Investigation of Dioxin Concentrations in the Lower Roanoke River Basin, North Carolina, February 26–March 7, 2001

By Kimberly F. Miller and Douglas A. Walters

U.S. GEOLOGICAL SURVEY

Open-File Report 01–345

Prepared in cooperation with the

U.S. Environmental Protection Agency, Region IV

Raleigh, North Carolina
2001

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CONVERSION FACTORS, SPECIFIC CONDUCTANCE, TEMPERATURE, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	0.4047	hectare
square mile (mi^2)	2.590	square kilometer
	Volume	
cubic foot (ft^3)	0.0283	cubic meter
	Flow	
inch per year (in/yr)	2.54	centimeters per year
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second

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

Temperature can be converted to degrees Fahrenheit (°F) or degrees Celsius (°C) by using the following equations:

$$°F = (°C \times 1.8) + 32$$
$$°C = (°F - 32) / 1.8$$

Sea level refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929), a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated water-quality units:

L, liter
µL, microliter
µm, micrometer
µg, microgram
fg/L, femtogram per liter
mg/L, milligram per liter

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ABSTRACT

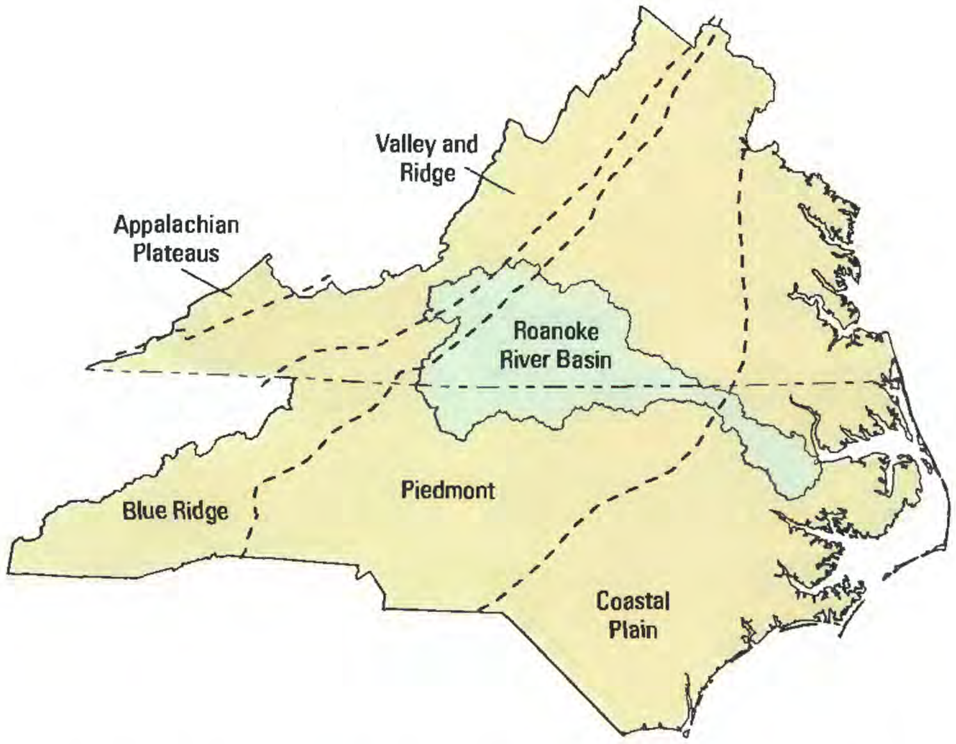
Dioxin is a toxic chemical that, when present in the environment, can cause cancer and birth defects in humans. Dioxin is of particular concern because concentrations of dioxin that were released into the environment many years ago remain a contributing factor to current exposure. Dioxin exposure often occurs in surface-water systems downstream from contaminated sites and is detrimental to aquatic life. For these reasons and because the U.S. Geological Survey has expertise in conducting high-volume dioxin sampling, the U.S. Environmental Protection Agency and the State of North Carolina asked the U.S. Geological Survey to collect water samples in the lower Roanoke River to be analyzed for the presence of dioxin.

Water quality of the lower Roanoke River Basin in North Carolina was assessed at eight sites during February 26–March 7, 2001. Water-quality samples were collected for analysis of suspended-sediment and dioxin concentrations; high-volume (750-liter) water samples were collected for dioxin analysis. Discharge measurements were made at or near the high-volume sampling sites. Suspended-sediment sampling and water-quality measurements of specific conductance, pH, water temperature, and dissolved-oxygen concentrations made at each sampling site included multidepth measurements at two cross-section transects and hourly measurements at the point of high-volume sampling. Multidepth measurements were made near the surface, mid-depth, and near the bottom of the water column. These values were averaged for each cross section.

During the sampling period, all sites sampled had dioxin concentrations above detection limits (1 part per quintillion) for both suspended and dissolved dioxin. Suspended dioxin ranged from 5.1 to 900 femtograms per liter, and dissolved dioxin values ranged from 0.31 to 41 femtograms per liter. Suspended-sediment concentrations ranged from 1.1 to 14 milligrams per liter. Specific conductance values ranged from 111 to 340 microsiemens per centimeter at 25 degrees Celsius. The range of pH values at the sampling sites was from 6.6 to 7.7. Water temperatures ranged from 8.9 to 13 degrees Celsius. Dissolved-oxygen concentrations ranged from 7.3 to 10.9 milligrams per liter.

INTRODUCTION

The Roanoke River drainage basin encompasses approximately 9,666 square miles (mi^2) in North Carolina and Virginia (fig. 1). The upper Roanoke River Basin (above Roanoke Rapids Dam) constitutes the major portion of the river drainage system (87 percent) and is located within the Piedmont, Blue Ridge, and Valley and Ridge Provinces. The lower Roanoke River Basin (below Roanoke Rapids Dam to the mouth of the river, about 7 miles (mi) downstream from Plymouth) constitutes a small part of the river drainage basin (13 percent) and is totally within the Coastal Plain Province. Flow in the lower 137 mi of the Roanoke River has been controlled by a series of reservoirs since 1952. The Roanoke River drains into



