.6	na	53.0	0.13	e	3	na	nd	nd	e	0.021
10.3	na	1.0	0.13	na	2,600	na	2,100	yes	e	0.067
9.3	na	30.0	0.13	e	10	e	23	nd	e	0.055
10.5	na	4.0	0.13	e	8,100	na	nd	nd	e	0.034
nd	na	2.0	0.13	e,<	3	na	nd	blank	e	0.004
8.4	na	2.0	0.13	na	1,233	na	nd	yes	e	0.09
11.1	na	2.0	0.13	na	520	na	nd	yes	e	0.183
9.0	na	2.0	0.13	na	177	na	nd	yes	e	0.013
8.3	na	2.0	0.13	e	7	na	nd	yes	e	0.003
10.3	na	2.0	0.13	na	290	na	nd	nd	e	0.135
9.0	na	9.0	0.13	na	77	na	nd	yes	e	0.043
6.0	na	3.0	0.25	e	28	na	nd	nd	e	0.026
7.6	na	15.0	0.37	na	230	na	nd	nd	e	0.065
7.0	na	7.0	0.13	e	100	e	45	yes	e	0.101
10.4	na	3.0	0.13	na	340	na	320	yes	e	0.093
10.8	na	2.0	0.25	e	64	na	nd	nd	e	0.047
7.0	na	15.0	0.37	e	15	na	nd	nd	e	0.001
9.1	na	3.0	0.13	na	546	na	nd	nd	e	0.104
7.7	na	2.0	0.25	e	8	na	nd	yes	e	0.011
8.0	na	2.0	0.25	e	15	na	nd	nd	e	0.011
10.8	na	10.0	0.25	e	32	na	nd	nd	e	1.423
10.1	na	2.0	0.13	e	53	na	nd	nd	e	0.771
10.4	na	1.0	0.13	na	162	na	nd	nd	e	0.392
9.7	na	2.0	0.13	na	87	na	nd	yes	e	0.299
9.3	na	4.0	0.13	na	123	na	nd	yes	e	0.257
8.8	na	6.0	0.13	e	20	na	nd	nd	e	0.17
10.0	na	6.0	0.13	e	7	na	nd	nd	e	0.000
9.2	na	7.0	0.13	e	49	na	nd	nd	e	0.148
10.7	na	5.0	0.13	na	167	na	nd	nd	e	1.59
10.2	na	3.0	0.13	na	73	na	nd	nd	e	0.395
10.1	na	30.0	0.37	e	163	na	nd	nd	e	0.730
11.0	na	2.0	0.13	na	103	na	nd	nd	e	1.11
10.3	na	4.0	0.13	na	192	na	nd	yes	e	0.446
8.4	na	3.0	0.13	na	260	na	nd	nd	e	1.709
8.9	na	3.0	0.13	na	350	na	nd	yes	e	1.42
10.2	na	2.0	0.13	na	600	na	nd	nd	e	0.788
11.2	na	3.0	0.13	na	250	na	nd	nd	e	0.623
12.3	na	3.0	0.13	na	208	na	nd	nd	e	1.009
12.5	na	6.0	0.13	na	470	na	nd	nd	e	0.314
8.7	na	4.0	0.13	na	123	na	nd	nd	e	6.449
11.5	na	3.0	0.13	na	120	na	nd	nd	e	0.807
11.4	na	2.0	0.13	e	7	na	nd	nd	e	0.234
12.0	na	3.0	0.13	na	350	na	400	nd	e	0.357
9.7	na	2.0	0.13	e	21	na	nd	nd	e	0.135
8.9	na	5.0	0.13	na	93	na	nd	yes	e	0.674
14.2	na	5.0	0.13	na	70	na	nd	nd	e	0.502
10.2	na	2.0	0.13	na	107	e	154	yes	e	0.109

Appendix 1. Indicator tracer data from synoptic sampling events for sites sampled in the Accotink Creek watershed, Virginia. — Continued

[rem, remark; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/10 0mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; na, not applicable; nd, not determined]

Site ID	Event	Sampling date	Sampling time	Bo rem	Boron (mg/L)	Br rem	Bromide (mg/L)	Chloride (mg/L)	Air temp	Water temp	pH	Specific conductance (µS/cm)
T34	5	4/16/2003	1600	na	0.015	na	0.298	60	30.0	17.6	6.9	245
T35	5	4/16/2003	900	na	0.026	na	0.07	77	22.0	13.7	7.3	343
T35A	5	4/16/2003	1110	na	0.017	na	0.073	69	29.0	14.0	7.2	327
T36	5	4/16/2003	1235	na	0.020	na	0.058	62	32.0	16.7	7.2	282
T36	5	4/17/2003	1420	na	0.033	na	0.062	58	13.0	14.3	7.5	284
T37	5	4/16/2003	1550	na	0.014	na	0.062	56	34.0	20.4	9.1	273
T38	5	4/17/2003	825	na	0.008	na	0.055	29	11.0	12.1	6.6	154
T39	5	4/17/2003	840	na	0.019	na	0.067	67	11.0	13.7	7.0	315
T40	5	4/17/2003	900	na	0.026	na	0.062	77	11.0	13.6	7.2	335
T41	5	4/17/2003	915	na	0.018	na	0.073	71	11.0	14.0	7.5	342
T43	5	4/17/2003	855	na	0.022	na	0.057	85	15.0	13.1	7.4	369
T44	5	4/16/2003	1540	na	0.024	na	0.054	33	27.0	17.8	8.4	230
T45	5	4/17/2003	850	na	0.033	na	0.09	80	11.0	14.0	7.1	410
T46	5	4/17/2003	855	na	0.027	na	0.083	188	11.0	14.1	7.5	780
T47	5	4/17/2003	930	na	0.024	na	0.063	212	12.0	13.8	7.7	882
T48	5	4/17/2003	915	na	0.024	na	0.094	185	12.0	14.2	7.3	744
T50	5	4/17/2003	1015	na	0.023	na	0.08	244	21.0	13.9	7.3	959
T51	5	4/17/2003	1030	na	0.026	na	0.123	88	15.5	13.0	7.4	436
T51A	5	4/17/2003	1300	na	0.029	na	0.106	78	17.5	13.6	7.3	409
T52	5	4/17/2003	1135	na	0.017	na	0.078	256	17.5	13.3	7.3	965
T53	5	4/17/2003	945	na	0.025	na	0.09	77	18.0	13.7	7.7	369
T54	5	4/17/2003	1200	na	0.017	na	0.068	51	13.5	14.4	8.0	322
T55	5	4/17/2003	1113	na	0.033	na	0.114	108	17.0	14.0	8.5	495
T56	5	4/17/2003	1125	na	0.022	na	0.049	45	17.5	13.0	7.3	256
T6	5	4/14/2003	1025	na	0.008	na	0.092	133	15.0	10.7	7.5	476
T60	5	4/16/2003	1005	na	0.014	na	0.07	53	21.0	15.2	7.4	272
T7	5	4/14/2003	1130	<	0.005	na	0.06	44	28.0	12.6	7.0	224
T8	5	4/14/2003	1150	na	0.008	na	0.058	66	23.5	12.8	7.3	303
T9	5	4/14/2003	1400	na	0.009	na	0.121	143	29.5	12.8	7.0	420
A1	6	11/10/2003	1119	na	0.022	na	0.103	38	8.0	7.5	7.3	247
A11	6	11/11/2003	935	na	0.016	na	0.094	52	11.5	7.7	7.1	298
A12	6	11/11/2003	1120	na	0.020	na	0.096	56	14.5	8.4	6.6	328
A13	6	11/11/2003	1610	na	0.016	na	0.096	59	nd	9.4	6.8	335
A2	6	11/10/2003	1203	na	0.019	na	0.105	40	11.5	8.1	7.3	256
A3	6	11/10/2003	1055	na	0.035	na	0.106	44	5.0	7.0	6.2	269
A5	6	11/10/2003	1220	na	0.025	na	0.107	40	13.5	7.8	6.7	271
A6	6	11/10/2003	1355	na	0.022	na	0.106	40	10.0	7.8	6.7	272
A7	6	11/10/2003	1700	na	0.018	na	0.097	41	12.0	7.9	7.2	261
A8	6	11/10/2003	1538	na	0.023	na	0.111	44	11.5	8.2	7.1	270
A9	6	11/10/2003	1715	na	0.009	na	0.099	45	5.0	8.0	7.1	280
S13	6	11/10/2003	1550	na	0.025	na	0.112	20	10.0	12.0	7.1	238
S15	6	11/10/2003	1625	na	0.019	na	0.139	61	8.5	13.8	6.9	311
S18	6	11/11/2003	1040	na	0.021	na	0.130	101	14.0	14.5	6.5	445
S20	6	11/11/2003	1250	<	0.005	na	0.078	15	13.0	6.5	7.8	146
S22	6	11/11/2003	1410	na	0.048	na	0.106	226	nd	12.1	7.4	864
S23	6	11/11/2003	1515	na	0.008	na	0.079	13	13.0	13.6	7.1	152
S24	6	11/11/2003	1525	na	0.007	na	0.089	25	14.0	13.3	7.1	196
S27	6	11/11/2003	1440	na	0.005	na	0.092	13	15.0	13.5	7.1	163
S28	6	11/11/2003	1410	na	0.008	na	0.074	23	14.0	13.4	7.2	202
S29	6	11/11/2003	915	na	0.018	na	0.079	29	10.0	14.9	6.4	214

Dissolved oxygen (mg/L)	Turbidity rem	Turbidity (NTU)	Surfactants (mg/L)	FC rem	Fecal coliform bacteria (col/100 mL)	Dup FC rem	Fecal coliform bacteria duplicate (col/100 mL)	Organics	Discharge rem	Discharge (ft^3/s)
11.1	na	3.0	0.13	e	28	e	22	nd	e	0.202
10.5	na	2.0	0.13	na	3,500	na	nd	yes	e	0.425
10.2	na	2.0	0.13	e	1,700	na	nd	nd	e	0.430
13.0	na	2.0	0.13	e	60	na	nd	yes	e	0.335
14.0	na	2.0	0.13	e	41	e	48	nd	e	0.328
12.4	na	3.0	0.13	e	24	na	nd	nd	e	1.097
10.8	na	4.0	0.13	na	210	na	nd	nd	e	0.254
11.7	na	3.0	0.13	e	66	na	nd	nd	e	0.646
9.7	na	4.0	0.13	e	61	na	nd	yes	e	0.113
12.0	na	2.0	0.13	na	127	na	nd	nd	e	0.370
11.5	na	2.0	0.13	na	450	na	nd	blank	e	0.407
12.2	na	3.0	0.13	na	230	na	nd	nd	e	0.395
9.9	na	2.0	0.13	e	18	na	nd	blank	e	1.142
10.4	na	3.0	0.13	na	580	na	nd	nd	e	1.337
11.3	na	6.0	0.13	e	11,400	na	nd	nd	e	0.372
9.3	na	5.0	0.13	na	400	na	nd	yes	e	0.965
11.3	na	3.0	0.13	na	210	na	nd	yes	e	0.497
11.3	na	2.0	0.13	na	140	na	nd	yes	e	0.340
10.6	na	24.0	2.50	na	4,800	na	nd	nd	e	0.203
12.5	na	2.0	0.13	e	205	na	nd	nd	e	0.51
11.8	na	3.0	0.13	na	67	na	nd	nd	e	0.853
15.3	na	2.0	0.13	e	28	e	20	nd	e	0.113
13.2	na	2.0	0.13	na	73	na	nd	yes	e	5.444
11.4	na	2.0	0.13	na	380	e	311	yes	e	2.723
11.0	na	2.0	0.13	na	77	na	nd	nd	e	0.113
10.2	na	4.0	0.13	na	183	na	nd	nd	e	1.214
10.9	na	2.0	0.13	e	10	na	nd	nd	e	0.339
11.3	na	3.0	0.25	na	100	na	nd	nd	e	0.547
10.8	na	4.0	0.13	e	26	na	nd	yes	e	0.433
12.1	na	6.0	0.13	na	90	na	nd	nd	e	19
14.0	na	5.0	0.13	na	198	na	nd	nd	e	6.582
11.9	na	5.0	0.13	na	200	na	nd	nd	e	5.02
10.4	na	4.0	0.13	na	400	na	nd	yes	e	4.217
10.7	na	6.0	0.13	na	93	na	nd	nd	e	13.94
nd	na	6.0	0.13	na	80	na	nd	nd	e	11.95
nd	na	7.0	0.13	na	200	na	nd	nd	e	12.211
11.1	na	6.0	0.13	na	180	na	nd	nd	e	10.646
11.0	na	7.0	0.13	na	260	na	nd	nd	e	8.753
10.6	na	6.0	0.13	na	330	na	nd	nd	e	10.66
11.1	na	5.0	0.25	na	180	na	nd	nd	e	8.999
nd	na	5.0	0.13	e	32	na	nd	nd	e	0.011
9.7	na	3.0	0.13	na	70	na	93	nd	e	0.368
7.7	na	1.0	0.25	na	155	na	nd	yes	e	0.026
7.0	na	1.0	0.13	na	1,267	na	nd	yes	e	0.029
11.3	na	2.0	0.25	e	220	na	nd	nd	e	0.023
12.9	na	1.0	0.25	na	145	na	nd	nd	e	0.067
13.6	na	3.0	0.13	na	157	na	nd	nd	e	0.136
9.6	na	1.0	0.13	na	100	na	nd	nd	e	0.015
10.1	na	2.0	0.13	na	200	na	nd	nd	e	0.118
9.9	na	2.0	0.13	na	3,600	na	nd	yes	e	0.064

