LEVEL ONE WATER-QUALITY INVENTORY AND MONITORING

GEORGE WASHINGTON BIRTHPLACE NATIONAL MONUMENT (GEWA), VIRGINIA

U.S. Geological Survey
1730 East Parham Road
Richmond, Virginia 23228

INTRODUCTION

The U.S. Geological Survey conducted a Level 1 Water-Quality Inventory and Monitoring (WAQIM) data-collection effort for George Washington Birthplace National Monument (GEWA) from October 1998 through June 1999. The primary objective of the WAQIM program was to provide the National Park Service (NPS) and GEWA with at least a nominal inventory of its natural resources and to provide those data in a data-management system consistent with park management needs. Water-quality inventory data (physical, chemical, and biological) were collected from "key" water bodies within the boundaries of GEWA. The key water bodies are those waters within park boundaries that are essential to the central cultural, historical or natural resources management themes of the parks or provide habitats to threatened or endangered plants and animals. Data were collected during the fall, winter, spring, and summer over a range of hydrologic conditions. Because of the drought conditions that persisted during the study period, variations in flow between seasons were less pronounced than during normal hydrologic conditions.

George Washington Birthplace National Monument is a 550-acre unit of the National Park System along the tidal portion of the Potomac River in Westmoreland County, Virginia. While the primary purpose of the park is the preservation of the historic setting, the park contains significant water-related resources including tidal estuaries that support extensive wetlands, freshwater wetlands, and a number of small streams, ponds, and springs. Many of these water-related resources are closely linked with the cultural and historic context of the site. The combined drainage basin area of the three-subbasin area within which the park is found is approximately 13,500 acres, of which the park, at 550 acres, comprises less than 5 percent. Although the area is rural and not heavily populated, the proximity of the park to the Washington, DC metropolitan area is expected to cause increased future developmental pressures, as roads are improved and sewer lines installed. GEWA and adjacent farms have been aggressively farmed in the past, and the surrounding area continues to be used for pastureland, cropland, and logging. As one of the earliest historic National Parks, farming at GEWA has been controlled, and recent and historic land use have been relatively well-documented.

Potential threats to water-quality in the park include: (1) encroaching development (primarily outside of the immediate area of the park) and (2) agricultural activities. Data-collection sites and the parameters analyzed were selected based on the spatial distribution of land-use activities inside and immediately outside of the park's boundaries and the nature of the potential threats to park water-quality.

DESCRIPTION OF INVENTORY PROCESS

Site Descriptions

The water-quality inventory for GEWA included the periodic collection of physical, chemical, and microbiological data from two sites on Popes Creek, one site on Bridges Creek, and one spring (fig. 1). These sites are: (1) Popes Creek at Point of Point near Wakefield, Va (0166087750), (2) Popes Creek at Burnt House Point near Wakefield, Va

(0166087760), (3) Bridges Creek at Mouth near Wakefield, Va (01660860), (4) Dancing Marsh near Wakefield, Va (0166087770), and (5) Spring at Dancing Marsh near Wakefield, Va - 55PS1 (381108076551101). Data-collection plans had originally targeted Digwood Swamp Creek for sampling, but due to drought conditions that persisted though the study, the site remained dry and no samples were collected.

Popes Creek at Point of Point near Wakefield, Va (0166087750) is located approximately 0.5 miles upstream from the south boundary of GEWA and 1.5 miles upstream from the Potomac River. The site is tidally influenced. Stream width is approximately 200 feet. Surrounding areas include woodlands, wetlands, and pasture. Access is via boat. Popes Creek at Burnt House Point near Wakefield, Va (0166087760) is located immediately adjacent to the southeastern boundary of GEWA and is approximately 0.75 miles upstream from the Potomac River. The site is tidally influenced. Stream width is approximately 2,000 feet. Surrounding areas include woodlands, wetlands, and pasture. Access is via boat. Bridges Creek at Mouth near Wakefield, Va (01660860) is located at the extreme northwest corner of the park. The site is immediately upstream from the Potomac River and is tidally influenced —a high sand beach can isolate exchange between the creek and river except during periods of high tide. The creek's headwaters are located outside the park boundaries. Stream width is typically less than 20 feet. The surrounding area includes woodlands and wetlands. Access is via a GEWA tour road. Dancing Marsh near Wakefield, Va (0166087770) is located in the southern end of GEWA and is approximately 1,000 feet upstream from Popes Creek. The site is tidally influenced. The headwaters of the creek are located outside and to the west of GEWA. Stream width is typically less than 10 feet. Surrounding area includes woodlands, wetlands, and pasture. The site is immediately downstream from a footbridge. Access is via footpath behind a private residence (park staff). Spring at Dancing Marsh near Wakefield, Va - 55PS1 (381108076551101) is located at the base of a terrace in GEWA approximately 200 feet upstream from site 0166087770. The surrounding area includes woodlands, wetlands, and pasture.