LOCATION OF ROANOKE RIVER BASIN AND PHYSIOGRAPHIC PROVINCES IN NORTH CAROLINA AND VIRGINIA

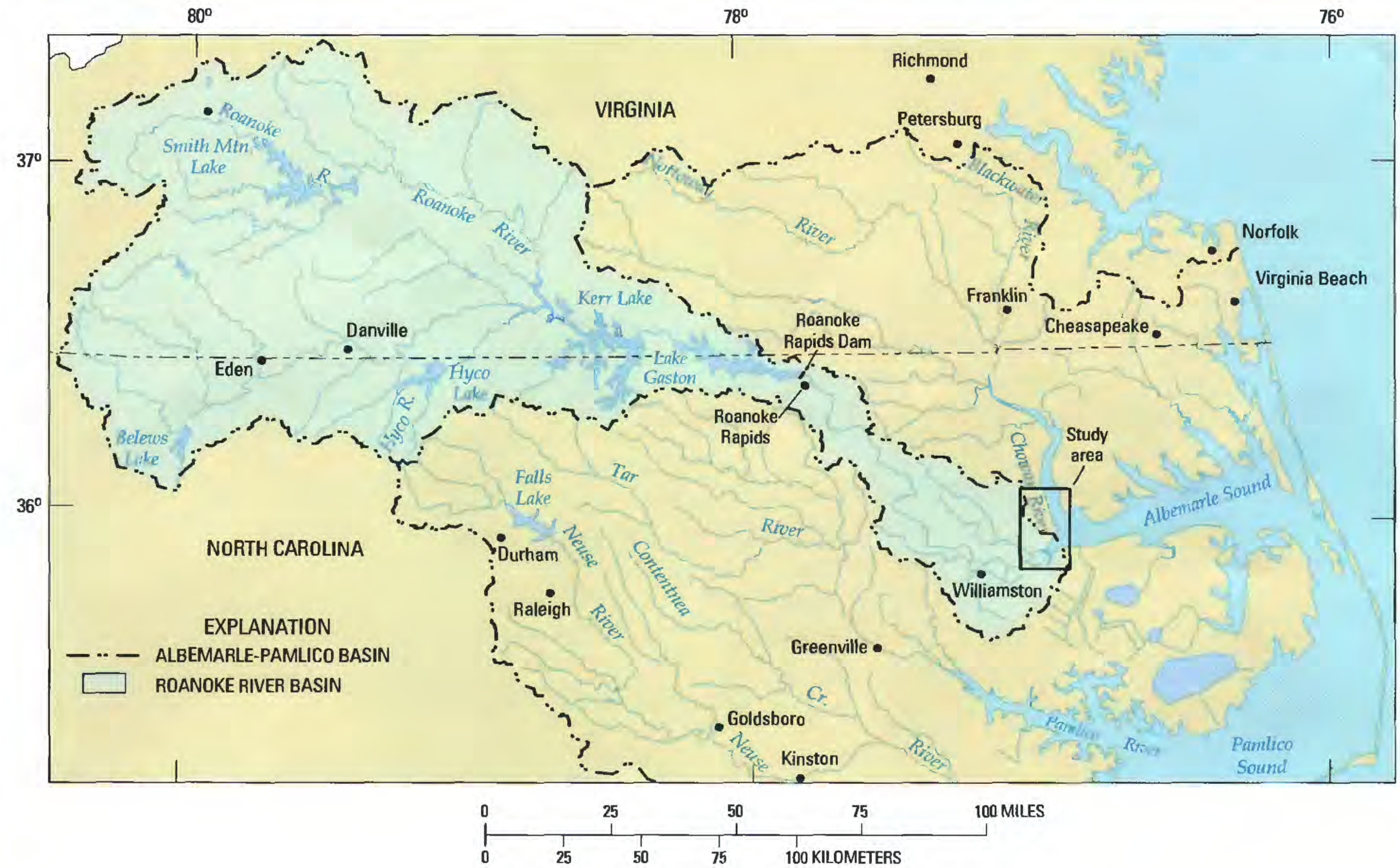


Figure 1. Location of the study area in the Roanoke River Basin, North Carolina.

the western end of the Albemarle Sound, an approximately 900-mi^2 complex network of fresh- to brackish-water estuaries.

In 1985, the State of North Carolina conducted an inspection of an area of the Roanoke River around a large industrial facility located near Plymouth (fig. 2). The inspection identified three potential source areas for contamination to the Roanoke River—outflow from Welch Creek, a former chlorine plant, and a former landfill (Beth Walden, U.S. Environmental Protection Agency, Region IV, written commun., 2001). Sampling by Rulifson (Rulifson and Manooch, 1993) indicated that significant concentrations of dioxins were widely distributed in fine bottom sediments from the mouth of the Roanoke River extending well into Albemarle Sound. Additional bottom-sediment samples collected in 1995 supported findings by Rulifson that the Roanoke River and Welch Creek were contaminated with dioxin (Beth Walden, U.S. Environmental Protection Agency, Region IV, written commun., 2001).

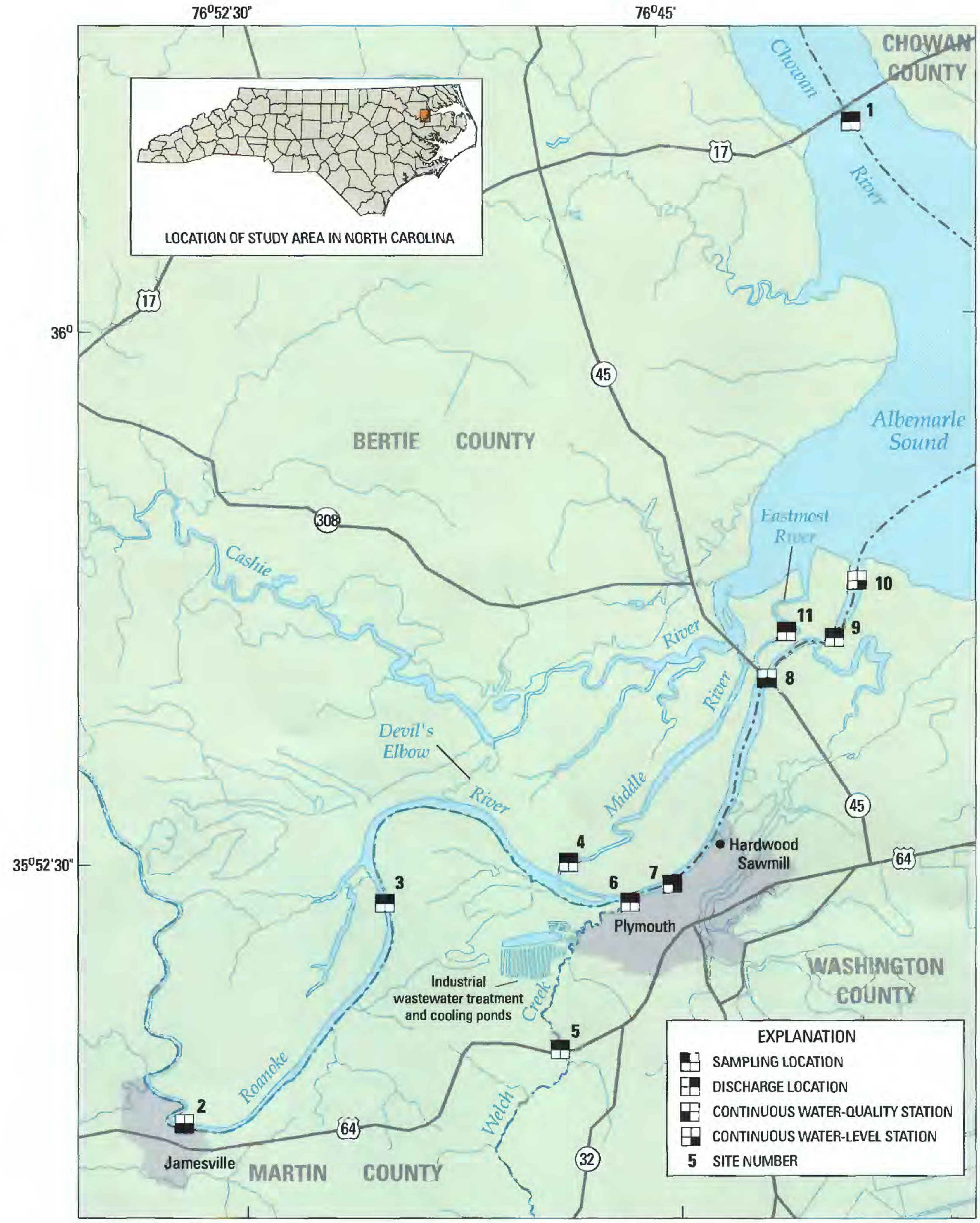
The industrial facility has been in operation in the study area since 1938 and presently (2001) consists of 1,200 acres, including 750 acres of industrial wastewater-treatment ponds (fig. 2). Originally, all industrial wastewater from the facility was discharged into the Roanoke River. Between the early 1960's and 1988, however, all industrial wastewater was discharged into Welch Creek upstream from the mouth of the Roanoke River. Beginning in 1968, all industrial wastewater from this facility, except cooling water, was processed through a secondary treatment plant before being discharged into Welch Creek. Since 1988, 55 million gallons per day of noncooling, industrial wastewater have been discharged into the Roanoke River through a diffuser pipe across the river bottom. This discharge pipe is located downstream from the industrial site and slightly upstream from the mouth of Welch Creek (Rulifson and Manooch, 1993).