Appendix 1. Indicator tracer data from synoptic sampling events for sites sampled in the Accotink Creek watershed, Virginia. — Continued

[rem, remark; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/10 0mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; na, not applicable; nd, not determined]

Site ID	Event	Sampling date	Sampling time	Bo rem	Boron (mg/L)	Br rem	Bromide (mg/L)	Chloride (mg/L)	Air temp	Water temp	pH	Specific conductance (µS/cm)
S3	6	11/10/2003	1200	na	0.006	na	0.113	39	14.0	13.9	7.0	274
S31	6	11/11/2003	1635	na	0.021	na	0.066	20	15.0	13.9	6.5	132
S32	6	11/11/2003	1720	na	0.018	na	0.166	19	13.5	nd	6.8	191
S5	6	11/10/2003	1305	na	0.014	na	0.117	25	14.0	13.8	6.7	216
S52	6	11/10/2003	1125	na	0.024	na	0.082	40	17.0	8.0	6.7	167
S6	6	11/10/2003	1230	na	0.008	na	0.044	5	13.0	nd	7.1	139
S7	6	11/10/2003	1345	na	0.009	na	0.111	27	13.0	12.6	6.9	234
S8	6	11/10/2003	1415	na	0.01	na	0.079	30	12.5	13.8	6.4	281
T1	6	11/10/2003	1158	na	0.018	na	0.065	9	11.5	11.8	6.9	138
T12	6	11/10/2003	1500	na	0.015	na	0.109	31	13.0	8.1	7.2	227
T13	6	11/10/2003	1645	na	0.012	na	0.146	52	12.0	8.8	7.2	267
T13A	6	11/10/2003	1545	na	0.013	na	0.154	52	12.5	10.2	7.0	159
T19	6	11/10/2003	1530	na	0.023	na	0.139	47	12.5	9.5	6.9	285
T2	6	11/10/2003	1434	na	0.019	na	0.110	26	13.5	8.9	7.1	195
T22	6	11/11/2003	835	na	0.023	na	0.151	28	10.0	8.7	6.3	207
T23	6	11/11/2003	835	na	0.015	na	0.114	51	8.0	7.8	7.1	301
T23A1	6	11/11/2003	840	na	0.015	na	0.115	53	9.0	8.3	6.7	207
T23A2	6	11/11/2003	920	na	0.014	na	0.116	53	11.0	9.0	6.8	310
T24	6	11/11/2003	1133	na	0.013	na	0.110	51	14.0	10.2	7.0	302
T24A1	6	11/11/2003	1105	na	0.014	na	0.107	65	14.0	9.2	6.9	340
T24A2	6	11/11/2003	1235	na	0.014	na	0.094	61	14.0	9.8	6.9	322
T24B1	6	11/11/2003	1200	na	0.016	na	0.097	68	12.5	9.8	7.1	273
T25	6	11/11/2003	1345	na	0.013	na	0.091	59	16.0	9.9	7.1	302
T25A	6	11/11/2003	1420	na	0.011	na	0.084	20	16.0	10.9	7.2	140
T27	6	11/11/2003	1240	na	0.017	na	0.090	42	12.0	9.5	6.4	260
T27A	6	11/11/2003	1330	na	0.013	na	0.094	46	15.5	10.0	6.5	277
T31	6	11/11/2003	1530	na	0.027	na	0.099	71	14.0	9.7	6.6	352
T31A1	6	11/11/2003	1600	na	0.016	na	0.106	72	16.0	10.5	6.9	310
T31A2	6	11/11/2003	1655	na	0.020	na	0.102	84	15.0	11.2	6.8	287
T32	6	11/11/2003	1635	na	0.023	na	0.094	84	14.0	11.8	6.8	389
T33	6	11/11/2003	1705	na	0.017	na	0.134	59	11.0	10.8	7.1	345
T60	6	11/11/2003	1045	na	0.017	na	0.092	37	12.5	8.2	6.4	241
T7	6	11/10/2003	1110	na	0.015	na	0.104	30	5.0	7.6	6.7	204
T9	6	11/10/2003	1230	na	0.021	na	0.159	71	13.5	8.7	6.7	393
A1	7	2/17/2004	1105	na	0.016	na	0.092	102	nd	1.7	7.4	458
A11	7	2/18/2004	920	na	0.013	na	0.096	112	2.0	2.0	7.3	513
A12	7	2/18/2004	1120	na	0.013	na	0.11	123	7.5	2.6	7.3	539
A13	7	2/18/2004	1605	na	0.017	na	0.104	116	6.0	4.4	7.4	512
A13A	7	2/19/2004	935	na	0.015	na	0.087	114	10.0	2.7	nd	500
A13B	7	2/19/2004	838	na	0.016	na	0.093	118	5.0	2.4	7.1	500
A14	7	2/19/2004	820	na	0.017	na	0.109	121	3.5	2.2	7.3	528
A14A	7	2/19/2004	905	na	0.016	na	0.108	119	5.0	2.4	7.4	526
A15	7	2/19/2004	945	na	0.016	na	0.113	135	6.5	2.9	7.4	575
A15A1	7	2/19/2004	1125	na	0.018	na	0.115	137	15.5	3.6	nd	600
A15A2	7	2/19/2004	1150	na	0.020	na	0.114	135	10.0	4.4	7.2	544
A15B	7	2/19/2004	1105	na	0.019	na	0.116	132	12.0	3.1	7.2	572
A16	7	2/19/2004	1215	na	0.023	na	0.121	139	16.5	5.5	nd	600
A16A1	7	2/19/2004	1320	na	0.018	na	0.121	139	17.5	6.0	nd	600
A2	7	2/17/2004	1300	na	0.013	na	0.074	100	5.0	2.0	7.5	460
A3	7	2/17/2004	1105	na	0.015	na	0.089	104	3.0	1.4	7.4	463

Dissolved oxygen (mg/L)	Turbidity rem	Turbidity (NTU)	Surfactants (mg/L)	FC rem	Fecal coliform bacteria (col/100 mL)	Dup FC rem	Fecal coliform bacteria duplicate (col/100 mL)	Organics	Discharge rem	Discharge (ft^3/s)
9.5	na	4.0	0.00	e	16	na	nd	nd	e	0.058
6.5	na	1.0	0.13	na	330	na	340	nd	e	0.010
5.0	na	1.0	0.13	e,<	3	e	3	nd	e	0.001
7.6	na	1.0	0.13	na	480	na	nd	yes	e	0.044
7.6	na	1.0	0.13	na	93	na	nd	nd	e	0.026
12.0	na	9.0	0.25	na	523	na	nd	yes	e	0.002
8.8	na	2.0	0.13	e	53,900	na	nd	yes	e	0.061
7.0	na	1.0	0.13	na	700	na	nd	yes	e	0.012
9.2	na	5.0	0.13	na	193	na	nd	nd	e	0.609
10.5	na	1.0	0.13	e	36	na	nd	nd	e	0.261
10.5	na	2.0	0.13	e	43	na	nd	nd	e	0.168
9.2	na	2.0	0.13	e	77	na	nd	nd	e	0.21
10.3	na	1.0	0.13	e	63	e	43	nd	e	0.213
10.1	na	2.0	0.13	na	103	na	120	nd	e	0.410
11.3	na	2.0	0.13	na	767	na	nd	nd	e	0.223
12.8	na	2.0	0.13	na	270	na	nd	yes	e	1.231
10.3	na	2.0	0.13	na	933	na	nd	nd	e	1.182
9.9	na	2.0	0.13	na	1,367	na	nd	nd	e	1.204
12.8	na	2.0	0.13	na	500	na	nd	yes	e	1.074
10.3	na	1.0	0.13	na	290	na	nd	nd	e	0.426
8.9	na	1.0	0.13	na	410	na	nd	nd	e	0.883
9.9	na	1.0	0.13	na	410	na	nd	nd	e	0.835
9.4	na	1.0	0.13	na	250	na	nd	yes	e	0.327
9.7	na	1.0	0.13	na	360	na	nd	nd	e	0.252
11.3	na	1.0	0.13	na	270	na	nd	nd	e	0.835
10.6	na	1.0	0.13	na	220	na	nd	nd	e	0.758
9.2	na	8.0	0.13	na	200	na	nd	yes	e	0.726
9.0	na	9.0	0.13	e	621	na	nd	nd	e	0.614
9.1	na	8.0	0.13	na	188	na	185	nd	e	0.481
12.6	na	7.0	0.13	na	240	na	nd	nd	na	nd
nd	na	1.0	0.13	na	270	na	nd	nd	e	0.111
11.7	na	2.0	0.13	na	170	na	nd	nd	e	1.196
nd	na	1.0	0.00	na	83	na	nd	nd	e	0.503
nd	na	2.0	0.13	na	110	na	nd	nd	e	0.563
13.9	na	6.0	0.13	e	15	na	nd	nd	e	18
13.3	na	5.0	0.13	na	240	na	nd	nd	e	7.89
15.1	na	7.0	0.13	na	83	na	nd	nd	e	6.334
17.0	na	5.0	0.13	e	20	e	9	nd	e	8.02
11.9	na	5.0	0.13	na	163	na	nd	nd	e	4.247
12.0	na	4.0	0.13	na	170	na	nd	nd	e	6.332
12.6	na	7.0	0.25	na	195	na	nd	nd	e	4.118
13.2	na	5.0	0.13	na	97	na	83	nd	e	3.789
13.2	na	6.0	0.25	na	80	na	nd	blank	e	2.965
12.5	na	7.0	0.25	na	110	na	nd	nd	e	2.857
16.3	na	5.0	0.13	e	45	na	nd	nd	e	2.992
15.4	na	4.0	0.25	na	147	na	nd	yes	e	2.923
13.3	na	14.0	0.25	e	10	na	nd	nd	e	2.643
13.6	na	5.0	0.13	e	10	na	nd	nd	e	0.946
14.5	na	8.0	0.13	e	33	na	nd	nd	e	14.3
15.9	na	4.0	0.13	e	58	na	nd	nd	e	14.62

Appendix 1. Indicator tracer data from synoptic sampling events for sites sampled in the Accotink Creek watershed, Virginia. — Continued

[rem, remark; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/10 0mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; na, not applicable; nd, not determined]