Description of Data Collection

Data-collection activities were conducted in October and December 1998 and in February and June 1999 (table 1). Data-collection and analysis were conducted according to standard USGS protocols (U.S. Geological Survey, 1997, 1998, 1999; Rantz and others, 1982). Stream water-quality samples were collected as point samples or cross-sectional depth-integrated samples, depending on streamflow conditions. Discharge, water temperature, pH, specific conductivity, dissolved oxygen, and alkalinity were measured at every site on every visit. Water samples were collected and analyzed for nutrients and bacteria at every site on every visit. Samples were collected and analyzed for major ion and trace element analysis on one visit. Also, during each data-collection trip, quality control/quality assurance (QA/QC) samples were collected and analyzed to insure data quality. Field blanks and duplicate samples were routinely employed for all analytical methods.

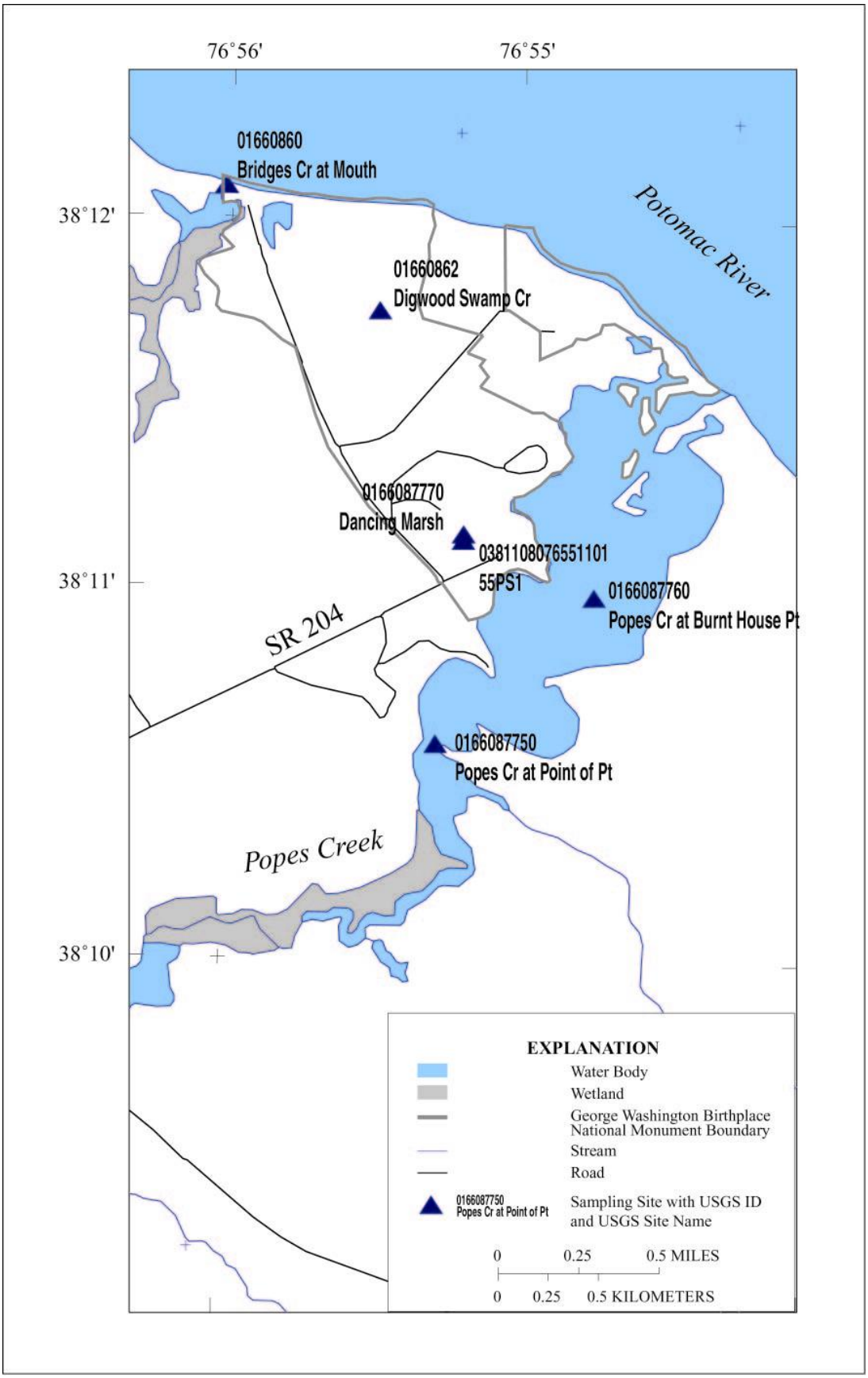

Figure 1. Location of study area and data-collection sites.

Table 1. Data-collection schedule

Parameter	Data-collection period			
	October 1998	December 1998	February 1999	June 1999
Field parameters	X	X	X	X
Fecal bacteria	X	X	X	X
Nutrients	X	X	X	X
Major Ions	X		X	
Trace elements				X

PRINCIPAL INVESTIGATORS