In addition to this facility, another major hardwood sawmill previously was located in the study area. Information is not available regarding operations and waste-management practices at this facility prior to 1950. After 1950, site operations involved debarking, sawing, and planing rough hardwood timber from logs. Surface treatment of some finished lumber occurred using a conveyor belt and dip vat. The sawmill was permanently closed after it was destroyed by a fire in 1983 (Camp Dresser & McKee, Inc., 2001).

The State of North Carolina conducted investigations at the hardwood sawmill location beginning in 1985. The studies concluded that surface-water runoff from the sawmill site resulted in chemical changes in the Roanoke River (North Carolina Department of Environment, Health, and Natural Resources, 1997). Sediment samples collected in 1995 downstream from this site contained elevated levels of dioxin that were attributed to the sawmill operation. Surface-water samples were found to be free of contaminants.

In 1996, the State of North Carolina referred both sites—the large industrial facility and the hardwood sawmill—to the U.S. Environmental Protection Agency (USEPA), Region IV, because the sites posed a potential threat to human health and the environment. The USEPA began a Superfund Site investigation of the lower Roanoke River in July 1998 as a result of wastewater releases from the large industrial facility and the hardwood sawmill. Discharges from these facilities are believed to be the main sources of contamination to the lower Roanoke River.

Additional information was needed, however, to assess the environmental effects of these discharges to the lower Roanoke River Basin. Because sediment samples indicated the presence of dioxin but surface-water samples did not, a technique capable of detecting very low levels of dioxin in the water column was needed. The U.S. Geological Survey (USGS) has expertise in high-volume water sampling that allows for a detection limit of 1 part per quintillion (1×10^{-18}) in 1,000 liters of sampled water. Therefore, the USEPA, Region IV, entered into an Interagency Agreement with the USGS, West Virginia District, to sample eight sites in the lower Roanoke River Basin in North Carolina during February 26–March 7, 2001. Because dioxin is chemically stable (Schecter, 1994), it is longlasting in the environment. In order to detect the presence of dioxin in the lower Roanoke River Basin, a single measurement was made at eight sites (table 1; fig. 2). Because of time constraints associated with short periods of daylight during the sampling period, the volume of water collected at each site was limited to 750 liters. However, because of the high levels of dioxin detected in the ambient samples, the laboratory was able to maintain the 1-part-per-quintillion detection limit.



Base from digital files of:
U.S. Department of Commerce, Bureau of Census,
1990 Precensus TIGER/Line Files-Political boundaries, 1990
National Hydrologic Data 1:100,000
U.S. Geological Survey, 1:100,000 scale

Figure 2. Study area in the lower Roanoke River Basin, North Carolina, and selected data-collection sites.

Table 1. Hydrologic data-collection sites in the lower Roanoke River Basin, North Carolina

[USGS, U.S. Geological Survey; SEO, sewage-effluent outfall; SR, secondary road]

Site no. (fig. 2)	USGS station number	Latitude	Longitude	County	Site name	Station type
1	0205365200	36° 02′ 42″	76° 41′ 42″	Bertie	Chowan River near Edenhouse	Sampling/discharge
2	02081094	35° 48′ 49″	76° 53′ 37″	Martin	Roanoke River at Jamesville	Continuous water level/ water quality
3	0208109415	35° 51′ 52″	76° 50′ 02″	Martin	Roanoke River above Broad Creek near Woodard	Sampling/discharge
4	0208113525	35° 52′ 23″	76° 46′ 52″	Bertie	Middle River above mouth near Plymouth	Sampling/discharge
5	02081138	35° 49′ 45″	76° 47′ 06″	Washington	Welch Creek above SEO near Plymouth	Sampling/discharge
6	02081140	35° 51′ 48″	76° 45′ 51″	Washington	Welch Creek at SR 1565 at Plymouth	Sampling/discharge
7	0208114055	35° 52′ 03″	76° 45′ 05″	Washington	Roanoke River at Plymouth	Sampling/discharge/ continuous water level
8	0208114150	35° 54′ 54″	76° 43′ 22″	Bertie	Roanoke River at N.C. Highway 45 near Westover	Continuous water level/ water quality
9	0208114210	35° 55′ 27″	76° 42′ 11″	Washington	Roanoke River at Light 13 near Westover	Sampling/discharge
10	0208114250	35° 56′ 15″	76° 41′ 47″	Bertie	Roanoke River at Light 11 near Westover	Continuous water level
11	0208114320	35° 55′ 32″	76° 42′ 51″	Bertie	Eastmost River below N.C. Highway 45 near Westover	Sampling/discharge

Purpose and Scope

This report presents water-quality data collected during February 26–March 7, 2001. The data were evaluated to determine the distribution of dioxin and selected water-quality characteristics at sites in the lower Roanoke River Basin of North Carolina (table 1; fig. 2). Water-quality data for the lower Roanoke River Basin were collected from Welch Creek, and the Roanoke River, Middle River, Chowan River and Eastmost River. Dioxin concentrations in the water column can be difficult to detect. Because the USGS has expertise in high-volume water sampling, the USEPA requested assistance from the USGS to investigate the presence of dioxin in the lower Roanoke River Basin. The presence of dioxin in the water column was determined by using a detection limit of 1 part per quintillion. Discharge and water level also were measured. Additionally, samples were collected for analysis of suspended-sediment concentrations so that, if needed, loads could be calculated. Field measurements were made of specific conductance, pH, water temperature, and dissolved-oxygen concentration.

Description of the Study Area

The lower Roanoke River Basin is in the Coastal Plain Province of North Carolina (fig. 1). The study area is an approximately 420-mi^2 area of the Roanoke River Basin and extends from Jamesville approximately 19 river miles to the mouth of the river in the Albemarle Sound (fig. 2). One of the world's largest wood-products facilities is located within the study area on the banks of Welch Creek and the lower Roanoke River west of Plymouth (fig. 2; Rulifson and Manooch, 1993).

The study area is characterized by a system of distributaries that carry water from the Roanoke River into the Cashie River and the Albemarle Sound. The most notable of these distributaries are Devil's Elbow, Middle River, and the Eastmost River (fig. 2).

Other streams that drain to the Roanoke River in the study area are relatively small and have basins with little topographic relief. Land-surface elevations within the study area generally are less than 40 feet (ft) above sea level and only a few feet above sea level in the swampy areas that occur within the distributary system.

The average annual outflow at the mouth of the Roanoke River is about 8,900 cubic feet per second

(ft^3/s). It is second only to the outflow of the Cape Fear River among North Carolina's rivers (Giese and others, 1985). The combination of relatively high outflow, small cross-section areas, and flow augmentation by Roanoke Rapids Dam effectively blocks saltwater from intruding into the mouth of the river. The effects of tide and wind on the flow in the study area are not well understood.

Climate in the region is mild and moderately humid. The annual mean temperature at Plymouth is about 60 degrees Fahrenheit (°F), and the mean annual precipitation is about 50 inches (in.). Annual precipitation varies greatly from year to year, ranging from less than 40 to more than 75 in. However, precipitation is relatively uniform throughout the year, with the highest amounts typically occurring in July, August, and September. Evapotranspiration rates average about 34 in. per year and vary less from year to year than precipitation (Wilder and others, 1978). On average, about 30 percent of the total precipitation in the study area reaches streams either through surface runoff or ground-water discharge (Wilder and others, 1978).

The study area is characterized primarily by agricultural land use and by a wide, perennially flooded, forested wetland, which includes endangered Atlantic white cedar forests. In terms of quality, extent, and contiguity, the forested, alluvial wetlands in the lower Roanoke River Basin are one of the best examples of this type of ecosystem in the southeastern United States (Rulifson and Manooch, 1993).