Site ID	Event	Sampling date	Sampling time	Bo rem	Boron (mg/L)	Br rem	Bromide (mg/L)	Chloride (mg/L)	Air temp	Water temp	pH	Specific conductance (µS/cm)
A5	7	2/17/2004	1255	na	0.019	na	0.1	105	5.5	2.0	7.6	472
A6	7	2/17/2004	1410	na	0.017	na	0.084	105	5.0	2.2	7.6	475
A7	7	2/17/2004	1649	na	0.015	na	0.08	106	6.0	2.6	7.4	470
A8	7	2/17/2004	1445	na	0.014	na	0.109	108	6.0	2.7	7.3	479
A9	7	2/17/2004	1520	na	0.015	na	0.111	113	5.5	2.8	7.4	497
S1	7	2/17/2004	1053	na	0.010	na	0.06	39	4.5	7.7	7.3	300
S13	7	2/17/2004	1520	na	0.015	na	0.097	76	5.0	nd	7.2	405
S15	7	2/17/2004	1605	na	0.027	na	0.162	133	4.0	9.1	7.1	539
S17	7	2/18/2004	955	<	0.007	na	0.109	69	5.0	9.6	6.6	208
S18	7	2/18/2004	1043	na	0.025	na	0.145	180	3.0	7.9	7.0	898
S19	7	2/18/2004	1140	na	0.011	na	0.116	132	8.0	6.5	7.1	680
S20	7	2/18/2004	1155	<	0.007	na	0.139	78	8.0	nd	7.3	372
S22	7	2/18/2004	1255	na	0.033	na	0.098	919	8.5	7.1	8.1	2,893
S23	7	2/18/2004	1420	<	0.007	na	0.074	16	8.0	7.4	7.0	133
S24	7	2/18/2004	1440	na	0.010	na	0.078	42	8.0	6.2	7.1	248
S27	7	2/18/2004	1443	<	0.007	na	0.099	56	6.5	6.6	7.2	282
S28	7	2/18/2004	1418	<	0.007	na	0.067	34	6.0	7.1	7.2	225
S29	7	2/18/2004	915	na	0.009	na	0.08	32	5.0	11.1	6.4	214
S3	7	2/17/2004	1145	na	0.012	na	0.103	48	5.5	9.0	7.1	325
S31	7	2/18/2004	1439	na	0.022	na	0.052	33	6.5	nd	6.3	198
S32	7	2/18/2004	1501	na	0.013	na	0.098	88	6.0	nd	6.4	433
S35	7	2/19/2004	823	na	0.030	na	0.094	103	3.0	13.5	6.9	483
S37	7	2/19/2004	1035	na	0.011	na	0.092	10	12.5	9.0	7.5	140
S39	7	2/19/2004	1250	na	0.009	na	0.074	51	12.0	7.4	7.1	270
S41	7	2/19/2004	1325	na	0.012	na	0.102	62	17.5	9.8	6.2	303
S42	7	2/19/2004	1415	na	0.023	na	0.140	145	16.5	7.0	7.6	648
S44	7	2/19/2004	1338	na	0.051	na	0.193	51	13.0	6.5	7.6	439
S46	7	2/20/2004	935	na	0.022	na	0.050	214	4.5	4.9	7.0	934
S47	7	2/20/2004	1115	na	0.028	na	0.114	375	10.0	6.0	7.6	1,304
S48	7	2/20/2004	842	na	0.015	na	0.262	204	11.0	10.0	7.4	828
S49	7	2/20/2004	1150	na	0.033	na	0.814	96	10.0	12.9	6.9	925
S5	7	2/17/2004	1332	na	0.015	na	0.091	26	3.0	9.1	6.8	229
S50	7	2/20/2004	925	na	0.014	na	0.280	141	6.5	8.4	7.0	565
S51	7	2/20/2004	1015	na	0.030	na	0.191	166	12.5	7.2	7.7	807
S52	7	2/17/2004	1225	na	0.013	na	0.075	57	5.5	2.5	7.4	343
S6	7	2/17/2004	1302	na	0.016	na	nd	1,572	5.5	nd	6.9	4,880
S7	7	2/17/2004	1416	na	0.013	na	0.110	48	3.5	8.1	7.0	320
S8	7	2/17/2004	1439	na	0.021	<	0.050	33	6.0	10.0	6.5	304
T1	7	2/17/2004	1230	na	0.015	na	0.054	57	5.0	4.4	7.0	278
T12	7	2/17/2004	1512	na	0.019	na	0.096	40	3.5	4.3	7.4	232
T13	7	2/17/2004	1700	na	0.012	na	0.108	89	5.0	4.0	7.3	294
T13A	7	2/17/2004	1600	na	0.017	na	0.104	87	6.0	4.9	7.3	277
T19	7	2/17/2004	1505	na	0.019	na	0.101	54	5.0	4.4	7.4	293
T2	7	2/17/2004	1340	na	0.018	na	0.081	33	5.5	3.9	7.4	162
T22	7	2/18/2004	830	na	0.014	na	0.133	38	-1.0	3.3	7.0	226
T23	7	2/18/2004	845	na	0.015	na	0.1	100	1.5	2.3	7.3	477
T23	7	2/19/2004	1515	na	0.015	na	0.1	97	16.0	6.7	8.0	445
T23A1	7	2/18/2004	904	na	0.013	na	0.1	104	2.5	2.6	7.1	458
T23A2	7	2/18/2004	956	na	0.009	na	0.1	104	4.0	3.2	7.1	484
T24	7	2/18/2004	1040	na	0.012	na	0.1	108	5.0	4.2	7.3	468

Dissolved oxygen (mg/L)	Turbidity rem	Turbidity (NTU)	Surfactants (mg/L)	FC rem	Fecal coliform bacteria (col/100 mL)	Dup FC rem	Fecal coliform bacteria duplicate (col/100 mL)	Organics	Discharge rem	Discharge (ft^3/s)
16.9	na	6.0	0.13	na	193	na	nd	nd	e	13.7
18.4	na	5.0	0.13	na	510	na	nd	yes	e	13.13
15.3	na	5.0	0.25	na	143	na	nd	nd	e	12.52
14.5	na	5.0	0.13	na	140	na	nd	nd	e	11.29
14.9	na	5.0	0.13	e	20	na	nd	nd	e	10.99
10.9	na	2.0	0.13	e	45	na	nd	nd	e	0.129
9.0	na	7.0	0.13	e	7	na	nd	nd	e	0.014
nd	na	3.0	0.13	e	10	na	nd	nd	e	0.348
11.8	>	1000.0	0.13	na	193	na	nd	nd	e	0.157
9.9	na	6.0	0.25	e,<	3	na	nd	nd	e	0.051
10.0	na	4.0	0.13	e,<	3	na	nd	nd	na	nd
nd	na	1.0	0.13	e	18	na	nd	nd	e	0.017
13.4	na	3.0	0.25	e	5	na	nd	nd	e	0.041
11.6	na	5.0	0.13	na	480	na	nd	nd	e	0.107
12.2	na	13.0	0.13	e	59	na	nd	nd	e	0.204
13.7	na	3.0	0.13	na	523	na	nd	nd	e	0.027
11.5	na	7.0	0.25	na	163	na	147	nd	e	0.123
8.9	na	1.0	0.13	e	7	na	nd	nd	e	0.063
8.0	na	6.0	0.00	na	290	na	nd	yes	e	0.075
6.0	na	3.0	0.13	e	8	na	nd	nd	e	0.009
7.0	na	29.0	3.80	e	43	na	nd	nd	e	0.014
10.5	na	1.0	0.13	e	10	e	15	nd	e	0.042
10.0	na	1.0	0.00	e	10,200	na	nd	nd	e	0.037
11.0	na	2.0	0.13	na	190	na	nd	nd	e	0.025
10.6	na	2.0	0.13	na	93	na	nd	nd	e	0.062
12.1	na	3.0	0.13	e	11,800	na	nd	nd	e	0.178
nd	na	3.0	0.25	e	2,300	na	nd	yes	e	0.062
11.0	na	3.0	0.13	na	5,500	na	nd	yes	e	0.01
12.9	na	3.0	0.13	e	30	e	27	nd	e	0.219
11.0	na	6.0	0.13	na	137	na	nd	nd	e	0.026
8.8	na	7.0	0.13	e	5	na	nd	nd	na	nd
8.8	na	1.0	0.00	na	177	na	nd	nd	e	0.050
10.8	na	1.0	0.13	e	5	na	nd	nd	e	0.041
12.5	na	5.0	0.13	na	4,300	na	nd	yes	e	0.141
12.6	na	1.0	0.13	e	14	na	nd	nd	e	0.038
7.0	na	11.0	0.50	e	3	na	nd	yes	e	0.001
10.2	na	2.0	0.13	na	2,000	na	nd	yes	e	0.094
8.1	na	3.0	0.13	e	3	na	nd	nd	na	nd
13.6	na	10.0	0.13	na	220	na	nd	nd	e	0.785
12.9	na	2.0	0.13	e	10	na	nd	nd	e	0.4
12.4	na	2.0	0.00	e,<	3	na	nd	nd	e	0.226
12.2	na	2.0	0.13	e,<	3	na	nd	nd	e	0.291
16.6	na	3.0	0.00	e	25	na	nd	nd	e	0.541
15.5	na	1.0	0.00	e	9	na	nd	nd	e	0.534
18.5	na	3.0	0.13	na	933	na	1,167	yes	e	0.345
12.3	na	9.0	0.25	na	550	na	600	yes	e	1.354
15.3	na	5.0	0.13	e	20	na	nd	nd	e	1.581
13.3	na	7.0	0.25	na	340	na	nd	yes	e	1.514
14.8	na	10.0	0.13	na	240	na	nd	nd	e	0.848
12.7	na	13.0	0.13	na	290	na	nd	yes	e	1.32

Appendix 1. Indicator tracer data from synoptic sampling events for sites sampled in the Accotink Creek watershed, Virginia. — Continued

[rem, remark; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/10 0mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; na, not applicable; nd, not determined]

Site ID	Event	Sampling date	Sampling time	Bo rem	Boron (mg/L)	Br rem	Bromide (mg/L)	Chloride (mg/L)	Air temp	Water temp	pH	Specific conductance (µS/cm)
T24	7	2/19/2004	1600	na	0.013	na	0.1	110	15.0	8.0	7.2	494
T24A1	7	2/18/2004	1112	na	0.011	na	0.11	124	5.0	3.3	7.1	546
T24A2	7	2/18/2004	1230	na	0.018	na	0.101	130	9.0	4.6	7.2	555
T24B1	7	2/18/2004	1205	na	0.015	na	0.10	129	5.0	3.9	7.2	554
T25	7	2/18/2004	1220	na	0.010	na	0.093	122	8.0	3.7	7.4	530
T25A	7	2/18/2004	1320	na	0.011	na	0.075	32	9.5	5.6	7.6	204
T27	7	2/18/2004	1229	na	0.008	na	0.092	62	9.0	4.0	7.0	323
T27A	7	2/18/2004	1315	na	0.012	na	0.095	69	8.5	5.0	7.1	344
T31	7	2/18/2004	1538	na	0.028	na	0.111	184	6.0	3.9	7.2	686
T31A1	7	2/18/2004	1404	na	0.019	na	0.112	176	7.0	5.5	7.1	690
T31A2	7	2/18/2004	1540	na	0.020	na	0.107	188	4.5	5.3	7.1	743
T32	7	2/18/2004	1515	na	0.015	na	0.102	172	6.5	6.4	7.0	690
T33	7	2/18/2004	1540	na	0.016	na	0.144	85	5.5	5.9	7.6	425
T35	7	2/19/2004	850	na	0.021	na	0.10	85	4.0	4.2	7.3	402
T35A	7	2/19/2004	930	na	0.014	na	0.091	80	5.0	4.5	7.3	373
T35A	7	2/20/2004	1200	na	0.013	na	0.089	76	14.0	6.1	7.4	358
T36	7	2/19/2004	1010	na	0.014	na	0.078	69	7.5	4.5	7.1	329
T37	7	2/19/2004	1024	na	0.015	na	0.099	88	10.0	3.2	7.5	399
T38	7	2/19/2004	1120	<	0.007	na	0.080	30	13.0	8.0	7.1	186
T40	7	2/19/2004	1205	na	0.019	na	0.092	119	16.0	4.1	7.2	505
T41	7	2/19/2004	1220	na	0.013	na	0.122	125	12.0	4.5	7.4	538
T43	7	2/19/2004	1255	na	0.018	na	0.082	80	12.0	8.4	7.5	195
T44	7	2/19/2004	1415	na	0.023	na	0.072	29	15.0	10.3	7.5	211
T45	7	2/19/2004	1415	na	0.012	na	0.11	113	12.0	6.0	nd	500
T46	7	2/19/2004	1507	na	0.017	na	0.111	154	12.0	6.1	7.5	649
T47	7	2/19/2004	1539	na	0.012	na	0.107	82	12.0	8.2	7.7	312
T48	7	2/19/2004	1610	na	0.017	na	0.113	190	12.0	6.0	7.6	744
T50	7	2/20/2004	1000	na	0.012	na	0.10	252	8.5	4.8	7.2	958
T51	7	2/19/2004	1505	na	0.017	na	0.106	97	14.0	7.1	nd	400
T51	7	2/20/2004	913	na	0.012	na	0.125	91	6.0	5.7	7.2	445
T51A	7	2/19/2004	1540	na	0.019	na	0.121	77	15.0	7.3	nd	400
T51A	7	2/20/2004	1035	na	0.022	na	0.119	76	14.5	6.0	7.2	405
T51B	7	2/20/2004	1000	na	0.016	na	0.121	78	11.0	5.8	7.2	405
T51C	7	2/20/2004	1133	na	0.020	na	0.085	65	11.0	7.3	7.4	331
T52	7	2/20/2004	1046	na	0.017	na	0.090	242	8.5	5.9	7.2	923
T53	7	2/20/2004	835	na	0.016	na	0.14	102	1.5	3.9	7.1	495
T54	7	2/20/2004	1102	na	0.013	na	0.093	53	11.0	6.1	6.5	345
T55	7	2/20/2004	835	na	0.019	na	0.182	124	4.0	4.0	7.6	567
T56	7	2/20/2004	900	na	0.011	na	0.093	67	7.0	5.7	7.1	360
T57	7	2/20/2004	1110	na	0.014	na	0.096	86	10.0	2.6	7.0	424
T60	7	2/18/2004	1045	na	0.015	na	0.10	76	4.0	2.2	7.2	367
T7	7	2/17/2004	1040	na	0.009	na	0.08	53	2.5	2.7	7.3	254
T9	7	2/17/2004	1230	na	0.011	na	0.132	128	4.0	2.6	7.4	490
A13	8	9/12/2004	1230	na	0.017	na	0.016	40	25.0	21.0	6.7	257
A13	8	9/14/2004	915	na	0.025	na	0.078	54	22.5	20.7	6.9	314
A15	8	9/12/2004	1035	na	0.023	na	0.016	54	26.0	20.8	6.7	324
A15	8	9/14/2004	1322	na	0.026	na	0.079	76	25.0	21.5	6.1	394
A15B	8	9/12/2004	1055	na	0.021	na	0.070	54	27.0	21.0	6.7	328
A15B	8	9/14/2004	1409	na	0.023	na	0.077	74	nd	21.5	6.2	312
A6	8	9/12/2004	1000	na	0.022	na	0.059	36	22.5	20.2	6.6	236