The principal investigators of the WAQIM program included staff of the U.S. Geological Survey (USGS), Water Resources Division (WRD) district office in Richmond, Virginia. Michael E. Lewis, Supervisory Hydrologist, supervised all work. J. Michael Gearheart, Hydrologic Technician, implemented all fieldwork. All water-quality samples collected as part of the inventory, with the exception of bacteriological samples, were submitted for analysis to the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado. Bacteriological samples were processed by field personnel at each site and analyzed in the Richmond, Virginia office of the USGS.

WATER-QUALITY RESULTS

Tables 2-6 provide all physical, microbiological, and chemical data collected as part of the GEWA WAQIM project. All data are also provided in a Microsoft Excel spreadsheet (WQDATA.XLS). In addition to the water-quality data spreadsheet, three additional supporting documents are included on the attached 3.5-inch diskette: (1) PARAMETER.DOC; (2) STATION.XLS; AND (3) README.DOC. “PARAMETER.DOC” is a Microsoft Word file that explicitly defines each water-quality parameter included in the following tables and in the water-quality data spreadsheet. “STATION.XLS” is a Microsoft Excel file that contains specific location data for each site where water-quality data was collected. “README.DOC” is a Microsoft Word file that contains basic information related to the project such as contact information for those who conducted the work and analyzed the samples.

Table 2. Field parameter data

[ft^3/s, cubic feet per second; ^{O}C, degrees Celsius; μ S/cm, microsiemens per centimeter at 25 ^{O}C; mg/L, milligrams per liter; mg/L as $CaCO_3$, milligrams per liter as calcium carbonate; <, less than; e, estimated value; --, no data]