Acknowledgments

The assistance of others during this study was invaluable. The authors thank USGS Hydrographers, Jamie I. Marlowe, Ryan B. Rasmussen, Geoffrey D. Cartano, and Carl W. Faulkenburg for their contributions in conducting sampling and flow-measurement activities. The authors also thank the U.S. Environmental Protection Agency, Region IV, for their support of this project.

DIOXIN

Dioxin became a health concern in the 20th century. As a by-product of the use of chlorine in industrial processes and the combustion of chlorine-containing fuels, dioxin is hydrophobic and readily adsorbs to sediment particles. It is a toxic chemical that, in exceptionally small amounts, can cause cancer and birth defects. Current scientific evidence indicates that dioxin appears to disrupt important physiological signaling systems, which leads to a host of biological changes, such as alterations in the development, differentiation, and regulation of cells in humans. Studies have shown that dioxin and dioxin-like compounds can have negative effects on human reproduction (Schecter, 1994).

Primary environmental sources of dioxin include chemical side reactions associated with the manufacture of a variety of chloroaromatic substances, the bleaching of brown pulp for white-paper production, and the production of chlorine. Combustion-related sources are widely believed to be the major known sources of global dioxin and include all forms of waste incineration, many forms of metal production, and fossil-fuel and wood combustion (Schecter, 1994).

Direct discharge of dioxin and dioxin-like compounds, including polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), into aquatic systems is detrimental to aquatic life. These chemicals are persistent organic pollutants. Lipophilic and hydrophobic dioxin and dioxin-like compounds tend to bioconcentrate from water to aquatic life and biomagnify up the food chain. The combined effects of bioaccumulation and the movement of sediment create long-term environmental problems (Schecter, 1994).

DATA-COLLECTION METHODS

The field data-collection network for the study consisted of eight sampling sites (fig. 2; table 1). Two of these sites were on Welch Creek (sites 5 and 6), three were on the Roanoke River (sites 3, 7, and 9), one was on the Middle River (site 4), one was on the Chowan River (site 1), and one was on the Eastmost River (site 11). Water quality in the lower Roanoke River Basin was determined from field measurements of specific conductance, pH, water temperature, dissolved-oxygen (DO) concentration, discharge, and water level; and by laboratory analyses for suspended-sediment and dioxin concentrations. Field data were collected during February 26–March 7, 2001. In addition, continuous (15-minute interval) water-level data were collected at four sites (sites 2, 7, 8, and 10), and continuous (hourly) specific conductance, pH, water temperature, and DO concentration data were collected at two sites (sites 2 and 8). Because of time constraints associated with short periods of daylight during the sampling period, the high-volume water sample for dioxin concentrations collected at each site was 750 liters instead of 1,000 liters. The laboratory was able to maintain the 1-part-per-quintillion detection limit, however, because of the high levels of dioxin detected in the ambient samples.

High-Volume Water Sampling for Dioxin

A high-volume sampler was used to sample for dioxin concentrations in the water column. This sampling method allows for very low detection limits for analysis of dioxin and furan concentrations. Large volumes of water (750 liters) were passed through a specialized sampler. The intake line of the high-volume sampler was secured at a fixed point 7.0 ft below the surface of the water at sites 3, 4, 7, and 9 where the water is 14 ft or greater in depth. At sites 4, 6, and 11, where the water was less than 14 ft deep, the fixed sampling point was one-half the total depth of the water. Hydrologically, these depths are thought to be the most representative of the water column. One exception was the Chowan River, where the total depth was 20.5 ft and the sampling depth was 10.0 ft.

Water was passed through three glass-fiber filters of decreasing pore sizes—150 micrometers (µm), 50 µm, and 1 µm—and through a specially packed XAD2™ resin column at a rate of 2.2 liters per minute or less. This rate allowed the water sample to be in contact with the XAD2™ resin column long enough for the dioxin and furan compounds to adsorb to the column, which was specifically designed to extract dioxin from the water. AXYS Analytical Services, of British Columbia, Canada, analyzed the XAD2™ resin columns and the glass-fiber filters using the USEPA's Method 1631 B (U.S. Environmental Protection Agency, 1997). The sampling period typically lasted approximately 8 hours.

Discharge and Water-Level Measurements

Because dioxin readily adsorbs to suspended particulates (Schecter, 1994), discharge measurements along with suspended-sediment concentrations allow for calculations of load and transport of dioxin. Discharge measurements were made, using an acoustic doppler current profiler (ADCP), several times at each of the sampling sites during high-volume sampling for dioxin. The frequencies of the discharge measurements were determined by the streamflow variability. Acoustic doppler technology makes it possible to measure profiles of water currents in the water column from a moving vessel. As the vessel crosses the stream, acoustic pulses are directed downward in the water column from the ADCP, and part of the transmitted acoustic energy is reflected back toward the instrument from particulate matter in the water column. The frequency of these reflected signals is shifted because of the doppler effect, and the magnitude of the frequency shift is a function of the velocity of the particulate matter in the water column. The ADCP converts these frequency shifts to water velocity (Simpson and Oltmann, 1993). The vessel velocity relative to the channel bottom also is measured by the ADCP. This measurement is distinct from the water-velocity measurement and is referred to as the bottom-track measurement.

The ADCP is capable of computing discharge based on water-velocity profile data and bottom-track data. For the lower Roanoke River study, unmeasured portions of the velocity profile near the water surface above the ADCP transducers, near the river bottom, and at the edges of the river were estimated based on standard open-channel velocity profiles. These estimated velocities were added to the measured data in the computation of overall discharge at a given measurement location.

Four tidal gages on the Roanoke River—one at Jamesville (site 2, fig. 2), one at Plymouth (site 7, fig. 2), one at the N.C. Highway 45 bridge (site 8, fig. 2), and one at the mouth of the Roanoke River at Light 11 (site 10, fig. 2)—were used to monitor continuous water level. All gages recorded data at 15-minute intervals. Instrumentation at Jamesville consisted of a Handar 436A incremental shaft encoder (float/stilling-well system) connected to a Sutron 8210 data-collection platform. Instrumentation at Plymouth and the N.C. Highway 45 bridge consisted of a Sutron 8400 data logger/incremental encoder combination with a float/stilling-well system. Instrumentation at Light 11 consisted of a Sutron Accububble pressure transducer and a Sutron 8210 data-collection platform.

Optic levels were used to determine water levels at sites 2, 7, and 8 from established benchmarks. An arbitrary water level was used at site 10 because of difficulty in establishing mean sea level at this location. All water-surface elevations are to mean sea level from National Geodetic Vertical Datum of 1929 with the exception of site 10, which is referenced to an arbitrary datum. All four tidal gages were serviced on a monthly basis, and the data were downloaded, processed, and stored in the USGS National Water Information System (NWIS) database.

Suspended-Sediment Samples

Point water samples for suspended-sediment concentrations were collected hourly at the location of the high-volume sampler intake. Samples were collected to accurately define suspended-sediment concentrations in the water column to facilitate use of the data for modeling and loading calculations. Gray and others (2000) describe the methods used for analysis. In addition to the hourly sampling for suspended sediment, cross-section sampling of suspended sediment was conducted. Cross-section samples were collected by using the equal-width increments (EWI) or equal-discharge increments (EDI) method (Wilde and Radtke, 1998). One modified EWI cross-section transect sample consisting of three multidepth point samples at 25-, 50-, and 75-percent of the cross-section width was made during the first 4 hours of the sampling period. Samples were collected at equal-width increments near the surface of the water, mid-depth, and near the bottom of the river. EDI measurements require stable discharge. When flow was sufficient for ADCP measurements to be made near the sampling point, an EDI cross-section measurement was made during the last 4 hours of the sampling period. At the 10-, 30-, 50-, 70-, and 90-percent discharge point on each EDI transect, a depth-integrated water sample was collected continuously from the bottom to the top of the water column for analysis of suspended-sediment concentration. When flow was insufficient for ADCP measurements or when measurements could not be made in close proximity to the sampling, integrated EWI cross-section sampling was conducted during the last 4 hours of the sampling period. The water samples were analyzed for suspended-sediment concentrations (Guy and Norman, 1977) at the USGS sediment laboratory in Louisville, Kentucky. Depth-integrated sample values in each cross section were averaged and reported as an average for the cross-section sample.