Dissolved oxygen (mg/L)	Turbidity rem	Turbidity (NTU)	Surfactants (mg/L)	FC rem	Fecal coliform bacteria (col/100 mL)	Dup FC rem	Fecal coliform bacteria duplicate (col/100 mL)	Organics	Discharge rem	Discharge (ft^3/s)
12.0	na	5.0	0.25	na	410	na	nd	yes	e	1.39
12.9	na	4.0	0.25	na	97	na	nd	nd	e	0.747
12.5	na	4.0	0.13	na	67	na	nd	nd	e	0.546
12.4	na	3.0	0.13	e	52	na	nd	nd	e	1.086
13.1	na	4.0	0.13	na	175	na	nd	nd	e	0.484
12.5	na	2.0	0.13	na	80	na	nd	nd	e	0.259
13.8	na	2.0	0.13	e	12	na	nd	nd	e	1.081
16.3	na	2.0	0.13	e	12	na	nd	nd	e	0.951
15.0	na	9.0	0.13	e	3	na	nd	nd	na	nd
13.0	na	6.0	0.25	e	49	na	nd	nd	e	0.861
12.1	na	16.0	0.25	e	3	na	nd	nd	e	0.804
13.5	na	15.0	0.13	e,<	3	na	nd	nd	e	1.388
13.9	na	3.0	0.13	e	5	na	nd	nd	e	0.175
15.1	na	2.0	0.13	na	2,500	na	5,200	nd	e	0.4
14.6	na	2.0	0.13	na	3,700	na	nd	yes	e	0.459
8.5	na	3.0	0.13	na	1,067	na	nd	nd	e	0.454
15.6	na	3.0	0.13	na	86	na	nd	yes	e	0.354
13.4	na	5.0	0.25	na	240	na	nd	nd	e	1.189
12.2	na	9.0	0.13	na	67	na	nd	nd	e	0.208
12.5	na	4.0	0.13	e	7	na	nd	nd	e	0.14
13.4	na	5.0	0.13	na	320	na	340	nd	e	0.440
15.2	na	5.0	0.13	e	90	na	nd	nd	e	0.599
13.2	na	2.0	0.13	e	40	e	53	nd	e	0.274
13.6	na	6.0	0.25	e	7	na	nd	nd	e	0.554
14.2	na	5.0	0.13	e	35	na	nd	nd	e	1.451
12.6	na	2.0	0.13	e	23	na	nd	nd	e	0.544
14.4	na	7.0	0.13	na	67	na	nd	nd	e	1.036
14.4	na	2.0	0.13	na	967	na	900	nd	e	0.669
10.5	na	5.0	0.75	na	767	na	nd	yes	e	0.556
11.1	na	7.0	0.13	na	1,100	na	nd	yes	e	0.595
10.7	na	6.0	0.75	e	10	na	nd	nd	e	0.51
11.2	na	5.0	0.25	na	87	na	nd	nd	e	0.581
11.6	na	8.0	0.25	e	65	na	nd	nd	e	0.450
11.2	na	4.0	0.13	na	360	na	nd	nd	na	nd
14.0	na	4.0	0.13	na	190	na	nd	nd	e	0.354
13.4	na	2.0	0.00	na	290	na	nd	nd	e	0.656
12.4	na	2.0	0.13	e	25	na	nd	nd	e	0.267
12.6	na	4.0	0.13	na	410	na	290	nd	e	0.316
12.5	na	2.0	0.13	na	4,100	na	nd	yes	e	0.272
10.8	na	2.0	0.13	na	87	na	nd	nd	e	0.157
14.7	na	4.0	0.13	e	58	na	nd	nd	e	1.658
15.5	na	2.0	0.00	e	10	na	nd	nd	e	0.366
15.3	na	3.0	0.25	e	7	na	nd	nd	e	0.437
6.5	na	8.0	0.13	na	1,100	na	nd	nd	na	nd
6.5	na	7.0	0.13	na	1,700	na	1,133	nd	e	1.185
7.6	na	3.0	0.25	na	2,000	na	nd	yes	na	nd
7.7	na	3.0	0.13	na	1,833	na	nd	nd	e	0.763
7.7	na	3.0	0.13	na	1,875	na	nd	nd	na	nd
7.9	na	4.0	0.13	na	2,800	na	nd	nd	e	1.067
8.1	na	7.0	0.50	na	1,067	na	nd	yes	na	nd

Appendix 1. Indicator tracer data from synoptic sampling events for sites sampled in the Accotink Creek watershed, Virginia. — Continued

[rem, remark; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/10 0mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; na, not applicable; nd, not determined]

Site ID	Event	Sampling date	Sampling time	Bo rem	Boron (mg/L)	Br rem	Bromide (mg/L)	Chloride (mg/L)	Air temp	Water temp	pH	Specific conductance (µS/cm)
A6	8	9/13/2004	1205	na	0.025	na	0.070	40	27.0	20.9	7.4	244
S13	8	9/12/2004	1130	na	0.018	na	0.073	28	25.0	nd	7.9	258
S13	8	9/13/2004	1345	na	0.021	na	0.075	29	27.0	21.0	7.5	241
S18	8	9/12/2004	1510	na	0.028	na	0.083	79	29.0	21.5	6.4	468
S18	8	9/13/2004	1425	na	0.039	na	0.016	71	31.0	21.7	6.1	441
S19	8	9/13/2004	1240	na	0.073	na	0.014	2	27.0	21.0	6.6	59
S20	8	9/12/2004	1535	<	0.007	na	0.051	19	33.0	21.0	7.2	153
S20	8	9/13/2004	1210	na	0.014	na	0.059	19	27.0	19.5	7.2	153
S22	8	9/13/2004	1410	na	0.041	na	0.041	38	26.0	22.0	7.4	108
S23	8	9/12/2004	1630	<	0.007	na	0.056	15	26.0	19.0	7.2	162
S23	8	9/13/2004	1530	<	0.007	na	0.059	12	27.5	17.5	7.3	153
S24	8	9/12/2004	1635	<	0.007	na	0.060	19	26.0	19.0	7.2	175
S24	8	9/13/2004	1545	<	0.007	na	0.059	18	27.5	19.0	7.3	170
S29	8	9/12/2004	1425	na	0.036	na	0.011	43	29.0	21.8	7.0	376
S29	8	9/13/2004	1415	na	0.032	na	0.080	51	28.0	21.5	7.0	392
S31	8	9/12/2004	1500	na	0.019	na	0.016	21	26.0	22.0	6.6	156
S35	8	9/12/2004	1315	na	0.026	na	0.127	85	28.5	22.7	7.4	457
S37	8	9/12/2004	1600	<	0.007	na	0.088	7	20.0	20.0	7.4	150
S37	8	9/14/2004	1054	na	0.014	na	0.101	7	24.0	nd	7.9	145
S41	8	9/12/2004	1615	na	0.006	na	0.098	48	26.5	18.0	5.2	255
S41	8	9/14/2004	1350	na	0.016	na	0.101	44	26.0	18.2	5.9	261
S42	8	9/12/2004	1630	na	0.018	na	0.092	49	26.5	19.8	6.8	306
S42	8	9/14/2004	1325	na	0.034	na	0.092	45	24.0	19.7	7.2	311
S44	8	9/12/2004	1835	na	0.047	na	0.122	31	27.0	22.4	7.4	305
S44	8	9/14/2004	1520	na	0.055	na	0.127	30	25.0		7.6	302
S46	8	9/12/2004	1805	na	0.087	na	0.016	60	27.0	22.0	7.8	643
S46	8	9/14/2004	1330	na	0.098	na	0.047	64	nd	nd	7.9	728
S47	8	9/12/2004	1900	na	0.017	na	0.016	155	23.0	20.8	8.0	698
S47	8	9/14/2004	1647	na	0.037	na	0.060	114	24.5	21.2	7.1	600
S48	8	9/12/2004	1715	na	0.007	na	0.151	131	26.5	19.3	7.5	601
S48	8	9/14/2004	1607	na	0.028	na	0.158	104	24.0	19.4	6.9	500
S5	8	9/12/2004	1110	na	0.009	na	0.080	23	23.0	18.9	6.3	208
S5	8	9/13/2004	1005	na	0.010	na	0.091	25	23.0	18.5	6.2	214
S50	8	9/12/2004	1800	na	0.024	na	0.137	74	26.5	20.5	6.2	373
S50	8	9/14/2004	1510	na	0.063	na	0.107	70	24.5	20.0	6.8	345
S51	8	9/12/2004	1430	na	0.032	na	0.167	86	26.0	21.3	7.4	505
S51	8	9/14/2004	1530	na	0.045	na	0.165	82	26.0	21.1	7.5	513
S52	8	9/12/2004	1050	na	0.038	na	0.056	30	26.5	19.6	6.9	231
S52	8	9/13/2004	940	na	0.036	na	0.066	33	24.5	19.4	6.6	251
S6	8	9/12/2004	1135	na	0.037	na	0.016	5	23.5	nd	7.1	147
S6	8	9/13/2004	1040	na	0.045	na	0.016	34	26.5	19.5	6.6	266
S7	8	9/12/2004	1200	na	0.007	na	0.087	27	25.5	19.5	7.0	257
S7	8	9/13/2004	1120	na	0.009	na	0.092	29	26.0	19.5	6.9	253
S8	8	9/12/2004	1210	na	0.018	na	0.005	34	26.0	19.1	6.3	328
S8	8	9/13/2004	1135	na	0.019	na	0.051	32	26.0	18.9	6.3	319
T18	8	9/12/2004	1100	na	0.014	na	0.016	33	24.5	20.4	6.0	242
T18	8	9/13/2004	1315	na	0.012	na	0.069	36	27.0	21.7	6.6	257
T22	8	9/12/2004	1125	na	0.028	na	0.269	35	28.0	20.7	7.2	295
T22	8	9/13/2004	1034	na	0.031	na	0.443	37	23.0	19.6	6.0	299
T23	8	9/12/2004	1150	na	0.017	na	0.100	53	28.0	20.3	6.8	320