Date	Time	Discharge (ft^3/s)	Water temperature (^{o}C)	pH (units)	Specific conductance (μ S/cm)	Dissolved oxygen (mg/L)	Alkalinity (mg/L as $CaCO_3$)
Popes Creek at Point of Point near Wakefield, VA (0166087750)							
Oct 07, 1998	11:00	--	18.4	7.4	17,100	6.0	84
Dec 16, 1998	12:15	--	6.7	7.3	18,800	9.4	61
Feb 02, 1999	09:20	--	6.1	7.2	15,000	10.8	48
Jun 14, 1999	11:45	--	26.8	7.4	15,700	--	66
Popes Creek at Burnt House Point near Wakefield, VA (0166087760)							
Oct 07, 1998	08:05	--	18.8	7.1	17,400	7.0	83
Dec 16, 1998	09:00	--	6.7	7.4	20,000	7.5	56
Feb 02, 1999	08:30	--	5.9	7.4	16,800	11.4	67
Jun 14, 1999	10:30	--	25.1	7.8	14,300	--	68
Bridges Creek at Mouth near Wakefield, VA (01660860)							
Oct 06, 1998	12:00	0	--	--	--	--	--
Dec 15, 1998	10:00	0	5.8	7.4	1,210	9.1	159
Feb 03, 1999	08:20	2.9	6.2	6.9	4,000	5.0	109
Jun 15, 1999	09:35	4.95	23.0	6.6	16,300	2.5	89
Dancing Marsh near Wakefield, VA (0166087770)							
Oct 06, 1998	13:00	0.07	18.7	6.8	655	9.3	26
Dec 15, 1998	13:00	.063	7.4	7.1	2,050	9.9	60
Feb 03, 1999	10:45	0.17	8.0	6.7	550	10.6	13
Jun 15, 1999	10:45	0.046	21.4	6.5	3,000	4.7	39
Spring at Dancing Marsh near Wakefield, VA - 55PS1 (381108076551101)							
Oct 06, 1998	11:00	0.05	17.0	6.6	311	8.7	65
Dec 15, 1998	14:40	<0.01e	11.0	--	296	--	--
Feb 03, 1999	12:30	0.00	12.6	6.5	240	3.2	44
Jun 15, 1999	13:30	0.002	16.5	6.5	220	2.5	36

Table 3. Bacteria data.

[col/100 ml; colonies per 100 milliliters; >, greater than; K, non-ideal colony count; --, no data]

Date	Time	Total coliform (col/100 ml)	Fecal coliform (col/100 ml)	Fecal streptococcus (col/100 ml)
Popes Creek at Point of Point near Wakefield, VA (0166087750)				
Oct 07, 1998	11:00	>1,300	1,100	580
Dec 16, 1998	12:15	180	67K	94K
Feb 02, 1999	09:20	>250	200	220
Jun 14, 1999	11:45	500	260	100
Popes Creek at Burnt House Point near Wakefield, VA (0166087760)				
Oct 07, 1998	08:05	310	150K	170
Dec 16, 1998	09:00	160K	76K	97K
Feb 02, 1999	08:30	100K	20K	67K
Jun 14, 1999	10:30	300	130	16K
Bridges Creek at Mouth near Wakefield, VA (01660860)				
Oct 06, 1998	12:00	--	--	--
Dec 15, 1998	10:00	4,000	2,700	1,800
Feb 03, 1999	08:20	1,700	660	740
Jun 15, 1999	09:35	1,500	1,080	1,440
Dancing Marsh near Wakefield, VA (0166087770)				
Oct 06, 1998	13:00	2,800	1,200	1,300
Dec 15, 1998	13:00	380	200	460
Feb 03, 1999	10:45	310	73K	170K
Jun 15, 1999	10:45	10,455	2,200	4,600
Spring at Dancing Marsh near Wakefield, VA -55PS1 (381108076551101)				
Oct 06, 1998	11:00	>10,000	>10,000	>10,000
Dec 15, 1998	14:40	--	--	--
Feb 03, 1999	12:30	>10,000	>10,000	>10,000
Jun 15, 1999	13:30	310	26K	64K

Table 4. Nutrient data
[mg/L, milligrams per liter; N, nitrogen; P, phosphorous; < less than; --, no data]