Water-Quality Field Measurements

Water-quality field measurements of specific conductance, pH, water temperature, and DO concentration were made with a portable, multiparameter water-quality system (Hydrolab Surveyor 3) at each sampling site. Each cross-section measurement included multidepth (near surface, mid-depth, and near bottom) measurements at three or five evenly spaced locations in two cross-section transects and hourly point measurements at the location of the high-volume sampler intake. In order to represent the entire river cross section, measurements were made during two cross-section transects. The first cross-section transect measurement consisted of three multidepth measurements made during the first 4 hours of the sampling period. These values were averaged for the cross section. The second cross-section transect measurement was made during the last 4 hours of the sampling period and consisted of five multidepth measurements, which were averaged for the cross section.

Quality Assurance

Prior to each sampling event, the high-volume sampler was cleaned to remove any dirt or other contamination from the unit. The filter housing and all intake lines were flushed with laboratory-grade detergent solution followed by a thorough rinsing with de-ionized water. Additionally, the filter housing and all intake lines were flushed with acetone and rinsed with de-ionized water. All tongs and forceps used in the sampling process were cleaned with laboratory-grade detergent and acetone, and rinsed with de-ionized water prior to use. All cleaned utensils were stored in a clean storage container until needed. Once equipment had been cleaned, particular care was taken to avoid contaminating any surfaces that would come into contact with the water sample.

Each XAD2™ resin column used for sampling was spiked with 1.4 microliters (µL) of dioxin (13C6–1234–TCDD). This known spiked amount of dioxin was used to test the extraction efficiency. During three of the sampling events, a second column was set up in series after the spiked column. The first column was the primary sample column and was spiked. The second column, a recovery column, was not spiked and was used to test the efficiency of the columns to extract dioxin from the water as it passed over the XAD2™

resin. One nonspiked column, present in the field but not used to filter sample water, was analyzed as a field blank. One unused glass-fiber filter of each size used was analyzed as a field blank as well.

The dioxin samples were analyzed in batches by AXYS Analytical Services alongside quality-control (QC) samples. Each analytical batch included a laboratory blank to demonstrate acceptable laboratory background levels, a spiked matrix reference sample to demonstrate analyte recoveries, and a duplicate sample to demonstrate the analytical precision achieved. The results of the batch QC samples, as well as the recoveries of labeled surrogate compounds for samples, fell within limits predefined by the laboratory. QC sample data are evaluated during the analysis period to ensure that the analytical system is operating properly. AXYS Analytical Services has an analytical quality-assurance and quality-control program that includes matrix-specific method recovery studies, verification of standard solution accuracy against recognized standard reference solutions, analysis of certified reference materials, and participation in interlaboratory comparison programs.

Discharge measurements were made with the ADCP in accordance with quality-assurance guidelines adopted by the USGS and referenced in Lipscomb (1995). During each sampling event, duplicate samples for suspended-sediment concentration were collected for one of the hourly samples. Duplicate suspended-sediment samples also were collected at a single point of the first cross section at each sample location.

Five to 10 percent of the sediment samples analyzed by the Kentucky District laboratory were QC samples inserted by the analyst. These samples consisted of field-collected replicate samples and blank samples. Blank samples were prepared from de-ionized water and distributed throughout the set of concentration-analysis samples (Sholar and Shreve, 1998). The Kentucky District sediment laboratory participates in the Sediment Laboratory Quality Assurance (SLQA) Program of the USGS Office of Water Quality, Branch of Quality Systems, and the QA/QC exercises developed by the USGS as part of the National Stream Quality Accounting Network (NASQAN).

The portable water-quality monitoring system was calibrated at the beginning of each sampling period in accordance with procedures recommended by the manufacturer (Hydrolab Corporation, 1991), and all parameters were checked against standard solutions at the end of the day for meter drift. Barometric pressure was recorded at the beginning and ending of each sampling period by using an analog barometer that was calibrated against a mercury barometer maintained by the National Weather Service Forecast Office in Charleston, W.V. The portable monitoring system measures DO concentrations electrometrically with a standard membrane electrode. The electrode was calibrated by reading the meter against water-saturated air at known temperature and barometric pressure. Specific conductance and pH were calibrated by using standard solutions. The temperature probe was checked by the manufacturer prior to the sampling effort to ensure proper functioning.

WATER-QUALITY DATA

Dioxin-concentration data collected in the lower Roanoke River Basin during February 26–March 7, 2001, are presented in table 2. Streamwater-level data from selected gages in the lower Roanoke River Basin for each sampling event are presented in table 3. Suspended-sediment concentration and water-quality data for the hourly measurements, cross-section transects, and discharge measurements are presented in tables 4–11. The data are arranged according to USGS downstream order number, date, sampling location, and parameter sampled.

Table 2. Dioxin toxic equivalents (TEQ) data for sampling sites in the lower Roanoke River Basin, North Carolina

[USGS, U.S. Geological Survey; ID, identification; µg, microgram; fg/L, femtogram per liter; ft, foot; SEO, sewage-effluent outfall; SR, secondary road]

Site no. (fig. 2)	USGS station number	Site name and sampling location	Sample ID	Date of sampling	Suspended dioxin 150-micrometer filter		Suspended dioxin 50-micrometer filter		Suspended dioxin 1-micrometer filter		Sum of suspended dioxin values (filters)		Dissolved dioxin value (column)	
					µg	fg/L	µg	fg/L	µg	fg/L	µg	fg/L	µg	fg/L
1	0205365200	Chowan River near Edenhouse (3,200 ft from left bank)	RR101	03-02-01	4.9E-05	65	9.3E-07	1.2	1.2E-06	1.6	5.1E-05	68	4.5E-06	6.0
3	0208109415	Roanoke River above Broad Creek near Woodard (180 ft from left bank)	RR108	02-28-01	3.4E-05	45	3.4E-06	4.5	9.9E-07	1.3	3.8E-05	51	5.3E-07	.71
4	0208113525	Middle River above mouth near Plymouth (30 ft from left bank)	RR107	03-01-01	5.4E-05	72	3.0E-06	4.0	2.7E-06	3.6	6.0E-05	80	2.3E-07	.31
5	02081138	Welch Creek above SEO near Plymouth (35 ft from left bank)	RR106	02-27-01	3.0E-06	4.0	2.6E-07	.35	5.4E-07	.72	3.8E-06	5.1	3.7E-07	.49
6	02081140	Welch Creek at SR 1565 at Plymouth (165 ft from left bank)	RR105	02-26-01	5.9E-04	790	7.0E-05	93	1.2E-05	16	6.7E-04	900	3.1E-05	41
7	0208114055	Roanoke River at Plymouth (290 ft from left bank)	RR104	03-07-01	8.8E-05	120	1.1E-05	15	9.8E-06	13	1.1E-04	150	1.6E-06	2.1
9	0208114210	Roanoke River at Light 13 near Westover (57 ft from left bank)	RR103	03-06-01	1.4E-04	190	1.4E-05	19	3.0E-06	4.0	1.6E-04	210	5.1E-06	6.8
11	0208114320	Eastmost River below N.C. Highway 45 near Westover (165 ft from left bank)	RR102	03-05-01	7.2E-05	96	5.9E-06	7.9	4.1E-06	5.5	8.2E-05	110	1.5E-06	2.0