Dissolved oxygen (mg/L)	Turbidity rem	Turbidity (NTU)	Surfactants (mg/L)	FC rem	Fecal coliform bacteria (col/100 mL)	Dup FC rem	Fecal coliform bacteria duplicate (col/100 mL)	Organics	Discharge rem	Discharge (ft^3/s)
9.7	na	4.0	0.13	na	867	na	nd	nd	e	3.295
7.0	na	6.0	0.13	na	167	na	nd	nd	na	nd
8.4	na	5.0	0.13	na	93	na	nd	nd	e	0.006
7.4	na	2.0	0.13	na	3,500	na	nd	nd	na	nd
5.8	na	2.0	0.13	na	2,100	na	nd	nd	e	0.037
4.0	na	4.0	0.00	e	600	na	625	nd	e	0.000
8.0	na	3.0	0.13	e	2,075	na	nd	nd	na	nd
6.0	na	2.0	0.13	na	2,000	na	nd	nd	e	0.015
6.6	na	1.0	0.13	na	210	na	203	nd	e	0.037
8.0	na	1.0	0.25	na	1,775	na	nd	nd	na	nd
7.0	na	1.0	0.00	na	900	na	nd	nd	e	0.033
8.0	na	2.0	0.13	e	627	na	nd	nd	na	nd
6.0	na	4.0	0.13	na	550	na	562	nd	e	0.033
8.4	na	3.0	0.13	na	330	na	nd	nd	na	nd
8.8	na	4.0	0.13	na	340	na	nd	nd	e	0.14
4.0	na	5.0	0.25	na	1,733	na	nd	nd	na	nd
7.4	na	2.0	0.13	na	1,533	na	nd	nd	na	nd
7.0	na	2.0	0.25	na	1,775	na	nd	yes	na	nd
7.0	na	1.0	0.00	na	608	na	nd	nd	e	0.009
5.1	na	1.0	0.13	na	5,100	na	nd	nd	na	nd
4.8	na	2.0	0.00	e	12,900	na	nd	nd	e	0.037
8.4	na	2.0	0.00	na	3,500	na	nd	nd	na	nd
9.1	na	3.0	0.00	na	1,200	na	nd	nd	e	0.013
5.3	na	4.0	0.13	na	1,200	na	nd	nd	na	nd
7.0	na	3.0	0.13	na	100	na	nd	nd	e	0.01
5.5	na	4.0	0.75	e	9,000	na	nd	yes	na	nd
5.0	na	2.0	0.25	na	2,400	na	nd	nd	e	0.001
7.9	na	1.0	0.13	na	2,100	na	nd	nd	na	nd
7.3	na	1.0	0.13	na	933	na	nd	nd	e	0.043
8.1	na	2.0	0.50	na	833	na	nd	nd	na	nd
8.6	na	4.0	0.13	na	508	na	nd	nd	e	0.023
6.4	na	2.0	0.13	na	410	na	nd	nd	na	nd
7.2	na	6.0	0.13	na	584	na	420	nd	e	0.035
7.1	na	6.0	0.50	na	420	na	nd	nd	na	nd
8.3	na	3.0	0.13	na	70	na	nd	nd	e	0.073
7.4	na	1.0	0.13	na	2,200	na	nd	nd	na	nd
8.5	na	1.0	0.13	na	1,233	na	nd	nd	e	0.061
5.0	na	7.0	0.13	na	833	na	nd	nd	na	nd
5.3	na	2.0	0.13	na	390	na	nd	nd	e	0.011
8.0	na	10.0	1.50	e	22,000	na	nd	yes	na	nd
3.7	na	5.0	0.50	na	1,900	na	nd	nd	e	0.001
7.4	na	8.0	0.13	na	1,133	na	nd	nd	na	nd
8.2	na	3.0	0.13	na	2,000	na	nd	nd	e	0.033
5.3	na	9.0	7.50	na	1,067	na	nd	yes	na	nd
6.6	na	1.0	0.25	na	1,033	na	nd	nd	e	0.01
3.0	na	26.0	0.25	e	1,975	na	nd	nd	na	nd
2.4	na	35.0	0.13	na	2,900	na	nd	nd	e	0.017
8.5	na	7.0	0.25	na	2,000	na	nd	nd	na	nd
7.2	na	6.0	0.25	na	1,300	na	1,767	nd	e	0.17
6.8	na	7.0	0.25	na	2,500	na	nd	yes	na	nd

Appendix 1. Indicator tracer data from synoptic sampling events for sites sampled in the Accotink Creek watershed, Virginia. — Continued

[rem, remark; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/10 0mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; na, not applicable; nd, not determined]

Site ID	Event	Sampling date	Sampling time	Bo rem	Boron (mg/L)	Br rem	Bromide (mg/L)	Chloride (mg/L)	Air temp	Water temp	pH	Specific conductance (µS/cm)
T23	8	9/13/2004	939	na	0.020	na	0.113	55	23.5	19.7	6.0	317
T23A1	8	9/12/2004	1220	na	0.018	na	0.122	55	27.0	20.1	6.8	336
T23A1	8	9/13/2004	1145	na	0.025	na	0.097	58	25.5	20.1	7.3	335
T23A2	8	9/12/2004	1240	na	0.017	na	0.102	55	28.5	20.9	6.8	348
T23A2	8	9/13/2004	1226	na	0.019	na	0.099	59	27.0	20.5	6.2	342
T24	8	9/12/2004	1455	na	0.015	na	0.091	58	28.5	21.6	6.7	358
T24	8	9/13/2004	1350	na	0.020	na	0.090	64	31.0	21.8	6.2	357
T24A1	8	9/12/2004	1245	na	0.022	na	0.076	80	24.0	20.0	7.2	414
T24A1	8	9/13/2004	1501	na	0.025	na	0.027	80	29.5	20.6	6.3	404
T24A2	8	9/12/2004	1335	na	0.024	na	0.062	79	26.5	20.8	7.0	338
T24A2	8	9/13/2004	1621	na	0.104	na	0.051	108	29.0	22.1	6.1	417
T24B1	8	9/12/2004	1305	na	0.021	na	0.017	80	26.5	20.1	7.1	237
T24B1	8	9/13/2004	1548	na	0.024	na	0.015	81	29.5	21.0	6.4	399
T25	8	9/12/2004	1600	na	0.014	na	0.016	44	30.0	20.3	6.6	396
T25	8	9/13/2004	1315	na	0.021	na	0.056	71	25.5	20.6	7.1	380
T25A	8	9/12/2004	1355	na	0.008	na	0.059	25	24.0	20.9	7.5	178
T25A	8	9/13/2004	1455	na	0.010	na	0.054	24	26.5	21.6	7.5	155
T29	8	9/12/2004	1715	na	0.015	na	0.054	31	26.0	20.4	6.7	228
T29	8	9/14/2004	1240	na	0.031	na	0.061	39	25.0	19.8	7.2	161
T3	8	9/12/2004	1020	na	0.019	na	0.107	40	25.0	18.9	6.7	221
T3	8	9/13/2004	915	na	0.024	na	0.113	42	25.0	18.1	6.2	220
T31	8	9/12/2004	1215	na	0.018	na	0.059	56	27.0	20.6	6.3	304
T31	8	9/14/2004	850	na	0.022	na	0.085	93	22.5	19.7	6.8	419
T31A1	8	9/12/2004	1515	na	0.015	na	0.061	73	26.0	21.1	7.1	356
T31A1	8	9/14/2004	926	na	0.026	na	0.090	105	21.5	19.8	6.2	455
T33	8	9/12/2004	1540	na	0.013	na	0.106	57	26.5	21.3	7.2	361
T33	8	9/14/2004	1022	na	0.027	na	0.101	58	24.5	20.0	6.6	363
T35	8	9/12/2004	1330	na	0.015	na	0.081	51	26.5	20.8	6.4	265
T35	8	9/14/2004	1005	na	0.028	na	0.090	58	24.5	19.7	7.0	319
T35A	8	9/12/2004	1345	na	0.011	na	0.079	51	26.0	20.0	6.4	292
T35A	8	9/14/2004	1045	na	0.020	na	0.092	58	23.5	19.9	7.0	306
T36	8	9/12/2004	1415	na	0.011	na	0.066	45	25.5	19.8	6.1	260
T36	8	9/14/2004	1120	na	0.023	na	0.073	49	23.5	19.1	6.7	270
T37	8	9/12/2004	1015	na	0.016	na	0.016	24	23.5	20.8	6.7	183
T37	8	9/14/2004	1257	na	0.023	na	0.050	28	25.5	21.8	7.5	192
T38	8	9/12/2004	1500	<	0.007	na	0.055	10	28.0	25.3	7.5	110
T38	8	9/14/2004	1200	na	0.016	na	0.054	12	25.0	22.8	7.1	112
T40	8	9/12/2004	1515	na	0.014	na	0.016	29	26.5	20.3	6.7	188
T40	8	9/14/2004	1220	na	0.025	na	0.051	31	nd	19.8	7.0	194
T42	8	9/12/2004	1530	na	0.007	na	0.051	39	28.5	20.9	6.3	217
T42	8	9/14/2004	1250	na	0.021	na	0.055	35	24.0	20.1	6.9	211
T44	8	9/12/2004	1850	na	0.023	na	0.045	23	26.0	22.8	8.1	210
T44	8	9/14/2004	1129	na	0.032	na	0.051	20	24.0	21.5	8.5	202
T50	8	9/12/2004	1825	na	0.011	na	0.086	171	28.0	22.8	7.5	714
T50	8	9/14/2004	1410	na	0.022	na	0.092	173	26.0	21.1	7.6	718
T51	8	9/12/2004	1640	na	0.014	na	0.070	61	24.5	22.6	7.1	363
T51	8	9/14/2004	1425	na	0.029	na	0.108	57	25.0	22.0	7.1	315
T51A	8	9/12/2004	1720	na	0.015	na	0.060	50	27.5	23.0	6.9	328
T51A	8	9/14/2004	1550	na	0.036	na	0.060	74	26.0	22.0	7.1	325
T51B	8	9/12/2004	1700	na	0.014	na	0.060	49	27.5	23.3	7.4	331

Dissolved oxygen (mg/L)	Turbidity rem	Turbidity (NTU)	Surfactants (mg/L)	FC rem	Fecal coliform bacteria (col/100 mL)	Dup FC rem	Fecal coli-form bacteria duplicate (col/100 mL)	Organics	Discharge rem	Discharge (ft^3/s)
6.1	na	3.0	0.25	na	1,500	na	1,133	nd	e	0.494
8.1	na	4.0	0.13	na	1,700	na	nd	nd	na	nd
7.1	na	2.0	0.00	na	1,133	na	1,775	nd	e	1.685
10.3	na	6.0	0.13	na	1,775	na	nd	nd	na	nd
8.9	na	3.0	0.13	na	2,200	na	nd	nd	e	0.462
8.5	na	4.0	0.13	na	3,500	na	nd	yes	na	nd
7.6	na	4.0	0.13	na	2,000	na	nd	nd	e	0.484
7.2	na	3.0	0.25	na	1,300	na	nd	nd	na	nd
6.8	na	3.0	0.25	na	1,850	na	nd	nd	e	0.08
5.9	na	8.0	0.13	na	2,500	na	nd	nd	na	nd
5.5	na	6.0	0.13	e	8,600	na	nd	nd	e	0.124
6.9	na	6.0	0.13	na	2,100	na	nd	nd	na	nd
6.5	na	4.0	0.13	na	3,100	na	nd	nd	e	0.196
5.6	na	4.0	0.13	na	2,025	na	nd	nd	na	nd
5.5	na	6.0	0.13	na	1,750	na	nd	nd	e	0.1
7.1	na	2.0	0.13	na	1,033	na	nd	nd	na	nd
7.3	na	2.0	0.00	na	1,567	na	nd	nd	e	0.053
8.6	na	2.0	0.25	na	1,667	na	nd	nd	na	nd
8.4	na	2.0	0.38	e	6,300	na	nd	yes	e	0.057
6.1	na	3.0	0.13	na	1,633	na	nd	nd	na	nd
6.1	na	2.0	0.13	na	1,600	na	nd	nd	e	0.035
6.2	na	13.0	0.13	na	2,800	na	nd	nd	na	nd
6.2	na	9.0	0.13	na	1,533	na	nd	nd	na	nd
7.2	na	8.0	0.25	na	2,600	na	nd	nd	na	nd
7.0	na	6.0	0.13	na	1,233	na	1,133	nd	e	0.279
5.8	na	2.0	0.13	na	2,200	na	nd	nd	na	nd
6.0	na	1.0	0.38	na	1,300	na	1,167	nd	e	0.06
7.3	na	2.0	0.50	e	48,000	na	nd	yes	na	nd
7.3	na	4.0	0.25	na	4,900	na	5,900	nd	e	0.163
7.4	na	3.0	0.25	e	10,700	na	nd	nd	na	nd
7.9	na	2.0	0.25	e	7,000	na	nd	nd	e	0.108
7.6	na	3.0	0.13	na	1,400	na	nd	yes	na	nd
8.2	na	2.0	0.00	na	1,133	na	nd	nd	e	0.093
7.5	na	4.0	0.13	e	686	na	nd	nd	na	nd
9.1	na	3.0	0.13	na	260	na	nd	nd	e	0.288
7.3	na	4.0	0.25	e	721	na	nd	nd	na	nd
8.7	na	3.0	0.13	na	73	na	nd	nd	e	0.167
7.2	na	5.0	0.25	e	182	na	nd	nd	na	nd
8.0	na	3.0	0.00	na	110	na	nd	nd	e	0.014
6.2	na	4.0	0.13	na	2,500	na	nd	nd	na	nd
6.3	na	2.0	0.00	na	1,633	na	nd	nd	e	0.085
8.9	na	1.0	0.13	na	2,600	na	nd	nd	na	nd
10.4	na	1.0	0.00	na	933	na	nd	nd	na	nd
11.4	na	8.0	0.13	na	2,700	na	nd	nd	na	nd
9.2	na	7.0	0.13	na	1,233	na	nd	nd	e	0.209
6.5	na	5.0	0.87	e	8,400	na	nd	yes	na	nd
6.9	na	3.0	0.25	na	6,000	na	nd	nd	e	0.186
7.0	na	5.0	3.00	e	24,000	na	nd	nd	na	nd
4.0	na	7.0	2.50	e	11,100	na	nd	yes	e	0.255
6.8	na	7.0	5.00	e	24,000	na	nd	yes	na	nd

Appendix 1. Indicator tracer data from synoptic sampling events for sites sampled in the Accotink Creek watershed, Virginia. — Continued