Date	Time	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, nitrate + nitrite, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia + organic, total (mg/L as N)	Nitrogen, ammonia + organic, dissolved (mg/L as N)
Popes Creek at Point of Point near Wakefield, VA (0166087750)						
Oct 07, 1998	11:00	<0.01	0.05	0.03	0.6	0.3
Dec 16, 1998	12:15	<0.01	0.06	0.03	0.4	0.3
Feb 02, 1999	09:20	0.01	0.22	0.09	0.5	0.3
Jun 14, 1999	11:45	<0.01	<0.05	<0.02	0.8	0.1
Popes Creek at Burnt House Point near Wakefield, VA (0166087760)						
Oct 07, 1998	08:05	<0.01	<0.05	0.02	1	0.3
Dec 16, 1998	09:00	0.01	0.05	0.03	0.5	0.3
Feb 02, 1999	08:30	0.01	0.36	0.12	0.5	0.4
Jun 14, 1999	10:30	<0.01	<0.05	<0.02	0.7	0.2
Bridges Creek at Mouth near Wakefield, VA (01660860)						
Oct 06, 1998	12:00	--	--	--	--	--
Dec 15, 1998	10:00	0.01	0.05	0.04	2.6	1.3
Feb 03, 1999	08:20	0.01	0.12	0.56	2.2	1.5
Jun 15, 1999	09:35	<0.01	<0.05	<0.02	0.8	0.4
Dancing Marsh near Wakefield, VA (0166087770)						
Oct 06, 1998	13:00	<0.01	0.39	0.18	0.8	0.4
Dec 15, 1998	13:00	0.01	0.07	0.07	0.6	0.4
Feb 03, 1999	10:45	0.01	0.32	0.06	0.5	0.4
Jun 15, 1999	10:45	<0.01	<0.05	<0.02	1.1	1.1
Spring at Dancing Marsh near Wakefield, VA - 55PS1 (381108076551101)						
Oct 06, 1998	11:00	0.04	4.9	0.03	0.7	0.2
Dec 15, 1998	14:40	--	--	--	--	--
Feb 03, 1999	12:30	0.01	3	0.03	0.6	0.2
Jun 15, 1999	13:30	--	--	--	--	--

Table 4. Nutrient data--Continued.
[mg/L, milligrams per liter; N, nitrogen; P, phosphorous; < less than; e, estimated value; --, no data]

Date	Time	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Orthophosphate, dissolved (mg/L as P)
Popes Creek at Point of Point near Wakefield, VA (0166087750)				
Oct 07, 1998	11:00	0.09	<0.05	0.03
Dec 16, 1998	12:15	0.04e	<0.05	0.01
Feb 02, 1999	09:20	0.034	0.011	0.01
Jun 14, 1999	11:45	0.097	0.012	0.01
Popes Creek at Burnt House Point near Wakefield, VA (0166087760)				
Oct 07, 1998	08:05	0.17	0.03e	0.03
Dec 16, 1998	09:00	0.05	<0.05	0.01
Feb 02, 1999	08:30	0.028	0.012	<0.01
Jun 14, 1999	10:30	0.076	0.011	0.01
Bridges Creek at Mouth near Wakefield, VA (01660860)				
Oct 06, 1998	12:00	--	--	--
Dec 15, 1998	10:00	1.4	0.85	0.78
Feb 03, 1999	08:20	0.69	0.56	0.51
Jun 15, 1999	09:35	0.19	0.13	0.01
Dancing Marsh near Wakefield, VA (0166087770)				
Oct 06, 1998	13:00	0.10	0.05e	0.05
Dec 15, 1998	13:00	0.06	0.04e	0.02
Feb 03, 1999	10:45	0.045	0.021	0.02
Jun 15, 1999	10:45	0.18	0.091	0.01
Spring at Dancing Marsh near Wakefield, VA - 55PS1 (381108076551101)				
Oct 06, 1998	11:00	0.09	<0.05	0.04
Dec 15, 1998	14:40	--	--	--
Feb 03, 1999	12:30	0.06	0.02	0.02
Jun 15, 1999	13:30	--	--	--

Table 5. Major-element data.
[mg/l, milligrams per liter, <, less than; --, no data]