Table 3. Daily water-level data for selected sites in the lower Roanoke River Basin, North Carolina, February 26–March 7, 2001

[Sites 2, 7, and 8 are elevations to mean sea level; site 10 is based on an arbitrary datum]

Date	Site number (fig. 2)	Daily water level, in feet		
		Maximum	Minimum	Mean
February 26, 2001	2	1.46	0.60	0.92
	7	1.18	.45	.79
	8	1.21	.50	.85
	10	1.14	.38	.77
February 27, 2001	2	.79	.34	.59
	7	.61	.24	.47
	8	.66	.32	.54
	10	.64	.23	.45
February 28, 2001	2	1.44	.42	.74
	7	1.23	.36	.61
	8	1.23	.42	.67
	10	1.18	.32	.60
March 1, 2001	2	.98	.31	.56
	7	.83	.25	.46
	8	.88	.33	.54
	10	.81	.26	.46
March 2, 2001	2	1.04	.61	.79
	7	.88	.50	.67
	8	.93	.57	.74
	10	.87	.48	.67
March 5, 2001	2	1.09	.17	.73
	7	.94	.12	.63
	8	1.01	.21	.69
	10	.94	.14	.63
March 6, 2001	2	.74	-.88	-.29
	7	.61	-.91	-.37
	8	.66	-.73	-.29
	10	.61	-.93	-.38
March 7, 2001	2	.51	-.32	.08
	7	.34	-.38	-.07
	8	.41	-.31	.01
	10	.34	-.42	-.07

Table 4. Water-quality field measurements and suspended-sediment data for the Chowan River near Edenhouse (site 1, USGS station 0205365200), North Carolina, March 2, 2001

[USGS, U.S. Geological Survey; ft, foot; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; mg/L, milligram per liter; ft^3/s, cubic foot per second; —, no data; EWI, equal-width increment; EDI, equal-discharge increment]

Type of sample	Time	Sampling depth (ft)	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Suspended sediment (mg/L)	Discharge (ft^3/s)
Hourly[a]	1215	9.7	334	7.5	9.9	10.7	2.5	—
Hourly[a]	1315	9.9	334	7.7	9.9	10.7	2.6	—
Hourly[a]	1415	9.8	337	7.7	9.9	10.8	1.3	22,200
Hourly[a]	1515	9.6	336	7.7	9.8	10.8	3.4	37,900
Hourly[a]	1615	9.8	333	7.7	9.8	10.8	2.7	39,500
Hourly[a]	1715	10.0	327	7.7	9.9	10.6	3.6	22,100
Hourly[a]	1800	—	—	—	—	—	—	-1,590[b]
Average EWI, point[c]	1600	8.7	340	7.7	10.1	10.3	3.8	—
Average EDI, integrated[d]	1715	11.2	317	7.7	10.0	10.8	5.5	—

[a] Hourly samples were collected at the point location of the high-volume sampler intake.

[b] Tidal effects forced the water to flow upstream.

[c] Equal-width point samples were collected at 25, 50, and 75 percent of the total width of the cross-section transect near the top, mid-depth, and near the bottom of the water column.

[d] Equal-discharge increment integrated samples were collected at 10, 30, 50, 70, and 90 percent of total discharge. Water-quality measurements were made near the top, mid-depth, and at the bottom of the water column. Sediment samples were depth integrated throughout the water column.

Table 5. Water-quality field measurements and suspended-sediment data for the Roanoke River above Broad Creek near Woodard (site 3, USGS station 0208109415), North Carolina, February 28, 2001

[USGS, U.S. Geological Survey; ft, foot; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; mg/L, milligram per liter; ft^3/s, cubic foot per second; —, no data; EWI, equal-width increment; EDI, equal-discharge increment]

Type of sample	Time	Sampling depth (ft)	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Suspended sediment (mg/L)	Discharge (ft^3/s)
Hourly[a]	1100	6.5	122	7.4	9.5	10.6	7.9	—
Hourly[a]	1200	6.4	122	7.4	9.5	10.7	9.4	—
Hourly[a]	1300	6.6	122	7.5	9.5	10.7	5.4	4,690
Hourly[a]	1400	6.6	122	7.4	9.5	10.7	6.1	5,040
Hourly[a]	1500	6.6	122	7.4	9.5	10.8	8.0	5,260
Hourly[a]	1600	7.0	122	7.5	9.6	10.9	9.1	5,620
Hourly[a]	1700	—	—	—	—	—	—	5,660
Average EWI, point[b]	1330	10.7	122	7.4	9.5	10.6	7.2	4,690
Average EDI, integrated[c]	1535	9.8	122	7.4	9.5	10.8	8.0	5,000

[a] Hourly samples were collected at the point location of the high-volume sampler intake.

[b] Equal-width point samples were collected at 25, 50, and 75 percent of the total width of the cross-section transect near the top, mid-depth, and near the bottom of the water column.

[c] Equal-discharge increment integrated samples were collected at 10, 30, 50, 70, and 90 percent of total discharge. Water-quality measurements were made near the top, mid-depth, and at the bottom of the water column. Sediment samples were depth integrated throughout the water column.

Table 6. Water-quality field measurements and suspended-sediment data for the Middle River above mouth near Plymouth (site 4, USGS station 0208113525), North Carolina, March 1, 2001

[USGS, U.S. Geological Survey; ft, foot; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; mg/L, milligram per liter; ft^3/s, cubic foot per second; —, no data; EWI, equal-width increment; EDI, equal-discharge increment]

Type of sample	Time	Sampling depth (ft)	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Suspended sediment (mg/L)	Discharge (ft^3/s)
Hourly[a]	0915	—	—	—	—	—	—	1,350
Hourly[a]	1015	6.6	121	6.9	9.2	10.5	8.8	—
Hourly[a]	1115	6.7	121	7.1	9.3	10.9	10.8	—
Hourly[a]	1215	7.1	122	7.2	9.5	10.5	8.8	—
Hourly[a]	1315	7.4	122	7.2	9.7	10.8	8.3	1,270
Hourly[a]	1415	—	—	—	—	—	—	1,040
Hourly[a]	1515	6.7	122	7.3	10.2	10.9	8.9	657
Hourly[a]	1615	6.7	122	7.3	10.0	10.8	11.1	356
Hourly[a]	1715	6.7	122	7.3	9.8	10.6	8.1	105
Hourly[a]	1815	6.7	122	7.3	9.9	10.7	8.6	-38[b]
Average EWI, point[c]	1150	8.7	122	7.2	9.4	10.6	8.8	—
Average EDI, integrated[d]	1738	9.4	123	7.3	10.0	10.8	8.2	110

[a] Hourly samples were collected at the point location of the high-volume sampler intake.

[b] Tidal effects forced the water to flow upstream.

[c] Equal-width point samples were collected at 25, 50, and 75 percent of the total width of the cross-section transect near the top, mid-depth, and near the bottom of the water column.

[d] Equal-discharge increment integrated samples were collected at 10, 30, 50, 70, and 90 percent of total discharge. Water-quality measurements were made near the top, mid-depth, and at the bottom of the water column. Sediment samples were depth integrated throughout the water column.