[rem, remark; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; col/10 0mL, colonies per 100 milliliters; ft^3/s, cubic feet per second; na, not applicable; nd, not determined]

Site ID	Event	Sampling date	Sampling time	Bo rem	Boron (mg/L)	Br rem	Bromide (mg/L)	Chloride (mg/L)	Air temp	Water temp	pH	Specific conductance (µS/cm)
T51B	8	9/14/2004	1450	na	0.027	na	0.058	43	25.0	22.5	7.3	326
T51BLD	8	9/14/2004	1500	na	0.031	<	0.250	67	nd	nd	nd	nd
T51C	8	9/12/2004	1750	na	0.007	na	0.094	56	27.0	21.0	6.6	264
T51C	8	9/14/2004	1630	na	0.020	na	0.090	53	24.0	21.0	7.1	253
T55	8	9/12/2004	1730	na	0.024	na	0.071	58	28.0	21.6	7.6	331
T55	8	9/14/2004	1425	na	0.040	na	0.117	60	25.0	20.6	7.2	344
T56	8	9/12/2004	1745	na	0.008	na	0.065	33	26.0	21.0	7.2	268
T56	8	9/14/2004	1440	na	0.027	na	0.072	34	25.0	20.1	7.1	273

Dissolved oxygen (mg/L)	Turbidity rem	Turbidity (NTU)	Surfactants (mg/L)	FC rem	Fecal coliform bacteria (col/100 mL)	Dup FC rem	Fecal coliform bacteria duplicate (col/100 mL)	Organics	Discharge rem	Discharge (ft^3/s)
7.2	na	3.0	1.50	e	10,400	na	nd	nd	e	0.165
nd	na	229.0	25.00	e	4,000,000	na	nd	yes	na	nd
6.0	na	6.0	0.37	na	4,200	na	nd	nd	na	nd
6.0	na	4.0	0.13	na	2,800	na	nd	nd	e	0.005
7.4	na	1.0	0.13	na	1,450	na	nd	nd	na	nd
7.3	na	2.0	0.13	na	2,100	na	nd	nd	e	0.122
7.3	na	13.0	0.25	na	1,100	na	nd	nd	na	nd
7.9	na	2.0	0.00	na	2,000	na	nd	nd	e	0.071

Appendix 2. Confirmatory wastewater organic compound data from each synoptic sampling event in the Accotink Creek watershed, Virginia.

[mg/L, milligrams per liter; PCODE, U.S. Geological Survey parameter code; nd, not detected; --, not available; light gray shading indicates quantitative concentration; dark gray shading indicates estimated concentration]

Event 3

Compound (mg/L)	PCODE	Log K_{ow}	S12	S15	S3	T24	T6	T9	NCP1	NCP4
Caffeine	81436Z	0.16	nd	nd	0.12	nd	0.097	0.061	36	160
Cotinine	61945Z	0.34	nd	nd	0.21	0.18	nd	nd	1	nd
Diethyl phthalate (DEP)	34336B	2.82	nd	nd	6	nd	nd	nd	6.8	11
Diethylhexyl phthalate (DEHP)	39100C	8.39	nd	nd	nd	nd	nd	nd	3.5	5.5
Galaxolide (HHCB)	62823Z	6.26	nd	nd	nd	nd	nd	nd	0.77	5.8
Menthol	62827Z	3.38	nd	nd	0.57	nd	nd	nd	18	18
NPEO1-total	61704A	--	nd	nd	1.2	nd	nd	nd	12	31
NPEO2-total	61703Z	--	nd	nd	1.7	nd	nd	nd	9.9	24
OPEO1	61706Z	--	nd	nd	nd	nd	nd	nd	1.8	nd
para-Nonylphenol (total NP)	62829Z	5.92	nd	nd	1	nd	0.65	0.56	36	59
Skatol	62807Z	2.60	nd	nd	nd	nd	nd	nd	1	38
Tonalide (AHTN)	62812Z	6.35	nd	nd	0.043	nd	nd	nd	3.8	8.2
Triclosan	61708Z	4.66	nd	nd	nd	nd	nd	nd	5.2	6.8
Number of detections			0	0	8	1	2	2	13	11

Event 4

Compound (mg/L)	PCODE	Log K_{ow}	A15	S29	S3	S44	S46	S48	S50	S51	T13	T16	T24	T31	T35
Caffeine	81436Z	0.16	0.06	0.34	nd	0.57	0.18	nd	nd	0.065	27	nd	0.069	0.065	0.097
Cotinine	61945Z	0.34	nd	nd	nd	nd	nd	nd	nd	nd	0.78	nd	nd	nd	nd
Diethyl phthalate (DEP)	34336B	2.82	nd	nd	nd	nd	1.5	nd	nd	nd	5.2	nd	nd	nd	nd
Diethylhexyl phthalate (DEHP)	39100C	8.39	4.3	nd	nd	8.4	nd	nd	nd	nd	3	2.2	3.7	46	nd
Galaxolide (HHCB)	62823Z	6.26	nd	nd	nd	nd	nd	nd	nd	nd	0.51	nd	nd	nd	0.051
Menthol	62827Z	3.38	nd	nd	nd	nd	nd	nd	0.17	nd	15	nd	nd	nd	nd
NPEO1-total	61704A	--	nd	nd	nd	nd	1.7	nd	0.88	nd	18	nd	nd	nd	1.3
NPEO2-total	61703Z	--	2.5	nd	nd	1.6	6.9	1	4.5	1.1	7.5	nd	nd	1.5	3.1
OPEO1	61706Z	--	nd	nd	nd	nd	nd	nd	nd	nd	1.7	nd	nd	nd	nd
para-Nonylphenol (total NP)	62829Z	5.92	nd	nd	nd	1.6	3.3	nd	nd	nd	19	nd	nd	nd	2.8
Skatol	62807Z	2.60	nd	nd	nd	nd	0.29	nd	nd	nd	0.66	nd	nd	nd	nd
Tonalide (AHTN)	62812Z	6.35	nd	nd	nd	nd	nd	nd	nd	nd	2.2	nd	nd	nd	0.13
Triclosan	61708Z	4.66	nd	0.16	nd	nd	nd	nd	nd	0.2	2.7	nd	nd	nd	0.26
Number of detections			3	2	0	4	6	1	3	3	13	1	2	3	7

Event 5

Compound (mg/L)	PCODE	Log K_{ow}	A13	A14	A15	A16	S15	S18	S20	S23	S29	S35	S37	S41	S42
Caffeine	81436Z	0.16	nd	0.079	0.08	0.048	nd	0.06	nd	nd	nd	nd	nd	0.32	nd
Cotinine	61945Z	0.34	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.22	nd
Diethyl phthalate (DEP)	34336B	2.82	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Diethylhexyl phthalate (DEHP)	39100C	8.39	nd	nd	nd	0.38	0.84	nd	nd	nd	nd	nd	nd	nd	2.4
Galaxolide (HHCB)	62823Z	6.26	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Menthol	62827Z	3.38	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
NPEO1-total	61704A	--	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
NPEO2-total	61703Z	--	nd	nd	nd	nd	nd	nd	2.6	nd	nd	nd	nd	nd	nd
OPEO1	61706Z	--	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
para-Nonylphenol (total NP)	62829Z	5.92	nd	nd	nd	nd	nd	nd	0.79	nd	nd	nd	nd	nd	nd
Skatol	62807Z	2.60	0.019	nd	nd	nd	nd	nd	nd	nd	nd	0.014	nd	0.026	nd
Tonalide (AHTN)	62812Z	6.35	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Triclosan	61708Z	4.66	nd	nd	nd	nd	nd	nd	nd	nd	0.22	nd	nd	nd	nd
Number of detections			1	1	1	2	1	1	3	0	1	1	0	3	1

T4	T47	T50	T51	T9
nd	nd	nd	0.12	nd
nd	nd	nd	nd	nd
nd	nd	nd	0.55	nd
nd	nd	4.1	nd	nd
nd	nd	nd	nd	nd
nd	nd	nd	nd	nd
nd	nd	nd	0.98	nd
nd	nd	nd	4.1	nd
nd	nd	nd	nd	nd
nd	nd	nd	1.3	nd
nd	nd	nd	nd	nd
nd	nd	nd	nd	nd
nd	nd	nd	nd	nd
0	0	1	5	0

S44	S46	S48	S50	S51	S8	T13	T22	T24	T31	T33	T35	T36	T40	T48	T50	T51	T55	T56	T9	T13A
4.3	0.27	0.19	0.18	0.29	nd	nd	nd	0.064	0.076	nd	0.061	nd	nd	0.079	nd	0.047	0.074	nd	nd	nd
nd	nd	0.24	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
nd	nd	0.3	nd	nd	0.32	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
0.41	nd	1.2	nd	nd	1.6	nd	nd	4.2	nd	nd	nd	nd	1.1	nd	nd	nd	8.5	nd	nd	nd
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
nd	0.62	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2.5	2.8	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
nd	0.18	0.17	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1.6	1.4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
nd	nd	nd	nd	nd	0.066	nd	nd	0.014	0.015	0.015	0.028	nd	nd	nd	0.013	nd	nd	nd	0.034	nd
nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.13	nd	nd	nd	nd	nd	nd	nd	nd	nd
nd	nd	nd	nd	nd	0.11	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4	5	5	1	1	4	0	0	3	2	1	3	0	1	1	1	1	2	0	1	0

Appendix 2. Confirmatory wastewater organic compound data from each synoptic sampling event in the Accotink Creek watershed, Virginia. — Continued

[mg/L, milligrams per liter; PCODE, U.S. Geological Survey parameter code; nd, not detected; --, not available; light gray shading indicates quantitative concentration; dark gray shading indicates estimated concentration]

Event 6

Compound (mg/L)	PCODE	Log K_{ow}	A13	S18	S20	S29	S5	S6	S7	S8	T23	T24	T25	T31
Caffeine	81436Z	0.16	0.081	0.018	0.045	0.2	nd	0.74	nd	0.025	0.068	0.068	0.02	0.094
Cotinine	61945Z	0.34	nd	nd	nd	nd	nd	0.28	nd	nd	nd	nd	nd	0.2
Diethyl phthalate (DEP)	34336B	2.82	nd	0.1	0.096	0.052	nd	0.23	nd	0.11	nd	nd	0.077	nd
Diethylhexyl phthalate (DEHP)	39100C	8.39	2.2	nd	nd	1.7	nd	nd	nd	nd	nd	nd	nd	nd
Galaxolide (HHCB)	62823Z	6.26	0.052	nd	0.072	nd	nd	nd	nd	nd	nd	nd	nd	0.063
Menthol	62827Z	3.38	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
NPEO1-total	61704A	--	nd	nd	1.4	nd	nd	3.7	nd	nd	nd	0.71	nd	0.77
NPEO2-total	61703Z	--	nd	nd	4.7	nd	nd	7.4	nd	nd	nd	1.8	nd	1.5
OPEO1	61706Z	--	nd	nd	0.62	nd	nd	nd	nd	nd	nd	nd	nd	nd
para-Nonylphenol (total NP)	62829Z	5.92	nd	nd	1.5	nd	0.74	nd	0.85	0.77	0.8	0.9	nd	0.79
Skatol	62807Z	2.60	0.04	0.04	nd	nd	0.014	0.2	0.014	0.024	0.039	0.057	0.14	0.023
Tonalide (AHTN)	62812Z	6.35	0.014	nd	0.017	nd	nd	nd	nd	nd	nd	nd	nd	nd
Triclosan	61708Z	4.66	nd	nd	0.045	1	nd	nd	nd	nd	nd	nd	nd	nd
Number of detections			5	3	9	4	2	6	2	4	3	5	3	7

Event 7

Compound (mg/L)	PCODE	Log K_{ow}	A15B	A6	S3	S44	S46	S51	S6	S7	T22	T23	T23A1	T24	T24
Caffeine	81436Z	0.16	0.22	0.3	nd	0.11	0.29	0.12	0.64	0.019	0.024	0.15	0.084	0.066	0.18
Cotinine	61945Z	0.34	nd	nd	nd	0.17	0.16	0.16	0.24	nd	nd	nd	nd	nd	nd
Diethyl phthalate (DEP)	34336B	2.82	nd	nd	nd	0.64	0.16	nd	0.32	0.098	0.12	0.22	0.12	0.08	nd
Diethylhexyl phthalate (DEHP)	39100C	8.39	nd	nd	nd	nd	2.4	nd	0.73	nd	nd	nd	nd	1.4	nd
Galaxolide (HHCB)	62823Z	6.26	nd	0.044	nd	nd	0.04	nd	0.044	nd	0.043	0.045	0.043	nd	nd
Menthol	62827Z	3.38	nd	0.062	0.056	0.078	0.17	nd	0.34	0.05	nd	0.05	0.046	0.05	nd
NPEO1-total	61704A	--	0.55	0.66	nd	1.2	0.71	nd	0.76	nd	nd	nd	nd	nd	nd
NPEO2-total	61703Z	--	nd	0.41	nd	3.8	2	nd	0.87	nd	nd	nd	nd	nd	nd
OPEO1	61706Z	--	nd	nd	nd	nd	nd	nd	0.42	nd	nd	nd	nd	nd	nd
para-Nonylphenol (total NP)	62829Z	5.92	0.87	0.91	1	1.8	1.4	0.95	1.1	0.96	0.85	0.93	0.94	1.2	0.86
Skatol	62807Z	2.60	nd	0.009	nd	nd	0.007	nd	0.046	0.004	nd	0.005	0.008	0.007	0.009
Tonalide (AHTN)	62812Z	6.35	nd	0.036	nd	nd	0.011	nd	0.023	nd	nd	nd	nd	nd	nd
Triclosan	61708Z	4.66	nd	0.052	nd	nd	nd	0.096	nd	nd	0.05	nd	nd	nd	nd
Number of detections			3	9	2	7	11	4	12	5	5	6	6	6	3