Date	Time	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)
Popes Creek at Point of Point near Wakefield, VA (0166087750)							
Oct 07, 1998	11:00	130	370	3,100	110	78	720
Dec 16, 1998	12:15	--	--	--	--	--	--
Feb 02, 1999	09:20	--	--	--	--	--	--
Jun 14, 1999	11:45	--	--	--	--	--	--
Popes Creek at Burnt House Point near Wakefield, VA (0166087760)							
Oct 07, 1998	08:05	130	380	3,100	110	76	740
Dec 16, 1998	09:00	--	--	--	--	--	--
Feb 02, 1999	08:30	--	--	--	--	--	--
Jun 14, 1999	10:30	--	--	--	--	--	--
Bridges Creek at Mouth near Wakefield, VA (01660860)							
Oct 06, 1998	12:00	--	--	--	--	--	--
Dec 15, 1998	10:00	--	--	--	--	--	--
Feb 03, 1999	08:20	37	76	620	26	49	150
Jun 15, 1999	09:35	--	--	--	--	--	--
Dancing Marsh near Wakefield, VA (0166087770)							
Oct 06, 1998	13:00	11	16	120	5.5	29	23
Dec 15, 1998	13:00	--	--	--	--	--	--
Feb 03, 1999	10:45	--	--	--	--	--	--
Jun 15, 1999	10:45	--	--	--	--	--	--
Spring at Dancing Marsh near Wakefield, VA - 55PS1 (381108076551101)							
Oct 06, 1998	11:00	42	3.1	11	1.2	65	22
Dec 15, 1998	14:40	--	--	--	--	--	--
Feb 03, 1999	12:30	33	2.6	8.1	1.0	54	22
Jun 15, 1999	13:30	--	--	--	--	--	--

Table 5. Major-element data—Continued.
[mg/l, milligrams per liter, <, less than; --no data]

Date	Time	Chloride, dissolved (mg/l as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)
Popes Creek at Point of Point near Wakefield, VA (0166087750)				
Oct 07, 1998	11:00	5,500	0.5	3.9
Dec 16, 1998	12:15	--	--	--
Feb 02, 1999	09:20	--	--	--
Jun 14, 1999	11:45	--	--	--
Popes Creek at Burnt House Point near Wakefield, VA (0166087760)				
Oct 07, 1998	08:05	5,500	0.5	4.1
Dec 16, 1998	09:00	--	--	--
Feb 02, 1999	08:30	--	--	--
Jun 14, 1999	10:30	--	--	--
Bridges Creek at Mouth near Wakefield, VA (01660860)				
Oct 06, 1998	12:00	--	--	--
Dec 15, 1998	10:00	--	--	--
Feb 03, 1999	08:20	1,100	0.2	13
Jun 15, 1999	09:35	--	--	--
Dancing Marsh near Wakefield, VA (0166087770)				
Oct 06, 1998	13:00	220	<0.1	11
Dec 15, 1998	13:00	--	--	--
Feb 03, 1999	10:45	--	--	--
Jun 15, 1999	10:45	--	--	--
Spring at Dancing Marsh near Wakefield, VA - 55PS1 (381108076551101)				
Oct 06, 1998	11:00	25	<0.1	13
Dec 15, 1998	14:40	--	--	--
Feb 03, 1999	12:30	20	<0.1	14
Jun 15, 1999	13:30	--	--	--

Table 6.Trace-element data.
[μ g/L, micrograms per liter; <, less than; --, no data]

Date	Time	Aluminum, total (μ g/L as Al)	Arsenic, total (μ g/L as As)	Barium, total (μ g/L as Ba)	Berylium, total (μ g/L as Ba)	Cadmium, total (μ g/L as Cd)	Chromium, total (μ g/L as Cr)	Cobalt, total (μ g/L as Co)	Copper, total (μ g/L as Cu)	Iron, total (μ g/L as Fe)
Popes Creek at Point of Point near Wakefield, VA (0166087750)										
Oct 07, 1998	11:00	--	--	--	--	--	--	--	--	--
Dec 16, 1998	12:15	--	--	--	--	--	--	--	--	--
Feb 02, 1999	09:20	--	--	--	--	--	--	--	--	--
Jun 14, 1999	11:45	502	<1	60.1	<20.0	<4	<1.0	<4	10	1,390
Popes Creek at Burnt House Point near Wakefield, VA (0166087760)										
Oct 07, 1998	08:05	--	--	--	--	--	--	--	--	--
Dec 16, 1998	09:00	--	--	--	--	--	--	--	--	--
Feb 02, 1999	08:30	--	--	--	--	--	--	--	--	--
Jun 14, 1999	10:30	322	<1	51.7	<20.0	<4	<1.0	<4	5	766
Bridges Creek at Mouth near Wakefield, VA (01660860)										
Oct 06, 1998	12:00	--	--	--	--	--	--	--	--	--
Dec 15, 1998	10:00	--	--	--	--	--	--	--	--	--
Feb 03, 1999	08:20	--	--	--	--	--	--	--	--	--
Jun 15, 1999	09:35	<140	1	72.5	<20.0	<4	<1.0	<4	<4	651
Dancing Marsh near Wakefield, VA (0166087770)										
Oct 06, 1998	13:00	--	--	--	--	--	--	--	--	--
Dec 15, 1998	13:00	--	--	--	--	--	--	--	--	--
Feb 03, 1999	10:45	--	--	--	--	--	--	--	--	--
Jun 15, 1999	10:45	99.8	<1	51.7	<4.0	<1	<1.0	<1	<1	2,230
Spring at Dancing Marsh near Wakefield, VA - 55PS1 (381108076551101)										
Oct 06, 1998	11:00	--	--	--	--	--	--	--	--	--
Dec 15, 1998	14:40	--	--	--	--	--	--	--	--	--
Feb 03, 1999	12:30	--	--	--	--	--	--	--	--	--
Jun 15, 1999	13:30	113	<1	12.6	<4.0	<1	<1.0	<1	5	152