Table 7. Water-quality field measurements and suspended-sediment data for the Welch Creek above the sewage-effluent outfall near Plymouth (site 5, USGS station 02081138), North Carolina, February 27, 2001

[USGS, U.S. Geological Survey; ft, foot; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; mg/L, milligram per liter; ft^3/s, cubic foot per second; —, no data; EWI, equal-width increment]

Type of sample	Time	Sampling depth (ft)	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Suspended sediment (mg/L)	Discharge (ft^3/s)
Hourly[a]	1100	3.0	111	6.7	13.0	7.5	1.7	—
Hourly[a]	1200	3.0	112	6.7	12.8	7.3	1.1	—
Hourly[a]	1300	3.0	112	6.7	12.6	7.3	7.2	27.2
Hourly[a]	1400	3.0	112	6.6	12.4	7.4	1.8	21.9
Hourly[a]	1500	3.0	112	6.7	12.4	7.5	3.1	14.0
Hourly[a]	1600	3.0	112	6.7	12.2	7.6	2.4	9.08
Average EWI, point[b]	1200	4.2	112	6.6	12.6	7.4	3.0	—
Average EWI, integrated[c]	1515	4.2	112	6.6	12.2	7.5	4.0	14.0

[a] Hourly samples were collected at the point location of the high-volume sampler intake.

[b] Equal-width point samples were collected at 25, 50, and 75 percent of the total width of the cross-section transect near the top, mid-depth, and near the bottom of the water column.

[c] Equal-width increment integrated samples were collected at 10, 30, 50, 70, and 90 percent of the total width of the cross-section transect. Water-quality measurements were made near the top, mid-depth, and at the bottom of the water column. Sediment samples were depth integrated throughout the water column.

Table 8. Water-quality field measurements and suspended-sediment data for Welch Creek at Secondary Road 1565 at Plymouth (site 6, USGS station 02081140), North Carolina, February 26, 2001

[USGS, U.S. Geological Survey; ft, foot; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; mg/L, milligram per liter; ft^3/s, cubic foot per second; —, no data; EWI, equal-width increment]

Type of sample	Time	Sampling depth (ft)	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Suspended sediment (mg/L)	Discharge (ft^3/s)
Hourly[a]	1115	4.0	165	6.7	10.1	8.7	11.0	—
Hourly[a]	1215	4.0	161	6.7	10.4	8.8	3.7	—
Hourly[a]	1315	4.0	161	6.7	10.3	8.7	7.7	91.9
Hourly[a]	1415	4.0	162	6.7	10.9	8.8	6.9	62.1
Hourly[a]	1515	4.0	163	6.7	10.8	8.8	8.6	-20.2[b]
Hourly[a]	1530	—	—	—	—	—	—	-48.4[b]
Hourly[a]	1600	—	—	—	—	—	—	-118[b]
Hourly[a]	1615	4.0	163	7.2	10.6	10.2	9.3	-268[b]
Hourly[a]	1645	4.0	166	7.2	10.6	10.1	14.0	-291[b]
Hourly[a]	1700	—	—	—	—	—	—	-241[b]
Hourly[a]	1715	—	—	—	—	—	—	-191[b]
Average EWI, point[c]	1245	3.6	166	6.7	10.1	8.6	7.7	—
Average EWI, integrated[d]	1600	3.6	159	6.9	10.4	10.0	12.4	—

[a] Hourly samples were collected at the point location of the high-volume sampler intake.

[b] Tidal effects forced the water to flow upstream.

[c] Equal-width point samples were collected at 25, 50, and 75 percent of the total width of the cross-section transect near the top, mid-depth, and near the bottom of the water column.

[d] Equal-width increment integrated samples were collected at 10, 30, 50, 70, and 90 percent of the total width of the cross-section transect. Water-quality measurements were made near the top, mid-depth, and at the bottom of the water column. Sediment samples were depth integrated throughout the water column.

Teble 9. Water-quality field measurements and suspended-sediment data for the Roanoke River at Plymouth (site 7, USGS station 0208114055), North Carolina, March 7, 2001

[USGS, U.S. Geological Survey; ft, foot; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; mg/L, milligram per liter; ft^3/s, cubic foot per second; —, no data; EWI, equal-width increment; EDI, equal-discharge increment]

Type of sample	Time	Sampling depth (ft)	Specific conductance (µS/cm)	pH (standard units)	Watar temperature (°C)	Dissolved oxygen (mg/L)	Suspended sediment (mg/L)	Discharge (ft^3/s)
Hourly[a]	0915	7.0	253	7.4	9.1	10.0	8.5	2,080
Hourly[a]	1015	7.0	223	7.4	9.1	10.1	8.4	—
Hourly[a]	1115	7.0	209	7.4	9.1	10.0	6.6	—
Hourly[a]	1215	7.0	193	7.3	9.0	10.1	6.1	—
Hourly[a]	1315	7.0	202	7.3	8.9	9.9	4.9	2,400
Hourly[a]	1415	7.0	240	7.4	9.1	10.0	6.2	3,390
Hourly[a]	1500	—	—	—	—	—	—	3,230
Hourly[a]	1530	—	—	—	—	—	—	3,060
Average EWI, point[b]	1240	9.3	217	7.3	9.3	10.0	7.9	—
Average EDI, integrated[c]	1020	10.5	251	7.4	9.1	10.0	9.4	1,500

[a] Hourly samples were collected at the point location of the high-volume sampler intake.

[b] Equal-width point samples were collected at 25, 50, and 75 percent of the total width of the cross-section transect near the top, mid-depth, and near the bottom of the water column.

[c] Equal-discharge increment integrated samples were collected at 10, 30, 50, 70, and 90 percent of total discharge. Water-quality measurements were made near the top, mid-depth, and at the bottom of the water column. Sediment samples were depth integrated throughout the water column.

Table 10. Water-quality field measurements and suspended-sediment data for the Roanoke River at Light 13 near Westover (site 9, USGS station 0208114210), North Carolina, March 6, 2001

[USGS, U.S. Geological Survey; ft, foot; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; mg/L, milligram per liter; ft^3/s, cubic foot per second; —, no data; EWI, equal-width increment]

Type of sample	Time	Sampling depth (ft)	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Suspended sediment (mg/L)	Discharge (ft^3/s)
Hourly[a]	0930	—	—	—	—	—	—	4,210
Hourly[a]	1030	7.0	169	7.1	9.7	9.7	6.4	—
Hourly[a]	1130	7.0	155	7.2	9.7	9.6	7.6	—
Hourly[a]	1230	7.0	154	7.2	9.6	9.7	8.9	—
Hourly[a]	1300	—	—	—	—	—	—	255
Hourly[a]	1330	6.5	156	7.2	9.6	10.0	7.9	-464[b]
Hourly[a]	1400	—	—	—	—	—	—	-1,090[b]
Hourly[a]	1430	6.6	164	7.2	9.7	10.0	8.9	-576[b]
Hourly[a]	1530	7.0	159	7.3	9.7	9.9	9.5	1,180
Hourly[a]	1630	—	—	—	—	—	—	353
Average EWI, point[c]	1220	12.3	160	7.2	9.5	9.8	8.2	—
Average EWI, integrated[d]	1600	11.5	164	7.3	9.7	9.9	11.7	—

[a] Hourly samples were collected at the point location of the high-volume sampler intake.

[b] Tidal effects forced the water to flow upstream.

[c] Equal-width point samples were collected at 25, 50, and 75 percent of the total width of the cross-section transect near the top, mid-depth, and near the bottom of the water column.

[d] Equal-width increment integrated samples were collected at 10, 30, 50, 70, and 90 percent of the total width of the cross-section transect. Water-quality measurements were made near the top, mid-depth, and at the bottom of the water column. Sediment samples were depth integrated throughout the water column.