Event 8

Compound (mg/L)	PCODE	Log K_{ow}	A15	A6	S37	S46	S6	S8	T23	T24	T29	T35	T36	T51	T51B
Caffeine	81436Z	0.16	0.028	0.046	0.009	0.089	0.1	0.21	nd	0.056	0.015	0.04	nd	0.22	0.87
Cotinine	61945Z	0.34	0.17	0.17	nd	0.19	0.22	nd	nd	nd	nd	0.19	nd	0.22	nd
Diethyl phthalate (DEP)	34336B	2.82	0.036	nd	nd	0.49	0.072	0.29	0.12	nd	0.053	0.04	nd	0.42	0.65
Diethylhexyl phthalate (DEHP)	39100C	8.39	nd	0.26	nd	nd	nd	1.3	nd	1.7	nd	nd	nd	0.34	2.5
Galaxolide (HHCB)	62823Z	6.26	nd	nd	nd	0.048	nd	0.053	nd	nd	nd	0.055	nd	nd	nd
Menthol	62827Z	3.38	nd	nd	nd	0.15	nd	0.16	nd	nd	nd	0.058	nd	0.089	nd
NPEO1-total	61704A	--	0.54	nd	nd	0.8	nd	0.94	nd	nd	nd	0.58	nd	1.3	6.6
NPEO2-total	61703Z	--	1.1	nd	nd	1.5	nd	4.2	1.1	1.6	nd	1.2	nd	4.5	9
OPEO1	61706Z	--	0.27	nd	nd	0.29	nd	0.31	nd	nd	nd	0.26	nd	nd	0.34
para-Nonylphenol (total NP)	62829Z	5.92	0.81	0.76	nd	2.1	nd	nd	0.79	0.86	nd	0.88	nd	1.2	2.2
Skatol	62807Z	2.60	nd	nd	0.006	nd	nd	nd	0.007	nd	nd	0.011	nd	nd	nd
Tonalide (AHTN)	62812Z	6.35	0.033	nd	nd	0.025	nd	0.12	nd	nd	nd	0.088	nd	nd	nd
Triclosan	61708Z	4.66	nd	nd	nd	nd	nd	0.19	nd	nd	nd	0.11	nd	0.11	8.1
Number of detections			8	4	2	10	3	10	4	4	2	12	0	9	8

T35A	T36	T51	T51	T56
0.078	0.024	2.1	2.1	0.052
0.14	nd	0.19	0.16	0.14
0.12	0.1	0.28	0.12	nd
nd	nd	nd	nd	nd
0.042	nd	nd	0.042	nd
0.27	nd	0.13	0.1	nd
nd	nd	1.2	0.72	nd
nd	nd	1.2	0.55	nd
nd	nd	nd	nd	nd
0.86	0.87	1.2	1	0.9
0.008	0.003	0.019	0.03	nd
0.045	nd	nd	nd	nd
0.057	nd	nd	nd	nd
9	4	8	9	3

T51BLD	T51A
2.8	0.32
3.2	0.2
1.2	2.2
24	2.3
nd	nd
2.1	nd
4	29
14	22
2.3	0.32
5	1.8
0.11	0.017
nd	nd
0.24	0.32
11	10

Appendix 3. Cross-reference listing of study site identifications and official USGS site identifications in the Accotink Creek watershed of Virginia, including site names and coordinates.

[Latitude and longitude in decimal degrees. Station locations shown in figure 3. Sites are ordered by site number, from upstream to downstream]

Site	Site number	Station name	Latitude	Longitude
T57	0165388130	ACCOTINK CREEK AT CEDAR AVENUE AT FAIRFAX, VA	385110.97	771853.97
T56	0165388205	ACCOTINK CREEK AB CHAIN BRIDGE RD AT FAIRFAX, VA	385103.19	771829.37
S51	0165388210	STORM DRAIN AT HALLMAN STREET AT FAIRFAX, VA	385102.13	771916.42
S50	0165388250	STORM DRAIN AT MAIN STREET AT FAIRFAX, VA	385053.50	771843.78
S49	0165388255	STORM DRAIN ABOVE PAGE AVENUE AT FAIRFAX, VA	385043.05	771840.62
T55	0165388290	ACCOTINK CR TRIB 1 AT CHAIN BR ROAD AT FAIRFAX, VA	385102.64	771829.19
S48	0165388320	STORM DRAIN AT KENMORE DRIVE AT FAIRFAX, VA	385103.89	771820.35
T53	0165388460	ACCOTINK CREEK AT DALE DRIVE AT FAIRFAX, VA	385126.21	771753.40
T45	0165388630	ACCOTINK CREEK BELOW STAFFORD DRIVE AT FAIRFAX, VA	385153.36	771717.69
S47	0165388695	STORM DRAIN AT OAKTON PARK AT FAIRFAX, VA	385157.50	771820.51
T52	0165388705	ACCOTINK CR TRIB 2 AT OAKTON PARK AT FAIRFAX, VA	385156.45	771820.89
T50	0165388740	ACCOTINK CR TRIB 2 BL EATON PLACE AT FAIRFAX, VA	385142.05	771801.34
T54	0165388785	ACCOTINK CR TRIB 1 TRIB 2 AT ORCHRD AT FAIRFAX, VA	385133.25	771836.03
T51BLD	0165388795	ACCOTINK CR TRIB 1 TO TRIB 1 TO 2 AT FAIRFAX, VA	385128.15	771836.09
T51C	0165388840	ACCOTINK CR TRIB 1 TRIB 2 BL CHN BR AT FAIRFAX, VA	385128.15	771821.51
T51A	0165388845	ACCOTINK CR TRIB 1 TRIB 2 NR EATON AT FAIRFAX, VA	385134.60	771817.17
T51B	0165388850	ACCOTINK CR TRIB 1 TRIB 2 AB EATON AT FAIRFAX, VA	385134.73	771816.14
T51	0165388880	ACCOTINK CR TRIB 1 TRIB 2 AT MOUTH AT FAIRFAX, VA	385141.95	771801.34
S46	0165388895	STORM DRAIN AT LEE HIGHWAY AT FAIRFAX, VA	385141.12	771755.67
T48	0165388995	ACCOTINK CR TRIB 2 BL STAFFORD DR AT FAIRFAX, VA	385157.54	771722.46
T49	0165389060	ACCOTINK CR TRIB 2 TO TRIB 2 AT FAIRFAX, VA	385211.02	771749.70
T47	0165389120	ACCOTINK CR TRIB 2 TRIB 2 AT MOUTH AT FAIRFAX, VA	385159.68	771722.24
T46	0165389140	ACCOTINK CREEK TRIB 2 AT MOUTH AT FAIRFAX, VA	385156.32	771716.62
A16A1	0165389205	ACCOTINK CREEK NEAR RANGER ROAD AT FAIRFAX, VA	385153.52	771709.15
A16	0165389220	ACCOTINK CREEK ABOVE LEE HIGHWAY AT FAIRFAX, VA	385152.13	771702.13
S45	0165389225	STORM DRAIN AT STRATHAVEN PLACE AT FAIRFAX, VA	385239.49	771725.31
T44	0165389250	ACCOTINK CREEK TRIB 3 AT PLATTEN DR AT FAIRFAX, VA	385229.29	771716.02
S44	0165389360	STORM DRAIN BELOW BEECH DRIVE AT FAIRFAX, VA	385157.35	771657.19
T43	0165389380	ACCOTINK CREEK TRIB 3 AT MOUTH AT FAIRFAX, VA	385153.05	771659.75
A15A2	0165389420	ACCOTINK CREEK BELOW ARLINGTON BLVD AT FAIRFAX, VA	385147.37	771651.77
S43	0165389440	STORM DRAIN AT GREAT OAKS WAY AT FAIRFAX, VA	385146.22	771645.97
A15A1	0165389450	ACCOTINK CREEK ABOVE OLD LEE HWY AT FAIRFAX, VA	385144.56	771642.76
A15B	0165389480	ACCOTINK CREEK BELOW OLD LEE HWY AT FAIRFAX, VA	385140.82	771636.87
A15	0165389490	ACCOTINK CREEK ABOVE DANIELS RUN AT FAIRFAX, VA	385138.83	771634.20
S42	0165389605	STORM DRAIN BELOW MAIN STREET AT FAIRFAX, VA	385046.38	771801.99
S41	0165389615	STORM DRAIN AT COVER PLACE AT FAIRFAX, VA	385045.39	771747.82
T42	0165389680	DANIELS RUN AT HERITAGE LANE AT FAIRFAX, VA	385104.90	771723.68
S40	0165389685	STORM DRAIN AT HERITAGE LANE AT FAIRFAX, VA	385106.84	771724.24
S39	0165389710	STORM DRAIN AT EMBASSY LANE AT FAIRFAX, VA	385108.25	771715.33
T41	0165389715	DANIELS RUN AT EMBASSY LANE AT FAIRFAX, VA	385105.97	771712.00
T40	0165389730	DANIELS RUN TRIBUTARY 1 AT MOUTH AT FAIRFAX, VA	385104.00	771710.00
S38	0165389740	STORM DRAIN AT ESTEL ROAD AT FAIRFAX, VA	385101.52	771657.90
T39	0165389770	DANIELS RUN AT ST ANDREWS DRIVE AT FAIRFAX, VA	385110.00	771646.00
T38	0165389785	DANIELS RUN TRIBUTARY 2 AT MOUTH AT FAIRFAX, VA	385111.60	771644.90
T37	0165389890	DANIELS RUN AT MOUTH AT FAIRFAX, VA	385135.68	771632.52

Appendix 3. Cross-reference listing of study site identifications and official USGS site identifications in the Accotink Creek watershed of Virginia, including site names and coordinates. — Continued

[Latitude and longitude in decimal degrees. Station locations shown in figure 3. Sites are ordered by site number, from upstream to downstream]