Table 6. Trace-element data—Continued.

[μ g/L, micrograms per liter; <, less than; e, estimated value; --, no data]

Date	Time	Lead, total (μ g/L as Pb)	Lithium, total (μ g/L as Li)	Manganese total (μ g/L as Mn)	Mercury, total (μ g/L as Hg)	Molyb-denum, total (μ g/L as Mo)	Nickel, total (μ g/L as Ni)	Selenium, total (μ g/L as Se)	Silver, total (μ g/L as Ag)	Zinc, total (μ g/L as Zn)
Popes Creek at Point of Point near Wakefield, VA (0166087750)										
Oct 07, 1998	11:00	--	--	--	--	--	--	--	--	--
Dec 16, 1998	12:15	--	--	--	--	--	--	--	--	--
Feb 02, 1999	09:20	--	--	--	--	--	--	--	--	--
Jun 14, 1999	11:45	<4	41.9e	94.6	<0.1	4.0	<4	<1	<4	<200
Popes Creek at Burnt House Point near Wakefield, VA (0166087760)										
Oct 07, 1998	08:05	--	--	--	--	--	--	--	--	--
Dec 16, 1998	09:00	--	--	--	--	--	--	--	--	--
Feb 02, 1999	08:30	--	--	--	--	--	--	--	--	--
Jun 14, 1999	10:30	<4	60.5	37.5	<0.1	4.0	<4	<1	<4	<200
Bridges Creek at Mouth near Wakefield, VA (01660860)										
Oct 06, 1998	12:00	--	--	--	--	--	--	--	--	--
Dec 15, 1998	10:00	--	--	--	--	--	--	--	--	--
Feb 03, 1999	08:20	--	--	--	--	--	--	--	--	--
Jun 15, 1999	09:35	<4	54.9e	295	<0.1	4.0	<4	<1	<4	<200
Dancing Marsh near Wakefield, VA (0166087770)										
Oct 06, 1998	13:00	--	--	--	--	--	--	--	--	--
Dec 15, 1998	13:00	--	--	--	--	--	--	--	--	--
Feb 03, 1999	10:45	--	--	--	--	--	--	--	--	--
Jun 15, 1999	10:45	<1	6.2e	219	<0.1	<1.0	<1	<1	<1	<40
Spring at Dancing Marsh near Wakefield, VA - 55PS1 (381108076551101)										
Oct 06, 1998	11:00	--	--	--	--	--	--	--	--	--
Dec 15, 1998	14:40	--	--	--	--	--	--	--	--	--
Feb 03, 1999	12:30	--	--	--	--	--	--	--	--	--
Jun 15, 1999	13:30	<1	<12	3.6	<0.1	<1.0	3	<1	<1	<40

SELECTED REFERENCES

U.S. Geological Survey, 1997, 1998, 1999, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9.

Rantz, S.E., and others, 1982, Measurement and computation of streamflow--v. 1, Measurement of stage and discharge, w*ith a section on* Discharge - Current-meter method: U.S. Geological Survey Water-Supply Paper 2175, p. 80-183.