Table 11. Water-quality field measurements and suspended-sediment data for the Eastmost River below N.C. Highway 45 near Westover (site 11, USGS station 0208114320), North Carolina, March 5, 2001

[USGS, U.S. Geological Survey; ft, foot; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; mg/L, milligram per liter; ft^3/s, cubic foot per second; —, no data; EWI, equal-width increment]

Type of sample	Time	Sampling depth (ft)	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Suspended sediment (mg/L)	Discharge (ft^3/s)
Hourly[a]	0915	—	—	—	—	—	—	38.9
Hourly[a]	0930	—	—	—	—	—	—	245
Hourly[a]	0945	—	—	—	—	—	—	372
Hourly[a]	1015	5.0	173	7.1	10.5	9.1	9.1	—
Hourly[a]	1115	5.0	173	7.2	10.5	9.0	9.0	—
Hourly[a]	1215	5.0	177	7.3	10.6	9.0	7.8	—
Hourly[a]	1315	5.0	180	7.3	10.6	8.9	10.9	596
Hourly[a]	1415	5.0	180	7.3	10.7	8.9	8.3	630
Hourly[a]	1515	5.0	166	7.3	10.7	9.0	6.7	493
Hourly[a]	1615	—	—	—	—	—	—	487
Average EWI, point[b]	1130	4.0	174	7.2	10.5	9.0	7.5	—
Average EWI, integrated[c]	1430	4.2	174	7.3	10.7	9.1	6.9	—

[a] Hourly samples were collected at the point location of the high-volume sampler intake.

[b] Equal-width point samples were collected at 25, 50, and 75 percent of the total width of the cross-section transect near the top, mid-depth, and near the bottom of the water column.

[c] Equal-width increment integrated samples were collected at 10, 30, 50, 70, and 90 percent of the total width of the cross-section transect. Water-quality measurements were made near the top, mid-depth, and at the bottom of the water column. Sediment samples were depth integrated throughout the water column.

Dioxin Data

Dioxin data are summarized in this report by using toxic equivalents (TEQ) values (table 2). These values are the summed concentration of the 2-, 3-, 7-, and 8-substituted polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). The data given in this report have been calculated by using the widely accepted International Toxic Equivalency Factors (I-TEF; Schecter, 1994). This method weights the values according to their toxicity. Values are reported in micrograms and femtograms per liter (µg and fg/L, respectively). The microgram value is the mass of dioxin measured in the entire 750-liter sample. The femtogram-per-liter value is the concentration calculated as microgram multiplied by 10^9 and divided by 750 liters. The filter data represent dioxin attached to the suspended particles, and reported values for the sum of the filters range from 5.1 fg/L measured at Welch Creek near Plymouth (site 5) to 900 fg/L measured at Welch Creek at Secondary Road 1565 at Plymouth (site 6). Dissolved dioxin is represented by the column data, and reported values range from 0.31 fg/L measured at Middle River near Plymouth (site 4) to 41 fg/L measured at Welch Creek at Secondary Road 1565 at Plymouth (site 6, table 2). The recovery columns, run in series for quality-assurance purposes, all had dioxin values above the detection limit (1 part per quintillion or 1 fg/L) indicating less than 100-percent adsorption of the dioxin to the primary XAD column. These values were not calculated as part of the TEQ value reported for the sampling site. Therefore, the values reported for each site represent conservative estimates of dioxin concentration present in the water column during the time of sampling. All sites sampled had dioxin concentrations above the detection limits for both dissolved and suspended dioxin.

Discharge and Water-Level Data

Discharge measurements at the sampling site or, when flow was not sufficient, near the sampling site were made in conjunction with the high-volume sampling for dioxin. The frequency of discharge measurements was determined by streamflow variability during the sampling. These data are presented in tables 4–11. Reverse flow, indicated by negative flow, was measured at four of the eight sampling locations.

Water-level measurements were recorded at sites 2, 7, 8, and 10 (fig. 2; table 3). For each sampling event, the daily maximum, minimum, and mean water levels at these four tidal gages in the lower Roanoke River Basin are presented in table 3.

Suspended-Sediment and Water-Quality Field Data

Suspended-sediment concentrations ranged from 1.1 milligrams per liter (mg/L) at Welch Creek above the sewage-effluent outflow (SEO) near Plymouth (site 5) to 14.0 mg/L at Welch Creek at Secondary Road 1565 at Plymouth (site 6). Specific conductance values ranged from 111 microsiemens per centimeter (µS/cm) at 25 degrees Celsius (°C) in Welch Creek (site 5) above the SEO near Plymouth to 340 µS/cm in the Chowan River near Edenhouse (site 1). The range of pH values measured in standard units was from 6.6 at Welch Creek (site 5) to 7.7 at the Chowan River (site 1). During this study, the water temperature ranged from 8.9 °C in the Roanoke River at Plymouth (site 7) to 13.0 °C in Welch Creek (site 5). Dissolved-oxygen concentrations ranged from 7.3 mg/L at Welch Creek (site 5) to 10.9 mg/L at Middle River above the mouth near Plymouth (site 4) and at the Roanoke River above Broad Creek near Woodward (site 3).

SUMMARY

The dioxin, suspended-sediment, discharge, and water-quality data presented in this report were collected during February 26–March 7, 2001, as part of a sampling program designed to assess the water quality of the lower Roanoke River Basin, an area of approximately 420 square miles in the Coastal Plain Province of North Carolina. The study area extends from Jamesville east approximately 19 river miles to the mouth of the Roanoke River in the Albemarle Sound. A large industrial facility specializing in wood products is located in the study basin in close proximity to the former location of a hardwood sawmill, which burned down in 1983. The industrial facility discharges 55 million gallons per day of non-cooling, industrial wastewater into the Roanoke River through a diffuser pipe on the river bottom.

High-volume water sampling was conducted for laboratory analysis of dioxin concentrations, and other water samples were collected for laboratory analysis for suspended-sediment concentrations. Discharge and water-level measurements were made at these sites. In addition, field measurements were made at eight sampling sites for specific conductance, pH, water temperature, and dissolved-oxygen concentration.

Dioxin concentrations were measured for both dissolved dioxin and suspended dioxin. A high-volume sampler was used to sample for dioxin in the water column. This sampling method allowed for analysis of very low detection limits (1 part per quintillion or 1 femtogram per liter) for dioxin and dioxin-like concentrations. Toxic equivalents values were used in reporting the data in micrograms and femtograms per liter. The filter data represent dioxin attached to suspended particles, and reported dioxin concentrations for the sum of the filters (150 micrometers, 50 micrometers, and 1 micrometer) ranged from 5.1 to 900 femtograms per liter. Dissolved dioxin is represented by the fraction sorbed to an XAD2™ resin column, and reported concentrations ranged from 0.31 to 41 femtograms per liter. All sites sampled had dioxin concentrations above the detection limit.

Discharge measurements were made at each of the sampling sites by using an acoustic doppler current profiler. Frequencies of the discharge measurements were determined by the streamflow variability. Reverse flow was measured at four of the eight sampling locations.

Water-quality measurements made at each sampling site included multidepth (near surface, mid-depth, and near bottom) measurements at three or five evenly spaced locations in two cross-section transects and hourly measurements at the point of high-volume sampling for dioxin. In order to collect a sample that was representative of the entire river cross section, two cross-section transect measurements were collected for comparison with the hourly suspended-sediment samples that were collected at the point of the high-volume sampler intake. Field measurements were made with a portable, multiparameter water-quality system (Hydrolab Surveyor 3). These measurements included specific conductance, pH, water temperature, and dissolved-oxygen concentration. The first cross-section transect measurement consisted of three multidepth measurements made once during the first 4 hours of the sampling period. These values were averaged and reported as an average for the cross section. The second cross-section transect measurement was made once during the last 4 hours of the sampling period and consisted of five multidepth measurements. These point samples were averaged for the cross section.

Specific conductance values ranged from 111 to 340 microsiemens per centimeter at 25 degrees Celsius in the study area. The range of pH values, measured in standard units, was from 6.6 to 7.7. The lowest recorded water temperature value during this study was 8.9 degrees Celsius, and the highest recorded temperature was 13 degrees Celsius. Dissolved-oxygen concentrations ranged from 7.3 to 10.9 milligrams per liter. Suspended-sediment concentrations ranged from 1.1 to 14 milligrams per liter.

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