Site	Site number	Station name	Latitude	Longitude
A14A	0165389920	ACCOTINK CREEK ABOVE PICKETT ROAD AT FAIRFAX, VA	385138.24	771626.13
A14	01653900	ACCOTINK CREEK AT PICKETT ST AT FAIRFAX, VA	385139.00	771617.00
S36	0165390048	STORM DRAIN BELOW PICKETT ROAD AT FAIRFAX, VA	385141.44	771611.75
S35	0165390050	STORM DRAIN AT OLD PICKETT ROAD AT FAIRFAX, VA	385143.84	771613.16
S37	0165390230	STORM DRAIN ABOVE SUTTON ROAD AT FAIRFAX, VA	385240.27	771650.31
T36	0165390505	ACCOTINK CR TRIB 4 ABOVE LEE HWY AT FAIRFAX, VA	385205.56	771622.02
T35A	0165390670	ACCOTINK CR TRIB 4 BL ARLINGTON AT FAIRFAX, VA	385150.95	771611.39
T35	0165390730	ACCOTINK CREEK TRIB 4 AT MOUTH AT FAIRFAX, VA	385145.09	771610.87
A13A	0165390845	ACCOTINK CREEK AB MILL SPRINGS DR AT FAIRFAX, VA	385142.55	771559.72
A13B	0165390850	ACCOTINK CREEK NEAR MILL SPRINGS DR AT FAIRFAX, VA	385141.39	771559.14
S34	0165390890	STORM DRAIN AT MILL SPRINGS DRIVE AT FAIRFAX, VA	385137.39	771558.02
A13	0165391005	ACCOTINK CREEK ABOVE EDENVALE ROAD AT FAIRFAX, VA	385139.08	771546.37
T34	0165391120	ACCOTINK CR TRIB 5 AB TAPAWINGO RD AT VIENNA, VA	385308.98	771615.29
T33	0165391150	ACCOTINK CR TRIB 1 TRIB 5 AT MOUTH AT VIENNA, VA	385308.98	771615.08
T32	0165391460	ACCOTINK CREEK TRIB 5 AT HERMOSA DR AT VIENNA, VA	385225.11	771552.56
T31A2	0165391505	ACCOTINK CREEK TRIB 5 BELOW LEE HWY NR FAIRFAX, VA	385216.25	771551.04
S33	0165391550	STORM DRAIN AT NUTLEY STREET AT FAIRFAX, VA	385212.87	771548.48
S32	0165391580	STORM DRAIN ABOVE BARRICK STREET AT FAIRFAX, VA	385206.83	771546.84
S31	0165391630	STORM DRAIN AT BARRICK STREET AT FAIRFAX, VA	385201.77	771545.43
T31A1	0165391660	ACCOTINK CREEK TRIB 5 AB ARLINGTON NR FAIRFAX, VA	385158.08	771548.05
T31	0165391805	ACCOTINK CREEK TRIB 5 AT MOUTH NEAR FAIRFAX, VA	385142.13	771542.69
A12	0165392005	ACCOTINK CREEK ABOVE BARKLEY DRIVE AT FAIRFAX, VA	385133.38	771524.12
S28	0165392098	STORM DRAIN BELOW COTTAGE STREET AT VIENNA, VA	385306.22	771511.50
T28	0165392145	BEAR BRANCH AT WARE STREET AT VIENNA, VA	385247.02	771510.06
S30	0165392148	STORM DRAIN AT ONONDIO CIRCLE AT VIENNA, VA	385349.00	771439.00
S27	0165392298	STORM DRAIN NEAR PATRICK STREET AT VIENNA, VA	385300.96	771458.63
T30	0165392305	BEAR BRANCH TRIB 1 BELOW COTTAGE ST AT VIENNA, VA	385300.99	771458.67
T29	0165392338	BEAR BRANCH TRIB 1 AT MOUTH AT VIENNA, VA	385247.84	771507.89
T27A	0165392363	BEAR BRANCH AT ALBANY COURT AT VIENNA, VA	385240.60	771513.26
T27	0165392387	BEAR BRANCH ABOVE HUNTER ROAD AT VIENNA, VA	385229.73	771515.03
S25	0165392390	STORM DRAIN 1 AT ESPANA COURT AT VIENNA, VA	385229.10	771510.65
S26	0165392395	STORM DRAIN 2 AT ESPANA COURT AT VIENNA, VA	385225.99	771510.64
T60	0165393045	BEAR BRANCH NEAR KAREN DRIVE NEAR FAIRFAX, VA	385139.60	771522.53
T26	0165393070	ACCOTINK CREEK ABOVE BARKLEY DRIVE NR FAIRFAX, VA	385133.61	771520.27
A11	0165394250	ACCOTINK CR ABOVE PROSPERITY AVE NEAR FAIRFAX, VA	385114.69	771458.76
S24	0165394258	STORM DRAIN 1 BELOW STONEWALL DRIVE AT VIENNA, VA	385319.27	771405.38
S23	0165394260	STORM DRAIN 2 BELOW STONEWALL DRIVE AT VIENNA, VA	385319.27	771405.34
T25A	0165394490	LONG BRANCH BELOW COTTAGE STREET AT VIENNA, VA	385303.24	771412.43
T61	0165394660	LONG BRANCH AT WESLEYAN STREET AT VIENNA, VA	385251.93	771418.51
S22	0165394695	STORM DRAIN AT PROSPERITY AVENUE AT VIENNA, VA	385251.85	771402.74
S21	0165394710	STORM DRAIN BELOW INTERSTATE 66 AT VIENNA, VA	385247.31	771419.69
T25	0165394715	LONG BRANCH BELOW INTERSTATE 66 AT VIENNA, VA	385246.88	771419.88
S20	0165394775	STORM DRAIN 1 NR PROSPERITY AVENUE AT VIENNA, VA	385242.43	771416.63
S19	0165394780	STORM DRAIN 2 NR PROSPERITY AVENUE AT VIENNA, VA	385241.51	771415.86

Appendix 3. Cross-reference listing of study site identifications and official USGS site identifications in the Accotink Creek watershed of Virginia, including site names and coordinates. — Continued

[Latitude and longitude in decimal degrees. Station locations shown in figure 3. Sites are ordered by site number, from upstream to downstream]

Site	Site number	Station name	Latitude	Longitude
T24A2	0165394960	LONG BRANCH ABOVE OLD LEE HIGHWAY AT VIENNA, VA	385227.40	771431.18
T24B1	01653950	LONG BRANCH AT LEE HWY AT VIENNA, VA	385223.00	771434.00
T24A1	0165395130	LONG BRANCH AT DOGWOOD LANE AT VIENNA, VA	385214.14	771434.08
S18	0165395865	STORM DRAIN AT EXECUTIVE PARK AVE NEAR FAIRFAX, VA	385201.83	771422.99
T24	0165395975	LONG BRANCH ABOVE ARLINGTON BLVD NEAR FAIRFAX, VA	385156.66	771435.65
T23A2	0165396330	LONG BRANCH NEAR COPELAND POND CT NEAR FAIRFAX, VA	385145.75	771444.72
T23A1	0165396825	LONG BRANCH NEAR MANTUA DRIVE NEAR FAIRFAX, VA	385131.47	771453.36
T23	0165397320	LONG BRANCH AT MOUTH NEAR FAIRFAX, VA	385116.73	771457.54
A10	0165397510	ACCOTINK CR BELOW PROSPERITY AVE NEAR FAIRFAX, VA	385111.00	771445.00
S17	0165397515	STORM DRAIN AT SHANDWICK PLACE NEAR FAIRFAX, VA	385143.27	771354.53
S29	0165397550	STORM DRAIN AT APPLEGATE COURT NEAR FAIRFAX, VA	385131.15	771406.02
T22	0165397590	ACCOTINK CR TRIB 6 AT HILLSIDE PL NR FAIRFAX, VA	385129.37	771426.00
T21	0165397640	ACCOTINK CR TRIB 6 AT MOUTH NEAR FAIRFAX, VA	385113.00	771444.00
A9	0165397705	ACCOTINK CREEK NEAR BEVERLY DRIVE NEAR FAIRFAX, VA	385055.40	771421.57
S16	0165397715	STORM DRAIN NEAR BEVERLY DRIVE NEAR FAIRFAX, VA	385054.25	771418.67
S15	0165397840	STORM DRAIN AT BOSWORTH COURT NEAR FAIRFAX, VA	385038.90	771549.98
S14	0165397875	STORM DRAIN AT CHANTAL LANE NEAR FAIRFAX, VA	385041.63	771533.14
T20	0165397915	CROOK BRANCH AT GLADE HILL ROAD NEAR FAIRFAX, VA	385042.93	771510.79
T19	0165397925	CROOK BRANCH TRIBUTARY 1 AT MOUTH NEAR FAIRFAX, VA	385042.22	771510.60
S13	0165397950	STORM DRAIN AT GLADE HILL ROAD NEAR FAIRFAX, VA	385039.32	771506.73
T18	0165398350	CROOK BRANCH AT MOUTH NEAR FAIRFAX, VA	385049.63	771422.72
A8	01653985	ACCOTINK CR AT WOODBURN DR NEAR ANNANDALE, VA	385046.00	771416.00
T17	0165398530	ACCOTINK CREEK TRIB 7 AT MOUTH NEAR ANNANDALE, VA	385045.26	771415.70
T59	0165398550	ACCOTINK CR TRIB 8 AT WOODBURN RD NR ANNANDALE, VA	385118.18	771336.61
S12	0165398555	STORM DRAIN ABOVE WOODBURN ROAD NEAR ANNANDALE, VA	385118.05	771336.65
T16	0165398590	ACCOTINK CR TRIB 8 AB CHIVALRY RD NR ANNANDALE, VA	385102.34	771337.61
T15	0165398660	ACCOTINK CREEK TRIB 8 AT MOUTH NEAR ANNANDALE, VA	385044.22	771402.02
T14	0165398670	ACCOTINK CREEK TRIB 9 AT MOUTH NEAR ANNANDALE, VA	385039.60	771404.49
S11	0165398685	STORM DRAIN AT KAY COURT NEAR ANNANDALE, VA	385032.26	771356.67
A7	0165399020	ACCOTINK CREEK NR HILLCREST LANE NR ANNANDALE, VA	385038.38	771319.69
T13A	0165399035	ACCOTINK CR TRIB 10 NR REBEL DR AT ANNANDALE, VA	385052.58	771309.97
T13	0165399055	ACCOTINK CREEK TRIB 10 AT MOUTH NR ANNANDALE, VA	385038.45	771319.41
S10	0165399060	STORM DRAIN NEAR THOR DRIVE AT ANNANDALE, VA	385039.94	771309.50
A6	0165399095	ACCOTINK CR AB LITTLE RIVER TPKE NR ANNANDALE, VA	385010.39	771312.81
S9	0165399132	STORM DRAIN AT MACGREGOR COURT AT ANNANDALE, VA	385036.29	771248.19
T11	0165399155	ACCOTINK CR TRIB 11 NR HIRST DR AT ANNANDALE, VA	385014.11	771256.13
T12	0165399190	ACCOTINK CR TRIB 1 TO TRIB 11 AT ANNANDALE, VA	385013.01	771256.22
T58	0165399215	ACCOTINK CREEK TRIB 11 AT MOUTH AT ANNANDALE, VA	385005.25	771307.01
A5	0165399225	ACCOTINK CREEK NEAR ACCOTINK PKWY AT ANNANDALE, VA	384957.34	771311.86
S8	0165399235	STORM DRAIN 1 AT CARMELO DRIVE AT ANNANDALE, VA	384950.33	771230.59
S7	0165399237	STORM DRAIN 2 AT CARMELO DRIVE AT ANNANDALE, VA	384950.40	771230.64
S6	0165399252	STORM DRAIN AT AMERICANA DRIVE AT ANNANDALE, VA	384957.83	771249.44
S5	0165399255	STORM DRAIN NEAR IVYMOUNT COURT AT ANNANDALE, VA	384949.35	771251.84

Appendix 3. Cross-reference listing of study site identifications and official USGS site identifications in the Accotink Creek watershed of Virginia, including site names and coordinates. — Continued

[Latitude and longitude in decimal degrees. Station locations shown in figure 3. Sites are ordered by site number, from upstream to downstream]

Site	Site number	Station name	Latitude	Longitude
T9	0165399285	ACCOTINK CREEK TRIB 12 AT MOUTH AT ANNANDALE, VA	384956.51	771311.01
A4	0165399313	ACCOTINK CREEK NEAR WOODLARK DR AT ANNANDALE, VA	384942.61	771325.71
T10	0165399345	ACCOTINK CR TRIB 13 AT HILLCREST NR ANNANDALE, VA	385017.57	771346.34
S4	0165399368	STORM DRAIN AT CAMPUS DRIVE NEAR ANNANDALE, VA	385006.13	771404.31
T8	0165399430	ACCOTINK CREEK TRIB 13 AT MOUTH AT ANNANDALE, VA	384942.05	771327.85
A3	0165399438	ACCOTINK CREEK NR BRIAR CREEK DR NR ANNANDALE, VA	384935.07	771326.14
T7	0165399495	ACCOTINK CREEK TRIB 14 AT MOUTH NEAR ANNANDALE, VA	384934.65	771327.79
S3	0165399507	STORM DRAIN AT PATRIOT LANE AT ANNANDALE, VA	384930.28	771305.47
T6	0165399515	ACCOTINK CREEK TRIB 15 AT MOUTH NEAR ANNANDALE, VA	384931.54	771325.95
S52	0165399522	STORM DRAIN NEAR COMMONS DRIVE AT ANNANDALE, VA	384920.27	771316.52
A2	0165399535	ACCOTINK CREEK ABOVE TURKEY RUN NEAR ANNANDALE, VA	384859.27	771340.95
T5	0165399573	TURKEY RUN NEAR BANFF STREET NEAR ANNANDALE, VA	384933.20	771428.66
T4	0165399575	TURKEY RUN ABOVE SUGARBUSH COURT NR ANNANDALE, VA	384933.20	771428.24
T3	0165399585	TURKEY RUN TRIB 1 NR SUGARBUSH CT NR ANNANDALE, VA	384929.37	771416.84
T2	0165399645	TURKEY RUN ABOVE PRIVATE LANE NEAR ANNANDALE, VA	384914.81	771356.15
S2	0165399675	STORM DRAIN AT OLD WELL ROAD NEAR ANNANDALE, VA	384905.14	771358.13
T1	0165399715	TURKEY RUN AT MOUTH NEAR ANNANDALE, VA	384859.00	771343.00
S1	0165399770	STORM DRAIN AT KALORAMA ROAD AT ANNANDALE, VA	384848.78	771304.14

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